Manchester Ice Nucleus Counter (MINC) measurements from the 2007 International workshop on Comparing Ice nucleation Measuring Systems (ICIS-2007)

Jones et al., Atmos. Chem. Phys. Discuss., 10, 19277–19307, 2010.

The authors had developed and constructed a new ice nucleation chamber based on the concentric cylinder design geometry. They have calculated the dust active fractions at various temperatures and also compared the fraction with other ice nucleus chamber. This is great work, and development of such instruments is necessary not only to understand the ice nucleation processes but also to understand the instrument itself. My comments are as follows, and after these revisions are made I recommend the manuscript for publication.

General comments:

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.

Specific Comments:

Page 19278:

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

Page 19279:

Line 1: It might be good idea to describe briefly the nucleation mechanisms. Also add what mechanisms can be investigated using MINC.

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.

Line 6: Parameterizations … please add the reference. Recently DeMott et al., PNAS, 2010 published a really good paper.

Line 9: The sentence '….between the two', here you mean two phases? Please clarify.

Line 14-17: Provide the reference.

Line 19: Possible processes – please clarify what processes.

Line 25: Regional and global hydrological pathways – provide the reference.

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.

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.

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Line 6: Was the rail frame was purchased off-the-shelve from Bosch? If yes put the model number. If not mention it was custom built.

Line 14-15: If available add the reference.

Line 17: Ebonizing is also done to obtain the uniform ice layer.

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Line 7: What is aspect ratio? Please clarify which width and height is used, also what is the aspect ratio of MINC.

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.

Line 25: The compressor unit model seems to be compressor and condenser unit, not just compressor unit.

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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.

Line 15-17: Do these filters remove the water vapor from the flow.

Line 17-18: Show the inlet and second drier and exhaust flow in the figure 1.

Line 20: 'The Airflow system is closed', but the sample flow is always added and could make the system open. Please clarify.

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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?

Line 7: Please write the software version and provider name. Correct CFDC to MINC.

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.

Line 14: what was the size range of distribution?

Line 16: Please clarify that to obtain more information about DMPS the readers should look into Williams et al., 2007 paper?

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.

Line 19: Please clarify – you mean sample flow was measured by a CPC or sample flow particle concentration was measured by a CPC.

Line 21: Please elaborate '…measured data…' sentence. Which data and where it was measured.

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?

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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.

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.

Line 9: what was the thickness of ice surface?

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.

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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.

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?

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.

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Line 10: You mean APC chamber?

Line 11 – 12: Please clarify RH with respect to ice or water.

Line 13: 'RH scan' is also used in the manuscript. Use either of these, but maintain consistency. Define what is RH scan.

Line 16: Figure 3 shows SSi, but figure text says RH.

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.

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.

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Line 1: Please mention the lowest temperature and corresponding maximum humidity that can be achieved within MINC.

Line 6: what was the original size of ATD?

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?

Line 15: Define SD.

Line 17-18: what were the limitations of OPC? Please mention these limitations under either sections 2.2.4 or 2.3.3.

Line 23: Please clarify the sentence' An inverse temperature …'. It is not really clear.

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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.

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Line 12: Figure 6 has been plotted using RH values. The word 'supersaturation' needs to be replaced or figure 6 should be modified.

Line 15-18: The experiments were scanned to maximum 100% RHw, but there is some data in Figure 4, 5 and 6 going up to 105% RHw. Please clarify what was the upper limit.

Line 20: Please clarify what you mean by 'same instrument'. Write example.

Line 20-23: Long sentence, break into two or use comma at appropriate places.

Line 22-25: The active fraction shown by 'C-5-3785' curve was produced by CSU-CFDC? Please clarify.

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.

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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.

Line 3: Define AF.

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.

Line 5: Remove word ‘how’.

Line 9: The words ‘physical changes’ in the sentence relates to the size of the particles?

Line 11-12: It might be important to mention why two chambers sampled at two different times.

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.

Line 19: Define T.

