

AeroCom Emissions

March 2004

Frank Dentener, JRC

aerosol emission datasets

recommended for year 2000
simulations of AEROCOM

Contributors:

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O. Boucher (*LOA, France*)

Goal

- **to provide recommended data-sets for anthropogenic aerosol and precursor gases for *year 2000* simulations**
 - **including recommendations for *size-distribution* of primary emissions**
 - **including recommendations for emission altitude**

Data-sets

- **Large scale biomass burning POM / EC / SO₂**
- **Fossil fuel/biofuel related POM / BC emissions**
- **SO₂ emissions** (fossil fuel, fraction emitted as sulfate)
- **SEA-SALT emissions size resolved**
- **DUST emissions size resolved**
- **DMS (sulfur) emissions**
- **SOA 'effective' emissions**
- **Height of emissions** (*volcanic and biomass*)

Spatial Resolution

- **1 degree latitude * 1 degree longitude**
 - averages are given for each grid-box
 - units are given in kg... /gridbox
 - for volcanic aerosol it is recommended to use the **ascii-files** (`continuous_volc.1X1`, `explosive_volc.1x1`) which contain the **exact** volcano locations
- NOTE: before February contained a mismatch of volcano locations**

Temporal resolution

- **Daily emissions**
 - DUST
 - SEASALT
 - DMS
- **Monthly emission**
 - Biomass Burning
 - SOA
- **Yearly emissions**
 - All other data-sets

*higher resolution data
will be adopted only in
sensitivity experiments*

Emission Heights (1)

- **Dust** lowest model layer < 100 m
- **Seasalt** lowest model layer < 100 m
- **DMS** lowest model layer < 100 m
- **SOA** lowest model layer < 100 m
- **POM/BC biofuel** lowest model layer < 100 m
- **POM/BC fossil fuel** lowest model layer < 100 m
- **Biomass burning (OC/BC/SO₂)** ECO-system dependent
 - **0-.1km / .1-.5km / .5-1km / 1-2km / 2-3km / 3-6km**
(data provided via D. Lavoue, personal communication, 2003)

Emission Heights (2)

- **SO₂**

- **domestic** < 100m
- **road /off-road** < 100m
- **industry** 100 - 300m
- **shipping** < 100 m
- **power-plants** 100 - 300m
- **volcanic** (**location and altitude are provided*)
 - continuous 2/3 to 1/1 of volcano top *
 - explosive .5 to 1.5km above top *

... other data

- for other data (*e.g. for 'full chemistry simulations'*) it is recommended to use
- **EDGAR 3.2, 1995** (*NO_x / anthropog.NMHC....*)
<http://arch.rivm.nl/env/int/coredata/edgar>
- no specific recommendations are given for oxidant fields.

Data Access by anonymous ftp

- **ftp.ei.jrc.it ... cd pub/Aerocom**

- **subdirectories**

- **dust_ncf**
 - **seasalt_ncf**
 - **DMS_ncf**
 - **other_ncf (or other_ascii)**

- BC: -biofuel, -fossil fuel, -wildfire (GFED – 6 altitude regimes)
 - POM: -biofuel, -fossil fue, -wildfire (GFED – 6 altitude regim.)
 - SO2: -domestic, -industry, -powerplants, -offroad, -road, -international shipping, -wildfire (GFED – 6 altitude regimes)
 - volcanic: -continuous, -explosive

File-formats:

- _ncf** : netcdf format
- _ascii**: ascii format
- _hdf**: hdf format

an overview is provided in a power-point file ([Aerocom....ppt](#))

data will be made available on CD / DVD (*contact kinne@dkrz.de*)

Details and Plots

Overview

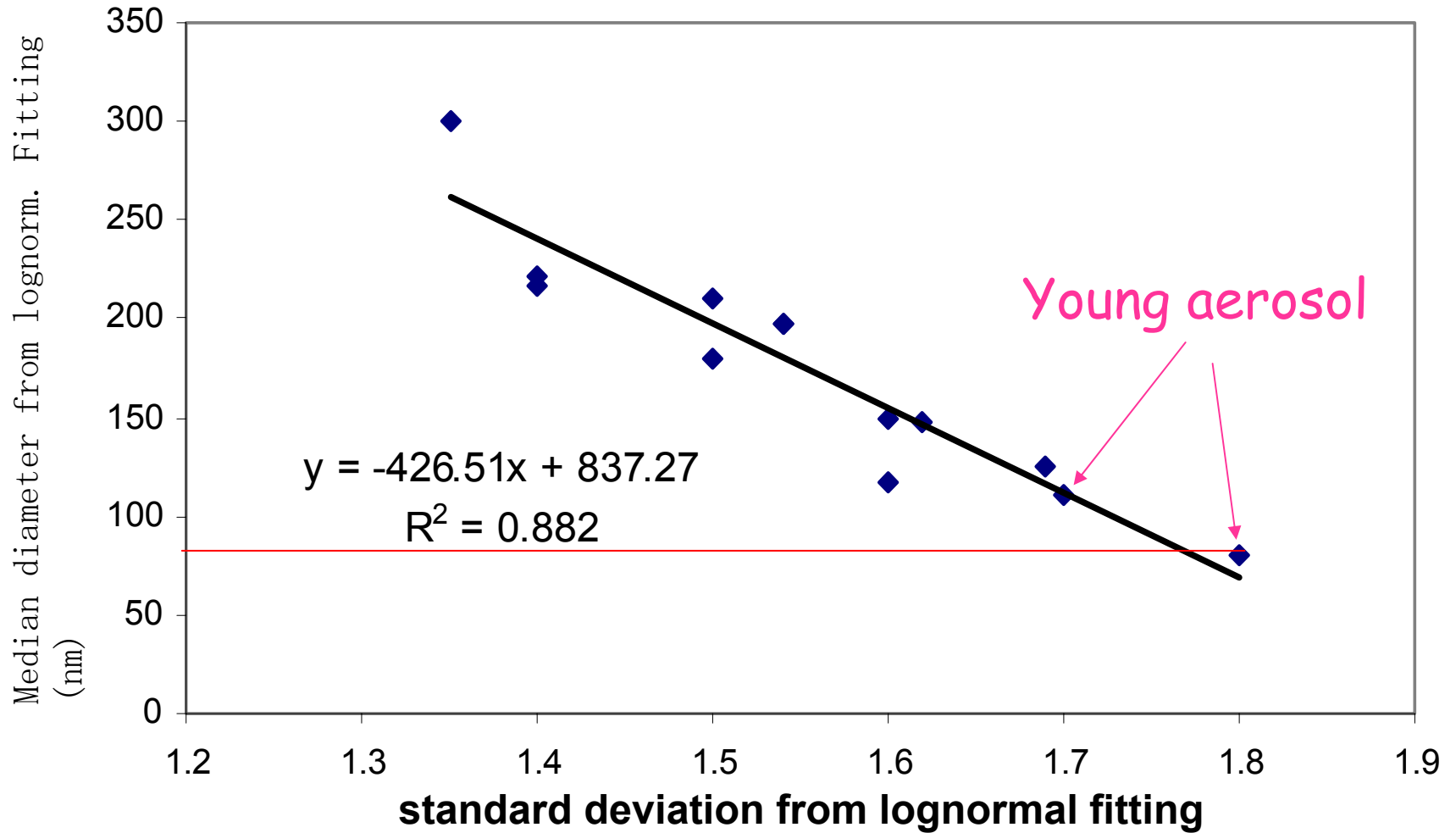
- **BIOMASS BURNING**
- **BIO FUEL / FOSSIL FUEL**
- **SO₂**
- **SO₂ - *volcanic contributions***
- **SOA**
- **DUST**
- **SEASALT**
- **DMS**
- **EMISSION HEIGHTS**
- **DATA ACCESS**

Biomass Burning

size recommendations for primary SO₄, OC and BC

- **particles size** (*log normal size-distributions*)
 - **industrial / power plant** (*fly ash*) (larger sizes)
 - **LN: $r_{mode} = .500\mu\text{m}$, $std.dev = 2.0$ ($r_{eff} = 1.6\mu\text{m}$)**
 - **biomass** (based on measurement close to biomass)
 - **LN: $r_{mode} = .040\mu\text{m}$, $std.dev. = 1.8$ ($r_{eff} = 0.077\mu\text{m}$)**
compilation by Marelli, 2003
 - **traffic** (kerbside / urban measurements at 5 European cities)
 - **LN: $r_{mode} = .015\mu\text{m}$, $std.dev. = 1.8$ ($r_{eff} = 0.029\mu\text{m}$)**
based on Putaud et al. 2003 <http://carbodat.ei.jrc.it/ccu/main.cfm>

Accumulation mode diameter vs standard deviation

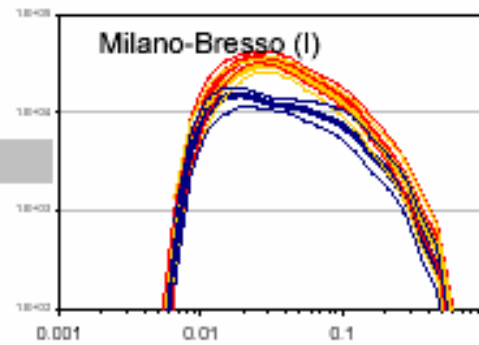
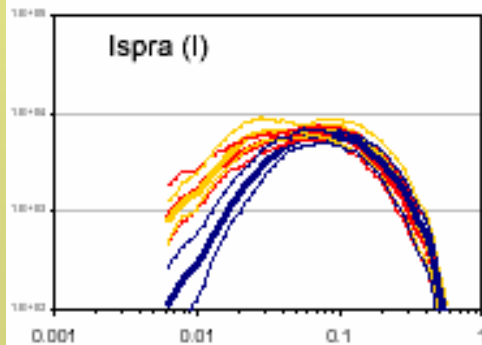
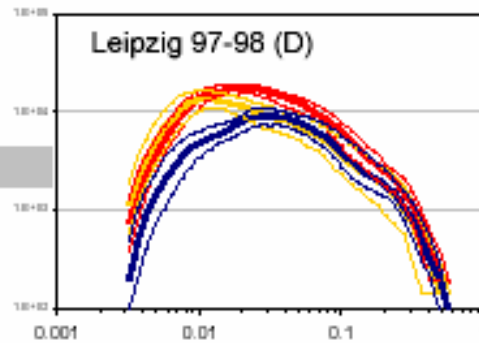
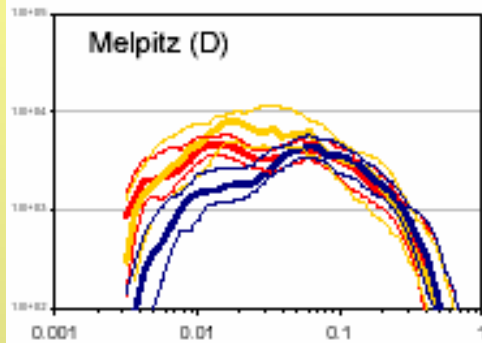
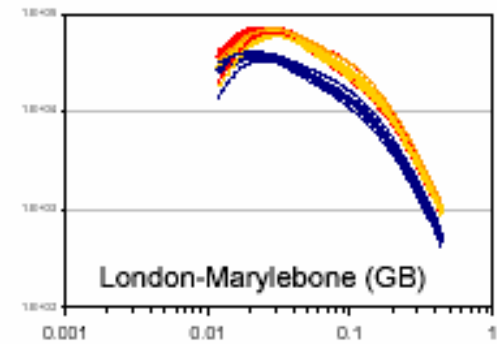
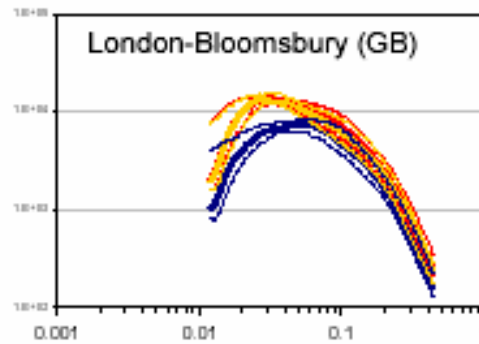


