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COMPARISON OF ON-LINE COUPLED AND CONSTANT TRANSFER SIMULATION METHODS FOR DIRECT RADIATIVE FORCING OF ANTHROPOGENIC SULFATE

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1 INTRODUCTION

Of three main methods for studying the radiative forcing of anthropogenic sulfate and climatic response on the regional scale, the first is, with given rates for transforming SO_2 to sulfate, converting actually released SO_2 into sulfate and acquiring the distribution of sulfate by computing transfer equations in the climate model. The second is obtaining the sulfate distribution through chemical reaction and transfer of matters in regional climate models online coupled with an atmospheric chemistry model that includes full chemical reactions for sulfides[1]. The third is to put sulfate distribution data from GCM and its coupled atmospheric chemistry model to regional climate model, which is so called off-line coupled method. As shown in comparisons between the online and offline modeling on the regional scale, the radiative climate effect of sulfate shows large uncertainty due to significant influence from various methods.

To understand the differences between results determined with the online and fixed rates of transfer and their applicability, the current paper, based on cases in China, compares the main differences in sulfate distribution, radiative forcing and climatic response as determined with the fixed transfer rate and online modeling in regional climate and atmospheric chemistry models. Causes are investigated for better understanding of the immediate climate effect of sulfate and its uncertainties.

2 BRIEF INTRODUCTION TO THE MODEL

Regional model RegCM2 comprises a column radiative model from the atmospheric circulation model CCM3, which takes into account the global mean base radiation of sulfate aerosols. The atmospheric chemistry model used includes the CB4 response, a mechanism considered reasonable across the world. There are 36 substances, 83 chemical reactions, of which 11 are for photodissociation reaction and 72 for thermal reaction, and the distribution of common substances and a number of rare substances, such as SO_2, SO_4, O_3 and NO_x, can be simulated. The model takes into detailed account of the transportation, dissipation and cleansing of various substances.

3 DATA AND SIMULATION SCHEME

The NCEP reanalysis data for Jan., Apr., Jul. and Oct., 2000 are the basis for initial field and lateral boundary forcing every 6 h for the regional climate model. The integration lasts for 45 days for each of the cases and the first 15 days are for spin-up time (initialization) and results for the remaining 30 days are analyzed. The center of the simulated region is at 105°E, 35°N, with 90-km horizontal grid space, 15 vertical layers and model top at the level of 100 hPa.

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The data used in the model are 1°×1° annual mean global pollution inventory[2] without seasonal changes, are interpolated to each of the gridpoints.

Three cases are simulated respectively for Jan., Apr., Jul. and Oct. Only the climate model is integrated in the first case as output without anthropogenic sulfate while the other two cases are simulated for the distribution of radiative effect of sulfate with the fixed transformission rate and online modeling method and differences are analyzed.

For the fixed transformation rate, 36.7% of released SO_2 (the Moore ratio) is taken as the substance of sulfate (being equivalent of a 55% mass transformation rate) [2], and processes of sulfate transportation and sedimentation, which are the same as those in the online modeling, are used in the model. One more substance is added to the chemical model to indicate SO_2, which takes part in the physical rather than chemical process. The rate at which SO_2 transforms to sulfate via chemical processes is determined from the model output that gives both modified and observed burdens of SO_2.

4 ANALYSIS

4.1 Comparison and verification of online simulations

To understand how well our simulation goes, the column burden of sulfate, direct radiative forcing at the atmospheric top and normalized radiative forcing, which are globally averaged over the year with a number of offline or online models as presented in the third IPCC assessment, are compared in terms of monthly mean over the four months for the region of interest in this work. As shown in the result, the above models yield results that are very close to those achieved with our online and offline simulation. The sulfate burden and radiative forcing are very similar to those in previous work on the regional scale in East Asia[3-5], suggesting reliable online model output.

4.2 Comparison and verification of online simulations

There are two obvious centers of sulfate distribution for the 4 months simulated with the fixed transformation rate, one being in Sichuan and the other in North China. There are small differences of distribution from month to month. For the online simulation, high levels of sulfate have been over the Sichuan area while a center of high values appears only in July in North China. There are two centers for each of the areas in July but only one for the remaining months. Even for the regional mean, the sulfate burden with the online method also sees significant seasonal changes while the fixed rate method does not have change as much. In addition, it is also noted that the sulfate obtained with the latter method distributes in much larger ratio in higher latitudes, giving rise to some deviation in terms of sulfate distribution.

With seasonal changes in the condition for chemical reaction with the online method, the transport of atmospheric circulation also varies, making it possible for substantial seasonal changes to appear in the sulfate burden simulated. With unchanged rates for all seasons and areas, the fixed transformation method does not describe objectively the effect of changes in the transformation rates between gas and liquid phases, which are resulted from seasonal factors like solar radiation, cloudage, vapor content in clouds and precipitation, on the level of sulfate. Consequently, the result only includes seasonal changes caused by the transport of atmospheric circulation, much less significant than with the online method. It is one of the main differences between them. Additionally, the results obtained with the fixed transformation rate also differ much with those achieved with either the online or offline method. The difference of sulfate burdens as simulated with the two methods will inevitably result in differences in radiative forcing.

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