Evaluation of Global and Regional Gridded Distribution of Emissions

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Abstract

During the past few years, different emissions inventories have been developed, which provide emissions of gaseous and particulate atmospheric species for the past few decades at both the global and regional scales. We have gathered the data provided by several inventories developed for the global as well as for the regional scale. A more detailed description of the emissions inventory developed in support of the next IPCC report is given in the paper: this dataset covers the 1850-2100 period, and considers anthropogenic as well as biomass burning emissions.

The emissions provided by many publicly available global and regional inventories have been intercompared, and the results of the comparisons for carbon monoxide, nitrogen oxides, sulfur dioxide and black carbon are presented. The work is focusing on the evolution of the emissions of these species between 1980 and 2100. The differences identified in anthropogenic as well as biomass inventories are discussed. Further work, which concerns the extension of the evaluation exercise to other compounds such as volatile organic compounds is discussed.

Introduction

An accurate knowledge of the spatial and temporal distribution of surface emissions and of their evolution is essential to address air quality and climate change issues, for which simulations of the changes in the distributions of atmospheric species are needed. Over the past few years, several inventories providing the distributions of surface emissions of different chemical compounds were developed, at both the global and regional scales. The quality of these inventories is very difficult to assess, since the methodology, input data and assumptions vary strongly between the inventories. Several evaluations of surface emissions inventories have been published in the literature, but they have either focused on a few selected datasets, on selected chemical compounds, or on a few regions.

The goal of the paper is to identify the species for which relatively consistent inventories exist for the past three decades, and the species for which more work needs to be done to obtain a better quantification and consensus on the total and regional emissions and on their changes with time. The discussion will concern both anthropogenic and biomass burning emissions. We have compared the different datasets at the global scale and for a few selected regions, i.e. Europe, the USA and China for anthropogenic emissions, and Africa and South America for biomass burning emissions.

Data used in the study

For the study discussed in this paper, the data provided by several publicly available inventories of anthropogenic and biomass burning emissions for the 1980-2010 period were gathered. This period was chosen, since most of the inventories currently available cover at least partially these three decades. The list of the inventories considered in the study is given in Table 1. Several inventories are giving the emissions for a large set of chemical compounds, while other provide emissions for a one or a limited number of species.

Acronym	Period used in the paper	Spatial res.	Reference and/or website
Inventories providing all species			
ACCMIP and MACCity	1980-2010	0.5x0.5	http://ether.ipsl.jussieu.fr – ECCAD ftp://ftp-ipcc.fz-juelich.de/pub/emissions/
RCPs	2000-2010	0.5x0.5	http://ether.ipsl.jussieu.fr – ECCAD ftp://ftp-ipcc.fz-juelich.de/pub/emissions/ http://www.iiasa.ac.at/web-apps/tnt/RcpDb
EDGAR v3	1990, 1995 and 2000	1x1	Olivier et al., 2005; http://edgar.jrc.ec.europa.eu
HYDE	1980, 1990	1x1	Van Aardenne et al., 2001 http://edgar.jrc.ec.europa.eu
RETRO	1980-2000	0.5x0.5	http://retro.enes.org/data_emissions.shtml
GAINS	1990-2005		http://gains.iiasa.ac.at/gains
Inventories providing a selected number of species			
BOND (BC)	1980-2000	1x1	http://www.hiwater.org/ Bond et al., 2007
J&L - BC/ Junker &Liousse	1980-2000	1x1	Junker and Liousse, 2008
AEROCOM (SO_2; BC)	1980-2006	1x1	http://dataipsl.ipsl.jussieu.fr/AEROCOM
PNNL-2004 PNNL-2010 (SO_2)	1980-2005	0.5x0.5	Smith et al., 2004 (PNNL-2004); Smith et al., 2010 (PNNL-2010)
Regional inventories			
EMEP	1980-2010	0.1x0.1	http://www.ceip.at/emission-data-webdab/emissions-used-in-emep-models/
TNO	2003-2007	0.1x0.1	ftp://neptunus.tno.nl/TNO/MEP/EM/MACC/
EPA	1980-2008	Not gridded	http://www.epa.gov/ttn/chief/trends/index.html
REAS	1980-2010	0.5x0.5	www.jamstec.go.jp/frcgc/research/p3/reas_h_a.html
ACCESS	2000 and 2006	0.5x0.5	http://www.cgrer.uiowa.edu/ACESS/acess_index.htm

Table 1: List of anthropogenic emissions inventories considered in this study.

