Regional properties of aerosol-cloud interaction estimated from long-term satellite analysis

Article *in* AIP Conference Proceedings · February 2017

DOI: 10.1063/1.4975507

Miho Sekiguchi
Tokyo University of Marine Science and Technology

Regional properties of aerosol-cloud interaction estimated from long-term satellite analysis

Miho Sekiguchi, Takashi Y. Nakajima, Takashi M. Nagao, and Teruyuki Nakajima

Citation: AIP Conference Proceedings **1810**, 040005 (2017);
View online: https://doi.org/10.1063/1.4975507
View Table of Contents: http://aip.scitation.org/toc/apc/1810/1
Published by the American Institute of Physics

Regional Properties of Aerosol-Cloud Interaction Estimated from Long-term Satellite Analysis

Miho Sekiguchi[1, a)], Takashi Y. Nakajima[2, b)], Takashi M. Nagao[3, c)] and Teruyuki Nakajima[3, d)]

[1]Tokyo University of Marine Science and Technology, Japan
[2]Tokai University, Japan
[3]Earth Observation Research Center, Japan Aerospace Exploration Agency, Japan
[a)] Corresponding author: miho@kaiyodai.ac.jp
[b)] nkjm@yoyogi.ycc.u-tokai.ac.jp
[c)] nagao.takashi@jaxa.jp
[d)] nakajima.teruyuki@jaxa.jp

Abstract. The present study investigated the correlations between aerosol and cloud parameters derived from satellite remote sensing to estimate properties of aerosol-cloud interactions. The global statistics showed that effective particle radius and optical thickness of low clouds correlate well with column number concentration of the aerosol particles in small – moderate amount of atmospheric aerosol loading (about $N_a < 10^9$ [particles/cm^2]), which are consistent with an aerosol indirect effect. In case of turbid atmosphere, inverse trends between aerosol and cloud microphysics parameters are appeared. These inverse tendencies can be founded in case of smaller LWP cases.

INTRODUCTION

Aerosols may affect cloud distributions and radiative properties. To understand those processes, satellite-based remote sensing data and its analysis are suitable because it can be derived globally and plenty data. The improvements in satellite instrumentations and retrieval methods have provided valuable data to minimize uncertainties in assessments of aerosol-cloud interactions. Many previous studies investigated the correlations between aerosol and cloud parameters derived from satellite remote sensing to estimate properties of aerosol-cloud interactions [1][2][3][4]. The methods used satellite data are pointed out two disadvantages. One is the observation for aerosols and cloud parameters are not coincident by passive remote sensing. In this study, spatial and temporal averaged data, which are considered to have typical characteristics in each region and period is used to understand the relation of aerosol and cloud properties. The other is retrieval aerosol is observed at clear condition, not in cloud field. We will compensate for the point with data by active remote sensing, but not shown. To achieve better evaluations, we arrange spatial and temporal range of data to gather to take correlations as for discussing targets. In this study, we introduce satellite data and the statistical method, show seasonal and regional results and discuss seasonal variability and regional properties.

DATA SOURCES AND METHODS

We use the datasets of aerosol and cloud parameters obtained from Terra/MODIS, because it is continuous and stable. Cloud parameters are analyzed cloud effective radius (r_e), cloud optical thickness (τ_c), cloud-top temperature (T_c) with the CAPCOM algorithm [5][6]. This algorithm is applied only to liquid water cloud. It is known the NIR channels used in such algorithm makes differences in effective radius [6]. To the consistency of previous studies, we adopt data by the 3.7 μm channel. For aerosol parameters, we use the column number concentration of aerosol

Radiation Processes in the Atmosphere and Ocean (IRS2016)
AIP Conf. Proc. 1810, 040005-1–040005-4; doi: 10.1063/1.4975507
Published by AIP Publishing. 978-0-7354-1478-5/$30.00

