Past/current anthropogenic emissions (1900-2000)

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Outline

1. Introduction
2. Inventory construction
3. Selection of present day emissions
4. Selection of historical emissions
5. Trends
6. Inventories on different scales
7. Issues

Anthropogenic emission sources and relative contribution to global emissions

	CO2	CH4	N2O	NOx	CO	NMVOC	SO2	BC	OC
Fossil fuel combustion	>30	<5	5-10	>30	10-30	10-30	>30	>30	5-10
Fossil fuel production	<5	10-30	-	-	-	10-30	-	-	-
Biofuel combustion	10-30	5-10	<5	5-10	10-30	10-30	<5	10-30	10-30
Industrial processes	<5	<5	10-30	5-10	<5	>30	10-30	-	-
Agricultural land	-	10-30	>30	10-30	-	-	-	-	-
Animals	-	10-30	>30	-	-	-	-	-	-
Savannah burning	-	<5	<5	5-10	10-30	5-10	-	10-30	>30
Deforestation	5-10	<5	<5	5-10	10-30	<5	-	10-30	>30
Agricultural waste burning	-	<5	<5	5-10	10-30	5-10	<5	5-10	5-10
Landfills	-	10-30	-	-	-	-	-	-	-

Source: Olivier et al. (1996) and Van Aardenne et al. (2001) except for BC/OC taken from Bond et al. (2004)

Not practical possible to monitor each individual emission source:

Emission factor approach is adopted:

$$E_i = A_i (EF)_i P_{1i}, P_{2i} \ldots\ldots$$

Structure

- selected source categories
- spatial scale
- temporal scale
- equations to calculate emissions

Input data

- emission factors
- activity data
- speciation (NMVOC)

EI: source categories

Energy
Industry
-Power generation
-Other transformation sector
-Residential, commercial, other
-Road transport
-Non-road transport
-Air transport
-International shipping
-Coal production
-Oil production
-Gas production

Industrial processes

-Iron and steel
-Non-Ferro
-Chemical industry
-Building materials
-Food
-Solvents
-Misc.

Agriculture

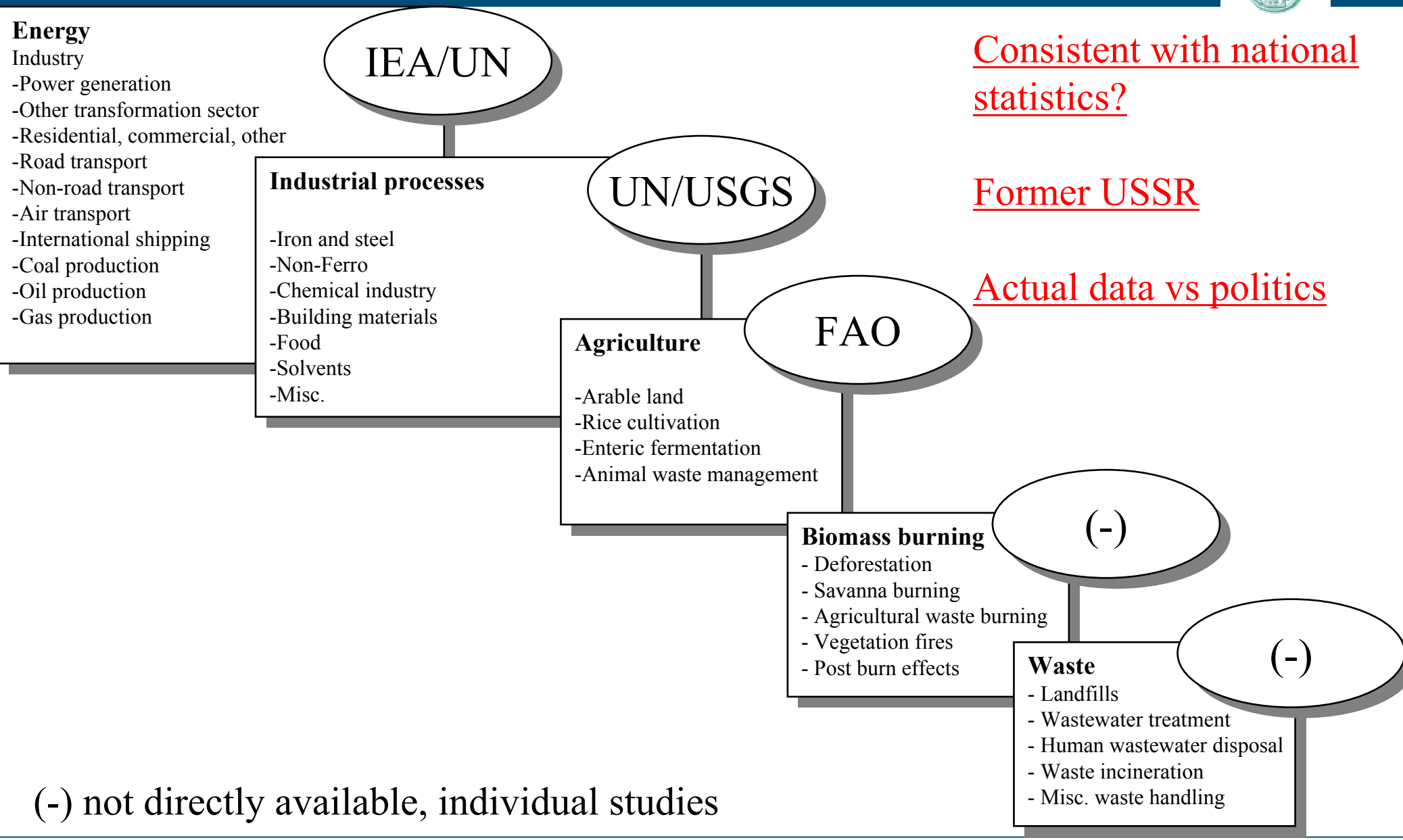
-Arable land
-Rice cultivation
-Enteric fermentation
-Animal waste management

Biomass burning
- Deforestation
- Savanna burning
- Agricultural waste burning
- Vegetation fires
- Post burn effects

Waste
- Landfills
- Wastewater treatment
- Human wastewater disposal
- Waste incineration
- Misc. waste handling

