AeroCom Emissions

aerosol emission datasets

recommended for year 2000 simulations of AEROCOM

Contributors:

Frank Dentener, Julian Wilson, Luisa Marelli, Jean Putaud *(IES, JRC, Italy)*
Tami Bond *(U. Washington, USA)*
Judith Hoelzemann, Stefan Kinne *(MPI Hamburg, Germany)*
Sylvia Generoso, Christiane Textor, Michael Schulz *(CEA, France)*
Guido v.d. Werf *(NASA-JPL, USA)*
Sunling Gong *(ARQM Met Service Canada)*
Paul Ginoux *(NOAA-GFDL, USA)*
Janusz Cofala *(IIASA, Austria)*
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 OC / EC / SO2**
- **Fossil fuel/biofuel related OC / 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

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** *(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**
    - **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

Large scale biomass burning

OC (POM) / BC (EC) / SO2

- **Global emissions** *(incl. large agricultural fires)*:

Tg/year	POM *	BC	SO2
	34.7	3.04	4.11

based on **GFED 2000**

REFERENCE: Van der Werf et al. : Carbon emissions from fires in tropical ecosystems, Global Change Biology, 2003

* 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)* SO2 *2.7 Tg*

size recommendations

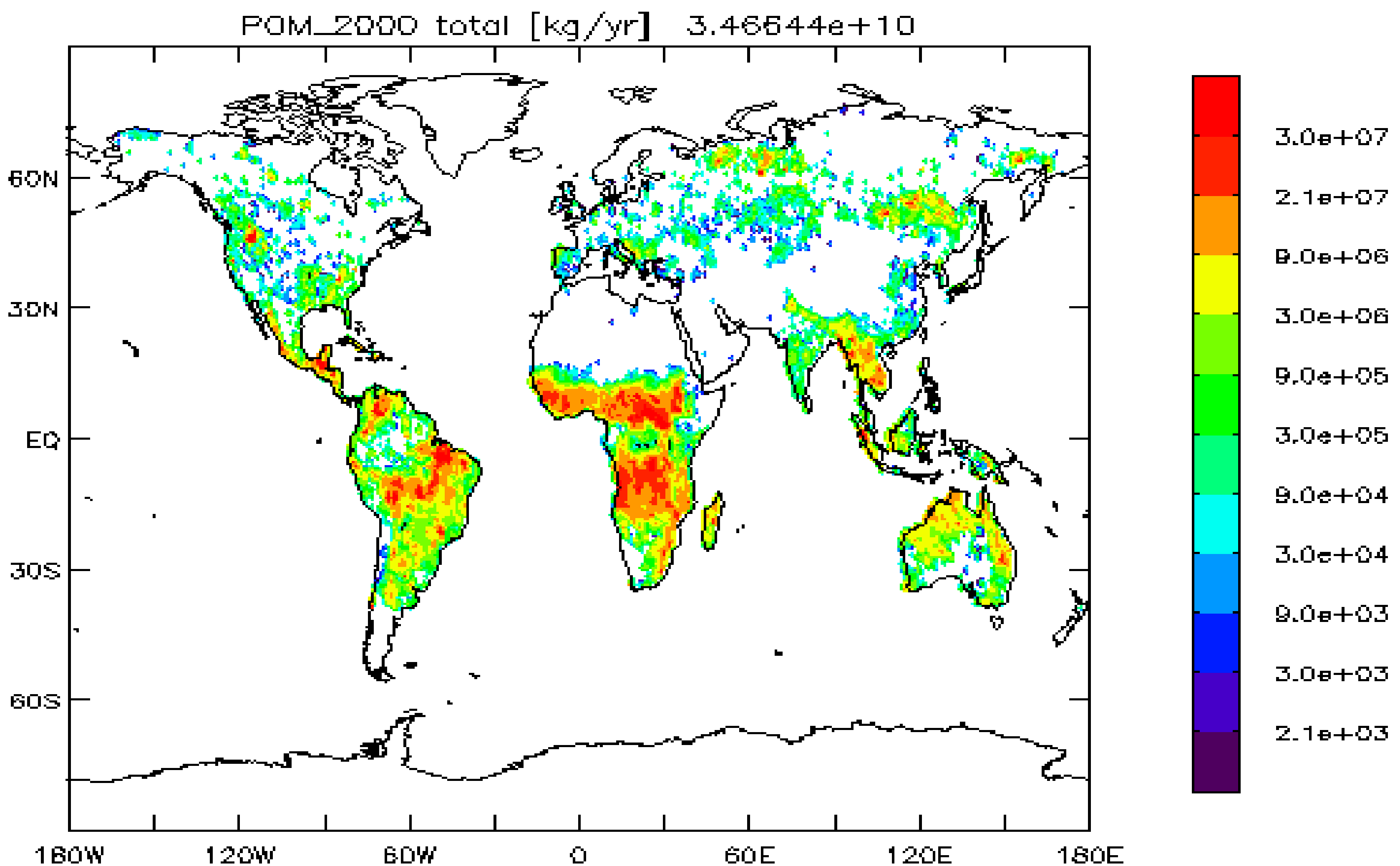
for primary SO4, OC and BC

- **particles size** ***(log normal size-distributions)***
  - **industrial / power plant** ***(fly ash)*** **(larger sizes)**
    - ***LN:*** **$r_{,mode}$ = .500μm , std.dev = 2.0 ($r_{,eff}$= 1.6μm)**
  - **biomass** **(based on measurement close to biomass)**
    - ***LN:*** **$r_{,mode}$ = .040μm , std.dev. = 1.8 ($r_{,eff}$= 0.077μm)**

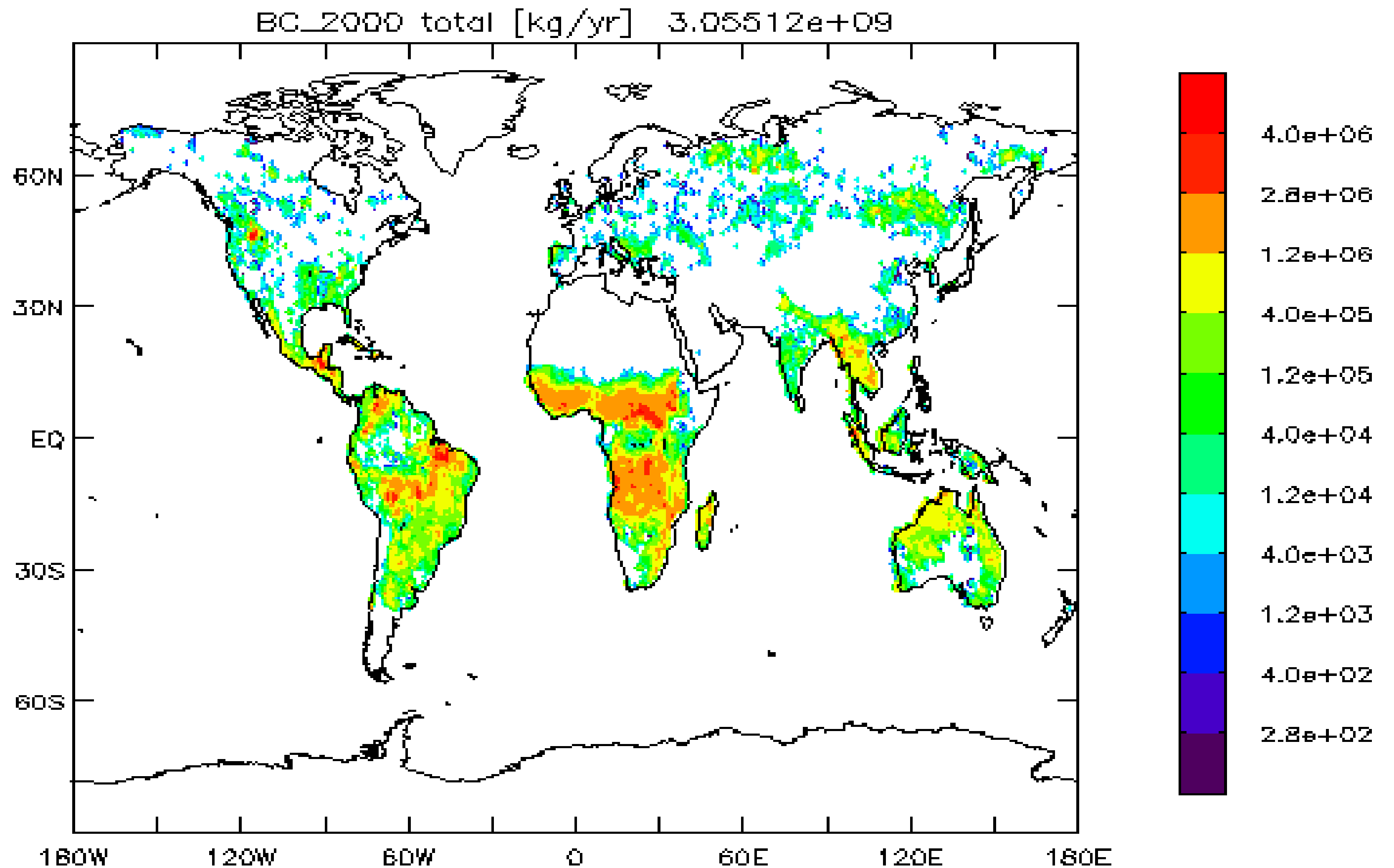
    compilation by Marelli, 2003
  - **traffic** **(kerbside / urban measurements at 5 European cities)**
    - ***LN:*** **$r_{,mode}$ = .015 μm , std.dev. = 1.8 ($r_{,eff}$= 0.029 μm)**

    based on Putaud et al. 2003 http://carbodat.ei.jrc.it/ccu/main.cfm

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)

Tg/year	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

size recommendations

for primary SO4, OC and BC

- **particles size** *(log normal size-distributions)*
  - **industrial / power plant** *(fly ash)* (larger sizes)
    - *LN:* $r_{,mode}$ = .500μm , std.dev = 2.0 ($r_{,eff}$= 1.6μm)
  - **biomass** (based on measurement close to biomass)
    - *LN:* $r_{,mode}$ = .040μm , std.dev. = 1.8 ($r_{,eff}$= 0.077μm)

    compilation by Marelli, 2003
  - **traffic** (kerbside / urban measurements at 5 European cities)
    - *LN:* $r_{,mode}$ = .015 μm , std.dev. = 1.8 ($r_{,eff}$= 0.029 μm)

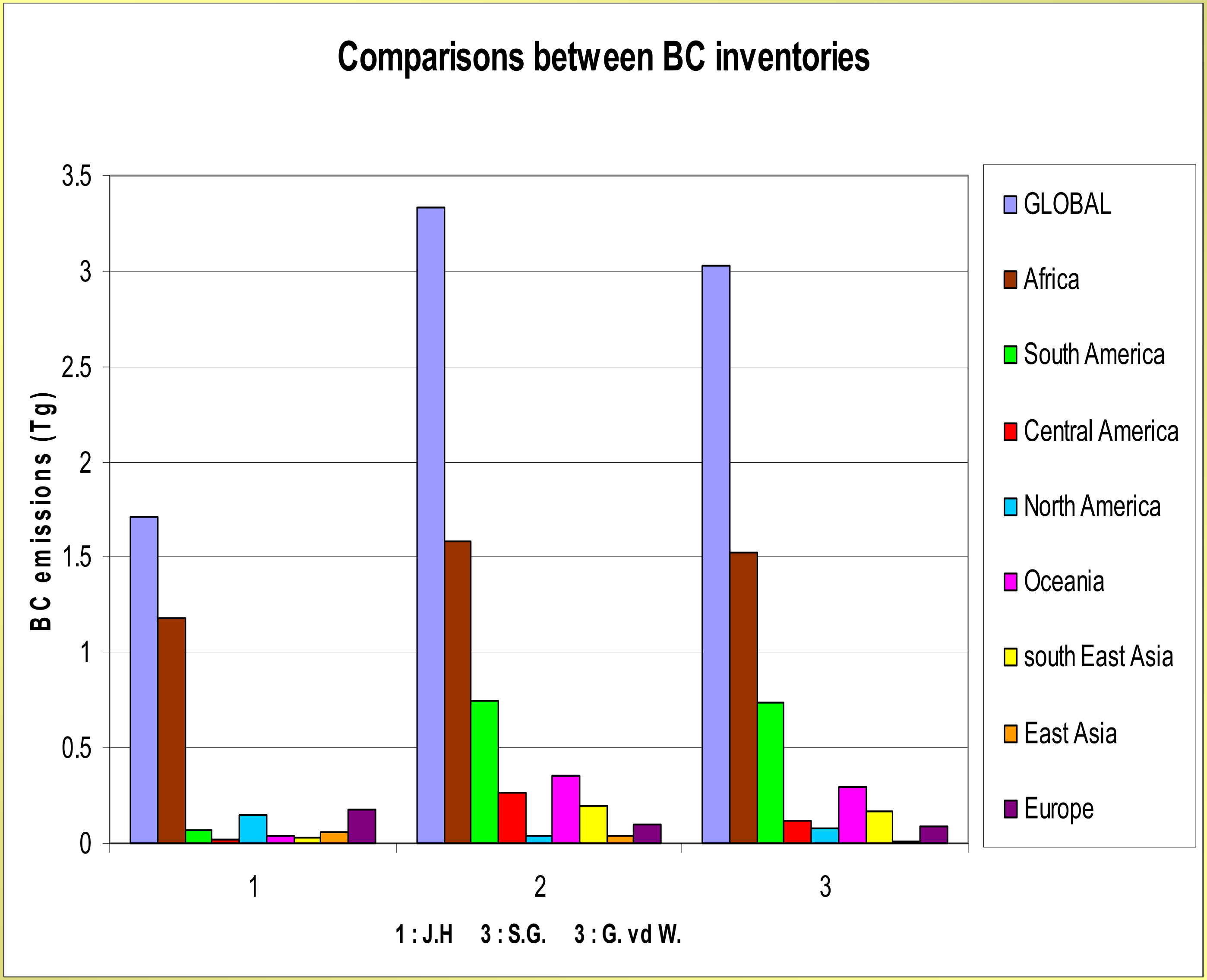
    based on Putaud et al. 2003 http://carbodat.ei.jrc.it/ccu/main.cfm

