Anthropogenic emissions at the global and regional scale during the past three decades

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Different types of emissions for different projects:

- Forecast of the atmospheric composition, observations from campaigns
  - → Wide range of chemical species
  - → high spatial and temporal resolution

- Global scale, long-range transport
  - → limited number of chemical species
  - → moderate spatial and temporal resolution
  - → long-term variation (a few decades)
  - → need some coupling emissions/meteorological conditions

- Climate studies: impact of climate on emissions and of emissions on climate
  - → long-lived species, aerosols and a few ozone precursors
  - → emissions models or algorithms
    to take into account land-use changes and human-related changes
  - → past/future realistic scenarios (decades-century)

Objectives of the study: Evaluation of available emissions for air-quality, long-range transport and climate studies

➔ comparison and evaluation of different emissions datasets providing global and regional anthropogenic emissions, focusing on their trends over the past decades

➔ Focus on 1980-2010, because most of the inventories currently available cover at least partially these three decades

➔ Use the ACCMIP-MACCity inventory, built and used as a basis for the IPCC on-going report. References:
Lamarque et al., *Atmos. Chem. Phys.*, 2010
Granier et al., *Clim. Change*, 2011

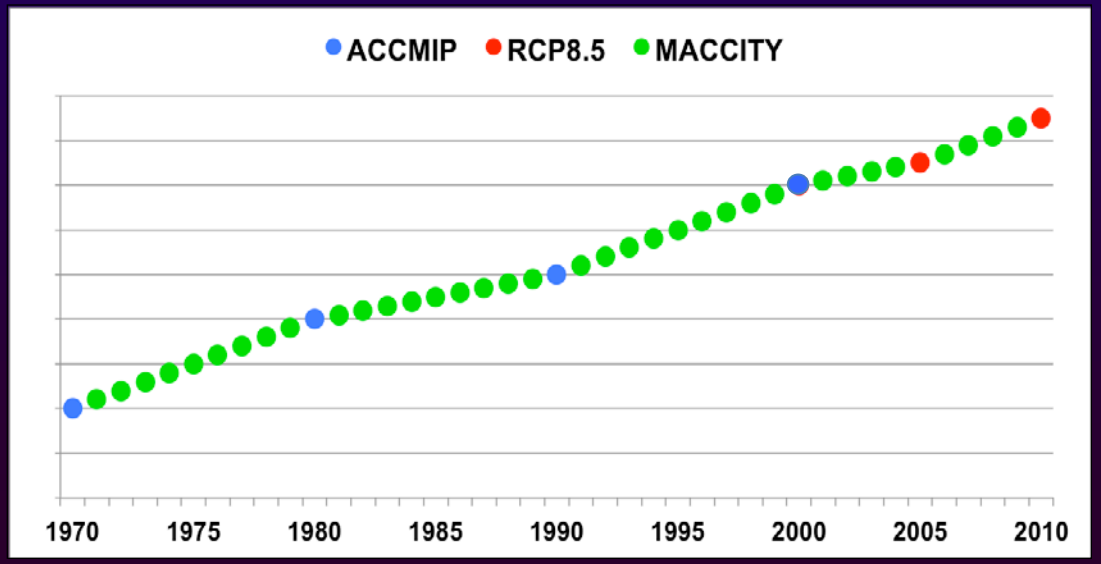
The ACCMIP-MACCity emissions dataset

➔ **ACCMIP:**

- Developed for the IPCC Assessment Report 5 (AR5) report, to be released in 2013
- Emissions provided on a decadal basis for 1850-2000, for many different species, at a 0.5x0.5 degree resolution

➔ **MACCity:**

- Emissions from 1960 to 2010
- Use of RCP 8.5 for 2005 and 2010 emissions
- Interpolation of ACCMIP emissions for different sectors
- Seasonal variation of emissions provided (based on RETRO)



Example of existing datasets:
List of most publicly available global inventories

Total emissions								
	CH4	CO	NOx	NMVOCs	BC	OC	SO2	NH3
ACCMIP/MACCity								
RCP8.5								
RCP6								
RCP4.5								
RCP2.6								
EDGAR3								
EDGAR4								
RETRO								
HYDE								
GAINS								
GEA_HIGH_CLE								
GEA_LOW_CLE								
Bond								
Junker&Liousse								
PNNL 2004&2010								
Ito&Penner								
Novakov								
Stern								

Orange rectangle: emissions for this species not provided

Are any of these emissions accurate?

➔ A systematic evaluation of surface emissions has started, with the support of GEIA (Global Emissions Inventory Activity)

➔ Open to all people willing to propose new data / analyze results

➔ Start with the 1980-2010 period

➔ Only publicly available gridded inventories considered so far

➔ Focus on: CO, NOx, SO2 and BC, and more recently, CH4, OC, total NMVOCs and NH3

➔ Assess the main differences between inventories providing emissions at the global and regional scales

Inventories providing global emissions of different species			
Acronym	Time period	Spatial resol.	Reference / website
ACCMIP	1980-2010	0.5x0.5	Lamarque et al., 2010 http://eccad.sedoo.fr http://www.iiasa.ac.at/
MACCity	1980-2010	0.5x0.5	Granier et al., 2011 http://eccad.sedoo.fr
RCP 2.6; RCP 4.5 RCP 6; RCP 8.5	2000-2010	0.5x0.5	Van Vuuren et al., 2011 http://www.iiasa.ac.at/
EDGAR v4.2	1970-2008	0.1x0.1	http://edgar.jrc.ec.europa.eu
EDGAR v3	1990, 1995 2000	1x1	Olivier et al., 2005 http://edgar.jrc.ec.europa.eu
HYDE	1980, 1990	1x1	Van Aardenne et al., 2001 http://www.pbl.nl/
RETRO	1980-2000	0.5x0.5	http://retro.enes.org/
GAINS	1990-2010	0.5x0.5	Amann et al., 2011 http://gains.iiasa.ac.at/
GEA	2005-2010	0.5x0.5	Riahi et al., 2012; Colette et al., 2012 https://wiki.met.no/cityzen
Global inventories providing a selected number of species			
BOND (BC and OC)	1980-2000	1x1	Bond et al., 2007 http://www.hiwater.org/
Junker & Liousse (BC)	1980-2000	1x1	Junker and Liousse, 2008 http://eccad.sedoo.fr
AEROCOM (SO_2 and BC)	1980-2006	1x1	http://dataipsl.ipsl.jussieu.fr/
PNNL (SO_2)	1980-2005	0.5x0.5	Smith et al., 2010; Smith et al., 2011
Ito and Penner (BC)	1980-2000	1x1	Ito and Penner, 2005
Novakov (BC)	1980-2000		Novakov et al., 2003

List of global inventories used in this study

Several inventories provide an access to the emissions of a large list of compounds, while others focus only on a limited number of species

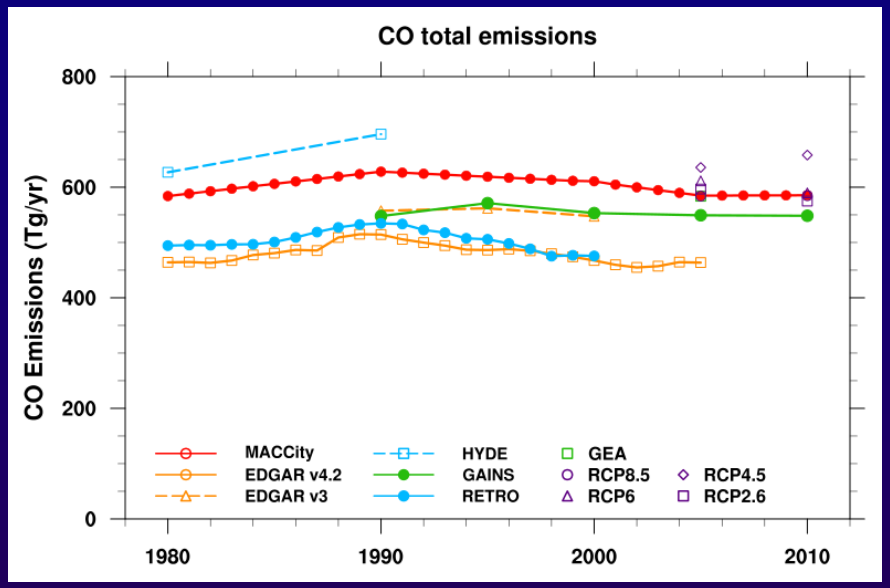
Regional inventories			
Acronym	Time period	Spatial resolution	Reference / website
EMEP	1980-2010	0.5x0.5	http://www.ceip.at/
TNO	2003-2007	0.125 x 0.0625	Denier van de Gon et al., 2010 ftp://neptunus.tno.nl/
INERIS	1998-2007	0.1x0.1 / 0.5x0.5	http://cityzen-project.eu/
EPA	1980-2008		http://www.epa.gov/ttn/ 2008 and 2012 Trends Data
Environment Canada	1985-2010		http://www.ec.gc.ca/
REAS	1980-2010	0.5x0.5	Ohara et al., 2007 http://www.jamstec.go.jp/
ACCESS	2000 and 2006	0.5x0.5	Streets et al, 2003; Zhang et al., 2009 http://www.cgrer.uiowa.edu/
Garg	1985-2005		Garg et al., 2006
Zhao et al.	2005		Zhao et al., ACP, 11, 2011
Cao et al. (BC and OC)	2000		Cao et al., Atmos. Env., 2006
Lu et al. (SO_2)	2000-2007		Lu et al., ACP, 10, 2010
Lu et al. (BC, OC, SO_2)	1996-2010		Lu et al., ACP, 11, 2011
Lei et al. (BC and OC)	1990-2005		Lei et al., ACP, 11, 2011

