ACTIVE REMOTE SENSING AND CLIMATE STUDIES

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ABSTRACT

Lidar and cloud radar measurements started providing new information on the aerosol and cloud properties. This paper discusses new prospects of the active remote sensing technology for studying the climate effects of aerosol and clouds. SKYNET has been established in the Asia region with dual frequency 24 hour continuous lidar system with sky radiometers and broad band flux radiometers for evaluation of aerosol and cloud radiative forcings. Satellite missions of CLOUDSAT/CALIPSO and EarthCARE will provide new data sets for improving high resolution weather forecasting and climate modeling.

1. Introduction

Climate effects of anthropogenic aerosols are large but uncertain, because the involved processes are complicated. Direct radiative forcing has been evaluated as small as -0.02 W/m^2 to -0.5 W/m^2 (IPCC, 2001), but has a large forcing at the surface reaching -2 W/m^2 on global average (Takemura et al., 2006). Regionally the surface forcing is as large as -10 W/m^2 in heavily polluted regions as Asia (Nakajima et al., 2003). The indirect forcing has not been accurately evaluated, and there are largely different estimates from almost 0 to -2 W/m^2 (IPCC, 2004).

Recent development of networks of lidars, sky radiometers, and broadband flux radiometers start providing useful data for improving the present knowledge of the climate effects of aerosols.

2. Radiation budget measurements

NASA AERONET has proven that the sun/sky photometry is one of important remote sensing methods for deriving columnar aerosol optical thickness, single scattering albedo, and size distributions. SKYNET is an another sun/sky photometry network with PREDE sky radiometers mostly distributed in Asia (Fig. 1). Figure 2 shows views of large-scale observatories joining the UNEP/ABC project (Ramanathan et al., 2003). These sites are implemented by multiple instruments, such as lidar, sky radiometer, broad band flux radiometers, microwave radiometer, and others. With such comprehensive system of instruments, it becomes possible to study the effect of aerosols and clouds to the surface radiation budget.

Figure 3 shows observed and theoretical values of the 24 hour mean clear sky radiative focings, *ARF*, at Gosan and Amami-Oshima sites. The figure shows that the forcing efficiency factor, $\beta = -ARF/\tau_{500}$ is dependent on year and location. β values range from 50 to 100

Fig. 1 Networks for lidar and radiation flux measurements.

Figure 2. View of large-scale observatories.

W/m². As shown by theoretical curves with different imaginary index of refraction of aerosols, the β-value depends on single scattering albedo and asymmetry factor in a unique way as shown by Nakajima et al., 2003. The period mean ARF also depends on the aerosol optical thickness ranging from -15 W/m² to -40 W/m².

Detailed investigation of Fig. 3 shows, however, that a simple analysis with optical thickness and efficiency factor is not so useful because it is found that the slope of the curve differs for small τ cases and large τ cases, indicating the dominating aerosol species is different depending on the atmospheric turbidity. For two species system, the efficiency factor can be expressed as $ARF = -\beta_1\ \tau_{1,500} - \beta_2\ \tau_{2,500}$.

3. Use of active remote sensing

As discussed in the previous section, it is important to monitor the aerosol stratification through which we can understand the change of aerosol species. Figure 4 shows time series of ligar signals in ABC/EAREX05 regional experiments. It is found that the dust aerosol signal can be traced from in-land China to the outflow region around Korea and Japan.

Combined use of lidar and 3 mm cloud radar can be used for obtaining effective particle radius and extinction coefficient profiles of the cloud system, by which we can make a correlation study between aerosol and cloud parameters. Establishment of surface networks of active sensing along with radioemters are highly needed for the coming period of satellites with

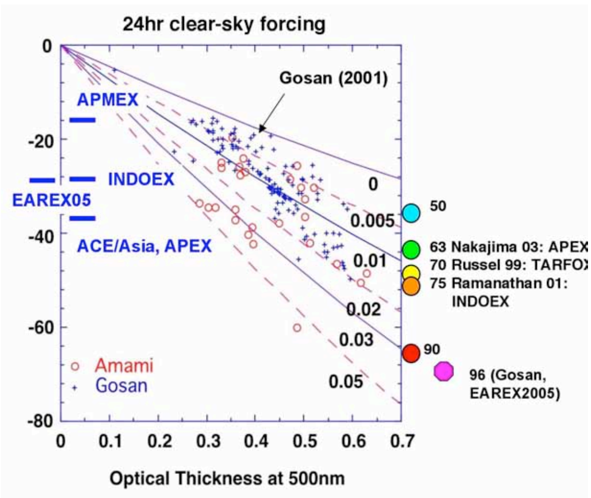

Figure 3. The 24 hour mean clear sky radiative forcing of aerosols as a function of the aerosol optical thickness at 500nm at Gosan and Amami-Oshima sites. Period mean forcing values and efficiency factor are shown by horizontal bars and circles respectively.

active sensors, similar to those of the surface networks. Important issues for studies with these active sensings are (i)Dependence of cloud particle radius and liquid/ice water contents at near cloud layer bottom on the aerosol number; (ii) Simultaneous model simulation using a binned microphysical model to simulate the cloud size distribution development.

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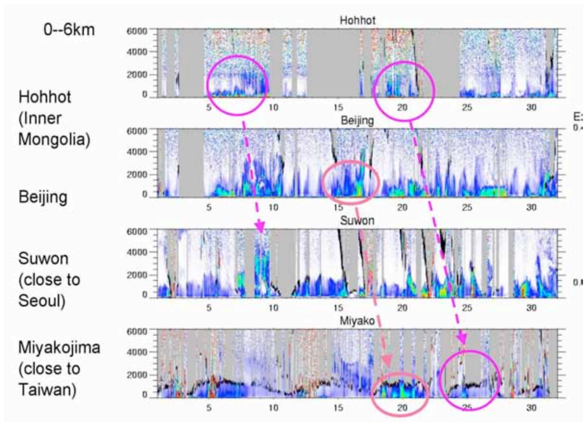

Figure 4. Time series of lidar backscattering coefficient profiles at sites of Hohhot, Beijing, Suwon, and Miyakojima. (Provided by Dr. N. Sugimoto of NIES)