Reply to reviewer 1

In the following, we address all reviewer comments point-by-point. The reviewer comments are shown in black, the author responses are shown in green and changes to the manuscript are shown in orange.

This manuscript presents eddy covariance measurements of turbulent particle fluxes in the High Arctic from the the ARTofMELT campaign. This manuscript describes a technically competent measurement campaign that yields results broadly consistent with prior studies. It is reported that net deposition dominates over closed ice (median -0.02 × 10^6 m^{-2} s^{-1}), while emission events up to 0.98 × 10^6 m^{-2} s^{-1} occur during high-wind conditions associated with blowing snow. The manuscript was interesting and nice to read and the resulting dataset is potentially valuable to further the understanding of dynamics governing particle fluxes in the Arctic.

However, in its current form, the manuscript reads primarily as a data description rather than a hypothesis-driven scientific investigation. The analysis remains superficial, and the conclusions do not offer the substantial new mechanistic or process-level insights required for publication in Atmospheric Chemistry and Physics, for which (citing the Aims & Scope of the journal):

"Articles should have important and clearly argued implications for our understanding of the state and behavior of the atmosphere and climate or present substantial new insights into the atmosphere's role in other parts of the Earth system."

Because the manuscript does not present significant insights or testable hypothesis, but is rather a dataset and campaign measurement description, I recommend rejection, with the suggestion that the authors consider a more specialized journal after major revision. Below I provide a non-exhaustive list of methodological issues and suggestions to strengthen the results, should the authors choose to revise for another venue.

We would like to thank the reviewer for their thorough and constructive review of our manuscript, and for appreciating the interesting manuscript and potentially valuable dataset. We are grateful for the time and effort invested in providing such detailed feedback. We have carefully considered all of the comments and addressed each point in the revised manuscript. We are convinced that these revisions have improved the clarity and methodological description of the manuscript, as well as its overall quality. Our detailed responses to the individual comments are provided below. In addition, we have also restructured the Methods section to provide a clearer separation between particle concentration data, turbulence data, particle flux calculations and quality control, surface characterization, and dry deposition modelling. The order of the individual sections was revised to provide a clearer and more coherent description of the data processing and analysis.

As a further note: Michael Tjernström and Birgit Wehner do not appear to meet the criteria for co-authorship. I suggest removing them from the author list unless their role is clarified and justified.

We respectfully disagree with the reviewer's suggestion and tried to improve explaining the substantial contributions of all co-authors.

Michael Tjernström contributed substantially to the scientific interpretation of the results and to the development of the manuscript through extensive comments, conceptual suggestions, and revisions of several manuscript versions that considerably improved the final version. These contributions influenced both the interpretation of the findings and the presentation of the study. We therefore consider his contribution sufficient to meet the criteria for co-authorship.

Birgit Wehner conceived and co supervised the project and contributed scientific expertise to the particle flux measurements, data analysis, interpretation of the results, and critical revision of the manuscript. We therefore also consider Birgit Wehner to meet the criteria for co authorship.

Line 589-585: Author contributions. TM: Conceptualization, methodology, measurements, formal analysis, and writing. Review and editing, with conceptual contributions from IB, SM, MT, JK, PZ, JP, BW, and AH. IB provided the surface images. SM and JP provided the motion corrected sonic data, meteorological data, and sensible heat flux data. JK and PZ measured and provided the particle size distribution data. MT, PZ contributed to the planning and coordination of the field campaign, supported the successful execution of the field measurements, and contributed to the scientific interpretation of the results. BW and AH conceptualized the project, provided instrumentation and expertise for the particle flux measurements and data analysis, and contributed to the scientific interpretation of the results.

Major comments:

1. The authors use an empirical wind-speed/temperature threshold to define blowing snow. As one of the implied claims in the article is that emission events are linked to blowing snow, the authors should provide direct evidence or explicitly acknowledge this as a major caveat. Additionally, other possible causes of emission events should be explored through further data analysis.

Thank you for this important comment. We agree that our observations do not provide direct evidence that the observed particle emission events were caused solely by blowing snow. We have therefore revised the manuscript to be more cautious in our interpretation, and now consistently refer to blowing snow as a likely explanation rather than a confirmed source. In addition, we have expanded the discussion of alternative mechanisms. In particular, we discuss sea spray and new particle formation as alternative sources of the observed particles. Although the precursor gases required for new particle formation are unlikely to originate from the surrounding closed ice surface, they may have been transported from more distant source regions due to the high winds. However, the measured particle size distributions do not exhibit a pronounced nucleation mode typically associated with local new particle formation. Instead, the observed size distributions are more consistent with those reported in previous blowing snow events. These additions have been incorporated into the revised discussion.

Line 518-531: An alternative source of the observed particles could be sea spray aerosol generated from leads or open water (Kirpes et al., 2019; Dall'Osto et al., 2026). The classification as closed ice indicates that closed ice accounted for at least 70% of the surface within the selected area. Therefore, small fractions of leads or open water may have been present during some intervals, and a contribution from sea spray aerosol cannot be completely excluded. However, the predominance of closed ice and the coincidence of positive particle fluxes with blowing snow conditions suggest that sea spray aerosol was unlikely to be the main source. New particle formation is also considered unlikely to explain the observed positive particle fluxes. This process requires precursor gases and oxidants, and particle formation may occur within or above the atmospheric boundary layer rather than directly at the surface (Burkart et al., 2017; Simon et al., 2026). Newly formed particles would therefore not necessarily produce an upward particle flux originating within the flux footprint. Furthermore, the measured particle size distributions during Events A and B did not exhibit a distinct nucleation and growth pattern. Instead, elevated particle concentrations were observed across a broad size range, supporting the interpretation that blowing snow was the more likely source of the observed particle emissions (Gong et al., 2023; Ranjithkumar et al.,2025).

The inference of emissions as measured net flux minus modelled deposition involves significant uncertainty. The manuscript should explicitly quantify the contribution of both deposition model error and measurement error to the final emission estimates.

Thank you for this comment. We agree that uncertainties of both the measured net flux and the modeled deposition flux contribute to significant uncertainty of the inferred particle emission fluxes. We have revised the manuscript and now address various aspects of the uncertainty associated with the inferred particle emission fluxes both due to model and measurement uncertainty. Regarding the deposition model, various aspects such as different parameterization options representing processes such as Brownian diffusion or interception, contribute to the overall model uncertainty. To better quantify one particular aspect of the uncertainty associated with the deposition model, we compared the original Brownian diffusion parameterization of Zhang et al. (2001) with the parameterization based on observations proposed by Emerson et al. (2020). This comparison is shown in Fig. R1 and yields a linear regression with a slope of 7.43 and an intercept of −0.156, indicating a difference within one order of magnitude. The median absolute difference between the two parameterizations is 0.62×10^6 m^{-2} s^{-1}, which can be considered an estimate of the absolute uncertainty associated with the parameterization of Brownian diffusion in the deposition model for our dataset. Overall, when comparing state-of-the-art size-resolved particle deposition models and measurements, deviations of one to two orders of magnitude are considered typical (Petroff and Zhang, 2010; Emerson et al., 2020).