Variety of classifications
IPCC
EMEP/CORINAIR
EDGAR
RAINS
Individual studies

EI: source categories and 'global' information sources



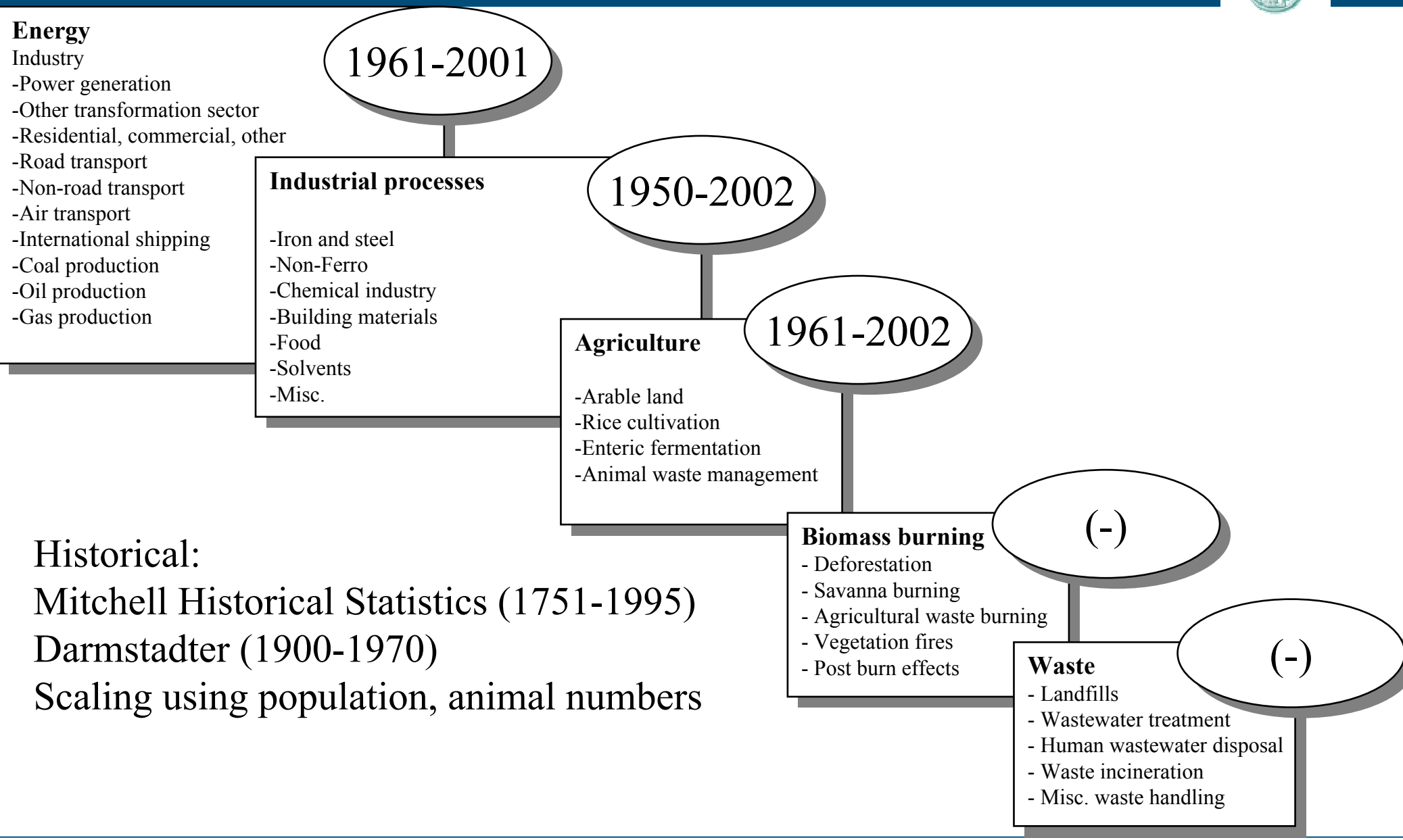
Consistent with national statistics?

Former USSR

Actual data vs politics

(-) not directly available, individual studies

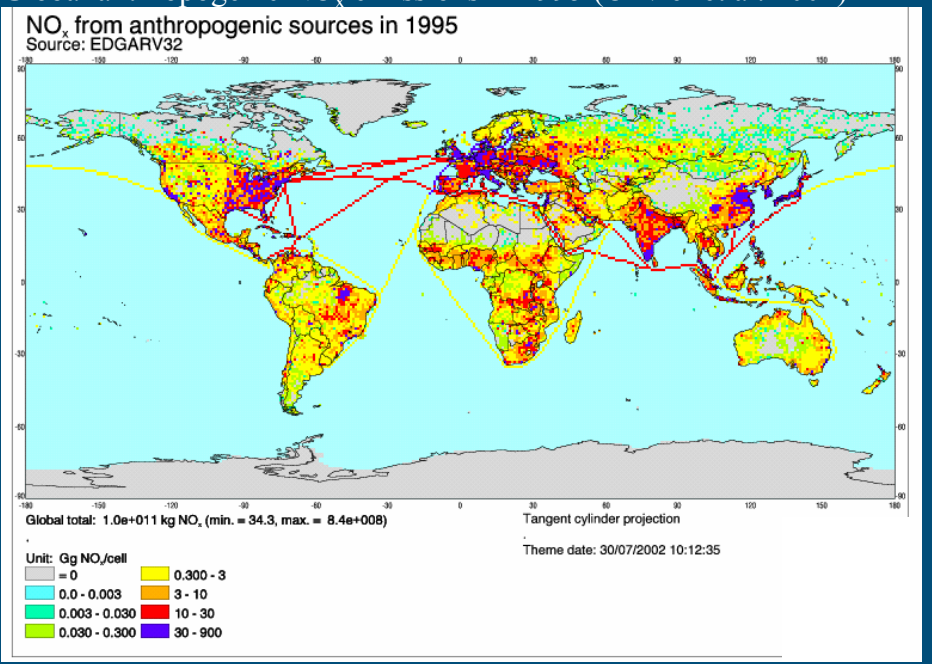
EI: time frame of 'global' information sources



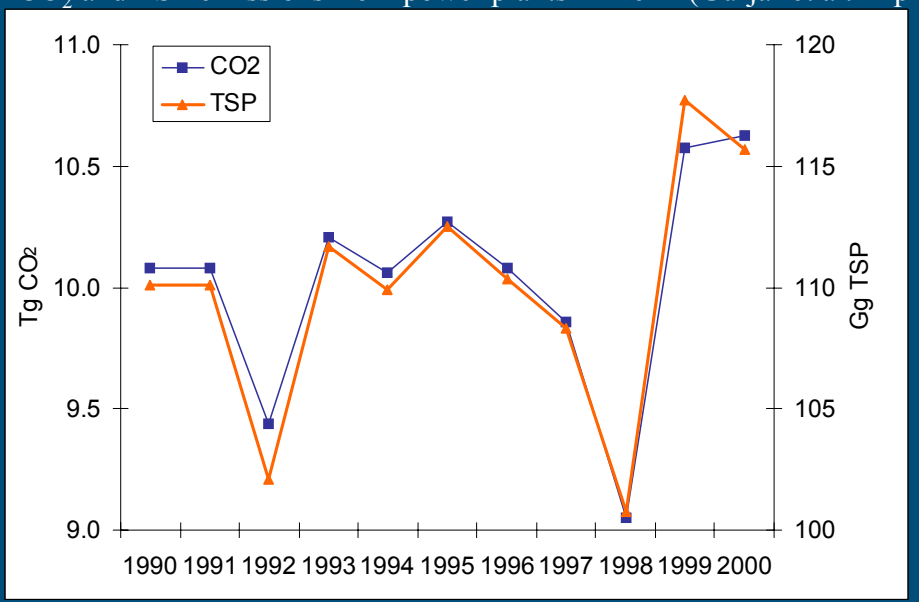
Historical:
Mitchell Historical Statistics (1751-1995)
Darmstadter (1900-1970)
Scaling using population, animal numbers

