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# Modelling choices with regard to aerosol-cloud interactions and their impact on effective climate sensitivity in the NorESM2 model

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Aerosol-cloud interactions (ACIs) continue to be subject to much uncertainty, supporting a large set of parametric and structural variants of a global climate or Earth System Model (ESM), especially regarding its aerosol and cloud microphysics components. This structural model uncertainty is relevant not only for the quantification of the climate response to anthropogenic aerosols: Because aerosol-cloud interactions are at the core of cloud and precipitation formation, they might also affect model-simulated cloud adjustments and feedbacks in response to greenhouse gases, and hence the model's effective climate sensitivity (ECS). In-situ observations, satellite retrievals, and large-eddy simulations point to discrepancies between the effects of aerosol-cloud interactions in the real world and as modelled in ESMs, with potential implications for the model range also for ECS.

Here, we explore how different choices in ACI modelling affect the model's ECS. For this case study the CMIP6-generation Norwegian Earth System Model version 2 (NorESM2) is used, which has a sophisticated aerosol module and in its 'default' version contributed to the CMIP6 suite relatively weak positive cloud feedbacks compared to the other models within the 150 years used to calculate the regression-based ECS (EffCS). The climate change feedback and hence ECS of each modified model version compared to that of the default one is estimated by prescribing a uniform rise of 4K in the sea-surface temperature boundary conditions and evaluating the resulting top-of-atmosphere imbalance difference. A similar or better representation of present-day mean climate in general and ACI effects in particular is ensured by comparing a suite of evaluation metrics with their observationally derived pendants and results from the literature.

The ACI effects and relevant model-observation discrepancies targeted with the model modifications include models' excessive cloud brightening over stratocumulus regions compared to satellite products, excessive increase in liquid water path associated with increased aerosol amount, and model bias in the climatological fraction between supercooled liquid water and cloud ice in mixed-phase clouds. For each of these, experiments with multiple combinations of modifications in the model code are analysed, exemplifying the numerous different processes and parameters that together determine the model response. The findings complement approaches to explore models' parameter spaces systematically by informing the choices physically and restricting the modifications not only to parametric changes. The range of models obtained sets the default NorESM2 version, with its ECS being part of the CMIP6 ensemble, into the context of

ACI uncertainty, informs on the so far possibly underappreciated relevance of ACIs for climate change beyond anthropogenic aerosols, and suggests alternative parameterisations for future 'default' model versions.

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