Trends in anthropogenic emissions from 1960 to 2015

Claire Granier

University of Colorado/CIRES and NOAA/Earth System Research Laboratory

Laboratoire d'Aerologie, Toulouse, France

Thanks to my co-authors:

Thierno Doumbia, Meteo-France, Toulouse, France

Louise Granier, LATMOS, Paris, France

Katerina Sindelarova, Charles University, Prague, Czech Republic

Cathy Liousse, Laboratoire d'Aerologie, Toulouse, France

Sabine Darras, Observatoire Midi-Pyrenees, Toulouse, France

Idir Bouarar, MPI-Meteorologie, Hamburg, Germany

Hugo Denier van der Gon, TNO, The Netherlands

Gregory Frost, NOAA/ESRL/CSD, Boulder, CO, USA

Greet Janssens-Maenhout and Monica Crippa, Joint Research Center, Italy

Jenny Stavrakou, BISA, Belgium

Rachel Hoesly and Steven Smith, PNNL, College Park, MD, USA

Introduction

Many inventories developed by different international groups in the past few years, mostly on the US, Europe, and many in Asia/China

Global and regional models need information on which inventory is the most accurate for air quality forecasting and analysis of the atmospheric composition

Most inventories do not provide emissions for the most recent years
→ many groups use the RCPs scenarios to provide emissions for the most recent + short future emissions

Our work:

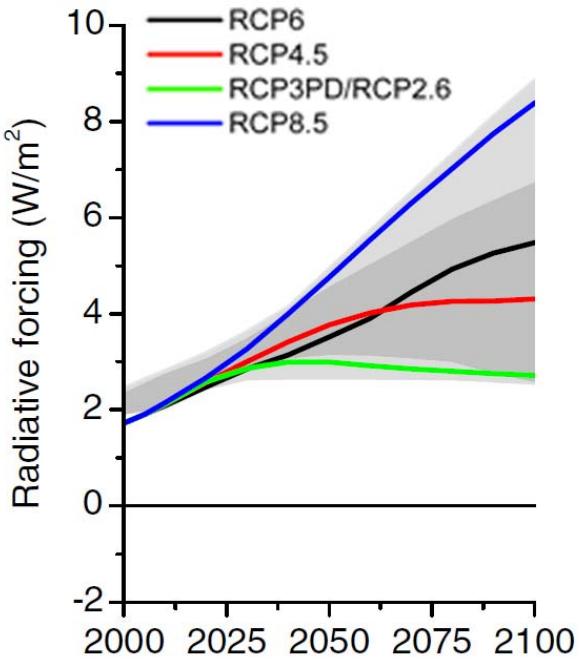
- **Evaluation of all public datasets providing emissions of chemically active species, aerosol precursors, greenhouse gases**
- **Provide an easy access to many emissions datasets from an emissions database**
- **Link with the GEIA international project on emissions**

Global inventories:

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
CEDS	1950-2014	Hoesly et al., 2017 http://www.globalchange.umd.edu/ceds/

In green: inventories providing just a few species

The RCPs (Representative Concentration Pathways) in a few words:
future scenarios used as a basis for the 2013 5th report of the Intergovernmental Panel on Climate Change (IPCC)



The RCPs are defined by their total radiative forcing (change in the net radiative flux) from the preindustrial period (year 1750).
Each RCPs provides only one of many possible scenarios that would lead to the specific radiative forcing characteristics.

RCP 8.5 → Radiative forcing of 8.5 W/m2 in 2100
RCP 3PD/2.6→ Peak at 3 W/m2 followed by decline to reach 2.6 W/m2 in 2100

Note: the next IPCC 6th assessment, to be released in 2021, will use a new set of scenarios, the SSPs (Shared Socio-Economic Pathways), not yet fully released.

Regional inventories in Europe, North America and Africa

Author	Acronym	Reference or Website	Years	Resolution
Europe				
TNO group	TNO-MACC	Kuenen et al., 2011	2003-2007	7x7 km
TNO group	TNO-MACCII	Kuenen et al., 2014	2003-2009	7x7 km
TNO group	TNO-MACCIII	Kuenen et al., 2014	2003-2011	7x7 km
EMEP	EMEP	Ceip.at	1980-2014	0.1x0.1 deg
Africa				
DACCIWA	DACCIWA	eccad.aeris-data.fr	1990-2013	0.125x0.125
North America				
EPA	EPA	epa.gov/chief	1970-2016	variable
Env. Canada	HuangX	ec.gc.ca	1990-2013	country

Asian inventories

Author	Acronym	Reference or Website	Years	Resolution
Q. Zhang et al.	MEIC	Meicmodel.org	2008, 2010, 2012	0.25x0.25
Ohara et al.	REASv1	jamstec.go.jp	1980-2003	0.5x0.5
Kurokawa et al.	REASv2	nies.go.jp/REAS	2000-2008	0.25x0.25
Zhang et al.	TRACE-P INTEX-B	cgrer.uiowa.edu	2000, 2006	0.5x0.5
Li et al.	MIX	http://www.meicmodel.org/dataset-mix	2008, 2010	0.25x0.25
B. Zhao et al.	ZhaoB	ACP, 13, 9869, 2013	1995-2010	country
Y. Zhao et al.	ZhaoY	ACP, 13, 4872013	2005, 2010	country
Cao	Cao	Atm. Env, 40, 6516, 2006	2000	0.2x0.2
X Huang et al.	HuangX	Glob. Bio. Cyc, 26, 2012	2006	1x1 km
Kang et al.	Kang	ACPD, 15, 26959, 2015	1980-2012	1x1 km
Bo et al.	Bo	ACP, 8, 7297, 2008	1980-2005	40x40 km
Lei et al.	Lei	ACP, 11, 931, 2011	1990-2005	30'x30'
Wei et al.	Wei	Atmos. Env., 2011	2005-2020	36x36 km
Su et al.	Su	Env. Sci. Tech.,	1990-2007	province
Lu et al.	Lu	ACP, 10, 6311, 2010	1996-2010	province
R. Wang et al.	WangR	Env. Sci. Tech., 46, 2012	1949-2007	0.1x0.1
S. Wang et al.	WangS	ACP, 14, 6571, 2014	2005-2030	country

In green: data available on a website or ftp site

All others: a few values published, but inventory not publicly available

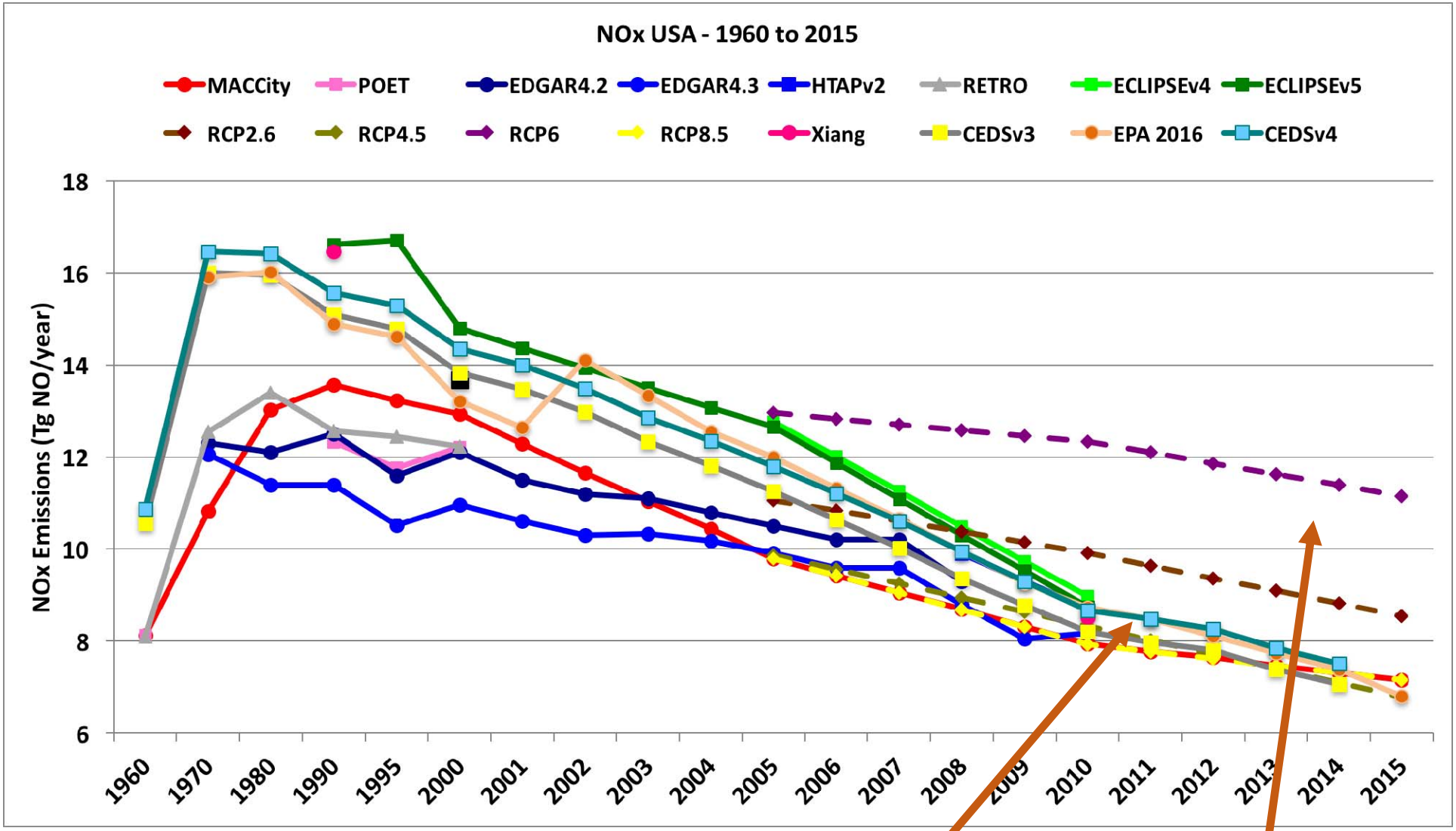
Evaluation of the inventories:

- Comparison of all emissions available for 26 world regions
  → Focus on the USA, Europe, China and India
  → 1960 to 2014

- Comparison of:
  → Sum of emissions for all sectors
  → Emissions from different sectors

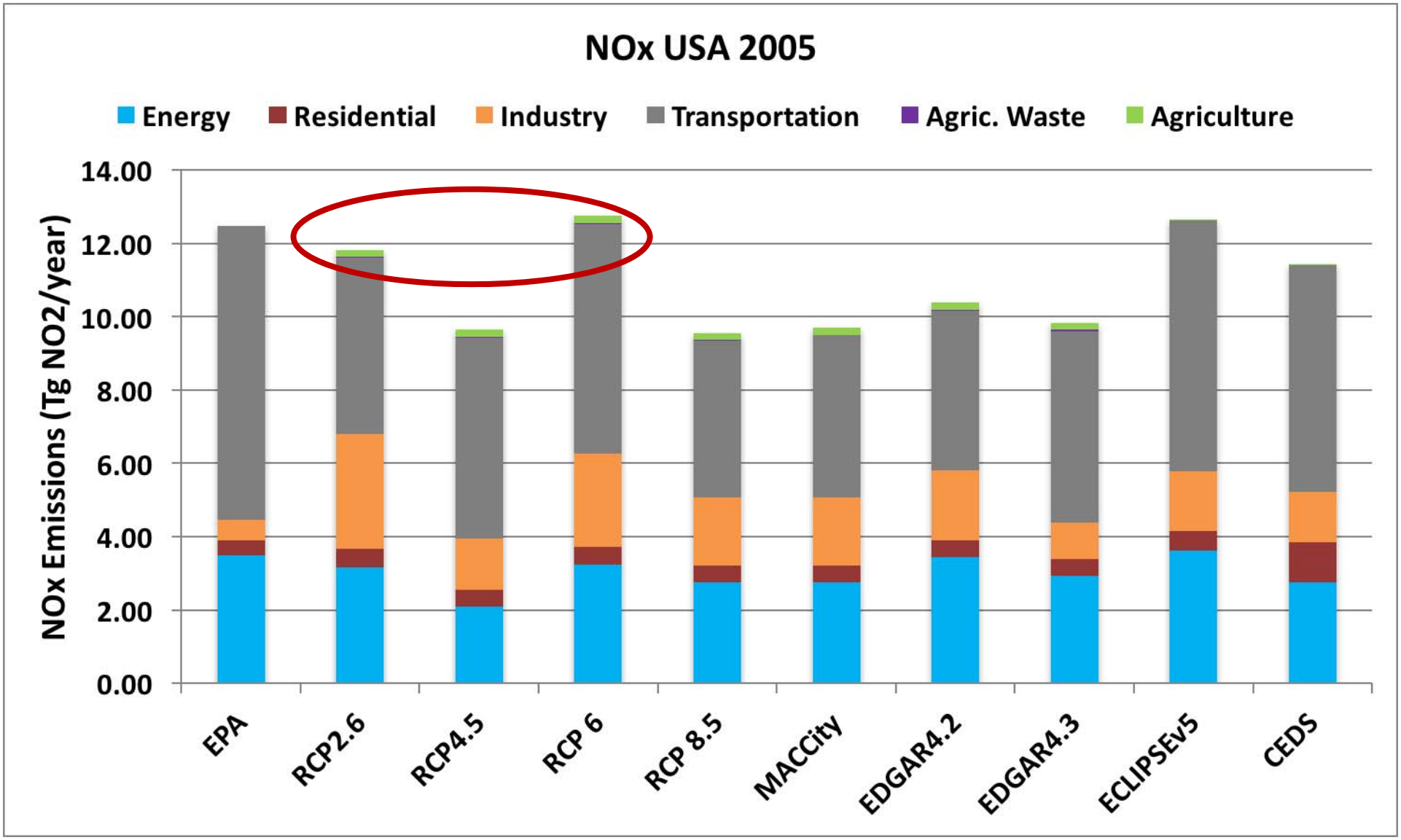
- Scale on the plots:
  → 1960, 1970, 1980, 1990, 1995, and all years after 2000

