**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 () is expressed as

 (1)

In equation 1, the  and  are aerosol backscatter coefficient and PDR retrieved by polarization Raman Lidar, respectively.  and  are PDR typical values of dust and anthropogenic aerosols, respectively. It's worth noting that, if , we set , and if , we set . Thus, the anthropogenic aerosols backscatter coefficient () can be calculated by

 (2)

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

 (3)

 (4)

 and  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 sr, = 45.7±5.1 sr, = 0.043±0.021, and = 0.287±0.430, both of which are retrieved by limiting the PDR less than 0.09 and greater than 0.23.

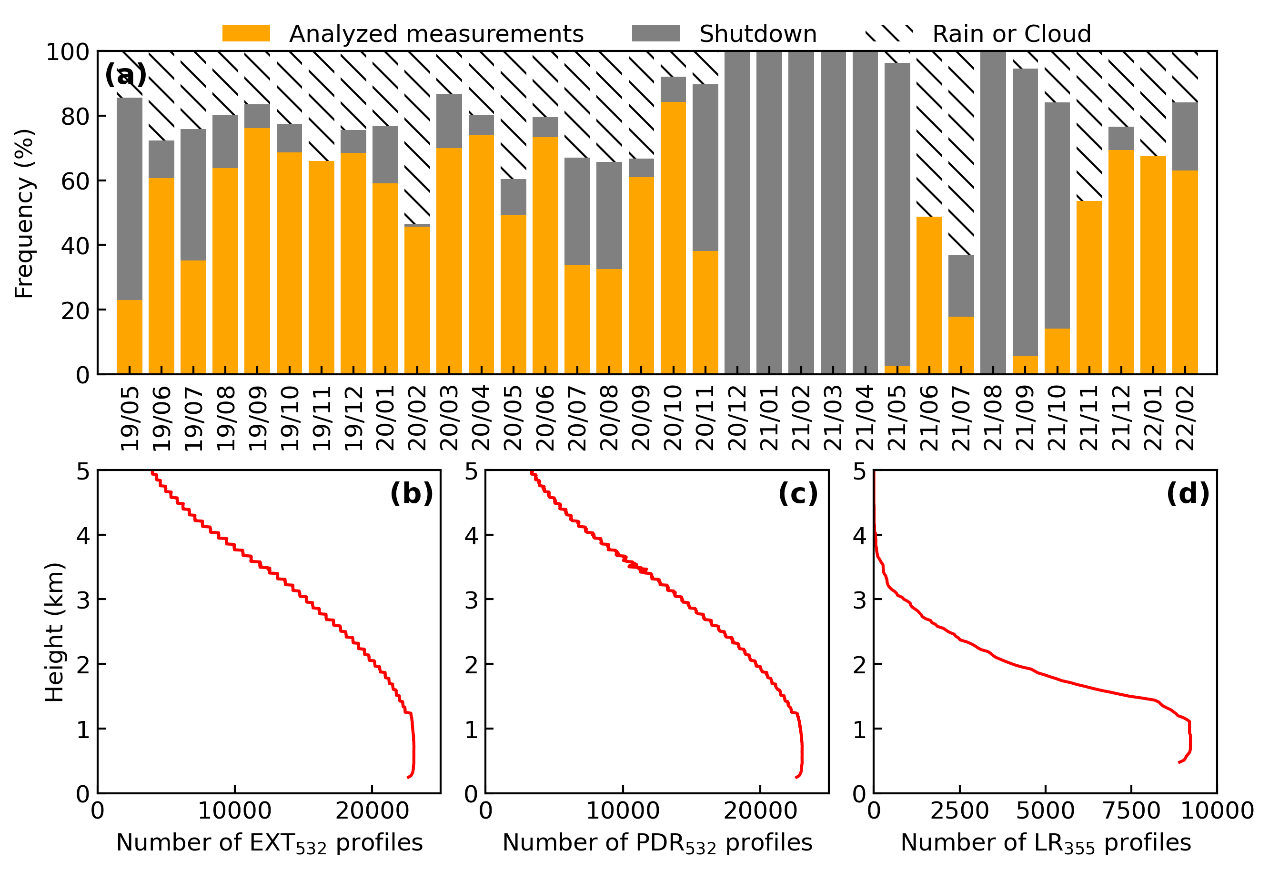
In the second step, converting the extinction coefficient of dust and anthropogenic aerosols into mass concentration (Ansmann et al., 2012; Mamouri and Ansmann, 2014). The dust mass concentration (), anthropogenic aerosols mass concentration (), and total aerosol mass concentration () can be estimated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

