We are grateful for the reviewers' careful reading of our manuscript and their exceptionally helpful comments. Their suggestions helped to significantly improve the content and structure of this manuscript. In this author comment, we reply (in blue font) to each of both reviewer's comments (in black font) and explain our suggested changes which we made in the attached revised version of the manuscript (deleted parts marked up in strikethrough red font, and newly added parts marked up in blue font).

RC1

Summary:

This paper focuses on an inter-comparison between polarized lidar data in New Zealand, Chile and Germany. The different locations of these lidar systems allows the authors to examine the impact of different aerosol environs on heterogeneous ice formation. The relationship between aerosol and ice formation is a complex one and an extremely high priority for improving model simulations. The data underlying this paper provides a unique opportunity to separate out the influences of different aerosol loads and allows the authors to extend existing research on heterogeneous ice formation. I think this paper is a valuable contribution to the scientific literature and hope that future work will be done to extend this line of research.

Minor comments:

Some of the paragraphs are excessively long, particularly in the introduction and conclusions, which serves to obscure some of the points of the paper. Splitting some of these paragraphs would lead to an improved experience for future readers.

Thank you for pointing that out. We therefore suggest line breaks in the introduction before "In observational studies," on original line 27, before "The strong contrast in aerosol particle load and composition" on original line 31, before "On the other hand, marine organic aerosol" on original line 42, before "The representation of above mentioned contrasts" on original line 49, before "In the Southern Hemisphere mid-latitudes," on original line 71, and before "This is strong motivation" on original line 82.
In the summary section, we suggest line breaks before "Based on a long-term radiosonde dataset" on original line 309, before "Next, the general aerosol conditions over Lauder" on original line 313, before "Overall, ice-formation efficiency in clouds above Lauder" on original line 320, before "In conclusion, it can be stated" on original line 326, before "Our study made use of a unique" on original line 330, and before "Future studies might also make further use" on original line 338.

The sentence starting on line 28 ("Even though.....") is confusing to read. I would appreciate it if this sentence could be rewritten for clarity.

For better understanding, we split up this sentence in two and slightly reformulated it.

The two sentences starting on line 54 (“Too few.... . Via too strong....) are separated in a way which muddles the meaning. Once again, I think this should be rewritten for clarity.

Again, we split up this sentence in two.

Line 96 change “are” to “have been”

We changed that tense.

The sentence starting on line 118 (“By considering.....”) is confusing to read due to the complex clausal structure. This should be rewritten for simplicity.

Again, we split up this sentence in two.

For completeness, a reference should be included after the statement that dew point spreads of 2k are needed for cloud formation (line 217)

We added a reference.

This discussion of figure 10 is a little underdeveloped (lines 298 - 301). I’m unsure if an unfamiliar reader would be able to interpret the results of figure 10 based on the existing discussion. I also think additional discussion here is warranted, given the results of the figure.

We first added a clearer and more extended explanation of the quantities used in this figure, and secondly, we added a sentence at the end stating the main conclusion drawn from this figure.

RC2

General comments

In this paper, the efficiency of ice formation in clouds over New Zealand has been investigated, focusing on the effect of the different aerosol loads and their origin above the area of study. The study is focused in clouds for which the top temperature falls within the heterogeneous freezing range (-40^{o} to 0^{o} C) making use of a combined dataset comprising of ground-based lidar observations for detection of liquid and ice-containing clouds, radiosondes and Global Data Assimilation System (GDAS) for profiles of atmospheric parameters, CAMS-MACC model runs for aerosol re-analyses data, HYSPLIT model runs for air-masses backward trajectories, and TRACE profiles for air-mass source attribution analysis. A case study is selected to demonstrate how the different type datasets are/can be used to study the relationship between the mixed-phase cloud formation and the aerosol load and type, before presenting the overall results and statistics from the analysis on the clouds and the air-masses using the available long-term datasets. Overall, the manuscript is well-structured, well-written, and its scientific significance makes it suitable for publication, after some minor revisions to be kindly considered from the authors.

Specific comments

- Section 2.1: I think a brief description of the lidar specifications (e.g. laser energy and repetition rate, telescope diameter, FOV, spatial resolution, measured optical products) could be added here.

  We added a complete but still brief description of the specifications and products.

- Lines 103-104: I kindly suggest to name also the lidar products that are used in the study (backscatter coef., depolarization ratio) instead of the lidar signals.

  You are right, this sentence was misleading anyway, since the polarization signals are of course themselves backscatter signals. We used the co- and cross-polarized signals at 532 nm wavelength to retrieve range-corrected signals and volume depolarization ratios, but also to calculate aerosol optical properties like particle depolarization ratios and particle backscatter coefficients. Therefore, we changed the sentence, which states now that we used co- and cross-polarized signals.

- Lines 110-111: The authors state that the volume depolarization ratio is used along with the backscatter coef. to identify the cloud base and top, but in line 160 and Fig. 1 the particle depolarization ratio is used instead in the visual inspection for clouds in the scene. Which product is really used? If both, then please clarify.

  The volume depolarization ratio and the range-corrected signal are used in the evaluation.
  As it better adheres to standard ways of presenting aerosol optical properties, uncalibrated attenuated backscatter coefficient and particle depolarization ratio plots (and calibrated particle backscatter for the profile in Fig. 1ci)) are presented for the measurement example.

