# Review for ACP manuscript EGUSPHERE-2025-132.

The influence of Amazonian anthropogenic emissions on new particle formation, aerosol, cloud, and surface rain. From Xuemei Wang1,2, Ken S. Carslaw1, Daniel P. Grosvenor1,3, and Hamish Gordon2

This manuscript, EGUSPHERE-2025-132, addresses crucial processes that connect particle formation in the remote tropical atmosphere, particle growth, and CCN concentrations in Amazonia. This manuscript investigates the impact of anthropogenic emissions from Manaus, Brazil, on new particle formation (NPF), aerosol concentrations, cloud properties, and rainfall in the Amazon region. The authors used the HadGEM3 climate model as a nested regional climate model to simulate various emission scenarios and analyze the effects of these emissions. The use of a high-resolution nested regional domain (3 km resolution) in the HadGEM3 model enables a highly precise representation of local atmospheric processes and their interactions with anthropogenic emissions. The study highlights the complex interactions between anthropogenic emissions, aerosol formation, and cloud processes in this relatively pristine environment, but very significantly, regionally and globally.

In terms of methodology, the use of a high-resolution regional model nested within a global model allows for detailed simulations of aerosol and cloud processes. The study design, with its various emission scenarios, is effective in isolating the impact of anthropogenic emissions. The inclusion of observational data from the GoAmazon2014/5 campaign provides a strong basis for model validation. Comparing model results with aircraft measurements and radar data enhances the credibility of the findings. The paper is generally well-structured, with a clear introduction, detailed methods section, well-organized results, and a comprehensive discussion. The figures and tables are effective in presenting the data.

The authors acknowledge several limitations in their model, including the exclusion of upper tropospheric NPF and simplifications in cloud microphysics. These limitations may affect the accuracy of the simulated aerosol-cloud interactions. However, it is well recognized that NPF in high altitudes is a very recent finding. In all climate and regional models, cloud microphysics must be simplified to a great extent.

Some of the emission scenarios, particularly those involving very strong reductions in aerosol number concentrations, are considered unrealistic. While these scenarios help to explore the system's sensitivity, their relevance to real-world conditions is limited. The complex nature of aerosol-cloud-precipitation interactions leads to some difficulties in interpreting the model results. The authors acknowledge the non-

linearities and buffering effects in the system, which can make it challenging to draw definitive conclusions.

Future work should focus on incorporating more comprehensive representations of cloud microphysics and aerosol-cloud interactions. Including upper tropospheric NPF would provide a more complete picture of aerosol formation and transport. **:** The study could benefit from a more in-depth analysis of the mechanisms driving the observed relationships between anthropogenic emissions, aerosols, and cloud properties. For example, a more detailed examination of the role of specific chemical species and microphysical processes would be valuable.

The finding that even drastic reductions in aerosol concentrations lead to only a 4% increase in rainfall raises questions about the model's sensitivity. This outcome may suggest limitations in the model's ability to capture the complexities of cloud and precipitation processes in a non-linear convective environment. I think a more comprehensive discussion on this aspect could be good for the manuscript.

**Overall Recommendation:**

This is a well-executed and valuable study that contributes to our understanding of the complex interactions between anthropogenic emissions and the Amazonian “natural” atmosphere. The authors use appropriate methods and present their data clearly. While the model has some limitations and challenges in interpreting the results, the study offers valuable insights into the complex interactions between anthropogenic emissions, aerosols, and cloud processes in the Amazon. I believe that the most valuable finding in this study is that the Amazonian climate-aerosol-CCN system is **highly resilient to change** (see the first specific comment). I recommend that the title could include the high resilience of the system.

**I recommend that ACP accept the manuscript for publication, after responding to the specific questions listed below.**

## Some specific comments.

**Abstract:** It focuses on how resilient the Amazonian system is: “The 7-day simulations show that, in the areas that are affected by anthropogenic emissions, when aerosol and precursor gas emissions are doubled 10 from the baseline emission inventories, aerosol number concentrations increase by 13 %.”. “We also found that doubling the anthropogenic emission can increase the cloud droplet number concentrations (Nd) by 9 %”. “Even extreme reductions in aerosol number concentrations by a factor of 4,

which is an unrealistic condition, cause only 4 % increase in rain over the domain." This could be somewhat included in the article's title.

**Introduction line 20:** Are you sure that for this statement, you need 14 references at the same point? Maybe choosing one or two as the best reference would be better. This is also true for lines 34, 52, and others. Far too many citations that are not actually relevant to the manuscript.

Section 2.2 - Line 150: "CMIP6 emission inventories provide CH4, and monoterpene, isoprene and natural SO2 are from CMIP5 inventories." I think we need more details on the isoprene emission inventory since it plays a critical role in natural aerosol production in Amazonia.

Section 2.2 - The manuscript does not mention the natural primary biogenic aerosol particles. This is a crucial component of the Amazonian background aerosol, and it must be considered. How was it treated in the manuscript?

Section 2.2 – Anthropogenic SO2 is obtained from Edgar. What about the sulfate precursors that could come from DMS and sulfur compounds from flooded areas?

Section 2.3 – line 180-185: Monoterpenes are the main VOCs for boreal forests, but NOT for Amazonia. Isoprene chemistry is the primary particle precursor in Amazonia, as reported by numerous studies spanning the lower troposphere to the high troposphere, as shown in the Curtius et al. paper from 2024.

Section 2.3 - What about NPF driven by isoprene-NOx system? The GoAmazon papers show that the increase in ozone is driven by NOx emissions, which have significant consequences for aerosol production.

Results line 255: It is not true that the model represents N > 100 well, as can be seen on 20140312. These are logarithmic plots, so there are differences by a factor of 10. In the legend, make clear that the plots are on a logarithmic scale.

Section 4 discussions and conclusions - Line 570 – Your strong statement "Thus, this study may not fully represent the response of cloud to changes in aerosol". Needs better qualification, as this was one of the study's primary objectives. On line 84, you explicitly mention the objective: "(2) What are the mechanisms that drive changes in aerosol and cloud properties?".