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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Anthropogenic, biomass burning, and volcanic emissions of black carbon, organic carbon, and SO_2 from 1980 to 2010 for hindcast model experiments" *by* T. Diehl et al.

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We thank both anonymous reviewers for their assessments and constructive comments on our submitted manuscript. Below we answer the non-technical issues raised. All noted typos and technical comments are also taken into account in the revised manuscript.

From Anonymous Referee #2

1. My suggestions for improving the manuscript focus on clarifying the presentation and helping readers understand the big picture of what they should take away from this very detailed work. For example, the authors should be clearer about whether

the inventories discussed here are the same or different from those presented in other publications. Is some of the analysis presented here also published in the paper by Granier et al. (2011)? Also, are there overlaps in the input data and methods between the A2-MAP and A2-ACCMIP inventories, or are they fully independent? Finally, the authors should emphasize that these are two of a very small number of publicly available, gridded, global historic emission inventories, and that's why we need to know the important differences between them to understand their general usefulness for various modeling applications.

Response: We have changed the last 2 paragraphs of section 1 as follows, and also added a table (Table 3) with website addresses for download of emission data:

"This paper describes two global emission datasets used in the AeroCom Phase II hindcast model experiments. The first one is the MAP dataset, referred to as A2-MAP in this paper, The second one contains emissions whose anthropogenic component was derived from the historic emissions which Lamarque et al. (2010) had created for the ACCMIP project from 1850 to 2000 in decadal increments, and from projected emissions for 2005 and 2010 from the Representative Concentration Pathways (RCP) 8.5 scenario (Riahi et al., 2011). The biomass burning component of this second dataset was used to construct the wildfire part of the ACCMIP emissions for decades 1980-2000. This dataset, referred to as A2-ACCMIP in this paper, covers the period 1980 to 2010. Parts of it are also described in Granier et al. (2011), where they are referred to as MACCity emissions.

These two datasets are part of a very small set of global gridded datasets of historic BC, OC, and SO2 emissions, covering approximately the period 1980-2000 and beyond. BC and OC are also available from the inventories of Bond et al. (2007) (only for decadal averages 1980, 1990, and 2000), from Junker and Liousse (2008) as annual averages from 1980-2003, and from Ito and Penner (2005) as annual averages from 1980 to 2000. SO2 data is available from Smith et al. (2011) annually from 1980-2005. Additionally, wildfire emissions for all 3 species are available from the RETRO

project from 1980-2000 (Schultz et al. (2007, 2008)), and for carbon emissions from Kloster et al. (2010) from 1980-2004. For a more comprehensive overview of emission inventories, see the paper from Granier et al. (2011).

In the remainder of this paper, we will discuss the methodologies used to create the A2-MAP and A2-ACCMIP datasets (section 2 and 3), analyze their temporal and spatial features (section 4), and discuss the application of the two datasets (section 5). The overall goal is to provide choices of emission databases for aerosol hindcast studies, and some guidance on how to apply them in model experiments. Readers who are mainly interested in applying one of the datasets to their model experiments and/or are already familiar with methodologies for creating emission databases can skip section 2 and 3.

The two datasets discussed in this paper and some of the inventories used for their construction, as well as some of the other inventories mentioned above, are publicly available for download from web sites, which are listed in Table 3."

See also our responses to items #3 and #5 below.

2. Abstract. Mention the actual names of the two inventories right here in the abstract. There are not very many global inventories, and the community should know by reading the abstract which of them you're comparing.

Response: We have added the names to the abstract.

3. A2-ACCMIP vs MACCity: In Sections 1 and 3, it's implied that the A2-ACCMIP inventory is the same as the MACCity inventory presented in Granier et al. (2011). If they are the same, changing the name of the dataset in this manuscript will be very confusing to readers. If they are not the same, a clearer explanation is needed of precisely how these two seemingly very similar datasets differ. Furthermore, if the inventories are the same, then please comment more fully on how your findings compare to what is already presented in Granier et al. (2011) with respect to SO2 and BC.

