A study of atmospheric radiation budget in Asia

M. Sekiguchi, T. Nakajima, K. Suzuki, and T. Takemura
Center for Climate System Research, The University of Tokyo
4-6-1 Komaba, Meguro-ku, Tokyo 153-9804, Japan
and
T. Takamura and I. Okada
Center for Environmental Remote Sensing, Chiba University
1-33 Yayoicho, Chiba 263-8522, Japan

1. Introduction

The earth's radiation budget, that is the result of surface-atmosphere exchange of solar and thermal radiation energy, is controlled strongly by existence of clouds and aerosols. There has been a substantial progress in the last two decades to understand the role of clouds and aerosols in the earth's radiation budget through surface radiation budget measurements, satellite remote sensing, and model simulation. In spite of such effort, it is recognized that there are several unresolved problems in this topic. One of important problems is so called "cloud anomalous absorption" problem. That is, the cloud laden atmosphere absorbs more solar radiation than predicted by theory. For example, Cess et al., (1995) compared cloud radiative forcing (CRF) at surface and top of the atmosphere (TOA). Though theoretical models typically yield a ratio (CRF(SRF)/CRF(TOA)) near unity, they found the ratio about 1.5 from collocated satellite and surface measurement radiative flux data. This large ratio means that the cloudy atmosphere is absorbing about 30W/m^2 more solar radiation than expected. The other important problem is the evaluation of the aerosol indirect effect. Aerosols can act as cloud condensation nuclei (CCN) to change the cloud optical properties, and hence cause a change in the cloud radiative forcing. The forcing of the indirect effect has not been well accessed and the estimate ranges from 0 to -2 W/m^2.

In this study, we perform radiative transfer calculation based on recent new data sets of clouds and aerosols to estimate surface and TOA radiative budget for investigating the above mentioned two problems.

2. Model and data description

We use a radiation code "mstrn8" for calculation which is used by CCSR/NIES AGCM(Nakajima et al.,2000). In global calculation, we use ISCCP D2 data for cloud amount statistics, cloud microphysics distribution from AVHRR (Kawamoto et al., 2001), and aerosol distribution from AVHRR (Higurashi et al., 2000). We also use aerosol distribution simulated by Takemura et al. (2000). For comparison of calculations with GAME data, we will use GMS data for cloud calculated by Okada et al. (2001).

3. Result and Discussion

Atmospheric absorption behaves in a complicated manner depending cloud amount, aerosol loading and surface albedo, because there are two competing effects. One is to disturb gaseous absorption by cloud absorption and scattering, and the other is to accelerate atmospheric absorption by multiple scattering by cloud particles. When we calculate the global distribution of the Cess ratio, CRF(SRF)/CRF(TOA) as in Fig. 1, we find a large ratio in the polar region and high latitude, and oppositely, we find the ratio smaller than 1 around Sahara desert and West Asia. Inhomonegeity of the distribution is similar to the distribution of absorbing aerosols. This suggests that the surface albedo and absorbing aerosols control the Cess ratio and hence atmospheric absorption.

We, therefore, investigated detailed dependence of the Cess ratio and atmospheric absorption changing the surface albedo and aerosol loading in a wide range. It is found that Cess ratio can become close to 1.5 for condition of unrealistically large surface albedo. For most cases of large loading of absorbing aerosols, on the other hand, Cess ratio results in values close 1. For realistic condition as shown in Fig. 1, the Cess ratio is difficult to be close to 1.5. In Asia the typical value of the aerosol optical thickness at wavelength of 500nm is of order of 10^{-1}, so that Cess ratio is very closed to 1. It is, therefore, concluded that Cess's observation of large anomalous absorption cannot be simulated even by the recent knowledge of aerosols and clouds.

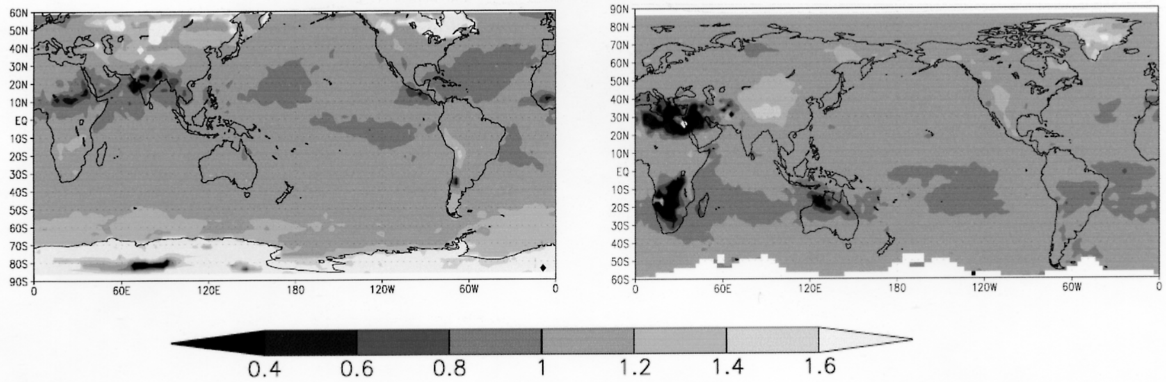

Figure 1. Global distribution of Cess ratio, CRF(SRF)/CRF(TOA) as calculated for whole sky condition in January (left) and July (right).

