

Vertical gradient of dust extinction coefficient detected by AD-Net lidars in Japan

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Abstract: The vertical gradient of dust extinction coefficient is crucial to access the environmental impact of Asian dust to human health at the surface, and to validate the accuracy of chemical transport models. Asian dust and aerosol lidar observation network (AD-Net) was utilized to detect Asian dust cases in Japan and meteorological parameters were employed to analyze the floating dust layer which is separated from the earth surface. Diurnal variation of boundary layer structure is one of mechanisms to convey dust particles in upper layer to the surface.

1. Introduction

In spring seasons east Asian countries including China, Korea, and Japan are frequently covered by Asian dust layers. In recent years the density of anthropogenic particles in East Asian region is decreasing due to emission reduction activities, but the natural particles including Asian dust are still major components of particulate matters. Contrary to anthropogenic particles, Asian dust particles are transported above the boundary layer because the strong updraft in the source region brings up the sand particles into the free troposphere. Sometimes floating dust layer does not affect the surface atmospheric conditions when the bottom of the layer is located above several hundred meters altitude [1]. Such phenomena can be observed by only vertically resolving remote sensing method, namely lidars.

In this paper the dust extinction coefficients estimated from AD-Net lidars are utilized to describe such structures in the boundary layer in Japan to illustrate the actual dust impact at the surface.

2. Asian dust and aerosol lidar observation network (AD-Net)

AD-Net is a contributing network to the World Meteorological Organization (WMO) Global Atmospheric Watch (GAW) Program, and it forms an East Asian component of the GAW Aerosol Lidar Observation Network (GALION). Stations of AD-Net are currently located in Japan, Korea, and Mongolia (Fig 1).



Figure 1. Locations of AD-Net lidars

Basically, each AD-Net station has a dual-wavelength polarization Mie-scattering lidar with vertical resolution of 6 m and temporal resolution of 15 minutes [2]. All observation results are transmitted to NIES and analyzed/visualized every hour.

Typical products of AD-Net are dust extinction coefficient and spherical-particle coefficient at 532 nm including masks for clouds, rainy and non-observable region. They are estimated by combination of aerosol extinction coefficient retrieved by Fernald's method and particle depolarization ratio with an assumption of external mixture of spherical particles (mainly anthropogenic particles including sulfate / nitrate) and mineral dust (non-spherical) particles whose depolarization ratio is 35 % [3,4]. Such extinction coefficient is estimated up to 9 km (as far as the signal-to-noise ratio is large enough). All of visualized parameters including attenuated backscatter coefficient at 532/1064 nm, volume depolarization ratio at

532 nm, dust and spherical particle extinction coefficients at 532 nm are indicated at AD-Net home page with netCDF files within one hour after data acquisition [5].

3. Vertical structure of Asian dust in Japan

Kanto region of Japan (around Tokyo) is a typical area for floating dust layers because this region is surrounded by high mountains with the altitude of more than 2000 m and the Pacific Ocean. Tsukuba lidar in this area detected a floating dust layer on April 11, 2023 (Fig 2). The bottom of the layer was located around 800 m according to the observations of the volume depolarization ratio in the morning. Several hours later the depolarization ratio between the surface and floating dust layer increased homogeneously. In this period the solar radiation was strong and the vertical mixing by convective motions was expected. Unfortunately, the routine upper-air sounding by radiosondes in Japan are conducted at 0900LT and 2100LT only, thus the vertical structure of potential temperature around noon on this day was not observed. In the morning (0900LT), the depth of mixing layer was only few hundred meters and did not reach to the bottom of the floating dust layer.

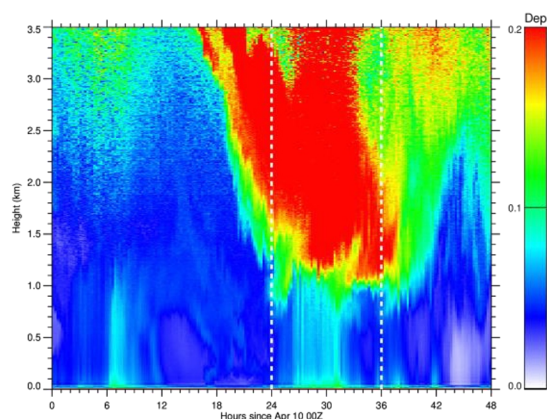


Figure 2. Volume depolarization ratio over Tsukuba, April 10-11, 2023

Similar time evolutions of the depolarization ratio were confirmed in other stations or seasons. For example, in Fukuoka and Tsukuba unusual summer dust was detected in July 2023 with such floating structure. In both places the mixing layer height was several hundred meters at 0900LT and few hours later

the enhancement of the depolarization ratio between the surface and the bottom of the dust layer was confirmed. Table 1 summarizes recent “dust touchdown” cases found in Tsukuba. As indicated, the vertical mixing caused a downward dust transportation before noon in many cases.

Table 1. Dust touchdown cases in Tsukuba, Japan

Date	Hour(LT)
March 13, 2018	17:00
March 22, 2020	11:00
March 5, 2022	14:00
March 11, 2023	11:00
April 11, 2023	11:00
July 7, 2023	11:00
March 30, 2024	10:00
April 28, 2024	11:00

As seen in Fig.2 the volume depolarization ratio in the free troposphere was larger even after the dust particles touched the surface, dust extinction coefficients at two altitudes were almost comparable (Fig.3). This difference infers the downward mixing of dust particles was faster than the upward mixing of spherical particles near the surface, and we must take account of the difference of relative humidity in the boundary layer and in the free troposphere because the hygroscopicities for two kinds of particles (mineral dust and spherical particles like sulfate) might differ.

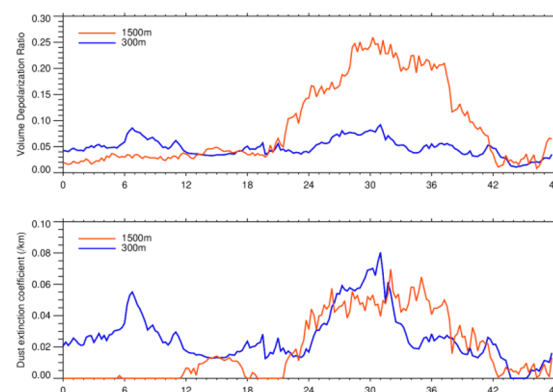


Figure 3. Time series of volume depolarization ratio (top) and dust extinction coefficient (bottom)

4. Discussion and future plan

As described in the previous section, the bottom of the floating dust layer is located below 1 km frequently. Several dust

forecasting numerical models output the surface dust mass concentration using the averaged value between 0 – 1 km altitudes [6,7]. If the dust layer is floating and separated from the surface like Fig.2, the averaged value (0-1 km) is different from the actual surface value. To validate models more precisely this vertical structure must be considered more carefully.

20-years record of Asian dust detected by AD-Net lidars are useful to identify the floating dust layers over Japan, and the statistical analysis of such phenomena will contribute to evaluate the surface dust impact accurately. The vertical gradient of dust extinction coefficient, the bottom height of the floating layer, and the vertical mixing speed must be determined to establish a criterion for the floating dust layers. Introducing meso-scale re-analyzed meteorological data will be also important to understand the mechanism of vertical mixing of dust particles.

5. References

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