We thank both reviewers for their constructive comments. Our replies and changes are given in blue below.

Reviewer 1

The manuscript entitled 'Importance of hydrated aerosol particles for aerosol-fog relationships in the Italian Po Valley', submitted by Neuberger et al. focuses on investigating the relationship between ambient air pollution (namely, aerosols) and fog. The study was conducted in the Italian Po Valley, which is infamous for being one of the most polluted regions in Europe, with frequent occurrences of radiation fog. The authors attempt to quantify the impact of hydrated aerosol particles on fog microphysical properties and visibility.

This is an interesting study with a well-designed approach that brings new important results to our understanding of fog behaviour. The scientific outcomes are interesting, the topic is within the scope of ACP and in interest of this journal readership, and as such deserves to be published.

However, I strongly feel that the basic terms used in this study should be properly defined, ideally in the introduction, as they can currently be perceived differently by the audience. I would like to see the difference between hydrated and activated aerosols clarified, as well as the difference between droplet activation and aerosol activation. Furthermore, it should be made clear that the authors are talking about radiation fog. This is specified in the title, but should also be stated explicitly in the text. For example, the statement 'the fog develops in calm and stable air, where supersaturation remains very low' (line 43) is not generally valid for fog formation, but is only valid for radiation fog.

Reply: We agree with the Reviewer that statements applicable to radiation fogs and not to fogs in general need to be better specified. In the revised version, we have made sure to refer to radiation fogs whenever appropriate and especially in the introduction and conclusions, while the instrumentation described in the experimental section is of general use for fogs (e.g. the GFAS or the PVM), and in the results and discussion section we simply describe our observations or modelling results (e.g. line 345: "The fog was primarily driven by radiative cooling, and vertical motions were very weak").

We made the definition of activated, interstitial and hydrated aerosol clear in the second paragraph of the introduction: *"**Particles that have acted as seeds for fog (or cloud) droplets are called activated particles.** The remaining particles persist as hydrated but non-activated aerosols (Pinnick et al., 1978; Hudson, 1980; Gerber, 1981), **which are termed interstitial particles.**"* Furthermore, we made sure that we talk about "**activated particles**" when addressing fog droplets throughout the manuscript.

Furthermore, we changed the sentence in line 43 to "*Unlike clouds that form in turbulent conditions with high supersaturation, **radiative** fogs develop in calm and stable air **through radiative cooling**, where supersaturation remains very low.*"

Line 73 - The authors declare that 'pollution levels have declined in the last decade'. It would be very useful to present at least some indicators of ambient air pollution in the Po Valley to support this general statement.

Reply: Declining PM10 and PM2.5 concentrations in the Po Valley have been consistently reported since the beginning of intense monitoring in the area around the early 2000's. A first systematic compilation of the measurements and a trend analysis for PM2.5 in the period 2005-2015 are presented by Bigi and Ghermandi (https://doi.org/10.5194/acp-16-15777-2016). Follow-up analyses are provided by the regional environmental protection agencies in North Italy. The graph below reports the average trend in PM2.5 concentrations (in ug/m3/y) from three groups of monitoring stations in Region Emilia-Romagna (where SPC is located) - urban background (blue), rural (green), traffic (on the right) - between 2013 and 2022, and confirming the decreasing trend in PM2.5 levels.

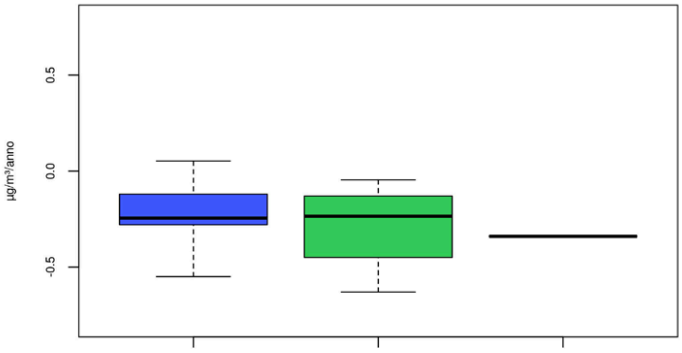

Figure: *Trends in PM2.5 concentrations (in ug/m3/y) from three groups of monitoring stations in Region Emilia-Romagna (where SPC is located) - urban background (blue), rural (green), traffic (on the right) - between 2013 and 2022 (Source: "La qualità dell'aria in Emilia-Romagna; edizione 2023" ISBN: 978-88-87854-55-8.)*

We changed the respective sentence in the revised manuscript: *"Although pollution levels have declined in recent decades, with clear reductions in PM2.5 (e.g. reduction of 2-5% per year depending on location, see Bigi and Ghermandi, 2016) and elemental carbon (around 4 % per year, see Gilardoni et al., 2020), the Po Valley remains one of Europe's most polluted areas …"*

Line 95 – The measurements were carried out between November 2021 and May 2022. The authors should explain why they selected this specific time period. For example, is it the period when the highest fog frequency can be expected?