NOx emissions in the USA

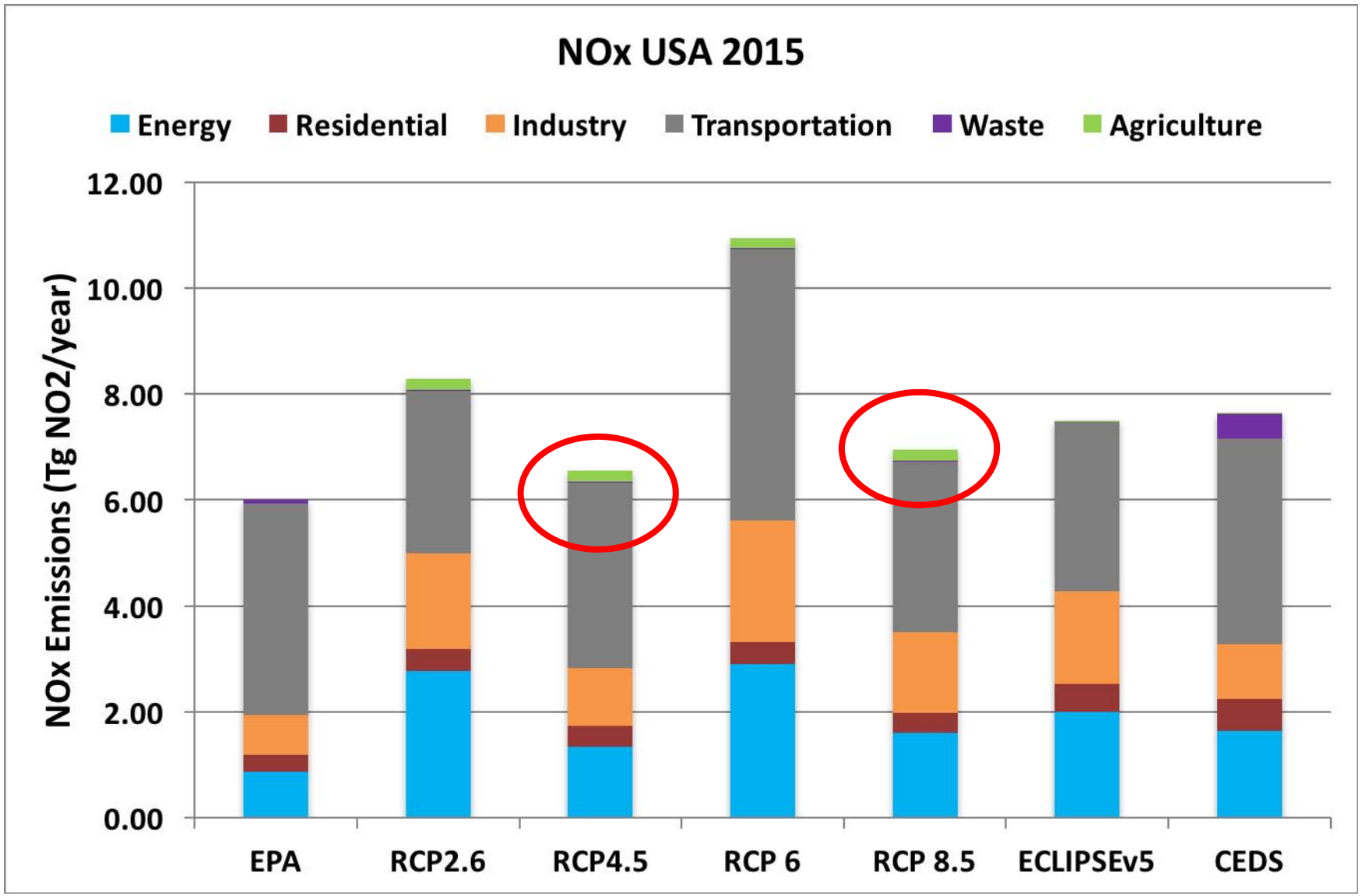


EPA

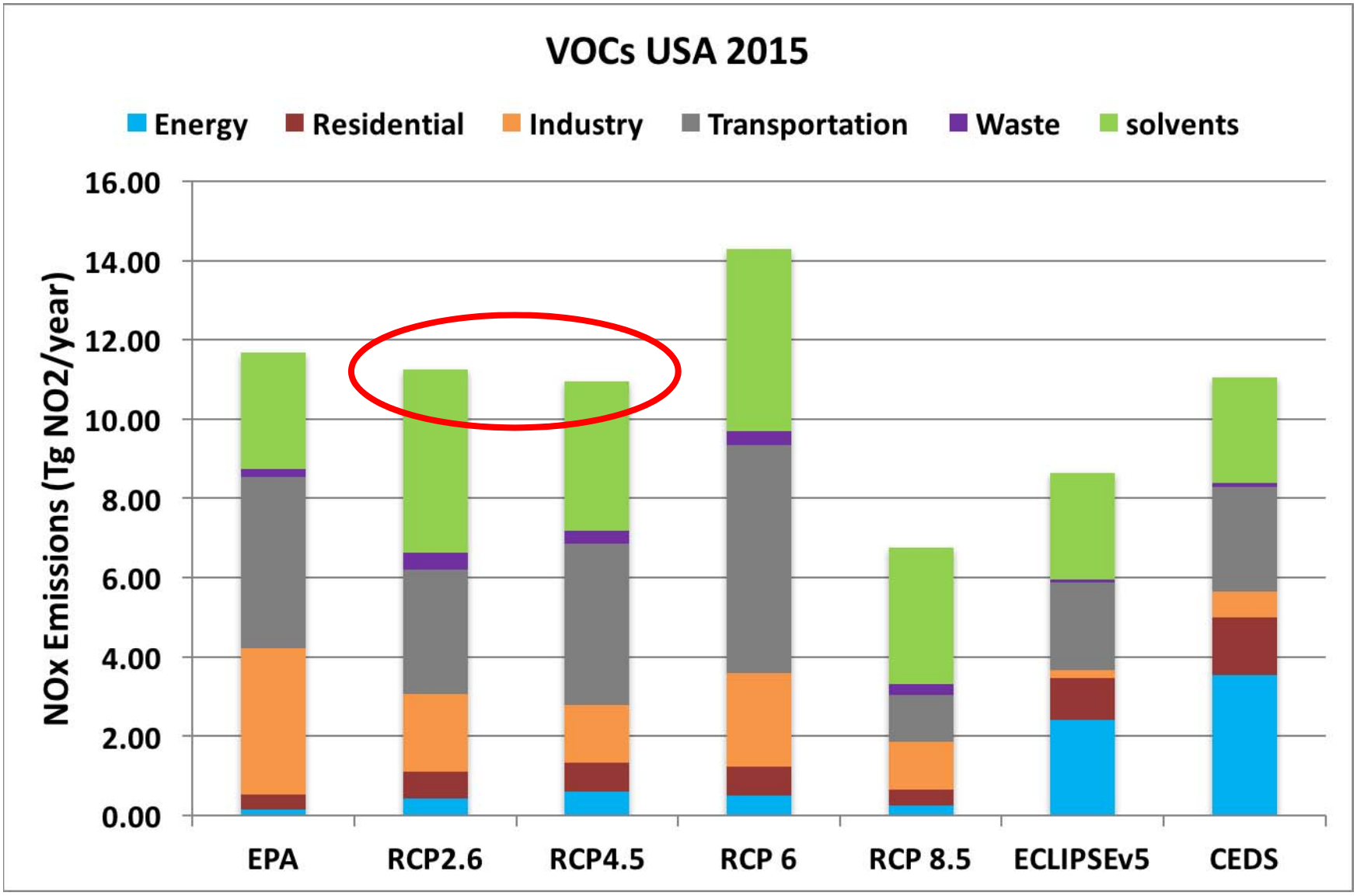
RCP 2.6 and RCP 6



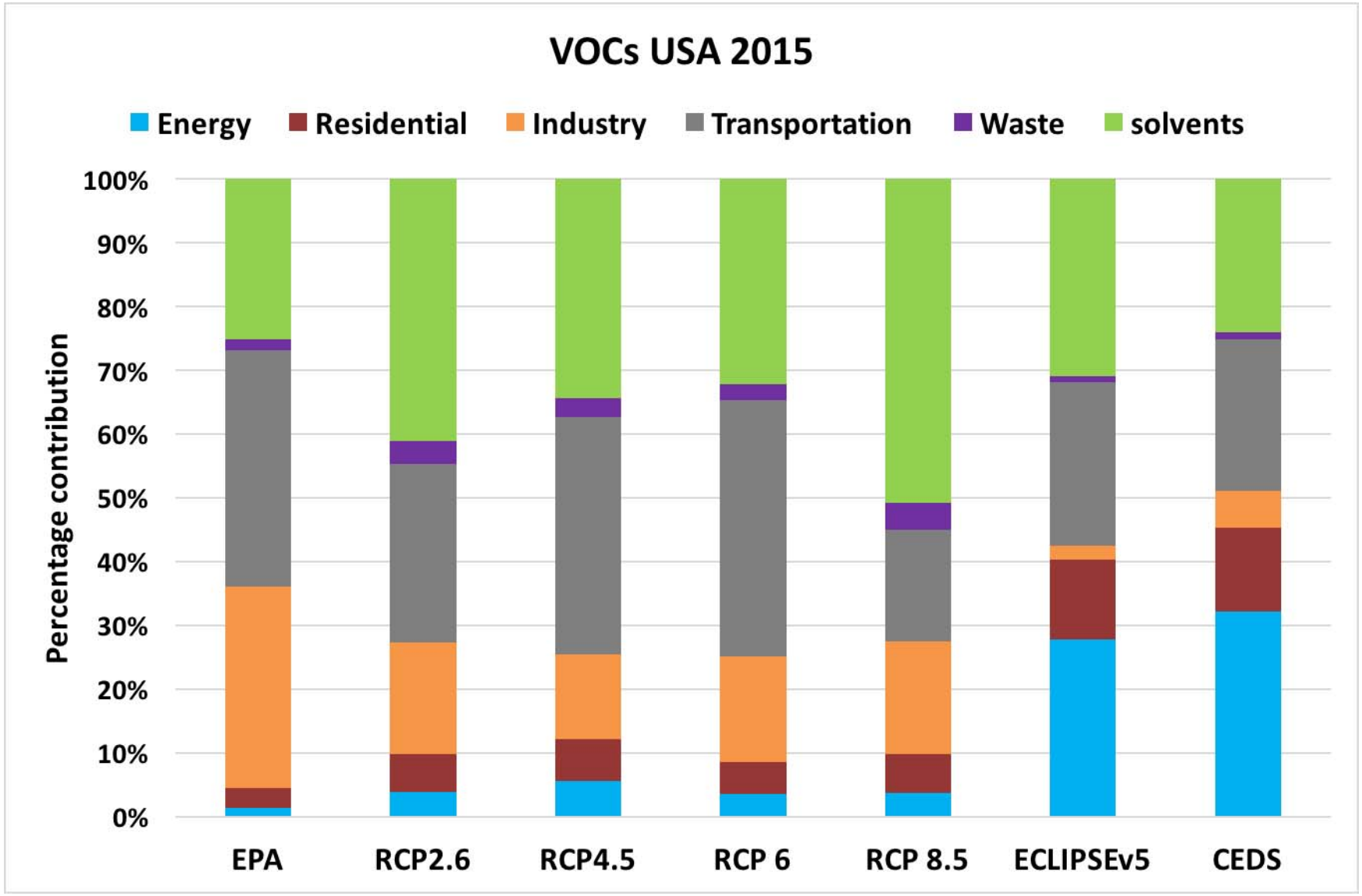
Large different in the industry sector:
all inventories except EPA use the same definition of the sectors



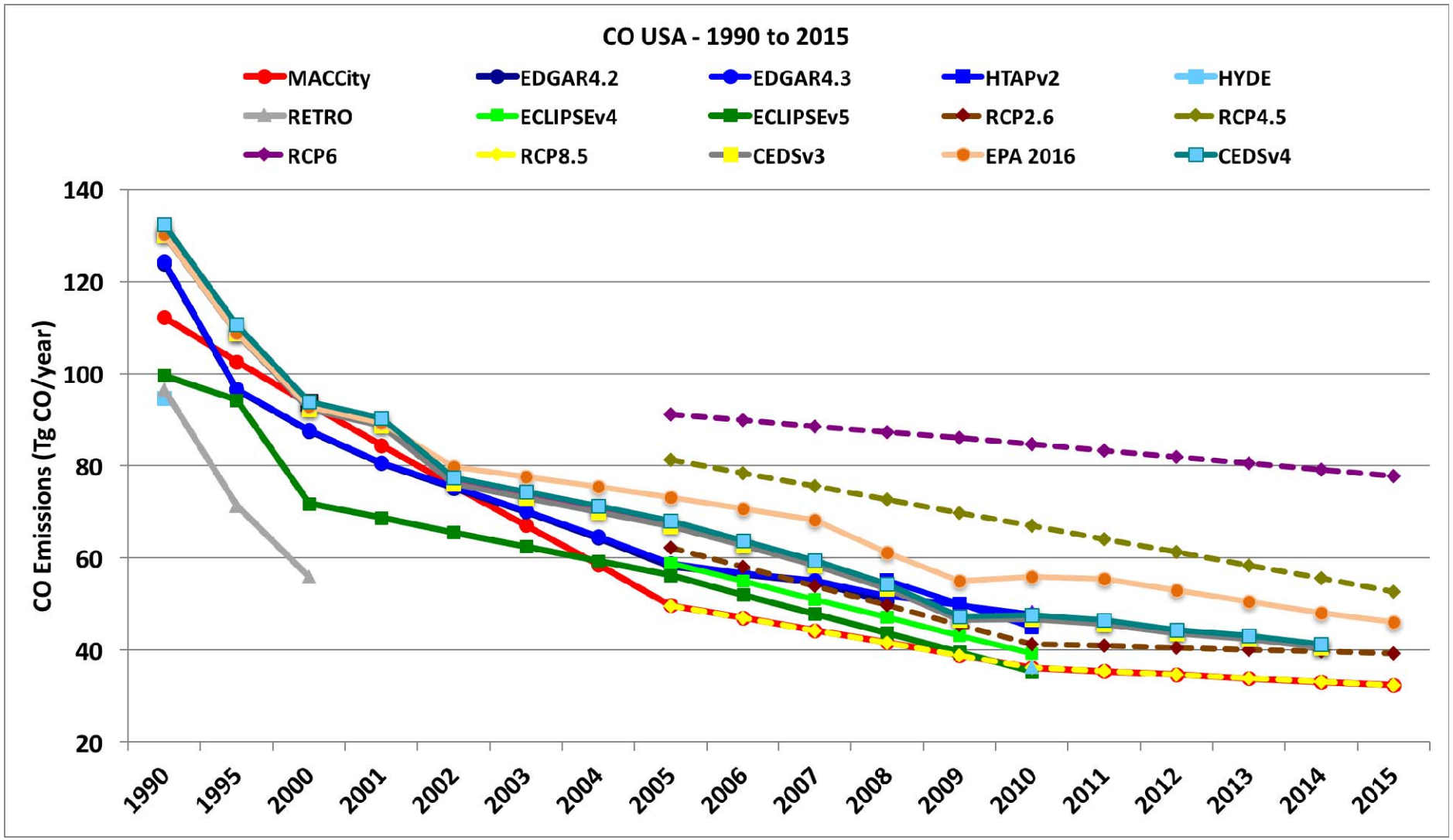
RCPs 4.5 and 8.5 are the closest to EPA emissions
(in 2005, RCP 2.6 and 6 were the closest)



