Retrieval of Aerosol Characteristics by Combining Ground-based and airborne Measurements

S.Kaneta T.Takamura N.Takeuchi
CEReS, Chiba University, 1-33 Yayoicho, Inage-ku, Chiba 263-8522, Japan

1 Introduction

Atmospheric aerosols have large influence on the earth-atmosphere system, and their characteristics are one of important parameters for the global climate system. However, our knowledge of aerosol characteristics (e.g., optical thickness, size distribution etc.) and their spatial and temporal variation is still not enough. There are many literatures about studies of global aerosol properties using space-borne sensor [6, 5, 2]. But these methods require assumed aerosol parameters (such as size distribution function, scattering phase function.)

In this studies we carried out the simultaneous observation by an airborne sensor (AMSS) and ground-based instrument (sun photometer). Using these data, we try to estimate aerosol optical thickness over Tokyo bay.

2 Observation

2.1 AMSS

Airborne multi-spectral scanner (AMSS) is the sensor simulating a space-borne sensor, Global Imager (GLI), proposed to the ADEOS-II satellite. AMSS has 46 channels from 0.4 to 12μm. Table 1 shows the AMSS observation channel and resolution. The measurements of the AMSS on-board in an aircraft were carried out over the Tokyo bay area, including over Chiba University during 13:07~13:21(JST) on Dec 3, 1996. Flight altitude is 19500feet (6km). Figure 1 is AMSS observation scheme.

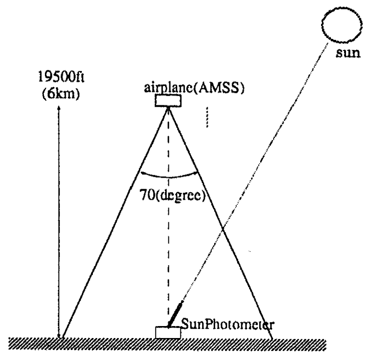

Figure 1. AMSS observation scheme

Table 1. AMSS resolution at 19500feet

ch.#	wavelength(μm)	pixel size(m)	IFOV(mrad)
1~37	0.4~1	15×7	2.5×1.2
38~42	1~3.7	30×30	5×5
43~46	7.5~10	15×15	2.5×2.5

2.2 Sun photometer

Simultaneous observation using a sun photometer is performed at CEReS, Chiba University. This sun photometer measured spectral optical thickness with 8 interference filter (0.368, 0.420, 0.500, 0.532, 0.675, 0.778, 0.880, 1.033μm) and the silicon photodiode sensor. To retrieve aerosol optical thickness, we subtract Rayleigh scattering and ozone absorption were corrected. Figure 2 is aerosol optical thickness measured by the sun photometer installed at CEReS, Chiba University (35.620N, 140.120E). Aerosol optical thickness during AMSS observation (13:07~13:21(JST)) is about 0.15 at 0.5μm.

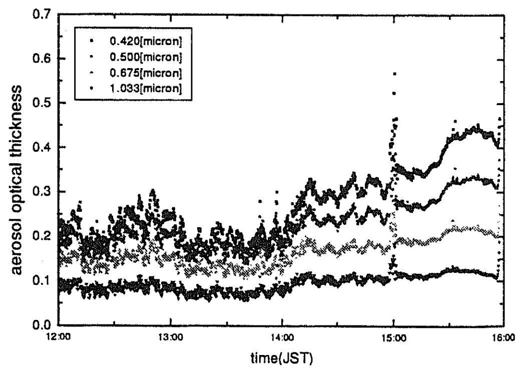

Figure 2. Aerosol optical thickness at Chiba on December 3, 1996

3 Analysis of AMSS data

To retrieve aerosol optical thickness over Tokyo bay from the aircraft data, some aerosol basic parameters, such as single-scattering albedo, asymmetry factor, were assumed using the grand-based data of the sun photometer. The flow of data analysis is shown in Figure 3.