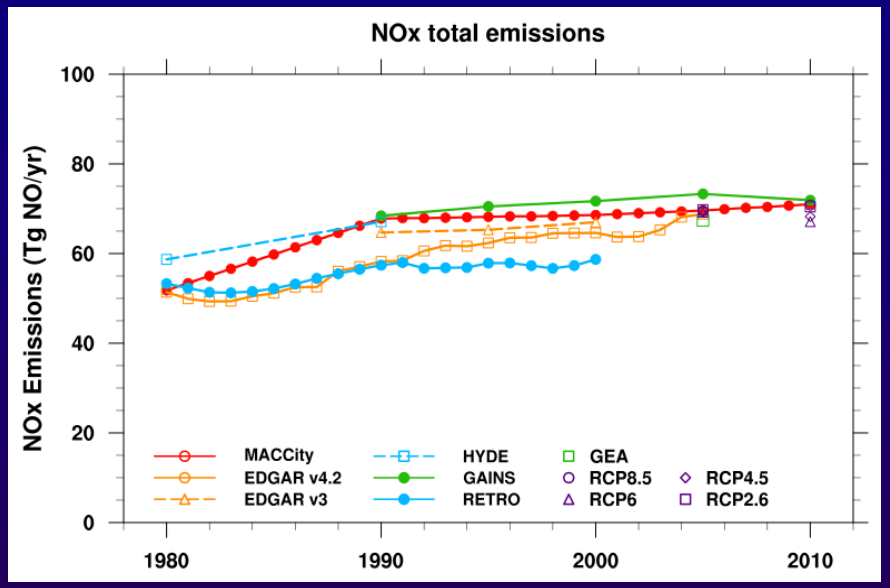
List of regional inventories used in this study

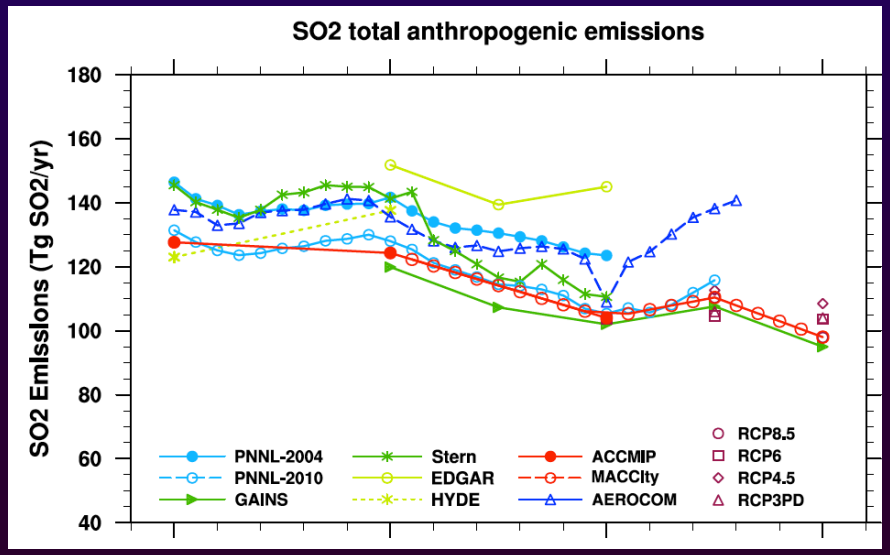
Use of regulatory inventories

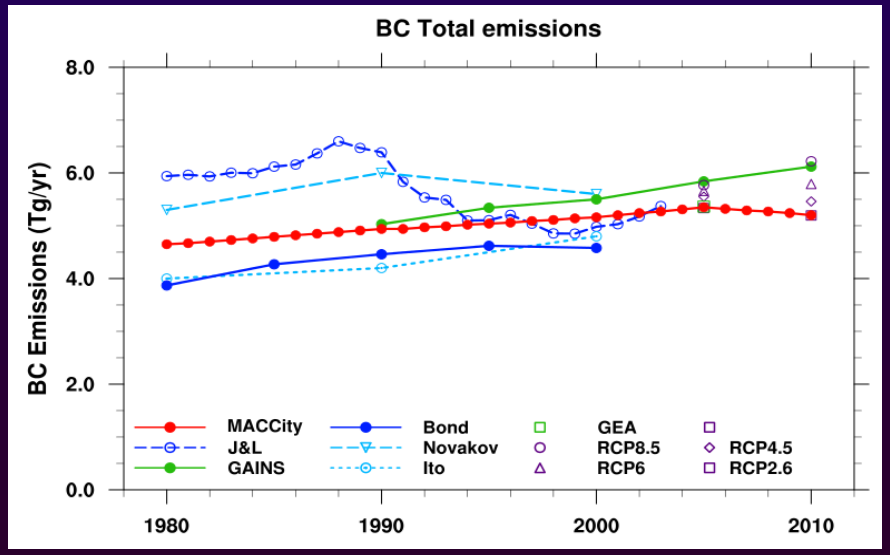
Several datasets are recently been developed for China, for BC, OC and SO2

