

Authors' response to Anonymous Referee #2 comments on “Using depolarization to quantify ice nucleating particle concentrations: a new method” by Jake Zenker et al.

The authors thank the anonymous reviewer for the detailed comments, published on Aug 9.

2017. In the response below, we address each of the suggestions of the reviews.

Referee Comment: The paper reports a new method, based on depolarization ratio, to enhance the calculation of ice nuclei concentrations in the occurrence of water droplet breakthrough. The method seems to be specific to the CFDC at Texas A&M University and to be applicable only in laboratory settings. For this reason, the wide applicability of the method might be limited. Despite that though, the issue to solve is an important one, especially considering the large uncertainties in the field of ice nucleation research. In addition, the technical work done for this comparison is considerable and involved also a modeling aspect. Therefore, I think the paper should be published. Overall the approach seems sound and well developed. Some clarification would be helpful in some instances, but overall the paper is well written.

Authors' response. Thank you for your positive review. We have revised the manuscript in order to provide clarification in the specific instances below.

Referee Comment: Some specific, rather minor comments:

1. Maybe I missed it, but I do not recall seeing mention of the specifications of the light source in the CASPOL (wavelength, polarization, source, e.g. laser etc.).

Authors' response. The light source is a linearly polarized 680 nm laser.

Authors' changes in manuscript. Added on pg 6 ln 20, "Laser light (680 nm) is scattered by single particles entering the CASPOL and detected by three detectors..."

Referee Comment 2: On page 5 the authors describe the APC chamber, how are clouds produced in it, also through adiabatic expansion?

Authors' response: No. To clarify, in this experiment, no clouds are produced in the APC chamber during the experiment. The APC is used to provide a uniform high concentration of aerosols generated by filling the APC chamber with aerosols produced by atomization and solid aerosol generation methods. The ice cloud particles sampled by the CFDC-CASPOL are produced within the CFDC's processing chamber under conditions of controlled saturation conditions produced by varying the temperature gradient between the inner and outer iced walls of the chamber.

Authors' changes in manuscript: On pg 4, ln 28, the text now reads, "The APC was used during FIN02 to provide a uniform high concentration of aerosols of various compositions, which were generated by filling the APC chamber with aerosols produced by atomization and solid aerosol generation methods and were subsequently distributed to the participating ice nucleation instruments"

Referee Comment 3: It would help to have some more detail on what causes the water droplet breakthrough, in what conditions, why it happens at different conditions in different instrument etc. For example around page 8 or so.

Authors' response: Thanks for this good suggestion. Water droplet breakthrough is the term used to describe the arrival of droplets reaching the detector of an ice nucleation chamber where they will be miscounted by most as ice particles by most detection methods. This arises when the chamber is operated under supersaturation conditions and supercooled droplets form in the initial sections of the processing chamber. Most CFDC designs include a section following growth chamber, referred to as an evaporation region. The evaporation region is maintained under conditions at which the Bergeron process is active, that is conditions, which are subsaturated with respect to droplets. Thus, droplets shrink or evaporate entirely while at the same time the conditions are supersaturated with respect to ice, allowing ice crystals to grow.

The specific conditions of the evaporation chamber vary from instrument to instrument. Another cause of differences in WDBT between instruments is the selection of the size cut-off for distinguishing INPs by size alone. For example, using the traditional strategy of relying on a nominal size-cutoff to define INP, if an operator chooses 2 microns as the diameter above which all particles are presumed to be ice, then a water droplet need only be 2 microns in diameter to "break through," whereas if the operator chooses a 5 micron size cut-off same detector operating under all the same conditions, only water droplets will necessarily have to grow to 5 microns to break through and be miscounted as ice. So, it is the combination of chamber dimensions, flow rates, operating conditions (temperature and supersaturation) in the growth and evaporation regions, and choice of detector and size cut-off which collectively determine WDBT for a certain instrument.

