CARBON DIOXIDE

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Contents

Summary

The components of the carbon dioxide global cycle are briefly outlined and characterized. The turnover time and the adjustment time for atmosphere, ocean surface and biosphere are determined and evaluated. Anthropogenic carbon dioxide emissions and their distributions in the carbon cycle reservoirs are described and their evolution in the past and in the future is discussed. Radiative impacts and carbon dioxide share evolution in the growing greenhouse effect on global climate are assessed for their current state and for their projections into the twenty-first century, according to the known IPCC (Intergovernmental Panel on Climate Change) scenarios.

1. Introduction

Carbon dioxide CO_2 is a colorless gas with a slight acidic smell and taste. Its density is 1.5 times that of air density. At 20 ^{o}C temperature, 0.88 liters of gas is dissolved in one liter of water. At -78.5 ^{o}C and normal atmospheric pressure, CO_2 transforms into a snow-like mass, bypassing the liquid state. CO_2 comprises 10-16% by volume, of the gaseous product, as a result of total carbon combustion (with air)

Carbon dioxide is the main component of global greenhouse gases in the atmosphere; it has increase during the last two centuries due to anthropogenic causes. Since the beginning of the industrial era, background CO_2 atmospheric concentration increased by about one third and is now the highest in all the current Quaternary geological period. This CO_2 content enhancement forms more than the half of the total global Radiative Forcing produced by all the atmospheric greenhouse gas anthropogenic increases.

The CO_2 (and also methane CH_4) atmospheric content relative to rapid changes in the current industrial era disturb noticeably the carbon cycle exchange between the geospheres which is extensively studied now. Carbon dioxide is the main source of the biota mass production by photosynthesis and also the principal product of the “living matter” degradation. The CO_2 exchange rate between the atmosphere and ocean waters depends also on the temperature of the sea surface. The CO_2 flow from the atmosphere to cold waters occurs in high latitudes and in temperate latitudes in winter; the opposite flow takes place there in summer and all the year in tropical waters. These processes cause a significant seasonal oscillation of CO_2 concentration in the lower atmosphere with amplitudes decreasing from north to south. Seasonal minima (maxima) occur at the end of the northern hemisphere summer (winter). These distributions show the predominance of the CO_2 exchange between the atmosphere and the land biota (vegetation) over other exchanges of atmospheric CO_2 with underlying surface. These seasonal CO_2 oscillations do not penetrate into the upper troposphere and stratosphere and have no practical influence on the Radiative Forcing of CO_2 increase.

According to some studies the CO_2 atmospheric content growth may enhance the photosynthesis intensity and the global land vegetation mass together with the oceanic CO_2 uptake. This makes a negative feedback in the global carbon cycle dynamics.

2. Carbon dioxide sources and sinks

CO_2 is the main component of carbon cycle exchange between geospheres, namely among atmosphere, ocean (surface layer and deep waters) and biosphere (long- and short-lived vegetation). The external natural input in this cycle is due to mostly rocks weathering and volcanic eruptions; fossil fuel burning and cement production are the main anthropogenic external sources. Other numerous sources of anthropogenic origin, such as biomass burning or soil humus ploughing in agricultural practice together with forest cutting are only transferring carbon and CO_2 between the carbon reservoirs.

The carbon contents in reservoirs and the rates of carbon exchange between them are demonstrated in Figure 1.

These averaged numbers are interannually fluctuating being coupled with climatic system component interactions. The rates of carbon exchange determine such important parameters as turnover time $\tau = M/R$ of a mass M in a reservoir, where R is the rate of its removal from there. The adjustment time τ_a is the decay time of a mass instantaneously introduced in a reservoir. Both are often called as “life time” of a mass, but e.g. for CO_2 in the atmosphere they are different: $\tau \approx 5$ years but $\tau_a \approx 100$ years due to subsequent CO_2 return in the atmosphere from its other reservoirs. From Figure 1 it may be estimated $\tau = 10$ years for surface ocean and $\tau = 35.5$ years for the land biosphere. CO_2 has the longest “life time” in the deep ocean and its sediments, having the turnover time of about 400 years and much more long adjustment time. Due to that all the external anthropogenic carbon, injected into the Earth carbon cycle, will be stored in the latter reservoir.

