AIR POLLUTION

László Makra

Tartalom

1. Air pollution

Natural and anthropogenic air pollution

What is air pollution?
It has two interpretations

- **Air pollution** – a process;
- **Air pollution** – a status;

- **What is air pollution, as a status?**
  - ✓ A level of presence of any substance in the atmosphere that is detrimental or harmful to human health, well-being, animal, or plant life, property, or unreasonably interfere with the life and property enjoyment of their intended use.

    Florida Administrative Code, Chapter 17-2.

  - ✓ Presence of foreign material of gaseous, liquid, or solid consistency in the atmosphere, which alters the natural composition of the air to such an extent that it may exert a negative impact on the environment.

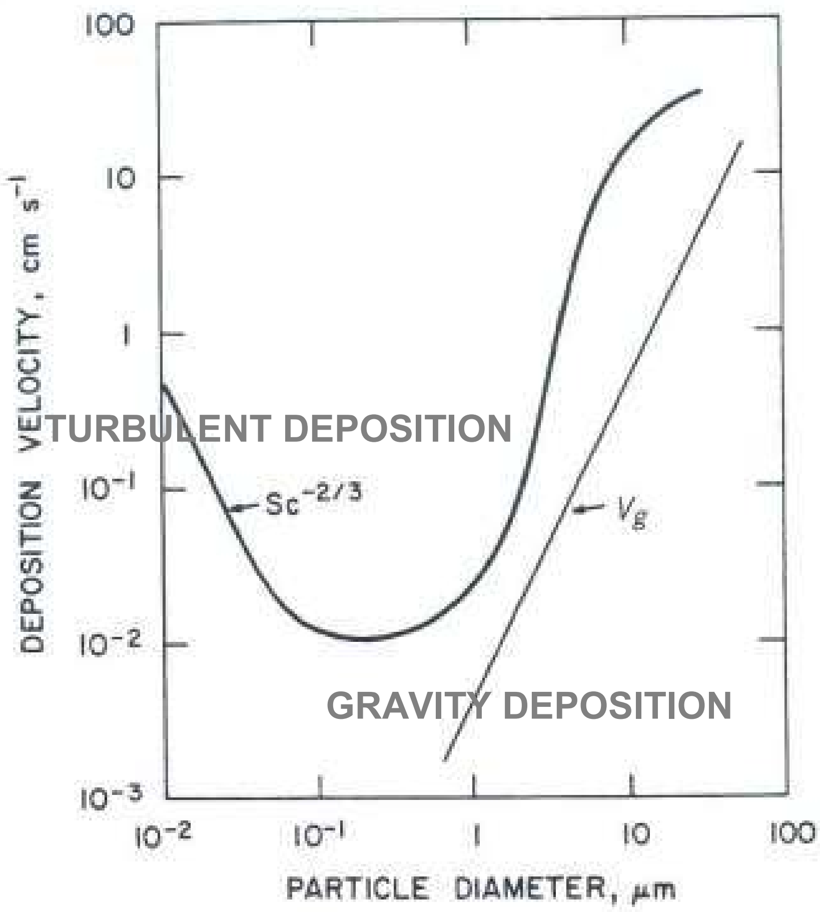
Czelnai, R., Szepesi, Dné, 1986: Meteorológia. (Meteorology.)Műszaki Értelmező Szótár, 56., Akadémiai Kiadó, Budapest, 596 pp.

What is air pollution?
It has two interpretations

- The air is polluted, if **not tasteless, odorless and colorless**.
- The air is polluted if gaseous substances or particles get into the air to the extent that are harmful for plants, animals and humans.
- Agents emitted and transported in the atmosphere which influence operation of body.

WHAT IS AEROSOL?

- liquid / solid particles
- 0.01-10 µm
- dust, smoke, fog
- short residence time
- condensation
- light absorption



DEPOSITION VELOCITY IN THE FUNCTION OF PARTICLE SIZE

Why is it important studying air pollution and air quality?

How important is air pollution compared to other types of pollution (from the perspective of spcial benefits)?

Examples from the scope of air pollution problem?

Pollution sources

Air pollutants:

- Suspended particles, which are present in high enough concentrations in the air to endanger human and animal health, to damage vegetation and plant associations, or to poison the given environment (*Ahrens*).

Natural sources:

dust picked up by the wind	**Suspended particles**
volcanic activity	**dust; ash; gases, e.g. SO_2, CO_2**
forest fires	**smoke, ash, unburned hydrocarbons, CO_2**
vegetation	**VOCs, pollen, spore**
ocean waves	**salt particles**

Anthropogenic sources

→ **point source (chimney of an industrial plant)**

→ **Aerial source (settlement – residential heating)**

→ **Line source (roads, highway)**

Industry

SO_2 : Fossile fuels (brown coal, oil, gas), sulphuric acid production, paper industry

CO : Incomplete combustion (energy industry, metallurgy)

NO_2 : High-temperature combustion (energy industry, electrical discharge)

Fluorine: Alumínum smelting, enamel manufacturing, phosphorous fertilizer manufacturing, brick and tile industry

Solid particles: In all combustion (metallurgy, energy industry)

Agriculture:

CO, C_xH_y:	Biomass burning
CH_4 :	Rice cultivation, ruminant animals
NH_3 :	Animal urine
N_2O :	Bacteria in soil (denitrification)
Solid particles:	Pesticide spraying

Deforestation:

CO_2 :	Reduction in storage capacity

Settlement (infrastructure):

CH_4, CO_2 :	Landfills
CO, CO_2, SO_2 :	Heating
CO, SO_2, NO, NO_2:	Transportation
Solid particles:	Transportation (tar, lead), heating

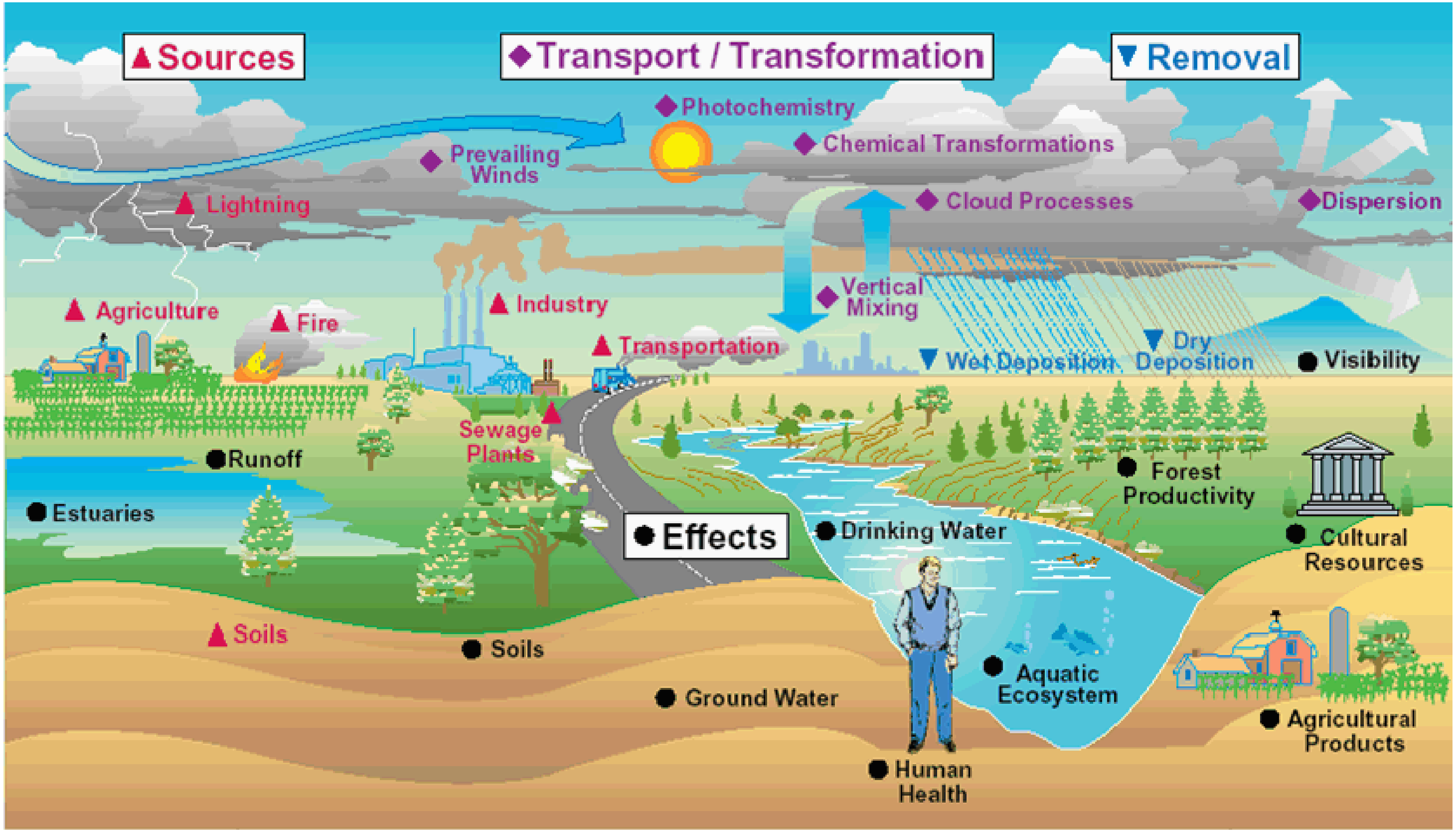
Gasoues emissions [Tg/yr = 10^{12} g/yr]

Gas	Anthropogenic	Natural	Anthropogenic, %
CO_2-C	7 000	100 000	7
CO-C	505	75	87
CH_4-C	270	120	69
SO_2-S	70	35	67
NO-N	20	10	67
N_2O-N	1	10	9
NH_3-N	20	20	50
VOC	75	750	9
Freons	1	0	100

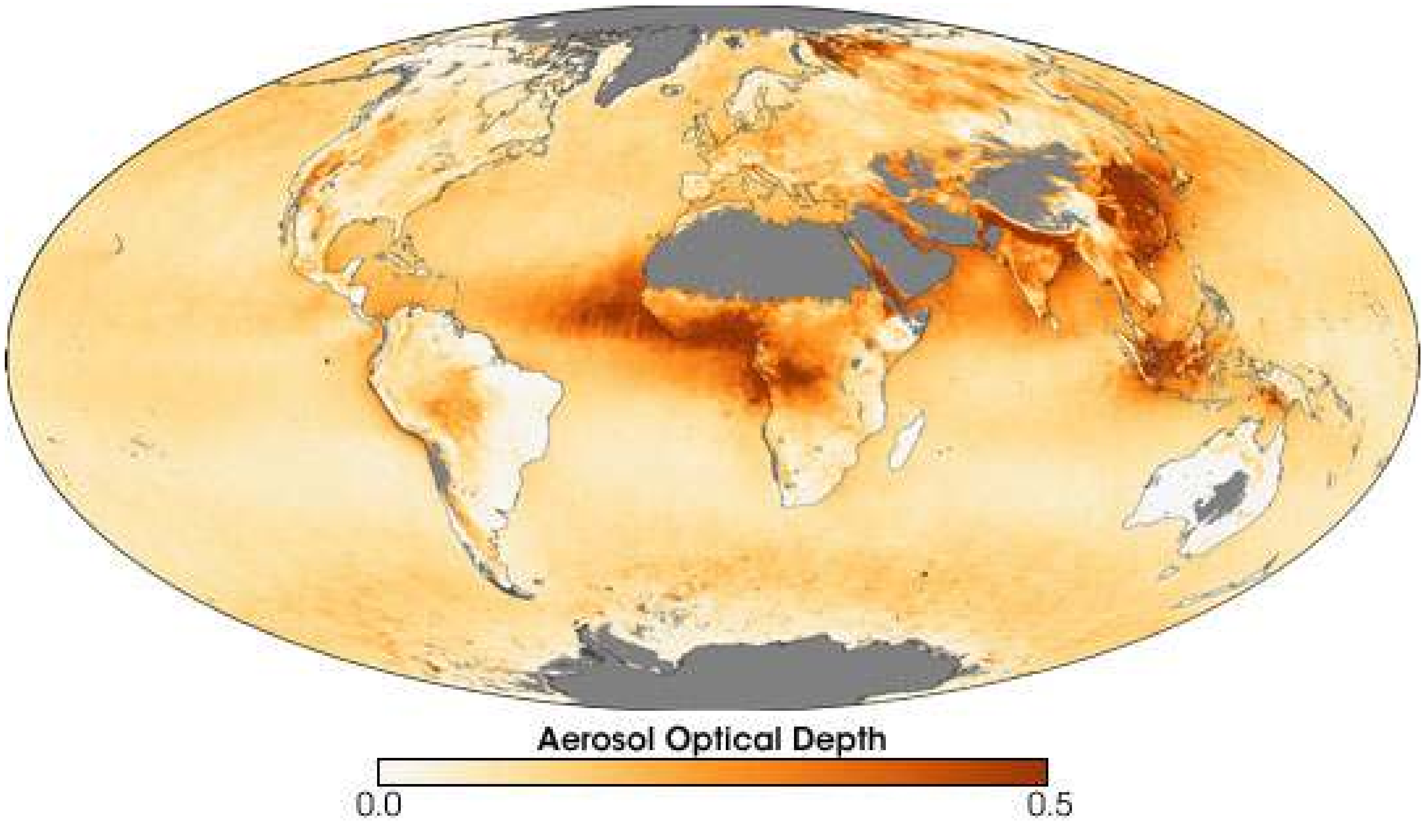
Air pollution – harmful substances in the air and their sources

