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Activities in 15 years of AD-Net, a lidar network for Asian dust studies

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Abstract

A lidar network constructed by Mie-scattering lidars with polarization capabilities, named AD-Net (Asian dust and aerosol lidar observation network) has been operated in east Asian region to study the four dimensional distributions of various aerosol particles in this area. Especially Asian dust (Kosa) is significant atmospheric phenomena and has some environmental impact including health effects on human. Nowadays National Institute for Environmental Studies (NIES) is operating 20 lidars in collaboration with many organizations, and supplying obtained optical properties in the near real-time to the public. Two components of extinction coefficient (dust extinction and spherical particle extinction) are useful to indicate concentrations of both Asian dust particles and anthropogenic particles, respectively. Dust extinction is utilized in the epidemiology, and the result shows that Asian dust has some health impact in the east Asia. Expansion of lidar equipment (Raman channels, high spectral resolution) are also planned in AD-Net.

Keywords: Lidar; Asian dust; Vertical distributions; Environmental impact

1. Introduction

Asian dust (Kosa), mineral particles transported from inner Eurasian continent to the Pacific Ocean has large impact on the environment in east Asia. For example, Asian dust indicates some health impact on human (Ueda et al., 2012; Kanatani et al., 2016), impacts on the ecosystems in open water (Mori et al., 2011), and act as ice nuclei (Sakai et al., 2003). It is very important to capture the actual distribution of particles to evaluate such impacts in the region. The light detection and ranging (LIDAR) is a powerful remote

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sensing method to accomplish the total understanding of Asian dust. National Institute for Environmental Studies (NIES) has conducted networked lidar observations in Japan, Korea, China and Mongolia (Fig. 1) since 2001. In this paper, the lidar equipment and analyzing method in AD-Net are described, then the utilities of products from AD-Net are introduced.

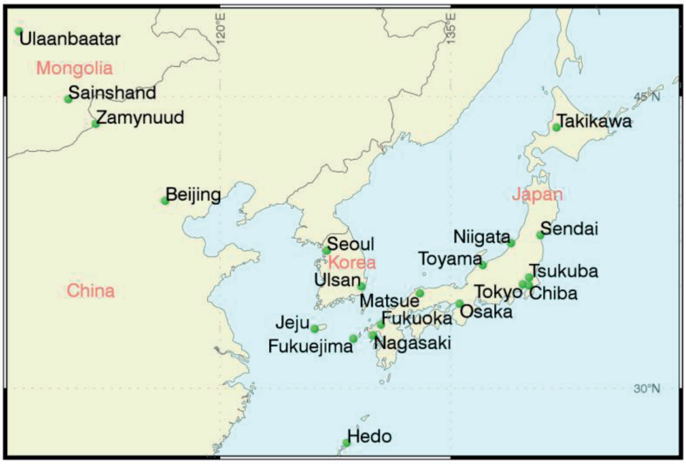

Fig 1. Locations of lidars in AD-Net

2. Lidar equipment and analysing method

Each lidar in AD-Net is constructed with a Q-switching flash-lamp pumped Nd:YAG laser which emits 532nm/1064nm in 10 Hz, a telescope of 20 cm diameter, cubic polarizer for 532 nm, two photomultiplier tubes (PMTs) for 532 nm detection and an avalanche photo diode (APD) for 1064nm detection. With this configuration, it captures three vertical profiles of the backscattered light from the sky. Two polarization components of 532 nm, 532s and 532p, are received inthe polarizing planes with perpendicular and parallel to the polarizing state of the emitted laser light. Total of them is the intensity at 532 nm, and the ratio between them is the linear (volume) depolarization ratio. As for 1064 nm, just the intensity is measured. One measurement is done in 5 minutes with summation of 3000 shots of laser pulses. Once a vertical profile is obtained, the system sleeps for 10 minutes. Thus, the time resolution is 15 minutes in normal operation. The sequence is controlled by a PC, and we do not regard weather condition for observation. Every hour, all measurement result files are transferred to NIES automatically, and the following analysing procedures are applied uniformly.

At first, cloud base height is detected using the vertical gradient of intensity at 1064 nm. Then, rainy/snowy profiles are identified using the ratio of intensity of two wavelengths. Profiles with rain/snow are eliminated for further analysis because 5 minutes averaged profiles during rain/snow conditions do not contain useful information related to the aerosols at all. Next, signal-to-noise ratio is checked to determine the height range where Fernald's method (Fernald, 1984) is applied. In optimal condition, 6 km is set to the top of analysing range. We only analyse below the cloud base if it is detected. Fernald's inversion method is applied with assumption of a lidar ratio S1 = 50 sr. Molecular density is quoted from CIRA86. As the backscatter from the stratosphericis not detected, upper boundary value of extinction coefficient (σi) is unknown for Fernald's method. In NIES, iteration is employed to infer σi. At first σiis set to zero and Fernald's method is applied. If the σiis too small, negative extinction is expected between surface and upper boundary. In such cases σiis slightly increased and again Fernald's method is applied. For fine (no cloud) condition, this is almost successful because aerosol optical depth (AOD) from lidar is comparable with AOD obtained by skyradiometer (Shimizu et al., 2004) except for the cases with continuous aerosol loading from the surface to 6 km. Finally, aerosol extinction is divided into two components (dust extinction and spherical particle extinction) using particulate depolarization ratio (δ). External mixture of dust whose δis 35% and spheres whose δ is 0% is assumed. Refer Sugimoto et al. (2003) and Shimizu et al. (2004) for detailed explanation of this method.

