Pollen Observations at Four EARLINET Stations in May 2020

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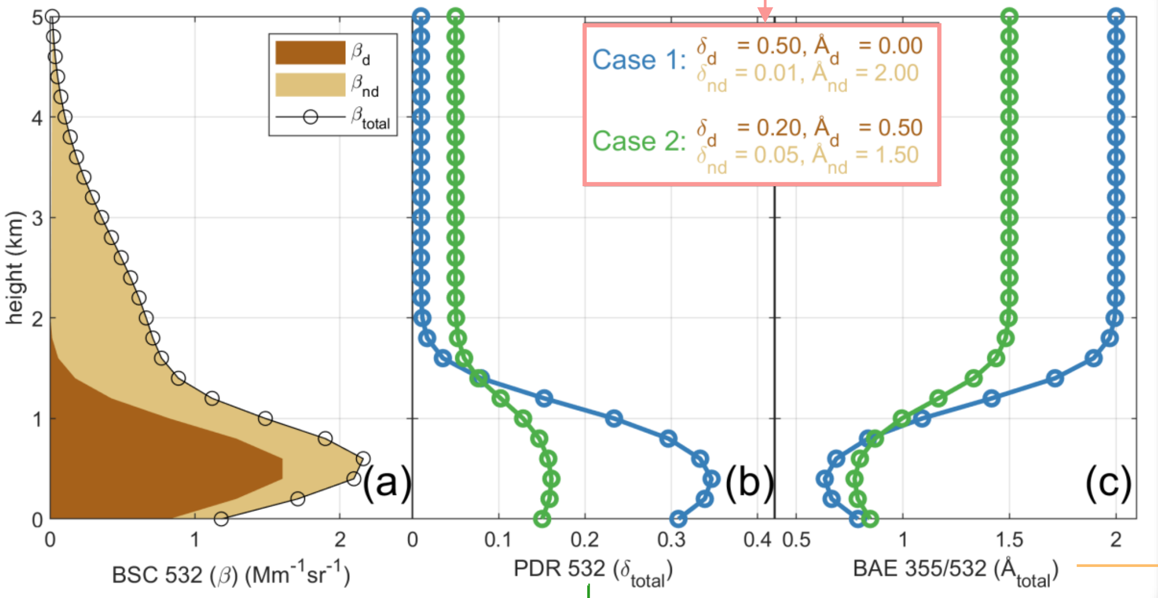
Methodology - PDR vs. BAE theory

A novel simple method for the characterization of the pure pollen is proposed, based on lidar-derived-

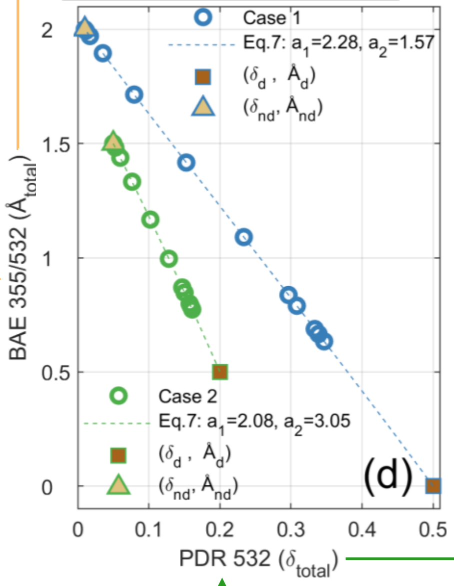
- backscatter-related Ångström exponents (BAEs, $\mathring{A}_{total}$),
- particle linear depolarization ratios (PDRs, δ_{total}).

