Responses to reviewer comments on the article "High ice-nucleating particle concentrations associated with Arctic haze in springtime cold-air outbreaks".

Response to comments by reviewer 1

We thank the reviewer for their general comments and address their specific comments below.

Reviewer comment:	Line 17: a bit weird that the "b" version of the Fletcher paper shows up first before the "a" version. --This may just be a citation manager software type of detail and not a big deal but it caught my eye.
Our response:	This is due to ACP's style for citations, where papers in the same year by a team with the same lead author are ordered chronologically, rather than by first appearance in the paper.
Old Text (if changed): *Location:*	N/A - No change made.
New Text (if changed): *Location:*	
Reviewer comment:	Line 58: "th" should be "the"
Our response:	Corrected.
Old Text (if changed): *Location: line 58*	…which results in th build-up of Arctic Haze…
New Text (if changed): *Location: line 60*	…which results in the build-up of Arctic Haze…
Reviewer comment:	Line 61: the part starting with "understanding" should likely start as a new sentence.
Our response:	Changed.
Old Text (if changed): *Location: line 61*	Since different types of INPs have different characteristic ranges of freezing temperatures (Kanji et al., 2017), understanding the aerosol sources…
New Text (if changed): *Location: line 63*	Different types of INPs have different characteristic ranges of freezing temperatures (Kanji et al., 2017). This means understanding the aerosol sources…
Reviewer comment:	Line 85: "subsequent" may work better than "later" here in the sentence. Not a big deal to change.
Our response:	Changed.
Old Text (if changed): *Location: line 85*	…were collected for specific periods for later offline analysis.
New Text (if changed): *Location: line 89*	…were collected for specific periods for subsequent offline analysis.
Reviewer comment:	Line 92: would sound better to say "..each inlet so that different.."
Our response:	Changed.
Old Text (if changed): *Location: line 92*	A different type of filter was used in each inlet in order that different types of analysis…
New Text (if changed): *Location: line 95*	A different type of filter was used in each inlet so that different types of analysis…

Reviewer comment:	Line 111: Can the aircraft really sample on a filter as low as 10 m? Seems highly unlikely for safety reasons so clarify better here what you mean about this lower bound of the altitude range.
Our response:	The aircraft can descend to a minimum height of 50ft (15.2m). Rather than give order of magnitude numbers, replace with the actual highest and lowest samples of the campaign.
Old Text (if changed):	The altitude of filter measurements was between 10–4000 m and all samples were taken in air with no cloud or precipitation.
Location: line 111	
New Text (if changed):	The altitude of filter measurements was between 40–3400 m and all samples were taken in air with no cloud or precipitation.
Location: line 117	
Reviewer comment:	Line 164: "Portions of filters…" might work better here
Our response:	Changed.
Old Text (if changed):	Portions of filter were mounted on…
Location: line 164	
New Text (if changed):	Portions of the filters were mounted on…
Location: line 174	
Reviewer comment:	Line 196: "CDP data have"
Our response:	Changed.
Old Text (if changed):	…CDP data has only been used…
Location: line 196	
New Text (if changed):	…CDP data have only been used…
Location: line 204	
Reviewer comment:	Line 253: "plumes" spelled wrong
Our response:	Corrected.
Old Text (if changed):	In dust plums emerging from Africa…
Location: line 253	
New Text (if changed):	In dust plumes emerging from Africa…
Location: line 282	
Reviewer comment:	Line 277: "CDP data were…"
Our response:	Changed.
Old Text (if changed):	…where PCASP and CDP data was available.
Location: line 277	
New Text (if changed):	…where PCASP and CDP data were available.
Location: line 308	
Reviewer comment:	Line 283: "were approximately constant at.."
Our response:	This was unclear, we have clarified this further.
Old Text (if changed):	…aerosol concentrations were approximately constant to 7500 m.
Location: line 283	
New Text (if changed):	…aerosol concentrations were approximately constant from the surface up to 7500 m.
Location: line 314	
Reviewer comment:	Line 297: ", ." needs to be fixed
Our response:	Superseded by changes made in response to Reviewer 2
Old Text (if changed):	N/A
Location: line 297	
New Text (if changed):	N/A

Location: line 334	
Reviewer comment:	Line 390: It'd be good to report which meteorological dataset was used in the HYSPLIT software to obtain trajectories and what the native spatial resolution is of that dataset. This can be helpful to others interested in doing similar analyses.
Our response:	Agree, have inserted this.
Old Text (if changed):	…(HYSPLIT) (Stein et al., 2015). The backward…
Location: line 390	
New Text (if changed):	…(HYSPLIT) (Stein et al., 2015). Meteorological data from the Global Data Assimilation System (GDAS) at 1° resolution was used to obtain the trajectories. The backward…
Location: line 436	
Reviewer comment:	Line 489: "…measurements during specific meteorological.." may work better here
Our response:	Changed.
Old Text (if changed):	…targeting INP measurements on specific meteorological events since…
Location: line 489	
New Text (if changed):	…targeting INP measurements during specific meteorological events since…
Location: line 554	
Reviewer comment:	Line 503: "…campaign raise…"
Our response:	Changed.
Old Text (if changed):	…ACAO campaign raises important questions…
Location: line 503	
New Text (if changed):	…ACAO campaign raise important questions…
Location: line 567	
Reviewer comment:	Line 517: what are examples of these regions you are encouraging more work to be done for? Would be nice to share explicitly a few example.
Our response:	We have rephrased this to make clearer what we mean.
Old Text (if changed):	We recommend that more aircraft measurements are made in regions where measurements of INP concentration have previously been dominated by ground studies in order to better understand the relationship between cloud properties and INPs.
Location: line 517	
New Text (if changed):	We recommend that more aircraft measurements are made in air of direct relevance to clouds in order to better understand the relationship between cold-air outbreak cloud properties and INPs.
Location: line 580	
Reviewer comment:	Line 522: "Flight data from the …., are stored…"
Our response:	Changed.
Old Text (if changed):	Flight data from the FAAM aircraft for flights c271–c279, is stored on the CEDA…
Location: line 522	
New Text (if changed):	Flight data from the FAAM aircraft are stored on the CEDA…
Location: line 604	
Reviewer comment:	Line 523: "…data….are stored…"
Our response:	Response: This change has been made redundant since all flight data are now stored at the same URL thanks to a change on the CEDA system.
Old Text (if changed):	N/A
Location:	
New Text (if changed):	
Location:	

Reviewer comment:	Table 2: I would suggest the authors define the four column headers on the far right of table in the caption.
Our response:	Agree. Additionally, the order of elements in the caption now matches the order of columns in the table.
Old Text (if changed): *Location: Tab. 2 caption*	Factors of change in the INP concentration at -15 °C, total aerosol surface area and INP concentration normalised by surface area at -15 ◦C between three pairs of below-cloud filter measurements.
New Text (if changed): *Location: Tab. 2 caption*	Factors of change in the INP concentration at -15 °C (F_{INP}), INP concentration normalised by surface area at -15 °C (F_{S}) and total aerosol surface area (F_{aer}) between three pairs of below-cloud filter measurements.
Reviewer comment:	Table A1: Suggest the authors define some of the column headers in the caption like a, b, vINP.
Our response:	We have adjusted the caption to clarify which parametrisations the columns refer to and direct the reader to longer definitions of the symbols which are used and defined in the main text. In the final version, the table will be nearer to the definitions, so we hope it will be easier for readers to find the definitions.
Old Text (if changed): *Location: Table A1 caption*	Parametrisations of INP concentration and INP concentration normalised by surface area according to Eqs. 4 and 5 respectively. There is no…
New Text (if changed): *Location: Table B1 caption*	Values of parameters that describe INP concentration (N_{INP}) and INP concentration normalised by surface area ($N_{\mathrm{INP}}/S_{\mathrm{aer}}$) using Eqs. B1 and B2 respectively. There is no…
Reviewer comment:	Throughout paper, it seems that the flight numbers are written in a different font which should be fixed.
Our response:	Changed
Old Text (if changed): *Location:* throughout	N/A
New Text (if changed): *Location:*	N/A

Response to comments made by reviewer 2.

