Authors' Response to Reviewers' Comments

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Title: ICON coupled to HAM-lite 1.0 in limited-area mode: an efficient framework for targeted kilometer-scale simulations with interactive aerosols

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We would like to thank the anonymous reviewer for her/his time and constructive comments, and hope that we have responded satisfactorily to all the points raised.

Anonymous Referee #2

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This study develops and introduces a new limited-area version of the ICON-HAM-Lite model, enabling higher-resolution regional simulations with interactive aerosol representation while maintaining minimal computational cost. The authors further evaluate their simulations against observations and demonstrate generally good performance.

Overall, I consider this a valuable contribution to the community. In particular, using insights from LAM simulations to improve the global ICON-HAM-Lite model appears to be a very promising direction, given their seamless coupling framework. The manuscript is well written and well structured. I only have minor comments below and recommend the manuscript for publication in GMD once these have been addressed.

L74–76: Please also clarify the volume fractions used in the four-mode setup. Although they appear in Table 2, a brief mention or cross-reference here would improve readability.

We thank the reviewer for this helpful suggestion. To improve readability and clarify the 4-mode aerosol setup, we added a brief cross-reference in the general model description pointing the reader to Table 1, where the aerosol composition, including the applied volume fractions, is summarised.

Table 1: Are the nucleation and Aitken modes not considered in the model? If so, it would be clearer to remove them from Table 1 to avoid confusion.

That is correct; the nucleation and Aitken modes are not taken into account in the current model configuration, although they are in principle possible. In the revised manuscript, we have removed the original Table 1 to avoid redundancy and potential confusion regarding aerosol mode representation. Instead, the information on aerosol size ranges has been integrated into Table 2 (now Table 1), which now provides a unified overview of aerosol modes, including their size regimes, compositions, and physical properties. This modification clarifies that accumulation and coarse modes represent the actively simulated aerosol populations.

L107: It would be helpful for general readers to specify which intermediate transformation steps are missing here.

We have clarified the description by explicitly indicating the types of intermediate processes that are not resolved in the prescribed emission approach. In particular, these include secondary aerosol formation and aging processes such as gas-to-particle conversion (e.g. secondary inorganic and organic aerosol formation), coagulation, and condensation-driven particle growth. In the revised manuscript, we now specify that these processes are not explicitly simulated but are partly represented in a bulk sense through the prescribed modal composition and size distribution.

The model offers good flexibility to adjust modal radii, volume fractions, and densities. However, this also raises a question: should the same setup be adopted in both the global and LAM versions of ICON-HAM-lite, especially if the LAM is intended to inform development of the global version?

In principle, using consistent aerosol settings in both the global and LAM configurations is desirable, especially since one aim of the regionalized ICON–HAM-lite framework is to support developments that can later be transferred to the global model version. At the same time, the prescribed aerosol properties in the present simplified modal setup represent effective aerosol characteristics at the respective model scale. Because explicit aerosol microphysics and aging processes are not included, the prescribed properties in the global configuration must implicitly reflect aerosol evolution during long-range transport and large-scale mixing, while regional LAM applications may focus more strongly on local or source-specific aerosol conditions. The extent to which identical parameter settings are appropriate may also depend on the aerosol species itself, as different aerosol types exhibit distinct source characteristics, atmospheric lifetimes, transport pathways, and aging behaviour. Therefore, identical parameter settings are not necessarily optimal for both configurations. Nevertheless, preserving a physically consistent framework between regional and global applications remains an important objective for future model development.

To address this particular point in the manuscript, the following sentence was added at the end of Section 2.1: 'The optimal choice of prescribed aerosol properties may differ between global and regional configurations, depending on aerosol-specific transport, mixing, and aging characteristics across scales.'

L191: The LAM model is run at 2.5 km resolution. It would be very interesting to clarify which key processes are still parameterized and which are explicitly resolved at this scale.

Although the 2.5 km configuration explicitly resolves deep convection and associated mesoscale dynamics, several sub-grid-scale processes still require parameterization. We therefore added a brief clarification in the manuscript noting that cloud microphysics, radiation, turbulence, and aerosol-related processes such as activation, deposition, sedimentation, and optical properties remain parameterized in the ICON–HAM-lite LAM configuration.

Table 3: The time periods listed in the table do not appear to be consistent with those in the main text. Please check and correct if necessary.

Thank you very much for pointing out this inconsistency, which originates from an earlier version of the manuscript. The data in the table were correct and have been incorporated into the main text.

L207: Are the biogenic emissions also taken from CEDS? If not, does it also provide data for the simulation year?

The biogenic emissions are not taken from CEDS but follow the inventory of Guenther et al. (1995), consistent with the original HAM configuration, as stated in the manuscript. The applied dataset is representative of climatological conditions around the year 2000 rather than the specific simulation years. To clarify this point, we extended the following sentence: "The biogenic emissions are taken from the inventory of Guenther et al. (1995), which represents climatological biogenic emissions."

L229-232: Have you tested how the results change if CAMS lateral boundary conditions are also applied to the Arctic and Australian cases?

Contrary to the original wording in the manuscript, CAMS aerosol lateral boundary conditions were also applied in the Atlantic Arctic case (April 2020) to account for long-range transport of sea-spray aerosols. Only the Australian bushfire smoke and desert dust case (December 2019) was performed without aerosol lateral boundary conditions, since the dominant aerosol sources are located within the model domain. We added a corresponding clarification to the manuscript.

L261-263: The ICON-HAM-lite model uses accumulation and coarse modes; I wonder how PM2.5 is calculated here. Typo: µor◊ µm

For comparison with measured PM2.5, aerosol mass concentrations are calculated offline from simulated number concentrations using the volume-mean (mass-equivalent) radius and prescribed particle density of each log-normally distributed aerosol mode. Total aerosol mass is obtained by summing contributions from the four model aerosol modes, and a PM2.5 size cut-off is applied. A corresponding sentence was added to this paragraph; the typo was corrected.

L304: I'm not sure if nitrates and ammonium are good examples here as HAM-lite doesn't consider these species. This also partially contributes the underestimation of PM2.5 by model.

We thank the reviewer for this helpful comment. We agree that nitrates and ammonium are not particularly good examples, as they are not explicitly represented in the current HAM-lite configuration, and therefore should not be highlighted in the introductory discussion of PM2.5. We revised the text accordingly and now refer more generally to long-range transport contributions and secondary aerosol formation. The missing representation of secondary inorganic aerosol is further discussed later in the manuscript as a likely contributor to the model underestimation of PM2.5.