Cirrus Horizontal Inhomogeneity and OLR Bias

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Introduction

Clouds exhibit dramatic variabilities at spatial scales smaller than typical grid cells of large-scale models used to study climate and weather. These unresolved cloud fluctuations are potentially important for parameterizations of both cloud radiative effects and cloud microphysical processes (e.g., Harshvardhan and Randall 1985; Jacob and Kein 1999). It is now well accepted that neglect of cloud subscale variability can seriously bias model estimates of the disposition of solar radiation in the earth-atmosphere system (e.g., Cahalan et al. 1994a; Barker 1996).

Much research has gone, and is going, into both investigating solar radiative transfer in horizontally inhomogeneous clouds (e.g., Stephens 1988; Evans 1993; Cahalan et al. 1994b; Fu et al. 2000) and developing techniques suitable for use in large-scale models (e.g., Cahalan et al. 1994a; Barker 1996). Of particular interest now is the development of accurate and efficient solar radiative transfer schemes to treat the cloud inhomogeneity (e.g., Oreopoulos and Barker 1999; Barker and Fu 1999; Barker and Fu 2000; Cairns et al. 2000), and the development of parameterizations to relate the cloud subscale variability to information available within the large-scale models (e.g., Considine et al. 1997; Pincus et al. 1999; Smith and Del Genio 2000).

By contrast, little attention has been given to the longwave radiative transfer within an inhomogeneous cloud (Stephens 1988). Previous studies have addressed the cloud geometry effects on longwave fluxes and heating rates (e.g., Liou and Ou 1979; Harshvardhan and Weinman 1982; Ellingson 1982). Here, we focus on the effect of horizontal inhomogeneity within cirrus clouds on the longwave radiative energy budget.

Main Results

In this study, we have examined the outgoing longwave radiation (OLR) bias due to the neglect of cloud horizontal inhomogeneities. It is argued that the OLR bias is most significant for semi-transparent cirrus clouds that are located in the cold upper troposphere. Using two cirrus cases observed at the

Atmospheric Radiation Measurement (ARM) Program Southern Great Plains (SGP) Cloud and Radiation Testbed (CART) site by cloud radar, it is found that the OLR biases due to the PPH assumption are ~14 W m^{-2}, which are largely caused by the horizontal variation of cloud optical depth. It is also shown that in general, the OLR biases are strongly dependent on the mean and standard deviation of cloud optical depth and the cloud height. We have demonstrated that the gamma-weighted radiative transfer scheme, which is sufficient for general circulation model applications, can be used to account for the effect of cloud horizontal inhomogeneity on the infrared fluxes. See Fu et al. (2000) for more details.

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