EI: Spatial scale

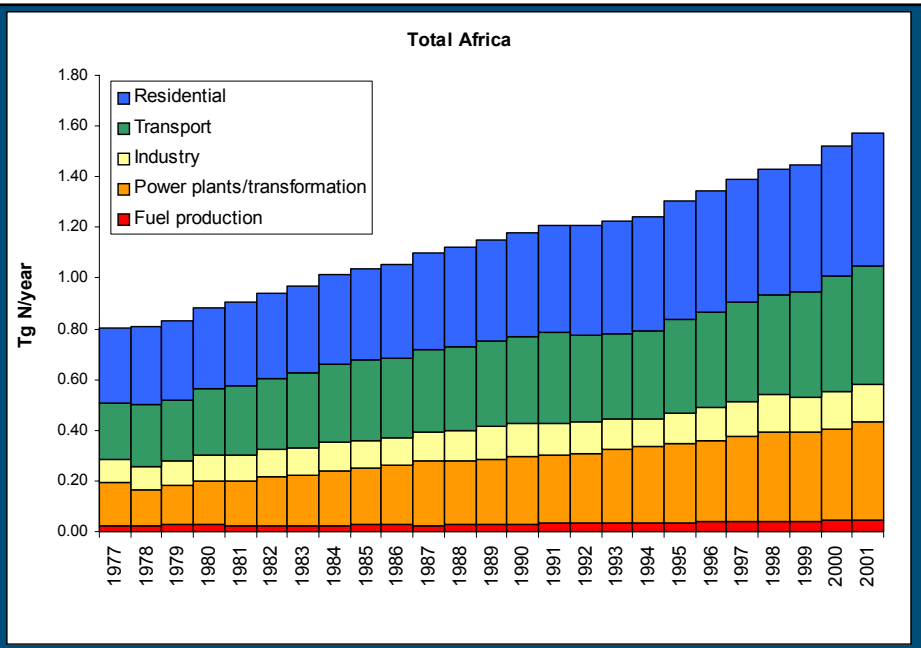
Global anthropogenic NO_x emissions in 1995 (Olivier et al. 2002)



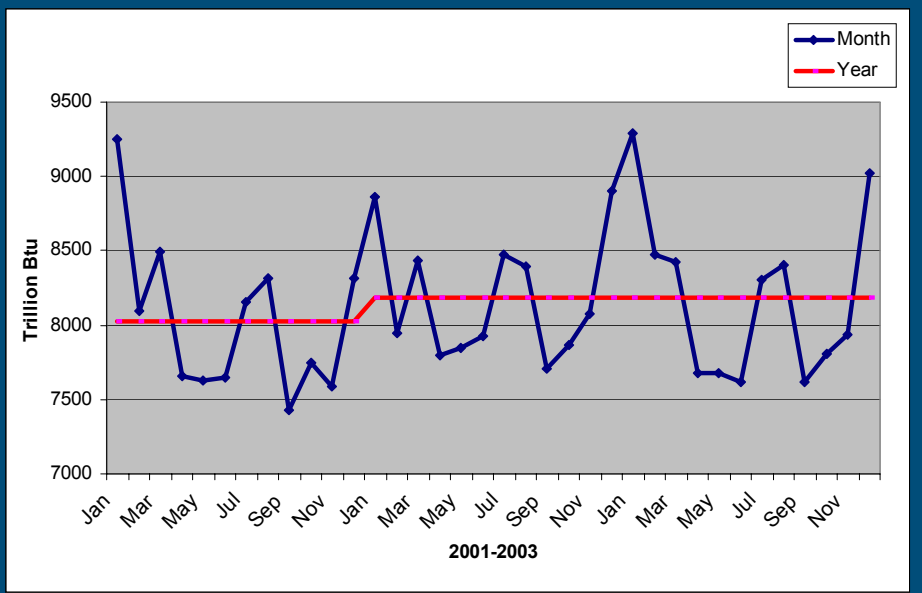
CO_2 and TSP emissions from power plants in Delhi (Gurjar et al. in press)



EI: Temporal scale



Annual NO_x emissions from fuel combustion in Africa, in the period 1977-2001. (Prel. results EDGAR v4)



Monthly energy consumption in USA RCO sector (EIA, monthly energy review, May 2004)

Method	CORINAIR 1994	National Communication
Species:	SO_2, NO_x, CO, NH_3, CH_4, POPs, NMVOC, N_2O, CO_2, heavy metals,	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, NMVOC, NO_x, CO, SO_2
Emission sources:	10 anthr. and 1 natural	5 major sectors
Temporal scale:	Annual totals	Annual totals
Spatial scale	Europe, countries	Country
Methodology	EF approach following EMEP/CORNAIR Guidebook	IPCC default method/national method
Uncertainty assessment	No	Partly, some country reports use error propagation techniques

Requirement: inventory is "good enough" too allow for effective decisions

Method	EDGAR	GEIA
Species:	CO_2, CH_4, N_2O, F-gases, SO_2, NO_x, CO, NMVOC, NH_3	CO_2, CO, BC, CH_4, VOC, N_2O, NO_x, NH_3, SO_2, CFCs, reactive chlorine
Emission sources:	25 anthropogenic and 4 natural	Anthropogenic and natural sources
Temporal scale:	Annual totals	Annual, partly seasonal/monthly
Spatial scale	World, countries, 1° x 1 ° grid	World, 1° x 1° grid
Methodology	EF approach, regression analysis, process based models	Selection of published inventories
Uncertainty assessment	Partly, indication quality of data, comparison with other inventories	No

Requirement: exact representation of "real" emission

Present day emissions: anthropogenic emissions from the GEIA website - I

BC	12 Tg C	Mid 1980s	Penner et al. (1996)
	14 Tg C	1984	Cooke and Wilson (1996)
CH_4	240 Tg C	1990	Olivier et al. (1996)
CO	418 Tg C	1990	Olivier et al. (1996)
CO_2	5834 Tg C (fossil fuel)	1990	Marland et al. (1996)
N_2O	10 Tg N	1990s	Bouwman et al. (1995)
NH_3	43 Tg N	1990s	Olivier et al. (1996)
NO_x	21 Tg N	1985	Benkovitz et al. (1996)
SO_2	65 Tg S	1985	Benkovitz et al. (1996)
VOC	178 Tg	1990	Olivier et al. (1996)