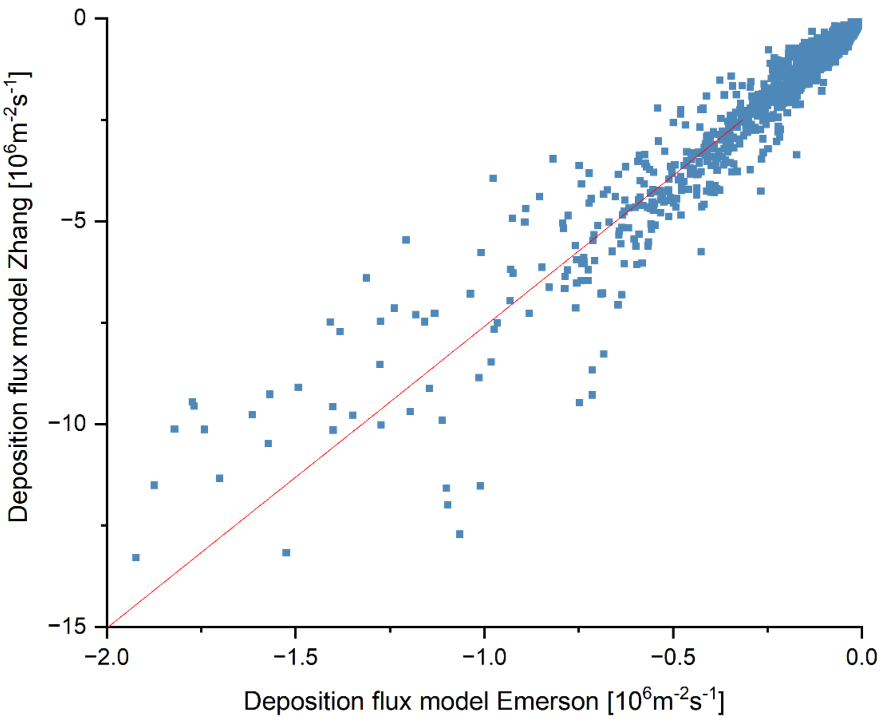

Figure R1: Comparison of modelled particle dry deposition fluxes calculated using the original Zhang (2001) parameterization and the updated Emerson et al. (2020) parameterization. A linear regression (red line) yielded a slope of 7.43 and an intercept of −0.16, indicating systematically higher deposition fluxes predicted by the Emerson parameterization. The median absolute difference between both parameterizations was 0.62 x $10^6 m^{-2} s^{-1}$.

Regarding flux measurement uncertainties, we quantified the random uncertainty of the measured net particle flux following Finkelstein and Sims (2001), accounting for the temporal autocorrelation of turbulence and the finite number of statistically independent turbulent eddies contributing to each 20-minute flux measurement. The median random uncertainty of the measured particle fluxes was 0.07×10^6 m^{-2} s^{-1}, and less than 0.26×10^6 m^{-2} s^{-1} for 95 % of the measurement intervals.

We also expanded the discussion of negative inferred emission values. Negative values occurred in 32 % of all cases. However, their median magnitude was smaller than the median random uncertainty of the measured net particle flux (0.05×10^6 m^{-2} s^{-1} and 0.07×10^6 m^{-2} s^{-1}, respectively). Furthermore, 60 % of all negative inferred emission values were smaller than the estimated random uncertainty (Fig. R2). Therefore, we conclude that most negative inferred emissions are within the uncertainty of the particle flux measurements. This clarification has been added to the manuscript.

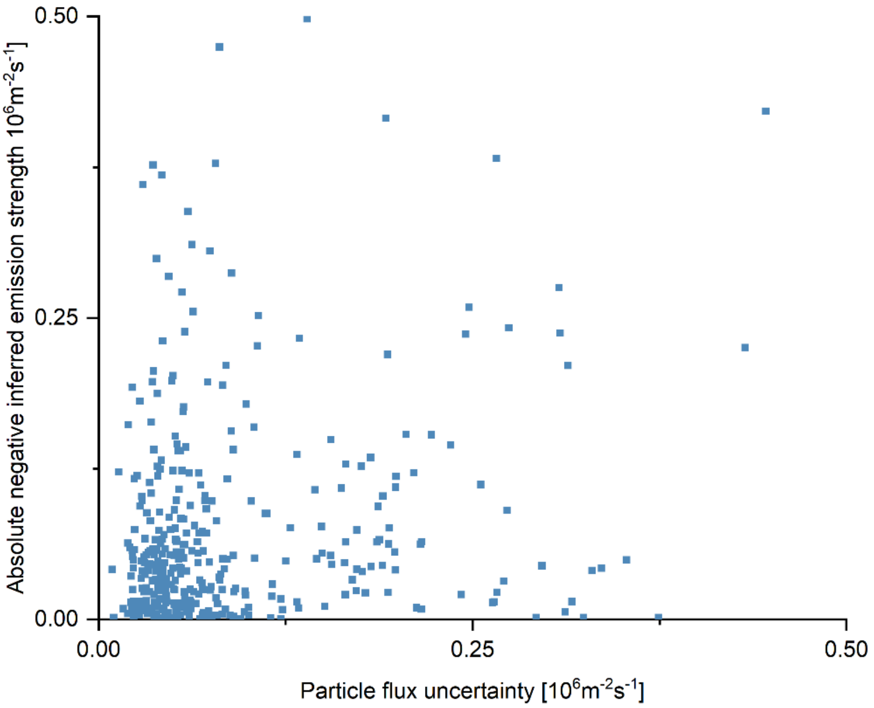

Figure R2: Comparison of the absolute inferred emission strength and the estimated random uncertainty of the particle flux measurements. The figure shows that the particle flux uncertainty exceeds the magnitude of most negative inferred emission values, indicating that these inferred emissions are generally within the measurement uncertainty.

Line 227-232: The random uncertainties of the particle fluxes were estimated following Finkelstein and Sims (2001). This approach considers the temporal autocorrelation of turbulence and estimates the number of statistically independent turbulent eddies contributing to each 20-minute flux measurement. Consequently, the uncertainty reflects the expected variability in the flux estimate resulting from the finite sampling period and the number of independent turbulent events. The median random uncertainty of the measured particle fluxes was 0.07×10^{6} m^{-2} s^{-1}. In extreme cases, the uncertainty may be 0.26×10^{6} m^{-2} s^{-1} (95th percentile).

Line 282-284: Uncertainties of both the measured net particle flux and the modeled deposition flux can lead to negative inferred emission fluxes, which indicate periods without particle emission or very low particle emission, typically within the estimated flux uncertainty.

2. Size distribution data are available but are used only to correct total particle losses and to model size-dependent deposition. The manuscript does not explore whether emission and deposition events show distinct size signatures. This is a missed opportunity.

Thank you for this constructive suggestion. It is correct that in this study, particle size distribution data were used primarily to correct measured particle fluxes for size dependent losses, calculate modelled dry deposition fluxes and support the interpretation of potential blowing snow events. We agree that particle size distributions can provide additional insight into particle emission and deposition processes, and we explored whether emission and deposition periods exhibited distinct particle size characteristics. No clear separation between net positive and net negative particle fluxes was found. The median geometric mean diameter (GMD) was 79.6 nm and 78.0 nm for net positive and net negative fluxes, respectively, indicating only negligible differences. We also analyzed the size distributions for the different surface types, but no clear differences were identified. This information has been added to the manuscript.

