

# RECENT DEVELOPMENTS WITH THE ASIAN DUST AND AEROSOL LIDAR OBSERVATION NETWORK (AD-NET)

Nobuo Sugimoto<sup>1\*</sup>, Atsushi Shimizu<sup>1</sup>, Tomoaki Nishizawa<sup>1</sup>, Yoshitaka Jin<sup>1</sup>

<sup>1</sup>National Institute for Environmental Studies, Japan, \*nsugimot@nies.go.jp

## ABSTRACT

Recent developments of lidars and data analysis methods for AD-Net, and the studies using AD-Net are presented. Continuous observation was started in 2001 at three stations using polarization-sensitive Mie-scattering lidars. Currently, lidars, including three multi-wavelength Raman lidars and one high-spectral-resolution lidar, are operated at 20 stations. Recent studies on validation/assimilation of chemical transport models, climatology, and epidemiology of Asian dust are also described.

## 1 INTRODUCTION

Continuous operation of AD-Net was started in 2001 with three stations (Tsukuba, Nagasaki, and Beijing). The number of stations increased in various research and international cooperation programs. Currently 21 lidars are operated in East Asia (Japan, (China), Korea, Mongolia, Thailand). The lidars at 12 stations are two-wavelength (1064 nm and 532 nm) polarization (532 nm) backscattering lidars. The lidars at 6 stations have additional nitrogen vibrational Raman receivers (607 nm). The lidars at 3 stations are multi-wavelength Raman lidars (backscattering at 1064 nm, 532 nm, and 355 nm, extinction at 532 nm and 355 nm, depolarization at 532 nm and 355 nm). Additionally, continuous observation was recently started at NIES in Tsukuba with a high-spectral-resolution and Raman lidar (HSR at 532 nm, Raman at 355 nm, depolarization at 532 nm and 355 nm) [1].

The lidar data from AD-Net are transferred to NIES. The backscattering lidar part of the data are automatically processed in realtime.

## 2 AD-NET DATA PRODUCTS

Basic real-time products of AD-Net are the attenuated backscattering coefficient at 532 nm and 1064 nm and the volume depolarization ratio. The extinction coefficient estimates for non-

spherical and spherical aerosols are also provided in realtime [2, 3]. Table 1 lists the realtime standard AD-Net products, and Figure 1 presents an example of the data.

Table 1 AD-Net standard data product

Level	Product	Used lidar channels	Other data used
1	Attenuated backscattering coefficient at 532 nm	532 nm co- & cross-pol.	No
1	Attenuated backscattering coefficient at 1064 nm	1064 nm	No
1	Volume depolarization ratio at 532 nm	532 nm co- & cross-pol.	No
2	Dust extinction coefficient estimate at 532 nm + cloud mask	532 nm co- & cross-pol + 1064 nm	S <sub>1</sub> =50 sr assumption, molecular profile
2	Spherical aerosol extinction coefficient estimate at 532 nm + cloud mask	532 nm co- & cross-pol + 1064 nm	S <sub>1</sub> =50 sr assumption, molecular profile

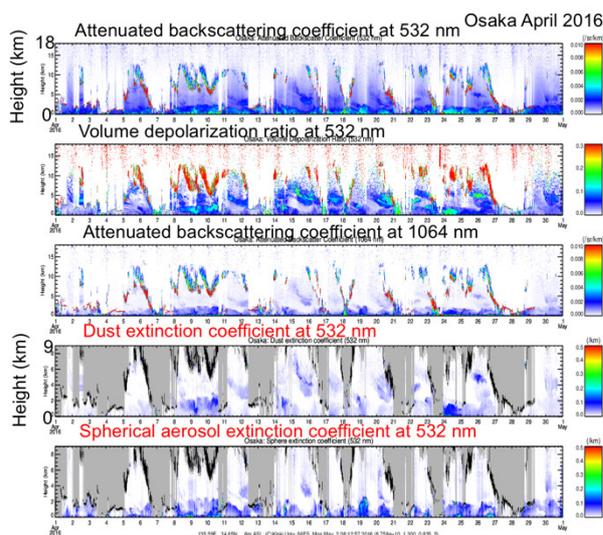


Figure 1 AD-Net standard data products (example for Osaka, April 2016).

The data are updated every hour and provided also in the NetCDF format through the AD-Net www page (<http://www-lidar.nies.go.jp/AD-Net/>).

Data from Raman lidars and a HSRL are also transferred to NIES and processed. Figure 2 shows an example of the data from the HSRL in Tsukuba. A near real-time data analysis system for multi-parameter lidars was developed to derive the backscattering coefficient at 1064 nm, 532 nm, and 355 nm, the extinction coefficient at 532 nm and 355 nm, and the depolarization ratio at 532 nm and 355 nm. Also, data analysis method for deriving concentration of aerosol components was developed [4, 5].

