Project no. 282688

ECLIPSE

Evaluating the **Cl**imate and Air Quality **I**m**p**acts of **S**hort-Liv**e**d Pollutants

Collaborative Project

Work programme: Climate forcing of non UnFCCC gases, aerosols and black carbon
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Coordinator: Andreas Stohl, NILU - Norsk institutt for luftforskning

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Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Introduction

Continental Europe has seen the emissions of sulfate and carbonaceous aerosols increase substantially from about 1960 – 1980. In the 1980s, clean-air regulation in Western Europe and in the late 1980s / early 1990s, economic restructuring in Eastern Europe after the fall of the Berlin wall led to substantial reductions in aerosol emissions (Vestreng et al., 2007; Wild et al., 2005; Stjern et al., 2011). These strong emission cuts from 1990 on can be seen as a historical analogue for strong reductions in short-lived climate forcer (SLCF) emissions. Observations of some relevant quantities exist, so that the climate response as simulated by Earth system models can be assessed (Wild and Schmucki, 2011).

Within the 5th Coupled Model Intercomparison Project (CMIP5; Taylor et al., 2012), many Earth system models from groups worldwide performed "historical" simulations (1850 – 2005) with time-varying greenhouse gas- and aerosol emissions, as well as natural forcings, prescribed as realistically as possible (Lamarque et al., 2010). Fig. 1 shows the temporal evolution of the sulfur dioxide (SO_2) and black carbon (BC) emissions averaged over Eastern Europe (defined as an area 15° - 45°E, 45° - 58°N) for the time 1960-2005. As explained above, emissions increased until about 1980, and decreased strongly after 1990.

Relevant observations that allow for trend analysis are for surface solar radiation from the Global Energy Balance Archive (GEBA; Ohmura et al., 1989) and for surface temperature from the Climate Research Unit (CRU, Brohan et al., 2006; Mitchell and Jones, 2005), University of East Anglia.

Results

The linear trends of various parameters over the Eastern European region for the two periods of rising (1960-1980) and declining aerosol emissions (1990-2005) are shown in Fig. 2 for the three ECLIPSE model systems (NorESM, HadGEM, MPI-ESM). A least squares linear regression method was applied for the linear trend analysis. Note that in the contribution of the MPI-ESM to CMIP5, aerosols were prescribed using the Kinne et al. (2013) aerosol climatology. These were scaled using the Lamarque et al. (2010) aerosol emissions, so AOD and absorption AOD change over time due to anthropogenic emissions. No aerosol-cloud interactions had been included, so that no cloud droplet number concentrations (CDNC) were diagnosed. In HadGEM, no absorption AOD has been diagnosed. As expected, emissions trends are very similar between NorESM and HadGEM. AOD trends are very similar among the models for the first period. However, in the second period, NorESM produces a much stronger decline than the other two models. However, when compared to nine other models, NorESM is within the inter-model uncertainty range (Cherian et al., 2013).
Absorption AOD trends are much larger in MPI-ESM than in NorESM, due to the high absorption in the Kinne et al. (2013) climatology. It is also very large compared to the ten other models Cherian et al. (2013) analysed. Consistent with the large AOD trend, NorESM also shows large trends in CDNC. HadGEM, in turn, shows only very little CDNC changes. Surface solar radiation trends in all three models are smaller than observed for both periods. Nevertheless, the simulated trends are consistent with the observations to within the uncertainty range. For temperature, in turn, the models show too strong trends compared to the observations for both periods. Where the observations actually show a (albeit very small) cooling in the first period, all models show a (small) warming trend. Consistent with the observations, the warming trend is much larger in the second period. It may be concluded that the greenhouse-gas forcing is too strong in the models in this region.

Conclusions

While the three ECLIPSE models show a relatively large scatter in simulated AOD and CDNC trends, still the surface solar radiation and surface temperature trends are consistent among the models. For all three models, the simulated trends are consistent with the observed trends to within the uncertainty range.

In conclusion, the models are fit for the purpose of assessing the climate change following a drastic reduction in aerosol (SLCF) emissions as can be judged from their ability to simulate the response to the increasing and then decreasing aerosol emissions over Eastern Europe.

References

Brohan, P., J. J. Kenndey, I. Harris, S. F. B. Tett, and P. D. Jones, Uncertainty estimates in regional and global observed temperature changes: A new data set from 1850, J. Geophys. Res., 111, D12106, doi:10.1029/2005JD006548, 2006.

Cherian, R., J. Quaas, M. Salzmann, and M. Wild, Pollution trends over Europe constrain global aerosol forcing, in preparation (2013).

Kinne, S., et al., A new global aerosol climatology for climate studies. J. Adv. Model. Earth Syst., submitted (2013).

