Response to Anonymous Reviewer 1

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Original report: Anonymous Referee #1, 1 August 2026

Revised response based on the available observations.

Revised title: Do PM mass and aerosol optical properties differ between pollen-labeled impactor filters and dust-event-associated impactor filters at Hyytiälä?

We thank the reviewer. The revision clarifies the research questions, adds selected independent pollen observations, and limits conclusions to collection-category differences supported by the measurements.

Box category
- Reviewer comments
- Revisions, evidence and interpretation

Reading guide: quotations and original line references concern the submission; revised locations identify sections, tables and figures in the main manuscript (MM) and supplementary information (SI). Nominal, pointwise 95% percentile bootstrap intervals quantify sampling variability; measurement uncertainty is not separately propagated.

Summary comment. Specificity and contribution

Reviewer comment. *This paper presents an interesting case study analyzing aerosol properties during pollen and dust events. However, several concerns need to be addressed before publication: reliance on general aerosol loading/optical properties rather than signals specific to pollen and dust, and the lack of a mechanism-based analysis that offers clear insight into pollen versus dust events. Please see detailed comments below:*

Response. The Introduction asks how mass and optics differ, which differences are robust, and what aerosol particle size distributions reveal. Three Conclusion paragraphs answer these questions using collection-category comparisons, seasonal and temporal sensitivities, and size context. Independent pollen observations establish presence during selected periods; neither collected-PM composition nor optical differences are resolved by source.

Major comment 1. Pollen identification and optical specificity

Reviewer comment. *Previous studies have typically used either the depolarization ratio alone, or the correlation between depolarization ratio and scattering Ångström exponent (SAE), to detect pollen, since pollen particles have an irregular shape. It's not clear why this paper instead relies solely on aerosol loading, SAE, and backscattering to identify pollen, without a clear demonstration of why this approach would work. Other particle types can produce similar optical signals to pollen. For example, pollen events are often wind-driven, and the same meteorological conditions that trigger pollen emission can simultaneously drive emission of other locally sourced aerosol types. Even if the presence of pollen is demonstrated, this alone would not be sufficient to distinguish pollen's contribution from that of other co-occurring aerosols.*

Response. Aerosol loading and bulk optics cannot uniquely identify pollen or isolate its contribution. Optics are compared outcomes, not labeling criteria. The nephelometer measures neither depolarization nor polarization through its backscatter fraction. Wind-driven co-emission may contribute to category differences; the revised Introduction and Discussion distinguish these comparisons from identification and source apportionment.

A pollen indicator requires flag 555 on at least one impactor stage or an explicit pollen note; dust requires overlap with an external dust-event calendar. Both are independent of optical values but do not establish deposit composition. Pollen labels and PM mass share the gravimetric sampling framework, so mass contrasts cannot independently validate labels. B means no recorded indicator, not verified pollen-free or dust-free air.

Separate Hyytiälä Burkard samples, identified and counted by the University of Turku (UTU) Aerobiology laboratory, corroborate pollen during seven selected fully covered 2011 collections in three blocks. UTU names the laboratory, not another sampling site. These observations cannot locate pollen on impactor stages, determine pollen-specific PM mass or optics, or validate later note-only records: 55 of 76 eligible pollen-positive collections (72.4%) and 46 of 58 primary optical P collections (79.3%). Six unflagged neighbors contain pollen during observed windows, but 13.8-33.4% coverage precludes complete-period negative controls.

Manninen et al. (2014) report a sampler height of 20 m, approximately 3 m above the canopy, for 2003-2004; Pessi recalls the same tower through 2011 (personal communication, 2026). Six scanned April-May 2011 weekly records name Veijo Hiltunen as tape changer and log 10 L min^{-1} at the start and end. These handling and flow records do not independently verify the 2011 inlet position, concentration calibration, or sampling efficiency.

Changes in the main manuscript. Introduction; Sect. 2.2; Sect. 3.4; Sect. 4.2. Distinguishes operational labels, independent pollen presence, and source attribution; Table 3 and Fig. 6 report the selected pollen observations and derived concentration ratio.