Reply: The measurement period covered the fog season, approximately between November and March (see for instance for the nearby station of Padua, Stefanini et al. https://doi.org/10.3390/cli13110224, their Fig. 8) and the transition toward fog-free conditions and enhanced photochemistry (for the FAIRARI project science objectives, refer to the overview paper Neuberger et al. BAMS 2025, DOI: 10.1175/BAMS-D-23-0166.1).

We modified the respective sentence: *"The FAIRARI campaign was carried out between November 2021 and May 2022 at the San Pietro Capofiume (SPC) research site located in the Po Valley, Italy,* ***to cover the intense fog period and the transition to spring with more fog-free periods*** *(see campaign overview by Neuberger et al., 2025)."*

Line 375 – It should also be noted what the shortest observed fog event was.

Reply: We have added this information and the sentence now reads as *"The analysed fog events lasted from around 36 min up to 13 hours …"*

Line 476 - 'These past results from the Po Valley are generally consistent with our observations, although the supersaturation levels in particular seem to have decreased over the years.' Could the authors please discuss this in more detail, explaining the likely reasons for the suggested decrease in supersaturation? If possible, could they support this statement with numbers?

Reply: It is difficult to speculate on the reasons for the observed decrease in supersaturation. Possible reasons could be changes in surface moisture, changes in the aerosol composition and size distributions and other changes in meteorological parameters that drive radiative fog, but we have no clear evidence here. We therefore tuned down the respective part:

"The dry activation diameter of the more hygroscopic ones was around 425 nm (Noone et al., 1992), ***while*** *the less hygroscopic ones activated at around 775 nm (Svenningsson et al., 1992). The resulting supersaturation reported by Svenningsson et al. (1992) fell in the range 0.018 to 0.03%. These past results from the Po Valley are generally in line with our observations, although particularly ~~the~~ lower supersaturations ~~seem to have decreased over the years~~ were also observed during FAIRARI (0.011 - 0.018%, Fig. 7)."*

Reviewer 2

This manuscript investigates the link between air pollution and fog by emphasizing the role of hydrated aerosol particles in fog microphysics. Using an extensive measurement dataset from a field campaign in the Po Valley together with large-eddy-simulations (LES), the authors quantify how hydrated aerosols affect fog effective diameter (ED), cloud-droplet number concentration (CDNC), liquid-water content (LWC), and visibility. Their results demonstrate that incorporating hydrated particles is essential for interpreting observations in particular in polluted areas and must also be represented in numerical models. The study is well presented, provides novel insights into the influence of hydrated aerosols on fog, and falls within the scope of ACP.   I recommend publication after minor revisions.

R1: Add a definition section for key terminology

Reply: See next comment.

I would suggest having a clear definition of the key terms in one place, very early in the manuscript: hydrated vs activated aerosols, activated/unactivated fog, activated droplets. the terms are defined, in different locations in the manuscript and it would be easier for the reader to have it in one terminology section

Reply: We have clarified in the introduction the difference between the different terms. It now reads: *"Particles that have acted as seeds for fog (or cloud) droplets are called activated particles. The remaining particles persist as hydrated but non-activated aerosols (Pinnick et al., 1978; Hudson, 1980; Gerber, 1981), which are termed interstitial particles."*

The other terms are all well defined within the text. In addition, there is a list of acronyms at the end of the paper.

R2: Clarify the use of GFAS data

In section 2.3.3. it was shown and mentioned that the GFAS is most likely underestimating LWC, I would clearly state in line 319 that in the following LWC measurement from the PVM are used for quantitative LWC assessment and GFAS data are only used for relative trends and patterns. Otherwise readers might wonder, why GFAS data is shown in later figures.

Reply: We can not fully rule out which instrument, GFAS or PVM, was more accurate in terms of LWC. Thus we discussed the differences and listed the potential reasons for their disagreements (which are common as also mentioned, see Guyot et al., 2015). The GFAS is the only instrument that gives size-resolved data needed to e.g. calculate the contributions of hydrated aerosol to the over fog droplet concentrations or liquid water content. Within each figure, it is clear which instrument was used. Therefore we prefer to keep the text as is.

Minor suggestions:

- L 211: typo: "normalized root mean square error (normalized root mean squared error (NRMSE))"

Reply: Corrected.

- L 238: how is droplet activation defined?

Reply: Here we defined it as a clear visible mode of droplets (observed by the GFAS) above 10 micron. We added to the respective sentence *"When the visibility was below 1 km due to hydrated particles only, i.e. when there was no droplet activation* ***(i.e. absence of a distinct droplet mode observed by the GFAS)****, we use the term unactivated fog. "*

- L340: "until 14 UTC" on the consecutive day

Reply: We added *"... on the following day…"* to the respective sentence.

- L355: S10 comes before other supplementary Figures in the text. E.g. S12 mentioned before S11. Please reorganize supplement figures to correct order

Reply: Fixed.

