Atmospheric Chemistry and Physics
An Interactive Open Access Journal of the European Geosciences Union

Atmos. Chem. Phys., 6, 5225-5246, 2006
www.atmos-chem-phys.net/6/5225/2006/

Radiative forcing by aerosols as derived from the AeroCom present-day and pre-industrial simulations

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Abstract. Nine different global models with detailed aerosol modules have independently produced instantaneous direct radiative forcing due to anthropogenic aerosols. The anthropogenic impact is derived from the difference of two model simulations with prescribed aerosol emissions, one for present-day and one for pre-industrial conditions. The difference in the solar energy budget at the top of the atmosphere (ToA) yields a new harmonized estimate for the aerosol direct radiative forcing (RF) under all-sky conditions. On a global annual basis RF is -0.22 Wm^{-2}, ranging from $+0.04$ to -0.41 Wm^{-2}, with a standard deviation of ± 0.16 Wm^{-2}. Anthropogenic nitrate and dust are not included in this estimate. No model shows a significant positive all-sky RF. The corresponding clear-sky RF is -0.68 Wm^{-2}. The cloud-sky RF was derived based on all-sky and clear-sky RF and modelled cloud cover. It was significantly different from zero and ranged between -0.16 and $+0.34$ Wm^{-2}. A sensitivity analysis shows that the total aerosol RF is influenced by considerable diversity in simulated residence times, mass extinction coefficients and most importantly forcing efficiencies (forcing per unit optical depth). The clear-sky forcing efficiency (forcing per unit optical depth) has diversity comparable to that for the all-sky/ clear-sky forcing ratio. While the diversity in clear-sky forcing efficiency is impacted by factors such as aerosol absorption, size, and surface albedo, we can show that the all-sky/clear-sky forcing ratio is important because all-sky forcing estimates require proper representation of cloud fields and the correct relative altitude placement between absorbing aerosol and clouds. The analysis of the sulphate RF shows that long sulphate residence times are compensated by low mass extinction coefficients and vice versa. This is explained by more sulphate particle humidity growth and thus higher extinction in those models where short-lived sulphate is present at lower altitude and vice versa. Solar atmospheric forcing within the atmospheric column is estimated at $+0.82\pm0.17$ Wm^{-2}. The local annual average maxima of atmospheric forcing exceed +5 Wm^{-2} confirming the regional character of aerosol impacts on climate. The annual average surface forcing is -1.02 ± 0.23 Wm^{-2}. With the current uncertainties in the modelling of the radiative forcing due to the direct aerosol effect we show here that an estimate from one model is not sufficient but a combination of several model estimates is necessary to provide a mean and to explore the uncertainty.

Final Revised Paper (PDF, 3298 KB)   Discussion Paper (ACPD)

Citation: Schulz, M., Textor, C., Kinne, S., Balkanski, Y., Bauer, S., Berntsen, T., Berglen, T., Boucher, O., Dentener, F., Guibert, S., Isaksen, I. S. A., Iversen, T., Koch, D., Kirkevåg, A., Liu, X., Montanaro, V., Myhre, G., Penner, J. E., Pitari, G., Reddy, S., Seland, Ø., Stier, P., and Takemura, T.: Radiative forcing by aerosols as derived from the AeroCom present-day and pre-industrial simulations, Atmos. Chem. Phys., 6, 5225-5246, 2006.   Bibtex   EndNote   Reference Manager