A Modeling Study of Aerosol Indirect Climate Effects

1 Introduction

The interactions among clouds, aerosols and radiation not only are one of the most uncertain factors, but also a difficulty in current climate study. Aerosol particles can be used as cloud condensation nuclei (CCN) or ice nuclei to change cloud microphysical and radiative properties and lifetimes. This is called indirect climate effect of aerosols (Guangyu Shi *et al*., 2008) [1]. Generally, the indirect climate effect of aerosols can be divided into two kinds: one means that when liquid water content is stable in clouds, the increase in aerosol particles can increase cloud droplet number and reduce cloud droplet effective radius, leading to the increase in cloud albedo; this is called cloud albedo effect. The other means that the reduction of cloud droplet effective radius caused by the increase in aerosol particles would weaken cloud precipitation efficiency and increase cloud lifetime or the amount of condensation water in clouds, leading to the increase in the temporal or local mean of cloud albedo; this is called cloud lifetime effect

The relationship between aerosol and cloud microphysical property was found by scientists long ago. The previous observational studies have shown that smokes from forest fires could increase cloud droplet number concentration and cloud droplet effective radius (Warner, *et al.*，1967 ；Eagan, *et al.*，1974) [2,3]. Recently, based on observational studies, a significant progress has been made in the study on aerosol indirect climate effects, especially the study on lower stratus; a set of relatively simple cloud observational system has been established. Nakajima *et al.* (2001) [4] had analyzed the relationship between marine aerosol column content and column cloud droplet number concentration by using AVHRR satellite observation data; the result showed that there was a positive correlation between them and the reflectance of lower warm cloud would increase with the increase in cloud optical thickness. The study by Twohy *et al.* (2005) [5] pointed out that in some heavily-polluted areas the cloud liquid water content would decrease, so did the cloud reflectance correspondingly. Chunsheng Zhao *et al.* (2005) [6] used atmospheric aerosol and cloud spectral-bin model to study what roles sea-salt aerosol and sulfate aerosol play in cloud microphysical process; the result showed that sea-salt and sulfate aerosols have some effects cloud droplet number concentrations. Moreover, the aerosols also have some influences on ice-nuclei number concentrations and sizes in mixed-phase cloud (Lohmann, 2004; Seifert, et al., 2006) [7, 8]. Nevertheless, no conclusion about how significant the influence of aerosol particles on higher clouds is has been reached by now. Because of the limitation of observational conditions, Global Climate Model (GCM) should be used as a very important tool to make research on aerosol indirect climate effects in recent years. After summarizing different models, IPCC(2007)[9] concluded that the radiative forcing influenced by cloud albedo of anthropogenic aerosols is in the range of -0.22to -1.85 W/m^2; the radiation flux influenced by cloud lifetime varies in the range of -0.3 to -1.4 W/m^2. Presently, there are a lot of uncertainties in aerosol indirect climate effects and further study should be required. Atmosphere General Circulation Model at National Climate Center,

In this paper, aerosol indirect climate effects have been studied by using the atmospheric general circulation model BCC_AGCM2.0.1 of National Climate Center of China Meteorological Administration. In the second part of this paper, the general situation of the model, the parameterization scheme for aerosol-cloud interaction and experiment design are introduced; in the third part different aerosol indirect climate effects are discussed; the forth part is the conclusion in this paper.

2 Model description and method

2.1 General situation of the model

The atmospheric general circulation model BCC_AGCM2.0.1 of National Climate Center of China Meteorological Administration is developed on the basis of NCAR Community Atmospheric Model (CAM3) and has a very good capability in climate simulation (the introduction, improvement and simulation effect of BCC_AGCM2.0.1 are shown in the references Wu, et al., 2008a, 2008b) [10, 11]. In this model, triangle truncation in the horizontal direction at the wave number of 42 (T42) is used (T42, approximating $2.8^o x 2.8^o$) and a mixed σ-pressure coordinate, , is adopted in the vertical direction, which is divided into 26 layers with the top layer pressure of 2.9 hPa. The two-stream δ-Eddington approximation of Spectral Band 19 is used as a radiative parameterization scheme (Briegleb, 1992) [12]. The parameterization scheme by Slingo (1989) [13] is used for the calculation of water cloud radiation. In the model, the NCEP reanalysis data about the monthly mean of weather changes in 1971-2000 is used as the initial field; the quality concentrations of aerosols are calculated through an aerosol assimilation system consisting of the MATCH (Model of Atmospheric Transport and Chemistry) and the satellite inversion of aerosol optical thickness (Collins, et al., 2001) [14].