We would like to thank the reviewer for the detailed feedback that has both improved the argument of this paper and the clarity with which the science is communicated. Additionally, we thank the reviewer for drawing our attention to several interesting recent papers which we have included reference to. Below, we respond to their general and specific comments.

Reviewer comment:	To support the presence of the proposed efficient INP reservoir (other than higher concentrations than previously observed) and to improve the readability of the manuscript, the way the individual flight data is presented should be improved. More specifically, it is impossible to understand the significance of where the INP measurements were taken relative to the meteorological/cloud conditions with this flight nomenclature. To remedy this, please group the INP spectra and corresponding aerosol size distributions by location with respect to the cloud/ boundary layer with a similar color as was done in Panel a of Figure 2 or change the naming of the flights (I know it is nice to keep the naming convention for other ACAO papers, but like this is it very difficult to

	interpret the results). This type of grouping should be done consistently throughout the manuscript.
Our response:	We agree that changing the presentation of flight data would improve the paper. Figures 3, 5, and 7 have been adjusted so that filter samples are coloured according to their location relative to the cloud. The use of colours for flights and symbols for sample location in Figure 10 (now Figure 9) has also been swapped to be consistent with this. Figures 1 and 6, as well as the caption of Figure 7, now refer to the meteorology of the flights. Versions of Figures 3 and 5 where each filter is individually identifiable have been moved to a new Appendix A, where they form Figures A1 and A2 respectively. Throughout, we have made greater reference to the meteorological conditions, and have clarified the relationship between sample locations and the boundary layer. Specific changes to the text are described in the responses to minor comments.
Old Text (if changed):	
Location:	
New Text (if changed):	
Location:	
Reviewer comment:	As a follow up, it would also be nice to present the spectra from a flight in series if possible ie from the upwind and downwind of the cloud as well as the cloud top temperature if available to understand how the INP were processed by the cloud/ removed by precipitation. At the moment, only a comparison at -15C is done but the entire spectra would be interesting to see. This would also help support the argument that washout/INP removal is the reason for the lower INP concentrations observed at the Norwegian coast by Geerts et al., (2022)
Our response:	We agree that highlighting a case where INP measurements were taken in series would strengthen the arguments about washout and removal. We have plotted the spectra from Figure 10, as well as the differential between them. We insert the following new paragraph describing this figure.
Old Text (if changed):	N/A
Location:	
New Text (if changed):	During flight c280, two pairs of above and below-cloud filter samples were taken along the same wind trajectory (Figure 1b). The northern pair were taken where the clouds had stratocumulus forms, whereas the southern pair were taken where the clouds were in the cumulus regime. Comparing the INP spectra for these samples in Figure 10 shows that except at the very highest temperatures, where the error is large, there is little difference between the samples taken above and below the stratocumulus (c280r1 and c280r2, respectively) and the sample taken above the cumulus (c280r3). Closeness between the three INP measurements may be expected if the main INP source entering the system is upwind of the CAO clouds. However, the southern sample taken below cumulus (c280r4) has over five times fewer INPs at temperatures below -11°C.
Location: line 418	
Old Text (if changed):	N/A
Location:	
New Text (if changed):	Panel **a** shows the four filter samples taken during flight c280 and describes their location relative to either stratocumulus (Sc) or cumulus (Cu) cloud. Panel **b** shows their INP concentrations relative to c280r3 (the
Location: Fig 10 caption	

	sample taken above cumulus) for the temperature ranges which they can be compared.
Reviewer comment:	It is my understanding that there were other INP measurements ongoing during ACAO related to HALO AC3 and ISLAS. Is it possible to compare with any of the INP measurements during those simultaneous campaigns rather than relying on past measurements from previous years? That said, there are several other INP measurements from the Arctic that should be added to the discussion including some that do not rely on the filter washing technique (e.g. Gjelsvik et al., 2024; Li et al., 2022, 2023; Rinaldi et al., 2021), or more generally that have taken place in the last few years in the study region (e.g. Freitas et al, 2023). These studies should be included in the discussion as they both support the authors hypothesis and offer conflicting results.
Our response:	ISLAS did not have any INP measurements. We have contacted members of the HALO-AC3 campaign who have told us that they are yet to analyse INP measurements made on the Polar 5/6 aircraft. We have added INP measurements from the Li and Rinaldi papers to Figure 3 and its associated discussion and referred to the Pereira Freitas and Gjelsvik papers. Specific changes to the text are described in the responses to individual minor comments.
Old Text (if changed):	N/A
Location:	
New Text (if changed):	N/A
Location:	
Reviewer comment:	I understand that the authors would like to include some fits to their data for implementation into models, but I found the location of this a bit distracting. I would consider moving the parameterization section to the Appendix or maybe move it to later on in the discussion? From my point of view, there is already enough really nice science in this paper and if the focus were to shift solely on the analysis on the INP variability with the CAO and meteorology/cloud fields, that would be enough for a great paper.
Our response:	We agree that Section 3.5 disrupts the flow of the paper but think the fits provided will be useful for future modelling of case studies. We have moved Section 3.5 and Figure 9 so that they are now Appendix B and Figure B1 respectively, but have included a median fit to the INP concentration in Section 3.1 in order to help modellers and data users more readily retrieve this information.
Old Text (if changed):	…recording an INP concentration below 0.1 L^{-1} at -15 °C (c273r2). Figure 4 shows that…
Location: line 214	
New Text (if changed):	…recording an INP concentration below 0.1 L^{-1} at -15 °C (c273r2). The median CAO INP concentration during the campaign, $\bar{N}_{\mathrm{INP}}$ was described by the function $$\bar{N}_{\mathrm{INP}} = \bar{\nu}_{\mathrm{INP}} \cdot \exp\left[\bar{a}\,(\bar{T}_{\max} - T)^{\bar{b}}\right],$$ with fitting parameters $\bar{\nu}_{\mathrm{INP}} = 1.480 \times 10^{-2}$ L^{-1}, $\bar{T}_{\max}$= 266.2 K, $\bar{a} = 1.271$ $K^{-0.5}$ and $\bar{b} = 0.5$. The fitting procedure used to obtain $\bar{N}_{\mathrm{INP}}$ is described in Appendix B, along with similar four-parameter fits for each individual filter measurement. Figure 4 shows that…
Location: line 222	
Reviewer comment:	Line 28-30: Is it really necessary that there are more cloud droplets than ice crystals for WBF to occur? Consider rephrasing this.
Our response:	Rephrased.