BC 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

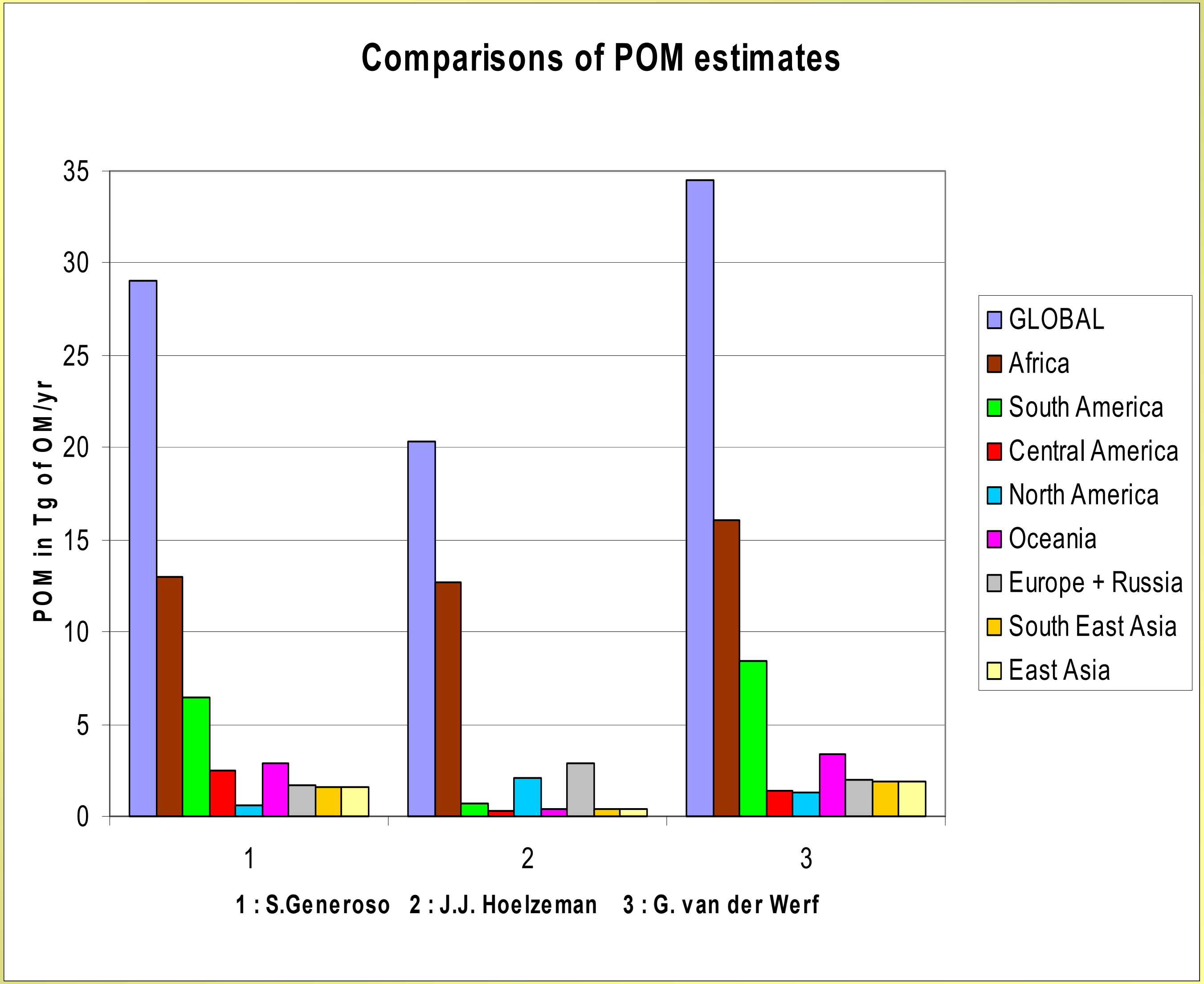
BC inventory comparisons

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

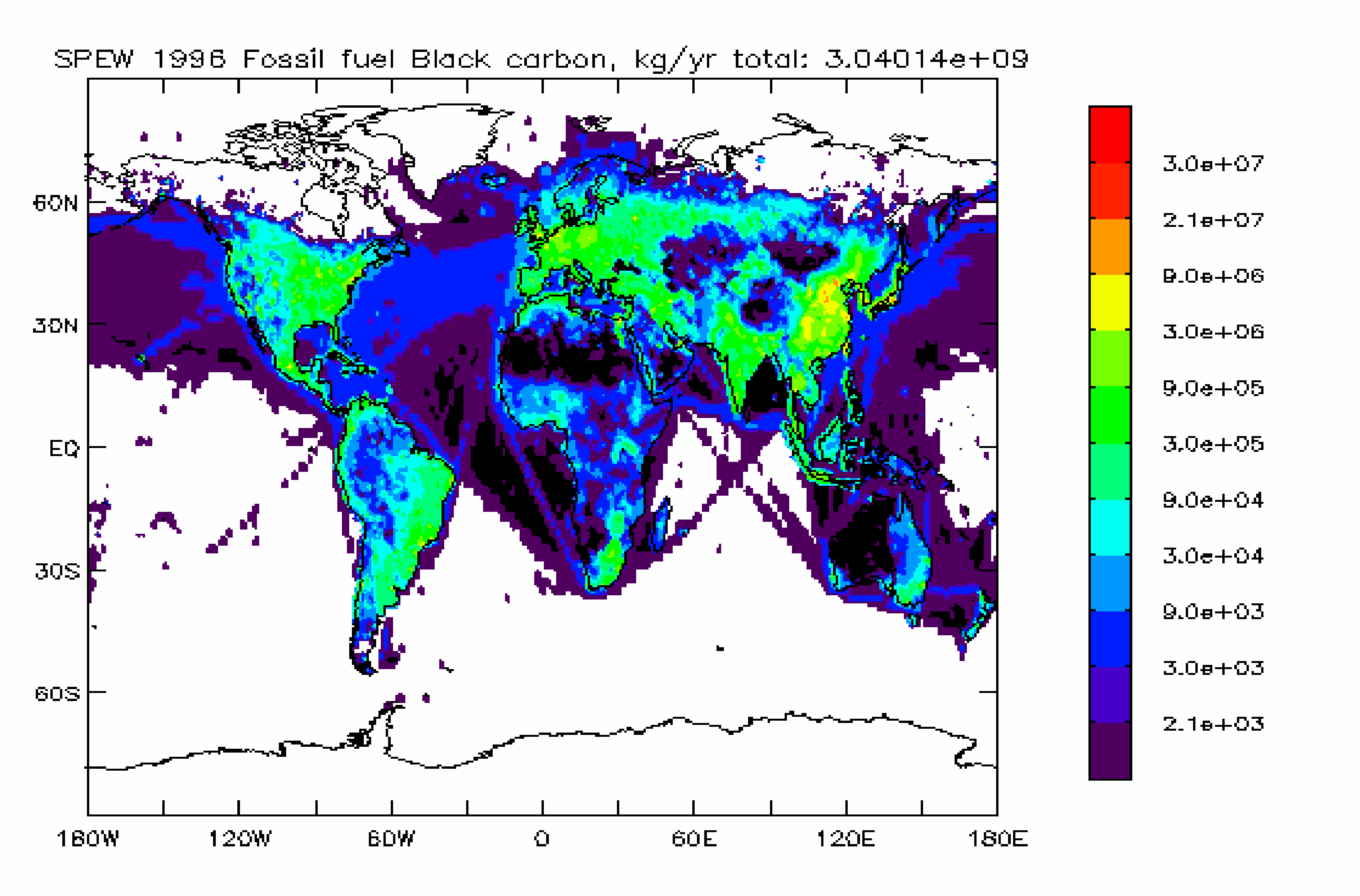


POM inventory comparisons

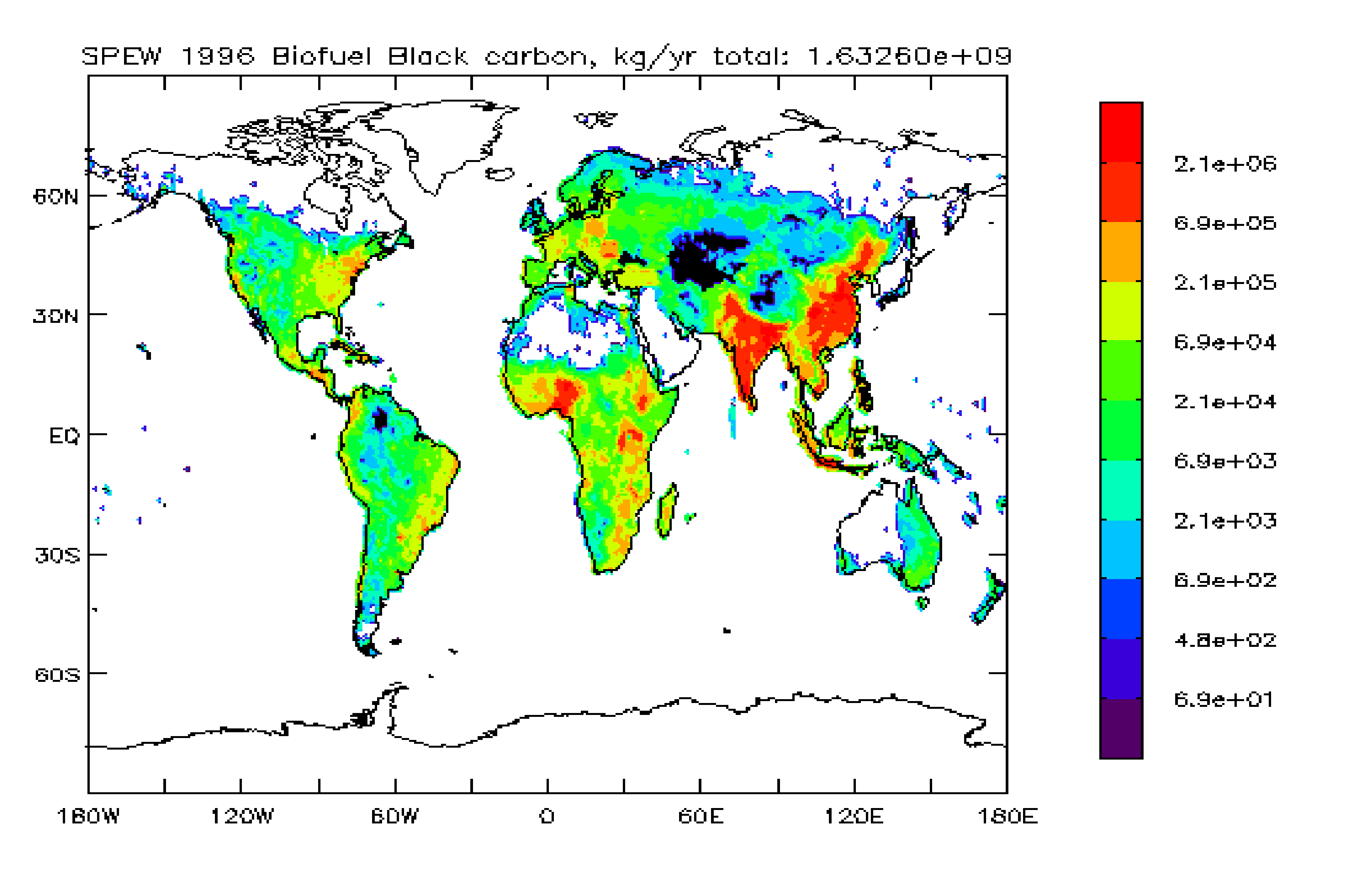
- **# 1**
  Generoso
- **# 2**
  GWEM
  Hoelzemann
- **# 3**
  GFED 2000
  van der Werf



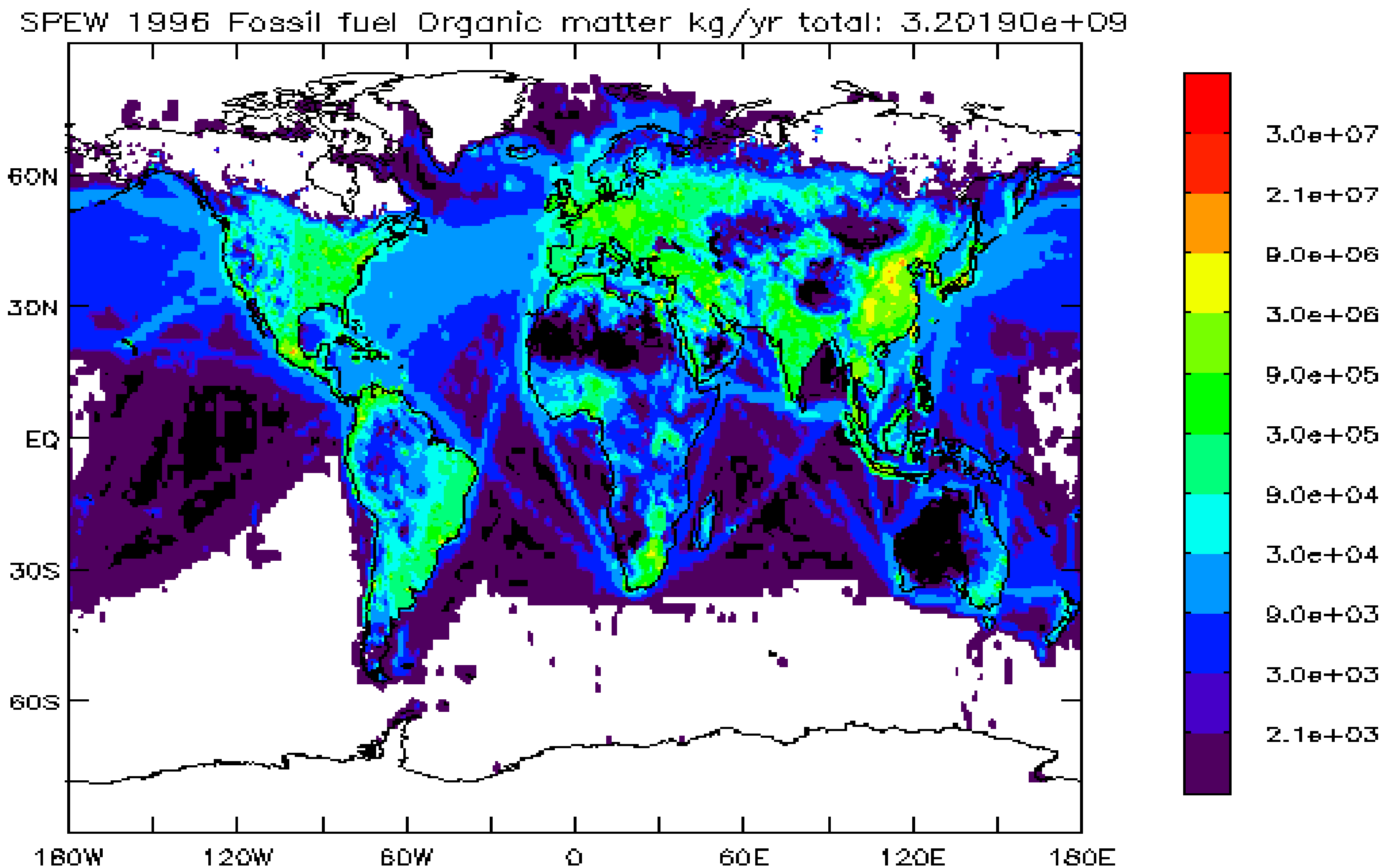
SPEW – BC fossil fuel emissions



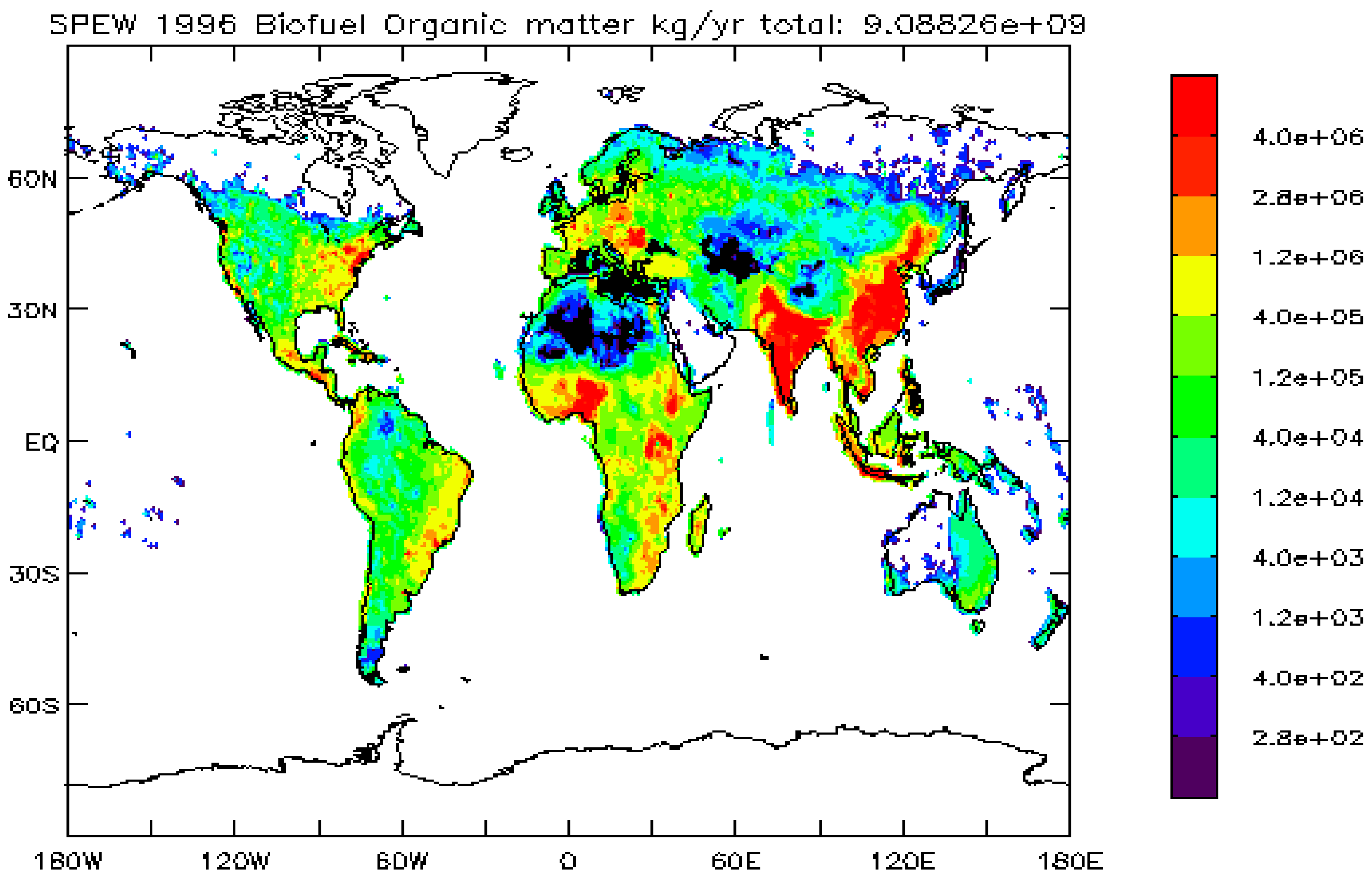
SPEW – BC bio fuel emissions



SPEW – OC fossil fuel emissions



SPEW – OC bio fuel emissions



SO_2

SO_2 - emissions

- **Global emissions**

  from Janusz Cofala (IIASA)

  Country based SO_2 emissions for the year 2000 using RAINS and the EDGAR 3.2 (1995) gridded distributions (in prep.)

