Aerosol properties over Japan during APEX experiments in spring of 2001 and 2003

Itaru Sano (1), Sonoyo Mukai (1), Brent N. Holben (2) ,
Yasuhiko Okada (3), and Masayoshi Yasumoto (4)

1. Faculty of Science and Technology., Kinki University, Japan
2. NASA/GSFC, U.S.A.
3. Faculty of Science, Kobe University, Japan
4. RIST, Kinki University, Japan

ABSTRACT:

Aerosol optical thickness, Ångström exponent, single scattering albedo and refractive index over Japan were measured by sun/sky radiometers from 2001 to 2003. We draw the following results through APEX experiments; 1.) Asian dust has a complicated feature mixing with the anthropogenic compound externally and/or internally, 2.)obtained size distribution of soil dust indicates the dominance of large particles, 3.) the soil dust is a weak absorber, 4.) dust event in 2003 is much less than that in 2001.

Key words: Aerosols, Asian dusts, AERONET, POLDER-2, ADEOS-2

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1.- Introduction.

It is well known that Asia is the most complicated region for aerosol study, because emission of aerosols, e.g. sulfuric, nitric, carbonaceous, is increasing due to the economic growing. The soil dust, which is named Kosa, Yellow sands or Asian dusts, is also famous and increasing over Asia increasing the desert area and decreasing precipitations. Yellow sand event due to Asia dust, which are carried over Japan from the Gobi and Taklamakan desert in China continent.

In order to investigate the Asian aerosol characteristics, field experiment campaigns of Asian Atmospheric Particulate Environment Change Studies (APEX-E1 in December 2000, -E2/ACE-Asia in spring 2001, and -E3 in spring 2003), have been done. The observational results of APEX-E1, E2, and ACE-Asia have been already shown [2]. This work focused on the observational period not only APEX-E2/ACE-Asia but also -E3 in 2003.

The Cimel sun/sky radiometers had been operated at the observational sites of Noto (37.3ºN, 137.1ºE), Shirahama (33.7ºN, 135.4ºE), and Fukue-jima (32.4ºN, 128.4ºE) both APEX-E2/ACE-Asia in 2001 and -E3 in 2003 filed campaigns. Brief description of each site is as follows:

1) Noto site locates in one of big peninsula beaked into the Sea of Japan. Therefore, the aerosols seem to be oceanic in usual and occasionally contaminated with the continental compounds transported from Korea and China.

2) Shirahama site locates in the middle of Japan and faces to the Pacific Ocean far away from huge city as Osaka, Kobe and Kyoto. Cimel CE-318-1 sun/sky radiometer has been set up at Shirahama since October 2000 as a part of NASA/AERONET[1].

3) Fukue-jima site is in the island in Nagasaki. This site exists in the most westward position in this work and close to Cheju Island in Korea. In other word, Fukue-jima site is an appropriate position to observe the influence of continental aerosols transported from Korea and China. Prede POM-100P radiometer has been working at Fukue-jima site since July 2002. The observational wavelengths are 0.34, 0.38, 0.40, 0.44, 0.50, 0.67, 0.87, 0.94, and 1.02 μm.

2.- Measurements.

The direct sun photometric measurements provide the aerosol optical thickness (AOT: τ_λ and the Ångström exponent (α) which is calculated from the spectral tendency of optical thickness of aerosols as below:

$$\alpha = -ln(\tau_{\lambda 1}/\tau_{\lambda 2}) \,/\, ln(\lambda_1/\lambda_2), \qquad (1)$$

where wavelengths λ_1 and λ_2 take values of the central wavelength of observing channels, respectively. The values of α are closely related to the aerosol size distribution. For example, the small values of α indicate the large particles, and the large values represent small particles such as artificial aerosols. In general, the values of Ångström exponent (α) from ~0 to 1 shows coarse particles (such as sea salt solution, and soil dusts), on the contrary, $1< \alpha < \sim 2.5$ indicates small particles (such as sulfate, biomass burning etc.). The accuracy of aerosol optical thickness is less than 0.01 at all observing channels. The cloud screening of the obtained data has been done before aerosol retrieval.

2.a.- The APEX-E2/ACE-Asia Experiments in Spring, 2001.

