# Estimation of surface emissions


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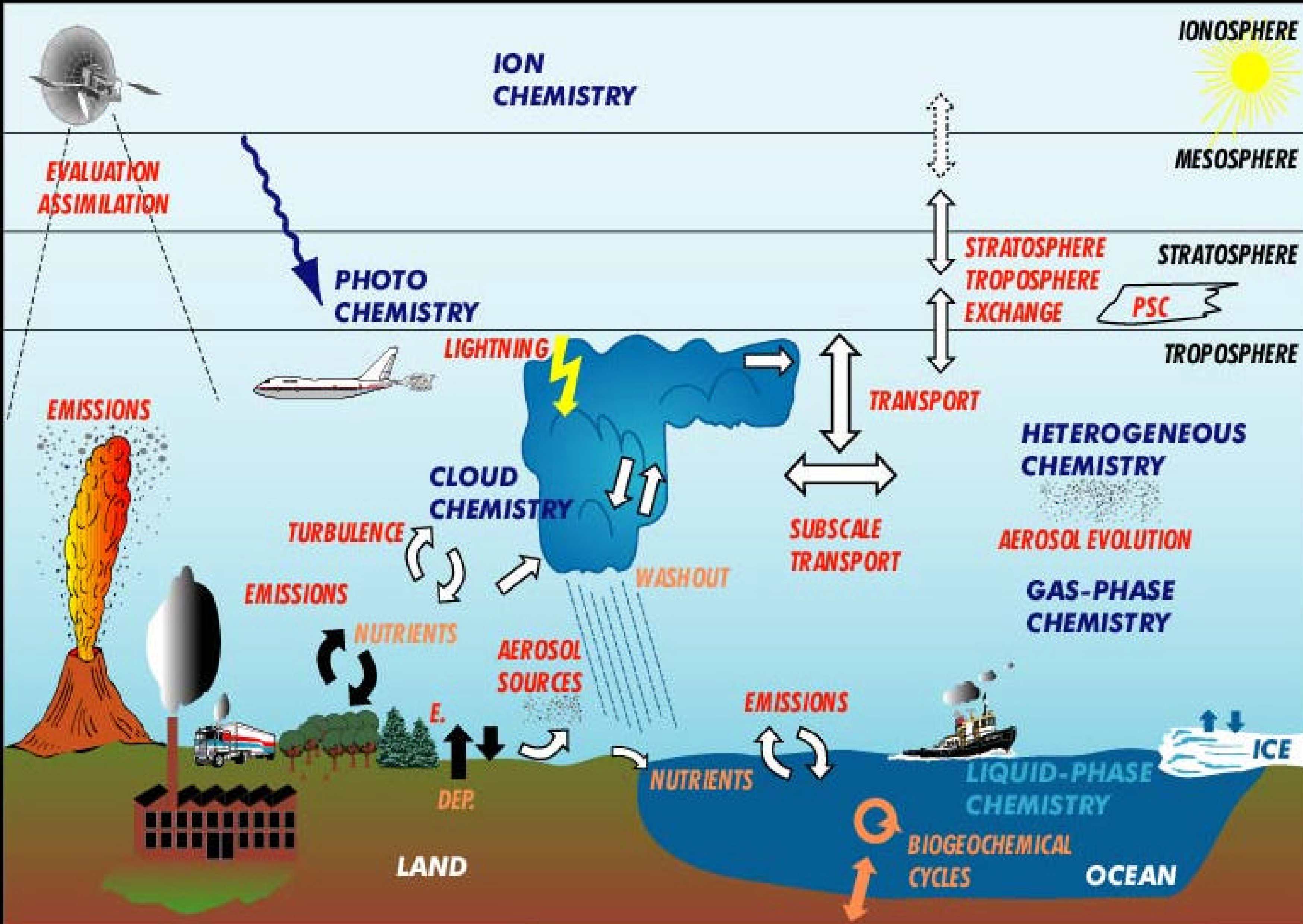



From MPI - Meteorologie

Where are emissions needed:

- Forecast of the atmospheric composition, campaigns (GEMS, AMMA)
  - → 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)

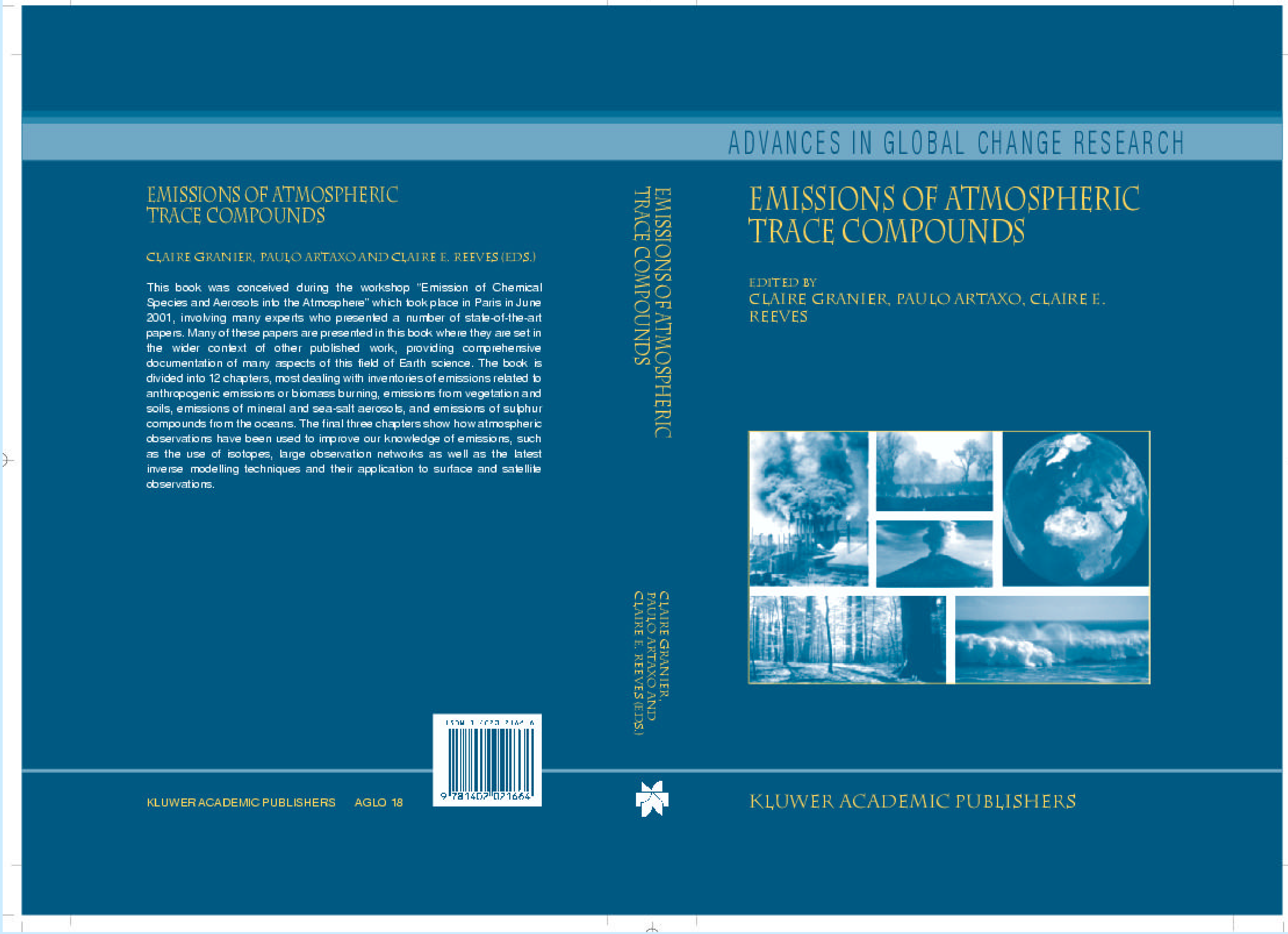
# Outline

- Technological emissions
  - → quantification of emissions
  - → available inventories
  - → main uncertainties

- Biomass burning emissions
  - → quantification of emissions
  - → satellite observations
  - → main uncertainties

- Natural emissions
  - → hydrocarbons
  - → methane
  - → lightning
  - → aerosols

- Conclusions




Several figures coming from this book: Emissions of Atmospheric Trace Compounds
Editors: C. Granier, P. Artaxo, and C. Reeves

# Technological emissions:

**Species considered:**

- ozone precursors: CO, CH4, NOx, hydrocarbons
- aerosol/aerosol precursors: BC, OC, SO2
- non-chemically active species: CO2, N2O, CFCs,
  HFCs, HCFCs, heavy metals, POPS, ..

General equation:

$$\text{Emission} = S\, A_i\, EF_i\, P1_i\, P2_i$$

$A_i$ = 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
$P1_i$, $P2_i$, … = parameters applied to the specified source types and species (ex: sulphur content of the fuel, efficiency, …)

Emissions calculated for different categories of emissions

# Sources of anthropogenic emissions

**Main IPCC categories** (as used in UNFCCC reporting)**:**

- 1. Energy (combustion / production)
- 2. Industrial processes
- 3. Solvents/other product use
- 4. Agriculture
- 5. Land-Use Change and Forestry (LUCF)
- 6. Waste
- 7. Other

Note: Other UN Conventions also starting to use this

Reference: http://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch1ri.pdf

From Olivier, April 2005

## ource 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

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

Variety of classifications
IPCC
EMEP/CORINAIR
EDGAR
RAINS
Individual studies

From Olivier, April 2005

# Where are the statistical data coming from?

- International organizations:
  - UN statistics (http://unstats.un.org/unsd//)
  - UNO: FAO, UNEP
  - World Bank: (http://www.worldbank.org/data/)

- Regional and National Organizations:
  - International Energy Agency: IEA: (http://www.iea.org)
  - OECD (http://www.oecd.org)
  - EUROSTAT: (http://epp.eurostat.cec.eu.int)
  - US EPA (http://www.epa.gov)

- Sectoral institutions
  - International Iron and Steel Institute:http://www.worldsteel.org
  - International Aluminium Institute: http://www.world-aluminium.org
  - International Rice Research Institute, ….

**and many others**

# Uncertainty in emissions mapping

Most data reported at country level (or also: county, district, …)
but model studies require gridded data ➔ requires proxy

Questions:

- How to assess the applicability of a selected type of grid map to a particular activity distribution:
- how good a proxy is the theme of the map for the source category (e.g. population density for industrial emissions)

Quality of the grid map itself:

- how good a proxy is the selected map for the theme
- how accurate are population maps (non available for the most recent years)
- are spatial distributions equal for all gases of a source (example: CO in road transport)

# Examples of inventories

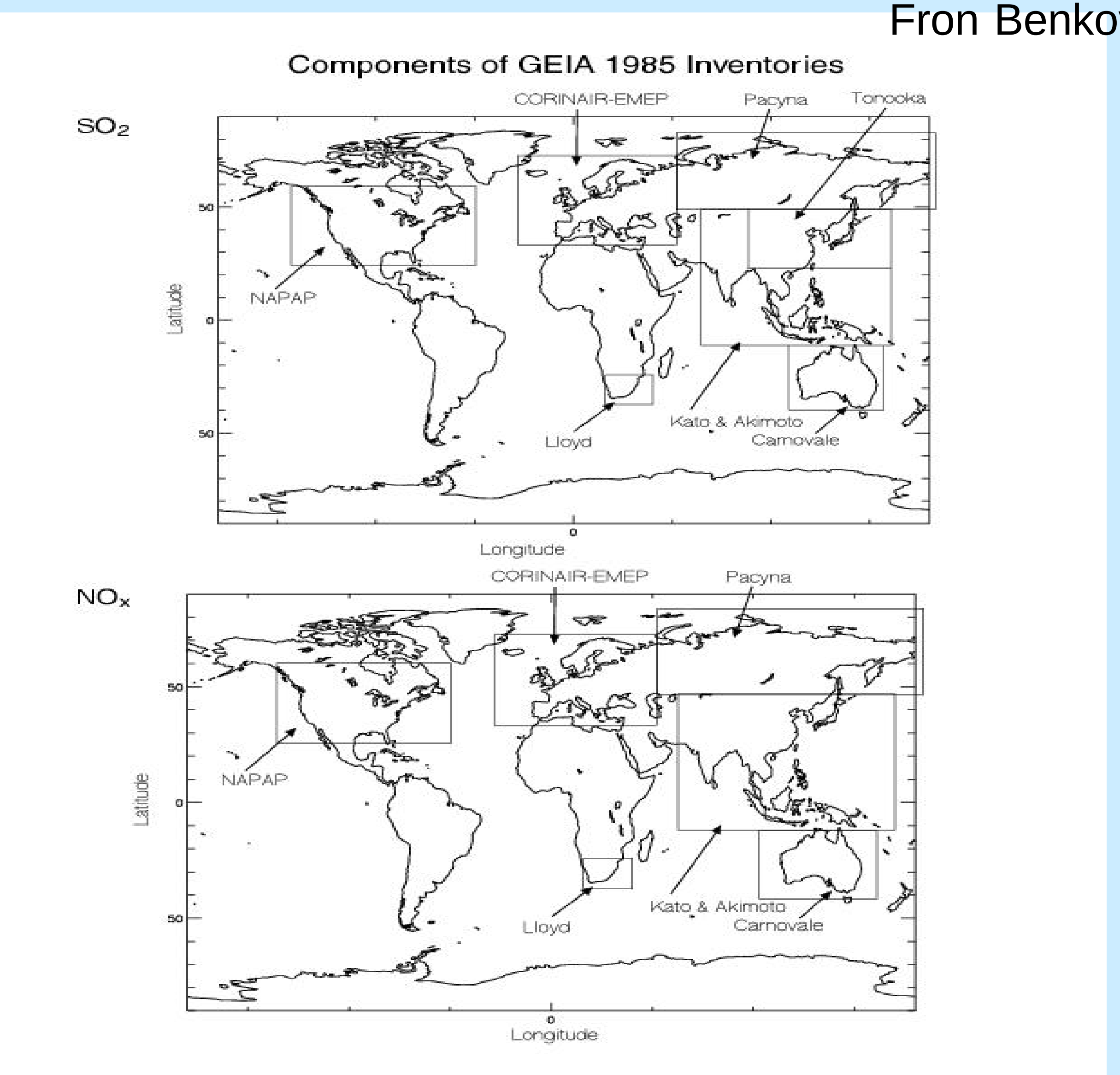
- Partial spatial coverage:
  - NAPAP, CORINAIR, EMEP, RAINS-ASIA, ACESS, TRACE-P
  - UN-ECE, UNFCCC (no spatial information)
  - Official national inventories, sometimes time series

- Global coverage:
  - GEIA (anthropogenic e.g. NOx, $SO_2$, NMVOC; natural e.g. S-volcanoes, NMVOC-soil, vegetation) (1985-1990)
  - EDGAR 3 (anthropogenic GG 1970-1995; other 90-95) + POET (1990-2000)
  - EDGAR-HYDE 1.3 (all 1890-1990)
  - RETRO (1960-2000)
  - AEROCOM (2000) particles only
  - IEA (fuel $CO_2$ 1971-2001, country level)

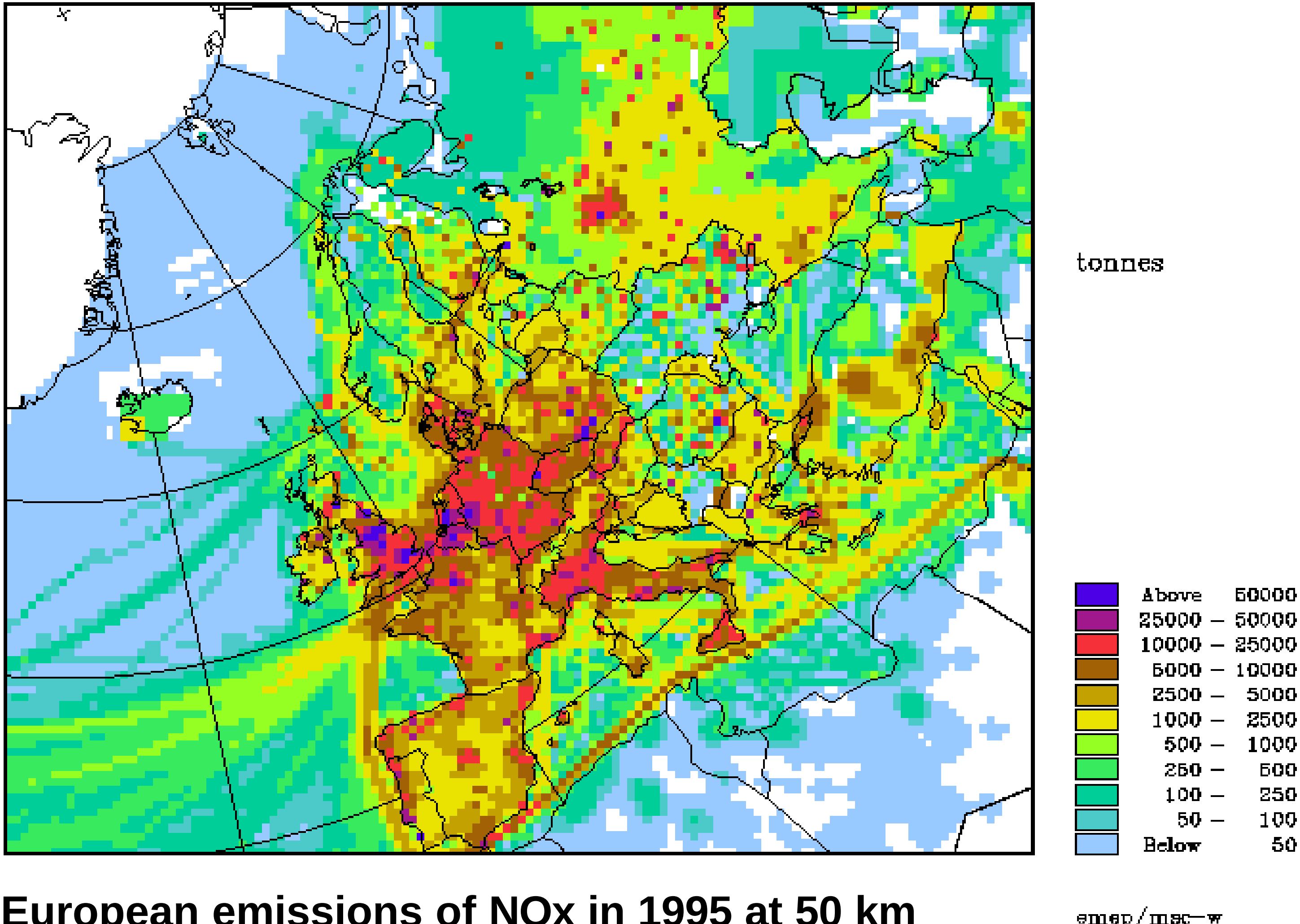
- Other inventories
  - In scientific literature (source-specific, e.g. biomass burning, or country-specific, or only global totals)
  - In scientific literature (new compounds, e.g. aerosols)
  - Other national inventories (e.g. GG in US-CSP)

Based on J. Olivier, 2005

Fron Benkovitz et al., 2003




Regional inventories overlaid on the default global inventories
of SO2 (top panel) and NOx.(bottom panel) for the GEIA 1985 inventories.




