Response to Referee #2

March 16, 2025

We thank the referee for the valuable comments, which we took into account in the revised manuscript. Below you find the referee's comment and our response.

1) **Comment:** *Transitions from emission and processing to accumulation and coarse mode is unclear.*

   Response: Due to the absence of microphysical processes, emissions are directly added to modes without any intermediate steps such as nucleation. The mass fluxes are converted into number fluxes based on the radius of average mass of the mode, i.e.,

   $$F_{\mathrm{em},j,k,s} = \frac{3}{4\pi \overline{r}_{\mathrm{m},j}^{3} \rho_k} S_{\mathrm{em},k,s},$$

   where $S_{\mathrm{em},k,s}$ is the mass flux of species k in sector s, $\overline{r}_{\mathrm{m},j}$ is the radius of average mass of mode j, and $F_{\mathrm{em},j,k,s}$ is the number flux. We extended the first paragraph of section 2.3.1.

   ⇒ **Change 12 and 14**

2) **Comment:** *Some emission inputs (e.g. biomass burning) are too coarse for km-scale modeling.*

   Response: We agree with the referee. In future simulations, we plan to use wildfire emissions from the GFAS database (Kaiser et al., 2012) and anthropogenic emissions from the CEDS database (Hoesly et al., 2018; Feng et al., 2020), which are based on more recent observations and provided at higher resolutions. We added a comment to section 4.1.

   ⇒ **Change 20**

3) **Comment:** *Fixed sizes seem too simple for interactions with ambient humidity (sulfate, seasalt).*

   Response: While the dry radius of a mode is constant, the wet radius varies based on the hygroscopic growth factor (f_{g})of Petters and Kreidenweis (2007), i.e.,

   $$\overline{r}_{\mathrm{w},j} = f_{\mathrm{g}}(T, RH, \overline{r}_j, \kappa_j)\overline{r}_j,$$

where $\overline{r}_j$ and $\overline{r}_{\mathrm{w},j}$ are the dry and wet radii of the mode, T is the air temperature, RH is the relative humidity, and κ_j is the hygroscopicity. The wet radius is used to calculate various aerosol processes as shown in section 2.2. We added a comment to section 2.1 and replaced "number median radius" with "dry radius" throughout the manuscript.

⇒ **Change 5, 6, 7, 16, 18, 25, and 36**

4) **Comment:** *60 / 74 is it unclear how humidity (via kappa) come into play, if size is fixed*

Response: As explained in the response to comment 3, the wet radius varies based on the hygroscopic growth factor of Petters and Kreidenweis (2007).

⇒ **Change 5, 6, 7, 16, 18, 25, and 36**

5) **Comment:** *92 interesting ... that no convection scheme/parameterization is needed*

Response: The Earth system model ICON-MPIM operates without a convection scheme. As outlined by Hohenegger et al. (2023), there are three main reasons for this choice. First, a lean code with few parameterization schemes can be ported more easily to new systems such as the new exascale cluster of the Forschungszentrum Jülich (2025). Second, parameterization schemes do not converge as the resolution is refined, which would be problematic for future simulations with ever increasing resolutions. Hohenegger et al. (2020) showed that some large-scale quantities such as net shortwave radiation start to converge at resolutions of about five kilometers. Third, ICON-MPIM is intended for Earth system research and not operational weather forecasting. Simple physics make it easier to understand, for example, the impact of processes that remain partially resolved or parameterized at kilometer scales. We added a paragraph to section 2.2.

⇒ **Change 11**

6) **Comment:** *107 emissions data are relatively coarse for km-scale models .... ?*

Response: As explained in the response to comment 2, we plan to use newer databases that are better resolved in future simulations.

⇒ **Change 20**

7) **Comment:** *191 displaying the reff (effective radii) would be better, as it includes the width information) ... there seems a size inconsistency to the MACv2 reference, as number mode radii are picked for the two coarse modes, while (larger) effective radii are picked for the fine-mode. The kappa approach (values are reasonable) might be useful for CCN estimates in the context of ambient rel. humidity but are they actually used? Densities are reasonable but on the high side for carbon and sulfate, and those might become smaller with increased aerosol water.*

Response: As explained in section 3.1, the dry radii of the modes were initially taken from the MACv2 aerosol climatology of Kinne (2019) and then adjusted to roughly match the aerosol lifetimes reported by Gliß et al. (2021). For the two coarse modes, the dry radii were adjusted only marginally. For the two fine modes, however, the dry radii were increased significantly since their initial lifetimes were too long. As explained in the response to comment 3, the hygroscopicities (κ) are used to calculate the wet radii and densities of the modes. The hygroscopicities are also used to calculate the aerosol activation as described in section 2.3.5. We added a comment to section 3.1.

⇒ **Change 18**

8) **Comment:** *238 is there a difference of Table 4 data between HAM and HAM-lite ?*

   Response: We added the burdens and fluxes of ECHAM6.3–HAM2.3, i.e., the values of the CLIM simulation of Tegen et al. (2019), to table 4.

   ⇒ **Change 20 and 21**

9) **Comment:** *252 the comparison to AeroCom median are quite interesting. Here also the optical depth data of the top-down approach of the MAC climatology can be added (see below). I also provide access to data so that in assessment annual and even monthly component spatial distributions differences can be examined. While global averages for seasalt and sulfate seem ok, global averages for dust and carbonaceous aerosol are ca factor 2.5 too low. Hereby the low dust AOD bias is not helped by the relatively small coarse dust size.*

   Response: We extended the last paragraph of section 4.1 including the predefined optical depths of the MACv2 climatology of Kinne (2019).

   ⇒ **Change 30**

10) **Comment:** *267 MODIS overestimates AOD, especially at low AOD values. In addition, listed global average might even on the low side as the applied dark-target data-set has no data over deserts. I suggest to use for MODIS data comparisons a combined darktarget/deep blue data set.*

    Response: We revised figure 6 using the combined dark target and deep blue product.

    ⇒ **Change 28**

11) **Comment:** *291 if aerosol modulate the intensity of cyclones is unclear ... and highly unlikely by sea-salt, as this type stays a low altitudes.*

    Response: We revised the corresponding statements in the abstract and sections 4 and 5.

    ⇒ **Change 3, 19, 33, and 37**

12) **Comment:** *302 what are the prescribed mean radii and std.dev s (incomplete in Table 2)*

Response: The standard deviation is 2.00 for the coarse modes (dust and sea salt) and 1.59 for the fine modes (carbonaceous and sulfuric). We extended the caption of table 2.

⇒ **Change 16**

13) **Comment:** *324 ... are blown off continents ... not just Africa*

Response: We corrected the sentence.

⇒ **Change 32**

14) **Comment:** *330+ I like most of the ideas for future work, in particular studies involving aerosol cloud interactions. For aerosol forcing, however, a better representation of AOD components and also a validation of assumed absorption (AAODf / AAODc) will be needed*

Response: We extended the outlook.

⇒ **Change 39**

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