Comparison of anthropogenic emissions : CO, NOx, SO2 and BC
Global totals

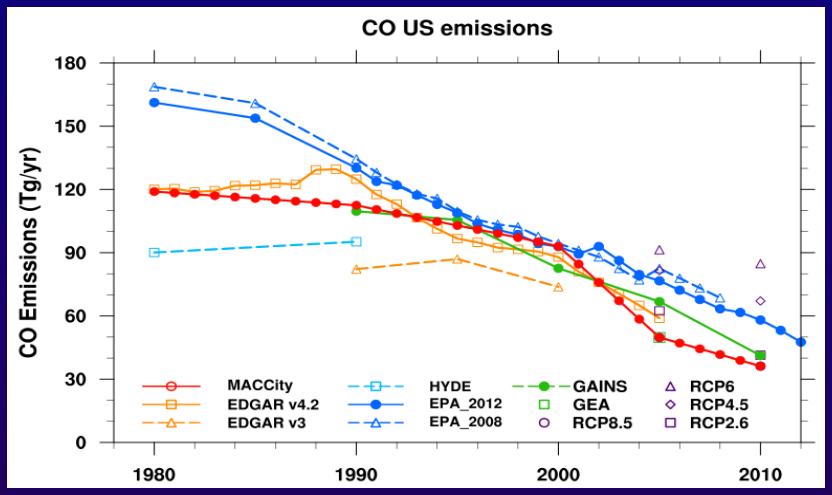


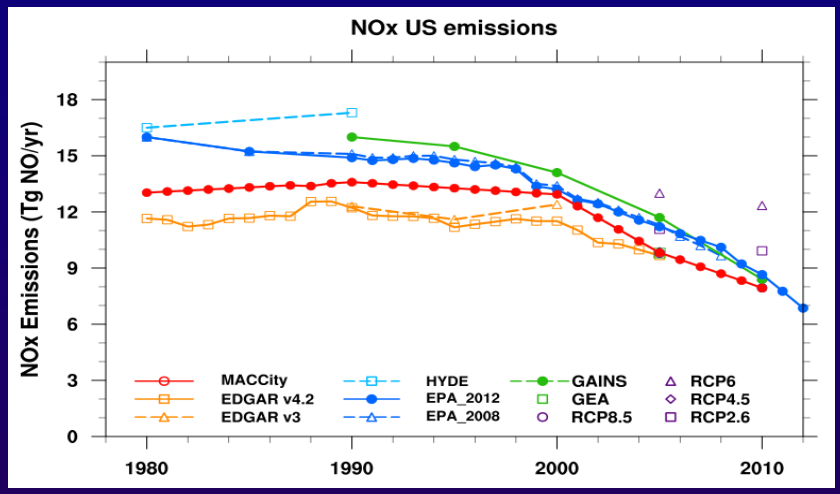


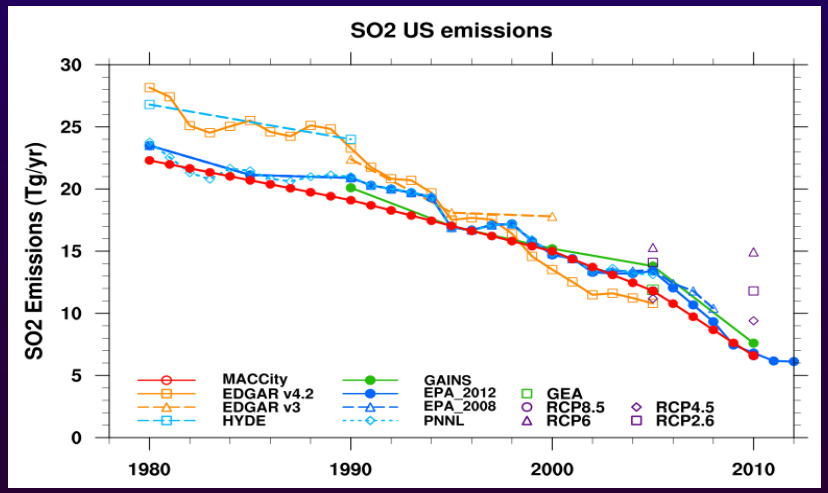


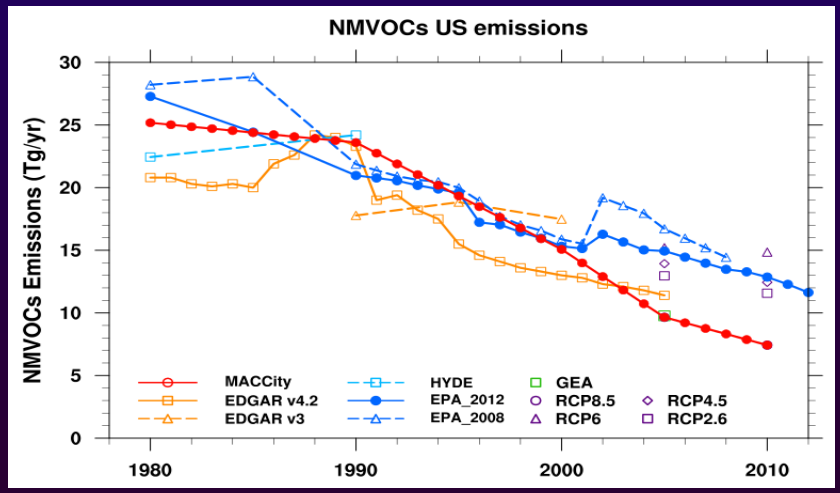


USA emissions of CO, NO_x, SO_2 and NMVOCs



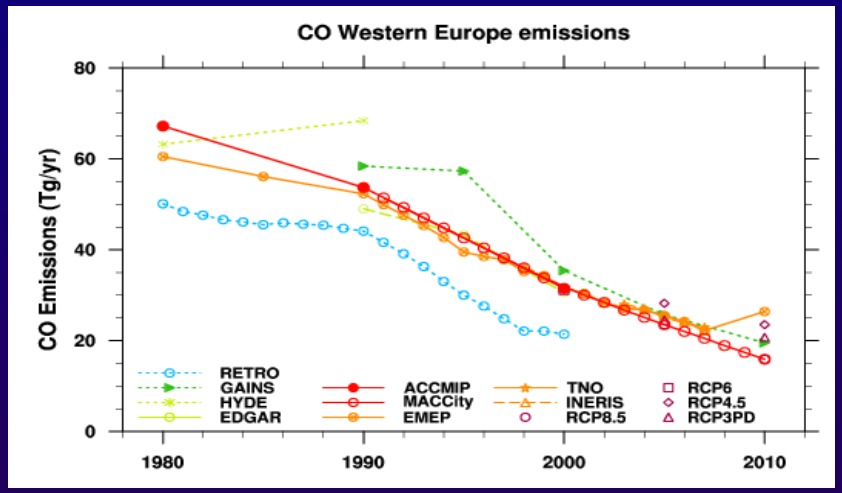


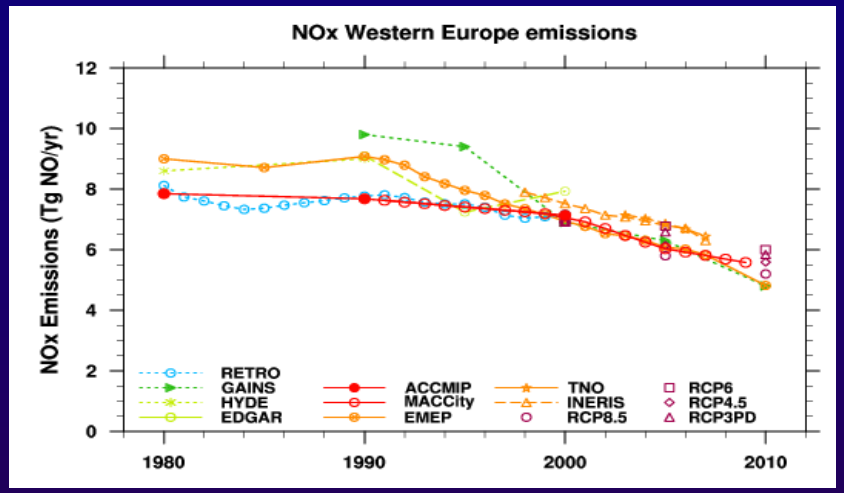


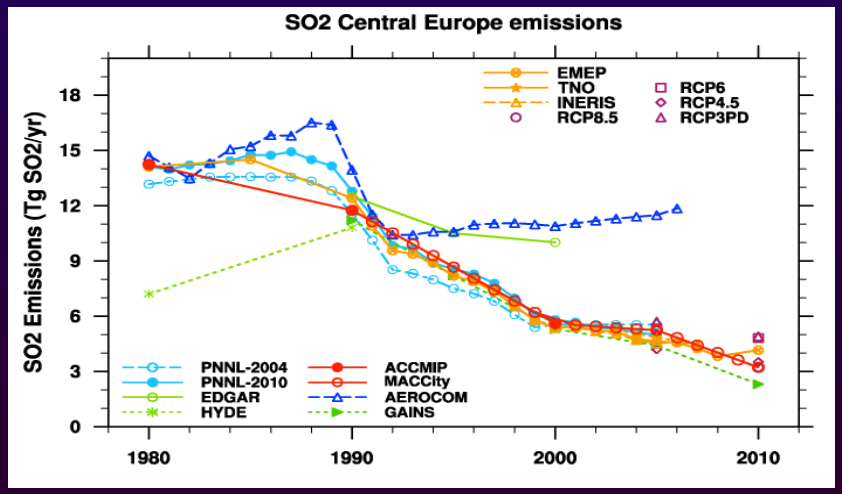


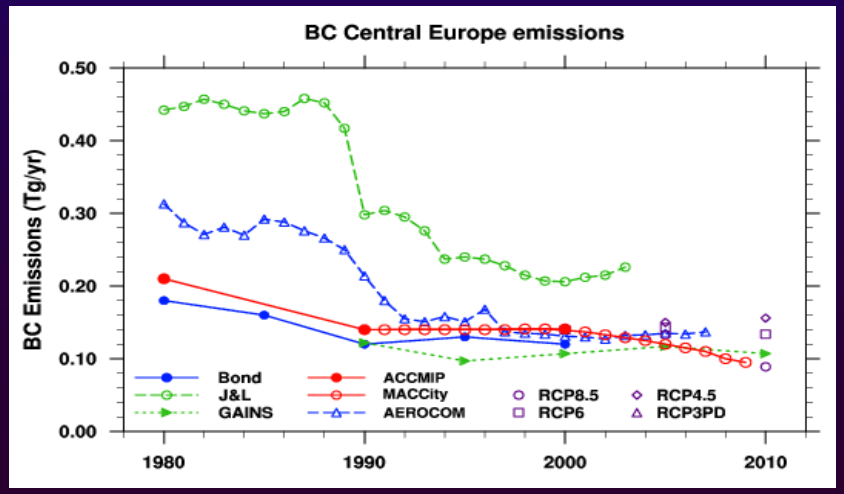
Note: global inventories provide BC and OC emissions; regional inventories provide PMs