**European emissions of NOx in 1995 at 50 km grid resolution (Mg as NO2) (from EMEP)**

**European emissions available from http://webdab.emep.int/**

Netherlands Environmental Assessment Agency

EDGAR

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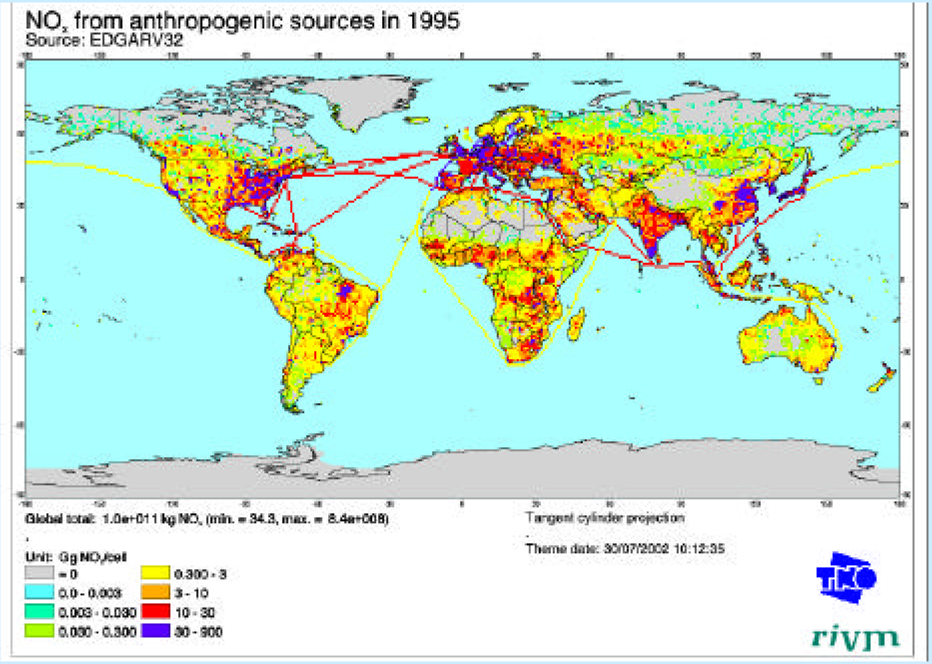
TNO

The EDGAR inventory Home page: http://www.mnp.nl/edgar/

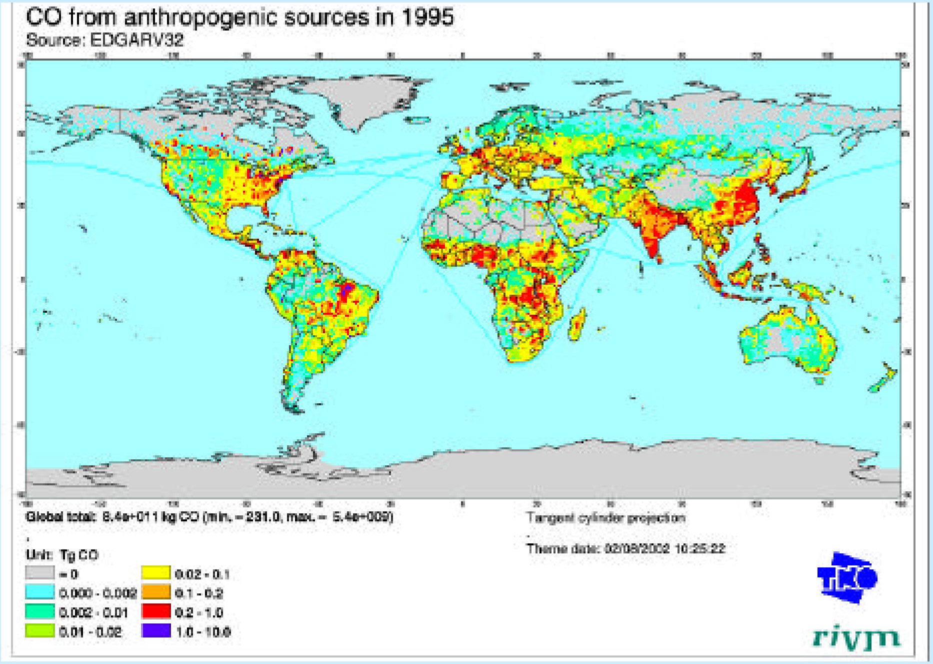
Welcome to the

**Emission Database for Global Atmospheric Research (EDGAR)**

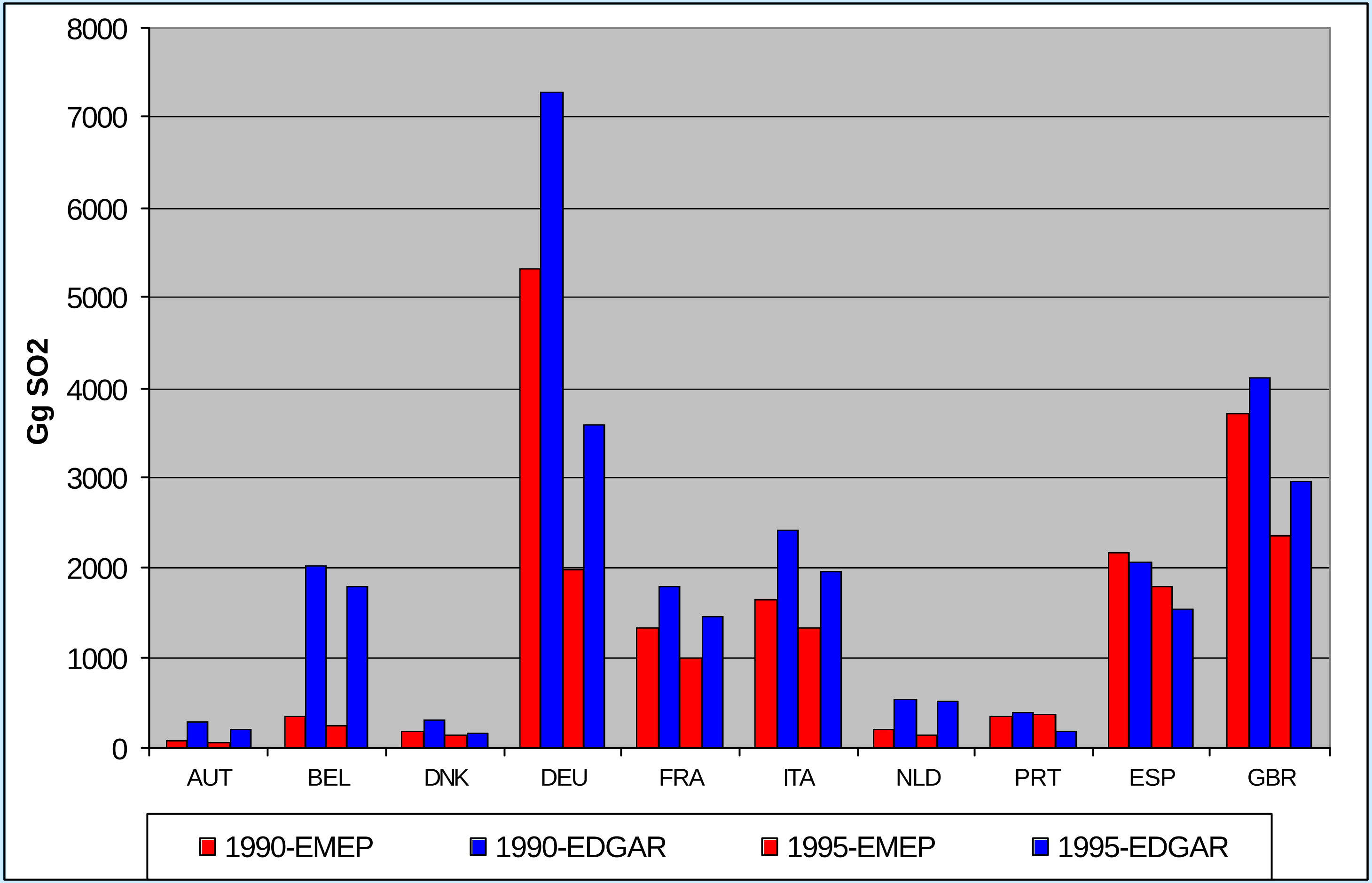
The EDGAR information system is a joint project of RIVM-MNP, Bilthoven (NL), TNO-MEP, Apeldoorn (NL), JRC-IES, Ispra (IT) and MPIC-AC, Mainz (D), and stores global emission inventories of direct and indirect greenhouse gases from anthropogenic sources including halocarbons and aerosols both on a per country and region basis as well as on a grid.




## Global distribution of NOx (top) and CO (bottom) anthropogenic emissions in 1995. Source: EDGAR 3.2



**Global emission database (EDGAR) compared to country data (EMEP)**




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

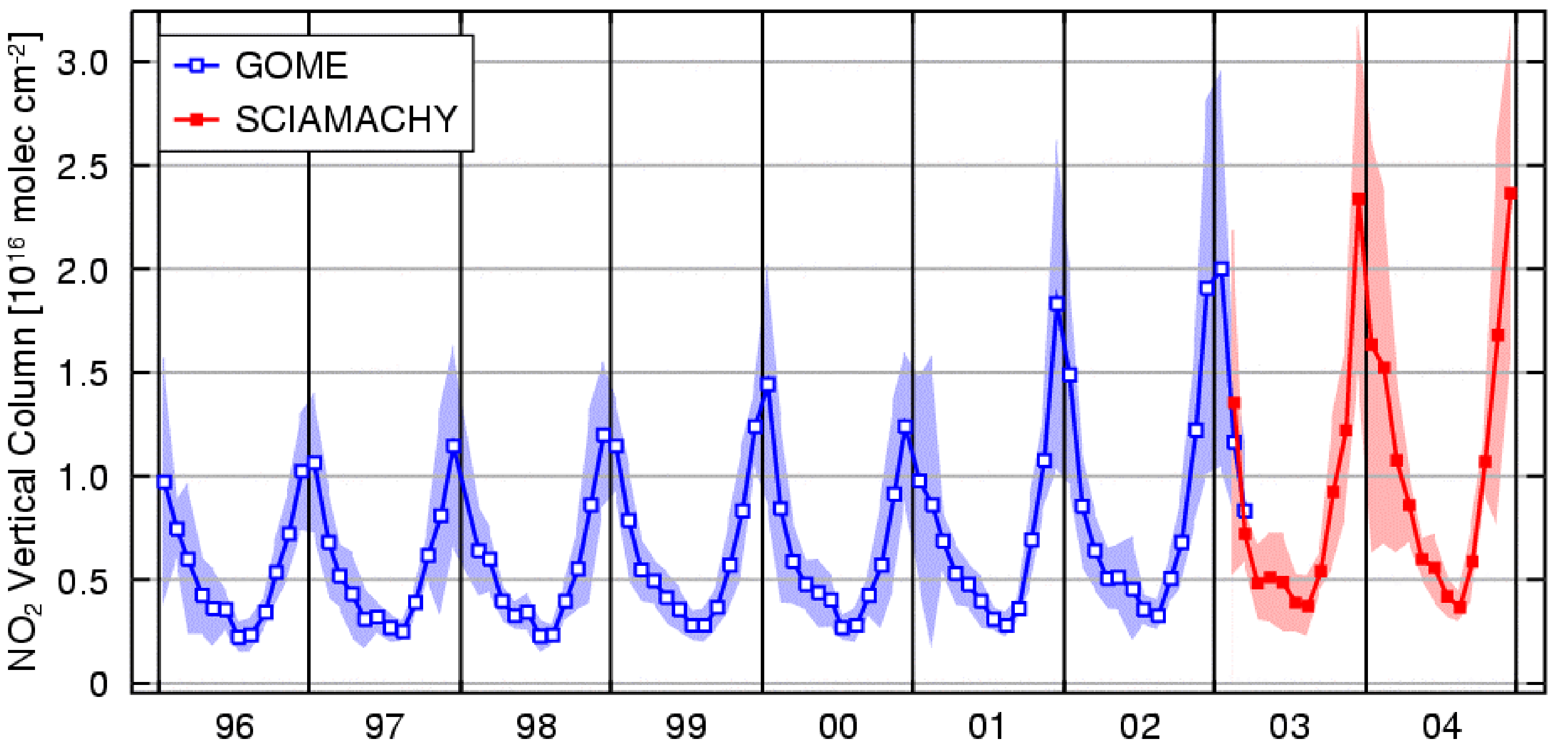
- activity data seems comparable

based on Olivier, 2005

# The most uncertain emissions: anthropogenic emissions in Asia and their recent changes

| Research group | Base year | Domain | Species | Grid size, degree | References |
|---|---|---|---|---|---|
| ACESS | 2000 | All Asia | $SO_2$, $NO_x$, CO, NMVOC, BC, OC, $NH_3$, $CH_4$ | 1 | ACESS (2002) |
| FRSGC | 1995 | All Asia | $SO_2$, $NO_x$, CO, NMVOC, BC, $NH_3$, $N_2O$, $CH_4$ | 0,5 | Ohara et al. (2001), Yan et al. (2002) |
| RAINS-ASIA | 1995 | All Asia | $SO_2$ | 1 | IIASA (2001) |
| Streets et al. | 1985-1997 | All Asia | $SO_2$, $NO_x$ | - | Streets et al. (2001, 2002) |
| Klimont et al. | 1995 | East Asia | $SO_2$, $NO_x$, NMVOC, $NH_3$ | 1 | Klimont et al. (2001) |
| Murano et al. | 1994-1996 | East Asia | $SO_2$, $NO_x$, NMVOC, $NH_3$ | 0,5 | Murano et al. (2002) |

**Statistical data: increase in Asian emissions up to 2000, and a decrease afterwards**




# NO2 tropospheric column in China

From Richter, Burrows, Nuess, Granier and Niemeier, Nature, Sept 1, 2005

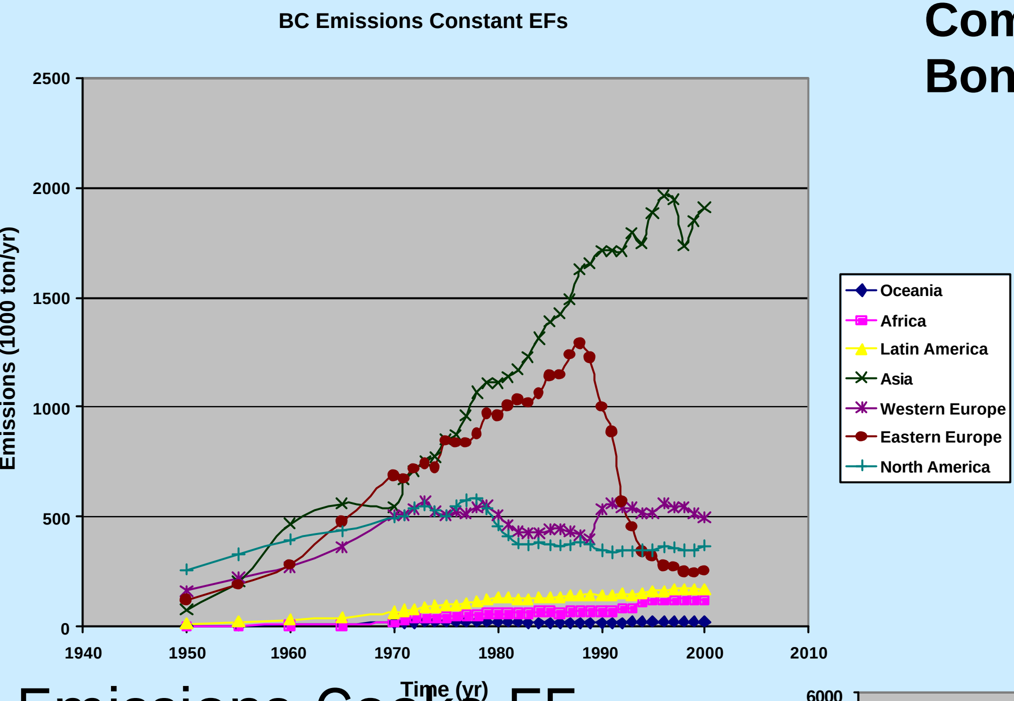
# Uncertainty on aerosols emissions

## Range of estimated emission factors for BC (g/kg)

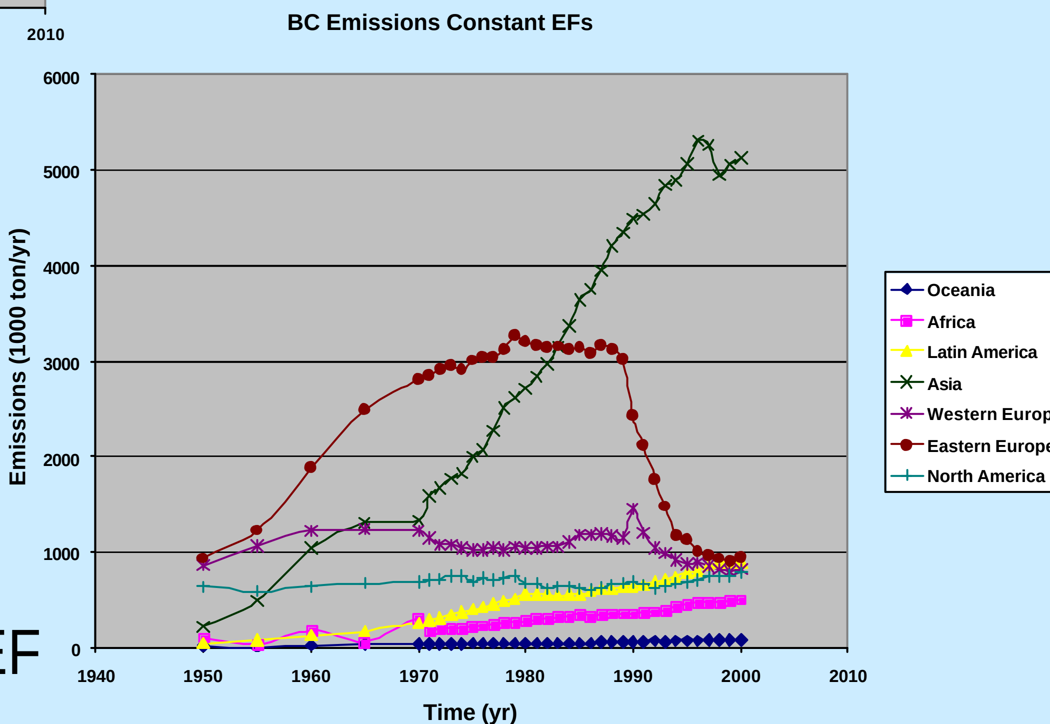
| | Cooke (JGR, 1999 | | Streets (Trace-P; China) |
|---|---|---|---|
| | Devel. to Undev. | | |
| • Hard Coal residential | • 1.39 to 2.28 | - | 0.12* |
| • Lignite residential | | | |
| • Coal industrial | • 2.50 to 4.10 | - | 3.6* |
| | • 0.15 to 1.10 | - | 0.003-0.33 |
| • Diesel transport | • 2.0 to 10.0 | - | 1.1 |
| • Gasoline transport | • 0.03 to 0.15 | - | 0.08 |

