Many thanks to the reviewer for his/her valuable comments and suggestions, which we have addressed as follows (the reviewer's comments are in italics, our reply is in standard text):

Major Comments

This paper reports on a major experimental effort to solve a difficult problem–the capture of ice crystals in a mixed-phase cloud. The paper is well written and the design is carefully and logically thought out. However, "before and after" checks with instruments built specifically for this purposes yielded differences that suggest the system is sublimating ice crystals, an unintended consequence. The field section (Section 3) should be expanded as suggested below. The design and theory is worth publishing, and I don't feel as strongly as the other reviewer that all aspects are required to be tested in the lab prior to deployment (although of course that would be useful). I suspect that the paper represents several years of effort for design, fabrication and characterization of various aspects of the instrument already. But, since the instrument was involved in a major field program, additional characterization with field data, and comparisons to both the Ice-CVI and microphysical instruments would be useful.

p. 12499-12500: Sublimation of ice crystals during sampling is seen as a "major obstacle" in sampling mixed-phase clouds. Please elaborate on this issue here, rather than in the Conclusions. What fraction of ice crystals in the target size range are actually missing? Are only qualitative results on the nature of ice crystal composition possible? How do results overall compare with the earlier technology, the Ice-CVI, and with concentrations of droplets and ice measured by microphysical instruments? What steps can be taken to pinpoint the problem and improve the new instrument? etc.

Before addressing the reviewer's specific comments, a few points should be made. Firstly, the main purpose of the ISI is the exclusive extraction of ice residuals (IR) from small ice crystals in mixed-phase clouds (MPC) for further physical and chemical characterization with appropriate (single particle) methods. This does not depend on extraction efficiency (as losses of small ice crystals can be expected to be independent of IR properties), except for limitations with counting statistics. Concentrations of ice crystals and supercooled droplets in MPCs should be determined with in-situ cloud probes, which are better suited for this purpose.

Secondly, the upper part of the ISI (down to the lower WELAS) should remove large ice crystals and liquid droplets in order to provide the PPD-2K exclusively with small ice crystals (thus gathering a high quality data set with the maximum of information on small ice particles, by avoiding limitations of duty cycle, disc space and artifacts in the patterns occurring when the dominant fraction of hydrometeors are droplets). The ISI isn't fully suitable for this purpose as the crystal shape is changed during transport through the inlet.

In order to address the questions concerning possible improvements to the setup, and address the issue of ice crystal losses, in the revised manuscript we have included selected results from a second campaign (CLACE 2014) in which a modified ISI setup was deployed. The primary modifications were a re-designed omni-directional inlet and a smaller droplet evaporation tube.

Quantitative determination of the fraction of missing ice crystals is hampered by the fact that the two WELAS optical particle size spectrometers (OPSS) which measure size distributions upstream and downstream of the droplet evaporation unit are not well suited to sizing the commonly aspherical ice crystals. While the targeted size range is given by the aerodynamic cut-offs of the cyclone and PCVI as 5-20 µm, the WELAS OPSS measure the optical diameter, which depending on the habit and orientation of the ice crystals in the sensing volume may vary greatly from the aerodynamic diameter. Nonetheless, we have attempted to quantify the losses in the droplet evaporation tube by comparing the size distributions measured upstream and downstream of the droplet evaporation tube by the WELAS sensors during the CLACE 2013 and 2014 campaigns (see Sect. 3.3 and Fig. 13 in the revised manuscript).

Furthermore, we have included a comparison of ISI and cloud microphysical probe measurements, i.e., a comparison of upper WELAS number concentrations for cloud particles > 10µm with ice concentrations measured with the Small Ice Detector probe, which is an open path cloud probe (see Sect. 3.1 and Fig. 10 in the revised manuscript). The comparison shows that while there are differences in the magnitude of the number concentrations, the time series trends measured for both instruments follow each other quite well, suggesting that the ISI does a reasonable job of sampling small ice crystals.

As regards a direct comparison of cloud particles sampled with the Ice-CVI, this is not possible as there are no instruments for counting, sizing or imaging hydrometeors within the Ice-CVI.