Tg/year	SO_2	S
total	**141.7**	**70.9**
as SO_2	***138.2***	***61.9***
as SO_4	***5.3***	***1.8***

ship - emissions: 1.5% per year increase since 1995

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

(compare to 1-5% in literature)

size recommendations
for primary SO4, OC and BC

- **particles size** *(log normal size-distributions)*
  - **industrial / power plant** *(fly ash)* (larger sizes)
    - *LN:* $r_{,mode}$ = .500μm , std.dev = 2.0 ($r_{,eff}$= 1.6μm)
  - **biomass** (based on measurement close to biomass)
    - *LN:* $r_{,mode}$ = .040μm , std.dev. = 1.8 ($r_{,eff}$= 0.077μm)

    compilation by Marelli, 2003
  - **traffic** (kerbside / urban measurements at 5 European cities)
    - *LN:* $r_{,mode}$ = .015 μm , std.dev. = 1.8 ($r_{,eff}$= 0.029 μm)

    based on Putaud et al. 2003 http://carbodat.ei.jrc.it/ccu/main.cfm

Log-normal mode partitioning

by number	R,mode # (μm)	Standard Deviation	R,effect. (μm)	Aitken % conc.	Accum. % conc.	Coarse % conc.
traffic	.015	1.8	.029	99	1	
biomass	.040	1.8	.077	66	34	
industry	.5	2.0	1.6		50	50

by mass	R,mode # (μm)	Standard Deviation	R,effect. (μm)	Aitken %mass	Accum. %mass	Coarse %mass
traffic	.015	1.8	.029	76	24	
biomass	.040	1.8	.077	9	91	
industry	.5	2.0	1.6		2	88

SO_2 – emissions by type

Tg /year	SO_2	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

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

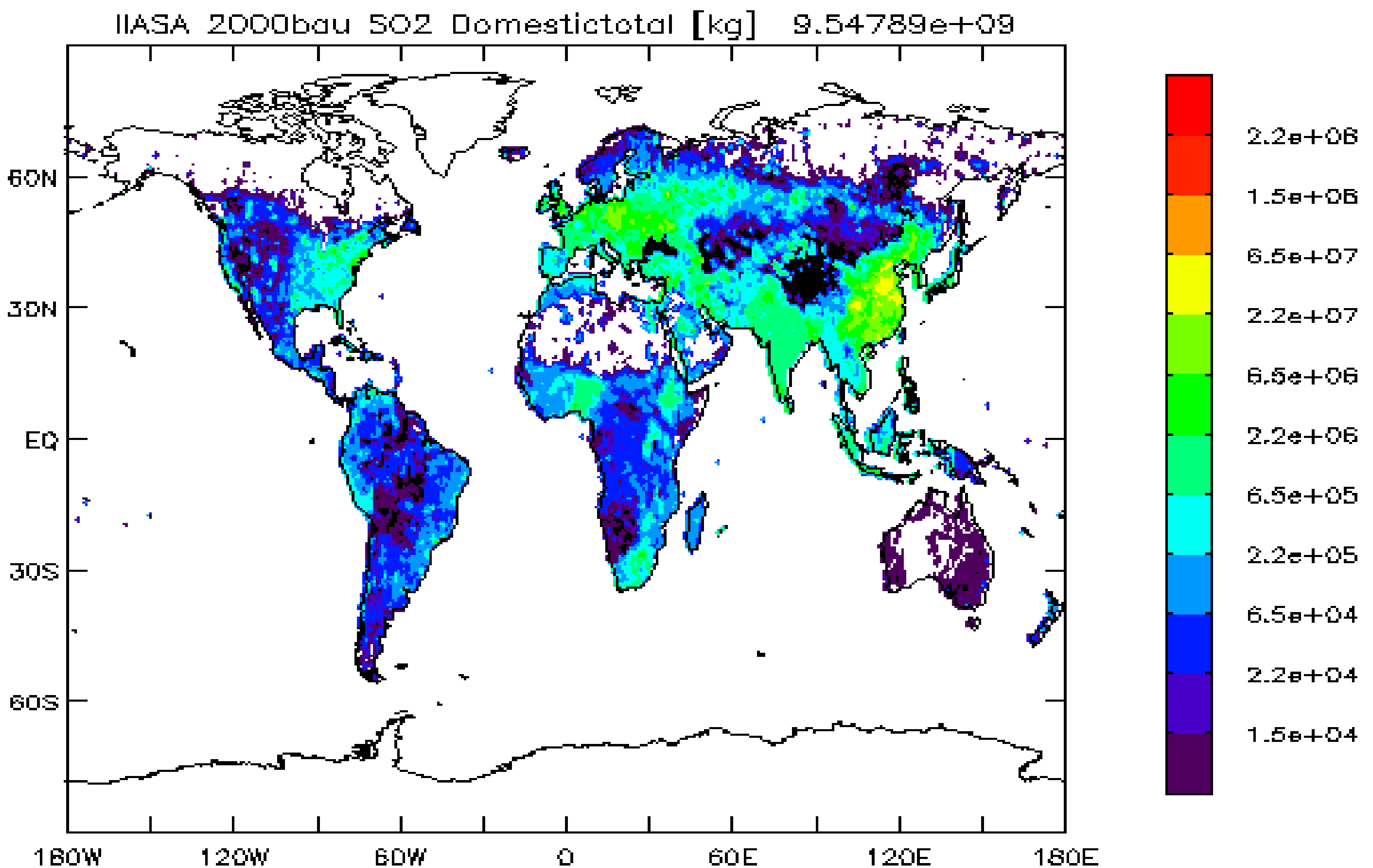
SO2 – emissions by region / type

REGIONAL ESTIMATES: kg SO2

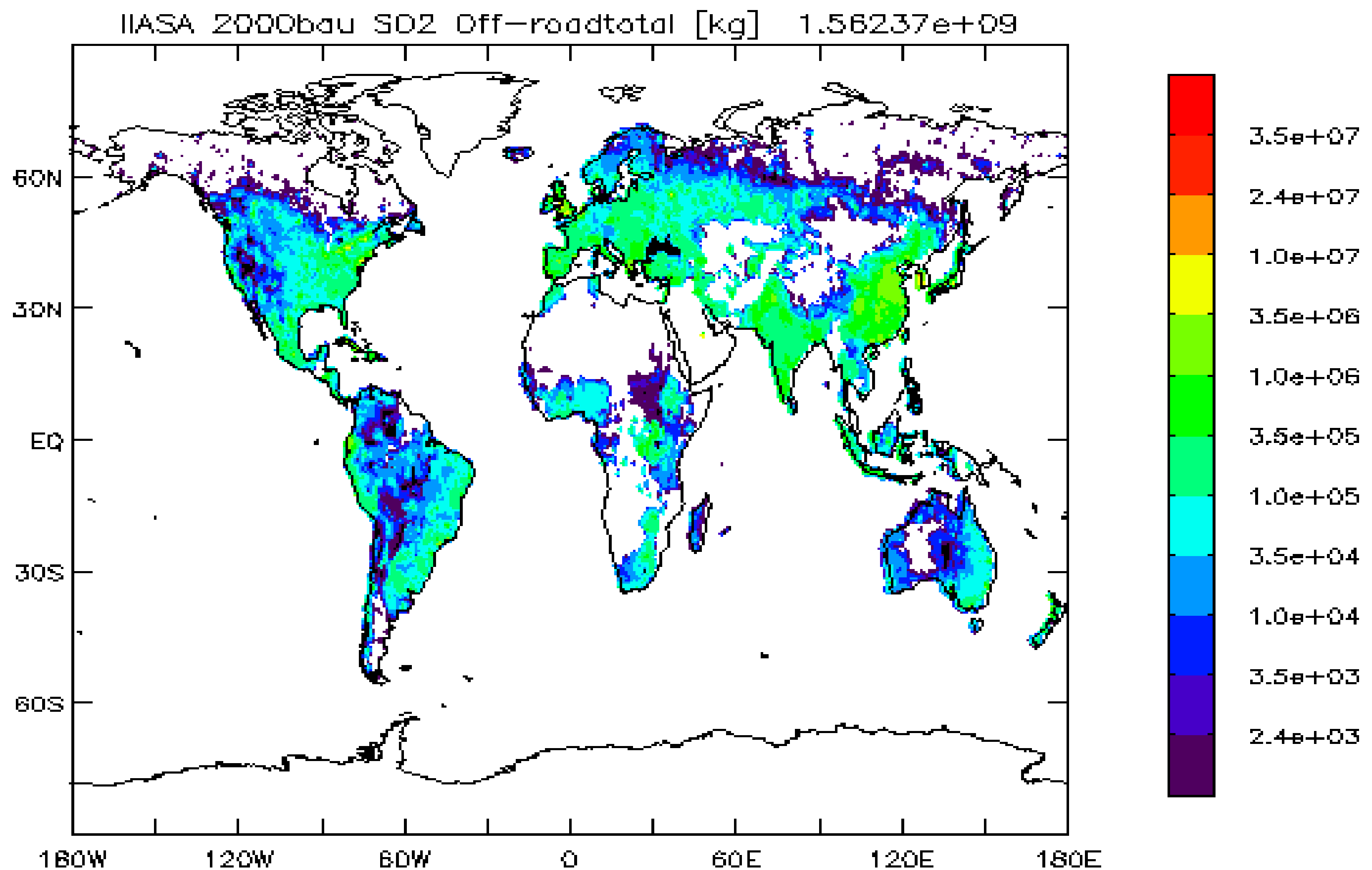
Region	Domestic_2	Industry_2	Intern. ship	Off-road_2	Powerplant	RoadTransp
OPEN OCEAN	0.00e+00	0.00e+00	5.05e+09	0.00e+00	0.00e+00	0.00e+00
CANADA	7.16e+07	1.19e+09	2.90e+07	5.30e+07	5.44e+08	1.35e+07
USA	3.11e+08	3.12e+09	8.45e+07	1.11e+08	1.25e+10	1.67e+08
LATIN AMERICA	1.96e+08	2.96e+09	1.71e+08	1.99e+08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

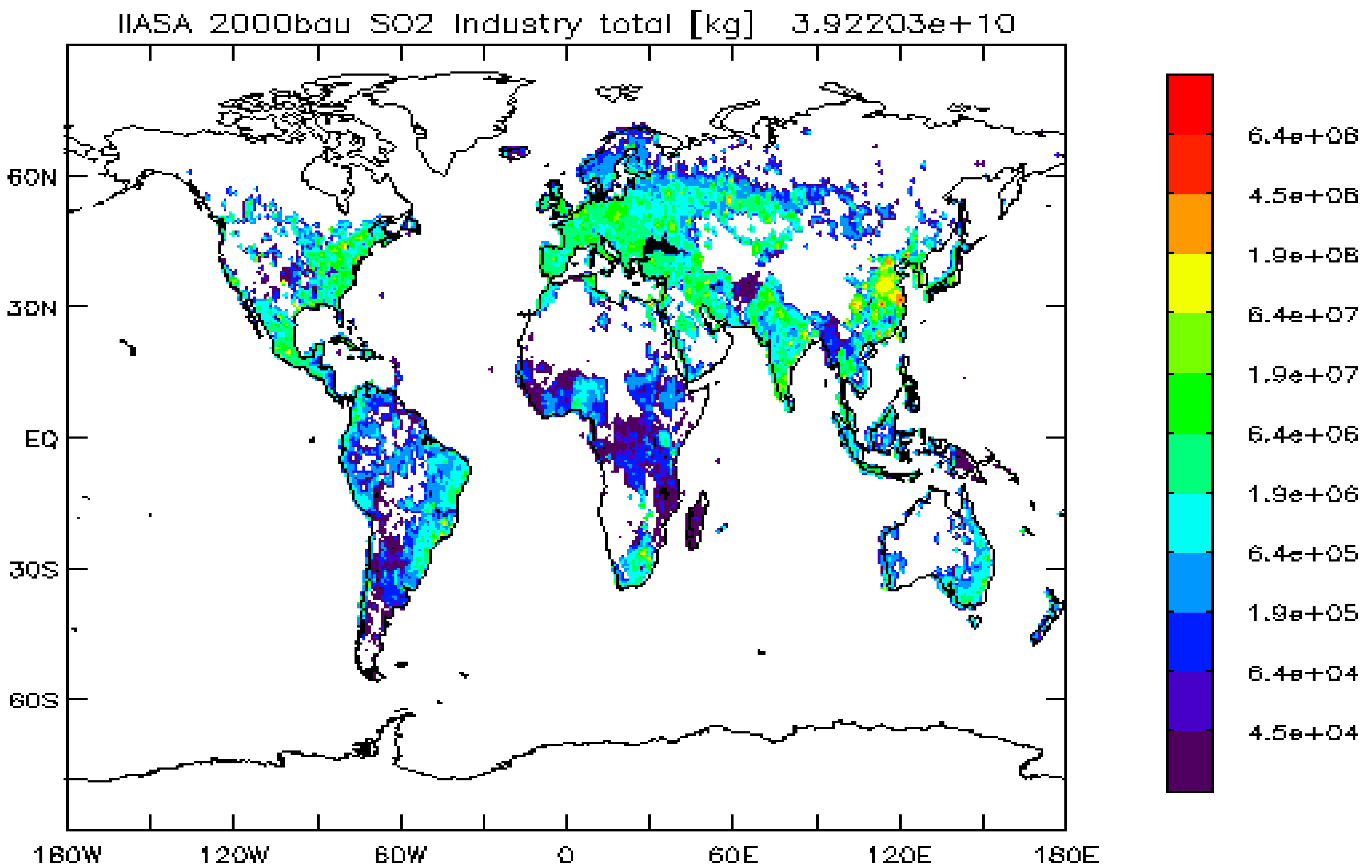
IIASA – domestic SO2



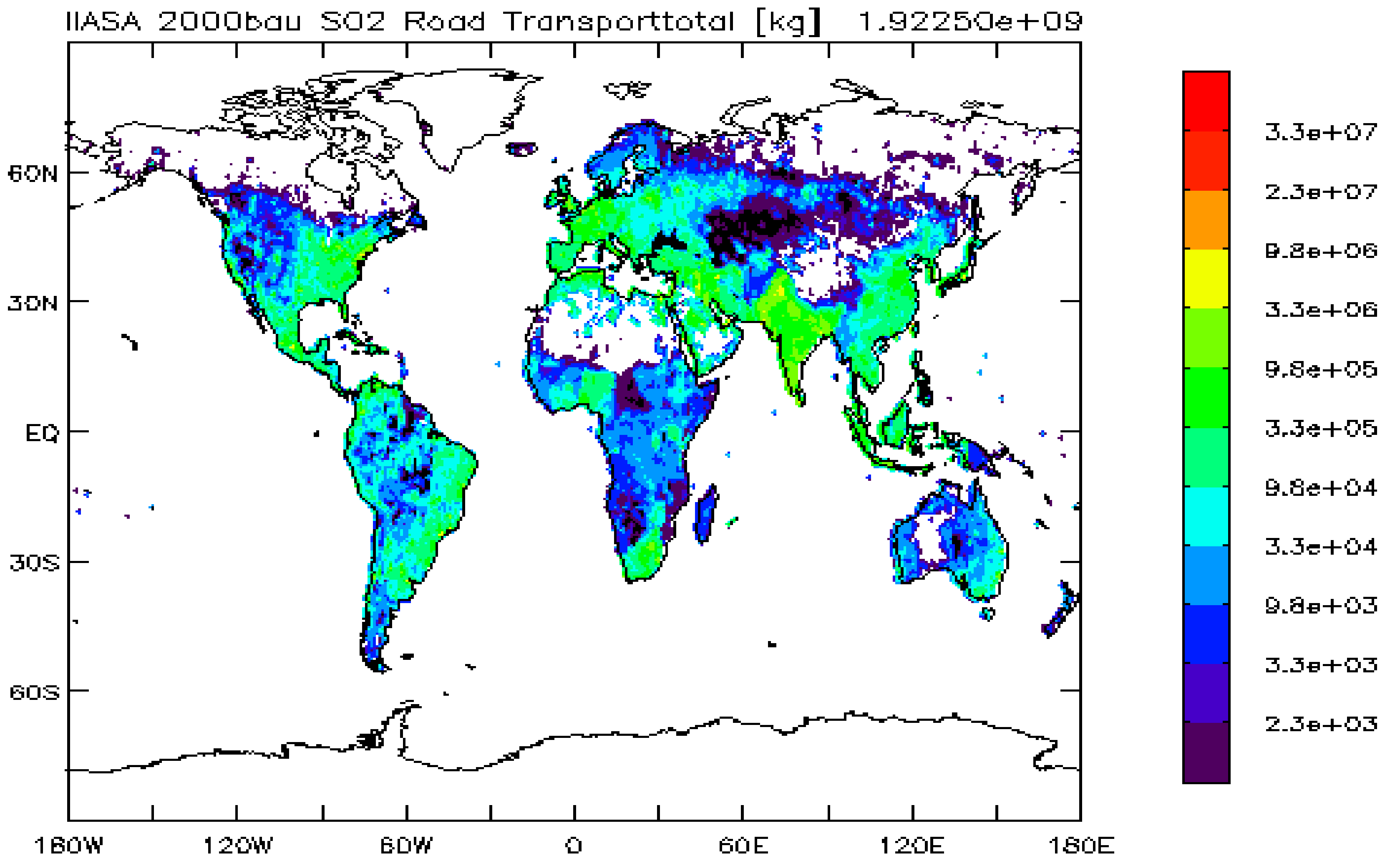
IIASA – off-road SO_2



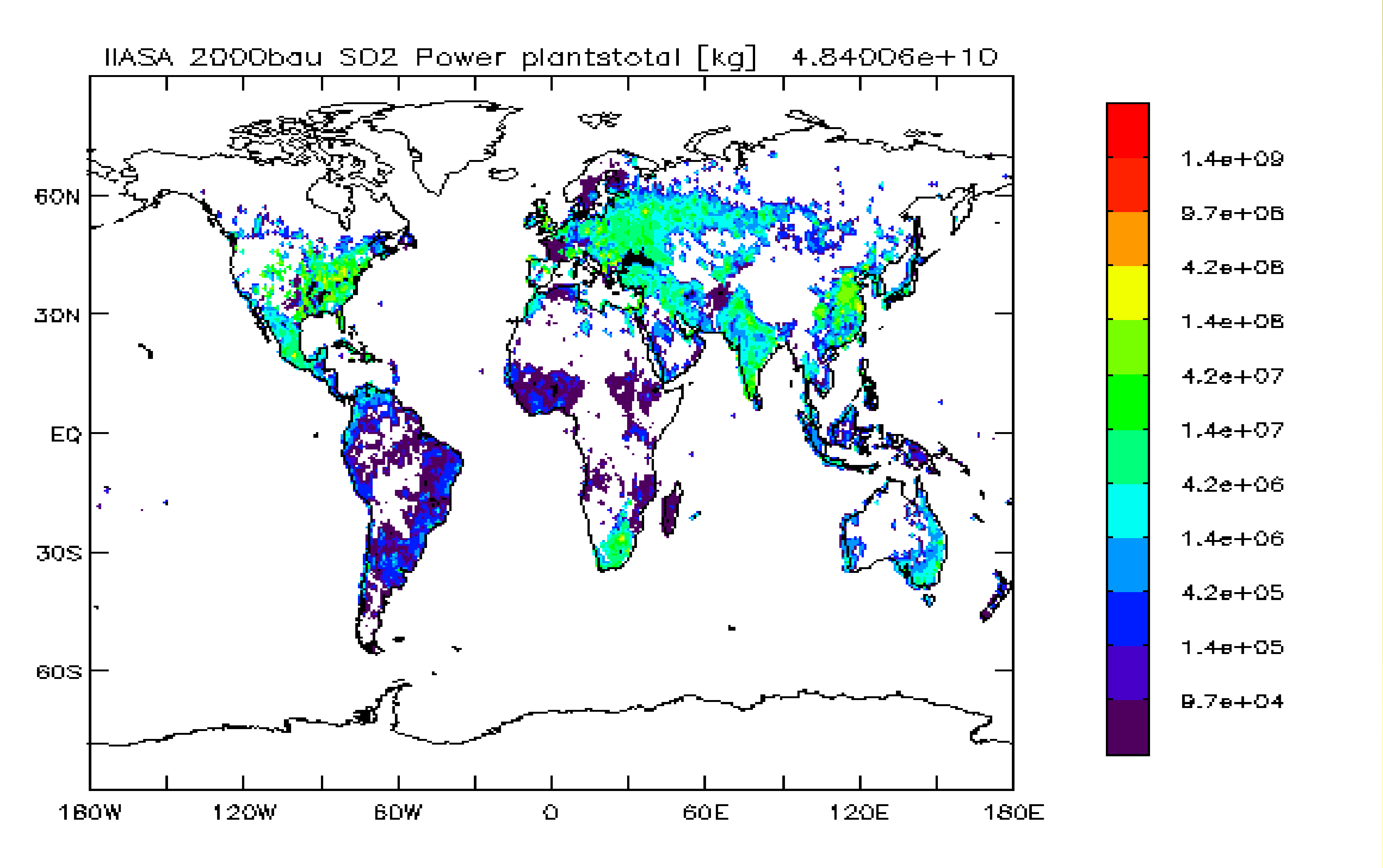
IIASA – industry SO2



IIASA – road transport SO2



IIASA – power plant SO2



SO_2 -volcanic

SO_2 – volcanic emissions

Tg /year	SO_2	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 1.5!)

