This publication investigates particle deposition (emission) over ice surfaces and thus an extremely important problem of changes in surface albedo and possible influences on the Arctic climate. The measurement concept corresponds to the current technical possibilities and the authors are recognised experts in this field. The measurement under Arctic conditions is a particular challenge. The theory used is state of the art, but the restriction to neutral stratification (which may not really correspond to reality after all) would not have been necessary, as the curvature of the gradients can certainly be taken into account by universal functions when determining the gradient (Foken and Mauder, 2024).

We sincerely thank the reviewer Thomas Foken for his time, effort and thoughtful feedback. The constructive comments have been highly helpful in improving the manuscript. Below, we provide a point-by-point response to each of the reviewer's comments. Reviewer comments are presented in black, our response in blue, and changes in the manuscript in orange.

The general verification of the systems by determining the friction velocity is very useful and should also be used for further classification of the measurements if necessary. The deviations shown in Fig. 2a are typical for the gradient-eddy-covariance comparison, but in Fig. 2b the measurements should be labelled with a different symbol if there are significant differences in the footprint of the two systems or if the eddy mast is located to leeward of the ship.

We follow the reviewer's recommendation and now use different symbol colors for the surface type influencing the gradient system. In addition, we add a third scatter plot comparing u* measured by the ship mast and by the ice mast to give a general impression of differences due to different footprints. The surface type for the measurements on the ship mast has not been evaluated in detail. For the entire measurement campaign, care was take to align the ship with the prevailing wind direction, so the ship mast was not located to leeward of the ship for extended periods.

Line 256: The results demonstrate that the eddy covariance measurements on the ship mast and ice mast show the highest degree of agreement (Fig.2(a)). Nevertheless, as can be seen in Fig. 2 (c), many of the u∗ values determined at the ice mast and gradient system sites are in good accordance and close to the 1:1 line. In particular, when both systems are influenced by the same surface type (closed ice), there is good agreement of u*. The agreement of the u∗ values determined at the ship mast and gradient system sites (Fig. 2 (b) is slightly lower, but still consistent with expectations. The deviation of u∗ between the gradient system and ship mast measurements was less than 50 % in 63 % of the cases. The deviation of u* between the gradient system and ice mast measurements was less than 50 % in 77 % of the cases, and between the ship mast and ice mast in 89 % of the cases.

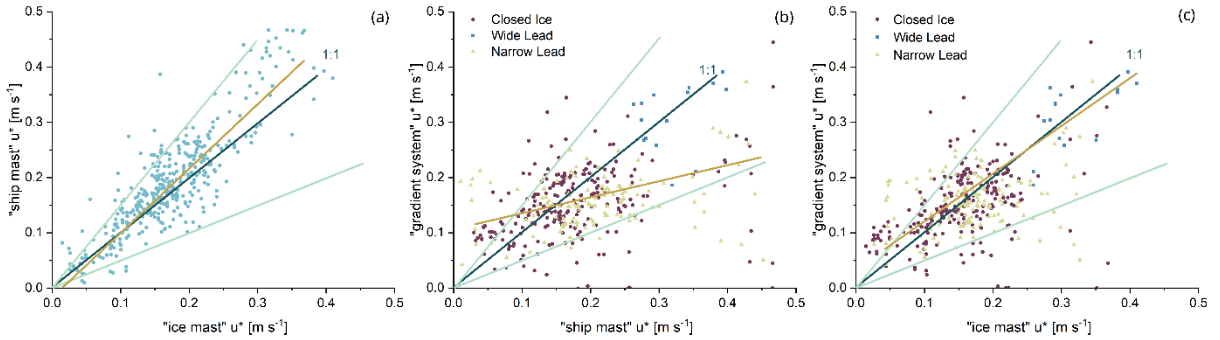

Figure 2. (a) Scatter plot between friction velocities [u*, m s^{-1}] measured by the ship mast (y-axis) and the ice mast (x-axis). (b) Scatter plot between friction velocities measured by the gradient system (y-axis) and the ice mast (x-axis). (c) Scatter plot between friction velocities measured by the gradient system (y-axis) and the ship mast (x-axis). The dark blue lines symbolize the 1:1 line, the turquoise lines the 50 % deviations. The beige line shows the linear regression fit. The three different symbol colors in (b) and (c) divide the measurements according to the surface type, which influenced the gradient system.

The reviewer cannot follow the discussion of the results of the sensible heat flux (Fig. 3 and 4). The gradient mast does not have a uniform footprint, i.e. the lowest height has a very small footprint which is probably exclusively ice in all situations. This means that the temperature is also very low in all situations and may 'simulate' stable stratification. This can be seen very clearly with 'Narrow Lead', where the eddy-covariance measurements correctly show a positive sensible heat flux, while the gradient mast always indicates stable stratification.