Line 360-363: When comparing emission- and deposition-dominated periods, no systematic differences in particle size distributions were observed between net positive and net negative flux periods. The median geometric mean diameter was 79.6 nm and 78.0 nm for net positive and net negative fluxes, respectively.

3. The authors exclude pollution events according to certain criteria, which effectively removes concentration peaks from the analysis. As can be seen in Fig. 4c, many peaks are excluded, but the rising and declining concentrations before and after those peaks are not. Not excluding these transitional periods may bias the fluxes. The authors should either exclude them as well (with a suitable buffer) or correct for remaining contamination. They should also consider improving the exclusion criteria; in this sense, particle size distribution could help identify ship exhaust events.

We understand the reviewer's concern that the calculated particle fluxes could be affected by pollution events. The pollution filtering procedure follows the pollution control strategy for atmospheric sampling applied to all aerosol and trace gas measurements aboard Oden (Tjernström et al. 2023). For example, the pollution control system automatically shut down inlet pumps for filter sampling whenever predefined pollution criteria were met, including unfavorable wind direction, elevated particle concentrations or weak winds.

For this study, we additionally removed 10 seconds before and after each detected pollution event. Furthermore, all 20-minute averaging periods with more than 10 % missing data were excluded from the flux calculations. Consequently, periods of extended or repeated pollution, where a 10-second buffer might not have been sufficient, were excluded from the analysis. As an example, the pollution event on 27 May in Fig. R3, demonstrates that no particle fluxes were calculated during the affected period because the corresponding averaging intervals were excluded from the analysis.

We agree that particle size distributions can provide additional information to identify ship exhaust events on a case-by-case basis. However, in order to be consistent with the pollution event classification applied throughout the ARTofMELT campaign, we prefer to retain this common pollution filtering approach. Along with the exclusion of all 20-minute periods containing more than 10 % missing data, we apply fully traceable and objective pollution filtering criteria.

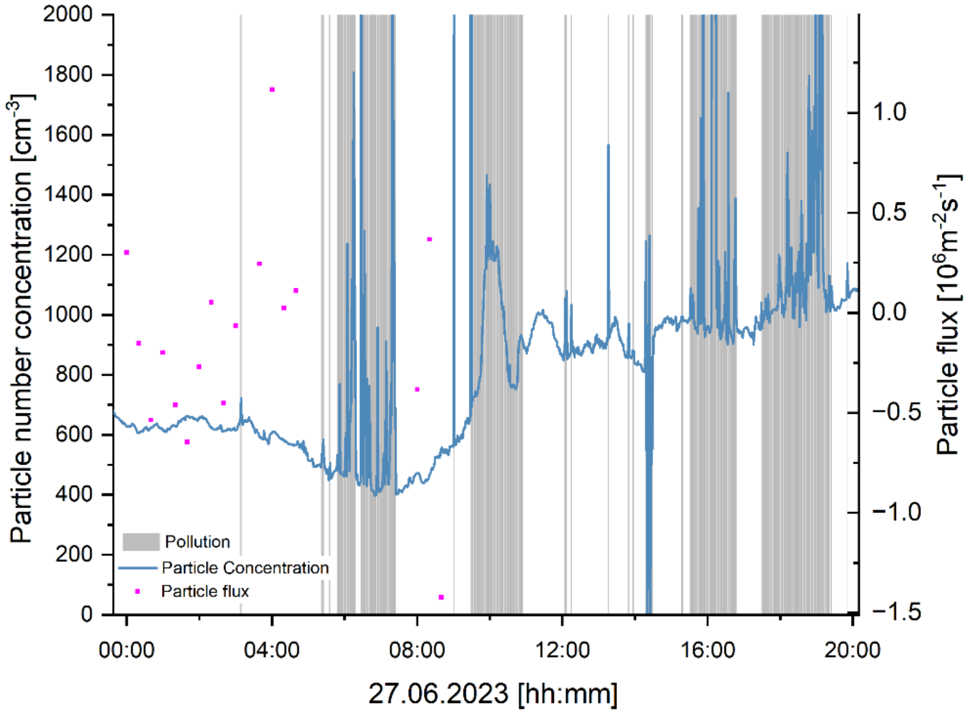

Figure R3: Example of the pollution filtering on 27 May 2023. Grey bars indicate pollution events. Particle number concentration is shown on the left y axis and net particle flux on the right y axis. No particle fluxes were calculated during the pollution periods because the corresponding averaging intervals were excluded from the analysis.

4. Because one of the main scopes appears to be the characterization of emission processes, Sections 3.2 and 3.3 could be merged. Similarly, Figures 8 and 9 could likely be combined (using kernel density estimation instead of histograms to improve visualization). Figures 10a and 10e could be made larger and represented within the same panel.

We agree that Figures 8 and 9 benefit from a more compact presentation. Following the reviewer's recommendation, we have combined Figures 8 and 9 into a single figure (Fig. R4, Fig. 9 in the manuscript), adding kernel density estimates to the histograms to improve visualization of the distributions. We also merged Figures 10a and 10e into a single panel, increasing their size to substantially improve readability (Fig. R5, Fig. 10 in the manuscript). Following the reviewer's suggestion, we introduced a common section heading with two subsections. In our opinion, this improves the organization of the Results section while preserving the distinction between the measured particle fluxes and the inferred particle emission strength.