- explosive erupting volcanos
  http://www.igac.noaa.gov/newsletter/22/sulfur.php

more to - volcanic emissions

continuous partitioning ⇨

GEIA contin. emissions	*Tg/year*
SO_2	6.7
- degassing	4.7
- explosive	2.0
H_2S	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**

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.

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

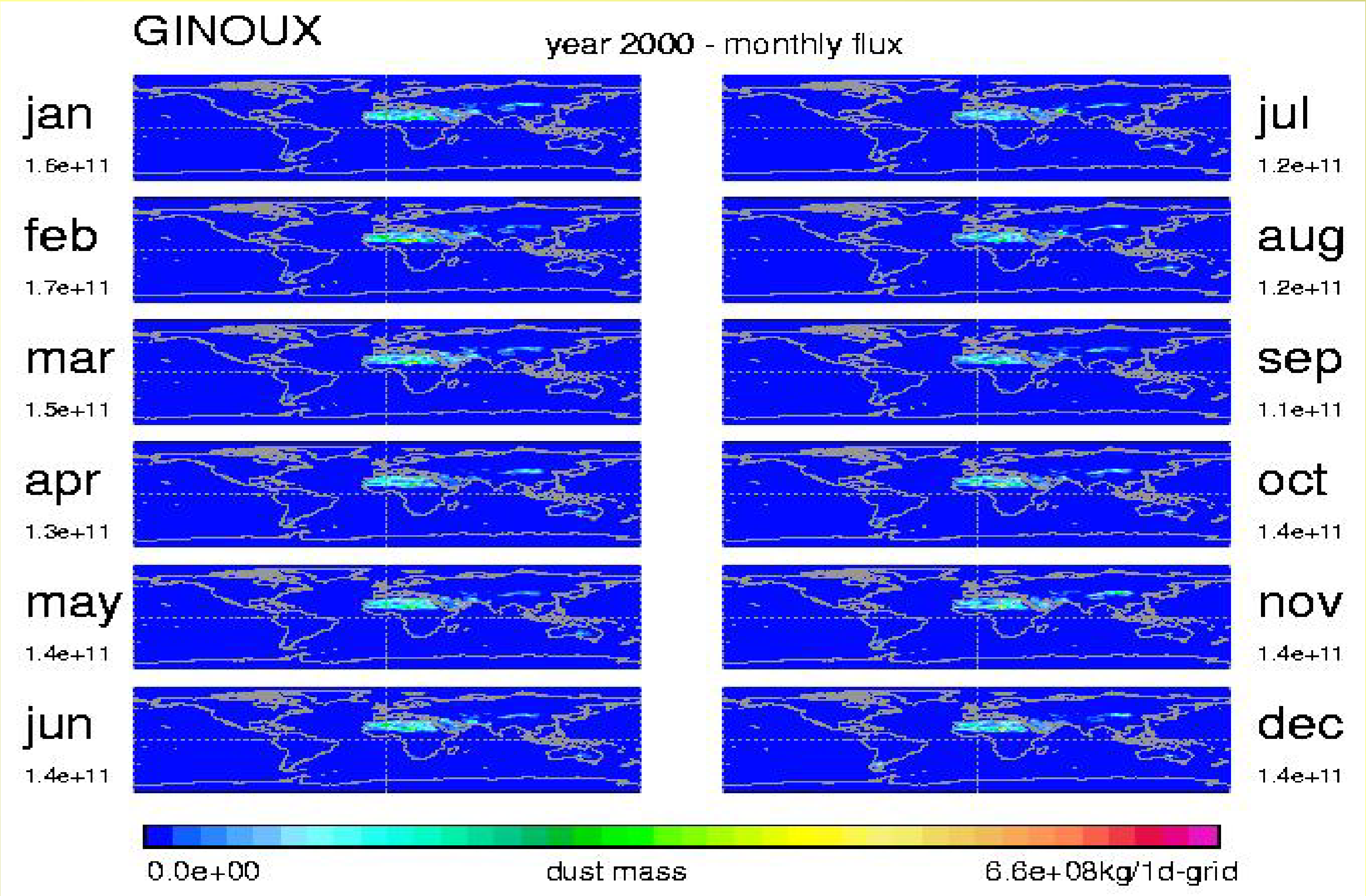
- **Accumulation mode** *(0.1 to 1μm sizes)*
  - Concentration /per grid-box * *(mode2_number)*
  - Mode radius (for number) *(mode2_radius)*
  - Standard deviation: 1.59 *(constant distribution width)*
- **Coarse mode** *(1 to 6 μm sizes)*
  - Concentration /per grid-box * *(mode3_number)*
  - Mode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

  - *conversion from "/gridbox" to "/m2" provided (gridbox_area)*

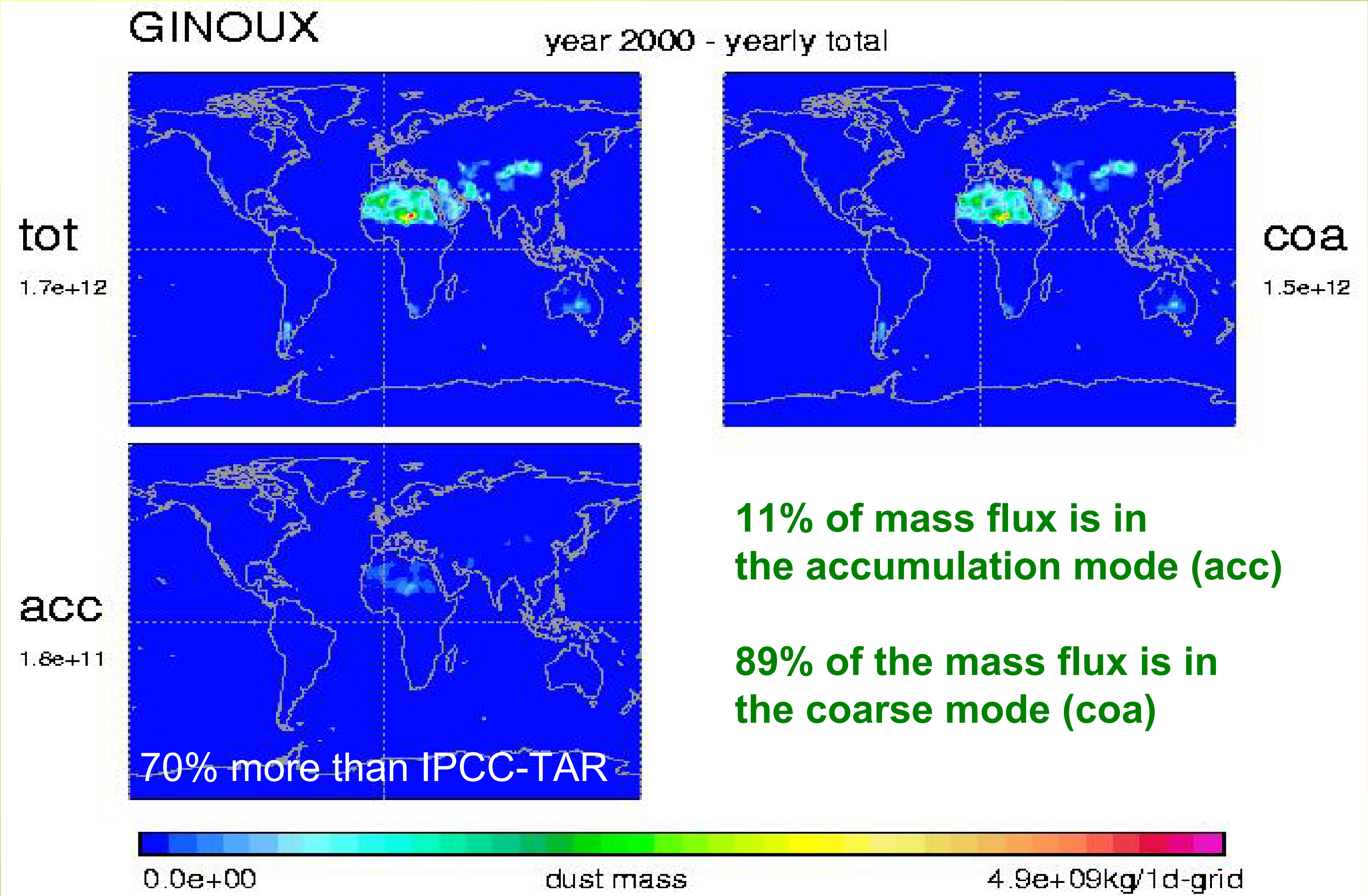
NOTE: for particular size-bins an idl-routine 'binflux.pro' (in "/help_ncf ") is provided, which determines the emission flux (from both modes) for any given size-interval

for interpolation help contact kinne@dkrz.de

Dust - monthly average mass-flux



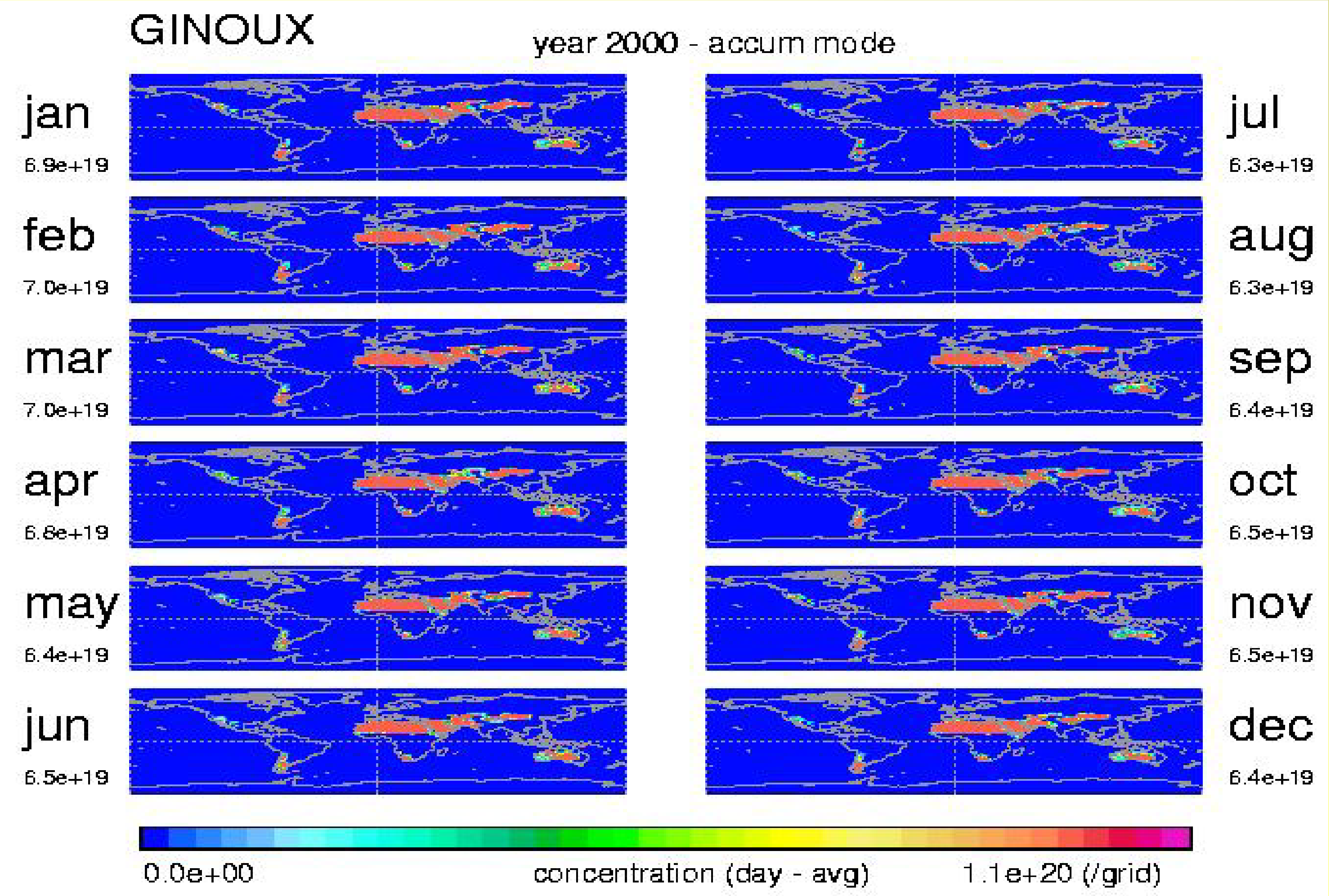
Dust - yearly average mass-flux



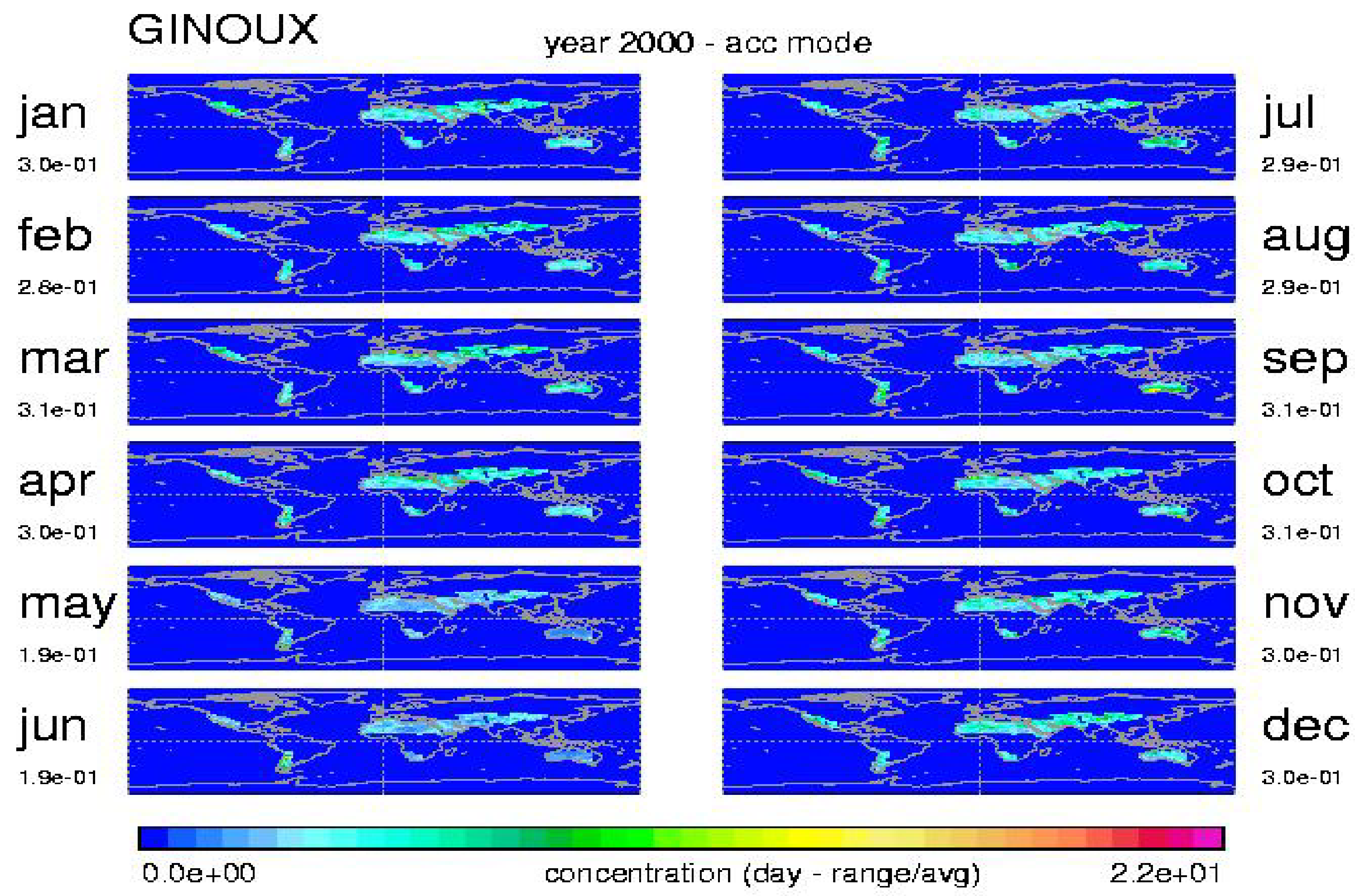
11% of mass flux is in the accumulation mode (acc)

