Trends in anthropogenic emissions from 1960 to 2015

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Abstract

Different research teams worked during the past years to develop anthropogenic spatial and temporal distributions for different periods and regions. These inventories provide emissions either on a national basis for different countries, or gridded emissions at the global or regional scale. We will present an evaluation of the most recent emissions datasets providing emissions for the 1960-2013 period, for different gaseous and particulate compounds, i.e. carbon monoxide, nitrogen oxides, volatile organic compounds, sulfur dioxide, ammonia, black and organic carbon, and particulate matter (PM10 and PM2.5). We will discuss the consistency between global and regional inventories, as well as between the different chemical compounds, for 26 world regions. This work will help quantifying the uncertainties on anthropogenic emissions in the different regions.

The simulations performed in support of the 2013 report of the Intergovernmental Panel on Climate Change (IPCC) used surface emissions from the Representative Concentration Pathways (RCPs) future scenarios. These scenarios provide emissions of greenhouse gases and atmospheric pollutants from 2005 to 2100.
We will compare the emissions provided by the four RCPs emissions scenarios from 2000 to 2015 with the most recent information on emissions during the past fifteen years. From these comparisons, we will assess if the RCPs emissions can be used for forecasting the distribution of atmospheric pollutants in the recent past and near future. This assessment, which focuses on the emissions of nitrogen oxides, carbon monoxide, sulfur dioxide, volatile organic compounds, ammonia and particulate matter, includes estimations of emissions using inverse modeling techniques and satellite observations.

1. Introduction

During the past years, several emissions inventories providing anthropogenic emissions for the past decades were developed, at different spatial and temporal distributions and for different periods and regions. The presentation discusses an evaluation of the most recent emissions datasets providing emissions for the 1960-2013 period, for different gaseous and particulate compounds, i.e. carbon monoxide, nitrogen oxides, volatile organic compounds, sulfur dioxide, ammonia, black and organic carbon, and particulate matter (PM10 and PM2.5). We discuss the consistency between global and regional inventories, as well as between the different chemical compounds, for 22 world regions. This work will help quantifying the uncertainties on anthropogenic emissions in the different regions.
The analysis includes emissions provided by the Representative Concentration Pathways (RCPs), i.e. the future emissions developed in support of the 2013 report of the Intergovernmental Panel on Climate Change (IPCC). The emissions provided by the RCPs start in 2005, and provide emissions for the future decades. Since recent emissions are generally not available in current global and regional inventories, modelling groups often use emissions from the RCPs to represent the most recent emissions. We will assess how well RCPs emissions represent recent emissions, and to which extent they can be used for forecasting the distribution of atmospheric pollutants in the recent past and near future.
We finally describe the ECCAD database of emissions, where information on most of the datasets used in the presentation is available. Emissions data can also be downloaded from ECCAD.

2. Datasets used in the study

Different datasets are used to evaluate the trends in the emissions in different regions of the world. A list of the datasets used in the analysis is shown in Tables 1 (global inventories) and 2 (regional inventories). It should be noted that only publicly available datasets are used in this study. These tables show a list of new inventories which have been published during the past years, particularly in Asia. In this study, we have also used results from inverse modeling studies focusing on the optimization of emissions in Asia.

Acronym	Period	Reference and/or website
MACCity	1980-2010	Granier et al., 2011 http://eccad.aeris-data.fr/
ACCMIP	1980-2010	Lamarque et al., 2010 http://eccad.aeris-data.fr/
RCPs	2000-2010	Van Vuuren et al., 2011 http://www.iiasa.ac.at/web-apps/tnt/RcpDb
EDGAR v4.2	1970-2008	Janssens-Maenhout et al., 2013 http://edgar.jrc.europa.eu/
EDGAR v4.3	1970 and 2010	Crippa et al., 2016 http://edgar.jrc.europa.eu/pegasos
HTAPv2	2008 and 2010	Janssens-Maenhout et al., 2015 http://edgar.jrc.europa.eu/htap_v2
RETRO	1980-2000	Schultz et al., 2007 http://eccad.aeris-data.fr/
ECLIPSE v4a	2005-2050	Stohl et al., 2015 http://eclipse.nilu.no
ECLIPSE v5	1990-2020	Klimont et al., in preparation, 2016 http://eclipse.nilu.no
Bond	1850-2000	Bond et al., 2007 http://hiwater.org
Junker&Liousse	1860-1997	Junker and Liousse, 2008
PKU	2002-2013	Y. Huang et al., 2014 http://inventory.pku.edu.cn

