Reviewer comments have been reproduced in **bold** and author responses in regular typeface. Locations to modified text in the revised manuscript is presented in highlighted text.

Review of
Development of a Horizontal Cloud Condensation Nuclei Counter (HCCNC) to detect particle activation at temperatures below 4°C and supersaturations below 0.05%
by
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This study presents the development of a CCN counter capable of measuring the CCN activity of particles at temperature as low as of 4°C and supersaturation (SS) levels down to 0.05%. The authors provided detailed design information and validated the instrument using ammonium sulfate particles. Overall, I find the work valuable and recommend it for publication after the following concerns are addressed:

We sincerely thank the reviewer for their thoughtful and constructive review. We greatly appreciate the insightful questions, detailed suggestions and future guidance.

1. **While the newly developed HCCNC has been well validated using ammonium sulfate particles, how does it perform when measuring ambient particles? Adding experimental data or discussion regarding its application to real atmospheric aerosols would strengthen the work and make the study more comprehensive.**

   We appreciate the reviewer's valuable comment. Currently the HCCNC has not been used to evaluate ambient particle activation. To conduct field experiments is beyond the current scope of the manuscript and project. However, we did test the HCCNC with chamber experiments where mixed particles were used with ammonium sulphate and levoglucosan and address these in Q4 related to the reviewer concern. The sampling of the mixed particles can be understood as a proxy for ambient aerosol where organic and inorganic aerosol are internally mixed. In the next project phase of the HCCNC, the instrument will be deployed in the field. Given that the chamber worked well for the mixed particles, we do not foresee an issue in ambient operation as long as the particle concentration is below 7400 cm^{-3} to avoid water vapour competition for activation and growth in the chamber (addressed in line 517-520 in the revised manuscript).

2. **The authors state that operating the CCNC at low SS allows for the activation of larger particles and provide an example where the critical SS for 111 nm ammonium sulfate particles is 0.13% (Lines 90–92). However, ambient URBAN aerosols are typically complex mixtures containing inorganics, organics, black carbon, dust, etc., and often exhibit lower hygroscopicity (kappa ≈ 0.3) compared to pure ammonium sulfate. This suggests that the D50 at SS = 0.13% for ambient particles would be significantly larger than 111 nm. Is it necessary to operate the CCNC at such a low SS? Would this low SS setting be more suitable for marine environments, where sea salt (e.g., sodium chloride) particles are much more hygroscopic? I recommend the authors clarify this point.**

   We agree with the reviewer that the lower supersaturations allowing the study of 200 nm particles is relevant for particles as hygroscopic as ammonium sulphate and would be relevant in marine environments. This also means for typically less hygroscopic aerosol such as in Urban environments particles even larger than 200 nm could be studied since the SS_{crit} would be lower for larger particles compensated by their larger size. As recommended by the reviewer this point has been clarified in lines 511-514 of the revised manuscript.

3. **The authors state that operating the CCNC at low temperatures enables accounting for or capturing the co-condensation effect. However, co-condensation depends on the difference between particle composition activity and the saturation ratio of condensable gases, rather than temperature alone. Although lowering the temperature can decrease the saturated vapor**

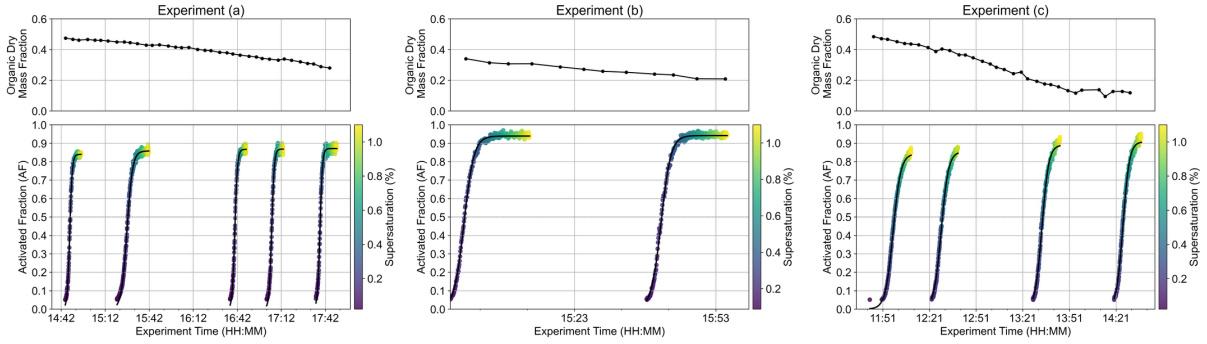
pressure of gaseous compounds, thereby increasing their saturation ratio and potentially enhancing co-condensation, this approach does not accurately reflect co-condensation processes under real atmospheric conditions. In fact, it may lead to an overestimation of the co-condensation effect compared to what occurs in the ambient environment.

You are correct that co-condensation is complex and that operating at a single low temperature could overestimate the effect compared to ambient conditions. Especially if the HCCNC is operating temperature that are significantly lower than ambient cloud temperatures. This could lead to an overestimation of CCN counts.

However, the key feature of the HCCNC is not its ability to generate the supersaturation at one low temperature (let's say 4°C) only, but its wide, controllable temperature range (4°C to 35°C) for supersaturation generation. This unique flexibility allows researchers to either match specific ambient thermal conditions or to systematically isolate and study the influence of temperature on aerosol activation and co-condensation.

4. **The maximum AF in Figure 4 ranges between approximately 0.7 and 0.9, which the authors attribute to uncertainties between CPC and OPC measurements. If this is the case, one would expect similar maximum AF values under different experimental conditions. Why does the maximum AF vary between 0.7 and 0.9? I am concerned that the AF could be even worse when measuring complex ambient particles. Could the authors provide some ambient particle measurement data to illustrate the instrument's performance in real-world conditions?**

This is a valid question. The differences in the AF could arise from the differences in counting efficiency between the CPC and OPC which has been shown to be uncertain in previous studies as well (Kumar et al., 2003). To demonstrate the instrument's capability with ambient-type aerosols, we conducted experiments with mixed ammonium sulfate and levoglucosan particles. The organic fraction from the Aerosol Mass Spectrometer (AMS) and the activated fraction (AF) measured by HCCNC over time are shown in plots below. These results indicate that for mixed inorganic-organic particles, similar to ambient aerosols, the AF reaches about 0.9. This work is in preparation for a follow up study to be submitted soon.



5. **The current title implies that the HCCNC can measure at temperatures BELOW 4°C and SS lower than 0.05%. However, based on the manuscript, the system achieves measurements at 4°C and 0.05% SS, not below these thresholds. Please revise the title and corresponding statements in the abstract to reflect the actual capabilities of the instrument.**

Agree. We have now updated the title accordingly.

References:

Pradeep Kumar, P., Broekhuizen, K., and Abbatt, J. P. D.: Organic acids as cloud condensation nuclei: Laboratory studies of highly soluble and insoluble species, Atmos. Chem. Phys., 3, 509–520, https://doi.org/10.5194/acp-3-509-2003, 2003.