An inventory of Gases and Particles Emissions for the 1900-2000 Period

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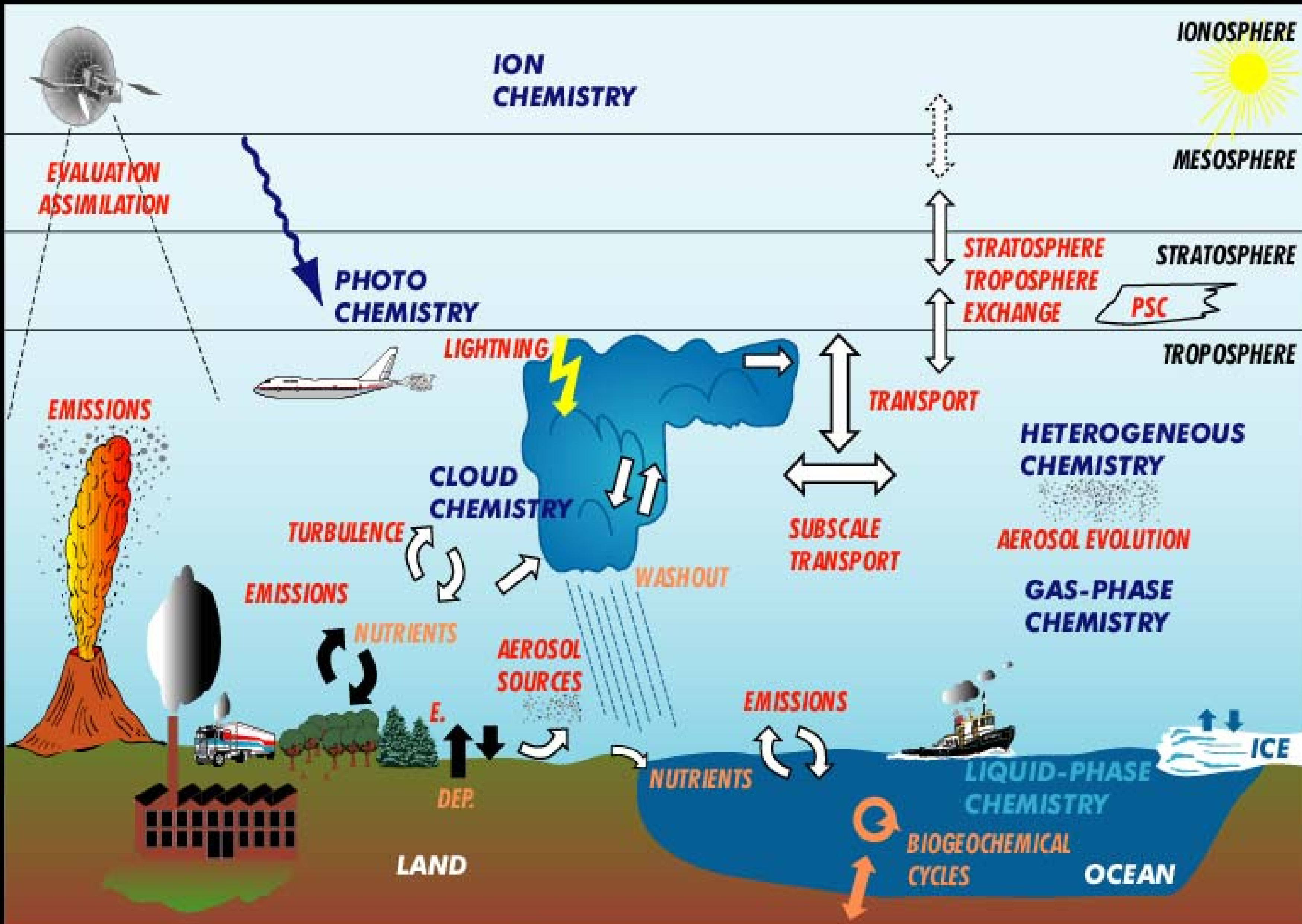
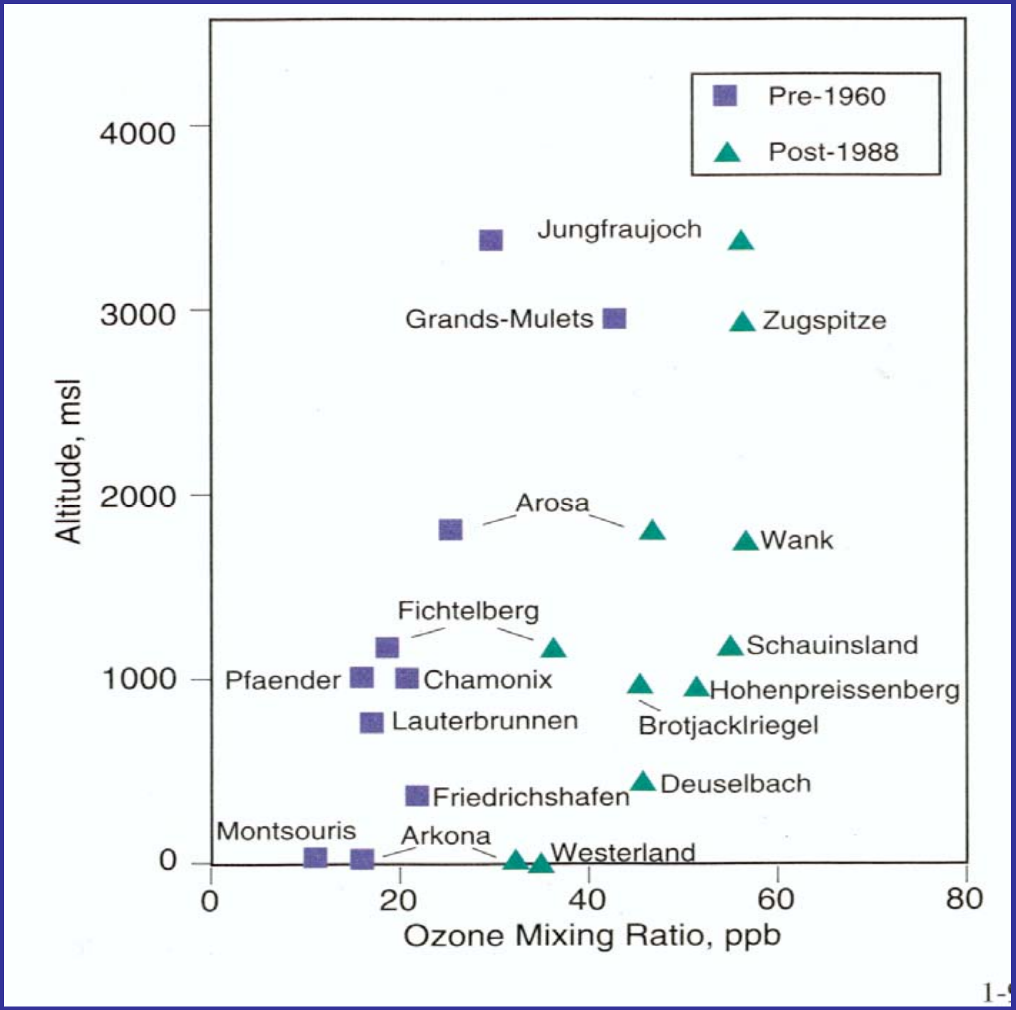


From MPI-Meteorologie

Historical ozone

Very few reliable measurements until 1960s. Oldest record: Montssouri, 1760. A few optical measurements from early 1900s.

The figure shows that ozone has increased throughout the (lower) troposphere.



From Stahelin et al., 1994

Motivation:

Development of a new inventory of emissions for studies of changes in atmospheric species since 1900

- **gases and aerosols**
  - → **consistent gas/aerosols emissions**
  - → **similar algorithms for both types of species**

- **sensitivity studies**
  - → **algorithms that can allow changes in energy use, emission factors, …**

Acronym of the inventory: GICC

Surface emissions of gases and particles

What has been done up to now:

- Inventory of surface emissions
    - → anthropogenic origin
    - → biomass burning

from 1900 to 2000

1x1 degree spatial resolution

- ozone precursors (CO, NOX, VOCs)

- particles (BC, OC) and precursors (SO2)

Technological emissions:

General equation used to generate emissions:

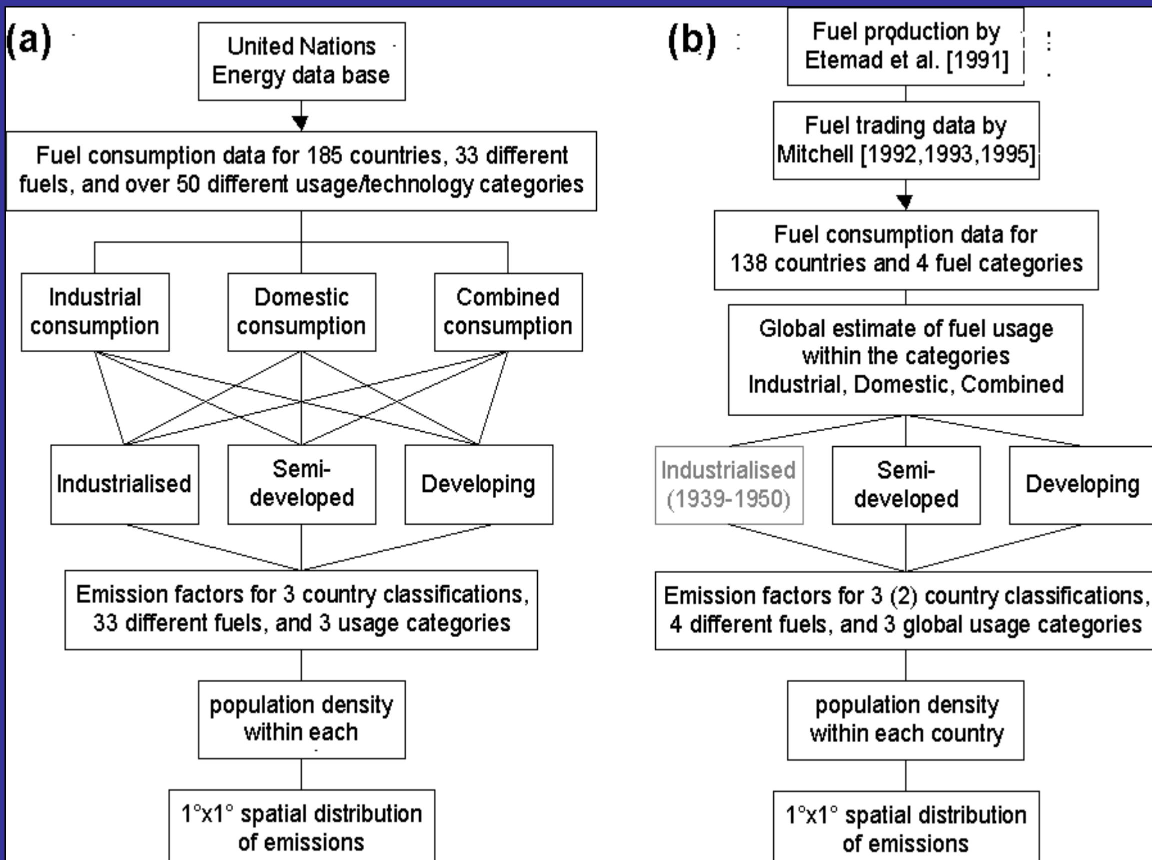
$$\text{Emission} = \Sigma A_i \, EF_i \, P_{1i} \, P_{2i}$$

