A study of regional and long-term variation of radiation budget using general circulation model

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Abstract

The analysis of solar radiation at the surface has great importance for the study of climate change, because scattering and absorption of solar radiation by green house gases and anthropogenic aerosol particles can result in a net decrease in global irradiance that reaches the ground. So, we can get the information about impact of human activity on climate from radiation data. In this study, we took particular note of effect of aerosol on climate. Because aerosol particles have a great impact on climate change through causing air pollution, reducing solar radiation, changing cloud property and so on. And anthropogenic aerosol emission increased with economic growth. To clarify the relation between human activity and climate change, estimating effects of aerosol on climate is one of the significant issues. *

The model that we used in this study is aerosol transport model called SPRINTARS [Takemura et al., 2000, 2002, 2005]. This model is coupled with CCSR/NIES/FRCGC Atmospheric General Circulation model and treats carbonaceous, sulfate, mineral dust and sea salt aerosols from various emission sources. There are two effects of aerosol particles on radiation. One is the direct effect that aerosol particles scatter and absorb radiation and the other is the indirect effect that aerosol particles change the property of cloud. Then the indirect effect can be divided into two categories and our model treats the first and second indirect effect.

From comparing the model simulation results with the surface observed data for variables relating to radiation budget, we have a good correlation between observation and model simulation in seasonal and annual trends. Both data show that anthropogenic aerosol increase caused solar radiation decrease in the industrial regions such as China where economic development is happening. Then we calculate contributions of aerosol effect on radiation from our model simulations. The next step is analysis of changing dynamical hydrological cycle by aerosol effect in this region.

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1. Introduction

Aerosol particles can influence the radiation budget not only directly by scattering and absorbing radiation, but also indirectly by changing the property of cloud that is the important role in climate change. After industrial revolution, emission of aerosol increased with economic growth. We study on relationship of anthropogenic aerosol increase to climate change and tried to estimate aerosol impact on climate.

2. Model description

We used the three-dimensional aerosol transport-radiation model, SPRINTARS [Takemura et al., 2000, 2002, 2005], that is driven by Center for Climate System Research (CCSR)/National Institute for Environmental Studies (NIES)/Frontier Research Center for Global Changing (FRCGC) Atmospheric General Circulation model [Numaguti et al., 1995]. This model treats carbonaceous, sulfate, mineral dust and sea salt aerosols. The aerosol transport processes include emission, advection, diffusion, sulfur chemistry, wet deposition, and gravitation settling. The radiation scheme in CCSR/NIES/FRCGC AGCM [Nakajima et al., 2000] is extended for the aerosol direct effect related to scattering and absorption by aerosol particles.

To compare the observed data, the model was forced to simulate the real atmospheric condition by a nudging technique with European Center of Medium-Range Weather Forecasts (ECMWF) reanalysis data of wind velocities, temperature, specific humidity and sea surface temperature. We simulated long-term trend from 1981 to 2000 with this model.

And we used anthropogenic aerosol emission inventory data sets [T. Nozawa et al., 2005]. The emissions of carbonaceous aerosols originating form biofuel, agricultural activity, and fossil fuel and the emission of SO_2 from fossil fuel are based on several databases from the Food and Agriculture Organization of the United Nations, Global Emissions Inventory and energy statistics in each nation.

3. Observational data

To investigate the trend of climate change, we also used surface observational data. The global radiation and direct radiation, sunshine duration and visibility are observed around the world. However few studies have attempted of compare these observational data with model simulation. We used observational radiation data provided by the Chinese Meteorological Office, the United Kingdom Meteorological Office, World Radiation Data Center (WRDC) and Global Energy Balance Archive (GEBA) and data about sunshine duration and cloud cover provided by Japan Meteorological Business Support Center. So, it’s one of the characteristics of our study to use model and surface observational radiation data.

4. Results and Discussion

At first, we compared model results and observational data in seasonal variation. Figure 1 is seasonal variation of model-calculated and observed global solar radiation, direct solar radiation, sunshine duration and cloud cover. We picked up some sites having adequate observational data. In Fig.1, left figure is data at Eskdalemuir in United Kingdom and right figure is data at Zhengdu in China. Model simulated seasonal trends are good correlate with observational seasonal trends. But, model simulated direct radiation over estimate and also value of sunshine duration and global radiation are greater than observational data and these discrepancies are large at low latitude and in summer. It is pointed out that GCMs show a tendency to overestimate the incoming solar radiation at the surface [Wild et al., 1995]. We found that from our simulation that one of the reason for overestimate surface solar radiation is underestimate aerosol amount in atmosphere.

