

Reviewers comments:

Reviewer's comment is given, with following response (in blue), and changes to text if required.

Reviewer 1:

General comment:

The Manchester Ice Nucleus Chamber (MINC) was deployed at ICIS 2007 campaign. The dust and Snomax aerosol ice active fraction calculations from MINC were compared with the CSU CFDC results.

This comparison shows the MINC works for two types of aerosols: dust and snomax, can the MINC be used to investigate active fractions for other aerosols (black carbon, coated and uncoated dust particles, different type of dust etc.)? To address this issue I would suggest if authors could validate MINC relative humidity and temperature conditions using standard organics and salts. For example the deliquescence of ammonium sulfate can be tested at different temperatures. The plot showing such results is important to demonstrate that chamber can work for other type of aerosol particles and wide temperature and humidity conditions.

The words 'supersaturation' and 'RH' are used throughout the manuscript. Please use only one word terminology to express the humidity and maintain the consistency.

The error calculations of humidity at various temperatures are not described. Please add the error bars or describe in the text.

Response:

We thank the reviewer for their thorough comments, and we have addressed each comment in turn below.

Whilst the paper shows the results from only three of the noted aerosol types listed in Table 1, results were gathered for all samples listed. They are not shown here as there are no corresponding measurements from the CSU instrument to compare to. They are not included on Figure 6 as for these other samples there are limited measurements, and in particular for the soot cases, the noted activated fraction was not reached as these were extremely poor (undetectable) ice nuclei in the mixed-phase regime (see Kanji et al. 2010).

The temperature and humidity range over which MINC can operate are given in the text, and a new figure is to be added to illustrate this, therefore the instrument can be used to probe the ice nucleation properties of any particles within this range. The authors accept that validation using standard salts would be a useful verification of the accuracy with which desired conditions can be obtained. However such tests have not been done as part of the current study, so cannot be presented here. Instead, the instrument was bought for inter-comparison with other such instruments, and that is the focus of this paper. Further, the passive evaporation region of the current chamber makes such tests of little utility. The lack of these tests does not in the authors opinion affect the validity of the data and inter-comparison of the two instruments employing the exact physical principles being presented here. During future work with MINC it is planned to design and carry out a variety of tests of this type.

We agree that the words supersaturation and RH are used interchangeably in the text, this will be corrected to refer only to supersaturation or SS for short, with the subscript of i or w to denote supersaturation with respect to ice or water respectively.

Regarding the error calculations, this will be addressed below in the specific comments.

Reference:

<http://www.atmos-chem-phys-discuss.net/10/20857/2010/acpd-10-20857-2010.html>

Specific comments:

1 – Page 19278

Line 19-22: The end of this sentence ‘The existence ...’ regarding local radiation budget, this needs reference.

Response:

DeMott et al 2010.

<http://www.pnas.org/content/107/25/11217.abstract>

2 - Page 19279: Line 1:

It might be good idea to describe briefly the nucleation mechanisms. Also add what mechanisms can be investigated using MINC.

Response: Whilst we felt that the reference to Vali, 1985 was sufficient, we agree that the information could be included here for completeness.

Current text:

There are currently four recognised fundamental heterogeneous ice nucleation mechanisms: deposition nucleation, condensation-freezing, contact-freezing and immersion-freezing nucleation (Vali, 1985).

Change to:

There are currently four recognised fundamental heterogeneous ice nucleation mechanisms: deposition nucleation (vapour transferred directly to the IN surface), condensation-freezing (water condenses onto the surface of the IN to form a supercooled droplet, then subsequently freezes), contact-freezing (supercooled water droplet freezes upon contact with the IN) and immersion-freezing nucleation (IN becomes immersed inside a supercooled water droplet, then subsequently freezes), (Vali, 1985).

Before the sentence 'Details of the operation...' at the end of section 1, add in the following sentence:

'This instrument is capable of detecting all modes of ice nucleation except contact-freezing nucleation, although there is no means to easily discern the combination of mechanisms near and above water saturation'

3 – Page 19279: Line 3:

why it is of critical concern. Please add the reference. IPCC report does not include the ice clouds, this could be a good reference, and also motivation to study the ice clouds.

Response: Ice nucleation is of critical concern for weather and climate models as this process is still not well understood, yet this process has the ability to drastically change the microphysical properties of a cloud, which can in turn drastically change the radiative properties of that cloud. This point is noted on line 23 of page 19278. We feel that this point has been covered, but do agree that the addition of the IPCC reference at this point is useful for the reader. This will be included.

4 – Page 19279: Line 6:

Parameterizations ... please add the reference. Recently DeMott et al., PNAS, 2010 published a really good paper.

Response: The sentence in the paper that the reviewer is referring to will have the following added to the end: “(e.g. DeMott et al. 2010)”

this paper: <http://www.pnas.org/content/107/25/11217.abstract?related-urls=yes&legid=pnas:107/25/11217>

5 – Page 19279: Line 9:

The sentence ‘...between the two’, here you mean two phases? Please clarify.

Response: To avoid confusing the reader, we will add the following to this sentence, ‘... between the two phases’.

6 – Page 19279: Line 14-17:

Provide the reference.

Response:

Reference for 'aerosol properties' – e.g. Meyers et al. 1992

Reference for 'climatologies' – e.g. Bigg 1990

http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V95-48B0KF0-1J&_user=10&_coverDate=06%2F30%2F1990&_rdoc=1&_fmt=high&_orig=search&_origin=search&_sort=d&_docanchor=&_view=c&_searchStrId=1556731328&_rerunOrigin=google&_acct=C00050221&_version=1&_urlVersion=0&_userid=10&md5=6030d4ec36172cc349549dcadda5486f&searchtype=a

7 – Page 19279: Line 19:

Possible processes – please clarify what processes.

Response: Change ‘... multitude of possible processes within the atmosphere...’ to ‘...the multitude of possible ice nucleation processes within the atmosphere...’.

8 – Page 19279: Line 25:

Regional and global hydrological pathways – provide the reference.

Response:

Reference IPCC, Denman et al 2007.

9 - Page 19280: Before lines 7-12:

please briefly describe how developing new diffusion chamber can reduce the uncertainty in the climate models.

Also briefly discuss the existing diffusion chambers: static (Kanji and Abbatt, JGR, 2006; Knopf and Koop, JGR, 2006; Dymarska et al., JGR, 2006, Kulkarni et al., AMT, 2009) and continuous (Stetzer et al., AST, 2008; Rogers 1988) flow chambers, and clearly describe the motivation to develop the MINC continuous flow chamber.

Response:

After the paragraph ending ‘...regional climate prediction models’, add in the following: ‘Several instrument exist that are capable of measuring ice nucleation properties, these include static

diffusion chambers (e.g. Kanji and Abbatt, JGR, 2006; Knopf and Koop, JGR, 2006; Dymarska et al., JGR, 2006, Kulkarni et al., AMT, 2009) and continuous flow diffusion chambers (e.g. Stetzer et al., AST, 2008; Rogers 1988). Developing instrument such as these, allows an increased collection of IN data, a clear need. The existence of so few of these instruments provides motivation into the development of new instruments to provide additional data to allow the progression of ice nucleation parameterisations and reduce the uncertainty in cloud microphysics models.

10 - Page 19281:

How icing operation is performed? What is the coating thickness? If outer wall of the evaporation section is not cooled, what temperature it is cooled (I imagine through passive cooling) to. It is not clear if this plastic outer cylinder tube section is coated with ice or not.

Response:

Add in line 20 page 19282: (chamber section, after '.....loss of particles'):

The chamber walls are iced by pumping water into the outlet of the CFDC chamber, with the chamber having been pre-cooled to -30oC. The chamber is quickly filled to a level 10 cm lower than the chamber inlet manifold, then is promptly pumped back out again such that during this time the wall temperatures do not rise above 0oC. *To increase the hygroscopicity of the copper wall surface to allow a smooth ice layer to be applied, the walls were treated with an 'ebonizing' solution that reacts with the copper to form a thin layer of black cupric sulphide crystals (see Rogers et al., 2001):* this provides a hydrophilic surface to allow a uniform ice coating (~0.1mm thick – tested via the collection of melt water).

The outer wall of the evaporation section is indeed passively cooled. If the insulation is sufficient, then the temperature at the outer wall in the bottom section should relax to the same temperature as the inner wall. There is no way to measure this temperature directly as a sensor cannot be fitted in this region. This plastic outer wall is not coated in ice as it is made from a hydrophobic material (polypropylene) to prevent this and is not expected to remain below 0oC during the icing process.

Add in to line 24 page 19282: (after '... droplet evaporation zone')

This section of the outer wall warms to 0oC during icing and it is not expected to retains any ice coating.

11 - Page 19282: Line 6:

Was the rail frame was purchased off-the-shelf from Bosch? If yes put the model number. If not mention it was custom built.

Response:

The frame was custom built in house using various components from the Bosch Basic Mechanical Elements range. Individual part numbers could be provided, but as the frame does not fulfil any scientific function the authors feel that such detail is unwarranted.

The text will be modified to: The MINC instrument is housed inside a custom built aluminium frame ...

12 – Page 19282: Line 14-15:

If available add the reference.