* Indicates $EF_{PM}$ from Beijing EPA

# Comparison of BC emissions using Bond et al. and Cooke et al. EF’s




Emissions-Cooke EF




Emissions-Bond EF

An other issue:
NMVOC speciation, not generally given in inventories

From EDGAR 2 version
No speciation in EDGAR 3

| Main group | Group code | Standard NMVOC Compound Group |
|---|---|---|
| Alkanols (alcohols) | v01 | Alkanols (alcohols) |
| Alkanes | v02 | Ethane |
| " | v03 | Propane |
| " | v04 | Butanes |
| " | v05 | Pentanes |
| " | v06 | Hexanes and higher alkanes |
| Alkenes/alkynes (olefines) | v07 | Ethene (ethylene) |
| " | v08 | Propene |
| " | v09 | Ethyne (acetylene) |
| " | v10 | Isoprenes : *no anthropogenic sources** |
| " | v11 | Monoterpenes : *no anthropogenic sources** |
| " | v12 | Other alk(adi)enes and alkynes (olefines) |
| Aromatics | v13 | Benzene (benzol) |
| " | v14 | Methylbenzene (toluene) |
| " | v15 | Dimethylbenzenes (xylenes) |
| " | v16 | Trimethylbenzene |
| " | v17 | Other Aromatics |
| Esters | v18 | Esters |
| Ethers | v19 | Alkoxy alkanes (ethers) |
| Chlorinated hydrocarbons | v20 | Chlorinated hydrocarbons |
| Alkanals (aldehydes) | v21 | Methanal (formaldehyde) |
| " | v22 | Other alkanals (aldehyedes) |
| Alkanones (ketones) | v23 | Alkanones (ketones) |
| Carboxylic acids | v24 | (Alkanoic) acids |
| Other NMVOCs | v25 | Other NMVOC (HCFCs, nitriles, etc.) |

# Detailed data on hydrocarbons speciation: from the UK NAEI inventory

http://www.aeat.co.uk/netcen/airqual/naei/annreport/annrep97/naei97.html

**(One file with > 500 compounds)**

| Emissions of the 50 most significent NMVOCs | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1,1,1-trichloroethane | | | | | | | | 0.39 | | | | 14.93 | 0.12 | 15 |
| 1,2,4-trimethylbenzene | 0.00 | | | | | 0.38 | 0.03 | | 0.42 | 2.35 | 10.71 | 9.14 | | 23 |
| 1,3,5-trimethylbenzene | 0.00 | | | | | 0.15 | 0.03 | | 0.42 | 0.57 | 3.34 | 3.33 | | 8 |
| 1-butanol | | | | | | | | 0.90 | | | | 7.10 | 0.01 | 8 |
| 1-butene | 0.00 | | | 0.74 | | 0.13 | 0.03 | 0.81 | 0.42 | 2.19 | 2.65 | | | 7 |
| 1-propanol | | | | | | | | 1.12 | | | | 19.26 | 0.07 | 20 |
| 2-butanone | | | | | | | | 1.84 | | | | 9.31 | 0.03 | 11 |
| 2-butene | | | | | | 0.21 | 0.00 | 0.81 | | 3.75 | 6.88 | | | 12 |
| 2-methylhexane | | | | 0.03 | | 0.16 | 0.00 | | | 1.35 | 5.17 | 0.22 | | 7 |
| 2-methylpentane | 0.00 | | | 1.65 | | 0.45 | 0.12 | | 1.76 | 4.44 | 7.74 | 0.27 | | 16 |
| 2-pentene | | | | | | 0.10 | 0.00 | | | 3.46 | 3.42 | | | 7 |
| 2-propanol | | | | | | | | 2.20 | | | | 20.07 | 0.03 | 22 |
| 3-ethyltoluene | 0.00 | | | | | 0.20 | 0.02 | | 0.42 | 0.94 | 4.68 | 2.31 | | 9 |
| 3-methylpentane | 0.00 | | | 0.69 | | 0.28 | 0.06 | | 0.92 | 2.96 | 5.38 | 0.25 | | 11 |
| 4-ethyltoluene | 0.00 | | | | | 0.20 | 0.03 | | 0.42 | 0.94 | 4.68 | 0.94 | | 7 |
| 4-methyl-2-pentanone | | | | | | | | 1.14 | | | | 10.40 | | 12 |
| acetone | 0.04 | 0.07 | 0.08 | | | 0.22 | 0.17 | 5.44 | 1.68 | | 0.33 | 12.85 | 0.00 | 21 |
| acetylene | 0.02 | 0.02 | 0.53 | | | 1.26 | 0.27 | 0.86 | 2.69 | | 19.18 | | | 25 |
| benzene | 2.95 | 0.15 | 0.96 | 0.56 | | 1.20 | 0.17 | 7.26 | 1.70 | 1.46 | 21.29 | | 0.08 | 38 |
| butane | 3.26 | 0.48 | 0.75 | 100.49 | | 0.85 | 0.20 | 16.58 | 3.36 | 29.41 | 14.38 | 23.32 | 0.81 | 194 |
| butyl acetate | | | | | | | | 0.11 | | | | 9.76 | 0.04 | 10 |

**Biomass burning emissions :**

**Are they really that important?**

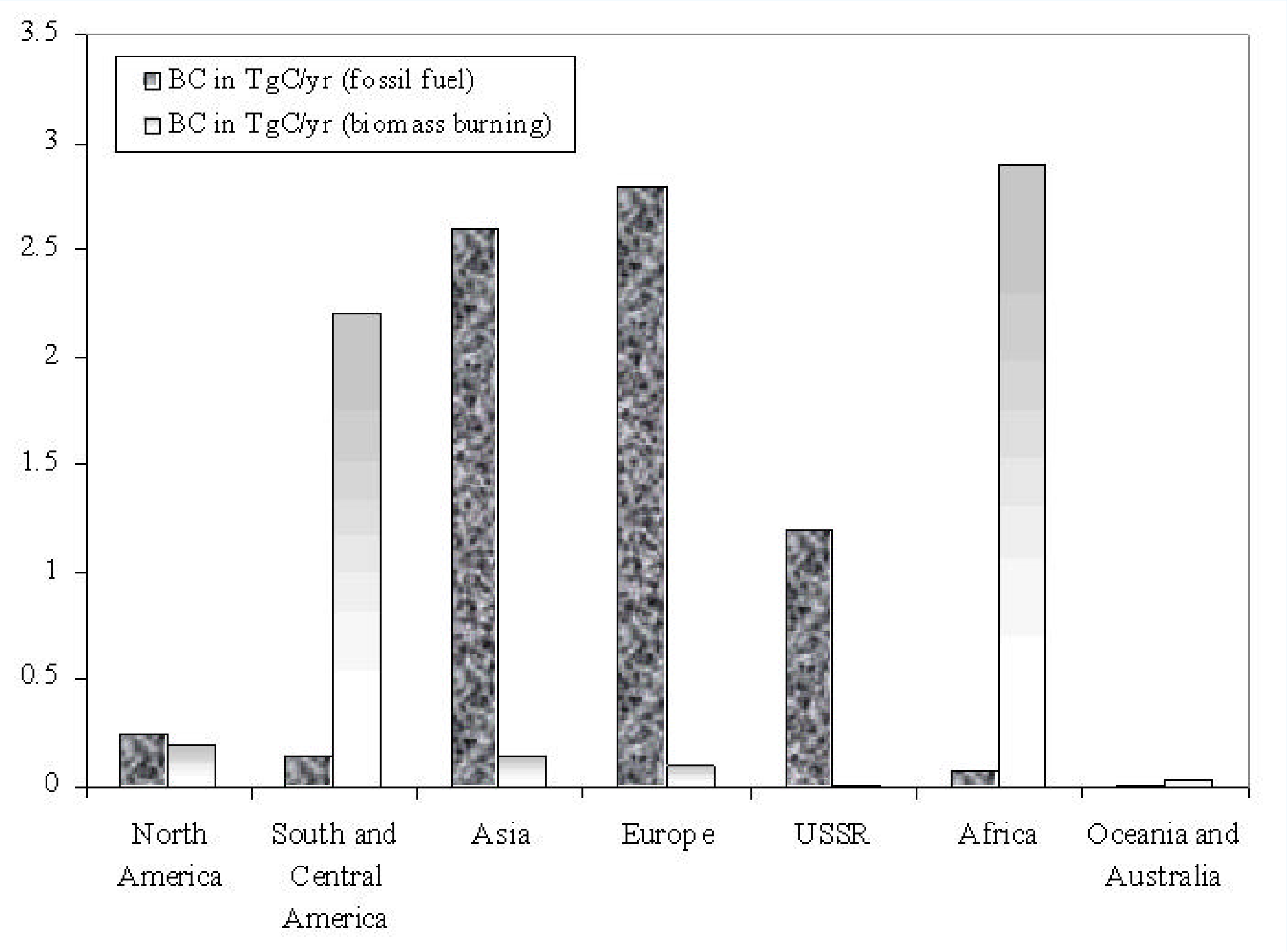
## Global budget of CO [from WMO, 1998]:

**Sources:**

| | | |
|---|---|---|
| | Fossil fuels and industry | 300-500 |
| | Biomass burning | 300-700 |
| | Oceans | 20-200 |
| | Vegetation | 20-200 |
| | CH4 oxidation | 400-800 |
| | NMHC oxidation | 200-600 |
| Total | | 1240-3000 |

**Sinks:**

| | | |
|---|---|---|
| | Reaction with OH | 1400-3000 |
| | Soil uptake | 100-600 |
| | Removal in the stratosphere | 100 |
| Total | | 1600-3700 |




From C. Liousse, 2003

# Calculation of emissions from biomass burning

$$[P]_{lm} = [A]_{lm} \text{ x } [B]_{lm} \text{ x } [CF]_{lm} \text{ ´ } [EF]_{lm}$$

**$A$ is the burned area per month at location $l$ ($m^2$ $month^{-1}$)**

**$B$ is the fuel load ($kg$ $m^{-2}$) expressed on a dry weight (DM) basis within each grid $l$**

**$CF$ is the fraction of available fuel which burns (the combustion factor)**

**$EF$ is the emission factor in gram $CO_2$ per kilogram of dry matter burned**

| Species | Savanna and grassland | Tropical forest | Extratropical forest | Biofuel Burning | Charcoal making | Charcoal burning | Agricultural residues |
|---|---|---|---|---|---|---|---|
| $CO_2$ | 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*[e] |
| $C_2H_2$ | 0.29±0.27 | 0.21-0.59 | 0.27±0.09 | 0.51-0.90 | 0.04 | 0.05-0.13 | *0.36*[e] |
| $C_2H_4$ | 0.79±0.56 | 1.0-2.9 | 1.12±0.55 | 1.8±0.6 | 0.10 | 0.46±0.33 | *1.4*[e] |
| $C_2H_6$ | 0.32±0.16 | 0.5-1.9 | 0.60±0.15 | 1.2±0.6 | 0.10 | 0.53±0.48 | *.97*[e] |
| $C_3H_4$ | 0.022±0.014 | 0.013 | 0.04-0.06 | *0.024*[e] | --- | *0.06*[e] | *0.032*[e] |
| $C_3H_6$ | 0.26±0.14 | 0.55 | 0.59±0.16 | 0.5-1.9 | 0.06 | 0.13-0.56 | *1.0*[e] |
| $C_3H_8$ | 0.09±0.03 | 0.15 | 0.25±0.11 | 0.2-0.8 | 0.04 | 0.07-0.30 | *0.52*[e] |
| isoprene | 0.020±0.012 | 0.016 | 0.10 | 0.15-0.42 | --- | 0.017 | *0.05*[e] |
| terpenes | 0.015 | *0.15*[g] | 0.22 | *0.15*[g] | --- | *0.0* | *0.015*[e] |
| benzene | 0.23±0.11 | 0.39-0.41 | 0.49±0.08 | 1.9±1.0 | --- | 0.3-1.7 | 0.14 |
| PAH | 0.0024 | *0.025*[f] | *0.025*[f] | *0.025*[f] | --- | *0.025*[f] | *0.025*[f] |
| methanol | *1.3*[e] | *2.0*[e] | 2.0±1.4 | *1.5*[e] | 0.16 | *3.8*[e] | *2.0*[e] |
| formaldehyde | 0.26-0.44 | *1.4*[e] | 2.2±0.5 | 0.13±0.05 | --- | *2.6*[e] | *1.4*[e] |
| acetaldehyde | 0.50±0.39 | *0.65*[e] | 0.48-0.52 | 0.14±0.05 | --- | *1.2*[e] | *0.65*[e] |
| acetone | 0.25-0.62 | *0.62*[e] | 0.52-0.59 | 0.01-0.04 | 0.02 | *1.2*[e] | *0.63*[e] |
| 2-butanone | 0.26 | *0.43*[e] | 0.17-0.74 | 0.03-0.06 | --- | *0.83*[e] | *0.44*[e] |
| formic acid | *0.7*[e] | *1.1*[e] | 2.9±2.4 | 0.13 | 0.20 | *2.0*[e] | 0.22 |
| acetic acid | *1.3*[e] | *2.1*[e] | 3.8±1.8 | 0.4-1.4 | 0.98 | *4.1*[e] | 0.8 |

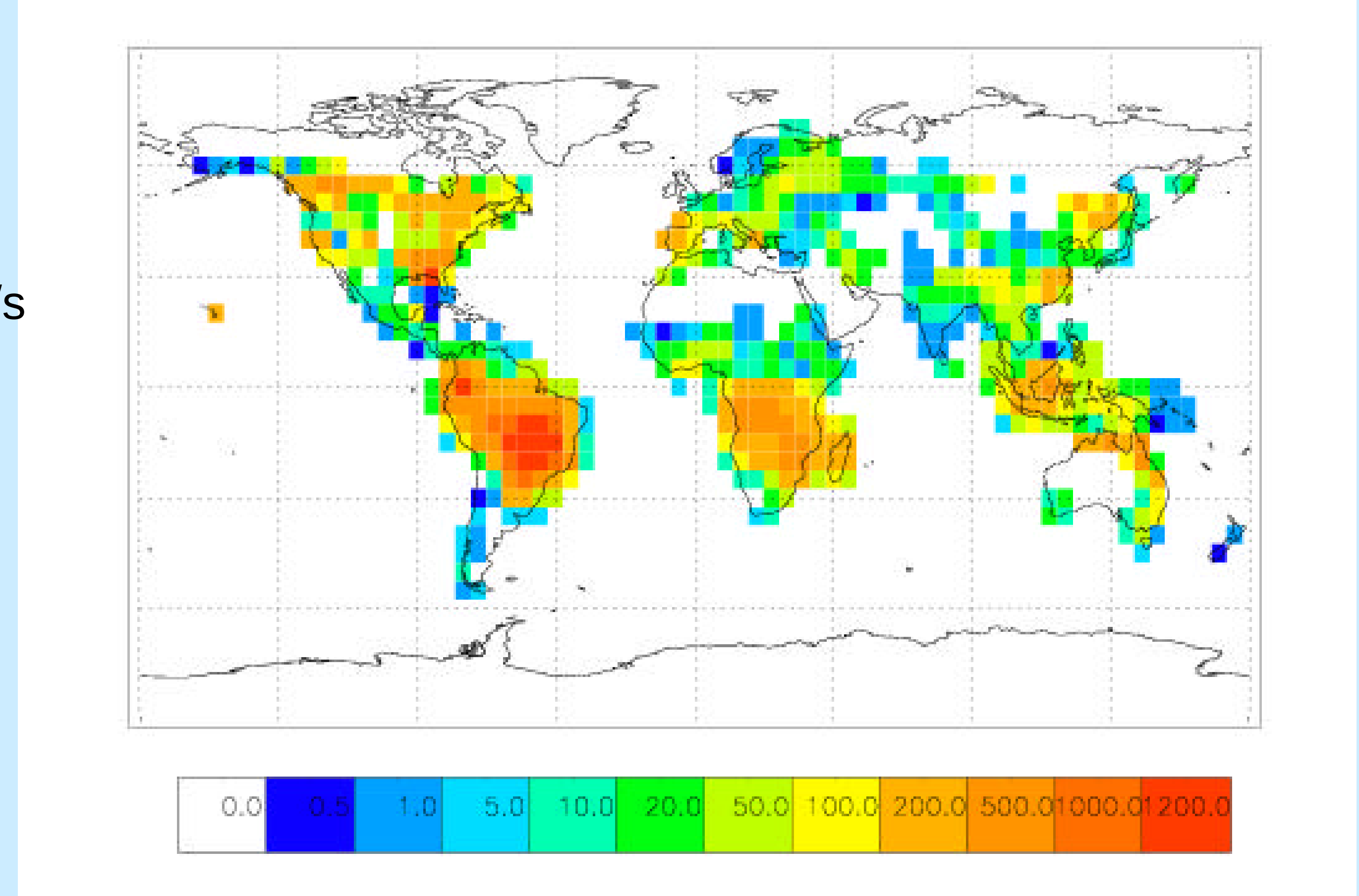
**Emissions factors: based on measurements in different countries, and campaign**

