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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Aerosol simulation applying high resolution anthropogenic emissions with the EMAC chemistry-climate model" *by* A. Pozzer et al.

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We thank referee #1 for the valuable comments.

The issues raised by the referee concern three major points, i.e. motivation of the study, benefit of high-resolution-in time inventory and improvement in the statistical analysis of the model performances. Here we address the three points.

Study motivation. This study has three objectives. The first is to evaluate the EMAC model with the state-of-the-art emission inventory EDGAR-CIRCE. This emission inventory is based on the year 2005 and includes monthly temporal varia-

tion of the emissions. To our knowledge the EDGAR-CIRCE inventory has not been used in any air quality modelling study. We evaluate calculated aerosol (precursors) concentrations by comparing with ground based measurements of the EMEP, EANET and CASTNET and calculated AODs with space born instruments.

The second objective is to perform a budget analysis of the aerosols and their precursors. This analysis is crucial to estimate the quality of the new emission inventory, of the model simulation and to study the aerosol life cycle. The latter is important because it provides information on the sources and removal mechanisms of the aerosol (precursors) and an estimation of the import and export transport terms of the aerosol (precursors) for a selected region. We believe that the comparison of the budgets with earlier studies (Aan de Brugh et al., 2011; Textor et al., 2006) is essential to evaluate the quality of the inventory and of the model simulation.

The third objective is to evaluate the role of the monthly distribution of the emissions on calculated aerosol (precursor) concentrations. Previous studies addressed the influence of different time resolutions of the emissions on a regional scale (de Meij et al., 2006), although (to our knowledge) this was never done on a global scale.

In this work an horizontal resolution of the general circulation model ECHAM5 of T106 (i.e. $\sim 1.1 \times 1.1$ degree) has been used. This resolution has been chosen based on two considerations:

- computation time requirement: as a multi year simulation was carried out, the computational requirement for a model of such complexity as the EMAC model is large. An even higher resolution would have been extremely time-consuming with the actual available High Performance Computers.
- resolution of the emission inventories: despite the availability of high resolution anthropogenic emissions (0.1×0.1 degree) and a somewhat lower reso-

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lution biomass burning (0.5×0.5 degree), the biogenic emissions included in this work are on a 1×1 degree resolution. A simulation at resolution higher than 1×1 degree would not have any addition to the processes influenced by biogenic emissions.

Further, a proper analysis of the advantages in using a T106 resolution for simulating the atmospheric composition (and ozone in particular) can be found in Wild and Prather (2006), who performed a set of simulations at different resolutions (T21,T42, T63 and T106) and showed that the simulated ozone is increasingly realistic (compared to the observations) with increasing of resolution. In the literature not many studies at T106 resolution on a global scale are available and the referee correctly mentioned the work of Lin et al. (2008). Nevertheless, the Lin et al. (2008) simulation was limited to the summer of 1999 and within a limited time frame, which requires less computational resources.

We are indeed aware that higher resolution is possible using the nesting techniques (Kerkweg and Jöckel, 2011; Hofmann et al., 2011), or with the usage of a non-uniform (stretched) grid (Park et al., 2004a,b), to reduce the computational costs of the overall simulations. Nevertheless, it must be stressed that these techniques can be implemented only in few regions of interest, while the global model has the advantage of having consistent information around the globe. In this work the budget calculation (see Sect. 4) has been possible only with the usage of global model. Finally, we completely agree with the referee that anthropogenic emissions datasets at higher resolution are available. We however mentioned in the manuscript that we refer to global datasets: "For example, most of the global anthropogenic emissions inventories currently neglect the seasonal cycle of emissions for the majority of precursor gases and generally have a resolution of 1×1." We will reformulate the introduction specifically mentioning that: " Regional inventories of anthropogenic emissions are available at much higher resolution (both spatially and temporally) but they do not have a global coverage

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as the dataset used in this work and are used in nested or regional model (see, for example, Warneke et al. (2007); Jacobson (2001); Jacobson et al. (2007))"

Benefit of high-resolution-in time inventory The referee correctly mentioned that we do not take full advantage of the high horizontal resolution of the model, but, instead, we took the advantage of the monthly temporal resolution in the inventory, and this should be underlined better in the text. The referee mentioned that "One way the authors can obtain new information from their study is to show that the use of the monthly inventory gives a better result, when compared with data, than the same inventory with the emissions annually-averaged." We agree with the referee and we have indeed performed this analysis, which is present in the paper (Sect.5). In this section we actually performed the simulation and the analysis suggested by the referee, by comparing the standard simulation (named *ST* in the manuscript) with a simulation which does not include monthly varying emissions but only yearly averages calculated from the original emissions (named *NS*, i.e. No Seasonality). Thus we have performed what has been suggested by the referee, and we also stated in the conclusions that "The usage of monthly varying anthropogenic emissions improves the model ability to reproduce the observations compared to yearly constant emissions, with an improved temporal correlation between 5 to 10 %, depending on the aerosol type and the location. The only exception appears for NH_4^+ , for which neglecting the seasonal cycle improved the simulation results over the USA, partially correcting the wrong seasonal distribution of the emissions. This improvement is, however, limited to the USA, while in the other regions a degradation of the model results compared to the observations is obtained.". However, this aspect of the paper was not mentioned in the abstract; we will correct the abstract in the revised version of the manuscript adding some specific statement with respect to this.

