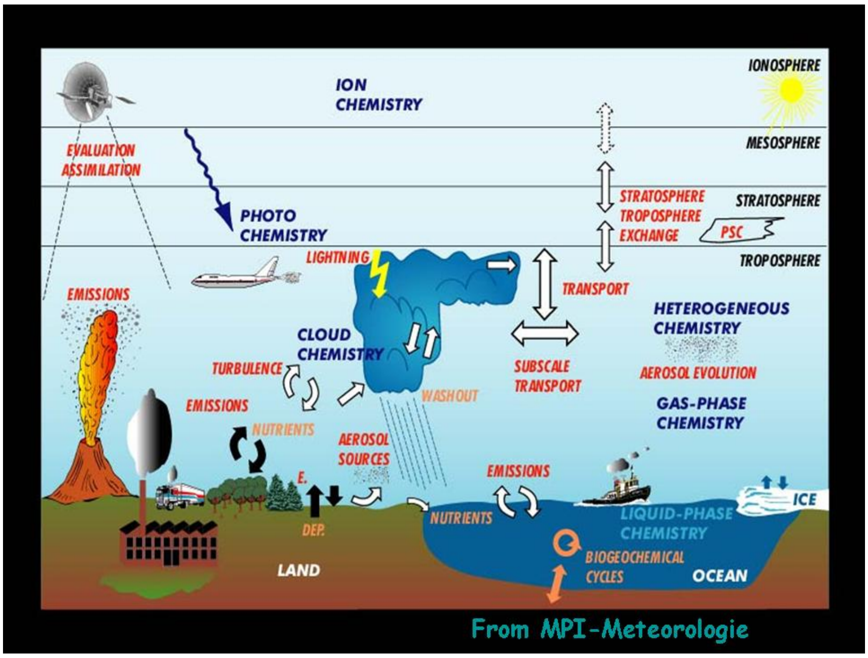
Estimation of surface emissions

Claire Granier

Service d'Aeronomie/IPSL, Paris, France
Max-Planck Institute for Meteorologie, Hamburg, Germany
CIRES/NOAA Aeronomy Laboratory, Boulder, USA



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)

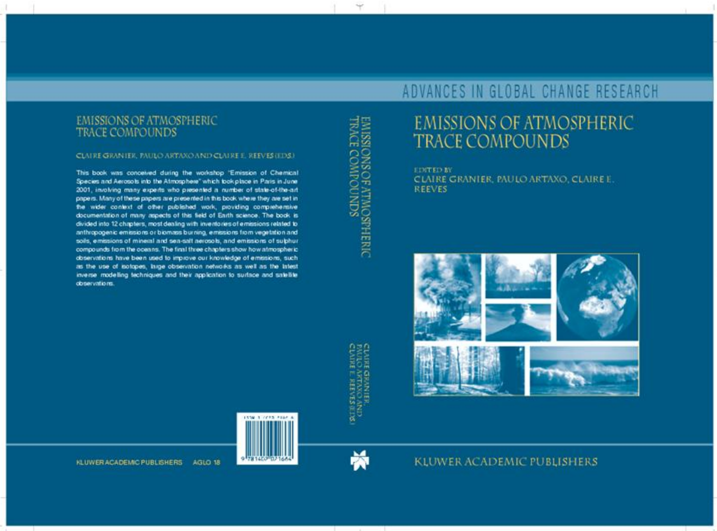
Outline

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, CH_4, NO_x, hydrocarbons
- aerosol/aerosol precursors: BC, OC, SO_2
- non-chemically active species: CO_2, N_2O, CFCs, HFCs, HCFCs, heavy metals, POPS, ..

General equation:

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

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):

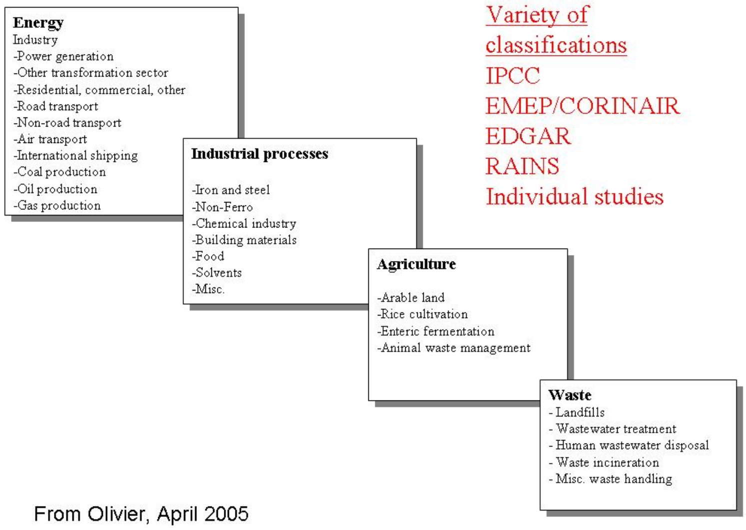
– 1. Energy (combustion / production)
– 2. Industrial processes
– 3. Solvents/other product use
– 4. Agriculture
– 5. Land-Use Change and Forestry (LUCF)
– 6. Waste
– 7. Other