Europe emissions of CO, NO_x, SO_2 and BC

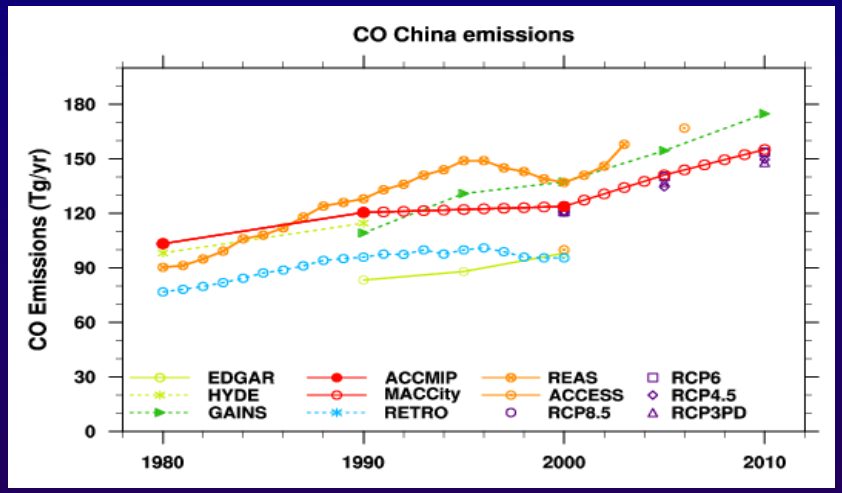


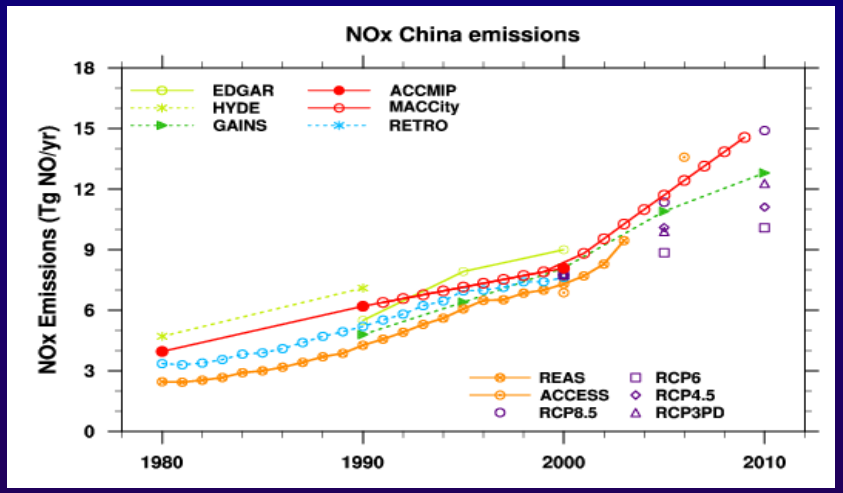


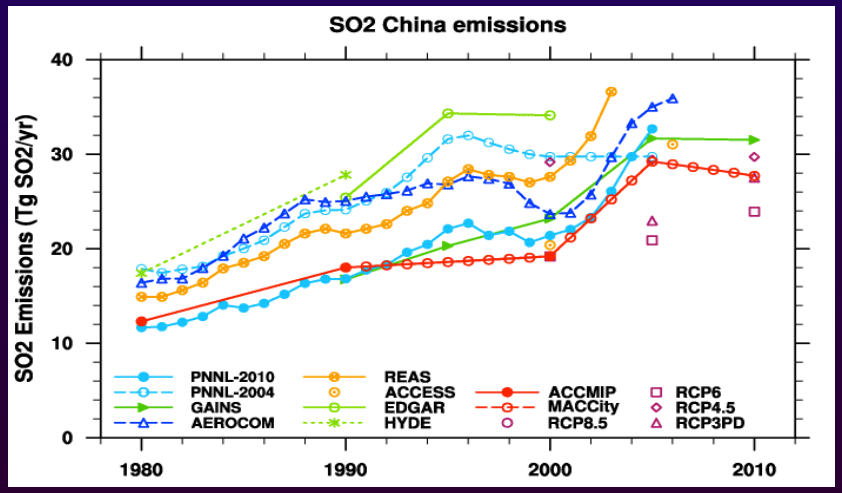


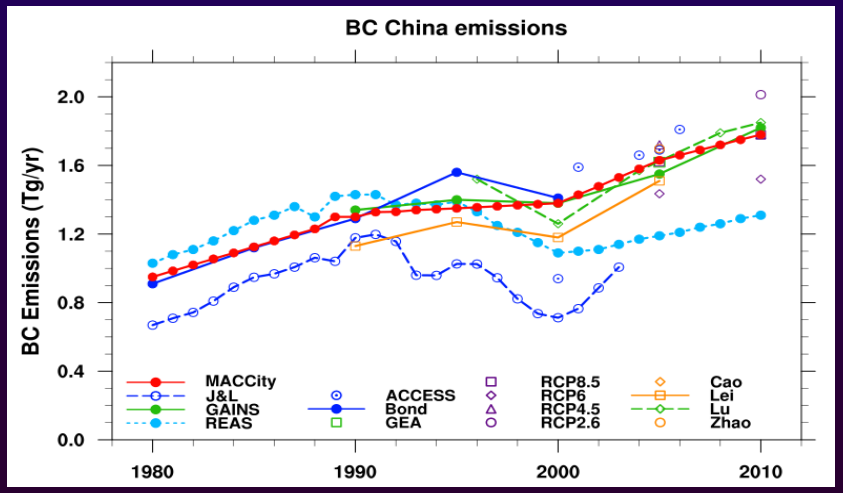


China emissions of CO, NO_x, SO_2 and BC









Year 2000 emissions	CO		NO_x		CH_4		NMVOCs	
	Min	Max	Min	Max	Min	Max	Min	Max
Global	467.5	610.8	58.7	68.6	275.2	310.3	121.0	139.5
Western Europe	21.4	35.4	5.9	9.0	16.3	22.0	9.2	14.3
Central Europe	7.8	12.3	1.6	1.9	6.1	7.7	2.3	3.5
USA	55.9	94.4	11.5	14.1	26.2	40.7	13.0	17.5
Canada	4.2	11.2	1.2	1.7	3.9	5.0	1.5	3.4
Central America	10.0	15.1	1.5	2.1	8.4	9.1	2.9	4.1
South America	22.3	26.5	2.8	3.8	26.4	30.0	8.4	12.9
Africa	49.4	83.2	2.7	5.9	25.0	29.4	10.8	14.5
China	95.5	137.3	6.9	9.8	33.1	49.4	11.5	24.5
India	40.3	79.4	2.7	4.9	25.7	33.8	7.3	10.8
Oceania	2.6	5.7	1.1	1.9	6.4	6.8	0.0	1.5

Year 2000 emissions	BC		OC		SO_2		NH_3	
	Min	Max	Min	Max	Min	Max	Min	Max
Global	4.6	5.6	6.4	12.7	102.0	145.0	37.5	38.9
Western Europe	0.32	0.38	0.32	0.40	6.1	14.1	3.4	4.5
Central Europe	0.11	0.21	0.25	0.39	4.6	10.0	1.1	1.2
USA	0.27	0.40	0.36	0.51	13.5	17.8	3.3	4.4
Canada	0.04	0.04	0.03	0.06	2.2	2.9	0.5	0.6
Central America	0.11	0.11	0.17	0.35	3.7	4.1	1.1	1.1
South America	0.20	0.33	0.32	0.83	3.8	8.8	3.4	3.5
Africa	0.46	0.62	1.05	1.91	5.3	8.8	2.3	2.4
China	0.71	1.41	1.10	3.80	19.2	21.1	8.9	13.6
India	0.45	0.84	1.00	3.27	4.0	7.9	3.7	8.5
Oceania	0.03	0.04	0.04	0.08	2.4	2.7	0.72	0.72

Better understanding of differences between inventories; could be obtained by comparisons of emissions by sectors.

But … the sectors used in global and regional datasets are generally quite different. Example shows the sectors in ACCMIP/MACCity global dataset and in the EMEP regional inventory

Sector number	Sector name
1	Energy production and distribution
2	Industry (combustion and non-combustion)
3	Land transport
4	Maritime transport
5	Aviation
6	Residential and commercial
7	Solvents
8	Agriculture
9	Agricultural waste burning on fields
10	Waste
11	Open vegetation fires in forests
12	Open vegetation fires in savanna and grasslands
13	Natural emissions

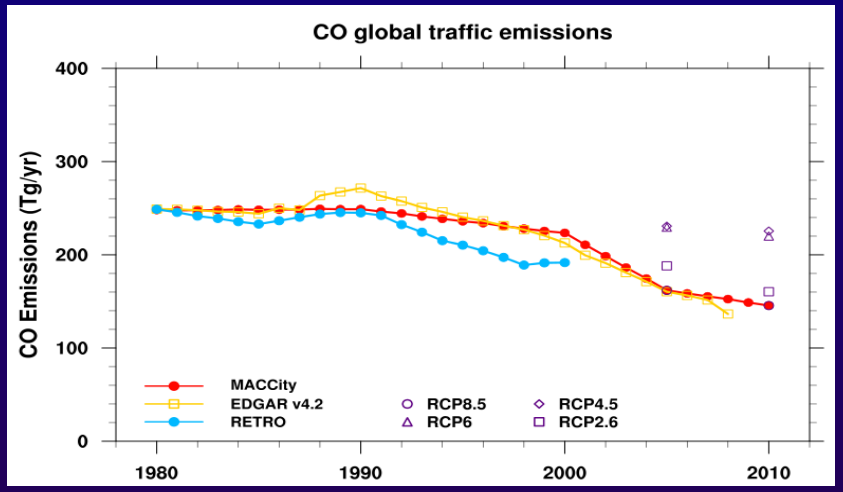
ACCMIP/MACCity = IPCC sectors

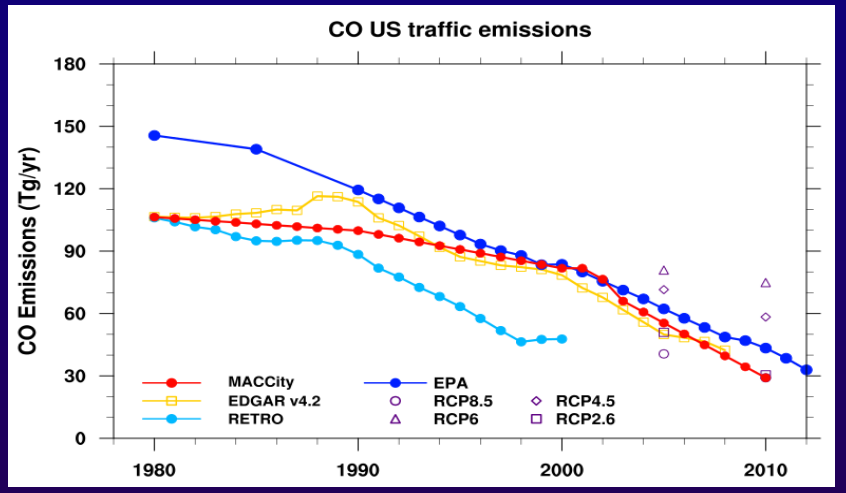
EMEP = SNAP sectors

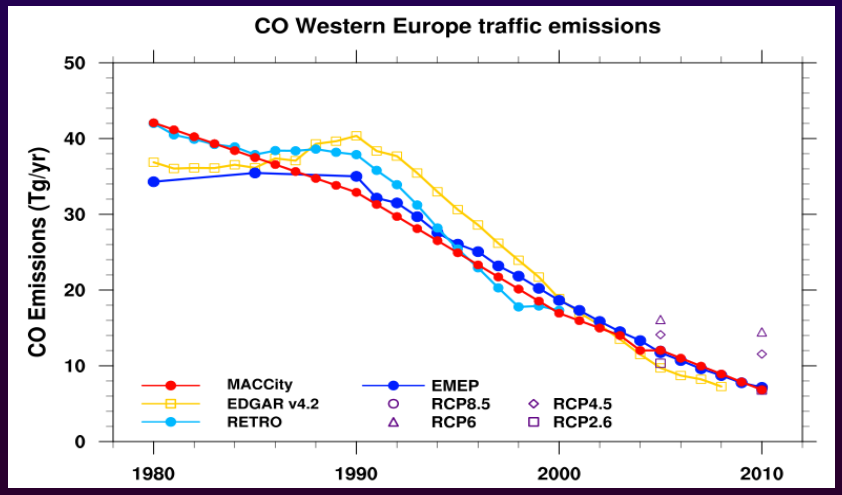
SNAP	Description
1	Public electricity and other energy transformation
2	Small combustion plants
3	Industrial combustion and processes with contact
4	Industrial process emission
5	Fossil fuel production
6	Solvent and product use
7	Road Transport
8	Other (non-road) transport and mobile machinery
9	Waste disposal
10	Agriculture
11*	Nature