Old Text (if changed): *Location: line 28*	Since ice crystal concentrations are typically lower than liquid droplet concentrations in mixed-phase clouds, ice crystals are able to grow through this process to sizes at which they can precipitate, enhancing precipitation (Bergeron, 1935; Findeisen, 1938).
New Text (if changed): *Location: line 28*	Through this process, ice crystals are able to grow to sizes at which they can precipitate, enhancing precipitation (Bergeron, 1935; Findeisen, 1938). Since ice crystal concentrations are typically lower than liquid droplet concentrations in mixed-phase clouds, this process can be highly efficient.
Reviewer comment:	Line 55: Could cite e.g. Pereira Freitas et al., (2023) here
Our response:	Agree.
Old Text (if changed): *Location: line 56*	…sandy deserts in Iceland (Sanchez-Marroquin et al., 2020), boreal forests (Brasseur et al., 2022) and thawing permafrost (Creamean et al., 2020).
New Text (if changed): *Location: line 58*	…sandy deserts in Iceland (Sanchez-Marroquin et al., 2020), boreal forests (Brasseur et al., 2022), Arctic surface vegetation (Pereira Freitas et al., 2023) and thawing permafrost (Creamean et al., 2020).
Reviewer comment:	Line 58 – 60: Could be worth mentioning other studies who have looked at INPs in CAOs like during AGASP2 (Borys, 1989; Borys and Grant, 1982) already here.
Our response:	Response: It is not clear from the Borys paper that the AGASP-2 measurements were made in CAO conditions, but we do discuss their measurements of INP in Arctic Haze in the discussion. Similarly, although Borys' 1982 thesis discusses IN measurements in multiple Arctic locations in the winter, and some of the sourcing, the measurements were not targeted to CAO conditions and does not appear to differentiate IN concentrations between CAO/non-CAO.
Old Text (if changed): *Location:*	N/A
New Text (if changed): *Location:*	N/A
Reviewer comment:	Line 66: Consider adding Gjelsvik et al., (2024) here
Our response:	Agree.
Old Text (if changed): *Location: line 67*	INP measurements have been made in CAOs from the ground in the northern hemisphere (Geerts et al., 2022)…
New Text (if changed): *Location: line 70*	INP measurements have been made in CAOs from the ground in the northern hemisphere (Geerts et al., 2022; Gjelsvik et al., 2024)…
Reviewer comment:	Line 80-84: Consider including a table or something describing the flights and the associated meteorology instead of a list like this. Also as previously mentioned, would be nice to use a different naming convection that is more easily linked to meteorology or date etc. I now realize this shows up in Table 1, it would be really nice if this could be made a bit more compact and moved into the text instead of at the end of the manuscript.
Our response:	Response: In the final version, this will be in-place in the text, but the Copernicus LaTeX template automatically sends tables to the end. We think it will be useful for people who wish to use these results in their own studies to be able to quickly see the time and location of each of the flights, especially given that there were other campaigns happening in the same region at the same time, so we leave Table 1 as is.
Old Text (if changed): *Location:*	N/A

New Text (if changed): *Location:*	N/A
Reviewer comment:	Figure 1b: Was this a flight day? If yes can you add the corresponding flight track and sampling locations? If not, can you choose an example when the samples were being taken? I think it would be very helpful to have context about how the cloud field looked and where the sampling took place with respect to it. I know this can be tricky with MODIS overpasses but it should be doable this far north within an hour or two of the actual flight time.
Our response:	Response: Figure 1 has been modified such that panel (b) now shows the appropriate flight track and sampling locations from that day. Note the day has now changed from 30/03/22 to 29/03/22 – both were flight days but using the 29th facilitates discussion of flight c280, following on from the reviewer's major comments. Changes to caption described in next response.
Old Text (if changed): *Location:*	
New Text (if changed): *Location:*	
Reviewer comment:	Figure 1c: Is there some purpose to this flight coloring? Please choose a color scheme that is meteorologically/time relevant etc and then stick with it throughout for the flight tracks/ filter samples if possible.
Our response:	*Response: In the updated figure, we have chosen to colour according to meteorology when referring to flights in 1c. When referring to filter legs in other figures, we colour according to the filter leg's location relative to cloud.*
Old Text (if changed): *Location: Figure 1 Caption*	Figure 1. Panel **a** shows a schematic representation of an Arctic cold-air outbreak and the potential sources of aerosol to the cloud system. Stratiform cloud forms off the sea-ice edge and develops into cumulus cloud as the CAO airmass moves south. Biological and abiological INP are represented by green and red circles respectively, while aerosols that do not actively nucleate ice in CAOs are represented by grey and white circles. Panel **b** shows a satellite image taken on 30 March 2022 by the Moderate Reolution Imaging Spectroradiometer (MODIS) of a typical CAO measured during the ACAO campaign (MODIS Land Science Team, 2020). Sea-level pressure isobars from ERA5 reanalysis are overlaid (C3S, 2018). Panel **c** shows flight tracks from the nine flying days during the campaign. Sea-ice extent in this and other maps was obtained from the Multisensor Analyzed Sea Ice Extent dataset (U.S. National Ice Center et al., 2010). The flight track for flight c278 is incomplete due to equipment failure.
New Text (if changed): *Location: Figure 1 Caption*	Figure 1. Panel **a** shows a schematic representation of an Arctic cold-air outbreak and potential sources of aerosol to the cloud system. Green and red circles depict biological and abiological INPs respectively, while grey and white circles depict aerosols that do not nucleate ice in CAOs. Panel b shows satellite imagery taken on 29 March 2022 by the Moderate Resolution Imaging Spectroradiometer (MODIS) of a typical CAO measured during the ACAO campaign (MODIS Land Science Team, 2020). The path of flight c280, which probed this CAO, is overlaid along with the locations of INP filter samples, which were taken between 30 min and 2 h before the image time. Sea-level pressure isobars from ERA5 reanalysis are also overlaid (C3S, 2018). Panel **c** shows flight paths from all nine flying days

