Retrieval of Cloud Physical Parameters on a Global Scale using NOAA/AVHRR

Kazuaki Kawamoto and Teruyuki Nakajima
Center for Climate System Research, University of Tokyo
4-6-1 Komaba, Meguro-ku, Tokyo 153, Japan

1. Introduction

Clouds actually occupy about 60% coverage of the earth's surface and play a considerably important role for formation of the climate through radiative processes. Their large variations both in horizontal and vertical extent make situations more complex. In order to evaluate the effects of clouds on the earth's radiation budget, it is important to observe globally not only the macroscopic variables, such as cloud amount and height, but also cloud optical and microphysical properties such as cloud optical thickness and effective particle radius (hereafter cloud physical parameters), which are more closely related to the radiation budget.

Motivated by this background, we have developed a retrieval algorithm which can be expanded into global scale based on Nakajima and Nakajima (1995) for cloud physical parameters .

2. Retrieval Principles

We use cloud-reflected solar radiation for retrieving cloud physical parameters. The fact that the cloud optical thickness is mainly a function of channel-1 (visible, ch1. 0.63μm) signal, while the effective particle radius is mainly a function of channel-3 (near-infrared, ch3. 3.73μm) signal is applied to analysis. Both signals, however, contain undesirable components for determination; in ch1, surface reflection, in ch3, surface reflection and thermal emissions from the ground, the cloud layer, and the atmospheric layers. These undesirable components must be removed from observed signals. Moreover, water vapor absorption affects ch3 signal, while it is negligible in ch1.

In actual data analysis, we adopted a look-up table (LUT) method. LUT is sets of solutions of radiative transfer equations under various conditions of geophysical and angular parameters, such as cloud optical thickness, effective particle radius, cloud top height, cloud geometrical thickness, satellite zenith and solar zenith and relative azimuth angles. As mentioned above, since ch3 has water vapor absorption, LUT for ch3 is made to be feasible for various water vapor amount. So our LUT, or algorithm is independent of atmospheric conditions. It means its applicability of expanding into global scale analysis. The ancillary data such as temperature, humidity, and geopotential height are from NCEP reanalysis objective analysis data. Observed radiance corrected and theoretical radiance stored in LUT are compared, and an iteration is continued until the optimal solutions will be obtained.

3. Comparison with In situ measurements

In order to verify the accuracy of the algorithm, we compare satellite retrievals to which this algorithm is applied with in situ measurements synchronous to satellite observations.

We have surveyed in situ cloud microphysical measurements with aircrafts and balloons conducted from 1981 to 1992, and among them, the ones whose location and time had been close to satellite passage were only selected.

Fig. 1 shows the result of the comparison. Within satisfactory errors are retrieved the effective particle radii of both stratiform and convective clouds. As error sources in analyzing actual satellite data, we can cite cirrus contamination, partial cloud cover, and cloud inhomogenity argued in Han et al.(1994), sensor discretization and calibration uncertainties summarized in Pincus et al.(1995), slight gaps between satellite imagery and in situ measurement point temporally and spatially, and uncertainties of meteorological parameters taken from the ancillary data.

