AeroCom Emissions

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aerosol emission datasets

recommendations for the year 2000
recommendations for the year 1750

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Goal

- **to provide recommended data-sets for anthropogenic aerosol and precursor gases for year 2000 simulations and pre-industrial (year 1750) simulations**
  - **including recommendations for *size-distribution* of primary emissions**
  - **including recommendations for emission *altitude***

Emission data-sets

- **large scale biomass burning POM / BC / SO2 emissions *(altitude resolved)***
- **fossil fuel / biofuel related POM / BC emissions**
- **SO2, including *(altitude res.)* volcanic emissions**
- **SEA-SALT emissions *(size resolved)***
- **DUST emissions *(size resolved)***
- **DMS *(sulfur)* emissions**
- **SOA 'effective' emissions**

POM Particulate Organic Carbon (1.4 OC [Org.Carbon] = 1POM)
BC Black Carbon (or EC Elementary Carbon)
DMS DiMethyl Sulfide
SOA Secondary Organic Carbon

Spatial Resolution

- 1 degree latitude * 1 degree longitude
  - averages are given for each grid-box

Units

- kg /(time-period*) /(1x1 gridbox)

  ** yearly, monthly or daily*

  - for daily sea-salt and dust data log-normal distribution parameters are provided from which the emission flux can be calculated

Temporal resolution

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

higher temporal resolution data will be adopted only in sensitivity experiments

Emission Heights

- **all emissions < 100m** ***(in lowest modeling layer)***

  except

  - **biomass burning (POM / BC / SO2)**

    ECO-system dependent – six altitude regimes:

    - **0-.1km /.1-.5km /.5-1km /1-2km / 2-3km /3-6km**

  - **SO2 industry** **100 - 300m**
  - **SO2 power-plants** **100 - 300m**
  - **SO2 volcanic** ***(* location and altitude are provided)***
    - **Continuous:** **2/3 to 1/1 of volcano top** *
    - **Explosive:** **.5 to 1.5 km above volcano top** *

… other data

- **for other data** *(e.g. for 'full chemistry simulations')* **it is recommended to use**
- **EDGAR 3.2, 1995** ***(NOx / 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 (dust_small_ncf: 50% smaller dust)
seasalt_ncf
DMS_ncf

other_ncf_2000:
BC: bio-, fossil fuel, wildfire
POM: bio-, fossil fuel, wildfire
SO2: domestic, industry, powerplants, off-road, road, -intern.shipping, wildfire, volcanic: continuous and explosive
SOA: secondary org. carbon

other_ncf_1750:
BC: biofuel, wildfire
POM: biofuel, wildfire
SO2: domestic, wildfire, volcanic (continous and explosive
SOA: sec. org. carbon

an overview is provided in a power-point file (AERO*YRMO*.PPT)

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

Details and Plots

Overview

- **BIOMASS BURNING**
- **BIO FUEL / FOSSIL FUEL**
- **SO_2**
- **SO_2 -** ***volcanic contributions***
- **SOA**
- **DUST**
- **SEASALT**
- **DMS**
- **EMISSION HEIGHTS**
- **DATA ACCESS**

Biomass Burning

Large scale biomass burning

POM (OC) / BC (EC) / SO_2 YEAR 2000

- **Global emissions**

(incl. large agricultural fires):

Tg/year	POM	BC	SO_2
	34.7	3.06	4.11

based on **GFED** 2000

van der Werf, Gl.Ch.Bio, 2003, "Carbon emissions from fires in tropical ecosystems"

* note: in AEROCOM: we use Particulate Organic Matter (POM) rather than organic carbon (OC) - 34.7Tg POM correspond to 24.8Tg OC

http://www.gps.caltech.edu/~jimr/randerson.html

compare to:

T. Bond POM *34.6 Tg*, OC *25.05 Tg*, BC *3.32 Tg* 'open burning'

S. Generoso POM *29.3 Tg*, BC *3.33 Tg* *(ACP, 2003)*

EDGAR3.2 *(deforestion+savannah+mid-lat.burning)* SO_2 *2.7 Tg*

Large scale biomass burning

POM (OC) / BC (EC) / SO_2 YEAR 1750

- **Global emissions**

(incl. large agricultural fires)

Tg/year	POM	BC	SO2
	12.8	1.02	1.45

based on scaled GFED 1997-2002 average

- **use present day land cover (Olson)**
- **use 1750/1990 pop ratio (Hyde)**
- **double hi-lat forest emission (Brenkert)**
- **wet forest emission: scale by population**
- **grassland and agricultural fires:**

  0.4 +0.6*(population ratio)

* note: in AEROCOM: we use Particulate Organic Matter (POM) rather than organic carbon (OC): **12.8Tg POM** equals **9.15Tg OC**

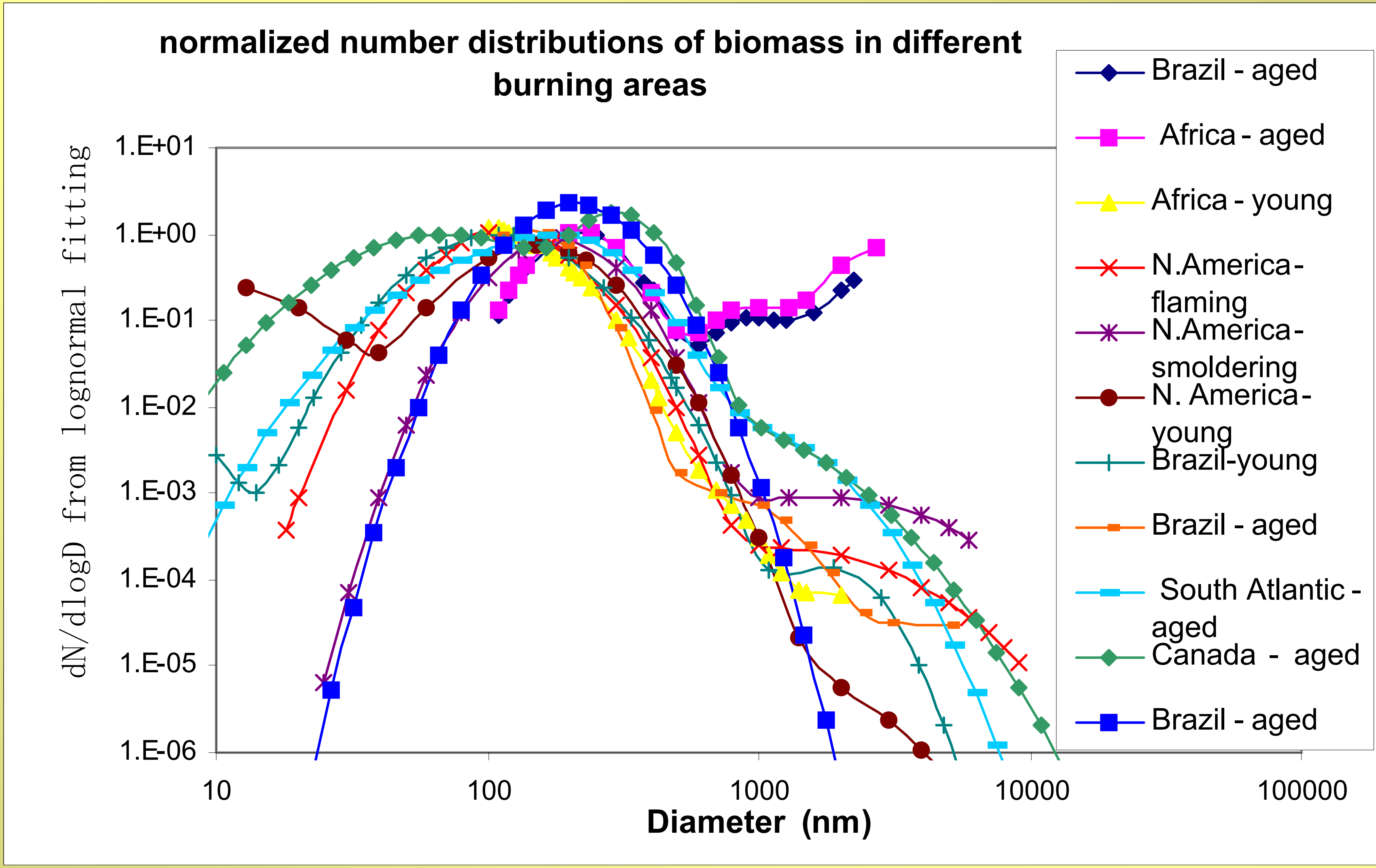
size recommendations
for primary SO4, OC and BC

- **particles size** ***(log normal size-distributions)***
  - **industrial** ***(fly ash)*** **(for power plants)** **(larger sizes)**
    - ***LN:*** **$r_{,mode}$ = .500μm , std.dev = 2.0** **($r_{,eff}$= 1.6μm)**
  - **biomass** **(for biomass and biofuel)**
    - ***LN:*** **$r_{,mode}$ = .040μm , std.dev. = 1.8** **($r_{,eff}$= 0.077μm)**

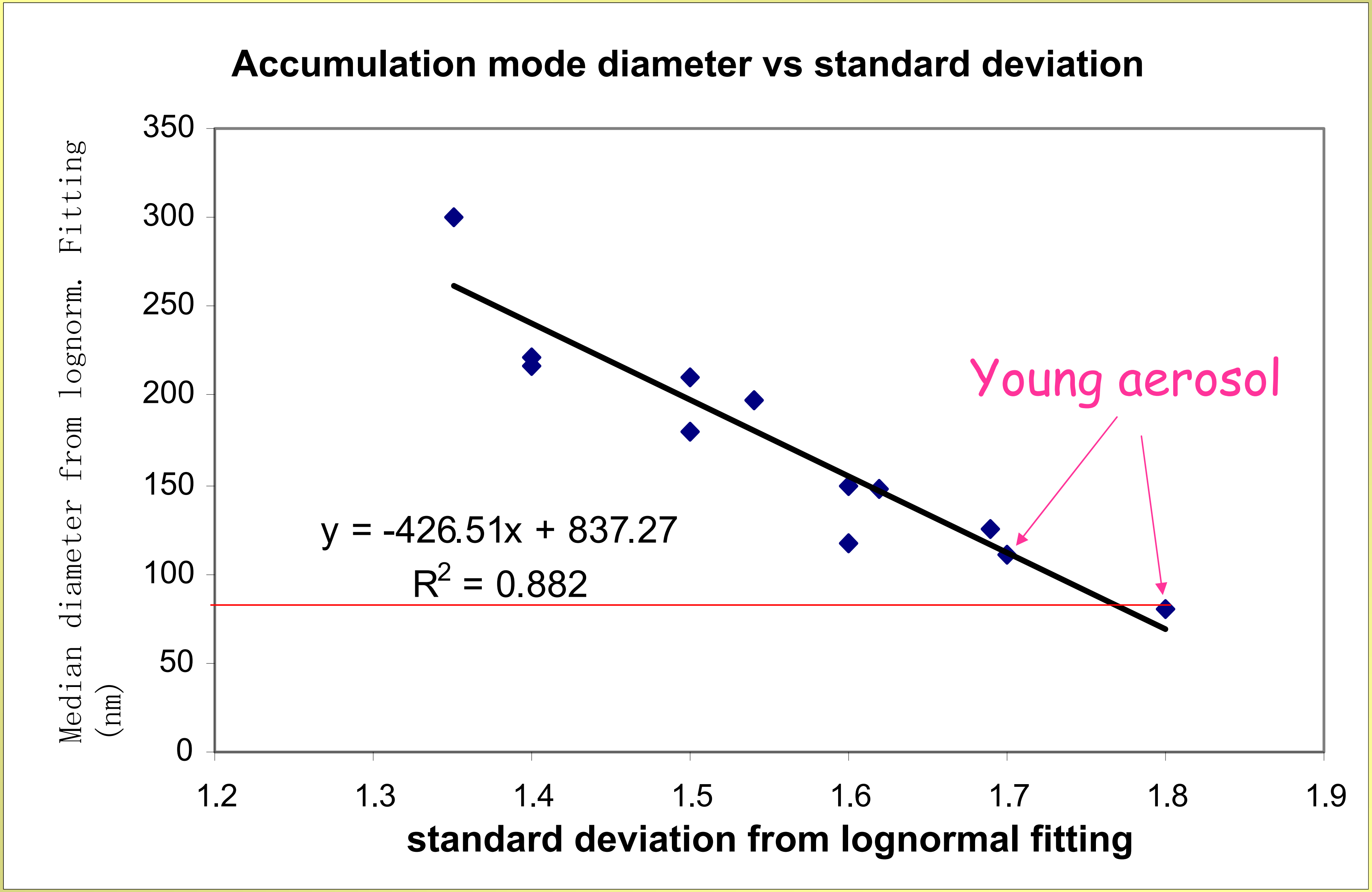
    (based on measurement close to biomass by Marelli, 2003)
  - **traffic** **(for fossil fuel)**
    - ***LN:*** **$r_{,mode}$ = .015 μm , std.dev. = 1.8** **($r_{,eff}$= 0.029 μm)**