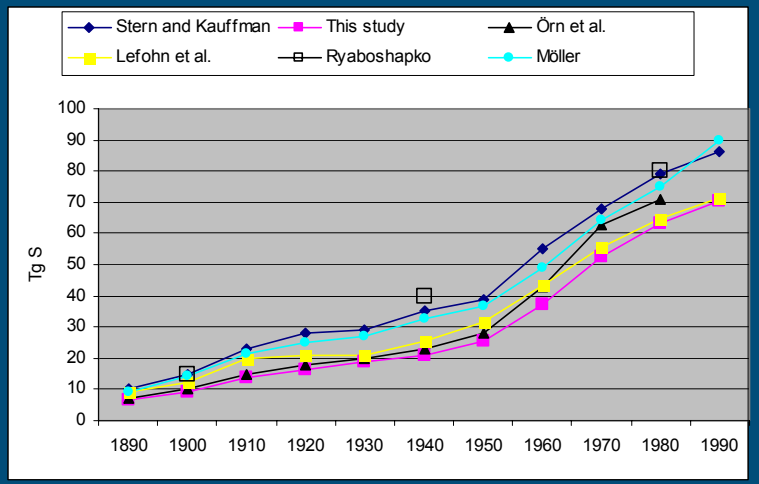
Present day emissions: anthropogenic emissions from the GEIA website - II

CFC-11	0.08 Tg	2000	McCulloch et al. (2001)
CFC-12	0.13 Tg	2000	McCulloch et al. (2001)
HCHC-22	0.27 Tg	2000	McCulloch et al. (2001)
Hg	0.002 Tg	1990	Pacyna et al. (1996)
MCF	0.02 Tg	2000	McCulloch et al. (2001)
Pesticides	0.0002 Tg α-HCH	2000	Li et al. (2000)
Reactive CL			
- Inorganic CL	30 Tg CL (incl soils)	1990s	Keene et al (1999)

Emission inventories of the past: a selection

	Period	Global	Regional/ Country	Grid	Sectors	Reference
CO_2	1860 - 1969 (yr) 1949 - 1969	*	-	-	Fossil fuel, Cement	Keeling, 1973
	1950 - 1990 (yr)	*	Country	-	Fosssil fuel, Cement	Marland et al., 1994
	1950 - 1990 (dec) 1751 - 1990	*	Country	1 x 1	Fossil fuel, Cement	Andres et al., 1996 Andres et al., 1999
CH_4	1860 - 1993 (yr)	*	-	-	Fossil fuel, Biomass burning, Animals, Rice, Landfills	Stern and Kaufmann, 1995
SO_2	1860 - 1993 (yr)	*	USA, OECD, Rest of the world	-	Fossil fuel, Industry	Stern and Kaufmann, 1996
	1860 - 1985 (dec)	*	Regional data used to contruct global	5 x 5	Fossil fuel, Industry	Orn et al., 1996
	1850 - 1990 (yr)	*	Country	-	Fossil fuel, Industry	Lefohn et al., 1999
	1880 - 1991 (5yr)	-	Europe	1 x 1	Fossil fuel, Industry	Mylona, 1996
	1900 - 1980 (yr)	-	USA	-	Fossil fuel	Gschwandtner, 1985
	1860 - 1985 (dec/yr)	*	Some countries	-	Fossil fuel, Industry	Moller, 1984
	1960 - 1980 (yr)	*	USA, OECD, Rest of the world	10 x 10	Fossil fuel	Hameed and Dignon, 1988
NO_x	1960 - 1980 (yr)	*	USA, OECD, Rest of the world	10 x 10	Fossil fuel	Hameed and Dignon, 1988
	1900 - 1980 (yr)	-	USA	-	Fossil fuel	Gschwandtner, 1985
N_2O	1500 - 1994 (centuries, dec)	*	-	-	Fossil fuel, Industry Biomass burning, Agriculture	Kroeze et al, 1999

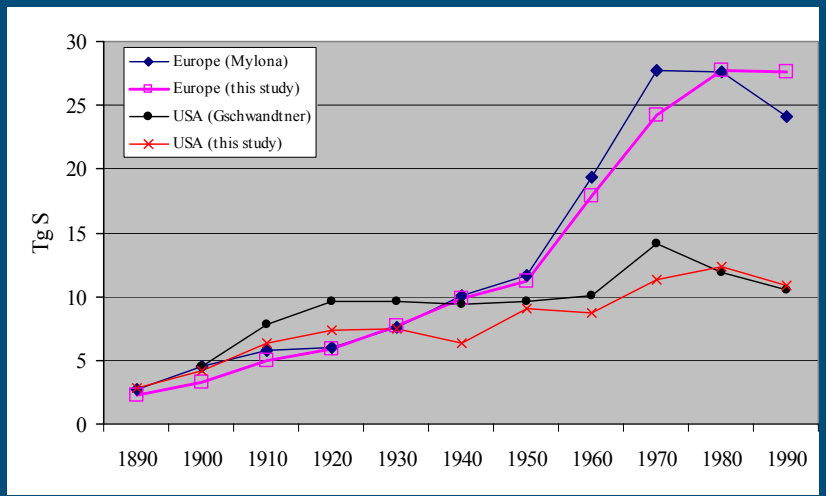
Emission inventories of the past: global and regional inventories of SO_2