The ACCMIP and MACCity datasets

During the past few years, a community effort led to the development of a dataset of gridded anthropogenic and biomass burning emissions covering the historical period (1850–2000) in decadal increments, at a horizontal resolution of 0.5° in latitude and longitude (Lamarque et al, 2010). The primary purpose of this inventory was to provide consistent gridded emissions of reactive gases and aerosols for use in chemistry model simulations needed by climate models for the Climate Model Intercomparison Program #5 in support of the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5). The details of this intercomparison project are available at: https://cmip.llnl.gov/cmip5/docs/Taylor_CMIP5_dec31.pdf. The year 2000 was chosen as the reference year: the 2000 emissions represent a combination of the best information available on existing regional and global inventories in the years 2008-2009 when the inventory was built. 40 regions and 12 sectors were used to combine the various sources. The historical reconstruction of each emitted compound, for each region and sector, was then forced to agree with the 2000 estimate, ensuring continuity between past and 2000 emissions. The acronym for this inventory, which is currently used in different studies on chemistry-climate interactions is ACCMIP = Inventory for Atmospheric Chemistry and Climate – Modeling Intercomparison Project).

Projections of future emissions, i.e. emissions associated with the four IPCC Concentration Pathways (RCPs) and generated by Integrated Assessment Models are using the 2000 emissions as a starting point. A detailed documentation on the RCPs is available at the following website: http://www.iiasa.ac.at/web-apps/tnt/RcpDb. This "hand-shake" requirement is ensuring the continuity in the emissions between historical and future distributions. The RCPs are named according to their 2100 radiative forcing level, i.e. RCP 8.5 corresponds to a radiative forcing of 8.5 $W.m^{-2}$ in 2100. It should be noted that the RCPs are four independent pathways developed by four different modeling groups, and the differences between the emissions from each RCP cannot be directly be interpreted as a result of climate policy or particular socioeconomic developments: the differences are mostly due to differences between models and scenario assumptions.

As part of two projects funded by the European Commission, MACC (Monitoring Atmospheric Chemistry and Climate: http://www.gmes-atmosphere.eu/) and CityZen (MegaCity: Zoom for the Environment: https://wiki.met.no/cityzen/), the ACCMIP historical emissions dataset has been extended: in these two projects, simulations of the chemical composition of the atmosphere during the past decades are performed. Since no global emissions currently exist, which provide emissions of the main tropospheric gases for each year of the 2000-2010 period, a dataset was created, based on the 2000 IPCC emissions and the 2005 and 2010 emissions provided by RCP8.5. The emissions for each compound were linearly interpolated, for each sector, using the IPCC and RCP 8.5 emissions. In the figures displayed in the next section, the ACCMIP emissions inventory and its extensions performed as part of the MACC and CityZen projects will be referred to as MACCity.

Selected results

In this study, comparisons of global and regional emissions have been made for BC, CO, NO_x and SO_2. In the paper, we present a few results obtained for SO_2: Figure 1 displays total anthropogenic emissions of at the global scale for SO_2: these total include international shipping emissions.

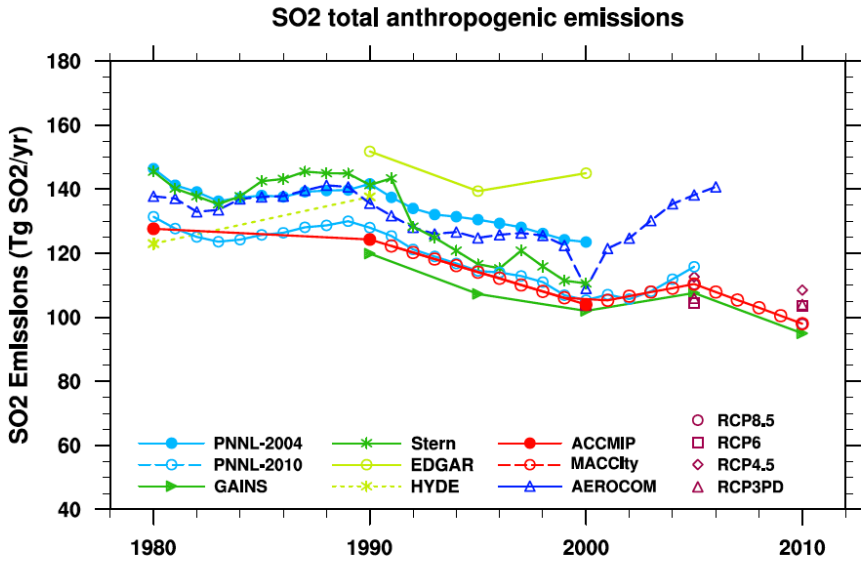

Figure 1: Comparison of SO2 total emissions, as provided by different inventories.

