

Summary

This manuscript addresses an important and timely topic—the vertical transport and distribution of ice-nucleating particles (INPs) by deep convective clouds (DCCs). The study presents valuable in situ vertical observations of INPs in the UTLS and around deep convective clouds, a type of field measurement that remains relatively scarce. This confers good scientific merit to the work. However, several issues still require revision, particularly those concerning data availability and the main conclusions. Overall, the manuscript is suitable for publication in ACP after careful revision.

General comments

1. I agree with the general physical reasoning that deep convection is capable of transporting boundary-layer INPs upward to upper atmospheric layers. However, the conclusion stating that “Deep convective clouds act as a major mechanism for lifting INPs from the boundary layer into the free troposphere” and “Overall, deep convection should be considered as an important transport and transformation pathway of INPs from lower altitudes to the free troposphere” are overstated, given that this interpretation is exclusively derived from a single research flight. Please revise such strong categorical statements throughout the manuscript to align with the limited observational basis.
2. I agree with the authors’ finding that the in-situ measured INP concentrations aloft are roughly two orders of magnitude lower ($\sim 0.01\text{--}0.1\text{ L}^{-1}$) compared with previous ground-based observations. However, the observed ice crystal number concentrations in the atmosphere are substantially higher than the measured ambient INP levels (3-4 orders). It would be helpful if the authors discuss and elaborate on potential physical pathways responsible (such as secondary ice production...) for such abundant ice formation under low INP abundance in the upper troposphere.
3. The authors performed a rather concise single-particle composition analysis, which is presumably aimed at constraining the chemical composition of INPs. However, the manuscript explicitly states “Unfortunately, the proportion of INP in the total number of aerosol particles is too low for establishing a robust link between INPs and specific particle

types”. Given this inherent limitation, the motivation for carrying out only a simplified single-particle analysis needs to be justified. Standard comprehensive single-particle characterization to unravel aerosol physicochemical processes routinely covers mixing state, surface coating property, core-shell structure, internal/external mixing status and elemental association information. The absence of such supporting information makes Figure 2 and its associated discussion confusing to readers.

4. Figure 6: It needs to be confirmed whether the convective inflow of this studied convective case is indeed located on the western side of the storm. Considering Germany lies in the mid-latitude westerly belt of the Northern Hemisphere, organized mesoscale convective systems generally propagate eastward, with low-level inflow typically feeding the storm from its eastern leading flank. If the inflow position in Figure 6 is plotted oppositely to the structural feature, I suggest horizontally flipping (mirroring left and right) Figure 6 to conform to the canonical dynamical structure of European mid-latitude convection; the current layout appears physically inconsistent.
5. Line 400: Data availability. “Processed data from the CIRRUS-HL campaign will become publicly available on the HALO database (<http://doi.org/10.17616/R39Q0T>) at <https://halo-db.pa.op.dlr.de/mission/125> in June 2026. Earlier access to the data is available by contacting the principal investigators of the campaign.” As the current calendar has reached June 2026, the processed INP datasets from the CIRRUS-HL campaign are still not publicly accessible via the provided HALO database link and DOI as stated in the manuscript. Please revise the data availability section and ensure the related INP data can be made accessible.

Specific comments

1. The manuscript employs an excessive number of abbreviations throughout the conclusion section and the main text, for example: “To distinguish the effect of DCCs in UTLS INPs,” “Sampling of CPRs within DCCs during other CIRRUS-HL research flights...”. Frequent and dense use of acronyms affects reading fluency and makes the overall narrative less accessible. It is recommended to appropriately replace some overused abbreviations with full terms where appropriate, especially for repeatedly mentioned concepts, to improve readability and logical smoothness.

2. In abstract, the sentences starting with “While INP-temperature spectra of convective inflow...”, “In contrast, INPs active at lower...” are quite long and could be split for readability.
3. Since the full name of CIRRUS-HL has already been provided in parentheses, for consistency, it is recommended to also supplement the full name of HALO upon its first appearance for the readability of manuscript.
4. The caption of Figure 5 could be better structured for readability. It is suggested to revise it by separately describing each panel in sequence, which will help readers understand the figure more easily.
5. Line 163: It is unclear what “S2” refers to in the sentence “and the sampling altitude ranged between 5 km and 15 km at ambient temperatures from 0 to -65 °C (see S2)”. Please define S2 explicitly (e.g., supplementary Figure S2, supplementary Table S2 or supplementary Text S2) and revise the citation format accordingly.
6. Line 396: The slash symbol between “universal” and “generally valid” looks informal and ambiguous for formal manuscript writing. Please replace the slash with appropriate wording (e.g., “or”) to polish this sentence.