



## Corrigendum to

# “Aerosol indirect effects from shipping emissions: sensitivity studies with the global aerosol-climate model ECHAM-HAM” published in *Atmos. Chem. Phys.*, 12, 5985–6007, 2012

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**Abstract.** An error in the calculation of the emitted number of primary sulfate particles for a given mass of emitted elementary sulfur has recently been identified in HAM, i.e. the aerosol module utilised in the ECHAM-HAM aerosol climate model. Correcting for this error substantially alters the estimates of top-of-atmosphere radiative forcing due to aerosol indirect effects from global shipping emissions (year 2000) as presented in Peters et al. (2012). Here, we shortly present these new results.

## 1 Discussion of model corrections and results

An error in the calculation of the emitted number of primary sulfate particles for a given mass of emitted elementary sulfur has recently been identified in HAM, i.e. the aerosol module utilised in the ECHAM-HAM aerosol climate model. Specifically, emitted number densities of primary sulfate were incorrectly diagnosed from emitted mass densities of SO<sub>2</sub> gas because of an incorrect conversion factor. This error led to an underestimate of emitted primary sulfate aerosol numbers by a factor of about 3.1. Correcting the faulty calculation of primary sulfate number density emissions increases globally averaged cloud droplet number concentration (CDNC) by 3.2 % in standard AeroCom-style (cf. Kinne et al., 2006) simulations. Locally however, the effects are more pronounced, with heavily polluted regions like western Eurasia and the US

East Coast showing annual mean increases in CDNC  $\mathcal{O}$  (10–20 %) (N. Schutgens, University of Oxford, personal communication, 2013). In those simulations, the effect on cloud properties in the pristine marine boundary layer is negligible. A sound estimate of changes in top-of-atmosphere (TOA) radiative forcing (RF) due to aerosol indirect effects (AIEs) is not yet available for these simulations.

On the contrary, we show here that the estimates of TOA RF due to AIEs from shipping emissions presented in our original paper (year 2000 emission levels, Peters et al., 2012) are substantially altered for some experiments.

We have rerun the experiments CTRL, A, Asc, B and Bsc by using the same methodology as in Peters et al. (2012). We did not rerun the experiments BnoBC and BnoC as we have shown that omitting carbonaceous aerosol does not have a noticeable impact on the AIE estimates. We show five-year annual means of selected model diagnostics in Table 1. Note that Table 1 shows the same parameters as Table 3 in Peters et al. (2012).

Correcting the faulty calculation of emitted sulfate aerosol particle numbers barely changes the results for simulations A and Asc as presented in Peters et al. (2012). Five-year mean globally averaged TOA RF due to AIEs from shipping emissions slightly increases in magnitude from  $-0.07$  to  $-0.08 \text{ W m}^{-2}$  or remains unchanged for experiment A or Asc, respectively.

**Table 1.** Global, five-year averaged changes of aerosol- and cloud properties for the experiments A, B, Asc and Bsc with respect to experiment CTRL, i.e. “experiment – CTRL”, as described in Peters et al. (2012), including the modifications described in the main text. The results for cloud droplet number concentration (CDNC) and cloud droplet effective radius ( $r_{\text{eff}}$ ) represent values at cloud top as diagnosed by the model. The values in parantheses represent globally averaged relative changes in % as  $\left(\frac{\text{“experiment”} - \text{CTRL}}{\text{CTRL}} \cdot 100\right)$ . Cf. Table 3 in Peters et al. (2012).

	AOD	AOD FMF	ADE [m W m <sup>-2</sup> ]	CDNC [cm <sup>-3</sup> ]	$r_{\text{eff}}$ [μm]	LWP [kg m <sup>-2</sup> ]	AIE [W m <sup>-2</sup> ]
A	1.8E-3±0.12E-3 (1.46±0.07)	4.6E-3±0.1E-3 (0.86±0.02)	-21.9±2	0.74±0.1 (3.1±0.4)	-0.02±0.005 (-0.01±0.005)	0.001±0.3E-4 (0.6±0.04)	-0.08±0.01
B	2.4E-3±0.07E-3 (1.9±0.04)	5.4E-3±0.01E-3 (1±0.02)	-21±1.6	2±0.13 (5.2±0.3)	-0.08±0.005 (-0.45±0.05)	3.7E-3±0.06E-3 (1.59±0.12)	-0.3±0.03
Asc	3E-3±0.01E-3 (2.47±0.06)	7.5E-3±0.01E-3 (1.39±0.03)	-38±1.2	1.15±0.09 (3.63±0.33)	-0.03±0.003 (-0.12±0.03)	1.5E-3±0.08E-3 (0.75±0.1)	-0.11±0.01
Bsc	3.9E-3±0.09E-3 (3.1±0.06)	8.6E-3±0.07E-3 (1.61±0.02)	-36.2±2	3.2±0.1 (7.2±0.22)	-0.11±0.004 (-0.72±0.05)	5.6E-3±0.1E-3 (2.3±0.1)	-0.45±0.02

