Response to Reviewer 1

Manuscript title: *Non-monotonic response of net dust deposition kinetics to low wind speeds*

Manuscript No.: egusphere-2026-261

Dear Reviewer,

We sincerely thank you for your careful reading of the manuscript and for your constructive comments. Your central observations concerning secondary re-entrainment, collector representativeness, wind-profile characterization, and the interpretation of the fitted kinetic parameters led us to substantially revise the manuscript. In particular, we now distinguish gross downward deposition from the experimentally measured cumulative tray-retained net accumulation; explicitly document the unsuppressed rebound/re-entrainment processes; correct and fully reanalyse the wind-profile data; provide the monitor position and the available concentration time series; add an auxiliary threshold-screening test; and revise the interpretation, limitations, figures, equations, and terminology throughout.

General assessment

Reviewer comment:

Dry deposition of atmospheric dust is a key process controlling the atmospheric lifetime of dust, source-region removal, and long-range transport. This is particularly important in the post-dust-storm low-wind phase, where its behavior directly affects the accuracy of global dust cycle simulations and climate radiative forcing estimates. For a long time, dust deposition processes under low wind speeds have remained difficult to quantify accurately, and most models adopt monotonically wind-speed-dependent parameterization schemes. This study utilized a closed-circuit recirculating wind tunnel and employed a two-stage experimental protocol (high-wind loading followed by low-wind deposition). Combined with laser diffraction particle size analysis and a first-order exponential kinetic model, the study systematically quantified the deposition kinetic parameters (a, k, τ, J_0) for different particle sizes under wind speeds of 0–6 m s^{-1}. The results revealed a non-monotonic response in the net deposition of fine-to-medium particles, with a peak at approximately 2 m s^{-1}, leading to the proposal of a potential “low-wind window”. This work provides important process-based experimental constraints for improving the parameterization of dry deposition in atmospheric models.

The manuscript is generally well written and logically structured. The experimental design is systematic, and the kinetic model fits the data well, providing valuable measured data and physical interpretations for low-wind dust deposition research. However, I have the following suggestions for improvement regarding the experimental design, particle physics processes, and the physical interpretation of net deposition.

Response:

We appreciate the reviewer’s positive assessment and the clear identification of the issues that required further qualification. The revision retains the central empirical result: a size-dependent, non-monotonic response of the mass stably retained by the trays, but narrows the claim to the quantity that was actually measured. The title now refers to “net dust deposition kinetics,” and the Abstract defines the observations as cumulative retained mass and the fitted quantities as an asymptotic retained mass, an effective net-accumulation rate coefficient, a characteristic time scale, and an initial net accumulation flux. Throughout the manuscript, “dry deposition” is retained when referring to the established atmospheric process or existing parameterizations, whereas the experimental observations are described as “tray-retained net accumulation,” “effective surface retention,” or “net accumulation flux.” We also make clear that the measurements provide benchmark behaviour for coupled deposition–retention–re-entrainment treatments rather than a direct measurement of gross deposition velocity.

Major Comments

Major Comment 1: Separation of deposition and secondary re-entrainment

Reviewer comment:

In practical scenarios, the dry deposition of dust is almost always accompanied by secondary resuspension. For this reason, previous studies on dust dry deposition mechanisms, especially experimental research, have generally suppressed or eliminated the influence of secondary resuspension to investigate the pure mechanism of dust dry deposition. Since no measures were adopted in this experiment to inhibit secondary resuspension, the final results reflect the combined effect of two physical processes: deposition and re-entrainment. The non-monotonic variation of dust dry deposition with wind velocity observed in this study arises from the competition between these two mechanisms, which is not inconsistent with existing physical models of dust dry deposition. It is suggested that the author revise the relevant statements to avoid misleading readers.

Response:

We agree with this interpretation and have revised the manuscript accordingly. No water, beads, grease, adhesive coating, or other retention medium was present in the collection trays. The recorded tray mass therefore cannot be interpreted as gross downward deposition alone. We now define it explicitly as cumulative tray-retained net accumulation, which integrates particle arrival at the tray surface and subsequent losses through rebound, local re-entrainment, and removal from the tray. The original soil source was completely covered with steel plates before the low-wind phase, preventing continued direct emission or re-erosion from that source; however, the steel cover did not suppress particle loss from the trays or deposition onto other tunnel surfaces.