We fully agree that the different measurement footprints at different heights of the gradient mast will complicate the interpretation of the profiles. Indeed, for 'Narrow Lead' conditions the scatter plots in the revised Figure 3 (b,c) clearly show that the sensible heat fluxes derived from the gradient mast are mostly negative and almost always lower than the mostly positive eddy-covariance fluxes. We add a brief discussion of the potentially non-uniform footprints in the revised manuscript.

Line 264: The comparison of the sensible heat fluxes between the three systems shows the dependence of the sensible heat flux on the type of surface surrounding the system (Fig. 3 (b), (c). As for the friction velocity, the sites ship mast and ice mast (Fig. 3 (a)), both evaluated with the eddy covariance method, show the highest degree of agreement. The comparison between the ice mast and gradient system shows that for the narrow lead surface type, the fluxes differ in sign and thus in direction. It must be noted that the footprint area affecting the lowest measurement heights of the gradient system becomes very small, and even for the narrow lead surface type, the ice surface with low temperatures will influence these measurements. Also, when the gradient system is influenced by wide leads, clear differences can be seen, which is to be expected due to the different surface types influencing the two systems. However, when influenced by the same surface type (closed ice) the values are of the same magnitude (Fig. 3 (c)). When comparing the gradient system with the ship mast (Fig. 3 (b)), the opposite sign is also evident for the narrow lead. For the wide lead, high positive sensible heat fluxes are observed with both systems. This is consistent with the ship mast being surrounded by wide leads at the same time as the gradient system.

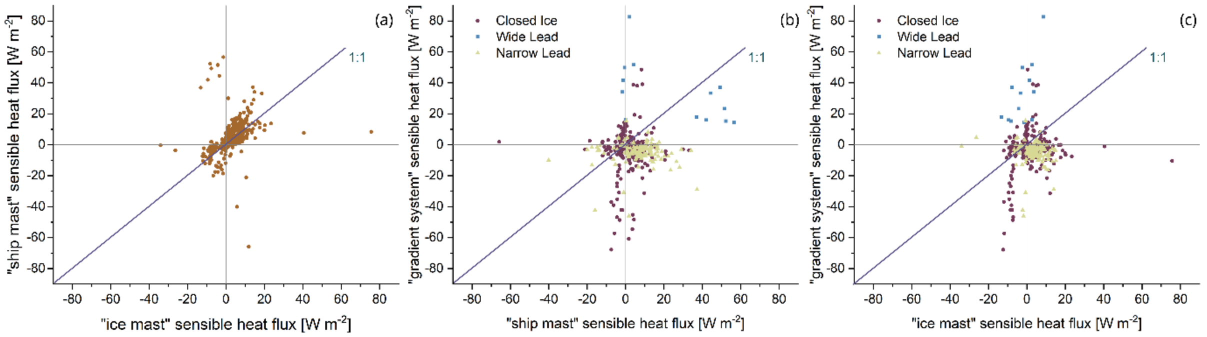

Figure 3. (a) Scatter plot between sensible heat fluxes [H, W m^{-2}] measured by the ship mast (y-axis) and the ice mast (x-axis). (b) Scatter plot between sensible heat fluxes measured by the gradient system (y-axis) and ship mast (x-axis). (c) Scatter plot between sensible heat fluxes measured by the gradient system (y-axis) and ice mast (x-axis). The dark blue lines symbolize the 1:1 line. The three different colors divide the measurements according to the surface type, which influenced the gradient system.

The situation becomes even more problematic with ‘Closed Ice’. The measurements are increasingly stable and can in no way be assigned to the neutral range (however, the specified range for z/L is also very narrowly defined). The gradient mast in particular measures relatively large downward sensible heat fluxes, i.e. the gradient is comparatively large. Various phenomena such as decoupling, counter-gradients and coherent structures occur particularly at very low friction velocities (Foken, 2023;de La Casinière, 1974;Grachev et al., 2005;Sodemann and Foken, 2005;Lüers and Bareiss, 2010). To discuss the data, they should be categorised into u* classes. With regard to the interpretation of the particle fluxes, fluxes with u*<0.10... 0.15 m/s must probably be excluded after this investigation. The discussion of all the phenomena mentioned is too complicated and the data set only allows this in part. It may be possible to estimate the possibility of decoupling with the Brunt-Väisälä frequency (Foken, 2023;Peltola et al., 2021).

