Transported smoke layers detected over northern France

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Introduction

From 23 August to 12 September 2017, aerosol layers in UTLS (Upper Troposphere/ Lower Stratosphere) are repeatedly observed by Lidar systems in northern France. Lidar measurements show that the UTLS aerosol layers suspending at an altitude of 12-20 km and during the same period, tropospheric smoke layers are frequently observed. The dispersion back trajectory model shows that the tropospheric layers originate from Canadian wildfires. Two elastic-Raman Lidar systems in northern France, a mobile Lidar system and sun photometer recorded this event.

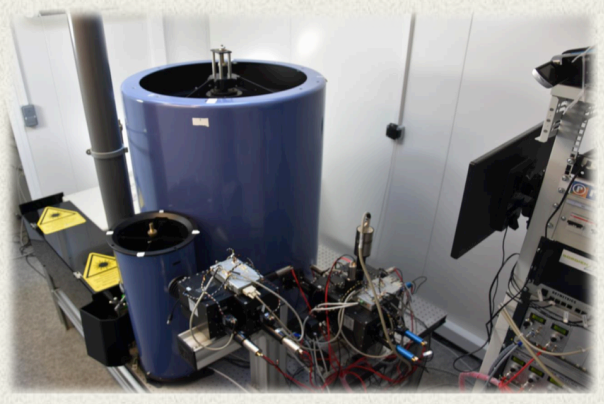
This study presents the optical properties of the transported layer in the troposphere and stratosphere derived from Lidar observations. And the particle micro-physical properties are retrieved by using regularization algorithm (I. Veselovskii et. al 2002).

Instrumentations and observations

On 29 August, the aerosol layers in the UTLS, stretching from 16 to 20 km, were detected by three Lidar systems: elastic–Raman Lidars in Lille (LILAS) and Palaiseau (IPRAL), and a mobile Lidar system traveling between the two cities.

AOD in Palaiseau fluctuates between 0.3 and 0.4. IPRAL system detected two separate layers attaching closely before 1400 UTC. Afterwards, the thinner layer below disappeared and the upper layer remained. AOD on–route is around 0.4, very stable along the trip. AOD in Lille increased from 0.2 to 0.4 as the UTLS layer appeared and thickened from 0800 UTC to 1800 UTC.

IPRAL system in Palaiseau



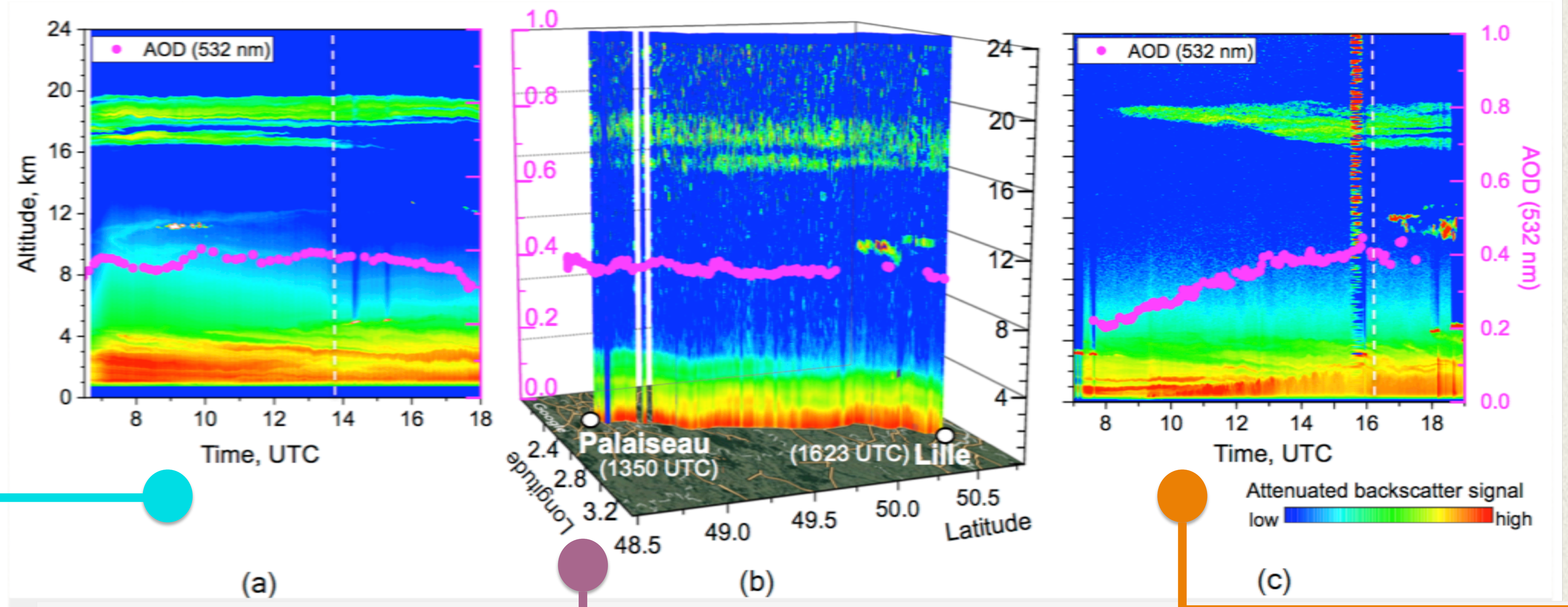
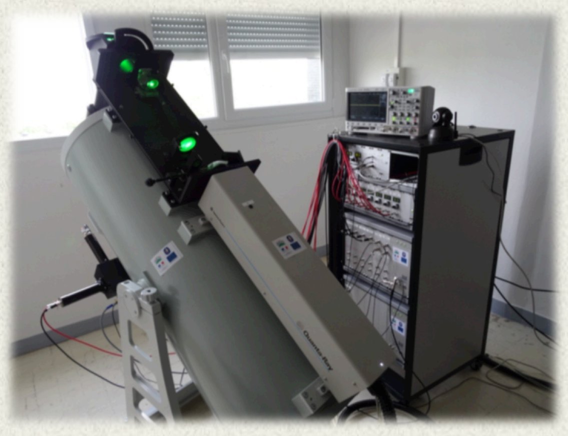