**Compilation by Andreae and Merlet, 2001**

**For many years, most of the inventories of biomass burning emissions based on climatology and statistics from different countries.**

**Widely used inventory: Hao et al., 1994**
**Monthly average, 5x5 degree resolution**

CO2 emissions
July
In 1.e10 molec/cm2/s



# Biomass burning emissions :

**Significant progress in the past few years, through the use of satellite data**

→ **fire counts**

→ **burned areas**

## Global scale fire products derived from EO systems
## (from Gregoire, 2005)

### Existing

**Active Fires ("hot spots")**

- ❑ IGBP-JRC Global Fire Product (GFP)
- ❑ ESA World Fire Atlas (WFA)
- ❑ TRMM
- ❑ NASA MODIS Active Fire

**Burnt Areas**

- ❑ JRC et al., Global Burnt Area 2000 (GBA2000)
- ❑ ESA GLOBSCAR

### Under development

**Active Fires ("hot spots")**

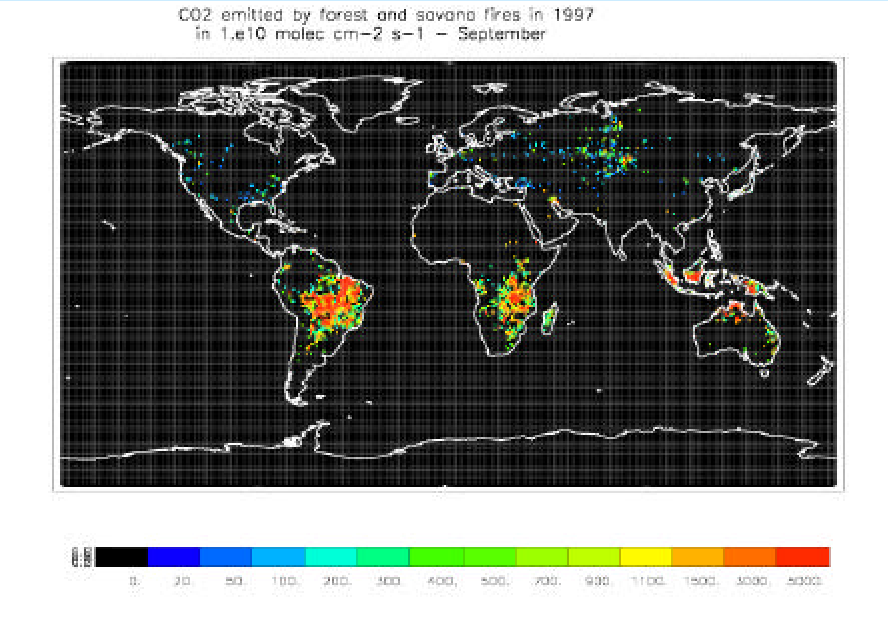
- ❑ ESA et al., GLOBCARBON

**Burnt Areas**

- ❑ JRC et al., VGT4Africa
- ❑ JRC et al., GEOLAND

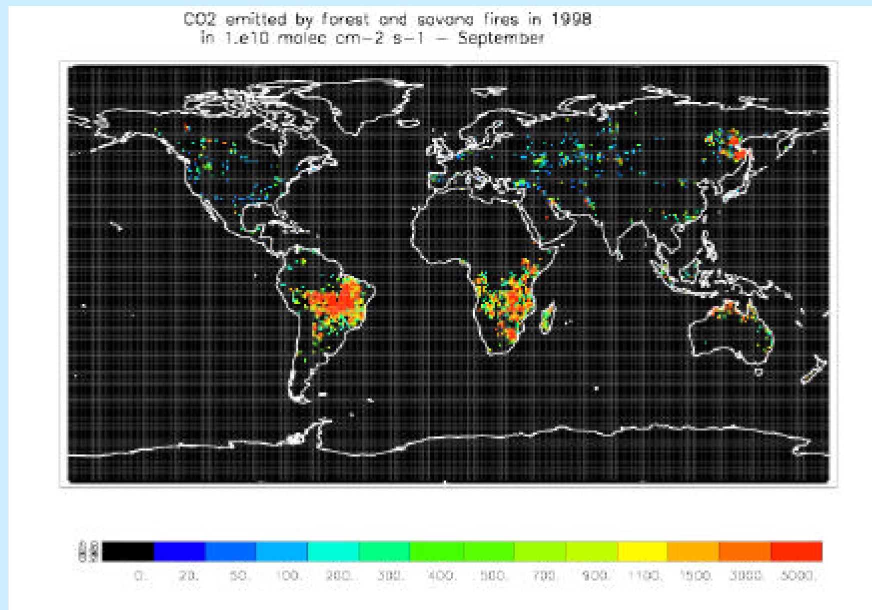
# Satellite derived global fire products (from Gregoire, April 2005)

| Product name<br>EO system<br>product type | Resolution<br>sensor<br>product | Time step<br>sensor<br>product | Coverage | Period | Source | Documentation |
|---|---|---|---|---|---|---|
| TRMM<br>TRMM-VIRS<br>fire (day & night) | 2.2 km<br>0.5 degree | day<br>month | +/- 40° (from equator) | Jan. 98 to mid-04 | NASA | Giglio *et. al.* 2000, IJRS(**21**)<br>http://earthobservatory.nasa.gov/Observatory/Datasets/fires.trmm.html |
| WFA<br>ERS-ATSR,AATSR<br>ENVISAT-AATSR<br>fire (night) | 1 km<br>1 km | day<br>day | Globe | July 1996 to now | ESA | http://shark1.esrin.esa.it/ionia/FIRE/AF/ATSR/ |
| IGBP-GFP<br>NOAA-AVHRR<br>fire (day) | 1 km<br>1 km | day<br>day & 10-day | Globe | April 1992 to December 1993 | JRC | Dwyer *et al.*, 1999, J. Biogeography (**27**)<br>From May 1st: http://www-gvm.jrc.it/tem/ |
| MODIS Active Fire<br>AQUA,TERRA-MODIS<br>fire (day & night) | 250 m<br>lat long position | day<br>day | Globe | ~ 2001 | MODIS team | http://rapidfire.sci.gsfc.nasa.gov/ |




**← September 1997**

**↓ September 1998**

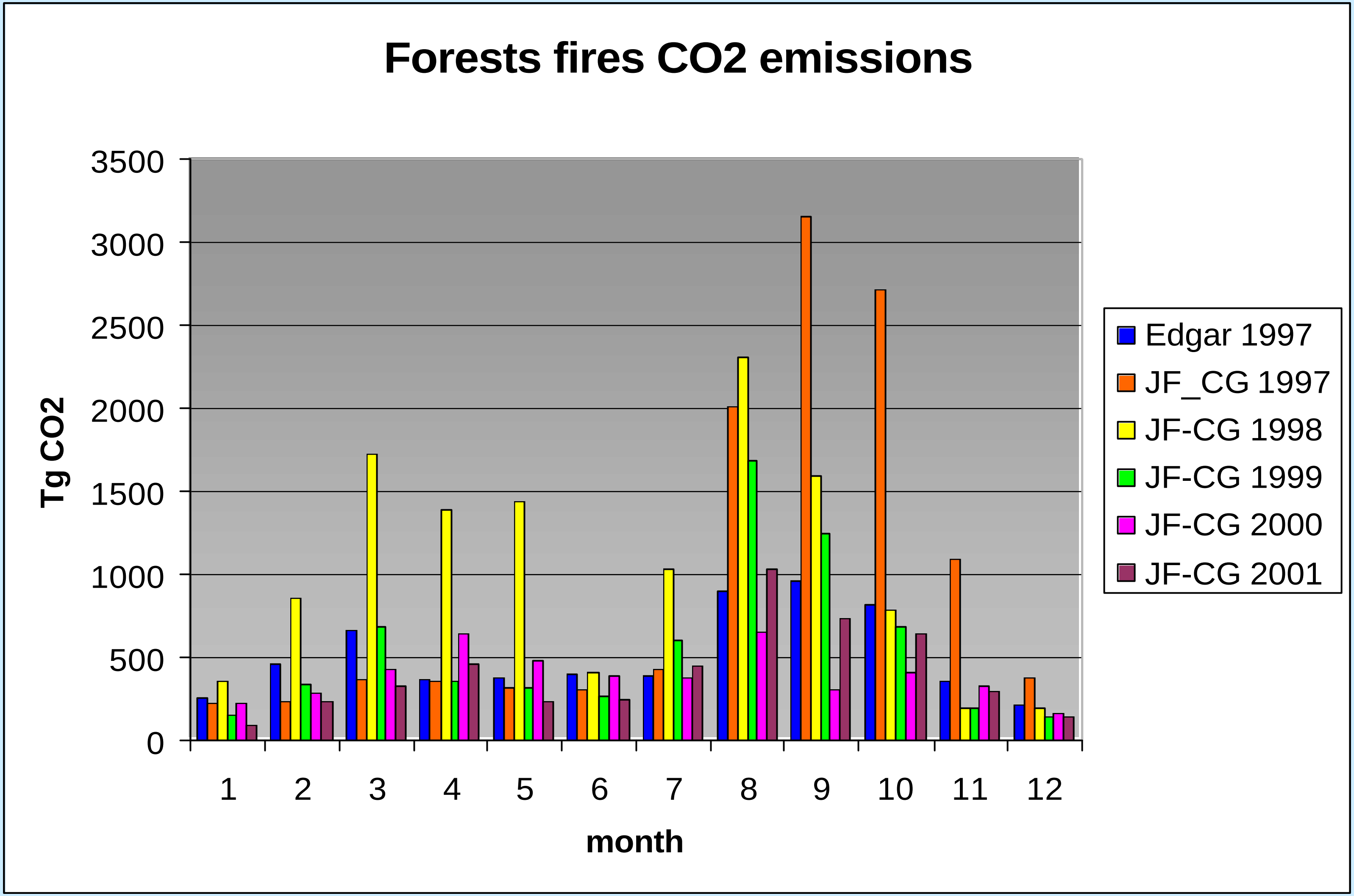



**1x1 degree distribution**

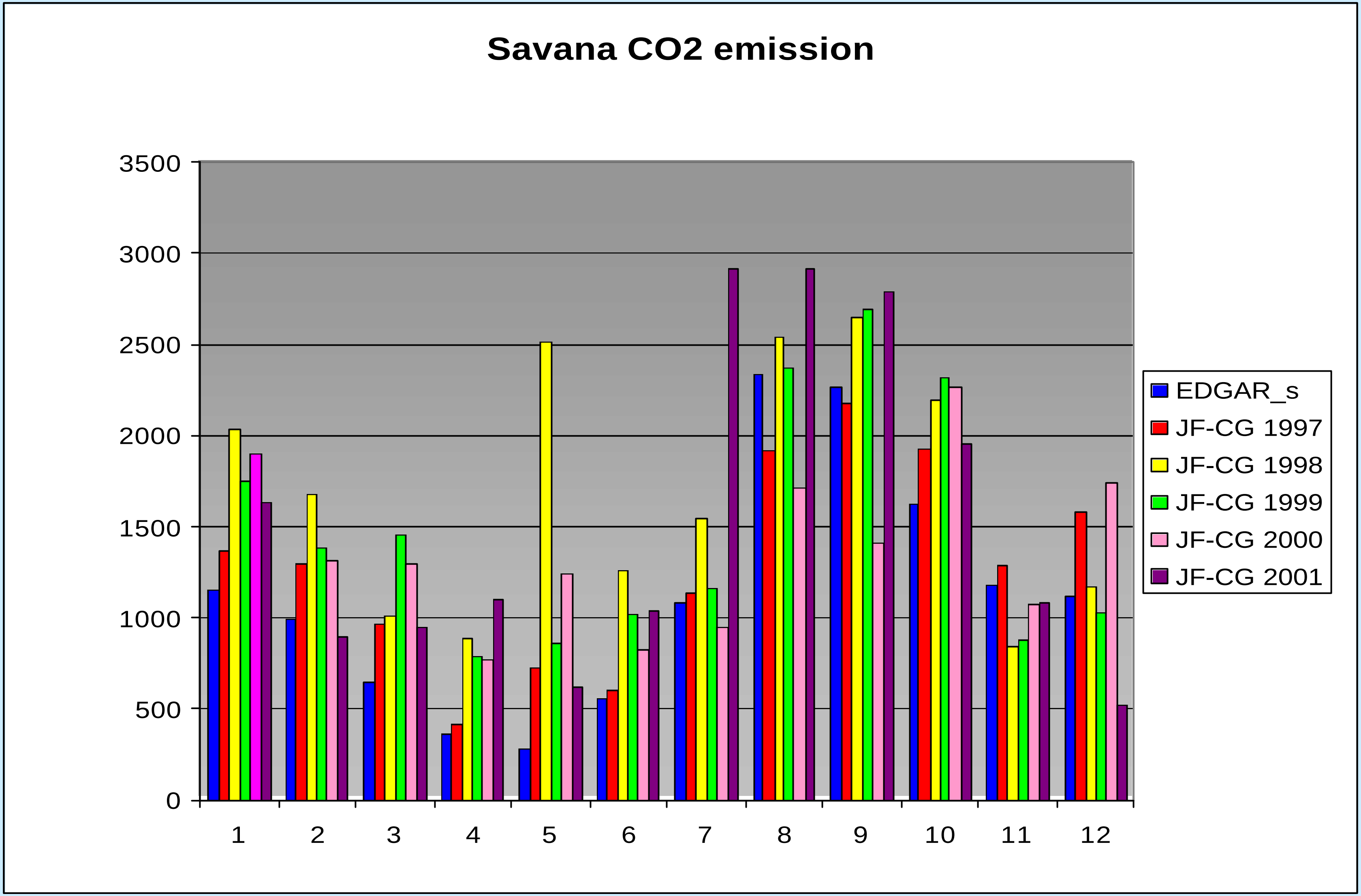
**of biomass burning**

**Emissions of $CO_2$**

**Based on ATSR fire counts**



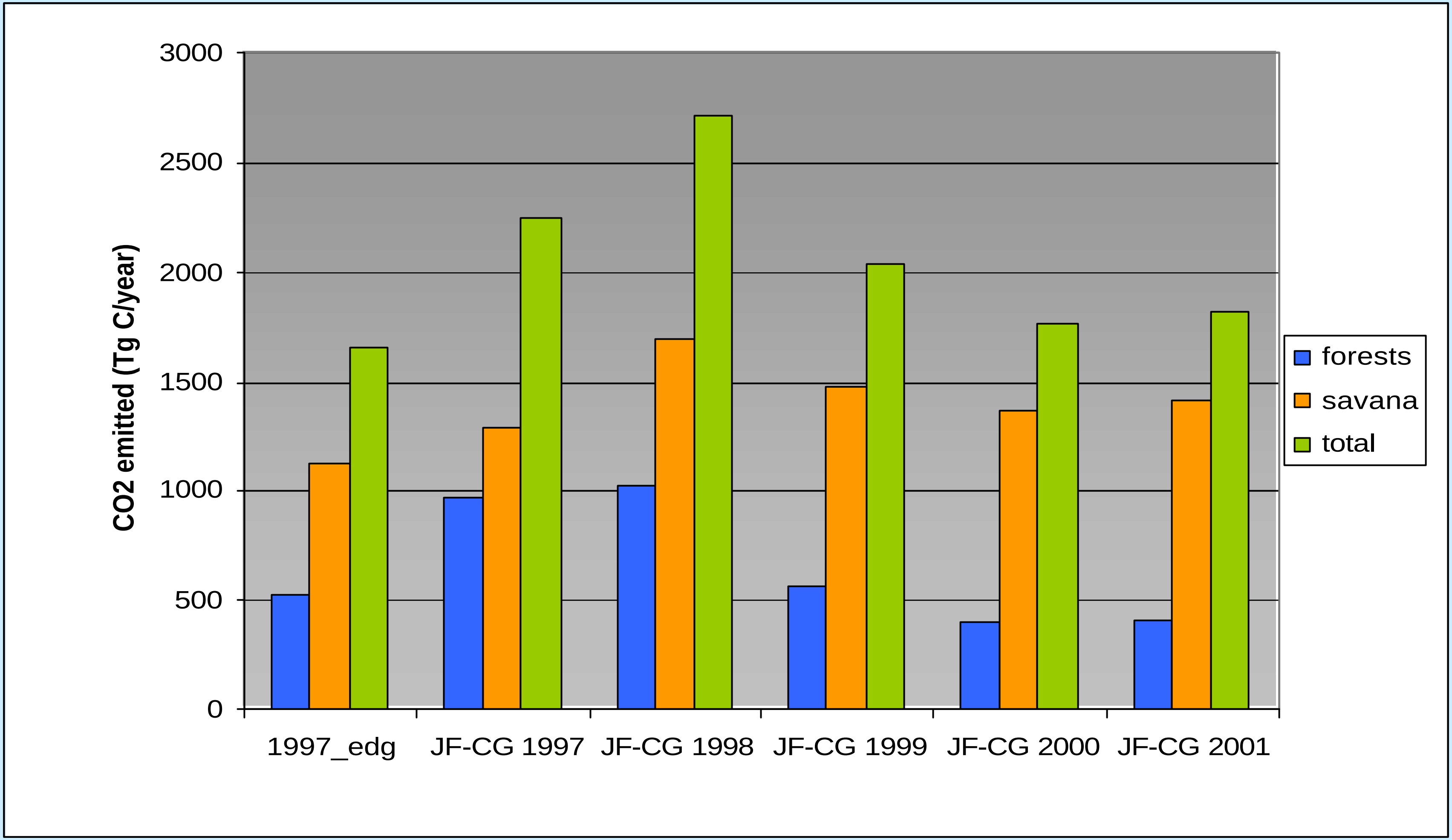

CO2 emitted monthly by forest fires.
EDGAR 1997: EDGAR-3
JF-CG: emissions based on ATSR satellite data developed by J.F. Lamarque and C. Granier




CO2 emitted monthly by savanna fires.