Changes in the supplementary information. S8.1-S8.3 and Table S5; S12, Table S7. Documents the provider methods and scanned sampling records, retrospective selection, partial controls, flag-versus-note recording methods, and the remaining limits of validation.

Pollen evidence and its scope. Exported concentrations equal 68.64 times the sum of four counted fields in 17 matches of exact date, taxon, and bin with four numeric inputs and zero residuals (SI S15.4). This verifies arithmetic, not the factor's physical area/volume basis, blank and year-field conventions, measurement uncertainty or exact 2011 relative inlet positions. Supplied concentrations and the descriptive cross-instrument grains-per-gram ratio retain these limits and the validation limits above; pollen mass fraction is not established.

Completed check. Checks of how pollen labels were recorded and of optical processing periods are complete (SI S15.3). Flag-and-note years retain 12 P and three D with reportable direct intervals. Note-only years retain 46 P and five D, but only 90.7% of bootstrap draws are valid, below the original 95% gate; their direct intervals are withheld. Later processing-period D observations occur in only 2022 and fail the two-year gate. P-B intervals meet the reporting gates in both processing periods, but different interval outcomes do not test a difference between effects. The label-recording method and year remain inseparable; these checks do not validate labels or calibration.

Major comment 2. Source mechanisms, transport, and contribution

Reviewer comment. *In boreal forest regions, pollen is typically a regional/local source, whereas dust is more likely to originate from long-range transport. This means the two events likely differ in their underlying source mechanisms. Given that both events increase overall aerosol loading, it's unsurprising that optical properties, aerosol surface area, and number concentration all increase as well. Without linking these changes back to source attribution or transport pathways (e.g., using back-trajectory analysis), the study's conclusions do not provide a clear contribution to the field.*

Response. Loading increases alone offer limited mechanistic information, and mass and optics need not increase together. In the same primary optical collections, coarse P and B mass medians are 6.17 and 1.5 μg m^{-3}, but 550 nm scattering medians are 2.25 and

2.57 Mm^{-1} (MM Sect. 3.1). This descriptive comparison does not test the difference between responses. Updated labels, populations and reference uncertainty support category comparisons and seasonal and temporal sensitivity checks, without establishing a causal pollen-versus-dust mechanism.

In independently selected PM-mass populations, raw whole-year P-D median differences are 3.48 [0.37, 6.43] for coarse and 5.24 [2.89, 8.4] $\mu g\ m^{-3}$ for super-PM_{10}. Monthly adjustment leaves super-PM_{10} positive under both designs, but the whole-year coarse median interval includes zero despite a positive rank interval. Common-month restriction lacks support; these checks neither establish season-independent separation nor control meteorology.

For primary optics, D has higher median 550 nm scattering in all three fractions, but every direct whole-year rank-effect and median-difference interval includes zero. At 520 nm, absorption D-minus-P rank intervals are positive; the coarse median-difference interval includes zero. These nominal pointwise results from related properties do not independently confirm source identity.

Primary optical retention is $\frac{8}{19}$ for D (42.1%) and $\frac{58}{71}$ for P (81.7%). Matched collection IDs retain opposite coarse-mass and scattering P-D point directions, but both median-difference intervals include zero; only the mass rank interval remains positive.

All five eligible collections carrying both indicators remain; four enter primary optics. P+D means co-recording within a multiday collection, not simultaneous exposure, a pure mixture or synergy. Retaining the full inventory avoids treating selected mixed cases as representative.

The dust catalog supplies regional long-range-transport evidence, without new collection-specific back trajectories or confirmation of dust at the inlet. Pollen can also undergo regional transport; source attribution remains unavailable.

Changes in the main manuscript. Sect. 2.2, and Table 1; Sects. 3.1-3.3; Sects. 4.4-5. Defines the overlap category and reports direct contrasts, paired context, seasonal support limits, and the narrower observational contribution.

Changes in the supplementary information. S1 and S12; S6-S7; S11.2 and S11.5; S13, Table S9; S14.3, Tables S10-S12. Gives category definitions and record history, temporal and seasonal methods, overlap sensitivities, and the focal direct optical comparisons.

Observational contribution. The label criteria in Major comment 1 and contrasts above support reproducible collection-type comparisons within the sampled ranges. Regional dust-event association does not supply collection-specific receptor composition or transport; PM mass and optics cannot be assigned to mineral dust.

