

Peer Review Report

Manuscript title: Frequent new particle formation events in the Indo-Gangetic Plain occur under reduced condensation sink but are obscured by air mass heterogeneity

Journal: Atmospheric Chemistry and Physics

Manuscript number: egusphere-2026-2212

Summary

This manuscript presents an observational study investigating new particle formation (NPF) at a suburban site in the Indo-Gangetic Plain (IGP) between May and December 2023. By combining measurements from a Scanning Mobility Particle Sizer (SMPS) with a Neutral Cluster and Air Ion Spectrometer (NAIS), the authors extend their aerosol characterization down to the sub-10 nm size range, for which observational data in this region is limited. This combined instrument approach allows the authors to evaluate particle size distributions ranging from 2.5 to 570 nm to characterize seasonal and diurnal variability in aerosol populations.

A main focus of the study is the comparative evaluation of three NPF event classification schemes: Dal Maso et al. (2005), Dada et al. (2018), and Aliaga et al. (2023). The Dal Maso et al. method relies on visual inspection, the automated Dada et al. method compares 2–4 nm ion bursts with larger particle concentrations to distinguish regional from transported events, and the statistical Aliaga et al. method groups events into activity percentiles based on 2.5–5 nm concentration changes. All three methods show general qualitative agreement but quantitative discrepancies. These discrepancies are attributed to the complex interplay of meteorological variability, high background aerosol loading, and overlapping anthropogenic sources that mask genuine nucleation signals.

The study also quantifies important NPF parameters, finding that particle growth rates (GR) are elevated compared to those in cleaner environments, indicating enhanced growth. Condensation sink (CS) on event days was roughly half that of non-event days. While higher than in clean environments, the CS remained below the suppression thresholds typical of heavily polluted regions, positioning this suburban site within an intermediate-pollution regime. Ultimately, the manuscript underscores the critical need for refined NPF classification methodologies specifically tailored for multi-source, high condensation sink environments.

General Impressions

Combining SMPS measurements with NAIS measurements to observe particle size distributions within the IGP is worthwhile and expands our scientific understanding of particle formation at different global sites. Evaluating and comparing different classification methods for particle formation events is also important, as a rigorous, consistent, and accurate method is necessary. Although the manuscript stops short of proposing a novel classification solution tailored for such environments, the insights it provides into the limitations of current metrics are inherently valuable to the aerosol physics community.

Overall, I find this manuscript a valuable contribution. However, currently, the manuscript is marred by confusion about the coverage of the observed data. While Figure S6 in the supplementary material provides a timeline of the NAIS and SMPS overlap, this figure is not referenced in the main text. Consequently, it remains unclear during the reading of the main text how many days actually had proper instrumental overlap, and the implications of these severe data gaps are never discussed. This issue is further explained in my major comment and should be resolved before publication. I, therefore, recommend publication with minor revisions.

Major Comments

- 1. Inconsistent and Unclear Data Coverage:** The manuscript states that observations were conducted from May to December 2023. Assuming continuous operation, this period spans approximately 214 days. However, Section 3.2.1 abruptly introduces a study period of only 108 days. While Figure S6 in the supplementary material visualizes the NAIS and SMPS data availability across this period, this figure is never referenced or discussed in the main text, leaving the reader without a clear accounting of the operational gaps.

More concerning is a brief statement at the end of Section 3.2.2: “Also it is to be noted that only 11 NPF days where overlapping SMPS and NAIS measurement days were available”. Because combining NAIS and SMPS data is a central methodological feature of this study, this severe limitation must be featured prominently at the beginning of the methodology or results section, rather than as a concluding side note. Furthermore, the implications of this statement are confusing. According to the Dal Maso classification in Section 3.2.1, there were 50 event days (Classes I and II). Even when referencing Figure S6, does this mean that NAIS and SMPS measurements overlap for less than 25% of the identified event days? If so, what is the reason for this lack of overlap over the studied period?

Continuing, the text states that “after filtering only 3 such days were possible where we could reliably calculate the growth rate”. Deriving growth rates (and subsequently, particle formation rates, which depend on these growth rates) from a sample size of $N = 3$ is insufficient to establish statistically robust conclusions or regional averages. The results derived from these 3 days must be explicitly framed as isolated case studies rather than representative climatological values.

The authors must explicitly reference and discuss Figure S6 in the Methods section to clearly document the exact measurement coverage (NAIS, SMPS, and meteorological variables) over the May–December 2023 period. Additionally, for all calculated properties (growth rate, condensation sink, and formation rates), the exact number of days used for the calculations must be stated upfront in the relevant subsections. The authors must also include a robust discussion on how this limited data coverage, and any potential seasonal biases within the available data, impacts the statistical significance and general applicability of their findings.