Response:

We think the reviewer is asking for a reference regarding edge effects for flat plate design. We will add the reference Al-Naimi and Saunders, 1985

http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B757C-48C7CFC-65&_user=10&_coverDate=12%2F31%2F1985&_rdoc=1&_fmt=high&_orig=search&_origin=search&_sort=d&_docanchor=&_view=c&_searchStrId=1556754173&_rerunOrigin=google&_acct=C00050221&_version=1&_urlVersion=0&_userid=10&md5=22d68c1dd9b2b73c3ec480d0a6b2738c&searchtype=a

13 – Page 19282: Line 17:

Ebonizing is also done to obtain the uniform ice layer.

Response:

The reviewer is correct. This will be mentioned in the text as part of the icing paragraph, see above

14 - Page 19283: Line 7:

What is aspect ratio? Please clarify which width and height is used, also what is the aspect ratio of MINC.

Response:

Aspect ratio is defined as the ratio of width to height as is noted in the text. In the case of an annular space, this is: length of cylinders / annular space. The length of the chamber is 75 cm, and the annular gap is 1 cm, therefore the aspect ratio is $75/1 = 75$.

Replace '(width:height)' with '(length of cylinder: annular space = 75 for MINC)'

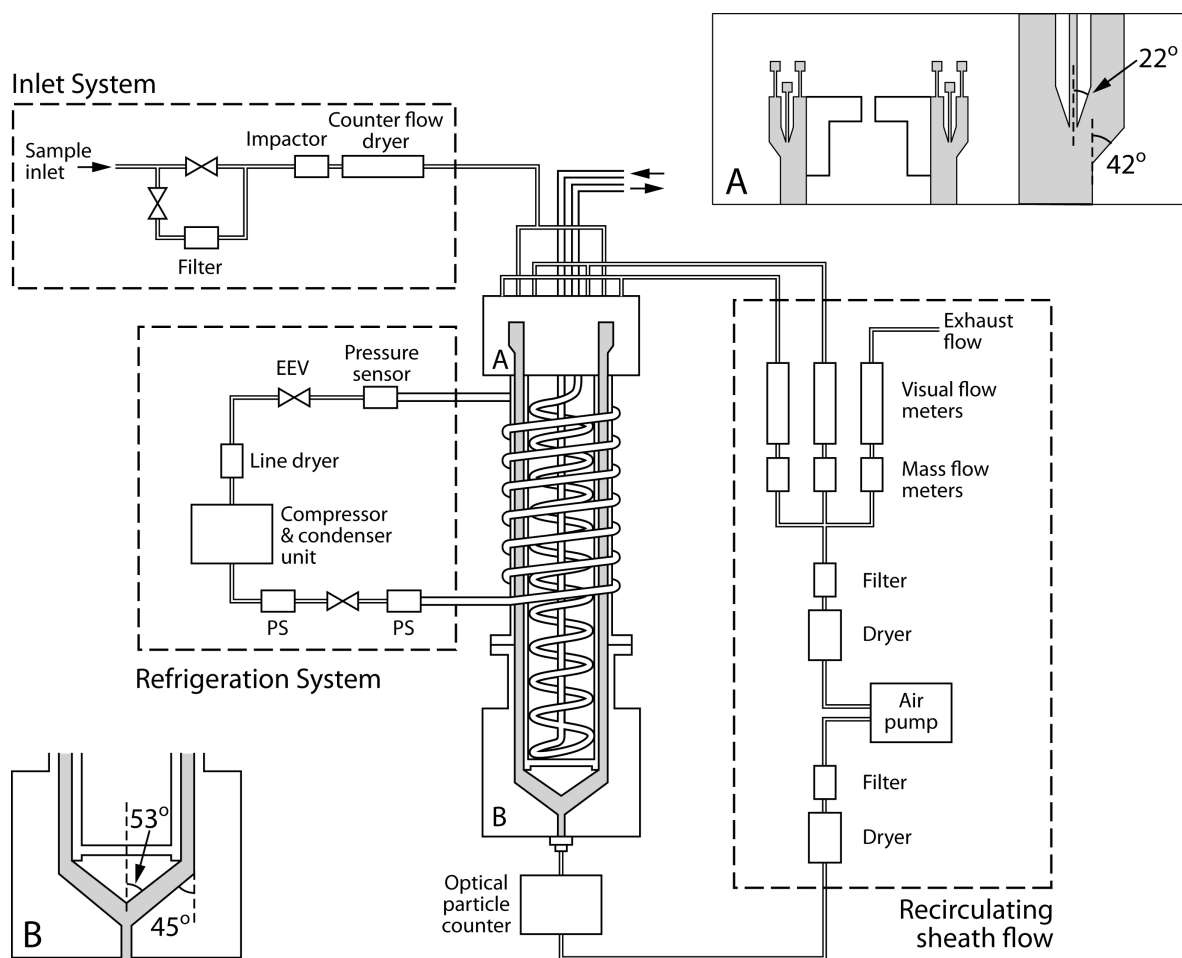
15 – Page 19283: Line 15:

I guess two refrigeration systems were used (one compressor on each wall), but only one system is shown in figure 1. Unless the system is very specifically designed, the more details such as expansion valve, drier, pressure sensors etc. are not necessary to show here. Most of standard refrigeration system includes these components.

Response:

It is correct that two refrigeration systems were used. Only one system is shown in figure 1 as space is limited. However, we are replacing figure 1 with what we believe to be a better system outline diagram. The expansion valves, driers, pressure sensors are in addition to the compressor unit and that is why they have been shown separately. This is not a standard refrigeration system.

New version of Figure 1:



16 – Page 19283: Line 25:

The compressor unit model seems to be compressor and condenser unit, not just compressor unit.

Response: Whilst this fact is true, this is how the part number was described. In the new version of figure 1, this correction will be made. (Noted as compressor/condenser unit), see comment 15.

17 - Page 19284: Line 10:

The word 'filter' has been used many times in the text with referring to figure 1. To reduce the confusion it would be nice if the filters can be named.

Response: The filters were HEPA capsules (99.97% retention of 0.3 μm DOP aerosol).

After '... zero particle filter' add: (HEPA capsule; 99.97% retention of 0.3 μm diameter aerosol particles). A similar sentence is lower down, so this will be removed, such that the model of filter used is only named once. Please see comment 20 below for a new version of this paragraph

18 – Page 19284: Line 15-17:

Do these filters remove the water vapor from the flow.

Response: As is already stated in the text there are separate line dryers for the air flow that effectively remove any moisture from the air. (Drierite columns)

19 – Page 19284: Line 17-18:

Show the inlet and second drier and exhaust flow in the figure 1.

Response: Figure 1 to be redone. Inlet and exhaust flow are shown. Second drier was not shown to allow a simpler diagram. See comment 15.

20 – Page 19284: Line 20:

‘The Airflow system is closed’, but the sample flow is always added and could make the system open. Please clarify.

Response: This is terminology used in instrument design. The wording will be changed so that all may understand what is meant by this statement. WE suggest rewording this paragraph as follows:

Sample air (1 LPM) initially passes through the inlet system, which consists of an impactor (design as per Rogers et al., 2001) that has a nominal 1.3 μm 50% cut-off to remove larger particles and a counter-flow gas drying column (Permapure Nafion, PD- 100T) to remove any moisture from the sample that would result in frosting of the inlets and consequently lead to false readings due to ice splinter formation and release into the sample stream. The inlet system also has a set of valves that allow a clean-room grade particle filter (HEPA, removing at least 99.97% of airborne particles 0.3 μm in diameter) to be placed in-line ahead of the impactor and so allow a background test to ensure there is no frosting in the chamber. As outlined in Sect. 2.1, this sample air enters the chamber between two layers of dried, particle free air (4.5 LPM each). The sheath air is dried by passing it through desiccant drying columns (Drierite, size 8 mesh) and then filtered (HEPA filter), see Fig. 1. Air exits the bottom of the chamber through the OPC (see section 2.2.4) and then passes through the air flow pump, a drier and filter to provide the counter-flow to the inlet drier. After the inlet drier, the airflow passes a second dryer and filter before the flow (10 LPM) is split, with 1 LPM forming an exhaust flow and the remainder being recirculated to form the two sheath flows. A pressure relief valve is provided at the top of the chamber for use during the wall icing process.

21 - Page 19285: Section 2.2.5:

Only software is not essential to run the ice chamber. Please add details about the computer hardware used including the data logger. What was the frequency of data logging?

Response:

Current Wording:

A LabVIEW program is used to monitor and record data from the CFDC. Wall temperatures, refrigeration pressures, air flow temperatures, air pressure, air flow rates and OPC data are constantly monitored to ensure correct operation and the data are recorded. The program also allows the use to control the refrigeration valves.

Reword to:

Software written in-house using the LabVIEW development system (National Instruments, LabVIEW 7.0) and running on a standard PC is used to monitor and record data from the MINC at one second intervals. Wall temperatures, refrigeration pressures, air flow temperatures, air pressure, air flow rates and OPC data are constantly monitored via NuDam data acquisition modules (ND 6013, ND 6017, ND 6520). The program also allows the user to control the refrigeration valves using a relay output board (Amplicon, PCI 236).

22 – Page 19285: Line 7:

Please write the software version and provider name. Correct CFDC to MINC.

Response:

This is given in the above comment

23 – Page 19285: Section 2.3.1:

At what MINC temperatures the aerosol losses experiments were carried out? Can the losses remain constant after icing the chamber? It is mentioned that losses are because of the inlet system geometry. But losses can also occur within the MINC, in particular evaporator section, and exit line. These losses would be comparatively less, but their quantification is necessary to obtain the total losses.

