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Measurement report: Dust and anthropogenic aerosols' vertical distributions over northern China dense aerosols gathered at the top of the mixing layer

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Section S1. Polarization lidar photometer networking (POLIPHON) method

The polarization lidar photometer networking (POLIPHON) method was applied to retrieve dust and anthropogenic aerosols mass concentration (Tesche et al., 2009; Sugimoto et al., 2003; Shimizu, 2004; Ansmann et al., 2012; Tesche et al., 2017; Ansmann et al., 2019). Assuming that dust and anthropogenic aerosols are externally mixed, there are two steps to obtain dust and anthropogenic aerosols mass concentration by the POLIPHON method. In the first step, the contributions of dust and anthropogenic aerosols to the total backscatter coefficient are separated. The key principle of this step is to obtain priori information on the particle depolarization ratio (PDR) of dust and anthropogenic aerosols. The dust backscatter coefficient (β_d) is expressed as

$$\beta_d = \beta_p \frac{(\delta_p - \delta_{ap})(1+\delta_d)}{(\delta_d - \delta_{ap})(1+\delta_p)} \tag{1}$$

In equation 1, the β_p and δ_p are aerosol backscatter coefficient and PDR retrieved by polarization Raman Lidar, respectively. δ_d and δ_{ap} are PDR typical values of dust and anthropogenic aerosols, respectively. It's worth noting that, if $\delta_p < \delta_{ap}$, we set $\beta_d = 0$, and if $\delta_p > \delta_d$, we set $\beta_d = \beta_p$. Thus, the anthropogenic aerosols backscatter coefficient (β_{ap}) can be calculated by

$$\beta_{ap} = \beta_p - \beta_d \tag{2}$$

The dust extinction coefficient (α_d) and anthropogenic aerosols extinction coefficient (α_d) profile can be estimated by

$$\alpha_d = \beta_d \times S_d \tag{3}$$

$$\alpha_{ap} = \beta_{ap} \times S_{ap} \tag{4}$$

S_d and S_{ap} are lidar ratio typical values of dust and anthropogenic aerosols, respectively. All of these aerosol optical parameters can be determined by polarization Raman Lidar. The lidar ratio and PDR typical values of anthropogenic aerosols/dust particles are $S_{ap} = 52.1 \pm 11.3$ sr, $S_d = 45.7 \pm 5.1$ sr, $\delta_{ap} = 0.043 \pm 0.021$, and $\delta_d = 0.287 \pm 0.430$, both of which are retrieved by limiting the PDR less than 0.09 and greater than 0.23.

In the second step, converting the extinction coefficient of dust and anthropogenic aerosols into mass concentration (Ansmann et al., 2012; Mamouri and Ansmann, 2014). The dust mass concentration (M_d), anthropogenic aerosols mass concentration (M_{nd}), and total aerosol mass concentration (M_p) can be estimated by

$$M_d = \rho_d \times (\overline{v_c / \tau_c}) \times \alpha_d \tag{5}$$

$$M_{ap} = \rho_{ap} \times (\overline{v_f / \tau_f}) \times \alpha_{ap} \tag{6}$$

$$M_p = M_d + M_{ap} \tag{7}$$

ρ_d and ρ_{ap} are dust and anthropogenic aerosols mass density, respectively. where ρ_d = 2.6±0.6 g/cm^3, and ρ_{ap} =

1.5±0.3 g/cm^3 (Ansmann et al., 2012). ν and τ are volume concentration and AOD observed by sun–photometer, the subscript *c* and *f* represent the coarse and fine mode particles, respectively.

Figures:

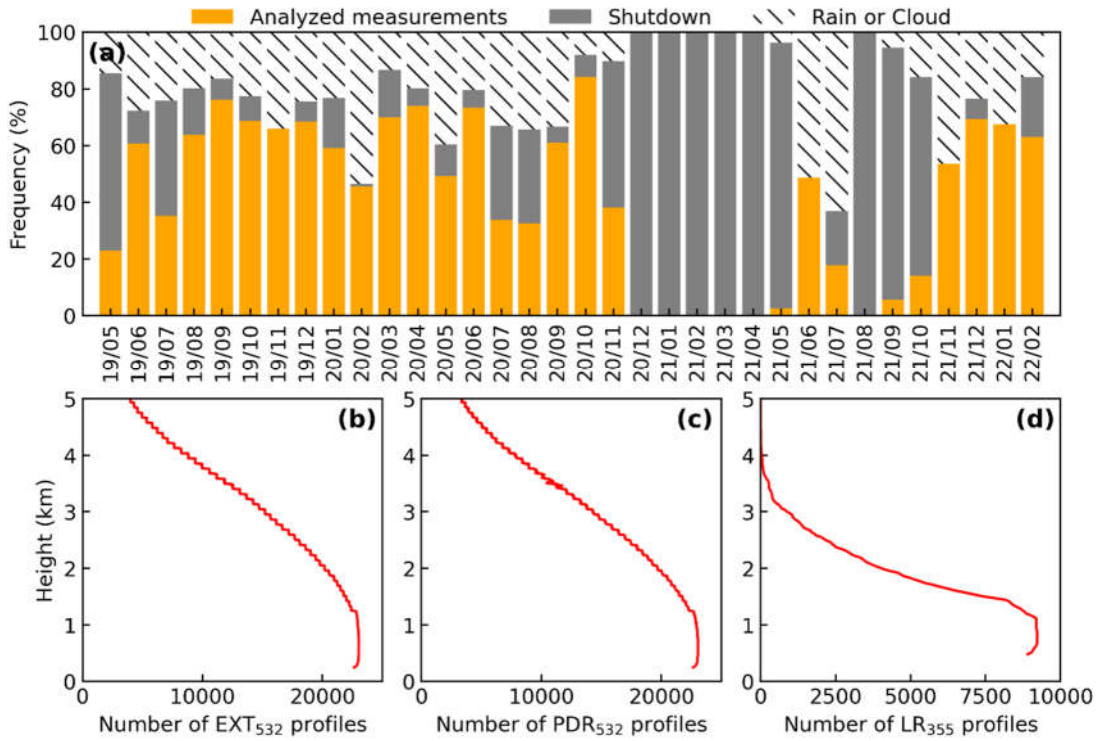

Fig.S1. Coverage of Polarized Raman Lidar (PRL) measurements from May 2019 to February 2022. (**a**) Percentage of analyzed PRL measurements, the unanalyzed measurements of "Shutdown" and "Rain or Cloud" are due to instrument failure or weather conditions. The analyzed number of (**b**) EXT_{532}, (**c**) PDR_{532}, and LR_{355} points at different heights. The PRL detection error increases with the increase of height, and the number of points also decreases with the increase of height.

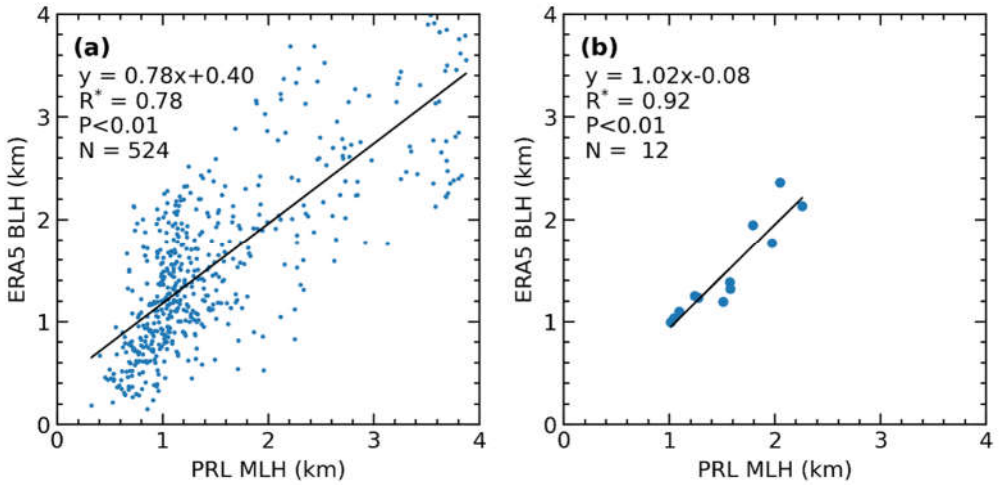

Fig.S2. Data comparison of (**a**) daily and (**b**) monthly BLH from ERA5 and MLH retrieved by PRL. Note that the MLH and BLH are the values at 15:00 LT. The correlation coefficients are shown in the top left, N = number of samples, the asterisk on correlation coefficients R stands for P<0.01.

Table S1. Mean values and one standard deviation of input parameters in dust and anthropogenic aerosols mass concentration retrieval.

Parameter	Value	Reference
Anthropogenic aerosols lidar ratio S_{ap}	52.1±11.3 sr	PRL observations
Asian dust lidar ratio S_{d}	45.7±5.1 sr	PRL observations
Anthropogenic aerosols particle depolarization ratio δ_{nd}	0.043±0.021	PRL observations
Asian dust particle depolarization ratio δ_{d}	0.287±0.430	PRL observations
Anthropogenic aerosols mass density ρ_{nd}	1.5±0.3 g/cm^3	(Ansmann et al., 2012)
Asian dust mass density ρ_{d}	2.6±0.6 g/cm^3	(Ansmann et al., 2012)
Anthropogenic aerosols conversion factor $\overline{v_f / \tau_f}$	Monthly average	Sun–photometer observations
Asian dust conversion factor $\overline{v_c / \tau_c}$	Monthly average	Sun–photometer observations

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