Putaud et al, Aerosol Phenomenology, 2003

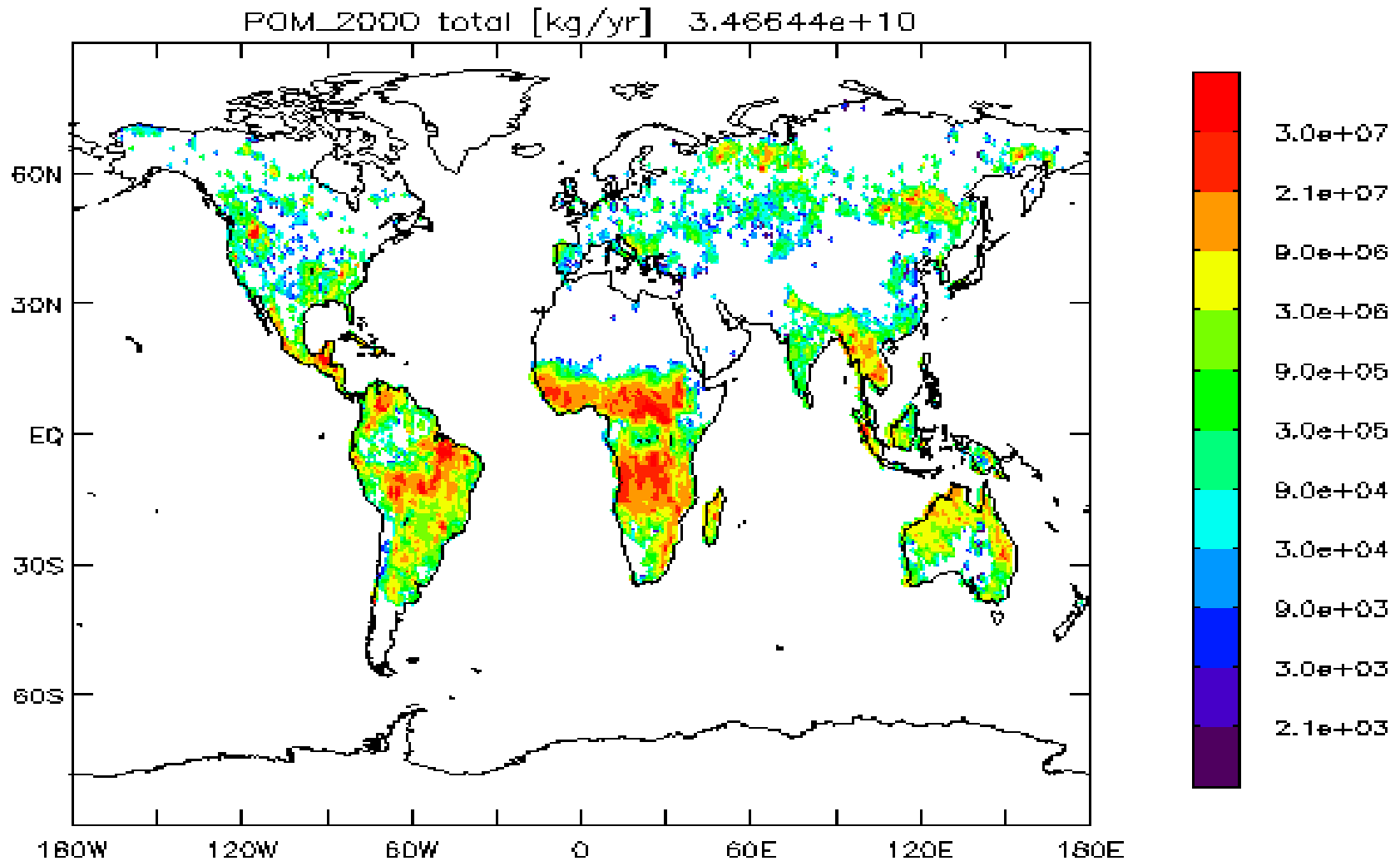
Near-City

Urban

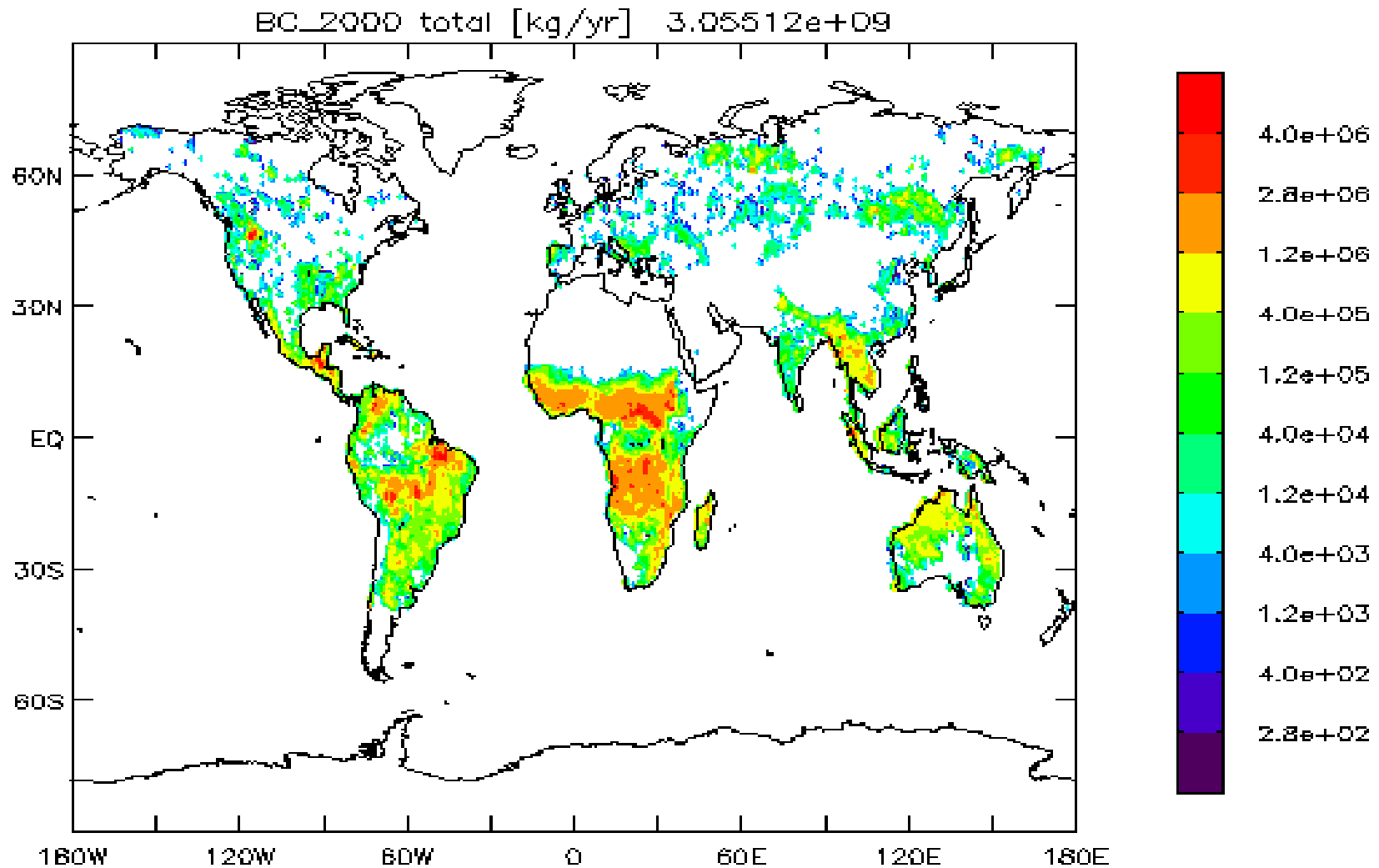
Kerbside



GFED (1*1 resolution) 'POM'



GFED (1*1 resolution) 'BC (EC)'



Bio-Fuel / Fossil-Fuel

Fossil (bio-)fuel related emissions

POM/ OC / BC

- based on **SPEW**
also see: Tami Bond -
a technology based
global inventory of
black and organic
carbon emissions
from combustion,
revised to JGR, 2003.
- based on **GEFD** for
large scale burning
(open fires)

<i>Tg/year</i>	BC	OC	POM
fossil	3.04	2.41	3.20
biofuel	1.63	6.50	9.1
open fire	3.32	25.08	34.6
total	8.0	34.0	46.9

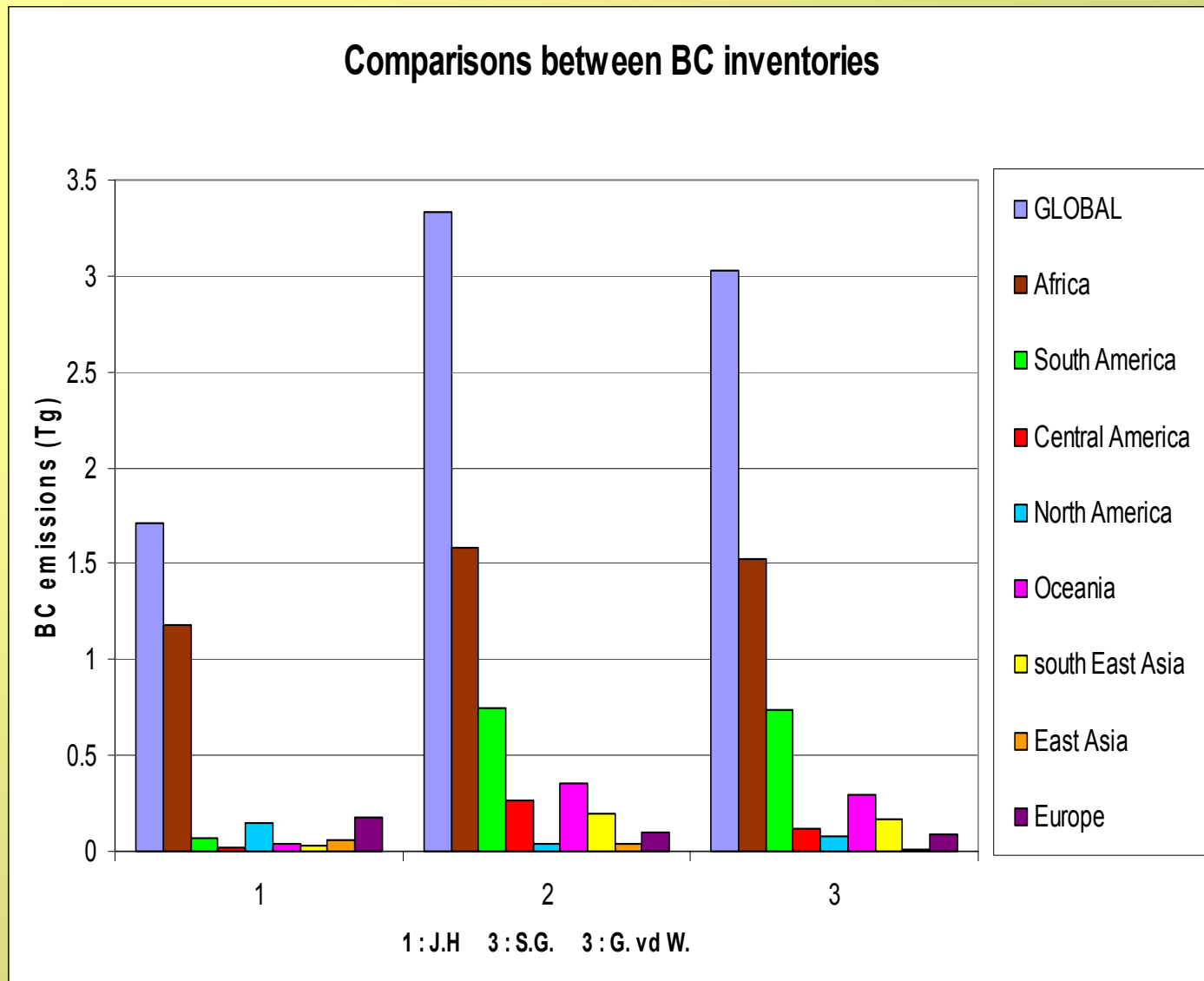
note, these emissions are 35 % lower than those of a previous inventory, which was based on 1984 statistics

