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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Ice nuclei properties within a Saharan Dust Event at the Jungfraujoch" *by* C. Chou et al.

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Comment) This paper describes a new ice nucleation chamber (PINC) and shows results obtained over extended time periods at the Jungfraujoch research station. The ice nuclei concentration active in deposition mode increases from a typical background of 10 per litre up to a few hundreds per litre when Saharan dust was observed. These observations are good and contribute towards the understanding of ice nucleation and the paper should therefore be published subject to minor revisions. I have three main issues, but none major: Firstly, there is a lot of detail on the instrument that is not directly relevant to the observations discussed. Although, since this is first paper using the PINC, a more detailed instrument section might be justified. Secondly, the background counts in the PINC are significant especially during non Saharan dust events

and therefore should be better described. Thirdly, the Saharan dust event should be determined by back trajectories rather than a scattering parameter given the limited aerosol instrumentation.

Reply) We acknowledge reviewer 2 for the useful comments and suggestions. The detailed responses as well as their location in the revised manuscript are indicated.

Comment) abstract: This paper does not determine the relative contribution of deposition nucleation to mixed phase clouds.

Reply) This statement has been removed from the revised version of the manuscript.

Comment) page 23708, subsection 2.1.1: A table which summarises both ZINC and PINC (activation/ growth and droplet evaporation chamber dimensions, gap-width, residence time, operating temperature and humidity range, time taken to flood the chamber with water, etc) would be useful to show differences between the two instruments.

Reply) The main differences between ZINC and PINC have been included in Table 1 of the revised manuscript.

Comment) page 23709, line 13: Why can't the PINC measure immersion mode ice nucleation? By removing the inlet sample drying system.

Reply) Removing the inlet drier would not ensure that all particles sampled are fully immersed as droplets which would be required to quantify immersion freezing. In addition the large amounts of moisture coming into the CFDC could lead to a spurious RH profile in the chamber due to cooling of the sample layer. Furthermore from a practical point of view, one issue that comes after $\sim$1 hour of sampling is clogging of the sample inlet due to moisture freezing at this location. Thus the drier becomes necessary to allow longer sampling times.

Comments) page 23709, line 21: The refrigeration systems could be identical, its just that to reach colder temperatures more easily you have added a compressor in series. The actual cooling system layout is not really relevant to the IN measurements discussed here and could be better summarised or removed completely.

page 23710, line 15: Given that this paper only discusses IN activating in deposition mode, the droplet evaporation section is not really doing anything, and figure 2 showing maximum RHW before droplet breakout is not relevant.

page 23710, line 1: Aircraft usually operate in balanced flight so significant tilting of instruments should not be an issue.

page 23710, line 19: Again, details of Compact-RIO architecture not really relevant.

Replies) As these are the first published measurements with PINC, we think it is appropriate to give a more complete description of the instrument (also suggested by reviewer 3) so that further papers involving PINC could refer to the present paper even if some information might seem obvious or not relevant for the discussion in this specific paper.

Comment) page 23710, line 4: So is -51C the coldest you can achieve on the cold-wall?

Reply) This is correct for sampling conditions of RHw = 100%.

Comment) page 23710, line 8: What range of temperature inhomogeneities do you see (both with and without the heating pads) and what is it caused by? Can you say what the error on sample humidity is given this level of inhomogeneity.

Reply) We observed inhomogeneities of $\pm$1.5 K from the temperature set along the warm wall when the heating pads are not connected. When connected, the inhomogeneities are up to $\pm$0.5 K from the set temperature. Along the cold wall, inhomogeneities of $\pm$0.5 K are observed with or without the heating pads. For our working conditions at the Jungfraujoch this would lead to approximately a 7% error for the calculated RHw and 9% for the calculated RHi without the heating pads. With heating pads this error is approximately reduced to 3% and 4% for RHw and RHi, respectively.

Comment) page 23710, line 30: Is this 3 micron optical size threshold for latex spheres

or similar? Or have you corrected for refractive index etc.

Reply) The optical particle counter was calibrated with polystyrene latex sphere. The optical size threshold was set to 3 microns in order to make sure that the particles measured and counted as ice crystals were really ice crystals and not large aerosol particles. No specific corrections for refractive index were performed.

Comment) page 23711, line 8: The impactor used has a relatively low cut size of 0.9 microns. Why did you not use one with an larger cut size? Rogers CFDC has similar residence time but used a 2.0 micron cut (although not very sharp). Especially as large aerosol are expected to be better IN. Can you operate the droplet evaporation section not as an isothermal chamber at ice saturation, but as two independent walls extending the main activation/growth chamber and therefore increasing ice crystal residence time. This would allow for a higher OPC threshold and a larger impactor cut size.

