REVIEWER No. 1

Major comments

1.On coupled vs decoupled, lead vs sea ice: By reading the title only, I would expect the authors are referring this asymmetry to cloud properties observed with and without upwind sea ice leads. Yet, the abstract and the main results are instead focusing on cloud comparisons under coupled versus decoupled scenarios. So I wonder are the authors trying to emphasize the asymmetries of cloud property differences between coupled and decoupled cases when lead fraction is small (<0.02) versus large (>0.02)? It might be helpful to clarify this in the title and main text in the first place.

Reply: Thank you for the observations. We want to emphasize the fact that cloud observations above the RV Polarstern cannot directly be associated to sea ice leads observed afar from the RV Polarstern, but rather by means of using a mechanism to link these two observables. This mechanism is proposed in the manuscript to be the water vapour transport (WVT). We do agree that the title does not reflect this idea, therefore we changed the title to "Asymmetries in cloud microphysical properties ascribed to sea ice leads via water vapour transport in the central Arctic".

2. If the above-stated is the case, a follow-up question emerges. I see the value to sample the cases based on surface coupling state, and most often clouds are coupled with the surface when leads are present (also evidenced by Fig.8). There might be abnormal cases (e.g., when clouds are surface-coupled even with the absence of leads and vice versa), but I would expect these should rarely happen. Based on Table 3, it seems that the authors do detect such cases and the surface-coupled cases are in fact quite often (up to 64%) when lead fraction is less than 0.02, which I would take it as sea ice scenario considering (a) the uncertainty in the divergence-based lead fraction product and (b) the focused area (i.e., a conical sector centered at RV *Polarstern* and extended up to 50 km radius and angular span of 5 degrees) is relatively small and so is the actual lead area. In other words, I am worried about the reliability of the method used to detect coupled case when lead fraction is quite small (for example less than 0.02 in this study). This is somewhat exhibited by looking at the example case (Fig. 6c): the maximum ∇WVT (~9 g/m2/s) detected near the surface is not very distinguishable as there is a second maximum (~8 g/m2/s) right above it at ~ 1.5 km high. In addition, how far the detected leads relative to the cloud observation site might be another factor influencing the surface-coupling state detection.

With that said, I wonder can the authors provide some convincing evidence to demonstrate the coupled case when leads are almost absent and explain why? If the above-stated (i.e., emphasize the asymmetries of cloud property differences between coupled and decoupled cases when lead fraction is small (<0.02) versus large (>0.02)) is not the case, given the uncertainty in coupling state detection, I don't see the necessity to divide the samples into coupled versus decoupled cases when lead fraction < 0.02, such as the results in Figure 9. Figures like 8 or 11 showing the entire range of lead fraction tell a nice story.

Reply: We generally refer to cloud coupling to the WVT which is related to the presence of upwind sea ice leads, in other words, the coupling concept used in the manuscript encompass the sea ice lead-WVT-cloud system. We did that because sea ice leads are not generally present just below the observed cloud and because about only 6.5% of cases show a cloud surface coupling in the classical sense, this is due to the persistent intermittent boundary layer near surface level which serves as decoupling agent between the surface and the cloud above (as illustrated in Fig. 4).

It is true that coupling case happens even though no sea ice leads are observed, this is not generally abnormal since it happens due to: 1. WVT exist and it is either weak or comes from a location further away than 50 km, 2. There is in fact a sea ice lead but it is outside our considered range i.e. 50km radius centered at RV *Polarstern*. The latter implies that clouds will be classified as coupled (because is interacting with WVT) but will also be classified to cases with LF<0.02. That is why the reviewer noticed (point (b) in the comment) based on the Table 3. Regarding the reviewer comment point (a), in fact the methods used in the study to detect sea ice leads have limitations and it can produce under- or over-estimation of sea ice openings. We found the Sentinel 1A divergence product for LF the best product for this study because of its higher resolution and its ability to only detect leads when they open, avoiding therefore the consideration of newly frozen leads which has been argued to serve as a dissipation mechanism for low level clouds (Li et al., 2020). Furthermore, as explained in the methodology, we intentionally use the vertical gradient of the WVT to find its maximum and hence the wind direction at that altitude. This is done in order to stress the WVT at lower altitudes under the hypothesis that this WVT is more likely to be interacted with leads within the 50km range. WVT maximums located at higher altitudes can happen and can be weaker in magnitude, this still can be due to leads further away from the 50km, but clouds above RV *Polarstern* are either classified as decoupled (because WVT maximum is at higher altitude) or classified as coupled but with LF<0.02. This is why we separate the statistical analysis between coupled/decoupled cases and LF<0.02 and LF>0.02. Unfortunately, with the current available observations, we cannot determine how far the WVT filament extends, so that only WVT originated within the 50km can be considered. Back-trajectories analysis show that during MOSAiC the air masses have origins far from the Artic circle (Silber & Shupe, 2022) that is why in our manuscript we state that the WVT does not exclusively originate from the sea ice leads but rather that the sea ice lead release of latent and sensible heat interact with the WVT and this serves as conveyor belt to transport the energy (and eventually sea spray as aerosol sources from leads) toward the cloud observed above RV *Polarstern*.

Furthermore, we separate the coupling state when LF<0.02 to have an insight on the situation where WVT is present and leads can be located at ranges further than 50km. For instance, when the probability distribution function (PDF) - of a certain cloud property - shows basically the similar shape for coupled cases with LF<0.02 and LF>0.02, it means there might be still leads located further away which produce similar PDF e.g. same PDF maximum location but less frequent. On the contrary, for coupled cases and with LF>0.02, the PDFs are different from the decoupled ones (e.g. multiple peaks versus mono-modal distributions) is an indication that the leads-WVT-cloud coupling system is separating the observations into two distinguishable distributions.