	during the campaign. Blue, pink and brown flight paths represent CAOs with predominantly N, NW and W flows respectively. Flight c272 probed a warm-air intrusion and is coloured grey. Sea-ice extent in this and other maps was obtained from the Multisensor Analyzed Sea Ice Extent dataset (U.S. National Ice Center et al., 2010). The flight track for flight c278 is incomplete due to equipment failure.
Reviewer comment:	Line 104: I know you normalize for the air sampled, but how do your maximum and minimum volume sampled filters compare with the other filer volumes sampled in terms of INP concentration? Is it completely random or does it look like there is some relationship between INP conc and volume of air sampled?
Our response:	We add the following to clarify this.
Old Text (if changed):	…while the smallest was (276±6) L. Handling blanks…
Location: line 105	
New Text (if changed):	…while the smallest was (276 ± 6) L. There was no correlation between the INP concentrations measured and the volume of air sampled by each filter. Handling blanks…
Location: line 110	
Reviewer comment:	Line 105-109: For the handling blank, was this done while in flight or at the ground i.e. was the filter exposed to the setup under flight conditions? If not, could there be any sources of contamination that would be identified at flight speed that is not found while sitting at the ground?
Our response:	We clarify this with the following change.
Old Text (if changed):	This was achieved by loading filters as normal into the aircraft filter holder system…
Location: line 106	
New Text (if changed):	These handling blanks were collected during the flight by loading filters as normal into the aircraft filter holder system…
Location: line 112	
Reviewer comment:	Line 113: If the sample time was set for 20 minutes, why did the volumes vary by so much? Did you have a different flow rate at different altitudes? It would be nice to have a table describing the sampling settings etc for each filter. I see this is in Table 1, but it might be nice to have more on this if it does seem to matter.
Our response:	**Part 1:** There is an imprecision in the text – flights were designed with 20 minute sampling periods but in practice the sampling time varied and we were often able to sample for slightly longer. We make the following change:
Old Text (if changed):	Sampling periods were approximately 20 min excluding pauses…
Location: line 113	
New Text (if changed):	Sampling periods were typically between 18–28 min excluding pauses where the aircraft turned or…
Location: line 119	
Our response:	**Part 2**: Secondly, we had reduced flow rate at higher altitudes. Additionally, as mentioned on lines 101—104, the two different meshes caused changes to the flow rate. We only noticed this from c275 onwards. As such, we can only infer which meshes were used on flights c271-c274 from the flow rate and altitude. We did not notice correlations between flow and INP concentration and so think that it would not be a helpful addition to Table 1 – as the reviewer mentions in a previous comment, there is already a lot of (hopefully useful!) information in this Table.
Old Text (if changed):	…flow rates were consistently greater through PTFE filters than polycarbonate filters. The largest…
Location: line 103	
New Text (if changed):	

Location: line 107	…flow rates were consistently greater through PTFE filters than polycarbonate filters. Flow through the filter was also dependent on altitude, with higher flow rates at lower altitudes. The largest…
Reviewer comment:	Line 118: But there was a flight where the filter was processed three days later, maybe mention that as it is the only filter with that kind of info in the table.
Our response:	Agree.
Old Text (if changed):	Filters were typically processed within hours to a day after collection.
Location: line 118	
New Text (if changed):	All but one of the filters was processed within 24 h of collection.
Location: line 126	
Reviewer comment:	Line 140-145: How about liquid impinger techniques? There are several studies in the Arctic that have used this method and been compared in Li et al., (2023).
Our response:	We have added reference to this.
Old Text (if changed):	…compared to other techniques (Hiranuma et al., 2019).
Location: line 144	
New Text (if changed):	…compared to other techniques (Hiranuma et al., 2019). Similarly, the wash-off technique has produced lower INP concentrations than a liquid impinger technique when measuring INP in the Arctic, which was attributed to the larger size cut-off of the impinger technique (Li et al., 2023).
Location: line 152	
Reviewer comment:	Line 158: Why is Af calculated and not a known quantity? Also, how much does Ad vary due to the precision of the pipettor used? Is the pipettor manual or automatic?
Our response:	**Part 1**: Insert type of pipette.
Old Text (if changed):	…were pipetted directly on to the filter.
Location: line 125	
New Text (if changed):	…were pipetted directly on to the filter using a manual electronic pipette.
Location: line 133	
Our response:	**Part 2**: insert uncertainties and clarify sentence.
Old Text (if changed):	…where V_a is the volume of air sampled, A_f is the surface area of the filter exposed to aerosol (11 cm^2) and A_d is the surface area of the filter in contact with a droplet (0.01357 cm^2). A_f and A_d were calculated using spherical cap geometry with a contact angle of 126° as in Price et al. (2018).
Location: line 158	
New Text (if changed):	…where V_a is the volume of air sampled, A_f is the surface area of the filter exposed to aerosol (11 ± 2 cm^2) and A_d is the surface area of the filter in contact with a droplet (0.014 ± 0.002 cm^2). A_d was calculated using spherical cap geometry with a contact angle of 126° as in Price et al. (2018).
Location: line 168	
Reviewer comment:	Line 191: Is it possible to compare the PCASP aerosol concentration/ surface area with that of the SEM analysis? Shouldn't these match quite closely?
Our response:	The PCASP-CDP size distribution is compared to the SEM analysis in Figure 7. The agreement between the two techniques is never one-to-one because both techniques require assumptions to get to particle size. This was discussed in our technique characterisation paper, which is cited (Sanchez-Marroquin et al., 2019). One reason for discrepancy can be the choice of refractive index, but the error associated with refractive index was small (choice of refractive index is discussed in section 2.4 with reference to Sanchez-Marroquin et al. 2019). We further discuss this by adding the following:

Old Text (if changed): *Location:*	N/A
New Text (if changed): *Location: line 342*	The aerosol number measured by the SEM is generally 2-4 times below the aerosol number reported by the PCASP and CDP probes, or shifted to about 30% smaller sizes. Previous studies using this technique have also found similar magnitudes of discrepancy between the techniques. In these cases, SEM has sometimes measured more particles than the optical probes, and sometimes less (Sanchez-Marroquin et al., 2020; Sanchez-Marroquin et al., 2021). Using a different SEM technique, Young et al. (2016) found the PCASP and CDP probes reported concentrations up to 100 times greater than SEM and attributed this larger discrepancy to measurements of cloud droplets or swollen aerosol since they sampled at high relative humidity (RH), often with RH > 90%. We discarded PCASP measurements made in-cloud or above RH = 80% to bias against swollen aerosol. However, even at RH = 80%, the diameter growth factor of typical organic aerosol has been reported between 20-50% (Martin, et al., 2003; Latimer and Martin, 2019). For sea salt, the diameter growth factor at RH = 80% has been reported between 60% and 100% (Tang, et al. 1997; Martin, et al. 2003; Murray, et al., 2012). Hygroscopic growth of these species might go some way to explaining our discrepancy. However, the measured size and number of the mineral dust particles should not be affected by humidity.
Reviewer comment:	Seems a bit out of place and redundant. Consider removing this as it is already state earlier in the methods.
Our response:	We were trying to emphasise the way this applies to the PCASP-CDP system. We have rephrased this.
Old Text (if changed): *Location: line 192*	Previous studies have found that the INP filter system may enhance coarse-mode aerosol number relative to measurements made by the PCASP-CDP probe (Sanchez-Marroquin et al., 2019; Barr, 2023). This discrepancy was minimised by fully opening the bypass line open as recommended by Sanchez-Marroquin et al. (2019). In addition, use of the larger pore filters results in a greater sample flow which further reduces sub-isokinetic sampling biases.
New Text (if changed): *Location: line 201*	Previous studies have found that the coarse mode aerosol number reported by the PCASP and CDP probes is suppressed relative to particles counted on filter samples using SEM (Sanchez-Marroquin et al., 2019; Barr, 2023). The use of larger pore filters and a fully-open bypass line (as described in Sect. 2.2) minimised this discrepancy.
Reviewer comment:	Figure 2: Panel b shows the INP concentration at -15 C. Also the lines are really small as are the flight labels.
Our response:	Labels and linewidths enlarged. Typographical error in caption corrected.
Old Text (if changed): *Location: Fig 2 caption*	… panel **b** shows the temperature at which an INP concentration of 0.5 L^{-1} was measured for each sample.
New Text (if changed): *Location: Fig 2 caption*	… panel **b** shows $N_{\mathrm{INP}}(-15\ °C)$, the INP concentration at -15 °C for each sample.
Reviewer comment:	Figure 3: As previously mentioned, this coloring is really difficult to interpret. Please consider presenting the results grouped by conditions or something to make the interpretation cleaner.

