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Interactive comment on "Integrating laboratory and field data to quantify the immersion freezing ice nucleation activity of mineral dust particles" by P. J. DeMott et al.

Anonymous Referee #2

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This work combines laboratory and field measurements to develop a parameterization to predict the ice number concentration formed via the immersion freezing mode, based on the mineral dust number concentration and size. The authors point out that there are fundamental issues to be investigated and solved concerning the use of a CFDC type experiment to obtain immersion mode data. This important analysis sets the direction for future instrumental development and experiments.

I recommend the paper for publication, after the authors have addressed the points below.

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Major comments:

The developed parameterisation is not able to quantify immersion freezing ice nucleation activity in a microphysical manner. Eqs. (1) and (2) provide empirical relationships between the INP concentration detected with the CSU-CFDC, temperature and particle concentration larger 0.5μm. These relationships might be limited to their experimental conditions, but not generally valid. This limitation should be reflected in the paper.

An experimental demonstration that CFDC experiments running above water saturation or 105% RHw respectively, approximates immersion freezing is missing. Mainly the unknown CCN active particle fraction is an issue. E.g. Welti et al., 2014 observed only 4% CCN active particle in their CFDC experiments covering a wide temperature range and RHw up to 110%.

Comparing to the AIDA expansion chamber with an uncertainty in the CCN active particle fraction of +/-30% (Niemand et al., 2012) seems not optimal. A comparison to immersion freezing experiments ensuring particles are immersed in droplets (IMCA, coldstage, EDB, DSC) would be interesting.

Another option would be a characterisation following the homogeneous freezing curve to determine the fraction of CCN active particles. From the discussion in Appendix B it appears that this is not feasible due to the lower temperature in the evaporation region, it that the case?

Has the active fraction in the breakthrough regime been observed to reach 100%? According on Fig.2 it seems that only 4% of the particles are CCN active. Is that the case?

Detailed comments:

17368, line 19 and Fig. 3: What is the RHw for CCN activity setting in AIDA and how long does it take to form a cloud once this RHw is reached?

17370: One particular feature of Eq. (2) is that it predicts the fraction of particles (which are larger than 0.5μm) initiating ice formation to increase with increasing na>0.5μm at a given temperature. Accordingly fractions above 1 can result for high na>0.5μm and low temperatures. Does this indicate that the parameterisation is only valid for a specific range of particle concentration or activation of smaller particles? Where does the choice of a>0.5μm originate from?

17382 line 13-15: Looking at Fig. 1 the evaporation region is at -35°C for an experiment at -30°C and 105% RHw. But the droplets seem to only be cooled down by 3°C and not by 5°C, why?

17383 line 15-17: The statement that the RHw dependence can be ignored should be supported by more discussion. Fig.2 shows that not all particles are activated at 105% and that the activated fraction is increasing with increasing RHw. These results show a RH dependence and thus contradict the above statement. Doesn't Fig.2 also disprove the Petters et al (2009) assumption on p. 17367/17368 that the nucleation mode observed at 105% RHw is immersion freezing? It seems necessary to reconcile these apparently contradicting results.

Fig.2: As pointed out before the active fraction is increasing with increasing RHw. This is either a disagreement to an immersion mode mechanism taking place or an indication of incomplete CCN activation of the particle population.

Fig.3: Why does the scale of the number fraction go up to 3? At what RHw is complete CCN activation at -30°C detected in AIDA? Please consider adding a third panel showing the RHw, RHi conditions prevailing during the experiment.

Fig.5: A red line for high- blue for low temperature would be more intuitive. Some dashed lines are not reproduced. Please also add error bars (in both directions).

Fig. 6: I would expect D10 to be a straight line in this figure. Why isn't it, i.e. where does the scatter come from? Please add in the caption that cf=1 was used.

Fig. 7: RHmax is instrument specific and therefore an arbitrary condition to compare to. The active fraction would increase further for higher RHw as can be seen e.g. in Welti et al, 2009. Isn't the correction factor an indication that the mechanism looked at is different from immersion freezing?

Fig. 10: Should the RHw range be 105 +/-3% as stated in the text?

Fig. A1: b) The scale "Fraction of particles observed" should end at 1.

Interactive comment on Atmos. Chem. Phys. Discuss., 14, 17359, 2014.

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