Global SO_2 emissions

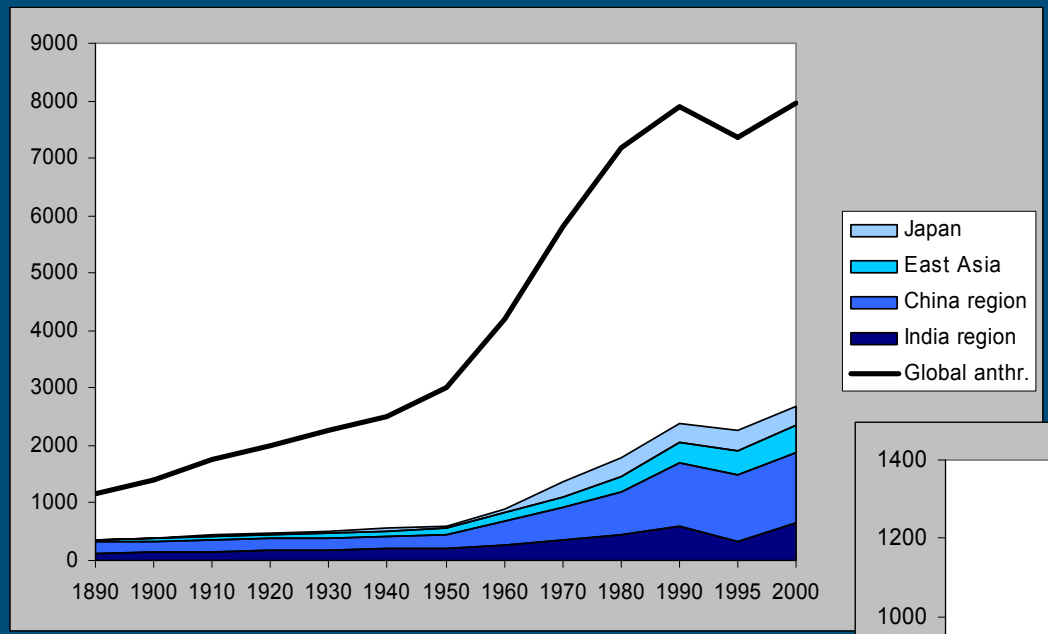
Highly uncertain due to lack of activity data and emission factors

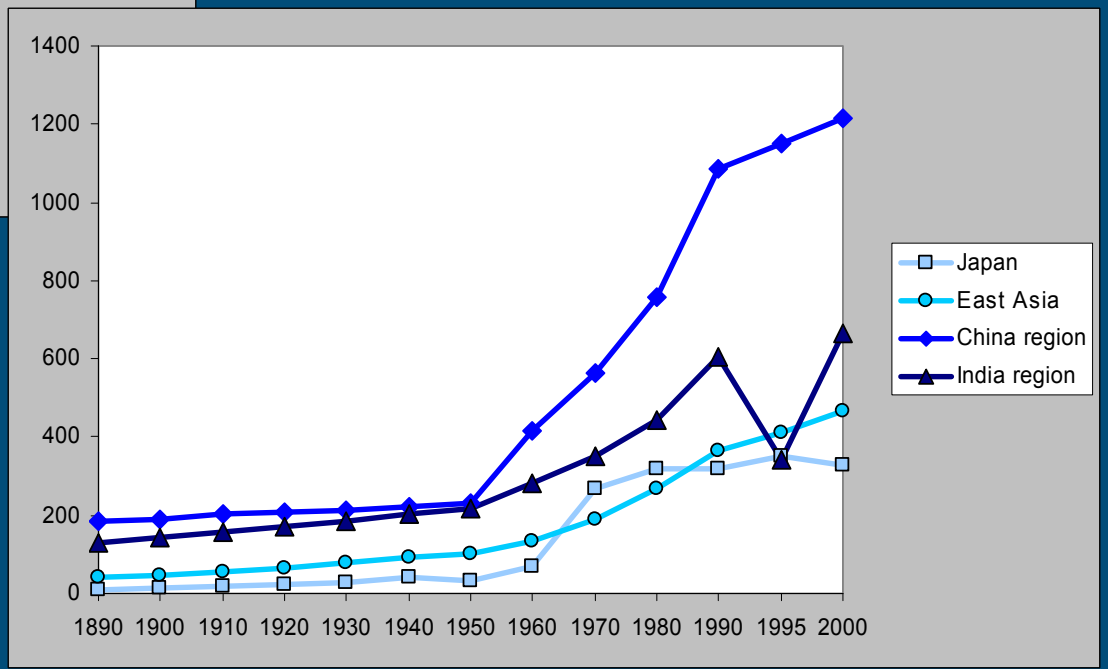
Reviewer: „this is emission inventories going wild“



SO_2 emissions in Europe and USA

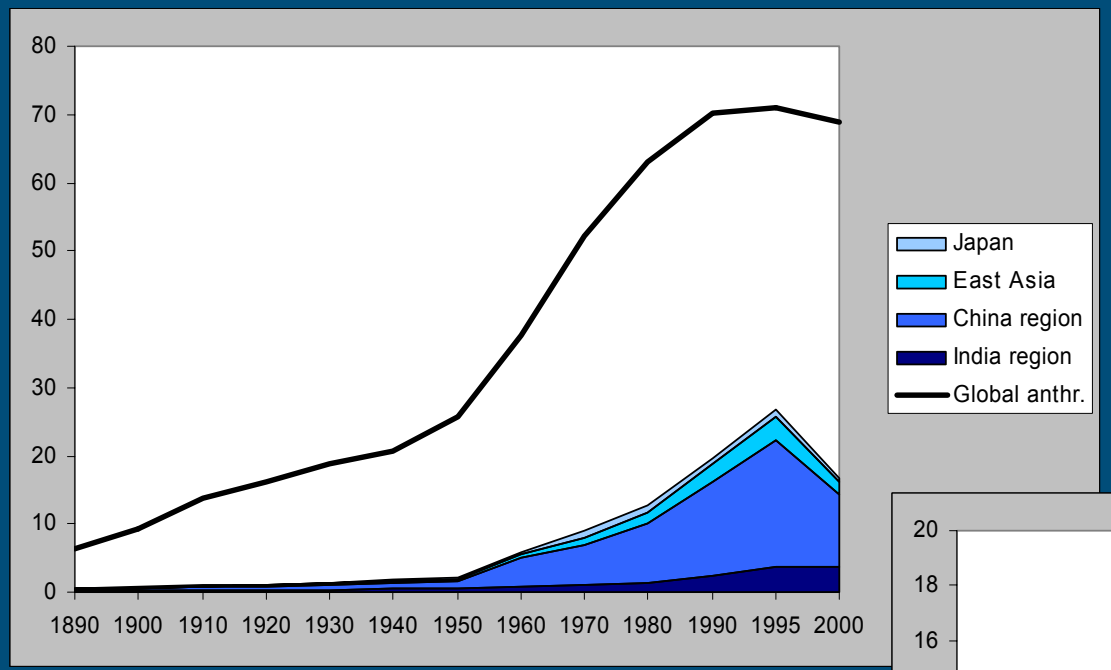
Emission trends: CO_2 (Tg C)