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

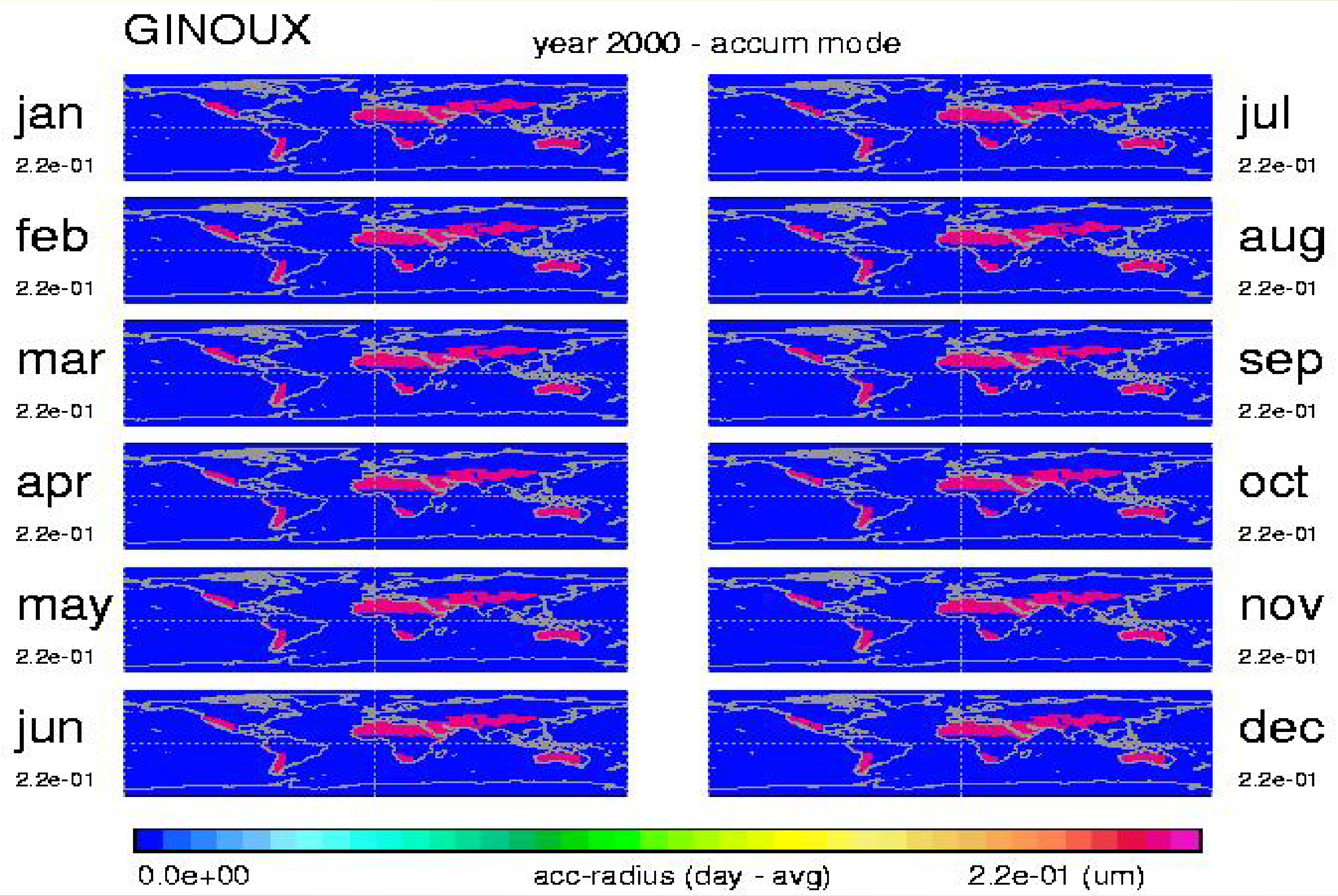
DUST – daily avg. accum. mode concentration



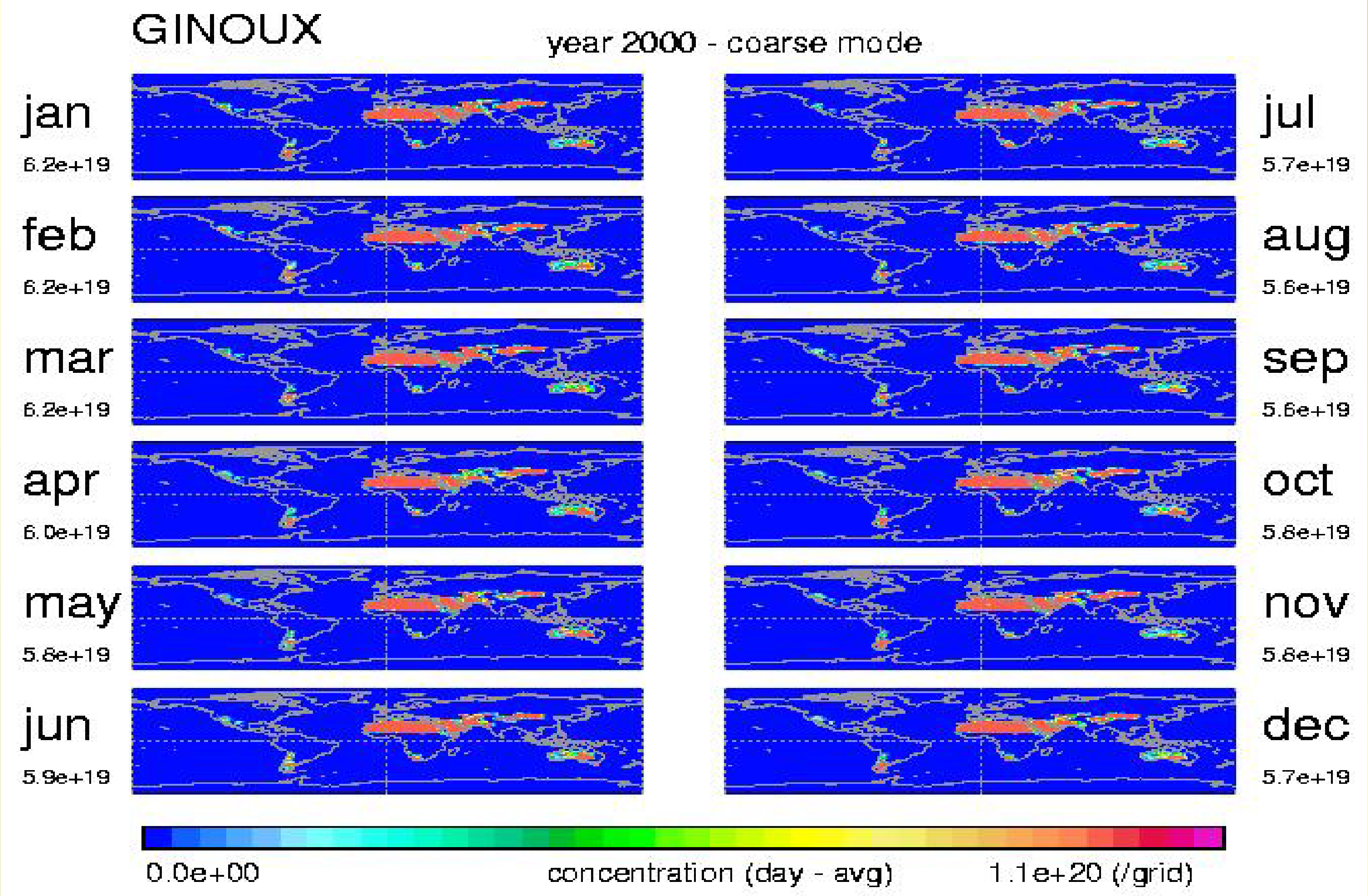
Dust – monthly variations for accum. concentrations



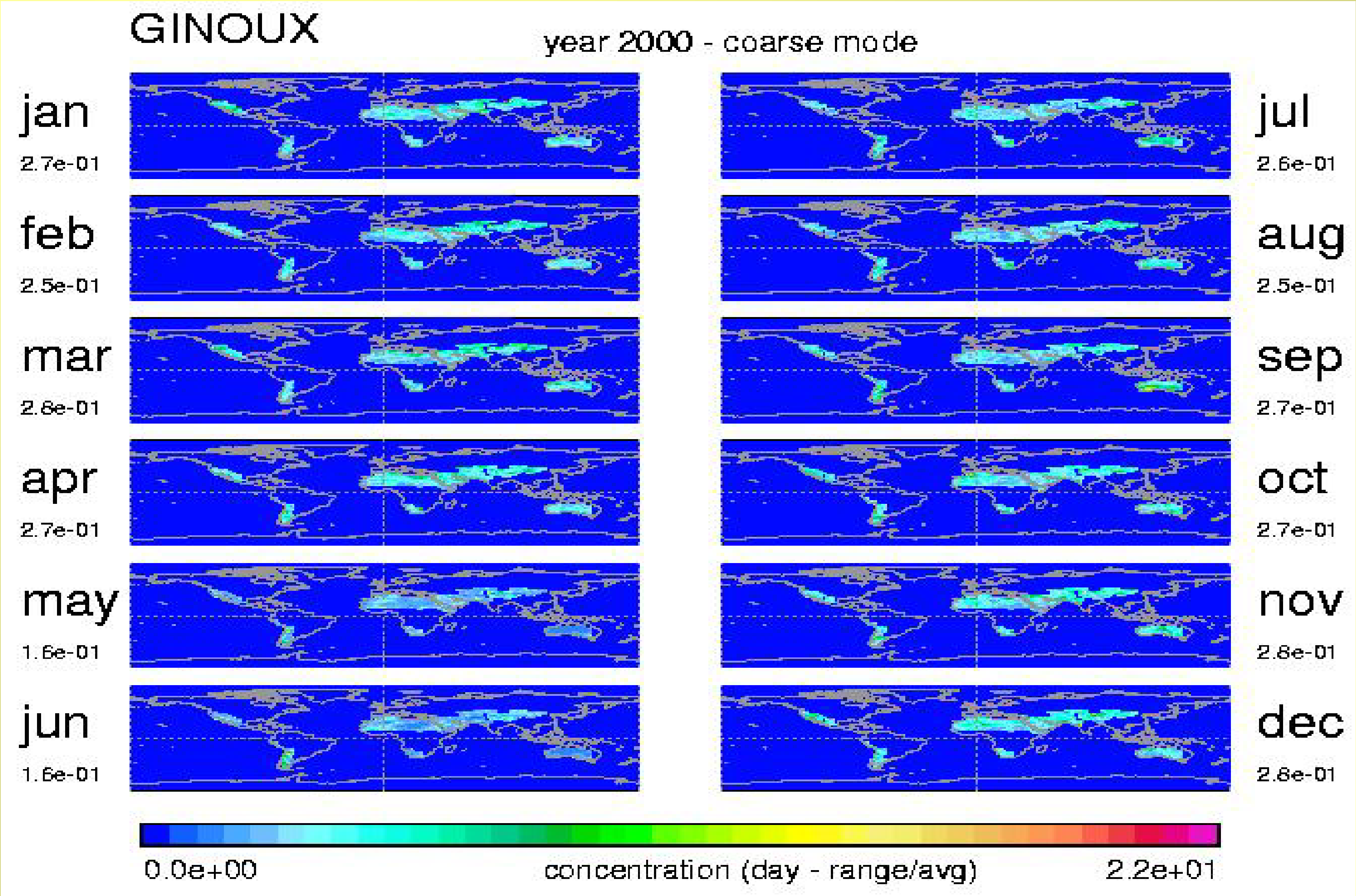
Dust – daily average accum. mode radius



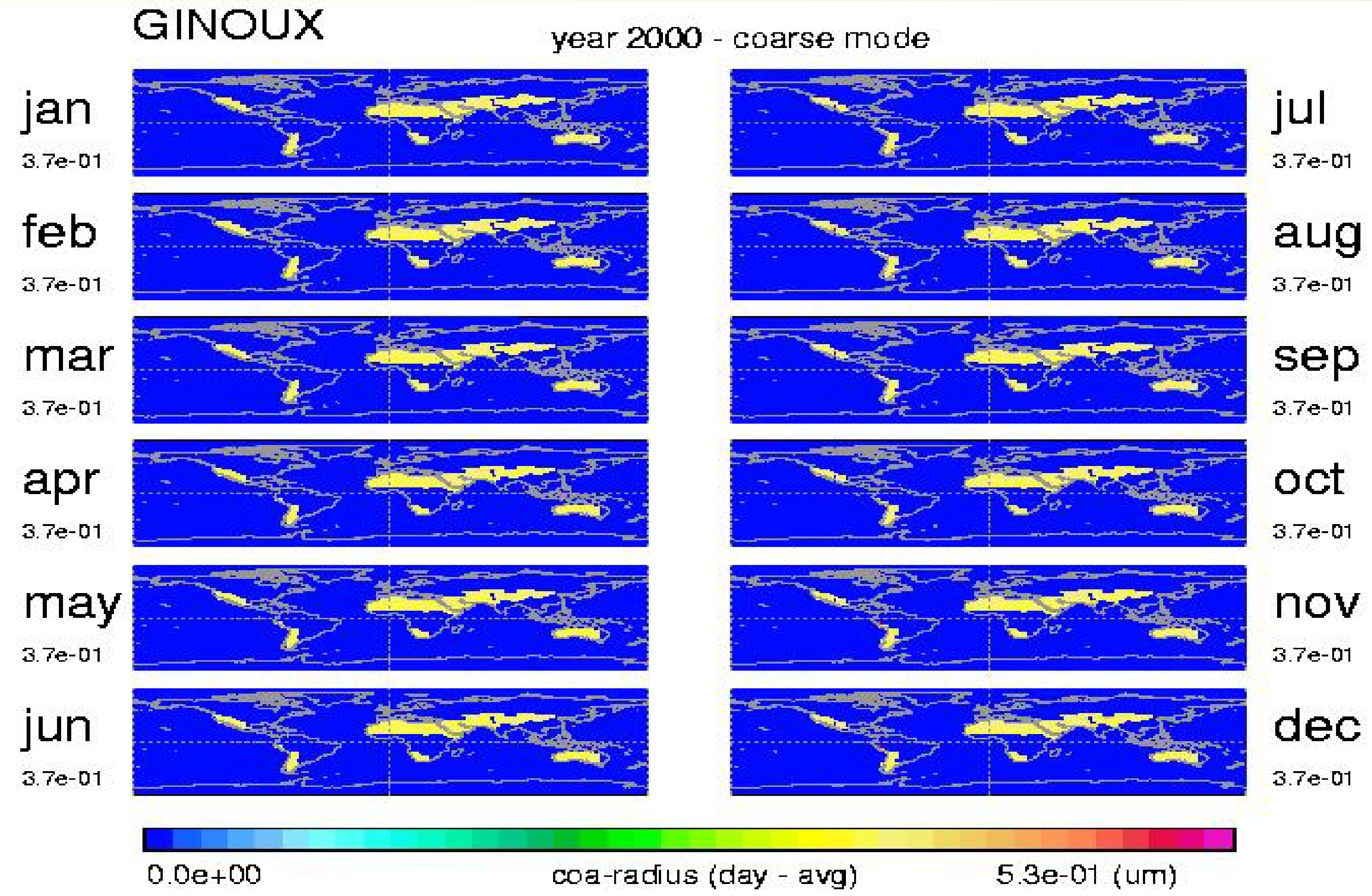
DUST – daily avg. coarse mode concentration



Dust – monthly variations for coarse concentrations



Dust – daily average coarse mode radius



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 20μm diameter are considered)

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

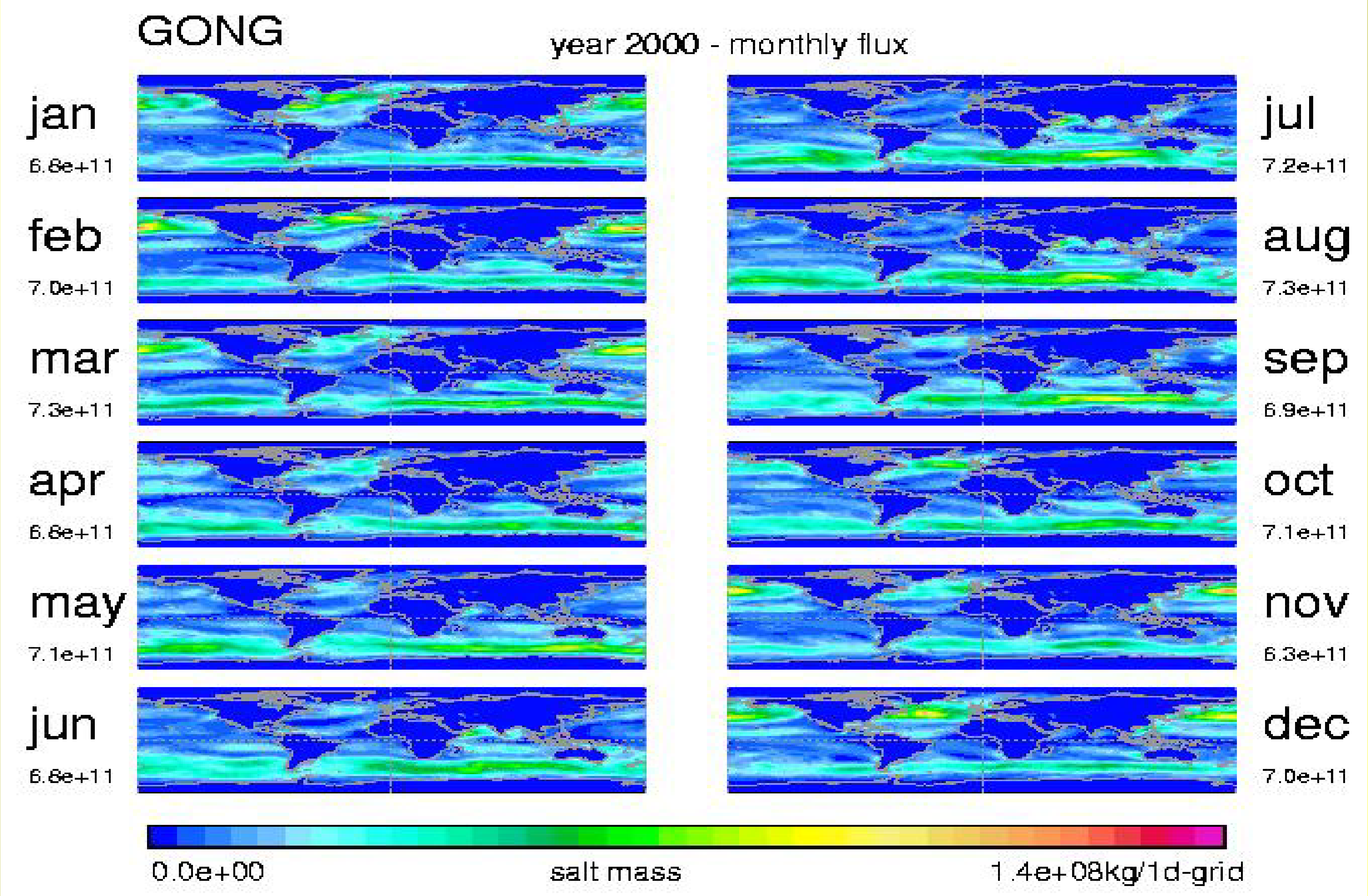
Sea-Salt Size Modes

- **Aitken mode** *(sizes smaller than 0.1μm)*
  - 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)*