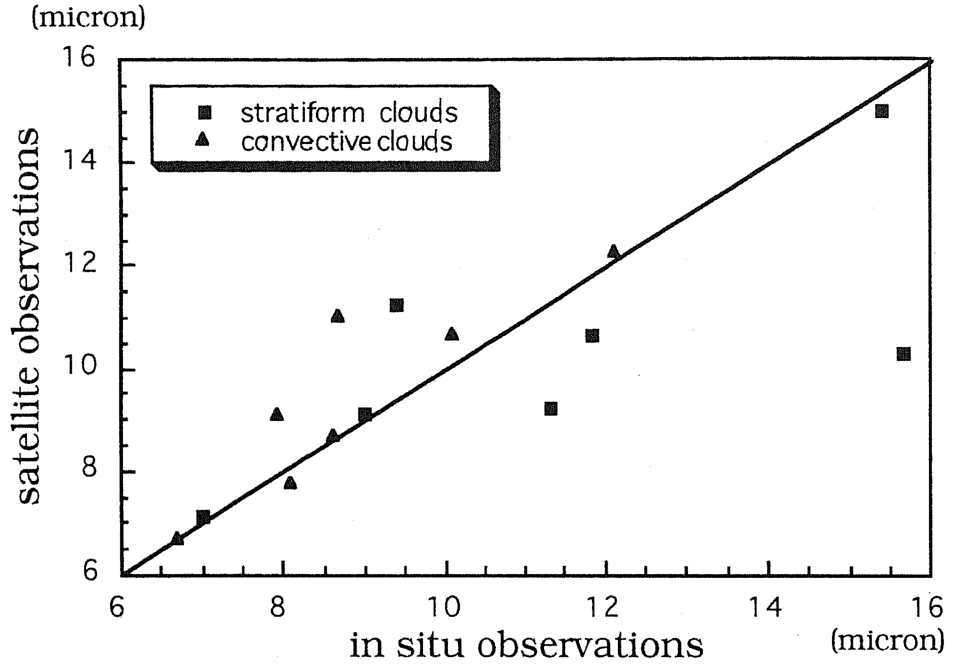

Fig. 1

4. Global Analyses

We have performed global analyses of cloud physical parameters of Jan., Apr., Jul., and Oct. in 1987. Fig. 2 shows maps of cloud physical parameters in Jan. and Jul., and Fig.3 illustrates the latitudinal distribution of cloud physical parameters, along with Han et al. (1994) 's result, which analyzed also 1987 case. Since these figures are monochromatic, see Kawamoto et al. (under preparation) in datail.

As for cloud optical thickness, differences of summer stratus clouds, which occur around 40~50 (deg.) over the summer hemispheric ocean, and optically thick clouds due to ocean upwelling regions such as off Peru between Jan. and Jul. are apparent. While as for effective particle radius, generally the values over ocean are larger than those of land, suggesting difference of aerosol abundance. In coastal regions, even over ocean, the values are similar to those of land. This may be caused by continental airmass flown into ocean. The seasonal variation over equatorial Africa and Amazon basin can be explained by the difference of rainfall, since CCN (cloud condensation nuclei) removal due to rainfall (precipitation scavenging) would increase cloud droplet radius. GPCP(Global Precipitation Climatology Project) results (not shown) support this idea.