However, the magnitudes of the RF values due to AIEs from ships obtained from experiments B and Bsc are substantially increased. Note that B and Bsc utilise a different emission parameterisation than the standard AEROCOM setup (cf. Peters et al., 2012). Thereby, the number of emitted primary sulfate particles was already 2–3 orders of magnitude larger in experiments B and Bsc compared to A and sAsc in Peters et al. (2012). Correcting the calculation of emitted sulfate particle number densities now increases the difference in AIE estimates between the two sets of experiments. In particular, the magnitude of our highest AIE estimate increases from  $-0.32 \pm 0.01 \text{ W m}^{-2}$  to  $-0.45 \pm 0.02 \text{ W m}^{-2}$  compared to the original paper. Although much higher than our previous estimate, the estimate presented here is still well below other published upper estimates for year 2000 global shipping emissions ( $-0.6 \text{ W m}^{-2}$ , Lauer et al., 2007) and agrees well with more recent estimates resulting from both simple and more sophisticated global aerosol modelling (Righi et al., 2011; Lund et al., 2012; Righi et al., 2013).

## References

Kinne, S., Schulz, M., Textor, C., Guibert, S., Balkanski, Y., Bauer, S. E., Bernsten, T., Berglen, T. F., Boucher, O., Chin, M., Collins, W., Dentener, F., Diehl, T., Easter, R., Feichter, J., Fillmore, D., Ghan, S., Ginoux, P., Gong, S., Grini, A., Hendricks, J., Herzog, M., Horowitz, L., Isaksen, I., Iversen, T., Kirkevåg, A., Kloster, S., Koch, D., Kristjansson, J. E., Krol, M., Lauer, A., Lamarque, J. F., Lesins, G., Liu, X., Lohmann, U., Montanaro, V., Myhre, G., Penner, J., Pitari, G., Reddy, S., Seland, O., Stier, P., Takemura, T., and Tie, X.: An AeroCom initial assessment – optical properties in aerosol component modules of global models, *Atmos. Chem. Phys.*, 6, 1815–1834, doi:10.5194/acp-6-1815-2006, 2006.

Lauer, A., Eyring, V., Hendricks, J., Jöckel, P., and Lohmann, U.: Global model simulations of the impact of ocean-going ships on aerosols, clouds, and the radiation budget, *Atmos. Chem. Phys.*, 7, 5061–5079, doi:10.5194/acp-7-5061-2007, 2007.

Lund, M. T., Eyring, V., Fuglestedt, J., Hendricks, J., Lauer, A., Lee, D., and Righi, M.: Global-Mean Temperature Change from Shipping toward 2050: Improved Representation of the Indirect Aerosol Effect in Simple Climate Models, *Environ. Sci. Technol.*, 46, 8868–8877, doi:10.1021/es301166e, 2012.

Peters, K., Stier, P., Quaas, J., and Graßl, H.: Aerosol indirect effects from shipping emissions: sensitivity studies with the global aerosol-climate model ECHAM-HAM, *Atmos. Chem. Phys.*, 12, 5985–6007, doi:10.5194/acp-12-5985-2012, 2012.

Righi, M., Klinger, C., Eyring, V., Hendricks, J., Lauer, A., and Petzold, A.: Climate Impact of Biofuels in Shipping: Global Model Studies of the Aerosol Indirect Effect, *Environ. Sci. Technol.*, 45, 3519–3525, doi:10.1021/es1036157, 2011.

Righi, M., Hendricks, J., and Sausen, R.: The global impact of the transport sectors on atmospheric aerosol: simulations for year 2000 emissions, *Atmos. Chem. Phys. Discuss.*, 13, 13119–13189, doi:10.5194/acpd-13-13119-2013, 2013.