Anonymous Referee #2

General comments: *The paper represents a comprehensive compilation of the characteristics of natural ice crystals. It also includes a detailed review of previous measurements with comparisons. The evaluation of the data sets from three diverse geographic regimes and different cloud types includes extensive analyses of cloud particle images and a complex assessment of the results. I think the manuscript is nearly ready for publishing except some minor revisions regarding mainly the representation of the paper.*

We thank the reviewer #2 for careful reading of the manuscript and the suggestions.

Specific comments:

1. *Introduction, page 31114, line 7: Please include a short discussion why the aspect ratio is described in different ways and what is the significance of it.*

The following sentence has been added in the revised manuscript. "Um and McFarquhar (2009) showed several definitions of AR have been used in theoretical studies and in situ data analysis, which might impact derived scattering properties of ice crystals (Korolev and Isaac, 2003)".

2. *Introduction, page 31114, line 13: What is the difference between the L-W ratio and the aspect ratio?*

Basically, they are the same, but different representations have been used depending on a purpose of study (e.g., numerical model) as stated in previous paragraph. The phrase "or the AR" has been removed to avoid any potential confusion.

3. *Section 3.1, page 3117, line 7 to the end of the paragraph: Resolution of 2.3 μm: Does this mean that smaller particles are not detected?*

Due to a resolution of CPI approximately particles smaller than 10 μm are not counted. A sentence to this effect has been added in Section 3.1.

4. *Section 3.2, page 3119, lines 4ff: Does this means that only 10% of the ice crystals in the investigated cloud were analyzed? However, I fully agree that the analyses of pristine crystals is important because of the reasons you give.*

We thank the referee for mentioning this point. A total of 341,093, 846,534, and 122,871 particles from TWP-ICE, SPARTICUS, and ISDAC, respectively, were analyzed. Among these particles, 0.58% (0.61%; 0.22%) of crystals were columns (plates; bullet rosettes) whose dimension could be measured unambiguously for TWP-ICE, whereas they were 0.79% (0.18%; 0.67%) and 2.18% (0.28%; 0.62%) for SPARTICUS and ISDAC, respectively. The fractions of crystals whose dimensions were measured are now included in section 3.2 together with the total numbers of particles obtained from each flight in Tables 4-6.

5. *Section 3.2, page 31120, line 1 and 2: Please include a more detailed discussion about the consequences of the fact that ice crystals characteristics are projected ones.*

The following sentence has been added in the revised manuscript. “In general, the projected dimensions are shorter than the actual dimensions, which causes errors in determining aspect ratios depending on particle orientations”.

6. *Section 3.2, page 31120, line 14: What does “manually measured” exactly mean?*

The boundaries of the ice crystals were identified and the particle dimensions were then determined by applying a scaling factor using the IC-Ruler. Please also see the response of comment 7.

7. *Section 3.2, page 31120, line 16: Please include a discussion to explain the differences between the IC-Ruler and the automatic CPIView software.*

The following sentences have been added in the beginning of the last paragraph of Section 3.2. “The boundaries of the ice crystals were identified and the particle dimensions were then determined by applying a scaling factor using the IC-Ruler. The CPIView software supplied by SPEC Inc. automatically determines dimensions of particles based on the gradient of pixel intensity. However, most particle dimensions

analyzed in this study could not be determined from CPIView and, thus, the manually determined IC-Ruler dimensions are used.".

8. *Section 4.3, page 31127, line 23: Explain in the text the meaning of "r".*

The corresponding sentence has been replaced with "However, the *r* were extremely small suggesting the dependence of AR on *T* was very weak".

9. *Section 4.3, page 31128, fist paragraph: From the description in the text the meaning of Figure 15 is not clear to me, the same in the caption of Figure 15: what do the equations mean? It might be better to explain this in the text. Furthermore, it is written that "y" are indicated in the figure legend but is not shown.*

We agree that the caption of Fig. 15 and corresponding sentences in the manuscript are not clear. The sentences have been revised as "In this study, several *L*-*W* relationships and hence different ARs were derived depending on the dimensions used to define the ARs and the methodology used to measure the dimensions. The *L'*-*W'* relationship for HCOLs is the closest to that of actual columns and, thus, is used as a reference value. Figure 15 illustrates the differences between *W'* of HCOLs derived from *L'*-*W'* relationship for HCOLs and four different *W'*s derived from *D'*-*W'* relationships (i.e., all columns, CPIView, OCOLs, and HCOLs, which denoted as *y* in Fig. 15) for the same *D'* corresponding to the *L'* of HCOLs.". The caption of Figure 15 has been changed as "Calculated differences between *W*′ of HCOLs derived from *L*′-*W*′ relationship for HCOLs and four different *W*′s derived from *D*′-*W*′ relationships (i.e., CPIView, all columns, OCOLs, and HCOLs) for the same *D*′ corresponding to the *L*′ of HCOLs. Differences are calculated as 100×(*W*′ of *y* - *W*′ of HCOL (*L*′-*W*′ relationship))/(*W*′ of HCOL (*L*′-*W*′ relationship)), where four different *y* relationships are indicated in the figure legend.".