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

source categories



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

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

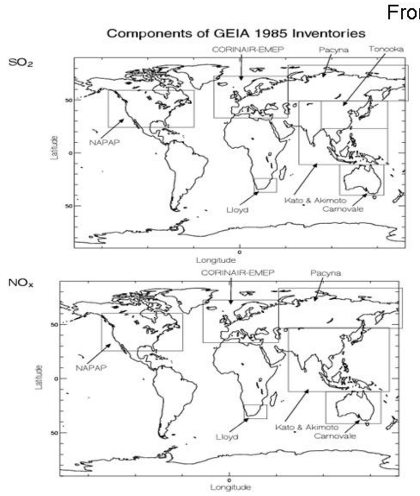
Examples of inventories

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

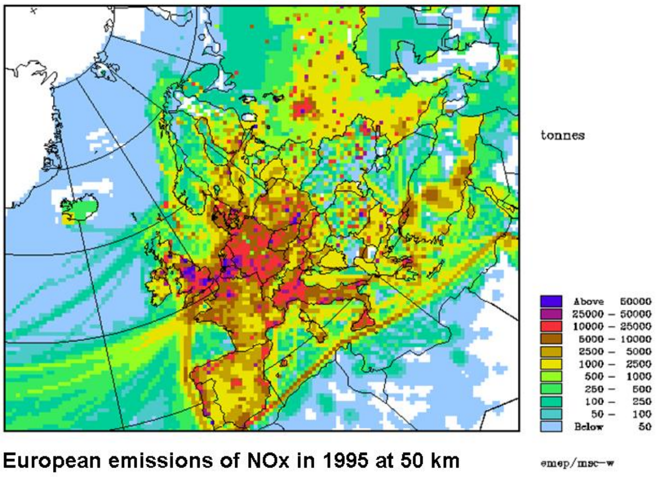
- Global coverage:
  - GEIA (anthropogenic e.g. NOx, SO2, NMVOC; natural e.g. S-volcanoes, NMVOC-soil, vegetation) (1985-1990)
  - EDGAR 3 (anthropogenic GG 1970-1995; other 90-95) + POET (1990-2000)
  - EDGAR-HYDE 1.3 (all 1890-1990)
  - RETRO (1960-2000)
  - AEROCOM (2000) particles only
  - IEA (fuel CO2 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)

Fron Benkovitz et al., 2003

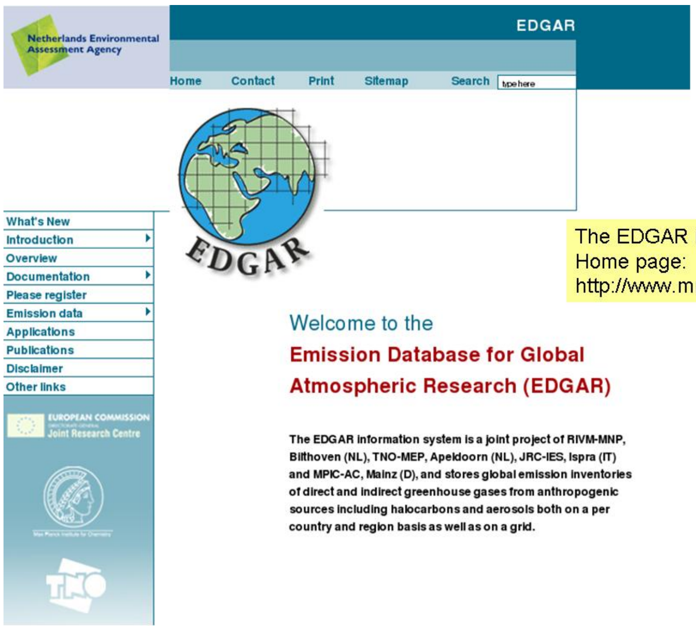


Regional inventories overlaid on the default global inventories of SO2 (top panel) and NOx.(bottom panel) for the GEIA 1985 inventories.

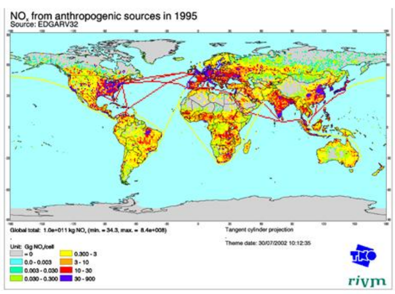


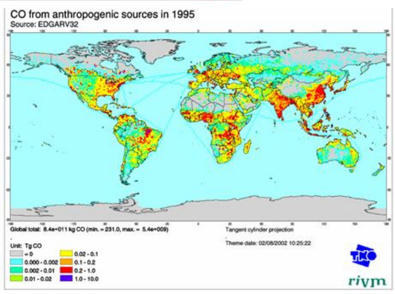
European emissions of NOx in 1995 at 50 km grid resolution (Mg as NO2) (from EMEP)