Response: We have modified section 3 to explain in greater detail the relationships between the various datasets and their creation history. Although some small differences between A2-ACCMIP and MACCity exist, the main reason why we think it is better to keep the acronym A2-ACCMIP is that it has already been used by several modelers under this name and it would cause confusion within the AeroCom modeling community. We agree that the multitude of acronyms is sub-optimal (it occurred due to independent activities of the AeroCom community and the Granier et al. group in the past), but we hope that the revised section 3 will clarify the situation.

The original first 3 paragraphs of section 3 have been replaced with:

"The A2-ACCMIP emission dataset has been prepared from the ACCMIP historical emission dataset described in Lamarque et al. (2010), the so-called MACCity biomass burning emissions (included in the study by Granier et al., 2011), and the RCP8.5 (Representative Concentration Pathways) future emission scenario described in Riahi et al. (2011).

The ACCMIP dataset provides 0.5°x0.5° horizontally gridded emission estimates for 10 anthropogenic sectors and 2 biomass burning categories for the years 1850 to 2000 as monthly means in decadal intervals. The ACCMIP data represents a best guess emission estimate constructed from a harmonized combination of existing regional and global inventories. RCP emission estimates for the decades 2000 to 2100 (with an additional estimate for 2005) were developed as projections starting from the decade 2000 ACCMIP emissions. Both the historic ACCMIP emissions and the RCP projections provide a seasonality only for the biomass burning and ship emissions.

The A2-ACCMIP emissions for each year (i.e. years 1850, 1980 to 2010) were calculated from linear time interpolation (for each month and sector) of the ACCMIP and RCP85 data with the exception of biomass burning emissions of the years 1980 to 2008. Here, we used the MACCity biomass burning dataset, which has explicit interannual and seasonal variation, and which has been created by two of us (A. Heil,

M. Schultz). This dataset covers the years 1960 to 2008 and served as input for the construction of the ACCMIP biomass burning data of the decades 1960 to 2000. It was eventually named MACCity biomass burning emission dataset, since it was also used for two projects funded by the European Commission, MACC and CityZen, as described in Granier et al. (2011).

The entire MACCity biomass burning dataset is available for download at ftp://ftp-ipcc.fz-juelich.de/pub/emissions/gridded_netcdf/ACCMIP_MACCity/. For convenience, a supplementary dataset, interpolated from ACCMIP and all four RCP emission scenarios, covering the entire period from 1850 to 2100 and comprising a large set of species, has been produced using the same interpolation methodology as for A2-ACCMIP. These data are provided at ftp://ftp-ipcc.fz-juelich.de/pub/emissions/gridded_netcdf/ACCMIP_interpolated.

In the historical decadal ACCMIP emission files described in Lamarque et al. (2010), the land-based anthropogenic and aircraft emissions represent the first year of the decade (e.g. 1980 for decade 1980), while ship emissions represent year "5" of the decade (e.g. 1985 for decade 1980). The biomass burning emissions represent average conditions of the respective decade (e.g. 1980-1989 mean values of the MACCity biomass burning data are contained in the year 1980 file), except for the 2000 estimate which is calculated from the 1997-2006 average. The RCP scenario emissions are representative for the first year of the decade, except for the year 2005 RCP emissions, which are representative for the year 2005.

In their overview paper, Granier et al. (2011) presented annual anthropogenic emissions of BC and SO2 (OC was not included in their study) from 1990-2010 (decade 1980 was not included), which had been independently derived from linear interpolation of ACCMIP and RCP8.5 data, using a similar method as for A2-ACCMIP. This dataset together with the MACCity biomass burning emissions described above is presented as "MACCity" emissions in their analysis. Anthropogenic and biomass burning emissions, respectively, were analyzed as totals, but not by individual emission sector.