Minor comments

p. 12483, line 16: Insert "in mixed-phase clouds" after "enhance precipitation", as this is likely not the case in cirrus clouds. Line 21: Awkward wording. Suggest changing ", besides" to "in addition to".

Changed

p. 12484, line 4: Change "would" to "could", as this part of the chain is still speculative.

Changed

p. 12485-12486: What flow speed are the particles separated at? What prevents larger ice crystals from breaking up in the flow due to aerodynamic stresses (e.g., what are the Weber numbers)? What about impaction while making the turn into the "omnidirectional inlet"?

The volumetric flow through the inlet is maintained at 7 L min^{-1}. The aerodynamic stresses on the ice crystals vary therefore depending on the tubing diameters of the individual inlet components. The most critical in this regard is the PCVI, where the flow is accelerated with the use of a nozzle (reaching velocities of approximately 80 m/s). Pekour and Cziczo (2011) have discussed the possibility of droplet and ice crystal breakup in the PCVI. As shown in their work, droplets smaller than 25 µm do not reach the critical Weber number. However, it is much harder to predict the breakup of ice crystals, due to the variable density and morphology of ice crystals, as well as potential structural defects. While Pekour and Cziczo (2011) calculate the aerodynamic stress on ice for a variety of sizes and densities, they show that there is no consensus on the tensile or compressive strength of ice, and therefore it is difficult to establish whether ice crystal breakup could occur in the PCVI. However, as suggested by the reviewer, we have calculated the Weber number (We), defined as follows:

$$We = \rho V^2 D/\gamma, \qquad (1)$$

Where air density ρ is set to 0.9 kg/m^3, the flow velocity V is set to 80 m/s, the ice crystal diameter is set to 20 µm (shape is assumed to be spherical) and the ice surface energy γ is 0.12 J m^{-2}.

The Weber number for these settings is calculated to be 0.96. Meanwhile, the critical Weber number, above which droplet breakup occurs is on the order of 10-14 (e.g. Helenbrook, 2001; Pilch and Erdman, 1987; Tarnogrodzki, 1993). While recognizing as noted above that ice crystals may have a different breakup threshold than droplets, it seems reasonable to assume that considering the order of magnitude difference in the calculated Weber number and the critical Weber number it is unlikely that ice crystal breakup in the PCVI would occur for these sizes and velocities.

As regards impaction for particles making the turn into the omnidirectional inlet (note: the same discussion is also presented in the reply to review 3, where an almost identical question was posed), in order to establish whether impaction and breakup of cloud particles could lead to sampling artifacts we have calculated the ratio of kinetic to surface energy L (Eq. 2) for ice crystals following the approach used by Mertes et al. (2007), assuming a spherical ice particle.

$$L = 1/2 m v^2 / (\sigma_i A) \qquad (2)$$

Where *m* is the particle mass, *v* is its impact velocity (taken here as the wind velocity), σ_i is the surface energy of the crystal (replaced by the surface tension σ_w when calculating *L* for liquid droplets) and *A* is the particle surface area.

It has been shown by Hallett and Christensen (1984) that droplet splash occurs when the *L* value exceeds 7. Vidaurre and Hallett (2008) give the critical *L* value above which droplet splash takes place to be 7 for rough surfaces and 20 for smooth surfaces, while major fragmentation of cloud particles takes place for *L* values approaching 100. As in Mertes et al. (2007) and Vidaurre and Hallett (2008), due to lack of an empirically defined critical *L* value for ice crystals, we apply the same criterion to ice particles.

As seen from the Fig. R2-1 (shown below), an *L* value of 20, which is a reasonable critical value to assume for cloud particles impacting on the smooth surface of the omni-directional inlet, is exceeded only at high wind velocities and for large cloud particles over approximately 100 µm diameter. Furthermore, it should be noted that the values given here are upper limits as the impact velocity will be lower than the wind velocity due to the particles slowing down as they pass into the slower moving air around the inlet (Vidaurre and Hallett, 2008). For liquid droplets of an equivalent diameter the *L* values will be lower than for ice crystals, as the slight (~9%) increase in density for water vs ice is more than offset by the lower surface energy σ_w of a droplet (~0.073 J m^{-2}) compared to the surface energy σ_i for ice crystals (0.12 J m^{-2}).

