CLIMATE SENSITIVITY STUDIES WITH RADIATIVE-CONVECTIVE MODELS

by

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CERTIFICATE

This is to certify that the thesis entitled "CLIMATE SENSITIVITY STUDIES WITH RADIATIVE-CONVECTIVE MODELS", being submitted by Mr. Atul Kumar Jain for the award of the degree of DOCTOR OF PHILOSOPHY, is, a record of the original bonafide research work carried out by him. He has worked under our joint supervision and has fulfilled the requirements for the submission of this thesis. The results presented in this thesis have not been submitted in part or full to any other University or Institute for award of any degree/diploma.

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SUMMARY

This thesis focusses on the numerous climate sensitivity experiments that have been performed by the author with the aid of one-dimensional radiative-convective (RC) model described in Ramanathan (1981). This model has several advantages over other models including its ability to realistically simulate the feedbacks between surface temperature, water vapor, cloud cover and a number of major and minor optically active trace constituents in the atmosphere. The primary objective of our experiments has been to examine the relative contributions of increasing anthropogenic constituents on the changes in the thermal structure of the globally-averaged atmosphere and to elucidate their potential role in future climate trends.

It is not possible in 1-D RC models to include adequately the contributions to global mean energy fluxes that arise from coupling horizontal variation of thermal fluxes with horizontal variation of other parameters such as temperature, cloudiness and ice and snow cover. With this in view, a 2-D RC model has been developed and applied by the author for climate sensitivity studies which are also discussed in detail in the thesis. A brief outline of the thesis is as follows:

Chapter 1 gives a brief account of the relevance of radiative-convective processes for studies pertaining to the climate theory and climate change.

A comprehensive description of the 1-D RC model adapted for our study is described in Chapter 2. In particular, we discuss the technique of detailed radiative transfer analyses for the earth's atmosphere as incorporated in the model. The chapter highlights the importance of various interactive feedback mechanisms incorporated in the model. Also discussed herein is the observational data prescribed in the model with a detailed list of their sources.

Chapter 3 discusses the significant findings of various numerical experiments performed on the sensitivity of the model in relation to radiative and other physical processes governing the thermal structure of the atmosphere. We describe in detail the dependence of model computed surface temperature changes due to perturbations in atmospheric CO_2 and solar insolation on the radiative and convective processes viz., convective parameterisations and H_2O-long wave radiative treatment which are important in the warmer regions (e.g., tropics) of the present-day atmosphere.

Chapter 4 highlights the significant role of a large number of minor trace gases on the atmosphere's thermal structure which have undergone substantial changes during the last few decades under the influence of anthropogenic effects as inferred from our study using 1-D model. The model computed changes in the atmospheric thermal structure for perturbations in each of the 8 species of atmospheric trace constituents are presented. The relative contribution of each of the trace gases to the lowering of surface equilibrium temperature from present-day atmosphere to that of the pre-industrial atmosphere are discussed. Our calculations of both shortwave and infrared radiation fluxes also include the presence of background tropospheric aerosols with their observed optical characteristics.

In Chapter 5 we describe a detailed structure of the two-dimensional radiative-convective model which includes meridional heat transport and impacts of surface albedo and lapse rate feedback mechanisms. This model has been developed to calculate a mean annual zonally-averaged temperature profile for 18 latitudinal belts each of 10^o width with symmetry on both sides of the equator. The source of climatological parameters which specify the annual mean zonally-averaged climatic state and serve as a basis for calculating zonally-averaged thermal structure of the model atmosphere are also listed.

Chapter 6 begins with a presentation of the mean annual zonally-averaged thermal structure for the standard atmosphere as simulated by the model under equilibrium condition and then proceeds to analyse the meridional distribution of climatic response to doubled CO_2. The model has also been applied to evaluate the impact of atmospheric aerosols on the earth's climate and the results are discussed in this chapter.

The performance of 2-D model enabled us to formulate local radiative-convective model for its application to investigate climatic implications of depletion of atmospheric ozone in Antarctica, the findings of which are presented in Chapter 7.

The last chapter summarises the major findings of our numerical experiments on climate changes with 1-D and 2-D RC models. The 2-dimensional model presented in this thesis is computationally efficient as well as highly flexible in that improved feedback mechanisms can be easily incorporated for future climate sensitivity studies. As an improvement to the total heat transport mechanism parameterized in our 2-D model, the inclusion of individual transport mechanisms e.g., latent heat transport may provide further insight in climatic response to external forcings. This could be accomplished by either existing flux parameterizations, or continued research in the area of geophysical fluid dynamics.

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