GREENHOUSE GASES, AEROSOLS AND OZONE LAYER

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Summary

A general outline of radiatively active substances in the atmosphere and of their role in formation of greenhouse effect of the Earth atmosphere is presented. The greenhouse gases, aerosols and clouds are substances affecting the short wave (solar) and long wave (Earth surface and the atmosphere) radiation fluxes at various atmospheric levels and ground surface at different latitudes and seasons. General features and parameters of these substances, atmospheric cycles and their differential effects on the radiative regime and air temperature are analyzed and discussed.

1. Introduction

The greenhouse effect of the Earth atmosphere increases the ground surface and adjacent air temperature by about 30 K over the surface radiative-equilibrium temperature. This makes possible the presence of liquid water and all living biota including humans on the Earth. The greenhouse effect is produced mainly when the long wave radiation photons (wave length of 1 μm (1 μm = 10^{-6} m) and more) emitted from the Earth surface and from the atmosphere are absorbed by molecules of greenhouse gases, by some aerosols and by cloud particles. The absorbed photons are then reemitted towards the top and to the bottom of the atmosphere. This additional radiative energy downward flux leads to increase of the lower atmosphere temperature - to additional greenhouse effect. The upward radiative energy flux is irradiated into space and by this it lowers the upper atmosphere temperature. Therefore an increase in the abundance of greenhouse effect producing agent abundance in the atmosphere results in the change of air temperature profile. This change is enhanced or decreased by numerous feedbacks produced by interactions of radiative and temperature changes with elements of the atmosphere and of the underlying surface.

The short wave solar radiation photons in ultraviolet and visible bands (wave length less than 0.7 μm) move almost unchanged through the cloudless atmosphere and are absorbed or scattered mostly by aerosols and by cloud particles. The absorbed by clouds and by the ground surface solar radiative energy is the main energy source of atmospheric processes and of all other phenomena on the Earth.

According to the well known physical Stefan-Boltzmann law the black body model total radiance B(T) is proportional to the fourth power of the absolute temperature T: $B(T) = \sigma T^4$ and the Wien displacement law $\lambda_{max}T = A$ = constant states that the maximum emission wave length λ_{max} is inversely proportional to T. This means that the radiative flux emitted from the "averaged" Earth surface (T = 293 K) peaks at about 9.9 μm wave length while radiation emitted from the tropical lower stratosphere ($T \approx 200$ K) has maximum intensity at 14.5 μm wave length. The observed intensity of solar flux at 0.47 μm corresponds to T = 6 100 K of solar surface.

Due to rather small absolute temperature variation in the atmosphere and at the Earth surface the Stefan-Boltzmann formula may be linearized making the linear connection between the radiance ΔB and temperature ΔT variations. This connection is the basis of the well known M.I. Budyko formula $B_o = A + B\ T_s$ for the outgoing long wave radiation B_o at the top of the atmosphere where T_s is the ground level temperature and A and B parameters depend on the cloud coverage. This simple relation was obtained from the analysis of global observational data and it is widely used in climate studies with parameter values A = 202 Wm^{-2}; B = 2.1 $Wm^{-2}K^{-1}$ for T in K; B_o in Wm^{-2} and assuming that the global cloud coverage is about 0.5.

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Bibliography

Climate change. *The Intergovernmental Panel on Climate Change Scientific Assessment (1990).* /Eds. Houghton J.T., Jenkins G.J., Ephraumis J.J. - Cambridge University Press, UK, 365p. [This contains the scenarios of probable emissions of greenhouse gases, including methane, during 21st century and change of atmospheric composition due to these scenarios.]

Climate Change 1994 (1995). *Radiative Forcing of Climate Change and an Evaluation of the IS92 Emission Scenarios* /Eds. Houghton J.T., Meira Filho L.G., Bruce J., Lee Hoesung, Callander B.A., Haites E., Harris N., and Maskell K. - Cambridge University Press, UK, 339p. [This evaluates the climatic effect of evolution of the "Earth-atmosphere" system due to natural and anthropogenical factors.]

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. [This is comprehensive most update review of current knowledge of climate system and of its current and future state.]

Forster P.M. de F., R.S. Freckleton and K.P. Shine (1997). On aspects of the concept of radiative forcing. *Climate Dynamics*, **13**, 547-560. [An important refining of general concepts and methods of radiative forcing calculations.]

Karol I.L. (1998). *Global Climate Warming and Stratospheric Ozone Depletion Potential as Environmental Change Indices. Environmental Indices. Systems Analysis Approach* /Eds. Pykh Yu.A., D.E. Hyatt, R.J. Lenz. EOLSS Publishers Co., Oxford UK, 680p. [Paper introduces the GWP, ODP and Global Warming Commitment factors and discusses their connections and using in various assessments.]

Peixoto J.P. and A.H. Oort (1992). *Physics of Climate*. Amer. Inst. of Phys., N.Y., 520p. [A comprehensive review and analysis of the Earth's climatic system components and interactions and of their basic physics.]

Pinnock S., M.D. Hurley, K.P. Shine, T.J. Wallington and T.J. Smyth (1995). Radiative Forcing of climate by hydrochlorofluorocarbons and hydrofluorocarbons. *Journal of Geophysical Research* **100**, 23 227-23 238. [Results of infrared spectra measurements and calculations of RF and HCFCs and HFCs are presented.]

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.