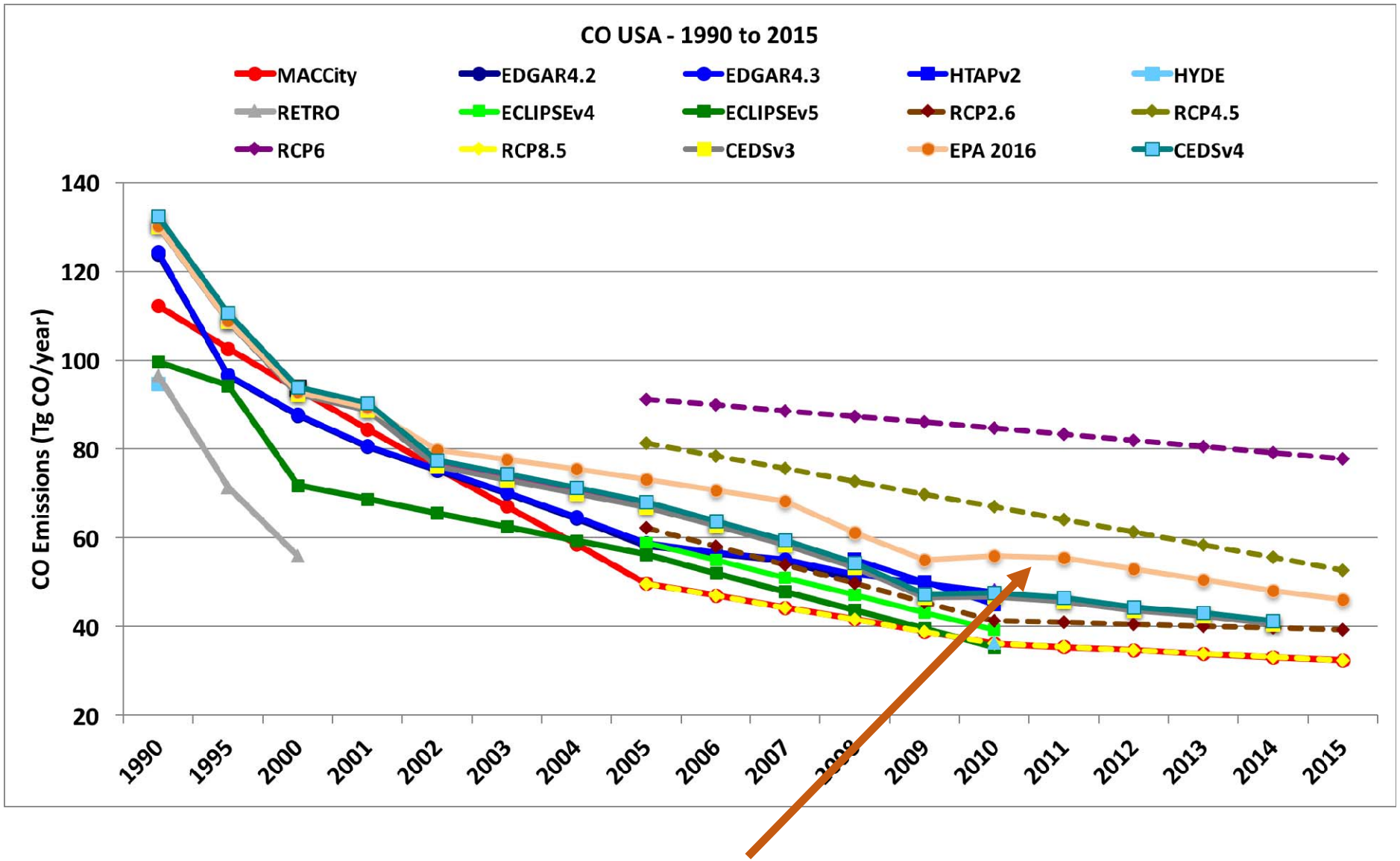
VOCs in 2015: RCPs 2.6 and 4.5 are the closest to EPA



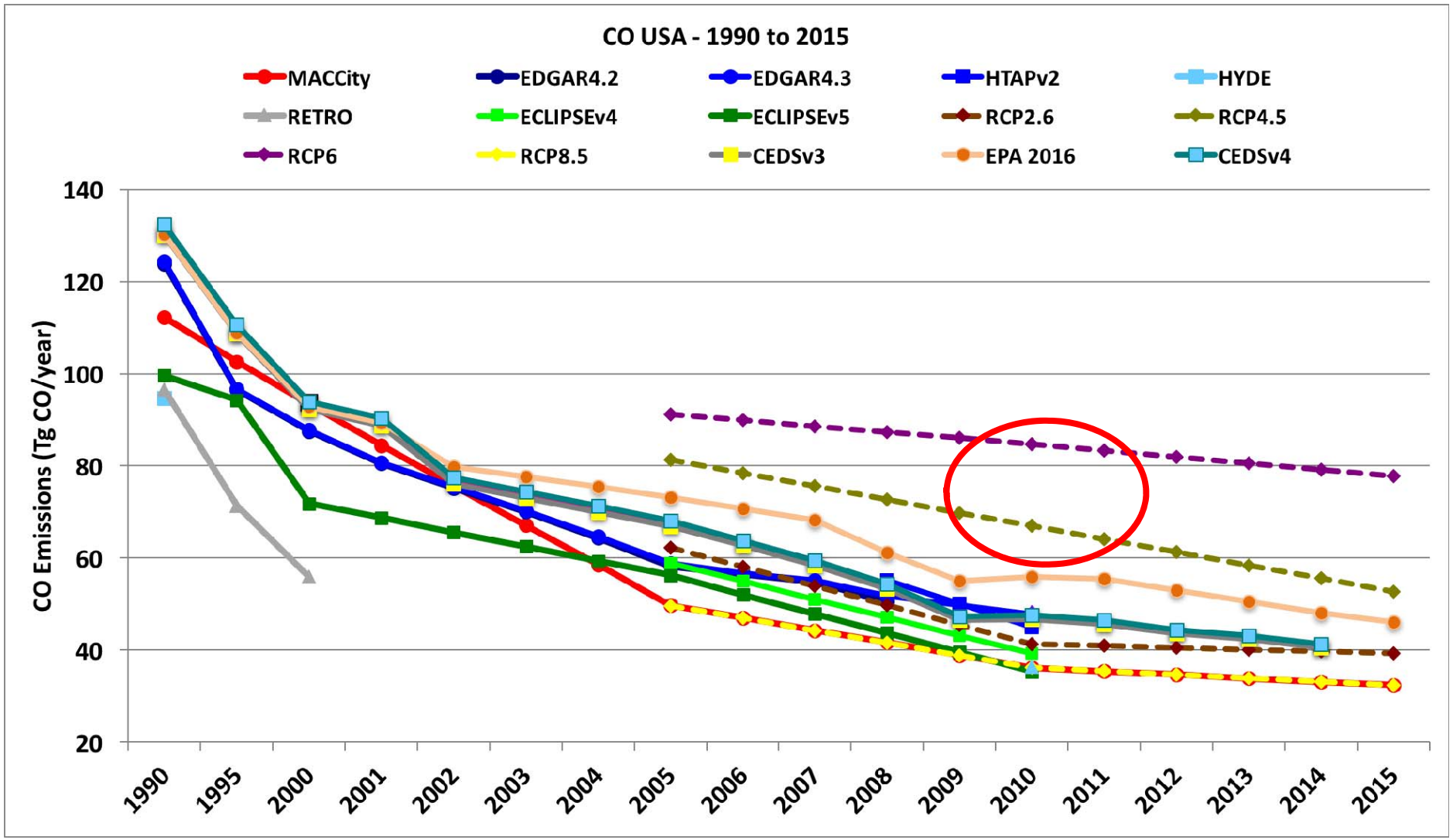
VOCs in 2015: need to make sure of the definition of energy and industry sectors. Contribution of solvents is large.



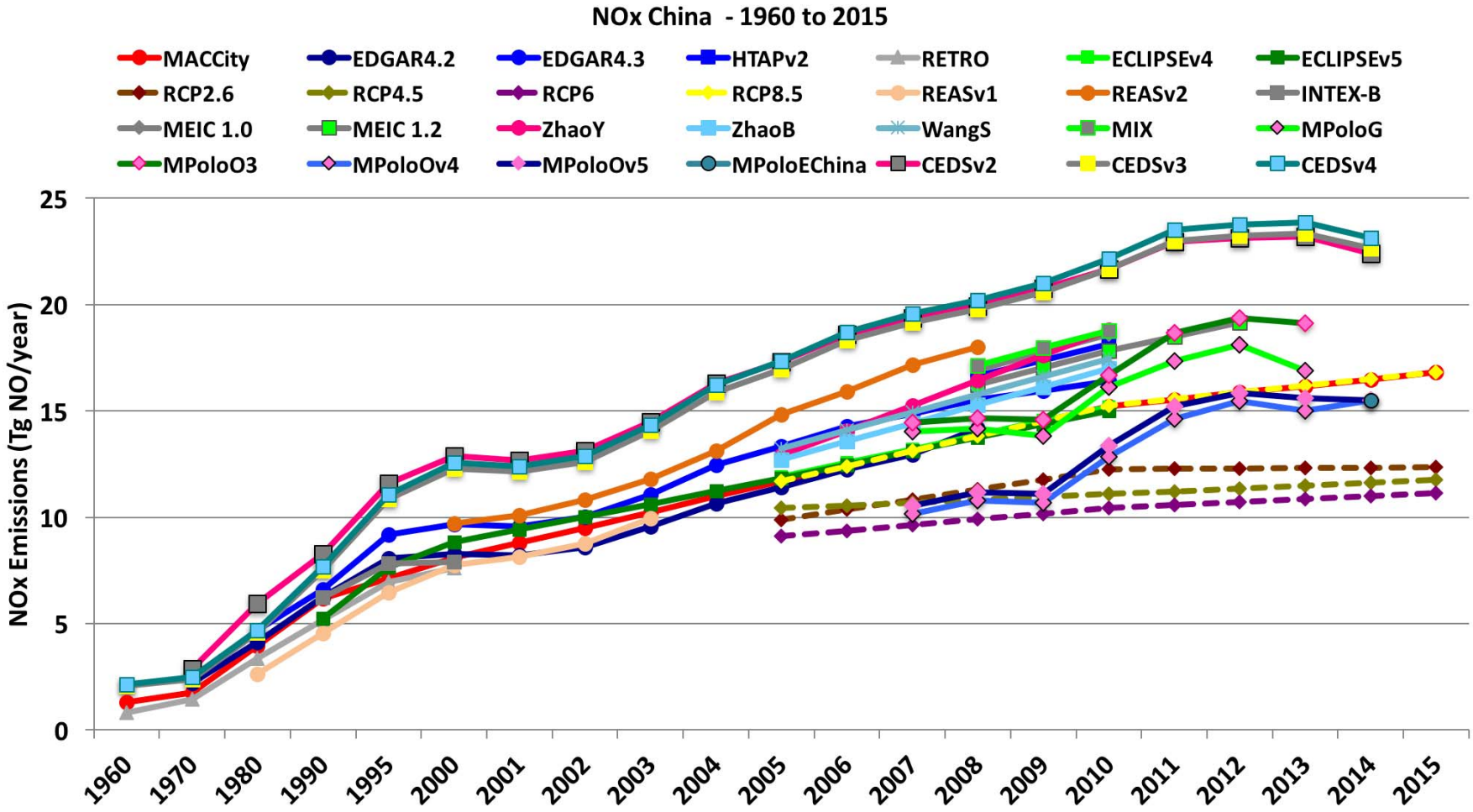
CO: CO emissions larger since 2000 than any other datasets. Needs to make sure that other inventories consider the same type of emissions.