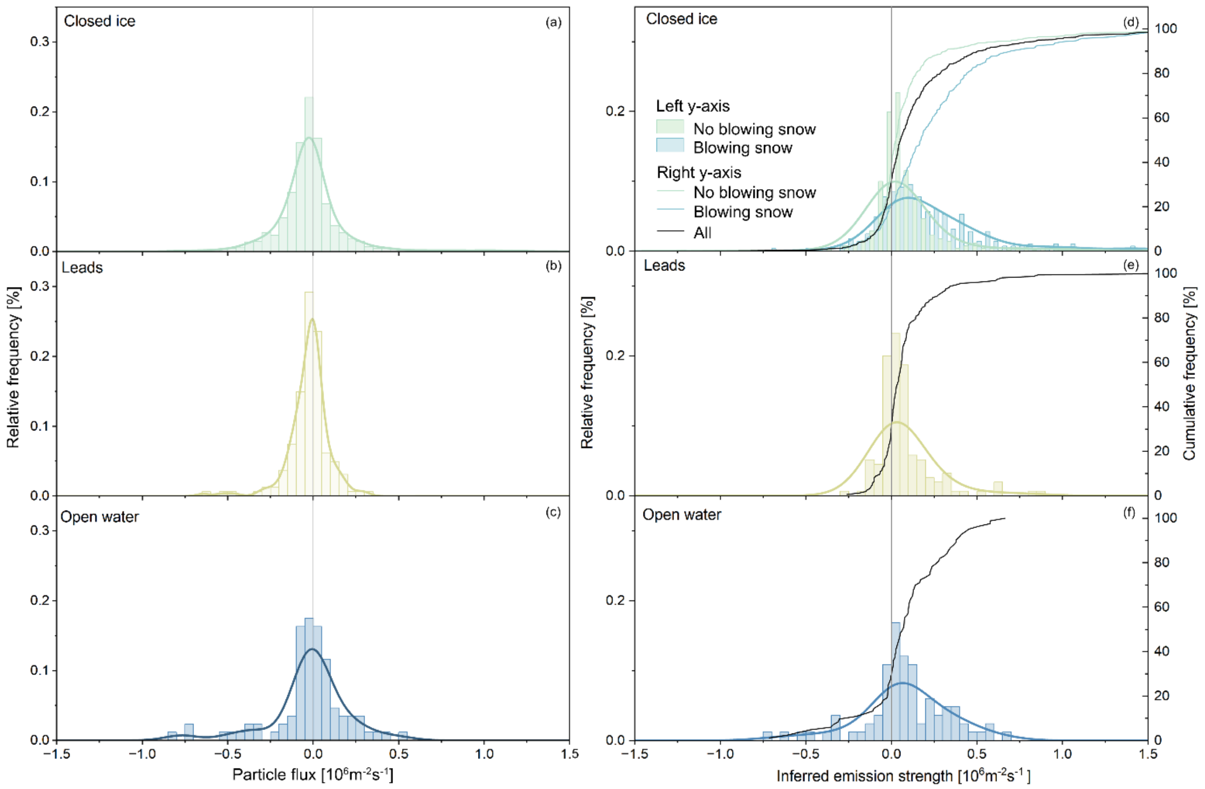

Figure R4: The left panels (a-c) show the relative frequency distributions of particle number fluxes (in 106 m−2 s−1) for the three surface types: (a) closed ice, (b) leads, and (c) open water. The vertical grey line indicates zero flux, separating net particle deposition from net particle emission. Only stationary periods with ship speed ≤ 1 kn are included. The bold curves show the kernel density estimation. The right panels (d-f) show relative and cumulative frequency distributions of inferred emission strength (in 106 m−2 s−1) for the three surface types: (c) closed ice, (d) leads, and (e) open water. The distributions are derived from observed particle fluxes and modeled deposition velocities, shown separately for periods without potential blowing snow (green) and with potential blowing snow (blue), depending on the blowing snow threshold. The bold curves show the kernel density estimation. The left y-axis (histograms) shows the number of observations, while the right y-axis shows the cumulative frequency distributions for no potential blowing snow (green line), potential blowing snow (blue line), and all observations (black line).

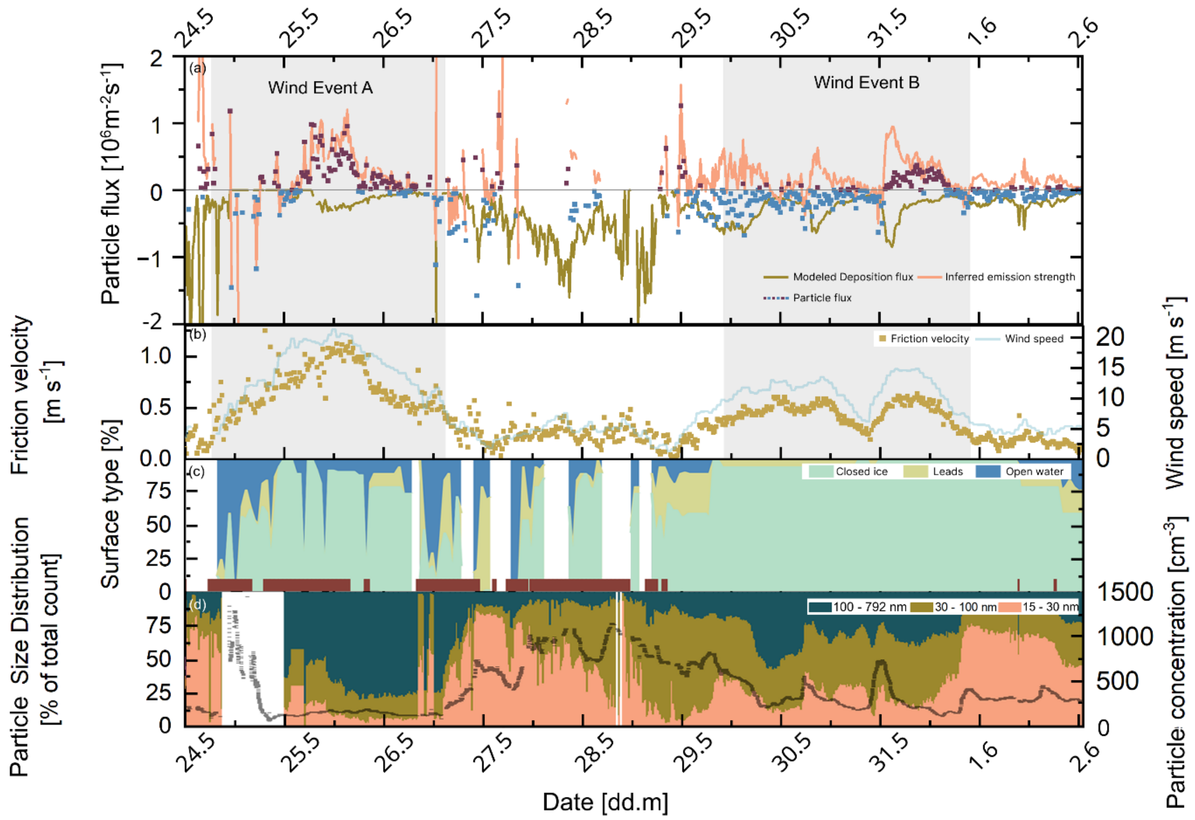

Figure R5: a) Particle fluxes (red squares indicate net particle emission, and the blue squares indicate net particle deposition), modeled deposition flux (dark beige) and inferred emission strength (salmon-colored) from 24 May to 2 June evaluated in 20-minute intervals (in 106 m−2 s−1). Panel (b) shows the friction velocity (u∗, beige, in m s−1) and wind speed (light blue, in m s−1). The grey shading in (a, b) shows the time periods when the threshold for blowing snow is exceeded. Panel (c) shows the hourly distribution of the three surface types: closed ice (turquoise), leads (beige), and open water (blue). Periods with ship speeds ≥ 1 kn are indicated in red. (d) Particle size fractions from 15 to 792 nm in three accumulated groups (left y-axis, in % of total particle number concentration) measured with a DMPS on the fourth deck of Oden and total particle number concentration (cm−3), measured with an MCPC at the foremast (black symbols; right y-axis). (e) Modeled deposition flux (turquoise) and inferred emission strength (brown).

5. Section 3.5 attempts to estimate Arctic-wide net particle fluxes and project changes to 2040 using median springtime fluxes from a single campaign. This analysis is far too simplified and should either be developed much more thoroughly or, preferably, removed entirely.

We agree that the analysis presented in the former Section 3.5 was based on a simplified approach, and that the available observations are insufficient to provide robust quantitative projections of Arctic wide particle fluxes or their future evolution. We have therefore removed this section from the manuscript.