Pollutant group	Solid+aerosol	Gas+vapour	Pollution percentage from pollutant material
Fossil fuel combustion	dust, smoke, soot	SO_2, NO_x, CO, CO_2	0,05-40
Motors	smoke (oil smoke)	NO_x ,CO, acidic vapours	4-7 for hydrocarbons
Petrochemistry	fog, smoke	SO_x, H_2 S, NH_3, hydro-carbons, mercaptans	0,25-1,5
Chemical industry	fog, mist, smoke, inorganic and organic salts	SO_x, CO, NH_3, organic and inorganic acids	
Metallurgy, metalworking	dust, smoke, ore dust, sand	SO_2, CO fluorides, organic substances	0,5-2
Mineral industry, mills	dust, soot, silicon compounds	SO_2, CO	
Coal mining, coal industry	dust, soot	fluorides, tar, phenol, SO_2, H_2S, hydrocarbons	
Agriculture and food industry	dust, fog	organic substances, NH_3, CH_4, odorous substances	0,25-1

Overview on air pollution

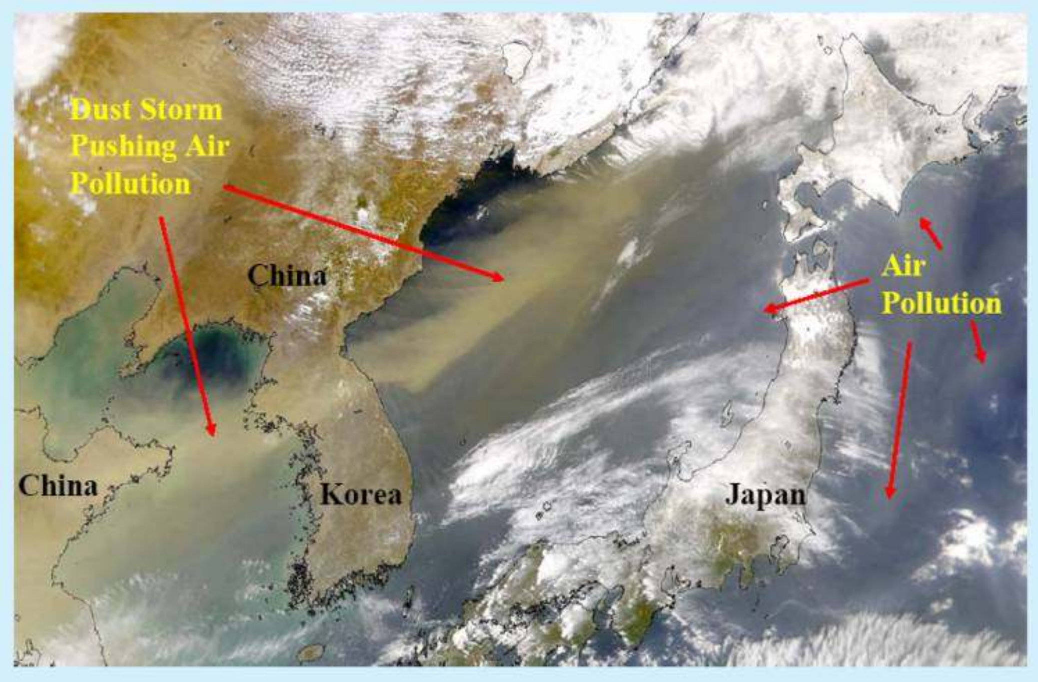


Aerosol Optical Depth 2006
http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=17575



Natural sources

Dust storm in Asia



http://www.cmdl.noaa.gov/images/asian_dust.jpg

Street view from Beijing (**China**) during a dust storm.

www.lakepowell.net/asiandust.htm

Intense storms could reach North America in 5-7 days.

Is there any advantage of dust storm?

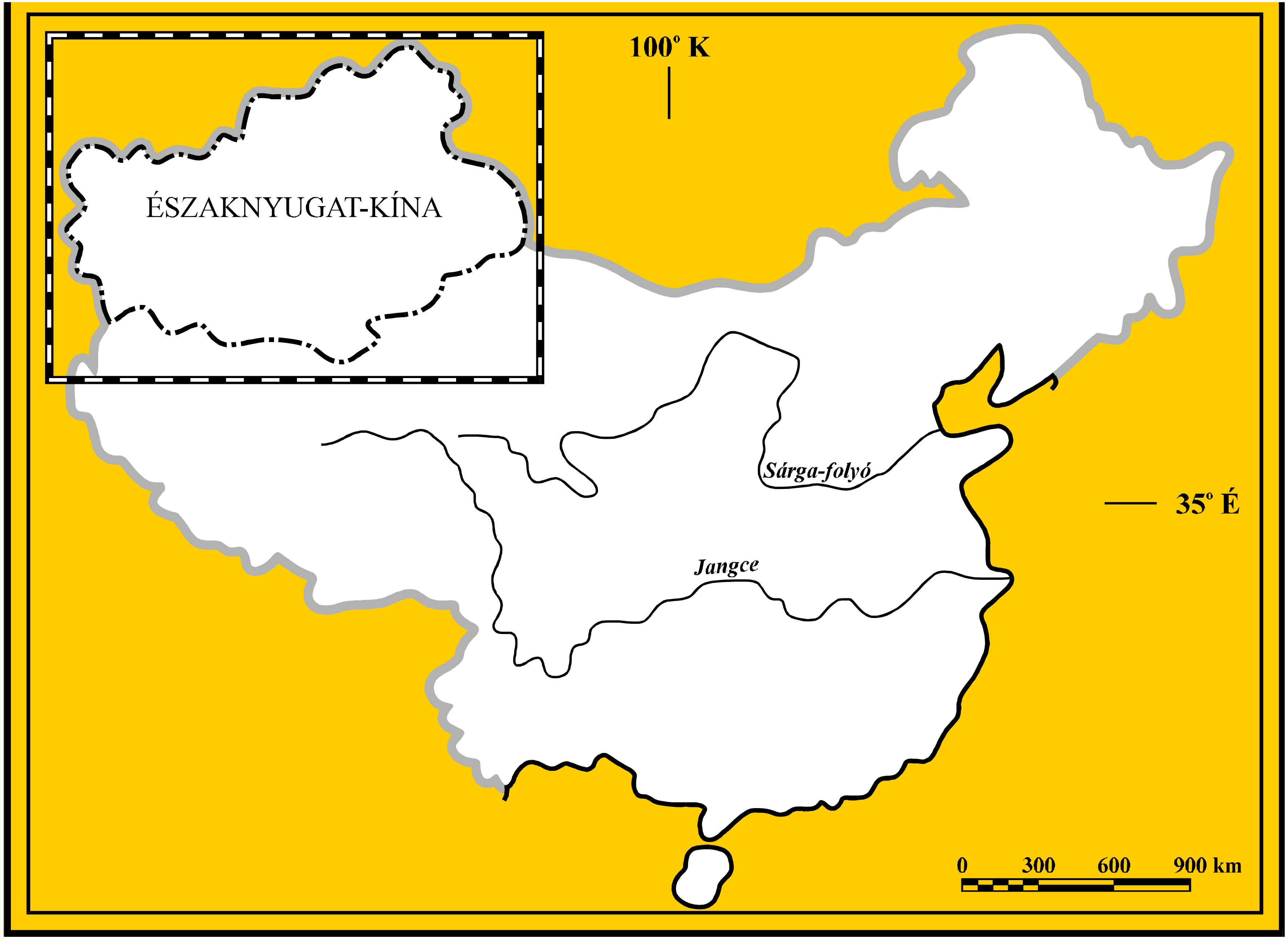
László Makra

1990-2000: 8 travels in China, among them 2 field research expeditons;

1st China-expedition, 1990

Beijing – Nanjing – Shanghai – Suzhou – Guilin – Jangzhou – Kunming – Csengcsou – (Chang Jiang) – Vuhan – Hsian – (Ordos-Plateau) – Lanzhou – Urumqi (Xinjiang-Uygur Autonomous Territory);

→ Dzhungarian Basin, northern slopes of Tien Shan, Turpan Basin, northern entrance of Takla-Makan Desert (Yuli), southern slopes of Tien Shan;



Map of China with North-western China

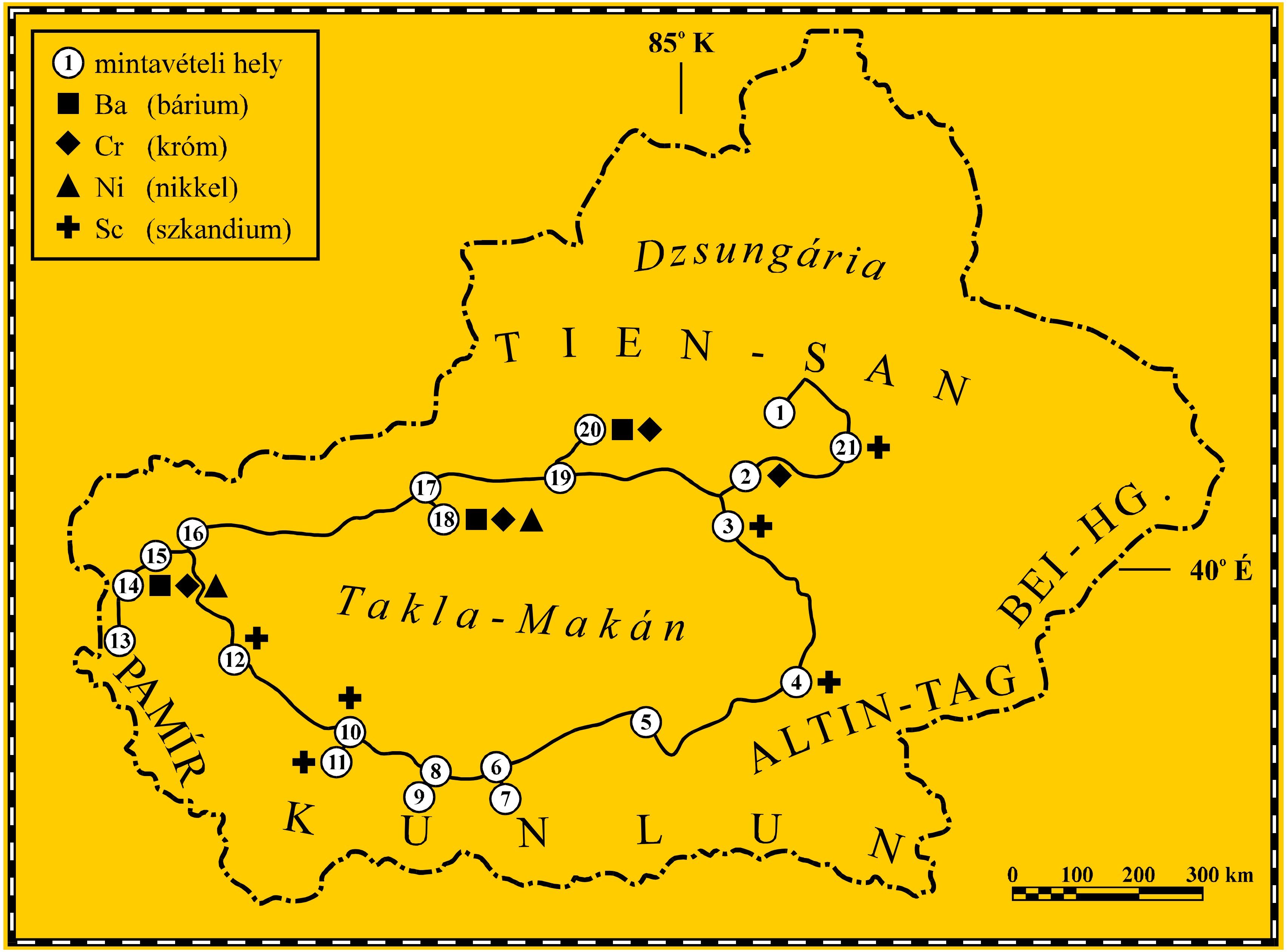
1st China-expedition: sampling sites in Northwestern China