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



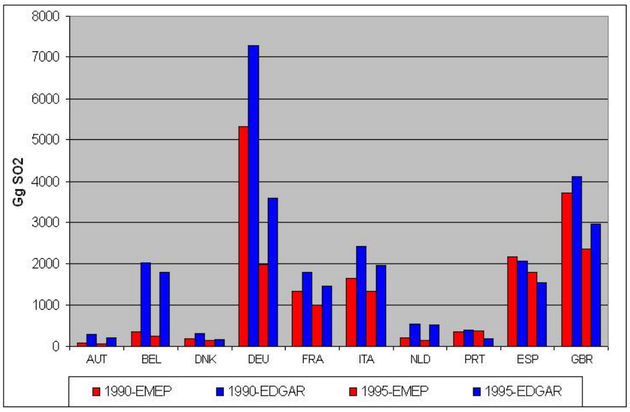
The EDGAR inventory Home page: http://www.mnp.nl/edgar/





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)



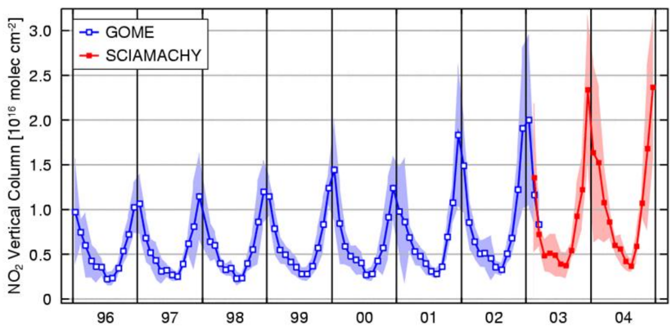
- SO_2 emission factors update needed for EDGAR in countries with recently implement control technologies

- 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

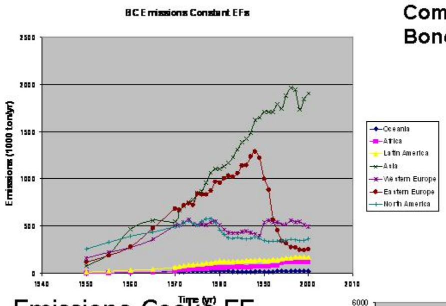
Uncertainty on aerosols emissions

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

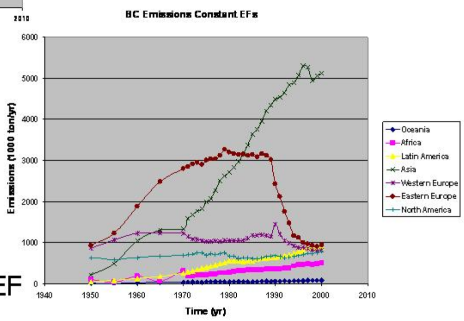
	Cooke (JGR, 1999	-	Streets (Trace-P; China)
	Devel. to Undev.		
• Hard Coal residential	• 1.39 to 2.28	-	0.12*
• Lignite residential			
• Coal industrial	• 2.50 to 4.10	-	3.6*
	• 0.15 to 1.10	-	0.003-0.33
• Diesel transport	• 2.0 to 10.0	-	1.1
• Gasoline transport	• 0.03 to 0.15	-	0.08

* 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)

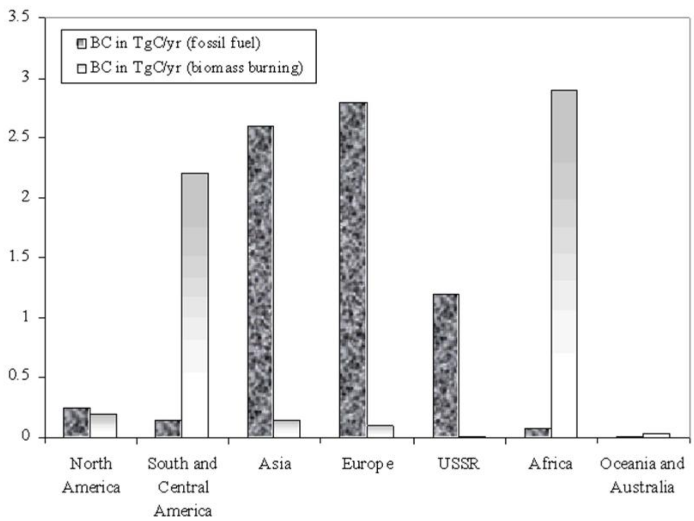
Emissions of the 50 most significant NMVOCs	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1,1,1-trichloroethane								0.39				14.93	0.12	15
1,2,4-trimethylbenzene	0.00					0.38	0.03		0.42	2.35	10.71	9.14		23
1,3,5-trimethylbenzene	0.00					0.15	0.03		0.42	0.57	3.34	3.33		8
1-butanol								0.90				7.10	0.01	8
1-butene	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