 (5)

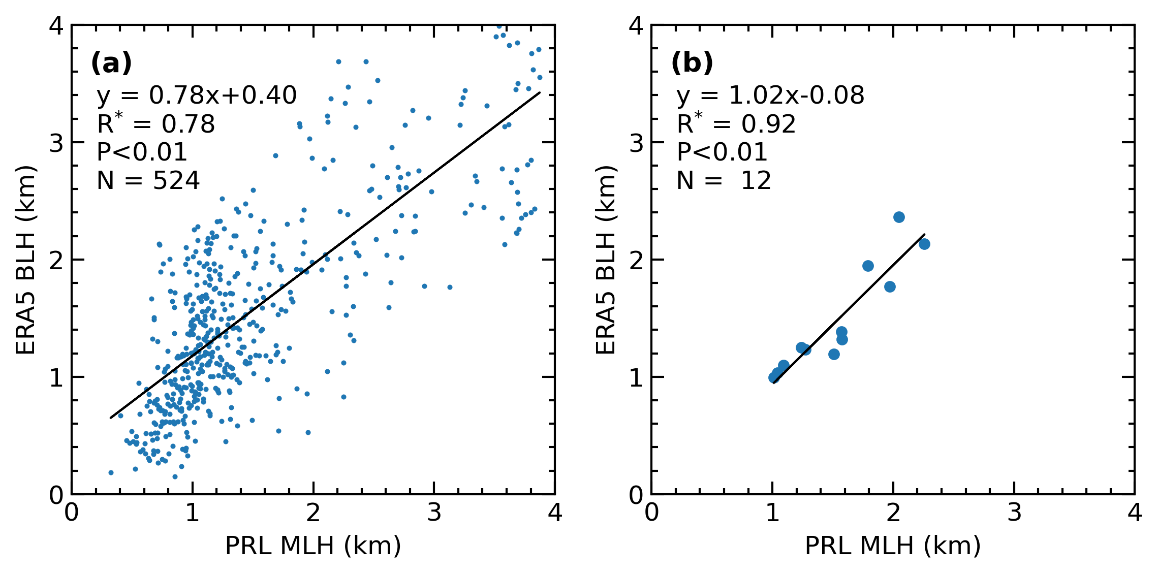
 (6)

 (7)

 and  are dust and anthropogenic aerosols mass density, respectively. where  = 2.6±0.6 g/cm3, and  = 1.5±0.3 g/cm3 (Ansmann et al., 2012).  and  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**) EXT532, (**c**) PDR532, and LR355 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 | 52.1±11.3 sr | PRL observations |
| Asian dust lidar ratio | 45.7±5.1 sr | PRL observations |
| Anthropogenic aerosols particle depolarization ratio | 0.043±0.021 | PRL observations |
| Asian dust particle depolarization ratio | 0.287±0.430 | PRL observations |
| Anthropogenic aerosols mass density | 1.5±0.3 g/cm3 | (Ansmann et al., 2012) |
| Asian dust mass density | 2.6±0.6 g/cm3 | (Ansmann et al., 2012) |
| Anthropogenic aerosols conversion factor | Monthly average | Sun‒photometer observations |
| Asian dust conversion factor | Monthly average | Sun‒photometer observations |

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