A Stochastic Formulation of Radiative Transfer in Clouds and Radiative Properties of Non-Uniform Clouds

G. L. Stephens
P. D. Gabriel
Colorado State University
Department of Atmospheric Science
Ft. Collins, CO 80523

Introduction

The research conducted as part of these projects breaks down into three broad areas:

1. Radiative transfer involving study of the radiative transfer in 2/3 dimensions as well as the issue of stochastic transfer.
2. Radiative transfer parameterization for use in general circulation models (GCMs) and other climate models.
3. Remote sensing focusing on using our radiative transfer knowledge to address key issues concerning the remote sensing of clouds. In this regard, we focus on new ways of remotely sensing cirrus ice water content.

A list of publications in various stages of progress is provided at the end of this paper.

Radiative Transfer

Our research on radiative transfer has developed along three directions. The first deals with development of Monte Carlo models that are used to test out the numerical models. The second stage involves the development and testing of these numerical models. Two different types of numerical solutions have been formulated and results comparing these with Monte Carlo solutions were presented. The agreement between all models is excellent.

Parameterization

This effort has not progressed as far nor as quickly as the radiative transfer work described above. We seek to develop these parameterizations using a stochastic transfer formulation as an overall framework. Aspects of the parameterization problem have been addressed (such as parameterization single scatter properties of clouds), and we hope to have a coherent set of models available in the near future.

Remote Sensing

In this research we describe new methods for the remote sensing of cirrus. The idea is to utilize measurements of high-frequency microwave radiation which are modulated primarily by scattering of ice particles. The advantage of this method is that both the temperature of the cloud and the properties of the underlying atmosphere are not important to the upwelling radiation measured above the cloud. Other advantages were described. Difficulties associated with the idea arise from the effect of particle shape and size on the scattering. A quantitative assessment of this effect was given using scattering calculations based on the discrete dipole approximation. We propose to extend this research and hope that these new methods will be exploited in future ARM research using airborne platforms.

Publications

Evans, K. F., and G. L. Stephens. 1992. A Theoretical Basis for Passive Microwave Remote Sensing of Cirrus. Reprint: *Specialist Meeting on Microwave Radiometry and Remote Sensing Applications*. Boulder, Colorado, January 14-16, 1992.

Evans, K. F. 1992. Two-dimensional Radiative Transfer in Cloudy Atmospheres: Part I: Spherical Harmonic Spatial Grid Model. Submitted to *J. Atmos. Science*.

Evans, K. F. 1992. A Fast Multi-Dimensional Radiative Transfer Model. In proceedings of the *International Radiation Symposium*, Tallinn, Estonia, August 1992.

Gabriel, P., S-C Tsay, and G. L. Stephens. 1992. A Fourier Riccati Approach to Radiative Transfer, Part I: Foundations. Submitted to *J.Atmos. Science,* July 1992.

Gabriel, P., S-C Tsay, and G. L. Stephens. 1992. A Fourier Riccati Approach to Radiative Transfer, Part II: Spectral Heating Rate. In preparation.

O'Brien, D. M. 1992. Accelerated Quasi-Monte Carlo Integration of the Radiative Transfer Equation. *J. Quan. Spectrosc. Radiat. Transfer* 48:41-59.