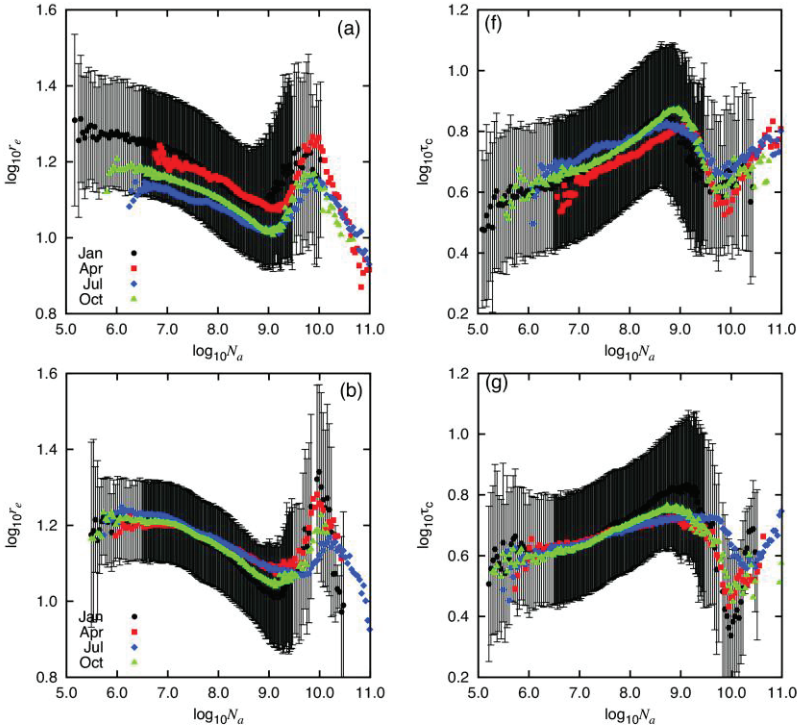
particles (N_a) calculated from aerosol optical thickness, small/large particle ratio, mass concentration using the defined aerosol size distribution retrieved by the MOD04 algorithm [7][8]. Aerosol and cloud parameters are spatially averaged for 0.25 degrees grid and temporally averaged daily. Those averaged data can be treated as a representative in each grid, it means, it represents a characteristic feature of each grid and time. They are available from January 1st 2001 to December 31st 2010.

Cloud microphysical parameters are mainly affected by meteorological factors at observation point. To filtered the effect of the factors to some extent and pick up the aerosol effect, we pick up N_a and cloud parameters in same grid and time over a focusing area and season, and put every matched cloud parameter into a bin, which is consisted to divide a value of $\log_{10}N_a$. We calculate average and standard deviation in each bin, take correlations between bin-centered $\log_{10}N_a$ and bin-averaged cloud parameters. Different bin size is set for percentile of cloud parameters, larger bin is defined for smaller than 2.5 and larger than 97.5 percentile data. We also compute regression analysis between bin-centered $\log_{10}N_a$ and bin-averaged cloud parameters. To judge significances, we set thresholds for the number of cloud parameter, standard deviation and remove the bin from an analysis if those are larger than the thresholds.

Seasonal and Regional Dependencies

To study seasonal variability and regional properties, we divide the area with every 10 degrees of latitude to gather matched data. Effective particle radius and optical thickness of low clouds correlate well with column number concentration of the aerosol particles in small – moderate amount of atmospheric aerosol loading (about $N_a < 10^9$), which are consistent to aerosol indirect effect.

In case of turbid atmosphere, inverse trends between aerosol and cloud microphysics parameters are appeared, and then, inverted again around $N_a = 10^{10}$. These inverse trends are rarely or weakly appeared in the southern subtropics. In mid-latitude, we find regression slopes between aerosol number concentrations and cloud parameters are steeper, it means, aerosol affects clouds greater in winter than summer, in northern than southern hemisphere. It is considered that cloud formation process is strongly affected by atmospheric dynamical processes in summer, that aerosols' effect is appeared relatively weak. That seasonal variation does not appear in tropics and subtropics about $N_a < 10^9$.