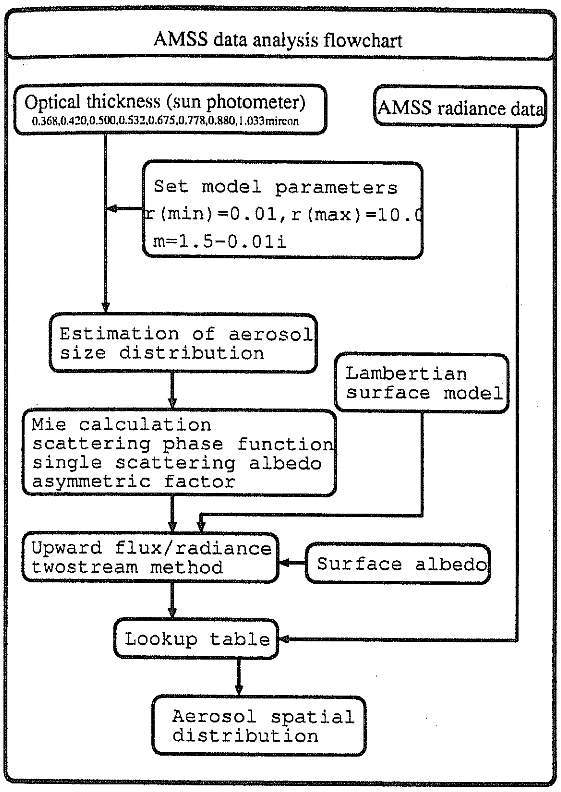

Figure 3. Aerosol data analysis flowchart

3.1 Aerosol size distribution

The relation of aerosol optical thickness and aerosol size distribution can be written as [3]

$$\tau_A(\lambda) = \int_0^\infty \pi r^2 Q_{\text{ext}}(r, \lambda, m) n_c(r) dr, \quad (1)$$

where r is particle radius, m is the refractive index of the aerosol particles, λ is wavelength of incident illumination, and $Q_{\text{ext}}(r, \lambda, m)$ is the extinction efficiency factor from Mie theory. $n_c(r)$ is the columnar aerosol size distribution. In present studies we assume $m = 1.5 - 0.01i$, and particle size range is $0.01 \leq r \leq 10.0\mu$m. By inverting equation (1) then we can estimate aerosol size distribution (Figure 4).

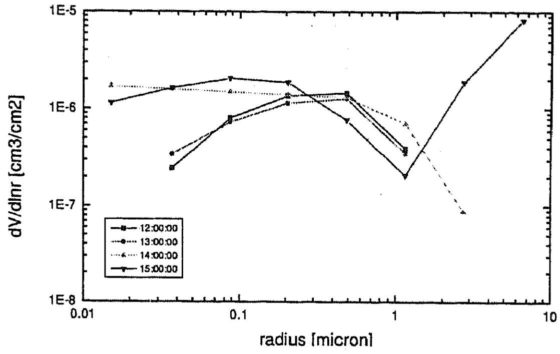

Figure 4. Aerosol size distribution at Chiba on December 3, 1996

3.2 Aerosol phase function

Aerosol phase function were calculated from Mie theory using aerosol size distribution estimated by inversion of aerosol spectral optical thickness [1]. In this calculation the complex refractive index of aerosol is assumed to be 1.5-0.01i. Figure 5 shows the scattering phase functions for several wavelengths. These are not so serious difference between each wavelengths for the sharp forward scattering.

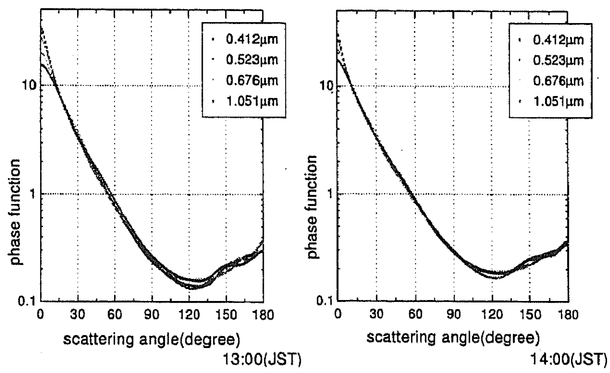

Figure 5. Scattering phase functions at Chiba on December 3, 1996

3.3 Upward radiance at AMSS altitude

The azimuthally independent radiative transfer equation for diffuse radiation can be written as [4]

$$\mu \frac{dI(\tau, \mu)}{d\tau} = I(\tau, \mu) - \frac{\tilde{\omega}_0}{2} \int_{-1}^{1} I(\tau, \mu') P(\mu, \mu') d\mu' - \frac{\tilde{\omega}_0}{4\pi} \pi F_0 P(\mu, \mu_0) e^{-\tau/\mu_0}. \quad (2)$$

Here $\mu = \cos\theta$, $\mu_0 = \cos\theta_0$, θ and θ_0 are the AMSS and solar zenith angles. $\tilde{\omega}_0$ is single scattering albedo. $I(\tau, \mu)$ is radiance at optical thickness τ and its direction μ.