Reply) We acknowledge this suggestion from the reviewer. The evaporation section can unfortunately not be extended to a growth section without major modifications because the cooling tubing of the evaporation region that regulates its temperature is directly connected to the tubing of the warm plate. This results in the evaporation section having both its walls at the same temperature as that of the warm wall. In Figure 8 (Figure 1 there after) we show the size distribution during the strongest SDE of the measurement period, and it is true that we missed some particles from the second small mode around 2 microns and therefore miss potential IN counts. Nevertheless we do believe that most of the IN was sampled. Using a 2 microns cut-off impactor is a good suggestion and this will be taken into consideration for future campaigns.

Comment) page 23713, line 5: The background signal seems to be comparable to your observations when there is no Saharan dust and should be better described. How does the background compare to that from ZINC? For each 15 minute measurement cycle, how long do you measure the aerosol free background signal? Do these wall-grown crystals occur randomly throughout the sampling? Do the error bars represent the combined error from sample and background count statistics? The time-series of IN concentration might be better plotted with both the uncorrected and background values.

Reply) The background of ZINC is higher than the one of PINC and is in the order of 10 to 20 particles per liter. For our lab instrument, it is not as crucial as in the field, as lab measurements deal with several hundreds of mineral dust cm-3. The background signal and aerosol free measurements periods have been better described in the revised version of the manuscript on page 6, lines 178-187. The wall-grown crystals fall randomly during the sampling, so in a time interval of 5 minutes for example, it could be either 0 or 3 particles per liter. The error bars do represents the combined error from the sample and background count statistics. The time-series show the corrected IN number concentration. Adding the uncorrected IN number concentration would make the plot confusing, so we would like to keep the corrected time-series. Nevertheless, below (Figure 2 there after) we present the uncorrected and background (aerosol free) measurements for the period of March (as the IN concentration were the lowest).

Comment) page 23714, line 8: Would it not be simpler to just use the dust model forecast and back-trajectories to forecast Saharan dust events, rather than the scattering parameter? The Atlantic source for the trajectories shown in figure 7 mean that the scattering parameter criterion sometimes gets it wrong.

Reply) The scattering parameter method has shown to be well suited for the Jungfraujoch site, as Coen et al., 2004 found in 92% of the cases that the dust episodes were correlated to backtrajectories, satellite observations or filter measurements. Figure 7 shows a source from the Atlantic Ocean. The scattering parameter criterion is reliable when a dust event is present for 4 consecutive hours. It also has a better resolution and allows real time assessment of dust load as compared to backtrajectories calculations. Nevertheless Section 3.1 (page 8) has been revised and now takes in priority the backward trajectories in order to discuss the presence of dust and the SSA exponent as a complement.

Comment) page 23716, line 25: So the 16 June dust event has a Atlantic source region? It should not be called a Saharan dust event at the start of this section then.

Reply) We agree with the reviewer that the dust event on June 16 (figure 7) showed an Atlantic source, but new backtrajectories ensemble calculations have been performed and are presented in Figure 10 which now shows air masses coming from North Africa on June 16. Furthermore the section has now been merged and renamed, “high IN number concentration events”.

Comment) page 23715, line 6: What is the typical ambient temperature and humidity upwind of the instrument station? Since biological material might initiate ice nucleation at warmer temperatures than mineral dust, might they already be activated?

Reply) The typical ambient temperature at the Jungfraujoch is between -10 and -15°C in March. They might have activated, but due to the use of the impactor, large biological materials are unlikely to be sampled through PINC. The assumption of ice crystals formed from biogenic aerosols has therefore been removed as suggested by reviewer 1 due to the lack of instrumentation able to detect biological activity.

Comment) page 23716, line 5: The time series figure 8 would be improved if you mark clearly the intervals that the Saharan dust events occur, defined by both back-trajectory and scattering coefficient.

Reply) Figure 8 (now Figure 7 in the revised manuscript) have been changed according to the suggestion of the reviewer. Shaded areas have been added and correspond to high IN number concentration.

Comment) page 23718, line 12: Is the 0.8 micron size the optical or aerodynamic size? This conversion is valid for spheres, What is the error on this size caused by non-spherical nature of dust?

Reply) The 0.8 micron size is the optical size. The error caused by the non-spherical shape of Saharan dust has been previously studied (Schladitz et al., 2008) and have shown that for submicron aerodynamic particles, the dynamical shape factor was below 1.2, and was 1 for particles up to 0.55 micron (Kaaden et al., 2008). Considering this shape factor value, the error on the largest particles would be less than 15%.

Comment) page 23718, line 16: Both plots in figure 11 really look similar in terms of correlation and the argument for an increased IN number when there are larger particles looks weak.