Our response:	Response: Results have been grouped by sample location relative to cloud. The previous figure has been moved to the appendix for those who wish to relate an individual sample to its measurements.
Old Text (if changed):	N/A
Location:	
New Text (if changed):	N/A
Location:	
Reviewer comment:	Line 234-245: As previously mentioned, there are also other ground-based measurements from Ny-Alesund, and in the same region as COMBLE (see major comments) that do not observe such high INP concentrations during this time of year. It would be worth mentioning these as they do not use the wash off method.
Our response:	Agree, these should be mentioned. We insert the following paragraph referring to them.
Old Text (if changed):	
Location:	
New Text (if changed):	Rinaldi et al. (2021) used two offline methods to measure INP concentrations sampled at a ground-based site near Ny-Alesund between April and August 2018. They found that using a Dynamics Filter Processing Chamber to measure INP concentration using condensation freezing yielded INP concentrations approximately eight times greater than those yielded by a droplet-freezing assay measurement using a wash-off technique. However, the highest concentrations measured by Rinaldi et al. (2021) were lower than the lowest observed during ACAO and were typically 1--3 orders of magnitude below those measured in this campaign. Similarly, Li et al. (2023) used several different techniques to measure INP at a Ny-Alesund ground site during October and November 2019. These included an impinger sampling method, a continuous flow diffusion chamber (CFDC) and a polycarbonate filter wash-off technique. These measurements had a much greater spread than those in ACAO and were typically 1--4 orders of magnitude lower. However, the measurement spread reduced at lower temperatures, and if extrapolated log-linearly, wash-off measurements were consistent with measurements made by the CFDC at $T = -30$ °C. Similarly, although the CFDC measurements were made at lower temperatures than INP measurements in ACAO, the two were consistent if the ACAO spectra were extrapolated log-linearly as the gradient of INP spectra in ACAO was lower than those measured by Li et al. (2023).
Location: line 259	
Reviewer comment:	Line 245-246: Consider citing Lacher et al., (2024) and Li et al., (2023) here as well as they also compared various offline measurement techniques.
Our response:	Agree, we have now referred to these papers.
Old Text (if changed):	…between different techniques for some INP types (Hiranuma et al., 2019). (Beall et al., 2020) report that biological INP…
Location: line 248	
New Text (if changed):	…between different techniques for some INP types (Hiranuma et al., 2019). Additionally, intercomparison of assay techniques on simultaneously-taken samples of ambient aerosol during field campaigns has shown both
Location: line 275	

	consistencies and inconsistencies between techniques (Li et al., 2023; Lacher et al., 2024). Beall et al. (2020) report that biological INP…
Reviewer comment:	Line 275-276: You could mention the aerosol size distribution during COMBLE and the comparison to Ny-Alesund in Williams et al., (2024) here
Our response:	Agree this would be a useful addition.
Old Text (if changed): *Location: line 276*	…by Song et al. (2021) from 2015–2019.
New Text (if changed): *Location: line 304*	…by Song et al. (2021) from 2015–2019. The number concentration of aerosol with diameter between 0.1–0.5 μm observed during ACAO was also an order of magnitude greater than that measured at Ny-Ålesund during the COMBLE campaign, though concentrations were similar between 0.5–1 μm (Williams et al., 2024).
Reviewer comment:	Line 282-285: Here is another example where I think the way the flights are labelled and discussed is a bit hard to follow. It would be much nicer if it was clearer which day corresponded to which flow regime etc. Even adding the flow regime on the title of the subplots of Figure 6 would help.
Our response:	The flow regime has been added to the subplots on Fig 6. Additionally, clarification has been made and detail has been added to the description of flying days.
Old Text (if changed): *Location: line 282*	However, the vertical distribution of aerosol varied much more between flight days. On three flying days (c274, c277/c278 and c281/c282), aerosol concentrations were approximately constant to 7500 m. These contrasted with three days where the aerosol concentration decreased with altitude in the boundary layer (c273, c275/c276 and c279) and one day where aerosol concentrations increased with altitude c280.
New Text (if changed): *Location: line 314*	On three flying days, aerosol concentrations were approximately constant from the surface up to 7500 m. These were c274, which had a northwesterly flow, and c277/c278 and c281/c282, which both had northerly flows. These contrasted with three days where the aerosol concentration decreased with altitude in the boundary layer. These were c273, which had a westerly flow, and c275/c276 and c279, which both had northerly flows. Finally, aerosol concentrations increased with altitude during flight c280, another day with a northerly flow.
Reviewer comment:	Section 3.3: Was it not possible to take comparison filters farther south? It would have been really nice to see if there is a difference between the composition before and after precip etc. Were these two filters at different locations relative to the boundary layer? It looks like one was very low and the other at 1750 m. It would be interesting to know if there were differences in this regard. If there are, it might be worth mentioning the studies by Knopf et al., (2023) and Moore et al., (2024). I see there is a discussion on being within or above the cloud layer later but maybe it should already be mentioned here?
Our response:	We chose these two filters since they were upstream of the CAOs and so could define the aerosol flowing into the outbreaks. Unfortunately, we had limited resources with which to perform SEM due to issues accessing the equipment required and the time-consuming nature of the experiments. In an ideal world, we would have loved to perform SEM on some downstream filters too. We have saved our samples and would ideally like to perform more SEM as part of work towards a future paper on composition. The

