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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Global model simulations of air pollution during the 2003 European heat wave" *by* C. Ordóñez et al.

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RC: Referee comments - AR: Author replies

RC1: This paper deals with modelling of the heat wave in Europe, August 2003. 3 global models are used. As the authors point out there are several papers already published dealing with modelling of this episode. As such this paper does not bring in many new points regarding this episode. The paper compares the performance of several models, including also some sensitivity studies.

In the conclusions the authors say: "The meteorological and photochemical modelling of such an extreme episode requires higher spatial resolution and finer temporally resolved emission data." Based on the sensitivity runs the authors conclude that re-

moving emissions outside Europe has little effects on concentrations in the European boundary layer. Based on these conclusions in the paper it seems likely that a set of (fine scale) regional models would be more suited for this study. The authors should give a motivation for using global models in this study. I believe that within GEMS/MACC there is a publication in preparation looking at the 2003 heat wave with regional models? If so, this could be mentioned.

AR1: We agree that there are a number of papers published that have modelled air pollution for the European heat wave of August 2003, but as we have already pointed out those papers mainly focus on surface fields. The aim of this manuscript is not to simulate air quality at surface level during that episode, for which regional models, with finer grid cell and more detailed parameterizations, are more appropriate at present time. More detailed emissions than those used here would also be needed for that. Our main motivation is to show the first evaluation of a number of global models for that extreme pollution episode in order to assess their capability to provide reasonable tropospheric concentrations that can be used as initial and lateral boundary conditions by finer regional air quality models. Because of that we have focused on the evaluation of modelled tropospheric profiles, particularly in the proximity of the boundary layer, and have paid less attention to surface fields. We have tried to make this clear in the new version of the manuscript.

The first evaluation of the reference simulations performed with the CTMs and coupled system has shown some successes (e.g. correct simulation of the evolution of O3 and CO during the period of analysis, improvement of CO modelling with the assimilation of satellite data), but also some deficiencies (e.g. overall underestimation of O3 and CO mixing ratios by most models) and some range of variability among the models. As a consequence we have performed a number of sensitivity runs to evaluate the relative importance of some possibly under-represented processes in global models with the view of providing improved boundary conditions for regional models in the future. We have found that emissions from outside Europe do not have a large impact

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on European pollution in the particular case of the heat wave, partly because of the stagnation of air masses over the European continent during that period, but this does not mean that a detailed evaluation of global models for this episode is not needed.

There is a follow-on publication in preparation which discusses 2003 runs that have been made with a number of regional models in the Regional Air Quality (RAQ) sub-project of GEMS. That publication will present simulations performed with two different chemical boundary conditions (time-dependent and monthly climatologies), and also a run for the heat wave period using forcings from a version of the IFS-MOZART coupled system shown in our manuscript. That publication will serve as an example of the relevance of the boundary conditions and usefulness of the coupled system presented here. It is now quoted in the new version of the text as: Rouil, L., Tarrason, L., Peuch, V.-H., et al., 2009: Impact of the 2003 heatwave in Western Europe on air quality: new insights from the GEMS multi-model system, in prep. for Atm. Chem. and Phys, 2009.

RC2: An improved representation of the Portuguese wildfires from GFED are also available from http://www.ess.uci.edu/_jranders/ with 8 days emissions. It is a pity that this has not been used instead of the monthly data.

AR2: In the new version of the manuscript we mention the existence of a more recent GFEDv2.1 dataset with 8-day fire emissions for the 2001–2005 period (Randerson et al., 2007). We did not consider such a product because it was still not available at the time when all the GEMS global runs presented here were set up.

Reference: Randerson, J. T., van der Werf, G. R., Giglio, L., Collatz, G. J., and Kasibhatla, P. S.: Global Fire Emissions Database, Version 2 (GFEDv2.1). Data set. Available on-line [http://daac.ornl.gov/] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A, 2007.

RC3: Some of the figure panels are very small (as an example Figure 9, first page). The Figures should be enlarged. Given that some white space is removed they should still fit into one page.

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AR3: Figure 9 has changed in the corrected version of the manuscript following another suggestion by the reviewer (please see below). However we think that some figures look small (e.g. Figure 9, first page) while others look somewhat large (e.g. Fig 11) because of the way figures are inserted (separately from the rest of the text) in ACPD. We will make sure that the size of all figures is appropriate in the final ACP version.

