Review of

A satellite-based estimate of aerosol-cloud microphysical effects over the Arctic Ocean

Lauren M. Zamora,
Ralph A. Kahn, Klaus B. Huebert, Andreas Stohl, Sabine Eckhardt

Summary

The paper presents an analysis of aerosol-cloud effects using data from satellites and FLEXPART to provide first observation-based constraint on regional aerosol microphysical effects on total nighttime CF over the Arctic Ocean. An important feature is that the study accounts for the co-variation of airmass aerosol and meteorology. The topic and findings seem appropriate for the *ACP* readership.

Overall, the methodology seems sound and findings of interest. However, while the text is very well written from a grammatical standpoint, particularly in the presentation of the results the text is either disjointed or lacks sufficient information to follow in the figures/tables. Specific examples are given below for improving the flow of the text, along with other comments and question. The suggestions are not comprehensive so the authors are advised to please use them as a necessary-but-not-sufficient guide of how the manuscript should be modified for an outside reader to follow and absorb the content. For these reasons it is recommended that the paper be accepted but with major revision.

Major Comments
(Each specific comment is preceded by the page and line numbers. If in the supplemental material, only the line number is used.)

1) In the supplement, the evaluation of FLEXPART BC concentrations is based on CALIPSO aerosol profiles. Arguments are provided as to why BC would likely be the dominant aerosol type for the location and period of study. However, since CALIPSO cannot tell the difference between BC and other aerosol types, a more direct comparison would be if FLEXPART could provide the total distributions of all relevant aerosols for the region. Is that a capability of FLEXPART? If so, then FLEXPART could also be used to assess the fraction of the total aerosols that are BC and support the arguments provided.

2) P3: The focus is on BC concentrations, why? Please provide a justification, which appears to have been buried in the supplemental material.

3) In the results section, there is a lot of jumping back and forth between the figures in the main text and the supplemental material. As such, some of the supplemental material did not seem very "supplemental". Recommend moving frequently referred to figures or tables to the main text.

4) L94-100: The supplemental summary statement seems inconsistent. The last sentence states that "the model does represent aerosol transport over the Arctic well" but the first sentence states that "CALIPSO aerosol layers contributed significantly smaller volume than in all and

model-identified polluted conditions"; if the latter is correct, how can the former be? How does this affect the results? (particularly Fig. 4)

5) The issue with (4) might stem from confusion regarding Figure S3. The plot shows that fraction of the different altitude layers where CALIPSO detects aerosol and FLEXPART identifies (a) are clear, and (b) are polluted.

    a) While (a) are false negatives (consistent with the header at the top of the plot), is seems that (b) is inconsistent with its header and it is not false positives; rather it is showing when FLEXPART accurately identifies aerosol layers (i.e., CALIPSO=yes, and Pollution=yes). Is the caption wording correct?

    b) Also, the caption and the headers refer to "likely at large values" and "likely at small values"; values in what, BC concentration? If so, the plot only displays part of the information, the layer fractions and, besides the "clean" and "polluted" columns, there is not information on concentration level (that is consistent with the headers at the top of the figure). Please clarify.

6) Fig. 3: There are too many different aspects are loaded into this figure, making it very difficult to follow the discussed patterns in a single variable type with altitude (e.g., dCF). Recommend moving 3b to a new figure, and make a-c panel plots in Fig. 3 with altitude separately for (a) dCF, (b) dpptn, and (c) dCP(IPC, MPC, LPC). For the old 3b, the current overlays are too cluttered and recommend separating into (a) and (b) the pptn and CF components.

Secondary Comments

(Some rewordings are suggested that were easier for me to understand.)

7) P6, L25, "very large (~25 W m^{-2})": Where does this value comes from? In the plots, values range from 0 to ~70 W m^{-2}. Please explain. In fact, more text is needed to explain Fig. 2 which is a 7 panel plot. Currently, it seems "dropped in" without many of its aspects discussed.

8) P7, L1, "up to 91% of the variability": Where is this value shown? I do not see any such value in Table S1.

9) P7, L11-13, "Cloud fraction substantially differed… At the lowest levels…": At the lowest level (0.6-1.5 km) over open ocean, almost all of the grids have Xs meaning that they are not statistically significant. Is it then a correct interpretation to say that they differed substantially?

10) P7, L20, "generally become more positive at constant RH with increasing T": This statement is not well supported given that many of the grids have white Xs preventing the "increasing with T" analysis.

11) Fig. 4: Please describe where the dots are from. Are they from the grids in the RH-T plots e.g. from Fig 1. but for each range of dBC? If so, are they only from those that are statistically different from zero?

12) P1, L19, "with implications for a warming Arctic." Such implications do not seem to have been discussed in the paper. Please add the discussion or remove this clause.