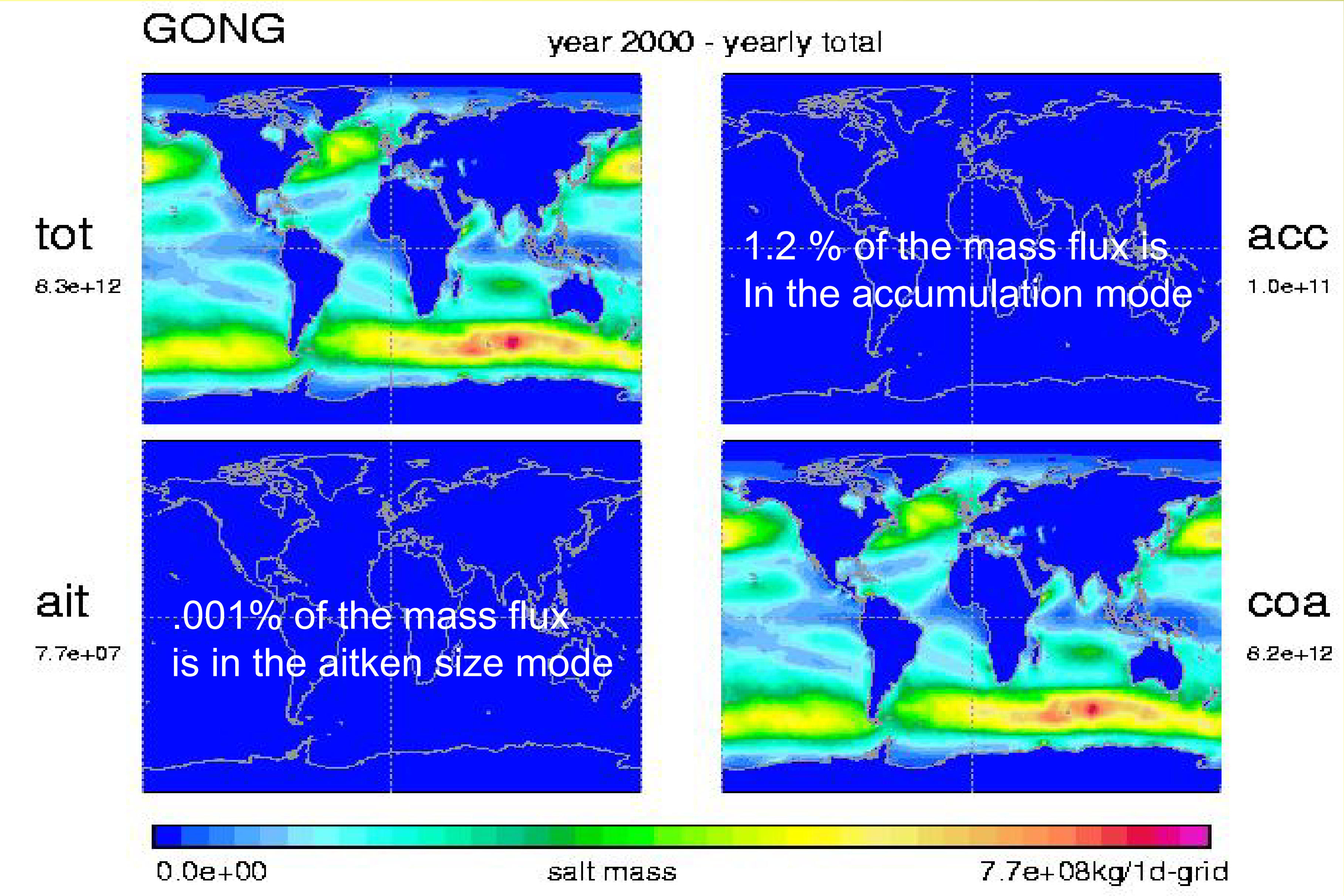
"/gridbox" to "/m2" conversion data provided

'binflux.pro' calculates fluxes for any size bin ("/help_ncf")

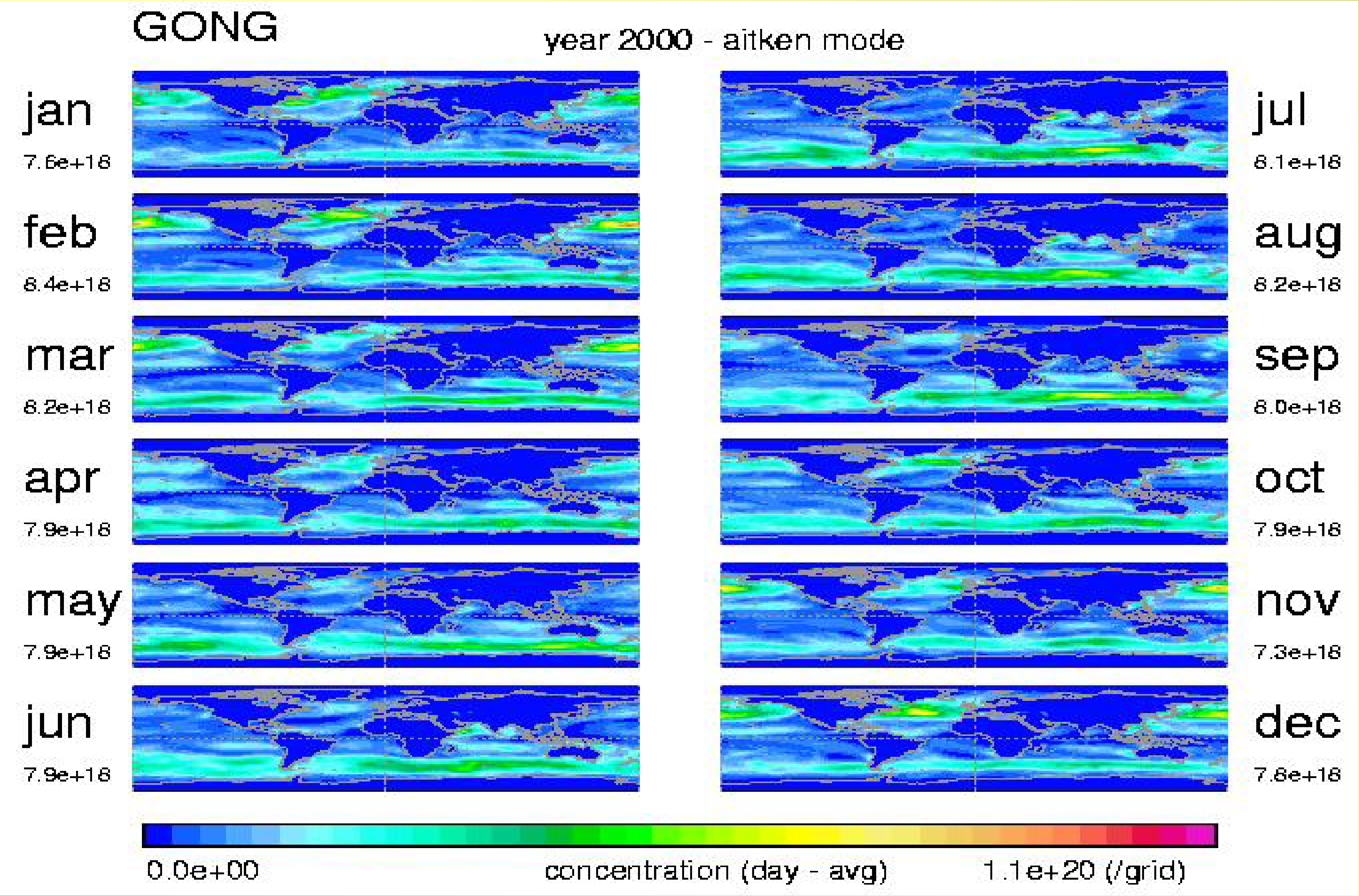
Seasalt - monthly average mass-flux



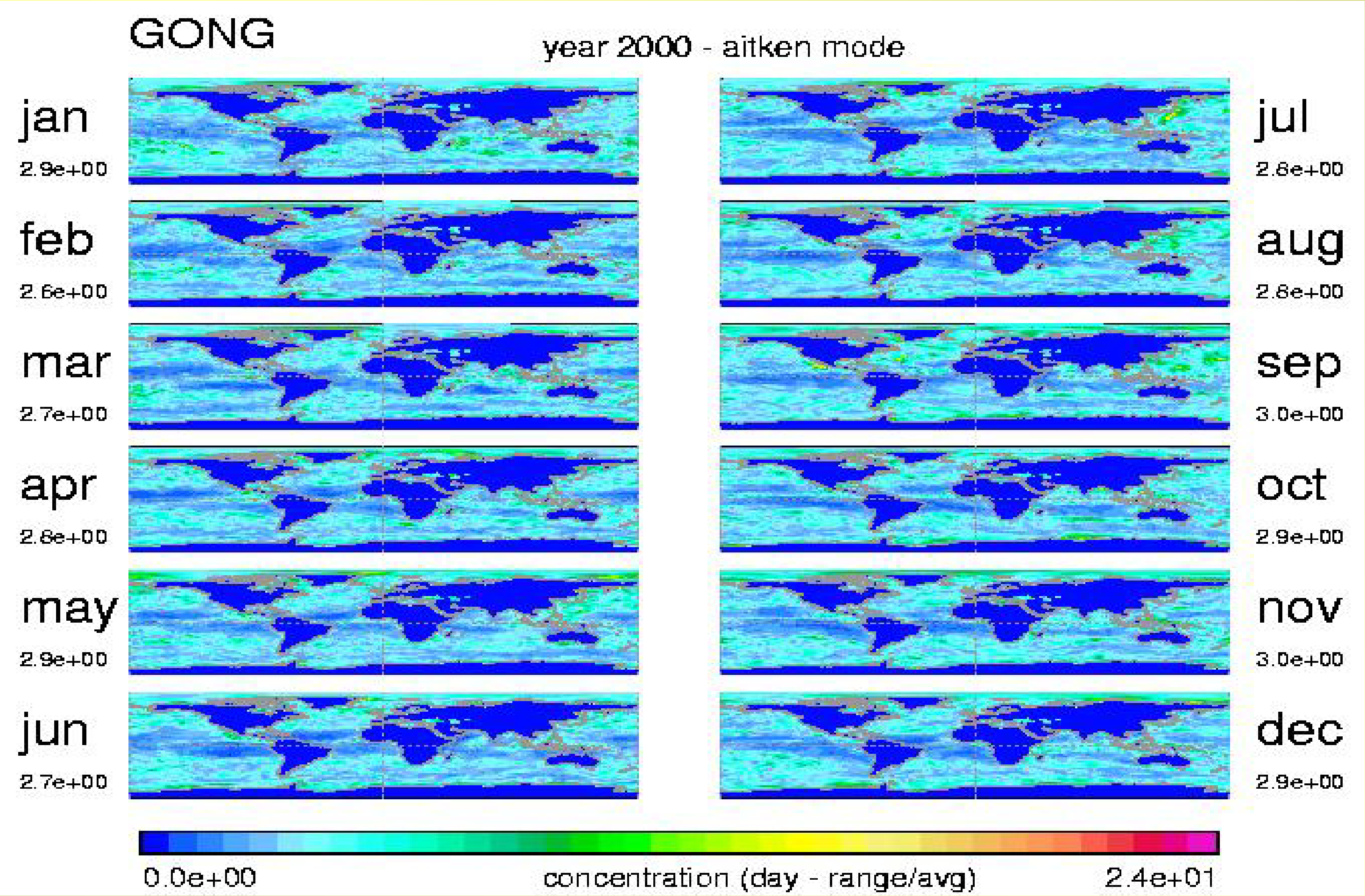
Seasalt – yearly average mass-flux



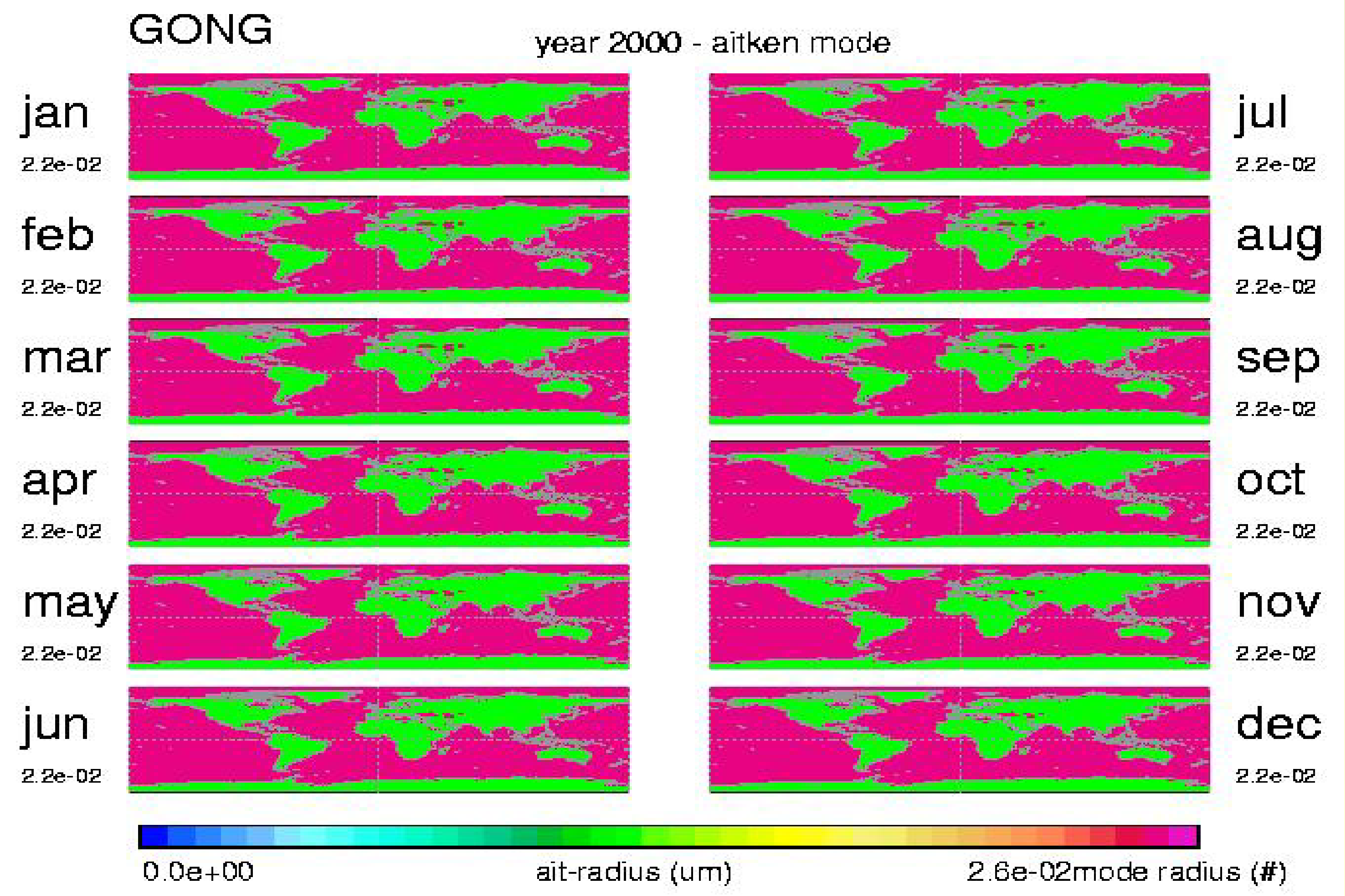
Seasalt – daily avg. aitken mode concentration



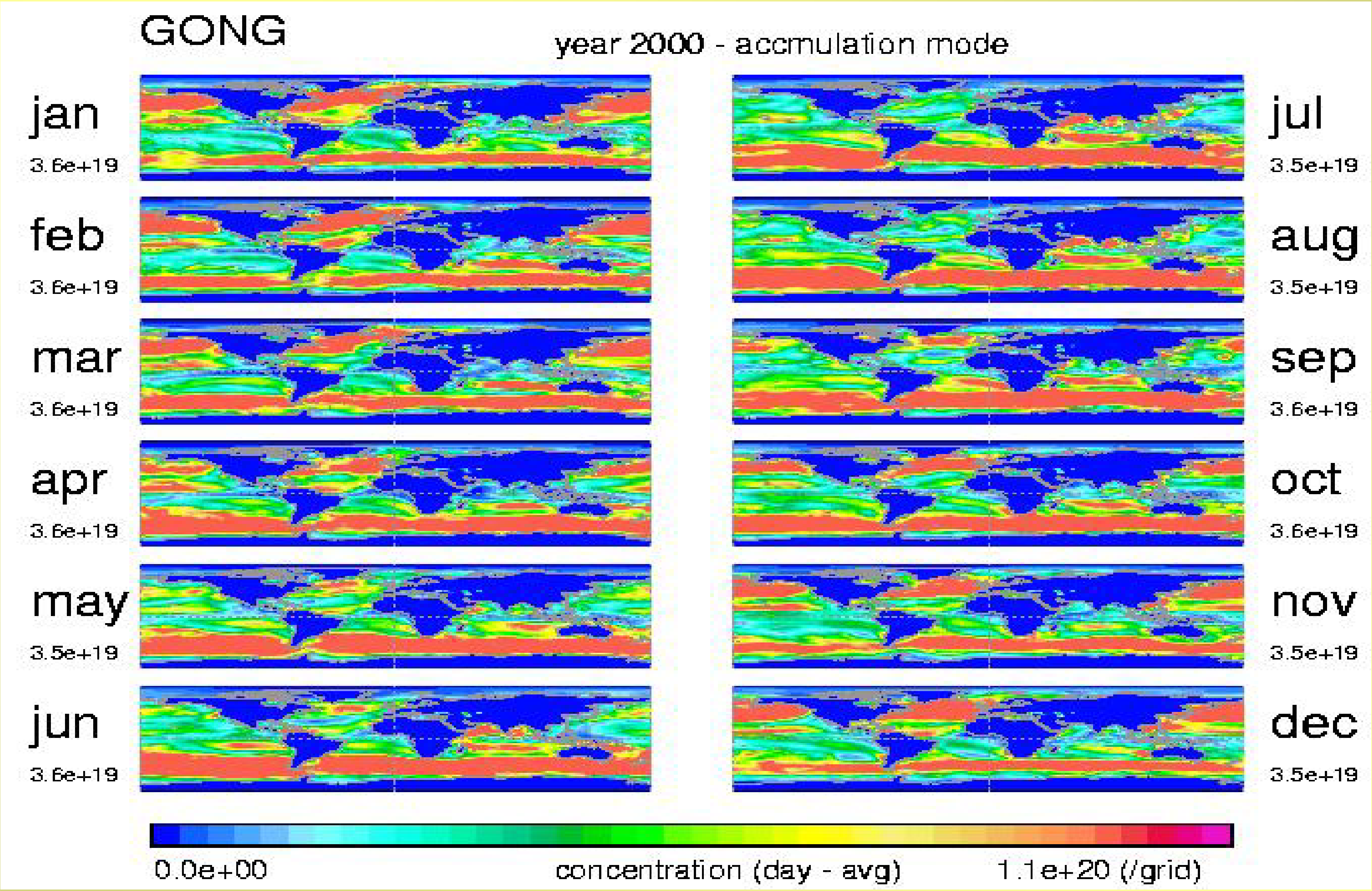
Seasalt – monthly variations for aitken concentrations