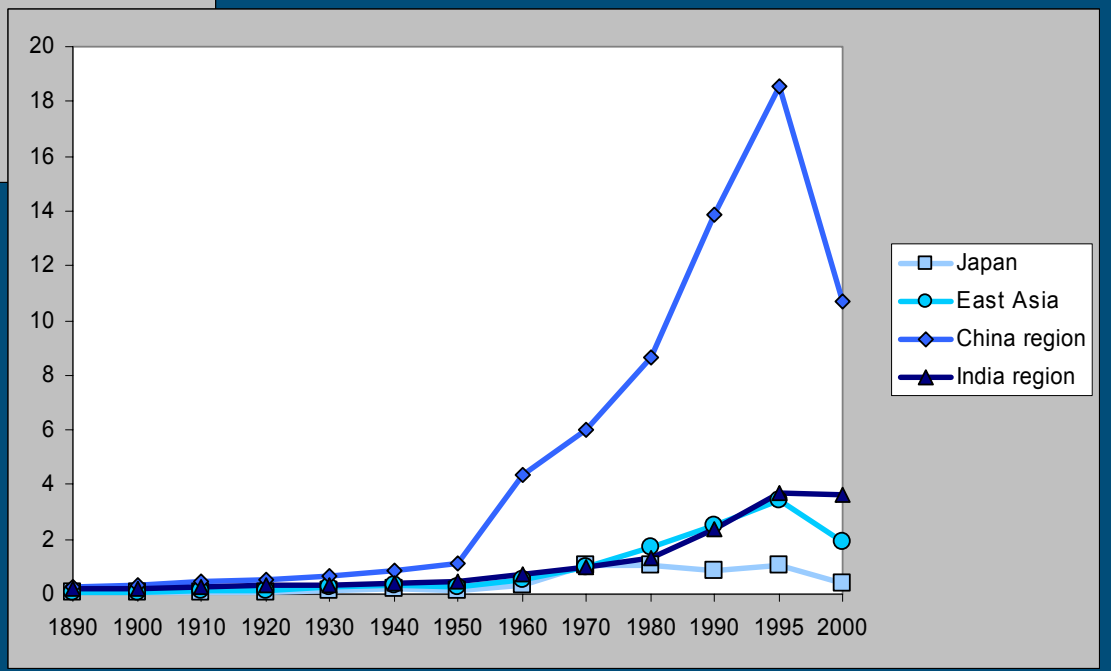




1990: (Van Aardenne et al., 2001)
1995: (Olivier et al., 2002)
2000: Asia: (Streets et al., 2003)
Global: (IPCC, 2001)

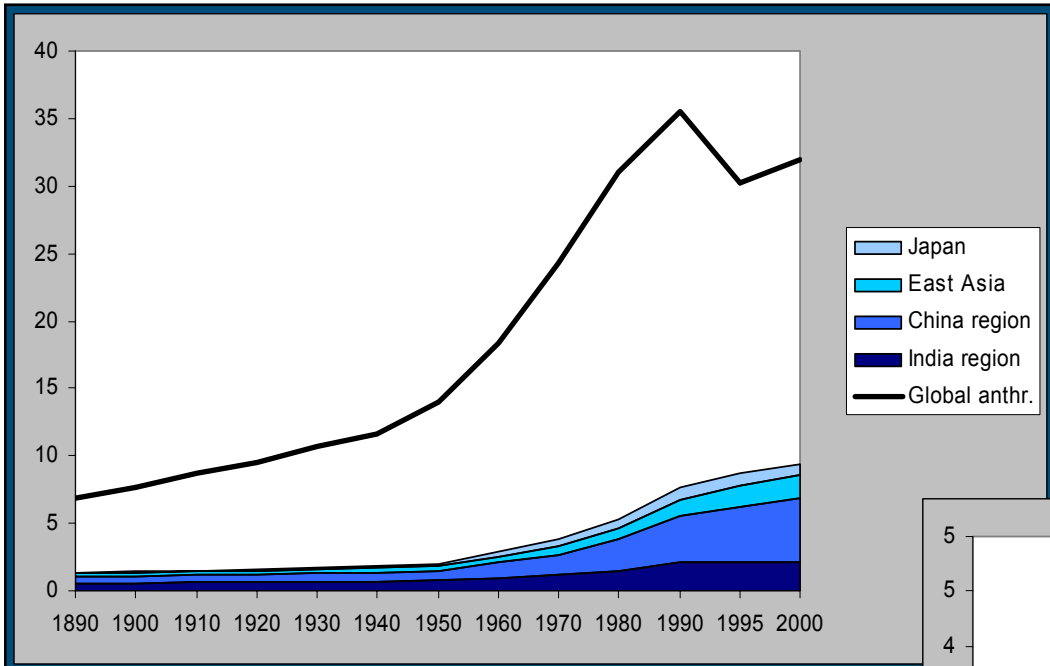
Emission trends: SO_2 (Tg S)

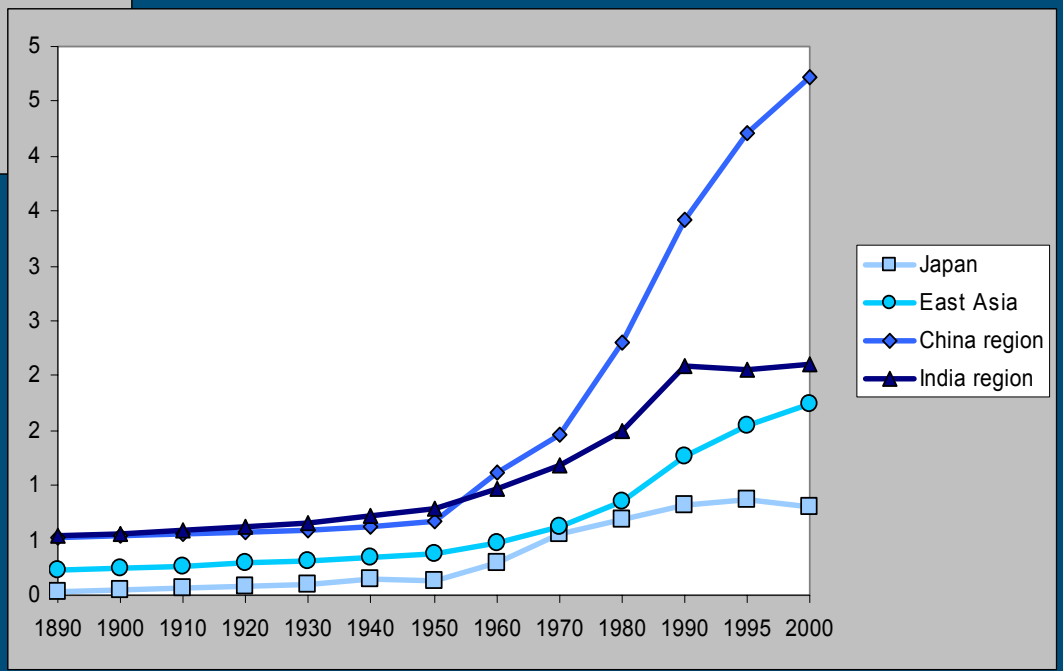




1990: (Van Aardenne et al., 2001)
1995: (Olivier et al., 2002)
2000: Asia: (Streets et al., 2003)
Global: (IPCC, 2001)