Figures 1a and 1b show the relationship between aerosol optical thickness (τ_a) at wavelength of 0.87 μm and Ångström exponent (α) in spring of 2001. The averaged values of AOT at a wavelength of 0.87 μm over Asian dust period alone are 0.37, and 0.33, respectively, at Noto, and Shirahama. The same values of AOT but for usual time are 0.15, and 0.12. It is found that aerosol optical thickness in Asian dust event is more than double of usual value. Although the Ångström exponent in spring is totally variable, the averaged value looks a good indicator for dust event. Ångström exponent takes small values in dust event. Namely Ångström exponent averaged over the dust event alone takes the value of 0.76, and 0.80 at Noto, and Shirahama. On the other hand, the value averaged over the dust free days takes 1.3, and 1.2 at Noto, and Shirahama. We found in Figures 1a and 1b that the value of Ångström exponent is decreasing with optical thickness, especially in large optical thickness region, where several characteristic clustering classes are found. Each class indicates each dust event.

2.b.- The APEX-E3 Experiment in spring, 2003.

Figures 1a', 1b' and 1c' are the same as figures 1a and 1b, respectively, but for Noto, Shirahama and Fukue-jima during APEX-E3 in 2003. We can see from these figures that the high AOT measurements are decreased compared to spring in 2001 because only one dust event was observed over Japan on 13 April 2003. But such an another aerosol event as the smoke of Russian forest fires was found over Japan in May in 2003, which provides the high values of AOT and Ångström exponent appeared in the upper right corner in Figures 1b' and 1c'.