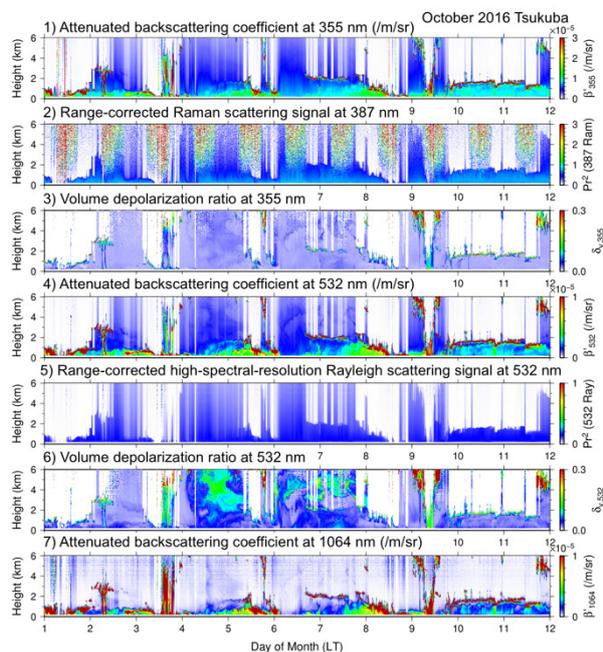


Figure 2 Continuous 532-nm HSR and 355-nm Raman lidar observation in Tsukuba.

### 3 APPLICATIONS OF AD-NET DATA

AD-Net data are used in various applications. The real-time data (extinction coefficient estimates for non-spherical dust) are used for nowcast of Asian dust on the www page of Japanese Ministry of the Environment for the public. The data are also used for real-time validation of dust transport models.

Data assimilation of chemical transport models (CTMs) is one of the primary purposes of AD-Net. A 4D-Var data assimilation system based on

regional chemical transport model (CFORS) was developed at Kyusu University and applied to analysis of several dust events successfully [6, 7]. The dust extinction coefficient was used in the data assimilation, but the assimilated model reproduced both optical and surface observations not used in assimilation (e.g. AOD and PM10) very well.

AD-Net data are not regularly used in data assimilation of aerosol climate models, so far. One of the reason is the lidar ratio problem with backscattering lidar data analysis. To improve the situation, we considered methods for using backscattering lidar data validation/assimilation of chemical transport models without using assumptions in lidar data analysis.

#### 3.1 Quantitative use of backscattering lidar data in validation/assimilation of chemical transport models

A method is to use the attenuated backscattering coefficient itself to compare with models. However, the method may have a problem for ground-based lidars. It is usually difficult to reproduce near-surface aerosol distribution accurately with models, and the modeled attenuated backscattering coefficient profile may contain large error.

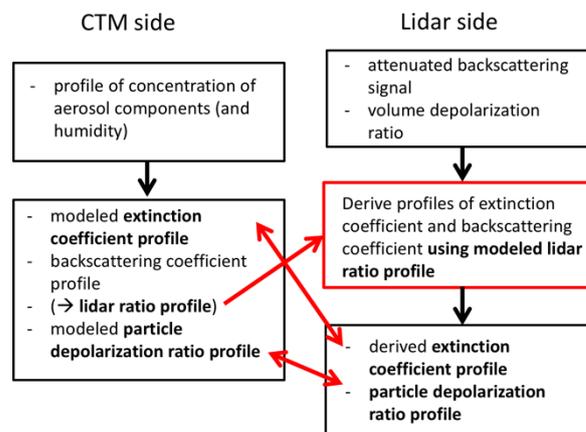


Figure 3 Validation of chemical transport model using the extinction coefficient profile derived from backscattering lidar data using the modeled lidar ratio.

An alternative method is using the extinction coefficient profile derived using modeled lidar ratio profile. Figure 3 shows the concept. If the

chemical transport model does not have optical models for aerosol components, we may calculate from the modeled mass concentrations using external module.

We tested the method using modeled lidar ratio with the AD-Net lidar in Fukuoka and the MASINGAR mk-2 model of Meteorological Research Institute of Japan. Figure 4 shows the results of the model calculation.