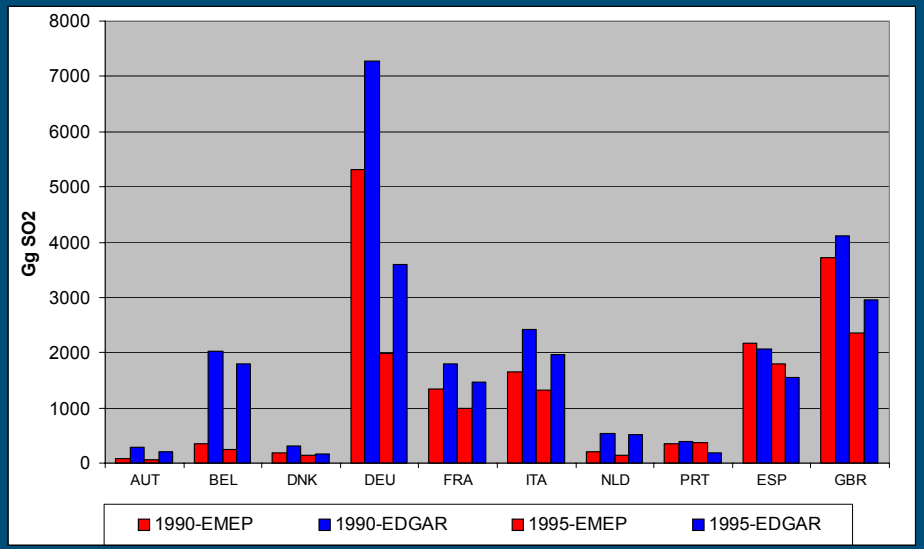
Emission trends: NO_x (Tg N)





1990: (Van Aardenne et al., 2001)
1995: (Olivier et al., 2002)
2000: Asia: (Streets et al., 2003)
Global: (IPCC, 2001)

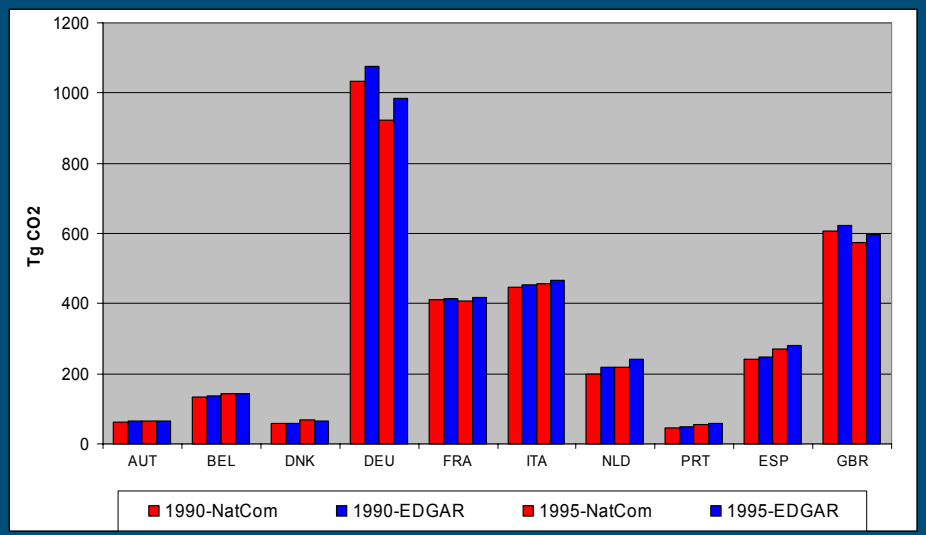
Global emission database compared to country data



10 EU countries and SO_2 emissions according to EMEP and EDGAR

- SO_2 emission factors update needed for EDGAR in countries with recently implement control technologies

- activity data seems comparable



10 EU countries and CO_2 emissions according to NatCom and EDGAR

EDGAR:
1995 emissions
National level
Global/regional EF
correct year, aggregated method

Tg NO2	Tg CO	Tg NMVOC
12	88	11

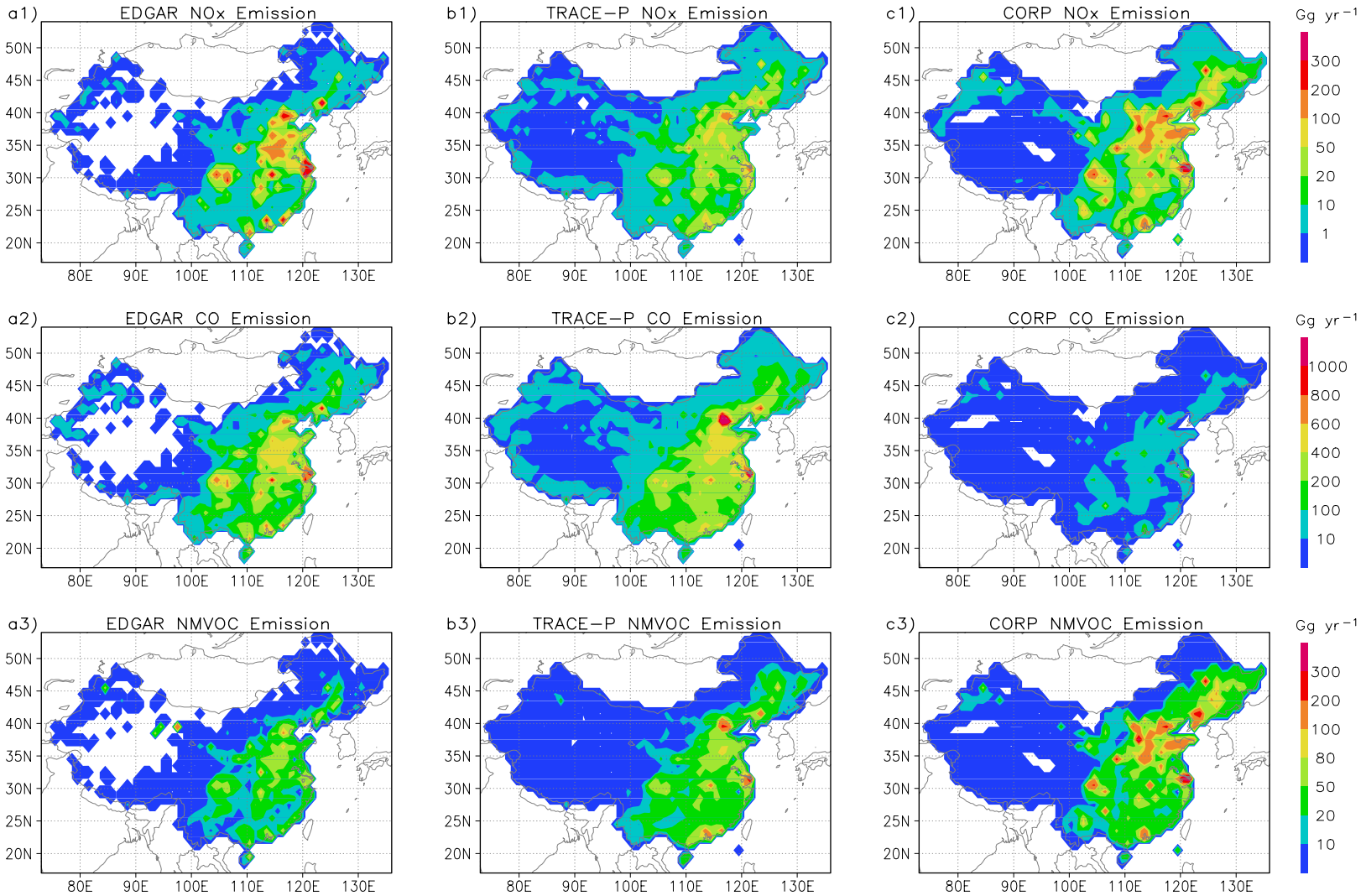
TRACE-P:
2000 emissions
Province level
Global/regional EF
LPS, road maps
incorrect year, detailed method

