Atmos. Chem. Phys. Discuss.,
doi:10.5194/acp-2017-226-RC1, 2017

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Classification of Arctic, Mid-Latitude and Tropical Clouds in the Mixed-Phase Temperature Regime" *by* Anja Costa et al.

Anonymous Referee #1

Received and published: 18 April 2017

This paper provides a statistical analysis of the microphysical properties of mixed phase clouds in three different areas of the globe: the tropics, the midlatitudes, and the Arctic. This paper is definitely a good fit for ACP and the results are timely, but I would like to see some concerns I have addressed before publication. The latter half of the introduction is worded in such a way that makes it look like there is no point to the study, which is clearly false. My largest concerns with the analysis are an inaccurate evaluation of the uncertainty due to shattered artifacts from the CIP probe and with a lack of discussion of the uncertainties associated with updraft velocity measurements, which can be on the order of 0.5 m/s for a given aircraft. The latter is especially important to the conclusions of the paper since the authors make several conclusions based

on p.d.f.s of vertical velocity that differ by less than this uncertainty.

Major concerns:

Page 4: The way the first paragraph is worded, a reader gets the impression that there are no advantages of using in situ observations over remote sensing for detecting the microphysical quantities of clouds since every technique out there has its flaws. It is not clear why you are using in situ measurements. For example, there are 4 sentences going into the flaws of shape identification algorithms in the first paragraph, and the CAS-DPOL is it's a good idea to say how the CAS-DPOL data helps to fill in the gap, but I think this should be emphasized more in this paragraph instead of 2 paragraphs down. Since the CAS-DPOL data in your paper are probably the most novel part of the paper, I would almost say that the limitations of current probes in identifying shape and the introduction of the CAS-DPOL and how it helps to provide a solution to this problem should be its own paragraph. I would also, after you mention the limitations of remote sensing measurements, go into some detail about how in situ measurements are the only direct way to measure the size, shape, and count of liquid and ice particles and are used to develop remote sensing retrievals. This would provide a better context as to why you specifically chose in situ measurements.

Lines 33-35, page 7: Why were the glaciated periods identified manually over using automated algorithms?

Line 12-14, page 8: While only 5% of the particles may be shattered artifacts as determined by IAT, these particles tend to be less than 500 microns in size. The sample volume of the CIP is significantly smaller for particles in this size range than for larger sizes, so any addition of smaller particles can easily change the number concentration by potentially a few hundred percent. Therefore, it is misleading to think that shattered artifacts would only have a 5% impact on the number concentrations. For example, Jackson et al. (2014) have shown that using IAT algorithms on 2DC probes with K-tips reduces the number concentration down by a factor of 2. Therefore, I think an analy-

sis of how different the number concentrations are when the IAT algorithm is used and when it's not provides a better way to quantify the uncertainty due to shattered artifacts.

Line 5, page 9: This analysis really needs to go into more detail as to how the modes were determined, because while the authors identify two modes in their data, a reader can look at Figure 6 and see at least five, with three in the Type 1 region alone. How were the number of modes determined? How did you determine where the overlap region is between the modes? Does the smallest mode really have a peak at 10-4 cm-3? It looks like it's more around 10-1 cm-3 if the two modes are defined as they are in Figure 6.

Line 10, page 9: Figure 7 shows data from all campaigns, not just VERDI, since it does not look like there is any data at < 255 K for the Arctic in your dataset.

Line 29, page 10: I do not think that you can exclude primary nucleation as a source of the ice particles shown. What Figure 10 shows is that the ice particle concentrations exceed ice nuclei concentrations by orders of magnitude, which shows that secondary production is likely occurring. It does not, though, exclude primary nucleation from also contributing to the observed concentrations. However, it would be safe to assert that primary nucleation does not make a large contribution to the number of ice particles observed.

Lines 21-26, page 11: Do you have any more in depth statistics for the amount of irregular particles as a function of temperature for the Type 1 and Type 2 clouds. I think two extra panels on Figure 11 showing how many spherical vs. irregular particles you identified for each of the cloud types would be of great use.

Section 3.5.1. You go into x% are weak updrafts versus very low updrafts. To me, it looks like, in general, |w| < 1 m/s, indicating weak vertical motion throughout, which would be expected with stratiform clouds. Given that the uncertainty in measured w from aircraft is on the order of 0.5 m/s, I would argue that the difference between the four curves is within measurement uncertainty and that there are no real differences

between them. The same applies for the other two panels as well.

Page 13, lines 12-13: You can't determine this by looking at Figure 13 alone, since you have no observations < 255 K, and the observations of INP concentration at > 255 K actually look higher in the Arctic than in the midlatitudes.

Page 14, lines 1-5: I would argue all 4 vertical velocity p.d.f.s differ by less than the uncertainty in the measured vertical velocities, and hence, the differences seen are not statistically significant.

Figure 14: I honestly do not think this figure adds a whole lot to the paper outside of saying that the arctic is colder than the midlatitudes which is colder than the Tropics. I think this can generally be assumed and Figure 14 removed.

Minor changes:

Line 7 of Abstract: "clouds," should be "clouds;"

Lines 9-11: p.2. Run-on sentence. I would suggest fixing this up.

Line 15: p.2. "Formed" → "forms"

Figures 7/8: Scale needed for CIP images. Do the habits change with temperature? I think that information would be useful to provide. Also, 275 K is above freezing. Are you sure you are observing ice at that temperature?

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