The kinetic notation has been revised to match this measurement. The fitted parameter a is now the asymptotic retained mass, k is the effective net-accumulation rate coefficient, τ is the corresponding characteristic time, and $J_0 = ak$ is the initial net accumulation flux. We removed the preprint's derivation and reporting of an "equivalent deposition velocity," because the experiment did not measure a vertical concentration gradient or a gross downward particle flux. The manuscript now states explicitly that $M(\mathrm{t})$, a, and J_0 are tray-based net-accumulation metrics and are not normalized by the time-varying concentration.

We also revised the conceptual comparison with model parameterizations. The non-decreasing reference curve is now introduced only as a simplified deposition-only expectation, in which deposition velocity increases or remains unchanged with wind or friction velocity while resuspension is treated separately. Departures from this reference are used as a diagnostic measure of the combined net-retention response; they are not presented as evidence that established deposition physics is internally inconsistent. The Discussion now interprets the 2 m s^{-1} maximum as the outcome of favourable particle delivery and stable retention under the present collector configuration, whereas the smaller retained masses at 4–6 m s^{-1} reflect increasing persistence in suspension, horizontal redistribution, reduced stable retention. At 6 m s^{-1}, local re-entrainment may also have contributed because this wind speed was within the apparent mobilization threshold range identified in the auxiliary test. The revised Implications section therefore recommends coupling conventional deposition with wind- and size-dependent stable retention and a surface-specific, threshold-dependent re-entrainment term.

Finally, the Abstract, Results, Discussion, Conclusions, figure captions, and terminology were revised to avoid presenting the response as pure dry deposition or a direct deposition-velocity measurement. The main empirical finding is now framed as a "low-wind window" in net retention under the present experimental configuration.

Location in the revised manuscript: Title; Lines 2–18, 53–63, 81–85, 103–118, 143–177, 218–263, 264–346, 383–518, 531–594.

Major Comment 2: Rationality and representativeness of the tray measurements

Reviewer comment:

Furthermore, it should be noted that since the experimental results incorporate the effect of secondary resuspension, which is closely correlated with surface properties, the shape and size of the trays used in the experiments will exert a direct impact on the findings. The author is advised to conduct in-depth analysis and discussion on the rationality and representativeness of the experimental results.

Response:

We agree that collector geometry and surface properties are integral to the measured net-retention response. We have therefore expanded both the Methods and the limitations discussion. Each collector was a cylindrical acrylic tray with a radius of 10 cm (20 cm diameter), a 3 cm rim, and a smooth, untreated collection surface. Twenty-five trays were installed at predefined floor positions at the start of every low-wind run. Five trays were assigned to each sampling time and removed after 30, 60, 90, 120, or 180 min. The same initial positions, time-specific assignments, and retrieval sequence were used for every wind-speed treatment. Thus, the tray configuration at a given sampling time was matched among treatments, although the number of trays progressively decreased within each run.

The wind profiles were measured with the complete initial array of 25 trays installed, so they include the collective aerodynamic influence of the array at the profile-measurement station. At the same time, the revised manuscript now states explicitly that the available profile measurements do not resolve flow separation, recirculation, or wakes immediately adjacent to individual 3 cm rims, nor changes in the local flow field caused by progressive tray removal. We removed the comparison between the fitted roughness length and bare sand and no longer report independently fitted aerodynamic roughness length or displacement height, because the tray array is a non-uniform roughness field and the vertical resolution is insufficient for robust simultaneous estimation of these quantities.

The revised limitations section now distinguishes internal comparability from external representativeness. The identical collector and matched sampling protocol support comparisons among the four wind-speed treatments. However, the absolute retained masses and fitted parameters are configuration-specific: the 20 cm diameter, rim height, smooth acrylic surface, local wakes, particle rebound, and progressive tray removal may all affect capture and subsequent loss. The results should therefore not be transferred directly to natural soil, vegetation, or collectors of different geometry without further calibration. We now present the measurements as controlled, surface-specific constraints on effective near-surface retention rather than universal deposition efficiencies.

Location in the revised manuscript: Lines 152–165, 178–203, 545–553.

Specific Comments

1. Definitions of u_* and δ in Figure 1

Reviewer comment:

It is suggested to define u_* and delta in the caption of Figure 1 to help readers quickly understand the information presented.