Figure 1. Lidar range-corrected signal and AOD from sun photometer at 532 nm, 29 August 2017.Lidar measurements are from (a) IPRAL system in Palaiseau, (b) mobile Lidar on-route from Palaiseau to Lille and (c) Lidar LILAS in Lille.

LILAS system in Lille



IPRAL is a multi-wavelength elastic-Raman Lidar operated in Palaiseau. It has 3 elastic channels (355, 532 and 1064 nm), 3 Raman (387, 407 and 607 nm) channels and 1 depolarization channel (355 nm).

Mobile Lidar is a CIMEL micro-pulse Lidar (532 nm) installed in a light mobile system. The mobile system is equipped with a mobile sun photometer, PLASMA, capable to measure aerosol optical depth (AOD) along the route. On 29 August, the mobile system traveled from Palaiseau to Lille.

LILAS is a transportable multi-wavelength elastic-Raman Lidar operated in Lille. It has 3 elastic channels (355, 532 and 1064 nm), 3 Raman (387, 407 and 530 nm) channels and 3 depolarization channels (355, 532 and 1064 nm).

Optical properties

Optical properties of the tropospheric and UTLS layers are derived from elastic-Raman Lidar measurements. In the UTLS layer, Klett inversion is applied given that the signal-to-noise ratio is not sufficient in Raman channels at this high altitude. Optical depth of the layers is derived by estimating the transmission of Lidar signal, and used as constraints in Klett inversion. In the tropospheric layer, Raman inversion is applicable.

➢ Tropospheric layers

- Low spectral dependence in extinction coefficient
- Backscattering coefficient increases as the wavelength decreases.
- Particle depolarization ratios in the tropospheric layer are very low, about 10% (355 nm), 5% (532 nm) and 1% (1064 nm), as shown in Figure 2(b).

