3.3 AN OVERVIEW OF THE ASIAN ATMOSPHERIC PARTICLE ENVIRONMENTAL CHANGE STUDIES (APEX)

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1. INTRODUCTION

There are still large uncertainties in the evaluation of the direct and indirect effects of man-made aerosols (IPCC, 2001; Takemura et al., 2001). The evaluation of IPCC (2001) of the indirect effect, for example, ranges from 0 to -2 W/m^2 in terms of the global mean radiative forcing at the top of the atmosphere. This estimate is only for the 1st kind indirect effect which is the effect of the cloud reflectivity change caused by cloud particle number increase and cloud effective particle size decrease under the assumption of the fixed liquid water path as assumed by Twomey et al. (1984). There is a proposal that the decreased cloud particle size further induces a change in the cloud efficiencies for precipitation and scavenging of aerosols (Albrecht, 1989). This 2nd kind indirect effect has been scarcely understood.

Another important conclusion of IPCC (2001) is that the there is a large uncertainty in the global warming forecast until the end of the 21st century. Global mean surface air temperature rise was estimated, for example, to be in a broad range from 1.4°C to 5.8°C. It is important to note in this regard that about half of this uncertainty comes from the uncertainty in the future social and economical scenario of the world countries. Especially the future trend of the Asian region has a large impact on the future climate projection, because this area is expected to continue increasing in their energy consumption and man-made pollutant emission within the entire period of the 21st century.

The above discussion suggests that the understanding and future forecasting of the indirect effect of man-made aerosols in the Asian region should be one of the highest priority subjects in the global warming studies. With this motivation, several important efforts have been made in INDOEX, ACE-Asia, and APEX for understanding the climate effects of aerosols. This paper will overview the APEX activities.

The project of APEX (Asian Atmospheric Particle Environmental Change Studies) has been initiated by one of JST (Japan Science and Technology Corporation) projects for the period of 1999-2004 in order to understand and model the aerosol-cloud interaction phenomenon, known as the aerosol indirect effect on climate, in the Asian region. The science objectives of the APEX project are set as follows:

- Understanding the detailed processes of the aerosol indirect effect to change the cloud physical properties and the earth's radiation budget.
- Modeling of the process of aerosol-cloud interaction.
- Estimation of the changes in the radiative budget and precipitation efficiency of the cloud system after the industrial revoplution.

2. SOME RESULTS FROM APEX

The APEX has been working since November 1999 along their science plan. We had two intensive field observations, named as APEX-E1 and APEX-E2 experiments, during 11-24 Dec., 2000 and 1-30 April, 2001, respectively in the region of the East China Sea and Japan. The latter experiment contributed to the ACE-Asia

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international field experiment carried out in the same period.

Figure 1 shows the time series of the single scattering albedo in April 2001 obtained from aethalometer/nephelometer measurements at Amami-Oshima Island (28°N22', 128°N30'). Chemical compositions of fine aerosol particles with radius less than 1 μm were also obtained by the method of Ohta et al. (1998). The single scattering albedo was generally as low as 0.85 through the period. As indicated by the high concentration of mineral dust aerosols, an intensive Asian dust event prevailed over the East China Sea in the period of 11-16 April. It is interesting to find the sulfate increased on 10 April at Amami-Oshima before the dust event. The value of the single scattering albedo had a sharp drop on this day. After then the single scattering albedo recovered to a value around 1 on the first day of the dust event and then gradually decreased to 0.8 during the dust event. These phenomena suggest that a plume of sulfate rich aerosols with soot particles was first pushed out from the industrial region of the continent by a low pressure system followed by a mineral dust plume of a high single scattering albedo, and then a slow mixing process of the two aerosol species gradually decreased the single scattering albedo after 15 April.

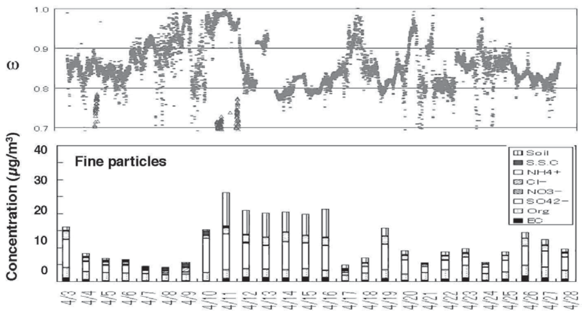

Figure 1. Time series of the single scattering albedo and chemical compositions of fine aerosol particles at Amami-Oshima Island in April 2001.