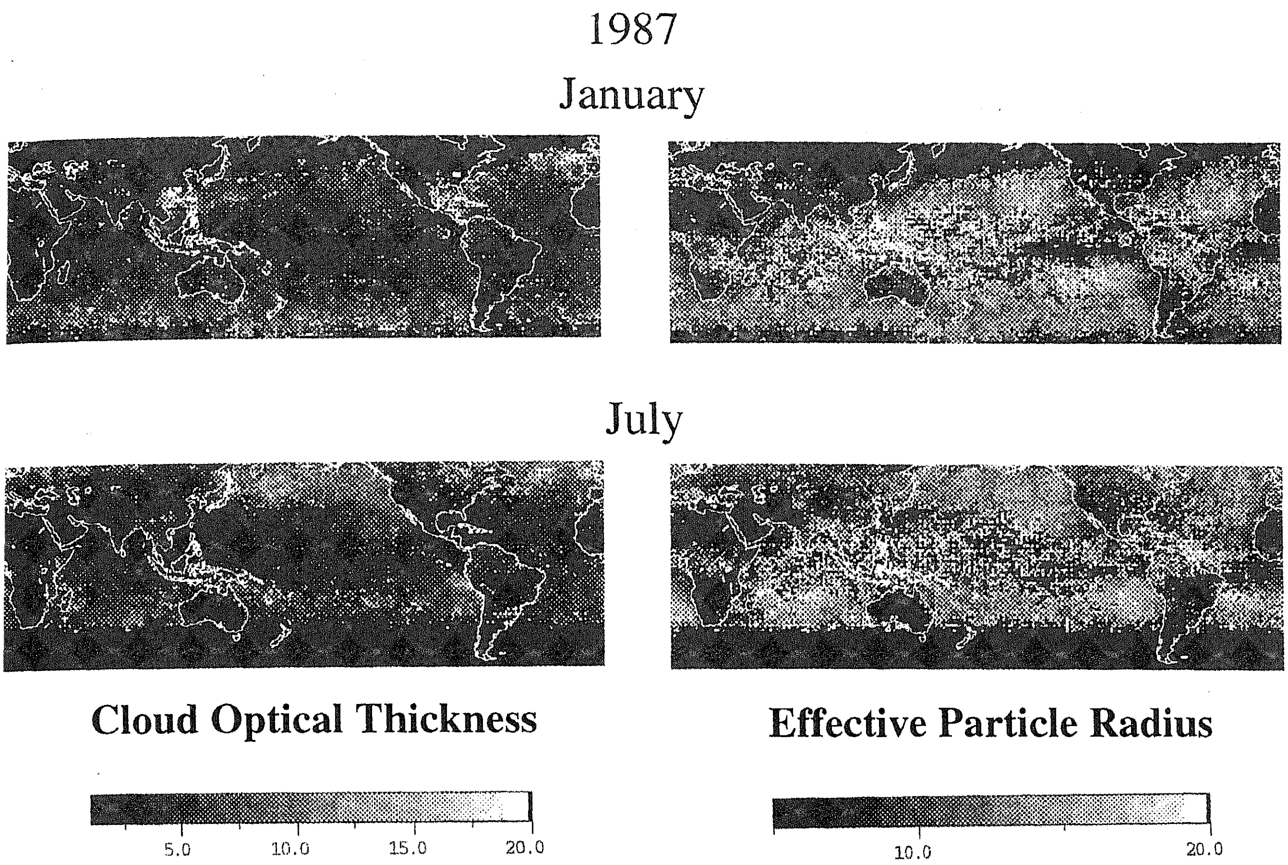
1987
January
July
Cloud Optical Thickness
Effective Particle Radius
5.0
10.0
15.0
20.0
10.0
20.0
(micron)

