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RADIATIVE TRANSFER MODELING

(Final report for Grant NCC 2-665)

Our research efforts addressed theoretical work in radiative transfer which focused the following five major items:

(1) Development of three dimensional radiative transfer methods
(2) Improvement to and maintenance of radiative transfer codes
(3) Creating new data-sets to define absorption by atmos.gases
(4) Model tests and validations with data from field experiments
(5) Model application to study climatic impact of aerosol/clouds

For each subject a few of our research results are summarized below:

(1) We successful developed several 3-D radiative transfer codes, an accurate method and an approximate method. The accurate method is build around the Monte-Carlo principle and slow. The other method is based on a subdivision by cubes, with interactions only limited through the normal of the cube's interfaces. Even though this method correctly reproduces increased transmission and reduced reflection and absorption for less homogeneous media, the restriction to a few scattering directions limits its accuracy, especially in anisotropic scattering media such as clouds. Even though corrections, such as an artificial transfer from the sides to the forward direction, provided some improvement, more than six directions seem necessary for an adequate representation of the scattering pattern of inhomogeneous cloud structures.

(2) We added a Monte-Carlo code as well as a faster four-stream code to our radiative transfer program library. We also conducted improvements to the program shell. It is now easier to prescribe atmospheric conditions and to understand the model results.

(3) We successfully derived from the HITRAN'92 data-base (for absorption by atmospheric trace-gases) sets of k-distribution coefficients for the infrared radiative transfer. We showed that even with a few carefully selected weight points and coefficients derived heating rates - even for the stratosphere - are in good to heating rates from elaborate line-by-line calculations.

(4) We validated model assumptions for cirrus properties based on a comparison of our model output to field measurements from the FIRE field experiments. Our comparison suggest that the cirrus microphysical assumptions (from geometrical optics simulations) are well described, however, that the neglect of macrophysical (cirrus cloud structure) effects with commonly used 1-D models can create significant errors.

(5) We investigated with our semi-climate model the effects of enhanced aerosol in the lower stratosphere following a major volcanic eruption in the tropics (Mt.Pinatubo) as function of time and latitude. Our calculated changes to the energy balance of the Earth Atmosphere System is in an overall agreement to satellite observations. Deviations for the solar and infrared spectral regions individually were found to be larger and anticorrelated. This is most probably caused by changes in cloudiness, for which no accurate data are currently available.

We also investigated with our radiative transfer models claims of unexplained solar absorption under cloudy conditions. We believe that this in part can be explained be effects of the overlooked cloud-structure. However, apparent underestimates of solar attenuation by models under cloud-free conditions are contributing. The reason for the clear-sky discrepancy, too large as to be attributed to measurements or model-method errors, is still subject to speculation.