EDGAR 1997: EDGAR-3

JF-CG: emissions based on ATSR satellite data developed by J.F. Lamarque and C. Granier

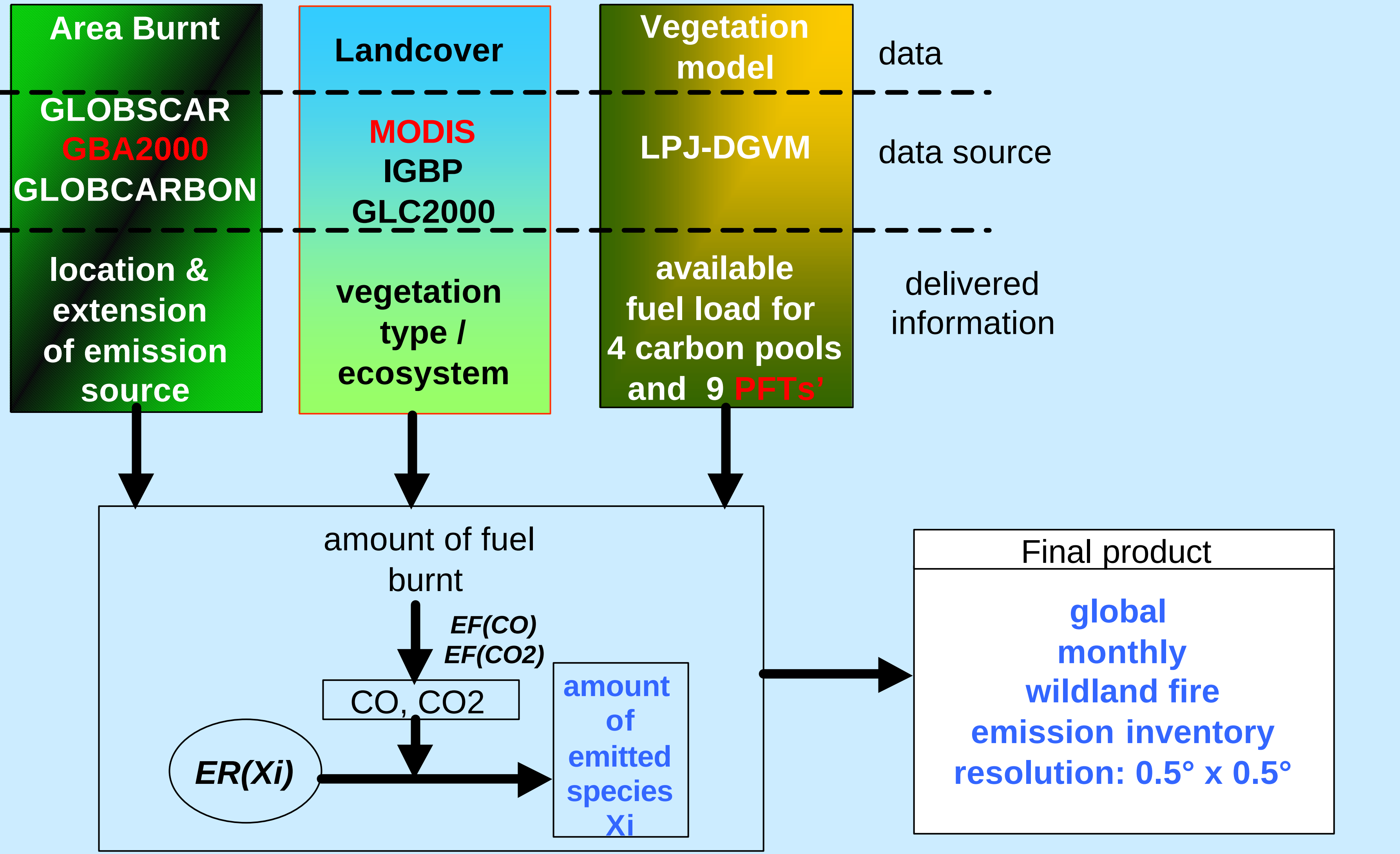



CO2 emitted yearly by forest and savanna fires
1997_edg: EDGAR-3
JF-CG: emissions based on ATSR satellite data developed by J.F. Lamarque and C. Granier

# Satellite derived global burnt area products (from Gregoire, April 2005)

| roduct name<br>O system<br>oduct type | Resolution<br>sensor<br>product | Time step<br>sensor<br>product | Coverage | Period | Source | Documentation |
|---|---|---|---|---|---|---|
| BA2000<br>POT-VGT<br>urnt area | 1 km<br>1 km² | day<br>month | Globe | Nov. 99 to Dec. 00 | JRC | Tansey et *al*., 2004, JGR(**109**) & Climatic Change (**67**)<br>http://www-gvm.jrc.it/fire/gba2000/index.htm |
| LOBSCAR<br>RS-AATSR<br>urnt area | 1 km<br>1 km² | day<br>month | Globe | 2000 | ESA | Simon *et al*., 2004, JGR(**109**)<br>http://shark1.esrin.esa.it/ionia/FIRE BS/ATSR/ |
| BA1982-1999<br>OAA-AVHRR<br>urnt area | 5 km<br>8 km² | day<br>week | Globe | 1982 to 1999 | JRC | Carmona-Moreno *et al*., 2005, Global Change Biology (**in press**) |

# GWEM: Global Wildland fire Emission Model




From Hoelzemann et al., JGR, 2004

# calculating the emissions per gridbox

$$M(X)_m = \sum_{k=1}^{n} EF_k(X) \times A_m \times b_k \times AFL_k$$

$$AFL_k = \sum_{t=1}^{9} fc_t \times \sum_{p=1}^{5} c_{t,p} \times m_{t,$$

**M (X)** $_m$ : amount of species X emitted per month **m**

**n**: number of ecosystems (5)

**EF$_k$ (X)**: emission factor for species X per ecosystem

**A** $_i$: area burnt per month

**ß** $_k$: combustion efficiency for ecosystem k

**AFL** $_k$: available fuel load per ecosystem

**fc** $_t$**: fractional cover of PFT t per gridbox**

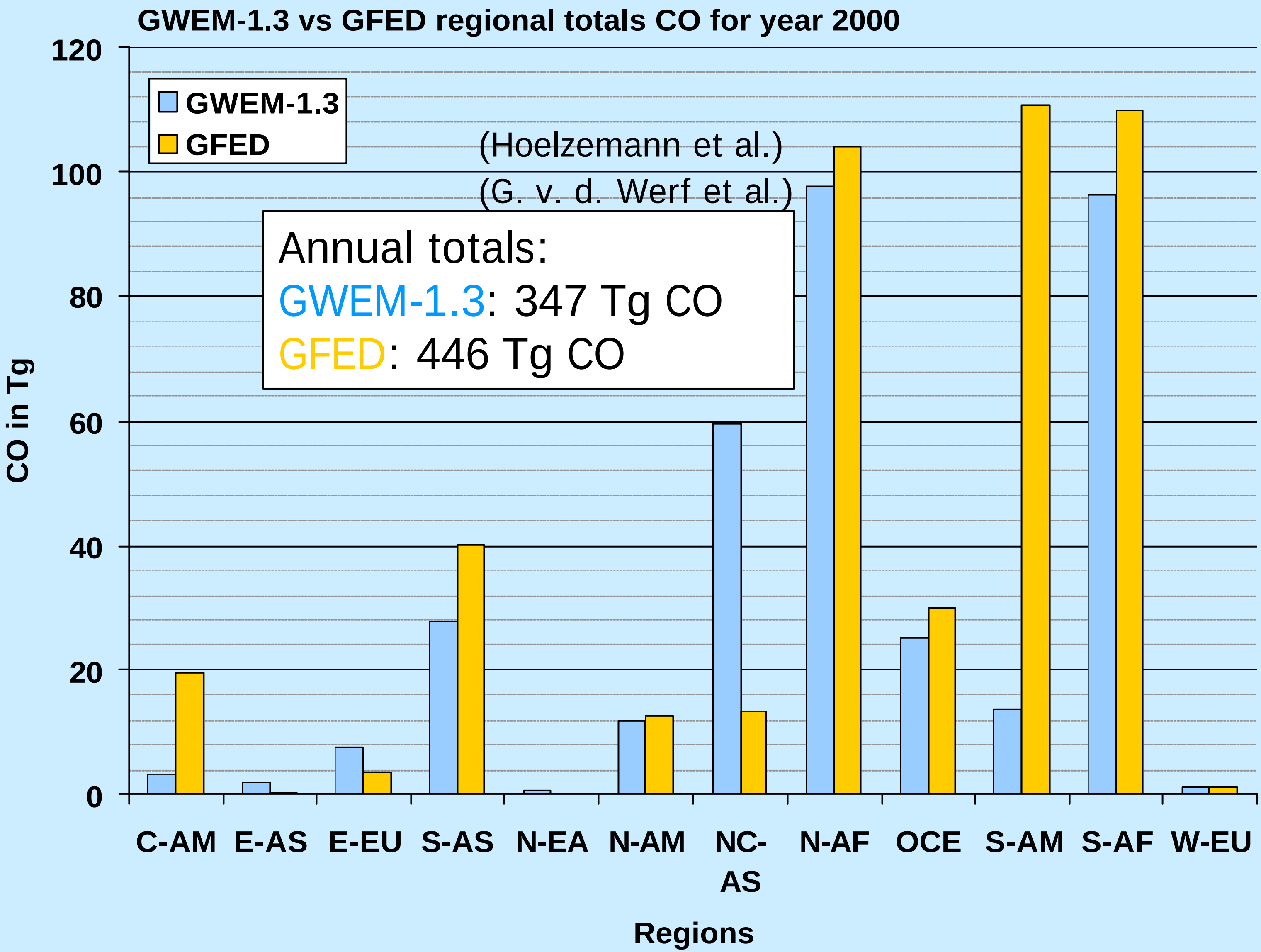
**t: number of PFT's (9)**

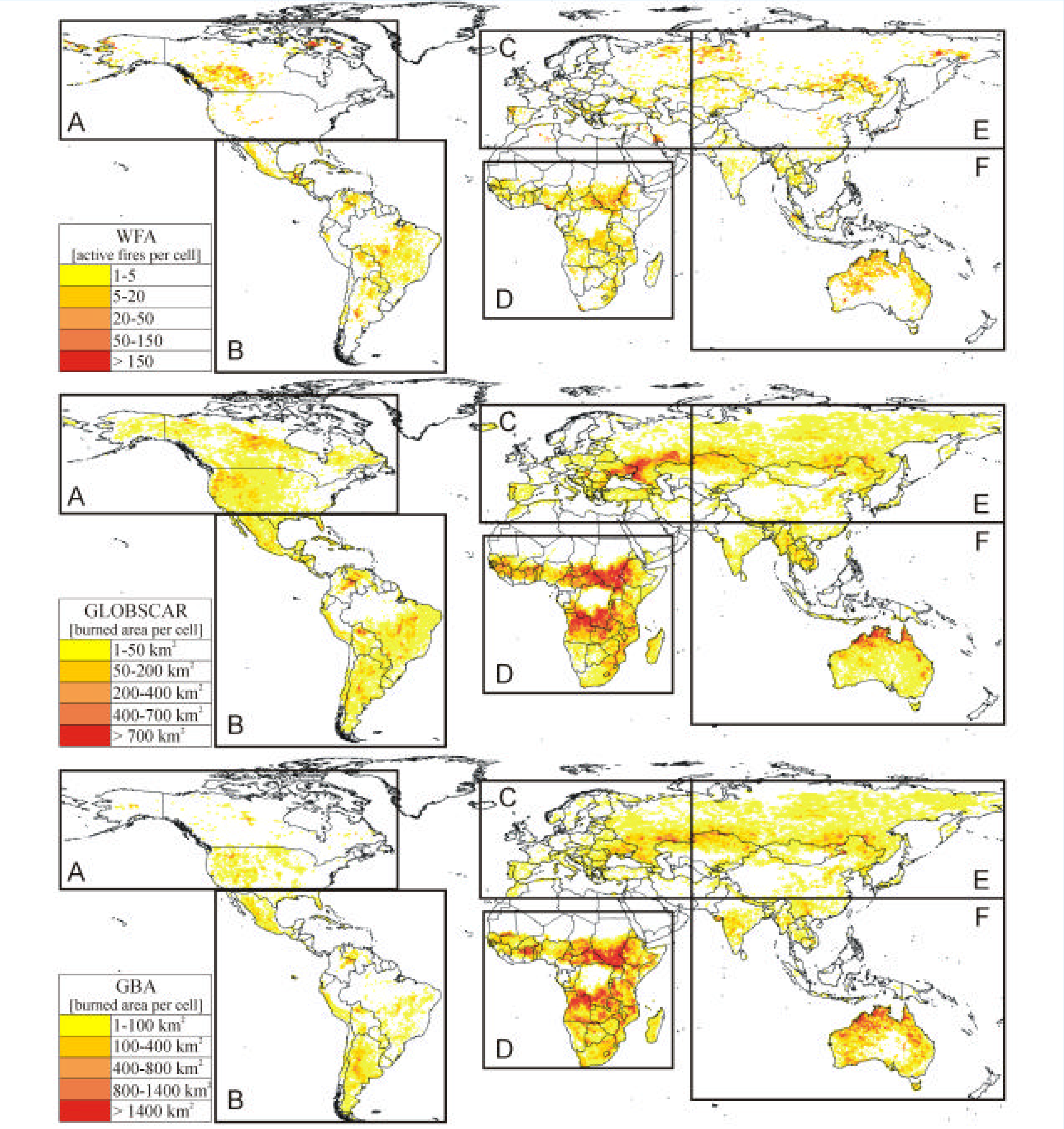
**p: number of carbon pools (5)**

C $_{t,p}$**: susceptibility factor**

**m** $_{t,p}$ **: dry matter per PFT and carbon pool**

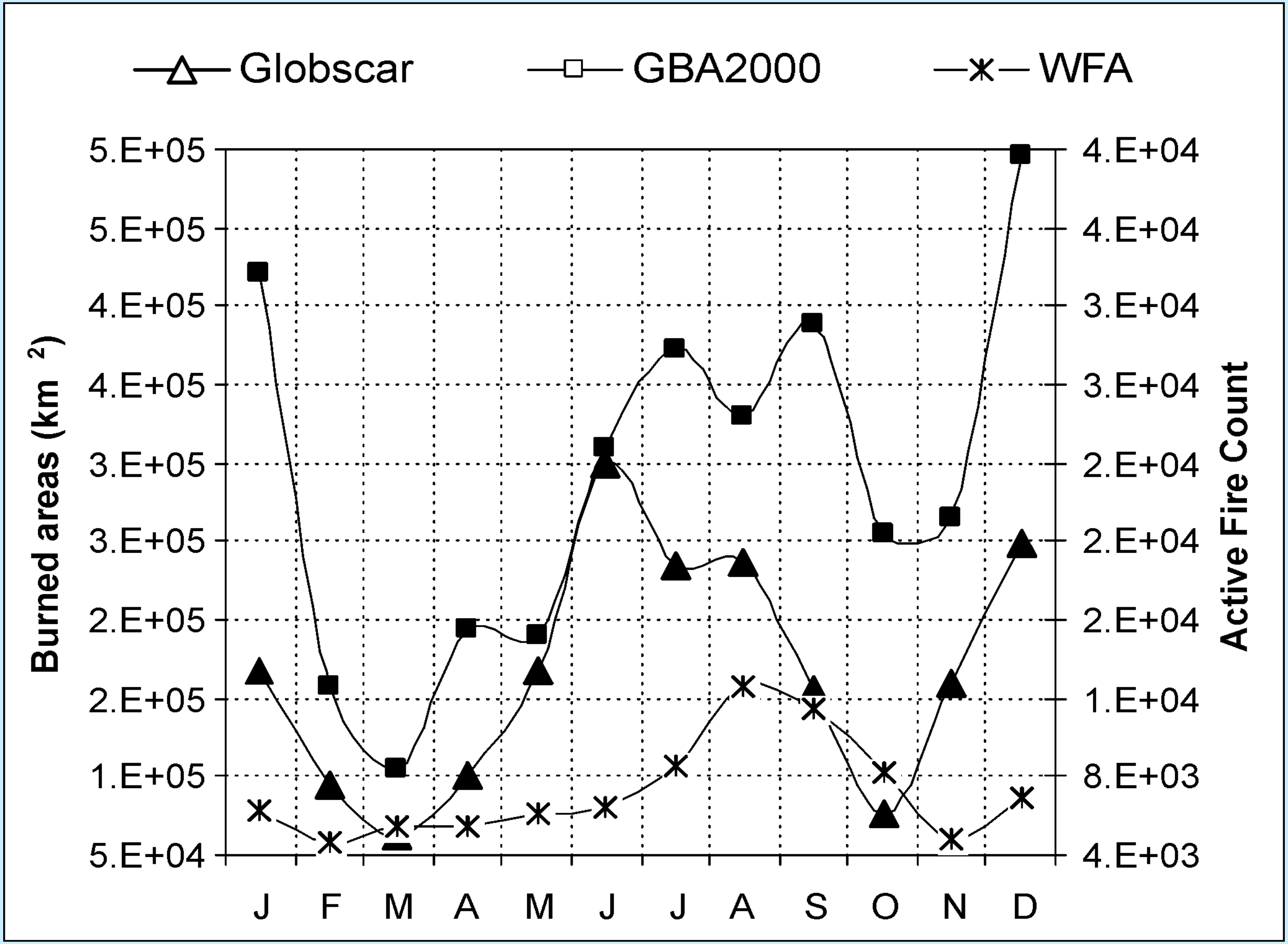
# GWEM-1.3 results: regional totals





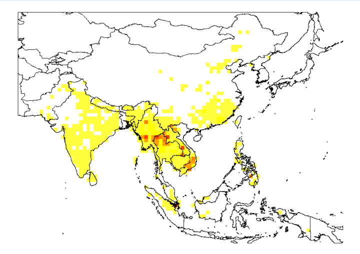

**Inter-comparison of global fire products:**
- World Fire Atlas (WFA)
- GLOBSCAR
- GBA2000

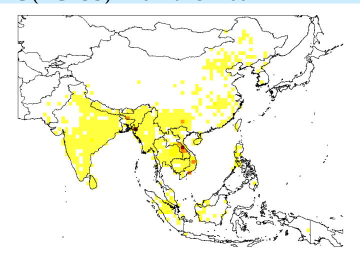
**Boschetti** et al., 2004
*Geophy. Res. Letters*
Vol. 31