Initial characteristic values of depolarizing (*d*) and non-depolarizing (*nd*) particles

Synthetic profiles of total particles (*total*)



Scatter plot for two synthetic cases



Non-linear least square regression fitting

$$\left(\frac{\lambda_1}{\lambda_2}\right)^{-\boxed{\mathring{A}_{\mathrm{total}}}} = \frac{a_1 + a_2}{(\boxed{\delta_{\mathrm{total}}}(\lambda_2) + 1)} - a_2$$

$$a_1 = \frac{\eta_{\mathrm{nd}}\delta_{\mathrm{d}}(\delta_{\mathrm{nd}}+1) - \eta_{\mathrm{d}}\delta_{\mathrm{nd}}(\delta_{\mathrm{d}}+1)}{(\delta_{\mathrm{d}} - \delta_{\mathrm{nd}})}$$

$$a_2 = \frac{\eta_{\mathrm{nd}}(\delta_{\mathrm{nd}}+1) - \eta_{\mathrm{d}}(\delta_{\mathrm{d}}+1)}{(\delta_{\mathrm{d}} - \delta_{\mathrm{nd}})}$$

This easy-to-apply algorithm can estimate two coefficients (a_1,a_2) to determine the relationship between PDR and BAE.

Such a relationship is valid under two <u>constraints</u>:

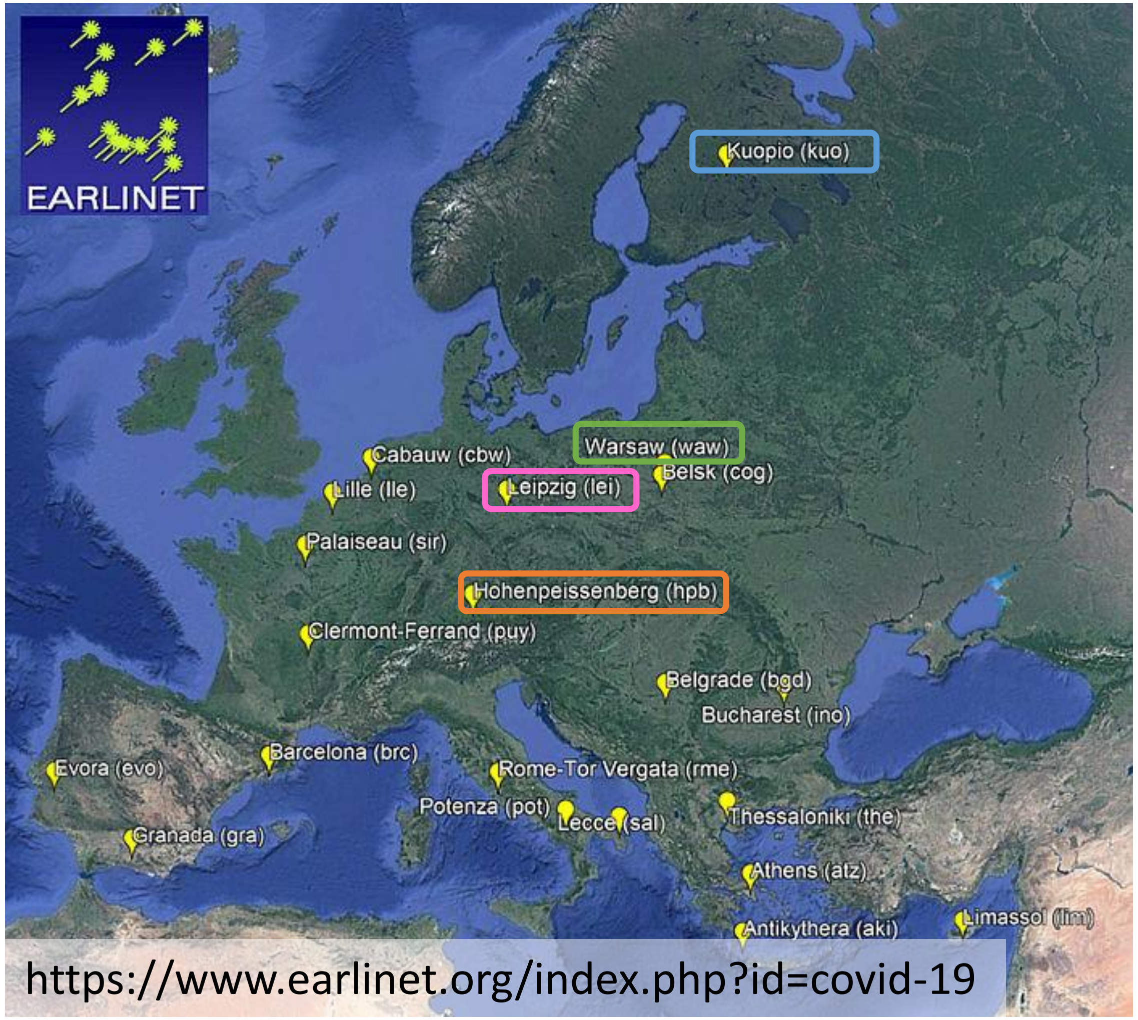
- only two aerosol populations present in the mixture,
- both $\mathring{A}$ and δ of the two aerosol types should be different.