	boundary layer issue is handled in response to the reviewer's comment regarding lines 442-446.
Old Text (if changed): *Location:*	N/A
New Text (if changed): *Location:*	N/A
Reviewer comment:	Line 287-290: It might be nice to highlight the INP concentrations over water vs. the marginal sea ice zone and Svalbard more clearly.
Our response:	Agree.
Old Text (if changed): *Location: line 287*	These filters were selected to represent the aerosol upstream of the CAOs.
New Text (if changed): *Location: line 321*	These filters were selected to represent the aerosol upstream of the CAOs, and had $N_{INP}(-15°C)$ of (0.49 ± 0.15) L^{-1} and (1.4 ± 0.4) L^{-1} respectively. These represent INP concentrations at the 33rd and 87th percentiles of samples taken in CAOs.
Old Text (if changed): *Location: Fig 7 caption*	…c278r2 (right). Solid lines…
New Text (if changed): *Location: Fig 7 caption*	…c278r2 (right). Sample c278r2 was taken upstream of cloud development, while sample c279r1 was taken below the northern extent of CAO cloud streets. Both were taken in northerly CAOs. Solid lines…
Reviewer comment:	Line 293: Please state that the size distributions are compared with the PCASP/CDP. Until I saw the Figure 7, I wondered why this wasn't shown.
Our response:	Changed.
Old Text (if changed): *Location: line 292*	Composition analysis and particle-size distributions for each of the filters are shown in Figure 7.
New Text (if changed): *Location: line 326*	Composition analysis and particle-size distributions derived using SEM for each of the filters are shown in Figure 7. Figure 7 also compares the particle-size distributions derived using SEM with those derived from the PCASP and CDP.
Reviewer comment:	Figure 6 is a great figure. It would be nice if the INP concentration at -15 C for example could be added to the corresponding filter time. Also, it would be nice if the boundary layer height/ cloud layer height could be denoted. As a side note, it sounds like the SEM filter was run over Svalbard or close to it. Were those points omitted as per the caption? If so, I think they should be included as it represents the airmass before it interacts with the ocean. Either way please clarify this.
Our response:	**Part 1 – Figure:** We have adapted this figure by including flow directions in sub-figure titles, recolouring the aerosol concentrations during filter measurements according to the INP concentration of the sample and adding annotations to make it clear which filters were above, below and upstream of the boundary layer. The caption has been adjusted.
Old Text (if changed): *Location: Fig 6 caption*	Measurements made during filter sampling are highlighted in orange.
New Text (if changed): *Location: Fig 6 caption*	Measurements made during filter sampling are coloured and labelled according to their INP concentration at T=-15 °C. The borders of each label and the arrows matching labels to measurements are coloured according to the location of the sample relative to the CAO cloud.
Old Text (if changed): *Location: line 277*	Measurements of aerosol concentration where INP concentration filter samples were made are highlighted in orange…

New Text (if changed): *Location: line 308*	Measurements of aerosol concentration where filter samples were made are highlighted according to their INP concentration…
Our response:	**Part 2 - Caption:** The previous caption was imprecise, we did include points over Svalbard.
Old Text (if changed): *Location: Fig 6 caption*	Measurements close to land were discarded to represent oceanic air only.
New Text (if changed): *Location: Fig 6 caption*	Measurements over or close to the Scandinavian Peninsula were discarded to represent Arctic and oceanic air only.
Reviewer comment:	Line 313-314: This has been observed quite a lot in the Arctic recently and as such it might be worthwhile mentioning some of those previous studies here.
Our response:	Agree.
Old Text (if changed): *Location: line 314*	…being the primary driver of variability in Saer and Vaer.
New Text (if changed): *Location: line 360*	Other studies of Arctic and high-latitude INP (e.g. Porter et al. (2022); Barr et al. (2023); Sanchez-Marroquin et al. (2023); Moore et al. (2024)) have also found that normalising by surface area fails to reduce the measurement spread.
Reviewer comment:	Line 349-351: It would be much more convincing if the clustering of the high, medium and low INP concentrations were somehow related to the meteorological scenario/ location in the CAO etc. Without this information, based on such a limited number of samples, and the fact that the observations don't fit with what has been previously observed, it might be best to recommend the median for comparison with ground-based obs etc.
Our response:	These were not clusterings, but examples to demonstrate that the fitting procedure works for all cases. As part of the movement of Section 3.5 to the Appendix, the caption of the former Fig 9, now Fig A1 has been adjusted.
Old Text (if changed): *Location: Fig 9 caption*	In both panels, examples of fits to a high, medium and low spectrum are demonstrated.
New Text (if changed): *Location: Fig A1 caption*	In both panels, examples of fits to randomly-chosen spectra with relatively high, medium and low INP spectra are demonstrated.
Reviewer comment:	Line 359-360: It would be really nice if these were plotted in a way that clearly showed this somewhere? Maybe also including the entire spectra?
Our response:	The new version of Figure 3 demonstrates this.
Old Text (if changed): *Location: line 359*	…the samples fall into two groups
New Text (if changed): *Location: line 391*	, the samples fall into two groups, as shown in Figure 3.
Reviewer comment:	Line 361-362: It would be good to mention that this has also been observed elsewhere e.g. (Knopf et al., 2023; Moore et al., 2024).
Our response:	Agree.
Old Text (if changed): *Location: line 364*	…larger than the below cloud values.
New Text (if changed): *Location: line 395*	…larger than the below cloud values. Similar relationships between INP activity and altitude were found by Moore et al. (2024) who observed INP concentrations normalised by surface area above cloud in the SOCRATES campaign were greater than those below cloud. Additionally, Knopf et al. (2023) found that during measurements on INP in the Eastern North

	Atlantic, the efficiency of deposition ice nucleation was greater for samples taken in the free troposphere than the marine boundary layer.
Reviewer comment:	Line 364: remove "are"
Our response:	Corrected
Old Text (if changed): *Location: line 364*	…with above cloud values are approximately 7.0 times…
New Text (if changed): *Location: line 395*	…with above cloud values approximately 8.8 times… [note the value change is explained in a later comment]
Reviewer comment:	Line 367-368: No it is not clear at all as there is no way of easily knowing which number corresponds to what location relative to the cloud. Even in Figure 6, there are only some instances where the aerosol number concentration drops off with height and then it also increases again. As such it would be hard to say there is a clear trend in terms of number at least, especially without the cloud layer or boundary layer noted.
Our response:	*Response: since the update to Figure 5 that the reviewer suggested, we believe this is now clear.*
Old Text (if changed): *Location:*	N/A
New Text (if changed): *Location:*	N/A
Reviewer comment:	Line 373-374: You could cite Williams et al., (2024) here to justify this.
Our response:	Agree.
Old Text (if changed): *Location: line 374*	…might efficiently remove particles.
New Text (if changed): *Location: line 410*	…might efficiently remove particles. A downstream decrease in aerosol number concentration in Norwegian Sea CAOs attributed to precipitation scavenging has previously been observed by Williams et al. (2024).
Reviewer comment:	Line 385-386: But the measurements by Geerts et al, (2022) are consistent with other measurements in the Arctic at higher latitudes such as in Ny Alesund. So how could those low concentrations observations be explained by precip etc?
Our response:	The intent of this statement was to suggest that the measurements by Geerts et al. could coexist with our measurements should precipitation scavenging of INP be strong. We clarify:
Old Text (if changed): *Location: line 384*	In the future, it would be helpful to have aircraft INP measurements much deeper into the cumulus regime (i.e. further south) to test if the very low INP concentration reported by Geerts et al. (2022) are a result of precipitation scavenging.
New Text (if changed): *Location: line 429*	If precipitation scavenging is strong, it is possible that the INP concentrations measured during ACAO could be consistent with the INP concentrations measured at Andenes by Geerts et al. (2022). As such, it would be helpful to test this with future aircraft INP measurements much deeper into the cumulus regime (i.e. further south).
Reviewer comment:	Line 393-399: Initially these lines suggests that Asia is the source for these highly efficient INP but then finishes by stating that there is no clear relationship based on the back trajectories. Please rephrase this to be more consistent or at least clarify what is meant here.
Our response:	We rephrase to clarify.
Old Text (if changed):	