10. *Section 4.4 in general: This complete section I found rather complicate to follow and to understand the basic results and conclusions. Maybe you could try to find a way to better present your findings.*

We carefully reread Section 4.4, but could not find major problems.

Technical corrections:

11. *Introduction, page 31113, lines 16 and 17: there are comma missing after 1948 and 1990.*

Done.

12. *Introduction, page 31114, line 10: I suggest to write the equation in a separate line.*

Since the equation is not referred in other parts of manuscript, we think that current form is OK.

13. *Introduction, page 31115, line 18: The expression "remainder" seems to be not appropriate here as the major part of the paper is still following.*

The sentence has been revised as "The paper is organized as follows.".

14. *Introduction, page 31114, lines 19/20: To underline the contrast of new to previous data I would suggest to write "the newly collected data" or something similar.*

The sentence has been corrected as referee's suggestion.

15. *Section 2, page 31116, line 3: Write "Tables 1 to 3", also in all other cases in the paper later on, just as "Figure x to Figure y", e.g., on page 31126.*

We are following what ACP is requiring.

16. *Section 3.1, page 31117, line 7 to the end of the paragraph: This sentence is too long, please split it.*

The sentence has been split.

17. *Section 3.1, page 31118, line 21: Please explain SD in the brackets (standard deviation).*

Originally we used "standard deviation", but it was changed to "SD" during the ACPD publication process. All "SD" have been changed back to "standard deviation" to avoid any confusion with "size distribution".

18. *Section 4.1, page 31121: I think it would help the reader if you mention the different geographic regimes where the field campaigns were performed, also in the other results sections.*

The geographic regimes have been added.

19. *Section 4.1, page 31121, line 13 and 14: Please reformulate this sentence, it is not clearly understandable.*

The "…**compared** with…" was missing. It has been added. Thank you.

20. *Section 4.1, page 31122, line 5: "Compared with **the** other campaigns, …"*

It has been corrected.

21. *Section 4.1, line 9: Include "bottom row **of Figure 4**".*

It has been added.

22. *Section 4.2, page 31123, line 18: Please reword "within which".*

It has been replaced with "for which".

23. *Section 4.2, page 31124, line 6: Reformulate the sentence after "further".*

The sentence has been revised as "Further, there may be more time for growth if the crystals are falling from aloft.".

24. *Section 4.2, page 31124, line 15: It is clear from the temperature ranges that during two campaigns mixed-phase clouds were investigated but this should be mentioned earlier in the text and in Tables 4 to 6. Again, as I mentioned above, I think it would help the reader by the understanding and interpretation of the results if the geographic regimes of the different campaigns are mentioned in the text at some places.*

We cannot determine cloud thermodynamic phase using temperature only. We think that current form is good enough to show ice crystals acquired from mixed-phase clouds. The geographic regimes have been added in Section 4.1.

25. *Section 4.2, page 31125, line 1ff: Reformulate this sentence for a better understanding.*

The sentence has been revised as "Although this selected threshold is purely empirical based only on the data used in this study and there might be influences of particle orientation, it successfully separate thick and thin plates with better correlation coefficients.".

26. *Section 4.3, page 31125, line 19: reformulate this part of the sentence.*

First 2 sentences of Section 4.3 have been replaced with following sentences. "There have been few studies that investigated *L-W* relationship or ARs of ice crystals over wide range of temperatures. Therefore, the large data set created here is used to stratify *L-W* relationships according to *T* and geophysical location".

27. *Section 4.3, page 31125, lines 22 to 24: Please reword this sentence in the way that "in this study" is put at the beginning.*

The sentence has been revised.

28. *Section 4.3, page 31126, lines 5 to 7. Split this sentence.*

Done.

29. *Section 4.3, page 31126, lines 8 and 9: Include "solid colored lines".*

It has been added.

30. *Section 4.3, page 31126, line 11: Add "This indicates* ***that****…".*

It has been added.

31. *Section 4.3, page 31126, line 14: Add "L and H showed* ***that*** *the…".*

It has been added.

32. *Section 4.3, page 31126, lines 20 to 22: Reformulate this sentence for a better understanding.*

The sentence has been revised as “Thus, further experiments measuring crystal growth by the rate of supply of water molecules from the vapor phase and by the rate at which latent heat of deposition removed are required at colder temperatures.”.

33. *Section 4.3, page 31127, lines 1 to 5: These sentences appear complicate because you always use “increase” and “decrease”. Try to replace it in some cases by other words, e.g., enhancement, rise, decline, reduction.*

They have been replaced with following sentences. “Further, ARs of columns and bullets increase with the minor (i.e., *W’*) and major (i.e., *L’* or *D’*) axis, albeit at a reduced rate for larger *W’*, *L’*, or *D’*. The dependence of the *D’-W’* relationship for bullets on the number of branches is also shown in Fig. 11, with the *W’* of bullets decreasing with the number of branches for a given *D”*”.