Response:

We thank the reviewer for this suggestion. The caption of Fig. 1b now identifies u_* as the friction velocity estimated from the slope of a log-linear near-surface wind-profile regression and identifies δ as the boundary-layer thickness obtained from the 99% upper-profile velocity criterion. The Methods provide the complete definitions: $U(z) = A \ln(z/z_{ref}) + B$, $u_* = \kappa A$ with $\kappa = 0.4$ and $z_{ref} = 1$ m; δ is the first height at which the shape-preserving interpolated profile reaches $0.99U_\infty$, with U_∞ defined as the mean velocity at 0.80, 1.20, and 1.60 m. The corresponding R^2 values are shown directly in Fig. 1b.

Location in the revised manuscript: Lines 136–142 and 178–197.

2. Wind-profile measuring position and consistency of the tray layout

Reviewer comment:

It is recommended to specify the measuring position for the wind velocity profile.

The trays, with a height of 3 cm, are obviously higher than the surface roughness length z_0 provided in the paper. Thus, the trays act as surface roughness elements under experimental conditions and exert a notable influence on the near-ground wind field. Given that the development of a turbulent boundary layer requires a certain fetch length, the measuring location of the wind velocity profile should be clearly stated. In addition, it needs to be clarified whether the trays were reset after each test run, so as to ensure consistent layout of the trays across all experimental tests.

Response:

We really thank the reviewer for identifying this issue. Wind profiles were measured at nominal speeds of 2, 4, 6, and 8 m s^{-1}. During preparation of the wind-profile dataset for the original analysis, however, the profiles measured at 4, 6, and 8 m s^{-1} were inadvertently selected and presented as corresponding to the 2, 4, and 6 m s^{-1} treatments. We sincerely apologize for this oversight. We have now reanalyzed the wind-profile data using the correct profiles measured at 2, 4, and 6 m s^{-1}, recalculated the associated profile-derived parameters, and replaced Fig. 1b accordingly. This error was confined to the wind-profile analysis. The deposited masses, particle-size distributions, and kinetic parameters were determined independently from the tray samples and are therefore unchanged, including their wind-speed ranking.

The revised Methods now specify that profiles were measured on the longitudinal centreline, 9 m downstream of the test-section entrance and immediately downstream of the collection-tray array. The complete initial array of 25 trays was present during profile measurement. Trays were positioned at predetermined locations with 20 cm spacing, and the initial layout was restored before each run. During an actual deposition run, however, five trays were removed at each scheduled sampling time. We now state this progression explicitly and clarify that the same time-specific tray assignments and removal sequence were used across treatments, ensuring a matched configuration at each sampling time.

The wind-profile analysis was also revised to avoid treating the array as a uniform bare-sand roughness surface. Apparent friction velocity was estimated from a two-parameter regression, $U(z) = A \ln(z/z_{ref}) + B$, over the common height range 0.05–0.40 m. This supplies four measurement points above the 0.03 m rims for all three treatments. With κ and z_{ref} fixed, u_* is calculated from κA; roughness length and displacement height are not fitted independently. The corrected apparent friction velocities are 0.063, 0.089, and 0.154 m s^{-1} at nominal speeds of 2, 4, and 6 m s^{-1}, with R^2 = 0.921, 0.933, and 0.883, respectively. The corresponding operational boundary-layer thicknesses are approximately 0.88, 0.73, and 0.48 m.

All derived quantities were recalculated. The nominal near-wall viscous length scale is now approximately 1.20, 0.85, and 0.49 mm, and the Rouse number for 2–10 µm particles ranges from approximately 0.006 to 0.32. The manuscript also states that the profiles represent profile-scale mean flow under the complete initial tray array but do not resolve local wakes around individual rims or flow changes caused by tray removal.

Location in the revised manuscript: Lines 136–142, 152–161, 178–203, 410–428, and 545–553.

3. Tray dimensions and absence of a resuspension-suppression medium

Reviewer comment:

With a diameter of 10 cm, the trays are prone to particle resuspension. Please clarify whether small beads or water were placed at the bottom of the trays to suppress resuspension.

Response:

We thank the reviewer for raising this important point. We clarify that 10 cm is the radius, not the diameter; each cylindrical acrylic tray had a diameter of 20 cm and a rim height of 3 cm. No water, glass beads, grease, adhesive coating, or other material was placed in the trays. We added this information explicitly to Sect. 2.2.