A_i = Activity rate for a source
(ex: kg of coal burned in a power plant…)
EF_i = Emission factor : amount of emission per unit activity
(ex: kg of sulfur emitted per kg burned
P_{1i}, P_{2i}, … = parameters applied to the specified source types and species
(ex: sulphur content of the fuel, efficiency, …)

Emissions calculated for different categories of emissions

Methodology

1950-2003 1860-1949



Crude oil into Diesel and Gasoline *(extrapolation from UN data for each country group and activities)*

Fuels into the three sectors

Country classification
<1940 : only 2 classes

EF values

Biofuel (1860-1969)
extrapolation from UN data and population trends for each country group and each activities)

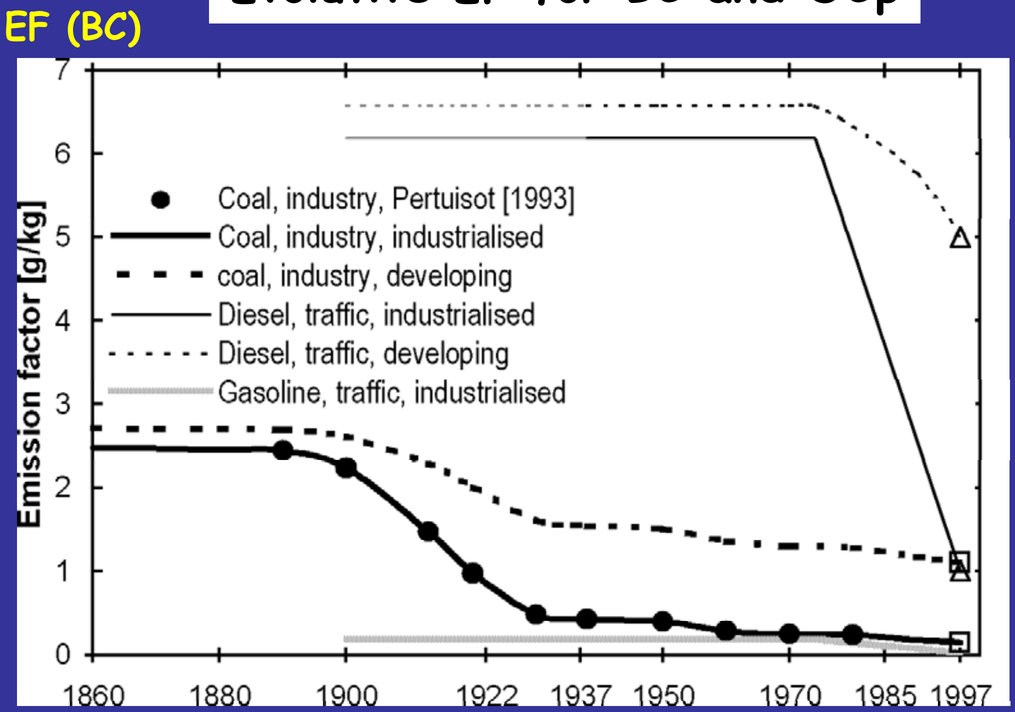
GICC Fossil Fuel and Biofuel inventories
Pollutants : CO, CO2, NOx, NMVOC, SO2, BC, OCp
Period : 1860-2030
Based on Junker and Liousse ACPD 2008 algorithm

Large uncertainties remain concerning emission Factors: example for BC

EF (gC/kg)	Liousse Domestic	Bond (1996) Domestic	Liousse Industrial	Bond Industrial	Liousse Traffic	Bond traffic
Hard coal Developed	1.4	3	0.149	0.001-0.006		
Hard coal Developing	2.3	3.2	1.1	0.28-4.5		
Lignite dev	2.5	0.2	0.3	0.015-0.3		
Lignite devping	4.1	0.22	1.98	0.01		
Diesel dev	2	0.25	2	0.25	2	0.8
Diesel devping	2	0.25	0.35	0.24	10	1.3
Gas dev	0.03	0.08	0.03	0.13	0.03	0.08
Gas devping	0.15	0.08	0.15	0.09	0.15	0.26

Emission factors are changing with time

Evolutive EF for BC and OCp



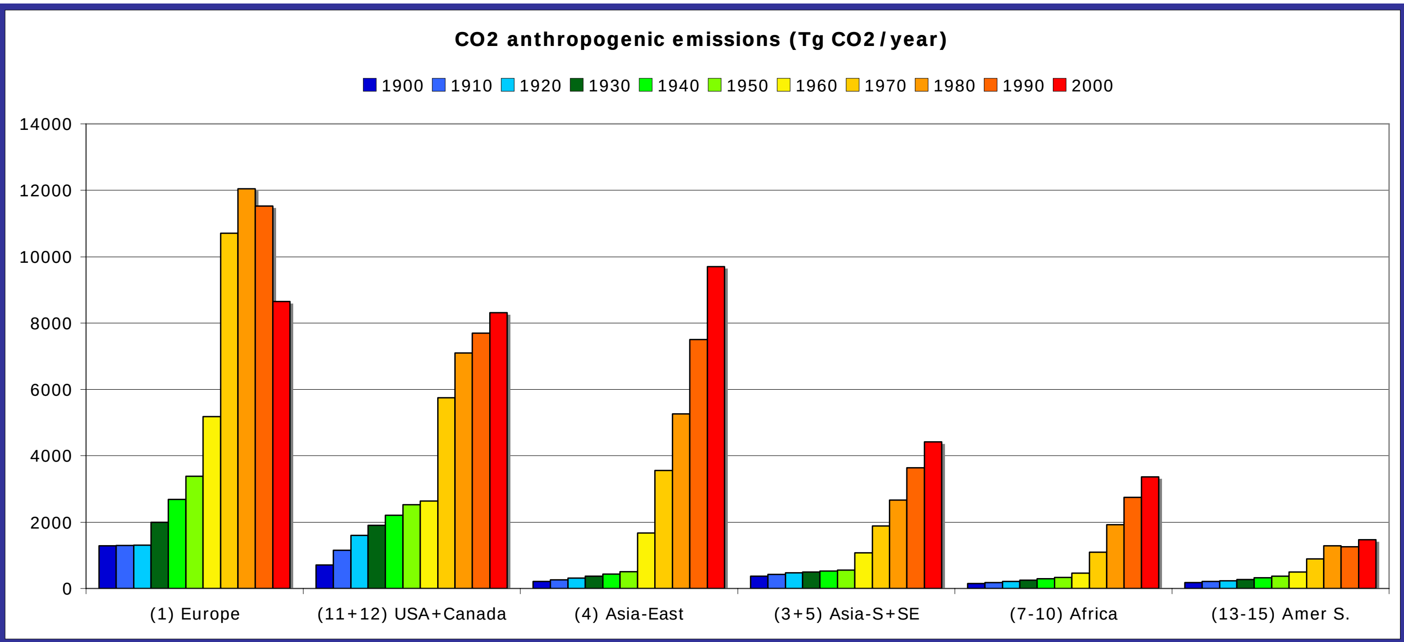
Junker and Liousse, 2006

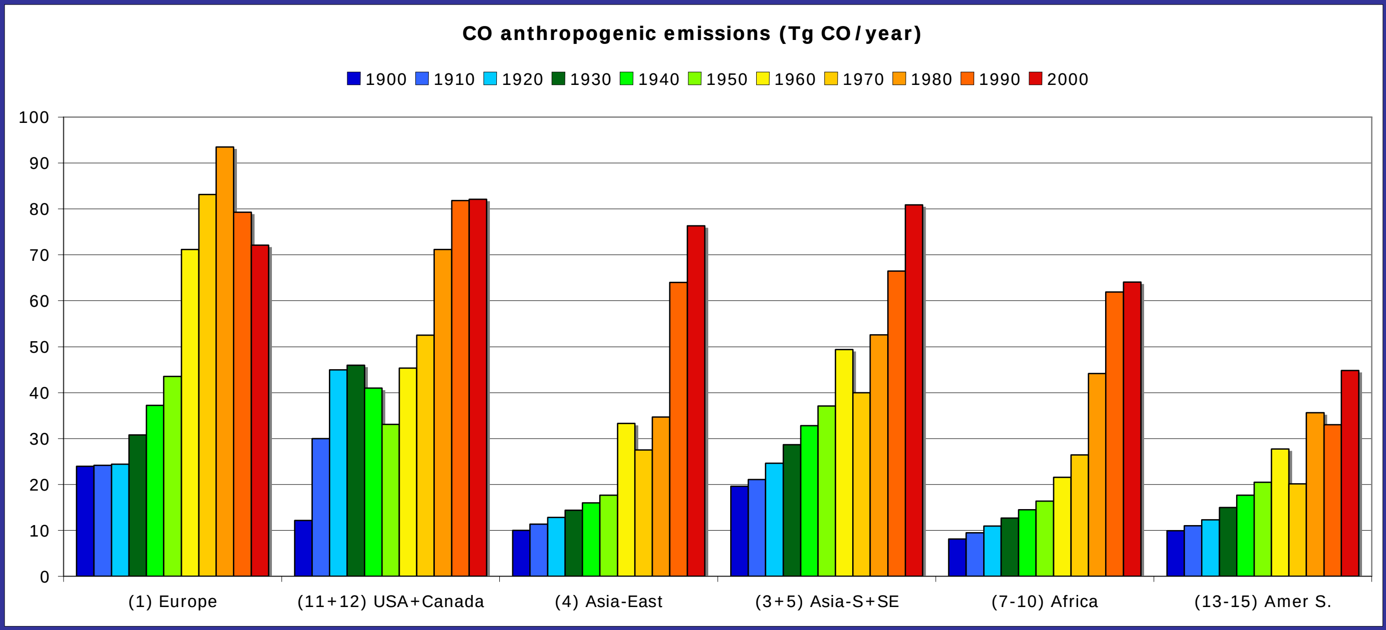
Evolution of emission factors for gases based on evolution of BC emission factors

Trends for Coal EF from trends of power plant efficiency; Trends for Diesel from Yanowitz et al., 2000

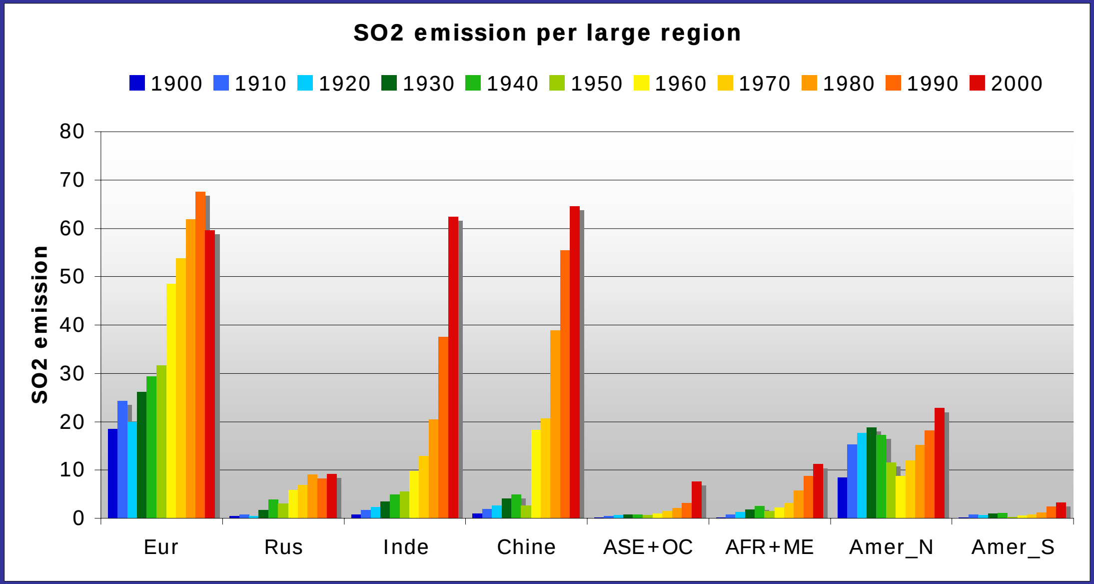
There is an even larger uncertainty on fuel consumption data for residential burning in Asia and Africa :
2 different scenarios are considered

