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Reduced effective radiative forcing from cloud-aerosol interactions with improved modelling of early aerosol growth in an Earth System Model

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Cloud-aerosol interactions are responsible for much of the uncertainty in forcing estimates from pre-industrial times and thus also climate sensitivity and future projections. Maybe the most important factor in this is our lack of knowledge about pre-industrial aerosols, their sources and their ability to act as cloud condensation nuclei (CCN). The number of CCN is highly dependent on secondary aerosol formation and in particular how much of this secondary aerosol mass that goes to new particle formation (NPF) and early particle growth, versus growing already large particles even larger.
Earth system models which seek to model this, face a challenge because we need to represent processes at a very fine scale (nanometers) to a sufficient accuracy, while simultaneously keeping computational costs low. A common approach is to use log-normal modes to represent the sizedistribution, while more computationally expensive sectional schemes are considered closer to first principles.

In this study, we investigate the effect of a newly developed scheme for early particle growth on the effective radiative forcing from cloud-aerosol interactions (ERF_{aci}) in the Norwegian Earth System Model v2 (NorESMv2). The new scheme, referred to as OsloAeroSec, presented in Blichner et al. (2020), combines a sectional scheme for the growth of the smallest particles (5 - 39.6 nm), with the original semi-modal aerosol scheme which would simply parameterize the growth up to the smallest mode with Lehtinen et al. (2007). This was shown to to improve the representation of CCN relevant particle concentrations, when compared to measurement data.

We find that ERF_{aci} is weakened by approximately 10 % with the new scheme (from -1.29 to -1.16 Wm^{-2}). The weakening originates from OsloAeroSec (the new scheme) reducing particle formation in regions with high aerosol concentrations while increasing it in very pristine regions. We find, perhaps surprisingly, that an important factor for the overall forcing, is that NPF inhibits aerosol activation into cloud droplets in high-aerosol-concentration regions, while the opposite is true in pristine regions.
This is because the NPF particles act as a condensation sink, and if they cannot activate directly themselves, they may reduce the growth of the larger particles which would otherwise activate.
Furthermore, we find that the increase in particle hygroscopicity with present day emissions of

sulphate pre-cursors, decreases the size of the activated particles, and thus makes NPF particles more relevant for cloud droplet activation.

References:

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