NETWORK OBSERVATIONS OF ASIAN DUST AND AIR POLLUTION AEROSOLS USING TWO-WAVELENGTH POLARIZATION LIDARS

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ABSTRACT

Network observations using ground-based two-wavelength (532 nm, 1064 nm) polarization (532 nm) lidars have been conducted since March 2001 to study movement of Asian dust and air-pollution aerosols in the East Asia region. At present, lidars are operated continuously at 14 locations in Japan, China, Korea, and Thailand in cooperation with various universities and research institutes. The data are used for analysis of aerosol events and validation/assimilation of chemical transport models and aerosol climate models. The results on general features of movement of Asian dust, air-pollution aerosols and biomass burning aerosols are reported. Also, Asian dust events in recent years are discussed.

1. INTRODUCTION

In the East Asian region, various kinds of aerosols such as dust, anthropogenic aerosols co-exist. To understand the effects of these aerosols on the climate and the environment, observations of spatial distribution and optical characteristics of aerosols are indispensable.

We operate a network of two-wavelength polarization lidars in Japan, China, and Korea in cooperation with various research organizations and universities [1]. Currently, the lidars are continuously operated at the following locations. Tsukuba (36.05N, 140.12E), Nagasaki (Nagasaki University) (32.78N, 129.86E), Cape Hedo (26.87N, 128.25E), Fukue (32.63N, 128.83E), Sapporo (Hokkaido University) (43.06N, 141.33E), Toyama (Toyama Prefectual Environmental Science Research Center) (36.70N, 137.10E), Matsue (Shimane Prefectual Institute of Public Health and Environmental Science) (35.21N, 133.01E), Sendai (Tohoku University) (38.25N, 140.90E), Suwon, Korea (Kyung Hee University) (37.14N, 127.04E), Beijing (Sino-Japan Friendship Center for Environmental Protection) (39.90N, 117.16E), Hefei (Anhui Institute of Optics and Fine Mechanics) (31.90N, 117.16E), Huhehaote (or Hohhot) (40.94N, 111.37E), and Phimai, Thailand (15.18N, 102.57E). We also conducted observations in Gosan, Jeju in Korea (33.60N, 126.50E) for February to June of 2005 in the UNEP Project Atmospheric Brown Cloud (ABC). The lidars in the network are two-wavelength (532 nm, 1064 nm) Mie-scattering lidars with the depolarization ratio measurement function at 532 nm.

To study the movement of Asian dust and air-pollution aerosols, we developed a method for estimating contributions of dust and spherical aerosols in aerosol mixture [2]. The method is based on an assumption that the observed aerosols are simply an external mixture of two types of aerosols having the different aerosol depolarization ratios. With this method, we obtained vertical distributions of non-spherical Asian dust and mostly spherical air-pollution aerosols. Recently, we further developed a method using the depolarization ratio at the two wavelengths (532 nm, 1064 nm) to obtain dust mixing ratio and backscattering Angstrom exponent for dust and air-pollution aerosols [3].

2. RESULTS AND DISCUSSION

Fig. 1 shows the Mie-lidar extinction coefficient (S1=50) time-height indications for Asian dust and spherical aerosols in March 2004 in Beijing, Hefei, Tsukuba, and Miyakojima. Features of distributions of Asian dust and air-pollution aerosols are well separated at each location with the method using the depolarization ratio. For major dust events the movement of the dust plume can be traced in the time-height indications. As for air-pollution aerosols, features of the regional-scale air pollution (variations with the temporal scale of several days) are seen clearly, for example, in Beijing. The regional air pollution is also significant in Hefei. However, features in temporal variation are different from that in Beijing. In Miyakojima, plumes of aerosols are often seen above the planetary boundary layer in spring season.

We compared the lidar extinction coefficients (S1=50) with the modeled extinction coefficients for various aerosols by the Chemical Weather Forecast System (CFORS) [4]. The results are shown in Fig. 1. We used an algorithm of Uno and Satake for converting the calculated mass concentrations to the extinction coefficients for different types of aerosols. The dependence on the size distribution is considered for Asian dust, and the effect of relative humidity is considered for water-soluble aerosols.

In Fig. 1, the forecast mode CFORS dose not necessarily reproduced the observed aerosol distributions very well. However, the results for Tsukuba and Miyakojima are quantitatively reasonable for both Asian dust and air-pollution aerosols (sulfate and carbonaceous (BC+OC) are shown here). The plumes observed above the boundary layer in Miyakojima are explained as plumes of biomass burning carbonaceous.