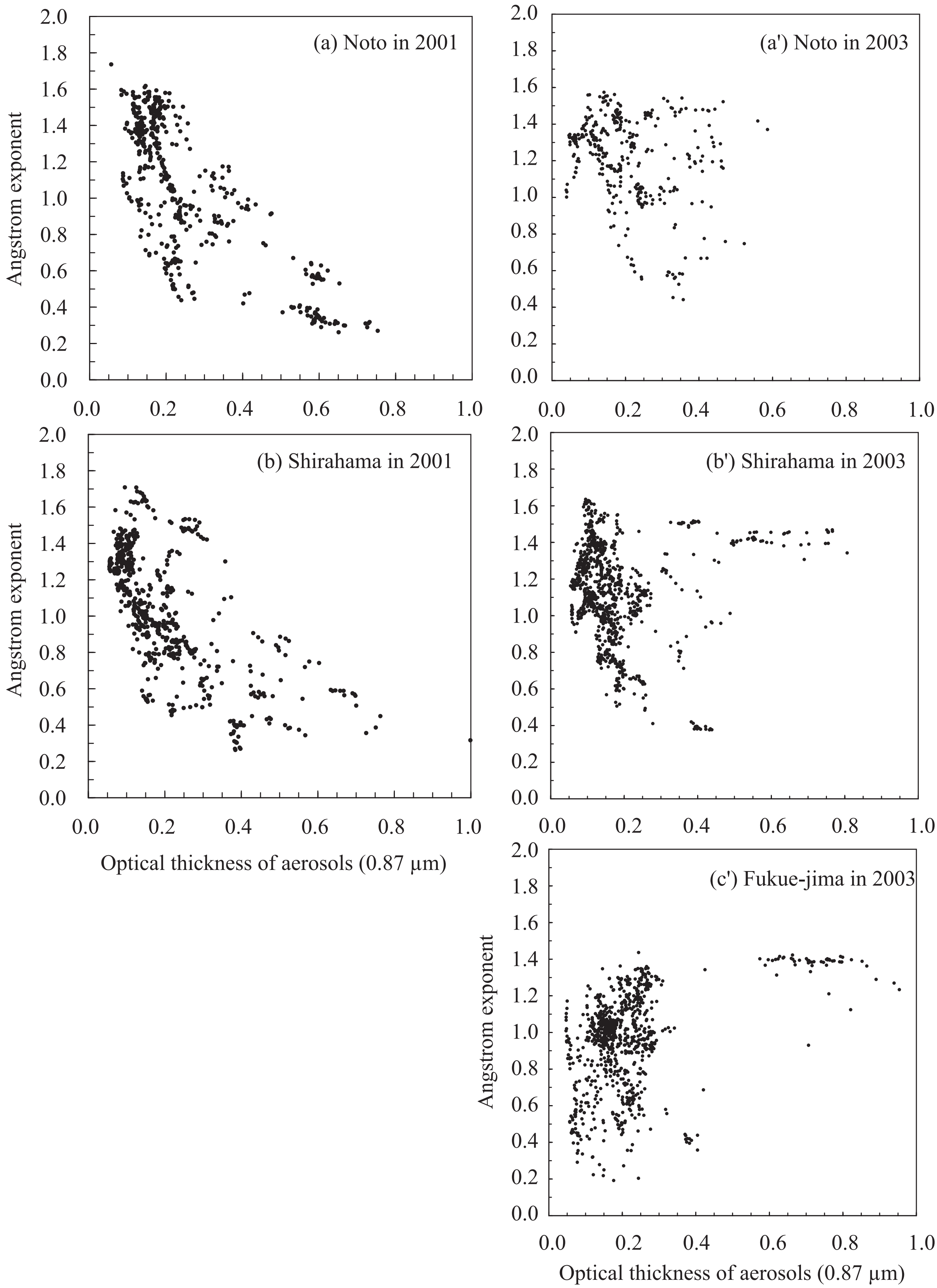

Figure.1.- Relationship between aerosol optical thickness at a wavelength of 0.87 µm and Ångström exponent.

3.- Aerosol Properties during the experiments.

Figure 2 represents the retrieved results of volume size spectrum derived from sun/sky photometry at Shirahama site through AERONET Level 2 standard process [3-4]. Thick Asian dust layers were covered over both observational sites on 14 April 2001 (panel a) and 13 April 2003 (panel b). Both results show the bimodal size distribution which represents the dust event. Because the coarse particles are unusually dominant. That is the large soil particles are loaded in the atmosphere on these days. Peak of Asian dust particles is around 1-2 µm. In addition, non-spherical particles are considered in the retrieval procedure [5].

Table 1 presents the derived single scattering albedo (SSA) and the complex refractive index, of which real and imaginary parts are denoted by RFR and RFI respectively, at a wavelength of 0.87 µm on the same each day in Figure 2 at Shirahama site. All days shown in Figure 2 and in Table 1 are chosen for the unusual heavy aerosol loading cases in order to reduce the retrieval errors. In respect of SSA, the two cases on 14 April, 2001 and 13 April, 2003 in Table 1 provide the larger values. It seems to be natural that the soil dust particles take rather higher values of SSA corresponding to the lower values of RFI. In other word, the soil dusts are not absorbing particles. The values of real part shows a bit smaller than typical soil dust refractive index. However, those values are corresponds to the results of different observational method based on polarization [2]. It is necessary to discuss more detail on refractive indices, but we can say at least that the Asian dust is an internal/external mixture of the soil dust and the anthropogenic compound.

TABLE I

Single scattering albedo (SSA) and complex refractive indices (RFR; real part, and RFI; imaginary part) at a wavelength of 0.87 µm at Shirahama site.

Date	SSA	RFR	RFI
14 April, 2001	0.95	1.52	0.0029
13 April, 2003	0.98	1.51	0.0014

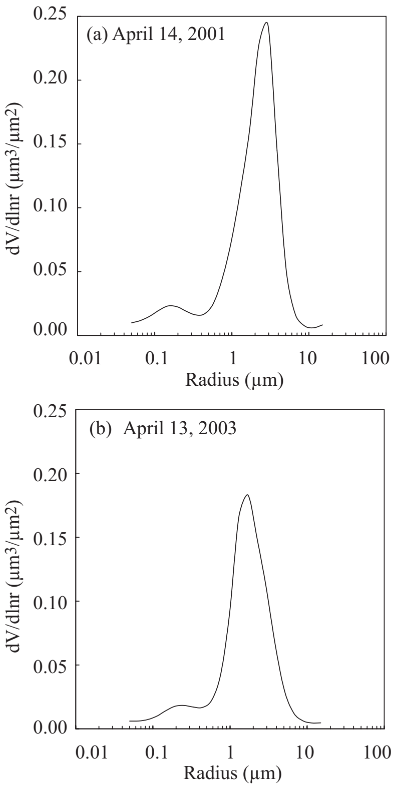

Figure.2.- Volume size distribution functions at Shirahama site.

