Geophysical Research Abstracts,
Vol. 11, EGU2009-8900, 2009
EGU General Assembly 2009

Constraining cloud droplet number concentration in GCMs suppresses the aerosol indirect effect

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Over the last decade, aerosol-climate models have evolved to include more and more sophisticated aerosol and cloud microphysics schemes. With a prognostic treatment of aerosol number concentration and a continuity equation for cloud droplets, very low values for the droplet concentration can occur, which are not considered realistic. To avoid this, several state-of-the-art GCMs constrain the droplet concentration such that it can not fall below a certain minimum value inside a cloud or impose lower bounds for aerosol concentration. While it can be argued that natural background aerosol particles (e.g. non-desert dust or bioaerosols) are missing in most GCMs and therefore the simulated concentrations are too low, observed cloud droplet concentrations can actually fall below 30 cm^{-3} in the remote oceans or even below 15 cm^{-3} in the Arctic. This suggests that lower bounds are problematic, especially for clean preindustrial conditions.

It has been shown previously (Lohmann et al, 2000: JGR; Wang & Penner, 2008: ACPD) that this constraint has the side effect of reducing the simulated aerosol indirect effect. Here we investigate this effect systematically with the CAM-Oslo GCM (Storelvmo et al, 2006: JGR; Seland et al, 2008: Tellus). Setting the lower bound for the cloud droplet concentration to 0, 1, 10, 20 and 40 cm^{-3} results in changes of the shortwave cloud forcing between present-day and preindustrial conditions which range from -1.9 Wm^{-2} (without a lower bound) to -0.6 Wm^{-2} (lower bound of 40 cm^{-3}). A similar effect is found if the cloud droplet concentration is treated diagnostically, for which case the results range from -2.4 Wm^{-2} (lower bound of 1 cm^{-3}) to -0.8 Wm^{-2} (lower bound of 40 cm^{-3}). We will discuss these simulations and the implications of our findings.