3. Validation and utilization of dust / spherical extinctions

Dust extinction coefficient near the surface was compared with other measurements. For example, Shimizu et al. (2011) compared dust extinction and filter sampled mass of particles during heavy Kosa events in Japan. Total suspended particles (TSP) and dust extinction below 1 km showed a good correlation, with relationship that 1mg/m^{3}of TSP corresponds to 1/km of dust extinction coefficient. Kaneyasuet al. (2012) compared iron (Fe) mass in PM 2.5 daily samples with dust extinction and confirmed that dust extinction well expressed the mass of Kosa. Both of dust extinction and spherical extinction were also compared with official records of Kosa by Japan Meteorological Agency and statistically agreed well in Nagasaki (Shimizu et al., 2015).

Horizontal variation of dust extinction coefficient obtained by 13 lidars in AD-Net is shown in Fig. 2. 5-25-50-75-95 percentiles of dust extinction coefficient at 500 m during 6 Kosa seasons (March – May) are presented with bars and boxes. In Korea and western Japan, dust extinction is higher than in eastern / northern part of Japan. Although Sainshand is considered as the closest observatory to the source of Kosa, percentile is lower than the downwind region. In the source region, the duration of Kosa is limited in the strong wind conditions (wind speed must exceed the threshold value of dust generation). However, in the downwind region, transported Kosa is observed for longer duration without limitation of local wind speed.

Dust extinction coefficient was utilized in both of data assimilation of chemical transport models (CTM) and epidemiology. Yumimoto et al. (2008) incorporated dust extinction to their CTM with a data assimilation method (4DVAR) and showed that assimilated dust concentration in the model became more realistically. In the epidemiology, dust extinction is precious data to evaluate the health effect of Asian dust because there is no other quantitative indexfor Kosa. Ueda et al. (2012) reported that emergency dispatches are increased after Kosa events in Nagasaki. Kanatani et al. (2016) showed that allergy of children is enhanced with Kosa phenomena in Toyama.

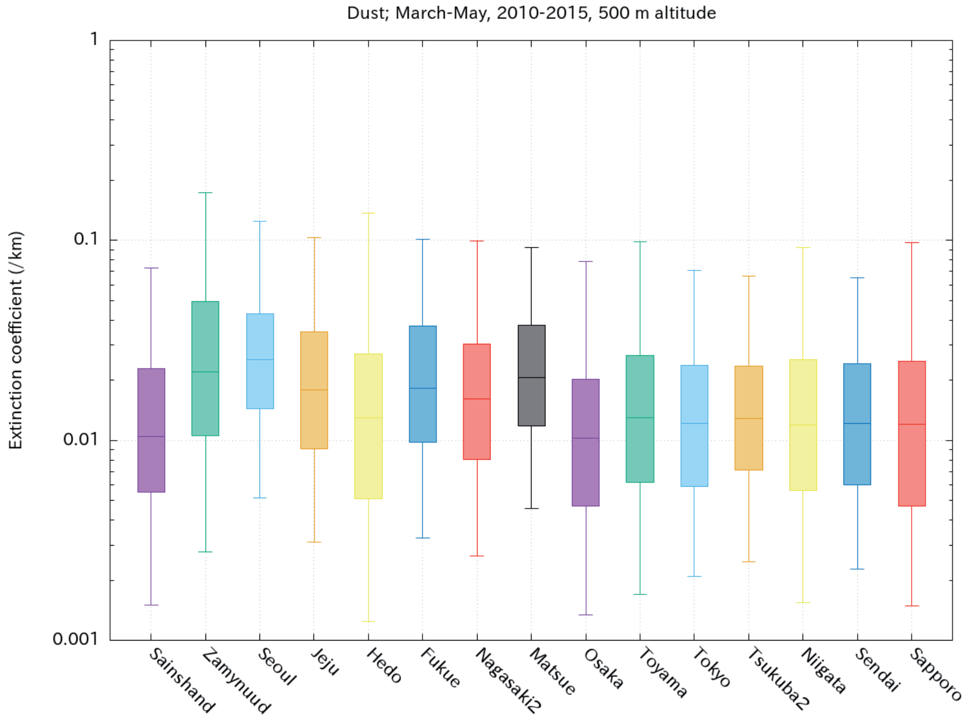

Fig. 2. 5-25-50-75-95 percentiles of dust extinction coefficient at 500m height in Mongolia, Korea and Japan. All observation results in the spring (March – May) in 2010-2015 were statistically analyzed

Another application is data publication to citizens. Dust extinction coefficient near the surface is converted to mass concentration of Kosa and provided every hour to citizens via web page on the Ministry of Environment, Japan (http://soramame.taiki.go.jp/dss/kosa). People who are sensitive to the dust particles can check the current status of the atmosphere by themselves through this website.

4. Future plan and concluding remarks

Although AD-Net has been providing information of aerosols in east Asian region, there is several limitations. One big assumption in the data processing is fixed lidar ratio (S1) in Fernald's method. Recently several lidars in AD-Net obtained capability of Raman signal detection at 607 nm which provides exact extinction coefficient without assumption of S1 in night time. More powerful lidars, multi wavelengths Raman lidars and a high spectral resolution lidar is now under development to measure extinction more effectively.

Lidar networks in the world now consist GAW Lidar Observation Network (GALION), a contributing component to Global Atmosphere Watch (GAW), World Meteorological Organization (WMO). AD-Net, a member of GALION is expected to provide ground based observation results which are suitable for validation of various CTMs.

AD-Net has a history of 15 years and provides useful information for aerosol science, especially studies related to Kosa. Further application is expected for the study of anthropogenic particles using spherical extinction. Also, information of cloud base height detected in AD-Net should be analysed more comprehensively to represent actual could base height distributions in this area.

5. Acknowledgements

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