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Aerosol–climate interactions in the Norwegian Earth System Model – NorESM1-M

A. Kirkevåg et al.

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Abstract. The objective of this study is to document and evaluate recent changes and updates to the module for aerosols and aerosol–cloud–radiation interactions in the atmospheric module CAM4-Oslo of the core version of the Norwegian Earth System Model (NorESM), NorESM1-M. Particular attention is paid to the role of natural organics, sea salt, and mineral dust in determining the gross aerosol properties as well as the anthropogenic contribution to these properties and the associated direct and indirect radiative forcing.

The aerosol module is extended from earlier versions that have been published, and includes life-cycling of sea salt, mineral dust, particulate sulphate, black carbon, and primary and secondary organics. The impacts of most of the numerous changes since previous versions are thoroughly explored by sensitivity experiments. The most important changes are: modified prognostic sea salt emissions; updated treatment of precipitation scavenging and gravitational settling; inclusion of biogenic primary organics and methane sulphonic acid (MSA) from oceans; almost doubled production of land-based biogenic secondary organic aerosols (SOA); and increased ratio of organic matter to organic carbon (OM/OC) for biomass burning aerosols from 1.4 to 2.6.

Compared with in situ measurements and remotely sensed data, the new treatments of sea salt and dust aerosols give smaller biases in near-surface mass concentrations and aerosol optical depth than in the earlier model version. The model biases for mass concentrations are approximately unchanged for sulphate and BC. The enhanced levels of modeled OM yield improved overall statistics, even though OM is still underestimated in Europe and overestimated in North America.

The global anthropogenic aerosol direct radiative forcing (DRF) at the top of the atmosphere has changed from a small positive value to −0.08 W m^{-2} in CAM4-Oslo. The sensitivity tests suggest that this change can be attributed to the new treatment of biomass burning aerosols and gravitational settling. Although it has not been a goal in this study, the new DRF estimate is closer both to the median model estimate from the AeroCom intercomparison and the best estimate in IPCC AR4. Estimated DRF at the ground surface has increased by ca. 60%, to −1.89 W m^{-2}. We show that this can be explained by new emission data and omitted mixing of constituents between updrafts and downdrafts in convective clouds.

The increased abundance of natural OM and the introduction of a cloud droplet spectral dispersion formulation are the most important contributions to a considerably decreased estimate of the indirect radiative forcing (IndRF). The IndRF is also found to be sensitive to assumptions about the coating of insoluble aerosols by sulphate and OM. The IndRF of −1.2 W m^{-2}, which is closer to the IPCC AR4 estimates than the previous estimate of −1.9 W m^{-2}, has thus been obtained without imposing unrealistic artificial lower bounds on cloud droplet number concentrations.

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