- Lines 113-114: Do the authors use a threshold in the volume depolarization ratio values to discriminate the clouds (liquid or ice-containing) from other depolarizing particles (e.g. dust)? Do the authors account for the contribution of molecular depolarization in the volume depolarization ratio? Maybe a more detailed description is needed here.

  No, we don't use a fixed threshold of volume depolarization ratio, neither for the discrimination of cloud phase (this is the advantage of an individual visual inspection, that it better allows to account for specific structures of the full profile to rule out misclassification due to multiple scattering or specular reflection, (Ansmann et al., 2009, Seifert et al., 2010)) nor to differentiate cloud and aerosol layers. The latter usually relies rather on peak-signal-to-base-signal ratio than on polarization (Wang and Sassen, 2001) for which, again based on individual visual inspection, mainly the range-corrected signal was used.
  In the case of the measurement example, the total (molecular plus particle) depolarization ratio at 4–5 km is about 0.2% to 0.3%. Since this is an almost aerosol free region, this value should be close to the molecular depolarization

ratio seen by this system, which was previously reported by Nakamae et al. (2016) as 0.37%. This is a low value which therefore does not interfere with cloud phase discrimination based on the volume depolarization, as for example Ansmann et al. (2009) stated "A very accurate determination of the [volume linear] depolarization ratio is not needed in this study. Only a clear discrimination of [liquid] water droplet depolarization (typically <0.2, including multiple scattering effects) and ice crystal depolarization (usually >0.4) is of importance". We added a comparable sentence to provide more detail.

- Line 165 "heights up to above 14 km": It is not clear if these elevated layers were observed during the case study. If yes, what is the height range that the elevated smoke layers are detected, up to 14 km or above 14 km? And, what is the base of the elevated smoke layer?

  We deleted the specific height information in this sentence as it is indeed misleading. This statement was made that way because for regular cloud classification, we only processed (by visual inspection) data up to 15 km a.g.l., so that, repeatedly, merely the lower parts of these smoke layers were visible during evaluation. The statement was not intended to be specifically made for this case study only but for a general description of the broader period in which the case study lies, namely January 2020, where layers of elevated smoke of the record-breaking Australian wildfires 2019/20 were observed at multiple days, e.g., on 15 January 2020 (roughly 11–13 km), 17 January 2020 (roughly 13–15 km), 18 January (diffuse from roughly 12 km up to above 15 km), 22 January 2020 (again diffuse from roughly 10 km up to above 15 km).
  On 19 to 20 January 2020, a smoke layer was present with a base height at roughly 13 km reaching up to 15 km or possibly even slightly above. But the detailed description of these smoke layers is not scope of this study.

- Section 3.3: It is not so clear that only the WD (well-defined) clouds are used in the cloud statistics and also in the following section (sec. 3.4 and Fig. 9 and 10) for the separation of clouds based on airmass statistics. Please clarify which sample of clouds (total or WD) the authors use

  Indeed, we later use only the well-defined clouds. We made this clearer in the captions of Figs. 9 and 10 and in Sect. 3.4 by adding "well-defined".

- Figure 9b: Kindly consider to use a different line color for clusters 3&4, since lightblue might be challenging for some readers to discriminate it from the cluster 2 blue line.

  We changed the color of the line for "Clusters 3&4" to a better distinguishable one (a darker green, "olivedrab", called now "green" in the caption).

Technical corrections

- Line 307 "the Seifert et al. (2010, 2015)**,** methods to asses …": is the coma after the parenthesis necessary?

  No, it is not needed. We corrected that typo.

- Figure 8: duplicated for in "Fraction of ice-containing clouds as function of cloud-top temperature in intervals of 5 K **for for** Leipzig"

  We corrected that typo.

- Line 295: typo in "…ice formation efficiency, **albeit** within statistical uncertainty."?

  This additional part of the sentence should indicate that the lower ice formation efficiency in that temperature range is not significantly lower than in Punta Arenas (looking at the error bars denoting the statistical uncertainty). We believe that it needs to be stated like this and therefore, we would like to propose to leave it as it is. If in doubt, this could be finally checked in proof reading.

- Section 4: Since the full "New Zealand" is used throughout the manuscript I would suggest to use it also here and avoid the abbreviation NZ (e.g. lines 304, 306, 310)

  We deleted the abbreviation and added the full name as in the sections above for the first use of Lauder (original line 304) and Invercargill (original line 310) in that summary section, and deleted it completely for the second use of Lauder in that section (original line 306). Furthermore, three typos in that section were corrected: on original line 303 "Conclusion" to "conclusion,", on original line 318 "Aoetearoa" to "Aotearoa", and on original line 323 "Aeotearoa" to "Aotearoa".

References:

Ansmann, A., Tesche, M., Seifert, P., Althausen, D., Engelmann, R., Fruntke, J., Wandinger, U., Mattis, I., and Müller, D.: Evolution of the ice phase in tropical altocumulus: SAMUM lidar observations over Cape Verde, J. Geophys. Res., 114, D17208, https://doi.org/10.1029/2008JD011659, 2009.

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