Specific line comments:

L1-4: This part of the abstract seems overly general and could be tailored better to the manuscript

We agree that the original opening of the abstract was too general. We therefore revised the first two sentences to focus more directly on the main objective of the study by highlighting the paucity of direct observations of turbulent particle fluxes over Arctic sea ice and the resulting uncertainty in aerosol source and sink processes.

Line 1-4: The Arctic is warming at a significantly faster rate than the global average. This is altering the sources and sinks of aerosols, which influence the regional radiation balance and cloud formation. However, direct observations of turbulent particle fluxes over sea ice are scarce, limiting our understanding of the processes that control the exchange of aerosols between the surface and the atmosphere.

L6: The terms "spatial and temporal" appear several times throughout the manuscript, but the study considers mostly surface-dependent variability. I suggest removing these terms throughout the manuscript

We agree that the term "spatial variability" may be misleading in the context of this study, as the analysis primarily focuses on differences between surface types rather than spatial gradients. We have therefore removed the terms.

Line 73: This study examines the surface dependent variability of particle sources and sinks in the Arctic Ocean.

Line 543-544: The results provide insight into the surface dependent variability of particle exchange processes over different surface types: closed ice, leads, and open water, in a region undergoing rapid climate change.

L6-7: specify surface types here

We now specify the surface types in the revised manuscript.

Line 4-6: e. During the ARTofMELT campaign in spring 2023, five weeks of continuous eddy covariance measurements of turbulent particle fluxes were conducted in the High Arctic to investigate particle sources and sinks over closed ice, leads, and open water.

L13-14: "The results … similations" indicates only one of the potentialities of the dataset, so this sentence should not be definitive

We agree that the original wording was too definitive. We have therefore revised the sentence to clarify that reducing uncertainties in Arctic model simulations is just one possible use of the presented dataset.

Line 12-14: The results provide observational constraints on particle fluxes and may help to reduce related uncertainties in Arctic aerosol and climate model simulations.

L20-31: this section is too general and should be better tailored to the manuscript scope or summarized

We have shortened the section and focused it more clearly on the relevance of particle sources and sinks for Arctic cloud formation and aerosol cloud interactions, which better reflects the scope of this study.

Line: 21-29: Aerosol particles, hereafter referred to as particles, play a central role in the Arctic climate system (Arctic Monitoring and Assessment Programme, 2021; Serreze and Barry, 2011). They influence the energy balance directly by scattering and absorbing solar radiation, and indirectly by acting as cloud condensation nuclei or ice nucleation particles (Twomey, 1977; Albrecht, 1989; Carslaw et al., 2013). As particle concentrations in the Arctic are frequently low, particularly in autumn (Tunved et al., 2013), even small changes can impact cloud formation and radiative processes (Mauritsen et al., 2011; Stevens et al., 2018). Furthermore, recent studies have demonstrated that Aitken mode particles (<70 nm) can act as to cloud condensation nuclei under conditions of sufficiently high supersaturation and low accumulation mode particle concentrations (Baccarini et al., 2020; Karlsson et al., 2022). Therefore, understanding the processes controlling particle sources and sinks is essential for improving our knowledge of Arctic aerosol cloud interactions.

L52: numerical models are mentioned, but the authors should be more specific in this regard, citing the actual models they refer to

Thank you for this comment. We agree that the original wording was too general. Rather than referring to 'numerical models', we now cite results from Arctic aerosol model intercomparison studies and studies investigating uncertainties in aerosol microphysical processes. These studies demonstrate variability in model simulations of Arctic aerosol concentrations, identifying uncertainties in aerosol microphysics and emission inventories as key contributing factors.

Line 48-55: The knowledge of the processes controlling aerosol abundance in the Arctic remains incomplete, particularly with regard to emissions, transport, transformation, and removal (Korhonen et al., 2008; Willis et al., 2018). These gaps hinder the representation of accurate aerosol-climate interactions. While aerosol microphysical properties and processes are important for these simulations, their quantitative contribution to uncertainties in simulated Arctic aerosol concentrations remains poorly constrained (Matsui and Liu, 2022). Incomplete emission inventories also contribute to these uncertainties (Whaley et al., 2022; Koike et al., 2025). Furthermore, dry deposition depends on the physical properties of the particles, meteorological and surface specific factors (Donateo and Contini, 2014; Mohan, 2015; Farmer et al., 2021; Donateo et al., 2023).

L73-74: the authors claim that this dataset is one of the longest dataset for the Arctic region. If this claim is to be made, the duration of other datasets should be explicitly stated in the introduction

We agree that the original wording overstated the uniqueness of the dataset. We have revised the text accordingly.

Line 74-78: Previous ship based eddy covariance studies in the Arctic have typically covered periods ranging from approximately five days (Nilsson et al., 2001) to about two weeks (Held et al., 2011a). Although longer measurements of several months have been reported, these were conducted at fixed land based sites in the polar region rather than over the Arctic Ocean (Donateo et al., 2025, 2023; Grönlund et al., 2002).

L78-79: similarly to the abstract, "The results might provide…"

We have revised the sentence.

Line 82-83: The results provide observational data that may help reduce uncertainties related to particle fluxes in Arctic model simulations.

L86-91: A map would be much clearer than this explanation. It would also allow to represent clearly further information, such as dominating surface type, or meteorological classification (I'm referring to classification 1-6 in Fig. 4)

We appreciate this suggestion and agree that a map provides a much clearer overview than a textual description. We have therefore added a new figure showing a map of the expedition track together with the dominant surface type and the meteorological periods used throughout the manuscript (Fig. R6, Fig. 1 in the manuscript).