$$[P]_{lm} = [A]_{lm} \times [B]_{lm} \times [CF]_{lm} \times [EF]_{lm}$$

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*[c]
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*[c]
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*[c]
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*[c]
C_3H_4	0.022±0.014	0.013	0.04-0.06	*0.024*[c]	---	*0.06*[c]	*0.032*[c]
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*[c]
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*[c]
isoprene	0.020±0.012	0.016	0.10	0.15-0.42	---	0.017	*0.05*[c]
terpenes	0.015	*0.15*[g]	0.22	*0.15*[g]	---	*0.0*	*0.015*[c]
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*[d]	*0.025*[d]	*0.025*[d]	---	*0.025*[d]	*0.025*[d]
methanol	*1.3*[c]	*2.0*[c]	2.0±1.4	*1.5*[c]	0.16	*3.8*[c]	*2.0*[c]
formaldehyde	0.26-0.44	*1.4*[c]	2.2±0.5	0.13±0.05	---	*2.6*[c]	*1.4*[c]
acetaldehyde	0.50±0.39	*0.65*[c]	0.48-0.52	0.14±0.05	---	*1.2*[c]	*0.65*[c]
acetone	0.25-0.62	*0.62*[c]	0.52-0.59	0.01-0.04	0.02	*1.2*[c]	*0.63*[c]
2-butanone	0.26	*0.43*[c]	0.17-0.74	0.03-0.06	---	*0.83*[c]	*0.44*[c]
formic acid	*0.7*[c]	*1.1*[c]	2.9±2.4	0.13	0.20	*2.0*[c]	0.22
acetic acid	*1.3*[c]	*2.1*[c]	3.8±1.8	0.4-1.4	0.98	*4.1*[c]	0.8

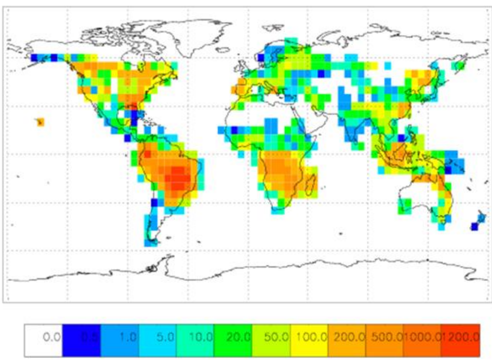
Emissions factors: based on measurements in different countries, and campaigns

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")

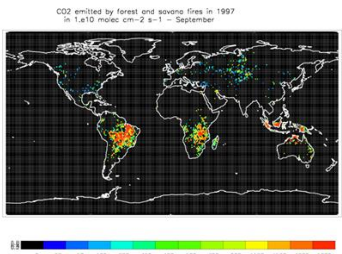
- ❑ ESA et al., GLOBCARBON

Burnt Areas

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

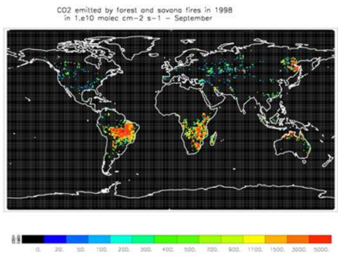
Satellite derived global fire products (from Gregoire, April 2005)