This clarification also prompted a substantive change in interpretation. Because rebound and re-entrainment were not suppressed, the collected mass is now defined as cumulative tray-retained net accumulation rather than gross deposition. The fitted a, k, τ, and J_0 parameters are described as effective net-retention descriptors. We also added a limitation stating in Sect. 4.4 that tray diameter, rim height, the smooth acrylic surface, local flow separation, particle rebound, and progressive tray removal can influence the absolute retained mass. The matched collector type and sampling sequence allow controlled comparison among wind speeds, but the absolute values are specific to the present configuration.

Location in the revised manuscript: Lines 152–165, 218–248, and 545–553.

4. Dust-concentration monitor position and absence of vertical concentration gradients

Reviewer comment:

Please specify the installation position and height of the dust concentration monitor. Given that the gradient of dust concentration is key environmental data for this experiment. Why relevant measurements were not conducted?

Response:

We thank the reviewer for this constructive suggestion. The sampling inlet of the real-time concentration monitor was located on the longitudinal centreline of the test section, 7.5 m downstream of the test-section entrance and 1.0 m above the tunnel floor. These details have now been added to Sect. 2.2.

We agree that multi-height concentration measurements would be required to characterize a vertical concentration gradient and, together with appropriate turbulence or direct-flux measurements, would be needed to resolve downward and upward particle fluxes and derive a deposition velocity. The original experiment was designed around time-dependent mass retained by the tray array; the single fixed-point monitor was installed as a quality-control instrument to compare the initial suspended loading among runs and to follow the persistence of airborne dust during the low-wind phase. A vertical concentration profile was not part of the original experimental design and cannot be reconstructed retrospectively. We now state this limitation directly and do not use the concentration record to infer a vertical flux, re-entrainment flux, or deposition velocity. Consistent with this limitation, the “equivalent deposition velocity” derivation in the manuscript was removed.

To make full use of the available data, we added the complete normalized 180 min concentration time series as Fig. S2 and summary values as Table S1. The recorded initial concentrations (C_0) were 191.35, 178.20, 186.36, and 189.44 mg m^{-3} at 0, 2, 4, and 6 m s^{-1}, respectively (range 178.2–191.4 mg m^{-3}; coefficient of variation 3.1%). A sensitivity analysis rescaled retained mass by C_{ref}/C_0 and confirmed that the principal wind-speed ranking was unchanged. The mean concentration during the final 20 min was 5.32%, 0.15%, 9.27%, and 4.24% of C_0 at 0, 2, 4, and 6 m s^{-1}. Thus, the 2 m s^{-1} treatment had the lowest late-stage residual concentration, whereas the 4 and 6 m s^{-1} treatments retained more airborne dust, especially at 4 m s^{-1}. These data support initial-condition comparability and the interpretation of airborne-dust persistence.

Location in the revised manuscript: Lines 166–175, 239–243, and 310–320; Supplement, Table S1 and Fig. S2.

5. Number of wind-profile points, fitted parameters, and R^2

Reviewer comment:

Line 171: When the boundary layer thickness is 0.48 m, there appear to be only three valid wind velocity measurement points. Since the adopted fitting function contains three unknown parameters, the fitting results are not meaningful. Please provide the coefficient of determination for each wind velocity profile fitting.

Response:

We agree that the original three-parameter fit was not adequately constrained. We therefore replaced it rather than retaining the original formulation. As noted in our response to Comment 2, we also identified and corrected the profile column-indexing error before reanalysis.

The revised analysis uses $U(z) = A \ln(z/z_{ref}) + B$ with fixed $z_{ref} = 1$ m and $\kappa = 0.4$, followed by $u_* = \kappa A$. Only A and B are fitted. A common interval of 0.05–0.40 m was used at all wind speeds, providing four points above the 0.03 m tray rims, including for the profile with $\delta \approx 0.48$ m. Aerodynamic roughness length and displacement height are no longer independently estimated or reported. The corrected apparent friction velocities are 0.063, 0.089, and 0.154 m s^{-1} for 2, 4, and 6 m s^{-1}, and their coefficients of determination are $R^2 = 0.921$, 0.933, and 0.883, respectively. These R^2 values are now reported both in Sect. 2.3 and directly in Fig. 1b.