34. *Section 4.3, page 31128, lines 12 to 14: Reformulate this sentence.*

It has been revised as “Thus, caution should be taken when comparing crystal dimensions and *L-W* relationships derived from different in-situ data sets, which frequently use different variables to describe the relationships.”.

35. *Section 4.4, page 31128, lines 22 to 23: Reformulate this sentence.*

This sentence has been deleted. Thank you.

36. *Section 4.4, page 31128, lines 23 to 25: Put “Additionally” at the beginning of the sentence instead of “also”.*

Done.

37. *Section 5, pages 31134 and 31135, points 1 to 6: Here is also some confusion with all the “increase” and “decrease”. I would suggest to replace some by similar expressions.*

The corresponding sentences have been revised as following:

1. The maximum occurrence frequency of bullet rosettes occurred at *T*~-45°C. Plates showed exactly the opposite pattern with a minimum occurrence frequency at *T*~-

45°C. Column crystals were ubiquitous for all temperature ranges even in the plate formation regime of -40 < T < -20°C.

2. The dimensions of ice crystals showed a strong dependence on temperature. All measured dimensions of columns, plates, and bullets increased with temperature except for the W' of columns which decreased between -10 and 0°C during SPARTICUS and ISDAC. The columns measured at such temperatures were grown in mixed-phase clouds where needles, sheaths, and long columns can grow.
3. Columnar crystals (i.e., columns and bullets) have larger dimensions (i.e., W') of the minor axis (i.e., a axis) for a given dimension (i.e., D' or L') of the major axis (i.e., c axis), and thus smaller AR, as temperature increases. This trend was not noted for plate crystals.
4. The AR of columnar crystals increased with the dimension of the major and minor axis, albeit at a reduced rate for larger crystal dimension. The AR of columns showed a weak temperature dependence with broad maxima at -55 < T < -45°C. The AR of columns showed a sharp peak at T~-5°C where long columns were sampled during SPARTICUS and ISDAC, whereas the minimum AR of plates was found at T~-15°C. The ARs of bullets and bullet rosettes slightly decreased with temperature.
6. The AR of bullets increased with the number of branches in the bullet rosettes. The mean and standard deviation of the numbers of bullets (i.e., branches) were 5.50±1.35 for all three campaigns and 6.32±1.34, 5.46±1.34, and 4.95±1.01 for TWP-ICE, SPARTICUS, and ISDAC, respectively.

38. *Section 5, page 31135, line 20: "measured" instead of "measuring"?*

It has been replaced with "measured".

39. *References, page 31139, line 7: The reference Goodman et al. is not mentioned in the text. Please do so or remove them from the list.*

It has been removed. Thank you.

40. *Tables: In some tables the type size should be enhanced as it is too small in comparison to the general type size, in particular in Tables 1, 2, 3, and 7.*

It will be handled accordingly during the ACP publishing processing.

41. *Captions of Table 1, 2, and 3: Please reformulate the part "when original work indicated". Add "NA indicates* ***that*** *corresponding…".*

The corresponding revisions have been made.

42. *Caption of Table 7: Please replace: "The number***s** *in parentheses indicate* ***the*** *numbers of samples…* ***The*** *occurrence percentage…".*

Done.

43. *Figures: Most of the figures are very small and should be enhanced, Figures 4, 5, 7 to 14, 16, and 17.*

It will be handled accordingly during the ACP publishing processing.

44. *Caption of Figure 2: Replace "… of ice crystals of (a)…" by "… of ice crystals: (a)…"*

Done.

45. *Caption of Figure 3: Add "… and those obtained from CPIView.".*

Done.

46. *Caption of Figure 4, last line: "total number***s** *…".*

Done.

47. *Caption of Figure 5, second line: "… are shown …".*

Done.

48. *Caption of Figure 8: last line: "…the number of bullet rosette***s***…".*

Done.

49. *Caption of Figure 9, last line: "indicated with dotted line**s**".*

Done.

50. *Caption of Figure 15, last line: "… **values of** y…".*

The caption of Figure 15 has been changed as "Calculated differences between *W′* of HCOLs derived from *L′-W′* relationship for HCOLs and four different *W′*s derived from *D′-W′* relationships (i.e., CPIView, all columns, OCOLs, and HCOLs) for the same *D′* corresponding to the *L′* of HCOLs. Differences are calculated as 100×(*W′* of *y* - *W′* of HCOL (*L′-W′* relationship))/(*W′* of HCOL (*L′-W′* relationship)), where four different *y* relationships are indicated in the figure legend.".

51. *Caption of Figure 16, second line "… when more than 14 crystals **are available** within each 5°C **interval**…".*

They have been added.

52. *Caption of Figure 17, last line: "… and 12 lines are shown in (b)." What does this mean?*

The sentence has been revised as "Dotted lines representing *L/W*=1, 2, 4, 7, and 12 are also shown in (b)".

53. *Figure 9 to 10 are somewhat overloaded with information. Please try to reduce it. For instance, the lines describing the temperature ranges are not needed in every diagram.*

Figures 9-11 have been revised according to the reviewer's suggestion.