More detailed comments:

RC4: Page 16857 lines 7 - 10: Reference also to AIRBASE?

AR4: The report by Fiala et al. (2003) quoted in this manuscript shows results from stations of the European Environment Information and Observation Network (EIONET), which is supported by the European Environmental Agency (EEA). The air quality monitoring data and information submitted by the participating countries throughout Europe is stored in the public air quality database system of EEA (AIRBASE). A short reference to EIONET/AIRBASE has been added to the new version of the manuscript:

"The described summer 2003 led to exceptionally long-lasting and spatially extensive periods of high ozone (O3) in Europe, mainly during the first half of August, as observed at the European Environment Information and Observation Network (EIONET/AIRBASE) supported by the European Environmental Agency (Fiala et al., 2003). Exceedance of the information threshold – hourly average concentrations of 180 μg/m3 – occurred in 23 of the 31 countries reporting and at about 68% of all stations (1220 stations)... "

RC5: Page 16857 lines 15 - 21: Some more explanation is needed here. Are you describing two different air masses here? Is it so that you get high global radiation in Switzerland because you are not affected by forest fires, whereas further west the optical thickness is affected by these fires? If so the reason for the ozone events in Switzerland and further west must be somewhat different. Under certain conditions the increase in optical depth will give higher actinic flux, and thereby affect ozone production, but I could only find two (relatively old) references for this from Science and

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JGR.

AR5: We agree with the referee that further explanations are needed. As indicated in the two papers that he/she mentioned (Dickerson et al., 1997; Jacobson, 1998), UV-absorbing aerosols such as mineral dust and soot reduce the flux of UV radiation and inhibit ozone production while UV-scattering aerosols can have a positive impact on the flux of UV radiation and enhance the production of ground-level ozone. Photolysis rates near surface also depend on the distribution of the different aerosols types with altitude. Some examples of aerosol effects that can enhance or inhibit ozone production are: the cooling and stabilisation of the PBL by scattering aerosols, the destabilisation (stabilisation) of the atmosphere by absorbing aerosols in the PBL (in the free troposphere), heterogeneous reactions such as the hydrolysis of N2O5 on aerosols, or effect of aerosols on cloud microphysics.

In the context of the influence of emissions from fires on ozone during the European heat wave of summer 2003, it is worthwhile to mention the analyses by Hodzic et al. (2007). They simulated aerosol optical properties and used them as inputs to a radiative transfer model to calculate the perturbation in photolysis rates induced by aerosols originating from fires. They found a significant reduction in photolysis frequencies of NO2 and O3 (J[NO2] and J[O3]) at Juelich, Germany, on 5–7 August, coinciding with the arrival over Northern Europe of smoke particles from Portugal forest fires. They also predicted the largest reductions in surface J[NO2] and J[O3] due to the effect of wildfire aerosol emissions at a number of European locations for the first 15 days of August 2003. Much smaller reductions were found for the rest of summer 2003. Hodzic et al. (2007) also suggests that the heating caused by injection of absorbing aerosols in the free troposphere might have contributed to reinforcing the atmospheric stability and to maintaining the heat wave conditions during summer 2003, which has not been considered in the ECMWF reanalysis run that drives the CTMs.

In the ACPD version of the manuscript we wrote: “An analysis of ozone trends in Switzerland during the reference period 1992–2002 indicates that the 15 ppb higher

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than usual daily O3 maxima registered during summer 2003 can be explained by elevated afternoon temperatures, absence of frontal passages and high morning global radiation (Ordóñez et al., 2005)." First of all, we should point out that the summer period referred here (June–August 2003) is longer than the 2-week period analysed by Hodzic et al. (2007) and by the present manuscript, so the air masses cannot be directly compared. However, we would also like to provide more explanations on the influence of radiation during that period. In Ordonez et al. (2005), a multilinear regression model was applied to establish the association of daily O3 maxima with a considerable number of meteorological parameters at a number of Swiss surface stations for the summer months (June-August) of the period 1992–2002. Afternoon temperature (aT), the number of days after a frontal passage (ndF) and morning global radiation were the most important variables in explaining the variability in ozone mixing ratios for that period. The resulting model, using the 3 mentioned explanatory variables, was extrapolated to summer 2003 and it successfully explained the very high daily ozone maxima (on average around 15 ppb higher than usual) observed at most stations in that specific summer. We cannot assess the overall effect of morning global radiation on surface ozone in Switzerland for summer 2003, because a model that only included radiation as explanatory variable (or a model that included aT and ndF but not radiation) was not tested. However, it is still correct to say that daily O3 maxima for that area during the whole summer season can be explained by the three mentioned parameters. For the sake of brevity these explanations will not be included in the revised version of the manuscript.

