Comment on "*Online single-particle characterization of ice-nucleating particles (INPs) at the High Altitude Research Station Jungfraujoch (3580 m a.s.l.), Switzerland*" by Zhang et al.

This manuscript presents online single-particle characterization of ice crystal residuals at Jungfraujoch by coupling a controlled ice-nucleation chamber with single-particle mass spectrometry. The observations provide useful information on mineral-dust-containing particles, including those associated with local construction activities. The study could make a useful contribution to Atmospheric Chemistry and Physics, but its principal contribution is currently observational, and its advance beyond previous work needs to be articulated more clearly. The manuscript also requires a more coherent focus and a more cautious interpretation of particle enrichment and depletion. I recommend major revision before the manuscript can be considered for publication.

Major comments

1. The Introduction describes previous observations of mineral-dust enrichment and lead-containing ice residuals at Jungfraujoch and elsewhere. Please explain more explicitly what new understanding this study provides beyond confirming these findings. In particular, distinguish the methodological contribution of the coupled measurement system from the new scientific insights supported by the observations.
2. A particular strength of Jungfraujoch is the opportunity to investigate background aerosol and long-range-transported particles, including INPs. I recommend excluding the construction periods from the main analysis of these populations, because the strong local emissions obscure the processes of interest. A pronounced local influence does not, by itself, establish regional atmospheric relevance. Repeatedly switching between construction and non-construction periods also makes the argument difficult to follow. If retained, the construction observations should be presented as a clearly separated case study, with their relevance and limitations explicitly explained. However, excluding them would leave only 25 characterized ice crystal residuals. The authors therefore need to assess whether the remaining dataset supports the proposed conclusions and narrow the scope accordingly.
3. The heading of Section 3.2.1, "SON, BBA, and SSA particles are not effective INPs," is stronger than the evidence supports. The authors should distinguish the relative depletion of SON and BBA from the mechanisms that explain their remaining presence in the residual population. As acknowledged in lines 299–300, these mechanisms may include ice nucleation, inadvertent transmission through the PCVI, scavenging, or internal mixing with other INPs. Their relative contributions are not clearly resolved. Please assess the available background and transmission measurements, particle mixing-state information, and ambient measurements bracketing the mixed-phase-cloud and cirrus-condition chamber runs. Such comparisons may help identify sampling or temporal effects, although they cannot by themselves establish the nucleation mechanism. If these processes cannot be separated, qualify the interpretation accordingly. In addition, the absence of identifiable

SSA particles in both ambient aerosol and residuals does not establish that they are ineffective INPs.

4. An enrichment factor compares a particle class's relative abundance in residuals with its relative abundance in ambient aerosol; it is not a direct measurement of activation probability or ice-active-site density. Differences in particle size, sampling transmission, and the timing of ambient and residual measurements may influence this ratio. Please provide class-resolved size distributions, explain how ambient observations were paired with residual measurements, and discuss how these factors affect the conclusions about ice-nucleating activity.

Minor comments

1. Line 183: Replace "The (EF)" with "The enrichment factor (EF)."
2. Line 291: Please distinguish tar or tar-ball particles from black carbon and provide evidence or appropriate references for the proposed composition of the biomass-burning aerosol. If either component is invoked to explain ice nucleation, clarify whether its contribution is demonstrated by the present measurements or inferred from previous studies.
3. Line 258 and Figure 4: Please make the distribution of the 2,248 characterized ice crystal residuals clearer. The non-construction mixed-phase-cloud and cirrus-condition subsets contain only 15 and 10 particles, respectively, whereas 2,223 were characterized during construction. State these sample sizes prominently and discuss the statistical uncertainty associated with the small non-construction subsets.
4. Line 423: The ozone concentration reported as "53.1 ± 1.8 ppm" should be "53.1 ± 1.8 ppb," consistent with the figure axes.
5. Line 443: A change from 0.32 to 0.38 is an increase, not a decrease. Please correct "drops only slightly" or verify the reported values.
6. Lines 444–445: The statement that no biomass-burning-associated ice crystal residuals were observed appears inconsistent with Table 2, which reports 20 during construction in-cloud periods. Please specify the population or conditions to which this statement refers and revise it accordingly.