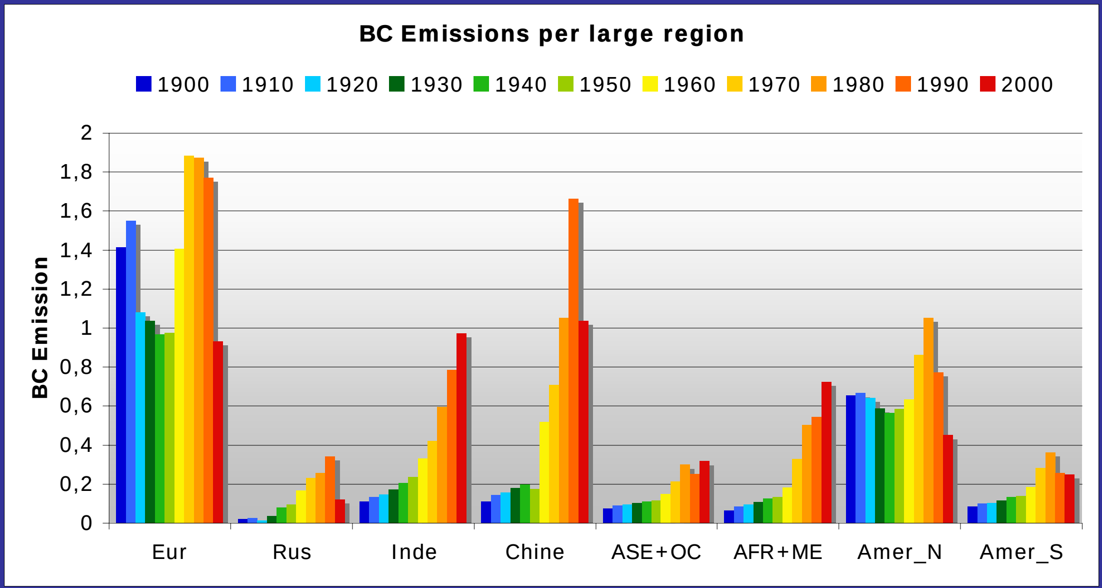
- **low value**
- **high value**



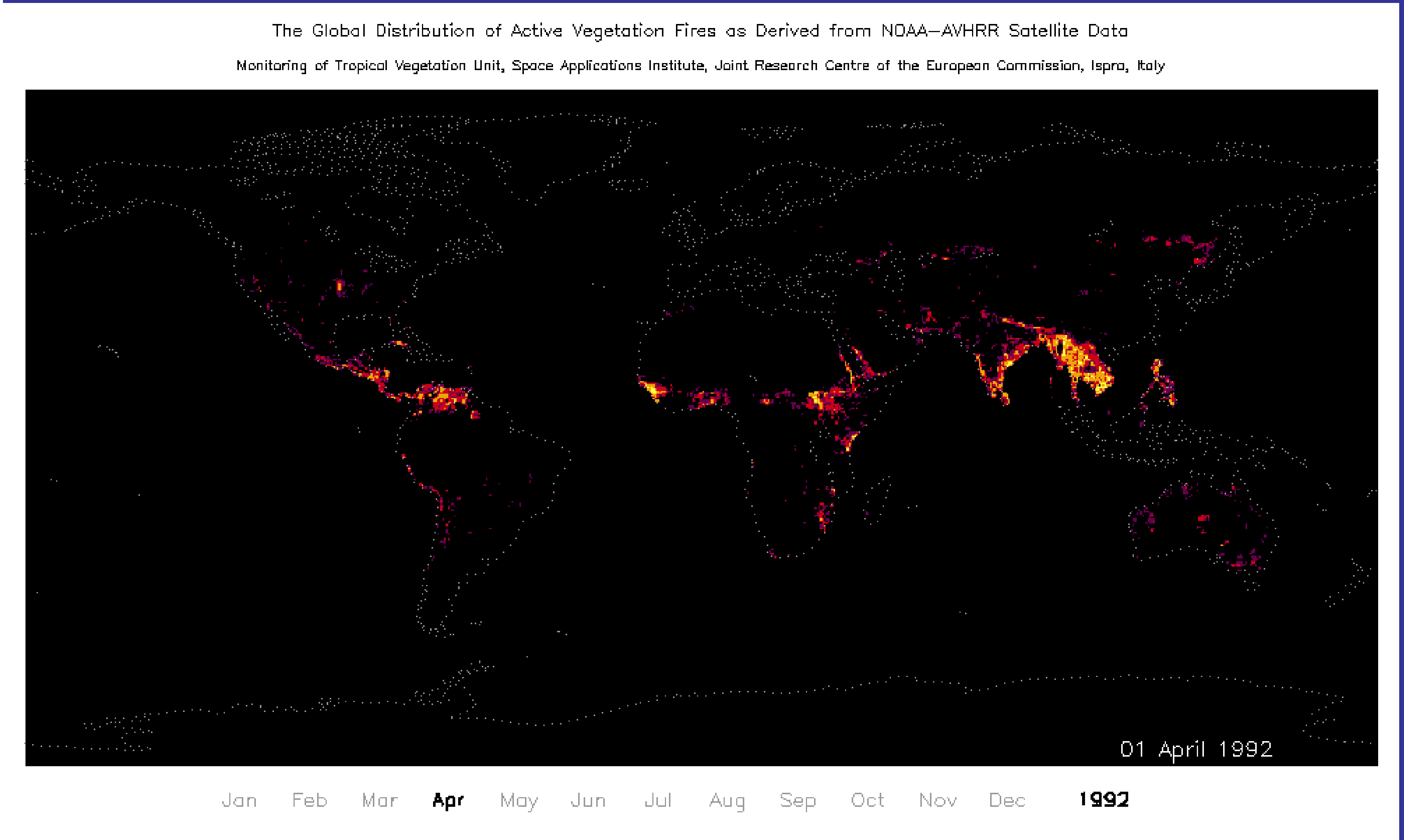


Change in the anthropogenic emission of CO_2 and CO for several large areas from 1900 to 2000.





Change in the anthropogenic emission of CO2 and CO for several large areas from 1900 to 1997.



Biomass burning emissions: large contribution to total emissions

Calculation of emissions resulting from biomass burning

$$Emission(CO_2) = BA \times BD \times BE \times EF(CO_2)$$

BA = Burnt Area
BD = Biomass Density
BE = Burning Efficiency
$EF(CO_2)$ = Emission Factor
(from Andreae and Merlet, 2001)

Emission (species) = Emission (CO_2) * emission ratio
emission ratio [Andreae and Merlet, GBC 2001]
given for boreal/temperate forest, tropical forest, savana

2. 1900-1996 biomass burning emissions: Use of historical data

Use of data compiled by Mouillot and Field:

Fire history and the global carbon budget: a 1x1 degree fire history reconstruction for the 20th century, Global Change Biology (2005) 11, 398–420.

Calculate CO_2 emissions for the 1990-2000 decade as the product :

$$Emissions(CO_2) = BA \times BD \times BE \times EF(CO_2)$$

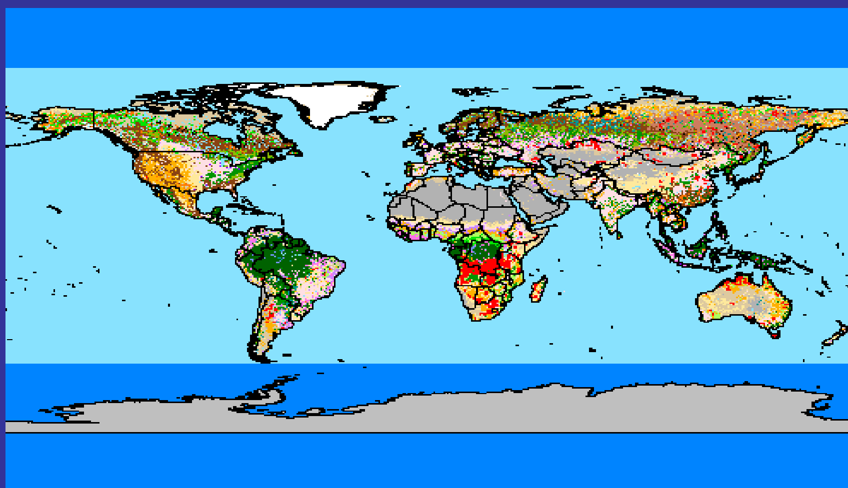
BA = Burnt Area (from Mouillot et al. paper)
BD = Biomass Density
BE = Burning Efficiency (Use GLC 2000 map)
$EF(CO_2)$ = Emission Factor for CO_2 (from Andreae and Merlet, 2001)

Scale 1990-2000 CO_2 emissions from forest/savanna burning so that they equal the 1997-2003 previously calculated

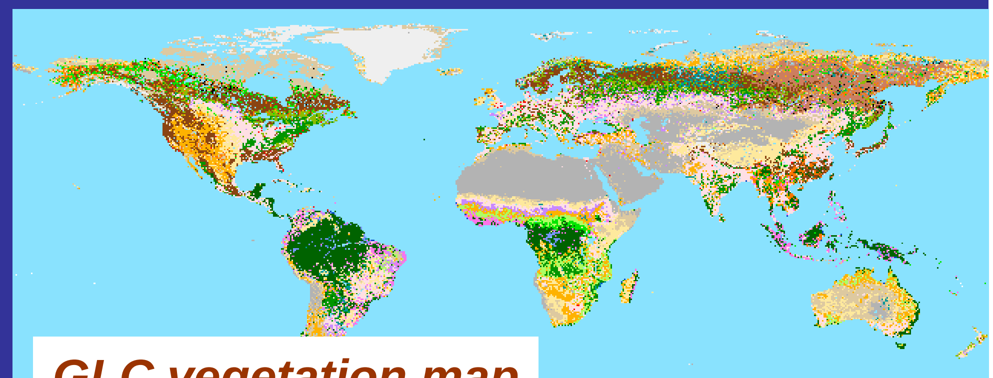
Use the same scaling for all other decades considering forest and savanna burning separately