    (based on kerbside [5 EU cities] by Putaud et al. 2003)

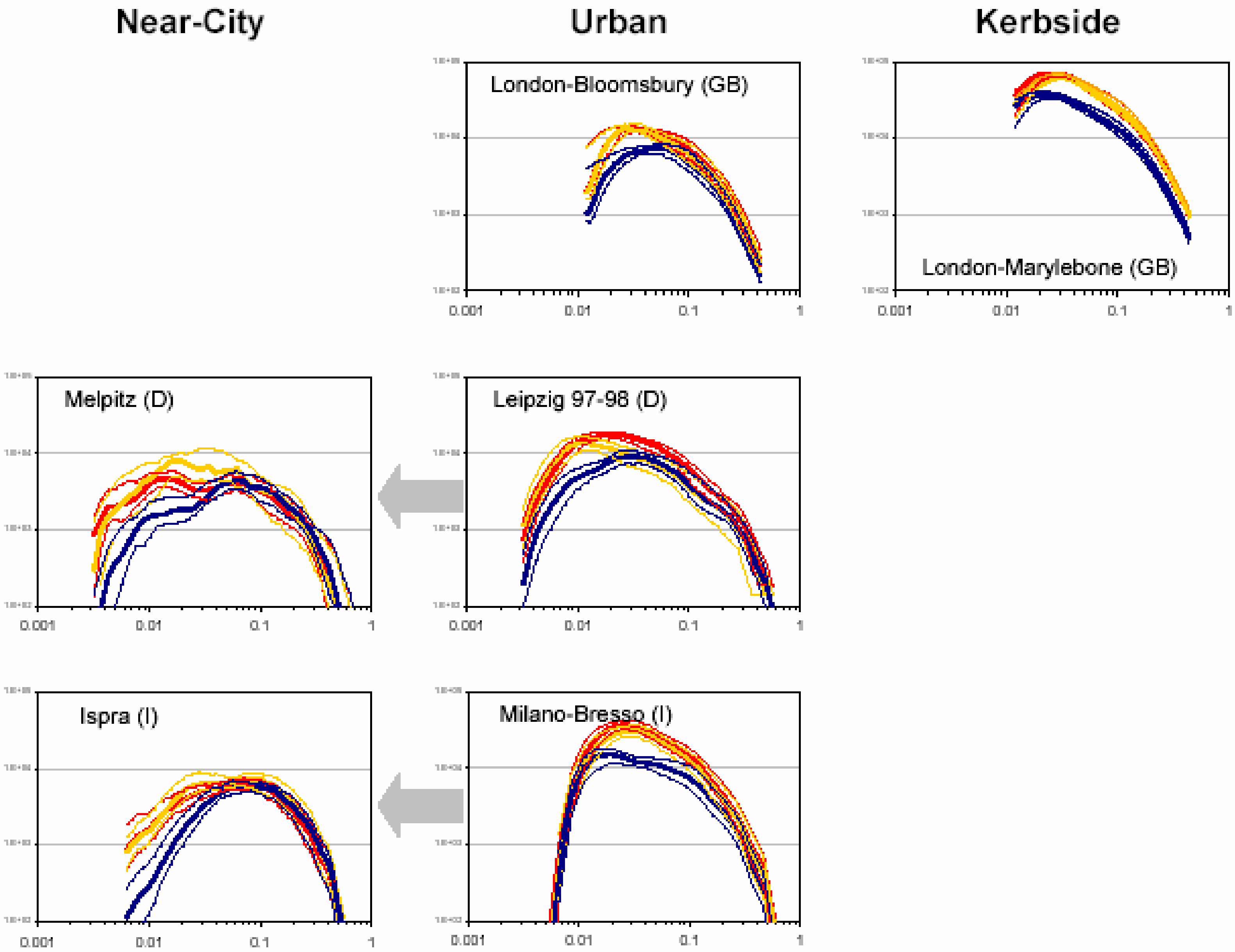
http://carbodat.ei.jrc.it/ccu/main.cfm



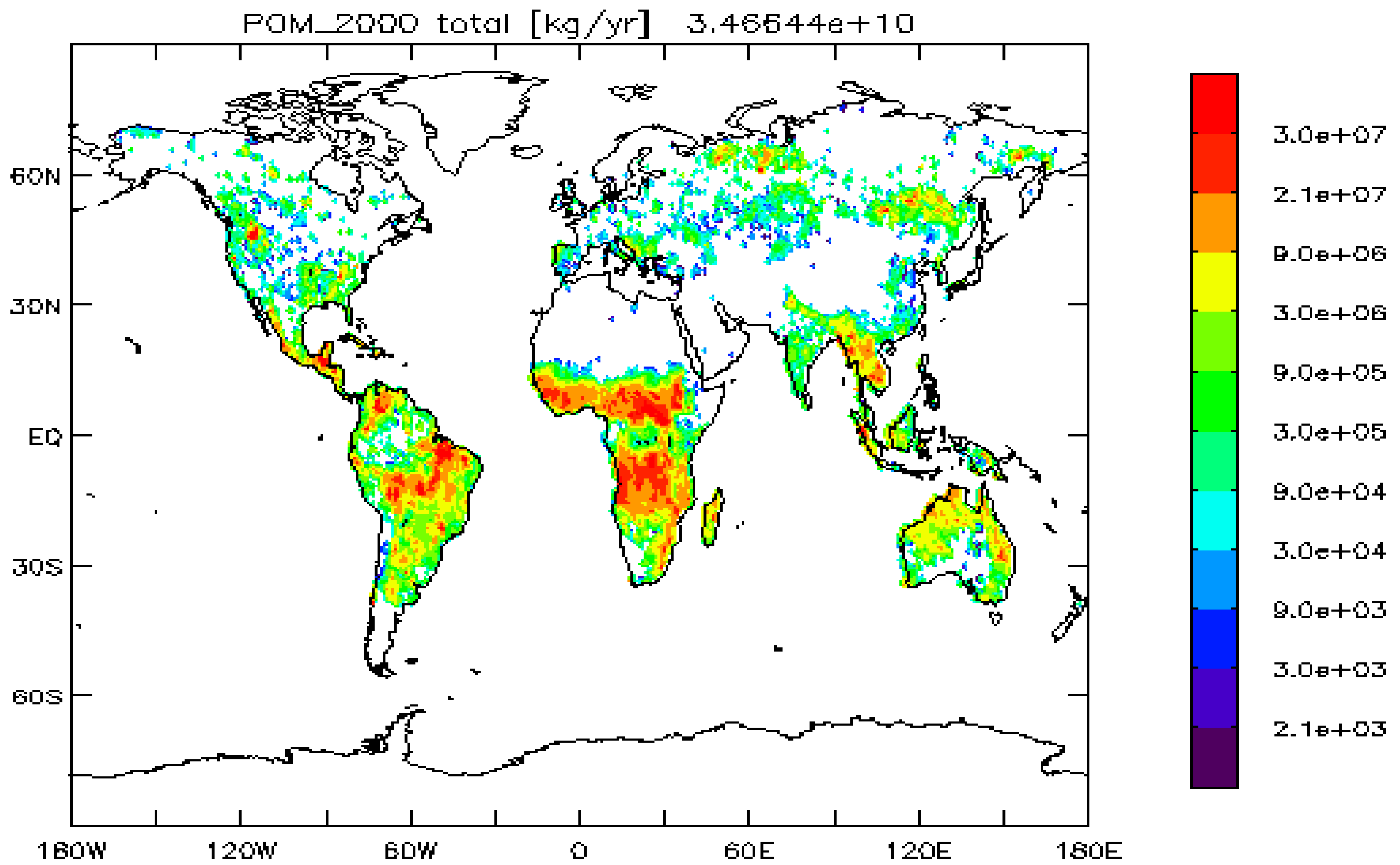
normalized number distributions of biomass in different burning areas
dN/dlogD from lognormal fitting
1.E+01
1.E+00
1.E-01
1.E-02
1.E-03
1.E-04
1.E-05
1.E-06
10
100
1000
10000
100000
Diameter (nm)
Brazil - aged
Africa - aged
Africa - young
N.America - flaming
N.America - smoldering
N. America - young
Brazil-young
Brazil - aged
South Atlantic - aged
Canada - aged
Brazil - aged


Accumulation mode diameter vs standard deviation
Median diameter from lognorm. Fitting (nm)
350
300
250
200
150
100
50
0
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
standard deviation from lognormal fitting
y = -426.51x + 837.27
R2 = 0.882
Young aerosol

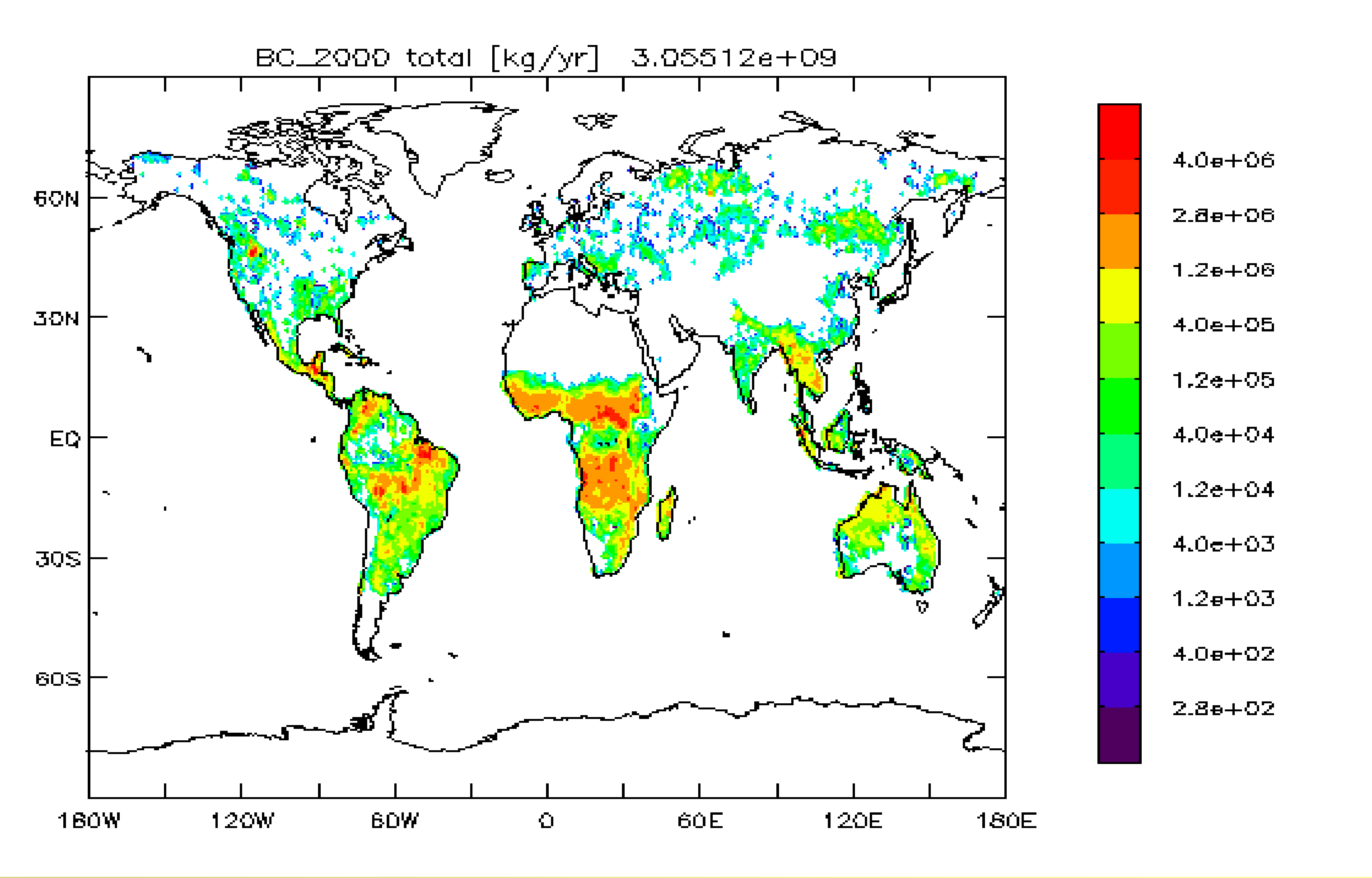
Putaud et al, Aerosol Phenomenology, 2003



GFED 2000 (1*1 resolution) 'POM'



GFED 2000 (1*1 resolution) 'BC (EC)'



Bio-Fuel / Fossil-Fuel

fossil (bio-)fuel related emissions

POM / OC / BC

YEAR 2000

- **based on SPEW**
  Tami Bond, JGR 2003
  "A technology based global inventory of black and organic carbon emissions from combustion"
  (base year: 1996)

- **based on GEFD**
  for large scale open fires (… see above)

Tg/year	POM	BC
fossil	**3.2**	**3.04**
biofuel	**9.1**	**1.63**
open fire	*34.7*	*3.32*
total	**47.0**	**8.0**