Most SO_2 inventories indicate a significant decrease in the emissions during the period considered in this study. In 1980, the differences between the lowest and highest estimate is 18%, and reaches 54% in 2000, when the EDGAR v3.2 inventory provides larger values than other inventories. After 2000, the emissions from the AEROCOM dataset show a significant increase, contrarily to the other inventories, which do not show significant changes. Most inventories indicate that SO_2 emissions have significantly decreased in most parts of the world after 2000, except in Asia. In the AEROCOM inventory, SO_2 emissions are also increasing in China, but they are either constant or increasing as well in other parts of the world, which explains the increase in the global emissions totals. It should be noted that the SO_2 ACCMIP and MACCity emissions up to 2000 are based in part on the PNNL-2010 dataset, which explains why the emissions totals are very close in these two datasets.

Figure 2 shows the SO_2 emissions for the USA (Figure 2, left) and for China (Figure 2, right). SO_2 emissions as proposed by the different inventories agree rather well, except for the HYDE inventory in the 1980s-1990s, which gives much higher values than other datasets. In 2000, the difference between the highest and lowest emissions is 18%. After 2000, the MACCity, PNNL-2010, AEROCOM and EPA inventories provide similar decreasing values, while PNNL-2004

emissions, based on older estimates on changes in US emissions, show a rather constant value up to 2005.

In China, SO_2 emissions differ significantly between the inventories considered in this study, with a 80% difference between the lowest and highest emissions in 2000. Most of the inventories show either a decline or a stagnation in the emissions between 1995 and 2000, except for the GAINS inventory, which displays a constant increase during the period considered. In 2005, the number of available inventories is lower; the difference between the highest (AEROCOM) and lowest (MACCity) estimates is about 20%. Most datasets show a limited increase in the emissions after 2005. The emissions estimated by the RCP3PD and RCP6 future scenarios provide much lower emissions.

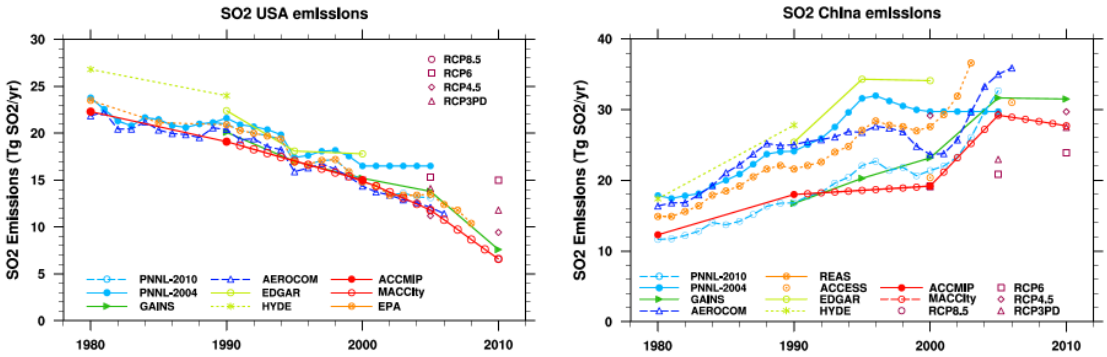

Figure 2: SO2 emissions for the USA (left) and China (right) from 1980 to 2010.

Conclusions

Several different inventories are assessed in this study, which show that large discrepancies still remain among available datasets. The understanding of the differences between the inventories will require a more detailed study, i.e. by evaluating the emissions for different sectors. This work, which is beyond the scope of the present paper, is planned for the coming months. It should be noted however that not all the inventories provide emissions for different sectors, and that not all inventories use the same sectors splitting, which will make the comparison and the evaluation of the different datasets even more difficult.

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