In our studies we assumed that single scattering due to the thin atmosphere, then the upward radiance at optical thickness τ is written by

$$I(\tau,\mu) = I(\tau_0,\mu)e^{-(\tau_0-\tau)/\mu} + \frac{\tilde{\omega}_0}{4\pi}\pi F_0 P(\mu,\mu_0) \times \frac{\mu_0}{\mu+\mu_0}e^{\tau/\mu}\left[1 - e^{-(1/\mu+1/\mu_0)(\tau_0-\tau)}\right]. \quad (3)$$

In equation (3), we calculated the upward radiance $I(\tau_0, \mu)$ by two-stream approximation [4] with assumption of Lambertian surface. Figure 6 represents relation of optical thickness and upward radiance in each surface reflectance. In Figure 6, it is clear that

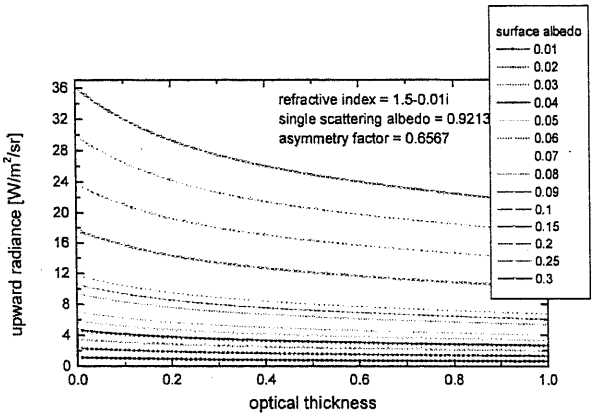

Figure 6. Upward radiance at the top of the atmosphere

upward radiance is strongly dependent on surface reflectance R as thick as optical thickness τ. The variation of upward radiance corresponding to the optical thickness is quite small, as shown in Figure 6. It should be noted to take care of this relation on retrieving aerosol optical thickness from AMSS data. That is,

- Over the land surface, the surface reflectance varies very wide range then we must know the surface reflectance in advance.
- Over the sea surface, it is easier to get the precise surface reflectance, but it is so low that the sensor sensitivity should be required to be high.

In our study we try to retrieve aerosol optical thickness over sea surface (Tokyo bay) according to the flow in Figure 3. Using the lookup tables, we evaluate AMSS's upward radiance data, with the surface reflectance R, 0.06.

4 Results

We retrieved aerosol optical thickness over Tokyo bay. The retrieved aerosol optical thickness is shown in Figure 7. The top of this figure is Yokosuka (south bound), and the bottom region is Chiba (north bound). The dark region (optical thickness is 0) is land surface, where aerosol optical thickness can not retrieved because of high surface reflectance. In this figure the variation of aerosol optical thickness over Tokyo bay is between 0.2 to 0.8. Aerosol optical thickness from sun photometer is around 0.15 at 0.5μm. The optical thickness retrieved from AMSS is higher than sun photometer's value. The problems are below.

- Surface reflectance
  The upward radiance depends on both optical thickness and surface reflectance. The effect of the variation of surface reflectance to the upward radiance is much larger than that of optical thickness. So even if the surface reflectance may be known, the retrieved optical thickness over lower reflectance surface condition may have large error.
- Sensitivity of AMSS
  The upward radiance over the sea surface is very low then AMSS sensor sensitivity under such a low radiance may be not enough to retrieve aerosol optical thickness in this observation.

5 Conclusions

Using airborne and grand-base measurements data, we tried to retrieve an aerosol optical thickness over Tokyo bay. The preliminary results were not so good accordance with the ground-based observations. For more accurate retrieval, we continue the following analysis.