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

*** note: in AEROCOM: we use Particulate Organic Matter (POM) rather than organic carbon (OC):**
3.2Tg POM equals **2.4Tg OC** or
9.1Tg POM equals **6.5Tg OC**

fossil (bio-)fuel related emissions

POM / OC / BC

YEAR 1750

- **based on year 1890 CO biofuel inventory** (J. Aardenne)
- **emission factors: BC .59, POM: 5.8, SO_2: .27** (A. Andreae**)**
- **time-scaled with pop number ratio year1750 / year1890** (Hyde)
- **factor 2 scaling north of 45 degree N latitude**

Tg/year	POM	BC
biofuel	2.49	0.26
open fire	12.8	1.02
total	15.3	1.3

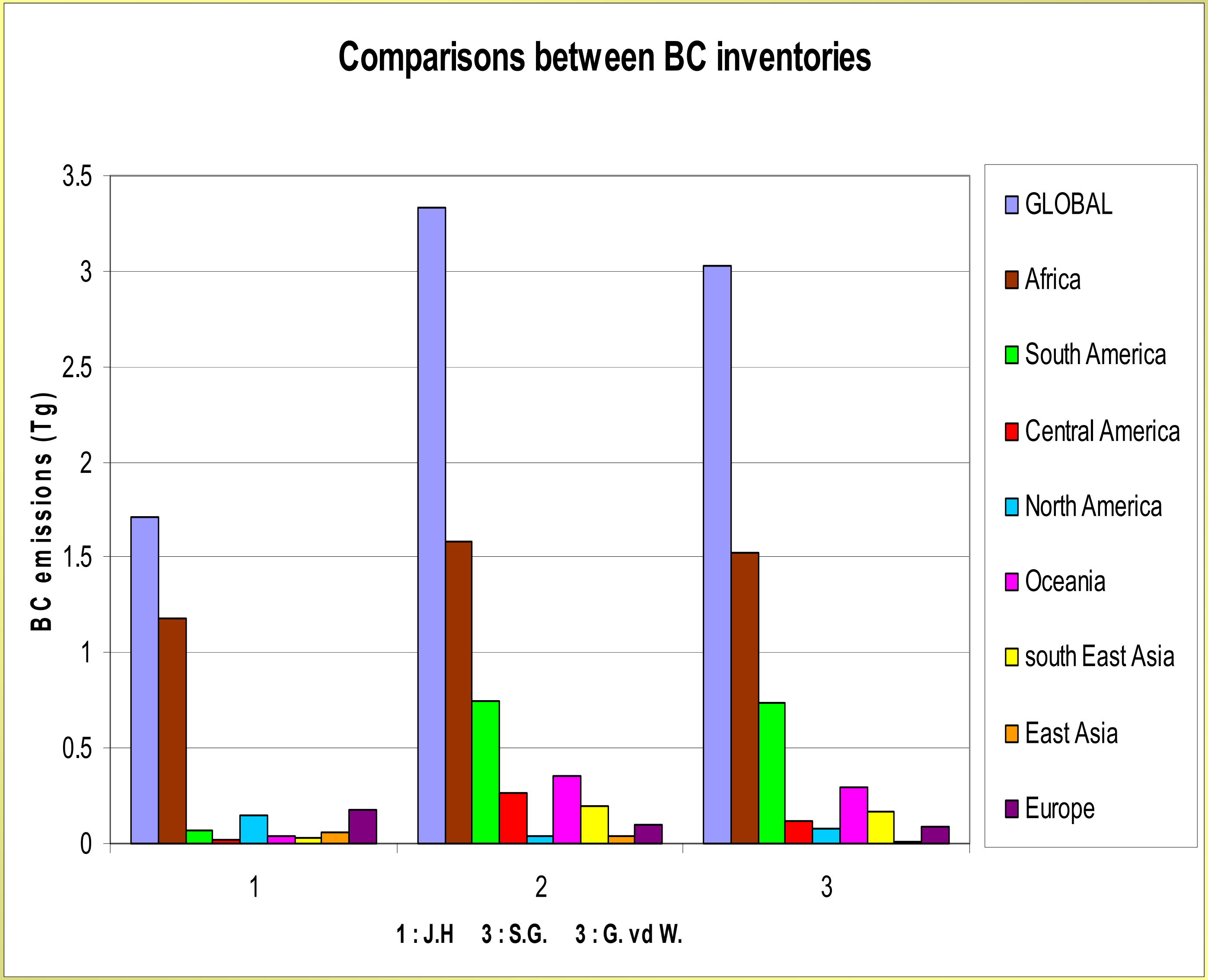
*** note: in AEROCOM: we use Particulate Organic Matter (POM) rather than organic carbon (OC):**
3.2Tg POM equals 2.4Tg OC or
12.8Tg POM equals 9.1Tg OC

