

The paper by Worringen et al. presents data on the characterization of ice nucleating and ice residual particles collected at an alpine site. The data itself is a worthy addition to the literature, however there are scientific and editorial issues which require attention before publication can be recommended. In general the manuscript was disorganized and at times difficult to read. However, as there are in my opinion only two major scientific issues I feel that this manuscript could be made publishable without too much difficulty.

Major issues:

INP compositions have been reported via activation by the FINCH instrument, however no mention was made of the operating temperature and relative humidity of FINCH. Were they constant? Chosen to match ambient conditions? If operating conditions were not constant or based on ambient, I would recommend extreme caution about presenting the FINCH results as a single data set. Likewise if the FINCH temperature (RH) is significantly lower (higher) than ambient then comparing FINCH results with the IPR compositions might not be appropriate.

The Ice-CVI reports much higher numbers of lead-containing particles. However after large amounts of discussion regarding lead containing particles, it is quietly mentioned on page 23045 that one of the components (the impactor) of the Ice-CVI is constructed from a lead containing aluminum alloy. If it hasn't been done already, I would strongly recommend running tests with a test material to confirm that the impactor is not the source of the unusually high levels of lead particles in this instrument. I find it hard to believe that even though ISI, FINCH and the Ice-CVI were run at random times during the whole campaign (and FINCH was run for much longer time periods) the much higher lead signal in the Ice-CVI is entirely natural.

Other issues/comments:

Throughout, repeated references to parallel measurements have been made. However, according to Figure 1 no parallel measurements were made. Please remove/reword these comments.

There is no actual explanation of how the particle classes are assigned, especially for internally mixed particles. For example, would a gypsum particle ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) be classified as Ca-rich + inclusion or Sulfate + inclusion? Either provide a thorough description or a brief description and a more in depth reference. Particles containing lead are classed as lead bearing regardless of amount – is there any way of telling the actual and/or relative concentration of lead?

The analysis of the data could go further – temperature and wind direction data is provided in figure 1; the trend of composition with ambient temperature or wind direction (as there is only 2) could produce an interesting result.

I would caution against the terms inclusion and coating. For me, coating has an implication that the additional substance was part of the primary ice nuclei, rather than an aerosol captured during post-freezing aggregation or accretion (e.g. Kumai, 1951). Likewise, inclusion implies that the second component is part of one large particle, rather than a secondary aggregated particle acquired separate to the freezing process.

In addition to compositions, FINCH should have been able to measure INP concentrations. Is this data available and not planned for separate publication? If so please include it here.

The analysis of the data could go further – temperature and wind direction data is provided in figure 1; the trend of composition with temperature or wind direction (as there is only 2) could produce an interesting result. For example, Figure 1 suggests that ISI data was mostly with a cold south wind whereas the ICE-CVI periods were nearly all with a north wind.

Pg. 23033, lines 2-11. Does FINCH take all ambient aerosol or is there a size distribution? What happens to any ice crystals or droplets in the flow – are they evaporated before insertion into FINCH?

Pg. 23034, line 6. Some small droplets could pass the pre-impactor without an impact. Please provide the d50% cut-off diameter for this section.

Pg. 23034, lines 17-22. Larger droplets could cool significantly during evaporation, and also not completely evaporate. Is there any estimate for the amount of freezing that may occur due to evaporative cooling? What is the liquid droplet break-through diameter?

Pg. 23035, line 17. Please explain or provide a reference for how the diameter was calculated.

Pg. 23035, line 24. Particle classes combined into particle classes. Please change one of these to a word other than classes.

Pg. 23037-8, Section 3.1. The effort to investigate and quantify artefact particles should be commended. As well as the Steel and Aluminum artefact particles, do the systems have any plastic and or rubber tubing that could be the source of carbonaceous particles? Additionally the comment regarding the lead content of the Ice-CVI needs to be moved here from pg. 23045.

Pg. 23040, line 12. Please clarify - FINCH and Ice-CVI have high amounts and much higher absolute numbers of silicates at submicron sizes.