BC Regional Comparison

<i>Tg /year</i>	SPEW	SPEW	SPEW	GFED
recommendations are shown in BLUE	bio-fuel	fossil fuel	open fire comparison	open fire
Open Ocean	1.42 e+6	7.80 e+5	2.93 e+7	0.0
Canada	8.08 e+6	5.28 e+7	3.57 e+7	8.75 e+6
USA	6.33 e+7	6.28 e+7	2.92 e+8	6.78 e+7
Latin America	1.08 e+8	9.10 e+8	3.04 e+8	8.63 e+8
Africa	3.48 e+8	1.47 e+9	1.25 e+8	1.54 e+9
OECD-Europe	2.96 e+7	5.26 e+7	2.78 e+8	6.42 e+6
Eastern Europe	3.36 e+7	6.40 e+6	9.88 e+7	6.21 e+6
CIS(old USSR)	1.77 e+7	1.01 e+8	1.67 e+8	9.31 e+7
Middle East	1.73 e+7	2.03 e+7	1.32 e+8	3.75 e+5
Indian Region	4.27 e+8	1.64 e+8	1.86 e+8	8.83 e+7
China Region	4.54 e+8	1.87 e+8	1.01 e+9	6.39 e+7
East Asia	1.23 e+8	1.28 e+8	1.99 e+8	1.14 e+8
Oceania	4.26 e+6	1.64 e+8	2.74 e+7	2.13 e+8
Japan	3.60 e+4	2.51 e+6	1.56 e+8	7.97 e+5
WORLD	1.63 e+9	3.32 e+9	3.04 e+9	3.06 e+9