Methodology – biomass burning emissions 1997-2003

Data used

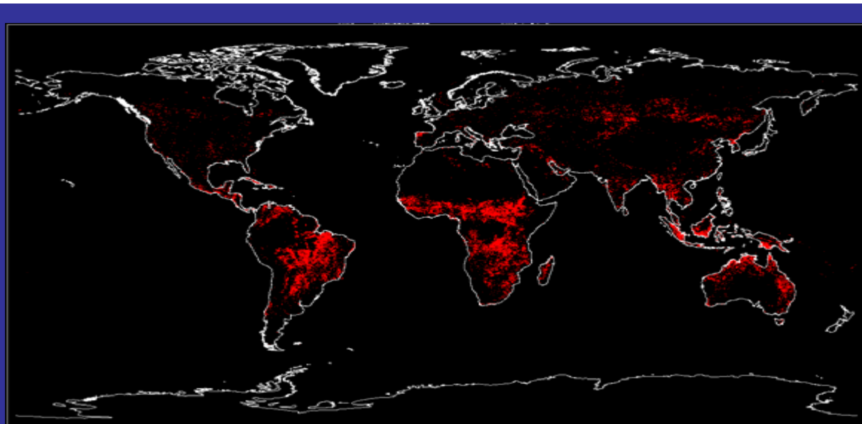


GBA 2000 burnt areas for 2000



GLC vegetation map

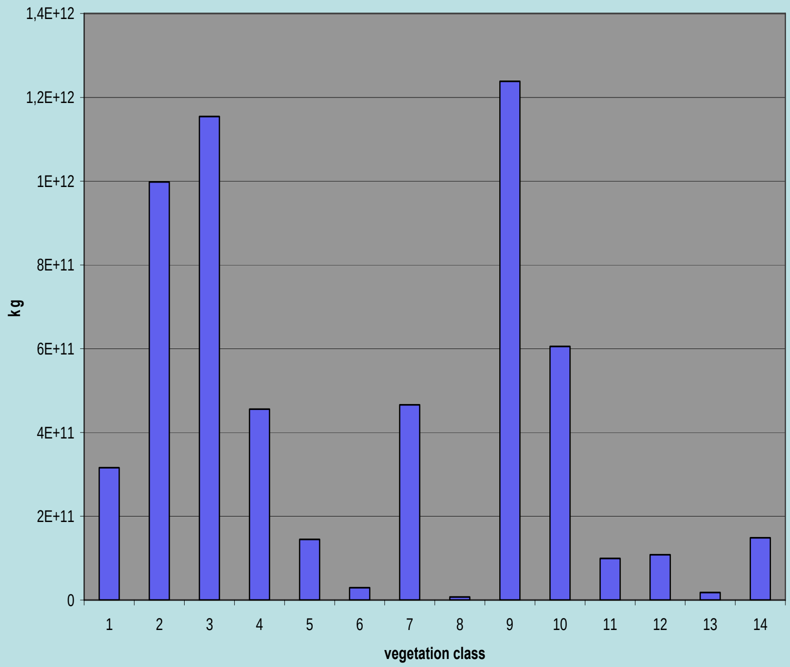
	GLC vegetation classes	Biomass density kg/m2	Combustion efficiency	EF CO2 g/kg	EF CO g/kg
1	Broadleaf evergreen GLC1	23.3	0.25	1580	104
2	Closed broadleaf deciduous GLC2	20	0.25	1569	107
3	Open Broadleaf deciduous GLC3	3.3	0.4	1613	65
4	Evergreen needleleaf forest GLC4	36.7	0.25	1569	107
5	Deciduous needleleaf GLC5	18.9	0.25	1569	107
6	Mixed leaf type GLC6	14	0.25	1569	107
7	Tree Cover, regularly flooded, fresh (-brackish) GLC	27	0.25	1580	104
8	Tree Cover, regularly flooded, saline, (daily variation	14	0.6	1596	82
9	Mosaic : tree cover/other natural vegetation GLC9	10	0.35	1591	86
11	Shrub, closed-open, evergreen GLC11	1.2	0.9	1613	65
12	Shrub, closed-open, deciduous GLC12	3.3	0.4	1613	65
13	Herbaceous cover, closed open GLC13	1.4	0.9	1613	65
14	Sparse herbaceous or sparse shrub cover GLC14	0.9	0.6	1567	78
16	Cultivated and managed areas GLC16	0.4	0.6	1515	92
17	Mosaic : cropland/tree cover/other natural vegetatio	1.1	0.8	1594	70
18	Mosaic : cropland/shrub or grass GLC18	1	0.75	1580	74



ATSR Fire Counts 1997 -2003

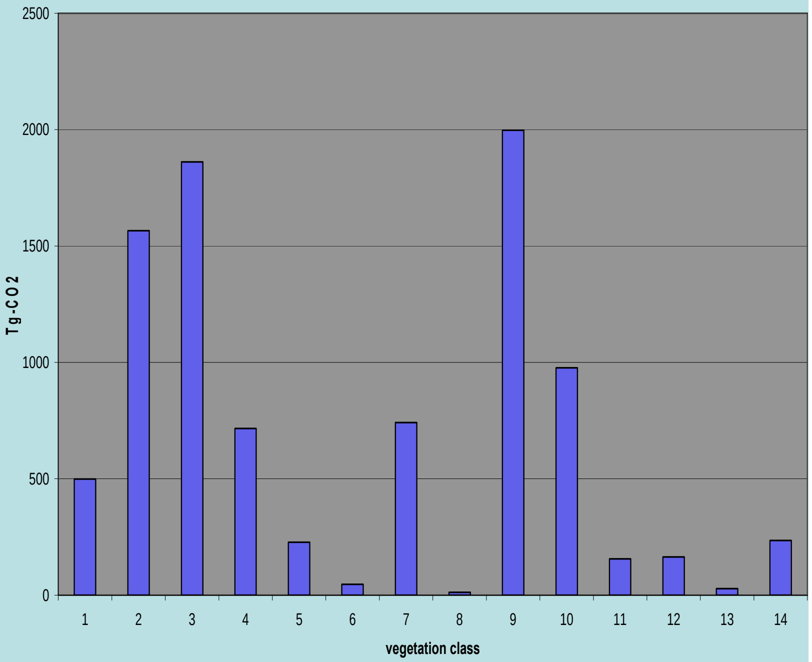
Methodology – biomass burning emissions 2000

Burnt area per vegetation type



x BD x BE x EF

CO2 emissions per vegetation type



Other years:

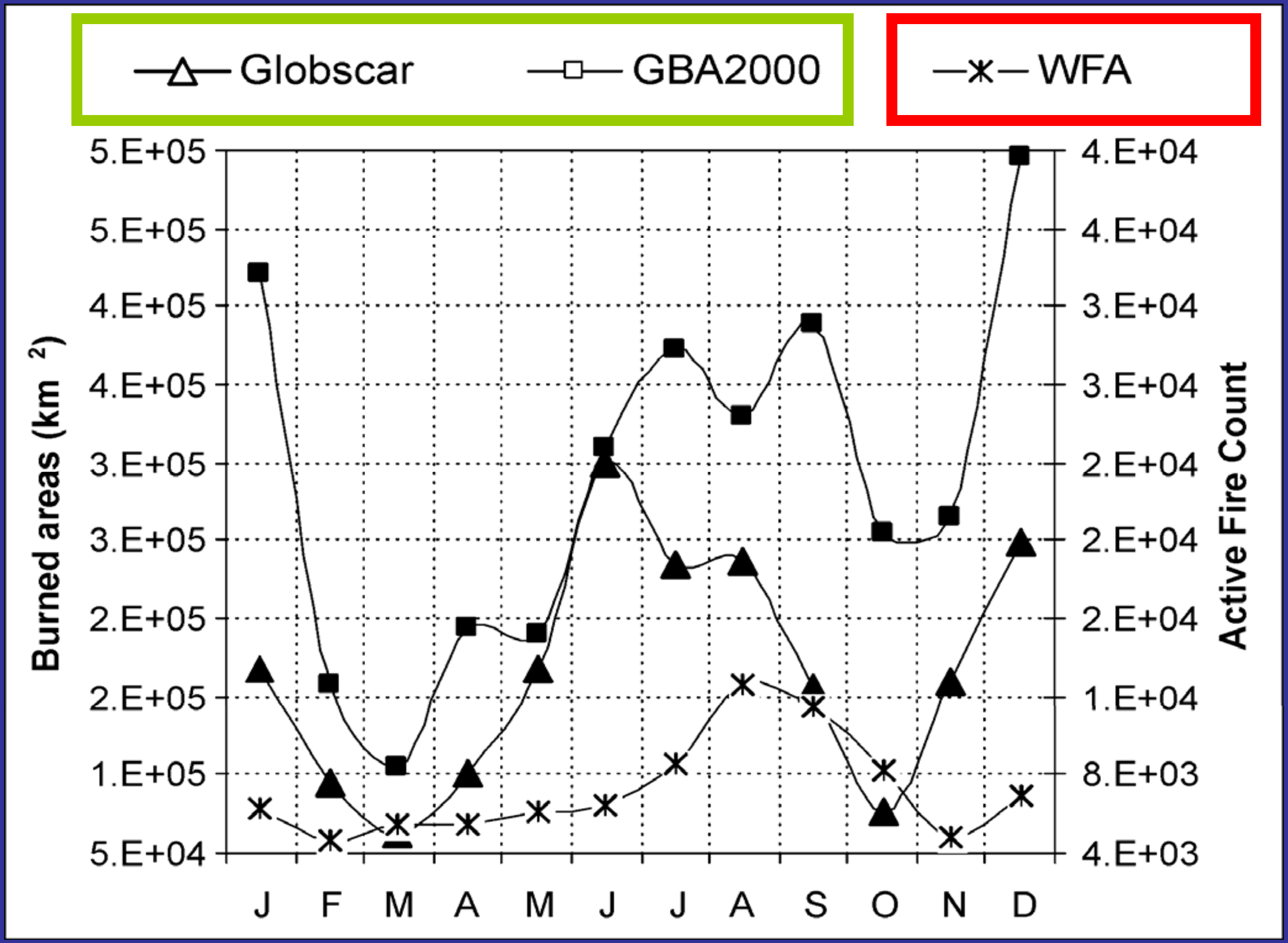
scaling of ATSR fire counts, using 2000 as a basis

Table 1. Emission Factors for Pyrogenic Species Emitted From Various Types of Biomass Burning[a]