2nd China-expedition, 1994

Beijing – Nanjing – Shanghai – Guangzhou (Kanton) – Macau – Hong kong – Jangshou – Guilin – Kunming – Chengdu – Lhasa (Tibet) – Lanzhou – Urumqi (Xinjiang-Uygur Autonomous Territory);

→ Turpan Basin, roundabout the Takla-Makan Desert (northern and southern silk road) (Yuli – Qarklik – Qerqen – Niya – Keriya – Hotan – Kargilik – Tashkurgan – Kunjirap Daban (4730 m) – Kashgar – Aksu – Kuqa (Thousand Buddha Caves, southern slopes of Tien Shan) – Janqi – Urumqi (Yuli);

Measuring site at the Bosten Lake, south-eastern foreground of the Tien Shan, 800 m above sea level (sampling site no. 2)



2nd China-expedition: geographical locations of the sampling sites in Northwestern China; with spatial distribution of the elements enriched in atmospheric aerosol (except for: sulphur, chlorine, copper and zink)

Results

- elemental concentrations and enrichment factors of aerosol samples → new information on the characteristics of the regional atmospheric dust in the Tarim Basin and its surroundings (an important aerosol source on global scale);
- comparison of aerosol data with regional soil analysis ⇒ high sulphur and chlorine content of regional aerosol is of natural origin, and is a consequence of widespread and intense salt accumulation in this closed and arid basin;

Measurement in High-Pamir, at 3600 m above sea level; in the background: Mustag Ata Mountain (7546 m)

- Elemental ratios of *Si/Fe*, and *Ca/Fe* from Takla Makan area are independent of the geographical locations of the sampling sites, at the same time they substantially differ from mean crustal concentration ratios, as well as from concentration ratios of sampling sites beyond the Takla Makan Desert ⇒ they can be used for follow up long-term transport of Takla Makan aerosol;
- Results received can be used for studying long-term transport of atmospheric dust from Takla Makan Desert to the central and eastern areas of China, Japan and the Pacific Ocean (*KOSA*-phenomenon) (Makra et al., 2002);

Makra, L., Borbély-Kiss, I., Koltay, E., Chen, Y., 2002: Enrichment of desert soil elements in Takla Makan dust aerosol. *Nuclear Instruments & Methods in Physics Research Section B - Beam Interaction*, B189, 214-220.

At glacier no. 1 in Tien Shan Mountains, at 3800 m above sea level (sampling site no. 1). Just measurements were carried out when a huge snow storm has emerged. The instruments needed to be fixed so that the wind not blow them away.

Publications associated with the Chinese research expeditions

International professional journals: 4 papers;

International conference proceedings : 3 papers;

Popular science journals: 27 papers;

Films: 2;

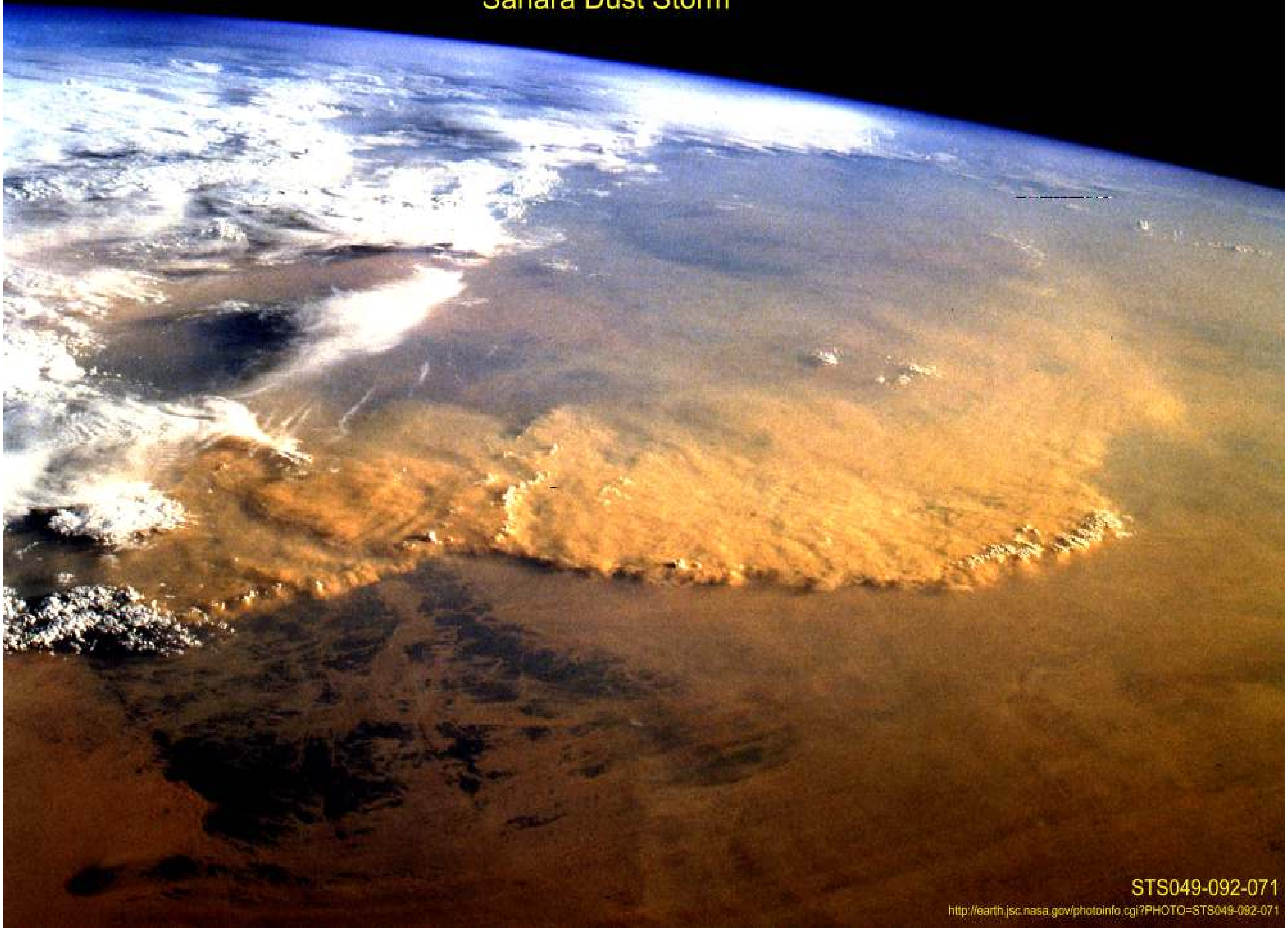
Photo exhibition, as part of the Hungarian Cultural Institute, National Photo Contest): 1;

„Journey around the world – 2002”, photo series, special prize;

Popular science books: 2;

Popular science CD (for geography teaching in primary and secondary schools): 1 db;

Sahara Dust Storm



Dust from Sahara

Dust storm, West Africa

www.nrlmry.navy.mil/.../20020107_sahara/

Saharan dust, Austria

http://www.captain.at/capages/sahara-dust-storm/

Pink sunset, Florida, US ←→ African dust

soundwaves.usgs.gov/2004/01/outreach2.html

Spectrometer data on dust moving towards west through the Atlantic Ocean

http://science.nasa.gov/headlines/images/dustmicrobes/movies/july00index.mov

For Szeged and whole Hungary the most important source areas of PM_{10} are Central Europe, Southern Europe and North Africa (Makra et al, 2013);

Makra, L., Ionel, I., Csépe, Z., Matyasovszky, I., Lontis, N., Popescu, F., Sümeghy, Z., 2013: Characterizing and evaluating the role of different transport modes on urban PM_{10} levels in two European cities using 3D clusters of backward trajectories. Science of the Total Environment, 458-460, 36-46.

Mobile homes of microorganisms: dust saturated with microbes.

http://science.nasa.gov/headlines/images/dustmicrobes/movies/dustPar2.mov

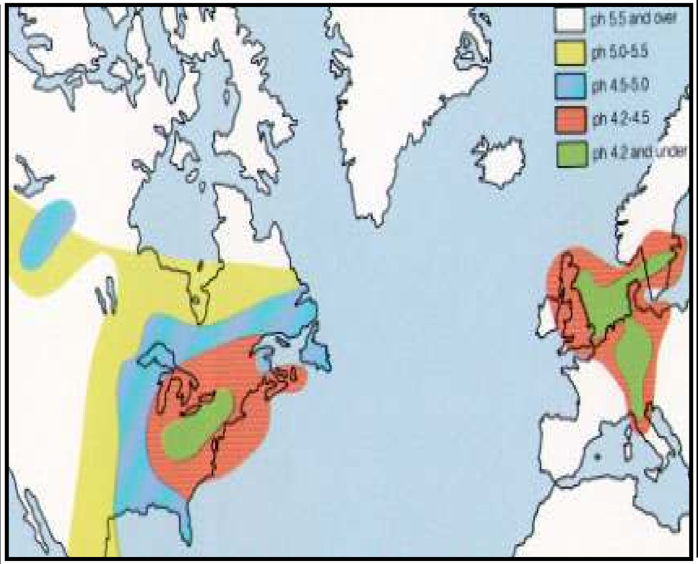
Anthropogenic sources

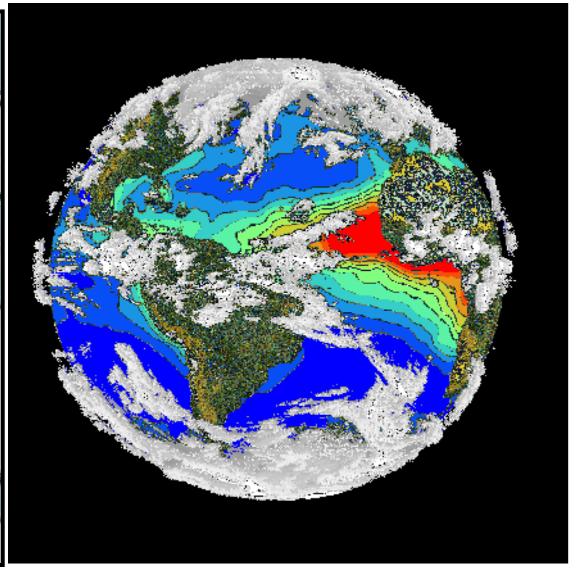
Local, regional and global air pollution

1950s:
Local
Smoke, ash

1970s -1990s:
Regional
Acidic rain, haze

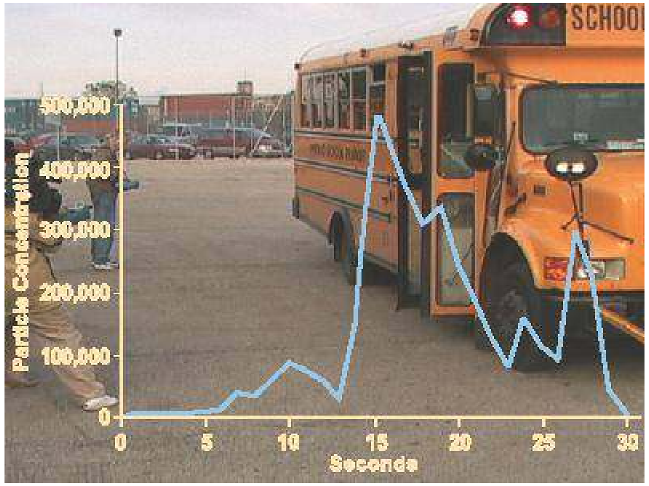
2000s:
Global
Global change





Polluted environment is a serious concern recently …

Soot from diesel engines



www.catf.us/projects/diesel/

Allergy

pested.unl.edu/chapter1.htm

Tooth damage from fluoride

homepage.eircom.net/~fluoridefree/home.htm

www.freakingnews.com/entries/3000/3388VbDA_w.jpg

Air polluiton is a serious problem in developing countries

Urban air in Cairo (**Egypt**)

Picture courtesy Dr. Peter Raven

In Indonesia air filter is used against polluted air.

cnn.com

www.e-waste.ch/.../processes/

www.crra.com/ewaste/ttrash2/ttrash2/

Open burning of waste.
Metal recycling.