4.- Aerosol Properties derived from satellite.

Figure 3 and 4 show the aerosol optical thickness and Ångström exponent on 13 April 2003. These results are derived from ADEOS-2/POLDER polarization as well as radiance data. Although the details of retrieval procedure have been interpreted in the previous paper [6], the basic idea of our aerosol retrieval is that the scattering behavior of aerosols plays a sufficient role in the polarization field of the Earth atmosphere-surface system in the near infrared wavelengths.

The area loading lots of Asian dust flown from China is circled by the dashed curve in Figure 3. It is clear that Asian dusts distribute over from the Yellow sea to Japan where all of three ground observational sites as mentioned in the section 2.b are involved. We found that both results from the satellite and the ground coincide with each other. Note that there are some uncertainties to distinguish the heavy aerosol loading from the thin cloud.

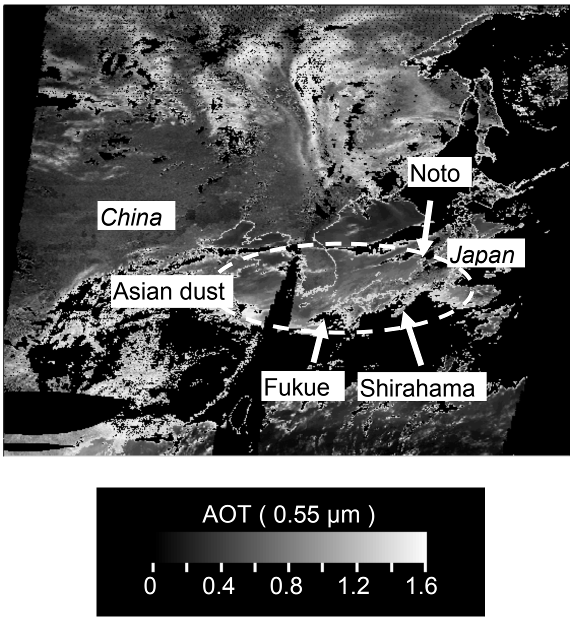

Figure.3.- Distribution of aerosol optical thickness at a wavelength of 0.55 μm over East Asia on 13 April 2003 derived from ADEOS-2 / POLDER.

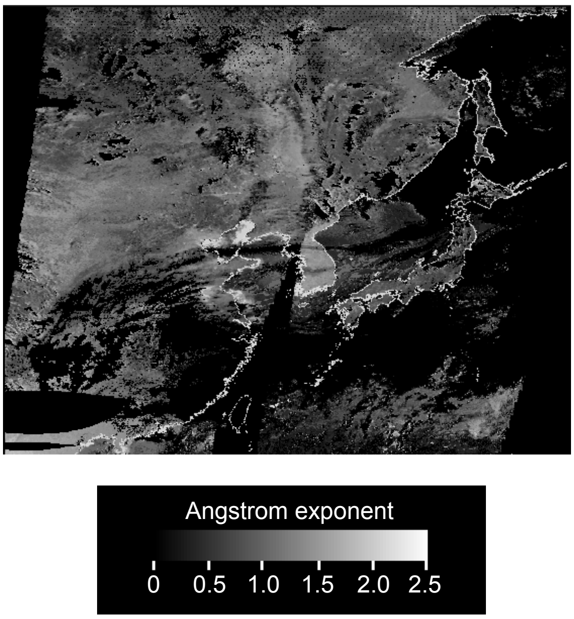

Figure.4.- Distribution of Ångström exponent on 13 April 2003 derived from ADEOS-2 / POLDER

Conclusions.

The aerosol optical thickness and Ångström exponent in dust season have been measured. It is found that aerosol optical thickness in the dust event is more than double of usual value, and Ångström exponent takes small values in dust event. Summarizing the results of our ground measurements during the ACE-Asia and APEX experiments;

1). Asian dust has a complicated feature mixing with the anthropogenic compound externally and/or internally,
2). retrieved size of soil dust indicates the large particles,
3). the soil dust is a weak absorber at 0.87 μm,
4). dust event in 2003 is much less than that in 2000, 2001, and 2002.

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