In Fig. (d):

- The dashed fitting line of each case is determined by the equation with parameters (a_1,a_2) given.
- The boundary points (dark brown squares and light brown triangles) are defined by the initial values (shown in the legend in b–c).
- Open circles present each bin.

Measurements & instrumentation

ACTRIS-COVID-19 NRT (near-real-time) lidar measurement campaign
(1 - 31 May 2020)



Four lidar stations

- Kuopio, Finland KUO
- Warsaw, Poland WAW
- Leipzig, Germany LEI
- Hohenpeißenberg, Germany HPB

Lidar and data processing

- All equipped with ground-based multi-wavelength Raman polarization lidars PollyXT
- Lidar data were processed in a centralized way using the Single Calculus Chain (SCC) tool

Ancillary data

- NMMB/BSC-Dust model (only dust-free periods were considered)
- SILAM model
- In situ pollen sampler (Hirst-type Burkard pollen sampler, pollen monitor BAA500)

Results

- Dust-free as indicated by the NMMB/BSC-Dust model
- Relatively high pollen concentrations (from the SILAM model forecasting and/or in situ measurements when available)

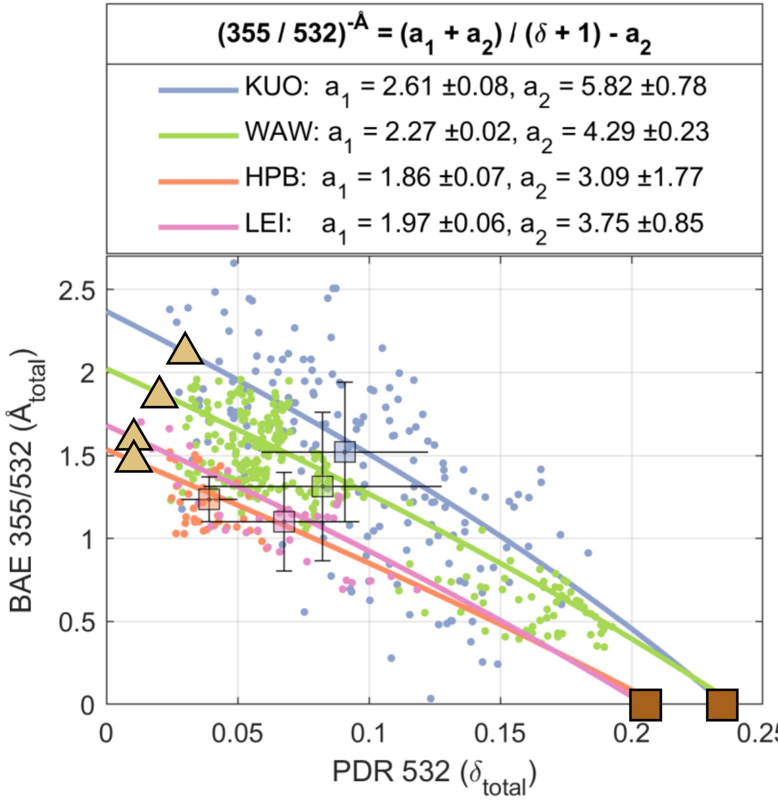
We assumed that inside the pollen layers there are only two aerosol types: pollen and non-depolarizing background aerosol.