How dangerous are these air pollutants?

How big concerns they are in Hungary?

Reduced visibility

Glen Canyon NRA

www.lakepowell.net/asiandust.htm

St. Louis, MO

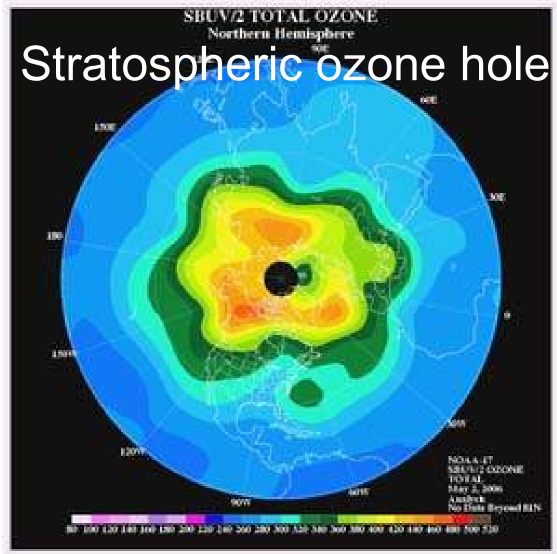
www.dnr.mo.gov/env/esp/aqm/archcam.htm

On global scale …

Global warming

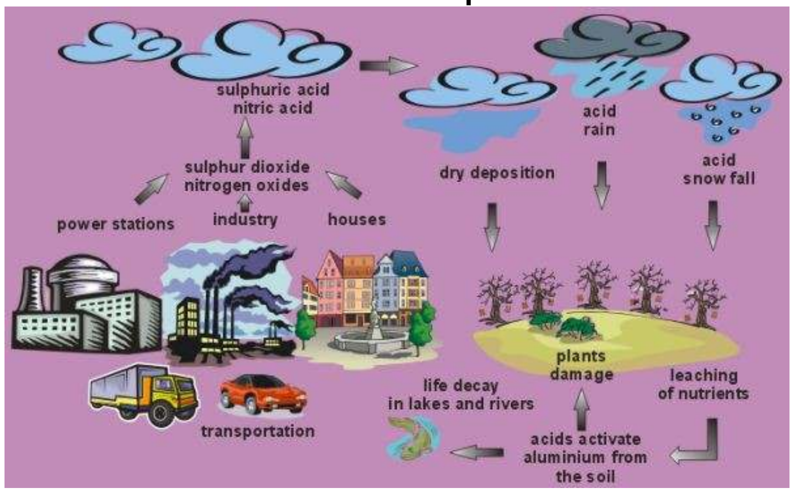
http://www.city.sendai.jp/soumu/kouhou/emailnews/ecolife-e/images/TokoroYukiyoshi.jpg

http://www.illinoisfamily.org/content/img/f32925/global-warming.jpg



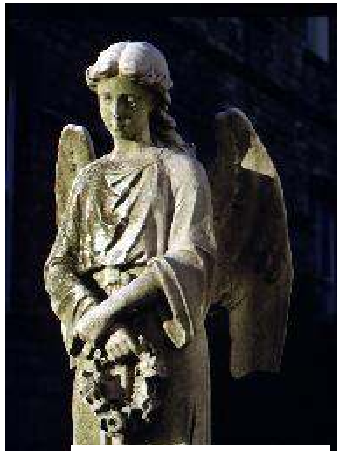
www.noaanews.noaa.gov/stories2006/s2624.htm

Acidic deposition



www.atmosphere.mpg.de

www.agen.ufl.edu



gallery.hd.org

2. Non-transport origin global air pollution load, 2001-2100

3.1. Global warming potential (GWP)

***GWP* and other emission metrics are used to economically take effective actions on reducing negative consequences of climate change.**

***GWP* is time integral of radiative forcing when emitting unit mass of gas.**

The formula of *GWP* for a given *x* gas simply is as follows:

$$GWP_x(H) = \frac{AGWP_x(H)}{AGWP_{CO2}(H)}$$

where *H* is the time horizon. Choise of the time horizon depends on us (20, 50 or 100-year time horizons used to be chosen).

The reference gas is CO_2, so *AGWP* values of both CO_2, and the given *x* gas should be calculated. The two claculations are not equivalent.

AGWP value of CO_2 can be calculated as follows:

$$AGWP_{CO2}(H) = A_{CO2}\left[a_0 H + \sum_{i=1}^{3} a_i \alpha_i \left(1 - \exp\left(-\frac{H}{\alpha_i}\right)\right)\right]$$

where A_{CO2} is the specific constraint of CO_2, while *a* and *α* parameters Are given in the table below:

	0	1	2	3
a_i (without units)	0.217	0.259	0.338	0.186
α_i (years)		172.9	18.51	1.186

AGWP value of the given x gas can be calculated with the following formula:

$$AGWP_x(H) = A_x \alpha_x \left[1 - \exp\left(-\frac{H}{\alpha_x}\right)\right]$$

where A_x is the specific constraint of gas *x*, while α_x is the lifetime of gas *x*.

3.2. Global temperature change potential (GTP)

GTP **is a new relative emission metric, which was suggested to introduce by Shine et al. (2005).**

GTP value of a given *x* gas can be formulated simply as follows:

$$GTP_x(H) = \frac{AGTP_x(H)}{AGTP_{CO2}(H)}$$

where $AGTP_x(H)$ is the globally averaged change of surface temperature after *H* years following emission of gas *x*.

The *GWP* and *GTP* metrics are two fundamentally different ways of comparing emissions.

***GWP* integrates radiative forcing according to time to the chosen time horizon;**

↑

↓

***GTP* focuses on a particular moment in time, and gives the tempereture effect of the given moment of time.**

The *GTP* metric uses the same parameters as the *GWP* metric (radiation efficiency and lifetime)**, and it is important to know the response time of the climate system, especially when lifetime of the *i*th greenhouse gas is significantly different from the lifetime of the basic gas life.**

AGTP value of CO_2 can be formulated as follows:

$$AGTP_{CO2}(H) = A_{CO2}\left\{\sum_{j=1}^{2} a_0 c_j \left(1-\exp\left(-\frac{H}{d_j}\right)\right) + \sum_{i=1}^{3}\sum_{j=1}^{2} \frac{a_i \alpha_i c_j}{\alpha_i - d_j}\left(\exp\left(-\frac{H}{\alpha_j}\right) - \exp\left(-\frac{H}{d_j}\right)\right)\right\}$$

where parameters *c* and *d* are given in the *GWP* table below:

	0	1	2	3
a_i (without unit)	0.217	0.259	0.338	0.186
α_i (years)		172.9	18.51	1.186
c_j $(K(Wm^{-2})^{-1})$		0.631	0.429	
d_j (years)		8.4	409.5	

AGTP value of the given gas *x* can be calculated with the formula below:

$$AGTP_x(H) = \sum_{j=1}^{2} \frac{A_x \alpha_x c_j}{C(\alpha_x - d_j)} \left(\exp\left(-\frac{H}{\alpha_x} \right) - \exp\left(-\frac{H}{d_j} \right) \right)$$

Where parameter *C* is climate sensitivity, while the remaining parameters are the same that have already been used in eq. (2) when calculating *AGWP* value of the given gas *x*.

3.3. Constants

Constants used in the calculations are as follows:

	CH4[(1)]	N2O[(1)]	CO[(2)]	SO2[(3)]	NOX[(2)]	CO2[(1)]
Specific constraint *(A_x)*	**1.46E-13** **1.45E-13**[a]	3.91E-13 **3.88E-13**[a]	8.96E-14	-3.2E-10	2.78E-12	1.98E-15 **1.82E-15**[a]
Lifetime *(α_x)*	12	114	10.8	0.01 **0.01087**[a]	10.8	-

(1) Fuglestvedt et al. (2008)

(2) Berntsen et al. (2005)

(3) Schulz et al. (2006)

(a) Fuglestvedt et al. (2009)

Former konstants

New konstants

Climate sensitivity: *C* = 1.40E-15

3.4. Results

3.4.1. Calculations

• *GWP* and *GTP* are independent of locations, they can be calculated with their formula, according to given years and gas parameters;

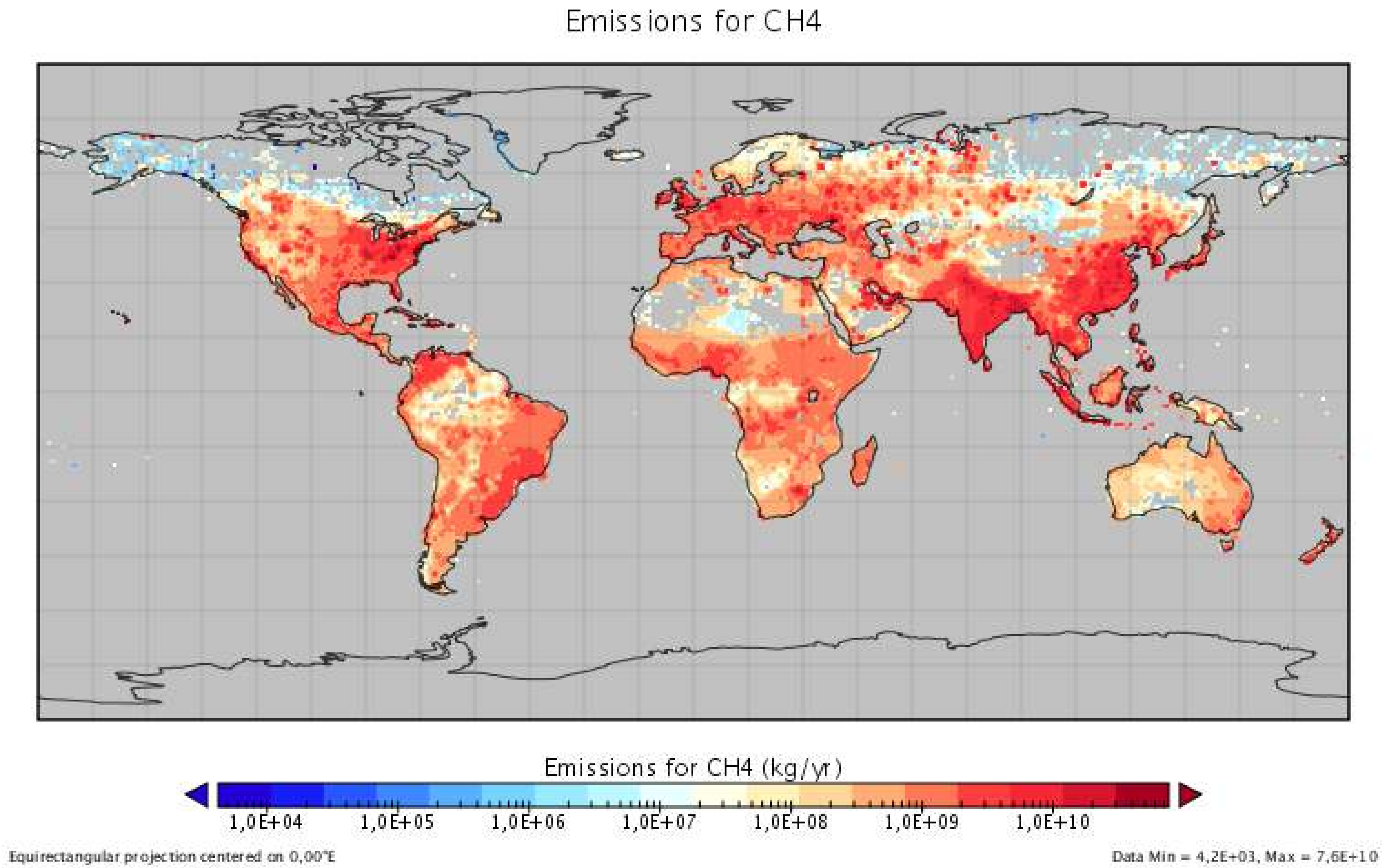
• Emission values are location-depedent,