We agree with the referee that especially with the surface type ‘Closed ice’ stable conditions close to the ground can exist. We thank the reviewer for suggesting to categorize our data by u* for the discussion, and to estimate possible decoupling with the Brunt-Väisälä frequency. First, we calculated the decoupling metric Ω according to Peltola et al. (2021) for flat surfaces without emergent vegetation. The height and temperature differences were calculated from the gradient profiles and thus served as a basis for N. σw was taken from the ice mast data. Peltola et al. (2021) define the following three regimes for the decoupling metric:

$\Omega \geq 0.61$ -> coupled

0.43 ≤ Ω < 0.61 -> weakly coupled

Ω < 0.43 -> decoupled

As suspected, the possibility of decoupling occurs frequently. Figure R1 shows that decoupling was likely particularly when the lift was surrounded by closed ice (29.05.-05.06.).

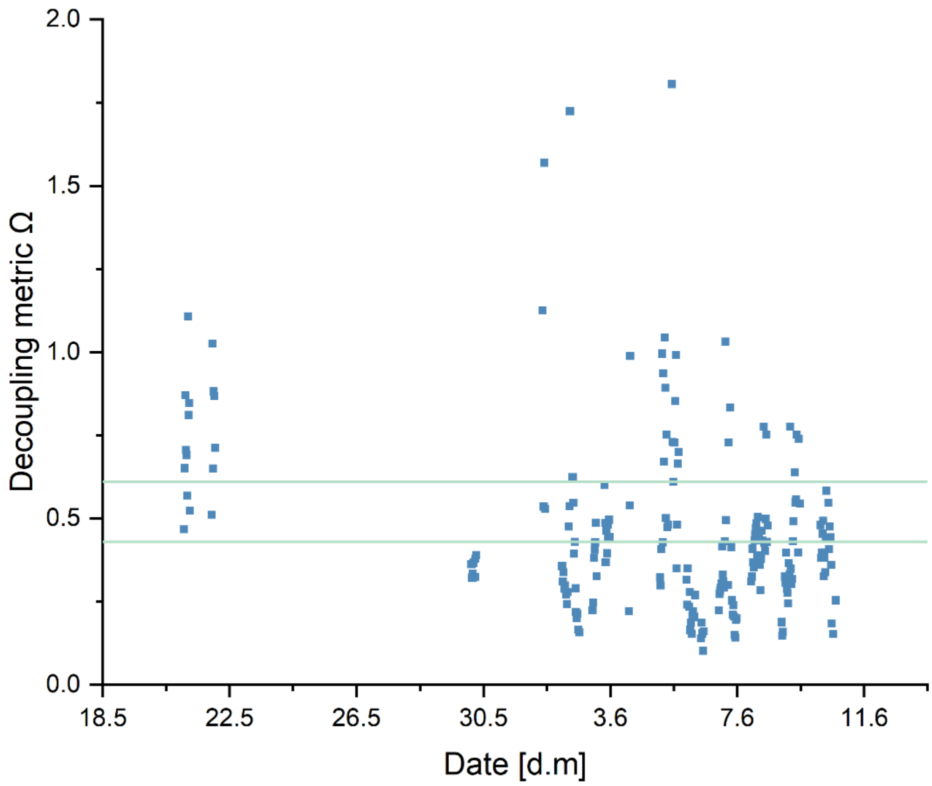

Figure R1: Decoupling metric Ω, calculated with the Brunt-Väisälä frequency (Peltola et al. 2021).

Second, based on these findings, we followed the reviewer's recommendation and categorized all flux data in two u* classes. All means and medians of the turbulent particle and sensible heat fluxes as well as the normalised fluxes in the revised manuscript now refer to periods when $u^* \geq 0.15$ m s^{-1}. The number of intervals has also been adjusted accordingly. A distinction has been made in the figures between intervals above and below the u* threshold.

We agree with the referee that it is out of the scope of this manuscript to discuss all the mentioned phenomena in detail. Here, we have made the following changes in the revised manuscript:

Line 201: In the case of stable stratification, strong temperature gradients can occur very close to the surface. In order to determine periods with possible vertical decoupling, a decoupling metric based on the Brunt-Väisälä frequency has been calculated (Foken 2023, Peltola et al. 2021). While the decoupling metric indicates coupled or weakly coupled periods when measuring at the lead, decoupling is frequently possible when measuring over closed ice surfaces. In order to exclude periods with weak turbulence and thus a high probability of vertical decoupling, the fluxes calculated from the gradient system were classified according to u*. For further discussion of the turbulent particle and sensible heat fluxes according to the flux-profile relationships, all mean and median values as well as the number of intervals are based on periods when u* ≥ 0.15 m s^{-1}.

Line 274: All measured values here are for conditions of u* ≥ 0.15 m s^{-1}.

Line 284: For this period, the low u* (beige circles) indicates possible vertical decoupling.