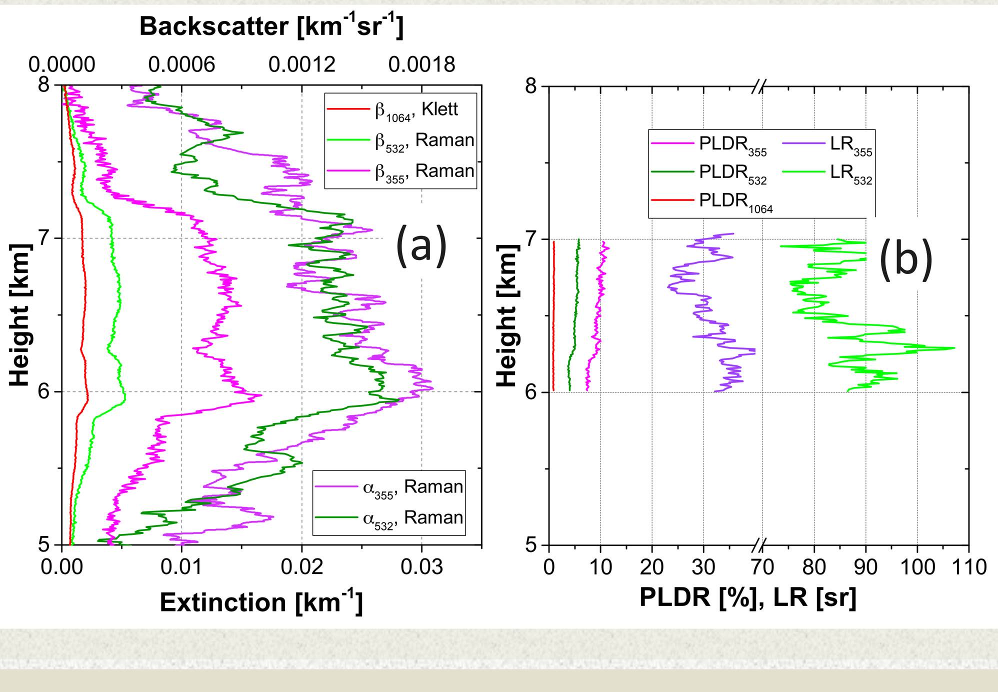
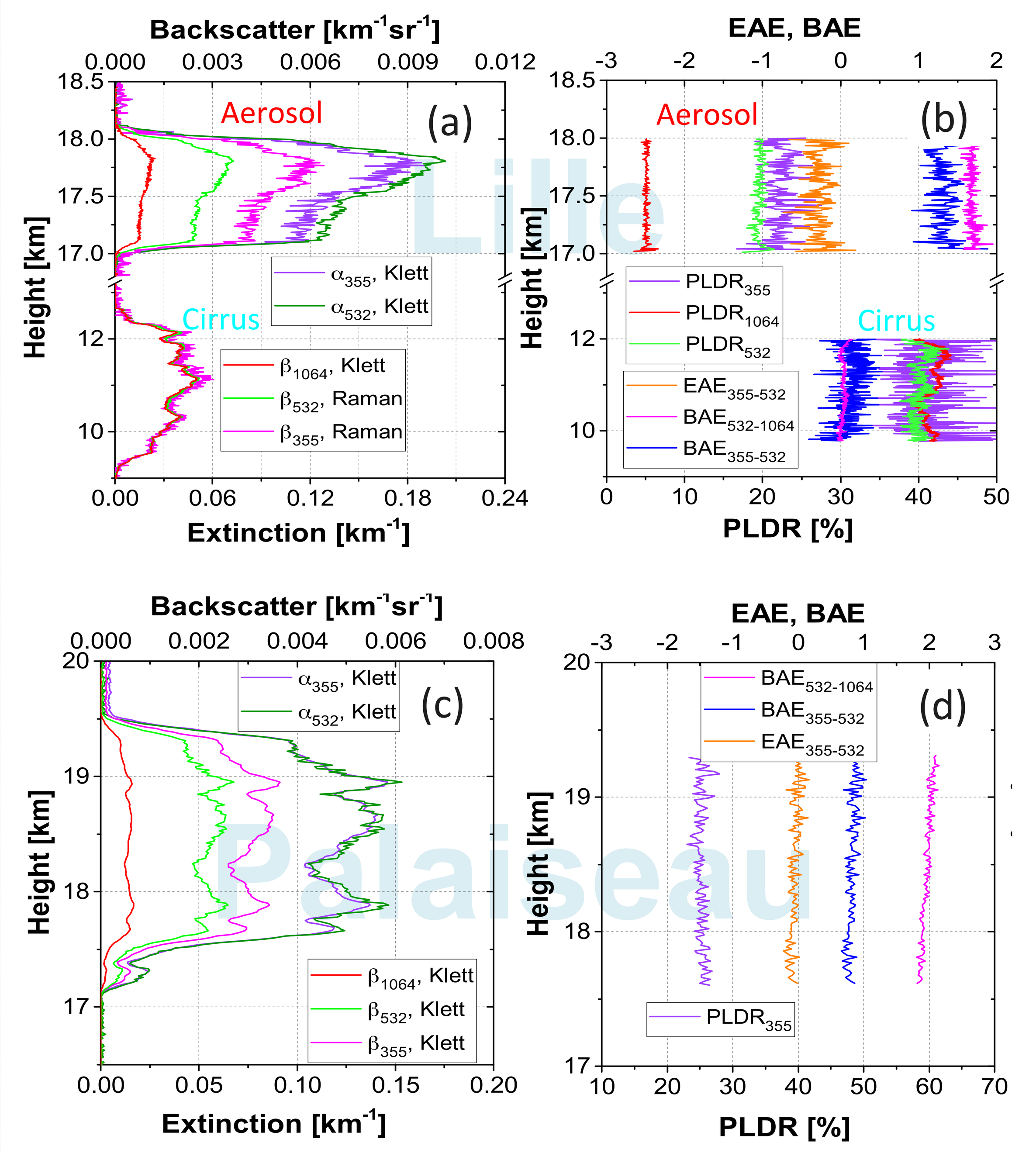


Figure 2. Profiles of optical properties derived from LILAS measurements, 2000 (31 August)–0300 UTC (01 September) 2017. Extinction and backscatter coefficient (α, β in Figure 2(a)). Particle linear depolarization ratio (PLDR) and Lidar ratio (LR) in Figure 2(b).