Line 23-28: It seems the onset detection limit for MINC is 94% RHw, which is also approximately 128% RHice 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 RHice = 128%, as follows, $t = (\rho_{ice}.r_2^3)/(3.r_1.D.\Delta\rho)$, 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 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.

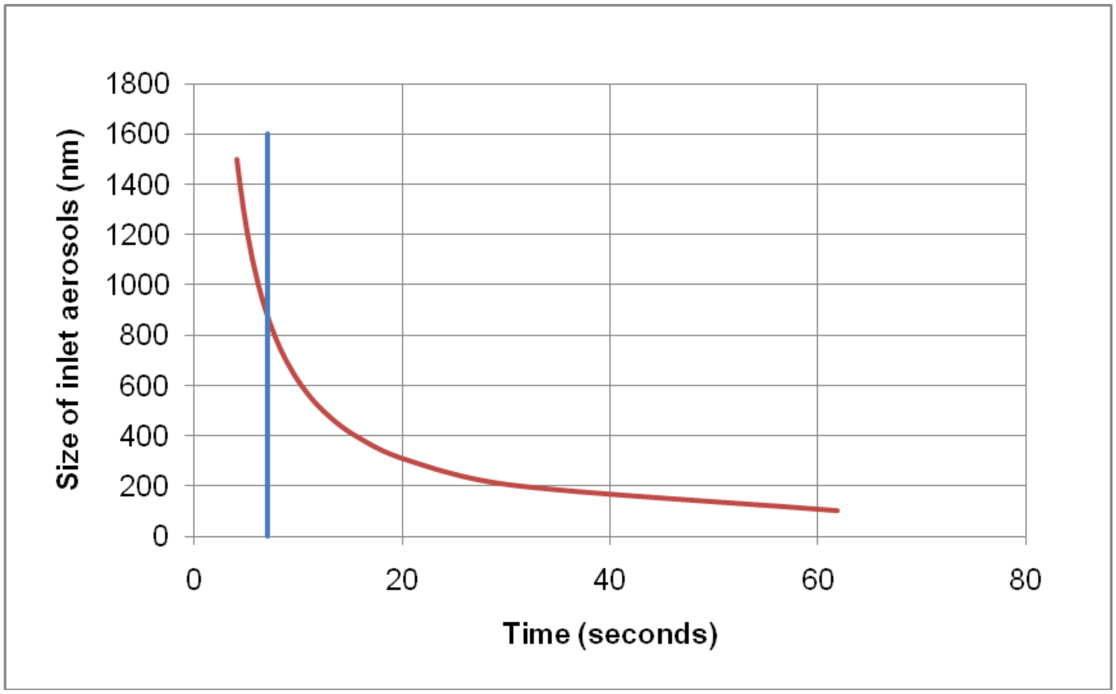

Fig: The red curve shows the time required for different size sample inlet aerosols to grow to OPC detectable size of 3 micrometers. Blue line is marked at 7 seconds. Inlet size aerosols less than ~900 nm cannot be investigated for ice nucleation efficiency because they do not grow to 3 micrometers. 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.

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Line 3-6: Are these onsets are derived from experimental results plotted in figure 4 and 5? Please clarify if they are separate.

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).

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.

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.

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.

Line 21-23: Can residence time might be important to explain the discrepancy. See above comment.

Line 24: Describe what is dead time.

Line 25-26: Do you mean that particle number concentration was higher at ICIS workshop, and might bias the results from OPC?

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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.

Line 5: ‘Fig. 5’ should be ‘Fig. 5b’.

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.

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Line 16-19: To strengthen the conclusion, add the results from figure 6.

Line 19: RH uncertainties are not mentioned in the text. Please add them.

Line 20: should read as ‘Sect. 6.1’

Line 23-26: The sentence ‘The move ….’ is not clear. Please elaborate.

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.’).

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.

Maintain the consistency of word font size across all Figures.

Figure 3:

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

Figure 4 and 5:

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

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.

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.

Figure 7:

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