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



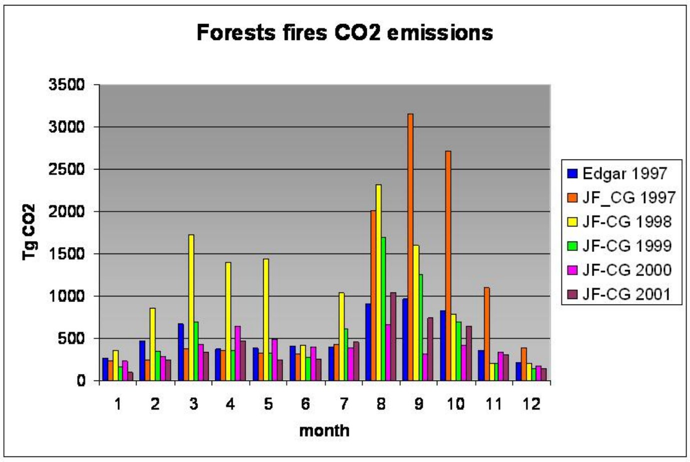
← September 1997

↓ September 1998

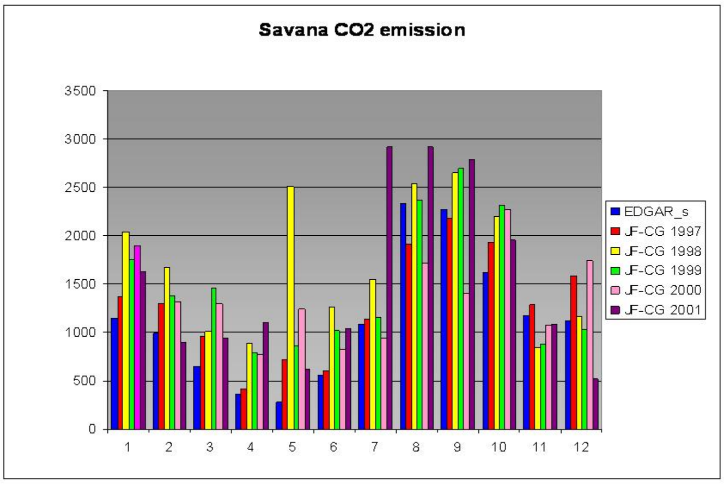


1x1 degree distribution of biomass burning Emissions of CO_2

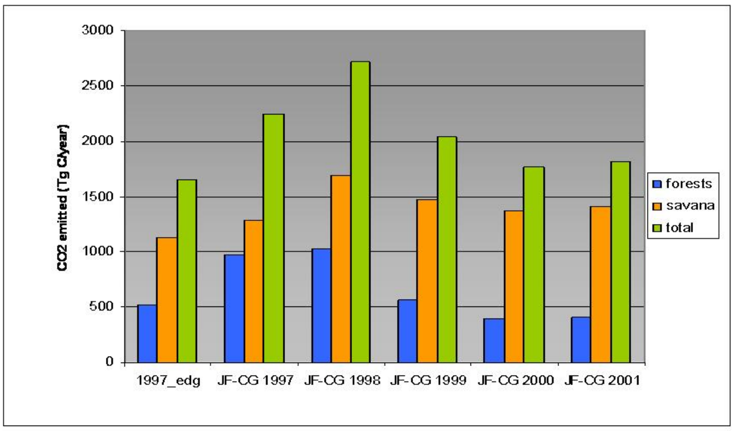
Based on ATSR fire counts



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

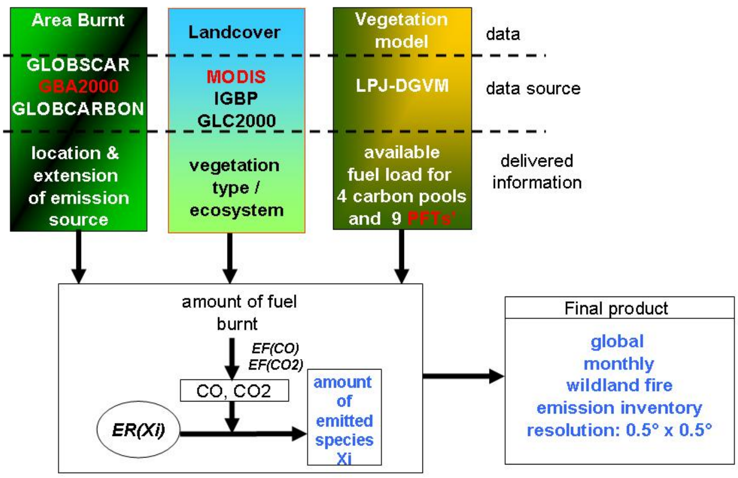


CO2 emitted yearly by forest and savanna fires
1997_edg: EDGAR-3
JF-CG: emissions based on ATSR satellite data developed by J.F. Lamarque and C. Granier

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

Product name EO system product type	Resolution sensor product	Time step sensor product	Coverage	Period	Source	Documentation
GBA2000 SPOT-VGT burnt area	1 km 1 km^2	day month	Globe	Nov. 99 to Dec. 00	JRC	Tansey et *al.*, 2004, JGR(**109**) & Climatic Change (**67**) http://www-gvm.jrc.it/fire/gba2000/index.htm
GLOBSCAR ERS-AATSR burnt area	1 km 1 km^2	day month	Globe	2000	ESA	Simon *et al.*, 2004, JGR(**109**) http://shark1.esrin.esa.it/ionia/FIRE/BS/ATSR/
GBA1982-1999 NOAA-AVHRR burnt area	5 km 8 km^2	day 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

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

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

n: number of ecosystems (5)

$\mathbf{EF_k(X)}$: emission factor for species X per ecosystem

A $_i$: area burnt per month

β_k: combustion efficiency for ecosystem k

AFL $_k$: available fuel load per ecosystem

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

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

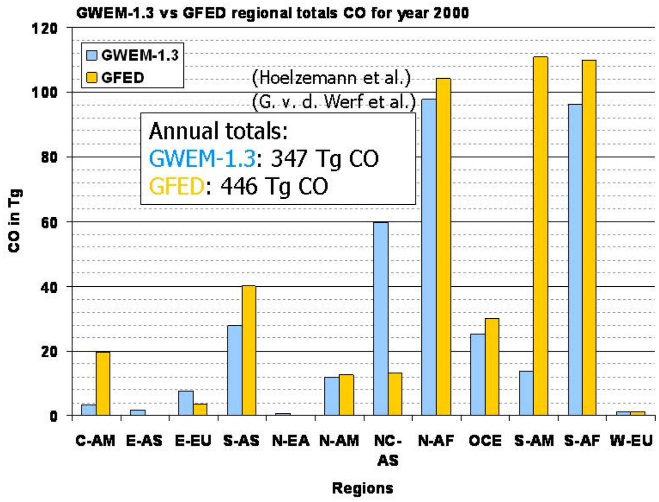
t: number of PFT's (9)

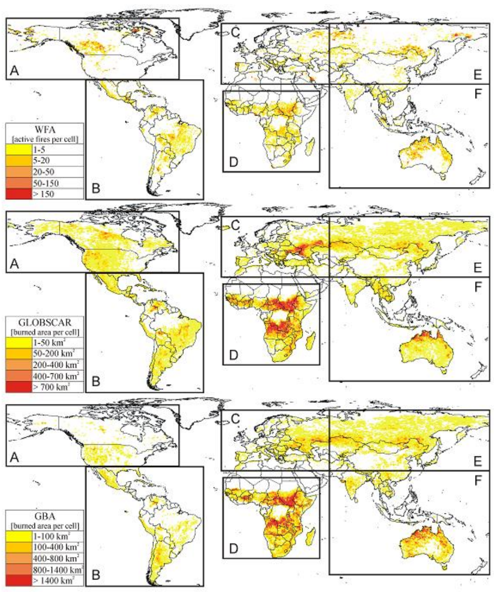
p: number of carbon pools (5)