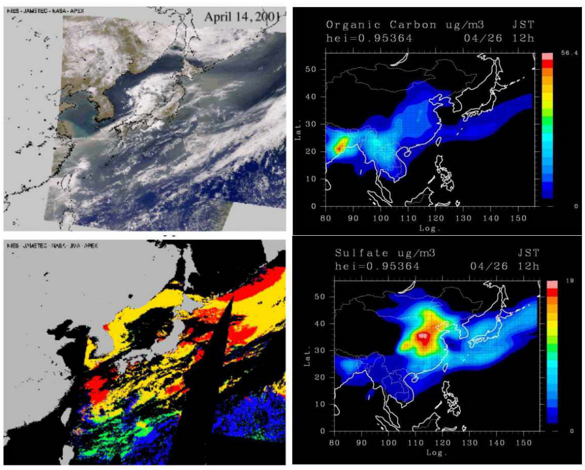

Figure 2. Near true color image (upper left panel) and aerosol classification from SeaWiFS (lower left panel; yellow for carbonaceous, red for mineral dust, green for sulfate, and blue for sea salt aerosols). CFORS model results are also shown for surface concentration distributions of carbonaceous (upper right panel) and sulfate (lower right panel) aerosols.

Such a mixing process is also supported by satellite remote sensing in Fig. 2, which shows an aerosol classification from a four channel remote sensing algorithm (Higurashi and Nakajima, 2002) applied to SeaWiFS radiance data of 14 April. It is found that the entire area around Japan had a mixed air mass of dust aerosols and other aerosols such as sulfate, carbonaceous, and sea salt aerosols. An interesting fact is that aerosols are classified as carbonaceous in a large portion of the area. This fact is consistent with the low single scattering albedo and the mass fraction of carbonaceous and soot particles more than 10% of the total mass observed at Amami-Oshima Island. Numerical tests have found that the satellite algorithm tends to classify aerosols as carbonaceous when carbon-origin aerosols are mixed with sulfate aerosols.

Figure 2 also shows a numerical simulation result of the near-surface aerosol concentrations of carbonaceous and sulfate aerosols on 26 April using the CFORS chemical transport model (Uno et al., 2002). The model result suggests that the aerosol chemical compositions are largely different between the Amami-Oshima region and the Korean Peninsula region. The former has more carbonceseous aerosols than the latter. It is, therefore, interesting to study the detailed difference in the aerosol and cloud characteristics in these two regions.

There are several comprehensive observation sites in these two regions. One is the Kosan site on Cheju Island, which is the ACE-Asia super site. The other is the Amami-Oshima site of SKYNET, which is the validation network for the ADEOS-II/GLI satellite-borne sensor project of NASDA (National Space Development Agency of Japan). The minimum instrumentation of SKYNET is

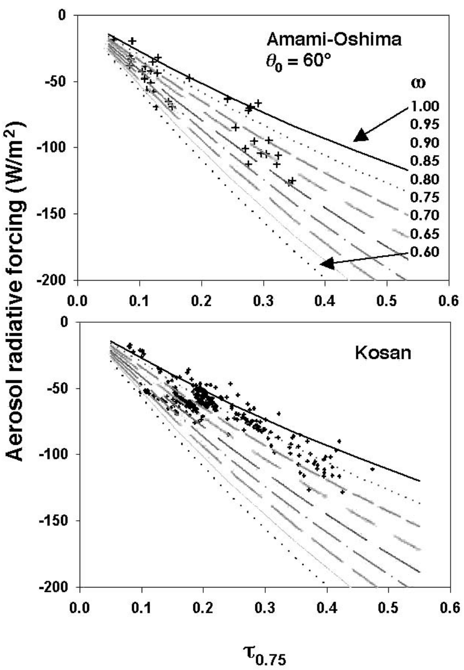

Figure 3. The aerosol radiative forcing (W/m^2) at Amami-Oshima Island and Kosan sites. Theoretical curves with various single scattering albedo values are shown with observed data.

