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SENSIBILITY OF CIRRUS RADIATIVE FORCING TO CLOUD MICROPHYSICAL AND OPTICAL PROPERTIES

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1. Introduction

Cirrus clouds are believed in general to have potential 'warming' effect on the earth's system as that by greenhouse gases. However, the effect of cirrus clouds depends on the difference between reflective and absorptive properties of the clouds, which are relevant with cloud microphysical features and optical properties of cloud crystals. In this work, cloud radiative forcing (CRF) was estimated for cirrus clouds with various kinds of microphysical features that based on the field-measured results collected from ICE, EURCEX and FIRE (Koch, 1996; Gayet et al., 1996; Arnott et al., 1994) and with optically spherical and nonspherical ice crystals. Currently, there are several kinds of definition to CRF. The instantaneous cloud radiative forcing is chosen here and defined as changes in radaitive budget at the top of atmosphere due to the cloud effects.

2. Method

A cloud microphysics-radiation model is employed for this research. The evaluation of CRF is based on the same atmospherical fields and surface albedo.

Nonspherical shapes of ice crystals chosen in this work are hexagonal column and random fractals that both exist commonly in cirrus clouds. Previous research by Macke et al. (1996) indicates that the optical properties of the former, hexagonal column, could representative for those of all column type ice crystals. The polycrystals with highly complex shape denoted as fractals have smooth angular dependency and relatively large side scattering. The optical parameters of the nonspherical ice crystals are calculated by ray-tracking method.

Single-modal and bi-modal patterns of ice particle size distribution are considered for the estimation of CRF.

3. Results

It is found that pattern of crystal size spectrum (single-mode or bi-mode), shape of ice crystals (spherical or non-spherical), the mean size and concentration of ice crystals are the essential microphysical features of cirrus clouds influencing the cloud radiative forcing. It is also confirmed that the normal natural cirrus that with single-modal crystal size distributions and with relative large ice crystals have the positive cloud radiative forcing, i.e. the potential impact of greenhouse warming to the earth system. However, for contrail-induced cirrus with extreme microphysical features (i.e. with huge number of small ice particles), the cloud radiative forcing would be negative. It means that the contrail cirrus clouds have potential cooling effect on the earth system. It is also found that cirrus clouds with bi-modal size distribution of ice crystals tend to have less warming effect or even cooling effect when the second maximum mean size of ice particles are relatively large, comparing to single-modal size distribution of ice crystals with the same value of IWC. Cloud radiative forcing also depends greatly on the ice crystal shape (in this work, hexagonal column and random fractals). Since nonspherical ice particles have higher albedo effects, the radiative forcing of cloud containing nonspherical ice crystals is much lower than that with optically spherical particles. When the second maximum size is relative large (> 170 μm for IWC=10 mgm^{-3}), the radiative forcing of cloud with bi-modal size spectrum of nonspherical ice particles is negative.

4. Conclusions

The results of evaluating CRF in this work indicates that CRF is essentially sensitive to the pattern of the size distribution, mean size and shape of ice crystals. Cirrus clouds with large number of very small crystals (e.g. contrail cirrus) have 'cooling' potential impact to climate, in stead of 'warming' one.

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