Statistical analysis of the model performances The referee mentioned that the statistical measures are not rigorous as not paired in time and space. We respectfully

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disagree, because the model has been sampled in the same locations of the observations and monthly averaged, so to apply the same temporal resolution of the observations. We think that this was not clearly explained in the manuscript and we will add the following sentence in Sect.3.2: "The model has been sampled in the same location of the observations in order to compare the model results with co-located observations". The referee also mentioned that in our comparison we did not list the root mean squared error (or the normalized gross error), and we totally agree that this information will improve the quantification of the model performances with respect to the observations. This information is partially contained in the Taylor diagrams present in Fig.5,7,9,11, where the distance from the point of correlation 1 and normalised standard deviation 1 is equivalent to the normalised centered pattern root mean squared error, which contains all the informations regarding the seasonal cycle differences between model results and observations (see Taylor (2001)). Hence we will extend the discussion adding the calculations of the root mean squared error.

Reply to the specific comments:

Section 3.1 We agree with the referee that the statement is not correct, and we will reformulate the section referring to the relative error. Nevertheless, we are not so sure that showing a relative error (instead of absolute one) in figure 1 would improve the clarity of the manuscript, as the relative error is strongly dependent on the absolute observed AOD. We will instead change figure 1 adding the average AODs as estimated by the model, so to have a context for the differences (see also comments on Fig.1 below).

Section 4 We agree with the referee that the ratio of wet to dry deposition is similar to the one estimated by the physical model of Jacobson (2010) and very similar to what obtained by Textor et al. (2006), using an ensemble of model. We will

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add the reference in the revised version of the paper. The wet deposition is fully described in two publications: Tost et al. (2006, 2007). While in Tost et al. (2006) the technical formulation is described, in Tost et al. (2007) the effect of the wet deposition on atmospheric composition in the EMAC model is analysed in detail. Analogously, in Kerkweg et al. (2006), the dry deposition is described in detail. We do not think that it is helpful to summarise these publications in few lines, and we prefer to maintain the text as it is, with the necessary references, so to avoid an increase in the manuscript size. All the informations on wet/dry deposition are easily accessible online and detailed described in the before mentioned publications.

Table 2 The emissions factor used in deriving BC from biomass burning can be obtained from van der Werf et al. (2010), i.e. 0.57, 0.46, 0.52, 0.56, 0.48 and 0.57 $g(\text{BC})/kg(\text{dry matter burned})$ from deforestation, savanna and grassland, woodland, extratropical forest, agricultural waste burning and peat fires, respectively. We refer to van der Werf et al. (2010) for a detailed explanation of the methodology used to estimate the biomass burning emissions. The fuel burnt areas are based on the work of Giglio et al. (2010), estimated from four satellite data sets.

"DU" stands for mineral dust and "SS" stands for sea salt. These acronym were defined well before the table (see Introduction, page 25207, line 26). We do not find reasonable to define again the acronyms on the table as we should also explain the BC (Black Carbon) and POM (Particulate Organic Matter) acronyms, contained in the same table and defined in the introduction together with DU and SS.

We will reduce the number of significant digit for SS and DU to three.

Table 3 We respectfully disagree with the referee. The arithmetic mean of the model and the arithmetic mean of the data *are* paired in space and (to some degree) in time. The model in fact, has been sampled at the same location of the observa-

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tions and monthly averaged (as the observations). We expected that the value MAM and OAM do indeed give information on the average bias of the model with respect to the observations. We think that this was not clearly explained in the manuscript and we will add the following sentence: "MAM (Model Arithmetic Mean) was calculated sampling the model in the location of the observations and monthly averaged, as the observations. Hence MAM and OAM (Observations Arithmetic Mean) represents co-located measurements and model results.". On the other hand we think that the referee correctly notes that the root mean squared error would give additional information on the model performance and we will add a column in the table with this calculation. This will indeed help in the quantification and we are grateful to the referee to point this out.

Table 6 We will add the root mean squared error also in this table, as suggested.

Figure 6 We will add also the actual model AOD, so to give a reference for the two figures representing the differences (see reply before).

Figures 5,7,9,11 We agree that the information that can be retrieved from the scatter plots is not large. As suggested by the referee, we will add in the manuscript some plots of the model results and observations vs time for some selected stations.

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