Boundary-layer thickness was calculated independently of the friction-velocity regression. For each profile, U_∞ was defined as the mean wind speed measured at 0.80, 1.20, and 1.60 m. Minor non-monotonic reversals across the eight measured heights were adjusted using isotonic regression, after which shape-preserving interpolation was used to identify the first height at which the profile reached 0.99 U_∞. This yielded $\delta \approx 0.88$, 0.73, and 0.48 m for the 2, 4, and 6 m s^{-1} profiles, respectively. This suggestion has helped us improve the clarity of the manuscript.

Location in the revised manuscript: Lines 136–142 and 178–203.

6. Equation numbering

Reviewer comment:

It is recommended to number all equations for ease of citation.

Response:

Thank you for this helpful comment. We have numbered all displayed equations used in the analysis and updated the text to refer to them consistently. These are the log-linear wind-profile relationship [Eq. (1)], the apparent-friction-velocity calculation [Eq. (2)], the first-order accumulation model [Eq. (3)], the initial net accumulation flux [Eq. (4)], and the ratio to the non-decreasing benchmark [Eq. (5)].

Location in the revised manuscript: Lines 185–197, 233–248, and 254–261.

7. Scope of the monotonic deposition–wind relationship

Reviewer comment:

Line 230: Generally, a monotonic relationship between deposition velocity and wind velocity is only recognized when solely considering dry deposition and ignoring the effect of resuspension.

Response:

We agree and have revised the text so that this distinction is explicit. The old manuscript stated too broadly that dry-deposition parameterizations assume a strictly monotonic relationship. The revised manuscript now states that many schemes describe deposition velocity for a fixed particle size and surface as increasing or remaining unchanged with wind speed or friction velocity while treating resuspension separately. The isotonic reference is therefore described as a non-decreasing, simplified deposition-only expectation.

The observed ratio $R(U) = J_0(U)/J_{0,\,\mathrm{mono}}(U)$ now quantifies only how the measured tray-retained net accumulation departs from that reference. It is not interpreted as showing that a deposition-only model is physically inconsistent; rather, it illustrates the additional influence of stable retention and particle loss when deposition, rebound, and re-entrainment act together. Correspondingly, the revised Discussion recommends a coupled treatment containing conventional deposition, wind- and size-dependent retention, and a surface-specific re-entrainment term.

Location in the revised manuscript: Lines 53–63, 81–85, 254–261, and 466–518.

8. Critical wind speed for dust mobilization

Reviewer comment:

The critical wind velocity for dust emission from the surface can be readily obtained. Please discuss its relationship with the three wind speeds adopted in the experiment, as this will effectively support the analysis of resuspension effects in the paper.

Response:

We agree with the reviewer's suggestion and have incorporated it into the revised manuscript. We conducted an auxiliary threshold-screening test using the same dust in the same wind tunnel. Inverted glass dishes bearing double-sided adhesive tape were positioned at the dust tray edge to capture mobilized particles. The upper surfaces of the inverted dishes were approximately level with the top of the dust tray. Wind speed was increased stepwise, and three replicate collectors were used at each speed. Captured mass remained low from 5.59 to 5.87 m s^{-1} and increased sharply at 6.01 m s^{-1}, defining an apparent critical range of 5.87–6.01 m s^{-1} for marked particle mobilization under this tray configuration. We use the term "apparent" because the result is configuration-specific and is not presented as a universal threshold for the source soil.

This screening clarifies the interpretation of the deposition treatments. The 2 and 4 m s^{-1} treatments were below the apparent critical range, whereas 6 m s^{-1} was close to or within it. Rebound and local re-entrainment are therefore physically plausible contributors at 6 m s^{-1}. By contrast, the reduced tray-retained mass at 4 m s^{-1} should not be attributed primarily to active threshold exceedance. Its combination of lower retained mass and the highest late-stage airborne concentration is more consistent with continued suspension, recirculation, horizontal redistribution, and reduced stable retention. However, because vertical fluxes were not measured, the relative magnitude of these mechanisms cannot be partitioned quantitatively.