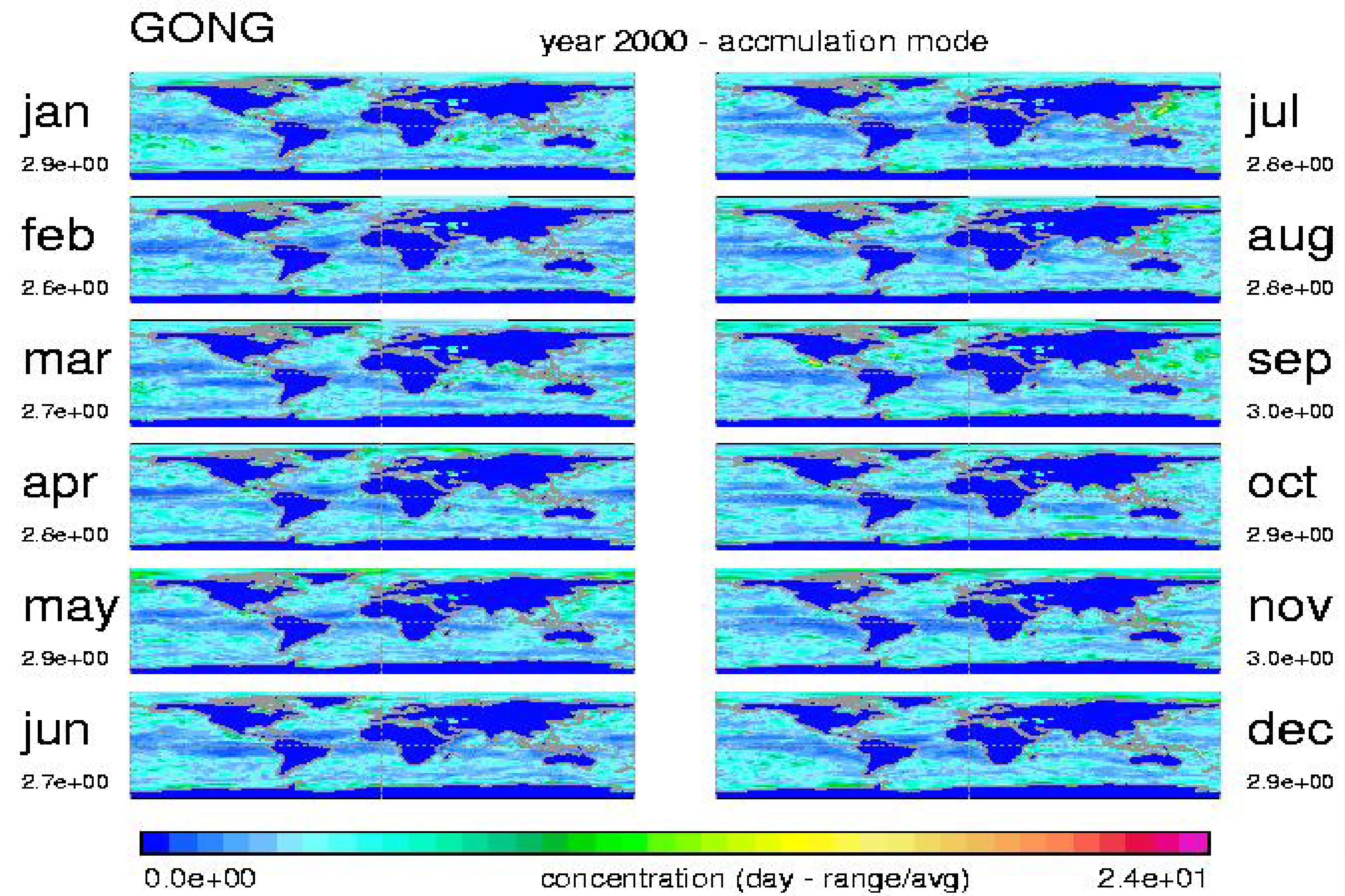
Seasalt – daily average aitken mode radius



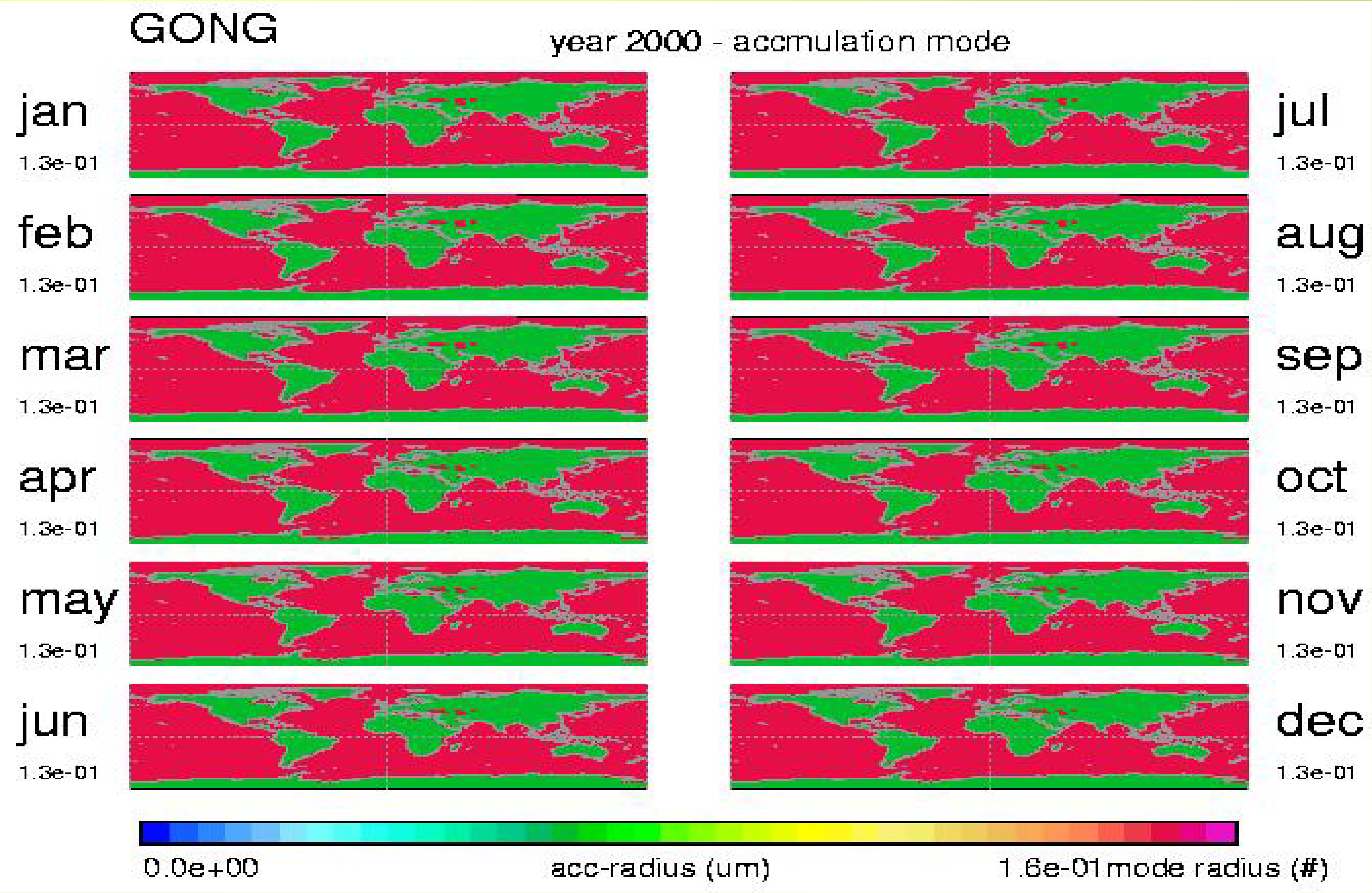
Seasalt – daily avg. accum. mode concentration



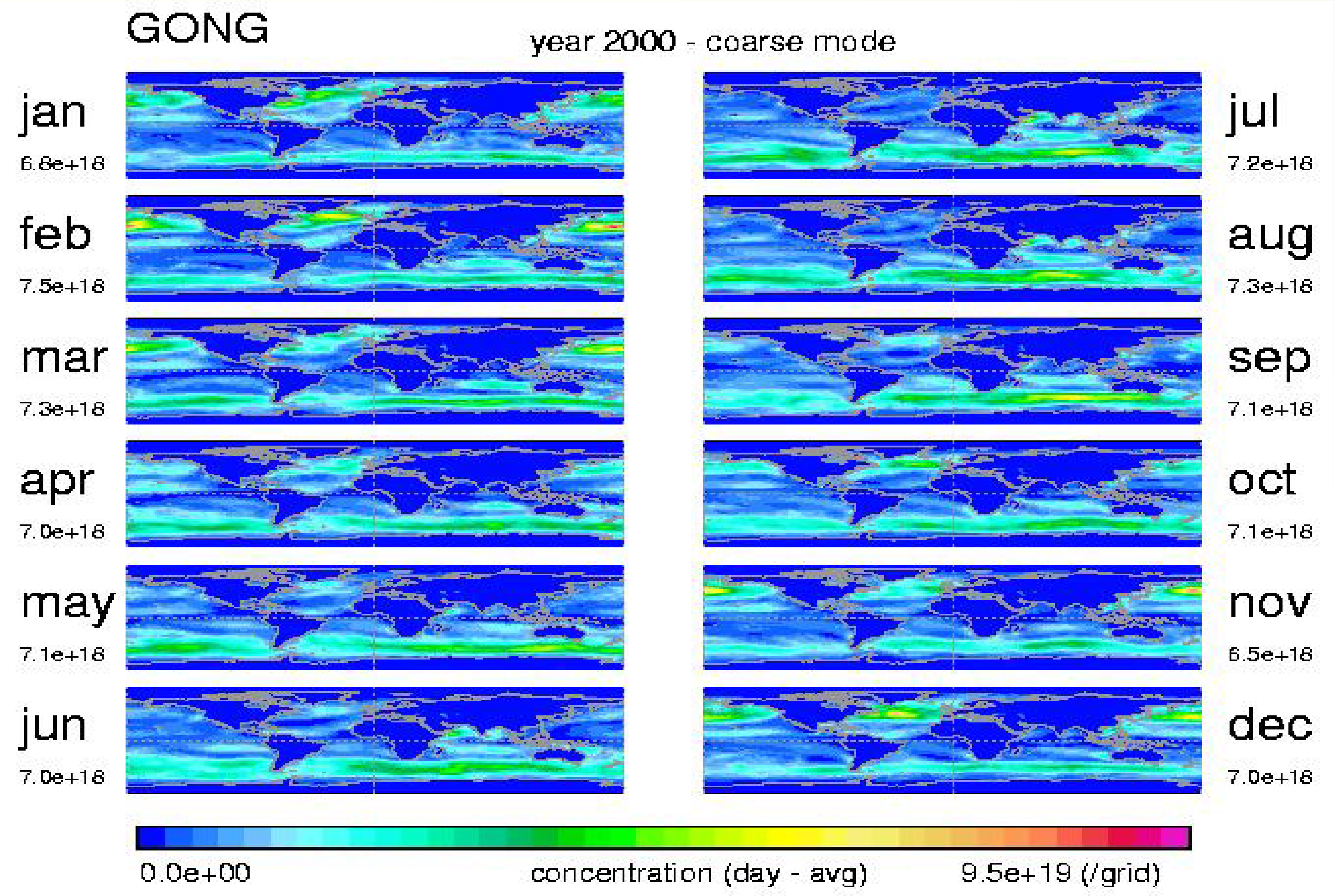
Seasalt – monthly variations for accum. concentrations



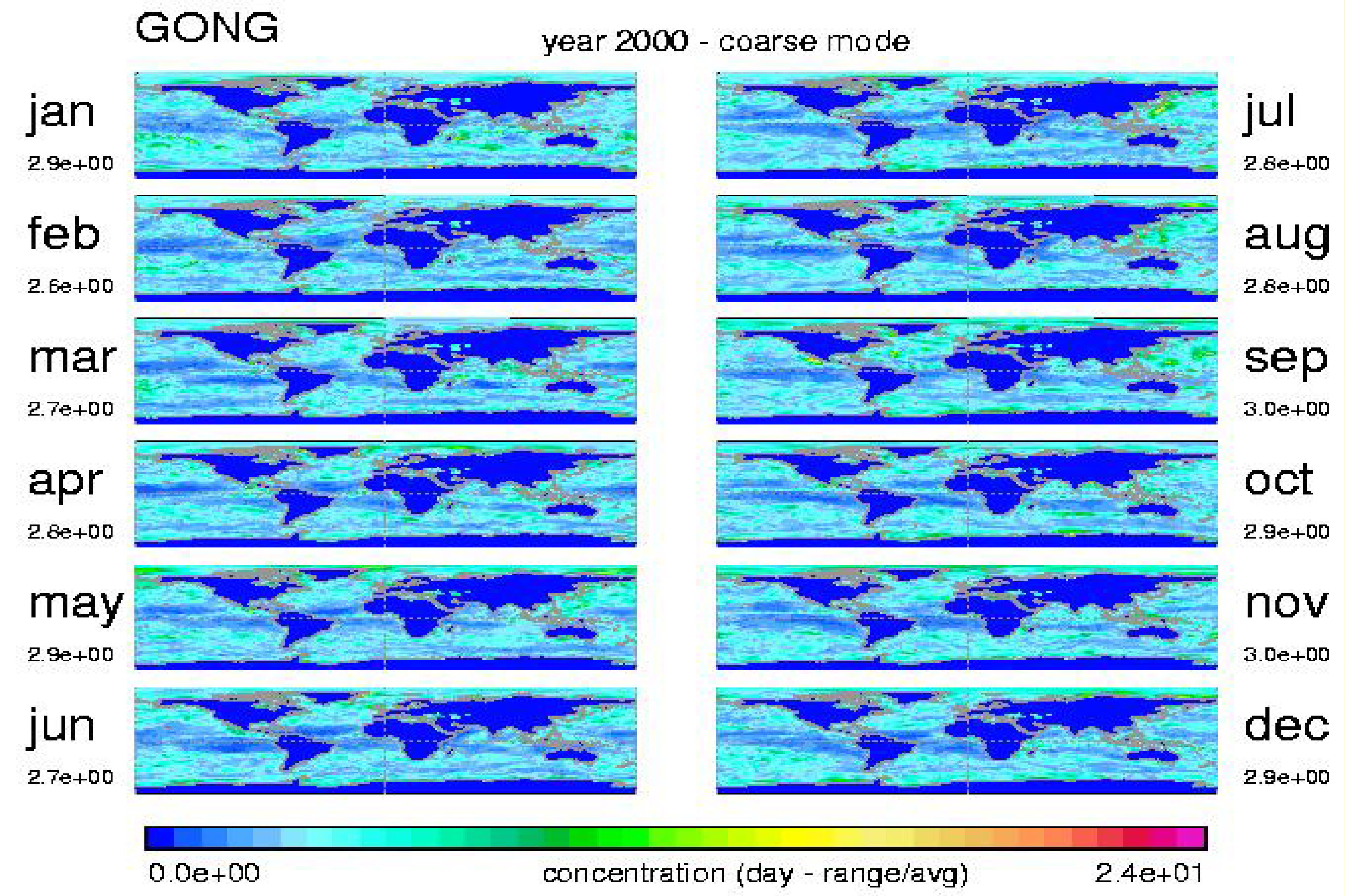
Seasalt – daily average accum. mode radius