$\chi_{t,p}$**: susceptibility factor**

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

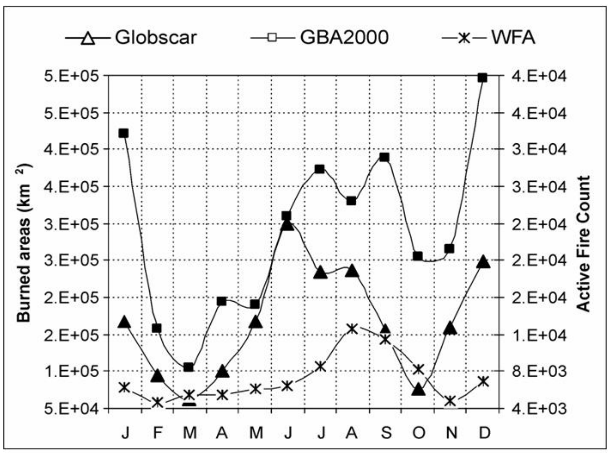
GWEM-1.3 results: regional totals





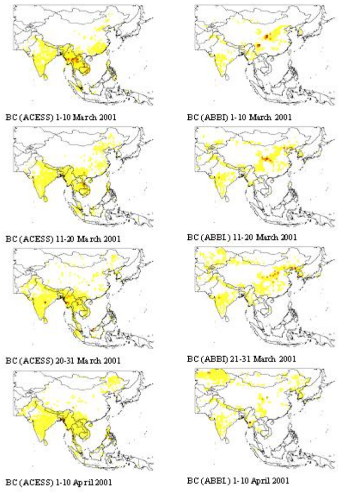
Inter-comparison of global fire products:
-World Fire Atlas (WFA)
- GLOBSCAR
- GBA2000

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

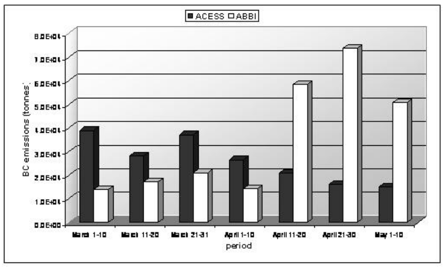


(from Gregoire, April 2005)

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



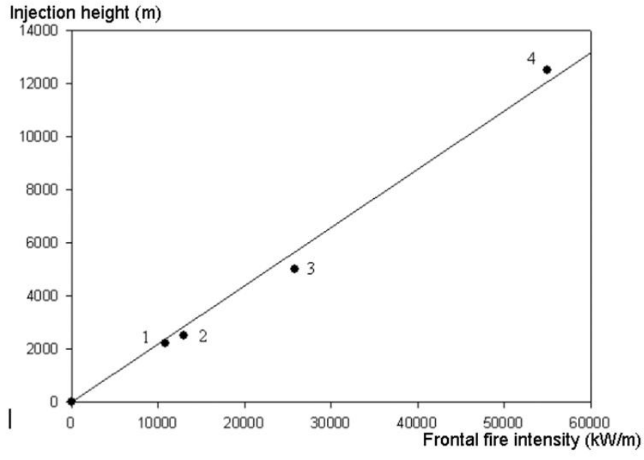
ACESS/ABBI (Michel et al. 05)
(TRACE P and ACE ASIA period)



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

Product name EO system product type	Resolution sensor product	Time step sensor product	Coverage	Period	Source	Documentation
GLOBCARBON ERS, ENVISAT, SPOT-ATSR,AATSR,VGT fire (day & night) burnt area	1 km ???	day month	Globe	1998-2003	ESA	http://dup.esrin.esa.it/projects/summaryp43.asp
VGT4Africa SPOT-VGT burnt area	1 km 1 km²	day 10 days	Africa	from 2005	JRC	from May 1st: http://www-gvm.jrc.it/tem/
GEOLAND = GLOBCARBON	1 km ???	day month	Africa & Eurasia	1998-2003	JRC	from May 1st: 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

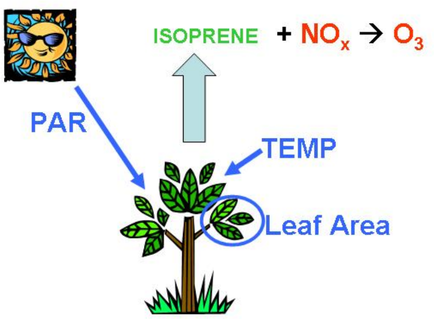
Natural emissions:

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

→ biogenic hydrocarbons: isoprene/terpenes and other compounds
→ CH4 from wetlands
→ NOx from soils
→ NOx 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)