Aircraft emissions were not included. Thus, the 1980-2008 biomass burning emissions in MACCity and A2-ACCMIP are identical. In the MACCity anthropogenic emissions, a source-specific seasonality developed for the RETRO project was applied to each sector, in contrast to the A2-ACCMIP and ACCMIP anthropogenic datasets, which have no seasonality. As a consequence, the MACCity dataset (available from the ECCAD GEIA database (http://eccad.sedoo.fr) and the A2-ACCMIP emissions differ by about 0.1% with respect to their yearly global anthropogenic totals. The sector-wise relative difference in the yearly global totals is up to 0.3% except for ship emissions. Due to different timestamps assigned to the historic ship emissions during the interpolation procedure, the relative difference of ship emissions is up to 20% in some years."

4. A2-MAP-v1: Have the BC and SO2 estimates from the A2-MAP-v1 inventory already been presented in Granier et al. (2011), labeled as "AEROCOM" in that work?

Response: Yes, anthropogenic A2-MAP-v1 SO2 and BC emissions for the years 1980 to 2006 are the same labeled as "AEROCOM" in Granier et al. (2011). We have clarified this in the text.

5. A2-MAP vs A2-ACCMIP: It would help to have a brief explanation of whether any of the same methods/input datasets are used in both of these inventories. Are these inventories fully independent? There is a lot of detail in the methods sections, but I still can't tell for sure if they have anything in common. Is it totally fortuitous that the inventories' estimates are nearly identical for some regions (as shown in Figs 2-4)?

Response: It is very difficult to assign differences (or agreement) among inventories for a certain species in a given region to individual variables which were used to create them. Two inventories could even appear to agree simply because the impacts of two different variables cancel each other out. Also, not all sources of activity data and emission factors are always well documented. Having said this, it is nevertheless likely that at least some of the A2-MAP and A2-ACCMIP coincidences are due to some cross-dependencies. ACCMIP uses data from the REAS inventory over Asia, which in

turn used data from some of the Streets et al. publications, which also informed the creation of A2-MAP. On the other hand, EPA data for U.S. emissions was used for the creation of A2-MAP and ACCMIP. Emission factors for ship emissions from Sinha et al. (2003) are used in both cases. In addition, the SO2 ship emissions in A2-MAP-v1 from Eyring et al. (2005a) also have some impact on the ship emissions in ACCMIP.

This discussion will be added to section 4.1.4.

For biomass burning, the 2 datasets are clearly not independent for years after 1996, since they are both based on the GFEDv2 inventory, and the only difference is due the choice of emission factors. This is already outlined in the paper.

6. A2-ACCMIP vs ACCMIP: When the years of the A2-ACCMIP and the ACCMIP/RCP8.5 datasets coincide (1980, 1990, 2000, 2005, and 2010), shouldn't the emissions values be identical? It appears that they differ slightly for some species in some regions.

Response: We thank the reviewer for pointing out this issue. It turned out that we had accidentally used data which had been regridded to 1.25x1 degrees in case of A2-ACCMIP, but used the original 0.5x0.5 data in case of ACCMIP/RCP8.5. We have now re-generated the figures using the original 0.5x0.5 data for both cases, and the emissions are now identical in those years. The revised paper will contain the updated figures.

7. Section 4.5.2: Is there a reason why only OC biomass burning predictions are compared on a regional basis, and the same regional comparisons aren't done for burning emissions of SO2 and BC?

Response: This was motivated by the fact that OC is by far the largest component of biomass burning emissions (although BC could be important because it has different radiative properties). Also, at least for A2-MAP, the BC and SO2 emissions differ only by a constant factor from the OC emissions. On the other hand, we acknowledge that

the variation across biomes of the BC and SO2 emission factors in A2-ACCMIP is different from the variation of the OC emission factor. Specifically the inclusion of peat fires in A2-ACCMIP causes significant regional differences (as mentioned in section 3) and higher SO2 emissions as compared to grassland/savannah, tropical forest and extratropical forest fires (by a factor of 6, 4.1, and 2.6, respectively). We will therefore include a brief discussion of BC and SO2 emissions by region in section 4.5.2.