Extrapolation of emissions (for *i*-th year and given grid) = (value of *GWP*, or *GTP* for *i*-th year) x emission$_{(given\ grid)}$(in year 2000)

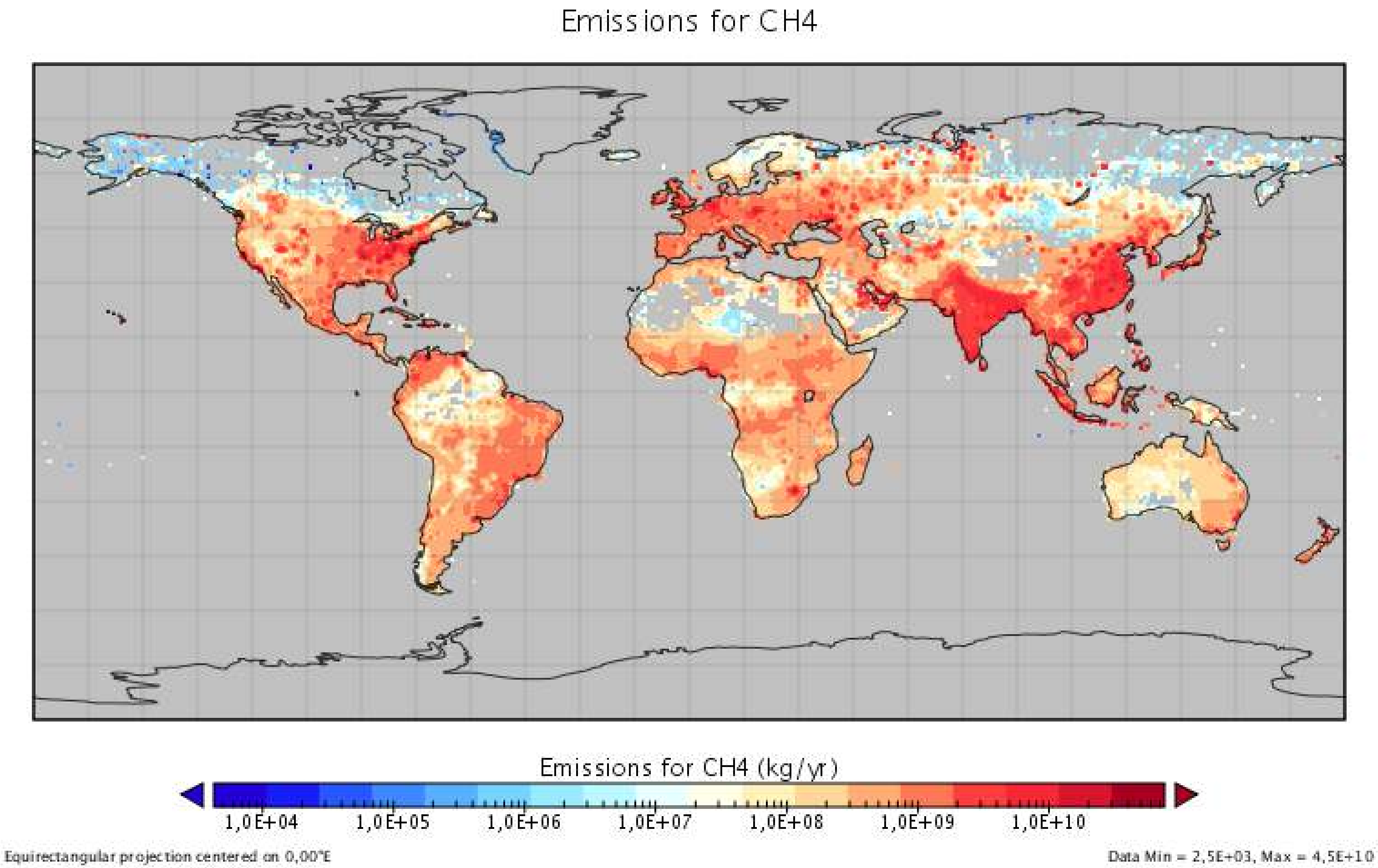
Emissions were calculated for each individual grid per pollutants.

Regional emission values (Earth, Europe, Hungary): emission average for the given grids involved;

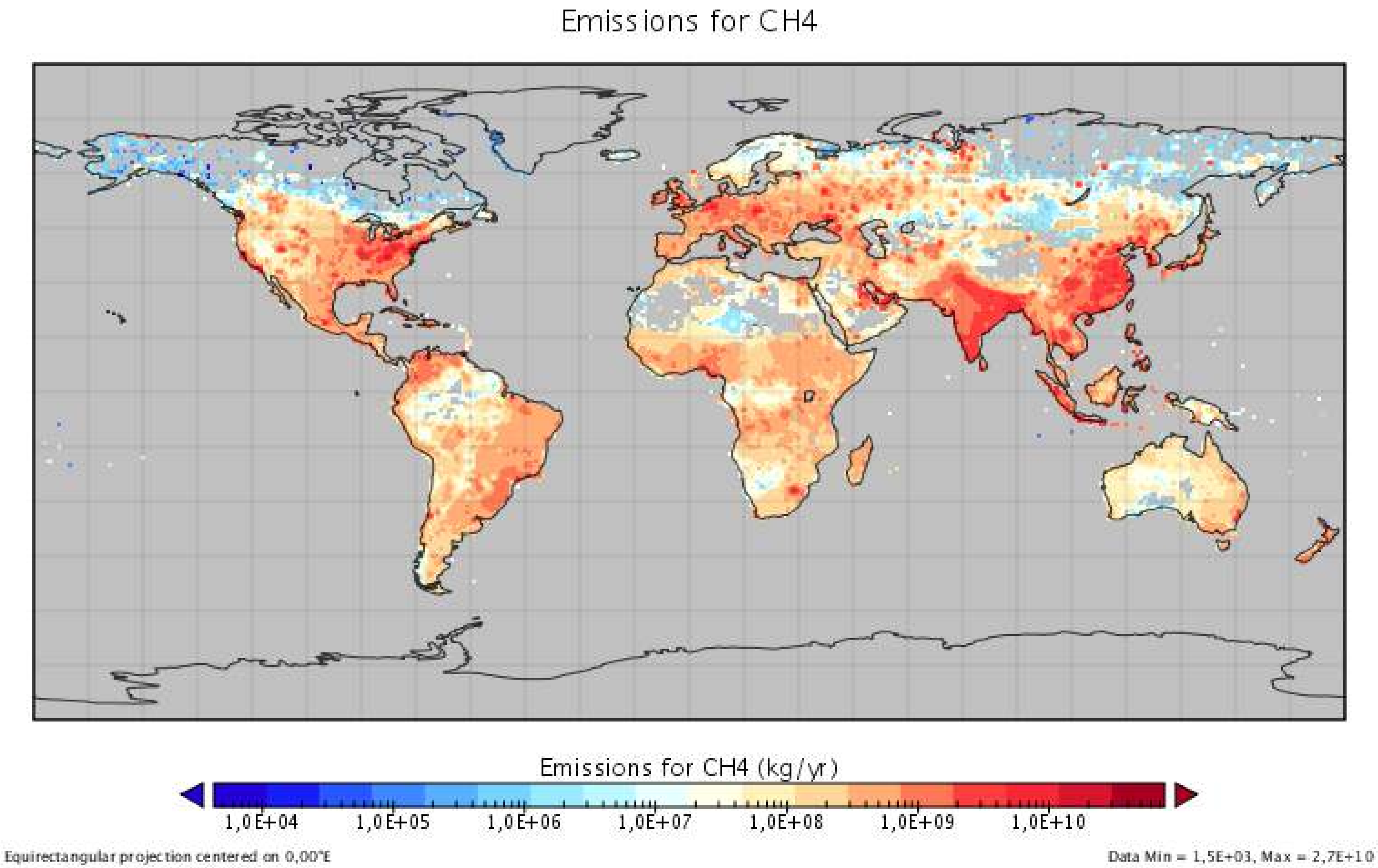
3.5. GWP-weighted emission maps of of the individual air pollutants, 20, 50, 100 years



GWP, 20 years

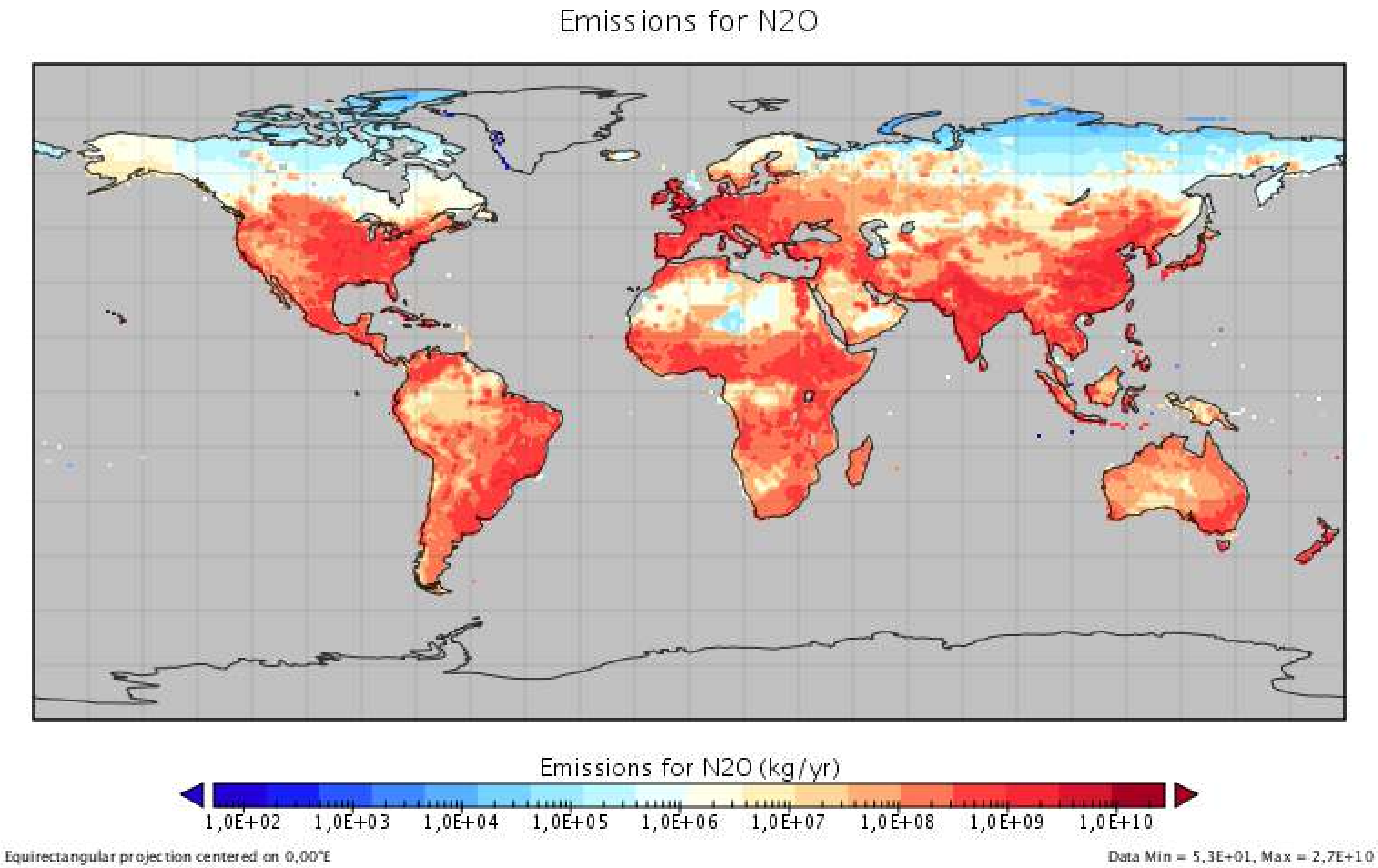

Emissions for CH4
Emissions for CH4 (kg/yr)
1,0E+04
1,0E+05
1,0E+06
1,0E+07
1,0E+08
1,0E+09
1,0E+10
Equirectangular projection centered on 0,00°E
Data Min = 2,5E+03, Max = 4,5E+10