Response:

The aerosol loss experiments for the inlet section were performed at room temperature. Icing the chamber would not affect the aerosol losses in the inlet system. We agree with the reviewer that there is potential for aerosol losses within the chamber section of the chamber, but that these losses will be much less than those within the inlet system. We would not expect large losses in a 1 cm gap as there is little time for diffusion and the lamina is focussed by sheath flows. Regarding the outlet cone – this has been addressed in previous work, where it has been shown that ice crystals to a least 10um should make it out without any impaction (Richardson, 2009). There is additional potential for losses in the outlet tubing between the instrument and the OPC, but this section of the chamber has been made as short as possible, and the effect is thought to be very minimal due to the short amount of time spent in this section.

As a result of the comments by both reviewers, we have extended the section regarding aerosol inlet losses, this will be included at the bottom of this document.

24 – Page 19285: Line 14:

what was the size range of distribution?

Response:

The DMPS scanned from 5 to 500 nm, only 5 to 200nm is shown here as the measured concentration dropped to very low levels after 200nm and the features at smaller sizes would not be easily seen if the full range of data was shown here. This information will be included as part of comment 23.

25 – Page 19285: Line 16:

Please clarify that to obtain more information about DMPS the readers should look into Williams et al., 2007 paper?

Response:

This is indeed the case. Will change text to: 'please see Williams et al., 2007 for more details on the DMPS set up'. See comment 23.

26 – Page 19285: Line 18:

the sentence '...counterflow to the drier...' is confusing. Please clarify what type of drier, where it is used and why counterflow is used.

Response:

At line 9 page 19284, it is stated that a counter-flow gas drying column is part of the inlet system. To aid in clarification, change the above to 'counterflow to the inlet drier'.

27 – Page 19285: Line 19:

Please clarify – you mean sample flow was measured by a CPC or sample flow particle concentration was measured by a CPC.

Response:

The statement in the text is true. The CPC samples at 1 LPM, this was used to draw the air flow through the inlet system. It also measured the particle concentration as the particles were drawn through the inlet system. We feel that this is clear in the text.

28 – Page 19285: Line 21:

Please elaborate ‘...measured data...’ sentence. Which data and where it was measured.

Response:

Sentence: Based on this information, see Fig 2, a correction was applied to the measured data to account for losses in the inlet system.

This address in the new version of the aerosol losses section as part of comment 23.

29 – Page 19285: Line 22-23:

Please revise the sentence, ‘Transmission efficiency was ...’ it is not clear what you trying to say. Would you also clarify why 40% losses were assumed?

Response:

Current sentence: 'Transmission efficiency was assumed to be 40% between 500nm and 1um, then the impactor transmission curve is applied ...'

This is now part of a the section added to the end of document

30 - Page 19286: Line 2:

Please put ‘model 1.108’ in brackets. What was the flow rate through the impactor, because usually the impactor 50% efficiency is a function of flow rate.

Response:

'model 1.108' will be placed in brackets. Flow rate for impactor test was 1 LPM.

31 – Page 19286: Line 6, section 2.3.2:

It is not clear at what locations (distance) either from top or bottom of the chamber the temperatures were measured. If possible I suggest plotting the temperatures measured inside versus outside along the length of the chamber. What airflow rate was used. Please define what is ‘calibrated PRT’, how these PRT’s are different than used described in section 2.2.1. Ideally both should show same temperatures. The reason for larger discrepancy at -40 compared to -20 should be mentioned. It is possible there could be some heat gain from top of the chamber. Last sentence of this section is unclear. If I’m correct temperatures deviate every 10 cm? How temperature differences observed is related to the aerosol exposure time. I think you want say the sample is exposed to desired temperature and humidity conditions quickly. This is actually useful, because you can increase the residence time of the aerosol exposed to desired conditions within the chamber.

Response:

As both reviewers commented on this section, we have decided to extend this section, explaining the process in more detail to avoid confusion and provide the data required. This section is added at the bottom of this document.

32 – Page 19286: Line 9:

what was the thickness of ice surface?

Response:

This has been answered as part of an above comment 10

33 – Page 19286: Line 24:

define supersaturation. How this is measured and is it with respect to ice or water. Also how do you calculate saturation vapor pressure, a reference would be suffice. Be consistent across the manuscript.

Response:

Are you asking us to define supersaturation in this paper? We feel that the target audience reading this journal would have a firm understanding of the term supersaturation.

Supersaturation is not measured directly, but is calculated using the Murphy-Koop (2005) calculations to calculate the saturation vapor pressure.

At line 30, page 19282, after '... inner and outer wall.' Add: 'Using these measured temperatures, sample laminar supersaturation was calculated using the equations for saturation vapour pressure given in Murphy and Koop (2005).

Add reference: Murphy, D. M. and T. Koop, Review of the vapour pressures of ice and supercooled water for atmospheric applications, Quart. J. Royal Met. Soc, 131, 1539-1565, 2005.

34 - Page 19287: Section 2.3.3:

Please mention the limitations of OPC used to detect the particles. Typically those include limit on the size threshold, and artifacts from ice and liquid elements as these cannot be distinguished. This is difficult to quantify, but at least these limitations should be mentioned. OPC calibration is performed with other OPC and APS. The other counters have different flows; did you take into account the flow differences? It is also important to mention the error in the size of particles detected by OPC.

Response:

As discussed in section 2.2.3 of the paper, the OPC was recalibrated to detect particles in the range 1 to 8 μm , comment 35 below outlines how this works. The detection limit is $\sim 0.5\mu\text{m}$, that being the lowest signal distinguishable from the baseline noise.

Regarding the GRIMM and APS, flow rates are always considered when comparing counting instruments, by comparing number concentration which factors in the flow rate.

Regarding the error in size of particles detected by the OPC used as part of the MINC instrument, this is mentioned in the paper in section 2.3.3, page 19287, lines 26-27.

35 – Page 19287: Line 6:

Does this mean the Climet OPC cannot detect particles in the range 2 to 3 micrometers? What gain was used in the experiments?

Response:

The description in the text refers to the nominal particle bin size (lower limit), so there is no gap in the measurement capability of the OPC. The text will be modified to clarify this. However at high particle concentrations (such as those measured at AIDA) different dead time issues for the high and low gain channels make it difficult to match up the counts to give a complete distribution (this is discussed in section 6 – discussion section). Because of this the low gain channel was used for these experiments.

Add in the following to the current text:

“...from which concentrations in the 1–2 μm particle channels and 3–8 μm particle channels respectively were derived (channels are named according to channel lower size limit)”.

36 – Page 19287: Line 15-20:

Sentence ‘ To confirm the calibration...’ but calibration is already performed with PSL (line 4).

Why it was necessary to calibrate one more time.

Response:

We think that the wording here is causing confusion, particularly the use of 'calibration'. What we did was test that the electronics were sizing the particles at the same size as the other two instruments, since the calibration with the PSLs was for the OPC unit on its own.

The Climet calibration relates the signal peak height to particle size, our electronics classify peak heights into 8 size bins, it is therefore important to confirm that this classification is done correctly, either by calibration using a primary calibration standard, or by comparison to a calibrated instrument (as is done here).

Current version:

To confirm the calibration was satisfactory and the pulse counter system was operating correctly, the modified CliMET complete with comparator electronics and pulse counter was compared in the laboratory to a calibrated OPC(...) and an Aerodynamic Particle Sizer (...).

Reword to:

To confirm that the electronics, as part of the OPC system, were able to size particles correctly, the modified CliMET was compared in the laboratory to a calibrated OPC(...) and an Aerodynamic Particle Sizer (...).

37 - Page 19289: Line 10:

You mean APC chamber?

Response:

This will be added in and checked through the manuscript

38 – Page 19289: Line 11 – 12:

Please clarify RH with respect to ice or water.

Response:

As the difference in wall temperatures increases, both the RH w.r.t ice and RH w.r.t water will both increase. We will however, change this to supersaturation to keep continuity within the paper.

39 – Page 19289: Line 13:

‘RH scan’ is also used in the manuscript. Use either of these, but maintain consistency. Define what is RH scan.

Response:

After '... “supersaturation scans” add: ' (SS-scan)

40 – Page 19289: Line 16:

Figure 3 shows SSi, but figure text says RH.

Response:

Change figure text to SS.

41 – Page 19289: Line 16:

Figure 3 top panel shows temperature is within 32 ± 0.3 deg C. Not sure how it can vary by one degree, please clarify.

Response:

Figure 3 shows one example of a SS-scan. Several others were performed, the worst variation in temperature over a scan was over 1 degree, that is what is stated here.

42 – Page 19289: Line 25:

There are other few samples listed in the table 1 and are not tested here. Here only ATD, Saharan and Snomax samples are used. Please revise the sentence and clearly specify what samples were used in the present study.

Response:

After the text '... except the live bacteria sample', add the following: ': results for Arizona Test Dust (ATD), Saharan Dust (SD) and Snomax are shown in this paper'.

43 - Page 19290: Line 1:

Please mention the lowest temperature and corresponding maximum humidity that can be achieved within MINC.

Response:

The below figure will be added into the paper. The following text will be added to the paper on page 19289, end of first paragraph in section 4: “Based on the wall temperatures attained during ICIS-2007, figure 3 shows the range of sample conditions available when using MINC to test the activity of IN.”

