EGUSPHERE- 2025-3842:

"Aerosol Size Distribution and New Particle Formation in High Mountain Environments: A Comparative Study at Monte Cimone and Jungfraujoch GAW Stations"

Answers of the authors to Reviewer#1

While the reviewer's comments are given in **bold red**, our answers are given below in black letters. Additionally, we added the changes made in the revised manuscript in *italic black text*.

The paper by Mazzini et al., investigates aerosol number size distributions (PNSD) and new particle formation (NPF) in the free troposphere (FT) using long-term measurements from two high-altitude observatories, Monte Cimone (2165 m, Italy) and Jungfraujoch (3580 m, Switzerland). The aim is to understand how aerosol formation, growth, and variability differ between the two sites. The results show that CMN is affected by more frequent and intense NPF and stronger PBL influence, while JFJ shows fewer NPF events, weaker growth despite more ultrafine particles. This is a good quality study that makes an important contribution to understanding aerosol formation in the free troposphere (FT). It is especially valuable because it contrasts two representative European high-altitude sites, applies three independent NPF classification methods and is based on a solid dataset consisting of two years of harmonized measurements. The paper also highlights how the condensation sink, cloud processes and boundary-layer strongly regulate NPF, providing a strong link between observations and their climate relevance.

The manuscript is well written and carefully developed. With the addition of some clarifications and details, it should be suitable for publication.

We would like to sincerely thank the reviewers for the time, effort, and thoughtful consideration given to our manuscript. We truly appreciate the positive assessment of our work and the constructive suggestions that have helped us improve the clarity, consistency, and overall quality of the paper. The feedback was extremely valuable and has been carefully addressed point-by-point below.

Specific comments:

Line 6: Sometimes "free troposphere (FT)" written in full, sometimes only "FT." Suggest spell out first time and then "FT" for consistency.

Revised for consistency as suggested.

Line 29: "The frequency of NPF events vary widely" → should be "varies widely."

Corrected to "*varies widely.*"

Line 59: "at 2165 m a.s.l.." double period. Should be "a.s.l."

Corrected to *"a.s.l."*

Line 63: the sentence "with this influence being most pronounced during summer daytime hours and diminishing at night, when the site predominantly reflects free tropospheric characteristics" is too long. I Suggest splitting into two sentences.

The sentence was split into two shorter sentences for clarity. The revised text reads: *The observatory is considered representative of the Mediterranean and Southern European FT. However, it can be significantly affected by air masses from the PBL, particularly those originating in northern Italy and the highly polluted Po Valley. This influence is most pronounced during summer daytime hours and diminishes at night, when the site predominantly reflects free-tropospheric characteristics (Cristofanelli et al., 2018; Rinaldi et al., 2015).*

Line 63: "2.5–560nm" should have space: "2.5–560 nm." Please check the entire document.

All instances have been checked and corrected.

Line 97: Datasets coverage: "31.2% at CMN… In contrast, summer months show notable data gaps". Could you provide the percentage of the different seasons for clarity?

We now report the seasonal coverage directly in the paragraph (Section 2.2). The revised text reads: *Overall, both datasets provide a representative seasonal distribution, though with some variability in coverage. At CMN, data availability was highest in winter (31.2%), followed by autumn (28.6%), spring (21.6%), and summer (18.7%). At JFJ, the corresponding seasonal coverage was 35.9%, 28.5%, 14.4%, and 21.2%, respectively. The summer months show the largest data gaps at both sites (Fig. S1).*

Line 104: "Scaling factors were derived individually for each measured size distribution, and applied to all NAIS channels accordingly." Please remove comma before "and."

The comma before "and" has been removed. We also identified and corrected a few other instances in the manuscript, where a comma was unnecessarily placed after "and."

Line 107: "a common range of 2.5–560nm" should be "2.5–560 nm" (space before nm). Please check the entire document.

Corrected throughout the manuscript.

Line 122: "originating from the nucleation of gas-phase precursors forming clusters approximately (~1–2nm)"; parentheses awkward, just write "forming ~1–2 nm clusters."

Revised to: *Atmospheric NPF events are characterized by rapid bursts of particles in intermediate and nucleation mode, originating from the nucleation of gas-phase precursors forming ~1–2 nm clusters that subsequently grow into the Aitken mode.*

Line 149 and 150: Equation 2 formatting inconsistent: bracket notation N[2.5–7) inconsistent with earlier N2.5–7. Please harmonize notation.

Harmonized using $N_{2.5–7}$.

Line 161-163: about RH threshold, you define out-of-cloud as RH < 94%, in-cloud as > 97%. But what about 94–97%? Please clarify explicitly.

Revised text:

Periods with RH between 94% and 97% were considered uncertain and, together with in-cloud periods (RH > 97%), were excluded from the NPF analysis. However, all measurement periods, including in-cloud, out-of-cloud, and intermediate cases, were retained in the overall statistical analysis of the dataset to ensure full representativeness of atmospheric conditions.

Line 163: "Webcam images were used to further validate cloud presence", could specify frequency or reliability (continuous, daily snapshots?).

Specified as follows:

At CMN, the cloud classification was further verified using webcam images with a 1-min time resolution, confirming station immersion within cloud layers during high-RH periods.

Line 171: "(770–3)" should be "(770 cm^{-3})".

Corrected.

Line 171: "across four defined mode" should be "modes."

Corrected.

Line 206: "These categories reflect distinct stages of aerosol…….These modes reflect distinct stages of particle growth and transformation", the two repeated sentences are redundant. Please rephrase them

Rephrased as:

The particle number size distribution at CMN and JFJ was initially divided into four a priori modes (intermediate, nucleation, Aitken, accumulation), based on commonly used size ranges in aerosol studies, as described in the Data Analysis Sect 3.1. These modes represent distinct steps of aerosol evolution from freshly nucleated particles to aged particles that

efficiently scatter or absorb radiation and act as cloud-condensation nuclei (CCN), thereby influencing radiative forcing and cloud properties.

Line 210: In Table 2, confidence intervals are in parentheses but not explained in caption. Please clarify.

Specified in the caption:

Statistics of modal structure for hourly particle number size distributions. The table reports the median geometric mean diameter (d_{pg}) and the median geometric standard deviation (σ) and particle number concentration (N), with 25th–75th percentile ranges shown in parentheses, for each lognormal mode at CMN and JFJ.

Line 227: "These elevated ratios has been observed" should be "have been observed."

Corrected following the suggestion.

Line 233: "One more possible explanation for the relative abundance…", awkward phrasing, better "Another possible explanation…"

Corrected following the suggestion.

Line 243: Figure references: sometimes "Fig. X," sometimes "Figure X." Pick one style.

Harmonized to "Fig. X" throughout.

Line 265: "Ions also shows different behaviour between out-of- and in-cloud" should be "Ions also show different behaviour between out-of-cloud and in-cloud conditions"

Corrected following the suggestion.

Line 274: Table 3 should be harmonized (e.g., JFJ summer values missing ±).

We thank both reviewers for noting the missing uncertainty values in Table 3 and the limited statistics for JFJ summer data. Indeed, the small number of valid summer observations at JFJ (only 2 days) did not allow for a meaningful calculation of standard deviations.