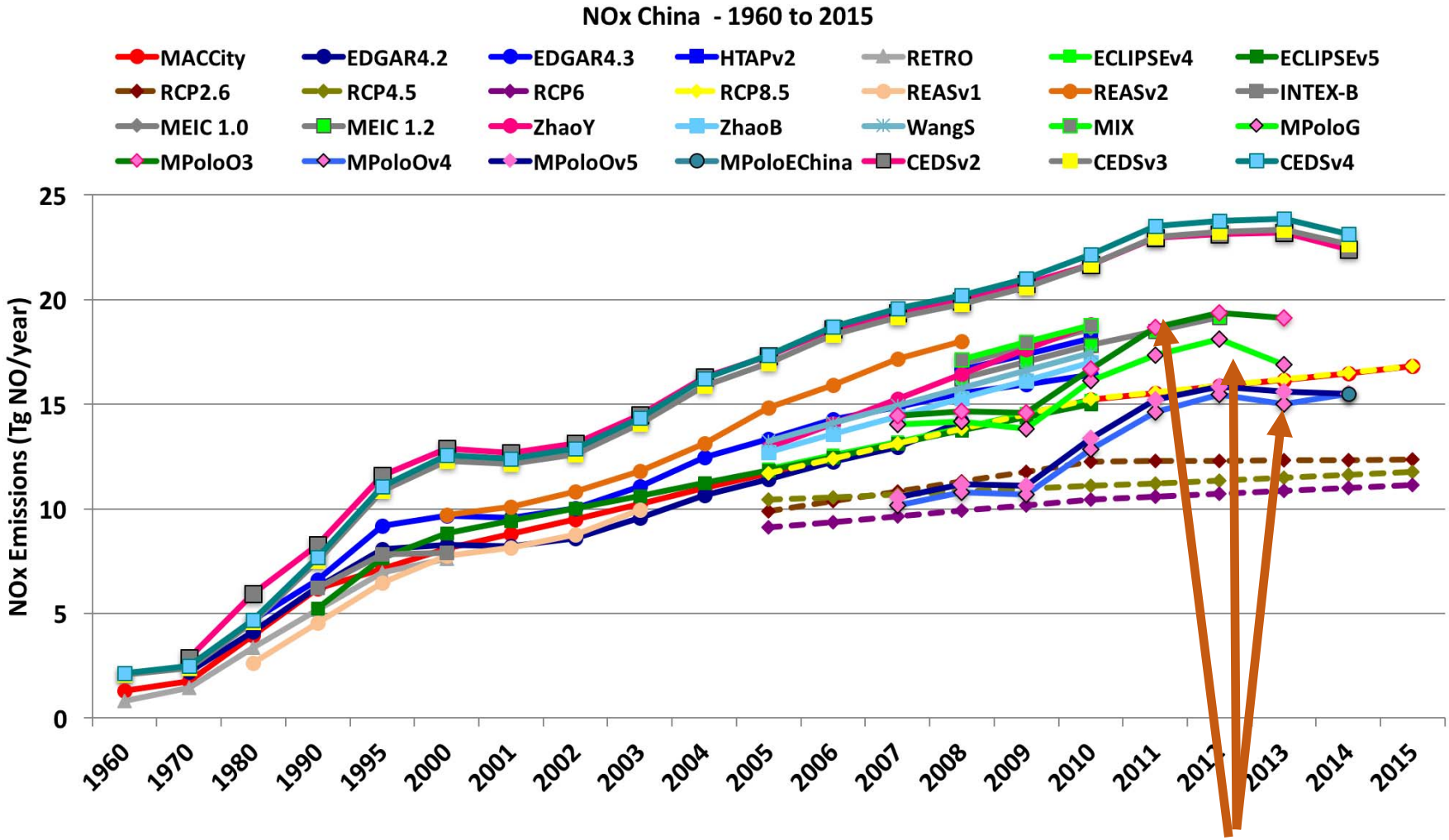
EPA CO emissions larger since 2000 than any other datasets. Needs to make sure that other inventories consider the same type of emissions.



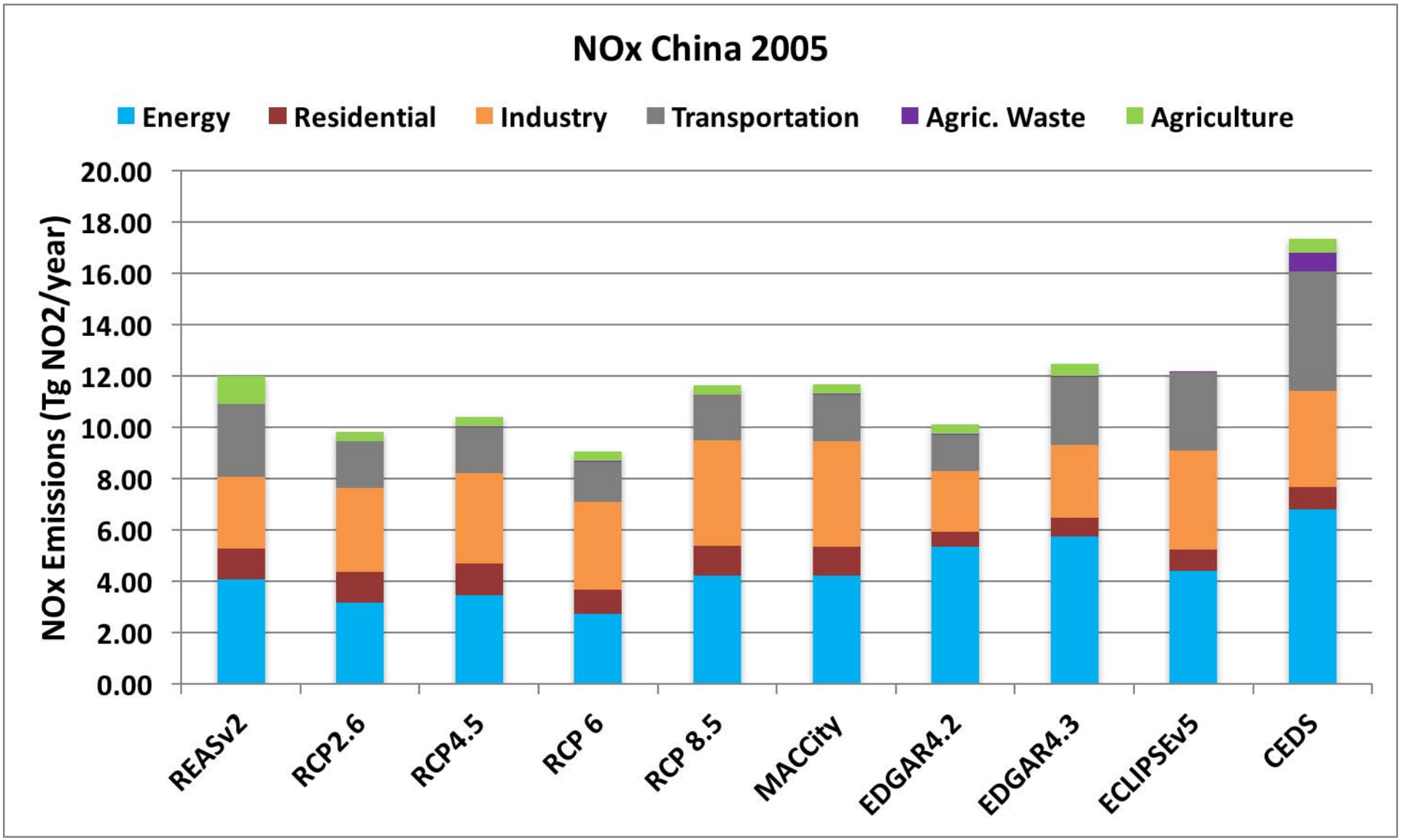
RPCs 4.5 and RCP6 provide too large emissions, when compared to oher datasets



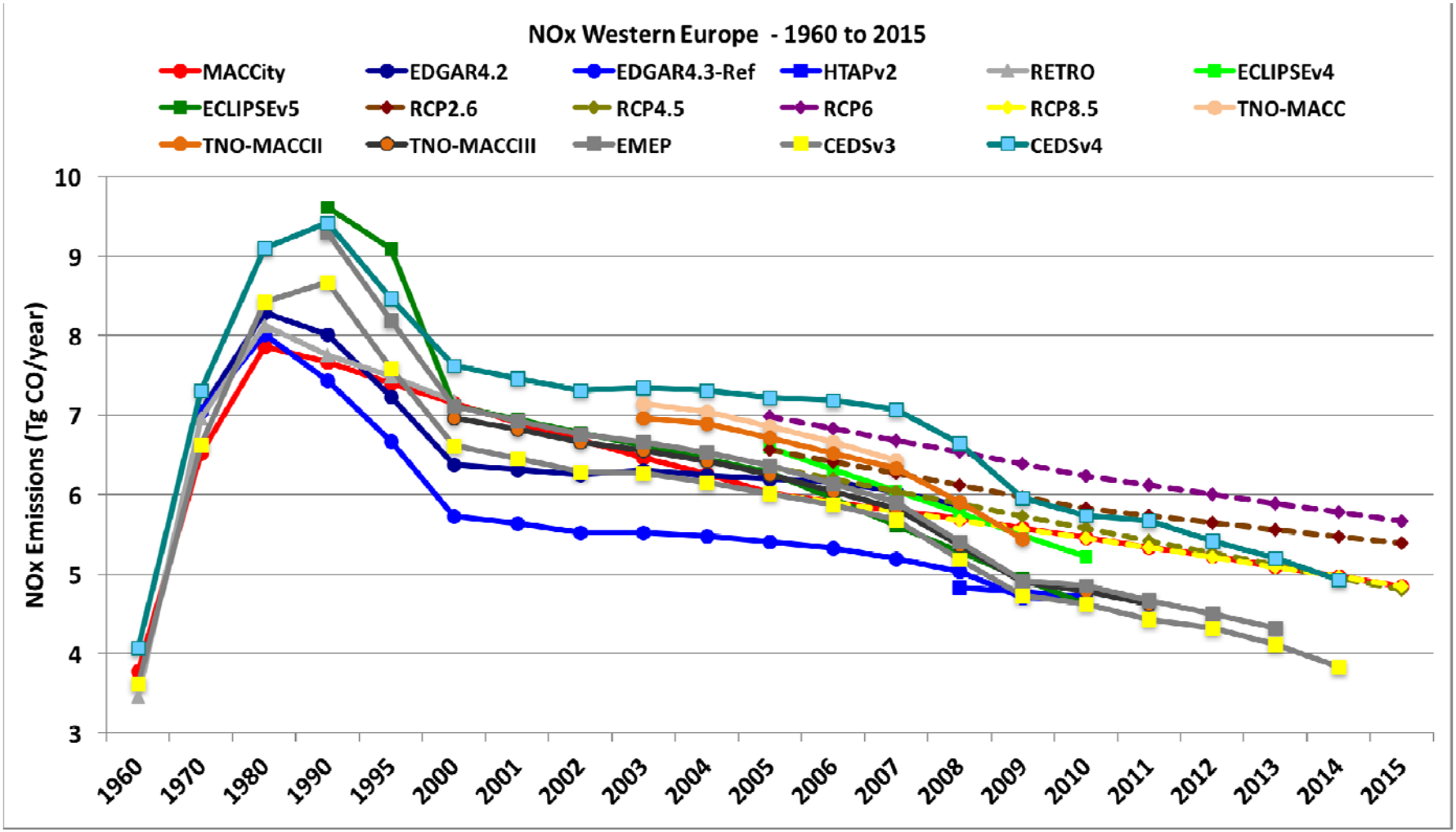
Nox emissions in China. Many datasets available, including inverse modeling using satellite data. Inverse results are satellite dependent.



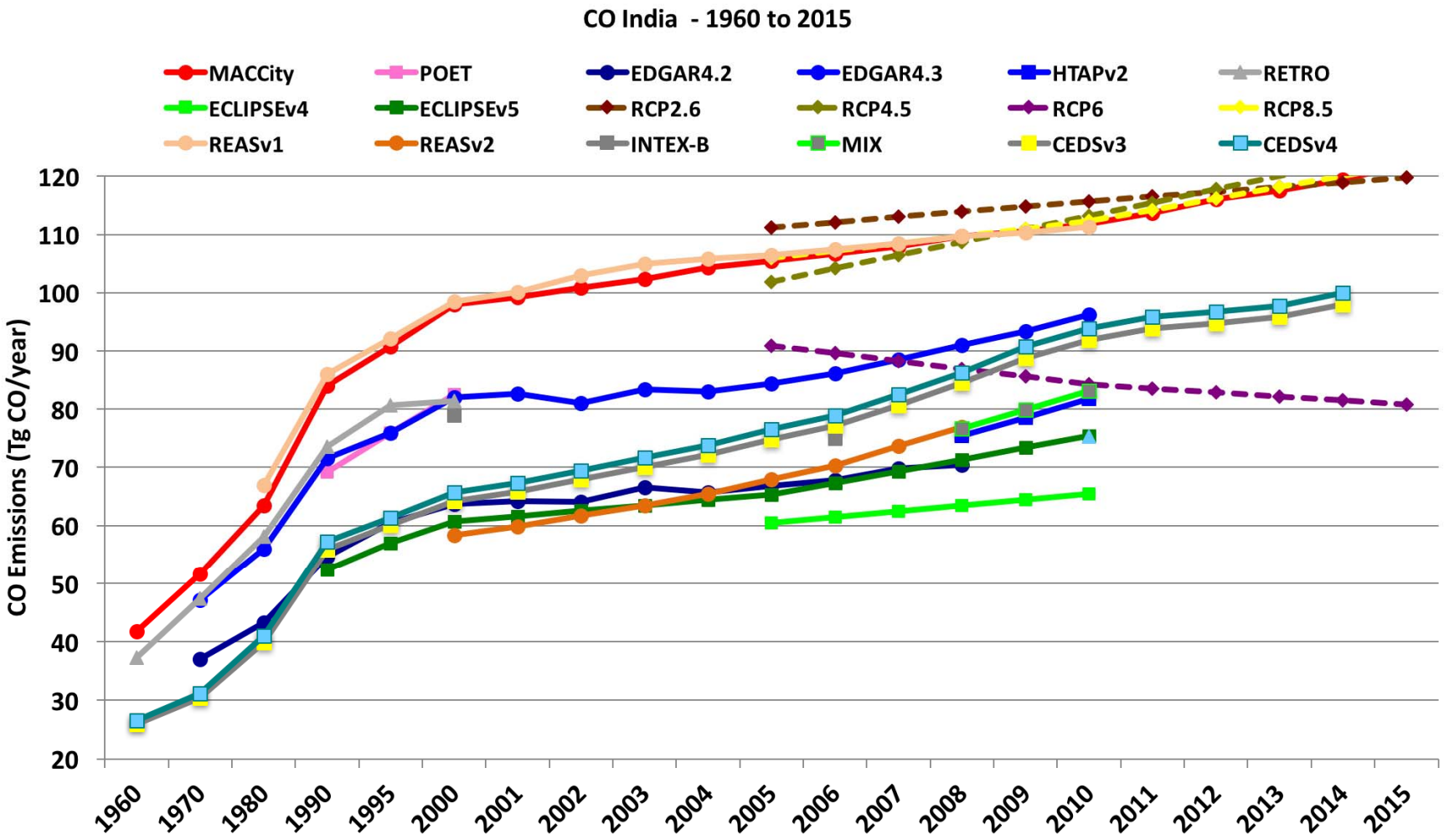
Nox emissions in China. Many datasets available, including inverse modeling using satellite data. Inverse results are satellite dependent. Inverse modelling emissions close to RCP8.5.