Table 1: List of global inventories used in the presentation

Acronym	Period	Reference and/or website
North America		
EPA (USA)	1970-2016	https://www.epa.gov/air-emissions-inventories/air-pollutant-emissions-trends-data
Environment Canada (Canada)	1990-2015	http://ec.gc.ca/inrp-npri/donnees-data/ap
Europe		
EMEP	1980-2020	http://www.ceip.at/ms/ceip_home1/ceip_home/webdab_emep database/
TNO-MACC	2003-2007	Denier van der Gon et al., 2010
TNO-MACC-II	2003-2009	Kuenen et at., ACP, 2014
TNO-MACC-III	2000-2011	Kuenen et al., ACP, 2014
Asia		
REAS v1 (Asia)	1980-2010	Ohara et al., 2007 http://www.jamstec.go.jp/frcgc/research/d4/emission.htm
REAS v2 (Asia)	2000-2008	Kurokawa et al., 2013 http://web.nies.go.jp/REAS/
MEIC 1.0 (China)	2008, 2010	http://meicmodel.org

MEIC 1.2 (China)	2008, 2010, 2012	
TRACE-P INTEX-B (Asia)	2000 2006	Streets et al., 2003; Zhang et al., 2009 http://cgrer.uiowa.edu/projects/emmison-data
MIX (Asia)	2008 and 2010	Li et al, 2015
ZhaoB (China)	1995-2010	B. Zhao et al., 2013 (NO_x)
ZhaoY (China)	2005 and 2010	Y. Zhao et al., 2011; Y. Zhao et al., 2013
Cao (China)	2000	Cao et al., 2006 (BC and OC)
HuangX (China)	2006	Huang et al., 2012 (NH_3)
Kang (China)	1980-2012	Kang et al., 2015 (NH_3)
Bo (China)	1980-2005	Bo et al., 2008 (NMVOC)
Lei (China)	1990-2005	Lei et al., 2011 (BC)
Wei (China)	2005-2020	Wei et al., 2011; Wei et al., 2008 (NMVOC)
Su (China)	1990-2007	Su et al. (2011)
Lu (China/India)	1996-2010	Lu et al., 2011 (SO_2 and BC)
WangR (China)	1949-2007	R. Wang et al., 2012 (BC)
WangS (Asia)	2005-2010	S. Wang et al., 2014
MPolo (China)	2005-2013	Mijling et al. 2013 (NO_x) [NO_x Inverse modeling] http://www.marcopolo-panda.eu/products/toolbox/emission-data/
Stavrakou (China)	2005-2014	Stavrakou et al., 2009, 2015 [VOCs Inverse modeling] http://www.marcopolo-panda.eu/products/toolbox/emission-data/
Africa		
DACCIWA	1990-2015	http://eccad.aeris-data.fr/

Table 2: List of regional inventories used in the presentation

3. Evaluation of the emissions for different regions of the world

The presentation focuses on five regions, i.e. the USA, Western Europe, Central Europe, China and India. These regions have been chosen, because several different inventories are available for them, and because large differences in the emissions have been seen in these regions during the past decades.

Figure 1 shows the changes in the emissions of NO_x in the USA since 1960 and the evolution of SO_2 emissions since 1990. Emissions provided by all inventories for both species show a significant decrease of the amounts emitted during the past decades.

While the inventories show quite different NO_x emissions at the beginning of the period considered, a better agreement exists after 2005. Two of the RCPs, RCP 2.6 and RCP 6 provide emissions that are much higher than all other emission datasets. RCPs 4.5 and 8.5 are, however, very close to the EPA emissions and other emissions after 2005. Results of the emissions from different sectors in 2005 and 2015 are given in the presentation.