Next, we show the annual variation of model simulated result and observational data. In order to check annual change, we subtracted annual mean sunshine hours averaged during 1980's from that averaged during 1990's (Fig.2). The sunshine hours show decrease trend in eastern China both in observational data and model in this term. Fig.3 is the change of model simulated aerosol optical thickness from 1980's average to 1990's average. This figure shows optical thickness increase over eastern China where sunshine duration decrease. Then we analyzed annual trend of radiation data over eastern China. Fig.4 shows the annual trend of radiation data averaged over six sites in eastern China. And it is found that direct radiation clearly decreased influenced decrease sunshine duration. Our model simulated aerosol optical thickness shows increase trend with anthropogenic aerosol emission increase. So, we concluded that anthropogenic aerosol increase over eastern China caused reducing sunshine reached the surface. The change of radiation forcing in clear sky averaged at these six sites from 1980's to 1990's are about –2W/m^2 at surface and –1W/m^2 at top of the atmosphere. The next step is analysis of changing dynamical hydrological cycle by aerosol effect in this region.

5. References

Nakajima, T., M. Tsukamoto, Y. Tsushima, A. Numaguti, and T. Kimura, 2000: Modeling of the radiative process in an atmospheric general circulation model, *Appl. Opt.*, **39**, 4869-4878.

Nozawa, T., and J. Kurokawa, 2005: Historical and future emissions of sulfur dioxide and black carbon for global and regional climate change studies, CGFR-REPORT, CGER/NIES, Tsukuba, to be published, 2005.

Numaguti A., M. Takhashi, T. Nakajima, and A. Sumi, 1995: Development of an atmospheric general circulation model, in Climate Systemre Dynamics and Modeling, edited by T. Matsuno, pp. 1-27, Cent, for Clim. Syst. Res., Univ. of Tokyo, Tokyo.

Takemura, T., H. Okamoto, Y. Maruyama, A. Numaguti, A. Higurashi, and T. Nakajima, 2000: Global three-dimentional simulation of aerosol optical thickness distribution of various origin, *J. Geophys. Res.*, **105**, 17,853-17,873.

Takemura, T., T. Nakajima, O. Dubovik, B. N. Holben and S. Kinne, 2002a: Single scattering albedo and radiative forcing of various aerosol species with a global three-dimentional model, *J. Clim.*, **15**, 333-352.

Takemura, T., T. Nozawa, S. Emori, T. Y. Nakajima, and T. Nakajima, 2005: Simulation of climate response to aerosol direct and indirect effects with aerosol transport-radiation model, *J. Geophys. Res.*, **110**, D02202, doi:10.1029/2004JD005029.

Wild, M., A. Ohmura and H. Gilgen, 1995: Validation of General Circulation model Radiatiove Fluxes using Surface Observations, *J. Clim.*, **8**, 1309-1324.

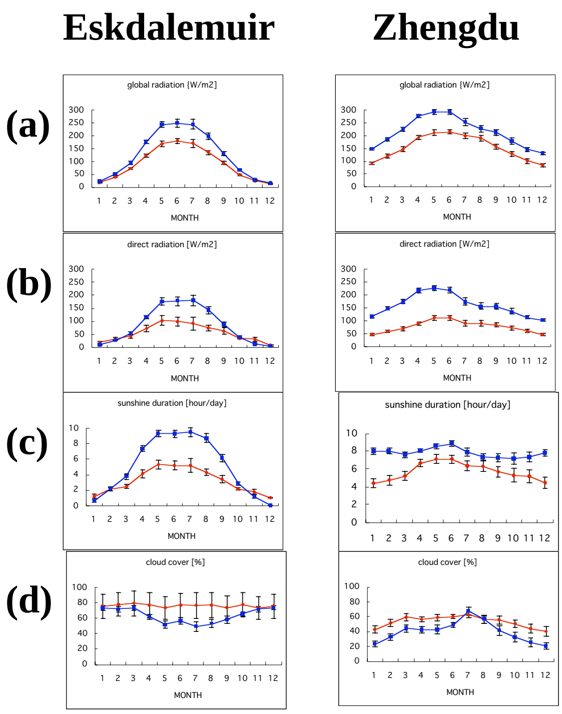

Figure 1. Seasonal variations of (a) global radiation [w/m^2], (b) direct radiation [W/m^2], (c) sunshine duration [hour/day] and (d) cloud cover [%]. Red lines indicate ground observation data and blue lines indicate model simulation. Error bars indicate standard deviation of each year.