Station	Selected period in May 2020	Dominant pollen types	Background δ_{bg}	Background $\mathring{A}_{bg}$	Pollen depolarization ratio δ_{pollen} if $\mathring{A}_{pollen}$ = 0	Pollen depolarization ratio δ_{pollen} if $\mathring{A}_{pollen}$: 0.5 to -0.5
KUO, FI	23–26	Birch[a,b]	0.03	2.1	0.24	0.20 to 0.27
WAW, PL	26–29	Birch[a]	0.02	1.9	0.24	0.19 to 0.28
HPB, DE	07–08	Birch, grass[a]	0.01	1.5	0.21	0.15 to 0.27
LEI, DE	26–27,30–31	Birch, grass[a,c]	0.01	1.6	0.20	0.15 to 0.25

Source of possible pollen types: [a] SILAM model, [b] Burkard pollen sampler, [c] pollen monitor BAA500.

a_1, a_2 The values of the coefficients (a_1,a_2) are different for stations, as they are defined from characteristic values of two aerosol types.

$\mathring{A}_x, \delta_x$ Regarding the fitting equation, the value couple of $\mathring{A}_x$ and δ_x of one pure particle type (pollen or bg) should be located on the fitting curve theoretically. Thus, with the knowledge of one parameter, the other can be evaluated.

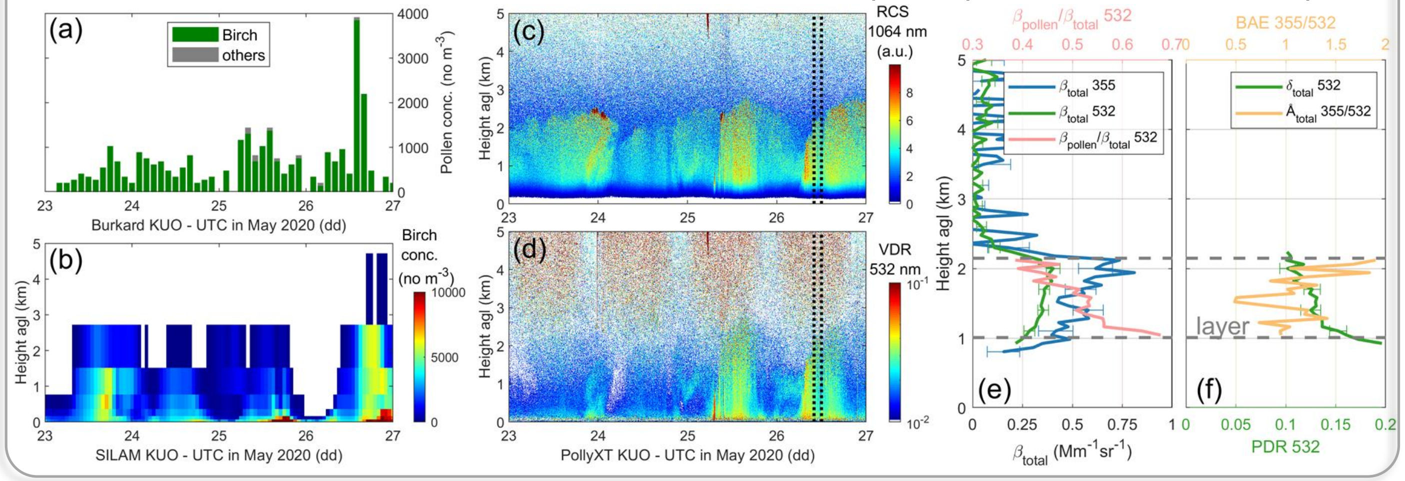


Relationships of lidar-measured PDRs and BAEs for 4 stations. All bins inside pollen layers are shown by dots for each station with different colours. Averaged layer-mean values are given by the square. Fitting regression lines are drawn with parameter values given.