For SO_2, the emissions provided by the different datasets are rather similar, and emissions from RCP 8.5 are very close to the most recent emissions up to 2015. However, for the three other scenarios, the emissions are significantly different, with a much lower decrease than shown in other inventories.

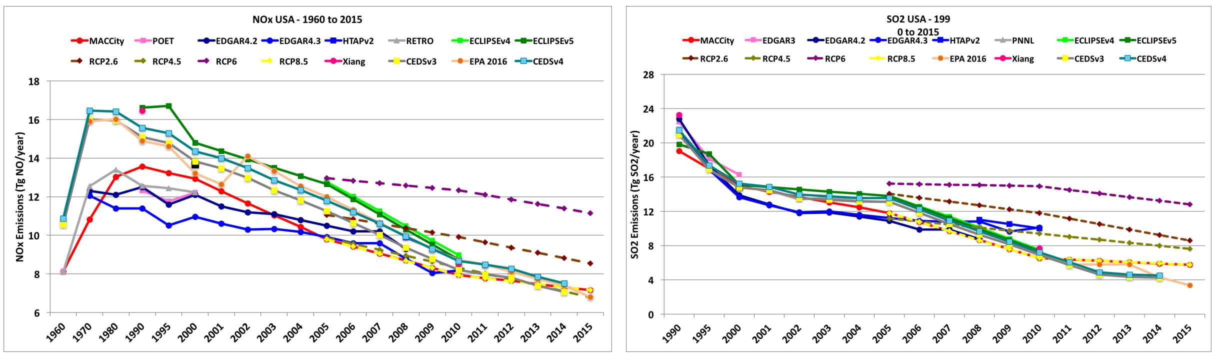

Figure 1: NO_x and SO_2 emissions in the USA from 1960 to 2015(NO_x, left) and from 1990 to 2015 (SO_2, right).

Figure 2 shows the changes in the emissions of ammonia in Western Europe and of NMVOCs in Central Europe from 1960 to 2015. There are large differences in the emissions of ammonia, which are mostly related to agricultural activities. The EDGAR and MACCity inventories give emissions of ammonia, which are about 30% higher than the emissions provided by the other datasets, including the regional TNO-MACC emissions. The four RCPs datasets give rather similar emissions, with somewhat constant values after 2005, and are closer to EDGAR emissions than to the other datasets.

NMVOCs emissions in Central Europe show as well significant differences. The EDGAR4.2 emissions are larger than all the other datasets but the newer EDGAR4.3 version provides the lowest emissions for the same years. All inventories show a slight decrease of the emissions after 2005. The RCPs provide almost similar values, with RCP4.5 giving slightly lower emissions, which are closer to most other inventories, including the regional TNO-MACC datasets.

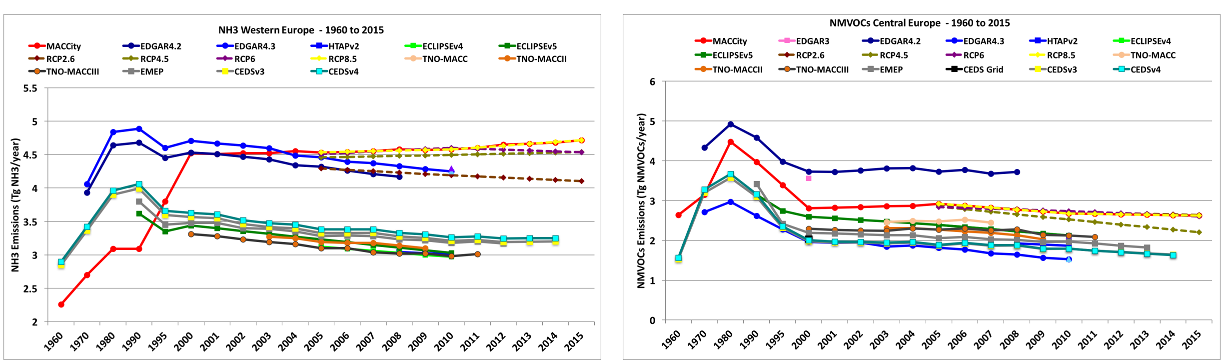

Figure 2: Emissions of NH_3 in Western Europe (left) and of NMVOCs in Central Europe (right).