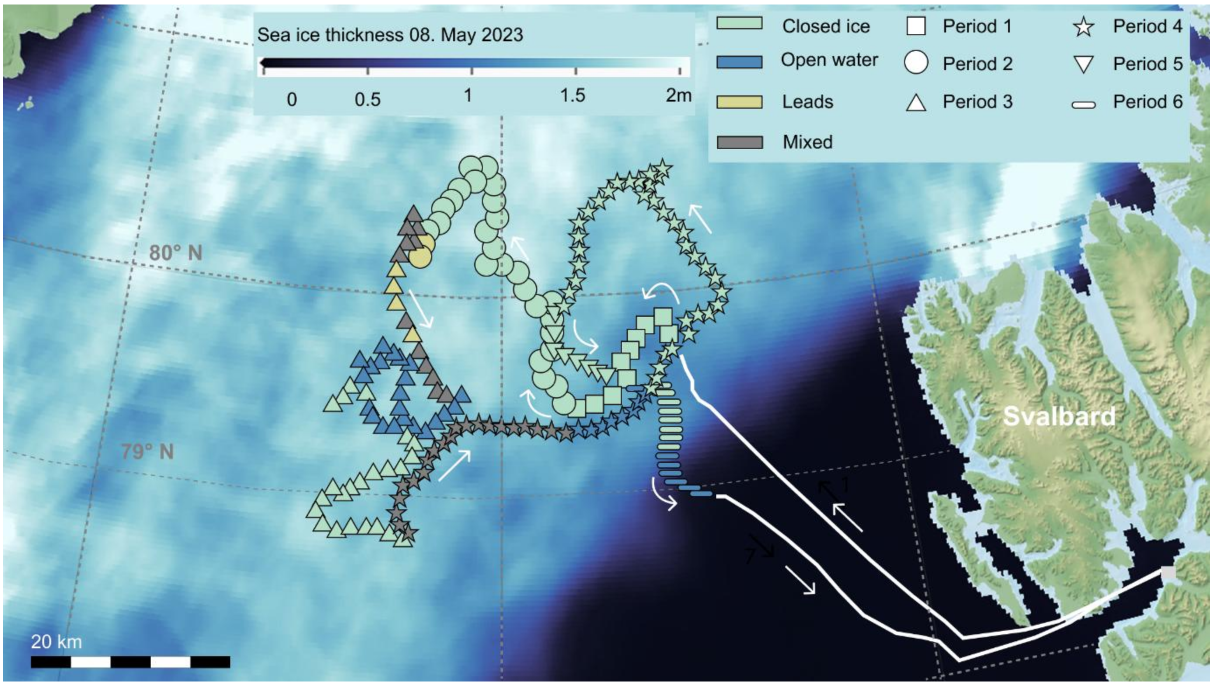

Figure R6: Expedition track of the ARTofMELT campaign overlaid on sea ice concentration on 8 May 2023 (Copernicus Marine Service, 2023). The different symbols indicate the meteorological periods. Colors show the dominant surface type. The white sections of the track indicate periods for which no surface type information was available, corresponding to the *transit into and out of the sea ice. The arrows indicate the direction of travel along the expedition track.*

L157: Depending on whether and how the scope of the manuscript is redefined, the authors might consider moving Figure 2 to the supplementary material/appendix, and to summarize the corresponding methodology paragraphs

Thank you for this suggestion. While we have considered it carefully, we would prefer to retain Figure 2 (now Fig. 3) and the corresponding methodological description in the main manuscript. Detailed descriptions of eddy covariance processing and quality assessment are essential for evaluating the reliability of the derived fluxes. The ogive analysis was specifically included to demonstrate the quality of the eddy covariance measurements and show that the turbulent fluxes were adequately resolved. We therefore believe that Figure 2 and the associated methodology are important for interpreting and assessing the quality of the presented flux measurements.

L164: The authors should specify how the high-frequency losses were corrected

We have clarified the description of the spectral correction. The manuscript now briefly explains that high frequency losses were corrected using the analytical approach of Horst (1997), which estimates flux attenuation from the transfer function of the eddy covariance system and parameterized turbulence cospectra.

Line 121-124: High-frequency losses were corrected after Horst (1997), using transfer functions of the eddy covariance system to estimate flux losses analytically, taking into account the measurement height, mean wind speed, system time constant, and stability dependent cospectral parameters.

L222-223: "Particle fluxes … atmospheric stability" is unnecessary

The original sentence was removed. The following sentence was inserted instead, to provide a transition to the equations:

Line 191: Friction velocity ($u*$, in m s^{-1}), was calculated as a measure of near-surface turbulence:

L230 (and following): units should be always reported the first time a variable appears

We have revised the manuscript accordingly. Units have been added when variables are first introduced throughout the Methods section.

L247: The same roughness length is applied to all surface types, but including a z0 that varies with surface type should be a fairly low-effort improvement

We agree that using surface type specific roughness lengths is a worthwhile improvement. We have revised the deposition model to account for different surface types by assigning roughness lengths specific to each surface type (closed ice = 3 x 10^{-4} , leads =1 x 10^{-3}, open water 1 x 10^{-4}) and evaluated its influence on the modeled deposition fluxes. The updated parameterization has resulted in only a small change to the modelled deposition fluxes, compared to using a constant roughness length. As can be seen in Fig. R7, there was almost no change in the resulting deposition fluxes with a median increase of 0.0016 × 10^6 m^{-2} s^{-1} (2.1%) when using surface type specific roughness lengths compared to a constant roughness length. Additionally, we conducted a sensitivity analysis employing roughness lengths spanning the range documented in the literature (10^{-5} to 10^{-2}m), yielding a median variation of 4.6% in the modelled deposition fluxes. These analyses suggest that the inferred deposition fluxes are only slightly influenced by the choice of roughness length within the plausible range for Arctic surfaces. The corresponding changes and uncertainty analysis have been added to the manuscript.

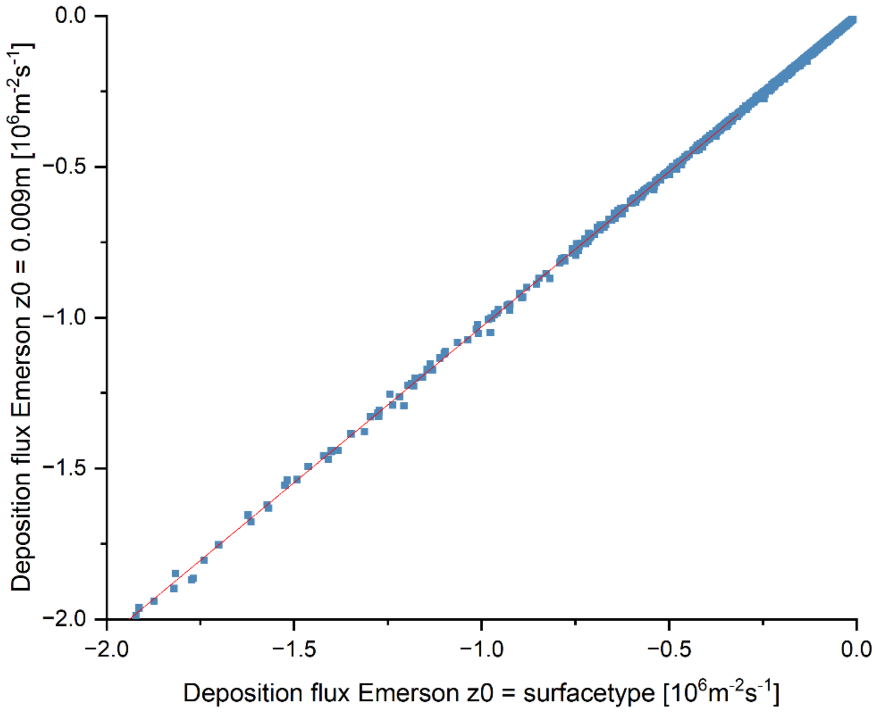

Figure R7: Comparison of dry deposition fluxes calculated using the Emerson et al. parameterization with a fixed roughness length ($z_0 = 0.009$ m; y axis) and with surface type specific roughness lengths (closed ice: 3×10^{-4}m, leads: 1×10^{-3}m, open water: 1×10^{-4}m; x axis). The linear regression yielded a slope of 1.0 and an intercept of 0.00042. Deposition fluxes calculated using surface type specific roughness lengths were higher by a median of 0.0016 (2.1 %) compared with those calculated using a fixed roughness length.

Line 238-244: Contrary to the original formulation by Zhang et al. (2001), Brownian diffusion efficiency was parameterized according to the method of Emerson et al. (2020). Previously, this parameterization showed better agreement with observations. Recent developments in dry deposition models have mainly focused on improving deposition over vegetated surfaces by refining impaction and canopy processes (Saylor et al., 2019; Farmer et al., 2021; Pleim et al., 2022). However, observational constraints for smooth ice and open water surfaces remain limited. The median difference between deposition fluxes calculated using the Emerson and Zhang parameterizations was large, with a median value of the absolute differences of 0.62 × 10^6 m^{-2} s^{-1}.