➔ Preliminary comparisons of global/regional transport emissions

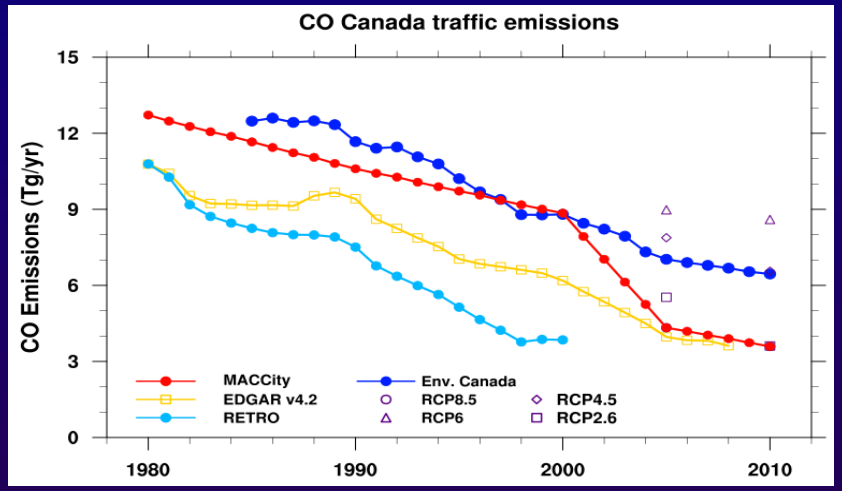
CO Transport emissions displaying reasonable agreement: Global, US and Western Europe

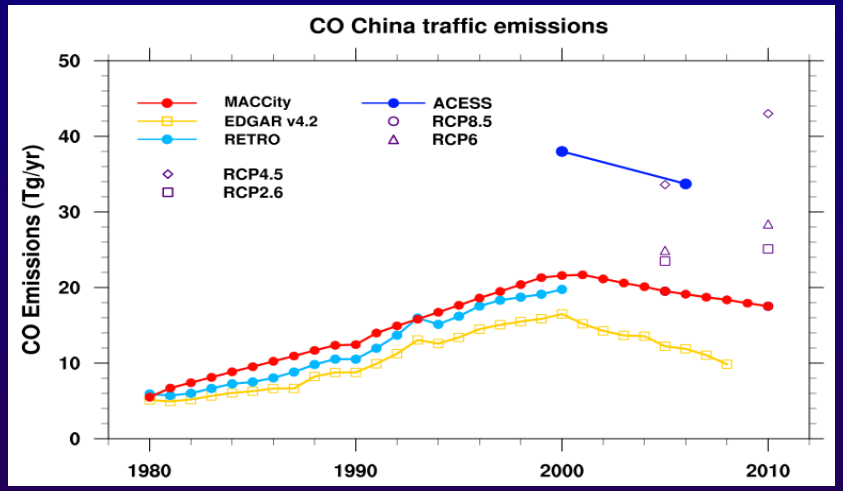


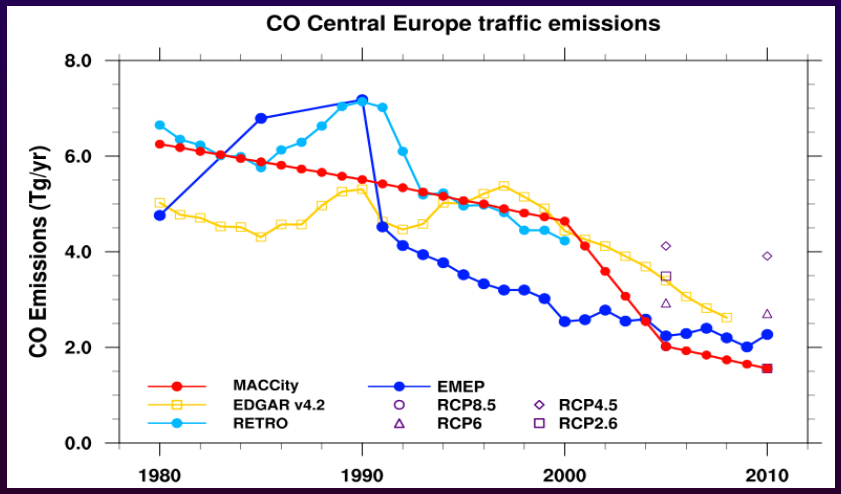




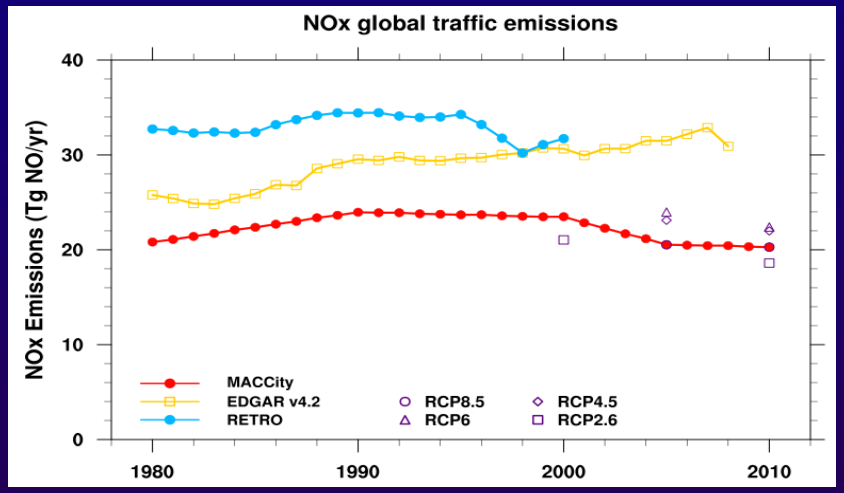
CO Transport emissions displaying significant disagreements: Canada, China and Central Europe

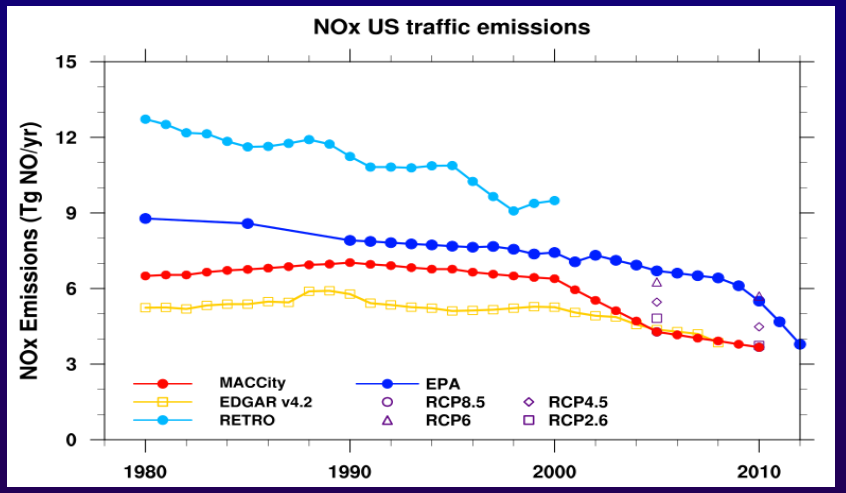


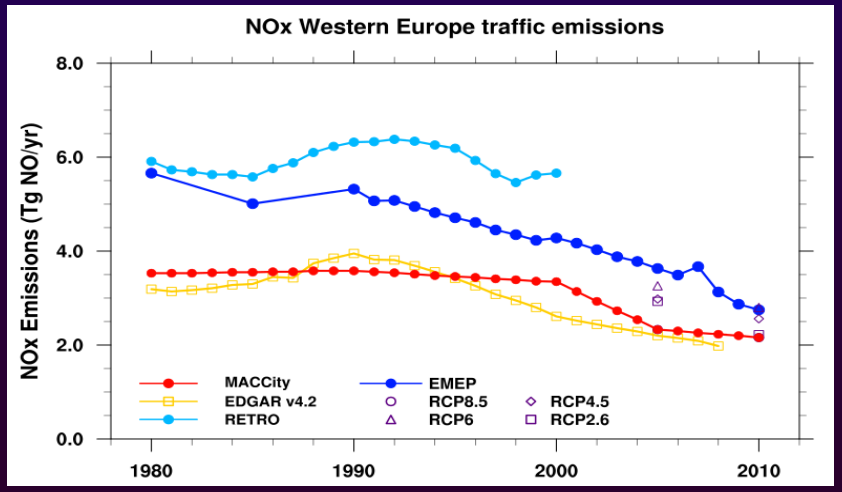




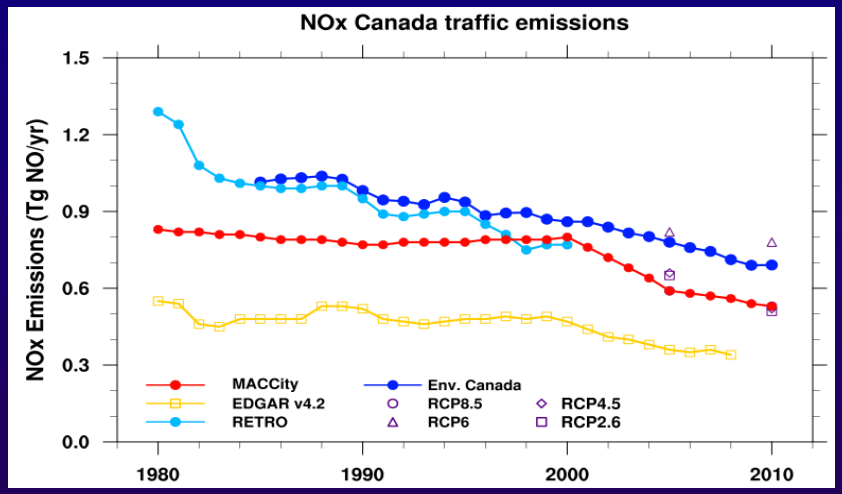
NOx Transport emissions all show significant differences: Global, US and Western Europe