(all subsequent figures will be re-numbered)

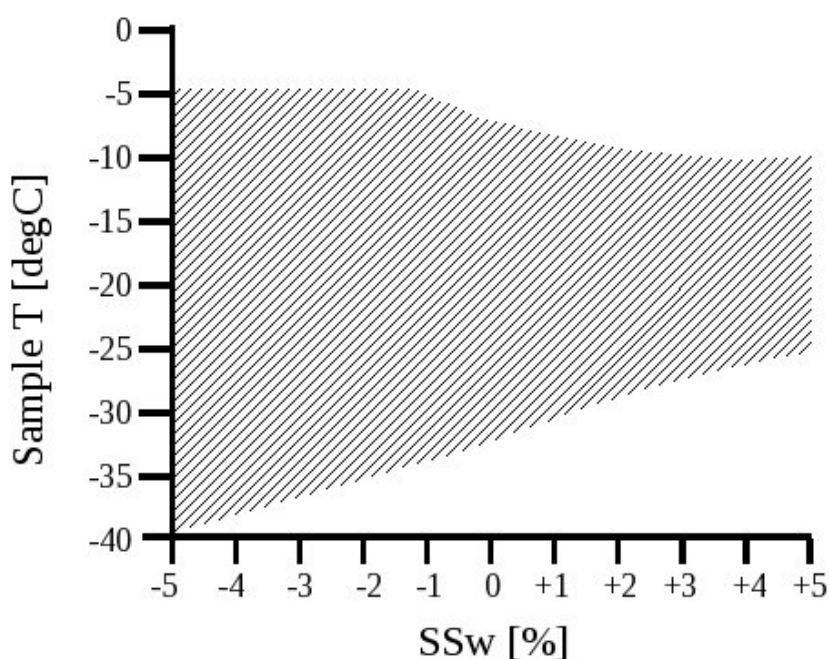


Figure 3: The range of sample conditions possible within the MINC chamber as indicated by the hatched area on this Sample temperature versus SSw.

44 – Page 19290: Line 6:

what was the original size of ATD?

Response:

This data is shown in what is currently figure 7. This connection will be made in the text.

45 – Page 19290: Line 12-15:

Please elaborate why integration and correction is applied. Explain in detail how this is done, as this

is important to obtain correct active fraction. Also how the transmission coefficients are obtained?

Response:

Please see section at the bottom of this document.

46 – Page 19290: Line 15:

Define SD.

Response:

SD = Saharan Dust – will be defined earlier in the text as shown above in previous comment

47 – Page 19290: Line 17-18:

what were the limitations of OPC? Please mention these limitations under either sections 2.2.4 or 2.3.3.

Response:

This is covered in another comment above

48 – Page 19290: Line 23:

Please clarify the sentence 'An inverse temperature ...'. It is not really clear.

Response:

Current wording:

An inverse temperature dependence to active fraction was also noted.

Reword to: For the same supersaturation value, higher activated fractions were measured for lower sample temperature.

49 - Page 19291: Line 4-19:

It is confusing to understand the similarities and differences between MINC and CSU-CFDC used at the workshop. It would be easy to read if different components (inlet geometry, length of chamber, cylinder diameters and dimensions, refrigeration system, detection system) of each chamber are compared in an order. References can be used where possible.

Response:

This comment will be addressed as part of a later comment – comment 73.

50 - Page 19292: Line 12:

Figure 6 has been plotted using RH values. The word 'supersaturation' needs to be replaced or figure 6 should be modified.

Response:

Replace with SS on the axis.

51 – Page 19292: Line 15-18:

The experiments were scanned to maximum 100% RH_w, but there is some data in Figure 4, 5 and 6 going up to 105% RH_w. Please clarify what was the upper limit.

Response:

The sentence in question reads '... most scans did not reach much higher than 100% Rh_w' – the few that did are the ones picked out here as they are the better scans to compare with the CSU instrument as they scan a greater range of SS_w. We think that this is clear, but we will replace the

word 'most' above, with 'many'.

52 – Page 19292: Line 20:

Please clarify what you mean by 'same instrument'. Write example.

Response:

What we are saying is results from the same instrument, i.e. two results from the MINC vary. To make this clearer, the text will be changed to: Variations in activated fraction measured at different times by the same instrument (MINC or CSU-CFDC) under apparently similar conditions as highlighted...

53 – Page 19292: Line 20-23:

Long sentence, break into two or use comma at appropriate places.

Response:

If we are to assume that it is the following sentence in question:

Variations in the activated fraction measured by the same instrument under apparently similar conditions as highlighted in Fig 5a may reflect spatio-temporal differences in the properties of the sample aerosol in the APC.

So in addition to the above comment, this will be reworded to:

Variations in activated fraction measured at different times by the same instrument (MINC or CSU-CFDC) under apparently similar conditions, as highlighted in Fig 5a, may reflect spatio-temporal differences in the properties of the sample aerosol in the APC chamber.

54 – Page 19292: Line 22-25:

The active fraction shown by 'C-5-3785' curve was produced by CSU-CFDC? Please clarify.

Response:

We agree there is confusion as the labelling is not explicitly explained in the text. We have rectified this.

Current text:

For example the C-5-3785 curve in Fig. 5A is data from the morning of 17 September 2007, while the C-6-5875 curve is from the afternoon.

Reword to:

For example, the C-5-3785 curve (CSU data from sample 5 starting at 3785 seconds from the reference time) in Fig. 5a is data from the morning of 17 September 2007, while the C-6-5875 curve is from the afternoon (note the new sample number).

55 – Page 19292: Line 25-26:

The APC was filled up with dust aerosols, and as experiments were run the number concentration decreased in time and resulted in different active fraction? Please clarify what you mean by aerosol population.

Response:

Aerosol population can be defined in the same way that human population is: it is the collective of aerosols within the APC chamber. We think that the target audience for this journal would sufficiently understand this term as it is common terminology for this topic.

As the aerosol population within the APC chamber ages over time, e.g. larger particles may settle, total number concentration decreases, etc, the shape of the size distribution will change. If it

changes such that the proportion of the size distribution that activates as IN increases or decreases as a fraction of the total population, then the measured active fraction should also change to reflect this.

56 – Page 19293: Line 1-3:

This means that one of the reasons for differences between the MINC and CSU-CFDC active fraction was because of inlet impactor transmission efficiency of particles? Please clarify.

Response:

We have noted this amongst a range of possible reasons why results between the MINC and CSU-CFDC results differ. If the inlet should stop different parts of the size distribution from entering the CFDC chamber, then the two chambers (neglecting other potential reasons for disagreement) would effectively measure a different subset of the incoming sample.

57 – Page 19293: Line 3:

Define AF.

Response:

AF = activated fraction, this will be defined where activated fraction is first mentioned: page 19290., line 9.

58 – Page 19293: Line 4-10:

Seems this paragraph is out of place. Section 6 is about discussion of the results. The figure 7 description could be added in section 4 and then rename it to figure 4.

Response:

This paragraph is an extension to the argument of changes in size distribution over time possibly affecting the measured activated fraction. We do not think that it would fit in section 4, but we have moved it to section 3 to incorporate it with the explanation of the AIDA set up and the APC chamber.

After '..... at or below around 104cm-3' the paragraph referred to here shall be inserted. The figure will be renumbered... as will all subsequent figures. This figure will then be referred back to when discussing the sample time issues in the discussion section.

59 – Page 19293: Line 5:

Remove word 'how'.

Response:

Current sentence:

Figure 7a shows how the total aerosol concentration varied with time and figure 7b shows size distributions (normalised to maximum value) at various times during the day...

Reword to:

Figure 7a shows the total aerosol concentration variation over time and figure 7b shows the size distributions (normalised to maximum value) at various times during the day...

60 – Page 19293: Line 9:

The words 'physical changes' in the sentence relates to the size of the particles?

Response:

The term 'physical changes' is common terminology within this subject, and in this case refers to the physical aspects of the aerosol population. Those being changes to particle shape and size.

To avoid confusion, we suggest to change the sentence:

Current wording:

These physical changes in the aerosol population are probably the result of particle coagulation and losses.

Reword to:

these changes to the aerosol size distribution are probably the result of particle coagulation and losses.

61 – Page 19293: Line 11-12:

It might be important to mention why two chambers sampled at two different times.

Response:

The fact that the chambers sampled the same temperature range at different times is unfortunate. The workshop was a busy two weeks spent gathering as much information as was possible at the time, as such, there were only a few times when scans coincided.

62 – Page 19293: Line 15:

The words 'different aerosol', please clarify what you mean by this. You are not using different type of aerosols such as soot, Kaolinite etc.

Response:

To avoid confusion here, we propose the following changes to the text:

Current text:

... could have effectively been measuring different aerosol, although....

Reword to:

... could have effectively been measuring a different subset of the aerosol population in the APC chamber, although....

63 – Page 19293: Line 19:

Define T.

Response:

T = temperature. Precede the 'T' with 'temperature'.

64 – Page 19293: Line 23-28:

It seems the onset detection limit for MINC is 94% RH_w, which is also approximately 128% RH_{ice} at -32 deg C. Please mention why chamber design geometry could be responsible for the higher onset. A simple water vapor diffusion growth equation can be used to calculate the time (t) required to grow a particle to a detectable limit (r₂) at -32 deg C and RH_{ice} = 128%, as follows, $t = (\rho_{ice} r_2^2) / (3 r_1 D \Delta p)$, where r₁ is sample inlet size of aerosols, D is diffusivity of water vapor and ρ is density. If we assume 7 second residence time within the nucleation chamber (not evaporation section) and OPC size detection lower threshold of 3 micrometers, the equation can be used to plot detection threshold limits. See following Figure. The blue line is marked at 7 second time, which crosses the red curve at ~900 nm size. This means the ice chamber can be used to investigate the ice nucleation efficiency of particles larger than 900nm only. The Figure shows sample inlet aerosols of size 300 nm will grow to 3 micrometers (OPC detectable limit) within ~ 20 seconds, but chamber has residence time of less than 20 seconds which means particles will grow to the size less than 3 micrometers and will cross the OPC undetected. These details including how to improve the

detection limit should be mentioned in the paper.