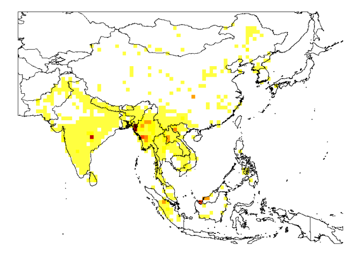


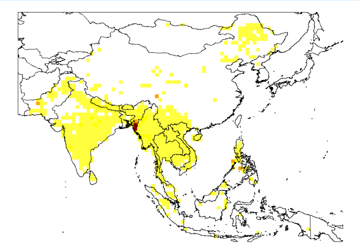

(from Gregoire, April 2005)

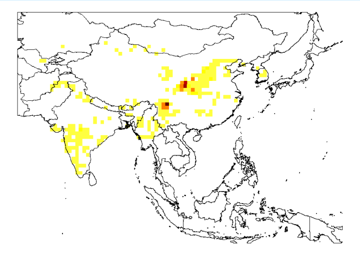
# Example of comparison between an inventory based on fire pixel counts (ACESS) and another on Spot burnt area data (ABBI) (from Liousse, April 2005)

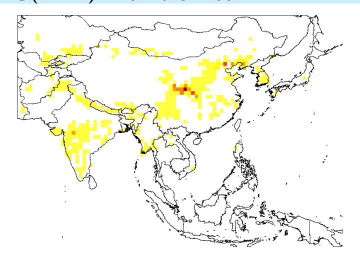

BC (ACESS) 1-10 March 2001

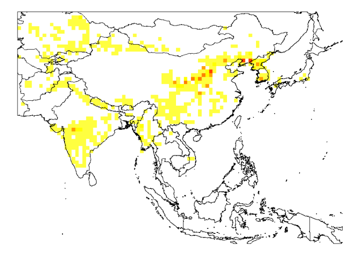

BC (ACESS) 11-20 March 2001

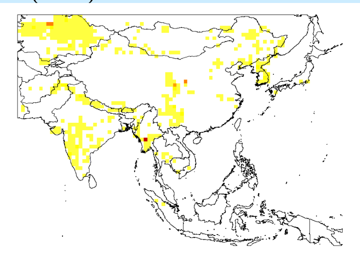

BC (ACESS) 20-31 March 2001


BC (ACESS) 1-10 April 2001

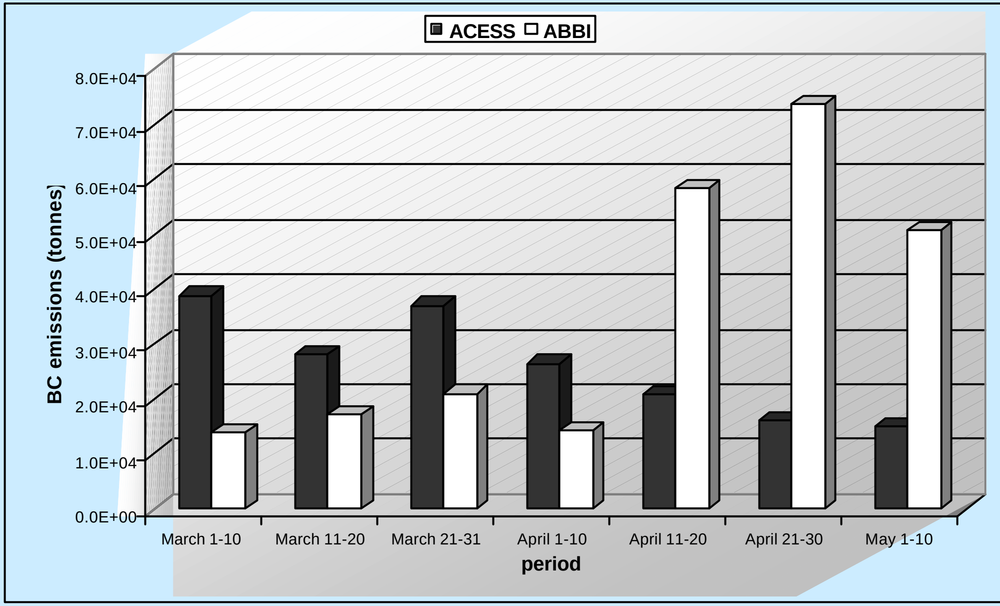

BC (ABBI) 1-10 March 2001


BC (ABBI.) 11-20 March 2001


BC (ABBI) 21-31 March 2001


BC (ABBI.) 1-10 April 2001

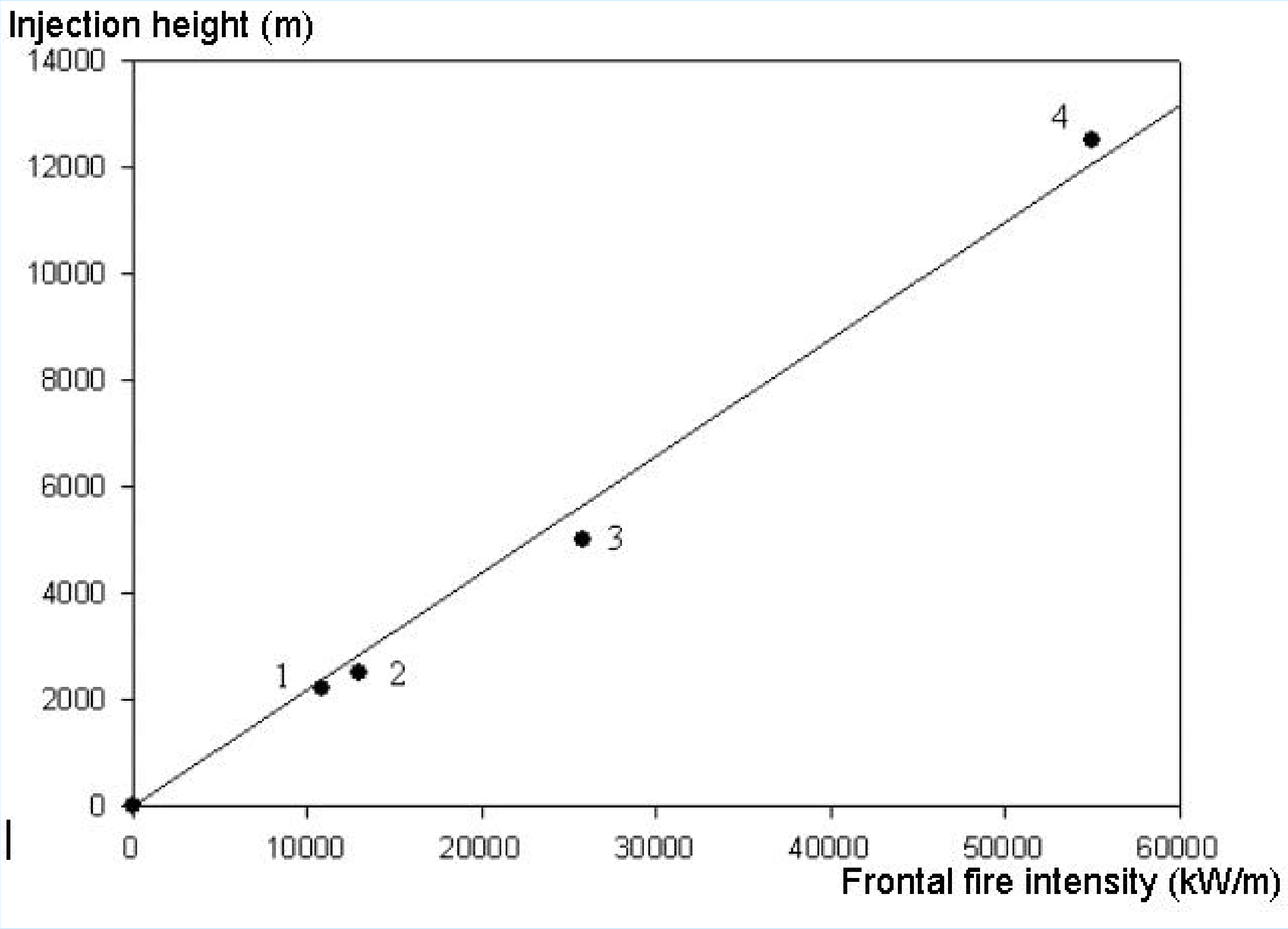
**ACESS/ABBI (Michel et al. 05)**
**(TRACE P and ACE ASIA period)**



## Satellite derived fire products: under development (from Gregoire, April 2005)

| Product name<br>EO system<br>product type | Resolution<br>sensor<br>product | Time step<br>sensor<br>product | Coverage | Period | Source | Documentation |
|---|---|---|---|---|---|---|
| GLOBCARBON<br>ERS, ENVISAT, SPOT-ATSR,AATSR,VGT<br>fire (day & night)<br>burnt area | 1 km<br>??? | day<br>month | Globe | 1998-2003 | ESA | http://dup.esrin.esa.it/projects/summaryp43.asp |
| VGT4Africa<br>SPOT-VGT<br>burnt area | 1 km<br>1 $km^2$ | day<br>10 days | Africa | from 2005 | JRC | from May 1st:<br>http://www-gvm.jrc.it/tem/ |
| GEOLAND<br>= GLOBCARBON | 1 km<br>??? | day<br>month | Africa & Eurasia | 1998-2003 | JRC | from May 1st:<br>http://www-gvm.jrc.it/tem/ |

Importance of the injection height




Average tropical forest and savanna fire: 2000m
Crown fires in the boreal forests: around 7500 m

Main uncertainties:

→ Large difference between the different products used

→ Amount of biomass burned: large uncertainty in vegetation maps

→ Emission factors: present a very large spatial variability:

→ What about past/future emissions

→ How to define the vertical profile of emissions

Work is under way for the improvement of products:
- AIMES/IGBP/QUEST workshop in October 2005
- GEIA/ACCENT workshop in December 2005

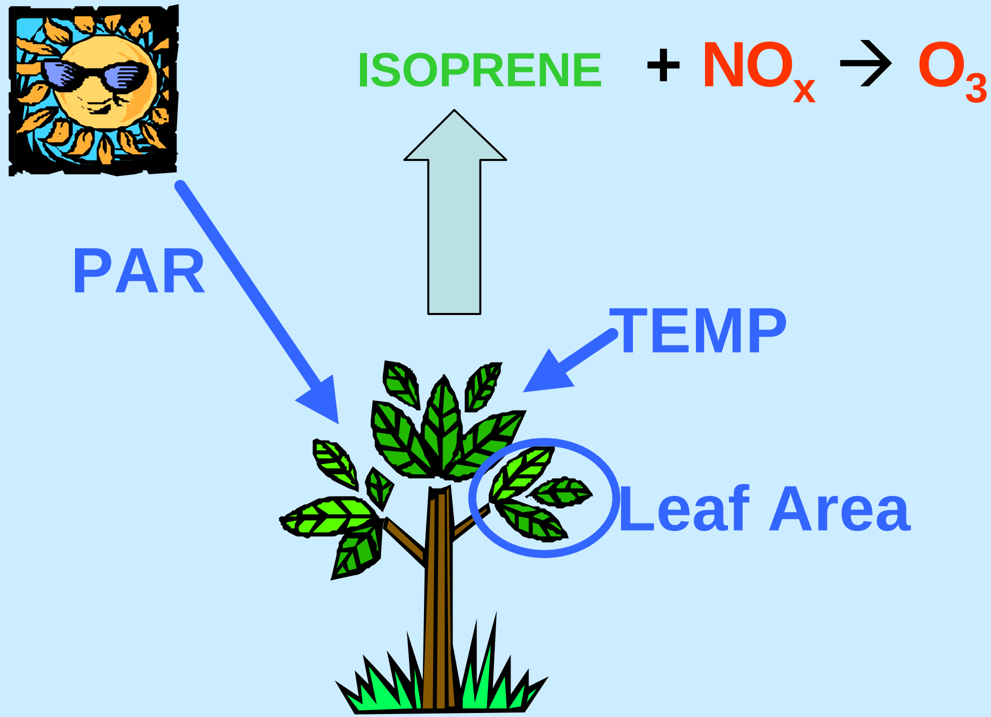
**Natural emissions:**

**For the past years, the focus has been mostly on:**

- → **biogenic hydrocarbons: isoprene/terpenes and other compounds**
- → **$CH_4$ from wetlands**
- → **$NO_x$ from soils**
- → **$NO_x$ from lightning**
- → **dust, sea-salt**
- → **sulfur and sulfates from volcanoes**
- → **etc…**

➔ **Inventories for specific years**
➔ **climatological inventories**
➔ **emissions models**

## Isoprene Emissions are generally thought to contribute to $O_3$ production over the eastern United States [*e.g.Trainer et al*., 1987; *NRC* 1991]




**Vegetation changes → Impact on $O_3$?**

**Importance of having emissions models for hydrocarbons**

**From A. Fiore, Harvard**

# Vegetation Emissions: chemical species

- **Isoprene**
- **Monoterpenes**
- **Other VOC**
- **CO**
- **NH3 and NO**

**Current model chemical schemes**

**More detailed hydrocarbons**

## Individual compounds

Methanol, acetaldehyde, acetone, ethene, ethanol, α-pinene, β-pinene, d-carene, hexenal, hexenol, hexenyl-acetate, propene, formaldehyde, hexanal, butanone, sabinene, limonene, methyl butenol, butene, β-carophylene, β-phellandrene, p-cymene, myrcene, Formic acid, acetic acid, ethane, toluene, camphene, terpinolene, α-terpinolene, α-thujene, cineole, ocimene, γ-terpinene, bornyl acetate, camphor, piperitone, linalool, tricyclene

**We should estimate individual compounds because controlling factors can differ**

From Guenther, April 2005

| Eastern U.S. | Western U.S. | Eastern Canada | Western Canada |
|---|---|---|---|
| Pinus taeda | Pseudotsuga menziesii | **Populus tremuloides** | **Picea spp** |
| Acer rubrum | **Pinus ponderosa** | **Picea spp** | **Populus tremuloides** |
| **Quercus alba** | Juniperus osteosperma | Abies spp | Pinus banksiana |
| **Liquidambar styraciflua** | **Pinus contorta** | Pinus banksiana | Abies spp |
| Acer saccharum | Tsuga heterophylla | Thuja occidentalis | Tsuga spp |
| **Quercus rubra** | Abies concolor | | |
| Pinus elliottii | **Picea engelmannii** | Northern Mexico | Southern Mexico |
| Liriodendron tulipifera | Abies grandis | Pinus durangensis | **Quercus resinoa** |
| **Populus tremuloides** | Pinus edulis | Pinus arizonica | Pinus oocarpa |
| **Quercus virginiana** | Abies lasiocarpa | **Quercus spp** | Acacia **spp** |

Bold = high VOC emissions
Green: temperate adapted

Red: species adapted to warm sunny climates
Blue: species found in cool or mountain climates

# Model of Emissions of Gases and Aerosols from Nature (MEGAN): Guenther et al. (NCAR)

## Emission Rate= EF x EA x LP

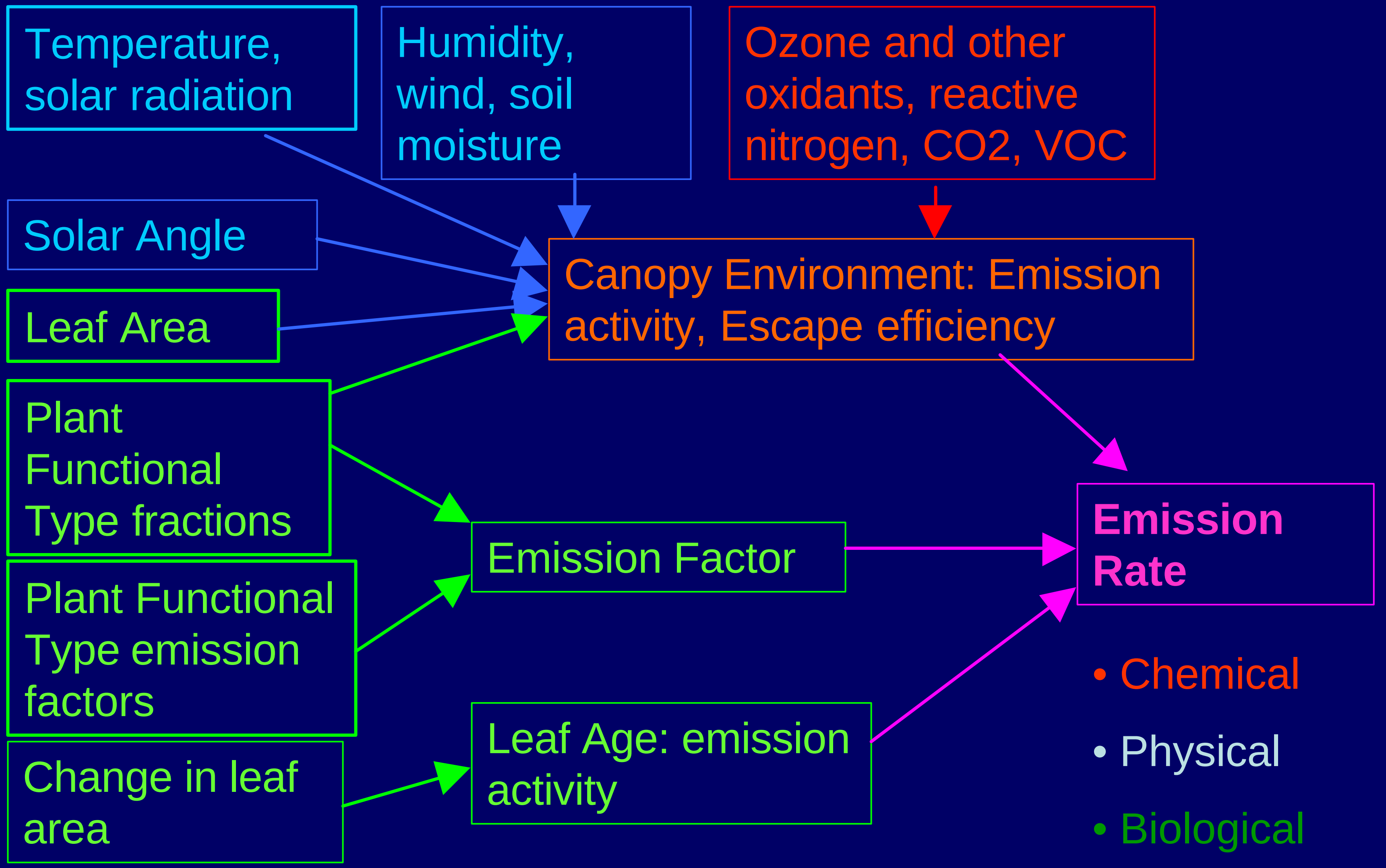
**Emission Rate:** Net canopy emission to the above-canopy atmosphere