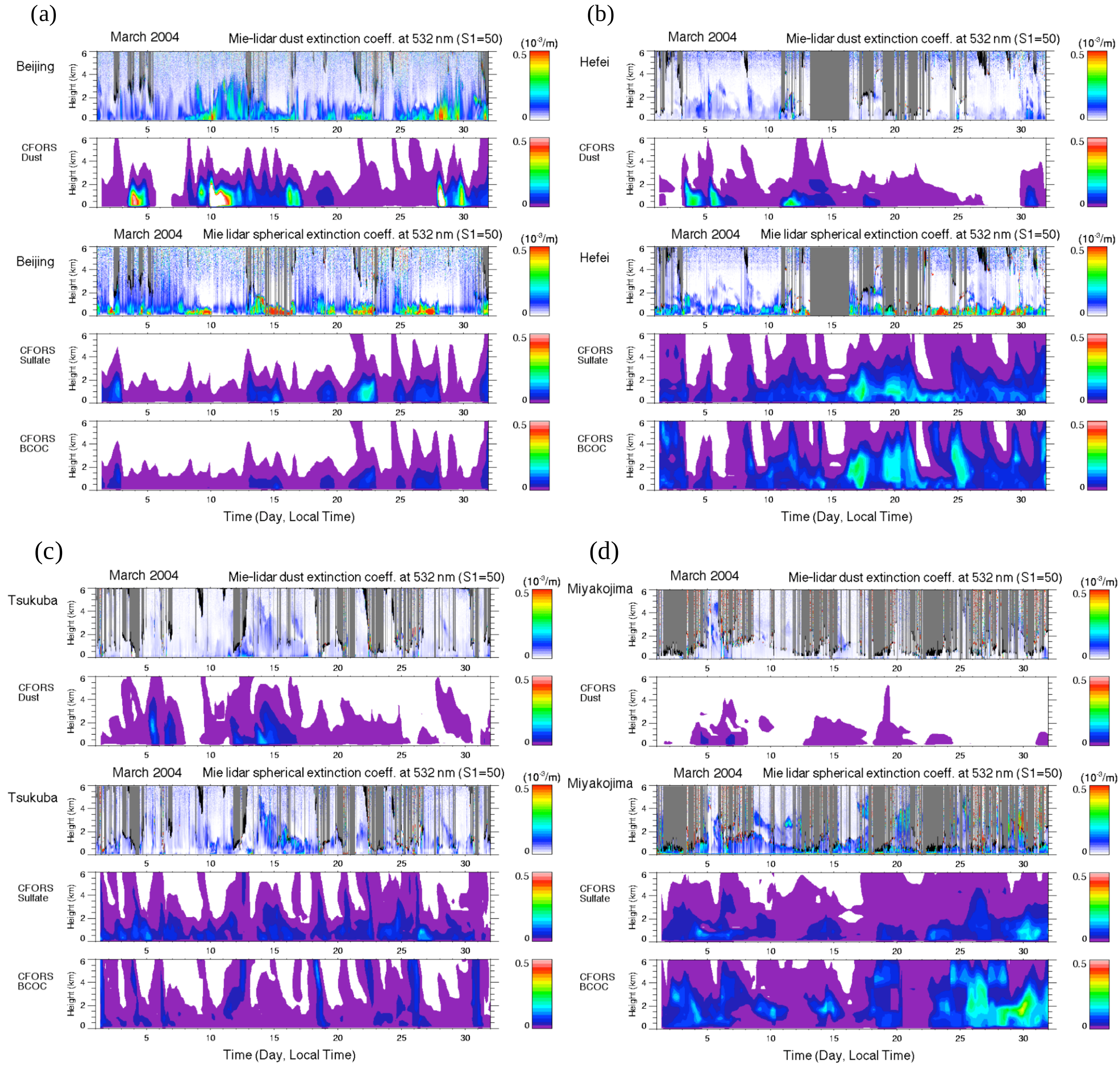

Fig. 1 Mie-lidar extinction coefficients of Asian dust and spherical aerosols compared with extinction coefficients of dust, sulfate, and carbonaceous (BC+OC) calculated by CFORS, for (a) Beijing, (b) Hefei, (c) Tsukuba and (d) Miyakojima in March 2004.

On the other hand, the high extinction coefficient in Beijing in heavy air pollution phenomena is not reproduced well by CFORS. Surface meteorological data showed relative humidity is high in such cases. However, CFORS does not reproduce the relative humidity very well because of the low spatial resolution (80 km).

In 2001 and 2002, we observed heavy dust events accompanying a strong low pressure in Siberia [5]. However, we did not observe such typical heavy dust events in 2003, 2004. In 2005, the seasonal progress was slow in contract to that in 2004. The frequency of dust events was low in March and high in April. In April and May, several major dust events were observed with the network.

A notable event observed in Japan was the elevated dust layer over Sendai on April 30. The optically dense but spatially thin layer was observed at 3-km height. The extinction coefficient at the layer exceeded 1 km^{-1} and was unusually high as an elevated dust layer over Japan. Fig. 2. shows the dust extinction coefficient observed at six lidar locations. The analysis with CFORS showed the origin of the dust was in Gobi desert in Mongolia. Back trajectories from Sendai are shown in Fig. 3. The result shows the most dense part of the dust layer was transported over Hohhot and Beijing. It is interesting that an elevated dust layer was actually observed in Beijing, and the layer was on the ground in Hohhot.