Lamarque, J.-F., et al., Historical (1850 – 2000) gridded anthropogenic and biomass burning emissions of reactive gases and aerosols: methodology and application, Atmos. Chem. Phys., 10, 7017-7039, doi:10.5194/acp-10-7017-2010, 2010.

Mitchell, T. D., and P. D. Jones, An improved method of constructing a database of monthly climate observations and associated high-resolution grids, Int. J. Climatology, 25, 693-712, doi:10.1002/joc.1181, 2005.

Ohmura, A., H. Gilgen, and M. Wild, Global energy balance archive (GEBA), World Climate Programme – Water project, Züricher Geografische Schriften, 34, Zürich, 1989.

Stjern, C. W., A. Stohl, and J. E. Kristjánsson, Have aerosols affected trends in visibility and precipitation in Europe? J. Geophys. Res., 116, D02212, doi:10.1029/2010JD014603, 2011.

Taylor, K. E., R. J. Stouffer, and G. A. Meehl, An overview of CMIP5 and the experiment design, Bull. Am. Meteorol. Soc., 93, 485-498, doi:10.1175/BAMS-D-11-00094.1, 2012.

Vestreng, V., G. Myhre, H. Fagerli, S. Reis and L. Tarrasòn, Twenty-five years of continuous sulphur dioxide emission reduction in Europe, Atmos. Chem. Phys., 7, 3663-3681, doi:10.5194/acp-7-3663-2007, 2007.

Wild, M., et al., From dimming to brightening: Decadal changes in solar radiation at the Earth's surface, Science, 208, 847-850, 2005.

Wild, M., and E. Schmucki, Assessment of global dimming and brightening in IPCC-AR4/CMIP3 models and ERA40, Clim. Dyn., 37, 1671-1688, doi:10.1007/s00382-010-0939-3, 2011.

Figures

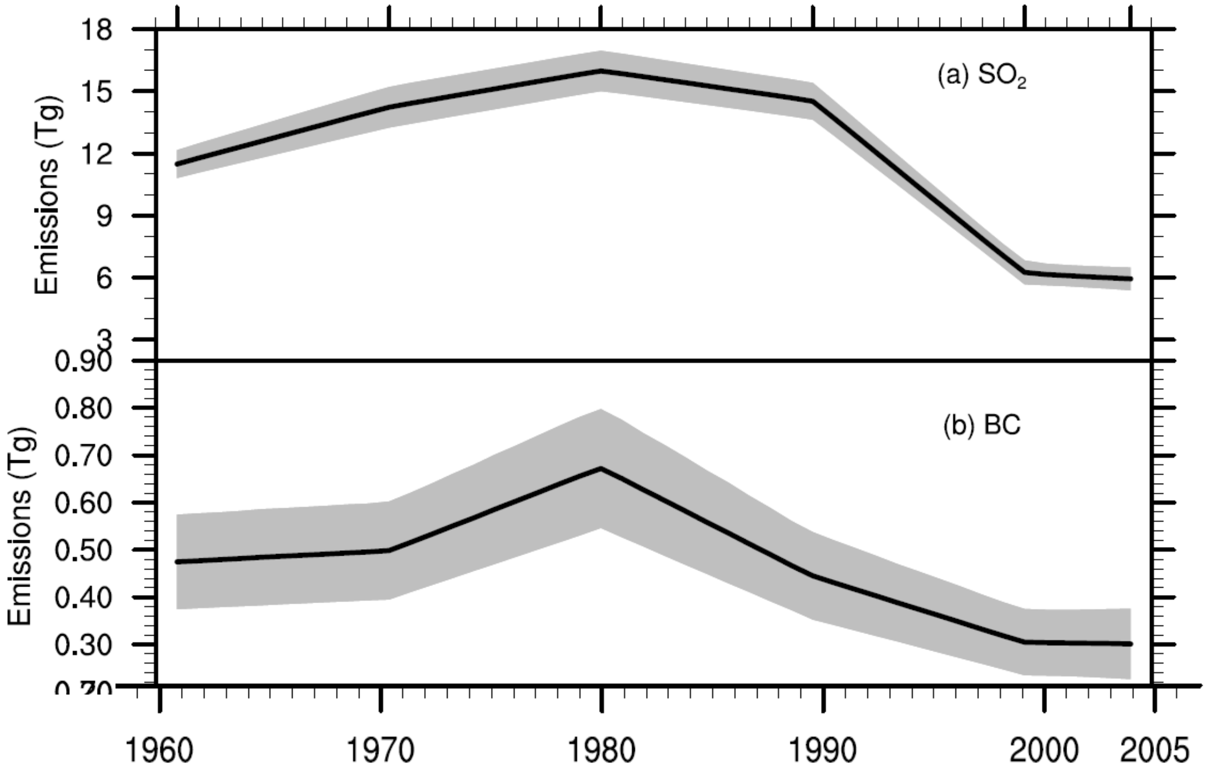

Fig. 1: Multi-model average (black line) and ensemble standard deviation (gray shading) of the annual-mean anthropogenic emissions of (a) sulfur dioxide and (b) particulate black carbon (Tg) averaged over the Eastern European region.