We further calculated the radiative forcing of aerosol indirect forcing assuming the statistics obtained by Nakajima et al. (2001) which proposed negative correlation between the low level cloud effective radius and column aerosol particle number N_a; positive correlation between cloud optical thickness and N_a. We have made similar correlation for each grid of globe and calculated the resulted radiative forcing due to 15% change of column aerosol number. This aerosol number change corresponds to the contribution of the anthropogenic aerosol number to the total aerosol (Charlson et al.,1992). The result of the calculation is shown in Fig. 2. It seems that strong cooling regions appears over the ocean. This phenomenon can be explained by the idea of "cloud susceptibility" that cloud is influenced more significantly in clean environments than in polluted ones. We obtained the global mean value of -0.95W/m^2 from Fig. 2 when we assume the cloud properties changed all over the globe. We performed similar estimation assuming the change occurred only in turbid region. In this case we have -0.39 W/m^2 as the global mean value.

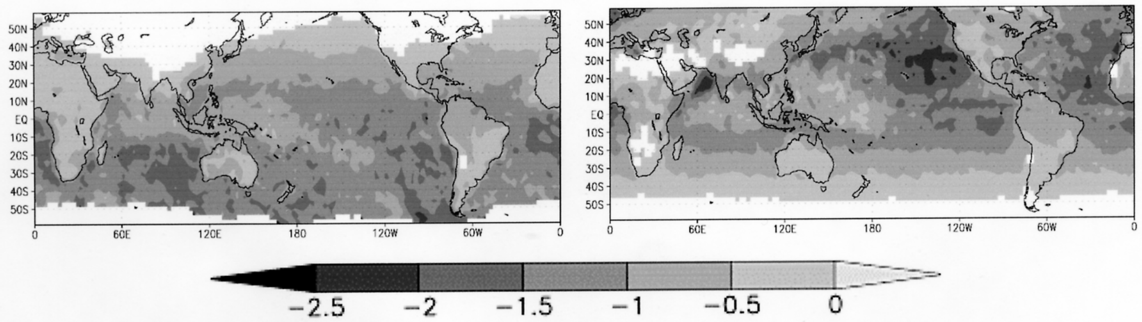

Figure 2. Global distribution of radiative forcing in W/m^2 by the aerosol indirect effects in January (left) and July (right).

References

Cess., R. D, M. H. Zhang, P. Minnis, L. Corsetti, E. G. Dutton, B. W. Forgan, D. P. Gates, J. J. Hack, E. F. Harrison, X. Jing, J. T. Keihl, C. N. Long, J. -J. Morcrette, G. L. Potter, V. Ramanathan, B. Subasilar, C. H. Whitlock, D. F. Young and Y. Zhou, 1995: Absorption of solar radiation by clouds: Observation versus models, *Science*, **267**, 496-499

Charlson, R. J., S. E. Schwartz, J. M. Hales, R. D. Cess, J. A. Coakley,Jr., J. E. Hansen and D. J. Hofmann, 1992: Climate forcing by Anthropogenic aerosols, *Science*, **255**, 423-430

Higurashi, A., T. Nakajima, B. N. Holben, A. Smirnov, R. Frouin, B. Chatenet, 2000: A Study of Global Aerosol Optical Climatology with Two Channel AVHRR Remote Sensing, *J. Climate*, **13**, 2011-2027.

Kawamoto, K., T. Nakajima, and T.Y. Nakajima, 2001: A global determination of cloud microphysics with AVHRR remote sensing. *J. Climate*, in press.

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

Nakajima, T., A. Higurashi, K. Kawamoto, and J. E. Penner, 2001: A possible correlation between satellite-derived cloud and aerosol microphysical parameters. *Geophys. Res. Lett.*, in press.

Okada, I., et al, 2001: The validation of insolation from GMS-5 by ground measurement at GAME observation sites. *J. Meteor. Soc. Japan*, submitted.

Takemura, T., H. Okamoto, Y. Maruyama, A. Numaguti, A. Higurashi, and T. Nakajima, 2000: Global three-dimensional simulation of aerosol optical thickness distribution of various origins. *J. Geophys. Res.*, **105**, 17853-17873.