Completed check. Paired-design mass and leave-one-dust-year-out checks (MM Sect. 3.6; SI S15.3) share raw and month-adjusted draws within each design, re-estimating monthly backgrounds each time. Whole-year adjusted P-D median differences are 2.74 [-0.46, 5.76] μg m^{-3} for coarse mass, whose rank interval remains positive, and 3.83 [1.65, 7.27] for super-PM_{10}, which remains positive under both designs. All five dust-year omissions cover all categories. Omitting 2022 leaves four D collections: all 550 nm scattering intervals and 520 nm absorption median-difference intervals include zero; absorption rank intervals remain positive only in fine and cumulative fractions. PM_1 MAC_{520} also loses rank support for higher D: its D-P interval is $[-0.19, 1]$. Failed support gates are reported, not treated as agreement.

Major comment 3. Particle size and the optical inlet

Reviewer comment. *Pollen is generally larger than 10 microns, and dust also have large sizes. It's unclear why the authors focus their analysis primarily on PM_1 and $PM_{1\text{-}10}$ size ranges when attempting to distinguish pollen from dust events.*

Response. The impactor separately measures super-PM_{10} mass; optics supply nominal PM_1 and PM_{10}. Essential mass above 10 μm was in original Fig. 3, Sect. 3.2 and SI Tables S4-S8; revised Fig. 4 gives it an updated category comparison and states that its optical contribution was not measured. Aerodynamic cuts define measurement ranges, not pollen and dust boundaries or perfect transmission thresholds.

Comparisons use PM_1, $PM_{1\text{-}10}$, and PM_{10} optics, without extrapolation above the cutoff. Five of seven fully pollen-covered collections were flagged only on super-PM_{10}; two also on 2.5-10 μm. As Major comment 1 explains, Burkard microscopy cannot locate pollen among impactor fractions. Smaller particles provide accompanying aerosol context; fragments remain unverified.

Coarse optics subtract alternating-inlet measurements; PM mass integrates the whole collection. Sampling bootstraps do not propagate parent-error covariance, gravimetric uncertainty, or mismatched accepted optical hours and full filter periods. Neither super-PM_{10} mass nor the cross-instrument pollen-grains-per-gram ratio establishes optical or PM-mass closure.

Interpretation of the supplied size scalars. The supplied size scalars' original integration limits and geometric definitions remain unrecovered. They are operational descriptors under their declared units, without assigning unverified bin edges or geometric meanings. The separate full-spectrum curves have documented diameter, projected-area and volume transformations; they provide descriptive size context, not independent scalar validation (MM Sect. 3.5 and Fig. 7; SI S9 and S11.4).

Changes in the main manuscript. Sect. 2.1; Sect. 3.2 and Fig. 4; Sect. 4.1. Separates the measured size ranges and explains subtraction, temporal-support, and measurement-error limitations.

Changes in the supplementary information. S3.2; S4.2; S8.2-S8.3; S12, Table S8. Gives processing assumptions, PM-mass uncertainty limits, sampler-comparability limits, and the handling-note omission check, extended with resampled contrasts in S15.5 and denominator sensitivities in S15.6.

Handling-note sensitivity now quantified. Jointly omitting the five noted P collections (four in primary optics), with original support rules and shared resampling schedules (MM Sect. 3.6; SI S12 and S15.5), leaves positive month-adjusted super-PM_{10} P-D differences: 4.09 [1.52, 7.84] μg m^{-3} with whole years and 4.09 [2.14, 6.81] with two-day blocks. Adjusted coarse mass is 3.02 [-0.53, 6.24] with whole years; its rank interval now also includes zero. The PM_{10} 520 nm absorption D-P median difference stays 1.51 Mm^{-1}, but its whole-year interval becomes [-0.02, 2.96]; its rank interval remains positive. Thus some inferences change.