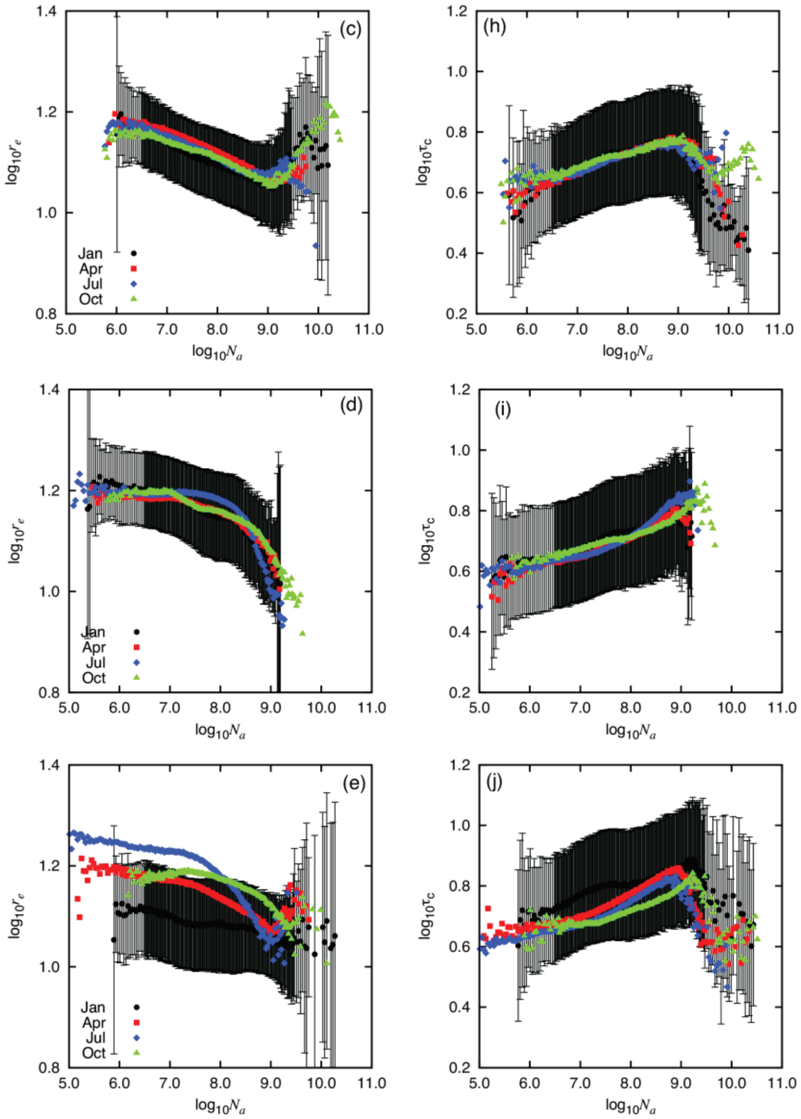
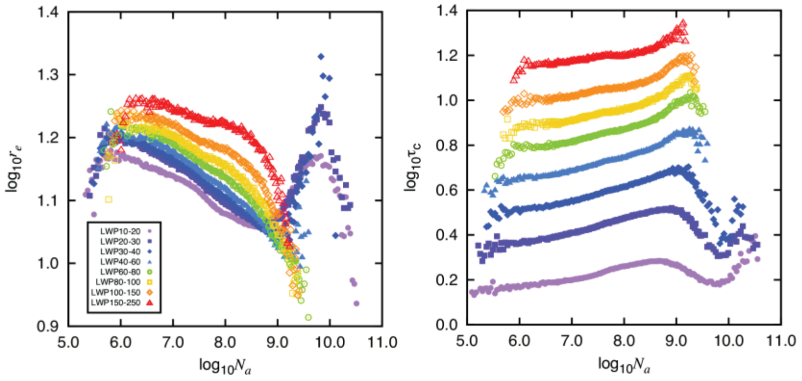


FIGURE 1. Correlation plots between column aerosol number and cloud effective radius (left panels), cloud optical thickness (right panels) using 0.25º grids daily averaged MODIS data for 10 years. The data ranges are divided into (a), (f) mid-latitude in northern hemisphere (35 – 45 N), (b), (g) subtropics in NH (15 – 25 N), (c), (h) tropics (5 N – 5 S), (d), (i) subtropics in SH (15 – 25 S) and (e), (j) mid-latitude in SH (35 – 45 S). Black, red, blue and green show January, April, July and October, respectively. Circles, squares, diamonds and triangles show the averaged values, and error bars indicate one standard deviation in each bins.

