Sensitivity experoments of regional radiative forcing due to dust aerosol under clear sky condition : Possible collaboration with Kanazawa University 21COE

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Possible collaboration with Kanazawa University 21COE

G.-y. Shi[1], H. Wang[1,2], B. Wang[1], S. Gong[3], T. Zhao[3], W. Li[1], and T. Aoki[4]

[1]State Key Laboratory of Numerical Modeling for Atmospheric Science and Geophysical Fluid Dynamics, Inst. Atmosph. Physics, CAS, Beijing 100029, China

[2]Center for Numerical Prediction Research, Chines Academy of Meteorological Science, China Meteorological Administration, Beijing, 100081, China

[3]Air Quality Research Branch, Meteorological Service of Canada, Tronto, Ontario, Canada [4]Meteorological Research Institute, Ibaragi 305-0052, Japan

Abstract.

Numerical sensitivity experiments to evaluate the impacts of optical characteristics on the radiative forcing have been performed in this study. The experiments involve in the effects of refractive indices, single scattering albedo, asymmetry factor and optical depth. An updated data set of refractive indicates representing East Asian Dust and the data recommended by World Meteorology Organization are used in our calculations. A k-distribution model for solar and thermal radiation transfer is employed. Studies show that comparing with WMO dust model, East Asian Dust model has stronger scattering and weaker absorption at solar regime, which leads to higher negative forcing at the top of atmosphere (TOA). The more important is the signs of radiative forcing at TOA over deseart regions could be reversed for the two dust models, which emphasizes the essentiality of accurate measurements of optical properties of dust aerosols for accurate estimating of radiative forcing.

1 Introduction

Dust aerosol is considered to be one of the major species of atmospheric aerosols (Penner et al., 2001). It can affect the earth's radiation budget and then the global atmospheric circulation and climate change. However, there are large uncertainties in the quantitative assessments of radiative effect due to dust (Rumaswamy et al., 2001; Sokolik et al., 2001, Tegan et al., 1996). Studies indicate that uncertainties in optical properties, including refractive indices, extinction coefficient, single scattering albedo, asymmetry factor and optical depth of dust particles are responsible for large fraction of the uncertainty in their radative forcing (Sokolik et al., 1993, 1996, 1998; Takemura et

al., 2002).

Studies (Zhang et el., 2003; Gong et al., 2003) showed that the dust storm occurred from 4 to 15 in 2001 spring is a very strong one with the longest transportation from East Asia crossing Pacific Ocean to the west coast of America, which is called as "perfect dust storm". In this paper we mainly focused on this dust storm to evaluate the radiative forcing over east Asia and North Pacific region (75E° - 225W°, 16 - 70N°) and examine the impacts of dust optical properties on it.

2 Data Description

Two data sets of refractive indices are used in this study. One is the latest East Asian dust model (Wang et al., 2004) obtained by analysis of the aerosol samples collected in western China desert during ADEC experiments (hereafter, noted as ADEC dust model) and another is the dust model recommended by WMO which has been widely used in the studies on dust radiative forcing calculations (Sokolik, 1993, 1998; Woodward, 2001).

The daily mean dust concentration data from April 4 to 15, 2001 are provided by NARCM model (Gong et al., 2003). The data of surface albedo are also taken from this NARCM model. The simulated domain covers the East Asia-North Pacific region from 75 E° to 225 W° and from 16 N° to 70 N°.

Daily averaged NCEP/NCAR 1°x1° reanalyzed meteorological fields including air temperature, pressure and humidity are employed as the background condition.

3 Radiative Transfer Model

The radiative transfer code of Shi (Shi, 1981, 1984, 1988; Wang, 1996; Wang et al., 2000) was employed in this paper, which is based on the k-distribution scheme incorporated into a two-stream model, dividing solar into five bands at the following wavelength: 0.18-0.36, 0.36-0.41, 0.41-0.86, 0.86-.89, 0.89-4.35 μ m with thirty-two k values and IR into seven bands at wavelengths: 4.35-8.33, 8.33-10.64, 10.64-12.35, 12.35-13.70, 13.70-15.87, 15.87-18.87,18.87- μ m with forty-eight k values. Radiative effects of Rayleigh scattering, gases (including H2O, CO2, O3, N2O, CH4, etc.) absorption, the detailed cloud and aerosol schemes are included in this code.

4 Experiments Description

In this section we focused on the dust storm occurred from April 4 to 15, 2001 to discuss the effects of optical features on radiative forcing in regional scale. Several

experiments have been performed to do this. Clouds are excluded and all the results are shown for clear sky.

5 The Effects of Optical Properties on Radiative Forcing

Generally speaking, the radiative forcing under clear sky in the Earth-atmosphere system depends not only on their absorption and scattering of short wave and long wave radiation, but also on the underlying surface condition. When the surface albedo is lower the adding aerosol leads generally a negative forcing, and vice versa. This is the reason for occurrence of different forcing over different regions. The absolute values of negative forcing over Pacific Ocean are larger than the values over land area, with a center in excess of -12 Wm^{-2} in the ocean north to Japan, which is resulting from the synthetic influence of lower surface albedo and high dust loading.

Refractive Indices, Optical Depth, Single Scattering Albedo, and Asymmetry Factor are discussed on the basis of the numerical experiments.

6 Summary and Future Study

Based on the updated dataset of refractive indices representing East Asian Dust and the dust loading provided by CARCM model, radiative forcing due to dust aerosol are calculated and analyzed. The peak value of TOA forcing of severe dust storm on 4-15 April 2001 is in excess of -12 Wm^{-2} and surface forcing reaches up to -70 Wm^{-2} over middle Inner Mongolia.

Several sensitivity experiments have been performed to evaluate the impacts of optical properties of dust aerosols on their radiative forcing. The results show that radiative forcing strongly depends on its optical parameters including refractive indices, SSA, asymmetry factor and optical depth. Comparing with the surface forcing, the TOA forcing is much more influenced by the dust optical parameters. Not only the magnitude but also the sign of TOA forcing may be changed by the refractive indices, SSA, asymmetry factor. In general, the solar radiative forcing more sensitive to changes in optical parameter than longwave radiative forcingexcept for refractive indices and optical depth. TOA forcing over desert area is more sensitive the optical properties than the forcing over ocean region.

Much more attention has been paid on the effects of dust refractive indices as the other optical features of dust may substantially are affected by it. East Asian dust particles have smaller imaginary parts and larger real part of refaractive indices than WMO dust model, which leads to less absorbing and more scattering of solar radiation, therefore yields stronger negative forcing, weaker positive forcing than WMO dust model.

It should be pointed out that if the WMO dust model is used, the positive forcing would be overestimated, negative forcing be underestimated and even the sign may be reversed over East Asia to North Pacific region, where is mainly influenced by the East Asian dust. This result suggests, in order reduce the uncertainties in estimation of regional or global radiative effects due to dust aerosol, that the most important thing is to further measure the physical and chemical characteristics, especially the optical parameters such as refractive indices of dust particles over various deserts and their changes on the physical and chemical characteristics during long range transportation.

Asian dust researches performed through Kanazawa University 21COE program also is desired to contribute to obtain useful knowledge to reduce the uncertainties in estimation and assessment of radiative effects on regional environment and/or climate changes.

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