JP2.17

GLOBAL AND REGIONAL CORRELATIONS BETWEEN AEROSOL AND CLOUD PARAMETERS

M. Sekiguchi[1]*, T. Nakajima[1], K. Suzuki[1], K. Kawamoto[2] and A. Higurashi[3]
1: Center for Climate System Research, Tokyo, Japan,
2: Research Institute for Humanity and Nature, Kyoto, Japan,
3: National Institute of Environmental Studies, Tsukuba, Japan

1. INTRODUCTION

Aerosols act as cloud condensation nuclei (CCN) to change the cloud optical properties, and hence cause a change in the cloud radiative forcing. But the forcing has not been well assessed as the estimate ranges from 0 to -2 W/m^2.

We perform a comprehensive investigation of the correlation between satellite-derived aerosol and cloud parameters to show a relationship. Cloud parameters include not only cloud effective radius and optical thickness, but also cloud fraction with aerosol number change.

2. DATA AND MODEL DESCRIPTION

We use the global distribution of aerosol optical parameters obtained by analysis of NOAA/AVHRR with the algorism developed by Higurashi and Nakajima (1999) and Higurashi et al. (2000). They obtained two aerosol optical parameters, i.e., the aerosol optical thickness at a reference wavelength of 500nm and Ångström exponent, from AVHRR GAC data in January, April, July, and October of 1990, for 0.5° x 0.5° box in the region from 60°N to 60°S over the ocean. We derive the column aerosol number concentration by the retrieved aerosol parameters.

We also use the global distribution of the cloud microphysical parameters obtained by an analysis of AVHRR with the algorithm developed by Nakajima and Nakajima (1995) and Kawamoto et al. (2001). This algorithm is applied only to water clouds. Analyzed cloud parameters are the effective radius, cloud optical thickness, cloud top temperature and cloud fraction. The time and spatial resolution of the data are as same as those of the aerosol data.

We use the radiation code mstrn8 adopted in the CCSR/NIES AGCM for calculation of the radiative forcing. The spatial resolution is 2.5° x 2.5° horizontal grids and 17 vertical levels. The code combines a k-distribution method with the discrete-ordinate method/adding method (Nakajima et al., 2000). We use an 18-band and 37-channel version of which wavelengths range from 0.2μm to 200μm. This code can treat Rayleigh scattering of gaseous matter and Mie scattering of particulate matter. For a multi-layered cloud system, this code adopts a semi-random overlapping scheme that is faster than the usual random overlapping scheme.

3. CORRELATIONS BETWEEN AEROSOL AND CLOUD PARAMETERS

In order to evaluate the quantitative magnitude of the aerosol and cloud interaction, we study correlations between the column number concentration of aerosol particles (N_a) and cloud parameters, i.e., effective radius (r_e), cloud optical thickness (τ_c) and cloud fraction (n).

3.1 Global Correlations

At first, we study correlations using various spatial and temporal averaged data, which is calculated from daily 0.5° x 0.5° data. Since there is a large variability in the averaged values, we bin the averaged data into number bins of $\Delta\log_{10}N_a = 0.02$ to calculate the mean value and standard deviation in each bin. Although the correlations significantly change with increasing averaging area and decreasing averaging time, there is a general tendency of negative correlation between logarithm of aerosol number to the base 10 ($\log_{10}N_a$) and cloud effective radius ($\log_{10}r_e$). Note that cloud effective radius appears to decrease linearly with increasing aerosol particle number. This tendency is consistent with the first indirect effect proposed by Twomey (1974). We also find a positive correlation between aerosol column number concentration and cloud optical thickness ($\log10\tau_c$). This relation indicates the first and second indirect effect. Furthermore, a positive correlation between aerosol column number concentration and cloud fraction is found. It is considered that that is caused by the cloud lifetime effect. A *t*-test confirms existences of these correlations as statistically significant (level of significance < 0.05) for each month.

3.2 Regional Correlations

In order to investigate regional correlations, we calculate the correlation of $\log_{10}r_e$, $\log10\tau_c$ and n with $\log_{10}N_a$ in each region. The 0.5˚ x 0.5˚ daily raw data are gathered for each 2.5˚ x 2.5˚ region to calculate correlations in each month. We further increase the area size for correlation calculations from 2.5˚ x 2.5˚ to 27.5˚ x 27.5˚. Correlations of τ_c and n are found to be positive in most areas, whereas the correlation of re with Na is not always negative in southern Pacific Ocean. This observation suggests that cloud particles do not react to a change in aerosol concentration because of complicated

---

* *Corresponding author address*: Miho Sekiguchi, Center for Climate System Research, Univ. of Tokyo, Japan, 153-8904; e-mail: miho@ccsr.u-tokyo.ac.jp

interaction mechanism including microphysical and dynamical processes.

4. RADIATIVE FORCING

We try to evaluate the radiative forcing of the aerosol indirect effect assuming that the cloud parameters have changed along the correlation curves obtained in the preceding section. We further assume that the globally averaged aerosol number has increased by 15% from the pre-industrial era (Charlson et al., 1992) for deriving the cloud parameter values in pre-industrial era. We calculate the indirect forcing as the difference of cloud radiative forcing between present and pre-industrial conditions thus obtained. This indirect forcing is only calculated over the Ocean because aerosol data have not observed over lands in our study.

Using the global correlations, we estimate the indirect radiative forcing through the change in r_e and τ_c, cloud fraction change, and their total effect as -0.45 ±0.14, -0.27 ±0.10, -0.72 ±0.22W/m^2 respectively. Using the regional correlations, they are estimated at -0.34 ±0.08, -0.37 ±0.11, -0.70 ±0.18 W/m^2. These estimates suggest that the effect of cloud fraction change is comparable with the first and second indirect effect.

5. CONCLUSIONS

In this study, we found a systematic global correlation of the cloud parameters with the column aerosol number and confirmed the indirect effect. We get the similar tendency between global and regional correlation, but regional correlation between $\log_{10}N_a$ versus $\log_{10}r_e$ indicates that first indirect effect does not occur in every area. We also find the correlation between N_a and n suggesting that the cloud lifetime effect cause a hydrological cycle change and an increase in the cloud fraction.

The total radiative forcing is estimated as about –0.7W/m^2. In our calculation we have assumed the same increase rate of the aerosol number concentration as 15% in all regions, so that this estimate may not be suitable, because aerosols increased more in urban regions than in the remote ocean area from the pre-industrial era. It should be said, therefore, we have a large room for future studies to improve the present estimates for the radiative forcing of the indirect aerosol effects, after solving several difficulties met in the present work.

6. REFERENCES

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.

Higurashi, A. and T. Nakajima, 1999: Development of a two-channel aerosol algorithm on global scale using NOAA AVHRR.

Higurashi, A., T. Nakajima, B.N. Holben, A. Smirnov, R. Frouin and B. Chatenet, 2000: A study of global aerosol optical climatology with two-channel AVHRR remote sensing.

IPCC, 2001: Climate Change 2001: The Scientific Basis.

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

Nakajima, T., A. Higurashi, K. Kawamoto and J.E. Penner, 2001: A study of correlation between satellite-derived cloud and aerosol microphysical parameters.

Nakajima, T., M. Tsukamoto, Y. Tsushima, A. Numaguti and T. Kimura, 2000: Modeling of the radiative process in an atmospheric general circulation model.

Nakajima, T.Y., and T. Nakajima, 1995: Wide-area determination of cloud microphysical properties from NOAA AVHRR measurements for FIRE and ASTEX regions.

Twomey, S., 1974: Pollution and the planetary albedo.