**Emission Factor (EF):** Landscape average net canopy emission to the above-canopy atmosphere at standard conditions

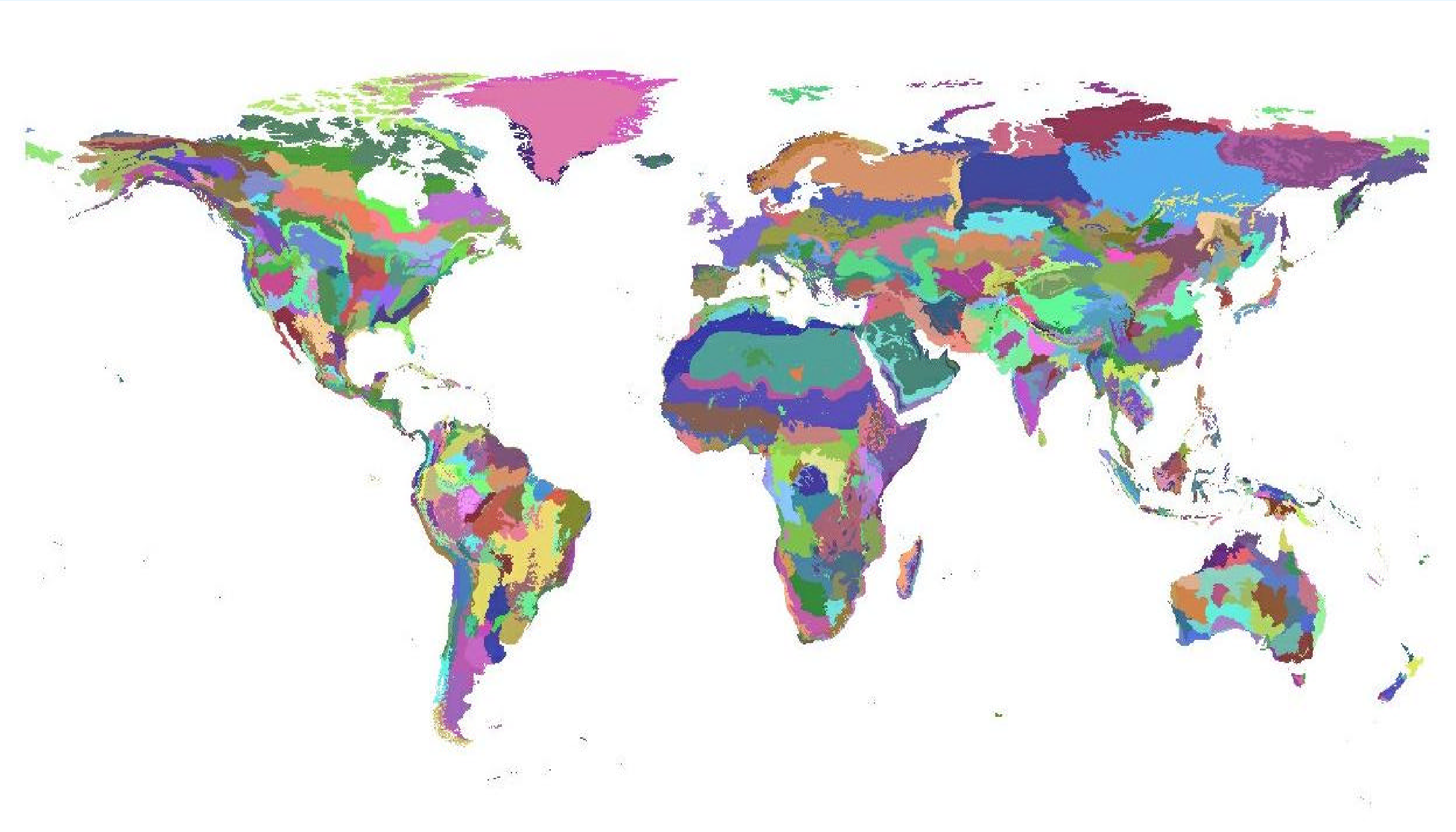
**Emission Activity (EA):** Nondimensional factor that accounts for variations in primary emissions (equal to unity at standard conditions)

**Loss and Production (LP):** Nondimensional factor that accounts for variations in canopy loss and production rates (equal to unity at standard conditions)

# Model of Emissions of Gases and Aerosols from Nature (MEGAN) driving variables




from A. Guenther, avril 2005

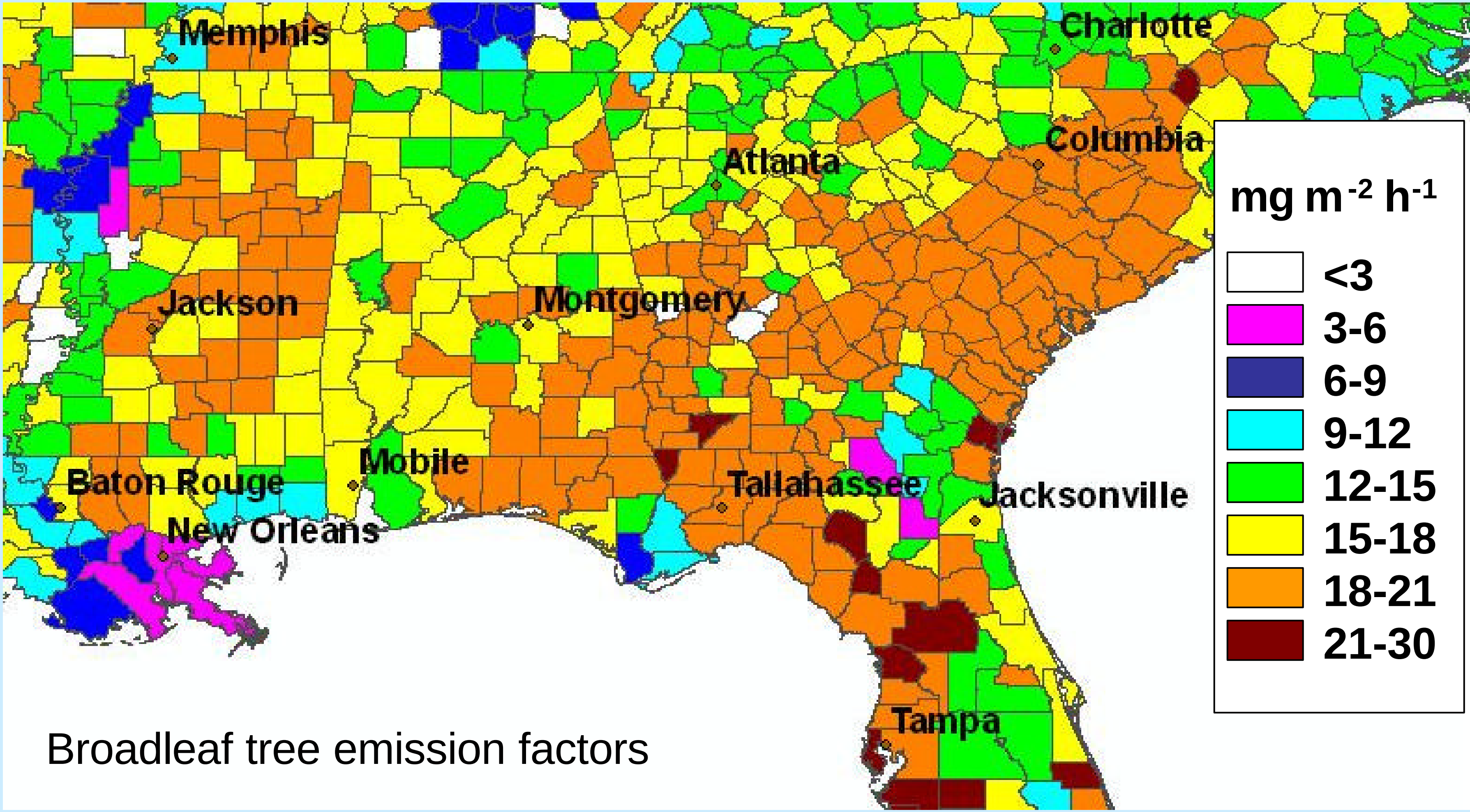


The global distribution of ecoregions as assigned by the World Wildlife Fund ecoregion scheme. Each color represents a different ecoregion (over 850 ecoregions are assigned to the global land area) (Based on Olson et al., 2001). For more information, visit http://www.worldwildlife.org/ecoregions.

# MEGAN Plant Functional Types

| | Global EF Average (range) | Global Area | Global Isoprene |
|---|---|---|---|
| Broadleaf Trees | 9.6 (0.1 - 30) | 16-39% | 58.3% |
| Shrubs | 9.5 (0.1 – 30) | 16-24% | 34% |
| Fineleaf Evergreen Trees | 2.7 (0.01 – 13) | 9-20% | 5.5% |
| Fineleaf Deciduous Trees | 0.6 (0.01 – 2) | 1.3-4% | 0.2% |
| Grass | 0.5 (0.005 – 1.2) | 17-39% | 1.8% |
| Crops | 0.05 | 8-37% | 0.2% |

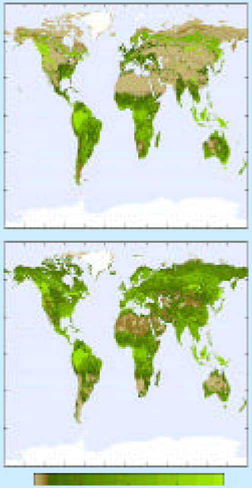
# Genera/species vegetation inventories and emission factors: Southeastern U.S.



| Annual emission ($TgC\ yr^{-1}$) | Compounds |
|---|---|
| 250-750 | Isoprene |
| 50-250 | methanol, α-pinene |
| 10-50 | acetaldehyde, acetone, β-pinene, d-carene, ethanol, ethene, hexenal, hexenol, hexenyl-acetate |
| 2-10 | propene, formaldehyde, hexanal, butanone, sabinene, limonene, methyl butenol, butene, b-phellandrene, p-cymene, myrcene |
| 0.4 – 2 | formic acid, acetic acid, ethane, toluene, camphene, terpinolene, a-terpinolene, a-thujene, cineole, ocimene, g-terpinene, bornyl acetate, b-carophylene, camphor, piperitone, linalool, tricyclene |

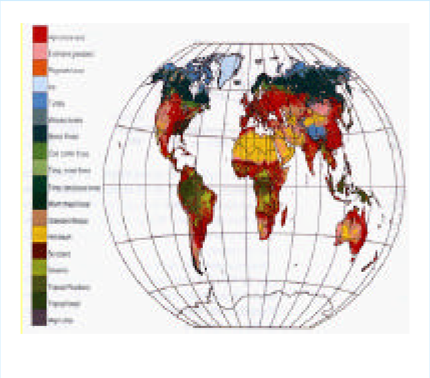
Total emitted for different VOCs

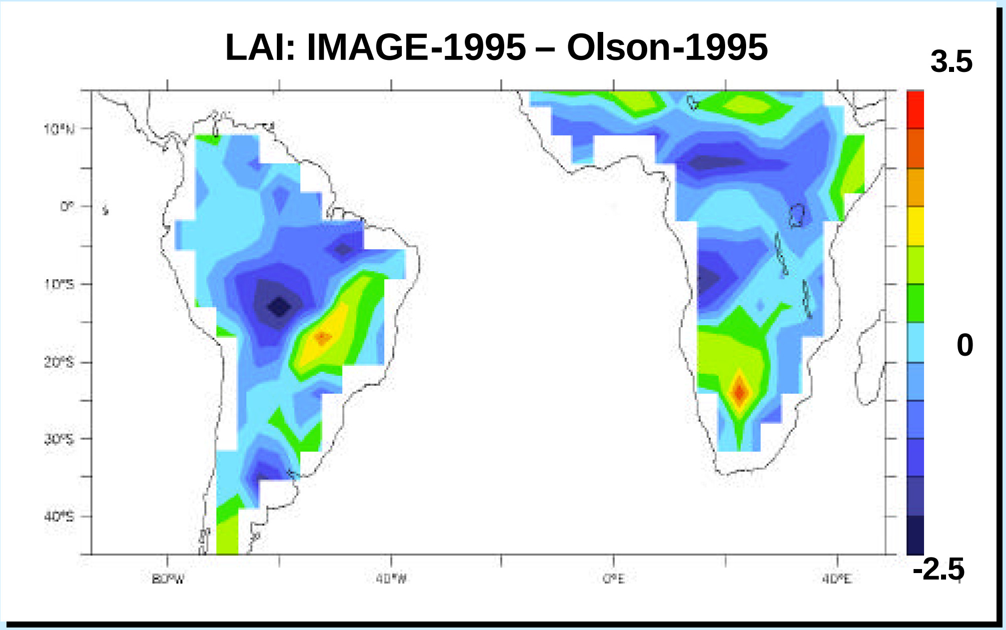
*Issue still remaining: distribution of vegetation:*
*Example: calculation of leaf area index*



***Olson '92**, 72 ecosystems & NDVI data: seasonal cycle in biomass*

***IMAGE**, 19 land cover classes, 10-year interval, Annual mean biomass*



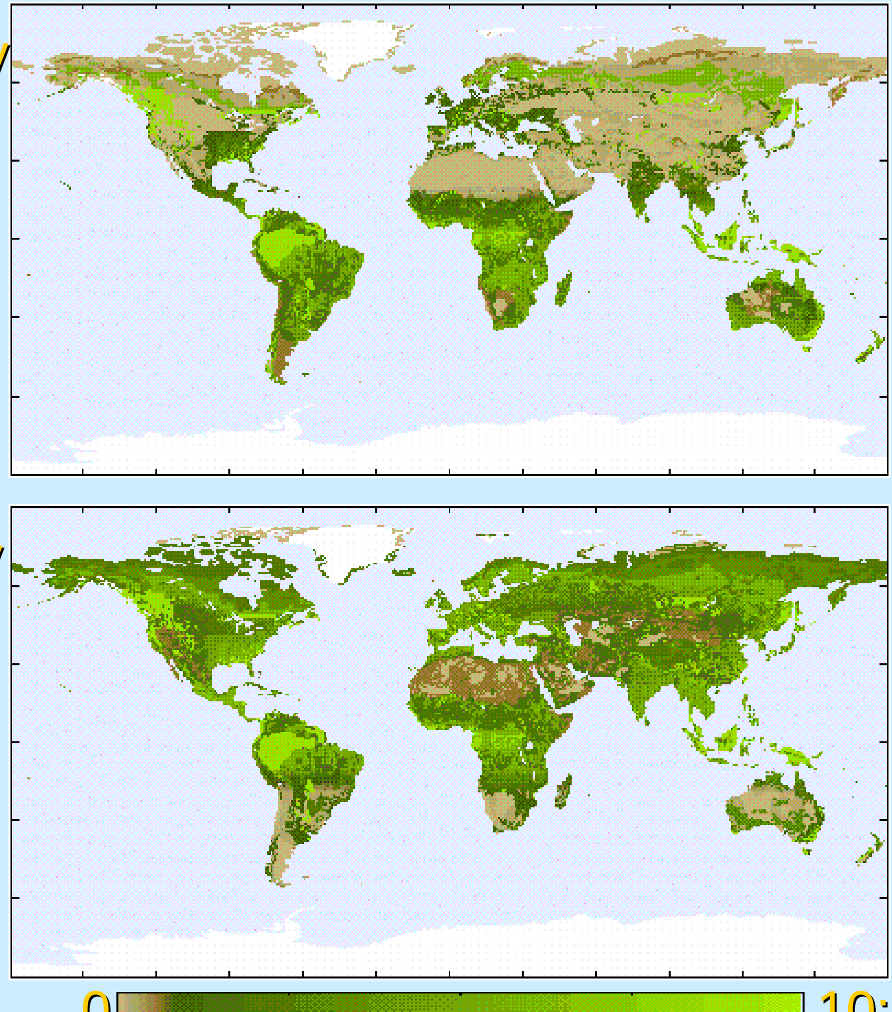



From Ganzeveld
April 2005

*What about the availability, quality and consistency of input databases required to constrain exchange models?*

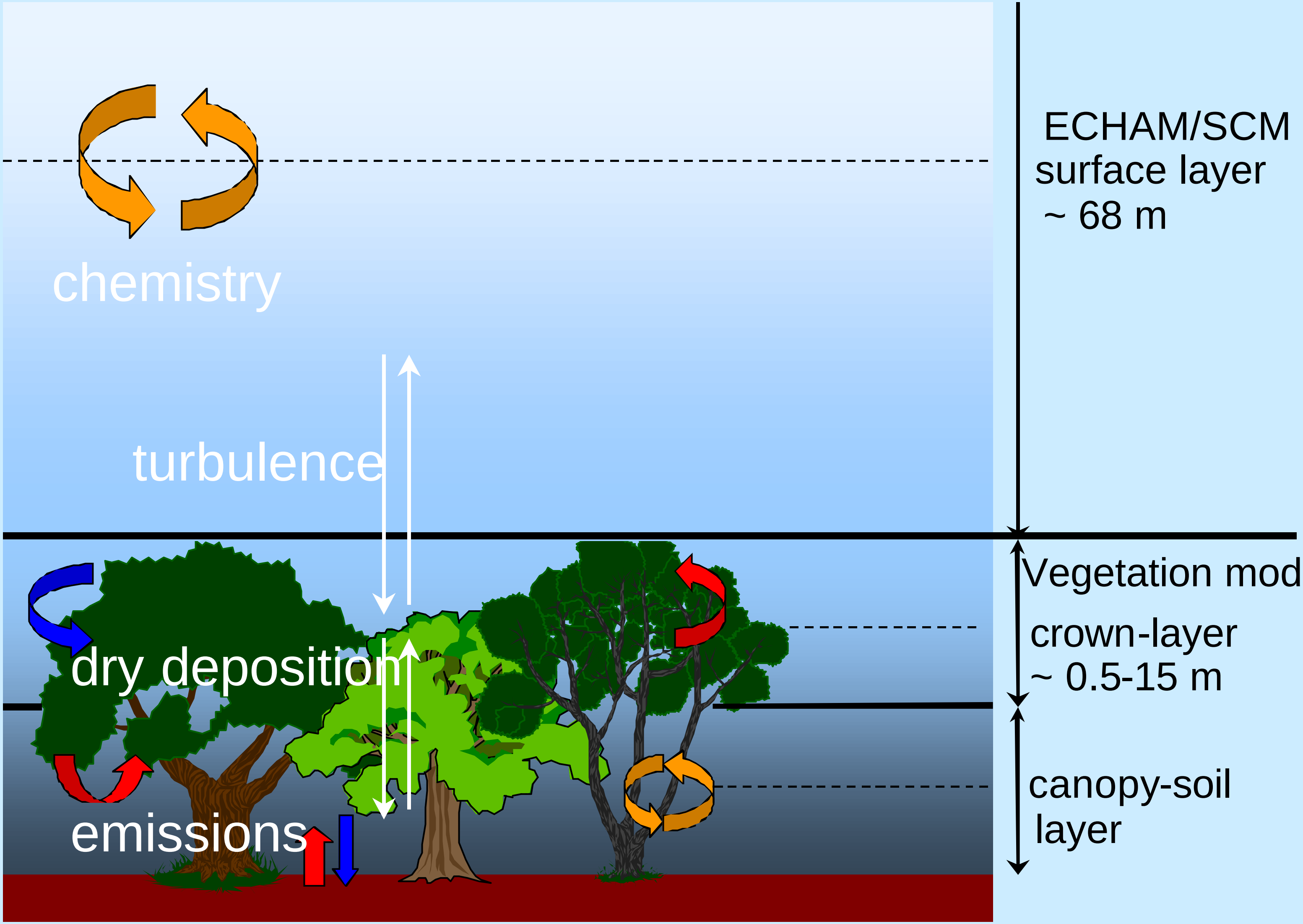
- ✓ Surface cover
- ✓ Land use management
- ✓ Soil properties
- ✓ Activity data