GWP, 50 years



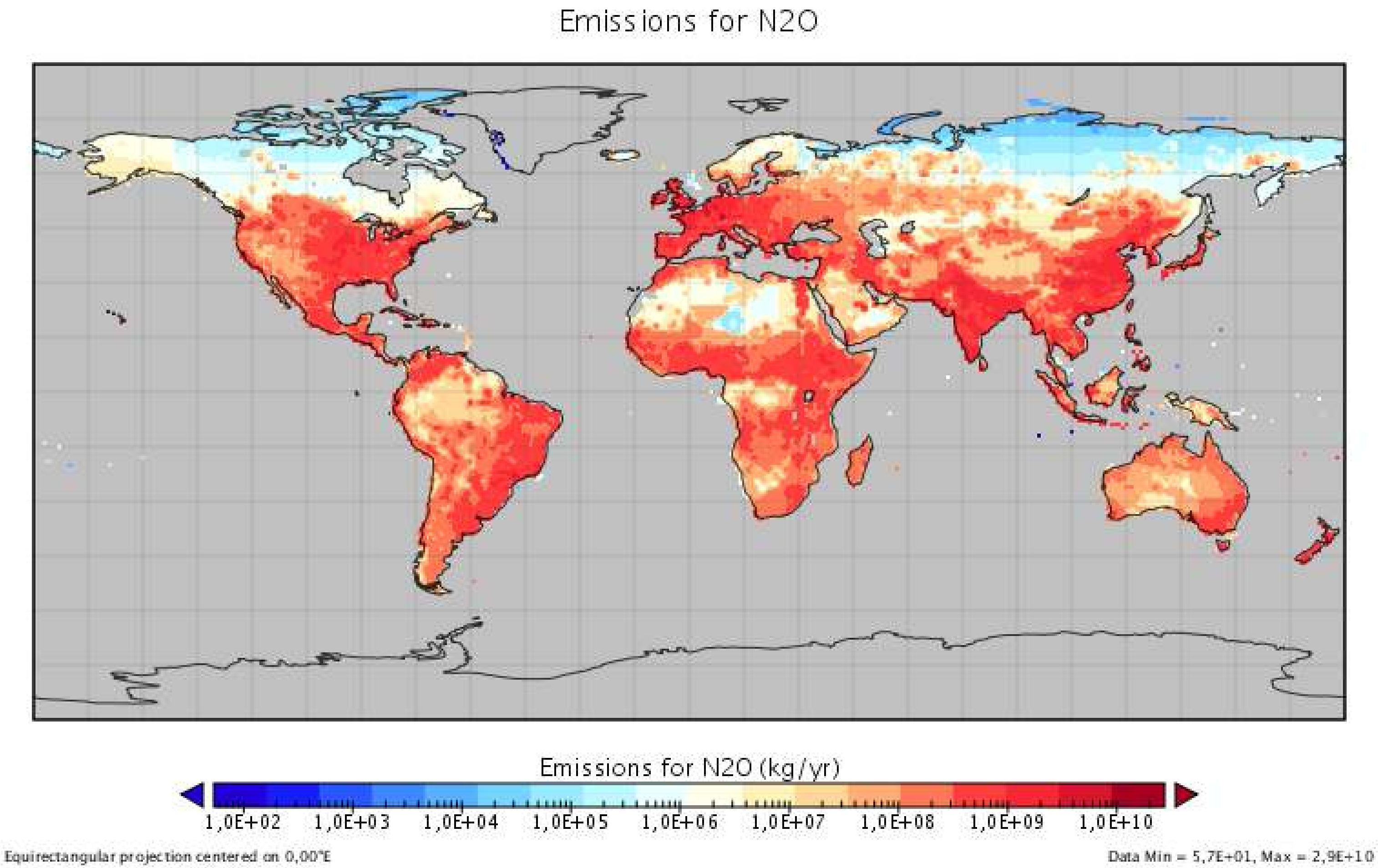
GWP, 100 years

QUANTIFY



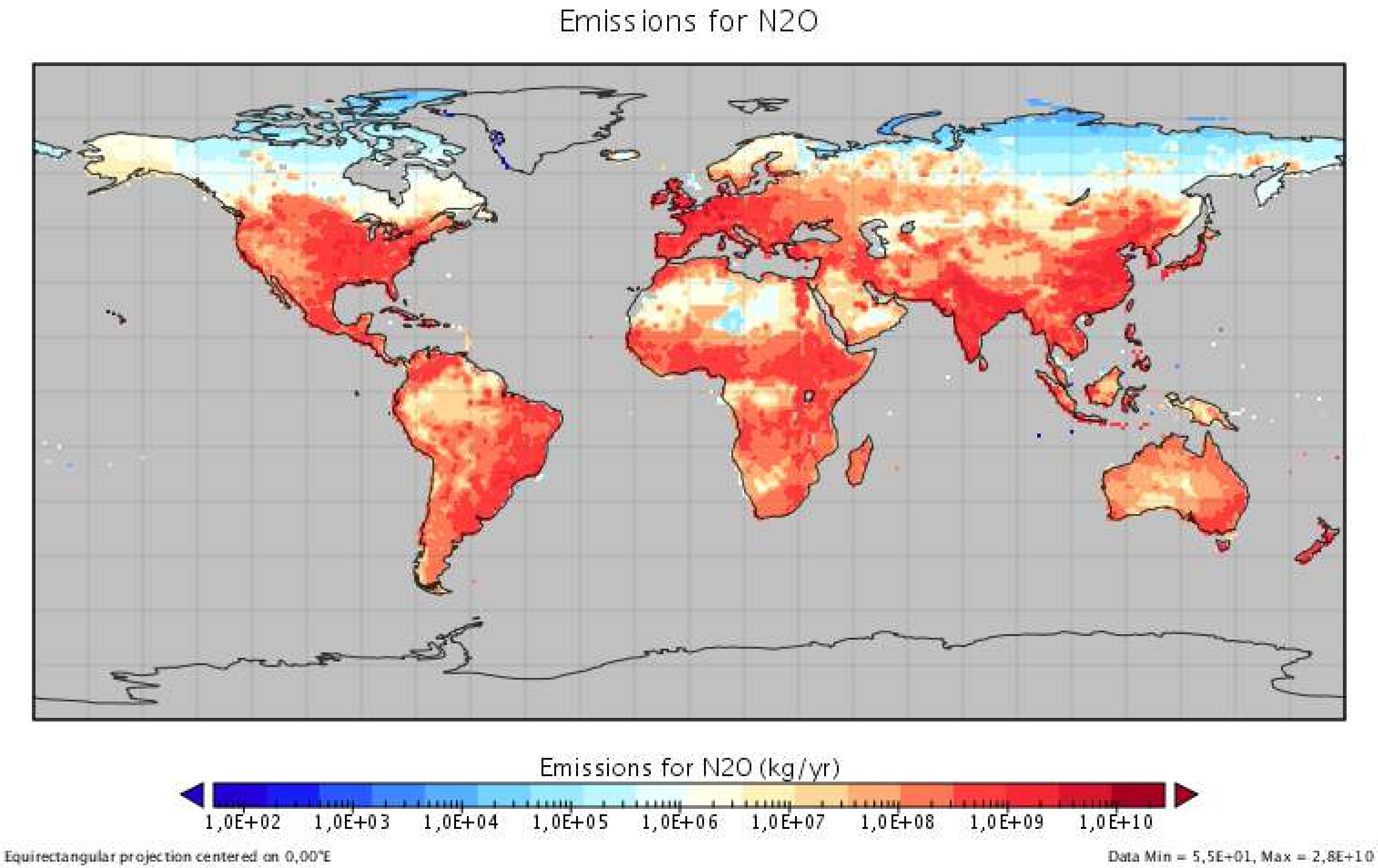
Emissions for N2O
Emissions for N2O (kg/yr)
1,0E+02
1,0E+03
1,0E+04
1,0E+05
1,0E+06
1,0E+07
1,0E+08
1,0E+09
1,0E+10
Equirectangular projection centered on 0,00°E
Data Min = 5,3E+01, Max = 2,7E+10

GWP, 20 years



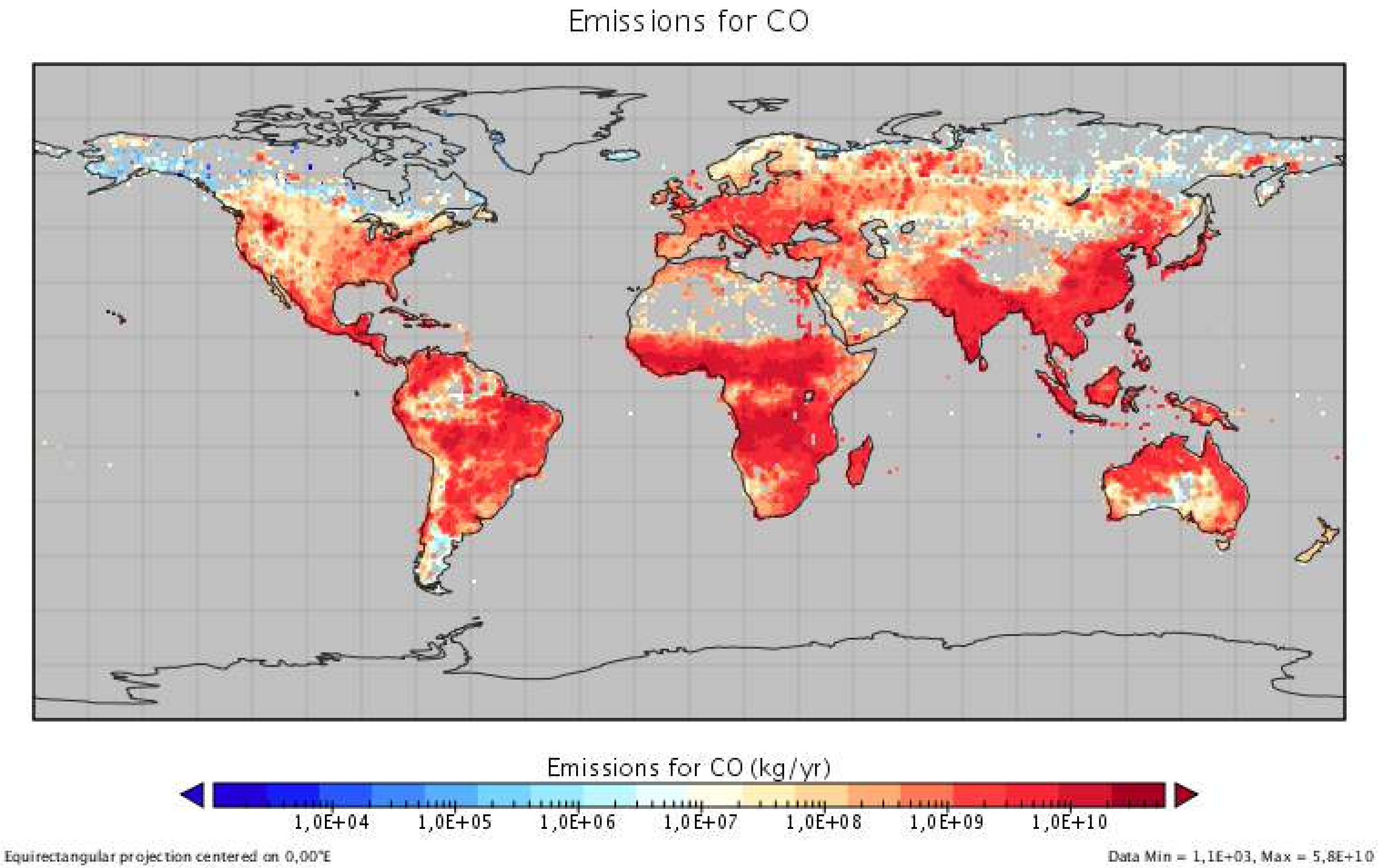
Emissions for N2O
Emissions for N2O (kg/yr)
1,0E+02
1,0E+03
1,0E+04
1,0E+05
1,0E+06
1,0E+07
1,0E+08
1,0E+09
1,0E+10
Equirectangular projection centered on 0,00°E
Data Min = 5,7E+01, Max = 2,9E+10