Small-denominator sensitivity. Here, P_p denotes the p^{th} percentile. Minimum and pooled P_1 and P_5 mass screens remove only B, leaving P-D comparisons unchanged by construction. Under the P_5 screen, fine B MSC's maximum falls from 1142.61 to 16.39 m^2 g^{-1}, its median from 3.23 to 3.21. Exploratorily omitting each category's smallest positive mass (SI S15.6) retains MSC rank and median intervals favoring D in all fractions, but fine MAC at 520 nm loses rank support: its D-P rank interval is [-0.18, 0.88]. All paired whole-year direct effect-shift intervals include zero. Changed zero exclusion or mechanically unchanged pooled-screen results demonstrate neither a change nor equivalence between effects.

These checks quantify influence, not measurement validity. The 18 May 2016 printer-off note has stored weights; notes establish neither invalidity nor final QC acceptance. Revised primary selection and figures remain the reference. The recovered 660–637 nm fit

does not independently validate every wavelength or era; screening thresholds are not detection limits. Bootstrap intervals have no physical error budget (reading guide). The efficiencies MSC_λ and MAC_λ describe sampled mixtures, not intrinsic pollen or dust optical constants.

Minor comment 1. Definition of APSD

Reviewer comment. *Line 40-45: Please define the acronym APSD at first use.*

Response. The revised Introduction expands the acronym at first use: **aerosol particle size distributions (APSDs)**.

Changes in the main manuscript. Introduction. Defines APSDs at first use.

Changes in the supplementary information. S1; S9. Uses APSDs as defined at first use in the main Introduction and provides the size-distribution methods.

Minor comment 2. Supplementary figure clarity

Reviewer comment. *The supplementary material figures are quite blurry and difficult to interpret; please provide higher-resolution version.*

Response. We rebuilt and checked the figures: S1-S3 are vector PDFs with explicit units and interval definitions. Across all figures, complete sentences end with full stops; short labels do not. The blue boxes below specify their retained summaries and revised styling. Main Figs. 2-5 also use tighter y-axis ranges. Earlier dense sub-100 nm panels are omitted; numerical summaries remain. Figure 6 uses a calendar axis, ratios of collection-average concentrations, and duration segments distinguished from uncertainty intervals.

Changes in the main manuscript. Sect. 2.4; Sect. 2.5; Sect. 3.1; Figs. 2-5. States the optical scope and statistical summaries. The boxplots omit individual observations, use shading only within the boxes, and explain the collection counts beneath each category.

Changes in the supplementary information. S14.2, Figs. S1-S3. Provides vector rank-effect and category-summary figures. Figures S2-S3 explain the collection counts and use coloured median markers without dark outlines; interval bars and caps are retained, and captions distinguish bootstrap intervals from interquartile ranges.

Current documentation and reproducibility. MM Code and data availability and AI-use sections; SI S14.4-S15 and AI-use section. Both documents include AI-use sections and a version-pinned Binder link. Verification on 27 October 2026 completed four hosted jobs and exactly reproduced eight main and three supplementary images, including $\sigma_{abs,520}$, MAC_{520}, revised labels, numerical formatting and Figure 6. The GitHub release includes matching data and code archives and the receipt. The supplied local archives also include the subsequent figure wording and punctuation updates. The default workflow uses frozen processed inputs, replays the dust-overlap diagnostic and retains saved bootstrap intervals. It does not rerun raw-data analysis or the locally run reconciliation and sensitivity scripts supplied separately in *Evidence-Resolution*.

Appendix. Record reconciliation and selection checks

Both versions compare optics and PM mass over impactor collection intervals. The recovered original run reproduces these totals and links records to the revised inventory. B = neither indicator, P = pollen only, D = dust only, P+D = both.

Population	B	P	D	P+D	Total
Original merged inventory	1,545	21	15	0	1,581
Original finite PM mass, each fraction	1,527	21	15	0	1,563
Revised eligible inventory	1,474	71	19	5	1,569
Revised primary optics	1,010	58	8	4	1,080
Revised PM_1 mass	1,457	70	19	5	1,551
Revised $PM_{1\text{-}10}$ mass	1,425	70	19	5	1,519
Revised PM_{10} mass	1,449	70	19	5	1,543
Revised super-PM_{10} mass	1,389	71	19	5	1,484
Revised full-range size spectra	1,454	71	19	5	1,549

Count sources: original SI Tables S1 and S4; revised MM Table 1. Derived optics may have fewer finite values than the primary optical population. Fraction-specific populations overlap and must not be summed.