- Using two altitude data
  In this observation we performed measurement at two altitude. We can reduce the influence of surface reflectance with those data.
- Using multi-spectral data
  But AMSS has 46 channels, can be used to retrieve aerosol optical thickness more accurately.
- Using aerosol vertical profile (LIDAR) data
  Aerosol vertical profile is very useful for retrieval. We should use those data.

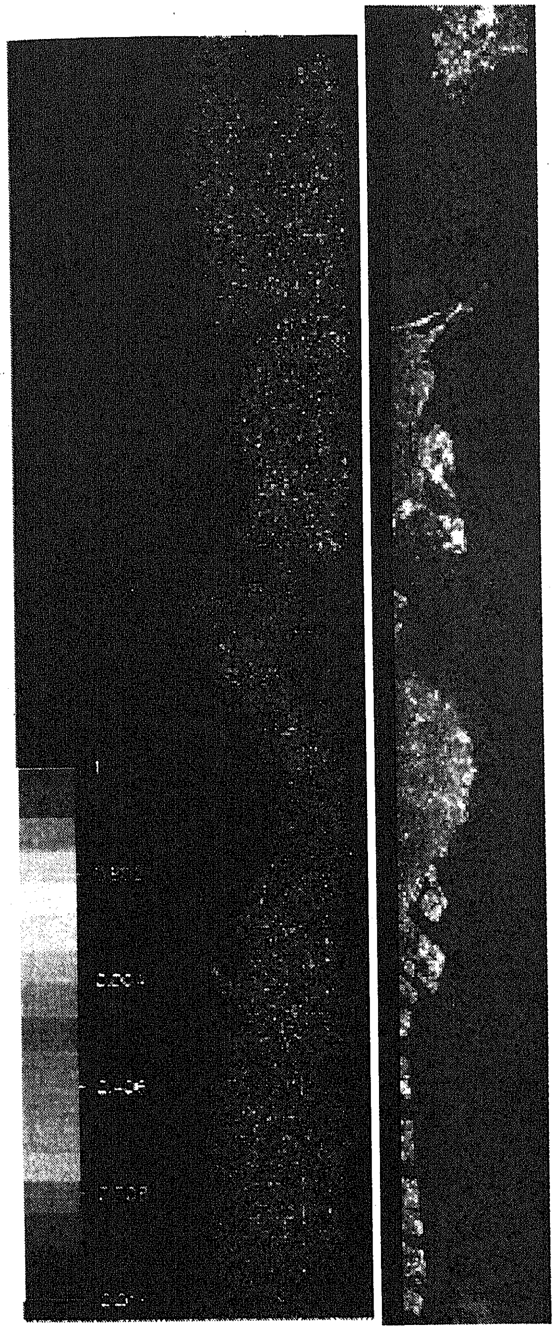

Figure 7. Retrieved optical thickness over Tokyo bay (left side), right side is AMSS radiance image as same place as left one, where λ=0.5228μm $\tilde{\omega}_0$=0.9213 g=0.6874 R=0.06

References

[1] Barber, P. W., and Hill, S. C. *Light Scattering by Particles: Computational Methods.* World Scientific Publishing, 1990.

[2] Isakov, V. Y., Feind, R. E., Vasilyev, O. B., and Welch, R. M. Retrieval of aerosol optical thickness from aviris data. *International Journal of Remote Sensing* **17**, (1996), 2165–2184.

[3] King, M. D., Byrne, D. M., Herman, B. M., and Reagan, J. A. Aerosol size distributions obtained by inversion of spectral optical depth measurements. *Journal of the Atmospheric Sciences* **35**, (1978), 2153–2167.

[4] Liou, K. N. *An Introduction to Atmospheric Radiation.* New York: Academic Press, 1980.

[5] Rahman, H. Atmospheric optical depth and water vapour effects on the angular characteristics of surface reflectance in noaa avhrr. *International Journal of Remote Sensing* **17**, (1996), 2981–2999.

[6] Wang, M., and Gordon, H. R. Estimating aerosol optical properties over the oceans with the multiangle imaging spectroradiometer: some preliminary studies. *Applied Optics* **33**, (1994), 4042–4057.