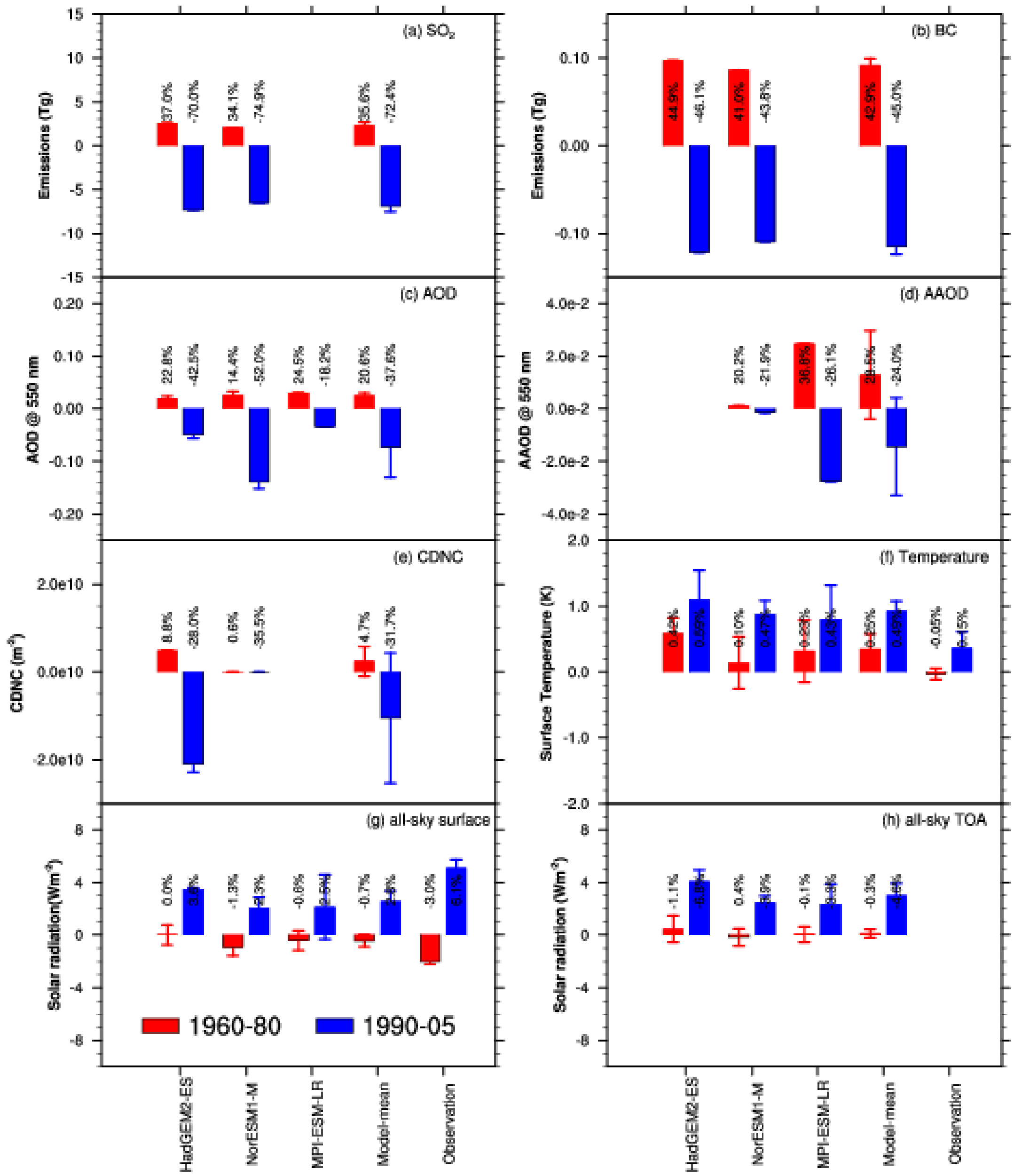

Fig. 2: Linear trends for the 1960-1980 period (red) and for the 1990-2005 period (blue) in absolute terms and statistical uncertainty (error bars), along with the relative trends (numbers) for (a) sulfur dioxide (Tg yr^{-1} decade^{-1}), (b) black carbon (Tg yr^{-1} decade^{-1}), (c) AOD (decade^{-1}), (d) absorption AOD (decade^{-1}), (e) CDNC (cm^{-3} decade^{-1}), (f) surface temperature (K decade^{-1}; observations are from the CRU dataset), (g) all-sky solar radiation at the surface (W m^{-2} decade^{-1}; observations are from GEBA) and (h) all-sky solar radiation at the top of the atmosphere (W m^{-2} decade^{-1}).