13) P2, L22, "Tropospheric cloud data…": Please indicate earlier/here the source here (CloudSat and CALIPSO); the details of the products can remain where they are.

14) P3, L26: "in general (Zamora et al. 2017)…" → "in general. Zamora et al. (2017)…"

15) P3, L27: What is meant by "strong aerosol layers"? Also, what does "aersosols[6]" mean?

16) P3, last line, "Cloud fraction is not well defined in the literature. Here, it is…": The statement is incorrect and unnecessary: CF is <u>defined</u> in the literature (tho its determination can be challenging). Recommend just starting off with "Cloud fraction is operationally…"

17) P4, L18, "and blowing snow": Your lowest altitude is 0.6 km; are you stating that blowing snow could be that high? If not, remove.

18) P4, L18-20, "Additionally, …": As stated, why is CloudSat mistaking precipitation for clouds an issue? If the lidar signal is attenuated it is attenuated and one has no signal to work with. This is true regardless of CloudSat's potential mistake. It would only factor in the precipitation counts, which does not seem to be the topic here.

19) P5, Section 2.3: Please include the local overpass time used from AIRS.

20) P6, L15, "Our focus on nighttime data over the flat ocean surface likely reduces effects from large-scale vertical motion": I do not know what you intend to mean by "large-scale vertical motion" since certainly large-scale synoptic phenomena exist at nighttime (fronts, highs, lows, etc.). Recommend rephrasing.

21) L17, What is the meaning of "convection[36]"?

22) Fig. 1: The white Xs indicate that the grid is not significantly different from zero. In the analyses that follow, are only the non-X grids used? Please state and/or give justification for inclusion if they are.

23) Fig. 3: Does the significance indicated by the asterisk apply to both the relative percent changes and absolute changes? Please state in text.

24) P7, L17, "1.7% to 0.7%": These values for sea ice do not match what I see, which is -2% to 1% (unless you maybe meant only at higher altitudes?).

25) P8, L1, "more influential at the lower temperatures": The values are near dCF=0 for the higher altitude points so is this an accurate statement, especially given the dramatic drop off over sea ice with lower altitude (warmer temperature) suggesting the dominance of the stability criterion?

26) P8, L6, "(Fig. 3)" → "(Fig. 3a)" for clarity.

27) P8, L11, "Over sea ice" → "From Table S2, over sea ice…" for clarity, as otherwise it was not clear what supported the last sentence in the paragraph.

28) P8, L18, "where LPC fractions were highest": Source for statement?

29) P8, L23, "An analysis…" → "We analyze the difference in precipitation frequency; however, an analysis…" (otherwise, the reader knows what you will not do, but it has not been stated what will be done).

30) P9, L1, "~91% of the MPCs": Shown where?

31) P8, L31, "night, potentially" → "night. This potentially leads to…" (break up the long sentence that also contains opposing points of view). And, which point of view does your study support?

32) P11, L12: Physically, why would one expect a larger aerosol effect for greater atmospheric stability?

33) P11, L25: Can you give a "for example" about what other cloud property relationships might exist?

34) Need the "author contributions" section for *ACP*

Supplemental material

35) L49-52: The concern about the variations in BC:OC ratios seems misplaced to me since the CALIPSO cannot tell the difference between those aerosol types.

36) L33-35, "it is unclear how thick an observed CALIPSO aerosol layer (measured in meters) must be to influence the average BC concentration in an altitude range…": The part "must be to influence the average BC concentration" seems odd in that there is no "influence" on the average BC concentrations. Please reword.

37) L38: "locations of false" → "locations of FLEXPART false"

38) L63-64: Please explain a bit more about how the FLEXPART and CALIPSO data are compared. Specifically, the text refers to percentages of a "layer volume"; is that to say that the CALIPSO layering is converted into a binary present/not present mask and compared to the equivalent binary from FLEXPART? If so, is there a criterion used for the binary CALIPSO masking?

39) L66: For clarity, recommend "so the fractions estimated" → "so the model false negative fractions estimated"

40) L69: Remove "However". It implies a course change from the prior text but one is not present.

41) L76: For clarity, "sea ice" → "sea ice (the pink line)"

42) L81: For clarity, recommend "detect non-dilute aerosol" → "detect (non-dilute) aerosol"

43) L82: "are likely to be"; shouldn't this be "will be" (?) since it is how you have defined false positives?

44) L86-87, "These aerosol…": I was looking for a figure to support the statement but it seems that one is not present? If there is, please indicate; if there isn't, please indicate "not shown."

45) Figure S4: Please rescale the y-axis to cover the range of the bars plotted (i.e., most "polluted" bars exceed the plot range).

46) Table S2: The values in the square brackets are defined in the caption, but what are the values in the parentheses that precede the square brackets? Recommend rearranging to be in column format as the font size to fit in portrait is too small to read easily.