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Influences of in-cloud aerosol scavenging parameterizations on aerosol concentrations and wet deposition in ECHAM5-HAM

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Abstract. A diagnostic cloud nucleation scavenging scheme, which determines stratiform cloud scavenging ratios for both aerosol mass and number distributions, based on cloud droplet, and ice crystal number concentrations, is introduced into the ECHAM5-HAM global climate model. This scheme is coupled with a size-dependent in-cloud impaction scavenging parameterization for both cloud droplet-aerosol, and ice crystal-aerosol collisions. The aerosol mass scavenged in stratiform clouds is found to be primarily (>90%) scavenged by cloud nucleation processes for all aerosol species, except for dust (50%). The aerosol number scavenged is primarily (>90%) attributed to impaction. 99% of this impaction scavenging occurs in clouds with temperatures less than 273 K. Sensitivity studies are presented, which compare aerosol concentrations, burdens, and deposition for a variety of in-cloud scavenging approaches: prescribed fractions, a more computationally expensive prognostic aerosol cloud processing treatment, and the new diagnostic scheme, also with modified assumptions about in-cloud impaction and nucleation scavenging. Our results show that while uncertainties in the representation of in-cloud scavenging processes can lead to differences in the range of 20–30% for the predicted annual, global mean aerosol mass burdens, and near to 50% for accumulation mode aerosol number burden, the differences in predicted aerosol mass concentrations can be up to one order of magnitude, particularly for regions of the middle troposphere with temperatures below 273 K where mixed and ice phase clouds exist. Different parameterizations for impaction scavenging changed the predicted global, annual mean number removal attributed to ice clouds by seven-fold, and the global, annual dust mass removal attributed to impaction by two orders of magnitude. Closer agreement with observations of black carbon profiles from aircraft (increases near to one order of magnitude for mixed phase clouds), mid-troposphere ^{210}Pb vertical profiles, and the geographic distribution of aerosol optical depth is found for the new diagnostic scavenging scheme compared to the prescribed scavenging fraction scheme of the standard ECHAM5-HAM. The diagnostic and prognostic schemes represent the variability of scavenged fractions particularly for submicron size aerosols, and for mixed and ice phase clouds, and are recommended in preference to the prescribed scavenging fractions method.

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