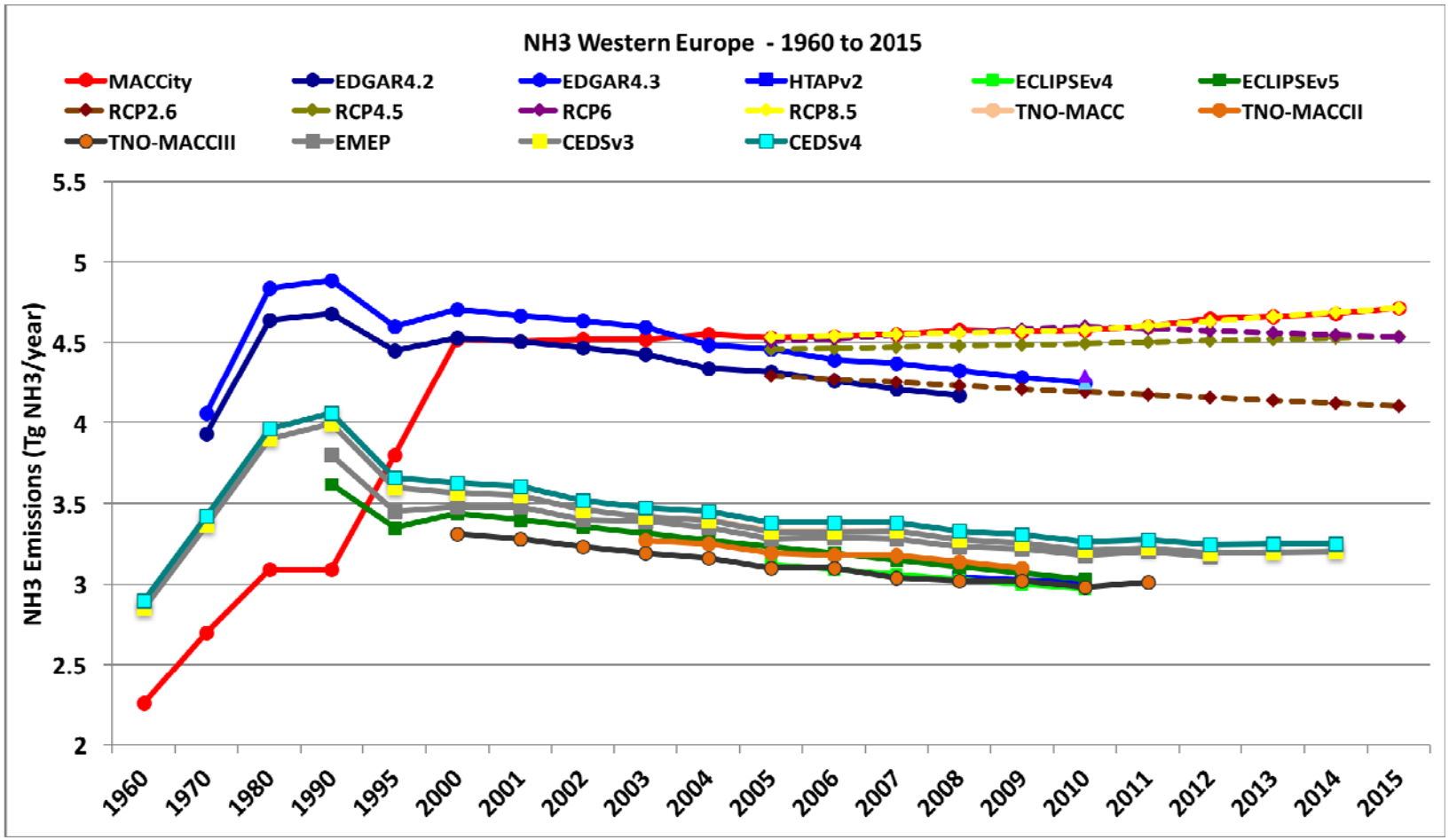
Results for China for 2005 - One regional inventory available, providing sectors



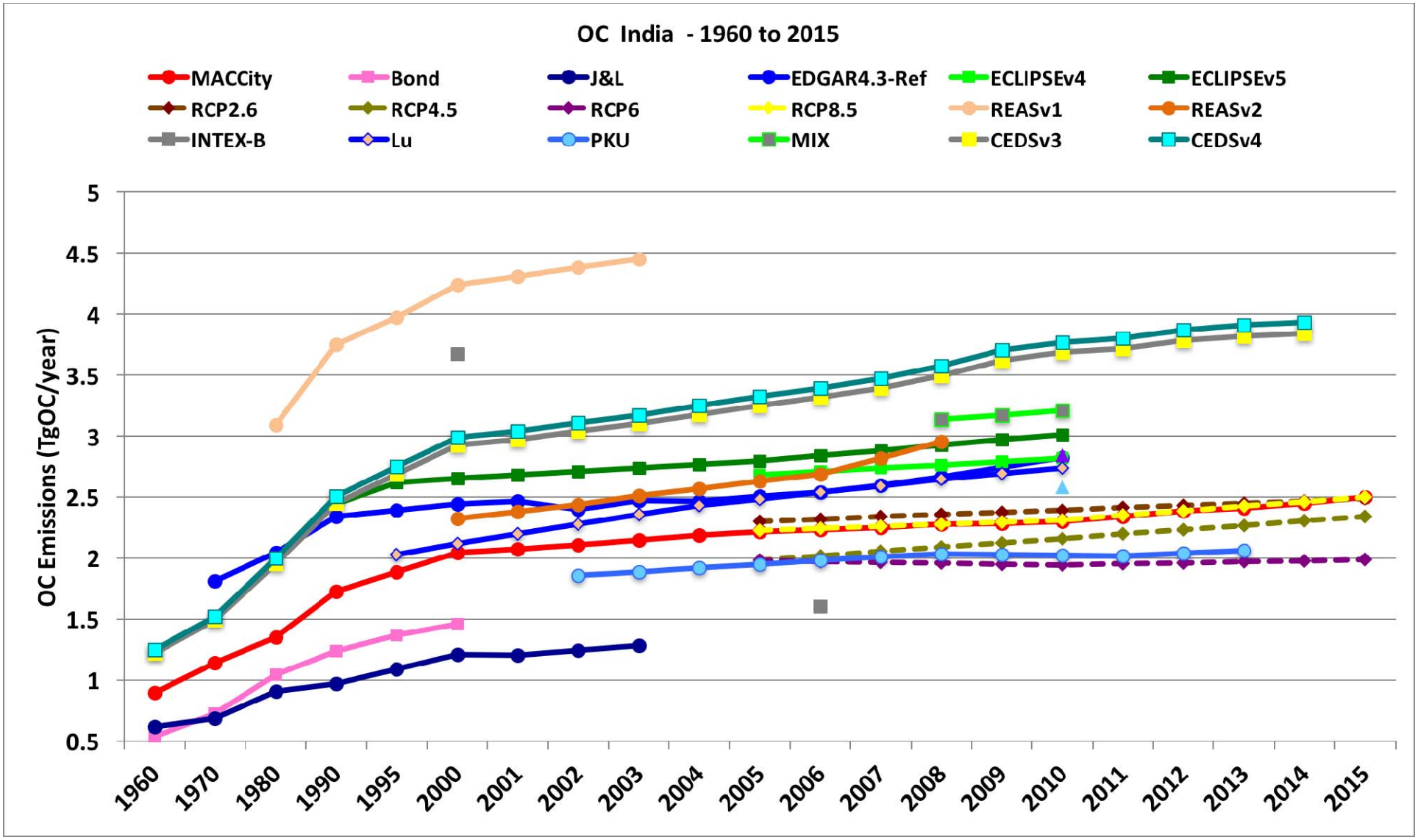
NOx emissions in Western Europe: significant differences, closer to RCP8.5 and RCP 4.5



A few more examples of large differences among datasets.
No specific inventory available for India. REASv2 is based on regional data, maybe the most accurate dataset

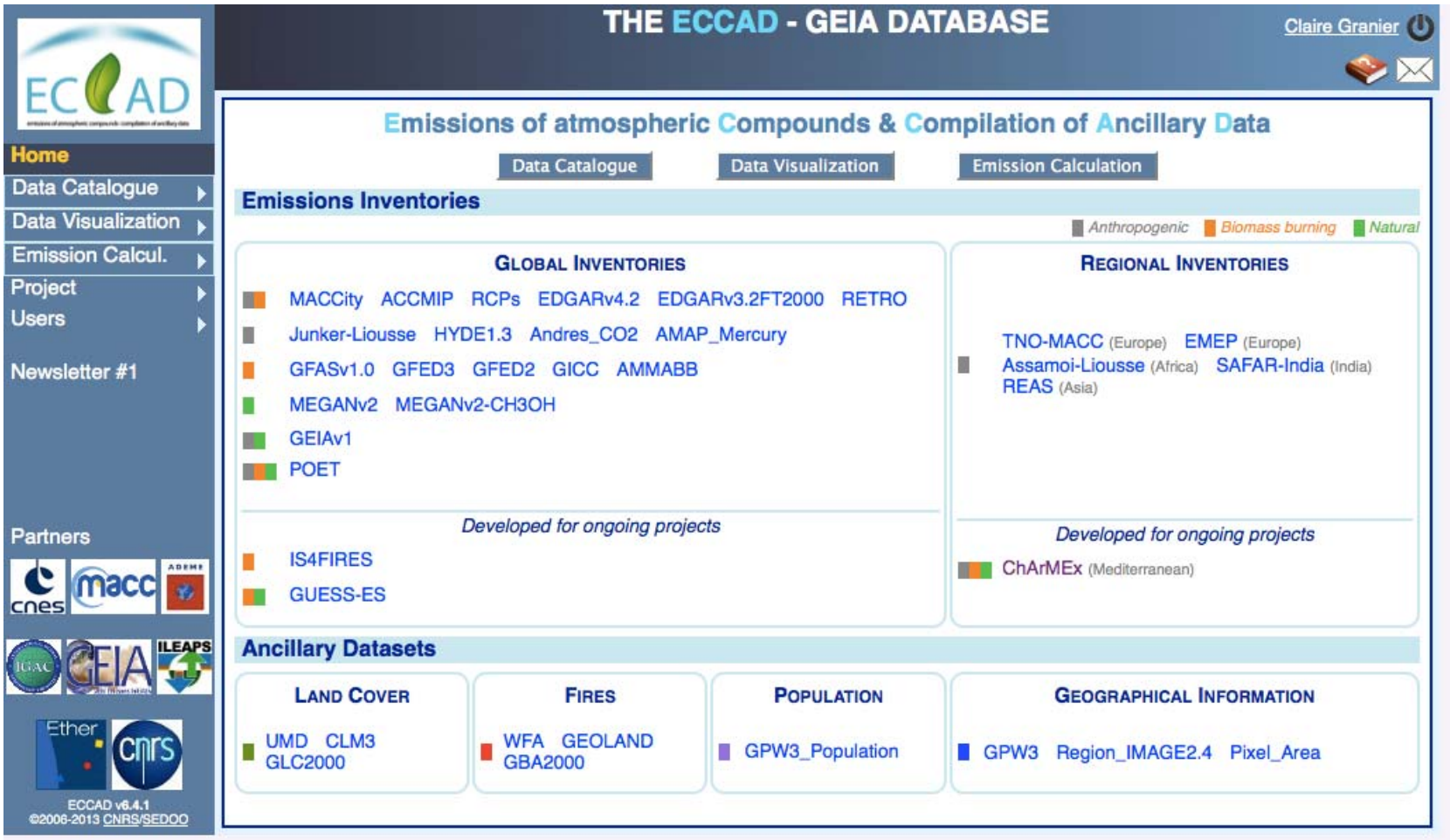


Example of emissions, where available datasets provide very different emissions. NH3 in Western Europe.


OC India - 1960 to 2015
MACCity
Bond
J&L
EDGAR4.3-Ref
ECLIPSEv4
ECLIPSEv5
RCP2.6
RCP4.5
RCP6
RCP8.5
REASv1
REASv2
INTEX-B
Lu
PKU
MIX
CEDSv3
CEDSv4
OC Emissions (TgOC/year)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
1960
1970
1980
1990
1995
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015

ECCAD = Emissions of Atmospheric Compounds and Compilation of Ancillary Data

- **http://pole-ether.fr/eccad ou eccad.sedoo.fr**
- Login : enter email + fill short form



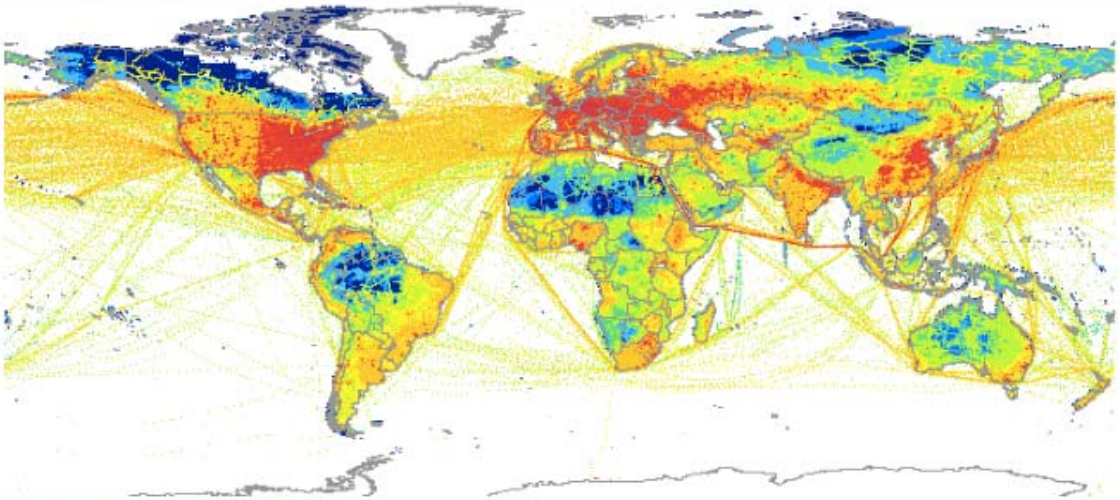
ECCAD-2 - http://eccad.aeris-data.fr/

ECCAD: Emissions of atmospheric Compounds and Compilation of Ancillary Data

Making data accessible and providing tools for data analysis

Sign in

Home | Catalogue | On-line Tools | Help



Antropogenic emmissions

About ECCAD

- Context
- Contact us
- Map of users

Last updates

Notice : ECCAD-2 is still under development. Do not hesitate to contact us if you have any problems or suggestions. The original ECCAD database is still operating at eccad.pole-ether.fr

Welcome to ECCAD - GEIA :

ECCAD database provides :

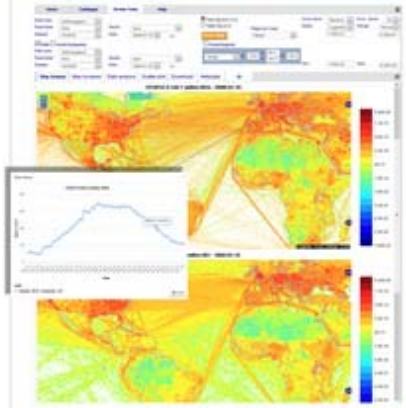
- A large number of datasets at global and regional scales, at various spatial resolution, time periodicity and temporal coverage.
- On-line data manipulation tools and statistical information over geographical regions.
- Detailed metadata for each of the datasets.
- Downloaded files as interoperable NetCDF CF-compliant files.