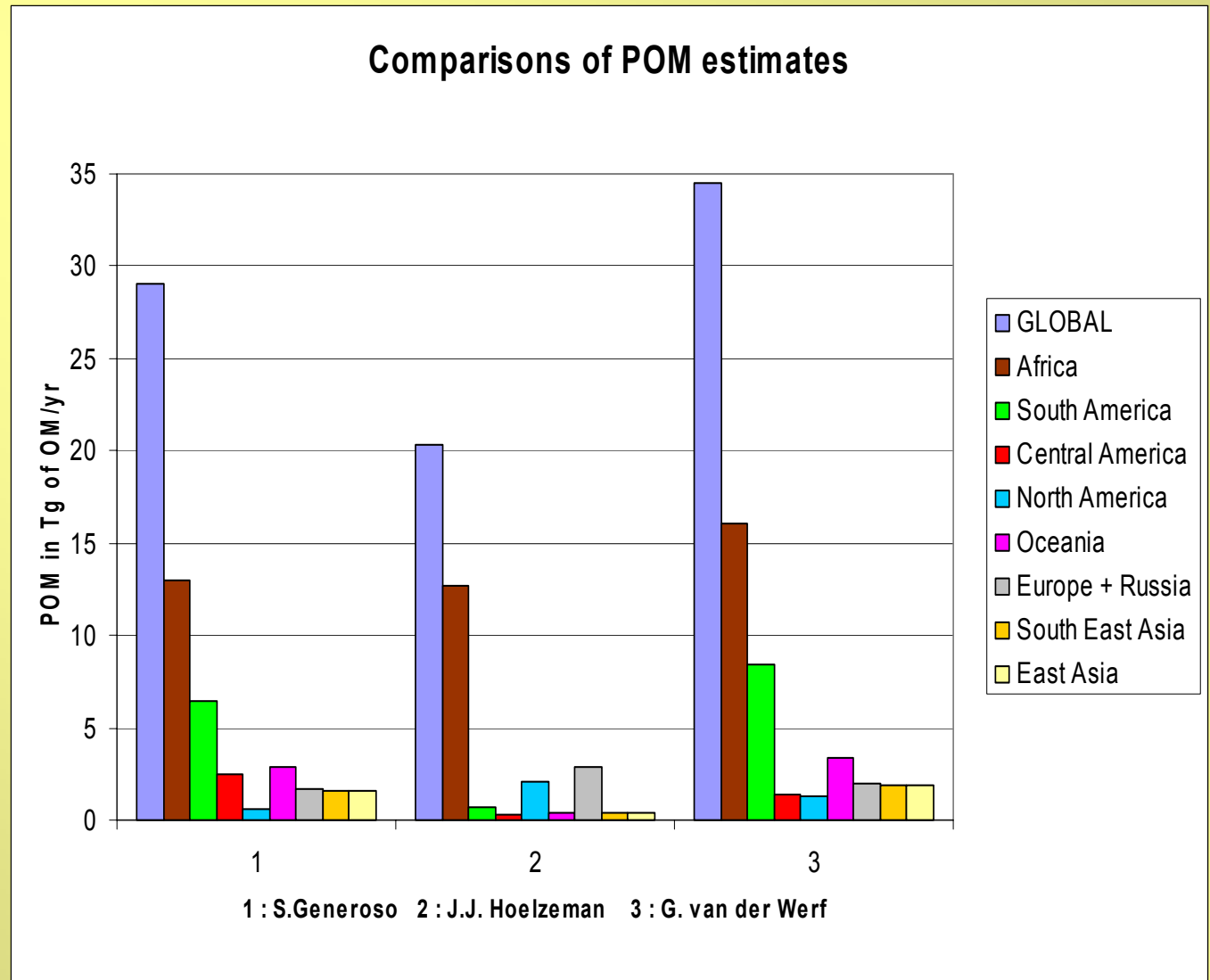
BC inventory comparisons

- **# 1**
GWEM
Hoelzemann
- **# 2**
Generoso
- **# 3**
GFED 2000
van der Werf



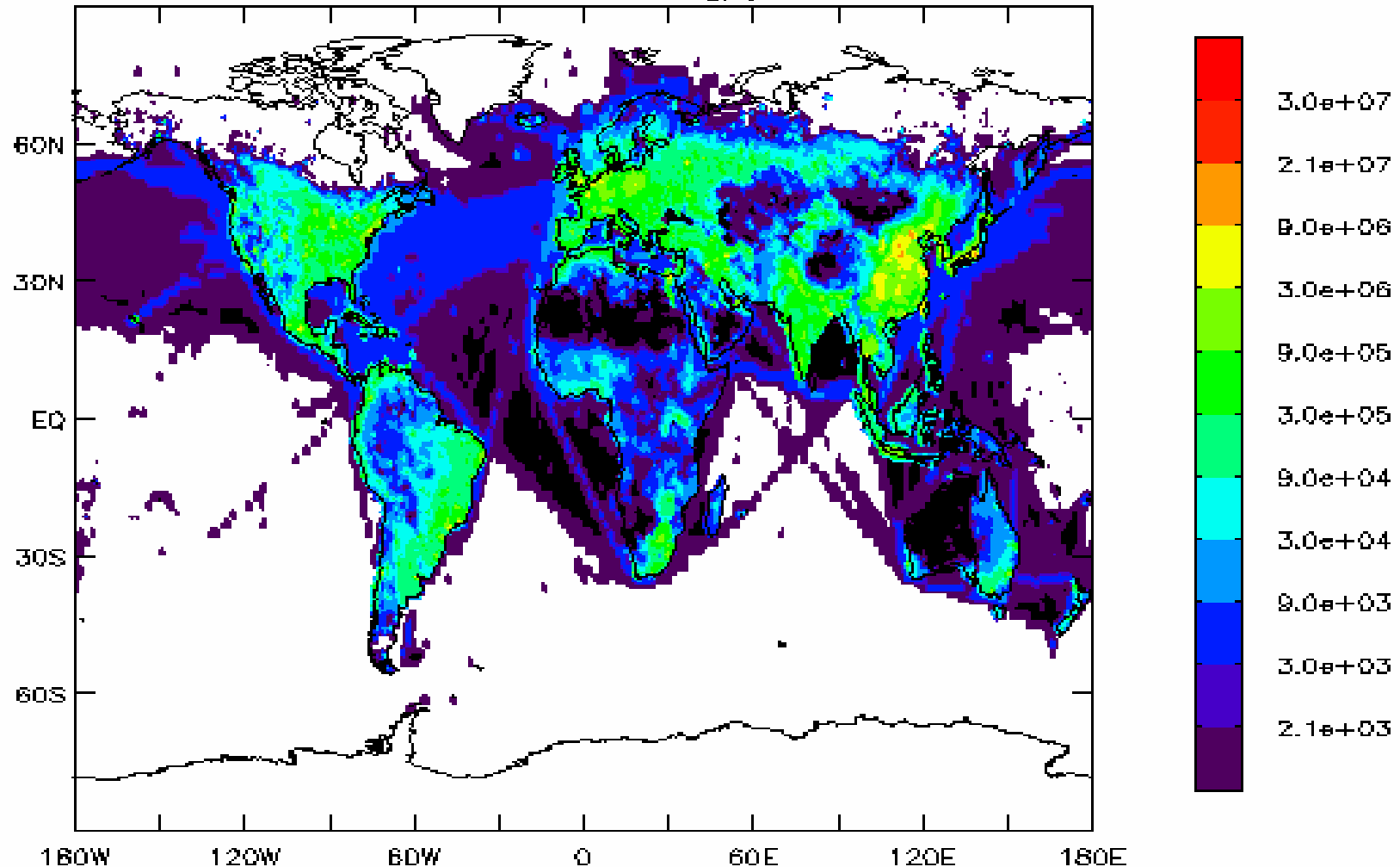
POM inventory comparisons

- **# 1**
Generoso
- **# 2**
GWEM
Hoelzemann
- **# 3**
GFED 2000
van der Werf



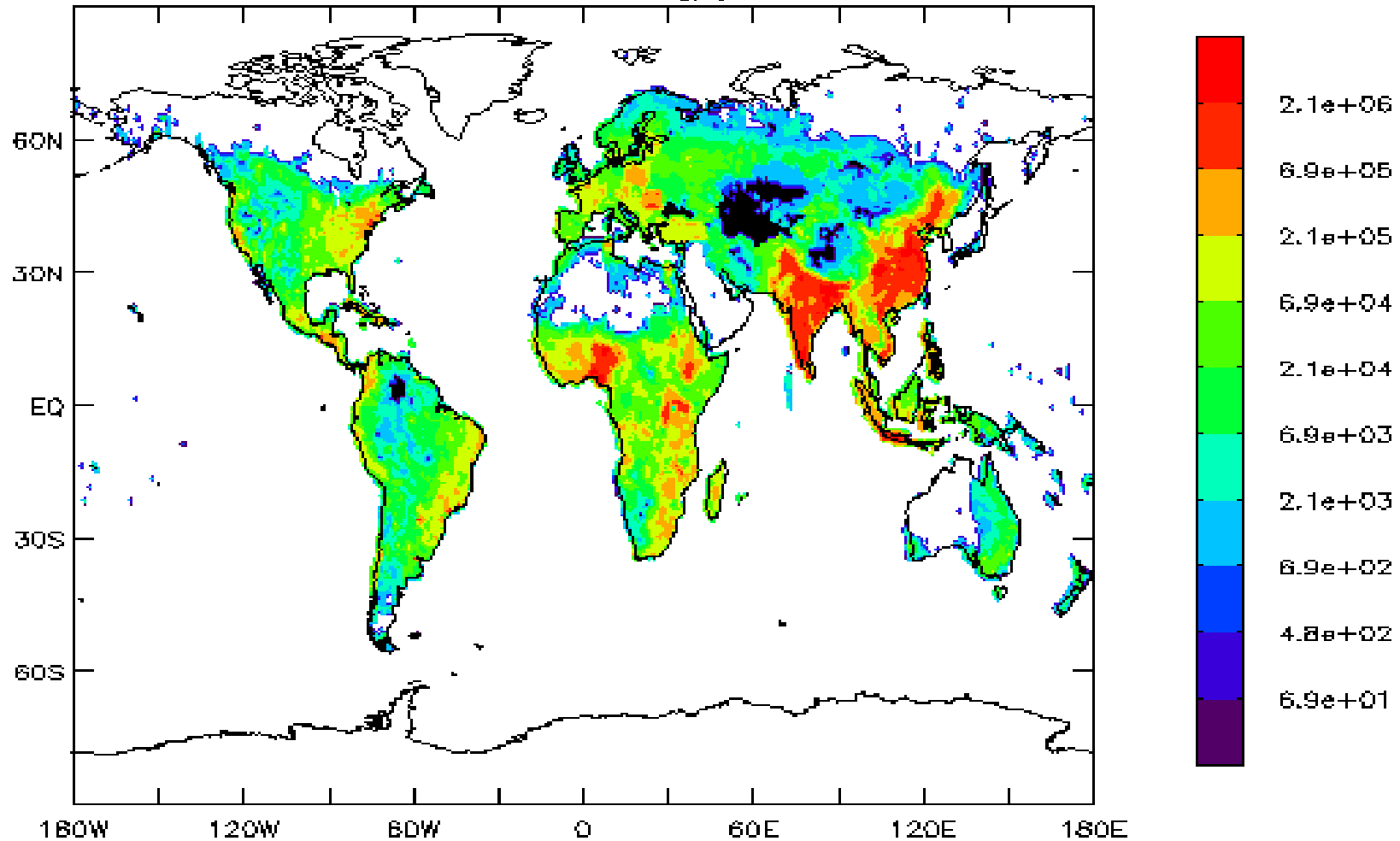
SPEW – BC fossil fuel emissions

SPEW 1996 Fossil fuel Black carbon, kg/yr total: 3.04014×10^9



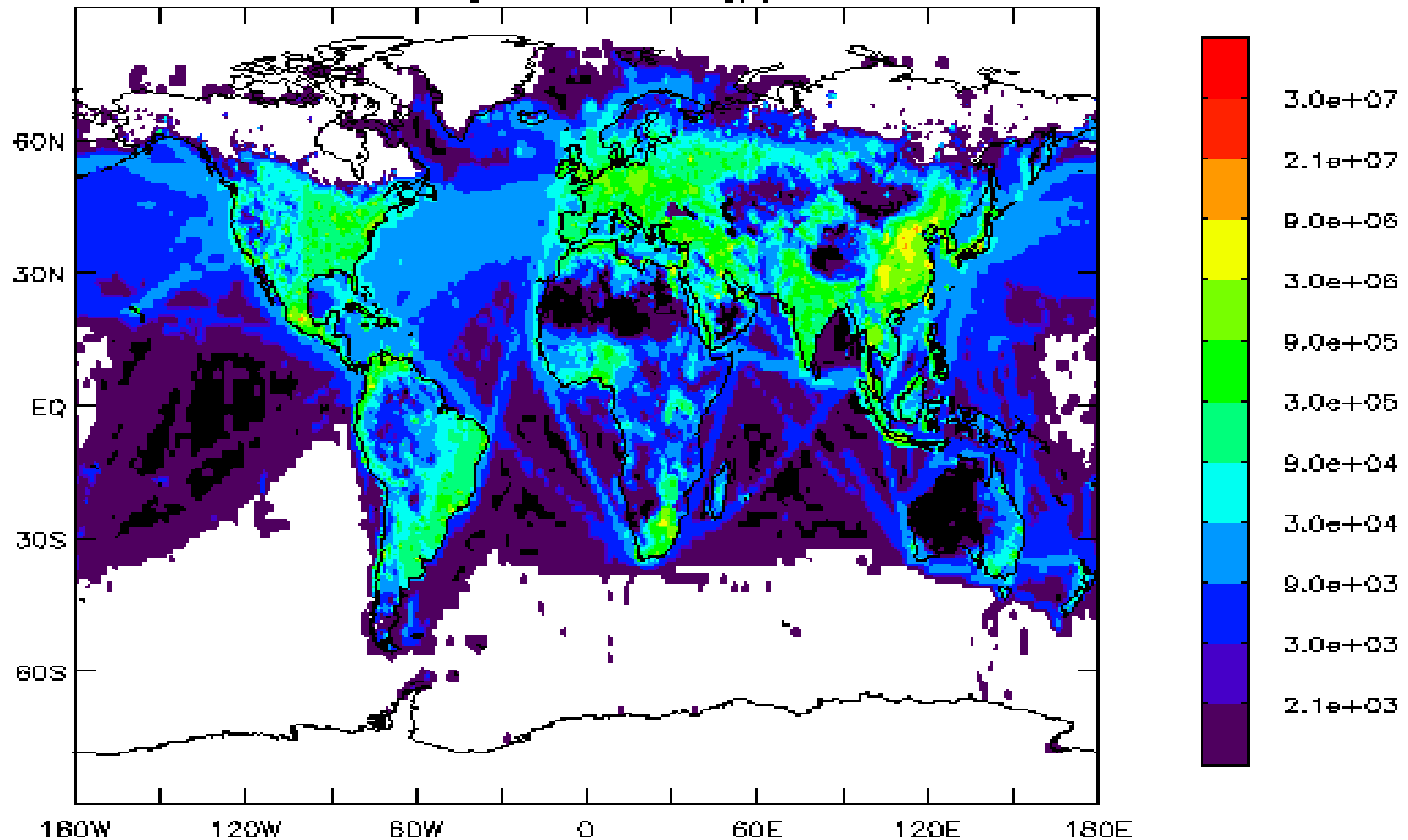
SPEW – BC bio fuel emissions

SPEW 1996 Biofuel Black carbon, kg/yr total: 1.63250e+09



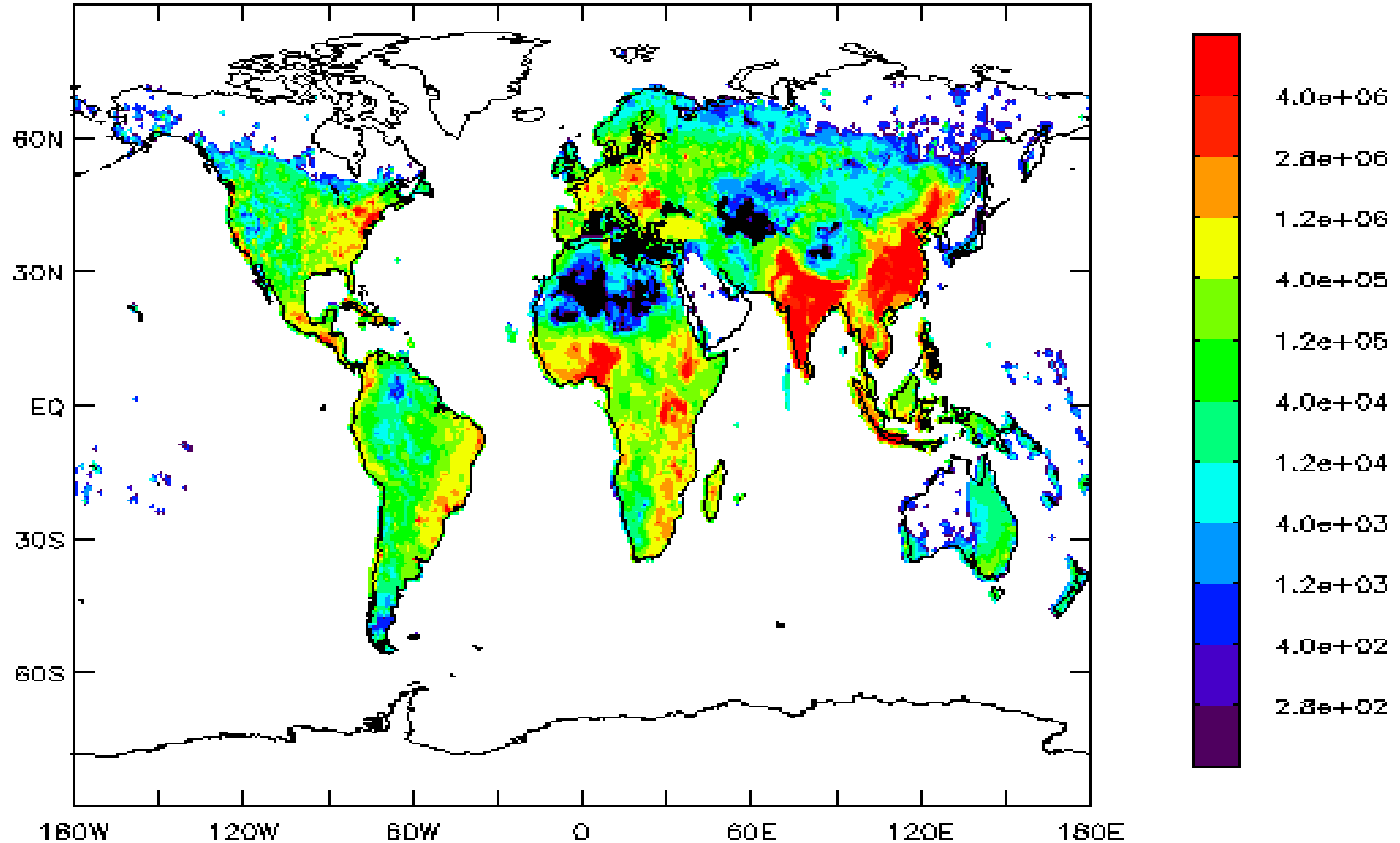
SPEW – OC fossil fuel emissions

SPEW 1996 Fossil fuel Organic matter kg/yr total: 3.20190e+09



SPEW – OC bio fuel emissions

SPEW 1996 Biofuel Organic matter kg/yr total: $9.08826e+09$



SO2

SO₂ - emissions

- **Global emissions**

from Janusz Cofala (IIASA)

Country based SO₂ emissions for the year 2000 using RAINS and the EDGAR 3.2 (1995) gridded distributions (in prep.)