Location: line 394	Some of these passed over Asiatic mid-latitudes 6–7 days prior to sampling. In contrast, airmasses associated with westerly cold-air outbreaks (c273, c274) typically passed over Greenland, the Atlantic Ocean or Canada. There was no clear correlation between INP concentration and airmass origin. This is consistent with there being no distinct sources of INP in 7 days transport.
New Text (if changed): *Location: line 441*	Airmasses associated with westerly CAOs (c273, c274) typically passed over Greenland, the Atlantic Ocean or Canada. Some of the airmasses associated with northerly CAOs passed over Asiatic mid-latitudes 6–7 days prior to sampling. However, there was no clear correlation between INP concentration and airmass origin, suggesting that the airmasses did not interact with a distinct source of INP in 7 days transport.
Reviewer comment:	Line 438: you could cite Gong et al., (2023) here as well.
Our response:	Agree.
Old Text (if changed): *Location: line 438*	…a source of sea salt aerosol (Yang et al., 2008)…
New Text (if changed): *Location: line 487*	…a source of sea salt aerosol (Yang et al., 2008; Gong et al., 2023)…
Reviewer comment:	Line 442-446: Figure 10 only goes up to 3 km. Also, without identifying the height of the boundary layer, it is hard to be sure that the convection within the CAO could not mix up the aerosol. Please consider adding the general PBL.
Our response:	Since the boundary layer height changes both with latitude and between days, it is not possible to depict the boundary layer on Figure 10. However, we have edited Figure 1 to schematically depict the boundary layer location in CAOs and in Section 3, when introducing the results as above/below/upstream of clouds, we add the following:
Old Text (if changed): *Location: line 205*	…development of the cloud in clear air. The locations, altitudes…
New Text (if changed): *Location: line 213*	…development of the cloud in clear air. These sampling locations were considered to represent air below, above and before the development of the atmospheric boundary layer over sea respectively. The locations, altitude…
Old Text (if changed): *Location: line 442*	Further evidence against a local surface source of INP is that INP concentrations were fairly constant with altitude up to 3.5 km (Fig 10).
New Text (if changed): *Location: line 490*	Further evidence against a local surface source of INP is that INP concentrations in northerly CAOs were fairly constant with altitude up to 3 km (Fig 10).
Reviewer comment:	Line 474-476: There are also several space-borne remote sensing studies that do not observe this reservoir in a statistical sense (e.g. Carlsen and David, 2022; Dietel et al., 2024; Murray-Watson and Gryspeerdt, 2024). This, in combination with the ground-based observations, raises the question if these reservoirs are frequently there or not and if they aren't, if it really makes sense to come up with parametrizations based on a few flights? As previously mentioned, it might make more sense to move the parametrizations to the appendix. Either way, it might be worthwhile mentioning the discrepancies to these studies as well.
Our response:	The parametrisations have now been moved to the appendix. As mentioned in the response to the major comments, we believe that these parametrisations will be useful for model case studies and sensitivity

	testing, rather than necessarily being used as a parametrisation to represent the Arctic, and intend to do so in future work. We adjust the (new) appendix.
Old Text (if changed): *Location: line 340*	To represent the INP concentration across the full temperature spectrum in future modelling work, we fitted all spectra to a four-parameter function.
New Text (if changed): *Location: line 587*	To represent the INP concentration across the full temperature spectrum in future modelling work, particularly when modelling individual case studies, we fitted all spectra to a four-parameter function.
Our response:	Regarding the remote sensing studies which do not suggest an INP reservoir, we add at the end of Section 4:
Old Text (if changed): *Location:*	N/A
New Text (if changed): *Location: line 527*	The hypothesis of an INP reservoir appears to contradict previous remote sensing studies that use observations of Arctic clouds to infer spatial variations in INP concentrations. For instance, Carlsen and David (2022) define a temperature, T*, at which mixed-phase clouds become more frequent than liquid clouds, and use this as a proxy for freezing initiated by INP. They find that in winter, when Arctic haze builds up, T* is lower over the sea-ice than the open sea, which they attributed to a suppression of INP emissions (and concentrations) caused by sea-ice cover. However, differences in ice concentrations between ice-covered and ice-free regions in high Arctic clouds may not reflect differences in INP concentration but rather differences in cloud microphysics related to cloud dynamics. For example, clouds over ice are shallow, long-lived and relatively stable compared to the deeper clouds with colder tops over ocean regions (Morrison, et al. 2012 ; Arteaga et al. 2024). The long lifetime of these arctic clouds provides time for INP to be scavenged from the atmosphere, thus their small ice content may be a consequence of their history rather than the INP concentration when they first formed. Similarly, Murray-Watson and Gryspeerdt (2024) used satellite observations to suggest that increasing ice concentrations downwind in CAOs imply increased INP concentrations downwind, associating this with increased emissions of sea-spray INP. This contrasts with our linked in-situ measurements of below-cloud INP that reveal a decrease in INP concentration downwind (Table 2). The increased downwind ice concentrations observed by Murray-Watson and Gryspeerdt (2024) may be related to secondary ice processes, rather than INP, since these are associated with strongly-convective clouds which are more likely to occur downwind. Additionally, clouds later in the CAOs tend to have lower cloud-top temperatures, naturally increasing the concentrations of ice.
Reviewer comment:	Line 505-506: Is it really clear that the cloud-phase feedback would work in this direction in the Arctic during fall, winter and spring (e.g. Tan and Storelvmo, 2019)?
Our response:	The cloud-phase feedback is negative over the ocean, which is where these clouds form. In the depths of winter, there is little insolation to the Arctic Ocean, but even by mid-February, the Norwegian Sea is receiving upwards of 6 hours of sunlight a day. Spring and fall are therefore key times for the

	cloud-phase feedback to be important. We adjust the introduction to clarify this.
Old Text (if changed): *Location: line 45*	…the magnitude of this cloud-phase feedback (Murray et al., 2021).
New Text (if changed): *Location: line 44*	…the magnitude of this cloud-phase feedback (Murray et al., 2021). The cloud-phase feedback is likely to be particularly sensitive to CAO clouds since they form over the relatively dark ocean, so microphysical adjustments to cloud albedo have the potential to be more impactful than for clouds over higher-albedo surfaces such as sea ice.
Reviewer comment:	Line 58: th -> the
Our response:	Corrected.
Old Text (if changed): *Location: line 58*	…which results in th build-up of Arctic Haze…
New Text (if changed): *Location: line 60*	…which results in the build-up of Arctic Haze…
Reviewer comment:	Line 80: Cold-air outbreak -> CAO
Our response:	Changed.
Old Text (if changed): *Location: line 80*	Cold-air outbreak conditions, of varying strength,
New Text (if changed): *Location: line 84*	CAO conditions, of varying strength,
Reviewer comment:	Line 143: that -> at
Our response:	Corrected.
Old Text (if changed): *Location: line 142*	lower INP concentrations that above
New Text (if changed): *Location: line 150*	lower INP concentrations at above
Reviewer comment:	Line 169: Aa -> a
Our response:	Corrected.
Old Text (if changed): *Location: line 169*	Aa minimum diameter of…
New Text (if changed): *Location: line 183*	A minimum diameter of…
Reviewer comment:	Line 171 – 175: there are some typos and some phrases are a bit awkward.
Our response:	The section has been rephrased.
Old Text (if changed): *Location: line 166*	Using AZtec 3.3 feature recognition software, the filters were scanned for aerosol particles, and a prescribed algorithm was used to automatically classify particles into types using their elemental composition. This classification algorithm is further described in SanchezMarroquin et al. (2019). The classified particles were then binned according to their equivalent spherical diameter. A minimum diameter of 0.3 μm was chosen as it is comfortably above the size threshold at which the feature recognition software detects erroneously features. Using the total area of filter analysed by the SEM multiplied by the air volume sampled through it during the sampling run, it is then possible to calculate total surface area of aerosol of a certain composition, for example mineral dust or sea-spray aerosol. The carbonaceous category of particles includes those which contain no elements other than those O and C, and therefore does not