- L360: more discussion and explanation of Fig. S11 would be helpful here

Reply: We added *"The comparative simulation results of these two events are presented in the Supplement (Fig.S11), indicating that the aerosol size distribution predominantly controls droplet activation, with CDNC and LWC showing substantially greater sensitivity to aerosol size distribution than to chemical composition."*

- L374: It would be nice to also have fog duration in the comparison plot of Fig 3

Reply: We added the fog duration for each event on top of panel (a) in the revised Figure 3. We also modified the caption accordingly (now: " … *The duration of each event is given above panel (a) in minutes. ….* ")

- Figure 4a: it is hard to make out the interstitial k distribution in yellow. Maybe another colour works better

Reply: We have now changed the color to darker orange and the histogram is now displayed as contour lines instead of a filled plot to improve readability.

Further changes:

1. We homogenized the nomenclature of kappa and N503
2. l 40: the LWC acronym error was corrected
3. We changed the following sentence as the chemical composition was also used to calculate kappa_residual and kappa_interstitial: " ~~The current study only used the chemical composition of the total aerosol, which"~~ **to**

"The chemical composition data from a second high-resolution time-of-flight aerosol mass spectrometer (HR-ToF-AMS, deCarlo et al. (2006), or interstitial AMS) and MAAP were used to estimate the hygroscopicity of the interstitial aerosol. The data from both AMS were processed and analyzed using the software packages SQUIRREL 1.66 and PIKA 1.26 (Sueper, 2024)."

4. In Section 2.4, the *UTC* time in the simulation setup has been corrected to *LST (Local Standard Time, UTC+1)*.
5. In the SI, we added the instruments used to calculate kappa_interstitial and kappa_residual to the set-up plot
6. In the SI, the description of the comparative simulations for fog events 7 and 15 has been reformulated.
7. In the references (line 928), the reference to Ranjan et al., 2025 (preprint) has been changed to Ranjan et al., 2025 (published).
8. We have updated the "Code and data availability" section and added all published datasets (some final DOI's will be added later, now only preliminary links are provided by the data center):

"The data are available on the Data Centre of the Bolin Centre for Climate Research (see https://bolin.su.se/data/fairari-2021-2022-3 for an overview of all FAIRARI data). The individual datasets used here are:

- *SP-AMS: Fredrik Mattsson, Almuth Neuberger, Liine Heikkinen, Paul Zieger, Claudia Mohr (2025) Aerosol chemical composition measured during the FAIRARI campaign, Po Valley, Italy, February – April 2022. Dataset version 1. Bolin Centre Database. https://doi.org/10.17043/fairari-2021-2022-aerosol-spams-1*
- *DMPS: Almuth Neuberger, Fredrik Mattsson, Paul Zieger (2024) Aerosol particle number size distribution measured during the FAIRARI campaign, Po valley, Italy, February – April 2022. Dataset version 1. Bolin Centre Database. https://doi.org/10.17043/fairari-2021-2022-aerosol-dmps1-1*
- *MAAP: Almuth Neuberger, Fredrik Mattsson, Paul Zieger (2024) Equivalent black carbon concentration measured during the FAIRARI campaign, Po valley, Italy, February – April 2022. Dataset version 1. Bolin Centre Database. https://doi.org/10.17043/fairari-2021-2022-aerosol-maap2-1*
- *Meteorological and visibility data: Marco Paglione, Stefano Decesari, Almuth Neuberger, Rahul Ranjan, Ilona Riipinen, Paul Zieger (2026) Meteorological parameters measured during the FAIRARI campaign, Po Valley, Italy, February – April 2022. Dataset version 1. Bolin Centre Database.*
- *GFAS: Almuth Neuberger, Lea Haberstock, Rahul Ranjan, Ilona Riipinen, Paul Zieger (2026) The fog and aerosol size distribution measured during the FAIRARI campaign, Po valley, Italy, February – April 2022. Dataset version 1. Bolin Centre Database.*

- *CCNC: Almuth Neuberger, Rahul Ranjan, Ilona Riipinen, Paul Zieger (2026) Cloud condensation nuclei concentrations measured during the FAIRARI campaign, Po valley, Italy, February – April 2022. Dataset version 1. Bolin Centre Database.*
- *LES model outputs: Hao Ding, Almuth Neuberger, Rahul Ranjan, Fredrik Mattsson, Lea Haberstock, Darrel Baumgardner, Stefano Decesari, Annica M. L. Ekman, Dagen Hughes, Claudia Mohr, Marco Paglione, Ilona Riipinen, Matteo Rinaldi, Paul Zieger (2025) Large-eddy simulation outputs of radiation fog events during the FAIRARI campaign, Po Valley, Italy, February 2022. Dataset version 1. Bolin Centre Database. https://doi.org/10.17043/fairari-2021-2022-les1-1*

The MIMICA model code is available via https://bitbucket.org/matthiasbrakebusch/mimicav5/src/master. The codes used to generate most of the figures can be accessed at https://github.com/rahulranjanaces/Hydrated_Aerosol_FAIRARI.git."