<i>Tg/year</i>	SO₂	S
total	141.7	70.9
as SO₂	138.2	61.9
as SO₄	5.3	1.8

ship - emissions: 1.5% per year increase since 1995

a flat percentage of 2.5% of all SO₂ is emitted as primary SO₄

(compare to 1-5% in literature)

SO₂ – emissions by type

<i>Tg /year</i>	SO₂	S
powerplants	48.4	24.2
industry	39.3	19.6
domestic	9.5	4.77
road-transport	1.9	0.96
off-road	1.6	0.78
biomass burning	4.1	2.06
intern. shipping	7.7	3.86
volcanos	29.2	14.6
TOTAL	141.7	70.9

<i>Tg /year</i>	IIASA +GFED +SHIP	EDGAR 3.2
1990	131.6	154.9
1995	118.5	141.2
2000	112.5	

decrease from 1990 to 1995 similar between EDGAR and IIASA - but IIASA+... 15 % lower than EDGAR

Good correspondance with EMEP country emissions

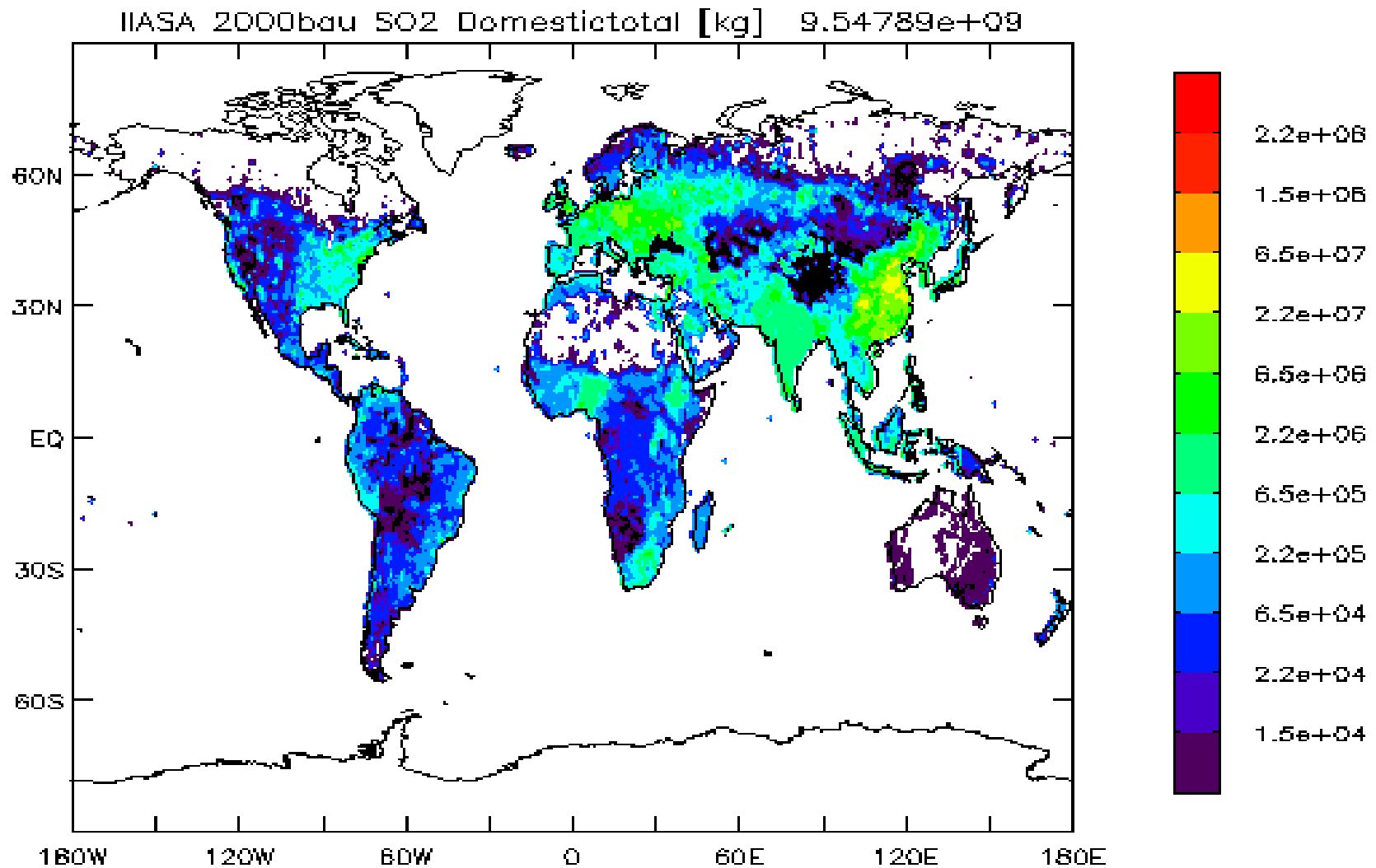
SO₂ – emissions by region / type

REGIONAL ESTIMATES: kg SO₂

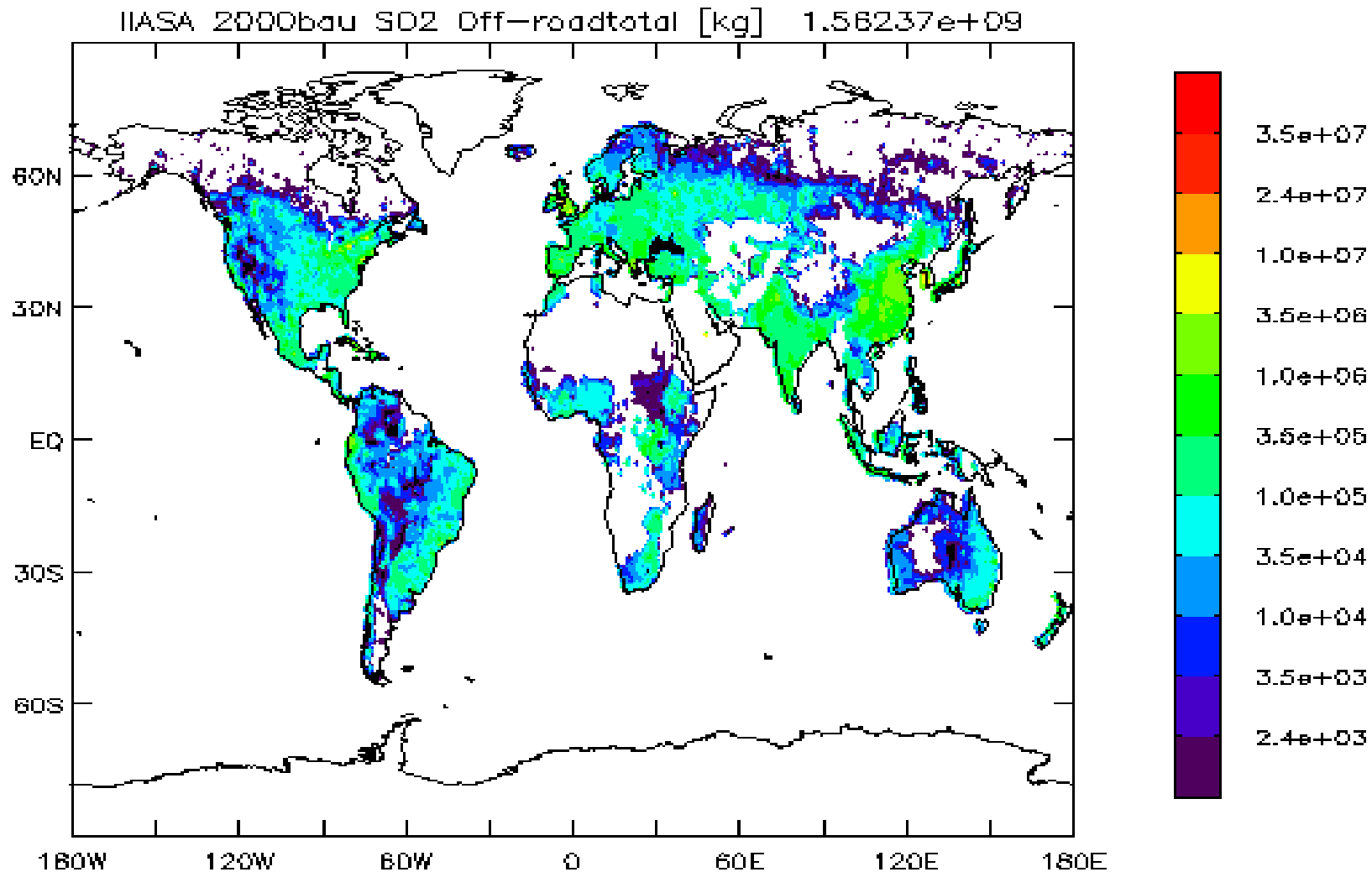
Region	Domestic_2	Industry_2	Intern. ship	Off-road_2	Powerplant	RoadTransp
OPEN OCEAN	0.00e+00	0.00e+00	5.05e+09	0.00e+00	0.00e+00	0.00e+00
CANADA	7.16e+07	1.19e+09	2.90e+07	5.30e+07	5.44e+08	1.35e+07
USA	3.11e+08	3.12e+09	8.45e+07	1.11e+08	1.25e+10	1.67e+08
LATIN AMERICA	1.96e+08	2.96e+09	1.71e+08	1.99e+08	2.37e+09	2.98e+08
AFRICA	3.95e+08	1.50e+09	2.54e+08	6.90e+07	2.56e+09	1.79e+08
OECD EUROPE	4.42e+08	2.05e+09	1.64e+09	1.89e+08	3.47e+09	1.43e+08
EASTERN EU	6.70e+08	1.01e+09	7.73e+07	3.63e+07	4.20e+09	2.96e+07
CIS (old UdSSR)	1.16e+09	3.99e+09	0.00e+00	1.23e+08	5.61e+09	5.82e+07
MIDDLE EAST	5.17e+08	2.44e+09	2.32e+08	6.30e+07	2.80e+09	2.48e+08
INDIA REGION	5.95e+08	2.90e+09	1.93e+07	1.34e+08	3.49e+09	4.36e+08
CHINA REGION	4.76e+09	1.47e+10	1.93e+07	3.45e+08	8.73e+09	1.24e+08
EAST ASIA	3.50e+08	2.08e+09	1.26e+08	1.55e+08	1.09e+09	1.52e+08
OCEANIA	8.30e+06	8.06e+08	7.24e+06	4.29e+07	8.50e+08	3.67e+07
JAPAN	6.76e+07	4.79e+08	4.10e+07	4.09e+07	2.45e+08	3.71e+07
WORLD	9.55e+09	3.92e+10	7.75e+09	1.56e+09	4.84e+10	1.92e+09