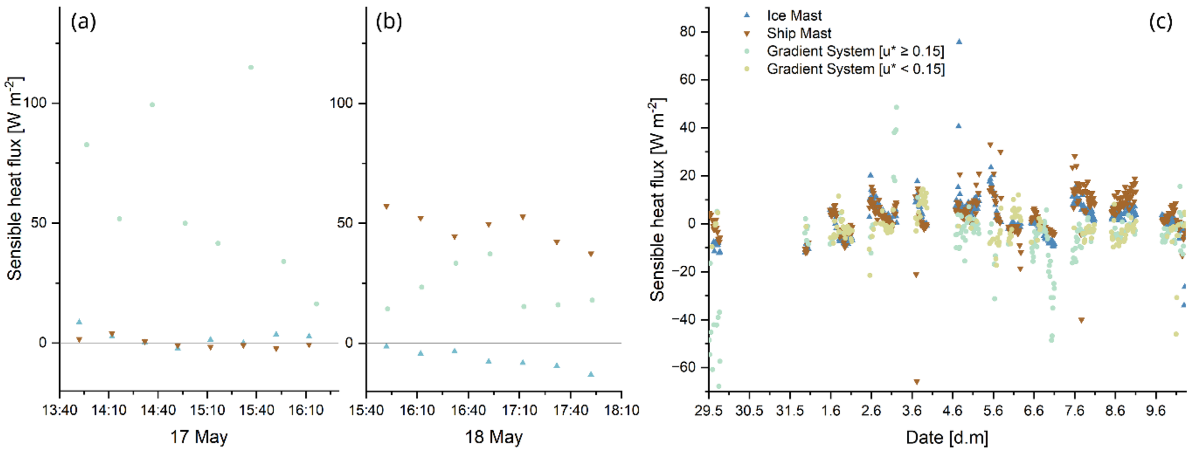

Figure 4. Sensible heat flux [H, W m^{-2}] on (a) 17 May and (b) 18 May 2023 from the gradient system setup influenced by wide leads with a time resolution of 20-minutes as well as sensible heat flux from the ship mast and ice mast with a time resolution of 20-minutes. (c) Sensible heat flux from the second ice camp from 29 June to 10 June 2023 from the three different measurement setups (gradient system, ice mast, and ship mast). In (a) and (b), all u* ≥ 0.15 m s^{-1}; in (c), gradient system data are shown in different colors depending on u*.

The conditions of the sensible heat flux naturally influence the particle gradient in the same way. At the very least, the proposed classification should be adopted. In a further study, it might be useful to investigate whether particles accumulate in the shallow layer above the ice in the event of decoupling. The layer is probably emptied of particles again with a short-term emission event. Perhaps Fig. A5 should be included in the text and compared with Fig. 3.

We agree with the referee that data analysis with respect to decoupling offers many possibilities for further analysis, especially since the data base in the Arctic for such shallow inversion layers is very limited, and we thank for this interesting suggestion. In this manuscript, we have adopted the u* classification as proposed and include a brief discussion of possible vertical decoupling. In the revised manuscript, we now distinguish particle fluxes in periods u* < 0.15 m/s and u* ≥ 0.15 m. Because Fig. A5 only serves to compare particle fluxes and wind speed conditions, we prefer to not include it in the main text. Further revisions have been indicated in our response to the previous comment.

In the conclusions, one would have to answer the question of why the ice surface is a sink for particles. Is the cause the surface itself or the stable stratification predominantly found there? Perhaps it is possible to subdivide the results into 2-3 stability classes (z/L) based on the eddy covariance data.

The z/L values based on the eddy covariance data show only neutral and stable conditions for the wide and narrow lead measurements. For the closed ice measurements, there were stable conditions temporarily, but no dependence of z/L on the particle flux direction direction is evident.

As is often the case with experimental studies, there are more questions at the end than were solved by the experiment. Thus, the manuscript should only be revised very carefully to the extent absolutely necessary, but problems should be pointed out. Possibly the discussion of the questions raised should be dealt with in another article.

Again, we sincerely thank the reviewer for his time and effort. His thoughtful feedback helped to make important revisions and substantially improve the manuscript.

Minor comments:

Line 148ff: Normalised size distribution should be defined or explained like all other normalisations.

The size distribution data are expressed in the conventional way using dN/dlogDp, and in addition, normalized by dividing by the total integrated concentration for each scan. In this way, the relative contribution of different size classes to the overall size distribution in Figure 6 e) and f) can be compared independent of the total particle concentration. The term "Normalized dN/dlogDp" better reflects the presented data and the term has been changed accordingly in Figure 6 and the caption of Figure 6.

Line 490: Please replace Foken (2017) with Foken and Mauder (2024)

The reference was replaced as suggested.

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