We will also complete Table 1 with numbers for BC and SO2 from biomass burning.

8. Section 5.4: It's not clear what the basis is for these recommendations, other than citing Chin et al (2000). Could you provide 1 or 2 sentences to explain them?

Response: The BC emission factor which was used in Chin et al. (2007) for studies with the GOCART CTM had been specifically adjusted to improve agreement with AERONET AOD measurements over biomass burning dominated locations. The OC EF was derived from an assumed OC/BC ratio of 8, which is within the range of typical values found in the literature. Chin et al. (2002) used a global estimate of SO2 emissions from wildfires from Spiro et al. (1992) to deduce the EF, as described in Chin et al. (1996).

9. Section 5.5: The uncertainty and global/regional inventory difference discussion presents information from this work as well as other papers, including Bond et al. (2004), Smith et al. (2011), and Petrenko et al. (2012). Aren't the comparisons of Granier et al. (2011) also relevant here?

Response: We agree, and have now included the following paragraph in section 5.5:

"In their assessment of a number of emission inventories for BC, SO2, and other species (but excluding OC) Granier et al. (2011) discussed emission differences for the years 1980, 1990, 2000, and 2005, as summarized in their table 4. This includes data from ACCMIP, MACCity, and A2-MAP-v1 ("AEROCOM" in their notation). Generally, their findings show a larger variation of both BC and SO2, both globally and on a

regional scale, as compared to our analysis above, with frequent deviations by more than 100%, which is partially caused by the larger number of inventories included in their study. However, their large SO2 differences over Central Europe, and also to a lesser degree over Western Europe, are influenced by the inclusion of the A2-MAP-v1 SO2 data in these regions, which we excluded in our discussion. Slightly different region definitions and using only 4 snapshots compared to all years in our study could also cause some deviations in the range of differences. Nevertheless, the findings agree on relative small differences of SO2 emissions in the USA, despite the larger number of years included in our study and the larger number of inventories in Granier et al. (2011), possibly indicating that most inventories use the same reported data from the EPA."

10. Section 6: Emphasize the need for objective analysis of these and other inventories using observations. Beyond AOD retrievals, one could also use more direct observations of SO2, BC and OC to evaluate inventory estimates. To truly understand uncertainties in these inventories, we must move beyond the inventories themselves.

Response: We have revised the last paragraph of section 6 as follows:

"Future improvements include updating the A2-MAP dataset with more recent data on a region-by-region basis, starting with China and India, which will be updated with the emissions developed by Lu et al. (2011). Volcanic emissions should be updated with eruptions from 2010-2012. The crucial role of emission factors became apparent, and their uncertainty must be further reduced by lab and/or field measurements, specifically for wildland fires. The temporal resolution should be increased to include seasonality for anthropogenic emissions, at least for mid-latitude regions and regions where travel patterns vary significantly throughout the year. More region-specific or country-specific inventories of emission measurements must be provided and incorporated into the global emission estimates, not only for stack emissions like the CEMS program in the USA but also for other sectors like transport. However, both measurement-based inventories as well as bottom-up calculations from activity data and emission factors

must be eventually assessed with independent global satellite observations to account for systematic errors in the local measurements, inadequate coverage of the measurement networks, under-reporting of activity or inventory data for political reasons, and other errors. Multi-year SO2 observations from instruments like OMI onboard the Aura satellite (e.g. Fioletov et al., 2011) and AOD retrievals from instruments like SeaWiFS (e.g. Yoon et al., 2011, and Hsu et al., 2012) can be used as a first step to evaluate the emission magnitude and trends in the databases. However, satellite retrievals are generally not a direct indicator of local emissions, since they are also impacted by a variety of other processes such as transport and chemical reactions. Inverse modeling methods are therefore needed to provide independent top-down emission estimates based on satellite retrievals, which could be used to constrain the uncertainty range of bottom-up emission estimates."

Technical Corrections: All technical corrections are taken into account in the revised manuscript.

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