BC 2000 Regional Comparison

Tg /year	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

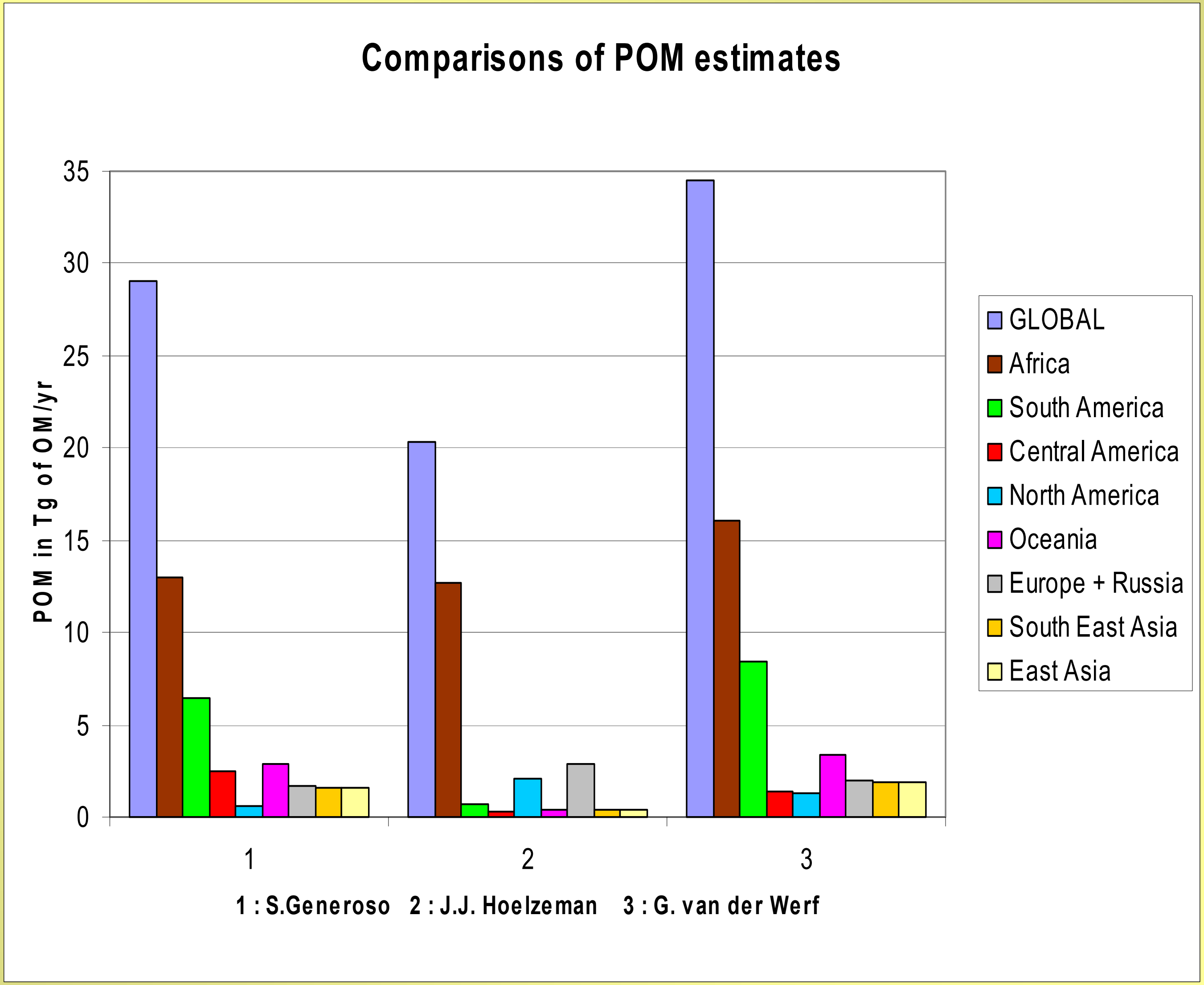
BC 2000 inventory comparisons

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

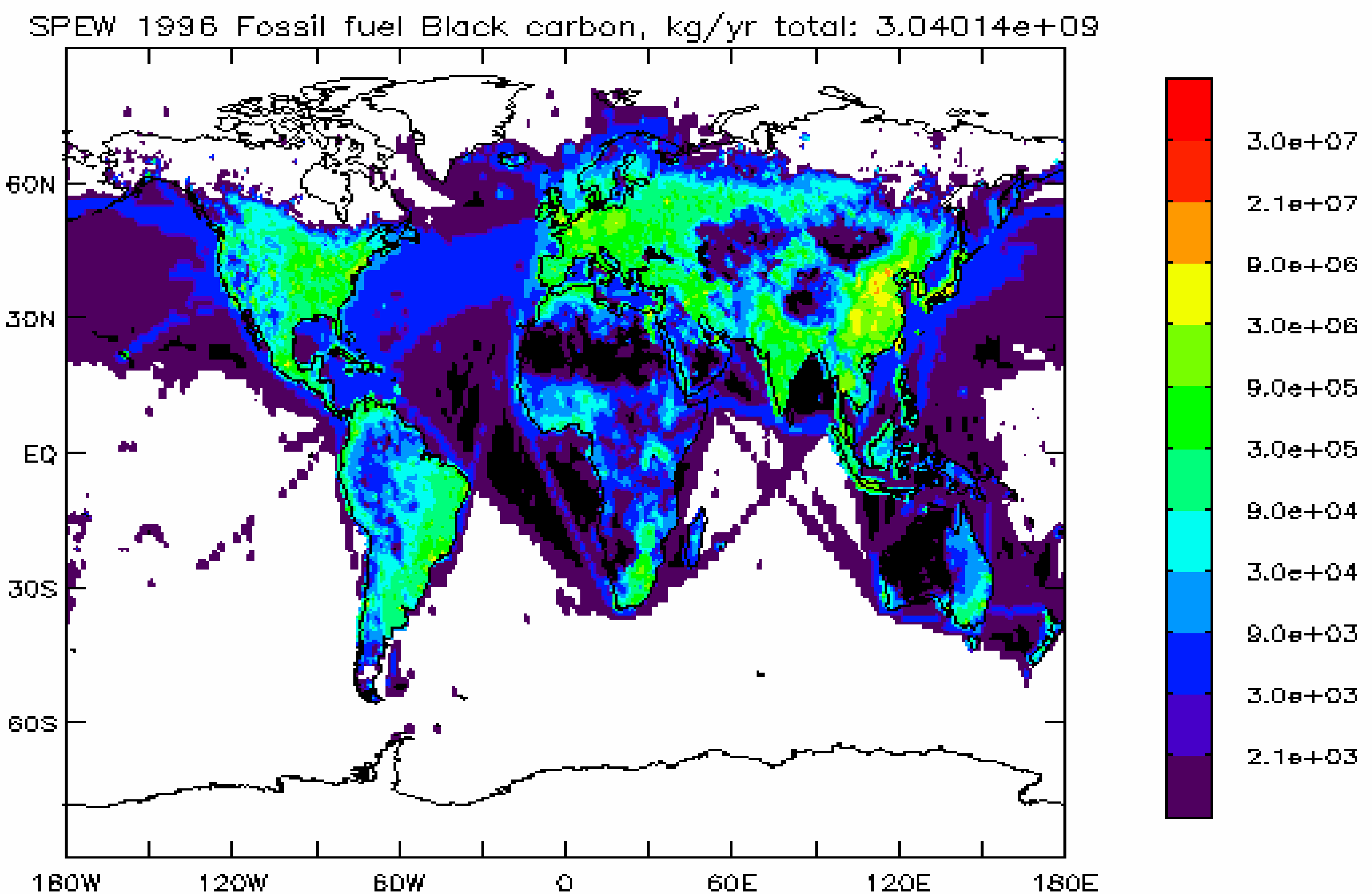


POM 2000 inventory comparisons

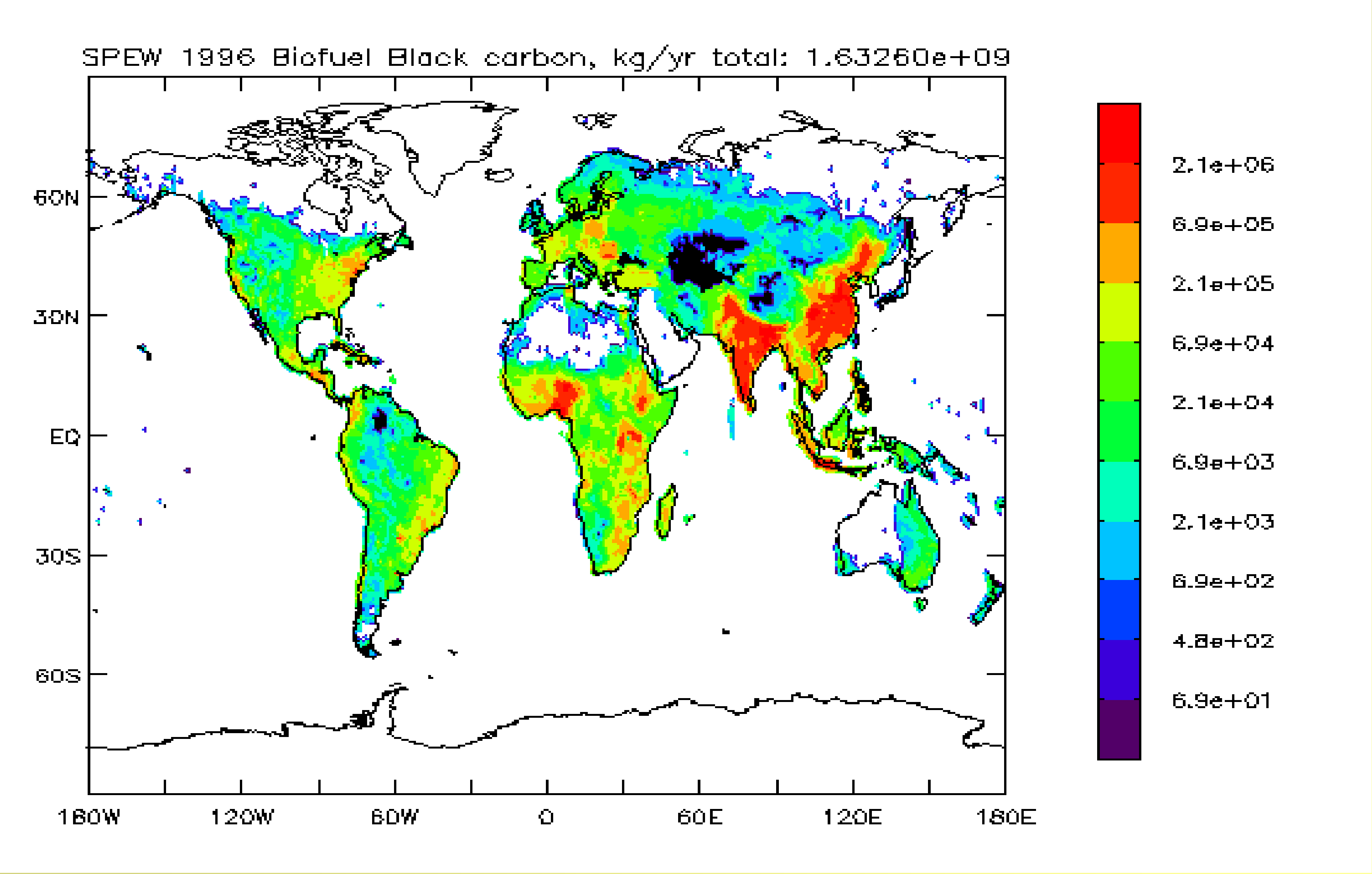
- **# 1**
  LSCE
  Generoso
- **# 2**
  GWEM
  Hoelzemann
- **# 3**
  GFED 2000
  van der Werf



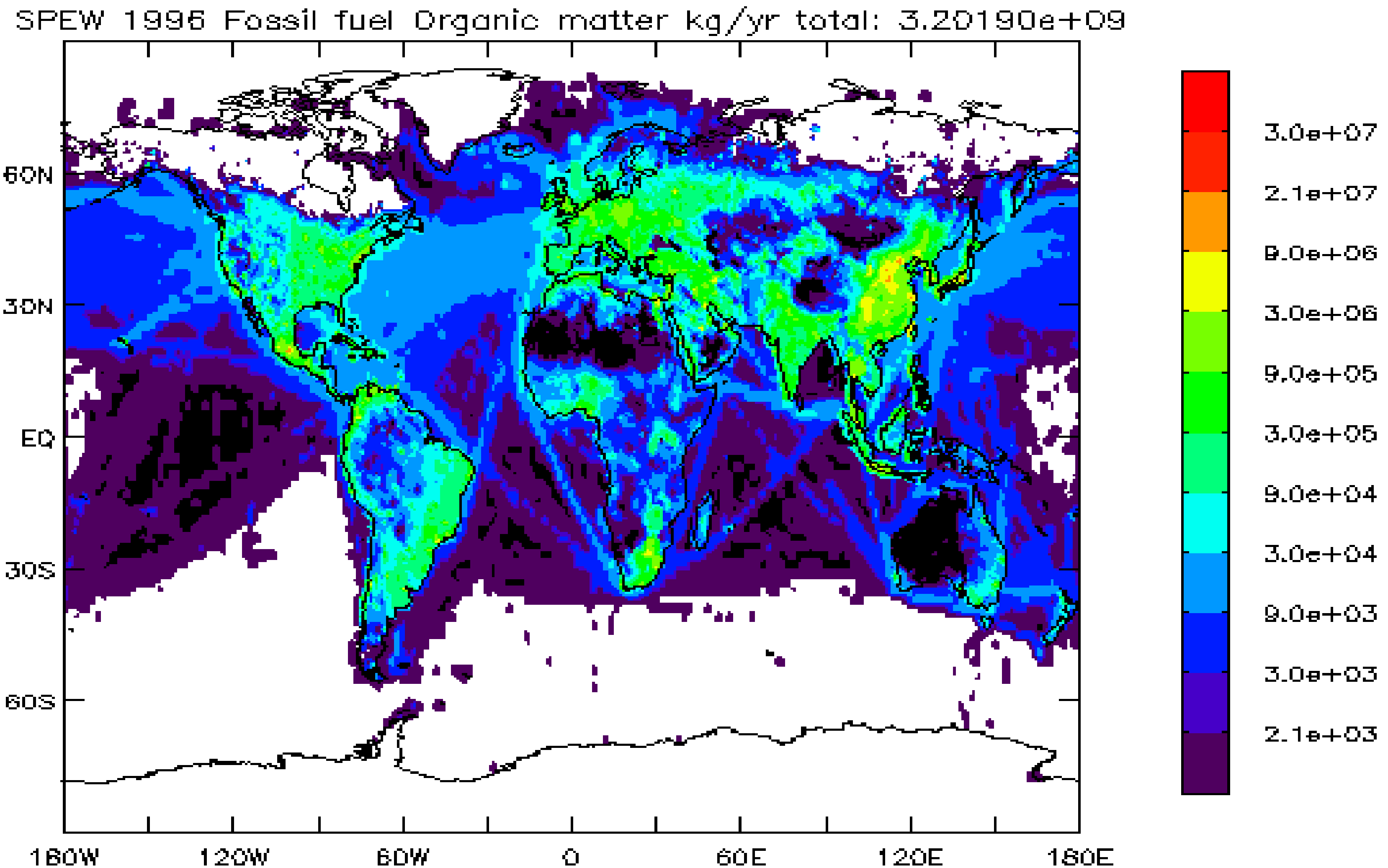
SPEW – BC 2000 fossil fuel emissions



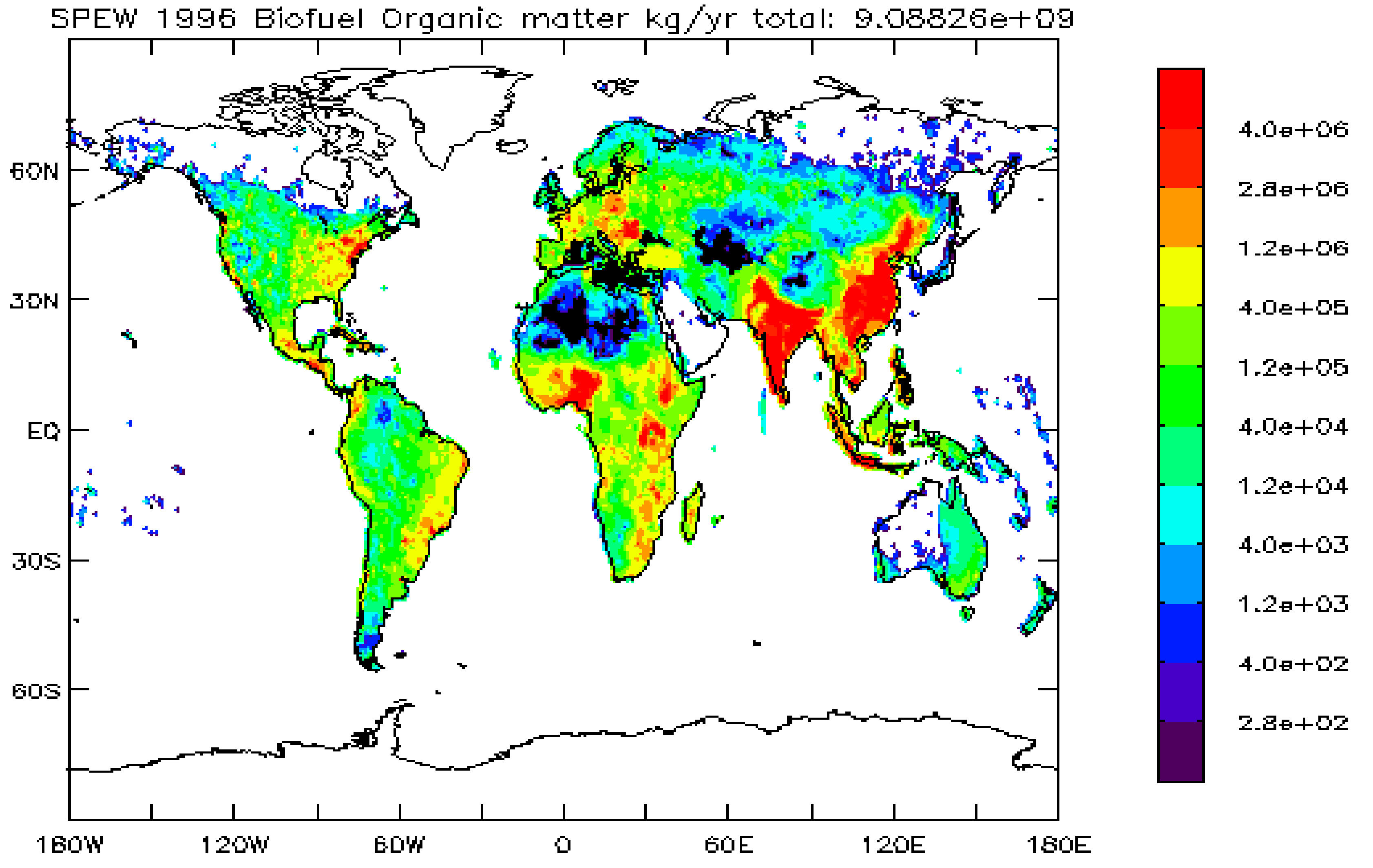
SPEW – BC 2000 bio fuel emissions



SPEW – POM 2000 fossil fuel emissions



SPEW – POM 2000 bio fuel emissions



SO2

SO_2 - emissions

YEAR 2000

- **global emissions**

  from Janusz Cofala (IIASA)
  "Country based SO_2 emissions for the year 2000 using RAINS, gridded according to EDGAR 3.2 (1995) distributions"

- **ship emissions**

  assume a 1.5% /year increase since 1995

*** a flat percentage of 2.5% of all SO_2 is emitted as primary SO_4**

Tg/year	SO_2	S
wildfire GFED	*4.1*	*2.0*
roads	1.9	1.0
off-roads	1.6	0.8
domestic	9.5	4.6
industry	39.3	19.6
shipping	7.8	3.9
powerplant	48.4	24.2
volc.expl.	4.0	2.0
volc.cont.	25.2	12.6
total	**141.8**	**70.9**
as SO_2	*138.3*	*69.1*
*as SO_4**	*3.5*	*1.8*

SO_2 - emissions

YEAR 1750

- **reduced wildfire emissions** (see biofuel section)
- **volcanic emissions as for the year 2000** (detailed description below)

Tg/year	SO_2	S
wildfire	1.5	0.7
biofuel	0.1	0.1
volc.expl	4.0	2.0
volc.cont	25.2	12.6
total	**30.8**	**15.4**
as SO_2	*30.0*	*15.0*
*as SO_4**	*.8*	*.4*

*** a flat percentage of 2.5% of all SO_2 is emitted as primary SO_4**

(compare to 1-5% in literature)

SO2 – yr 2000 emissions by type

Tg /year	SO2	S
power-plants	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	7.8	3.86
volcanos	*29.2*	*14.6*
TOTAL	141.8	70.9