Species	Savanna and Grassland[b]	Tropical Forest[c]	Extratropical Forest[d]	Biofuel Burning[e]	Charcoal Making[f]	Charcoal Burning[f]	Agricultural Residues[i]
CO_2	1613 ± 95	1580 ± 90	1569 ± 131	1550 ± 95	440	2611 ± 241	1515 ± 177
CO	65 ± 20	104 ± 20	107 ± 37	78 ± 31	70	200 ± 38	92 ± 84
CH_4	2.3 ± 0.9	6.8 ± 2.0	4.7 ± 1.9	6.1 ± 2.2	10.7	6.2 ± 3.3	2.7
Total nonmethane hydrocarbons	3.4 ± 1.0	8.1 ± 3.0	5.7 ± 4.6	7.3 ± 4.7	2.0	2.7 ± 1.9	(7.0)[b]
C_2H_2	0.29 ± 0.27	0.21–0.59	0.27 ± 0.09	0.51–0.90	0.04	0.05–0.13	(0.36)[h]
C_2H_4	0.79 ± 0.56	1.0–2.9	1.12 ± 0.55	1.8 ± 0.6	0.10	0.46 ± 0.33	(1.4)[b]
C_2H_6	0.32 ± 0.16	0.5–1.9	0.60 ± 0.15	1.2 ± 0.6	0.10	0.53 ± 0.48	(0.97)[h]
C_3H_4	0.022 ± 0.014	0.013	0.04–0.06	(0.024)[h]	–	(0.06)[h]	(0.032)[h]
C_3H_6	0.26 ± 0.14	0.55	0.59 ± 0.16	0.5–1.9	0.06	0.13–0.56	(1.0)[b]
C_3H_8	0.09 ± 0.03	0.15	0.25 ± 0.11	0.2–0.8	0.04	0.07–0.30	(0.52)[h]
1-butene	0.09 ± 0.06	0.13	0.09–0.16	0.1–0.5	–	0.02–0.20	(0.13)[h]
i-butene	0.030 ± 0.012	0.11	0.05–0.11	0.1–0.5	–	0.01–0.16	(0.08)[h]
trans-2-butene	0.024 ± 0.014	0.05	0.01–0.05	0.05–0.3	–	0.01–0.06	(0.04)[h]
cis-2-butene	0.021 ± 0.011	0.042	0.008–0.13	0.05–0.18	–	0.01–0.03	(0.05)[h]
Butadiene	0.07 ± 0.05		0.06–0.08	0.11–0.36	–	0.01–0.10	(0.09)[h]
n-butane	0.019 ± 0.09	0.041	0.069 ± 0.038	0.03–0.13	–	0.02–0.10	(0.06)[h]
i-butane	0.006 ± 0.003	0.015	0.022 ± 0.009	0.01–0.05	–	0.006–0.01	(0.015)[h]
1-pentene	0.022 ± 0.010	0.056	0.04–0.07	0.5	–	0.028	0.008
n-pentane	0.005 ± 0.004	0.014	0.05–0.06	0.07	–	0.10	(0.025)[h]
2-methyl-butenes	0.008 ± 0.004	0.074	0.033	0.16	–	0.015	0.007
2-methyl-butane	0.011 ± 0.012	0.008	0.026–0.029	0.08	–	0.07	(0.018)[h]
Isoprene	0.020 ± 0.012	0.016	0.10	0.15–0.42	–	0.017	(0.05)[h]
Cyclopentene	0.012 ± 0.008	(0.02)[b]	0.019	0.61	–	0.035	(0.02)[h]
4-methyl-1-pentene	0.048	0.048	(0.05)[b]	0.015	–	(0.09)[h]	0.016
1-hexene	0.037 ± 0.016	0.063	0.07–0.11	(0.05)[h]	–	(0.13)[h]	0.013
n-hexane	0.039 ± 0.045	(0.05)[b]	0.03–0.06	(0.04)[h]	–	0.063	(0.05)[h]
Isohexanes	0.05	(0.08)[b]	(0.08)[b]	(0.06)[h]	–	(0.15)[h]	(0.08)[h]
Heptane	0.05	(0.08)[b]	(0.08)[b]	(0.06)[h]	–	(0.15)[h]	(0.08)[h]
Octenes	0.003–0.008	0.012	0.005	(0.007)[h]	–	(0.017)[h]	0.004

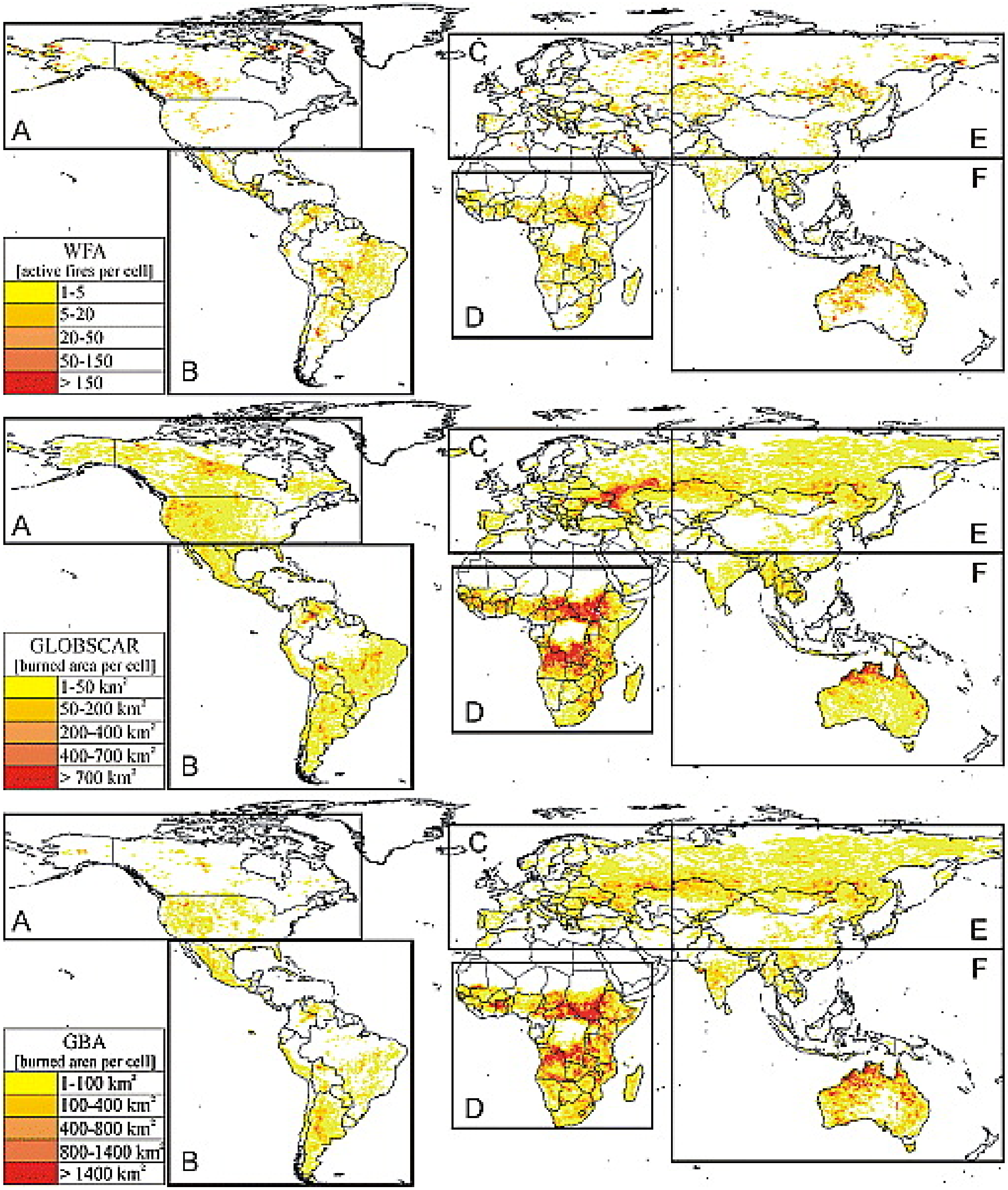
Emissions factors: based on measurements in different countries, and campaigns

Compilation by Andreae and Merlet, 2001



Uncertainty in biomass burning products: burned areas / fire counts

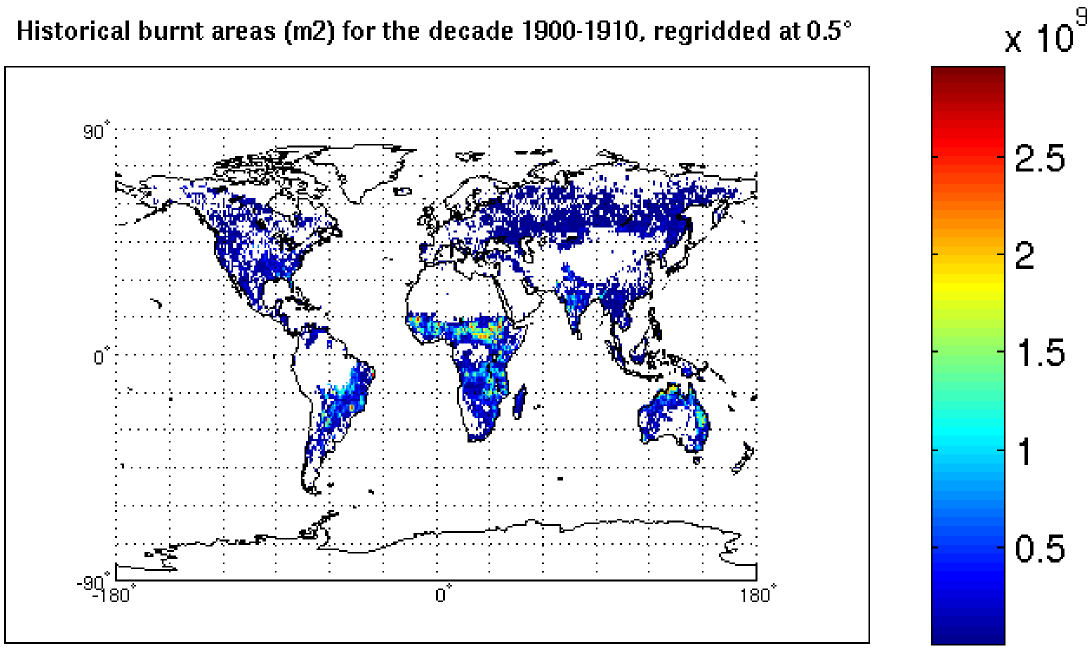
(from Gregoire, April 2005)



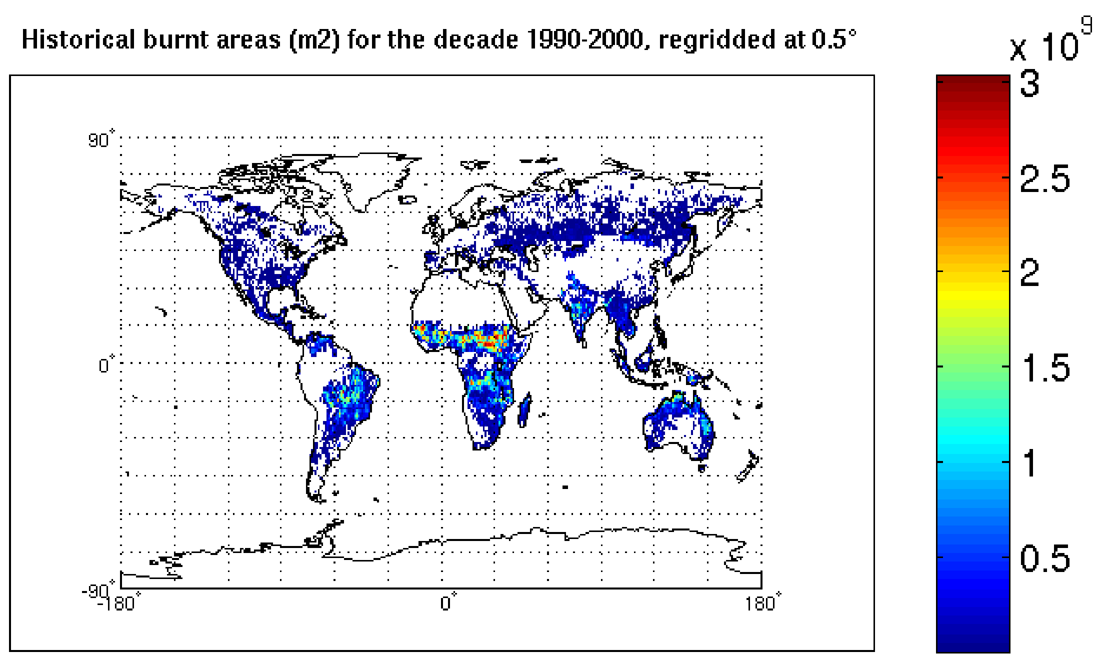
Inter-comparison of global fire products:
-World Fire Atlas (WFA)
- GLOBSCAR
- GBA2000

