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Comment on acp-2021-151

Anonymous Referee #2

Referee comment on "Reduced effective radiative forcing from cloud–aerosol interactions (ERF_{aci}) with improved treatment of early aerosol growth in an Earth system model" by Sara Marie Blichner et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2021-151-RC2, 2021

In this manuscript, the authors studied the effect of improved treatment of early aerosol growth (from 5 nm to 40 nm, with a sectional scheme) on effective radiative forcing associated with cloud-aerosol interactions (ERFaci) in the Norwegian Earth System Model v2 (NorESM2). Compared to the default scheme (OsloAerodef) that parameterizes the growth of freshly nucleated particles of a few nanometers and to the smallest mode in the model (>~40 nm), the explicit sectional treatment of this early growth (OsloAeroSec) enables the model to capture the variations in atmospheric condition and particle sizes during the growth that may take multiple hours. The results presented in this manuscript show that the ERFaci is sensitive to both the aerosol properties in the pre-industry (PI) simulation and parameterization of new particle formation (NPF), which are consistent with previous publications. The authors find that the ERFaci with the sectional scheme is 0.13Wm−2 weaker compared to the default scheme, resulting from OsloAeroSec producing more particles than the default scheme in pristine, low-aerosol concentration areas and less NPF particles in high-aerosol areas. The authors also show that NPF inhibits cloud droplet activation in high-aerosol-concentration regions but enhances cloud droplet activation in pristine/low aerosol regions, as a result of the difference in the cloud droplet activation sizes and the competition of condensing vapors between NPF particles and larger particles. This manuscript deals with the treatment of aerosol formation and growth processes and their impacts on ERFaci in an Earth System Model, which is important and is in the areas covered by ACP. The following comments should be addressed before I can recommend it for final publication in ACP.

- This work focuses on the effect of aerosol growth treatment. A comparison of simulated aerosol properties based on both aerosol schemes with observations is essential but is lacking in the present manuscript. Does OsloAeroSec indeed improve the simulated aerosol sizes and number concentrations that are important for aerosol-cloud interaction? Are the spatial and temporal variations of simulated aerosol properties consistent with observations? A large amount aerosol measurements are currently available for model validations (for example, see Fanourgakis et al., https://doi.org/10.5194/acp-19-8591-2019, 2019).
- I think that the nucleation scheme used in this study (Lines 152-153) is oversimplified and likely does not give the correct spatial and temporal variations of NPF which is critical for the present study. Eq. 18 of Paasonen et al (i.e., J2=As1[H2SO4]+As2[org])

does not consider the well-recognized temperature dependence of nucleation rates (e.g., Yu et al., https://doi.org/10.5194/acp-17-4997-2017, 2017). This parameterization significantly overestimates the NPF rates in the summer and in the tropic regions (including Amazon). At least, the authors should take into account the temperature dependence and do a reasonable validation of the model simulations in terms of spatial and seasonal variations of particle number concentrations. The manuscript can be further improved if the sensitivity of the ERFaci based on two aerosol schemes to the nucleation parameterizations can be presented.

- Figure 8a. Very high PI N_NPF in the tropic region is likely a result of the nucleation parameterization used (J2=As1[H2SO4]+As2[org]) and is against what is observed (for example over Amazon). As the authors acknowledge in the main text, PI aerosol characteristic is important for ERFaci calculation so it is essential to validate the PD aerosol simulations in pristine/low aerosol regions.
- Lines 10, 162-163, and Fig 1 caption: The descriptions of the size range considered in the OsloAeroSec appear to be inconsistent. Please clarify. OsloAeroSec starts at 5 nm, right? Why not 2 nm?