➢ UTLS aerosol layers



- Depolarization ratio decreases as wavelength increases, 24% (355 nm), 19% (532 nm) and 5% (1064 nm)
- Backscattering coefficient increases as the wavelength decreases
- Low spectral dependence in extinction
- Cirrus clouds provide good calibrations for the Lidar measurements: in cirrus clouds, Ångström of the backscattering coefficient close to **0.0**, depolarization ratios are about **45%** at 3 wavelengths
- Optical properties from Lille and Palaiseau are consistent, indicating that the layers are probably from the same source and the their optical properties are temporally and spatially stable.

P.S. Lidar ratio at 1064 nm in Figure 2 and 3 is assumed to be 70 sr. For the UTLS layers, the Lidar ratios at 355 and 532 nm are estimated by providing the best fit of optical depth.

Figure 3. Profiles of optical properties derived from LILAS measurements, 2200 (24 August)–0030 UTC (25 August) 2017, and IPRAL measurements, Palaiseau, 1920–2120 UTC, 28 August 2017. Extinction (α) and backscattering coefficient (β, in Figure 3(a) and Figure 3(c)). Particle linear depolarization ratio (PLDR), extinction-related Ångström exponent (EAE) and backscatter-related Ångström exponent (BAE) (in Figure 3(b) and Figure 3(d)).

Microphysical properties

Wavelength-independent complex refractive indices and size distribution are retrieved from *regularization* algorithm by using 2α + 3β derived from Lidar measurements in Figure 2 and 3.

Table 1. Microphysical properties retrieved from regularization

Lidar (date)	LILAS (24 August)		LILAS (31 August)		IPRAL (28 August)	
Model	Spheres	Spheroids	Spheres	Spheroids	Spheres	Spheroids
R_{eff} [um]	0.33±0.10	0.32±0.10	0.27±0.10	0.31±0.10	0.32±0.10	0.30±0.10
V_c [$\mu m^{-3} cm^3$]	24±7	19±6	2.6±0.8	2.8±0.9	16±5	13±4
m_R	1.61±0.05	1.60±0.05	1.50±0.05	1.51±0.05	1.56±0.05	1.58±0.05
m_I	0.044±0.02	0.003±0.002	0.010±0.005	0.002±0.001	0.033±0.02	0.002±0.001

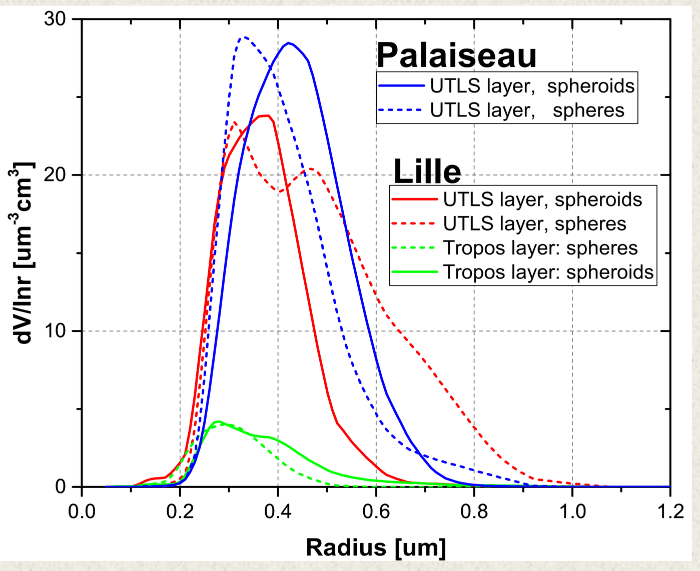


Figure 4. Size distribution retrieved from regularization using averaged extinction and backscattering coefficient in Figure 2 and Figure 3.

Summary

- Transported smoke in the troposphere and UTLS possibly underwent different aging process or meteorological conditions, which result in their different optical and microphysical properties.
- Properties of the UTLS aerosols observed by LILAS and IPRAL systems are consistent.
- Smoke particles could have complicated morphologies that cannot be represented by sphere or spheroid model.
- More information is needed for a better characterization.

Acknowledgement

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