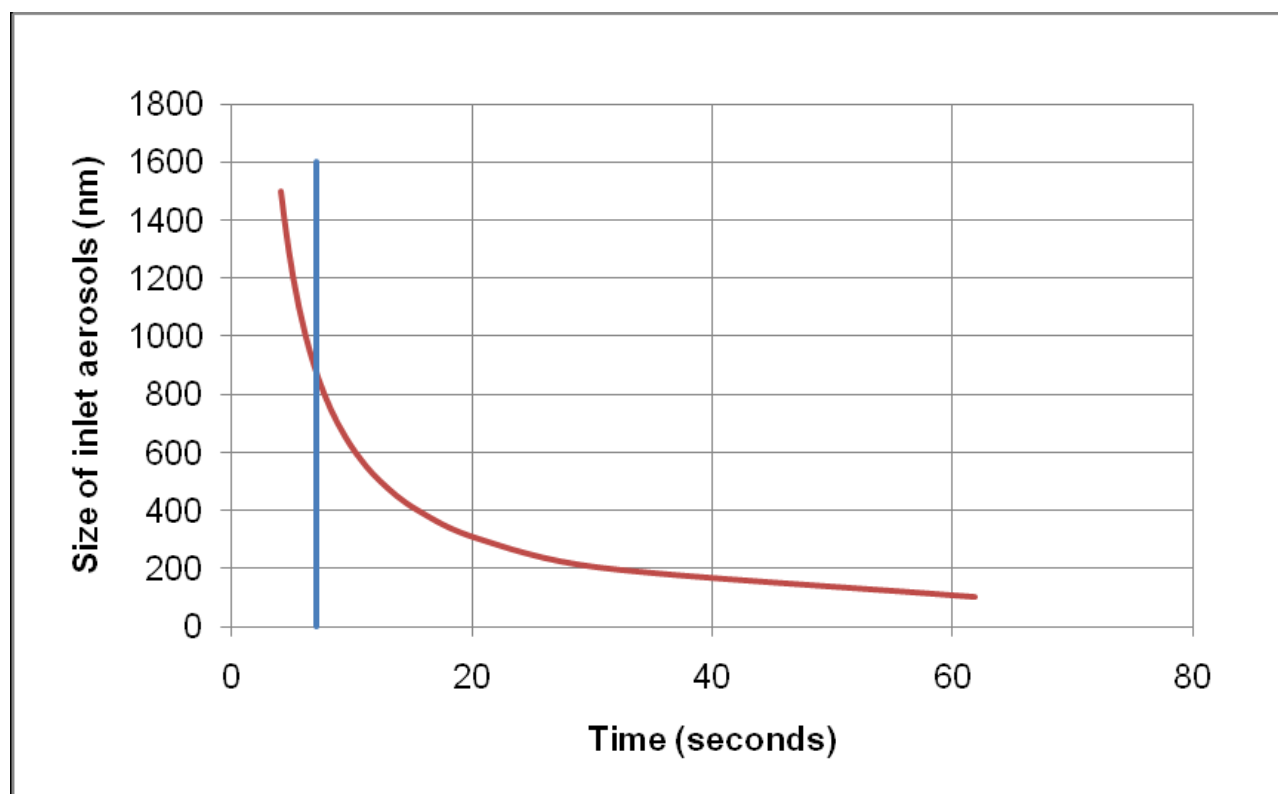
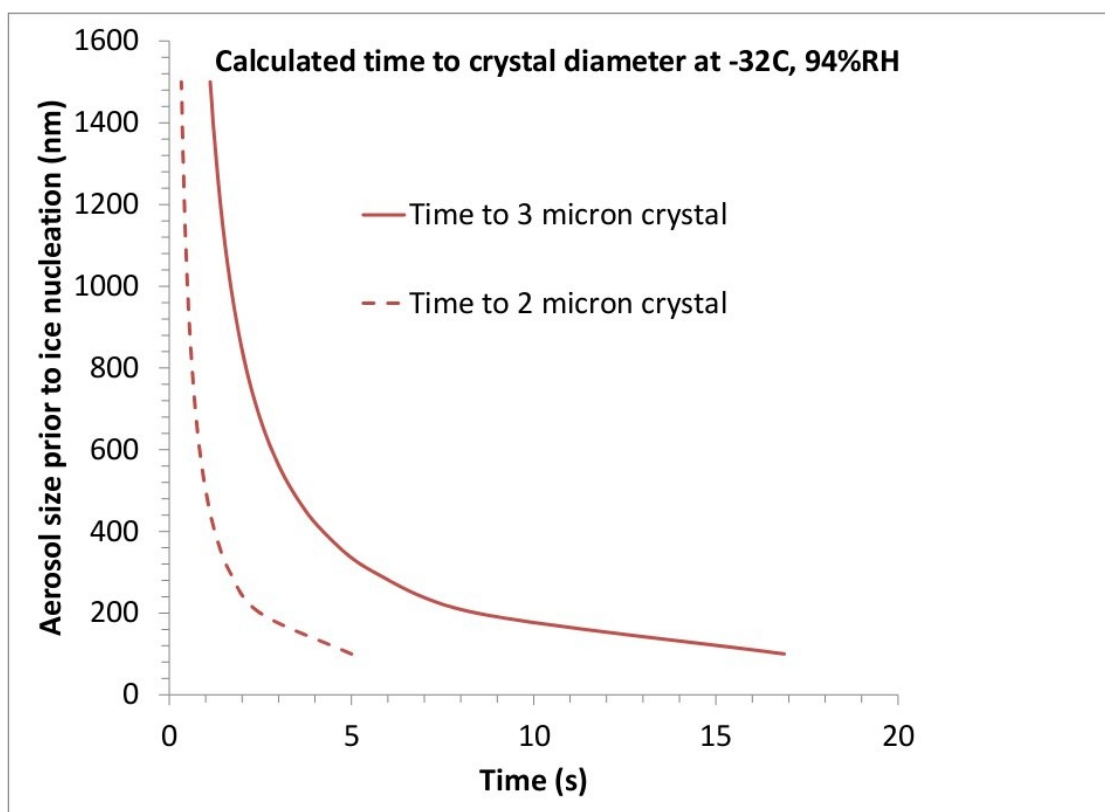


Fig: The red curve shows the time required for different size sample inlet aerosols to grow to OPC detectable size of 3 micrometers. Blue line is marked at 7 seconds. Inlet size aerosols less than ~900 nm cannot be investigated for ice nucleation efficiency because they do not grow to 3 micrometers. This is due to the residence time (~7 seconds) within the chamber, which cannot be extended because of space and flow constraints. The probable solution is to improve the detection limit of OPC.

Response:

The reviewer is correct to point out that the geometric and flow rate configuration of a CFDC in combination with microphysical growth considerations determines that at some low temperature there will be difficulty in growing particles to a detectable size if size alone is the method for differentiating ice crystals. Rogers (1988) discussed the impact of ice growth on detection at modestly cold temperatures, while Richardson (2009) has considered ice and liquid growth kinetics issues for ice detection in CFDC's into the cirrus temperature regime. The latter work also suggested that flow rate could be reduced below the "critical flow" level identified by Rogers (1988) in order to achieve adequate growth times. In our case, we do not feel that we achieved a limiting condition yet at -32C. This is because ice crystal diameter describes our OPC detection limit, whereas we believe that the reviewer has used ice crystal radius in his calculation of the time needed to achieve a spherical and unit density ice crystal size at -32C. We therefore believe that the MINC instrument could detect ice at -32C, even at 94% RH.



Richardson, M. S. (2009), Making real time measurements of ice nuclei concentrations at upper tropospheric temperatures: Extending the capabilities of the continuous flow diffusion chamber, Ph.D. dissertation, 249 pp., Colorado State Univ., Fort Collins, Colo. (Available at <http://chem.atmos.colostate.edu/Thesis2.htm>)

65 - Page 19294: Line 3-6:

Are these onsets are derived from experimental results plotted in figure 4 and 5? Please clarify if they are separate.

Response:

The results plotted in Figure 4 and 5 are included in this graph as a single point representing the point at which 1 in 1000 particles was activated. For example, the MINC curves in Fig 7b, are represented by the left most blue squares in figure 6. This has been made clear in the new figure caption:

Results from all MINC (squares) and CSU (circles) SS-scans for Arizona Test Dust (blue), Saharan Test Dust (red) and Snomax® (green). Points represent the conditions at which the 1 in 1000 particles were activated. CSU adjusted data points are also shown (cyan triangles). SS_{water} error bars are shown for Snomax® data (based on Richardson et al., 2010). The results shown in Figures 9 and 10 are represented on this graph.

66 – Page 19294: Line 3-11:

How these results compare with literature results. Please add the line saying these results are

in agreement with previous results (for eg. Bailey and Hallett, QJRMS, 2002; Archuleta et al., ACP,5,2005; Mohler et al., ACP,6, 2006; Knopf and Koop, JGR, 2006; Kanji and Abbatt, JGR, 2006; Kulkarni et al., ACP,10, 2010).

