Monte Carlo Simulation of Longwave Fluxes Through Broken Scattering Cloud Fields

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Introduction

The importance of cloud fields on the radiative energy budget is well known. For the sake of computational efficiency, cloud fields in general circulation models (GCMs) are approximated as flat black plates. This neglect of cloud geometry and transmissivity can lead to significant error in predicting radiative transfer. Increasing the sophistication of cloud models in GCMs has become a priority.

Proper modeling of clouds requires that both their geometry and optical properties be taken into account. Modeling clouds as flat plates neglects the geometry. It has been well documented that the sides can have a significant effect (Ellingson 1982; Harshvardhan and Weinman 1982; Killen and Ellingson 1994). In addition, clouds absorb and scatter. Scattering plays a significant role in the visible portion of the spectrum. The parameterized single scattering albedo for a cloud in the visible is above 0.99 (Hu and Stamnes 1993). As a result, most of the work on scatter in cloud fields has been done in the shortwave regime (Welch and Wielicke 1984; Evans 1993; Breon 1992). The parameterized cloud single scattering albedos in the long wave ranges from 0.5 to 0.75 (Hu and Stamnes 1993).

Model

One challenging aspect of modeling cloud fields is the fact that they are usually broken and irregular. This irregularity is extremely difficult to model in most methods; however, the Monte Carlo method adapts readily. For this reason, a Monte Carlo model based on a rectangular grid with constant optical properties within the grid was used. Note that the smaller single scattering albedos in the longwave leads to considerably shorter run times than those in the visible.

To simplify the analysis, we made several assumptions: the clouds were cuboidal; they were all identically sized and shaped; and they had constant optical properties.

Results and Discussion

The model was run for a set of cloud fields with clouds of varying optical thickness and scattering albedo. The predicted effective cloud fractions are shown in Figure 1, for cloud optical thicknesses (L) of 10 and 100. A single scattering albedo of 0.75 and Henyey-Greenstein coefficient of 0.65 was chosen (Hu and Stamnes 1993). Increasing the optical thickness beyond 100 does not change the effective cloud fraction. The lower effective cloud fraction for L=10, maximum difference at N=0.5, is the result of increased transmission through the cloud sides. This effect diminishes as the cloud fraction increases.

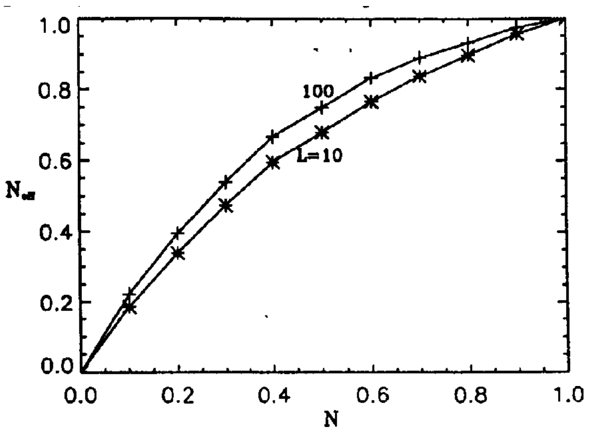

Figure 1. N_{eff} versus N for various optical thicknesses (L).

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