Tg /year	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

(this is in good agreement to EMEP country emissions)

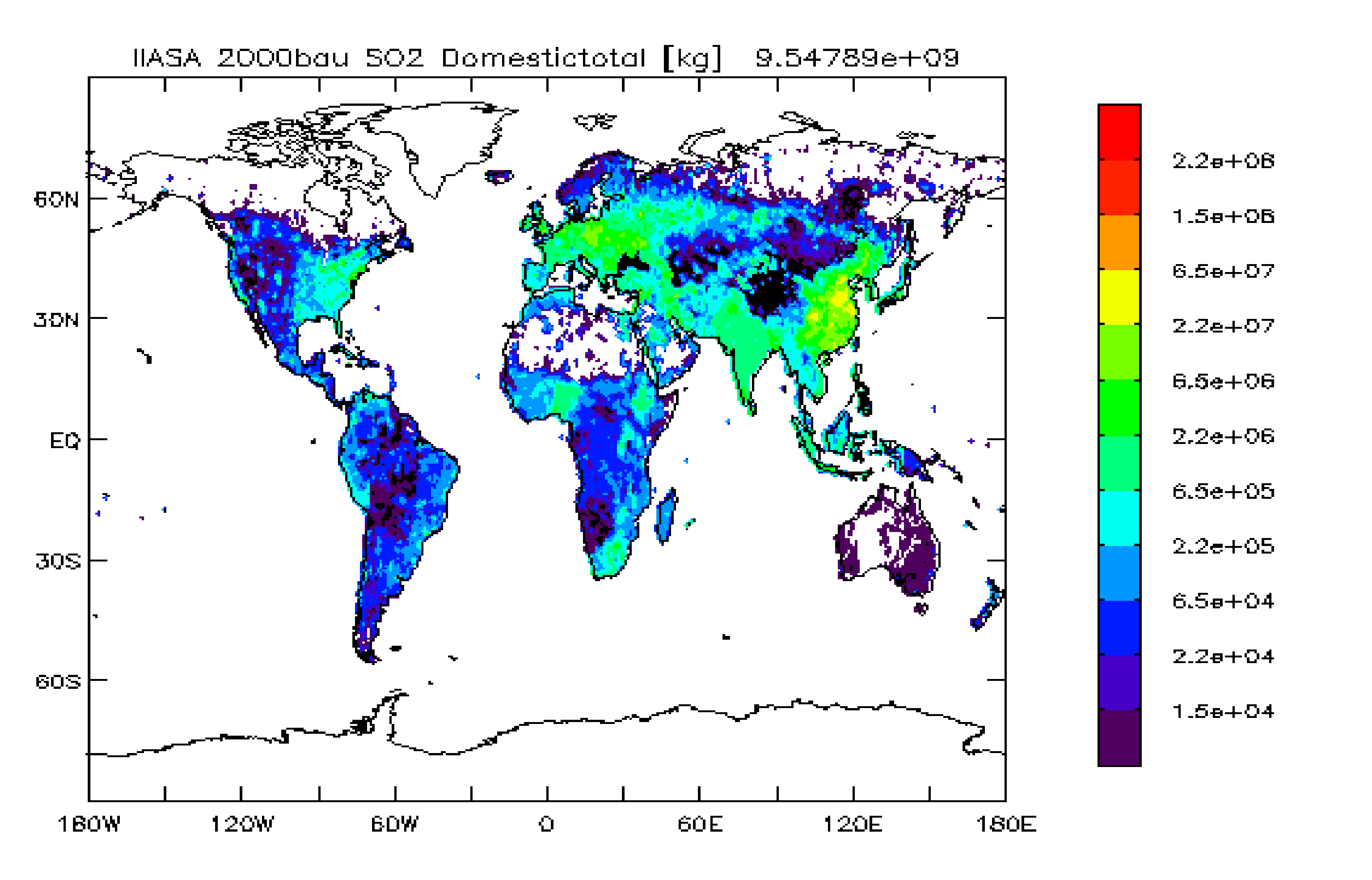
SO2 – 2000 emissions by region / type

REGIONAL ESTIMATES: kg SO2

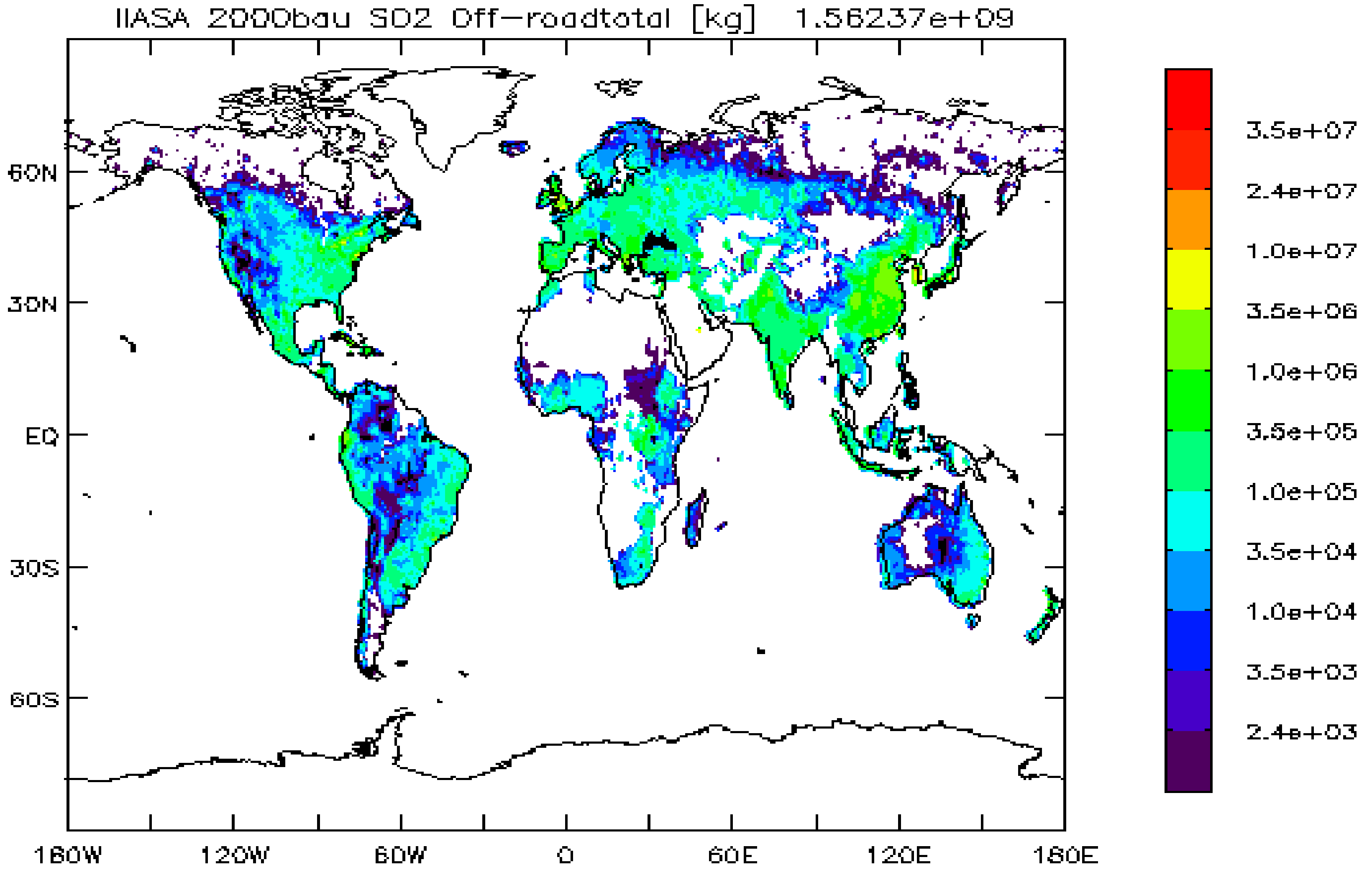
Region	Domestic_2	Industry_2	Intern. ship	Off-road_2	Powerplant	RoadTransp
OPEN OCEAN	0.00e+00	0.00e+00	5.05e+09	0.00e+00	0.00e+00	0.00e+00
CANADA	7.16e+07	1.19e+09	2.90e+07	5.30e+07	5.44e+08	1.35e+07
USA	3.11e+08	3.12e+09	8.45e+07	1.11e+08	1.25e+10	1.67e+08
LATIN AMERICA	1.96e+08	2.96e+09	1.71e+08	1.99e+08	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**