Response:

We feel that the inclusion of the above suggested sentence is not a suitable addition to this paper. The papers in question discuss results pertaining to different aerosol samples, generated in a different manner, therefore it is not a fair comparison to make.

67 – Page 19294: Line 12-14:

It is not clear how laboratory temperatures could affect the ice chamber temperatures. It might influence the temperature of sampling aerosols, but once the aerosols enter the chamber they might get equilibrated at chamber temperatures. Please clarify. Also it is possible that existing MINC heat insulation thickness may not be sufficient.

Response:

We agree with the reviewer here, and this is the point that this is not made clear, we shall rephrase this sentence.

Current wording:

During the AIDA workshop elevated laboratory temperatures compared with those at the University of Manchester lead to increased difficulties in obtaining constant wall temperatures along the length of the chamber.

Reword to:

During the AIDA workshop, elevated laboratory temperatures compared with those at the University of Manchester lead to heat transfer to the ends of the chamber from those parts exposed to the laboratory (e.g. inlet system). This lead to increased difficulties in obtaining constant wall temperatures along the length of the chamber.

68 – Page 19294: Line 16:

The temperature uncertainty within 10 cm at lower end of the chamber could influence the RH calculations. It is not clear if actually RH increased or decreased. I imagine walls might have warmed up and could increase the RH. This means particles which are not activated might activate, but the growth region is small and may not get detected. Please clarify and add these details.

Response:

A temperature change along the walls will affect the the sample conditions. The slight increase in temperature at the lower end of the outer-wall copper section will cause sample RH to increase at this point of the chamber, the sample temperature will also increase. So although an increase in RH might increase the likelihood of a particle activating, the increase in sample temperature might decrease it. As the reviewer has pointed out, if a particle should be activated in this section of the chamber, there is very little time for an ice crystal to grow to detectable size.

Add the following to the end of the paragraph:

We note here that, although the increase in the warm wall temperature at the copper/polypropylene interface increases the SS and sample temperature in this region of the chamber (and potentially activating extra IN), due to the short time before reaching the OPC any crystals activated at this point would not reach the detection limit for IN at the chamber exit and therefore not be counted.

69 – Page 19294: Line 17-20:

If residence time is assumed as 4 seconds, then from above Fig. the particles less than ~1300

nm cannot be detected because smaller particles do not grow to OPC detectable size threshold (3 micrometers). Figure 7b shows the particle size distribution with upper limit of 1000 nm. This raises the question that how many particles were present above 1000 nm in the APC chamber. Please mention these uncertainties and its influence on the active fraction calculations.

Response:

Please see the response to comment 65 above for growth calculations. Regarding particles above 1000nm, these were present. The CSU group attempted to impact them out of the sample. This only affects the background active fraction below which we cannot detect ice formation, but for us at least it was always below 1 in 10000 particles or less.

70 – Page 19294: Line 21-23:

Can residence time might be important to explain the discrepancy. See above comment.

Response:

We agree with the author, and this issue is already raised on Page 19295, line 8.

71 – Page 19294: Line 24:

Describe what is dead time.

Response:

Deadtime is defined as the short time after an event when a detector cannot process another event. This is common terminology with counting instrumentation. To avoid confusion here, we will change the text:

Current wording:

The modified climet counter is expected to encounter significant deadtime issues with particle concentrations of several tens of thousands per litre:

Re-word to:

In common with other optical particle counters, the modified Climet counter cannot distinguish multiple particles present simultaneously in the sample volume. Thus once a particle event has started the counter is effectively dead to new particle events until a short time after all particles have exited the sample volume (this is referred to as the ‘dead-time’). At concentrations of

72 – Page 19294: Line 25-26:

Do you mean that particle number concentration was higher at ICIS workshop, and might bias the results from OPC?

Response:

Yes. That is what we are saying.

73 - Page 19295: Line 1-16:

Details the causes of discrepancy between the chambers. It might be good idea if the other causes mentioned at difference places in the paper be combined and added here. One of them is aerosols sampling was not performed at similar time by both the chambers. On this note do you think the aerosols might be having a range of active site efficiency and could lead to different active fractions?

It is calculated previously that active sites are important (see Connolly et al. ACP, 9, 2009; Kulkarni et al., ACP 10, 2010), these active site calculations are not important here but should be at least mentioned the role of active sites could be important.

Response:

Whilst we agree with the reviewer that the presence of active sites on the surface of an IN is important when discussing the ability of particles to nucleated the ice phase, it is not possible to collect information regarding active sites with the MINC set up discussed here in this paper. We are reporting instrument development and an inter-comparison with another instrument, as such we feel we should not discuss active sites in detail here.

Regarding the collection of the MINC vs CSU-CFDC comparison items, reviewer 2 also requested this. We will move this portion of the paper to the end of Section 3 which discusses ICIS-2007.

End of section 3:

..... AIDA expansion experiments were carried out for all samples in Table 1. Further information can be found in Mohler et al. 2008.

This will be directly followed by:

This paper reports the results obtained by the MINC instrument described in the previous section. Also shown are comparisons with the CSU-CFDC instrument, an instrument of similar design, but with some notable differences. The CSU-CFDC is the same version (CFDC-1H) which was used in recent laboratory and field studies, e.g. Eidhammer et al. 2010; Richardson et al. 2010.

The CSU-CFDC design differs from the MINC design primarily in the use of an actively cooled evaporation section, and does not have heat-transfer fluid within the inner wall: instead the copper pipes have been directly attached to the inside wall surface. The CSU-CFDC is also longer than the MINC chamber, with the CSU-CFDC chamber section being 81 cm in length, with a reduced length of non-iced wall below the inlet manifold. Although the function of elements of the inlet section are the same, the physical arrangement and actual components used are different, such that the MINC experiences a lower transmission efficiency than the CSU-CFDC (0.8 – 0.9 for particles >100 nm). This discrepancy in the transmission efficiency between the two instruments is mainly due to the use of the Nafion counter-flow dryer in the MINC system, where the losses are much more extreme than those experienced in diffusion driers which the CSU-CFDC system employs.

The portion of text similar to this on lines 6 – 19 will be removed from what was section 5.2. The sentence starting 'Like MINC, the CSU...' shall also be removed from here.

The sentence 'Both instruments were...' will be changed to: 'MINC and CSU-CFDC were...'

74 – Page 19295: Line 5:

'Fig. 5' should be 'Fig. 5b'.

Response:

In the text here we are referring to both parts of Figure 5.

75 – Page 19295: Line 17:

This is good section. On line 24 it is mentioned that chamber length should be increased to 81 cm. Please mention why it should be 81 cm and give examples of existing instruments.

Response:

81cm is the current length of the CSU-CFDC chamber, we agree that this is not made clear here.

Current wording:

... it is suggested that the chamber be lengthened to 81 cm total length to allow easier comparison to

existing instruments....

Reword to:

... it is suggested that the chamber be lengthened to allow a longer growth time and so easier detection of IN; steps...

76 - Page 19296: Line 16-19:

To strengthen the conclusion, add the results from figure 6.

Response:

Add in '(see figure 6)' after '..comparable RH scans" on line 18.

77 – Page 19296: Line 19:

RH uncertainties are not mentioned in the text. Please add them.

Response:

We think that this information would sit better in what is currently section 5.2, where figure 6 is first introduced. RH uncertainty is rarely discussed in CFDC papers because it is relatively easy to state the spread of RH conditions across the apparent lamina, and to assume errors in the conditions at the average position of the lamina, but it is not so straightforward to calculate an uncertainty rigorously using standard approaches that accounts for uncertainties in the lamina position and/or in the distribution of particles across the lamina (or outside if there is any turbulence), especially if there are wall gradients. In Richardson 2009, Monte Carlo simulations were used to estimate RH uncertainties by imposing Gaussian noise. Computational fluid dynamics simulations reported in the thesis document a spread of RH conditions for tracked particles that support the calculated RH uncertainties. The uncertainties are most extreme at cold temperatures. A 3% value is used to err on the high side.

After the sentence 'Figure6 plots the function of sample temperature.', Add the following text: 'Error bars are shown at +/-3% RH as per the calculations shown in Richardson 2009 which simulate conditions within a CFDC'

78 – Page 19296: Line 20:

should read as 'Sect. 6.1'

Response:

This is correct, change will be made

79 – Page 19296: Line 23-26:

The sentence 'The move' is not clear. Please elaborate.

Response:

Current sentence:

The move to better ice crystal detection by phase detection of smaller particles, if feasible, would seem advantageous for IN detection systems because the need to grow ice crystals to much larger sizes than the largest sample aerosol particle is not required.

Reword to:

It is suggested that incorporating the use of phase detection within the counting system would be advantageous for IN detection systems. The use of this technique could remove the need for the impactor stage of the instrument, thus allowing a wider range of atmospheric particles to be tested. It is possible to distinguish between water, ice and marine boundary layer salt particles using

backscatter depolarisation measurements, although it is not yet completely clear that there are no other particle types which could confound this technique. Despite this, in light of recent developments (e.g. Nicolet et al. 2010), it is believed that depolarisation based phase discrimination of particles does offer promise with regard to the application proposed here, particularly in the elimination of false counts due to supercooled water droplets.

IODE paper (ZINC counter): <http://www.atmos-chem-phys.net/10/313/2010/acp-10-313-2010.html>

80:

Table 1:

There are other few samples which are not used in this paper, I suggest either remove these samples from the Table or highlight the ones which are used in the paper and add text to the header of the table.