Left: Eskdalemuir, U.K. (55.31˚N, 3.2˚W), averaged from 1983 to 1992.

Right: Zhengdu, China (34.72˚N, 113.7˚E), averaged from 1983 to 2000.

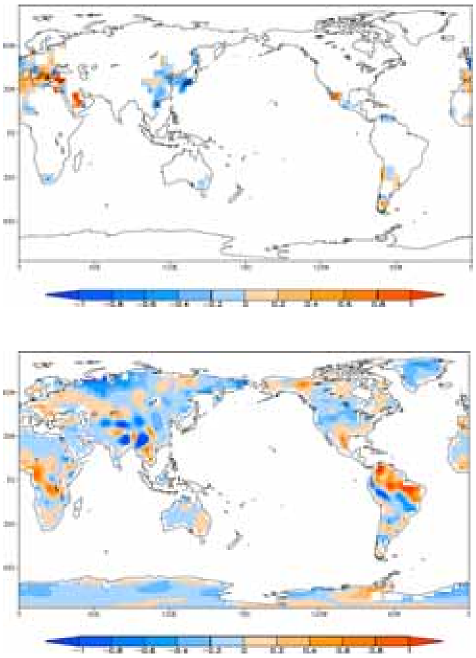

Figure 2. The difference between annual mean sunshine duration from 1991 to 2000 average and from 1983 to 1990 average.
Upper panel is observation and bottom panel is model simulation.

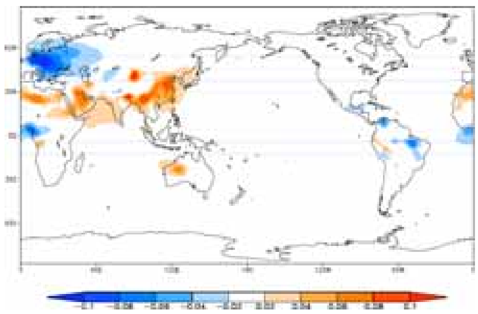

Figure 3. The difference between simulated annual mean aerosol optical thickness from 1991 to 2000 average and from 1983 to 1990 average.

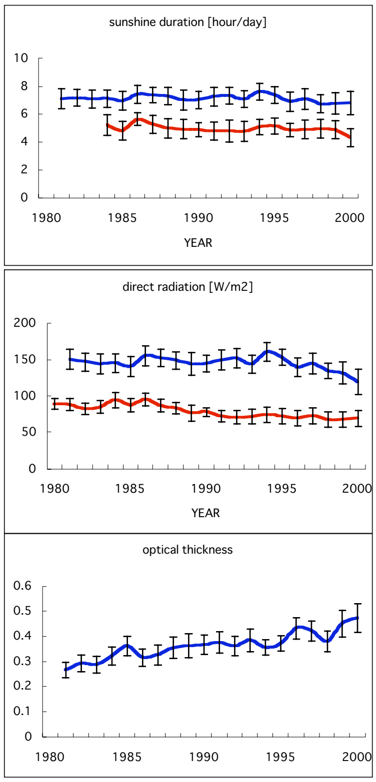

Figure 4. Annual trend of sunshine duration [hour/day], direct radiation [w/m^2] and optical thickness averaged over eastern China sites.
[Beijing(39.93˚N,116.3˚E),Chengdu(30.67N,194E),Kunming(25.02˚N,102.7˚E),Guangzhou(23.13˚N,113.3˚E),Zhengdu(34.72˚N,113.7˚E), Wuhan(30.67˚N, 114.1˚E)]
Red lines indicate ground observation data and blue lines indicate model simulation. Error bars indicate standard deviation of six sites.