Liquid Water Path Dependency

McComisky and Feingold[9] indicated cloud liquid water path (LWP) should be considered as a constraint for aerosol-cloud interactions. To study about LWP dependencies of aerosol-cloud interaction, we divide into eight categories of LWP and take correlations. Figure 2 shows correlation plots between column aerosol number concentration and cloud effective radius (Fig. 2a), and N_a and cloud optical thickness (Fig.2b) at tropics (20N – 20 S) in every January from 2001 – 2010. For effective radius in smaller LWP cases (about LWP < 60), negative correlations turn to positive around Na = 10^9, and turn to negative again around $N_a = 10^{10}$. This trend does not appear in larger LWP cases. In case of clear – moderate air ($N_a < 10^9$), correlation slopes can be approximated linear functions in smaller LWP cases but not good in larger LWP cases. For optical thickness, positive correlations turn to negative around $N_a = 10^9$ in all LWP cases, and turn to positive again around $N_a = 10^{10}$ in smaller LWP cases. In larger LWP case, the range of N_a is too narrow to find for second turn.



(a) (b)

FIGURE 2. Correlation plots between column aerosol number and (a) cloud effective radius, (b) cloud optical thickness using 0.25° grids daily averaged MODIS data for 10-years January. The data area is in Tropics (20N–20S). Violet, purple, darkblue, blue, green, yellow, orange and red indicate LWP cases (10 – 20, 20 – 30, 30 – 40, 40 – 60, 60 – 80, 80 – 100, 100 – 150 and 150 – 250 g/m^2).

CONCLUSION

To study the seasonal variability and regional properties, we divided the area covered by satellite observations and analyzed correlations between aerosol and cloud parameters. In mid-latitude, we find regression slopes between aerosol number concentrations and cloud parameters are steeper, it means, aerosol affects clouds greater in winter than summer, and in northern than southern hemisphere. That seasonal variation does not appear in tropics and the slope of regression line is almost same in mid-latitude summer. It is considered that cloud formation process is strongly affected by atmospheric dynamical processes in tropics and mid-latitude summer, that aerosols' effect is appeared relatively weak.

REFERENCES

1. Nakajima, T., A. Higurashi, K. Kawamoto, and J. E. Penner (2001) A study of correlation between satellite-derived cloud and aerosol microphysical parameters. *Geophys. Res. Lett.*, **28**, 1171–1174.
2. Sekiguchi, M., T. Nakajima, K. Suzuki, K. Kawamoto, A. Higurashi, D. Rosenfeld, I. Sano, and S. Mukai (2003) A study of the direct and indirect effects of aerosols using global satellite data sets of aerosol and cloud parameters. *Journal of Geophysical Research*, **108**(D22), 4699, doi:10.1029/2002JD003359.
3. Kaufman, Y. J., I. Koren, L. a Remer, D. Rosenfeld, and Y. Rudich (2005) The effect of smoke, dust, and pollution aerosol on shallow cloud development over the Atlantic Ocean. *Proc. Natl. Acad. Sci. U.S.A.*, **102**(32), 11207–11212.
4. Quaas, J., O. Boucher, and U. Lohmann (2006) Constraining the total aerosol indirect effect in the LMDZ and ECHAM4 GCMs using MODIS satellite data. *Atmos. Chem. Phys.*, **6**, 947-955.
5. Nakajima, T., and T. Nakajima (1995) Wide-area determination of cloud micro- physical properties from NOAA AVHRR measurements for FIRE and ASTEX regions, *J. Atmos. Sci.*, **52**, 4043–4059.
6. Nakajima, T. Y., K. Suzuki, and G. L. Stephens (2010) Droplet Growth in Warm Water Clouds Observed by the A-Train. Part I: Sensitivity Analysis of the MODIS-Derived Cloud Droplet Sizes. *J. Atm. Sci*, **67**, 1884–1896, doi:10.1175/2009JAS3280.1.
7. Levy, R., L. Remer, D. Tanré, S. Mattoo, and Y. Kaufman (2009) Algorithm for Remote Sensing of Tropospheric Aerosol over Dark Targets from MODIS: Collections 005 and 051: Revision 2.
8. Levy, R. C., L. A. Remer, R. G. Kleidman, S. Mattoo, C. Ichoku, R. Kahn, and T. F. Eck (2010) Global evaluation of the Collection 5 MODIS dark-target aerosol products over land, *Atmospheric Chemistry and Physics*, **10**, 10399–10420, doi:10.5194/acp-10-10399-2010.
9. McComiskey, A., and G. Feingold (2012) The scale problem in quantifying aerosol indirect effects, *Atmospheric Chemistry and Physics*, **12**, 1031–1049, doi:10.5194/acp-12-1031-2012.