Minor Comments

- In addition to Figure S6 (noted in the major comment), Figures S2, S3, and S4 are provided in the supplementary document but are never referenced in the main text. Please ensure that all supplementary materials are explicitly cited in the appropriate sections of the manuscript so that readers are directed to this supporting information.
- The manuscript contains several sentences that are grammatically incorrect, awkwardly phrased, or confusing, which occasionally obscures the scientific meaning. A non-exhaustive list of examples is provided below. I strongly recommend a thorough proofreading of the entire manuscript prior to publication.
 - **Page 3, line 77:** “In the overall aerosol loading, NPF contribution varies place to place and time to time but no doubt that it makes a significant part of that” Please clarify what ‘that’ refers to in this context and rephrase for formal tone.
 - **Page 3, line 79:** “we need to characterise them with getting their frequency, growth rate, and formation rate.” Consider revising to “...by determining their frequency...”
 - **Page 3, line 94:** “Some Industrial chimneys also exist on the other side of the cross highways.” Please correct the capitalization of the common noun (‘industrial’) and

- consider replacing ‘cross highways’ with a more precise term, such as ‘intersecting highways’.
- **Page 6, line 183:** “Unfavourable meteorological conditions often exacerbate pollutant accumulation...” Please clarify what constitutes an “unfavourable” condition in this context (e.g., conditions unfavourable for atmospheric dispersion, such as low wind speeds or temperature inversions?).
 - **Page 7, line 194:** “for days when event occur but visually not as well standard as Ia)” The phrasing here is awkward; please revise for grammatical correctness and clarity.
 - **Page 13, line 374:** “and rest 58 non-events days” Revise for grammatical correctness (e.g., “and the remaining 58 non-event days”).
 - **Page 21, line 545:** “Typical day time CS values observed in Delhi has been reported more than $\sim 0.06 \text{ s}^{-1}$ to sustain NPF events (Ali et al., 2025).” This sentence is confusing as it currently implies that the CS *must* be greater than $\sim 0.06 \text{ s}^{-1}$ to sustain NPF, which contradicts the physical mechanisms discussed. Please rephrase to clarify the threshold.
 - **Page 23, line 593:** “This observed decoupling between ion and nucleation-mode particle dynamics signals towards the fact that controlling influence of precursor vapor abundance and the condensation sink are play a more important role in controlling particle survival and growth.” This sentence contains grammatical errors (“are play a more important role”) and is difficult to parse. Please revise.
 - **Page 28, line 700:** “The relatively high-end threshold observed here suggests the strong sources of vapours that form clusters and grow them fast enough for maintaining high enough survival probability.” The current phrasing incorrectly implies that the *sources* themselves grow the clusters. Consider revising to: “...suggests strong sources of vapours that form clusters and enable rapid growth, maintaining a high enough survival probability.”
- The column headers in Table 1 currently display only the units (e.g., $\text{cm}^{-3}\text{s}^{-1}$) without specifying the corresponding physical parameters or variables (e.g., J_3 , J_7). Please update the headers to indicate both the parameter and its unit.
 - **Page 9, line 259:** “We have gone through days and further filtered days where NPF signals were less affected by other factors.” This statement is methodologically vague. Please explicitly define what these “other factors” are and outline the specific criteria used for this filtering.
 - **Page 9, line 269:** “The coagulation sink was calculated using the particle size distribution following standard coagulation theory” Please provide an appropriate citation for the standard coagulation theory referenced here
 - **Page 9, lines 261–275:** The text details the calculation of the particle formation rate at 3 nm (J_3). However, at the very end of the section (line 274), the calculation of J_7 is introduced abruptly. I recommend stating upfront that formation rates were determined for both sizes, and clarifying that the equation provided for J_3 serves as representative for both calculations.
 - The manuscript notes that both the Dal Maso et al. and Dada et al. classification methods were modified to mitigate noise in the dataset. While adapting these methods is understandable, restricting the particle growth criterion in the Dada et al. method from the standard 7–25 nm down to 7–12 nm alters the metric being evaluated. Please include

a brief discussion addressing how these site-specific adaptations impact the comparability of the reported results with other global studies that utilized the standard size bounds.

- The manuscript contains a number of redundant statements that disrupt the narrative flow. A few examples are provided below. I encourage the authors to thoroughly review the text and streamline these repetitions to improve overall conciseness and readability.
 - **Page 10, lines 291 and 295:** The text states, “Total particle concentrations in Fig. 2(a) shows clear daytime enhancements during May-June” and shortly thereafter repeats, “During the warmer months (May-June), total particle concentrations show pronounced daytime enhancements”. Please consolidate these discussions.
 - **Section 3.2 Introduction:** The introductory paragraph of this section (lines 365–371) largely reiterates site description and methodological context already established in the Methods section. Consider removing this redundancy or integrating it into the Methods section.
- While the manuscript predominantly uses British English spelling (e.g., vapour), instances of American English spelling (e.g., minimizing) occasionally appear. Please ensure consistent spelling conventions are applied throughout the text.