Get an account here

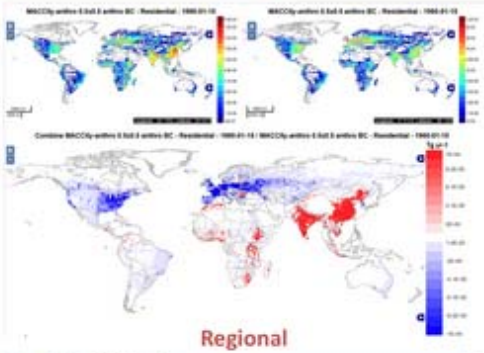
ECCAD at a glance

Catalogue & Metadata | Species | Temporal | Emissions Time Series | Inventory Time Series

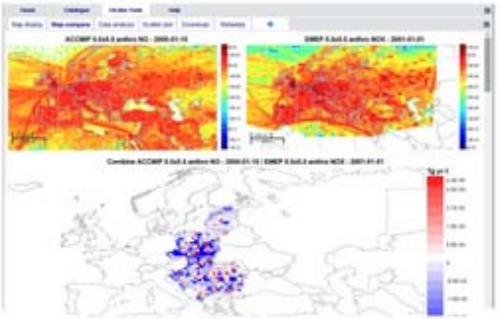
Display | Map Compare | Data Analysis | Scatter Plot

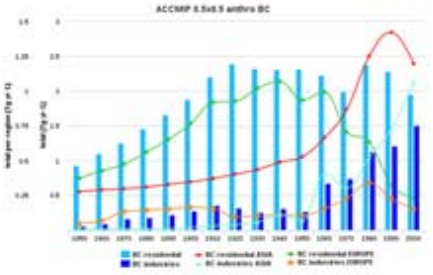


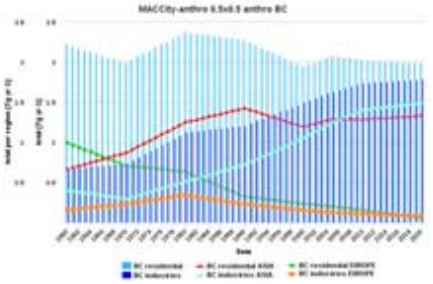
Regional totals

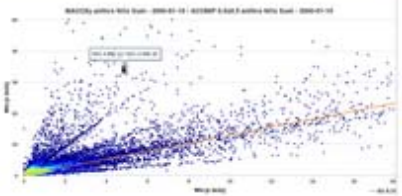


Regional

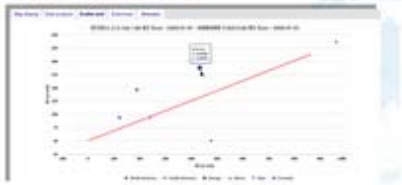








Regional



biomass burning · anthropogenic · biogenic · oceanic · lightning · volcanic

MAJOR SPECIES

Species	CH4	N2O	CO2	NOx	SO2	CO	DMS	NH4	NH3	H2	OC	TC	TPM	PM10	PM2.5	BC
Molecular Mass	16	44	44	30	64	28	62	17	17	2	12	12	1	1	1	12
MACCity-bb		●		●	●	●	●	●			●					
MACCity-anthro				●	●	●	●	●			●					
ACCMIP	●	●●		●●	●●	●●	●●	●●			●●					
RCPs		●●		●●	●●	●●	●●	●●			●●					
HTAPv2				●	●	●	●	●			●	●	●			
EDGARv4.2	●	●●	●●	●●	●●	●●					●●		●●			
CEDS				●	●	●	●	●			●					
ECLIPSE-GAINS-V5a		●		●	●	●	●	●			●	●	●			
ECLIPSE-GAINS-4a		●		●	●	●	●	●			●	●	●			
RETRO	●	●	●	●●● ●	●●	●	●	●			●	●		●	●●● ●	
Junker-Liousse							●	●								
Andres-CO2-v2016	●															
HYDE1.3	●	●	●	●	●	●					●					

ECCAD: Emissions of atmospheric Compounds and Compilation of Ancillary Data

Making data accessible and providing tools for data analysis

Sign out

Claire

Home | Catalogue | On-line Tools | Help

Data type: Anthropogenic
Parameter: CO
Dataset: MACCity
Reset | Compare datasets

Sector: Sum
Date: 1960-01-15

flux (kg m-2 s-1)
total (Tg yr-1)

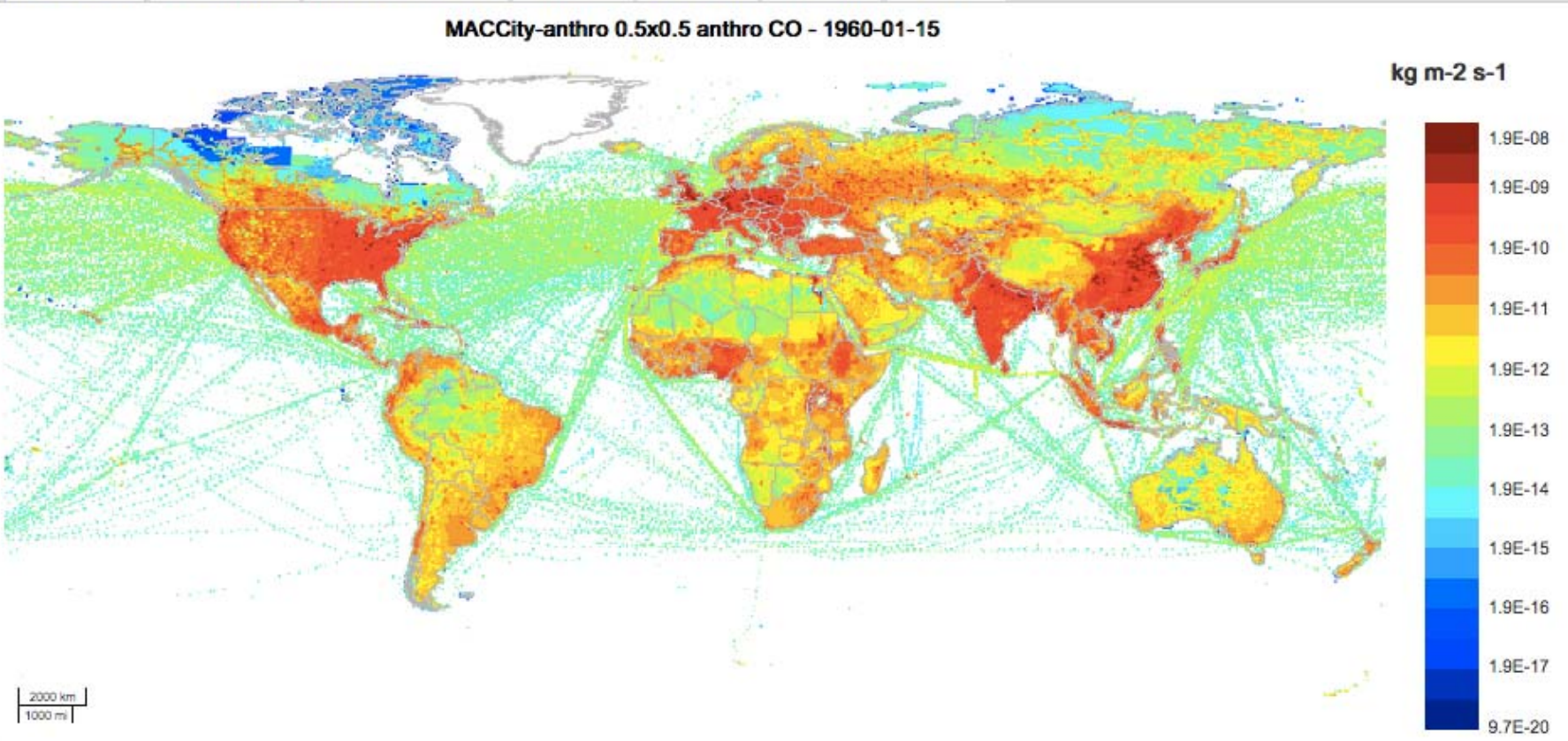
Draw Map

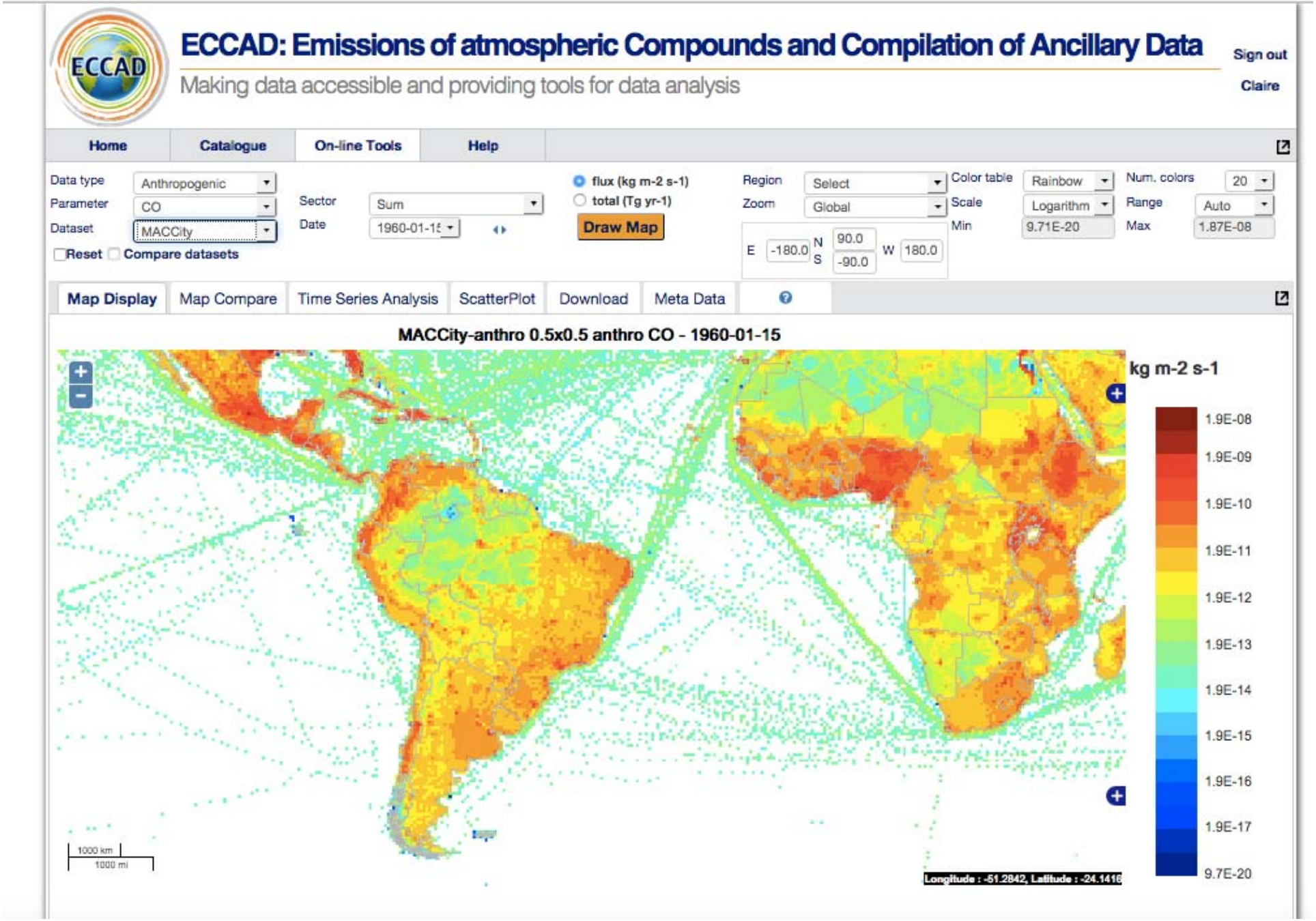
Region: Select
Zoom: Global
E -180.0 N 90.0 S -90.0 W 180.0