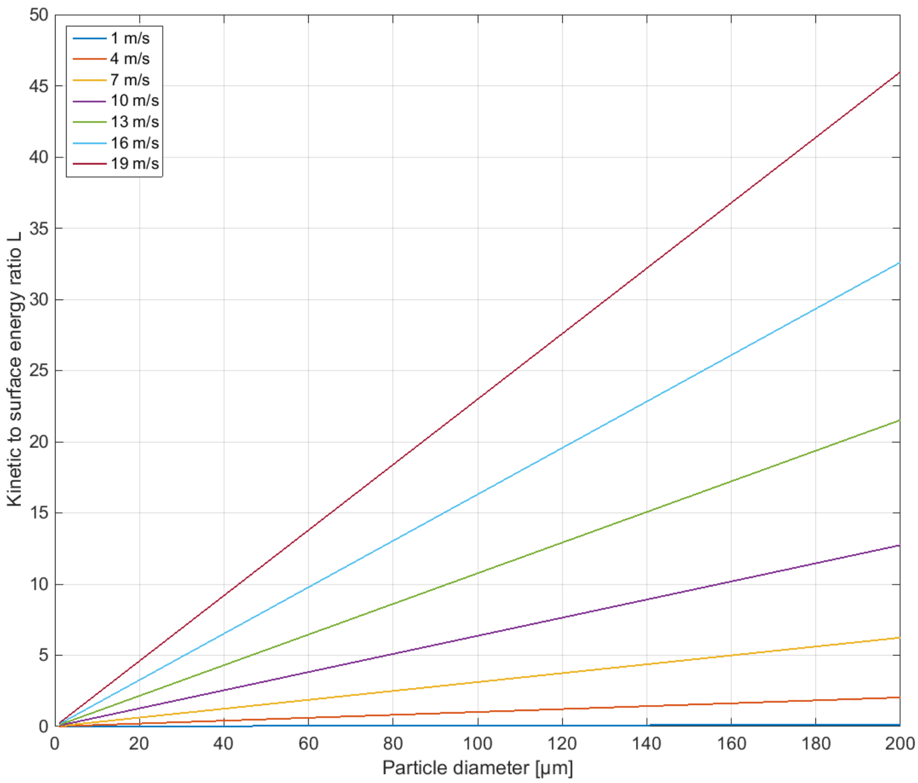

Fig. R2-1: Kinetic to surface energy ratio *L* for spherical ice particles as a function of their diameter.

p. 12486, lines 4-12: All good and underappreciated points.

Thank you.

p. 12490-12491: The potential weakness is the 50 micron droplet, which may not have time to evaporate fully, depending on the accommodation coefficient. Granted the mean droplet size is usually much smaller than this, but larger droplets do exist at times in MPC. However, as is mentioned near the end, the cyclone is expected to remove most larger hydrometeors. What is the transmission efficiency of the cyclone? Will any 50 micron droplets make it through? Perhaps you should just limit discussion of evaporation to droplet sizes that are expected to be transmitted at efficiencies of a few percent or more. Larger sizes are likely to have negligible impact on results (particularly since they usually will be present at lower concentrations than smaller droplets).

We have added a figure showing the modeled transmission efficiency of the cyclone (Fig. 2 in the revised manuscript; see Sect 2.3. of the revised manuscript for the calculation details). As can be seen from the figure, transmission of 50 µm particles is on the order of a few per cent. Therefore, combined with the low number concentration of such large droplets, we do not expect transmission of droplets of this size to be an issue for the measurements. This is also confirmed by the fact that the PPD-2K only observed a small fraction of droplets out of all particles >5 µm transmitted through the droplet evaporation unit.

Figure 1: I know this is primarily a schematic, but dimensions (at least lengths even if not to scale) should be included.

For the sake of keeping an easy-to-read schematic, we have decided not to add dimensions in the schematic itself. However, we have included the length and volume of the droplet evaporation unit within the text in Sect 2.4 and Sect 3.2 of the revised manuscript for the CLACE 2013 and CLACE 2014 droplet evaporation unit, respectively.

References:

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