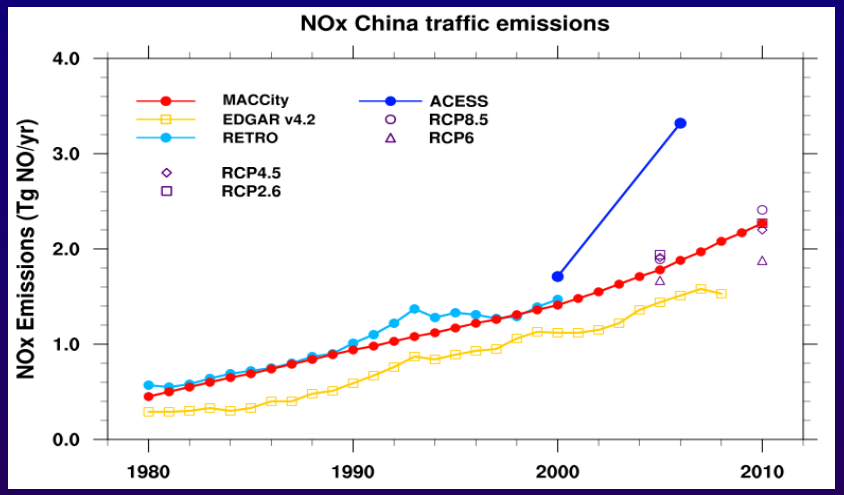


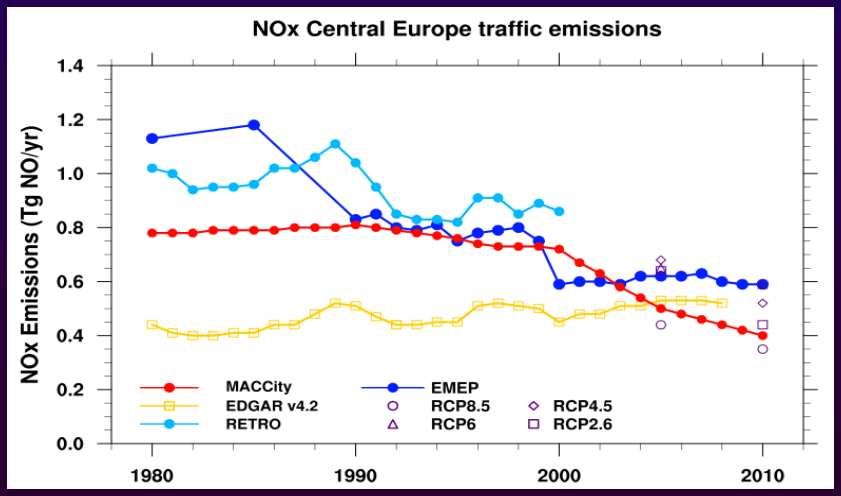




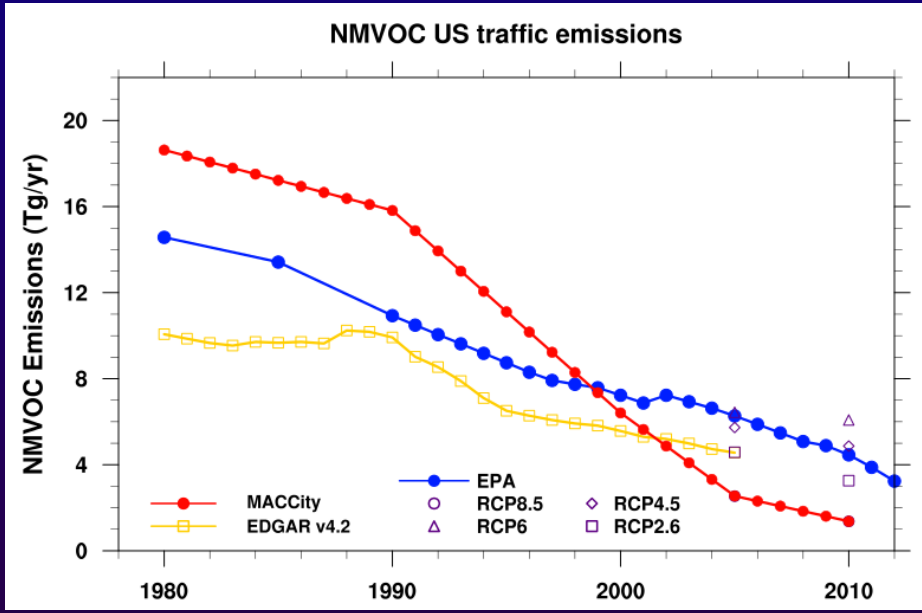
NOx Transport emissions all show significant differences: Canada, China and Central Europe

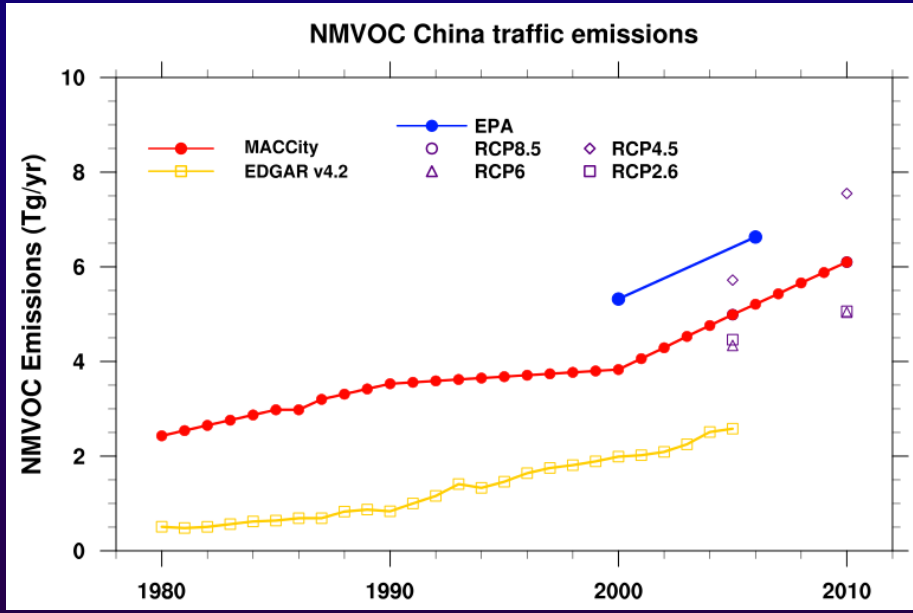






Preliminary results for Transport NMVOCs: US and China





Summary of the results:

- **Still very large uncertainties on emissions inventories**
- **Relatively good consensus for total NO_x emissions**
- **Improvements required for CO and BC emissions**
- **Emissions related to transport show very large differences**

But:

- **Good consensus does not mean that inventories are accurate**
- **A certain amount of overlap exists between the datasets**
- **More work needed for the evaluation of emissions by sector (when possible)**

Several reasons have been identified to explain the differences among the datasets

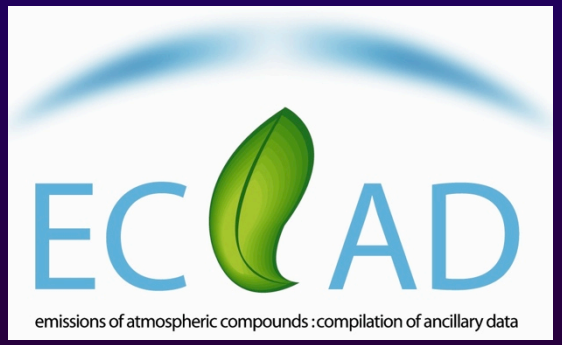
→ Large diversity in space and time, difficult to quantify
→ Lack of information: non reported, not existing
→ Extrapolation errors when information is lacking (after 2000)
→ Most inventories are non-transparent about method and data
→ Difficulties to compare data for sectors of different definitions
→ Lack of different independent inventories
→Lack of measurement data and model studies to confront inventories with

Where can you find most emission inventories used in this presentation?

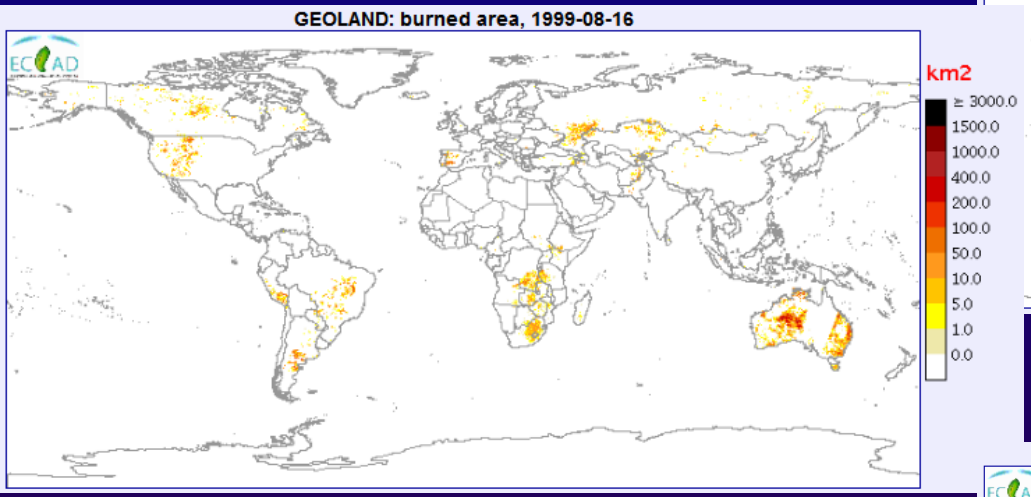
Most data are available from the ECCAD database