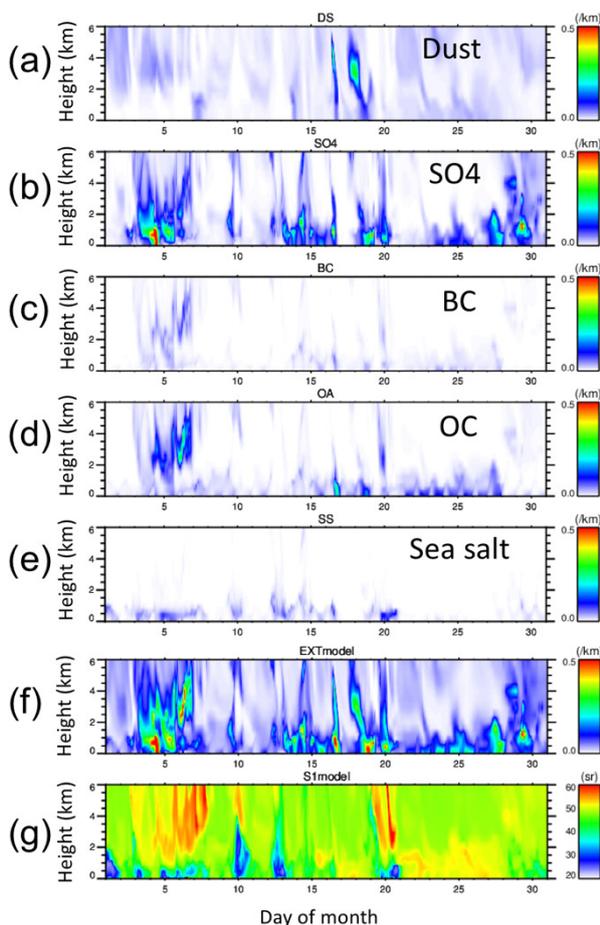


Figure 4 (a)-(f): Extinction coefficient time-height indications for (a) dust, (b) sulfate, (c) black carbon, (d) organic carbon, (e) sea salt, and (f) total, calculated by MASINGAR mk-2 for Fukuoka, April 2015. (g): lidar ratio calculated by the model.

The lidar ratio of the aerosol components in the optical models used in this calculation is as follows. Dust: 48 sr (spheroid model, mode radius 2  $\mu\text{m}$ ),  $\text{SO}_4$ : 50 sr (GEOS-Chem,  $R_h=60\%$  (dry radius 0.08  $\mu\text{m}$ )), BC: 101 sr (OPAC), OA: 52 sr (OPAC water-soluble model,  $R_h=60\%$ ), sea salt:

20 sr (OPAC,  $R_m=3\mu\text{m}$ ,  $R_h=60\%$ ). The particle depolarization ratio of dust is 0.35 and others is 0.00.

Figure 5 shows the extinction coefficient profiles derived using the modeled lidar ratio and the constant lidar ratio. The difference between them are also shown. Figure 6 compares the modeled and derived dust extinction coefficients.

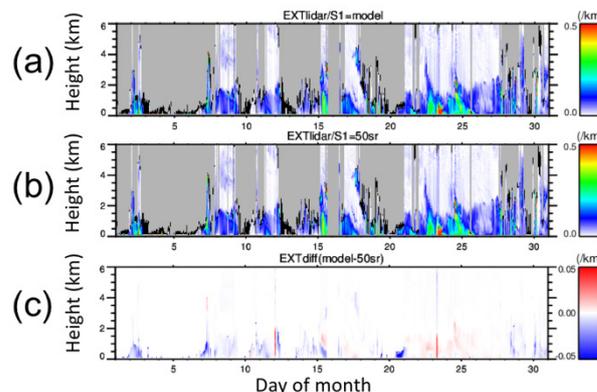


Figure 5 Extinction coefficient derived from the backscattering lidar data using (a) modeled lidar ratio, (b) constant lidar ratio ( $S_l=50$  sr), and (c) the difference (a-b).

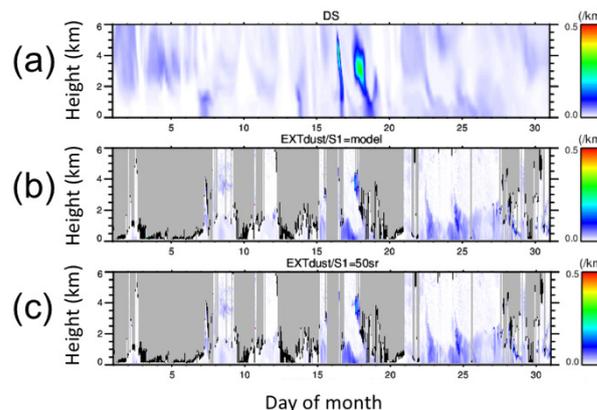


Figure 6 (a): Modeled dust extinction coefficient, (b)(c): lidar derived dust extinction coefficient using (a) modeled lidar ratio, (b) constant lidar ratio.

We showed that backscattering lidar data can be used quantitatively in validation/assimilation of CTM. The result also showed that the difference between the extinction coefficient derived with the modeled lidar ratio and the constant lidar ratio was not large except for the sea-salt dominant case. It was much smaller than the difference between the modeled extinction coefficient. We

think we may use backscattering lidar extinction coefficients derived with a constant lidar ratio in applications such as dust event analysis.

### 3.2 Epidemiology using AD-Net data

The dust and spherical aerosol extinction coefficients provided as standard AD-Net data are useful for epidemiology of Asian dust. We calculate daily near-surface dust and spherical aerosol extinction coefficients and provide to the researchers in epidemiology of aerosols. Statistically significant effects of Asian dust were found in asthma and other respiratory symptoms. So far, about 10 papers are published using AD-Net data [8-10]. A study for providing a qualitative index of internal mixing of dust and air pollution particles is being conducted [11].

## 4 CONCLUDING REMARKS

AD-Net celebrated 15<sup>th</sup> anniversary in 2016. Analysis of major aerosol events and climatology of Asian dust and anthropogenic aerosols are under way using long-term AD-Net data.

Development of multi-parameter lidars and data analysis methods are also conducted for better aerosol characterization. One of our major targets is assimilation of multi-parameter lidars with a CTM that resolves aerosol components.

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