• total world 2000: 112.5 Tg

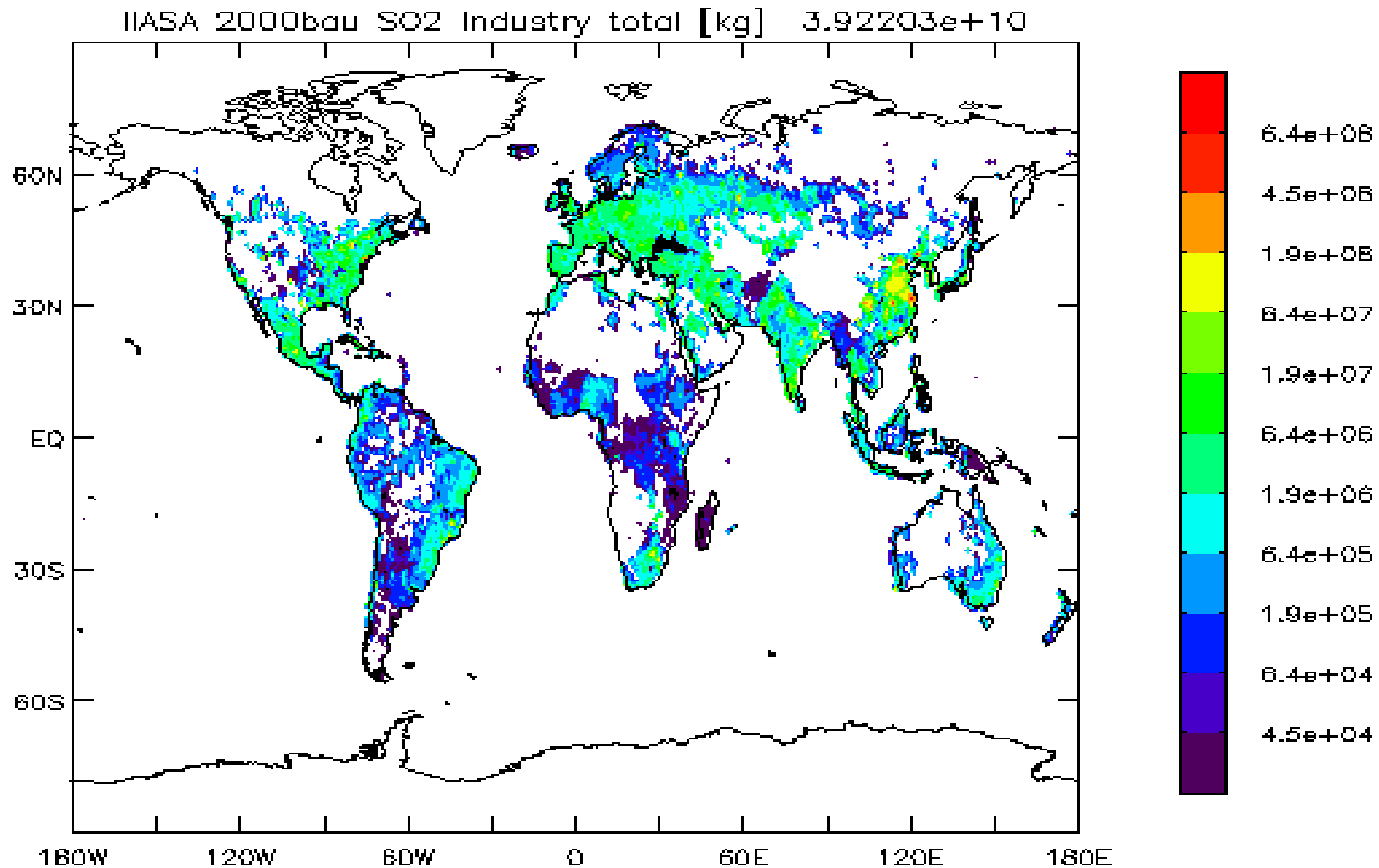
IIASA – domestic SO₂



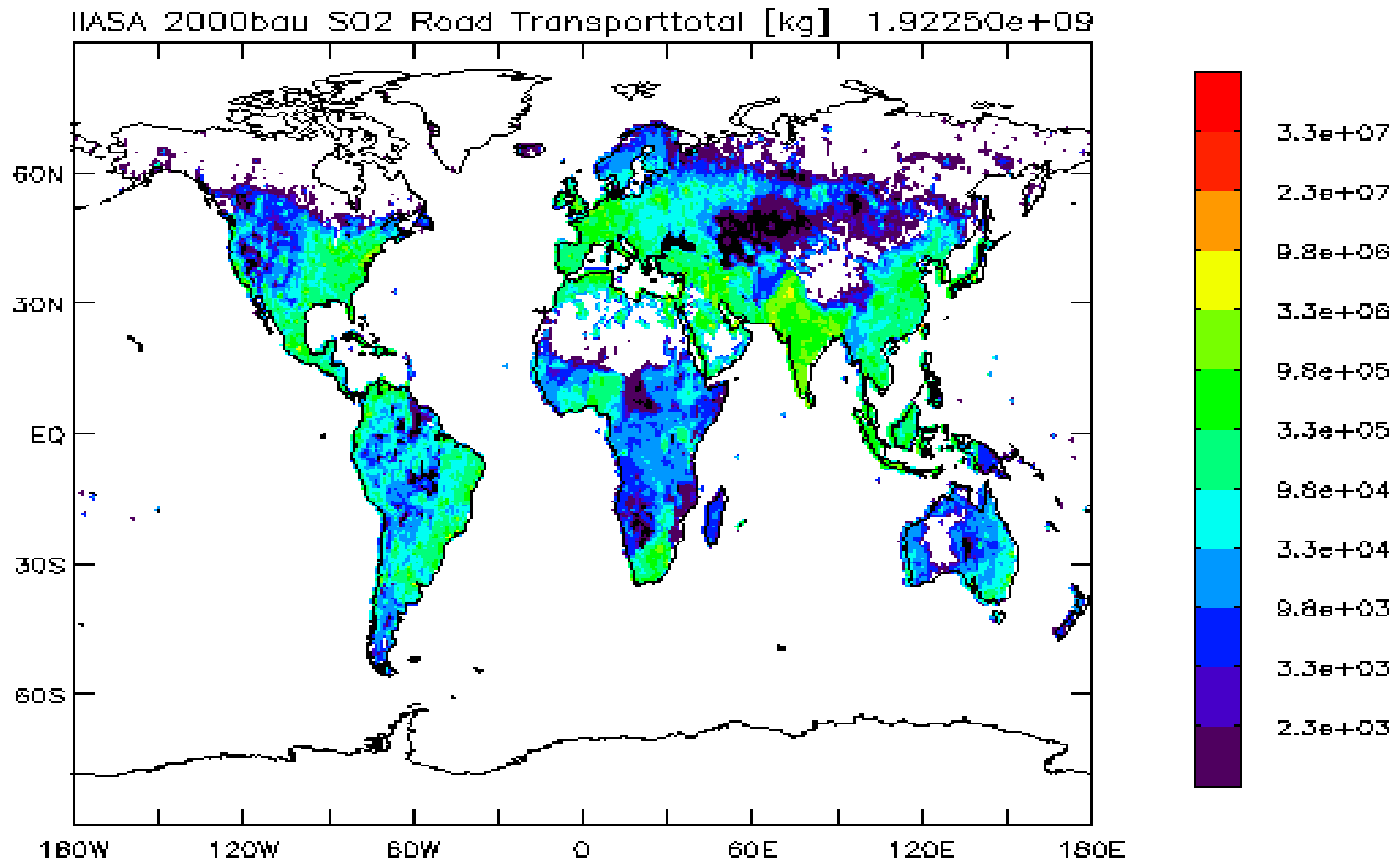
IIASA – off-road SO₂



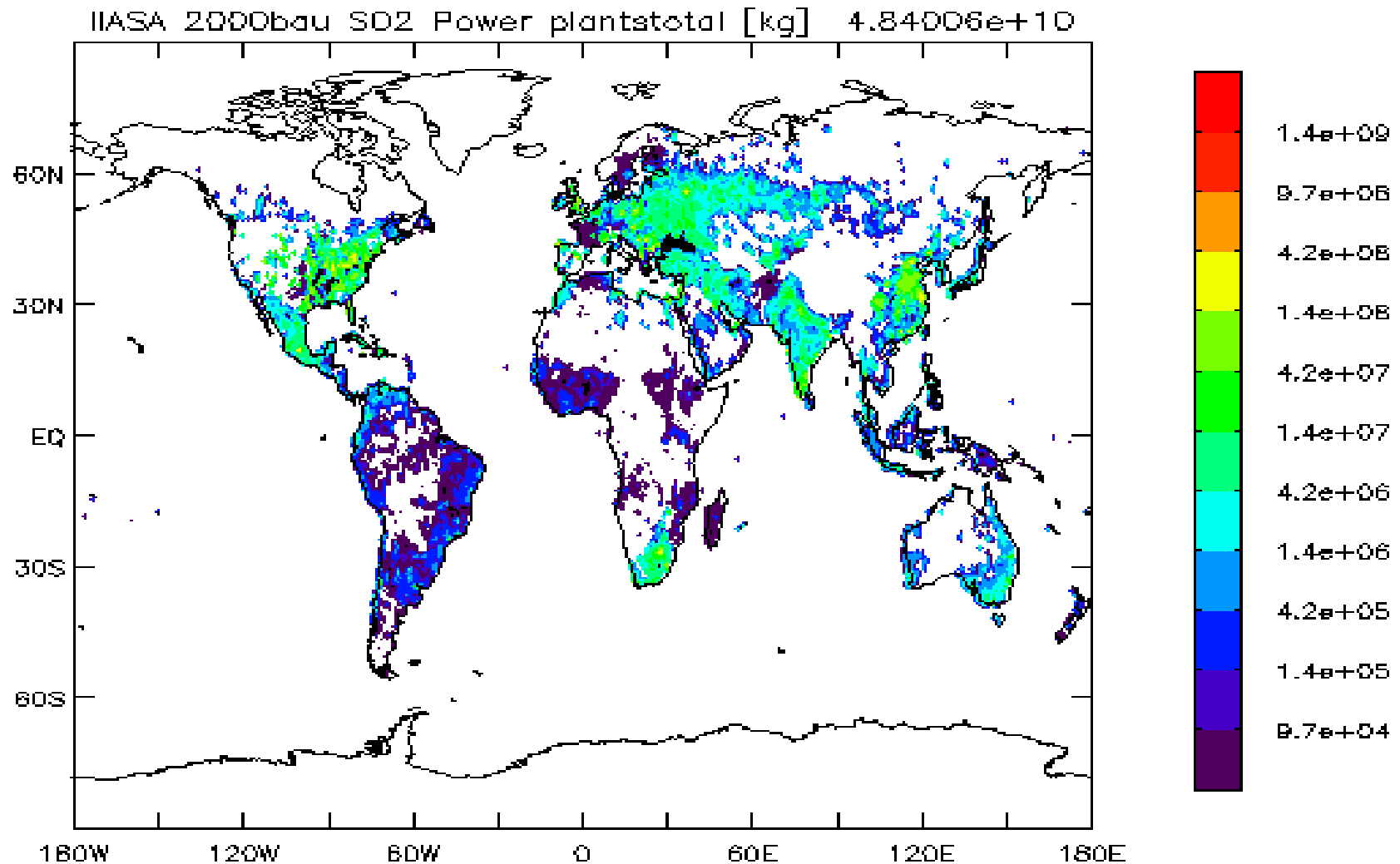
IIASA – industry SO₂



IIASA – road transport SO₂



IIASA – power plant SO₂



SO₂ -volcanic

SO₂ – volcanic emissions

<i>Tg /year</i>	SO₂	equiv. S	<i>injection height</i>
continuous	25.2	12.6	2/3 to 1/1 of volcano top *
explosive	4.0	2.0	.5 to 1.5km above top *
TOTAL	29.2	14.6	<i>* height boundaries provided – from Halmer et al JVGR 115, 2002</i>

- continuous erupting volcanos (Andres & Kasgnoc, JGR, 1998)
<http://www.geiacenter.org> (GEIA data [next slide] are too small
⇒ GEIA values multiplied by factor 1.5!)