Line 250-253: z0 was assigned according to the observed surface types. The effective roughness length (Table A1) was calculated as the fractional area weighted mean of the individual surface types. A comparison with calculations using a constant z0 value of 0.009 m showed a median difference in the modeled deposition flux of 0.0016 × 10^6 m^{-2} s^{-1}, indicating that the results are almost insensitive to z0.

L253: what does e0 depend on?

We have clarified the description of e_0. The manuscript now states that $e_0$is an empirical, dimensionless collection efficiency constant. Following Zhang et al. (2001), a value of $e_0 = 3$ was used for smooth surfaces throughout this study (see Table A1).

L285: The separation between meteorological periods could be made clearer by extending the dotted lines at the top all the way down through the panels

We agree that extending the dotted lines improves the visual separation of the different meteorological periods. The figure has been revised accordingly, and the lines now extend through all panels, making the transitions easier to follow (Fig. R8, Fig. 5 in the manuscript).

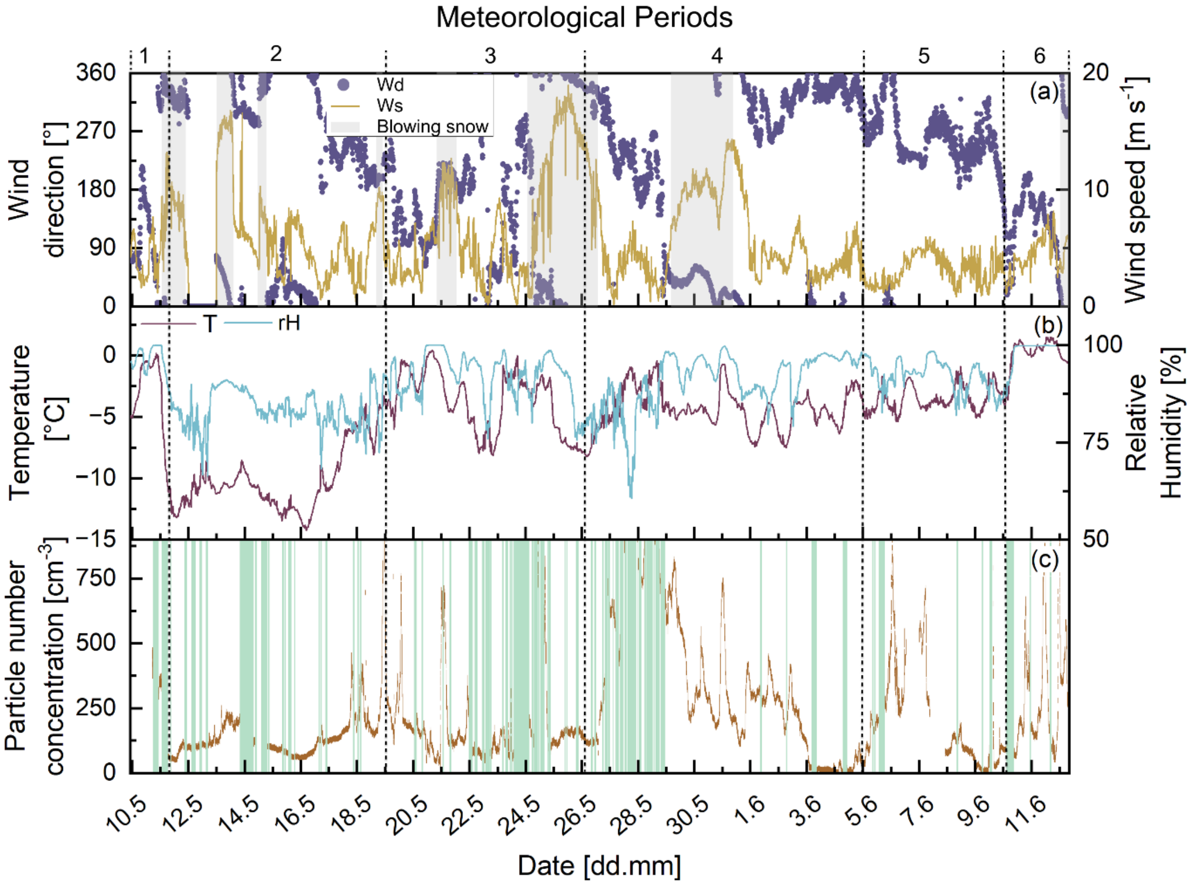

Figure R8: Overview of the six periods (dashed lines) for the entire measurement period, from 10 May to 12 June 2023, with (a) wind direction (Wd, purple, in °) on the left y-axis and wind speed (Ws, beige, in m s^{-1}) on the right y-axis. Meteorological data are shown as 10-minute averages. The high wind speed periods are shown in grey. Panel (b) shows the temperature (T, brown, in °C) on the left axis and the relative humidity (rH, blue, in %) on the right axis. Panel (c) shows the particle number concentration (cm^{-3}), with pollution periods marked in turquoise

L299-302: These concentration averages might be currently overestimated. The authors should revise this part after improving the exclusion criteria for pollution periods

We understand the reviewer's concern about potential pollution from the ship. However, we have found no evidence to suggest that the reported average particle concentrations are systematically overestimated. The pollution filtering used in this study is based on the pollution control system employed throughout the ARTofMELT campaign (see **Comment 4**). As an independent consistency check, we compared the concentrations with measurements from a second, independent particle number concentration measurement. During the ice camp periods, a gradient system was located on the sea ice at a greater distance from the ship and was therefore much less affected by potential ship pollution. The condensation particle counter of the gradient system had a different lower size cut-off (10 nm instead of 7 nm) and did not operate throughout the entire campaign. During the overlapping measurement periods, it measured a mean particle concentration of approximately 170 cm^{-3}. The corresponding mean concentration of the continuous eddy covariance dataset was 220 cm^{-3}.

Considering the different lower size cut-offs and typical uncertainties of CPC measurements of 8-20% (Brechtel 2021, TSI 2014), this suggests that the eddy covariance data are not biased. We hope that this additional comparison addresses the reviewer's concern and provides further confidence in the applied pollution filtering. We therefore did not modify the pollution filtering or the reported concentration statistics.

L339-354: Why are boxplots presented here instead of the usual plots? Why are the authors presenting binned regression analysis rather than analysis on the actual observations, which would be much simpler and more transparent?

We agree that using binned data could potentially obscure relationships in the raw observations. We have examined the unbinned data using scatter plots of absolute particle flux versus friction velocity and wind speed, as shown below in Fig. R9 (Fig. 7 in the manuscript). The raw observations exhibit substantial scatter and no obvious (linear or nonlinear) relationships become apparent. In order to present the substantial scatter shown in the binned boxplot more clearly, the raw data points are now shown together with the binned boxplots in the revised manuscript.