Boschetti et al., 2004
Geophy. Res. Letters
Vol. 31

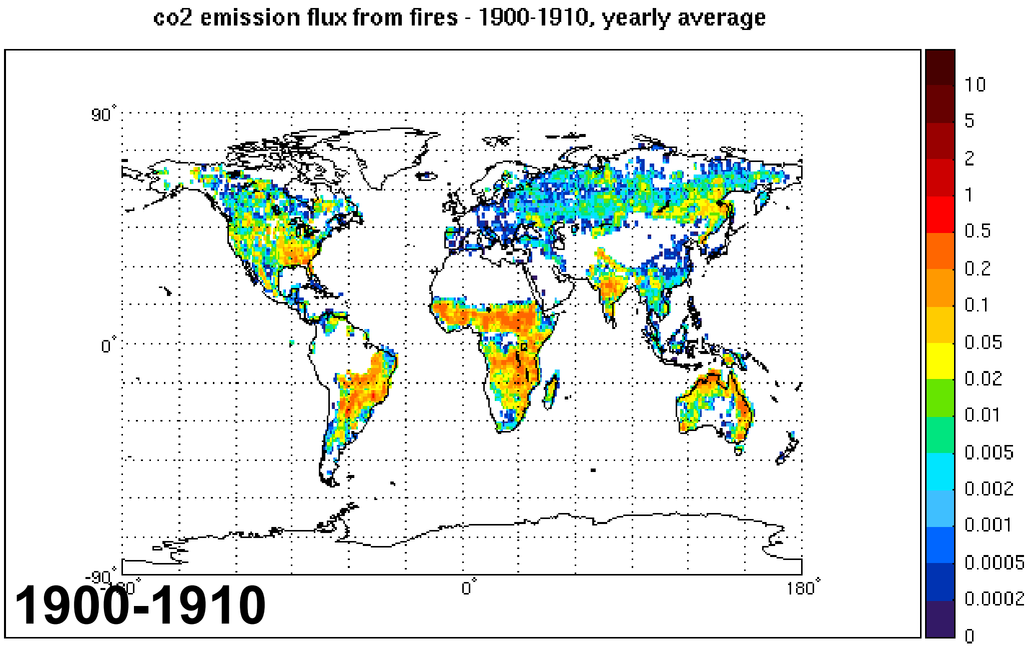
Burned areas (in m^2) for the 1900-1910 and 1990-2000 decades

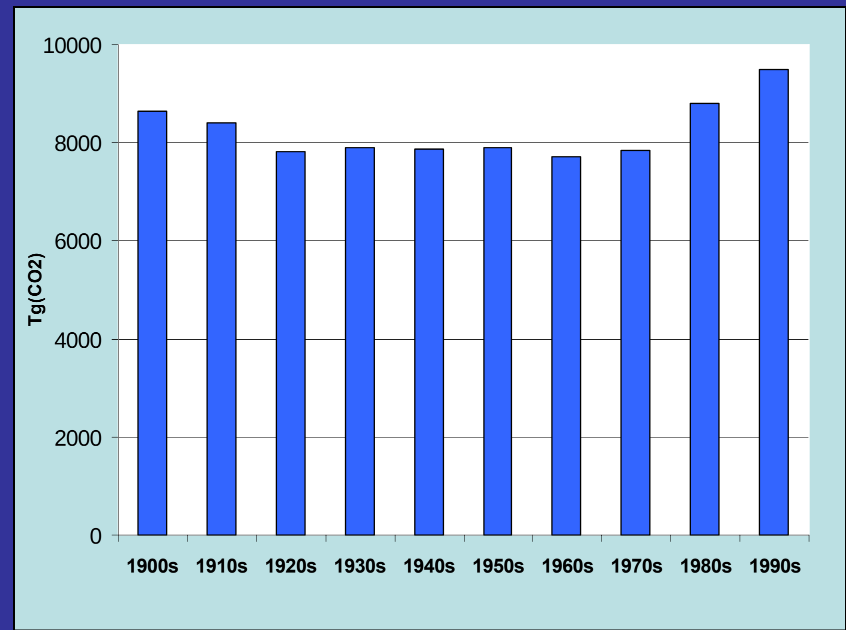


1900-1910



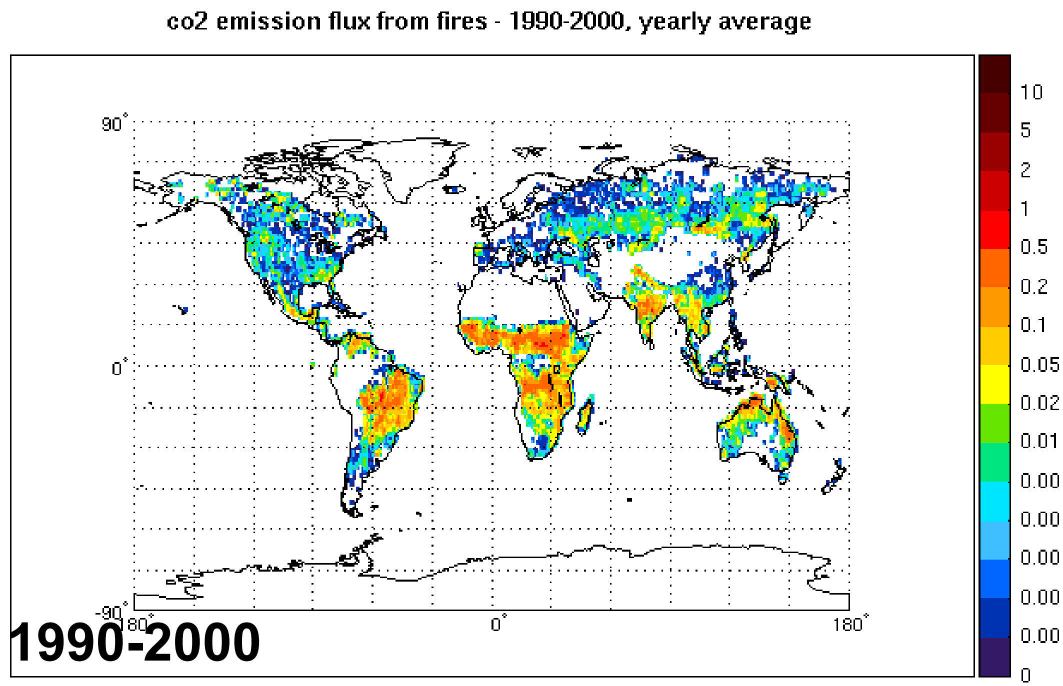
1990-2000

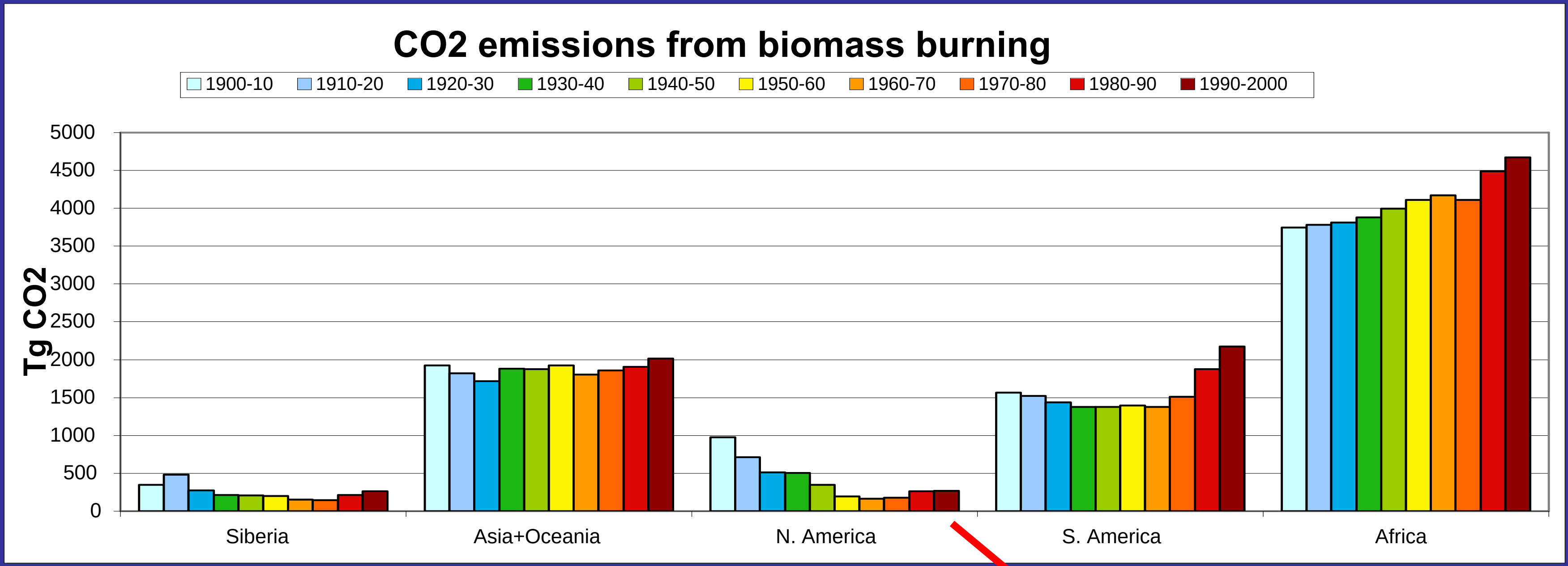


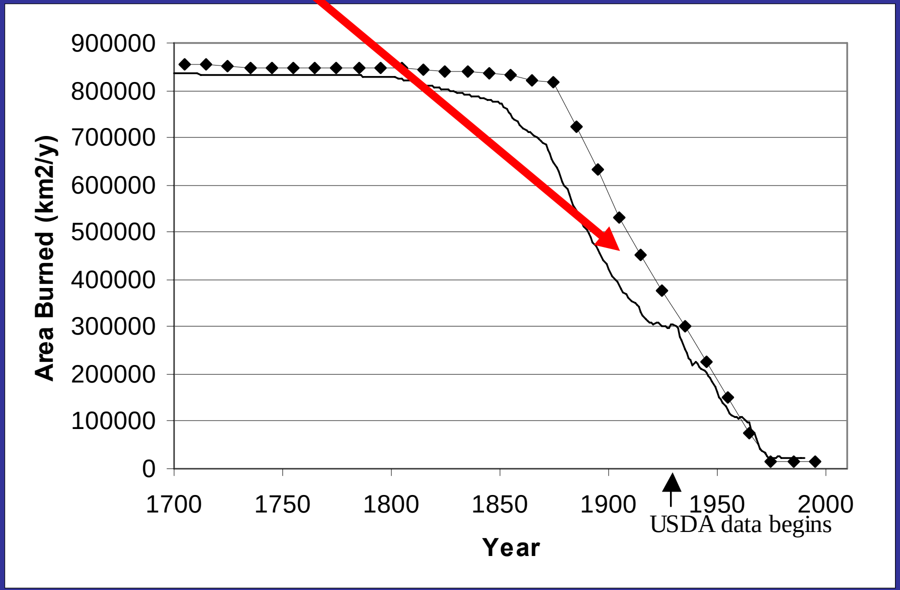


CO2 emissions for the 1900-1910 and 1990-2000 decades in 1.e13 molec/cm2/s

Not taken into account: Change in vegetation distribution over the 20th century.