Tg NO2	Tg CO	Tg NMVOC
11	116	17

CORP:
1995 emissions
Prefecture level
Chinese EF
LPS locations
correct year, detailed unknown method

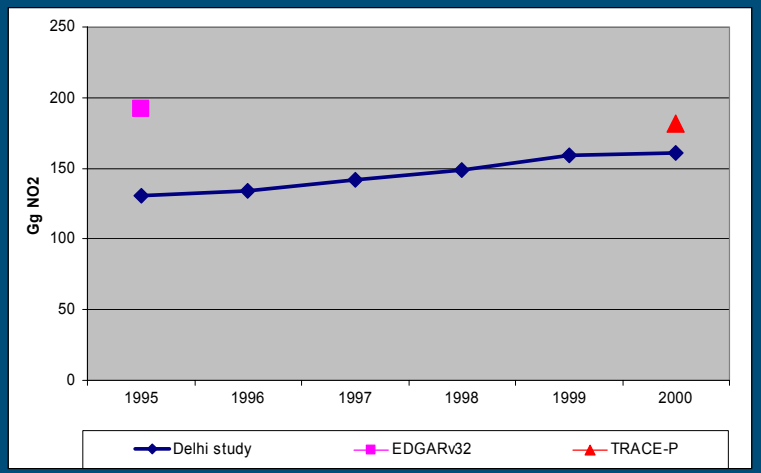
Tg NO2	Tg CO	Tg NMVOC
19	10	25

How good are the global/regional emission estimates? Emissions in China



Representation of megacities in large-scale inventories: Delhi

NO_x emissions in Delhi according to Gurjar et al. (in press), Olivier et al. (2002) and Streets et al. (2003)



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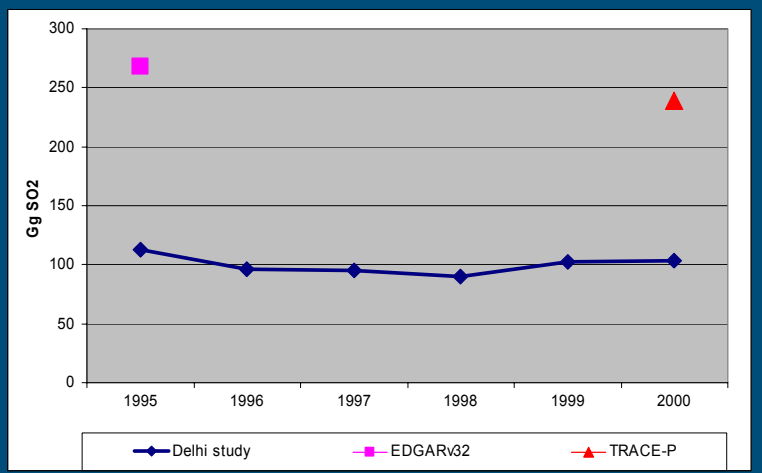

Issue: global emission inventories

EDGAR is widely used as reference for global modelling studies while city regional and country inventory data provide excellent addittion

- How to merge „LEIA to GEIA “ (methodological issues, credits)

Improvements in new inventories are needed:

- recent year (2001?)
- Monthly, daily emissions
- Improved NMVOC speciation
- Consistent 1960-2001 trend
- Improving distribution historical emissions (migration)
- Megacity developments

Issue: uncertainties

(i) Not practical possible to monitor each individual emission source:
Emission factor approach is adopted: **Emission = activity x emission factor**

(ii) We know that emission inventories are inaccurate representations of emission that has actually occurred:

$$E_{real} = E_{inventory} + \bigcup_{i=1}^{N} \varepsilon_i$$

Examples of errors ε_i:

aggregation error	Calculation of emissions on other spatial, temporal scale and for emissions sources that are different from scale on which emissions occur in reality
extrapolation error	Due to lack of measurements of emission rates or activity data, non-specific data are extrapolated
Measurement error	Errors in measurement lead to inaccurate values of emission factors of activity data

(iii) Often, we still do not know the extent to which emission inventories are inaccurate

Issue: Non-OECD emission inventories – capacity building needed

(i) Emission factor approach: Inconsistent time series of pre-industrial to present day emissions

(ii) Inaccuracy is a major problem:

aggregation error	Due to lack of data: • non-detailed source categories (total transport vs. vehicle types) • non-detailed statistics (annual km driven, vs. e.g. diesel/km in city)
extrapolation error	Due to lack data: • using European/U.S.A. no-control or old-control emission factors • using European/U.S.A. energy and production efficiencies • trend extrapolation of activity data towards past and future
Measurement error	• chemical interference of instrument in heavy polluted areas • use of older measurement equipment

(iii) Often, we do not know the extent to which emission inventories are inaccurate:

- detailed review of existing inventories not performed yet
- several inventories are non-transparent about method and data
- lack of different independent inventories
- lack of measurement data and model studies to confront inventories with

Issue: more mechanistic/dynamic emission inventories?

Method 1:
Hot emissions:
- total annual kilometers driven per vehicle
- share of kilometers driven in 'urban', rural', 'highway'
- speed and fuel dependent hot emission factors

Cold start emissions
- average trip length per vehicle trip
- average monthly temperature
- temperature and trip length dependent cold start correction factor

Method 2:
-total annual kilometres driven per vehicle
-share of kilometres driven in urban/rural/highway
-average speed of vehicles
-speed and fuel dependent emission factors

Method 3:
- annual fuel consumption of the vehicle category
- fuel consumption related emission factors

accounting for
emission mechanism

data
requirements

uncertainty?