Pollen ascertainment. Original SI Table S15 required flag 555. Revised SI Table S7 records 21 flag-and-note collections in 2011-2014 and the 55 note-only cases from 2016-2022 detailed in Major comment 1: **76 pollen-positive = 71 P + 5 P+D**. That answer gives primary optical P counts by recording method; four further pollen-positive optical collections are P+D. The seven fully covered collections match original 2011 entries

P1-P7 within timestamp precision; independent pollen data add no impactor collections. Of the original 21 P, 20 remain P and one becomes P+D; of 15 D, 12 remain D and three become P+D. The 55 note-only additions comprise 51 original B becoming P, one B becoming P+D, and three D becoming P+D.

Dust ascertainment. The 24 revised dust-positive collections (19 D + 5 P+D) overlap 18 catalog dates; the 12 primary optical dust-positive collections overlap nine. With the older calendar, replacing the midnight-within-interval test with positive full-day overlap changes 15 to 20. Restoring 2 February 2014, 6 June 2014 and 11 February 2018 changes 20 to 24 because 6 June overlaps two collections. This separates calendar and overlap-rule effects without altering the complete-calendar baseline or establishing receptor composition.

Measurement selection. Primary optics requires at least 75% coverage for ten channels in both inlets and valid paired PM_1, PM_{10}, and coarse mass (revised MM Sects. 2.3-2.5; SI S4-S5). Original PM_1 and coarse scattering counts were 1,481 (1,447 B, 21 P, 13 D) and 1,474 (1,440 B, 21 P, 13 D; original SI Table S4). These selections differ from revised fraction-specific mass selection, which excludes negatives. In PM_1, coarse, PM_{10}, and super-PM_{10} order, removing 2, 28, 5, and 69 negatives from 1,563 gives 1,561, 1,535, 1,558, and 1,494 (original SI Table S7), still 10, 16, 15, and 10 above revised totals. The crosswalk resolves these differences: each fraction loses ten no-foil zeros; PM_{10} and coarse mass withhold five inconsistent PM_{10} totals (rows 1508-1512); coarse mass also excludes row 2038, whose negative parents yield a positive subtraction. Both blanks were already missing; no replacement values were inferred. Size spectra independently require 75% complete-spectrum coverage (SI S9).

Category-specific optical retention. Percentages use revised MM Table 1. Mutually exclusive coverage and mass exclusion reasons appear below and in SI S15.1.

Category	Eligible	Primary optics	Excluded	Retained
B	1,474	1,010	464	68.5%
P	71	58	13	81.7%
D	19	8	11	42.1%
P+D	5	4	1	80%

Aggregate balance. 76 + 24 - 5 = 95 revised collections carry either indicator, versus 36 originally. The 59 additional labeled and 71 fewer background collections give a net inventory reduction of 12. The exact-time crosswalk establishes 12 removals and no

additions: rows 1621-1630 had no foils; rows 1438 and 1460 were blanks. The original 23 APSD episodes (15 dust and eight pollen) were temporal clusters, not collection counts; the seven fully pollen-covered collections form three blocks.

Completed check. All 1581 original records match unique revised workbook intervals exactly. The removals detailed above are all old B; no records were added. The cross-walk identifies category transitions, all five overlap records, dust-calendar effects and every fraction-specific mass-count difference (SI S15.1). This numerical consistency cannot independently certify the exact originally submitted file version.

Completed check. Category-specific exclusions and common-population contrasts (SI S15.1-S15.2) show B losses of 415 for coverage only, 44 for paired mass only and five for both; P losses are 12 and one respectively; all 11 D and one P+D losses concern coverage. Mass and optics share collection IDs for each property. With finite 550 nm scattering in the primary all-channel population (58 P and eight D), coarse mass has a P-D median difference of 3.74 [-1.16, 6.61] μg m^{-3} and a positive rank interval; scattering's median difference is -2.61 [-5.38, 0.3] Mm^{-1}. All 93 intervals for changes in each mass-effect measure between full and matched populations include zero. This establishes neither equivalence nor absence of selection bias; missing optics remain unknown.