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Impact of cloud-borne aerosol representation on aerosol direct and indirect effects

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Abstract. Aerosol particles attached to cloud droplets are much more likely to be removed from the atmosphere and are much less efficient at scattering sunlight than if unattached. Models used to estimate direct and indirect effects of aerosols employ a variety of representations of such cloud-borne particles. Here we use a global aerosol model with a relatively complete treatment of cloud-borne particles to estimate the sensitivity of simulated aerosol, cloud and radiation fields to various approximations to the representation of cloud-borne particles. We find that neglecting transport of cloud-borne particles introduces little error, but that diagnosing cloud-borne particles produces global mean biases of 20% and local errors of up to 40% for aerosol, droplet number, and direct and indirect radiative forcing. Aerosol number, aerosol optical depth and droplet number are significantly underestimated in regions and seasons where and when wet removal is primarily by stratiform rather than convective clouds (polar regions during winter), but direct and indirect effects are less biased because of the limited sunlight there and then. A treatment that predicts the total mass concentration of cloud-borne particles for each mode yields smaller errors and runs 20% faster than the complete treatment. The errors are much smaller than current estimates of uncertainty in direct and indirect effects of aerosols, which suggests that the treatment of cloud-borne aerosol is not a significant source of uncertainty in estimates of direct and indirect effects.

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