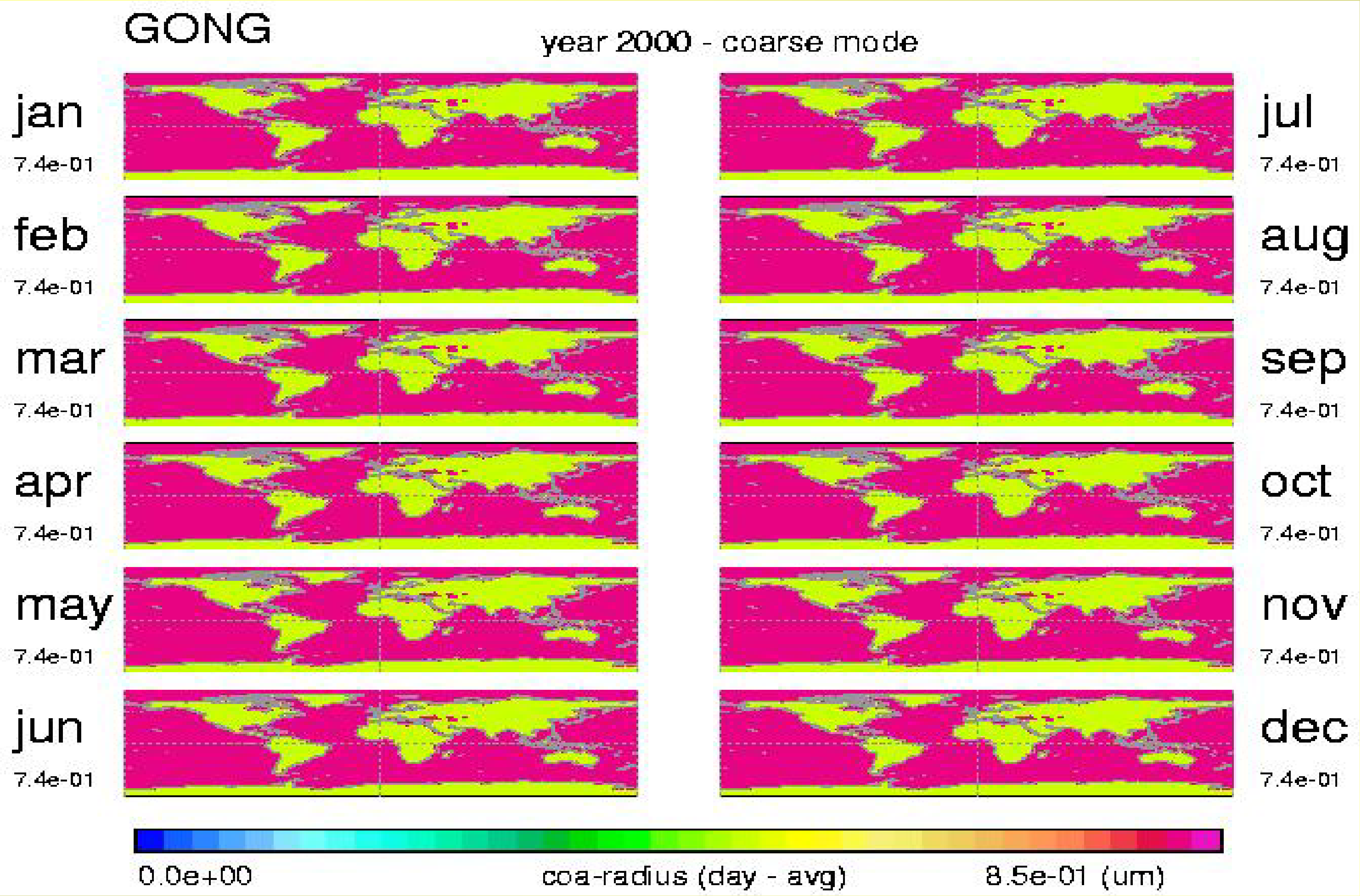
Seasalt – daily avg. coarse mode concentration



Seasalt – monthly variations for coarse concentrations



Sea-salt – daily average coarse mode radius



DMS

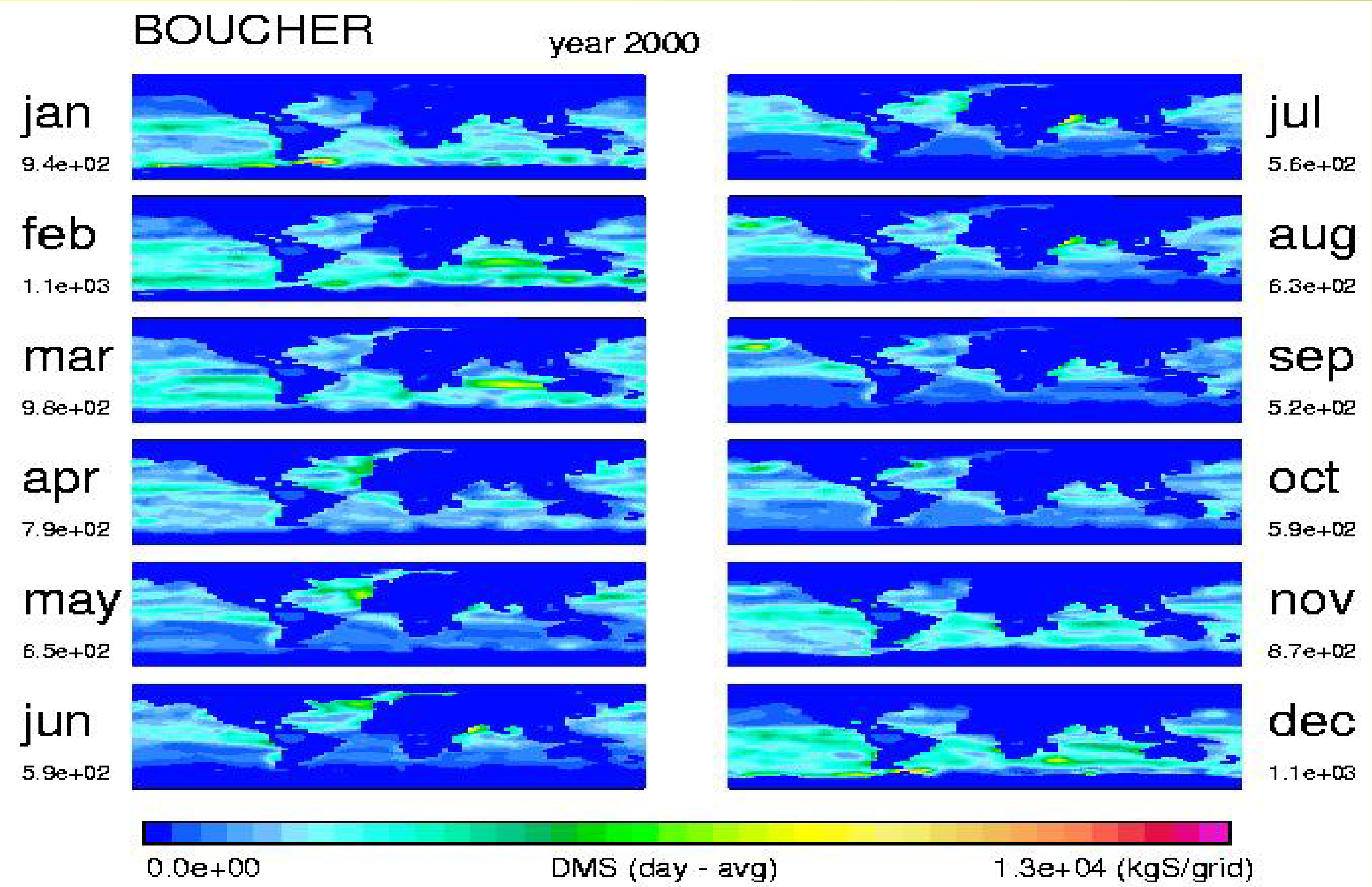
DMS

- **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)

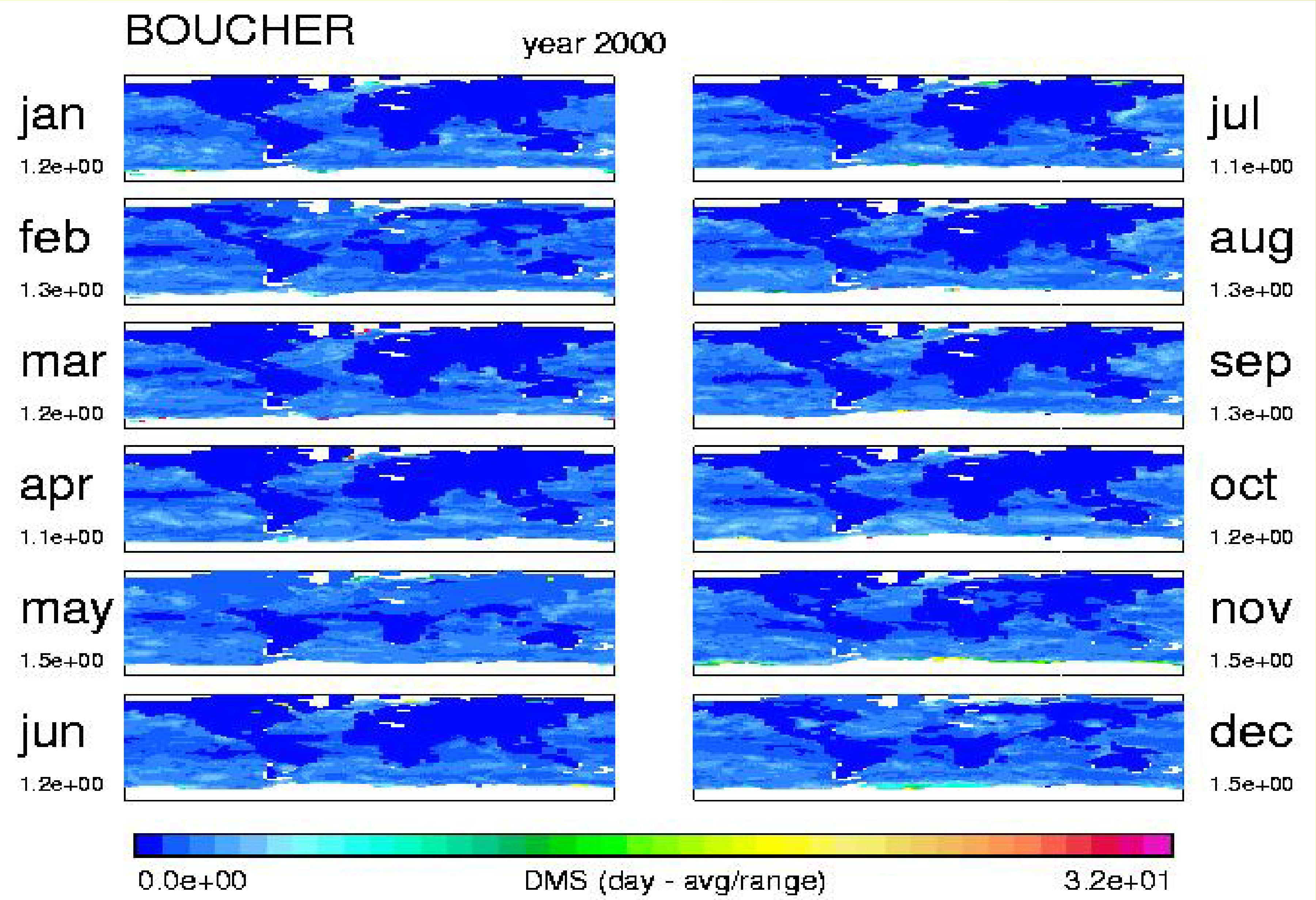
based on LMDZ-GCM simulations by Olivier Boucher

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

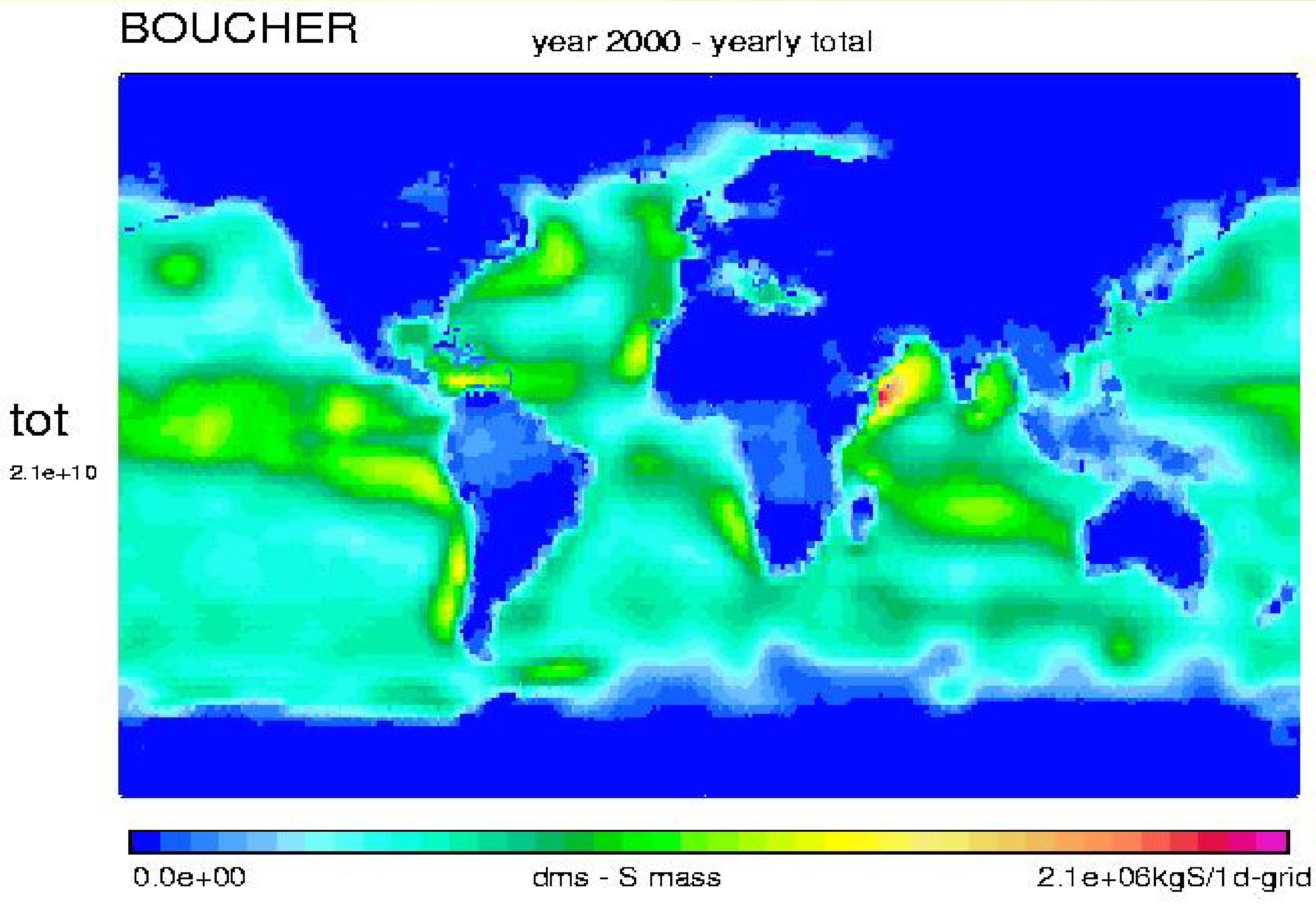
DMS - daily avg. mass-flux



DMS – mass flux monthly variability



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

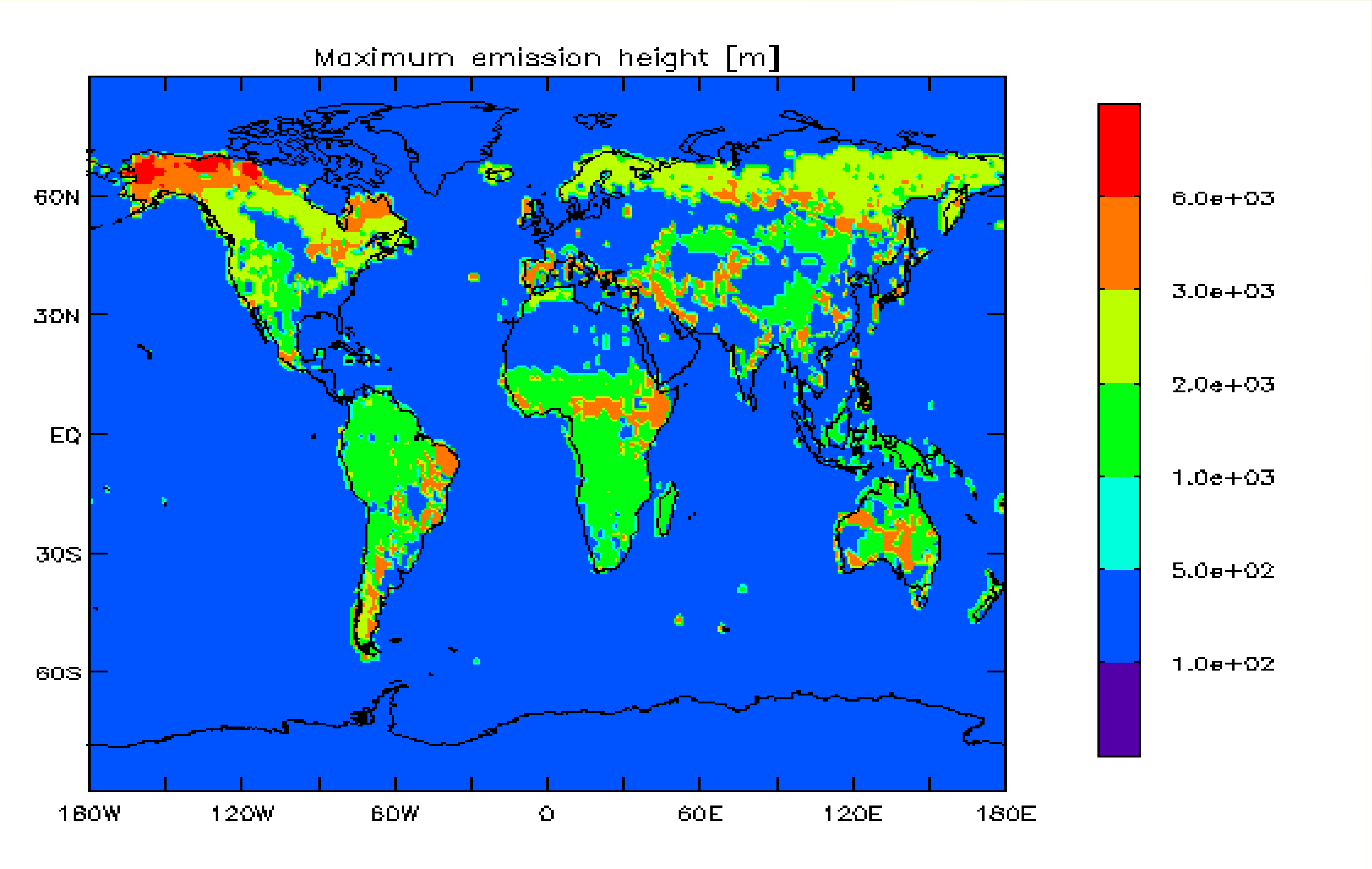
- **Biomass burning (OC/BC/SO2) ECO-system dependent**
  - 0-.1km /.1-.5km /.5-1km /1-2km / 2-3km /3-6km

  (**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

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!