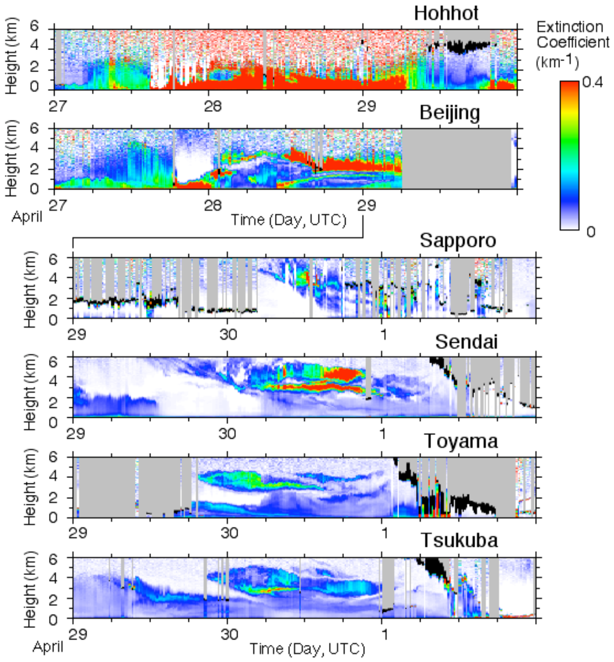

Fig. 2. Mie-lidar dust extinction coefficient (S1=50) at six locations in the dust event in April 2005.

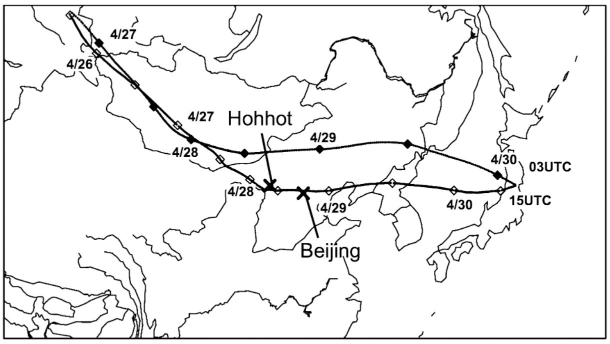

Fig. 3. Back trajectories from Sendai calculated with CFORS for the dust event shown in Fig. 2.

The analysis with CFORS showed there was a steep gradient of potential temperature between Hohhot and Beijing, and this fact explains how the dust layer was elevated.

In this event, the forecast mode CFORS, however, did not reproduce the observed dust layers very well. This was mainly caused by the fact that the snow coverage in Mongolia was smaller than usual and precipitation was larger in China. This event is consequently a good example for demonstrating the effect of the assimilation using the lidar network data in dust forecast models. Currently, a 4-dimensional assimilation model is being developed at Kyushu University [6]. The real time data assimilation enables not only accurate forecast but also accurate evaluation of dust emission in the source areas.

Another interesting episode in 2005 is the observation of Saharan desert [7]. An optically thin dust layer was observed at heights above 3 km with some of the lidars in the network in early March of 2005. The global dust transport model, NAAPS [8], and the aerosol climate model, SPRINTARS [9], showed the dust was transported from Sahara desert. It is usually difficult to identify the source region in observed data because the transport path overlaps with the dust from Taklimakan desert, but the emission from Taklimakan was very small in early March of 2005, and the source region was identified relatively clearly. The density of the dust estimated by SPRINTARS agreed reasonably with the observed results. However, NAAPS seemed to overestimate the density.

3. CONCLUSION

With the lidar network observations, general features of the movement of Asian dust and air-pollution aerosols were observed. The features of regional air pollution were clearly observed in Beijing, Hefei and Suwon. However, in Hohhot located about 450 km west of Beijing, the feature of the regional pollution was not significant, and the local pollution was dominant. These features were reproduced well with CFORS. In Miyakojima aerosol plumes were often observed above the boundary layer in the spring season, and the CFORS results suggest the source was biomass burning in South Asia.

The comparison of the lidar network data with CFORS showed the general features of the movements of Asian dust, air-pollution aerosols, and biomass burning aerosols were reproduced by CFORS. However, there are problems with the model in the details.

The results suggested the possibility of the real time data assimilation with the lidar network data. At present, the 4-dimensional assimilation model is being developed for Asian dust.

Also, comparison with the aerosol climate model, SPRINTARS is underway. We think the comparison of distributions of aerosols and clouds in actual time domain is useful for validating the processes in the model related to aerosols and clouds. We also think, as to the lidar data processing, the collaboration with model researchers is essential to the effective use of the lidar data.

4. ACKNOWLEDGEMENT

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