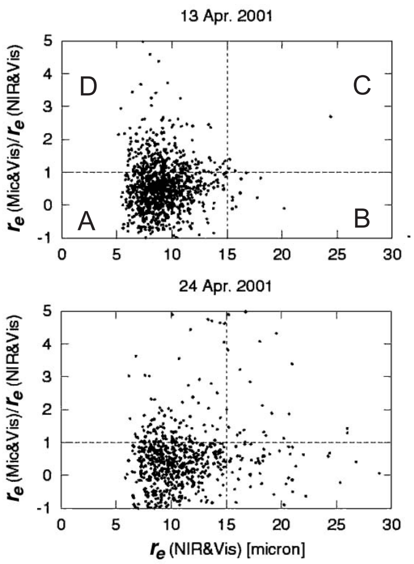

Figure 4. The ratio of the effective particle radius from visible and microwave radiances, r_e(*Mic&Vis*), to that from visible and near infrared radiances, r_e(*NIR&Vis*), as a function of r_e(*NIR&Vis*). TRMM/VIRS and TMI sensor data of 13 and 24 April 2001 were used.

a sun/sky-photometer, up-looking pynanometer and pyrheliometer. Some SKYNET sites have a lidar, mirowave radiometer, GPS sensor, and chemical filter samplers along with the minimum instrumentation. Data center is located at Chiba University (http://atmos.cr.chiba-u.ac.jp/aerosol/skynet/index.html). Figure 3 shows the shortwave aerosol surface radaitive forcing in clear sky condition at Amami-Oshima Island and Kosan sites with theoretical curves calculated with the size distribution retrieved from sun/sky photometry and with various single scattering albedo values. It is found that the fitted single scattering albedo at Amami-Oshima had a large variety from 0.8 to 1.0 regardless of the optical thickness, whereas the single scattering albedo at Kosan tended to increase with increasing optical thickness. This observation supports a large difference in the aerosol characteristics between Amami-Oshima and Kosan sites as discussed in Fig. 2.

As shown by Nakajima et al. (2001), the east coast regions of Aurasian and American continents have a strong proportionality between the column aerosol number and the low cloud particle number, suggesting these regions have significant aerosol indirect effects. One of the important issues in the aerosol indirect effect study is if the cloud liquid water path increases significantly with increasing cloud condensation nuclei (Albrecht, 1989). Masunaga et al. (2002) developed a satellite algorithm to obtain the effective particle radius, r_e(Mic&Vis), using the relation $r_e = 2\ W/3\tau_c$, where W is the liquid water path retrieved from microwave radiances and τ_c is the cloud optical thickness retrieved from a visible radiance. This effective radius, r_e(Mic&Vis), is regarded as the mean effective radius averaged though the cloud layer. On the other hand another value of the effective particle radius, r_e(NIR&Vis), can be derived from the visible-near infrared reflection method (Kawamoto et al., 2001) which represents the particle radius near the cloud top. Comparison of r_e(Mic&Vis) and r_e(NIR&Vis) can judge if the cloud system is in a non-precipitating condition without large drizzle or rain particles near the cloud base. It is also recognized that if the effective radius exceeds a critical value, 15 μm, gravitational falling of cloud particles dominates in the cloud layer.

It is, therefore, a plot of the ratio r_e(Mic&Vis)/r_e(NIR&Vis) versus r_e(NIR&Vis) as in Fig. 4 is useful to study the cloud condition. Figure 4 shows such plots for the East China Sea on 13 April and 24 April derived from

TRMM/VIRS and TMI satellite-borne sensors. These two days can be characterized by Asian dust event and backgroud conditions at Amami-Oshima according to the observed chemical compositions in Fig. 1. It is interesting to find that the number of pixels in the region B and C is smaller on 13 April than on 24 April suggesting the drizzling and precipitation decreased during the Asian dust event. This phenomenon can be understood as that air pollution aerosols associated with the dust storm acted as active cloud condensation nuclei to increase the cloud particle number and thus decrease the cloud particle size. This suggests that the low cloud microphysical state in the East China Sea was affected by outflow of the air plume from the continent in the period of APEX-E2 experiment.

3. CONCLUSIONS

The results shown in the preceding sections indicate the characteristic features of the East Asian air mass with complicated mixture of various aerosol species. It is also suggested that the low cloud system in the East China Sea region was also affected by the aerosol plume from the continent.

Acknowledgments

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