**LAI inferred from satellite data**




From Ganzeveld, April 2005

# Soil-biogenic $NO_x$ emissions
## Emissions and deposition have to be quantified together




Vegetation and wet skin fraction

Grom Ganzeveld, April 2005

## Dry deposition: required input datasets

# Dry deposition in online or offline models

*Databases for online and offline models*

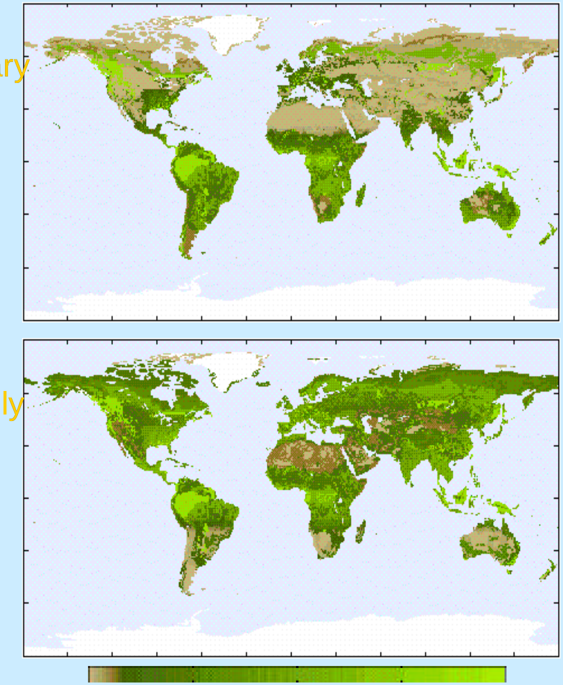
- Land cover: biomass (Leaf Area Index), roughness ($z_0$), canopy height
- Soil properties: e.g., pH, organic matter

*And additional one's for offline models*

- Surface cover fractions: Vegetation, wet skin, snow, bare soil
- Soil moisture
- Snow depth
- 2m dew point temp.
- Forest fraction
- field capacity, etc………..

January

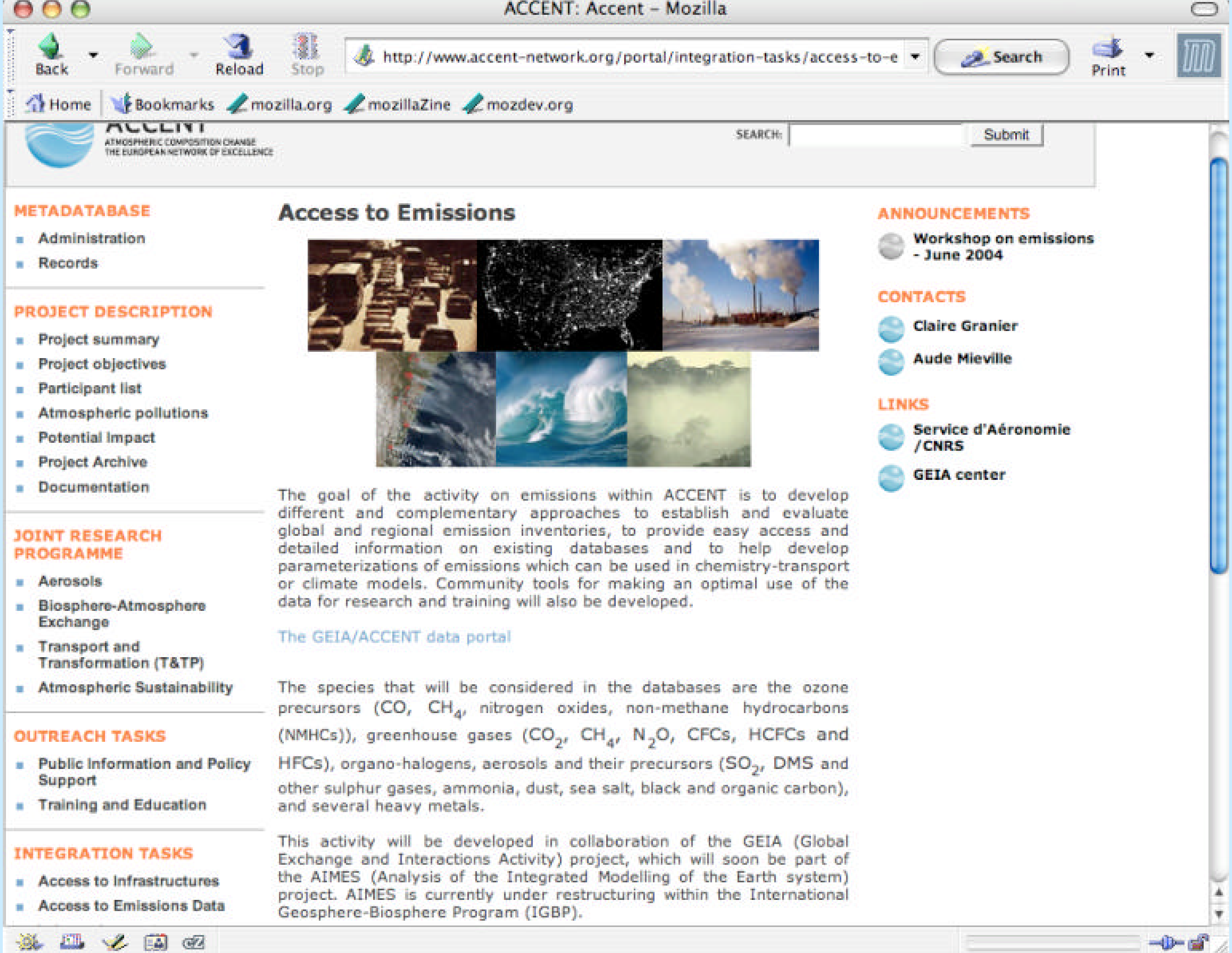
July



*From Ganzeveld, April 2005*

| | Biogenic and other continental sources | Biomass Burning | Fossil Fuel Burning | Ocean | Photo-chemistry |
|---|---|---|---|---|---|
| CO | significant | major | major | minor | major |
| $CH_4$ | major | significant | major | minor | no |
| $N_2O$ | major | significant | significant | significant | no |
| NOx | major | major | major | ? | minor |
| isoprene | major | ? | ? | ? | no |
| DMS | minor | ? | no | major | no |
| $SO_2$ | major* | minor | major | no | important |
| dust | major | no | no | no | no |
| sea-salt | no | no | no | major | no |
| ozone | no | no | no | no | major |

*: emissions from volcanoes




ACCENT access: www.accent-network.org

GEIA access: www.geiacenter.org (end of August)

ACCENT
ATMOSPHERIC COMPOSITION CHANGE
THE EUROPEAN NETWORK OF EXCELLENCE

# GEIA/ACCENT Emissions

## A cooperative effort

- Project description
- Emission Data portal
- Workshops & meetings
- ACCENT web portal
- GEIA project
- Web links
- Contacts
- Home

## GEIA/ACCENT Emission Data Portal

The GEIA /ACCENT data portal is composed of different inventories at global or regional scales, listed in the table below. It provides gridded data for three emission categories:

- anthropogenic (technological + biofuel + agriculture waste burning)
- biomass burning from wild lands (forest fires + savannah fires)
- natural: vegetation and oceans emissions

**Important notice : When using any data from the GEIA/ACCENT web portal, we request that you acknowledge the authors of the datasets of each inventory (as indicated in each inventory's documentation), as well as the GEIA/ACCENT database activity (see Project description)**

If you want to have access to more emissions categories, or higher resolution, go to the inventory home web site by clicking on the inventory "home site URL"

| Inventory | Coordinating Institute(s) | Home sites URLs (for detailed inventory) |
|---|---|---|
| POET | RIVM / IASB / Service d'Aéronomie(CNRS) | http://www.aero.jussieu.fr/projet/ACCENT/POET.php |
| RETRO | MPI-Met | http://retro.enes.org/emissions |
| GEIA v.1 | GEIA Network | http://www.geiacenter.org |

**News on Availability** : For now, emission data from the POET database are available for a large list of species and for many years. GEIA version 1 inventories are also accessible by the link in the previous table. For now, the RETRO CO and NOx data are available on this portal (other species are coming soon).

## Links to other Emission Inventories or Databases

| Inventory | Coordinating Institute(s) | Home sites URLs |
|---|---|---|
| EMEP | Norwegian Meteorological Institute | http://webdab.emep.int/ |
| EDGAR | RIVM | http://arch.rivm.nl/env/int/coredata/edgar/index.html |
| Aerocom | LSCE(CNRS) / MPI-Met | http://nansen.ipsl.jussieu.fr/AEROCOM/ |
| IIASA | International Institute for Applied Systems Analysis (IIASA) | http://www.iiasa.ac.at/rains/index.html |

Current data portal; Please use each dataset reference when using

# GEIA/ACCENT Emissions

A cooperative effort

ACCENT
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Search for another database

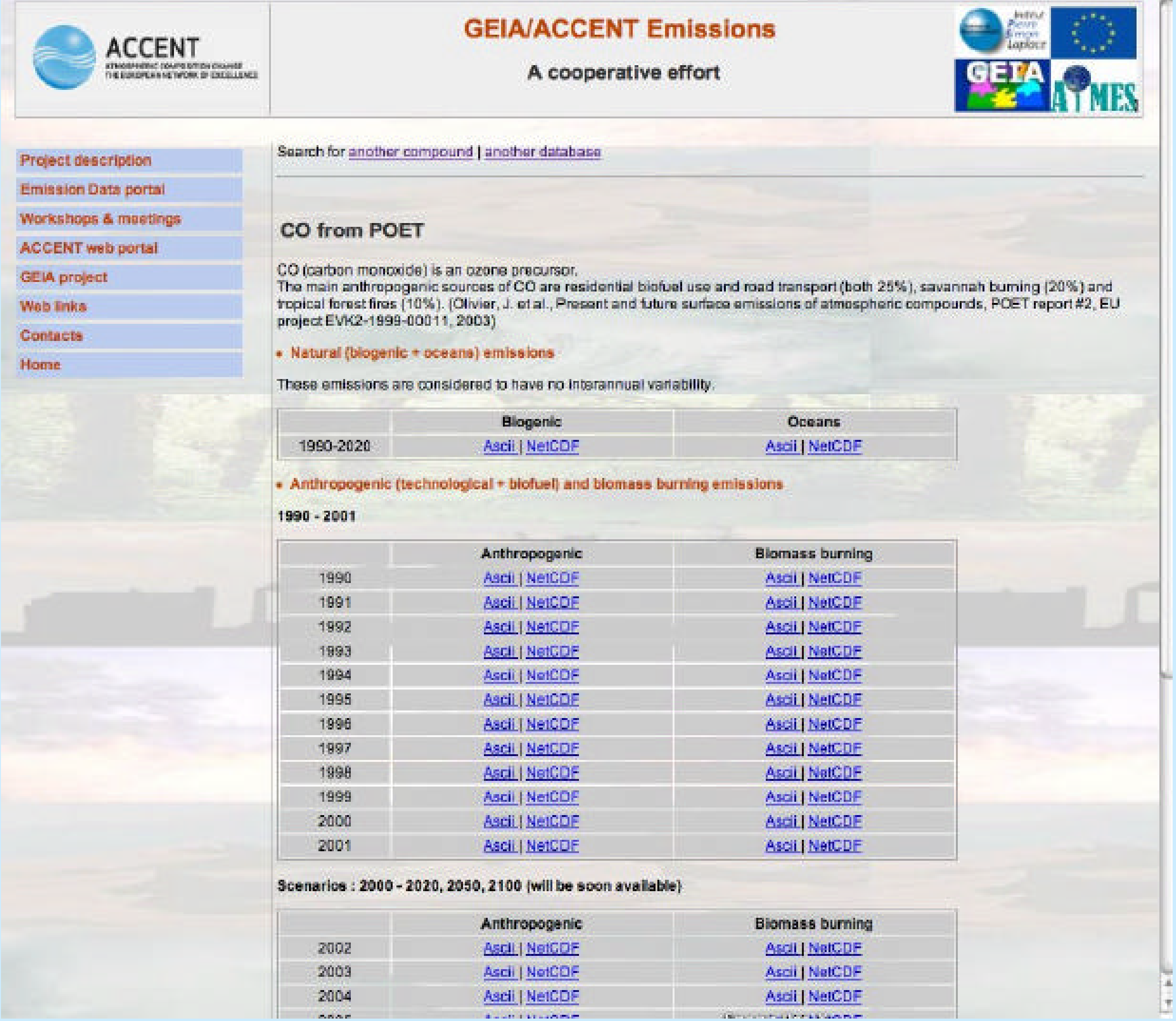
## POET inventory

This emission database was developed within the POET FP5 European project, by RIVM (The Netherlands), Service d'Aéronomie (France), and IASB (Belgium).
The reference document is : " Olivier J., J. Peters, C. Granier, G. Petron, J.F. Müller, and S. Wallens: Present and future surface emissions of atmospheric compounds, POET report #2, EU project EVK2-1999-00011, 2003 "

- **Documentation**
- **Data** : this database contains emission data for the following compounds. The gridded data are available in ASCII format, and will soon be available in NetCDF format.

- **Remarks:**
- CH3CHO is a lumped specie for all non-CH2O aldéhydes
- C2H5OH is a lumped specie for all non-CH3OH alcohols
- Mek (Methyl-ethyl-ketone) is a lumped specie for all non-acetone ketones

| Emission gridded data | Emission Totals (not available) |
|---|---|
| CO | CO |
| NOx | NOx |
| C2H4 | C2H4 |
| C2H6 | C2H6 |
| C3H6 | C3H6 |
| C3H8 | C3H8 |
| Higher alkanes | Higher alkanes |
| Higher alkenes | Higher alkenes |
| CH2O | CH2O |
| CH3CHO | CH3CHO |
| CH3OH | CH3OH |
| C2H5OH | C2H5OH |
| Acetone | Acetone |
| Mek | Mek |
| Terpenes | Terpenes |
| Isoprene | Isoprene |


GEIA/ACCENT Emissions

A cooperative effort

ACCENT

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Search for another compound | another database

## CO from POET

CO (carbon monoxide) is an ozone precursor.
The main anthropogenic sources of CO are residential biofuel use and road transport (both 25%), savannah burning (20%) and tropical forest fires (10%). (Olivier, J. et al., Present and future surface emissions of atmospheric compounds, POET report #2, EU project EVK2-1999-00011, 2003)

- Natural (biogenic + oceans) emissions

These emissions are considered to have no interannual variability.

| | Biogenic | Oceans |
|---|---|---|
| 1990-2020 | Ascii \| NetCDF | Ascii \| NetCDF |

- Anthropogenic (technological + biofuel) and biomass burning emissions

**1990 - 2001**

| | Anthropogenic | Biomass burning |
|---|---|---|
| 1990 | Ascii \| NetCDF | Ascii \| NetCDF |
| 1991 | Ascii \| NetCDF | Ascii \| NetCDF |
| 1992 | Ascii \| NetCDF | Ascii \| NetCDF |
| 1993 | Ascii \| NetCDF | Ascii \| NetCDF |
| 1994 | Ascii \| NetCDF | Ascii \| NetCDF |
| 1995 | Ascii \| NetCDF | Ascii \| NetCDF |
| 1996 | Ascii \| NetCDF | Ascii \| NetCDF |
| 1997 | Ascii \| NetCDF | Ascii \| NetCDF |
| 1998 | Ascii \| NetCDF | Ascii \| NetCDF |
| 1999 | Ascii \| NetCDF | Ascii \| NetCDF |
| 2000 | Ascii \| NetCDF | Ascii \| NetCDF |
| 2001 | Ascii \| NetCDF | Ascii \| NetCDF |

**Scenarios : 2000 - 2020, 2050, 2100 (will be soon available)**

| | Anthropogenic | Biomass burning |
|---|---|---|
| 2002 | Ascii \| NetCDF | Ascii \| NetCDF |
| 2003 | Ascii \| NetCDF | Ascii \| NetCDF |
| 2004 | Ascii \| NetCDF | Ascii \| NetCDF |

What you can get for each species:

ASCII files: total anthropogenic = technol + biofuel + agric. waste

biomass burning = forest + savanna fires

NetCDF files: all individual files

# Conclusions

Large uncertainties still remain in emissions quantification:

➔Reduce uncertainties; temporal and spatial resolution of inventories

- of anthropogenic emissions
- of biomass burning emissions

➔ Intercomparisons, evaluations and consistency

- Use of inverse modeling (for CO, NOx, other??)
- work on consistency of gaseous/aerosols emissions
- Define some ways of improving/evaluating emissions of NMVOCs

➔ Couple emissions models/algorithms with CTMs

- natural emissions of both gas/aerosols
- use consistent datasets (database of driving variables might help)
  same vegetation map biomass burning/ biogenic NMVOCs