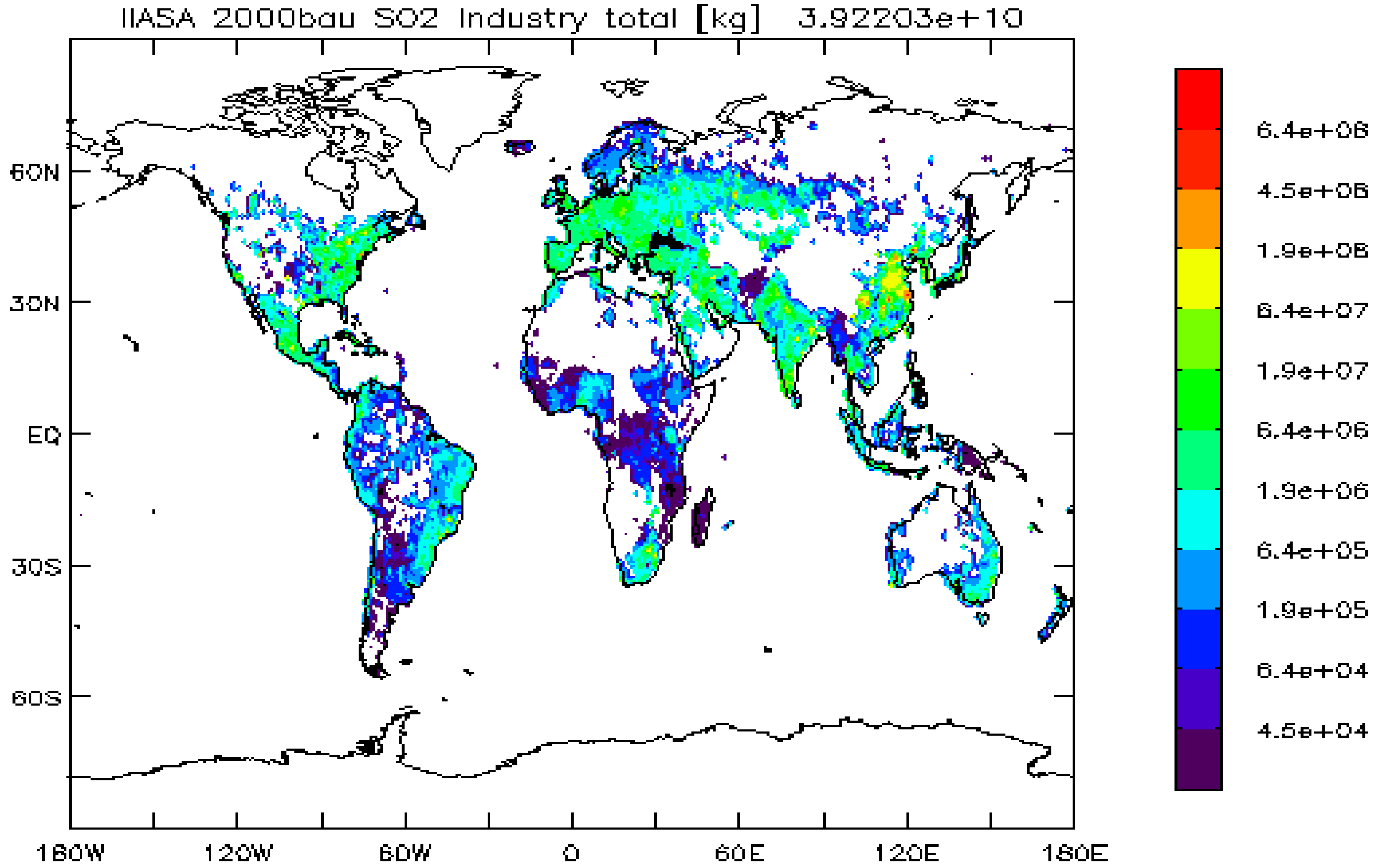
IIASA – 2000 domestic SO_2



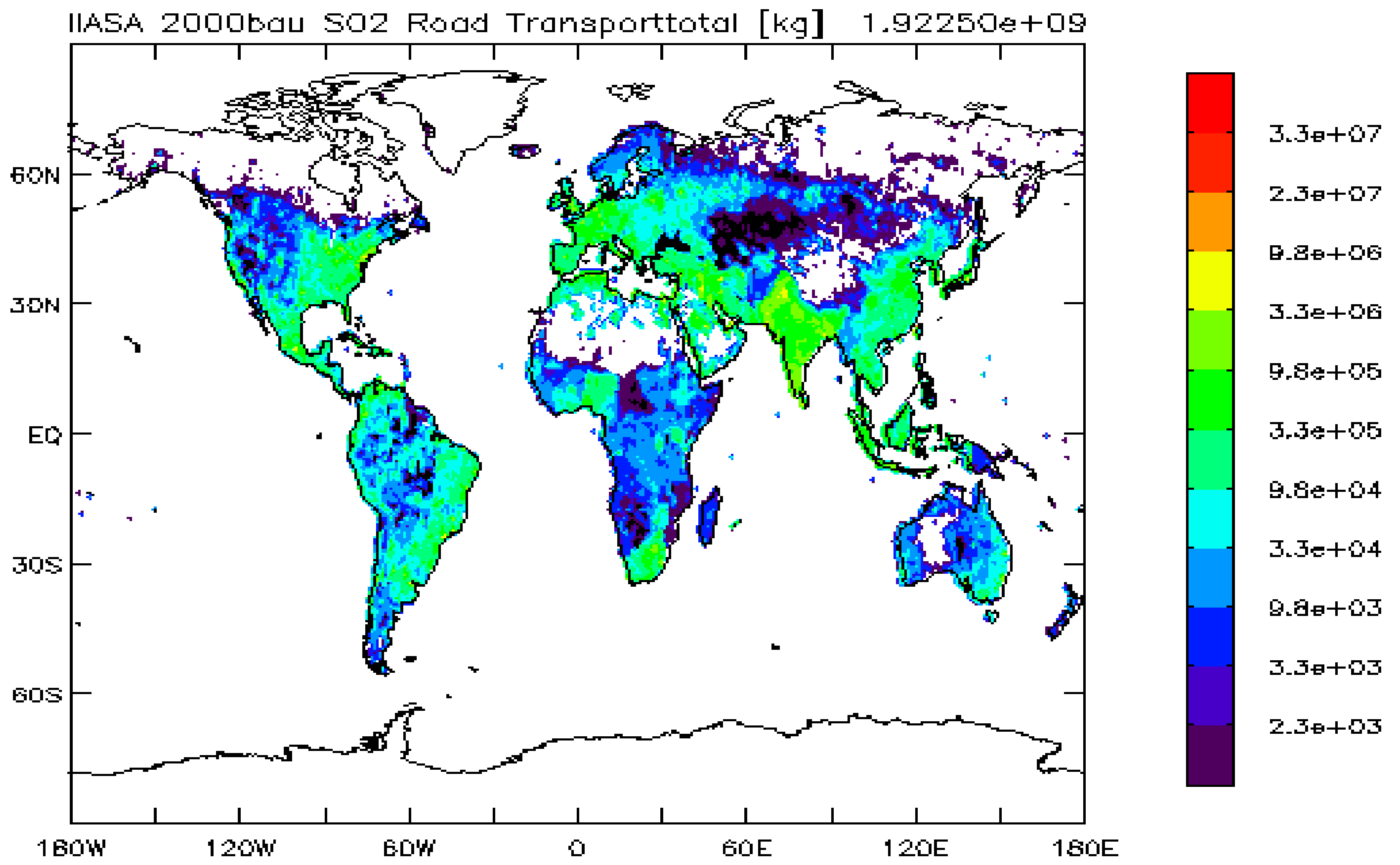
IIASA – 2000 off-road SO2



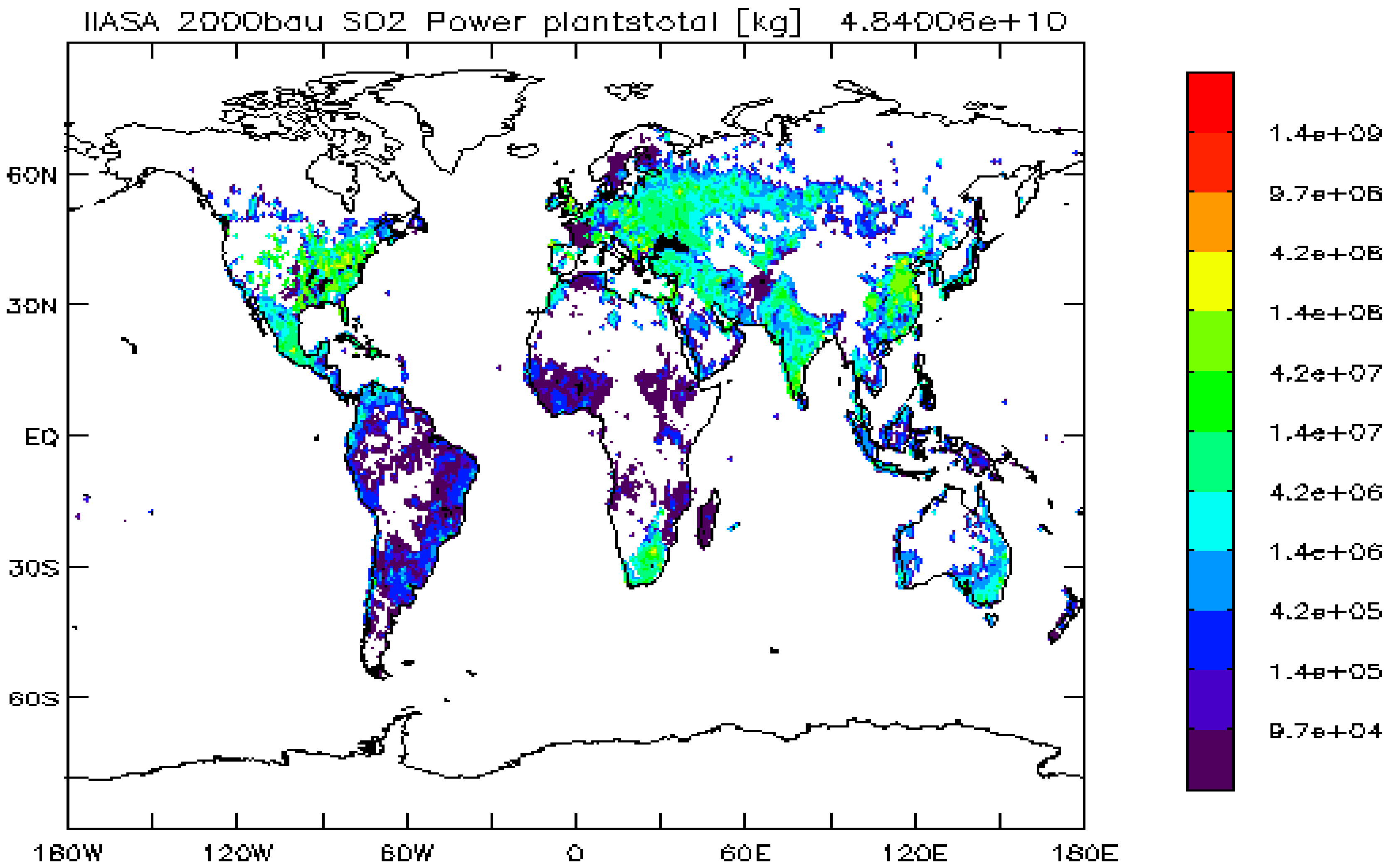
IIASA – 2000 industry SO2



IIASA – 2000 road transport SO2



IIASA – 2000 power plant SO2



SO_2 -volcanic

SO2 – volcanic emissions

Tg /year	SO2	equiv. S	*injection height*
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	** height boundaries provided – from Halmer et al JVGR 115, 2002*

continuous erupting volcanos *(Andres & Kasgnoc, JGR,1998)*
http://www.geiacenter.org (GEIA data *[next slide]* are too small ⇨ GEIA values multiplied by factor 1.2!)

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.**
- **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.**

the annual long-time average S emission recommend by GEIA of 10.4 Tg /year S is considered to be an underestimate ⇨

GEIA contin. emissions	*Tg/year*
SO2	6.7
- degassing	4.7
- explosive	2.0
H2S	2.6
CS2	0.25
OCS	0.16
SO4	0.15
part S	0.081
other S	0.54
GEIA total S	10.4
recommended S (1.2*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 GSFC DAO surface winds

Ginoux et al., JGR 102 3819-3830, 2001 (**pag@gfdl.noaa.gov**)

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

Dust - Size Modes

- **Accumulation mode** *(0.1 to 1μm sizes)*
  - **Concentration /per grid-box *** *(mode2_number)*
  - **Mode radius (for number)** *(mode2_radius)*
  - **Standard deviation: 1.59** *(constant distribution width)*
- **Coarse mode** *(1 to 12 μm sizes)*
  - **Concentration /per grid-box *** *(mode3_number)*
  - **Mode radius (for number)** *(mode3_radius)*
  - **Standard deviation: 2.00** *(constant distribution width)*

"/gridbox" to "/m2" conversion data provided in __.nc files

'binflux.pro' (in /idl_binflux) calculates fluxes for any size bin

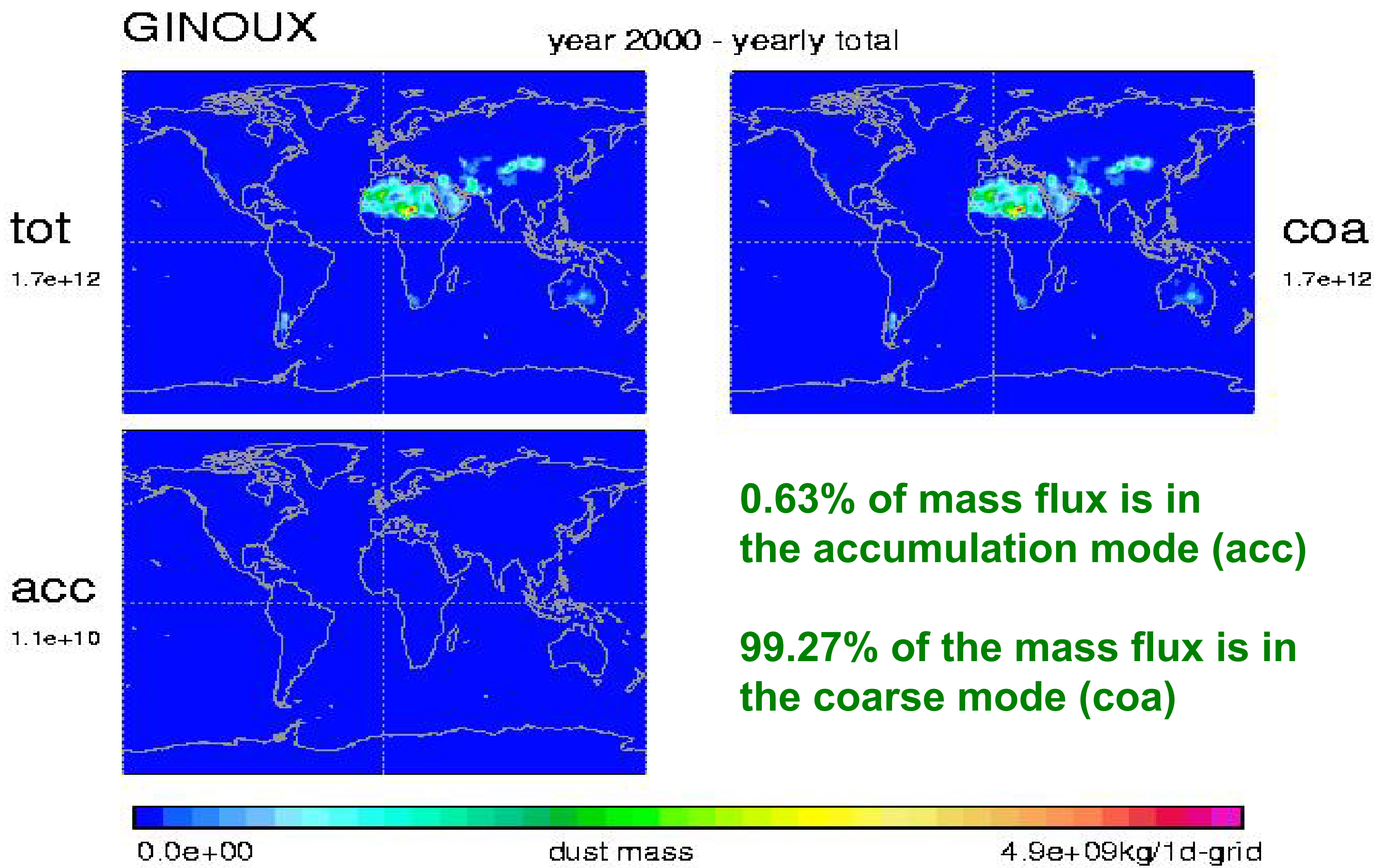
(make sure to include radii as large as 25 μm to conserve mass)

Dust mass flux

- **monthly totals** of daily fluxes

Tg/year	NH	SH	global
Jan	156	8	164
Feb	162	8	170
Mar	146	7	153
Apr	120	10	130
May	132	10	142
June	135	9	144
July	114	10	124
August	111	10	121
September	106	7	113
October	131	8	139
November	136	7	143
December	126	11	137
total	**1573**	**105**	**1678**