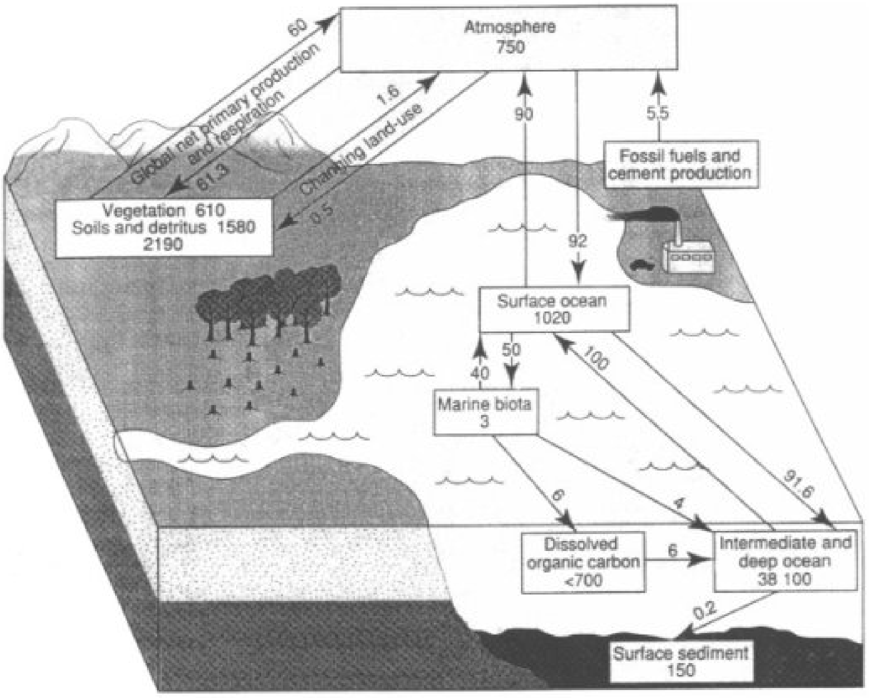

Figure 1. The global carbon cycle scheme, showing the reservoirs (Gt C in frames (1 Gt = 10^{15} g)) and fluxes (Gt C yr^{-1} as arrows) relevant to annual averaged anthropogenic perturbation over the period 1980-1989. Many of key fluxes are fluctuating significantly from year to year. From Climate change 1995 (1996). *The science of climate change* /Eds. Houghton J.T., Meira Filho L.G., Callander B.A., Harris N., Kattenberg A., and Maskell K. - Cambridge University Press, UK, 572p.

Recent estimations of annual CO_2 release in the atmosphere from fossil fuel burning and cement production in 1980-1989 amounted to 5.5±0.5 Gt C yr^{-1} and from changes in land use (in tropics) 1.6±1.0 Gt C yr^{-1}. From the sum of emissions 7.1±1.1 Gt C yr^{-1} , 3.3±0.2 (46.5%) is stored in the atmosphere; 2.0±0.8 enters the ocean; 0.5±0.5 enters Northern Hemisphere forest regrowth and the residual 1.3±1.5 Gt C yr^{-1} relates to various terrestrial sinks (e.g. CO_2 fertilization of vegetation) difficult to account.

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Biographical Sketch

I.L. Karol was born on 27 July 1927 in Leningrad, USSR. In 1944 he entered the Hydrodynamics Dept. of Leningrad State University, Mathematics and Mechanics Faculty, graduating in 1949. He passed postgraduate studies from 1949 to 1952, when he received a scientific degree of Candidate in Maths & Physics. After three years of lecturing in mathematics at the Ural University in Sverdlovsk, in 1956 he entered the Institute of applied Geophysics USSR Academy of Sciences in Moscow as a senior scientist. In 1959 he was transferred to Institute of Experimental Meteorology of USSR Hydrometeorological Service in Obninsk, near Moscow, where he was nominated as chief of laboratory in 1970. Since 1972 he has been with Main Geophysical Observatory of USSR Hydrometeorological Service in Leningrad (now St. Petersburg) after receiving the USSR scientific degree of Doctor of Math & Physics, presenting in 1970 his theses, which was published in 1972 as a book by Gidrometeoizdat Publishing House "Radioactive isotopes and global transport in the atmosphere". This book was translated into English and published in 1974. Since 1953 I.L. Karol has published 10 scientific monographs and more than 140 papers individually or with co-authors. The original papers are dealing with modeling of global atmospheric composition and climate changes due to natural and anthropogenic causes. During several periods he served as a member of various international commissions and committees of the International Association of Meteorology and Atmospheric Physics, of the World Meteorological Organization, of the World Climate Research Program Joint Scientific Committee. Since 1974 he has been the USSR (now Russian) co-leader of the joint project: "Composition of the atmosphere and climate changes" of the US-Russian Cooperation in Environmental Protection. He was the author or co-author of numerous scientific reports, which he presented at international and national scientific meetings throughout his scientific career.