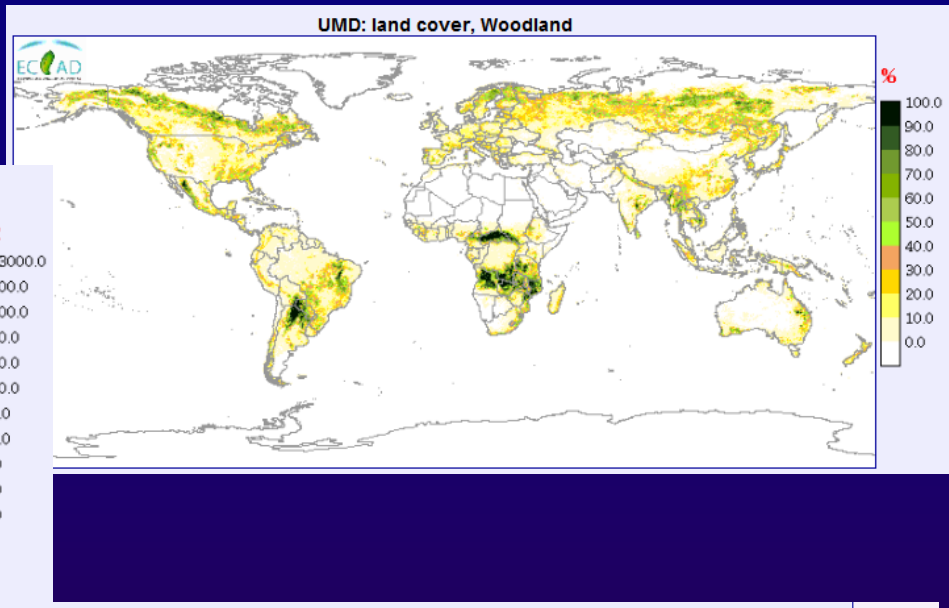
= Emissions of atmospheric Compounds: Compilation of Ancillary Data

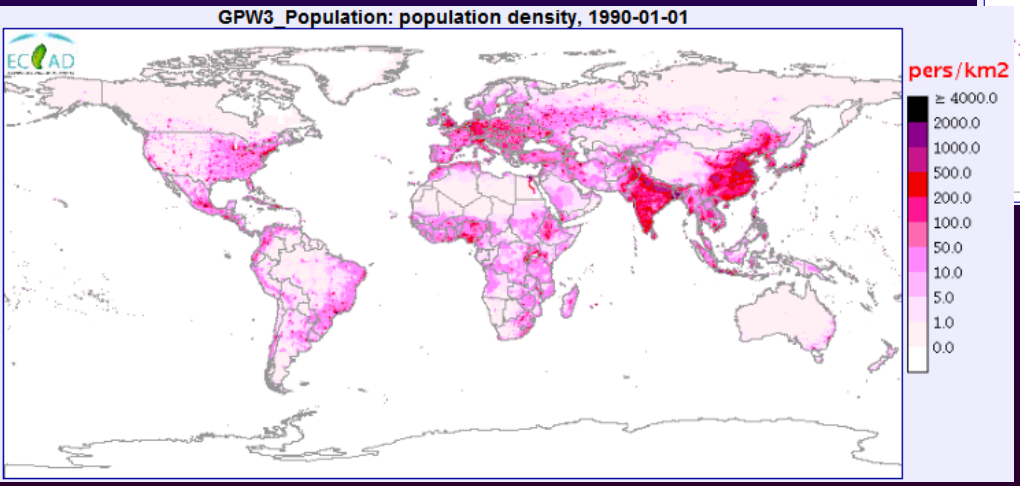
http://eccad.sedoo.fr

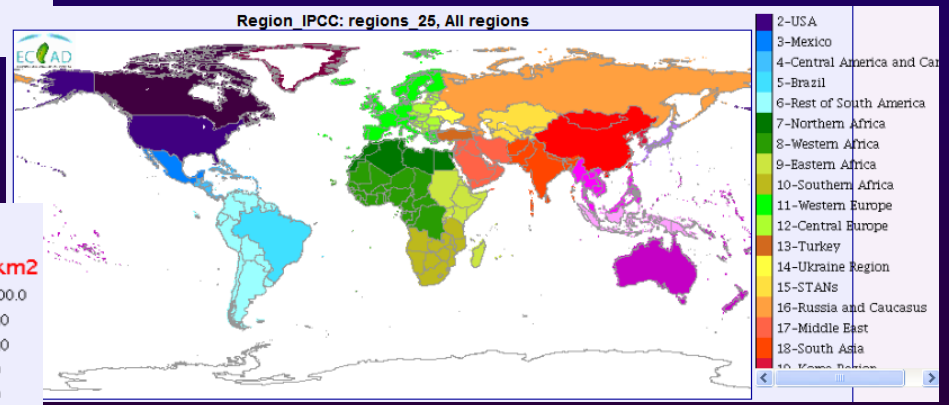


A few maps of ancillary data









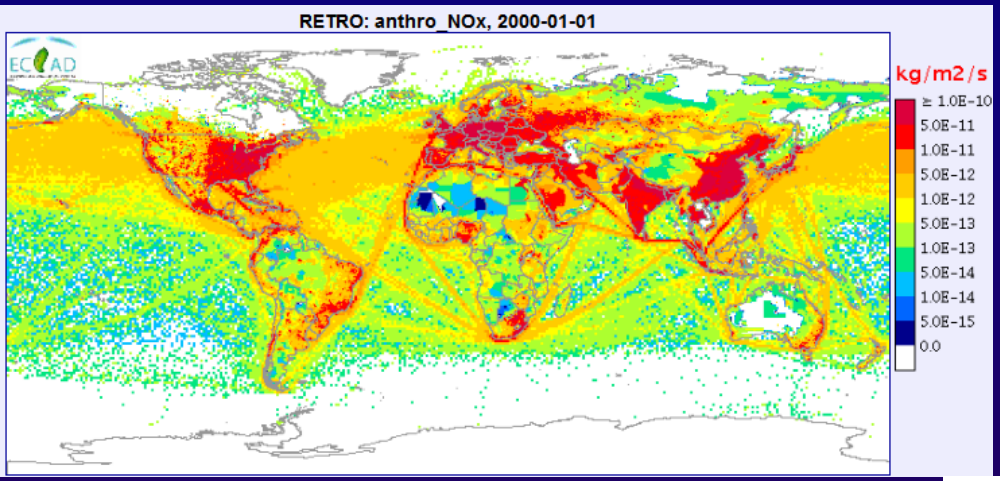
List of emissions inventories currently available in ECCAD

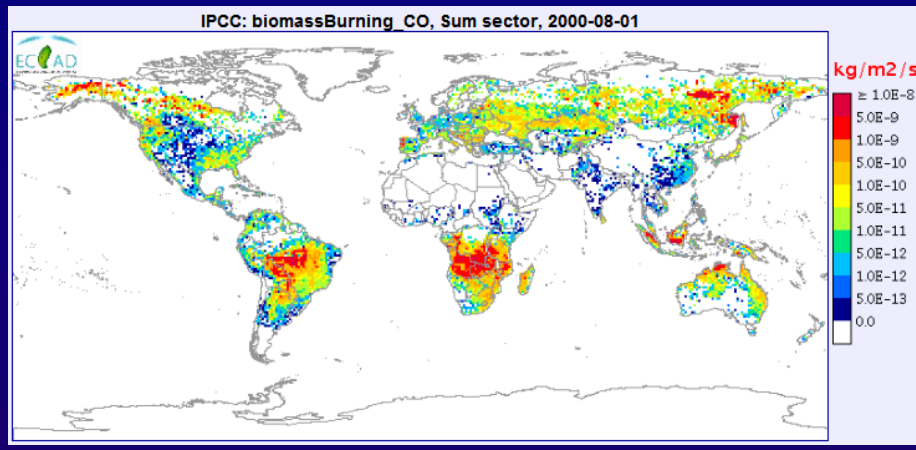
Product *release year*	Temporal Coverage	Time Resolution	Category *Species: mouse over*	Grid size	Data provider	Metadata
GLOBAL INVENTORIES (17)						
ACCMIP 2010	1850 - 2000	Decadal Decadal (seasonal)	Anthropogenic Biomass burning	0.5°	ACCMIP	
RCPs 2010	2005 - 2100	Decadal Decadal (seasonal)	Anthropogenic Biomass burning	0.5°	RCPs	
RETRO 2005	1960 - 2000	Monthly	Anthropogenic Biomass burning	0.5°	RETRO	
EDGAR3.2FT2000 2005	2000	Year	Anthropogenic Biomass burning	1°	EDGAR	
MACCity 2010	1960 - 2010	Monthly	Anthropogenic	0.5°	macc city	
Junker-Liousse 2008	1860 - 2003	Decadal/Yearly	Anthropogenic	1°	LA	
HYDE1.3 2001	1890 - 1990	Decadal	Anthropogenic	1°	EDGAR	
Andres_CO2 2007	1751 - 2003	Decadal / Yearly	Anthropogenic	1°	CDIAC	
AMAP_Mercury 2005	1995 - 2000	Half-decadal	Anthropogenic	0.5°	AMAP	
GFASv1.0 2012	2003 - 2011	Daily	Biomass burning	0.5°	gmes.info	
GFED3 2010	1997 - 2010	Monthly	Biomass burning	0.5°	GFED	
GFED2 2005	1997 - 2005	Monthly	Biomass burning	1°	GFED	
GICC 2010	1900 - 2005	Decadal (seasonal) / Monthly	Biomass burning	0.5°	LATMOS GICC	
AMMABB 2009	2000 - 2006	Daily	Biomass burning	0.5°	LA	
MEGANv2 2009	2000	Year (seasonal)	Natural	0.5°	NCAR	
MEGANv2-CH3OH 2011	2003 - 2009	Yearly (seasonal)	Natural	0.5°		
POET 2003	1990 - 2000	Yearly Monthly Yearly (seasonal)	Anthropogenic Biomass burning Natural	1°	GEIA	