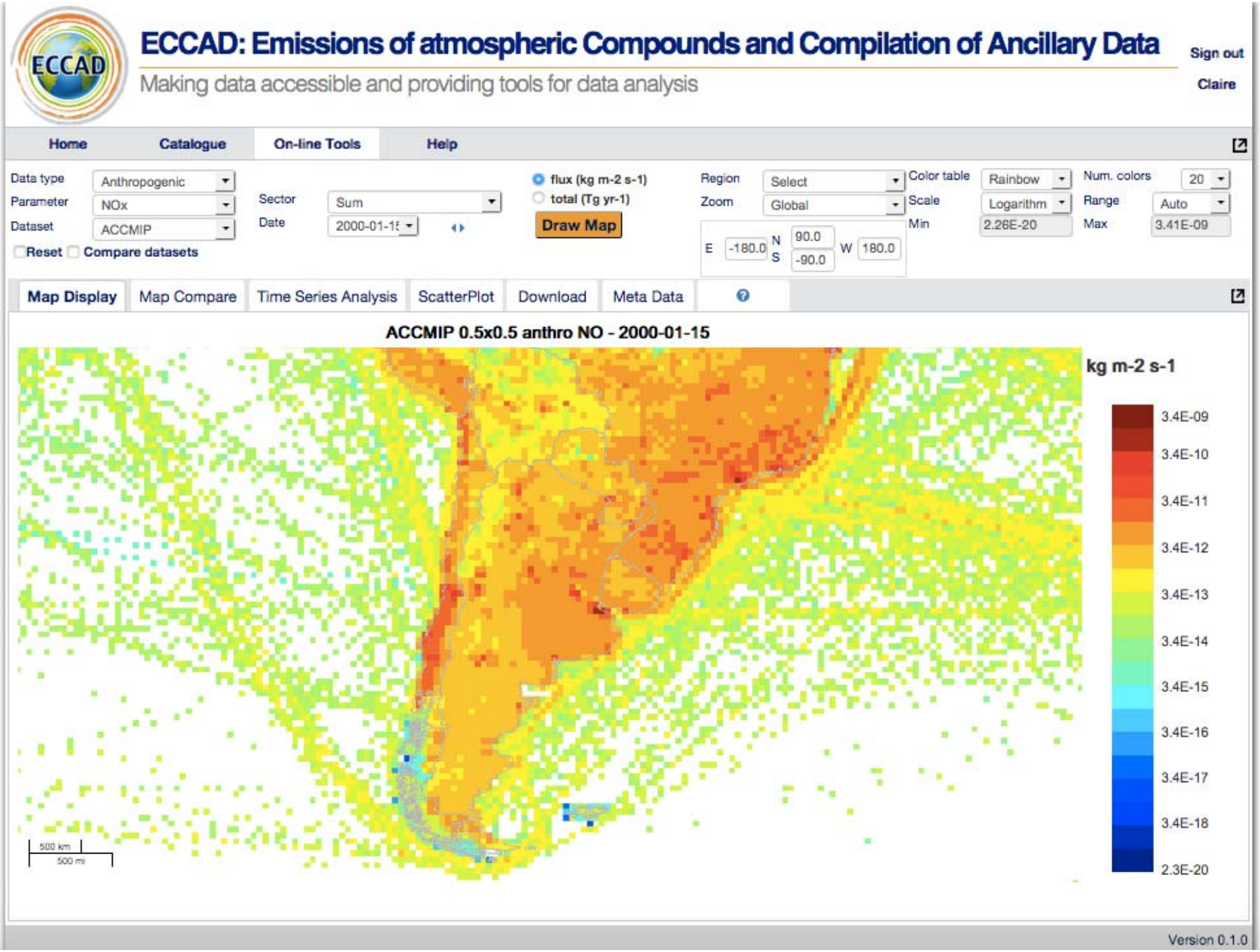
Color table: Rainbow
Scale: Logarithm
Min: 9.71E-20

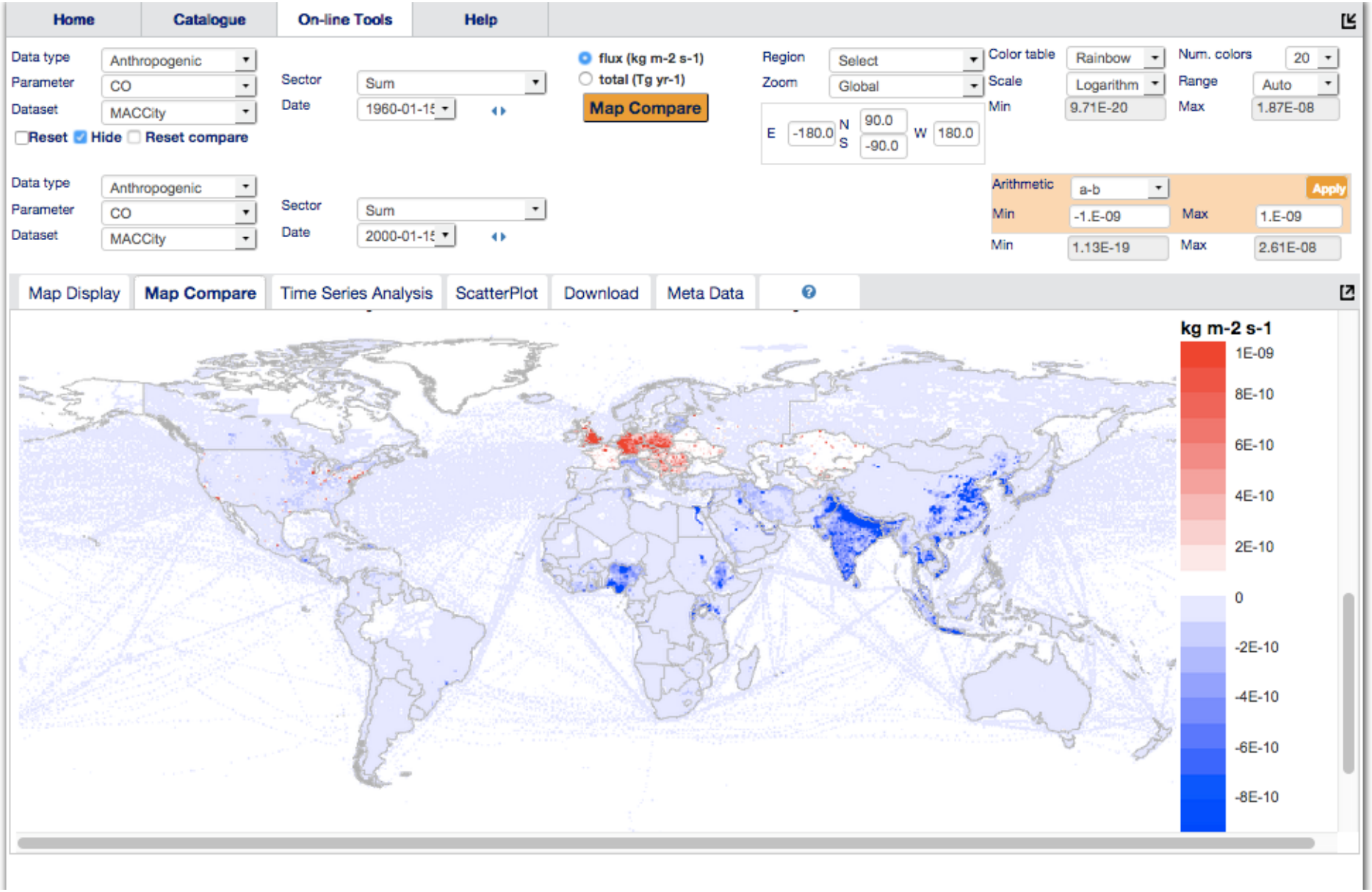
Num. colors: 20
Range: Auto
Max: 1.87E-08

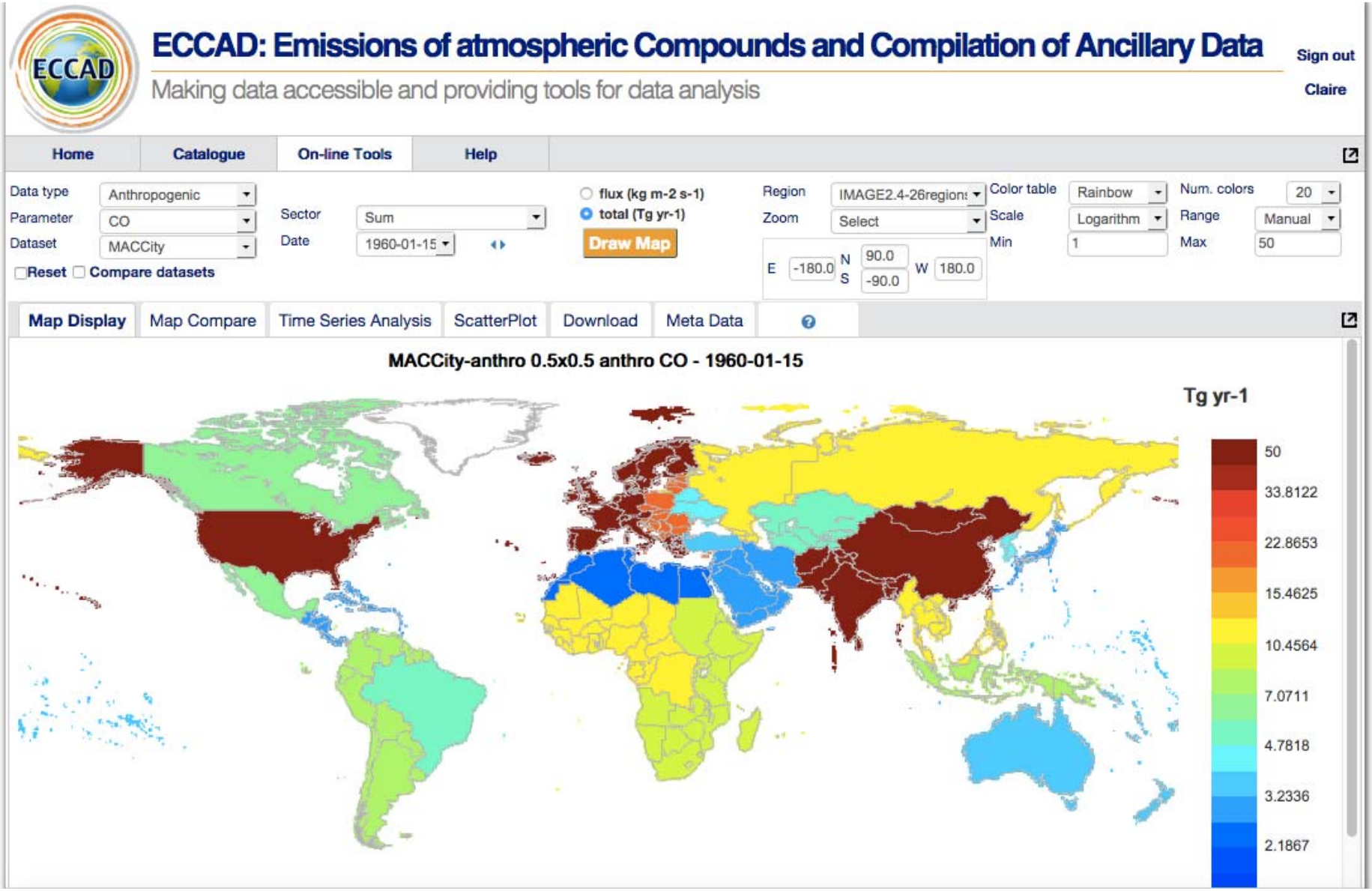
Map Display | Map Compare | Time Series Analysis | ScatterPlot | Download | Meta Data



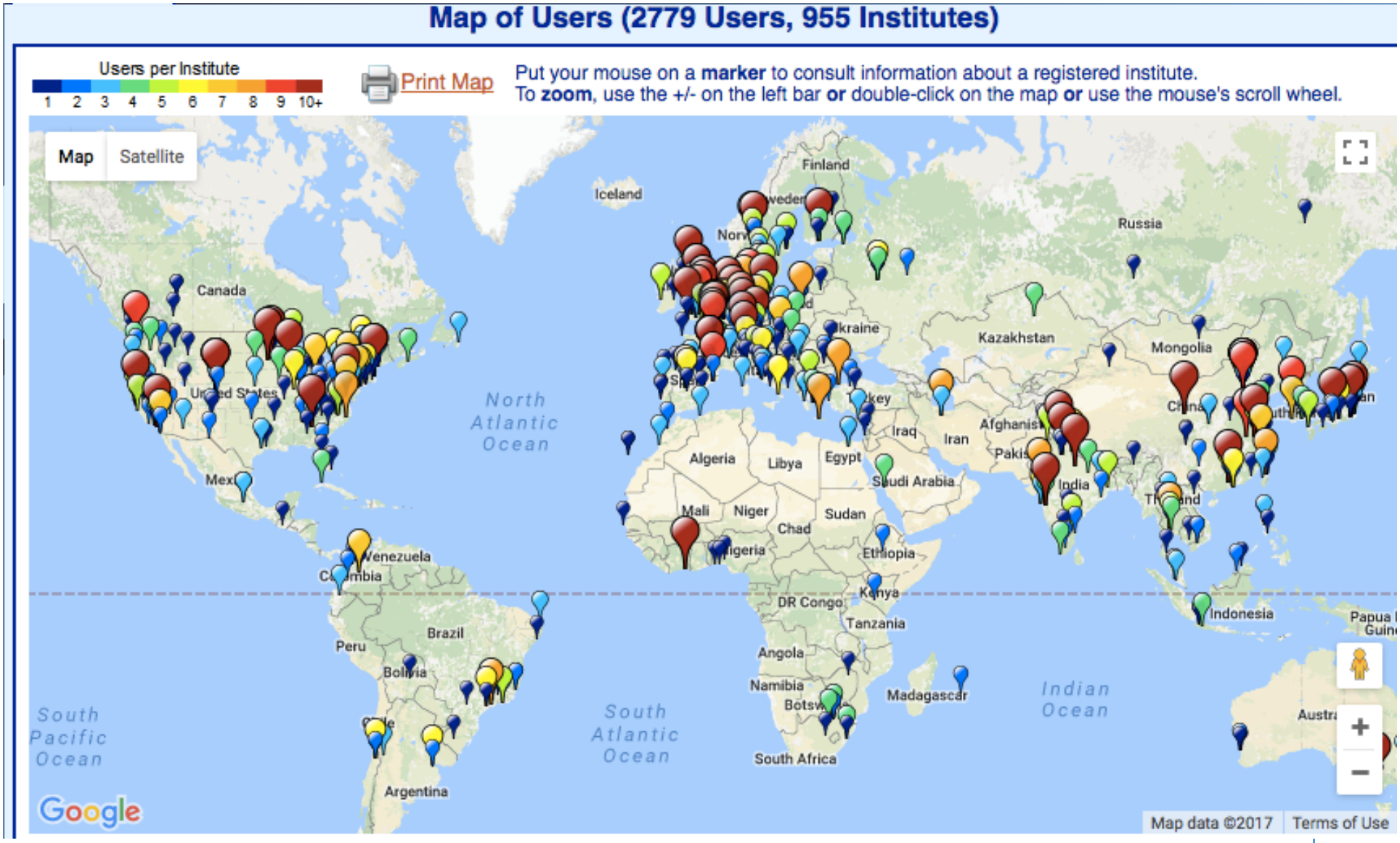

ECCAD: Emissions of atmospheric Compounds and Compilation of Ancillary Data
Making data accessible and providing tools for data analysis
Sign out
Claire
Home
Catalogue
On-line Tools
Help
Data type
Anthropogenic
Parameter
CO
Dataset
MACCity
Reset
Compare datasets
Sector
Sum
Date
1960-01-15
flux (kg m-2 s-1)
total (Tg yr-1)
Draw Map
Region
Select
Zoom
Global
E
-180.0
N
90.0
S
-90.0
W
180.0
Color table
Rainbow
Scale
Logarithm
Min
9.71E-20
Num. colors
20
Range
Auto
Max
1.87E-08
Map Display
Map Compare
Time Series Analysis
ScatterPlot
Download
Meta Data
MACCity-anthro 0.5x0.5 anthro CO - 1960-01-15
kg m-2 s-1
1.9E-08
1.9E-09
1.9E-10
1.9E-11
1.9E-12
1.9E-13
1.9E-14
1.9E-15
1.9E-16
1.9E-17
9.7E-20
1000 km
1000 mi
Longitude : -51.2842, Latitude : -24.1416