Reply) We agree that if supermicron particles were included, this might have shown a stronger correlation. Nevertheless the R2 of the plot taking particles below 0.5 micron is considerably smaller than when considering particles above 0.5 micron (0.69 versus 0.88) and this also agrees with the study from DeMott et al.,2010 (PNAS) who found a very good correlation of IN predicted as a function of particles above 0.5 micron concentration.

Comment) page 23719, line 1: Can you re-plot figure using only the back-trajectory criterion to define a Saharan dust event?

Reply) The figure has been modified according the above suggestion (see Figure 11)

Comment) page 23719, line 17: -31 C and 91% RHW operating conditions are stated in the abstract.

Reply) The sentence has been modified to “constant” instead of “ambient” (page 12 line 374).

References:

Collaud Coen M., et al., (2004). Saharan dust events at the Jungfraujoch: detection by wavelength dependence of the single scattering albedo and first climatology analysis. Atmos. Chem. Phys., 4, 2465–2480, 2004

DeMott, P., Prenni, A., Liu, X., Kreidenweis, S., Petters, M., Twohy, C., Richardson, M., Eidhammer, T., and Rogers, D.: Predicting global atmospheric ice nuclei distributions

and their impacts on climate, Proceedings of the National Academy of Sciences, 107, 11 217, 2010.

Kaaden, N., Massling, A., Schladitz, A., Müller, T., Kandler, K., Schütz, L. and co-authors. State of Mixing, Shape Factor, Number Size Distribution, and Hygroscopic Growth of the Saharan Anthropogenic and Mineral Dust Aerosol at Tinfou, Morocco. Tellus 61B, doi: 10.1111/j.1600-0889.2008.00388.x. 2008

Schladitz, A., Müller, T., Kaaden, N., Massling, A., Kandler, K. and co-authors. In situ measurements of optical properties at Tinfou (Morocco) during the Saharan Mineral Dust Experiment SAMUM 2006. Tellus 61B, doi: 10.1111/j.1600-0889.2008.00397.x. 2008

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 23705, 2010.

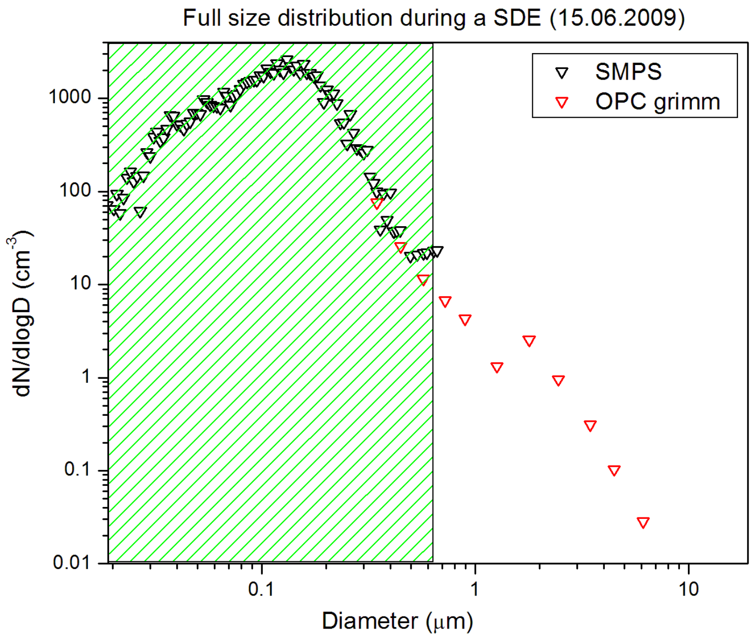

Fig. 1. Full size distribution during a Saharan Dust Event on June 15, 2009. The green shaded area corresponds to the fraction of particles sampled through PINC within a SDE.

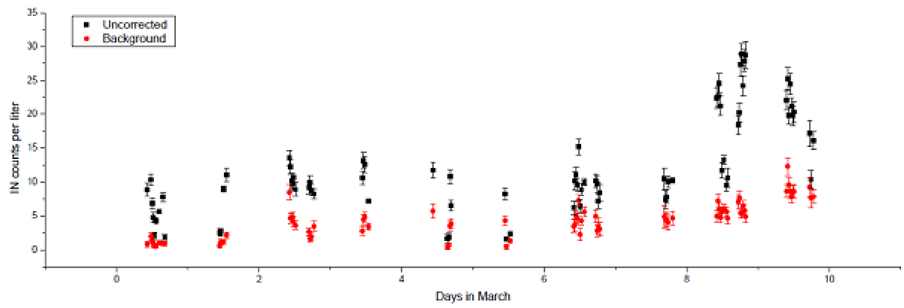

Fig. 2. Background and uncorrected IN measurements during the campaign in March