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Interactive comment on "Cloud vertical distribution from combined surface and space radar/lidar observations at two Arctic atmospheric observations" *by* Yinghui Liu et al.

Anonymous Referee #1

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The manuscript uses ground- and satellite-based retrievals of cloud fraction, cloud liquid and ice water content and cloud phase profiles from lidar and radar to compare their performance at two Arctic sites: Barrow and Eureka. They propose to merge ground and satellite retrievals of cloud fraction to compensate for their inherent limitations: issues for CloudSat and CALIPSO to detect low-level clouds versus issues for surface based measurements to detect high clouds. I do recommend major revisions as there are some issues with the presentation of the results and the actual content of the conclusions.

1. The method section needs some extensive work, because the explanations are currently confusing and insufficient. I have detailed the problems in the specific comments

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Discussion paper

below. Are monthly means calculated and used throughout? This is never explicitly said.

2. The detectability issue with CloudSat and CALIPSO for low level clouds is not new, there are already a number of papers that discuss this, e.g. Kay and Gettelman 2009, or Huang et al. (JCLI, 2012, doi: 10.1175/JCLI-D-11-00131.1). The real novelty of this paper is 1) to give an estimate/magnitude to this deficiency and 2) inspect the consequences when looking at the annual cycle of cloud cover in the Arctic. This should be made more prominent.

3. The authors have decided to separate the results from Barrow from Eureka. Why is this? Are the two sites giving different results other than differing climatologies?

4. Although a blended product is a good idea, because of the good performance overall of the surface-based observations (even if less high clouds are detected, the differences with the satellite based observations are small, possibly because of the location and type of clouds). I wonder if such a product is that needed for these two locations. It might be of more use if done for the tropics.

Specific comments:

1. The title is awkward: shouldn't "observations" be "observatories"? or add "sites" at the end.

2. Line 28, page 2: Here, and elsewhere, the authors refer to CloudSat&CALIPSO as "space-based radar-lidar" which makes it quite general when one could imagine that other (future) radars and lidars might have different sensitivities and consequently issues/strengths. If for example the characteristics of the Earthcare mission instruments will be such that they will experience the same problems, then this should be said. Otherwise it would be better in the introduction to say that when referring to "space-based radar-lidar" the authors mean CloudSat and CALIPSO.

Section 2:

3. What is the temporal resolution of the profiles, surface and satellite based, when they are compared? Monthly means? Does it mean that the surface profiles are accumulated over a month and then cloud fraction calculated using a cloud mask? Please explain.

4. Throughout the manuscript, please specify whether the lowest levels are identified about the surface or above mean sea level (which presumably is rather close at the two sites? This is not specified).

5. Page 3, line 17: when introducing VFM, please specify which resolution, vertical or horizontal? Depending on which the 1/3, 1 and 5 km refer to, then specify the other resolution. This might help understand the method described on page 4 (see point 10 below)

6. When using GEOPROF, the authors choose the CPR_cloud_mask variable to be above 20 for a range bin to be cloudy. What is the convention in GEOPROF-LIDAR? How does this choice affect the results?

7. Line 20, page 4: here the authors specify that the satellite based profiles are selected if found within 50 km from the sites. Given the narrow swath and polar orbit, how many orbits per month actually fulfill this condition of at least one profile within 50 km? Do "6000 total sample numbers" and "1500 total sample numbers" refer to the total number of profiles?

8. Page 4, lines 21-23: this sentence is confusing, maybe a simple schematic would help visualize what you mean? What is the original vertical resolution of each product?

9. Lines 23-25 page 4: this sentence does make any sense, what is a "cloud case number"? again maybe a schematic would help. Then at the end of the sentence "in a selected time period" refers to a month?

10. Page 4, Lines 25 onward on how the CALIPSO profiles are dealt with: again a schematic might help, as well as a clear explanation of what the horizontal and vertical

resolution of these profiles are, and what it means to combine the 1/3 and 1 or 5 km products. Finally, what is the final vertical resolution of all of the products (CloudSat alone, CALIPSO alone, combined and surface)? Also why use both the 1/3 and 1km combination and the 1/3 and 5 km combination?

11. Page 5, last paragraph of section 2: are the surface products only selected when coincident with an A-train orbit? And, most importantly, are the profiles to be used in section 3 monthly means/accumulations??

12. Figure 1, 2, 7, 9, 10 and 11: the color bar covers 0-50% but from the text cloud fractions exceed this value at low levels it seems. Why not use the full range of available values?

13. How is the "monthly mean total cloud amount" calculated for each instrument? (e.g. line 28, page 6)

14. Figures 4, 5, 6 need to be redone with either thicker lines or (better) in color, to help distinguish between the different lines. It is really hard to read these as they are.

15. Page 7, sentence on lines 3-4: this is awkward, since you've already explained that the surface products were described in Shupe (2007, 2011), why not skip this first sentence and add reference to these two studies in the next sentence.

16. Page 9, line 10: "Major differences" between what? Barrow and Eureka or surface and satellite?

17. Section 3.2: more information is needed: what is the temporal resolution of the combined product? If monthly means, then this is a combination of the monthly means from surface and satellite? Or are these constructed for coincident observations only? Then how are the two products reconciled in term of surface time average vs satellite spatial average? Line 27: "a complete picture of the " monthly "cloud fraction vertical distribution"?

18. Section 3.3: what is the take-home message for this section?

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19. Conclusions: the first "primary conclusion" is the direct consequence of the known limitations in the CloudSat (surface clutter/low sensitivity) and the CALIPSO (attenuation) instruments. References to other studies should be given. For the second "primary conclusion", I would be inclined to conclude that surface observations perform well, regardless of cloud altitude. For the third conclusion, I would encourage the authors to discuss a bit more the implications for the annual cycle of the satellite based deficiencies. Finally, although I agree that the blended product is more accurate than surface only observations, I think that the real advantage is if one is to calculate heating rates and/or TOA/surface fluxes, this is where this product might make a difference. This should be discussed.

20. Finally, two papers come to mind to address the very last sentence of the paper, where combined satellite products were used to evaluate cloud impacts in the Arctic in Kay et al (2008) and Kay and Gettelman (2009). The authors might want to mention these results.

Typos

1. Abstract, line 24: remove "annual cycle" after "vertical distribution"

2. Line 24, page 3: "negligible surface above 0.96 km" does not make sense, is "clutter" missing?

3. Line 26, page 6: please add "to" before "penetrate" and "thick" after "optically"

4. Line 34, page 6: replace "the" before "CloudSat" with "that".

5. Line 13, page 7: add "with" before "2B-CLDCLASS-lidar"

6. Page 8, line 21: remove "This" after "Whether"

7. Page 8. Lone 23: "the" instead of "he" before "whole Arctic"

Kay, J. E., and A. Gettelman (2009), Cloud influence on and response to seasonal Arctic sea ice loss, J. Geophys. Res., 114, D18204, doi:10.1029/2009JD011773 Kay,

J. E., T. L'Ecuyer, A. Gettelman, G. Stephens, and C. O'Dell (2008), The contribution of cloud and radiation anomalies to the 2007 Arctic sea ice extent minimum, Geophys. Res. Lett., 35, L08503, doi:10.1029/2008GL033451