ECCAD: Emissions of atmospheric Compounds and Compilation of Ancillary Data
Making data accessible and providing tools for data analysis
Sign out
Claire
Home
Catalogue
On-line Tools
Help
Data type
Anthropogenic
Parameter
NOx
Dataset
ACCMIP
Reset
Compare datasets
Sector
Sum
Date
2000-01-15
flux (kg m-2 s-1)
total (Tg yr-1)
Draw Map
Region
Select
Zoom
Global
E
-180.0
N
90.0
S
-90.0
W
180.0
Color table
Rainbow
Scale
Logarithm
Min
2.26E-20
Num. colors
20
Range
Auto
Max
3.41E-09
Map Display
Map Compare
Time Series Analysis
ScatterPlot
Download
Meta Data
ACCMIP 0.5x0.5 anthro NO - 2000-01-15
kg m-2 s-1
3.4E-09
3.4E-10
3.4E-11
3.4E-12
3.4E-13
3.4E-14
3.4E-15
3.4E-16
3.4E-17
3.4E-18
2.3E-20
500 km
500 mi
Version 0.1.0


Home
Catalogue
On-line Tools
Help
Data type
Anthropogenic
Parameter
CO
Dataset
MACCity
Reset
Hide
Reset compare
Sector
Sum
Date
1960-01-15
flux (kg m-2 s-1)
total (Tg yr-1)
Map Compare
Region
Select
Zoom
Global
E
-180.0
N
90.0
S
-90.0
W
180.0
Color table
Rainbow
Scale
Logarithm
Min
9.71E-20
Num. colors
20
Range
Auto
Max
1.87E-08
Data type
Anthropogenic
Parameter
CO
Dataset
MACCity
Sector
Sum
Date
2000-01-15
Arithmetic
a-b
Apply
Min
-1.E-09
Max
1.E-09
Min
1.13E-19
Max
2.61E-08
Map Display
Map Compare
Time Series Analysis
ScatterPlot
Download
Meta Data
kg m-2 s-1
1E-09
8E-10
6E-10
4E-10
2E-10
0
-2E-10
-4E-10
-6E-10
-8E-10


ECCAD: Emissions of atmospheric Compounds and Compilation of Ancillary Data
Making data accessible and providing tools for data analysis
Sign out
Claire
Home
Catalogue
On-line Tools
Help
Data type
Anthropogenic
Parameter
CO
Dataset
MACCity
Reset
Compare datasets
Sector
Sum
Date
1960-01-15
flux (kg m-2 s-1)
total (Tg yr-1)
Draw Map
Region
IMAGE2.4-26regions
Zoom
Select
E
-180.0
N
90.0
S
-90.0
W
180.0
Color table
Rainbow
Scale
Logarithm
Min
1
Num. colors
20
Range
Manual
Max
50
Map Display
Map Compare
Time Series Analysis
ScatterPlot
Download
Meta Data
MACCity-anthro 0.5x0.5 anthro CO - 1960-01-15
Tg yr-1
50
33.8122
22.8653
15.4625
10.4564
7.0711
4.7818
3.2336
2.1867

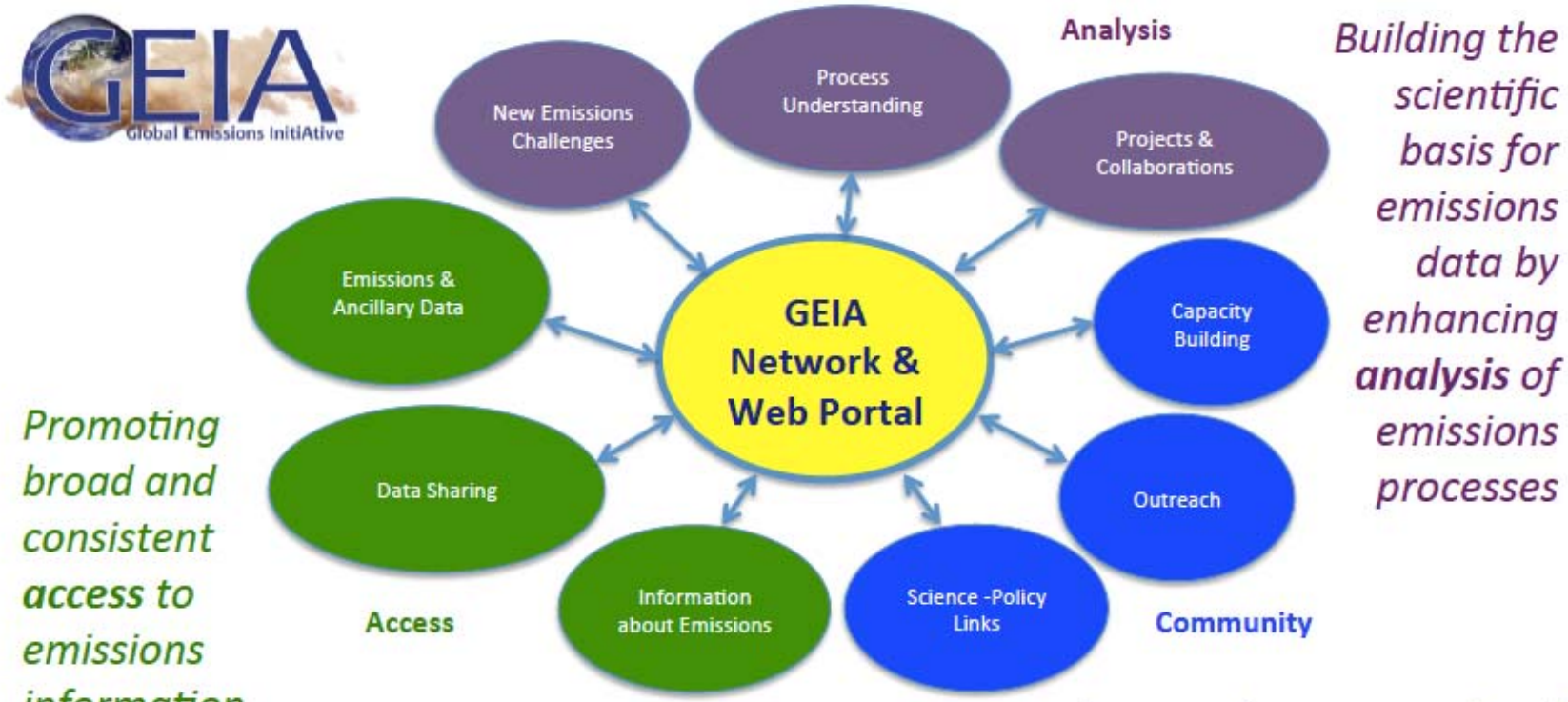
ECCAD users : 2779 users from 955 institutes



GEIA = Global Emissions Initiative

GEIA Vision

By 2020, **GEIA** will be a key forum for emissions knowledge that serves stakeholders and decision-makers in a rapidly evolving global society.



*Building the scientific basis for emissions data by enhancing **analysis** of emissions processes*

*Promoting broad and consistent **access** to emissions information*

*Strengthening the **community** of emissions stakeholder groups*

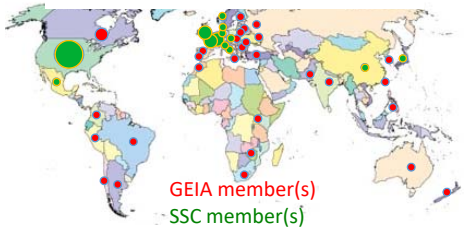
http://www.geiacenter.org/

International Emissions Efforts

www.geiacenter.org

Community
Strengthening the emissions community by connecting developers and users

2000 people worldwide

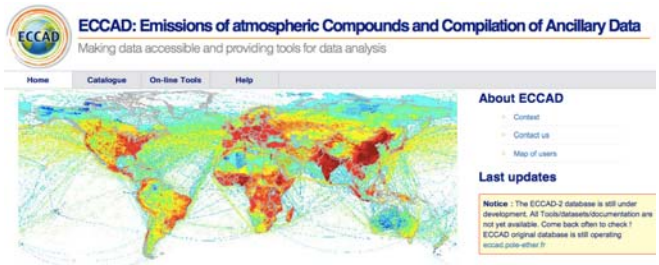


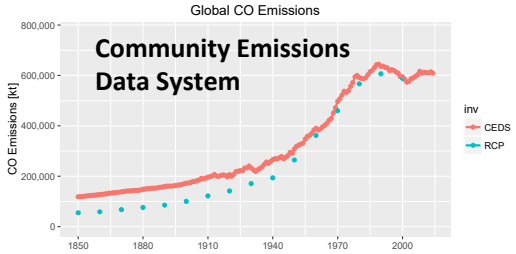
GEIA Global Emissions InitiAtive

IGAC ileaps AIMES

ccmi TOAR tropospheric ozone assessment report

Access
Creating easier, more open access to emissions data and information





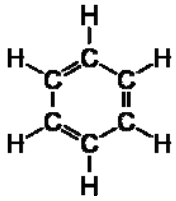
www.globalchange.umd.edu/ceds/

Analysis
Identifying priorities, facilitating research, and synthesizing findings to improve the scientific basis of emissions

China Working Group

Latin America/ Caribbean WG

VOC WG



Assessing Emissions Quantification using Inverse Modeling
(joint with IGAC)

18th GEIA Conference

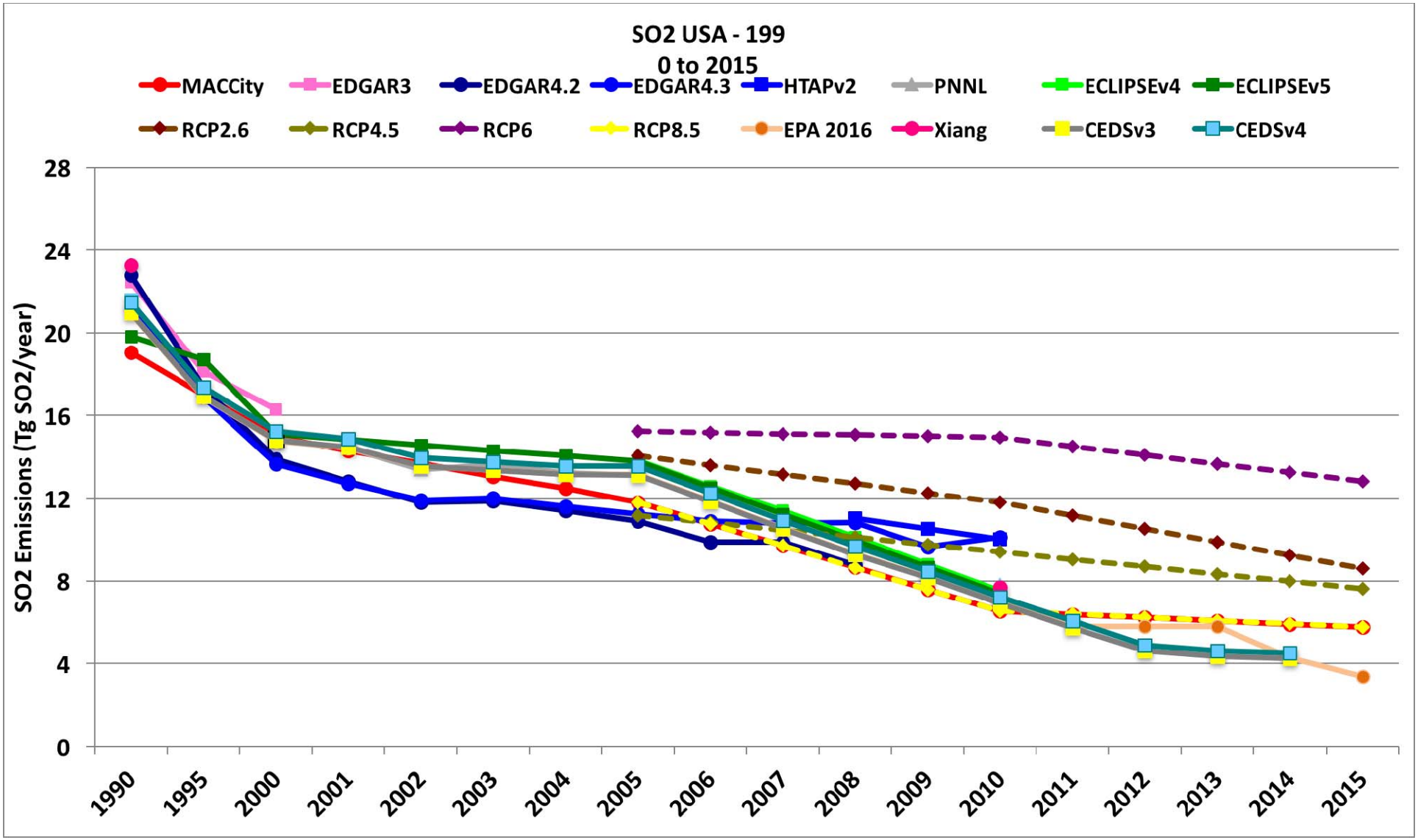
Emissions Science for a Healthy Environment

The interplay of human versus natural influences on climate and air quality emissions

13-15 September 2017
University of Hamburg
Hamburg, Germany

See www.geiacenter.org for more details

Thank you for your attention


SO2 USA - 199
0 to 2015
MACCity
EDGAR3
EDGAR4.2
EDGAR4.3
HTAPv2
PNNL
ECLIPSEv4
ECLIPSEv5
RCP2.6
RCP4.5
RCP6
RCP8.5
EPA 2016
Xiang
CEDSv3
CEDSv4
SO2 Emissions (Tg SO2/year)
28
24
20
16
12
8
4
0
1990
1995
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015