Figure 3 shows the emissions of CO in China and of OC in India since 1960. In China, many studies have been completed during the past few years, in order to develop more accurate emission datasets of different atmospheric compounds, as indicated in Table 2. Most of the inventories show an increase in the emissions for the full period considered: however, the MEIC regional inventory shows a decrease in the emissions from 2008 to 2012. Emissions from inverse modeling have also been developed in the recent years: the MarcoPolo emissions derived from inverse modeling in 2014 are very close to the MACCity and RCP 4.5, RCP6 and RCP 8.5 emissions, while RCP 2.6 predicts a decrease of the emissions after 2010.

Emissions in India contribute significantly to the global total of the emissions for all species; however, they are generally not well characterized. An example is shown in Figure 3 for organic carbon, for which the ratio between the lowest and highest emissions can reach more than a factor of 2 for some periods. All inventories show a significant increase in the emissions of OC during the past decades. OC emissions from the four RCPs are rather close, and are close to the lowest emissions proposed by two regional inventories, PKU and Lu et al. (2011). The MIX regional inventory gives much larger emissions, close to the global CEDS emissions.

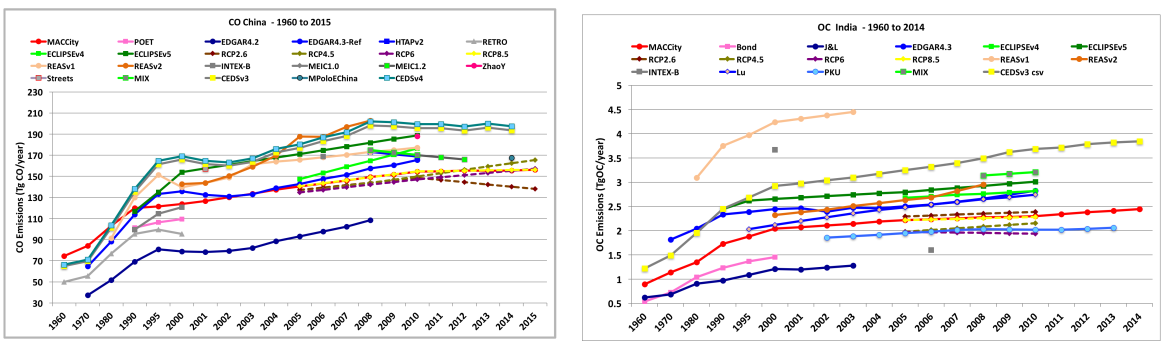

Figure 3: Emissions of CO in China (left) and of OC in India (right) from 1960 to 2015

4. Access to emission datasets

Many of the datasets used in this work can be accessed through the ECCAD (Emissions of Atmospheric Compounds and Compilation of Ancillary Data). The database is already used by more than 2700 users from more than 950 institutions across the world.

A new version of the database will be launched very soon (accounts can already be obtained), at the following address: http://eccad.aeris-data.fr. Contrarily to the previous version of ECCAD, which could accommodate inventories at a resolution of .5x.5 or 1x1 degree in latitude and longitude, this new version can include inventories at any spatial resolution. Many on-line tools for analyzing and downloading the datasets are available in ECCAD. Examples of work done using the ECCAD tools are given in Figures 4 and 5. Figure 4 shows the spatial distribution of NO_x emissions at the global scale in 2010 from the EDGARv4.3 inventory. This figure highlights the high values of NO_x emissions in the industrial areas of the planet, as well as the growing importance of emissions from ships. Figure 5 gives an example of emissions of $PM_{2.5}$ in Europe using ECCAD, from the TNO-MACC-II inventory for 2003.

