Overview

Sea ice leads plays a central role in surface energy balance and affect the overlying atmosphere over polar regions via the highly efficient exchange in both heat and moisture. Using observations from the MOSAiC filed campaign and novel vapor transport-based method, the authors investigate the influence of upstream sea ice leads on downstream cloud properties in the wintertime Arctic and observe different (asymmetric) micro- and macro-physical cloud properties when leads present versus not present. I appreciate the authors integrate a pile of data to make this happen and find the results overall reasonable and valuable, which offers detailed insights to understand the sea ice-cloud interactions. I do believe this work can be published on ACP after revisions listed below.

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.

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 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.

Minor comments

1. L10-11. "cloud-driven layer extending above the cloud top and below the cloud base, respectively"
2. L11-13: These are very detailed information on data, should be put in Method or elsewhere instead of Abstract.
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.
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.
5. L147: provide -> provided
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.
7. L175: "," -> "."
8. L180: are of having- > are having
9. Table 2: Table caption should appear above the associated table.
10. L269: downwind -> upwind
11. L273: of below cloud base's -> or below cloud base's
12. L277: to be take place-> to take place
13. L310: Fig. 5 -> Fig.7
14. L327: missed a comma before relationships
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.
16. Legend in Fig.8: the circle and triangle filled with color is unnecessary and misleading. Suggest use unfilled ones.
17. L351: Grammarly incorrect sentence. Please rephrase.
18. L387: any evidence for the argument that temperature inversions are found above the cloud base for those coupled case?
19. L395: any girds with mixed-phase clouds? How these are considered in the calculation of Eq(5).
20. L405: why choose based on temperature range?
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.