Atmos. Chem. Phys. Discuss.,
https://doi.org/10.5194/acp-2020-556-RC3, 2020

Atmospheric Chemistry and Physics Discussions

ACPD

Interactive comment

Interactive comment on "Ice nucleating particle concentrations of the past: Insights from a 600 year old Greenland ice core" *by* Jann Schrod et al.

Anonymous Referee #3

Received and published: 14 July 2020

Review of Ice nucleating particle concentrations of the past: Insights from a 600 year old Greenland ice core

In this study Schrod et al, present the ice nucleating particle (INP) concentrations from a Greenland ice core spanning the past 600 years. The collected data set shows that the concentration of INPs has been rather consistent over the past 600 years. However, since 1960, the concentration and variability in INPs has increased. This has led the authors to suggest that human activities may be influencing INP concentrations, which could have significant impacts on future cloud radiative forcing. I appreciate that the authors are very careful in not over interpreting their results and are very thorough

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in addressing potential issues with conversions and contamination. I support the publication of this manuscript and provide some minor technical revisions. Additionally, I think it would be very interesting to extend the analysis to investigate the role of changing atmospheric circulation and rising arctic temperatures may have on the observed changes in INP concentration in this ice core sample.

General comments:

Although all layers of the ice core were treated the same and likely experienced similar temperature variabilities while accumulating on the ice sheet, it would be worthwhile to mention the recently found impacts of the storage on INPs relative to freshly collected samples. For example see Beall et al., (2020) and Stopelli et al., (2014). As the long term storage of the INPs in the ice may contribute to the observed difference between the ice core samples and precipitation samples shown in (Petters and Wright, 2015).

As each of the samples used to probe the concentration of INPs every 10 years only covers a period of 6 months, is the 6 month period roughly the same for each of the 10 yr samples? Based on Fig. 6, the variability over a year (monthly sample from 1463-64) looks to be about an order of magnitude. Therefore, if the 6 months covered by a 10 yr sample differs, some of the variability between the 10 yr samples, albeit a small amount, could be explained.

The same question is also relevant for the modern day samples (Fig. 7) where there are some years with higher activity than others. It would be important to know if the yearly samples (actually only 6 months) cover the same 6 month period for each year.

Here it is shown that the Anthropocene samples are significantly different from the pre-industrial samples. This is a very interesting finding and something that the authors suggest may be due to a change in the dust due to desertification, and other anthropogenic related aerosols that reach the Greenland ice sheet. Although these seem like possibilities, it would be interesting to discuss the potential influence from changes in atmospheric circulation patterns such as the NAO (Pinto and Raible, 2012).

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Additionally, it has been shown that precipitation effectively removes precipitation (Stopelli et al., 2015) and as the ice core site is at a high altitude arctic site, it may be extremely sensitive to the temperature and amount of precipitation that falls (removal of INPs) upstream of the site. The fact that an overall increase in IN activity has been observed in more recent, warmer years may be consistent with warmer air masses precipitating over the ice sheet where fewer INPs have been removed upstream compared to previous (colder) years. Therefore, it may be worthwhile to compare the INP concentrations with the reconstructed temperature record over the same period from the ice core.

Minor comments:

Page 3, line 3: Consider adding the following references: Grawe et al., (2016, 2018); Kanji et al., (2020); Ullrich et al., (2016)

Page 3 line 14: Consider adding the following references: Hill et al., (2016); Steinke et al., (2016)

Page 3 line 20: It is highlighted here that the dominant dust sources in Greenland ice cores come from Chinese deserts and the Taklamakan. Therefore, it would be might worthwhile to discuss the observed ability of these mineral dusts to act as INPs. Do they match in terms of INA with the observed INPs found in the ice cores (it seems like they do)? Consider mentioning previous studies on INPs from this region such as Boose et al., (2016); Field et al., (2006); Paramonov et al., (2018); Ullrich et al., (2016).

Page 6 line 14: change “must” to “does”

Page 6 line 20-21: why was the seasonal variability explored in the 1463? Is there a reason for choosing this period? Wouldn’t a more recent year make it easier to identify the months of the year as the ice is less compact?

Page 6 line 28: “hast” should be “has”

Page 7 line 5: consider rephrasing “picked up” to “pipetted”

Page 7 line 7-8: Why is FRIDGE kept at 14 C initially? Based on what was stated earlier, the samples were defrosted at 6 C, so why wasn't FRDIGE set to 6 C to minimize the temperature range a sample was exposed to. Granted, all of the samples experienced the same treatment so this likely has no impact on the overall comparison between samples.

Page 7 line 8-10: Do you mean that the Lauda cryostat was used to dissipate heat from the Peltier element. Please rephrase this sentence to make that clearer.

Page 7 line 11: Does the synthetic air flush change the size of the droplets during the experiment via evaporation? If yes, would this be significant enough to increase the concentration of solutes in a droplet such that it may lead to a freezing point depression in the samples? In theory, the colder the cell gets (the longer the experiment lasts) the more concentrated these solutes would become.

Page 7 line 18: Here you mention mL of meltwater but then use mLice when reporting INP concentrations. Consider making the terminology consistent.

Page 8 line 6: Why was the SEM analysis conducted on the samples after being filtered (400 nm pore size) when the highest correlation between INP concentration and particles concentrations was for particles larger than 1.2 microns? Do these large particles make it through the filter?

Page 8 line 27: Check if "microscopical" should be "microscopic" in this case.

Page 9 line 29: Here it is mentioned that the freezing and melting of the same droplets does not influence the ice nucleating ability of the samples. As previously mentioned in the general comments, it might be worthwhile to mention other studies where it was shown that over longer periods, the storage and repeated melting and freezing of samples influenced the ice nucleating ability of samples.

Page 12 line 22: Remove extra "/" after gprecip in first term of equation

Page 14 line 8: please specify that this is the concentration at -20 C as mention of -20

C comes two sentences earlier.

Page 16 line 10-11: How do these large particles make it through the 400 nm pore sized filters described in the methods?

Page 16 line 27: Here it is mentioned that there is a seasonal cycle in INP and although the variability is significantly less than the over the entire period of the study, it may be worth mentioning if the 6 month samples are taken to over the same 6 months in every time point (as said in the general comments).

Page 17 line 15-25: Could some of the differences in the INP concentrations be due to the droplet size used in the studies? Perhaps the small droplet volume in this study makes the measurement of rarer INPs less quantifiable. Additionally, could location differences between sampling sites, lead to differences in the number and efficiency of INPs removed upstream of the sites (Stopelli et al., 2015). For example, Svalbard often experiences periods of relatively warm air masses laden with INPs that would precipitate out before reaching the high altitude location of this core. These points, although briefly mentioned, could be expanded on.

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