Minor comments

1. L10-11. “cloud-driven layer extending above the cloud top and below the cloud base, respectively”

Reply: Thank you, the abstract has been simplified and corrected.

2. L11-13: These are very detailed information on data, should be put in Method or elsewhere instead of Abstract.

Reply: We do agree with the reviewer observation. The abstract has been simplified.

3. L16: The comparison between coupled and decoupled clouds are not clear. Readers might think the decoupled clouds are also low-level clouds but only thinner than that coupled ones. Please rephrase it.
Reply: It has been rephrased as "Clouds coupled to WVT are found to have mostly lower cloud base and larger thickness than decoupled clouds".

4. L73-74: Sect. 4, 4.1 and Sect. 4, 4.2 are misleading. Suggestion either using Section 4.1 and Section 4.2 or just merger them into one. Also, fully spell all "Sect." in the text to avoid confusion with other short names.
Reply: Thank you for the suggestion. We changed to Section although Sect. seems to be the requirement of the journal specifications.

5. L147: provide -> provided
Reply: This has been corrected, Thanks.

6. L168-169: Spell out "CO" and other places appropriate; there are already too many acronyms which reduce the readability of the paper. You want the readers to remember the most important ones, like LF. Plus, "co" also represents coupled in the paper.
Reply: We do agree with the observation by the reviewer, we did take out the acronym CO from whole manuscript.

7. L175: "," -> "."
Reply: Corrected.

8. L180: are of having- > are having
Reply: This has been corrected.

9. Table 2: Table caption should appear above the associated table.
Reply: The caption of all tables have been placed above.

10. L269: downwind -> upwind
Reply: Thank you for noticing this mistake, it has been corrected.

11. L273: of below cloud base's -> or below cloud base's

Reply: Thank you, it has been corrected.

12. L277: to be take place-> to take place
Reply: Thank you, it has also been corrected.

13. L310: Fig. 5 -> Fig.7

Reply: Thank you, it has been corrected.

14. L327: missed a comma before relationships

Reply: Thank you, it has been corrected.

15. L328-331: These details on method should be better to put in the caption instead of the main text to make the manuscript more concise and readable.
Reply: The sentence has been simplified and the caption of Fig. 8 is better described.

16. Legend in Fig.8: the circle and triangle filled with color is unnecessary and misleading. Suggest use unfilled ones.
Reply: We apologize for the confusion. The intention was to also show the relationship with temperature. Now in Fig. 8 the color coded symbols have been removed, but for consistency purposes with the whole manuscript we keep the symbols colored as blue-circles and orange-triangles for for coupled and decoupled cases, respectively.

17. L351: Grammarly incorrect sentence. Please rephrase.
Reply: Thanks for point out this mistake, the grammar has been reviewed and the sentence corrected: "The 18 November, 2019 case study encompasses a situation where the observed clouds have a well-defined correlation with LF situation up-wind, mainly due to the occurrence of a single cloud layer.".

18. L387: any evidence for the argument that temperature inversions are found above the cloud base for those coupled case?
Reply: Temperature inversions above cloud base have also been reported by (Sedlar et al., 2012) where they found the inversion not only can take place at cloud top height but also inside the cloud. This is something we want to analyze better with our dataset, and determine whether there is any pattern on the thermodynamic structure of the cloud layer when separated by cloud coupling. However this is not within the scope of the present manuscript.

19. L395: any girds with mixed-phase clouds? How these are considered in the calculation of Eq(5).
Reply: This is a good observation. Indeed, one reason for why we use the ice water fraction, instead of the commonly used fraction of number of pixels with mixed-phase clouds to the total number of cloud pixels, is to consider the amount of water within the mixed-phase clouds into the calculation of Eq. (5). When a grid cell is classified as mixed-phase by the Cloudnet algorithm, then that grid cell has a value for ice and liquid water content. This is integrated along the cloud layer and therefore included in Eq. (5). If in our study we were to consider ice cloud occurrence instead of water content, then mixed phase clouds would only contribute to the denominator of Eq. (5).

20. L405: why choose based on temperature range?
Reply: The reason is to be consistent with most of the scientific literature where cloud top temperature at ranges from -40 to 0°C is used. This way we can also compare our findings with the ones from other studies.

21. L455: Discussion, Besides summarizing and listing these observed results and comparing to previous studies, one should say more about what these information can infer and provide insights for the community. More discussion regarding this would benefit the readers.
Reply: Thanks for the comment. In Discussion section after the summarizing the findings a paragraph has added to stress this point: "The findings presented here can be used as valuable constrains to evaluate cloud microphysical parameterizations for the Arctic system models. Since sea ice leads are not explicitly resolved in such models, lead-averaged surface heat flux, and its influence on clouds, is of considerable interest for the parameterization of energy exchange (Gryschka et al., 2023)*. The different features of ice water fraction χ_{ice}, as a function of cloud top temperature, found for coupled and decoupled cloud cases are a result*

that deserves to be deeply investigated by validating it with long-term observations but also by a better understanding the modelling of cloud microphysics that can lead to explain the findings."

Bibliography

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Sedlar, J., Shupe, M. D., & Tjernström, M. (2012). On the Relationship between Thermodynamic Structure and Cloud Top, and Its Climate Significance in the Arctic. Journal of Climate, 25(7), 2374–2393. https://doi.org/10.1175/JCLI-D-11-00186.1

Silber, I., & Shupe, M. D. (2022). Insights on sources and formation mechanisms of liquid-bearing clouds over MOSAiC examined from a Lagrangian framework. Elementa: Science of the Anthropocene, 10(1), 000071. https://doi.org/10.1525/elementa.2021.000071