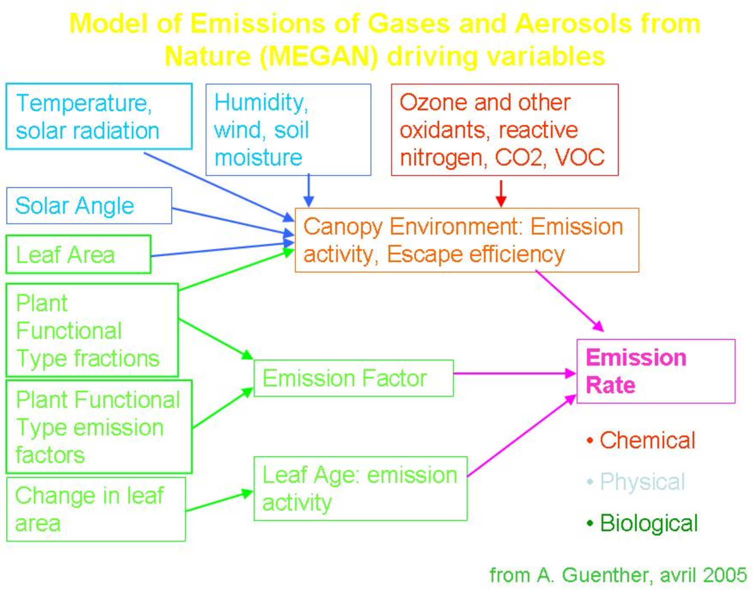
Emission Rate= EF x EA x LP

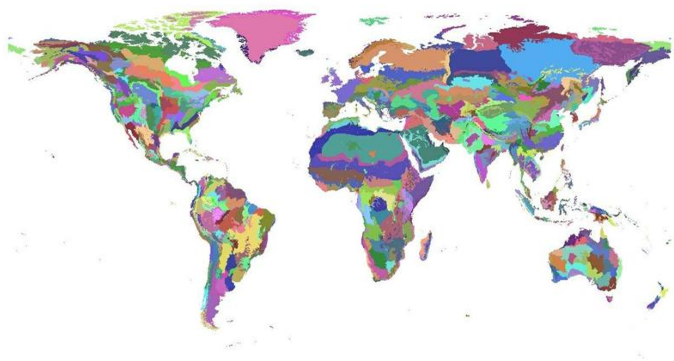
Emission Rate: Net canopy emission to the above-canopy atmosphere

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)



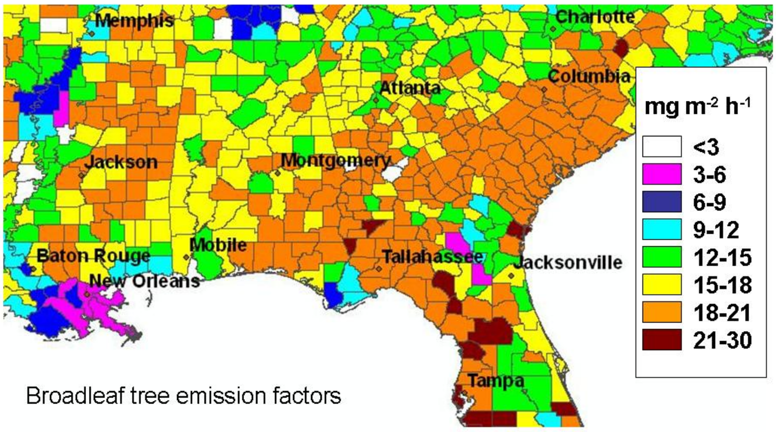


The global distribution of ecoregions as assigned by the World Wildlife Fund ecoregion scheme. Each color represents a different ecoregion (over 850 ecoregions are assigned to the global land area) (Based on Olson et al., 2001). For more information, visit http://www.worldwildlife.org/ecoregions.

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.