Fig. 2

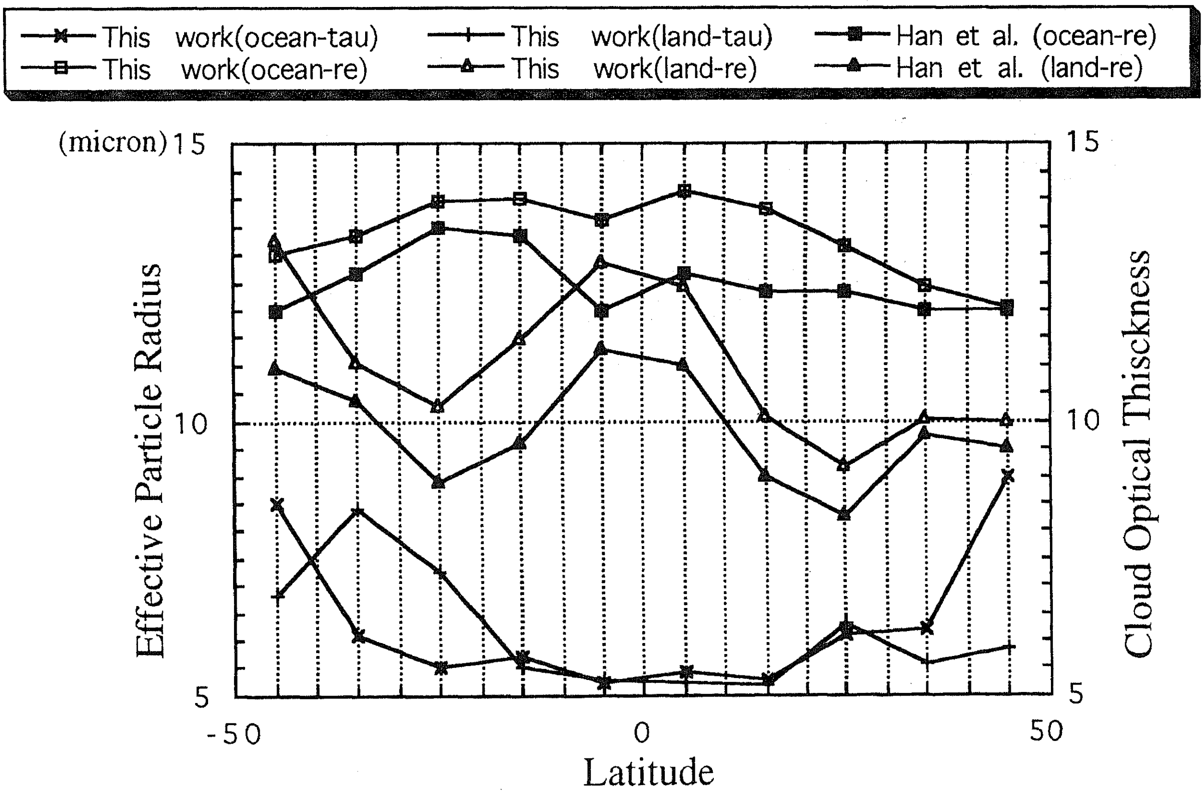
This work(ocean-tau)
This work(ocean-re)
This work(land-tau)
This work(land-re)
Han et al. (ocean-re)
Han et al. (land-re)
(micron) 15
10
5
15
10
5
-50
0
50
Latitude
Effective Particle Radius
Cloud Optical Thisckness

Fig. 3

From Fig.3 about effective particle radius, Han et al.'s result and ours are very similar in shapes, but ours is larger by about 1.5 μm than theirs. Han himself said it caused by the difference of calibration coefficients (private communication).

About cloud optical thickness, the values in higher latitudes tend to be larger. This feature may be caused by 3-D effect of clouds which are remarkable in larger solar zenith angles. (Loeb and Davies, 1996)

5. Concluding Remarks

We have developed the algorithm which is capable of global scale analysis of cloud physical parameters, and performed global analyses in a seasonal time scale. Some features of cloud physical parameters were described such as ocean-land contrast, near coastal regions influenced by different characteristics of airmass, and seasonal variation of effective radius caused by rainfall difference. Then the result of Han et al. (1994) and our result were compared. Their result is smaller by 1.5 μm than ours.

Recently, the research of aerosol-cloud interactions with satellite remote sensing has begun (e.g. Kaufman and Nakajima, 1993) . Our algorithm can be used for the purpose effectively combined with aerosol optical properties from Higurashi and Nakajima (1998).

Acknowledgement

The authors are grateful to Dr. C. J. Tucker at NASA/GSFC and Dr. R. Imasu at NIRE for providing AVHRR/GAC data, and Mr. A. Sinpo at Univ. of Tokyo for handling NCEP reanalysis data. Aircraft measurements data were provided by Meteorological Research Institute/Aircraft measurements group.

References

Han, Q., and W. B. Rossow, and A. A. Lacis, 1994: J.Clim.
Higurashi, A. and T. Nakajima, 1998: J. Atmos. Sci.
Kaufman, Y. J., and T. Nakajima, 1993: J. Appl. Meteor.
Loeb, N. G. and R. Davies, 1996: J. Geophys. Res.
Nakajima, T., and M. D. King, 1990: J. Atmos. Sci.
Nakajima, T., M. D. King, J. D. Spinhirne, and L. F. Radke, 1991: J. Atmos. Sci.
Nakajima, T. Y. and T. Nakajima, 1995: J. Atmos. Sci.
Pincus, R., M. Szczodrak, J. Gu, and P. Austin, 1995: J.Clim.