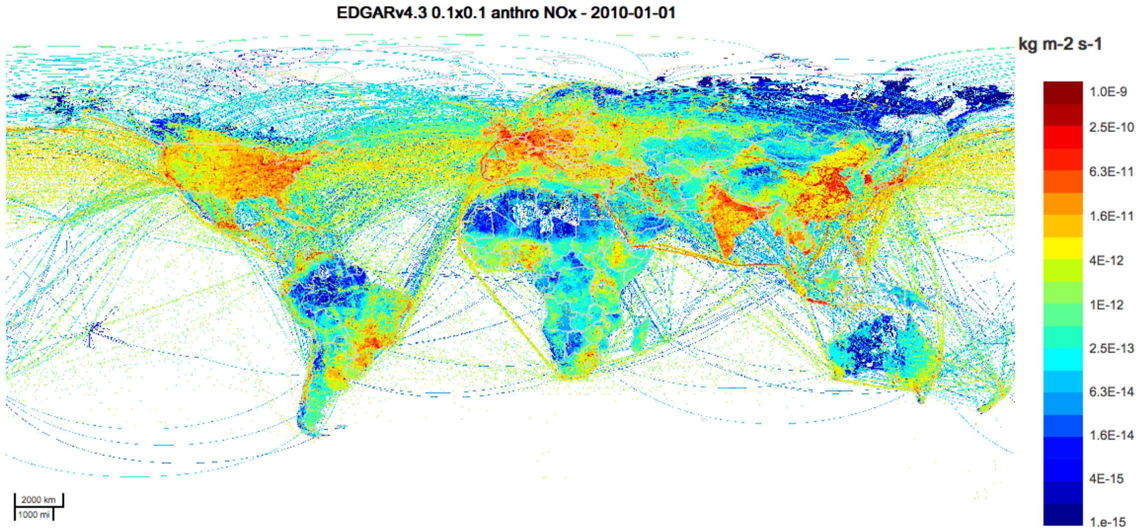

Figure 4: NO_x 2010 emissions from the EDGAR4.3 inventory using the ECCAD database

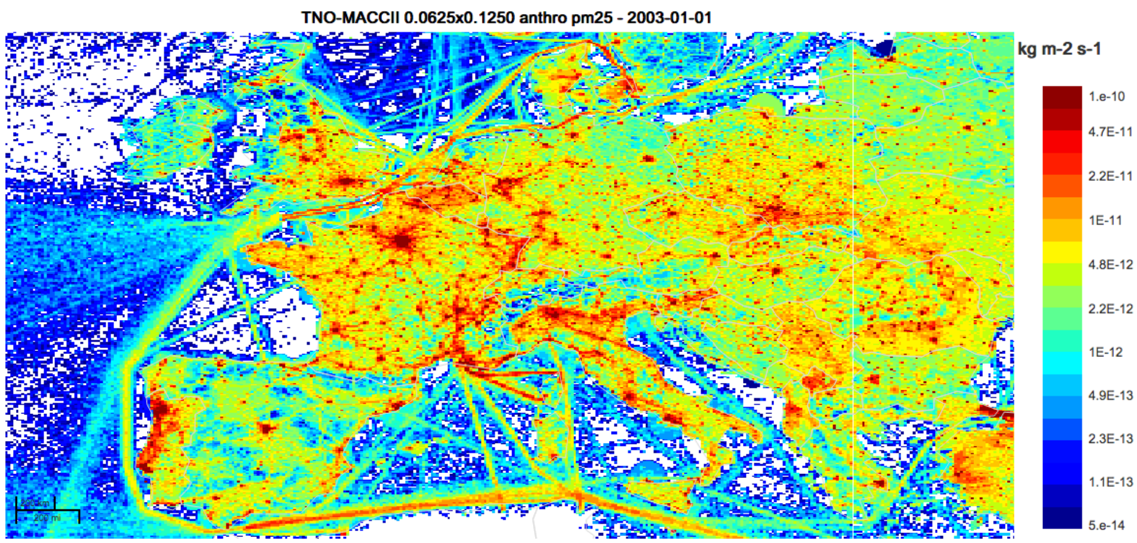

Figure 5: $PM_{2.5}$ emissions in 2003 from the TNO-MACC-II inventory using the ECCAD database

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