Please mention the source for Saharan and Snomax. Define PTI (which I guess is 'Particle Technology Inc.').

Response:

This table is included for completeness. This is addressed in a previous comments above.

Snomax source is from the York Snow company. Saharan dust sample was collected from source near Cairo. This information will be added to the table.

81:Figure 1:

The figure is not self explanatory. Clearly indicate the aerosol sample and exit, show connections of air flow recirculation system, refrigeration components can be added into one box, mark the mass flow controllers with different symbol, mark the nucleation and growth section and evaporation section of the chamber. Print of this figure is not coming clear; if possible please increase the format or scale.

Response:

Figure 1 is to be reworked to make it clearer. The system is complex and so some simplifications are required. See comment 15 for new figure.

82:

Maintain the consistency of word font size across all Figures.

Response:

This should be addressed now

83: Figure 3:

I would suggest name each plot (for example panel a to d) and briefly add the details about each panel.

Response:

Each plot will be labelled and the Figure caption will be re-worded accordingly.

New figure caption:

A typical SS-scan, performed for ATD sample. a) Sample temperature time series, b) Ssw time series, c) Ssi time series, d) Number of particles >3 μm versus time for the SS-scan.

84: Figure 4 and 5:

The legend details should be mentioned. It is not clear the meaning of for e.g. M-6-1020 etc.

Response:

Yes, it is important that the legend notation is explained.

Reword figure 4 caption:

Arizona test dust SS-scans performed by the MINC instrument. Legend: 'M' – MINC instrument results, first number: sample preparation number, second number: seconds from the start of the experiment at which the scan began, number in brackets: temperature at which the scan was performed.

Reword figure 5 caption:

Arizona test dust SS-scans. MINC results are shown in blue, CSU-CFDC results are shown in black (2 μm threshold) and red (3 μm threshold). Results are shown for a) Sample temperature -26°C, and b) sample temperature -31°C. Legend: 'M' – MINC instrument results. 'C' – CSU-CFDC instrument results, first number: sample preparation number, second number: seconds from the start of the experiment at which the scan began, number in brackets: temperature at which the scan was performed.

85:Fig 5a: The most temperatures in the legends show -25 deg C, but text shows ~-26 deg C. Please clarify the use of '~' symbol. Similarly for the Fig 5b.

Response:

This is a typographical error, it has been corrected. We believe that it is common usage to use '~' to indicate an approximate value.

86:Figure 6:

Except few points the comparison is not performed at similar temperatures. Please mention this in the text. Again the legend should be explained. For the Snomax data point at approximately -6.5 deg C and RHw = 102%, what were the cold and warm wall ice chamber temperatures. What is the temperature uncertainty? My thinking is that if the warm wall temperature is closer to zero deg C and if temperature uncertainty is quite large, then it is possible that ice was melting. This will not affect humidity values, but might produce irregular ice layer and consequent erroneous active fraction results.

Why only error bars are shown to Snomax data. If this data is from Richardson et al. 2010, but it was different ice chamber than MINC and would have different error bars. These errors cannot be the same as MINC. The circles represent the MINC data, but legend show 'C-SM', I guess this is CSU data. Please correct the figure.

Response:

It has already been mentioned in the text that samples were not tested at the exact temperatures for each instrument, and this is the reason for the chosen result shown here : their closeness in sample temperature. Every effort was taken at the workshop to provide MINC measurements at sample temperatures to match those performed by the CSU-CFDC.

Legend will be explained: C = CSU-CFDC, M = MINC.

For the Snomax point mentioned here. It was considered if the warm wall could be approaching the melting limit. We do not believe that ice was melting on the warm wall during this time. As the scan is performed, the warm wall started at -7°C and was increased, such that if the melting level was reached, it was at the end of this scan and you would expect to see a levelling off of the wall temperature as the ice melts – this was not observed.

Errors bars were only shown for Snomax so that the results could still easily be seen. When error bars are added for the other two samples, it is very hard to see the symbols and therefore hard to see which are MINC and which are CSU data points. Error bars were shown on the plot to give a visual

indication of the range of errors in RH that are possible with this type of instrument. Regarding the errors shown here, please see comment 77 above.

The reviewer is correct, circles show CSU data, and squares show MINC data, this will be corrected

87:Figure 7:

Mention the units. To be consistent please use Fig 7a and Fig 7b instead of left and right figures.

Response:

Units will be included to the axis and the figure caption.

Appendix A: Inlet aerosol transmission calibration

The sample inlet system is described in section 2.2.3 of the main text. Due to the nature of the system, size dependent losses are expected and so these should be corrected for when considering the ratio of measured ice nucleating particles to the total aerosol population (known as 'activated fraction' (AF)). To calibrate the inlet losses a polydisperse distribution of ammonium sulphate particles was provided by a Topaz aerosol generator. The size distribution of these aerosol was measured before and after the inlet system using a Differential Mobility Particle Sizer (DMPS, please see Williams et al., 2007 for details on the operation of this instrument). Total aerosol concentrations during these tests were of the order of 10^6 particles per cubic centimetre. During these tests, the counterflow to the inlet drier was provided by the MINC airflow system as in normal condition of operation, while the inlet flow was provided by a Condensation Particle Counter (CPC, TSI 3025A), part of the DMPS system. Figure A1 shows the measured aerosol size distributions for DMPS scans at the start of the inlet system (direct to the TOPAZ aerosol source), scans after the drier, and then scans after the drier and the impactor. As can be seen from figure A1, for this size range, most of the aerosol losses are due to the counterflow drier.

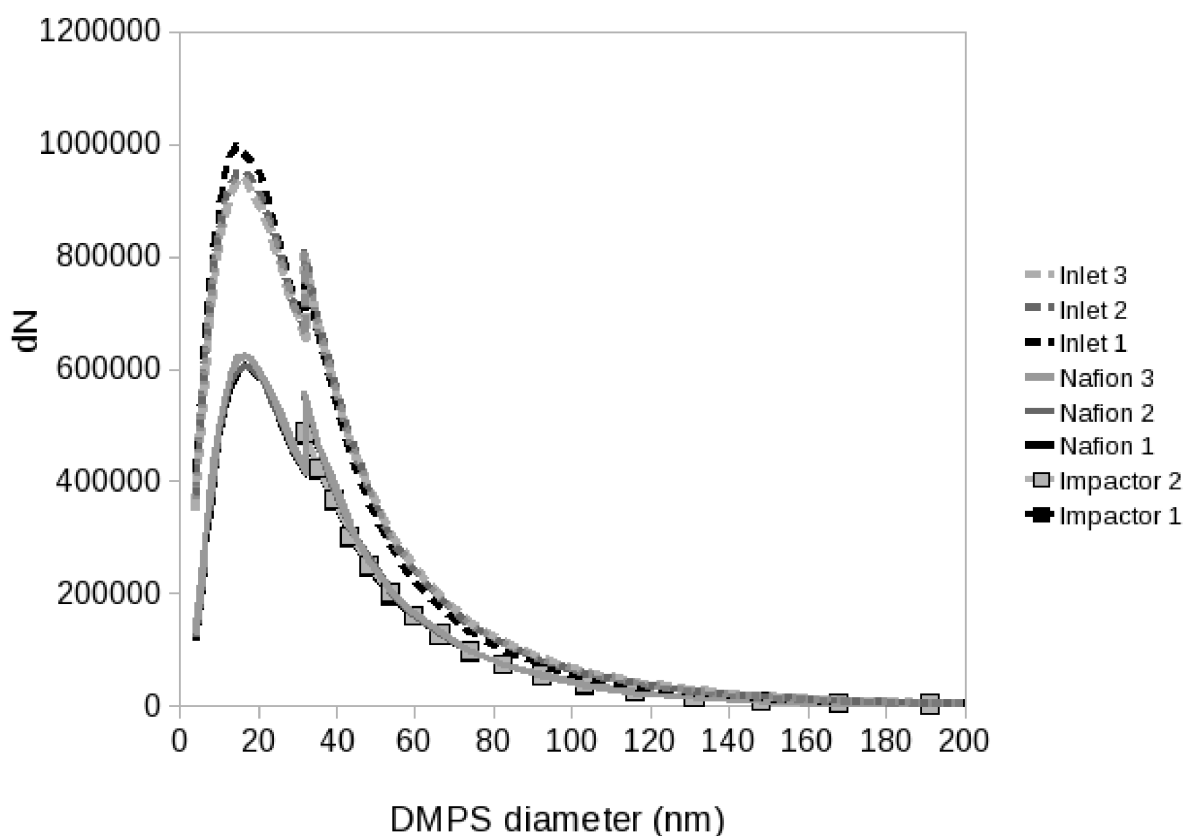


Figure A1: DMPS size distribution scans for the inlet system, showing results from before and after the inlet system.

Using the information given in figure A1, a size dependent transmission curve can be obtained. This is shown in figure A2: the transmission curve is shown for sizes 5 – 500 nm. For sizes 500 – 1000 nm the transmission is assumed to be 40 % as a continuation of the curve in figure A2 levelling off to this value. At sizes >1000 nm, the transmission curve for the impactor is then implemented.