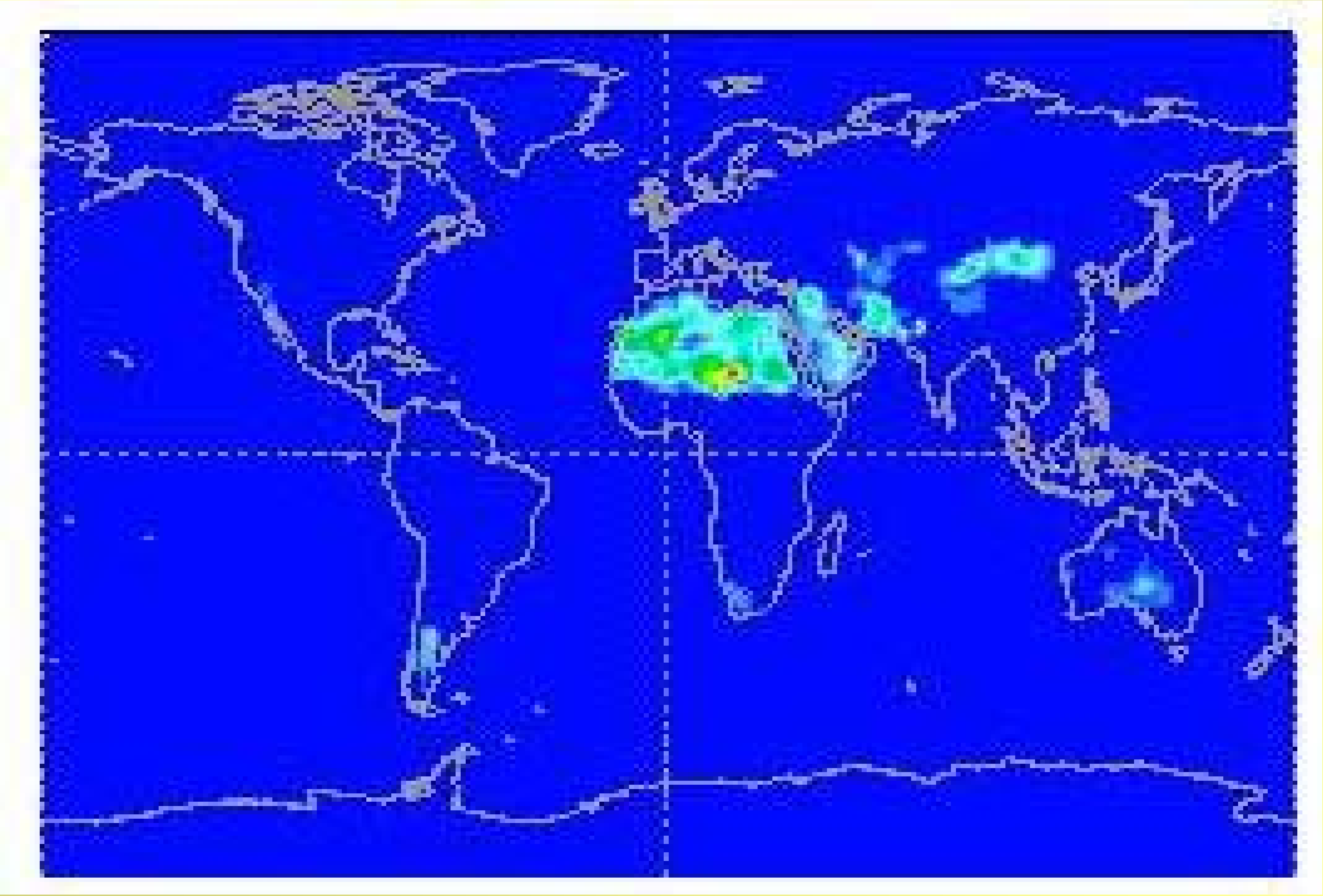
Dust - yearly average mass-flux



0.63% of mass flux is in the accumulation mode (acc)

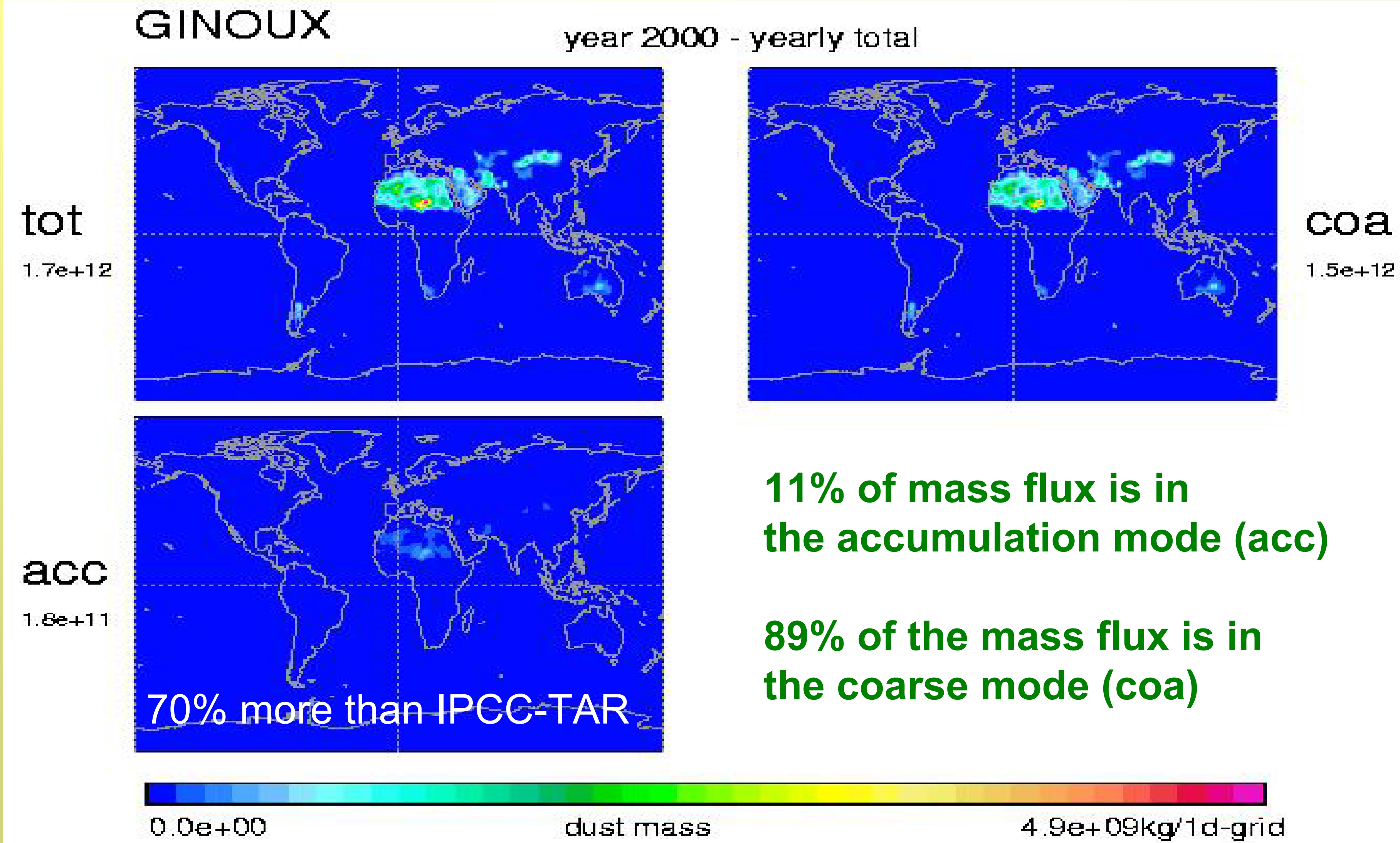
99.27% of the mass flux is in the coarse mode (coa)

Dust - yearly average mass-flux



data-set for sensitivity studies only:

"small" Dust - yearly avg. mass-flux



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**
- **no sea-salt over ice** ***(ECWMF ice cover data)***

based on year 2000 emissions by Sunling.Gong@ec.gc.ca

(here only sizes smaller than 20μm diameter are considered)

Gong et.al. JGR, 107, 2002,

Gong and Barrie, JGR, 108, 2003,

Gong Glo.Bio.Cycles, 17, 2003

Sea-salt mass flux

- **monthly totals** of daily fluxes

Tg/year	NH	SH	global
Jan	318	337	655
Feb	308	372	680
Mar	266	443	709
Apr	186	468	654
May	135	539	674
June	130	512	642
July	125	550	675
August	131	549	680
September	145	496	641
October	215	440	655
November	265	327	592
December	334	335	669
total	**2534**	**5301**	**7835**