GWP, 50 years



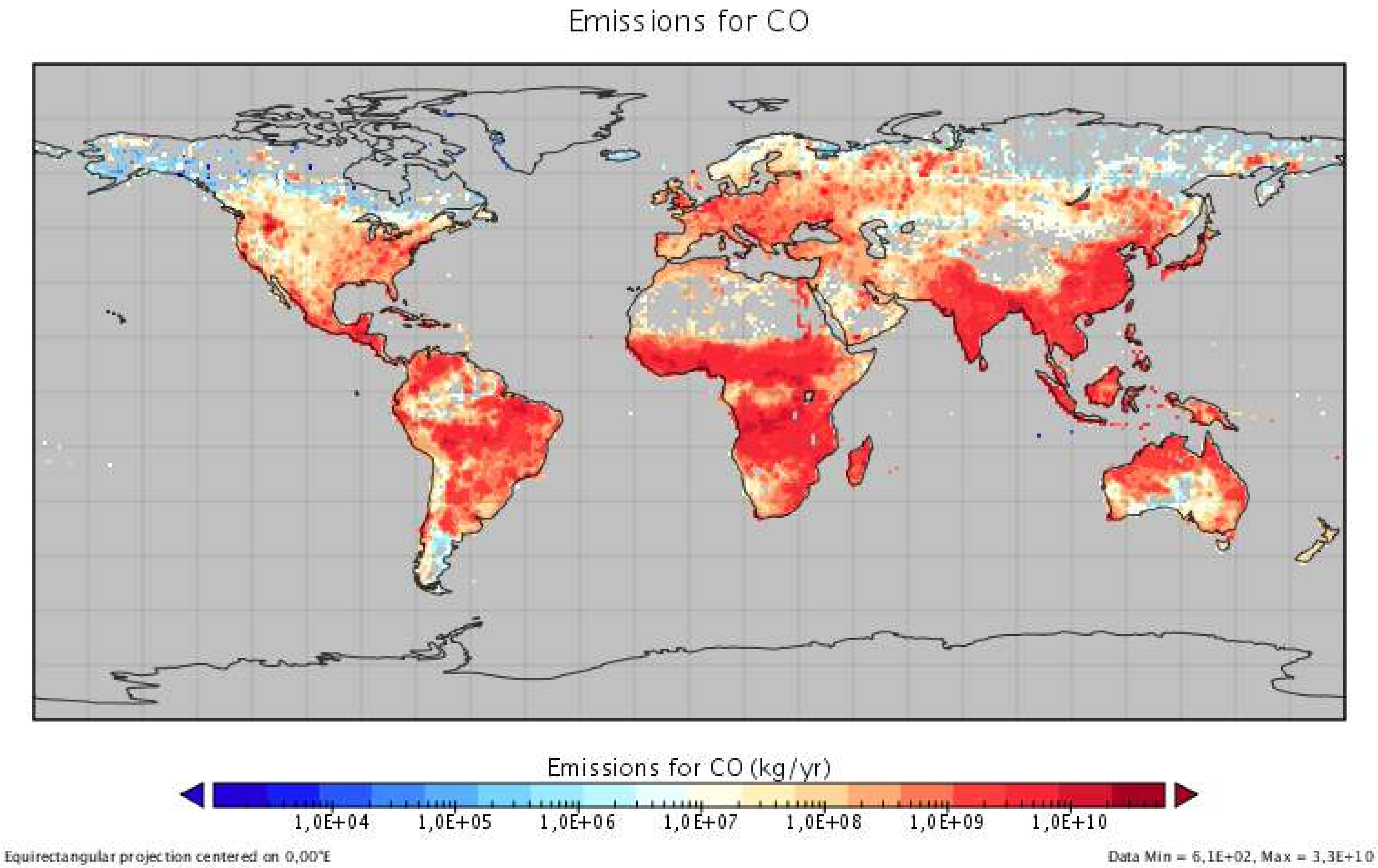
GWP, 100 years

QUANTIFY



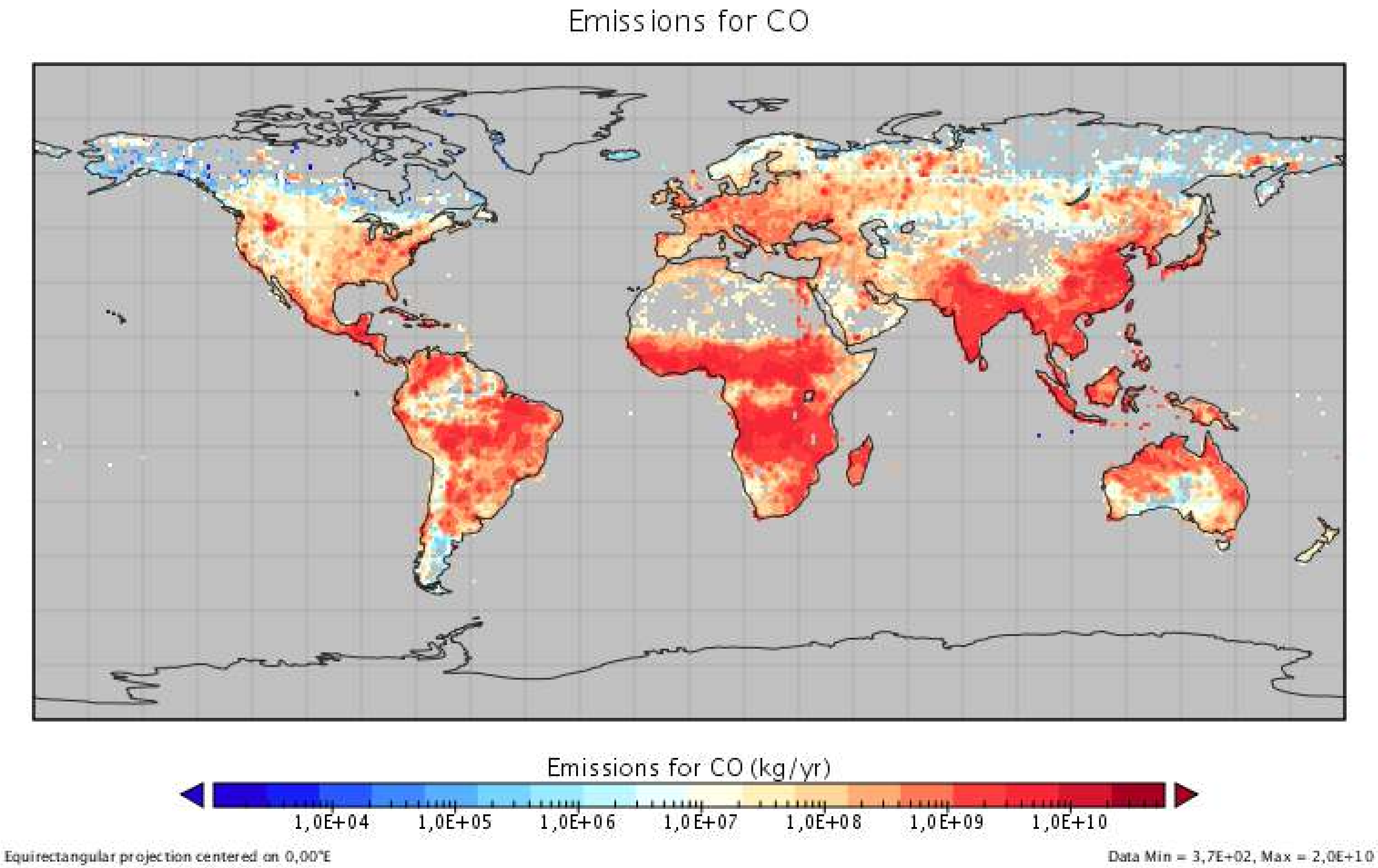
GWP, 20 years

QUANTIFY

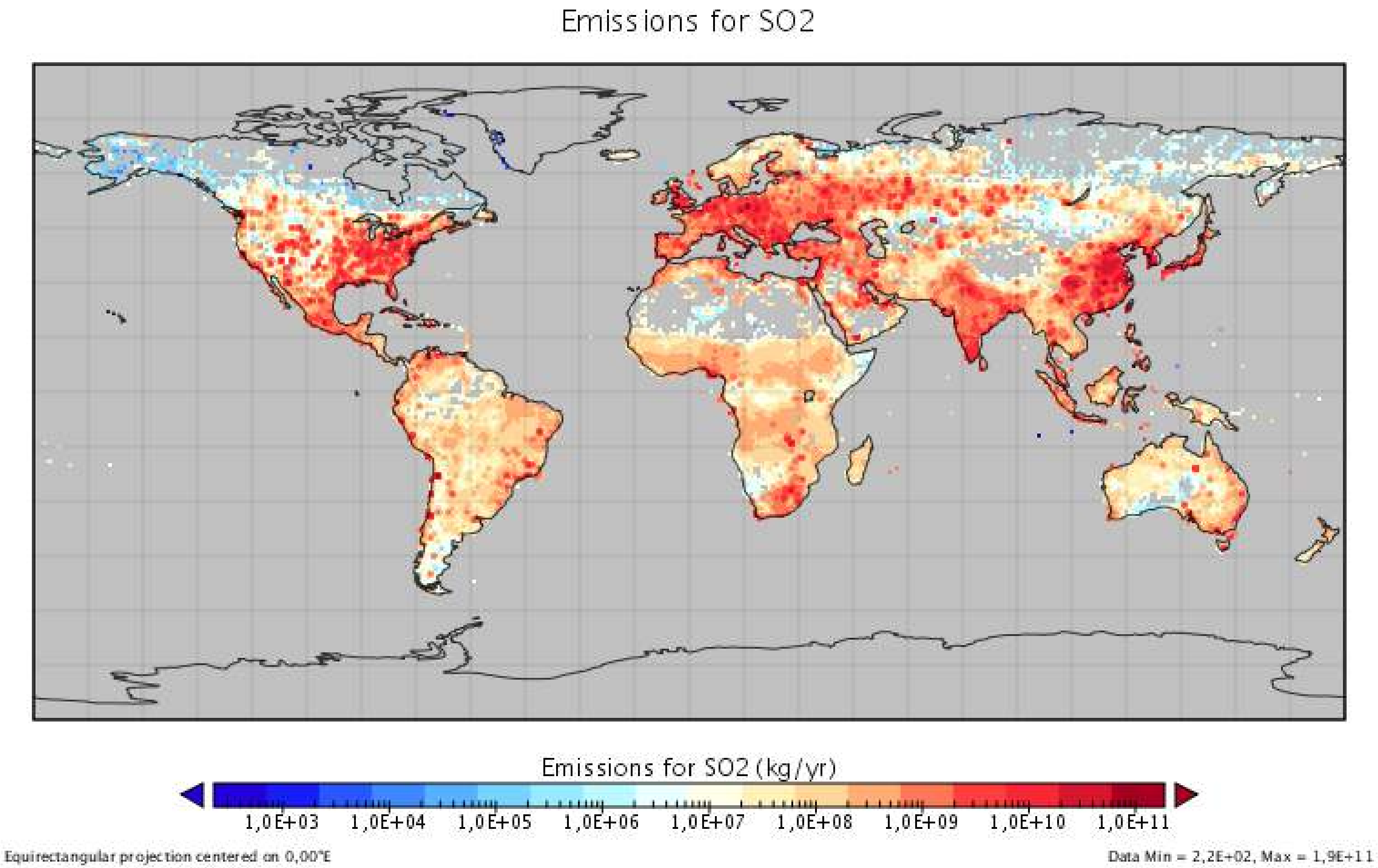


Emissions for CO
Emissions for CO (kg/yr)
1,0E+04
1,0E+05
1,0E+06
1,0E+07
1,0E+08
1,0E+09
1,0E+10
Equirectangular projection centered on 0,00°E
Data Min = 6,1E+02, Max = 3,3E+10