- explosive erupting volcanos

<http://www.igac.noaa.gov/newsletter/22/sulfur.php>

more to - volcanic emissions

continuous partitioning ⇨

for more reading:

- Graf et al. : The contribution of Earth degassing to the atmospheric sulfur budget, Chem. Geology, 147, 1998.
- Textor et al.: Emissions of Chemical Compounds and Aerosols in the Atmosphere, Chapter 7, 2003.
- Halmer et al. : The annual volcanic gas input into the (upper) atmosphere: a global data set for the past 100 years, J. Volc. Geoth. Res., 115, 2002.

<i>GEIA contin. emissions</i>	<i>Tg/year</i>
SO ₂	6.7
- degassing	4.7
- explosive	2.0
H ₂ S	2.6
CS ₂	0.25
OCS	0.16
SO ₄	0.15
part S	0.081
other S	0.54
GEIA total S	10.4
recommended S (1.5*GEIA S)	12.6

SOA

SOA - secondary organics

organic particles from the gas phase

- a fixed fraction of 15% of natural terpene emission form SOA
 - SOA production is more complicated
 - emission estim. between 10 and 60Tg/year
- 19.11 Tg /year POM

SOA is formed on time scales of a few hours

SOA emissions condense on existing pre-existing aerosol

Time resolution is 12 months

Dust

Mineral Dust

- global 1*1degree *daily* emission data
- derive emission fluxes from log-normal size-distribution parameters (fields provided in monthly netcdf-files in the “/Dust_ncf” sub-directory)
 - assume a dust density of 2.5g/cm³
- contributions from two size modes

based on year 2000 emissions by Paul Ginoux pag@gfdl.noaa.gov

Ginoux et al., JGR 102 3819-3830, 2001

Ginoux et al., Environ.M&S, 2004

Dust - Size Modes

- **Accumulation mode** *(0.1 to 1 μm sizes)*
 - Concentration /per grid-box * *(mode2_number)*
 - Mode radius (for number) *(mode2_radius)*
 - Standard deviation: 1.59 *(constant distribution width)*
- **Coarse mode** *(1 to 6 μm sizes)*
 - Concentration /per grid-box * *(mode3_number)*
 - Mode radius (for number) *(mode3_radius)*
 - Standard deviation: 2.00 *(constant distribution width)*
 - *conversion from “/gridbox” to “/m2” provided (gridbox_area)*

NOTE: for particular size-bins an idl-routine ‘*binflux.pro*’ (in “/help_ncf”) is provided, which determines the emission flux (from both modes) for any given size-interval

for interpolation help contact kinne@dkrz.de

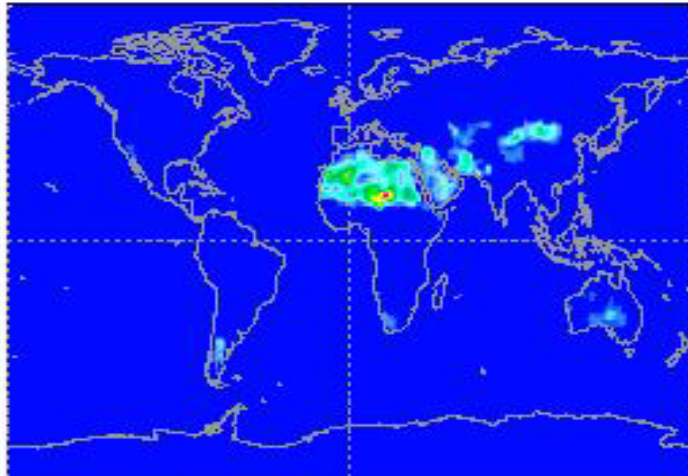
Dust - yearly average mass-flux

GINOUX

year 2000 - yearly total

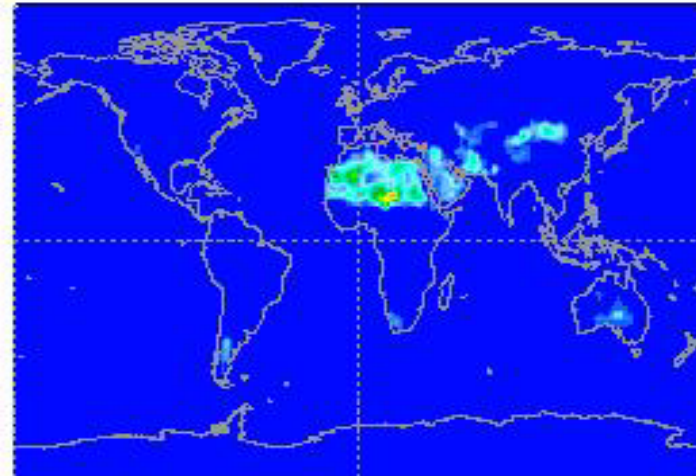
tot

$1.7e+12$



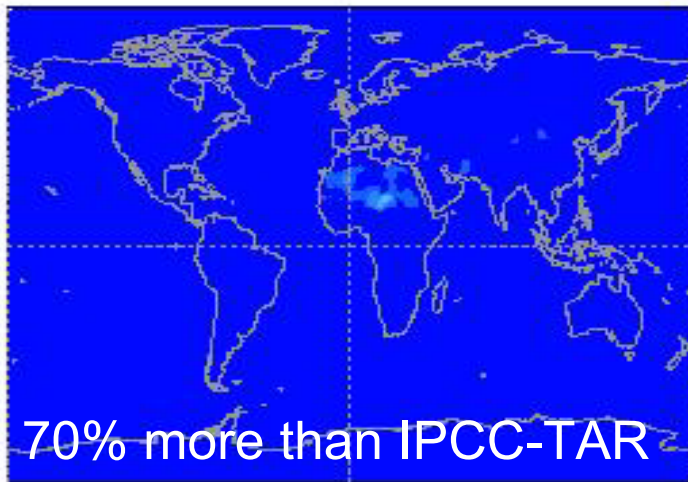
coa

$1.5e+12$



acc

$1.6e+11$



11% of mass flux is in the accumulation mode (acc)

89% of the mass flux is in the coarse mode (coa)

0.0e+00

dust mass

$4.9e+09$ kg/1d-grid



Sea Salt

Sea-Salt

- **global 1*1degree daily emission data**
- **derive emission fluxes from log-normal size-distribution parameters** (fields provided in monthly netcdf-files in the “/seasalt_ncf” sub-directory)
 - **assume a dry sea-salt density of 2.2g/cm³**
- **contributions from three size modes**

based on year 2000 emissions by Sunling.Gong@ec.gc.ca
(here only sizes smaller than 20 μ m diameter are considered)

Gong et.al. JGR, 107, 2002, Gong and Barrie, JGR, 108, 2003,
Gong Glo.Bio.Cycles, 17, 2003

Sea-Salt Size Modes

- **Aitken mode** *(sizes smaller than 0.1 μ m)*
 - Concentration /per grid-box * *(mode1_number)*
 - Mode radius (for number) *(mode1_radius)*
 - Standard deviation: 1.59 *(distribution width)*
- **Accumulation mode** *(0.1 to 1 μ m sizes)*
 - Concentration /per grid-box * *(mode2_number)*
 - Mode radius (for number) *(mode2_radius)*
 - Standard deviation: 1.59 *(distribution width)*
- **Coarse mode** *(1 to 20 μ m sizes)*
 - Concentration /per grid-box * *(mode3_number)*
 - Mode radius (for number) *(mode3_radius)*
 - Standard deviation: 2.00 *(distribution width)*

“/gridbox” to “/m2” conversion data provided

‘binflux.pro’ calculates fluxes for any size bin (“/help_ncf”)

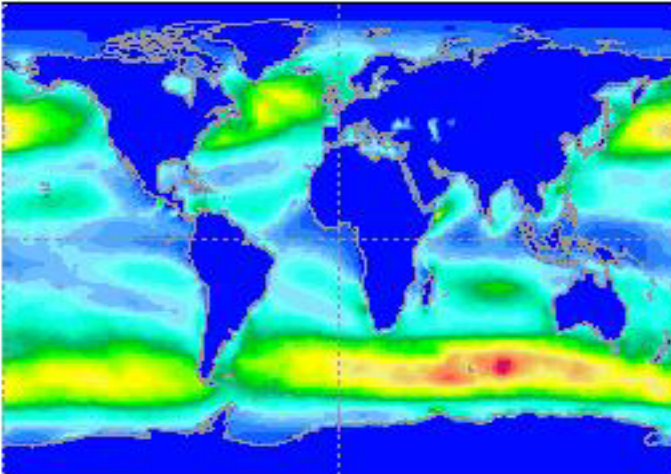
Seasalt – yearly average mass-flux

GONG

year 2000 - yearly total

tot

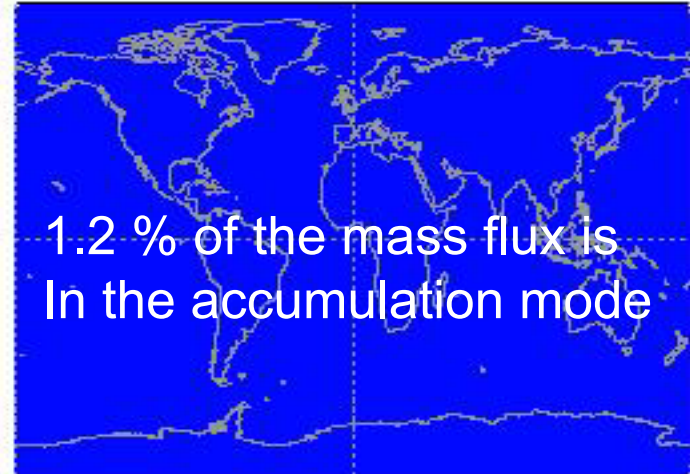
$8.3e+12$



1.2 % of the mass flux is
In the accumulation mode

acc

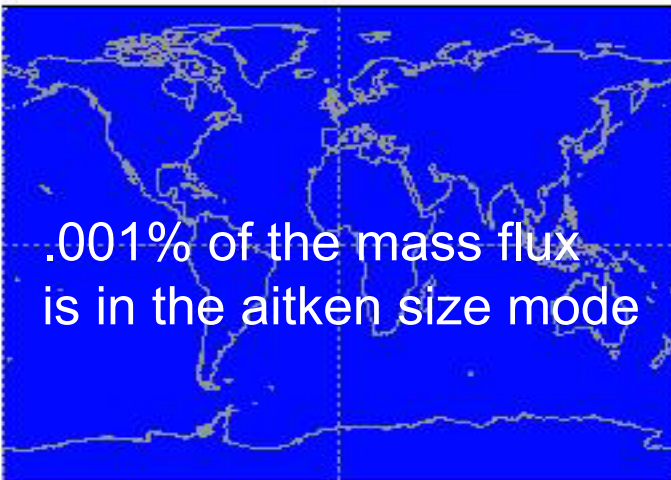
$1.0e+11$



ait

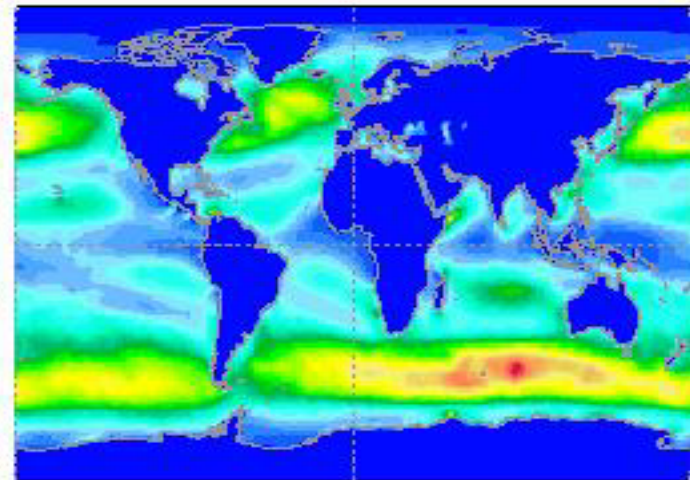
$7.7e+07$

.001% of the mass flux
is in the aitken size mode



coa

$8.2e+12$



0.0e+00

salt mass

$7.7e+08\text{kg/1d-grid}$

DMS

DMS

- **global 1*1degree daily emission data**
(data in monthly netcdf-files in the “/DMS_ncf” sub-directory)
- **conservative land screening to avoid high DMS concentrations over coastal land**
- **in units of kg Sulfur /gridbox. Annual total 18.3 Tg S.**
(“/gridbox” to “/m2” conversion data in netcdf-files)