Pg. 23041, lines 1-6. Maybe I am reading figure 8 wrong due to the y-axis, but the percentages given for ISI in the text look wrong.

Pg. 23041, lines 7-19. I have a number of issues with this section. I find the comparison of 28 samples with 395 difficult, especially since the Ice-CVI sees less than 1/28 of many of the particle classes. The FINCH sample is taken during the middle of the day when the sun is high and while aerosol concentrations are rising, whereas the Ice-CVI sample is at the end of the day (just before sunset) and the aerosol concentrations are dropping, suggesting that the two sampling periods are not that similar. Also, according to Table 1 FINCH samples $>2\ \mu\text{m}$ whereas Ice-CVI samples $>5\ \mu\text{m}$. This difference in size distribution could explain the larger numbers of the particles that would be expected to be smaller, such as carbonaceous and secondary.

Pg. 23041, section 3.3. I didn't get it from the earlier sections. Why are there so few Ice-CVI particles at $>1\ \mu\text{m}$? Is this real or instrumental? If instrumental could this explain the differences elsewhere?

Pg. 23042, lines 2-3. Again, maybe I am reading figure 8 wrong due to the y-axis, but it looks like the soluble has a definite tendency to be submicron.

Pg. 23043, section 3.5. When comparing table 3 with Figure 6 I would suggest that for most particle classes reporting mixed/unmixed ratios in ISI is a bad idea due to the very low particle numbers.

Pg. 23047, lines 6-9. Without defining the term 'rich', these sentences make no sense. What decides how strong the peaks in the EDX are? For K-feldspar, there are 3 Si atoms and 1 Al atom for every K. Would this fit the definition of 'not rich in potassium'?

Pg. 23047, lines 14-16. Zimmermann et al. showed that calcite is similar in deposition nucleation ability to quartz. However many other minerals, with better or worse abilities than quartz, can be classed as silicates.

Pg. 23047, lines 26-27. The definition of Ca-rich in table 1 includes carbon oxygen and sulphur. Is it possible therefore to be certain that the particle did not include some carbonaceous/secondary coating? Also note that the calcium carbonates primarily associated with this class are unstable in an aqueous environment, especially in the presence of acids.

Pg. 23048-9, section 4.3. The first paragraph of this section describes the campaign and analysis steps in general and should appear much nearer the beginning of the manuscript. The second paragraph is direct repetition of parts of section 3.5 and should be removed.

Pg. 23049, lines 13-16. According to section 4.1, sulphate particles are not INP/IPR. Why do they appear here?

Pg. 23050, lines 12-19. The past literature has found a dependence upon temperature and air mass history. This could be done – at least in comparison to wind direction and temperature.

Pg. 23050, lines 20-28. If the lead comes from avgas combustion as suggested, then due to the addition of lead scavengers to the fuel it could be expected to be found in the form of lead (II) bromide or chloride. Was bromine or chlorine seen in the EDX spectra? Why is ISI not included in the discussion?

Pg. 23051, lines 3-11. Please provide some information on the compared sampling periods. When was the LA-MS run? What were the meteorological conditions then? Was the SEM-EDX data limited to similar conditions or was the whole data set used?

Pg. 23051, lines 12-19. According to pg. 23035, LA-MS measures between 150-1500 nm, whereas the SEM particles (for ISI at least) go up to 3 μm . Could the authors speculate if this might have an effect? Could the SEM data be limited to particles in the same size range?

Pg. 23052, lines 3-5. How are elements classified as 'major' and 'minor'? Is Pb neglected if it is minor?

Pg. 23060, Table 1. Was FINCH operated out of cloud? Is this data included in the other analysis/figures, was there an observable difference between in and out of cloud INP? Please clarify the final column for FINCH – does $d > 2 \mu\text{m}$ refer to the aerosol inlet or the FINCH $\rightarrow$ IN-PCVI transfer?

Pg. 23071, Figure 9. This figure implies that the total aerosol samples were taking during an in-cloud scenario. This seems unusual to me. Considering how the data is swamped with droplets, I would wonder if it is of any benefit.