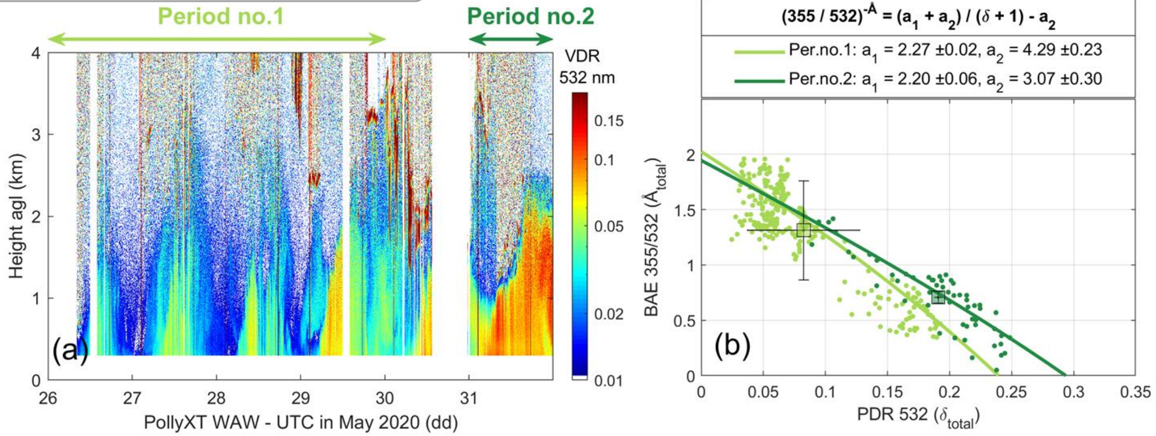
Case examples

Kuopio – birch pollen

Overview of the pollen period and a case example



Warsaw – different pollen types

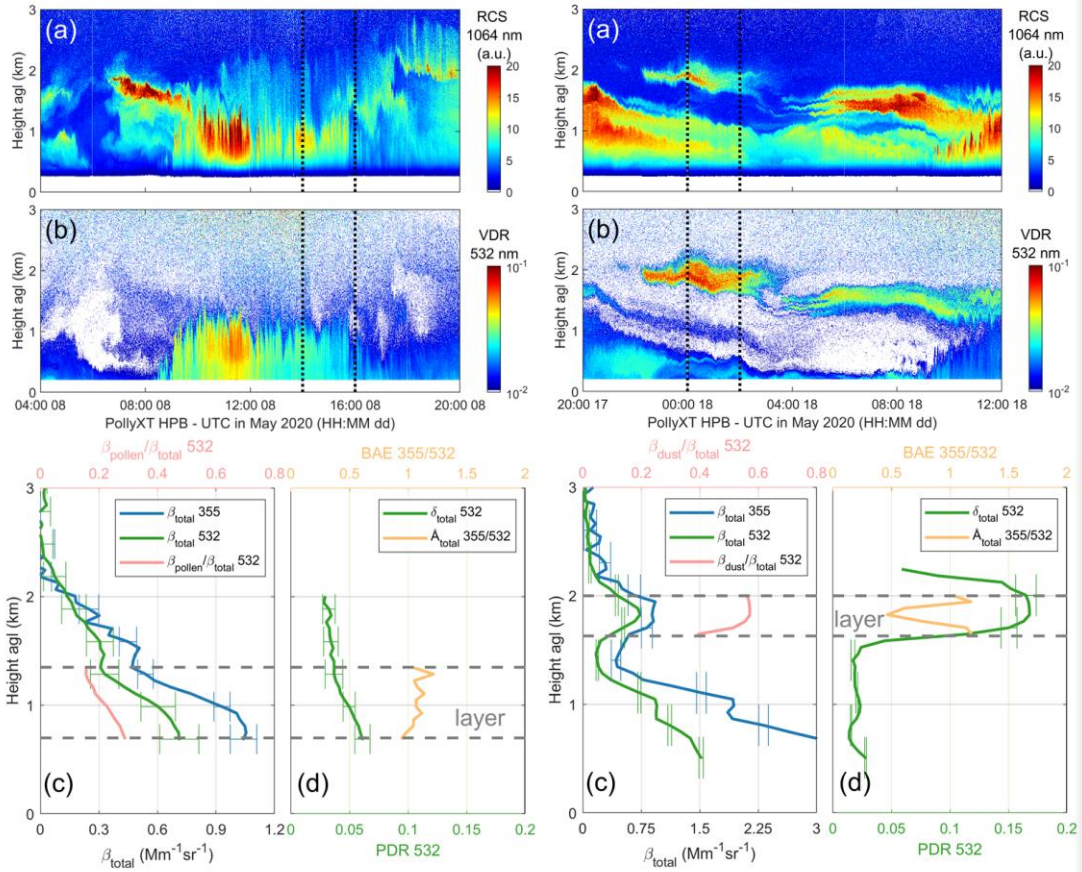


Selected period in May 2020	Background δ_{bg} $Å_{bg}$	Possible depolarizing particle types	Depolarization ratio (δ_{pollen}) if $Å_{pollen}$ = 0 if $Å_{pollen}$: 0.5 to -0.5
Period no. 1: 26–29	0.02 1.9	Pollen (birch)	0.24 0.19 to 0.28
Period no. 2: 31	0.02 1.8	Pollen (birch mixture)	0.29 0.23 to 0.35

Hohenpeißenberg – pollen and dust

In period no. 1 Pollen (birch and grass)

In period no.2 Dust



Selected period in May 2020	Background δ_{bg} $Å_{bg}$	Possible dep. particle types	Depolarization ratio (δ_d) if $Å_d$ = 0 if $Å_d$: 0.5 to -0.5
Per.no.1: 07–08	0.01 1.5	Pollen	0.21 0.15 to 0.27
Per.no.2: 18	0.01 1.7	Dust	0.32 0.24 to 0.40

Summary and conclusions

A novel easy-to-apply algorithm

- A method for the characterization of the pure pollen depolarization ratio was presented, based on the non-linear least square regression fitting using lidar-derived BAE and PDR.
- The relationship between BAE and PDR of total particles is fixed for the mixture of two aerosol types.

Lidar data

- Lidar observations were analysed to characterize atmospheric pollen at four EARLINET stations during the ACTRIS-COVID-19 campaign in May 2020.
- The reanalysis lidar data products, after the centralized and automatic data processing with the SCC, were used in this study, focusing on particle BSCs at 355 and 532 nm and PDRs at 532 nm.

Applications

- KUO and WAW stations: the pollen depolarization ratios at 532 nm were of 0.24 during the birch-dominant pollen periods.
- HPB and LEI stations: the pollen depolarization ratios of 0.21 and 0.20 were observed for periods of mixture of birch and grass pollen.
- The method was also applied for the aerosol classification.

Demonstrations

- This study shows that automatically retrieved lidar data profiles (using SCC) are suitable for pollen characterizations. The method was demonstrated for sites at which we have seldom or no long-range-transported dust.
- The proposed methodology demonstrated a first step towards automated pollen detection in lidar networks.

Constraints

- The algorithm is valid under two constraints: (i) only two aerosol populations, (ii) both Å and δ of the two aerosol types should be different.
- The uncertainty in the assumed Å of pure pollen will introduce non-negligible bias.
- Additional information, e.g. dust-free period, is needed to exclude dust impact in the areas where dust is present.