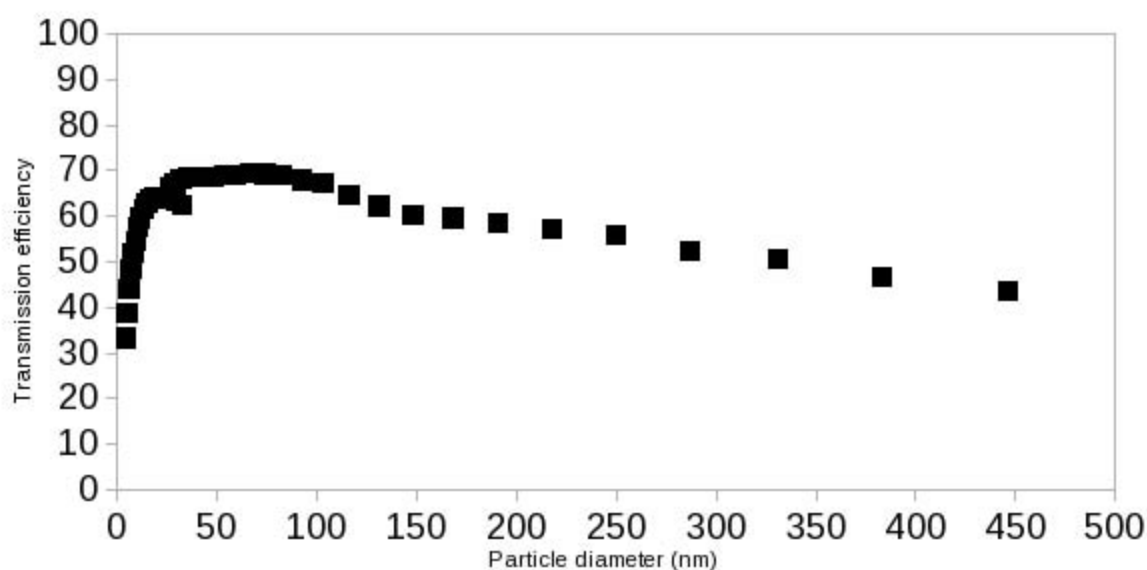


Figure A2: Transmission curve of aerosol particles through the MINC inlet system.

The impactor transmission and 50% cut-off were tested using a similar technique as described above. To test the size range of the impactor, a GRIMM optical particle counter (model 1.108) was used to sample laboratory air directly, and then through the impactor: this data is shown in figure A2. The 50% cut-off was found to be at 1.3 μ m, with 75% transmission at 0.8 μ m and 25% transmission at 1.7 μ m.

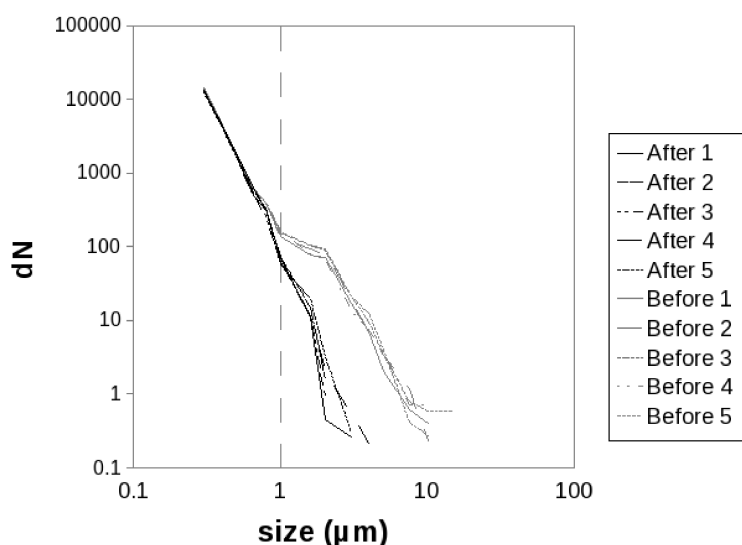


Figure A3: GRIMM size distribution for the impactor. Results shown for before and after the inlet system

The low transmission efficiency curve described above is primarily due to diffusional losses of smaller particles in the Nafion counterflow drier, and impaction losses of larger particles in the impactor and also in the connections between inlet parts. Coagulation is not thought to play a role here.

During the ICIS-2007 experiments, the size distribution of the aerosol population in the ACP chamber was not measured continuously, so applying a size dependent correction to the incoming sample aerosol could not be performed. Total aerosol number concentration was measured continuously, so we must provide a correction to this number. This was done by

comparing the calculated total number from the APC chamber non-corrected and corrected size distribution information. For each sample, the comparison was made for the size distribution information available across the measurement period. The transmission fraction of aerosol particles was found to be constant for size distribution data collected after approximately one hour had passed since the aerosol was injected. MINC results used in this paper were taken after an hour had passed. Transmission co-efficient used for this study are 0.55, 0.57 and 0.63 for ATD, SD and Snomax respectively.

In future experiments, it would be beneficial to measure the size distribution of aerosol at the inlet to the chamber continuously to allow more accurate results to be obtained.

Appendix B: Temperature calibration

As the temperature of each wall is not measured directly on the inside of the chamber, it is important to know how the recorded temperatures (measured at the back of the copper surface) relate to the ice surface temperatures. It is important to know this as it is these temperatures that are used to calculate the sample temperature and supersaturation conditions.

The instrument has three Platinum Resistance Thermometers (PRTs) on each wall, positioned at the top, middle and bottom of the copper sections (where the top and bottom PRTs are positioned 5 cm from the end of the copper tube). In order to calibrate the temperature difference between where we want to know the temperature (the inside walls of the chamber) and where we actually measure it (on the outside surface of the chamber), calibrated PRTs were placed inside the chamber against the copper wall at corresponding positions to the instrument PRTs. The walls were then cooled/warmed under conditions typical of those used at ICIS-2007. Typical airflow was also used to allow representative results, though the ice coating could not be applied as there was no way to seal the chamber as the calibration PRT wires must go through the chamber outlet. The calibration was performed at three different start temperatures to determine if start temperature has any effect on the results, this is shown in figure B1. Figure B1 has six panels, one for each of the instrument PRTs. It can be seen in each of these plots that a common straight line fit can be used for all three starting temperatures, indicating that starting temperature does not affect the calibration and that a simple correction can be made to each measurement.

Outer wall instrument temperatures agreed well with the calibration temperatures, mostly within 0.5°C. However, the inner wall instrument temperatures reported up to 5°C lower temperatures than the calibration PRTs, especially when operating at very low temperatures. The measurements at the top of the inner wall showed the most difference between instrument and calibration PRT values: 2°C difference at -20°C and 5°C at -40°C. Whereas the middle of the inner wall temperature comparison showed 0°C difference at -20°C and 3°C difference at -40°C.

The other piece of important information that these results show is that there does not appear to be a steady temperature along each of the walls. For example, consider the highest point on each of the outer temperature graphs in figure B1. The middle temperature is lower than the two ends. The same is true when considering the inner wall temperatures. Investigations using additional PRTs along the inside of each wall revealed that wall temperatures were steady along most of each wall, with temperature increasing slightly within ~10 cm at each end. This is mainly due to heat gain from the ends of the chamber.

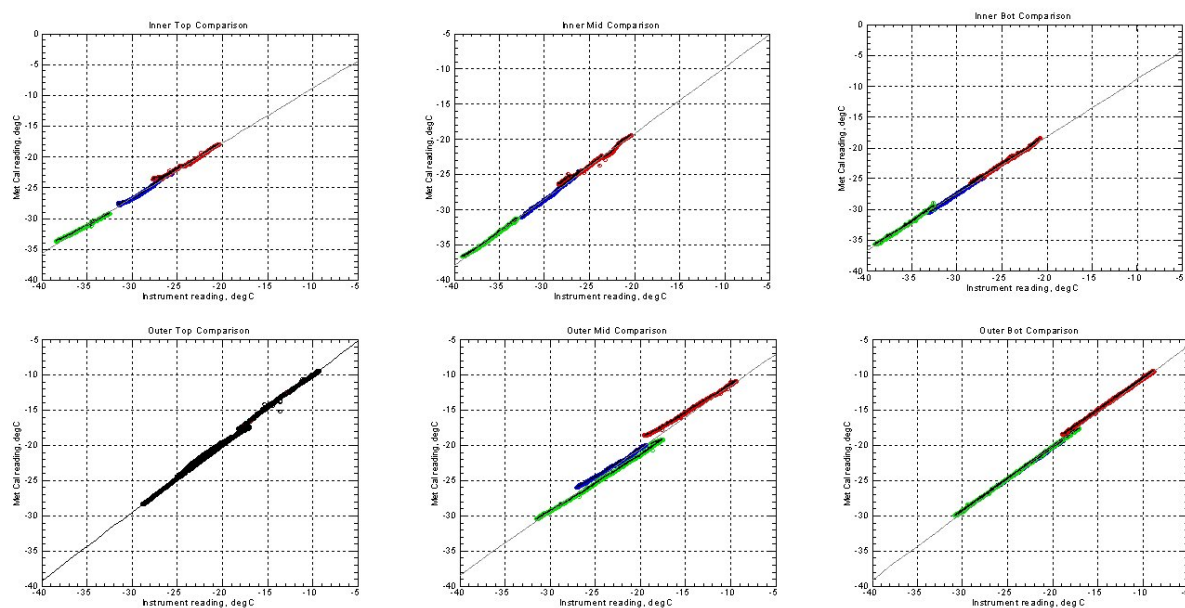


Figure B1: Temperatures as measured by instrument PRTs (x-axis) plotted against temperatures as measured by calibration PRTs* (y-axis) for three different start temperatures (-180°C, -250°C, -300°C)

*Deviations from straight-line fit for outer wall middle temperatures was due to calibration sensor not being firmly fixed to the wall.