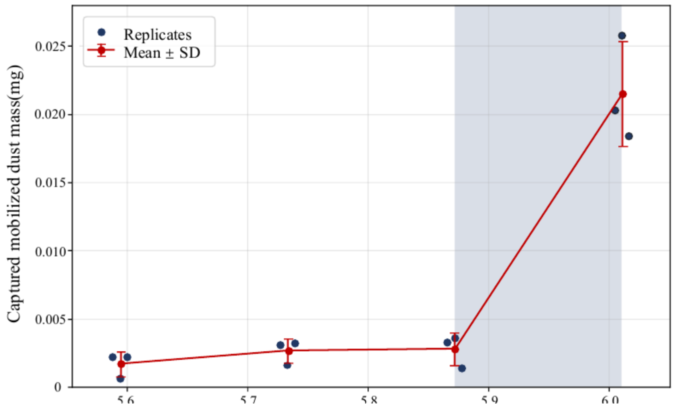

Figure S1. Auxiliary threshold-screening result. Captured mobilized mass increased sharply between 5.87 and 6.01 m s^{-1}.

Photograph of the auxiliary threshold-screening arrangement used to capture mobilized particles at the tray edge.

Location in the revised manuscript: Lines 303–305 and 444–454; Supplement, Fig. S1.

9. Closing parenthesis in the y-axis label of Figure 3b

Reviewer comment:

The y-axis label of Figure 3b is missing a closing parenthesis.

Response:

Corrected. The y-axis label in Fig. 3b now reads "J_0 (mg m^{-2} h^{-1})", including the closing parenthesis, and the associated caption consistently defines J_0 as the initial net accumulation flux.

Location in the revised manuscript: Lines 321–329 (Fig. 3b and its caption).

10. Italic formatting of *a*

Reviewer comment:

Line 274: Please set *a* in italic.

Response:

Corrected. The parameter *a* is now italicized at its definition and throughout the equations, figure captions, Results, Discussion, Conclusions, and supplementary tables. We also checked the formatting of the other mathematical variables (k, τ, J_0, U, U_{opt}, C_0, and D_{50}) for consistency.

Location in the revised manuscript: Lines 10–14, 233–248, and 277–302; Supplement, Tables S2–S4.

11. Capitalization and consistency of "Peak"

Reviewer comment:

In lines 329–330, "peak" should be corrected to "Peak". Please check the entire manuscript and ensure consistent formatting and capitalization of related symbols and terms for better readability.

Response:

Corrected. The modal-diameter annotations in Fig. 4 now consistently use "Peak" with an initial capital, and the caption explicitly defines the label as the modal diameter. We also reviewed the figure labels, captions, mathematical symbols, units, and capitalization of the related terms across the manuscript and Supplement for consistency.

Location in the revised manuscript: Lines 347–356 (Fig. 4 and its caption).

12. Consistency of the *k* value and the text describing its maximum

Reviewer comment:

In Figure 3(a), the *k* value for $PM_{2.5}$ at 4 m s^{-1} is shown as 4.03, whereas the text describes that k reaches or approaches its maximum at 2 m s^{-1}. Please check the data for consistency with the description and make corrections or provide clarification.

Response:

We thank the reviewer for identifying this inconsistency. We rechecked the fitted parameters against the source results and confirmed that the value shown in Fig. 3a was correct; the description in the old manuscript was inaccurate. For $PM_{2.5}$, *k* is 0.24, 3.03, 4.03, and 3.61 h^{-1} at 0, 2, 4, and 6 m s^{-1}, respectively, so its maximum occurs at 4 m s^{-1}. The revised text now gives the size-specific maxima correctly: the largest *k* occurs at 2 m s^{-1} for PM_{10}, at 4 m s^{-1} for $PM_{2.5}$ and PM_{30}–PM_{63}, and at 6 m s^{-1} for PM_{20}.

We also clarified the distinction between *k* and J_0. The coefficient *k* measures how rapidly the fitted curve approaches its asymptotic retained mass, whereas $J_0 = ak$ is the initial net accumulation flux. Consequently, the wind speed that maximizes *k* need not maximize J_0. Among the tested speeds, J_0 is highest at 2 m s^{-1} for $PM_{2.5}$–PM_{30} and at 4 m s^{-1} for PM_{40} and PM_{63}. The Abstract, Fig. 3 caption, and Results now report these rankings explicitly. No fitted values were changed in response to this comment; the correction was to the explanatory text.

Location in the revised manuscript: Lines 11–14 and 321–345; Supplement, Table S2.

We again thank the reviewer for all these comments. They substantially improved the precision of the experimental description and ensured that the conclusions are aligned with the measured quantity and the limitations of the collector-based design.