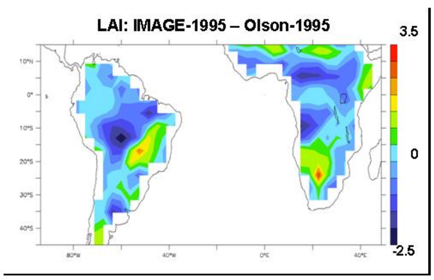


Broadleaf tree emission factors

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

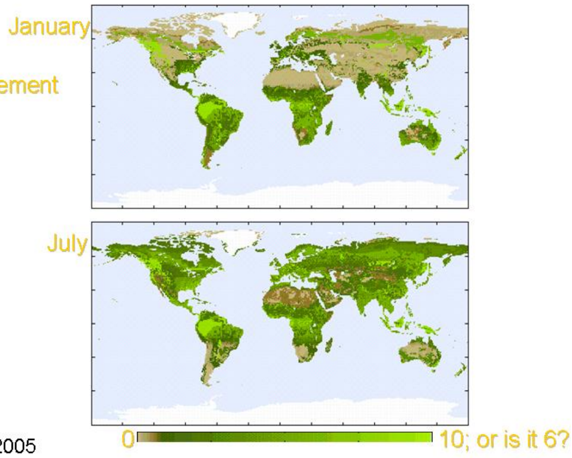


From Ganzeveld, April 2005

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

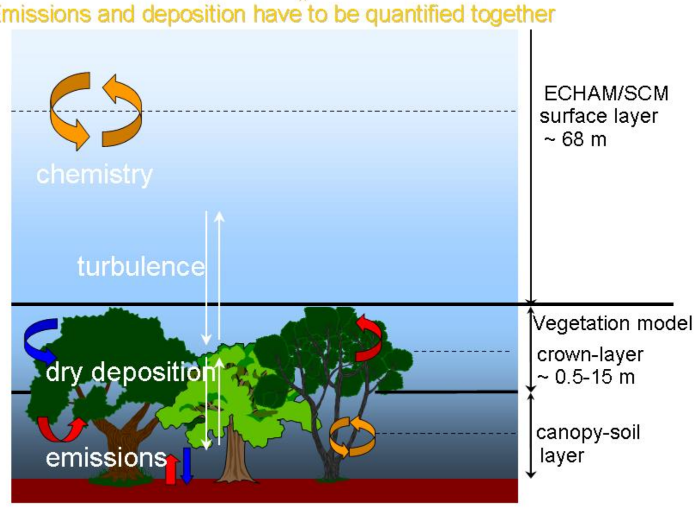
- ✓ Surface cover
- ✓ Land use management
- ✓ Soil properties
- ✓ Activity data

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

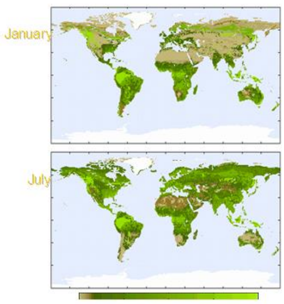
Grom Ganzeveld, April 2005

Dry deposition: required input datasets

Dry deposition in <u>online</u> or <u>offline</u> 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



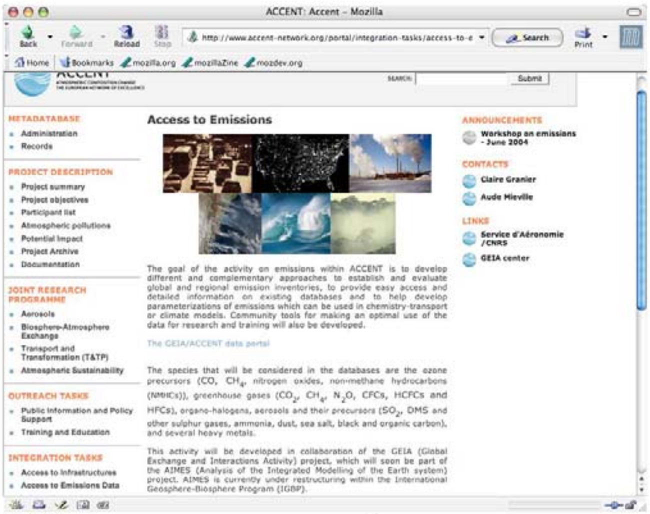
And additional one's for offline models

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

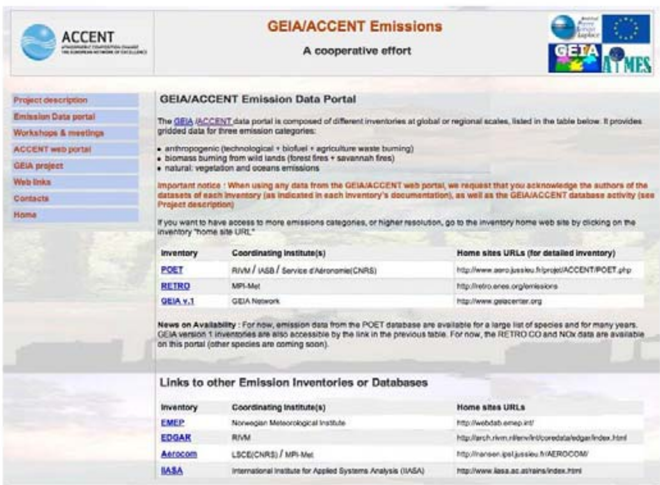
From Ganzeveld, April 2005

	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

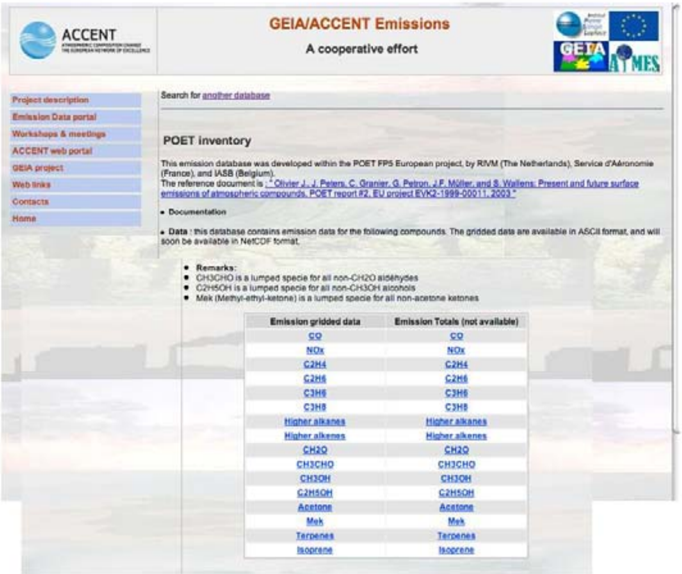
*: emissions from volcanoes



ACCENT access: www.accent-network.org
GEIA access: www.geiacenter.org (end of August)



Current data portal; Please use each dataset reference when using



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