based on LMDZ-GCM simulations by Olivier Boucher

oceanic: Kettle and Andreae, JGR, 105, 2000

surface (10m winds): Nightingale et al., Glo.Bio.Cycles, 14, 2000

biogenic: Pham et al. JGR, 100, 1995

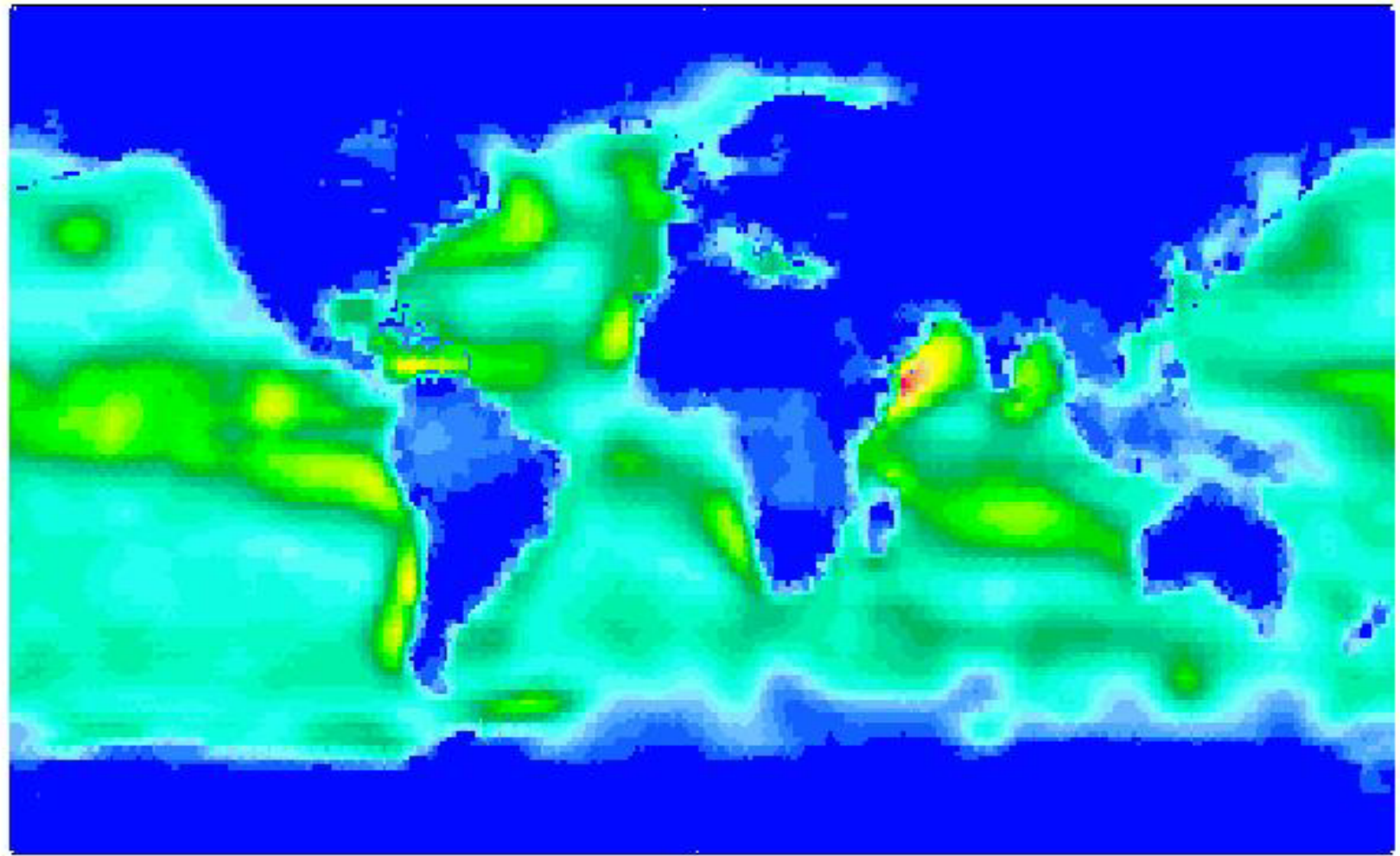
DMS – yearly average mass flux

BOUCHER

year 2000 - yearly total

tot

2.1e+10



0.0e+00

dms - S mass

2.1e+06kgS/1 d-grid

EMISSION HEIGHTS

Emission Heights (1)

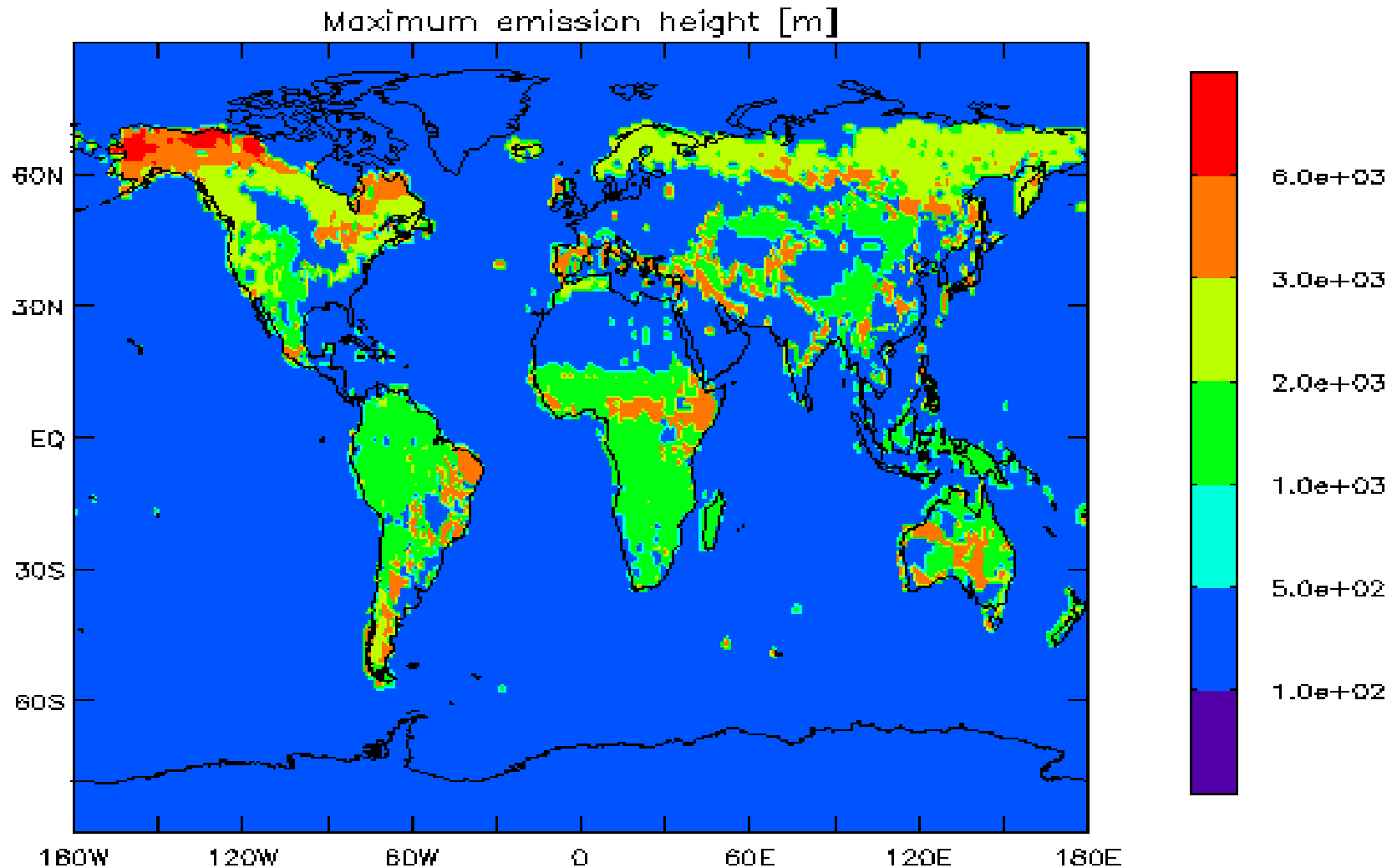
- **Dust** lowest model layer < 100 m
- **Seasalt** lowest model layer < 100 m
- **DMS** lowest model layer < 100 m
- **SOA** lowest model layer < 100 m
- **POM/BC biofuel** lowest model layer < 100 m
- **POM/BC fossil fuel** lowest model layer < 100 m
- **Biomass burning (OC/BC/SO₂)** ECO-system dependent
 - **0-.1km / .1-.5km / .5-1km / 1-2km / 2-3km / 3-6km**
(data provided via D. Lavoue, personal communication, 2003)

Emission Heights (2)

- **SO₂**

- **domestic** < 100m
- **road /off-road** < 100m
- **industry** 100 - 300m
- **shipping** < 100 m
- **power-plants** 100 - 300m
- **volcanic** (**location and altitude are provided*)
 - **continuous** 2/3 to 1/1 of volcano top *
 - **explosive** .5 to 1.5km above top *

maximum emission height for biomass burning



ACCESS

download via the web

ftp://ftp.ei.jrc.it *then* **cd pub/Aerocom**

– **subdirectories** (*you should find*)

- **dust_ncf** - dust data
- **seasalt_ncf** - seasalt data
- **DMS_ncf** - DMS data
- **other_ncf**

- **BC:** -biofuel, -fossil fuel, -wildfire (GFED – 6 altitude regimes)
- **POM:** -biofuel, -fossil fue, -wildfire (GFED – 6 altitude regim.)
- **SO2:** -domestic, -industry, -powerplants, -offroad, -road, -international shipping, -wildfire (GFED – 6 altitude regimes)
- **volcanic:** -continuous, -explosive

File-formats

_ncf : netcdf
_ascii: ascii
_hdf: hdf

an overview is provided in a power-point file (**Aerocom....ppt**)

data will be made available on CD / DVD (*contact kinne@dkrz.de*)

... thanks all authors for their work

**We plan to provide a more extensive description
of the selected data-sets
in a short 'AeroCom – emission' document**

*We extensively checked, tested and compared the data
and we did our best to make it fool-proof...*

*... but given the amount of data, we still expect errors,
omissions and ambiguities.*

Please, help identify and remove mistakes!