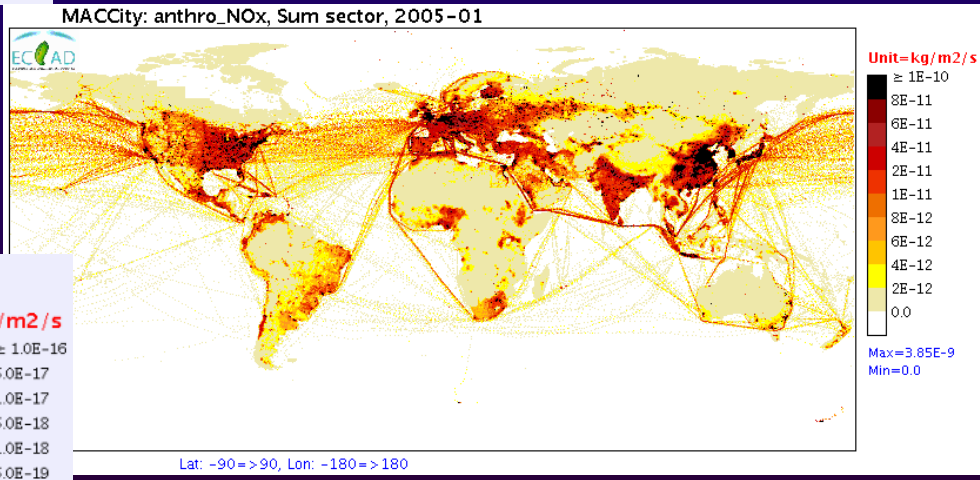
GLOBAL INVENTORIES DEVELOPED FOR ONGOING PROJECTS (2)						
IS4FIRES 2012	2000 - 2011	Daily	Biomass burning	0.5°		
GUESS-ES 2011	1970 - 2009	Monthly	Biomass burning Natural	1°		
REGIONAL INVENTORIES (4)						
TNO-MACC Europe 2009	2003 - 2007	Yearly	Anthropogenic	0.5°	TNO innovation for life	
EMEP Europe 2007	1980 - 2020	Yearly	Anthropogenic	0.5°	Convention on Long-range Transboundary Air Pollution emep	
SAFAR-India India 2012	1991 - 2011	Decadal	Anthropogenic	1°		
REAS Asia 2007	1980 - 2020	Yearly	Anthropogenic	0.5°	REAS	
REGIONAL INVENTORIES DEVELOPED FOR ONGOING PROJECTS (1)						
ChArMEx Mediterranean 2012	2000	Varied	Anthropogenic Biomass burning Natural	0.25/0.5/1°	ChArMEx	

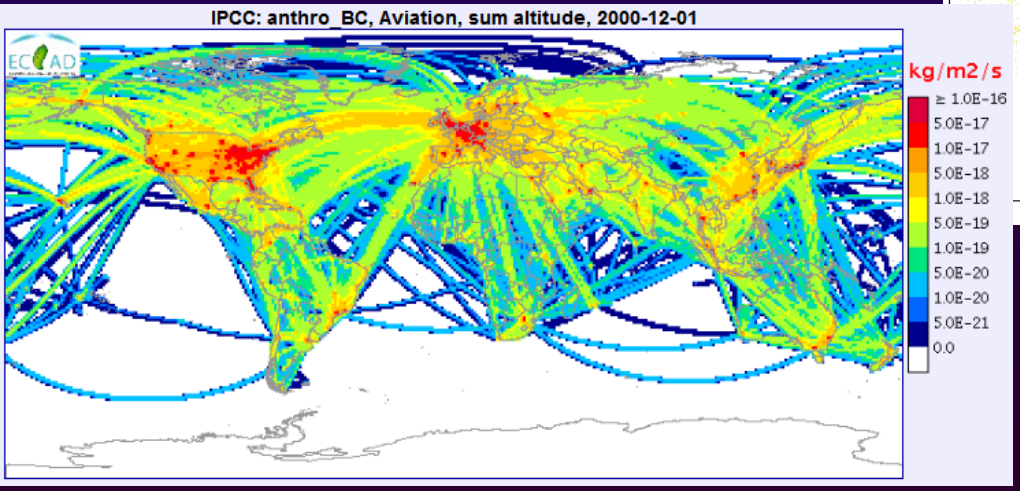
All data available for download

A few examples of emission maps





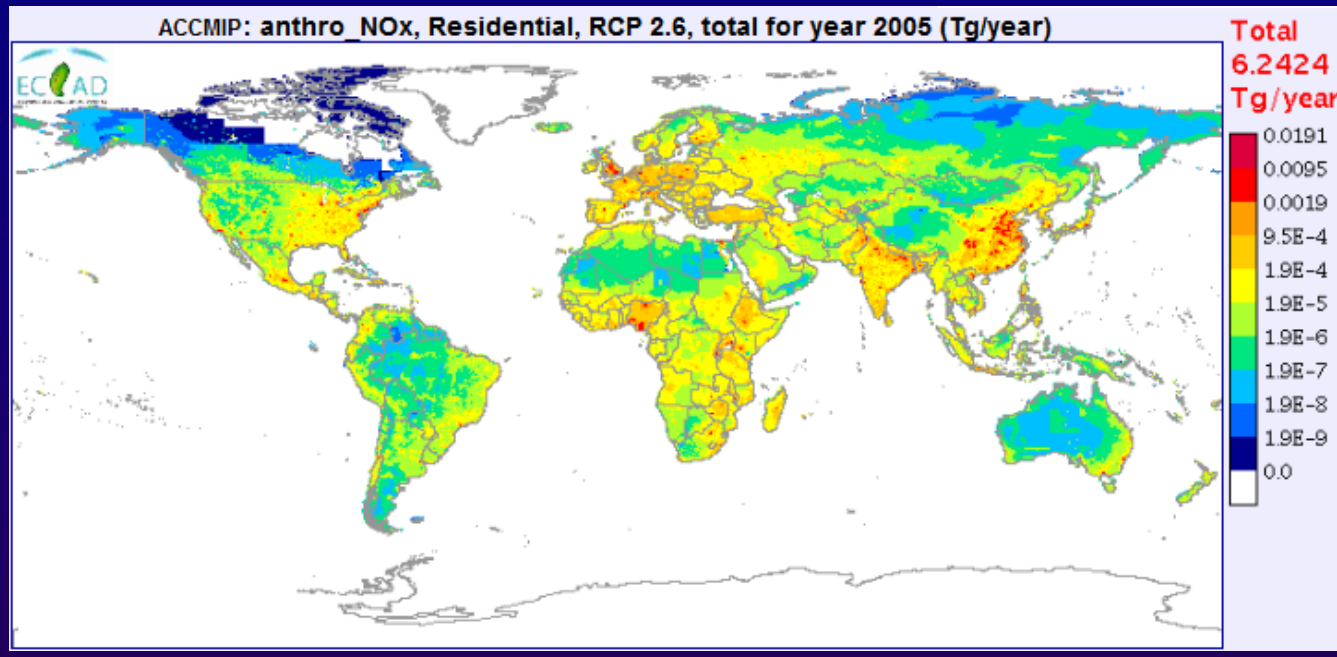




ECCAD – Emissions Totals

Global

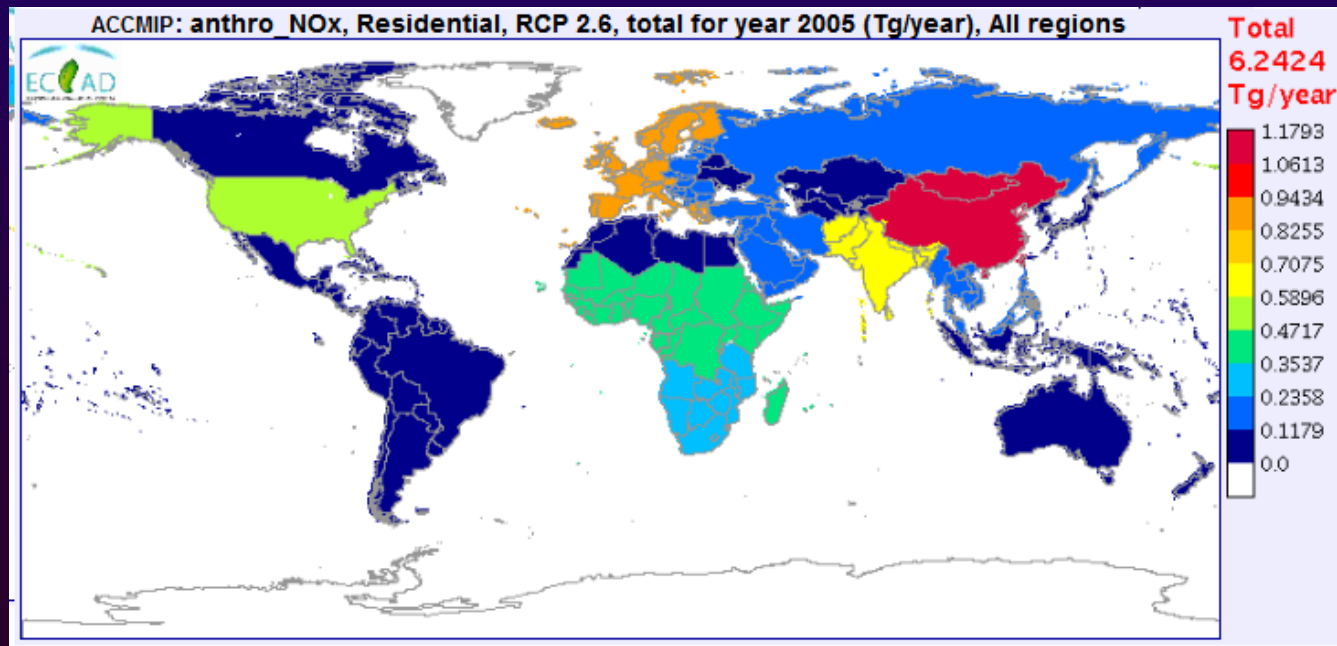
Total NOx, Residential, year 2005 : 6.24 Tg/year



Totals for different regions

Total by regions : from 0.1 to 1.18 Tg/year

Output in excel/csv



Thank you for your attention