Response to Referee #3

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:** *You mention that it would be too expensive to run the two-moment module HAM with 5 km grid spacing but I was hoping to see an intercomparison between the original HAM and HAM-lite even if it is only at 10 km or for a short period of time. Such a comparison would shed some light on the differences and potential implications of the simpler scheme and might also help to improve HAM-light. I understand that adding such a comparison would be a lot of work but would also bring a lot of benefits. If you decide to not work on this, I recommend to at least discuss potential differences and work on a comparison in the near future.*

   Response: A direct comparison of HAM and HAM-lite is not possible in the moment since these two modules are coupled to different Earth system models. HAM-lite is coupled to the new km-scale model ICON-MPIM (Hohenegger et al., 2023), whereas HAM is coupled to the coarse-scale models ECHAM (Tegen et al., 2019) and ICON-A (Salzmann et al., 2022). To allow for a comparison, we added the aerosol burdens, fluxes, lifetimes, and optical depths of ECHAM-HAM as reported by Tegen et al. (2019) and Gliß et al. (2021) to tables 4 and 5.

   ⇒ **Change 20, 21, and 22**

2) **Comment:** *Related to the above comment; Could you add a discussion on what the systematic impacts of using a single moment aerosol representation are? What processes would be better captured using a two-moment representation and where should users be careful when using the one moment output for process understanding?*

   Response: We acknowledge that a one-moment scheme imposes limitations in comparison to a two-moment scheme. Since it carries no information about the aerosol size, there is no explicit representation of nucleation, growth, and ageing. And there is no ability to adjust the aerosol size in response to activation and wet deposition (Stier et al., 2005; Siebesma et al., 2020). We added a comment to section 2.1.

   ⇒ **Change 8**

3) **Comment:** *L19: Do CMIP6 type models truly have complex microphysics compared to e.g., modern weather forecasting models. My impression was that they usually use single moment schemes without graupel/hail. Additionally, running deep convection schemes that produce precipitation complicates things.*

Response: We corrected the sentence and replaced the reference to Thornhill et al. (2021) with Tegen et al. (2019). Tegen et al. (2019) preformed simulations with the complex ECHAM-HAM model over the years 2003 to 2012.

⇒ **Change 4**

4) **Comment:** *L84-5: Currently this reads like there are three schemes for microphysics, radiation, and turbulence each. You could write: "There are three parameterization schemes, one for cloud microphysics, one for radiation, and one for turbulence..."*

Response: We corrected the sentence.

⇒ **Change 9**

5) **Comment:** *L109: "To forward emissions to modes,..." what is meant here? Please reformulate.*

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.,

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

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**

6) **Comment:** *L259-60: I do not see anything special at 500 hPa in the dust concentration profiles. It seems as if the peak of emissions is related to the height of the source region (e.g. dust emissions over the Tibetan Plateau should be around 600 hPa). Plotting the profiles regarding height above surface should help to reduce this effect.*

Response: We revised the figure and plotted the profiles based on the altitude.

⇒ **Change 23 and 24**

7) **Comment:** *L269-70: I appreciate that you mention satellite observation uncertainties. Could you add a sentence on how those might affect this comparison?*

Response: On average, the optical depth of MODIS is larger than those of other satellites especially over the ocean (Vogel et al., 2022, tables 2 and 3). We added a comment to the last paragraph of section 4.1.

⇒ **Change 27**

8) **Comment:** *L296: "The vertical velocities highlight diverging cold pool edges that lift air from convective downdrafts." This should probably be something like: ... diverging cold pools that originate from convective downdrafts and mesoscale circulation that lifts air at the gust front.*

Response: We corrected the sentence.

⇒ **Change 34**

9) **Comment:** *L299-300: It is not only the cold pools that are not captured but also the mesoscale circulation (e.g., mesocyclones, rear-inflow jets in MCSs...). One study that discusses this is: Prein (2023).*

Response: We revised the sentence.

⇒ **Change 35**

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