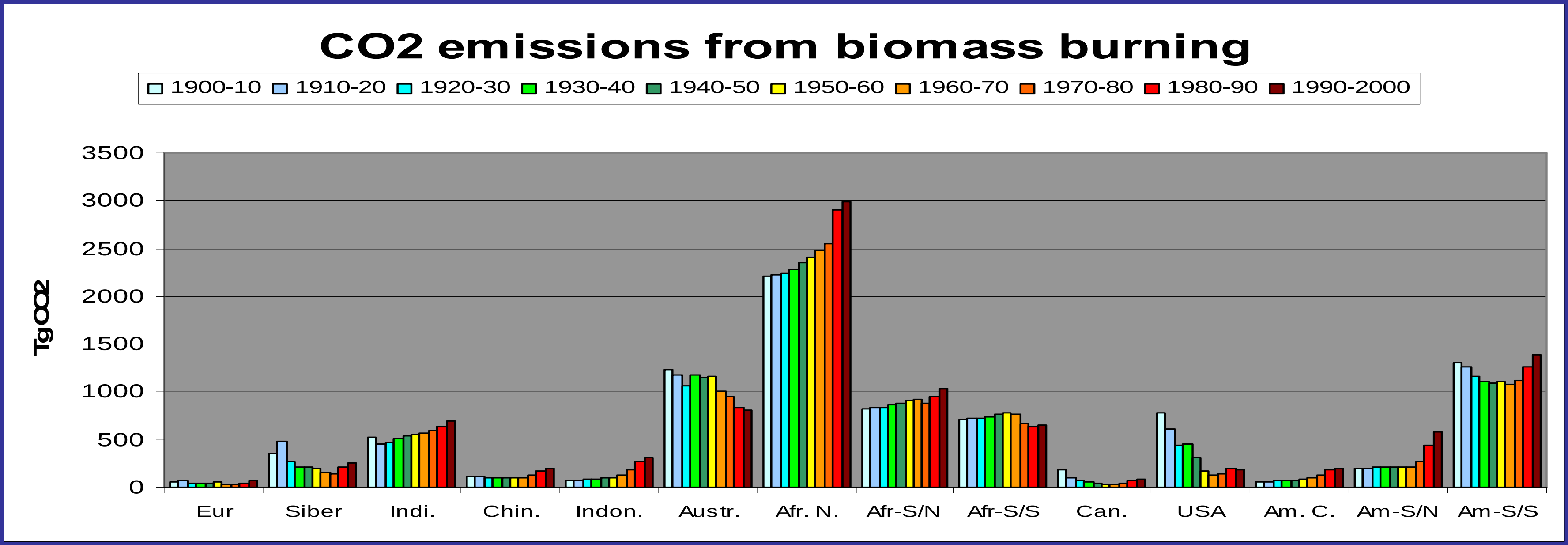


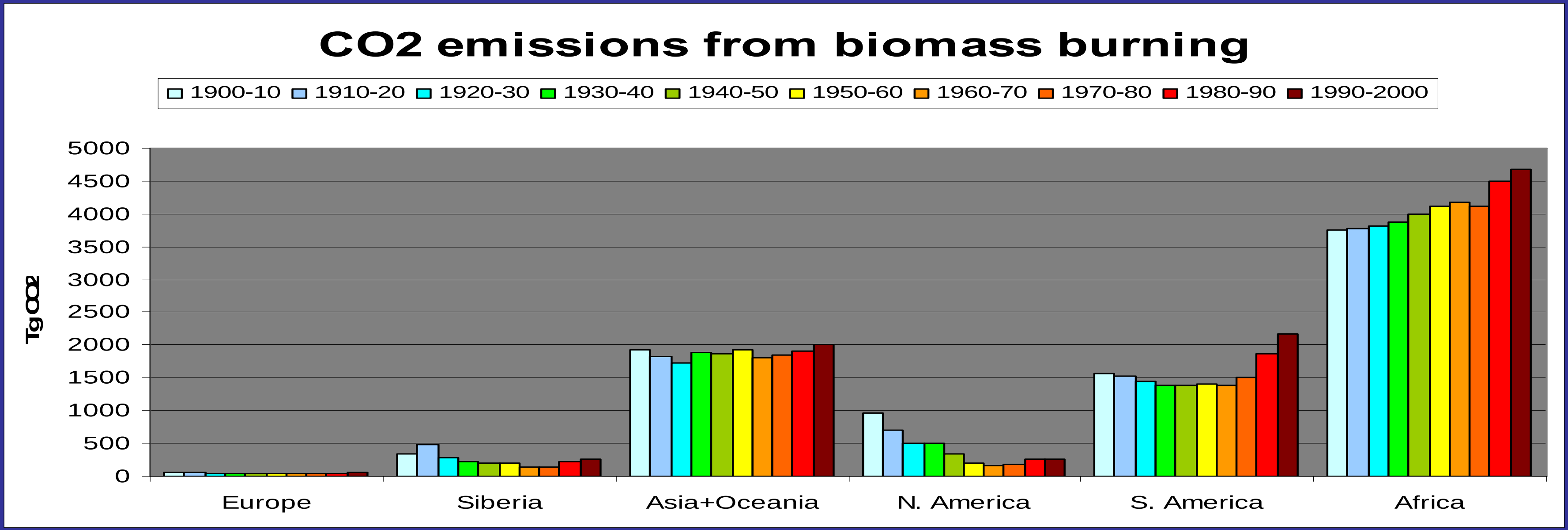




From Hurtt et al, PNAS, feb 2002, pp. 1389

CO_2 emissions resulting from biomass burning during the 20th century





CO_2 emissions resulting from biomass burning during the 20th century

Evaluation of the inventories under way:

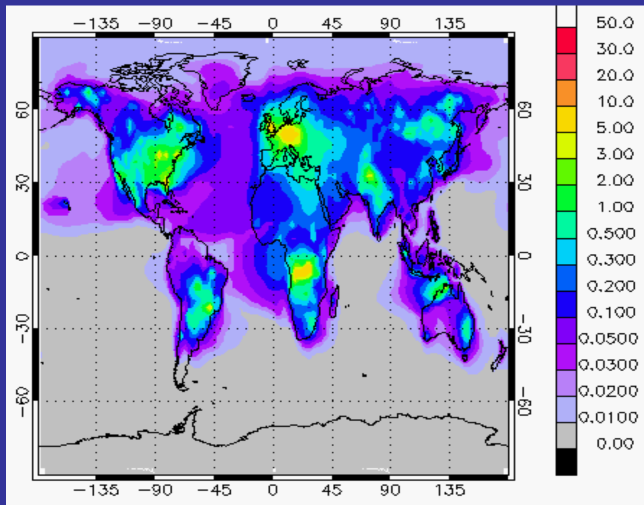
→Use of a chemistry-transport model and compare simulation results with observations

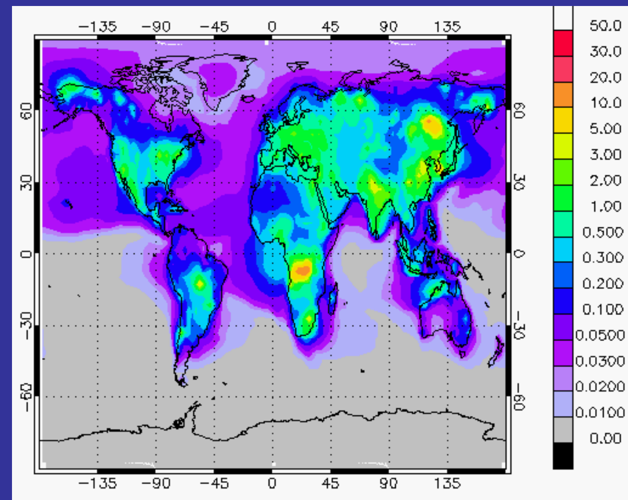
MOZART-4 model: available at http://gctm.acd.ucar.edu/mozart/
Global chemistry-transport model
Includes gaseous species and aerosols
Emissions (anthropogenic and biomass burning): from the GICC inventory
Natural emissions: algorithm included in the model

→ Comparisons with other inventories

Under way: already discussed in the GEIA presentation

Examples of results of simulations using MOZART-4

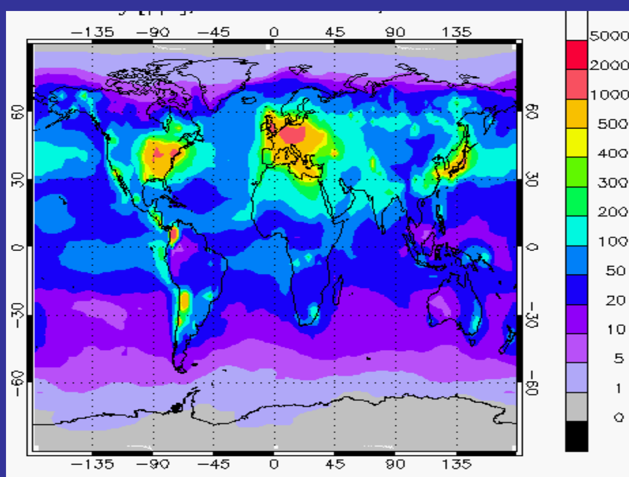


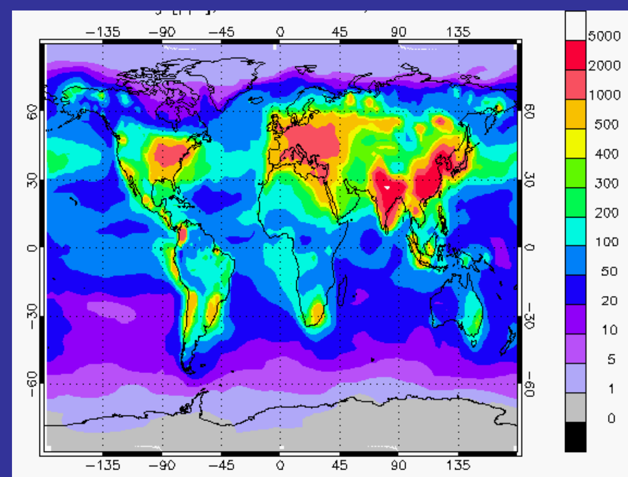


Black carbon (ppbv)