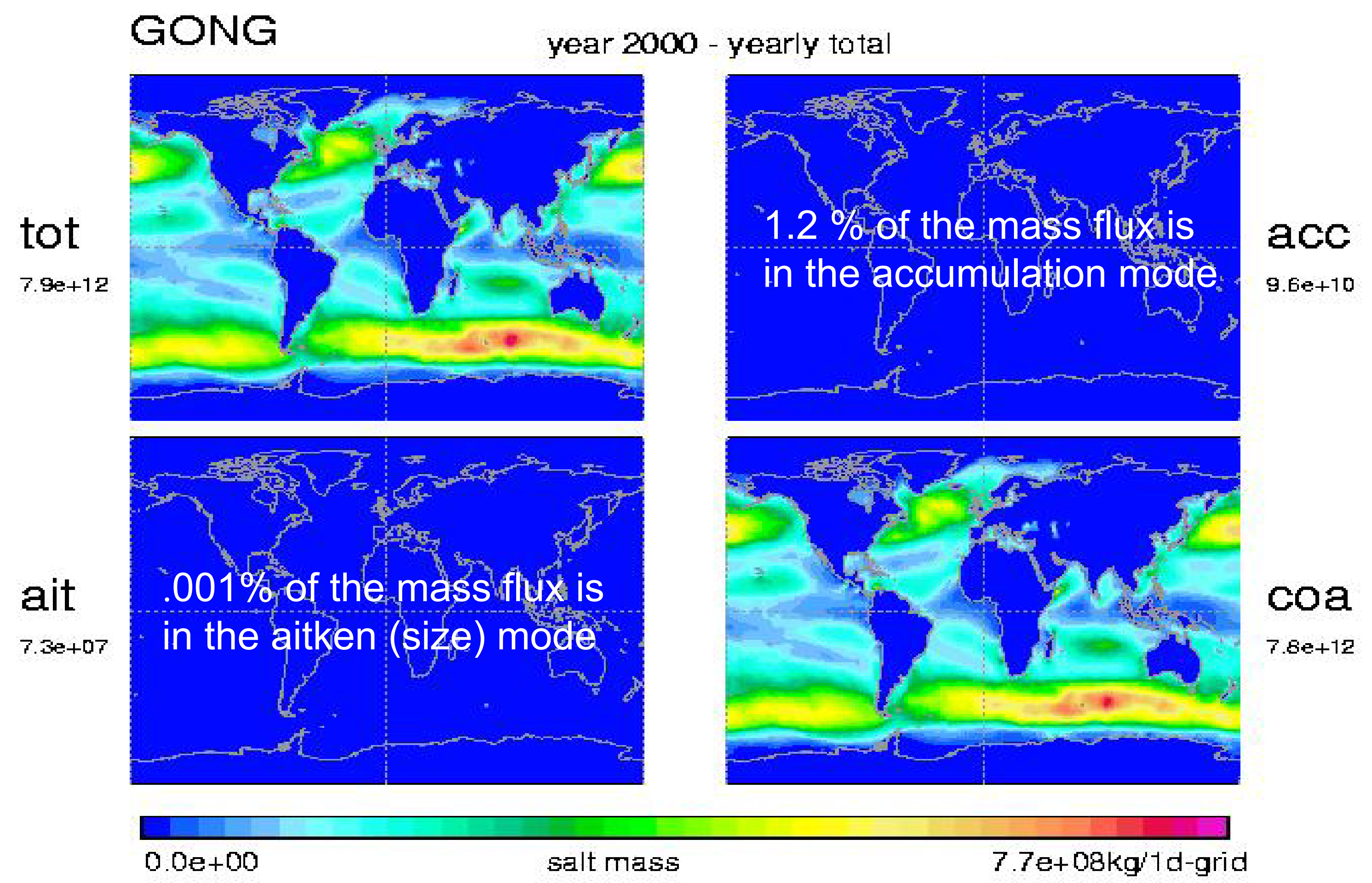
Sea-Salt Size Modes

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

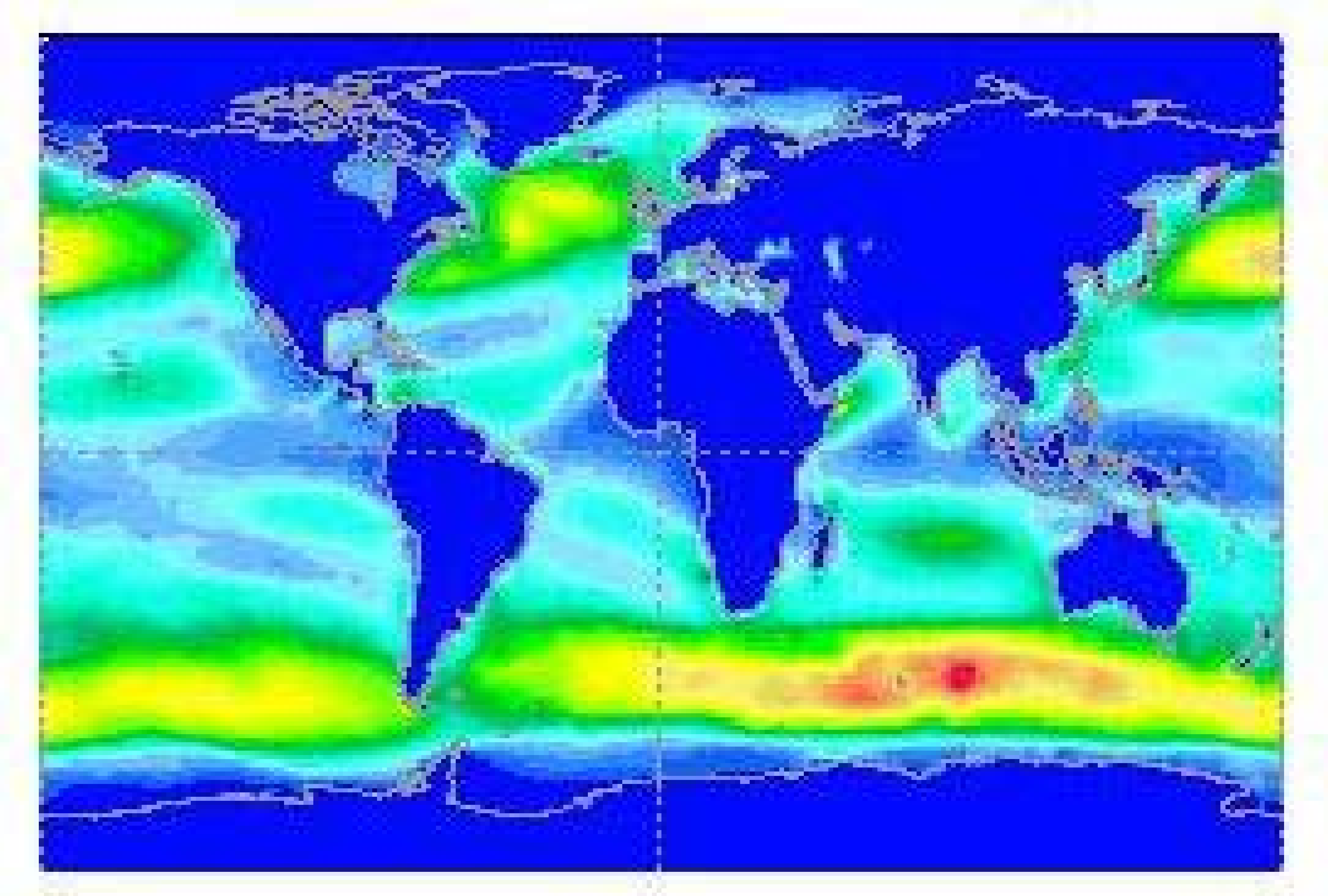
"/gridbox" to "/m2" conversion data provided in __.nc files

'binflux.pro' (in /idl_binflux) calculates fluxes for any size bin
(make sure to include radii as large as 25 μm to conserve mass)

Seasalt – yearly average mass-flux



Seasalt – yearly average mass-flux



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 S *(sulfur)* /gridbox**

  "/gridbox" to "/m2" conversion data provided in __.nc files

based on LMDZ-GCM simulations by Olivier Boucher

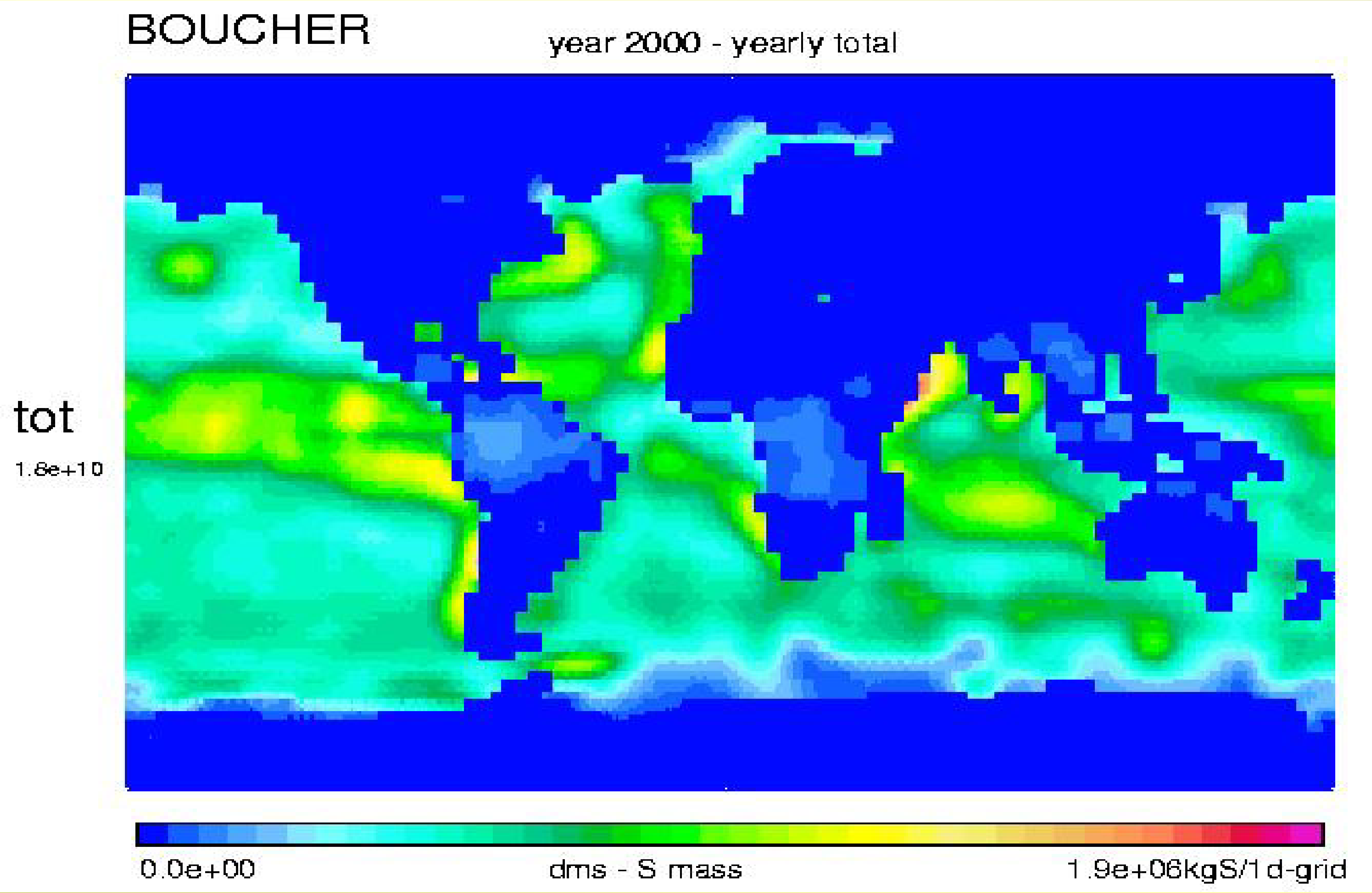
oceanic: *Kettle and Andreae, JGR, 105, 2000*
surface (10m winds): *Nightingale et al., Glo.Bio.Cycles, 14, 2000*
biogenic: *Pham et al. JGR, 100, 1995*

DMS mass flux

- **monthly totals** of daily fluxes

Tg/year	NH	SH	global
Jan	.48	1.41	1.89
Feb	.47	1.58	2.05
Mar	.53	1.43	1.96
Apr	.66	.87	1.53
May	.74	.56	1.30
June	.70	.44	1.14
July	.70	.43	1.13
August	.67	.60	1.27
September	.54	.47	1.01
October	.55	.63	1.18
November	.53	1.15	1.68
December	.50	1.62	2.12
total	7.03	11.10	18.13

DMS – yearly average mass flux



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**

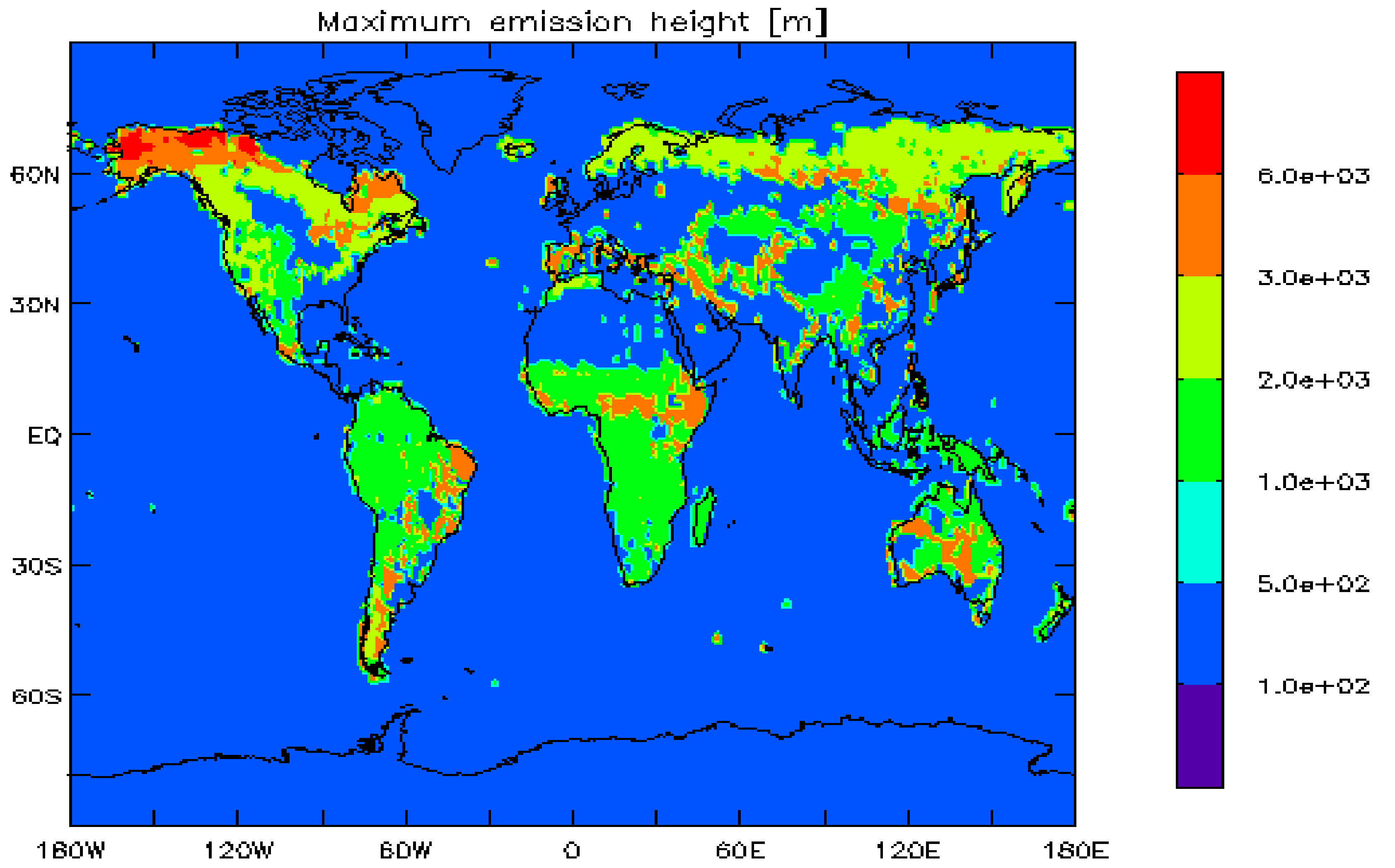
- **Biomass burning (OC/BC/SO2) ECO-system dependent**
  - **0-.1km /.1-.5km /.5-1km /1-2km / 2-3km /3-6km**

(**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

data access by anonymous ftp

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

dust_ncf: *DU* (dust_small_ncf: 50% smaller sizes)
seasalt_ncf: *SS*
DMS_ncf: *DMS*

other_ncf_2000:
BC: bio-, fossil fuel, wildfire
POM: bio-, fossil fuel, wildfire
SO2: domestic, industry, powerplants, off-road, road, -intern.shipping, wildfire, volcanic: continuous and explosive
SOA: secondary org. carbon

other_ncf_1750:
BC: biofuel, wildfire
POM: biofuel, wildfire
SO2: domestic, wildfire, volcanic (continous and explosive
SOA: sec. org. carbon

an overview is provided in a power-point file (AERO*YRMO*.PPT)

data can 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!