	distinguish between organic or elemental carbon. Biological particles are therefore not explicitly classified using this method but can be qualitatively identified on the basis on size and morphology (Sanchez-Marroquin et al., 2021).
New Text (if changed): *Location: line 174*	Portions of the filters were mounted on 25 mm diameter stubs, sputter-coated with 30 nm of platinum and analysed at the University of Leeds with a *Tescan* Vega3 XM electron microscope fitted with an *Oxford Instruments* X-max 150 SSD energy-dispersive X-ray spectrometer. Using AZtec 3.3 feature recognition software, the filters were scanned for aerosol particles, and a prescribed algorithm was used to automatically classify particles into categories (e.g. mineral dust and sea-spray) using their elemental composition. This classification algorithm is further described in Sanchez-Marroquin et al. (2019). The carbonaceous category of particles includes those which contain no elements other than those O and C, and therefore does not distinguish between organic or elemental carbon. Biological particles are therefore not explicitly classified using this method but can be qualitatively identified on the basis on size and morphology (Sanchez-Marroquin et al., 2021). The classified particles were then binned according to their equivalent spherical diameter. A minimum diameter of 0.3 μm was chosen as it is comfortably above the size threshold at which the feature recognition software detects erroneously features. The total surface area of aerosol sampled in each composition category was normalised by the fraction of filter area analysed and the volume of air sampled during the sampling run.
Reviewer comment:	Line 246: spacial is usually spatial.
Our response:	Corrected.
Old Text (if changed): *Location: line 246*	…a range of spacial and temporal scales
New Text (if changed): *Location: line 273*	…a range of spatial and temporal scales
Reviewer comment:	Line 494: remove “to be”
Our response:	Agreed.
Old Text (if changed): *Location: line 494*	…was likely to be dominated by…
New Text (if changed): *Location: line 555*	…was likely dominated by
Reviewer comment:	Table 2: Please add what the variables stand for in the table caption.
Our response:	Symbols have been copied from page 19 and added to the caption. Additionally, the order of elements in the caption now matches the order of columns in the table.
Old Text (if changed): *Location: Table 2 caption*	Factors of change in the INP concentration at -15 °C, total aerosol surface area and INP concentration normalised by surface area at -15 ◦C between three pairs of below-cloud filter measurements.
New Text (if changed): *Location: Table 2 caption*	Factors of change in the INP concentration at -15 °C (F_{INP}), INP concentration normalised by surface area at -15 °C (F_{S}) and total aerosol surface area (F_{aer}) between three pairs of below-cloud filter measurements.

Minor changes made aside from those noted in response to reviewer comments

All lines refer to the new version.

A small number of values associated with aerosol number and multiples thereof have been adjusted. This is because we have slightly changed how we handle one of the thirty PCASP size bins which previously created a systematic artificial overcount aerosol number in a single bin around 1.2 microns, which has now been removed. This changed the values of N_{aer}, S_{aer} and V_{aer} by amounts on the order of 1-5% in N_{aer} - well within the previously-given error. This has also resulted in small increases to the normalised INP spectra. The parametrisations of $N_{\mathrm{INP}}/S_{\mathrm{aer}}$ have also changed accordingly. There are no changes to the findings as a result of the difference in processing that has improved the accuracy of the measurement. Changes to values have been made in Tables 2 and B1, and to values related to $N_{\mathrm{INP}}/S_{\mathrm{aer}}$ in Sect. 3.5.

The following changes are all editorial changes to syntax or corrections of typographical errors.

Line 6 and 7: the word "upwind" has changed to **"upstream"** to be consistent with use in the paper.

Line 18: The second instance of airmass has changed to "**air**" to scan better.

Line 51: "on both" has been correctly ordered as **"both on"**.

Line 91: "**In this system**" has been added to improve flow.

Line 147: The sentence beginning "Comparison…" has been made clearer by rephrasing to **"Using filters collected in parallel, comparison between the wash-off and drop-on techniques shows good agreement in the INP concentration ranges where the techniques overlap (Sanchez-Marroquin et al., 2021)."**

Line 173: A typographical error in the word **composition** has been corrected.

Line 189: Italicisation has been corrected.

Figure 4 caption: Citations for **Prenni, et al. (2007)** and **Rogers, et al. (2001)** were included in the figure but not in the caption. This has been corrected.

Line 256: Clauses in the sentence beginning "Ship-based measurements" have been re-ordered for clarity.

Line 277: The citation of **Beall, et al. (2020)** was incorrectly formatted, this has been corrected.

Line 278: "avoid" has been corrected to **"avoided"**.

Line 330: The determiner "our" has been changed to **"this".**

Line 333: Filter **c279r1**, not c278r2, was the filter which was taken close to the marginal sea ice. This has been corrected.

Line 337: The citation of **Young et al. (2016)** was incorrectly formatted, this has been corrected.

Sect. 3.5 and Table 2: For consistency with the phrasing used when discussing Figure 10 (and to contrast from the definition of upstream in Figure 1), upstream and downstream have been changed to **upwind and downwind.**

Line 481: "Another final" has been replaced with "A final potential".

Line 501: A typographical error “well-know than” has been corrected to **“well-known that”**.

Line 544: delete the word “have”

Line 545: replace “made” with **“took”.**

Line 546: “between 39 and 3403 m altitude” has been clarified by changing to **“altitudes between 40-3400 m”,** consistent with a previous mention.

Line 547: A typographical error has been corrected whereby 3 L^{-1} should have been 2 L^{-1}. We have taken the opportunity to increase the stated precision of the measurements to 2sf – figures that were 1sf had survived from a previous draft.

Line 595: The left-hand side of the equation has been corrected to $N_{\mathrm{INP}}/S_{\mathrm{aer}}$.

Line 600: A typographical error in the word “**springtime**” has been corrected.

Table 1: All dates incorrectly shared a typographical error suggesting that the samples were taken in 2023 rather than 2022. **All dates have now been corrected**.

Figure B1 (formerly Figure 9) caption: The units **m^{-2}** and **L^{-1}** had been incorrectly swapped between the parametrisations. This has been corrected.

Code and data availability: The aircraft data from the ACAO flights has been merged into a single data collection on the CEDA archive – this has been reflected in the text.

Acknowledgements: Added acknowledgements to the reviewers and Cameron Belton.