July 1900

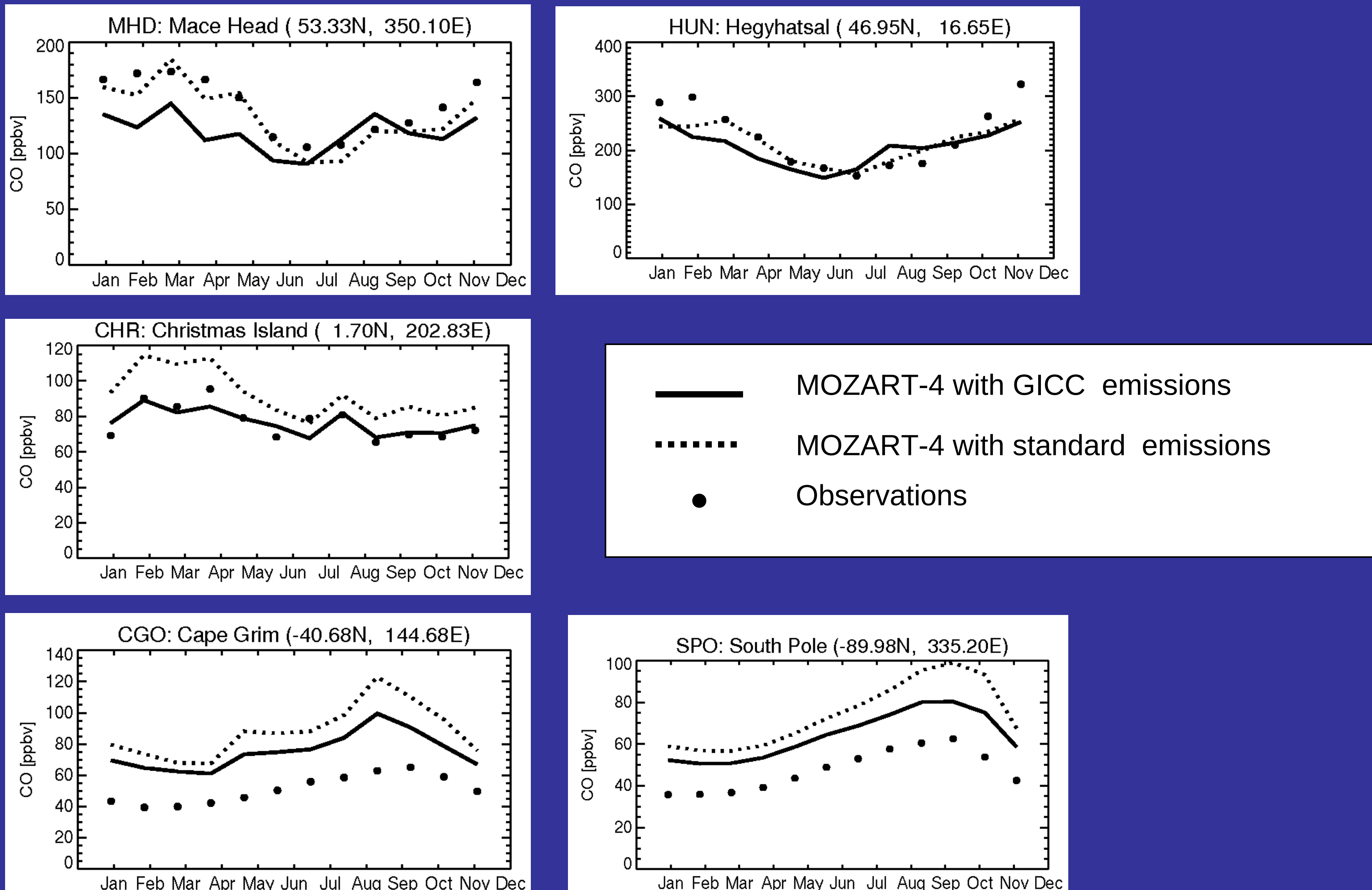
July 2000



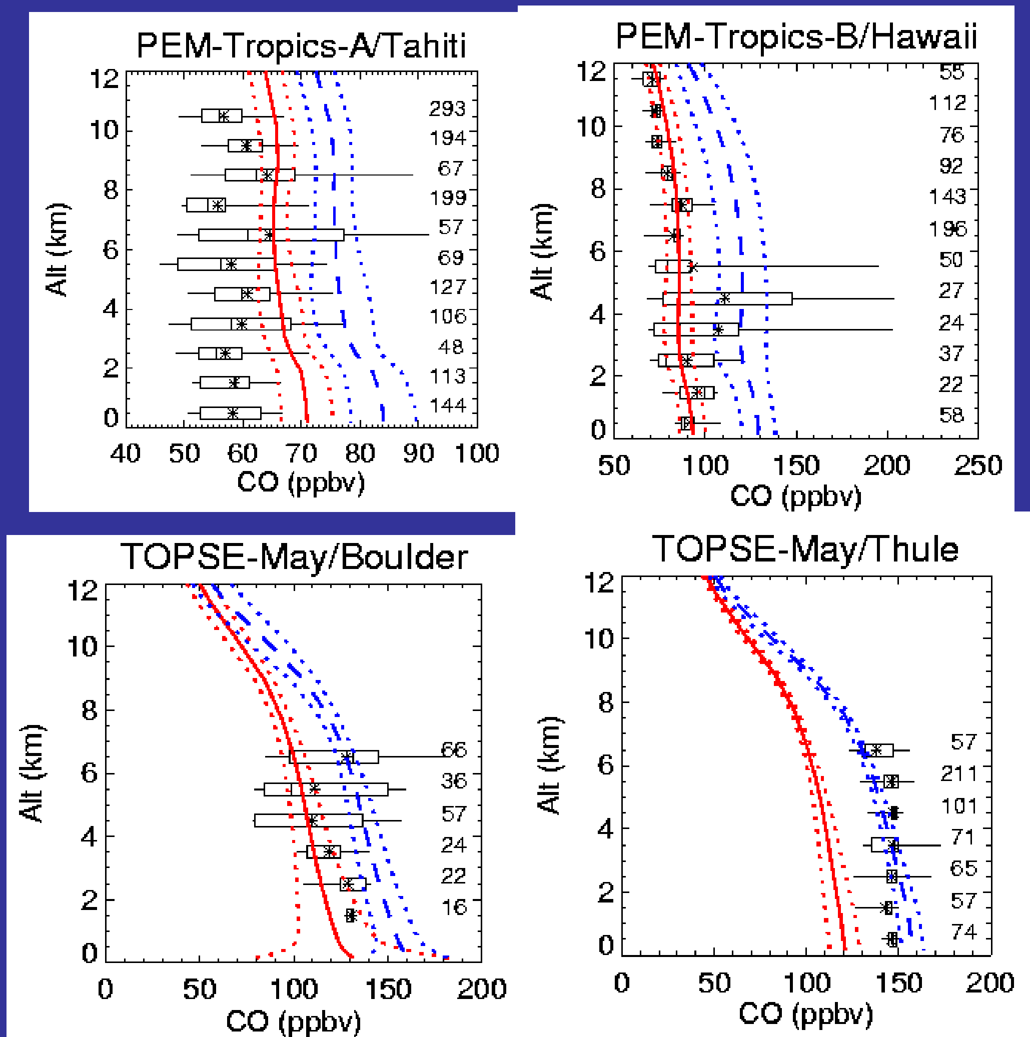


SO_4 (ppbv)

During the next months: look for available observations and comparisons model/observations



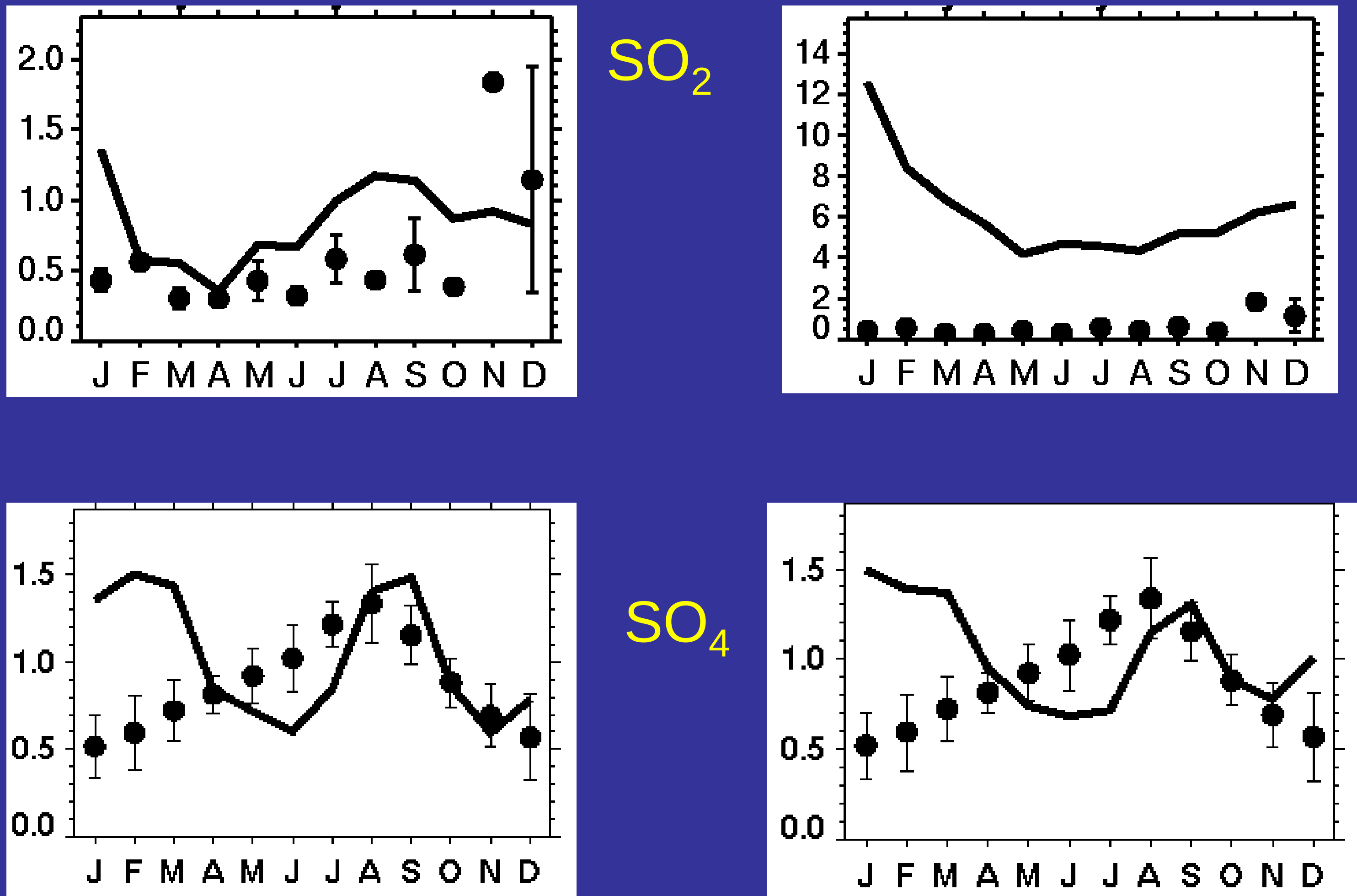
CO at different NOAA/GMD stations



MOZART-4 GICC emissions

MOZART-4 standard emissions

CO vertical profiles from different campaigns



Observed and calculated $SO2$ and $SO4$ (in μ g/m^3)
Observations from the IMPROVE US network,
at the Bryce Canyon National Park

Availability of the dataset:

It will be publically available through
the ACCENT/GEIA web portal for emissions

[RETRO, EDGAR, GFEDv2, etc.
already available within GEIA]

ACCENT access: www.accent-network.org
GEIA access: www.geiacenter.org

GEIA

ACCENT
ATMOSPHERIC COMPOSITION CHANGE
THE EUROPEAN NETWORK OF EXCELLENCE