Atmos. Chem. Phys. Discuss.,
https://doi.org/10.5194/acp-2020-186-RC2, 2020

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Finely laminated Arctic mixed-phase clouds occur frequently and are correlated with snow" *by* Emily M. McCullough et al.

Anonymous Referee #2

Received and published: 14 April 2020

General Comment: Arctic mixed-phase clouds play an important role in the Earth's energy and water budgets. However, its morphology is complex, and the occurrence of each cloud type is still unclear. This manuscript focuses on laminated mixed-phase clouds and its relationships with weather conditions using lidar data from multi-year observations. The manuscript is well organized, and figures and tables are very clear. The dataset and analysis technique are unique and interesting. Although the analysis method is well described and the limitations of the technique are considered the discussion, I have a few concerns in the method and definition, which might affect the conclusions. The concerns below should be addressed before the manuscript is accepted for publication.

Major comments

1. I have questions and concerns about definitions of the "laminated clouds" focused in this study. The manuscript stated "we focus on a different type of mixed-phase cloud which contains layers of ice and liquid throughout the volume of the cloud." Is this same as "ice (precipitating) cloud in which more than one liquid layers were embedded"? Because "Arctic mixed-phase clouds" implies that ice particles and liquid particles coexist and temperatures are below the freezing temperature in the cloud depth, so the liquid particles can be supercooled liquid droplets. However, the analysis of the study seems to also include rain precipitating clouds, where the temperature could be greater than 0°C. Please give more detailed descriptions of the target clouds in terms of this and the temperature information of the target cases.

2. I have a question about the third criterion for "Laminated." Based on the criterion, the laminated cloud can include three thin cloud layers (i.e. quasi-horizontal stripes) in the 75 m depth. I felt that this is too narrow. If the depth between the first layer and the third layer exceeded 75 m, was the cloud not included? Why was this criterion used to define laminated clouds? What kind of clouds did you want to include/exclude by this criterion?

3. What was the thickness of the "quasi-horizontal stripes"? How did you define the quasi-horizontal stripes (i.e. what is the vertical gradient of the lidar backscatter)? Was this definition same as one by O'Connor's et al. (2004) for ceilometer' cloud base height? O'Connor, Ewan J., Anthony J. Illingworth, and Robin J. Hogan. "A Technique for Autocalibration of Cloud Lidar." Journal of Atmospheric & Oceanic Technology 21, no. 5 (2004).

4. I have a concern about the way to count laminated cloud day. If my understand was correct, the laminated cloud day was counted when the laminated condition lasted 0.5 h at least within 24 hours. Based on this definition, it is possible that the most of time could be non-laminated condition in a day that was classified as "laminated day". Is

this reasonable to select laminated days? My concern is that if “non laminated day” was counted using a definition that non-laminated condition was lasted >0.5 h, many laminated days selected in the manuscript could be counted as “non-laminated day.” In that case, the results obtained in the present study could be opposite. Is the conclusion also affected by the criterion and selection?

5. While the minimum duration of laminated condition was 0.5 h, the weather condition used in the study was based on the daily reports which provide only a few condition categories per day. How did you ensure the correlation of these different time resolution data?

6. Based on the classification method, I think that the “Undetermined (obscured)” category implies a low-level thick mixed-phased cloud. I am curious about this category and wondering if this category was included in Investigation B, how this category was correlated with the weather conditions.

7. On p. 13, Pearson’s r correlation analysis: Please discuss the variability of r values over the years. What is the reason of the variability?

8. Discussion for Investigation A: Please more discuss about the seasonality of the occurrence in terms of meteorological conditions, environment, etc.. Figure 5 shows clear seasonal variability in each year except 2017; there is a peak at May and April. What is the reason of the seasonal variability? Why does 2017 show different variability from other years?

9. Lines 10-11 on p. 17: Same as comment #4, the laminated cloud case was identified when the laminated condition lasted only for 0.5 h. The most of time might be non-laminated condition. If “non-laminated cloud day” was counted as a day where non-laminated condition lasted for >0.5 h, the result could say “non laminated clouds may form an even larger component of the atmosphere at Eureka.” Please carefully mention/discuss considering the limitation of the analysis technique. I have the same comment a statement on lines 18-19 on p.18.

10. Please also discuss about the seasonal variabilities in terms of meteorological conditions, environment. etc.

Minor comments

1. Lines 21-22 on p.13: The occurrences in November and December show large variability in Figure 5. Therefore, this sentence can mislead the readers. This sentence should be rephrased carefully.

2. Figure1: Please specify the laminated cloud regions identified by the definitions.

3. Line 10 on p. 13: Remove “is.”

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