Authors' changes in manuscript: Page 8 has been revised to include addition details, "WDBT is a common issue in continuous flow ice nucleation instruments, although the point at which WDBT occurs varies between instruments of differing dimensions and even as a function of operating conditions (especially temperature) within a single instrument (Rogers et al., 2001, DeMott et al, 2015, Garimella et al., 2016). CFDCs in use today are custom-built instruments which vary in physical dimensions and choice of detector, although all operate under the same basic principles. Due to the combination of chamber dimensions, flow rates, operating conditions (temperature and supersaturation) in the growth and evaporation regions within the instrument, and the choice of detector and size cut-off, WDBT varies from instrument to instrument. In some cases, it can be difficult to determine when WDBT is occurring, and if the instrument is unintentionally operated at supersaturations above WDBT, droplets will be miscounted as ice crystals."

Referee Comment 4: On page 9 on the first line: "precisely" seems a bit too strong; also LIDARs will have some finite field of view.

Authors' response: We think our point is best made by keeping "precisely" here to emphasis the difference in backscattering angle of the lidar at 180° from the CASPOL backscatter at 168° to 176°.

Referee Comment 5: Still on page 9, the authors mention oil as having a similar real part of the imaginary index of refraction. I would think oil might have a different imaginary part of the index of refraction, with respect to water (also depending on the wavelength of the CASPOL).

Maybe this is completely negligible, but could the absorption make any difference in the measurements or numerical simulations?

Authors' response: The uncertainty in sizing due to differences in the complex refractive indices of oil and water are up to 30% based on a comparison of VOAG oil droplet calibrations of CASPOL performed in our laboratory in comparison to the manufacturer's water-based CASPOL size calibrations (with the oil droplets being overestimated). This is discussed in detail in our previous work (Glen and Brooks, 2013). Comparable uncertainties are expected for the simulations.

Authors' changes in the manuscript: Added "As reported in Glen and Brooks (2013), the uncertainty in sizing due to differences in the complex refractive indices of oil and water are up to 30% based on a comparison of VOAG oil droplet calibrations of CASPOL to water-based calibrations performed by the manufacturer."

Referee Comment 6: Page 10, line 7: remove "both"

Referee Comment 7: Page 11, line 9 to 12. This sentence is not very clear to me.

Authors' response: We have revised this text.

Authors' changes in manuscript. The text now reads, "Each training dataset contains some particles that are highly backscattering and some particles that are highly depolarizing, but only the ice crystal population contains particles that have both a high depolarization ratio and high backscatter signal."

Referee Comment 8: Referring to figure 1, it seems like the total backscatter signal should have parenthesis in the label of the y axis.

Author Response: This has been changed as suggested by the Referee.

Referee Comment 9: Page 13, line 12, why is 1.75 μm an upper limit for the CFDC? Are there some data on this item, or some published values?

Authors' response: The CFDC's standard procedure is to operate with a cyclone impactor installed at the inlet which removes particles larger than 1.75 micron diameter. This was mentioned earlier but not on page 13.

Authors' changes in manuscript. This sentence has been removed because aerosol calculations for larger sizes are included to address a different Referee suggestion.

Referee Comment 10: Page 13, lines 24-26 and related figures: maybe I missed it, but how were the size distributions measured?

Authors' response: The forward scattering detector of the CASPOL detects particles on an individual basis and sorts those particles into a series of size bins ranging from 0.6 to 50 micrometers optical diameter.

Authors' changes in manuscript. Details above are now included on pg 7, ln 4.

Referee Comment 11: Page 16, line 24, I think "large" should be "larger".

Authors' response: Changed.

Referee Comment 12: Page 17, line 3, it seems like a "different" is missing when discussing the "statistically significant..."

Authors' response: We agreed. Added.

Referee Comment 13: Page 18, line 7, "like" should be "likely"

Authors' response: Corrected.

Referee Comment 14: I found the section 3.7 hard to read and to follow. I am not sure what to suggest. Maybe a schematic of the algorithm would help, but as is, for me, it is very difficult to follow.

Authors' response: For clarity, we've structured the text and added details throughout the section to guide the reader. Further, we've added a table that lays out how the training datasets are generated. There were specific points of confusion pointed out by other referees that we addressed here that strengthen the paragraph as well.