We have extended the corresponding part of the text by adding a reference to Hodzic et al. (2007) at the end: "An analysis of ozone trends in Switzerland during the reference period 1992–2002 indicates that the 15 ppb higher than usual daily O3 maxima registered during summer 2003 can be explained by elevated afternoon temperatures, absence of frontal passages and high morning global radiation (Ordóñez et al., 2005). During the first half of August 2003, various processes such as stagnation, photochemistry or forest fires led to unusually high particle concentrations and optical thicknesses

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(Hodzic et al., 2006). In particular, the presence of elevated smoke layers over Europe decreased photolysis rates at surface by 10 to 30 %, which could have inhibited regional ozone production, but the heating caused by such aerosols might also have contributed to reinforcing the atmospheric stability and to maintaining the heat wave conditions during summer 2003 (Hodzic et al., 2007)."

We have also mentioned in the conclusions that the effects described by Hodzic are not considered in the model simulations evaluated in this manuscript.

References:

Dickerson, R. R., Kondragunta, S., Stenchikov, G., Civerolo, K. L., Doddridge, B. G., and Holben, B. N: The impact of aerosols on solar ultraviolet radiation and photochemical smog, Science, 278, 827–830, 1997.

Hodzic, A., Madronich, S., Bohn, B., Massie, S., Menut, L., and Wiedinmyer, C.: Wildfire particulate matter in Europe during summer 2003 - meso-scale modeling of smoke emissions, transport and radiative effects, Atmos. Chem. Phys., 7, 4043-4064, 2007.

Jacobson, M. Z.: Studying the effects of aerosols on vertical photolysis rate coefficient and temperature profiles over an urban airshed, J. Geophys. Res., 103(D9), 10593-10604, 1998.

Ordóñez, C., Mathis, H., Furger, M., Henne, S., Hüglin, C., Staehelin, J., and Prévôt, A. S. H.: Changes of daily surface ozone maxima in Switzerland in all seasons from 1992 to 2002 and discussion of summer 2003, Atmos. Chem. Phys., 5, 1187–1203, 2005.

RC6: Page 16875 Lines 5 - 9: Ozone above Paris most likely affected by ozone titration effects due to large emissions from larger Paris.

AR6: In that part of the text we indicated that ozone biases in the PBL tend to be less negative (mainly during the heat wave) or more positive (mainly outside the heat wave) above Paris compared to Frankfurt. We have considered the reviewer's suggestion

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and have included the following sentence: “Ozone above Paris is likely to be more affected by titration with NO than above Frankfurt due to larger emissions from Paris. It is possible that such effects, which constitute an important ozone sink, are not well represented in the coarse grid cells of the global models, leading to a compensation of the negative biases in ozone caused by other modelled processes around Paris”.

RC7: Page 16876, Effects of horizontal resolution and Figure 9: The authors give the impression that the increase in resolution results in an increase in pollutant levels everywhere. I would expect that there will also be areas where concentrations decrease. To illustrate this the panels on the right hand side could be exchanged with difference plots. If these figures become hard to read, this effect should be mentioned in the text.

AR7: The referee is right and we thank him/her for the suggestion. The figures showing output fields from two MOZART runs (reference run and high-resolution run) have been replaced by difference plots. To produce these new plots, output from the coarse reference run has been resampled to match the horizontal resolution of the high resolution run. We think that this way we better illustrate the areas over which pollutant levels increase or decrease. The text has also been modified accordingly.

RC8: Pages 16877 and 16878 Emissions: For the TM5-HWEE and in particular the TM5-HWEN model runs there is no information on what sort of spin-up times are used.

AR8: The model sensitivity runs TM5-HWEE, TM5-HWEN and TM5-HWDN cover the 3-month period from 1 June to 31 August 2003, as mentioned now in the new version of the manuscript. The same also applies to the high resolution MOZART simulation (MOZART t106). Since we show results from 16 July to 31 Aug, there is a spin-up period of one month and a half for all these runs.

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 16853, 2009.