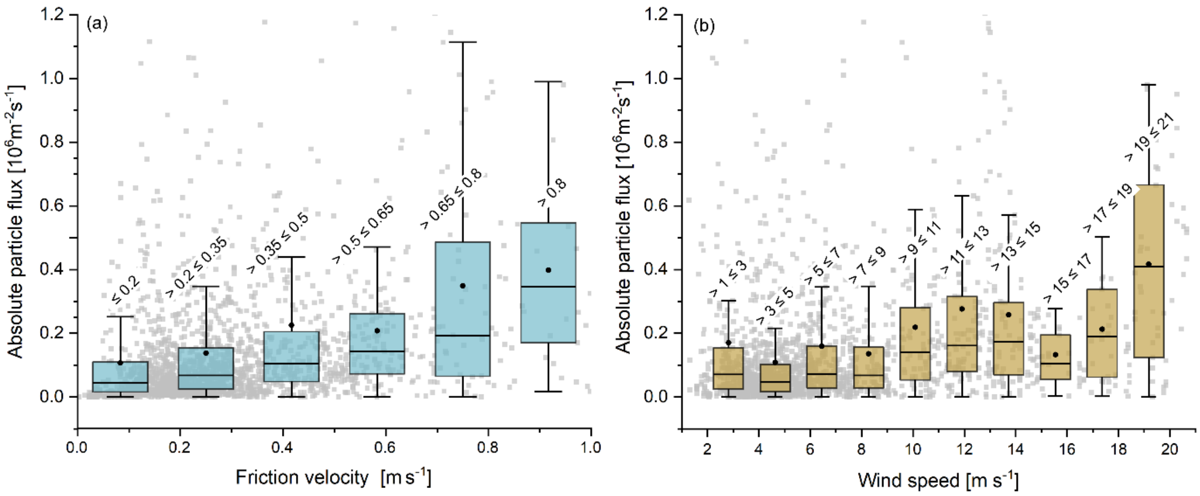

Figure R9: (a) Relationship between friction velocity (m s^{-1}) in different size bins and absolute net particle flux (in 10^6 m^{-2} s^{-1}). (b) Relationship between wind speed (m s^{-1}) in different size bins and net absolute particle flux (in 10^6 m^{-2} s^{-1}). The grey squares represent the individual 20-minute values plotted against the corresponding friction velocity or wind speed on the x-axis. The boxplots summarize these values within the bins indicated by the labels above each box. The boxes represent the 25th to 75th percentiles, while the whiskers indicate 1.5 times the interquartile range. The horizontal line denotes the median, and the black square represents the mean.

L353-354: The authors appear to consider only linear correlation (given that they use binned quantities). Do other relationships emerge when the actual non-binned data are considered?

Following the reviewer's suggestion, we examined the unbinned data using Pearson, Spearman and Kendall correlation analyses. We also evaluated linear, logarithmic, exponential, quadratic and cubic regression models. While the binned data were used primarily to improve the visualization of the overall trend, it should be noted that systematic deviations from a linear relationship would also be apparent in the binned representation.

The unbinned data revealed weak positive correlations between the absolute particle flux and both friction velocity and wind speed. Spearman's correlation coefficients were higher than Pearson's, indicating a weak monotonic rather than strictly linear relationship. This is consistent with the boxplots, which show that the probability of large absolute particle fluxes increases with increasing friction velocity and wind speed, while variability remains high.

Neither logarithmic, exponential, quadratic nor cubic models improved the fit for wind speed compared with the linear model (quadratic: R^2 = 0.0373 vs. 0.0374, p = 0.65). For friction velocity, the quadratic model provided the best description of the data. Logarithmic and exponential models did not improve the fit, and adding a cubic term yielded no further improvement. Although the quadratic term slightly increased the explained variance (R^2 = 0.061 vs 0.070), the overall explanatory effect remained low.

L371: Why do other studies in Figure 7 report multiple values while for the current study there is just one?

We agree that this may not be immediately intuitive from Figure 7. The multiple values reported in some previous studies do not consistently represent individual measurements, but instead originate from different measurement sites, periods, surface conditions or statistics reported in the respective publications. For the present study, we therefore present the median particle flux for each surface type as a representative value. This has been clarified in the figure caption in the revised manuscript.

Caption Figure 8: For this study, the grey circles indicate the median particle flux for each surface type. Multiple values shown for previous studies correspond to values reported by the respective authors (e.g. different measurement sites, periods, or statistics).

L421-424: How often do negative values appear? Could the author explore attribute causes more consistently? These instances seem to constitute a non-negligible fraction of the data

We agree that the occurrence of negative inferred emission values requires further discussion. As outlined in our response to Comment 2, we have carried out an expanded uncertainty analysis of both the deposition model and the measured particle fluxes. We have also clarified the expected relationship between measured net flux, modeled deposition, and inferred emission in periods without particle emission. We now state that negative inferred emission values occurred in 32% of cases. However, the median magnitude of these values is smaller than the median random uncertainty of the measured particle fluxes (following Finkelstein and Sims, 2001). Furthermore, 60 % of all negative inferred emission values are smaller than the estimated random uncertainty of the corresponding particle flux measurements. This suggests that most negative inferred emission values fall within the flux uncertainty range. Moreover, in the absence of particle emission, the measured net particle flux is expected to approach the modeled deposition flux, and the inferred emission should therefore scatter around zero within the associated uncertainties. The fact that most negative inferred emission values are small and within the estimated flux uncertainty is consistent with this expected behavior and provides additional confidence in both the measured net fluxes and the modeled deposition estimates. The corresponding discussion has been added to the manuscript.

Line 462-472: Negative values result from a measured net flux more negative than the modeled deposition. These cases result from the natural scatter in both the measured net particle flux and the inputs to the deposition model, as well as from uncertainty in the deposition model itself. In our study, negative inferred emission fluxes occurred in 32% of the evaluated measurement intervals. However, the median magnitude of these emissions (-0.0 10^6 m^{-2} s^{-1}) was smaller than the median random uncertainty of the measured net particle flux (0.07 10^6 m^{-2} s^{-1}). Furthermore, 60% of the negative inferred emission flux values were smaller than the estimated random uncertainty of the corresponding particle flux measurements. This indicates that most negative inferred emission fluxes are within the uncertainty of the particle flux measurements. In the absence of particle emission, the measured net particle flux is expected to approach the modeled deposition flux, resulting in inferred emission values that scatter around zero within the associated uncertainties. The predominance of small negative values is consistent with this expected behavior.

L454: It could be useful to specify particle sizes here

Thank you for this suggestion. We have added a brief clarification to the sentence, indicating that sea salt aerosols span a broad particle size range. The description of the particle sizes reported in previous studies, including the distinction between coarse mode particles and the 10 to 300 nm range observed by Gong et al. (2023), follows three sentences later (L 508). We therefore kept this structure to avoid unnecessary repetition.

Line 502-503: One type of particles associated with high wind speeds above sea ice is sea salt aerosol (SSA), which spans particle sizes from submicron to coarse ranges and can be produced by the sublimation of blowing snow.

Line 509-511: During Event B, enhanced concentrations were mainly observed between diameters of approximately 30 and 100 nm, while no distinct nucleation mode was evident.

L478-495: As mentioned above, this section appears redundant and superficial. I suggest removing it and summarizing it (if at all) as part of the conclusions or future directions

We agree that this section was oversimplified. It has therefore been removed from the manuscript.

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