Technical issues:

General: many paragraphs are formed of what seem to be lists of sentences with no flow or connection, making them difficult and unrewarding to read. This is especially true of the abstract and sections 2 through 4. Please try to remedy. In some sections the start and end of paragraphs seems to be a bit arbitrary, for example section 2.1 and 4.4. Throughout the manuscript is written in a mixture of past and present tense.

Introduction: Please include definitions of any abbreviations that were defined in the abstract.

Pg. 23031, lines 9-12. Is the IN-PCVI used in combination with FRIDGE? If not please re-organize this sentence to clarify. Please also reference some of the other methods used for the collection and identification of atmospheric INP (for example PALMS, Cziczo et al., 2006).

Pg. 23031, line 19. I'm assuming this personal communication reference refers to the in-prep AMTD paper, please update the in-text citation.

Pg. 23032, line 12. Is the FINCH+IN-PCVI reference Bundke et al. 2008, Schenk 2014 or both?

Pg. 23032, line 21. Please use $L \text{ min}^{-1}$ to be consistent with flow rates reported later on.

Pg. 23032, Section 2.1. The second paragraph in this section seems to have been inserted at a later date. Please proof this section properly. Specifically the use of (see above) and the use of INP and or IPR.

Pg. 23033, line 17. Please clarify the IN-PCVI cut-off diameters – are the sampled particles larger than $8 \mu\text{m}$, larger than $4.5 \mu\text{m}$ or between?

Pg. 23034, section 2.1.3. There are no references in this section.

Pg. 23039, section 3.1.2. Please provide references where things are expected – lines 4,15,17.

Pg. 23039, lines 20-21. Change to 'as a box-plot', or pluralize the sentence.

Pg. 23040, line 10. Change to 'INP/IPR independent of sampling technique.'

Pg. 23042, line 24. I think this is supposed to read 30 January?

Pg. 23044-6, section 4.1. I would argue that most of this section is discussing whether a particle class is real or artefact. It is also much more introductory in nature. As such, I would suggest moving this section further forwards as part of section 3.1. Having read many pages of discussion regarding figures 6-10, this is not a good point to be informed one of the categories isn't an INP/IPR. Several of the paragraphs in this section are very similar and seem to have been partially cut and pasted. Please reword them.

Pg. 23044, lines 5-7. The way this sentence is written implies that it is wrong to classify calcite as a component of mineral dust. Please reword.

Pg. 23046, line 5. Please make it easier for the reader by providing a number to go with the 'cold temperatures'.

Pg. 23046, lines 9-11. I don't understand. If sulfates are not considered as INP/IPR, then why are the still included? Justify.

Pg. 23046, lines 24-28. Please decide. Are sulfates INP/IPR or not?

Pg. 23047, line 1. Replace considerable with considerably.

Pg. 23049-50, section 4.4. This section is particularly disorganized and hard to read. Please rework it.

Pg. 23050, line 10. Found an enrichment relative to what?

Pg. 23050, line 16. What is 'low-Z'?

Pg. 23061, Table 2. Column 4 header – should be Morphology.

Pg. 23062, Table 3. Please provide a more informative and clearer caption. Specifically, what do the percentages relate to?

Pg. 23063, Figure 1. Please specify in the caption how the 'Homogeneous time periods' are marked. I must have missed it within the main text, what is the significance of time periods B-F?

Pg. 23066. Figure 4. I'm not certain that this figure adds much to the manuscript – consider its removal.

Pg. 23072. Figure 10. Secondary has become C-O-(S)-bearing in the legend – please make consistent with the rest of the figures.

Pg. 23073. Figure 11. Please make the color scheme consistent with the rest of the figures

Cziczo, D. J., Thomson, D. S., Thompson, T. L., DeMott, P. J., and Murphy, D. M.: Particle analysis by laser mass spectrometry (PALMS) studies of ice nuclei and other low number density particles, *International Journal of Mass Spectrometry*, 258, 21-29, 2006.

Kumai, M.: Electron-microscope study of snow-crystal nuclei, *Journal of Meteorology*, 8, 151-156, 10.1175/1520-0469(1951)008<0151:emsosc>2.0.co;2, 1951.