GWP, 50 years

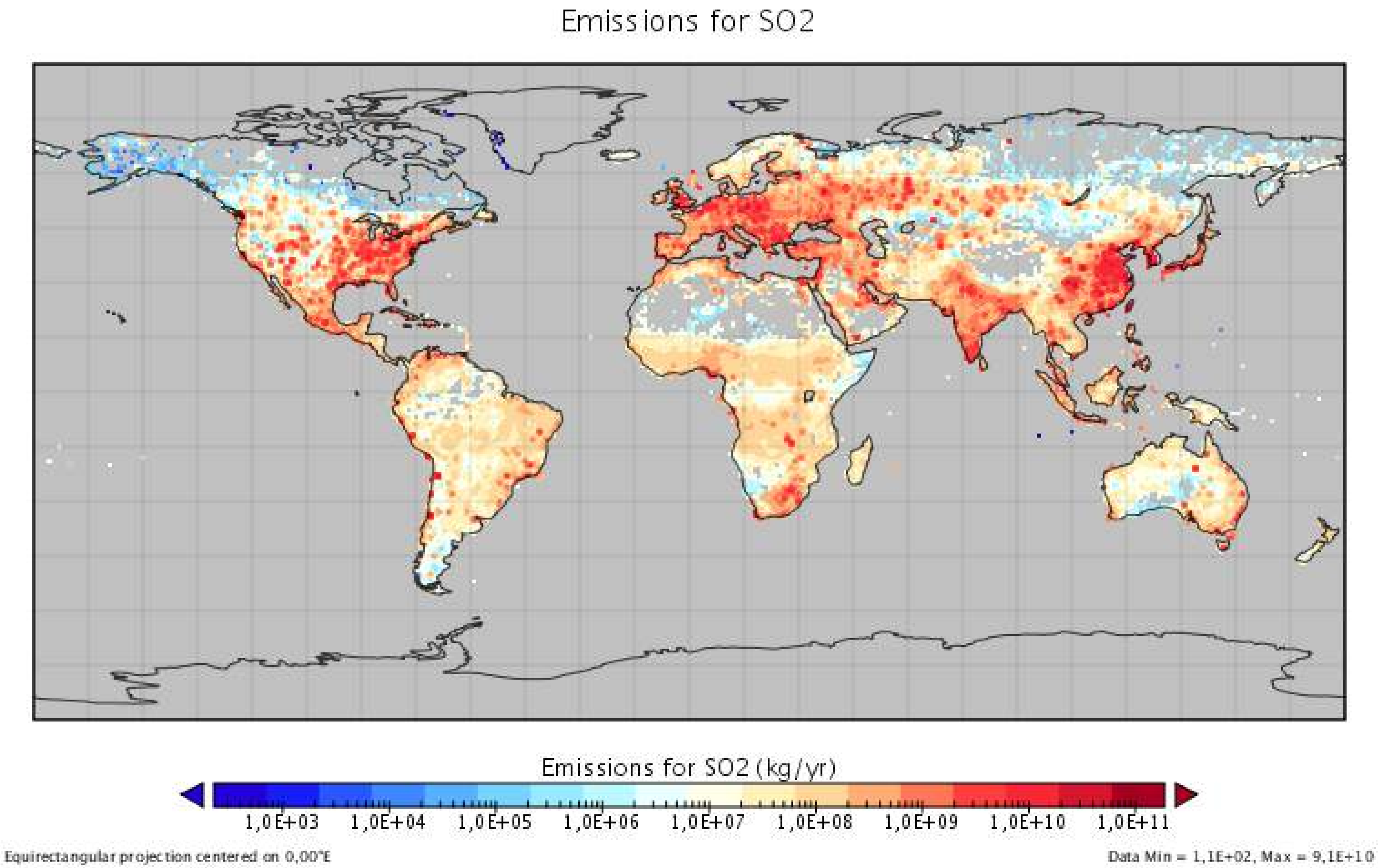


GWP, 100 years

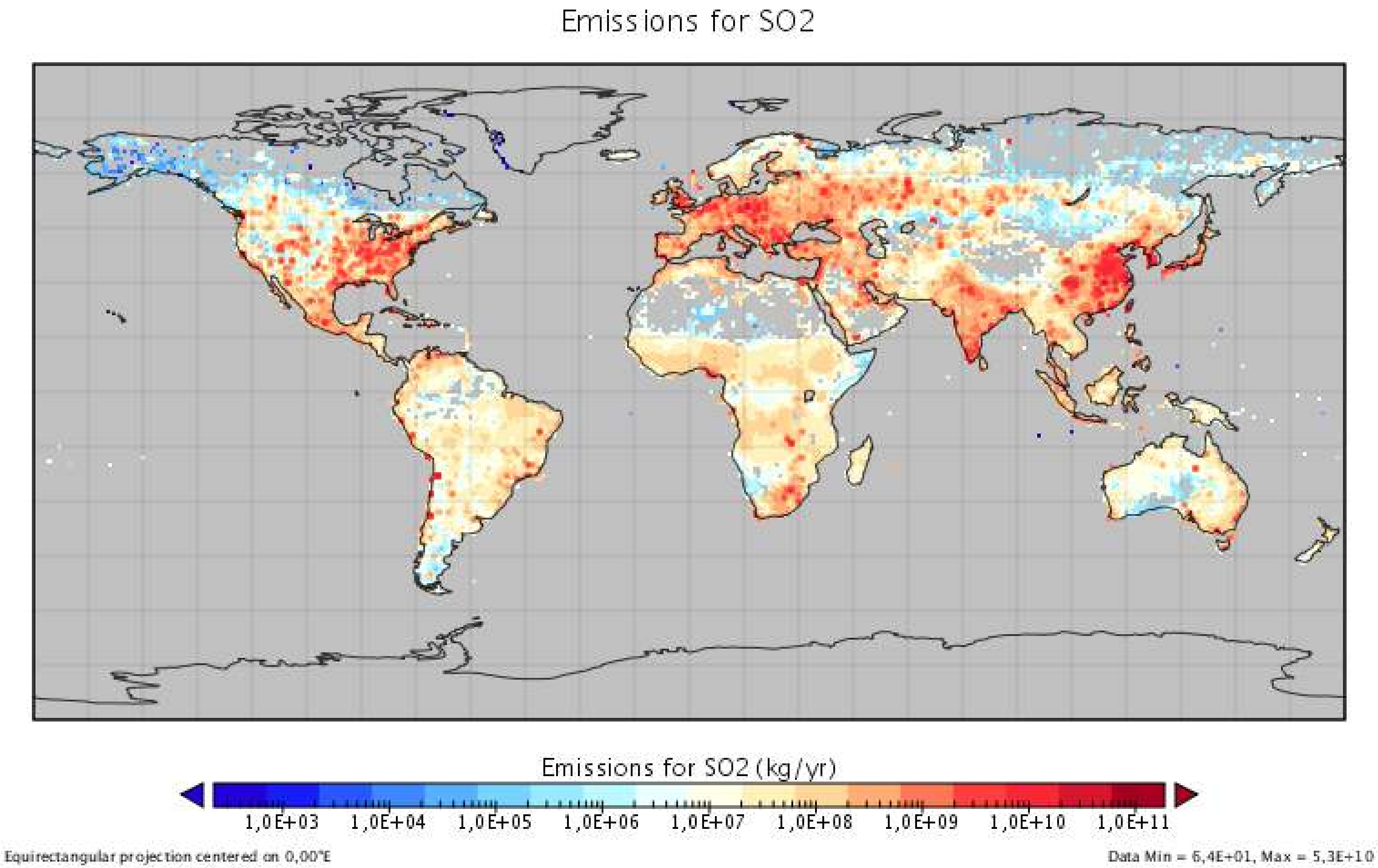


GWP, 20 years

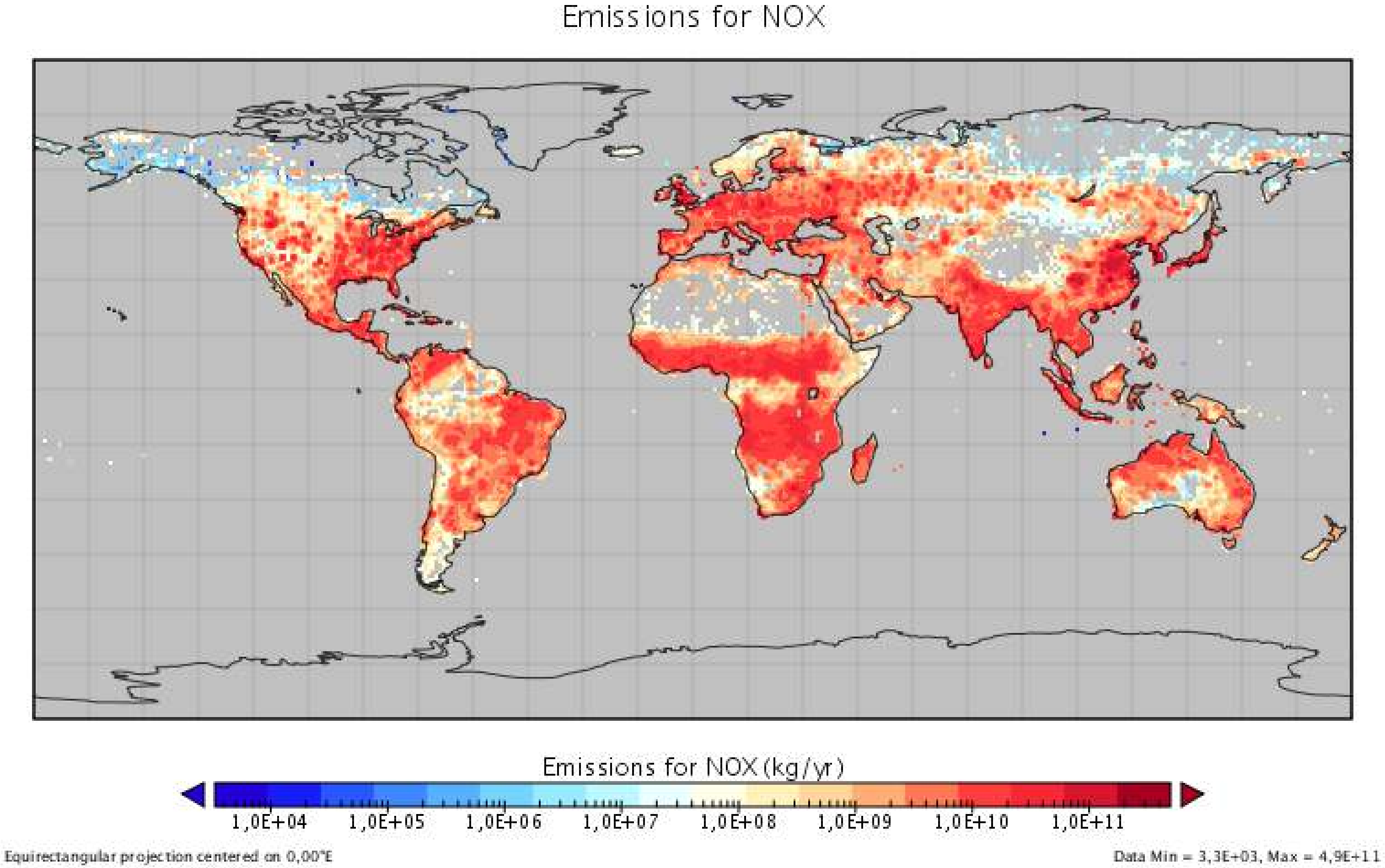
QUANTIFY


Emissions for SO2
Emissions for SO2 (kg/yr)
1,0E+03
1,0E+04
1,0E+05
1,0E+06
1,0E+07
1,0E+08
1,0E+09
1,0E+10
1,0E+11
Equirectangular projection centered on 0,00°E
Data Min = 1,1E+02, Max = 9,1E+10

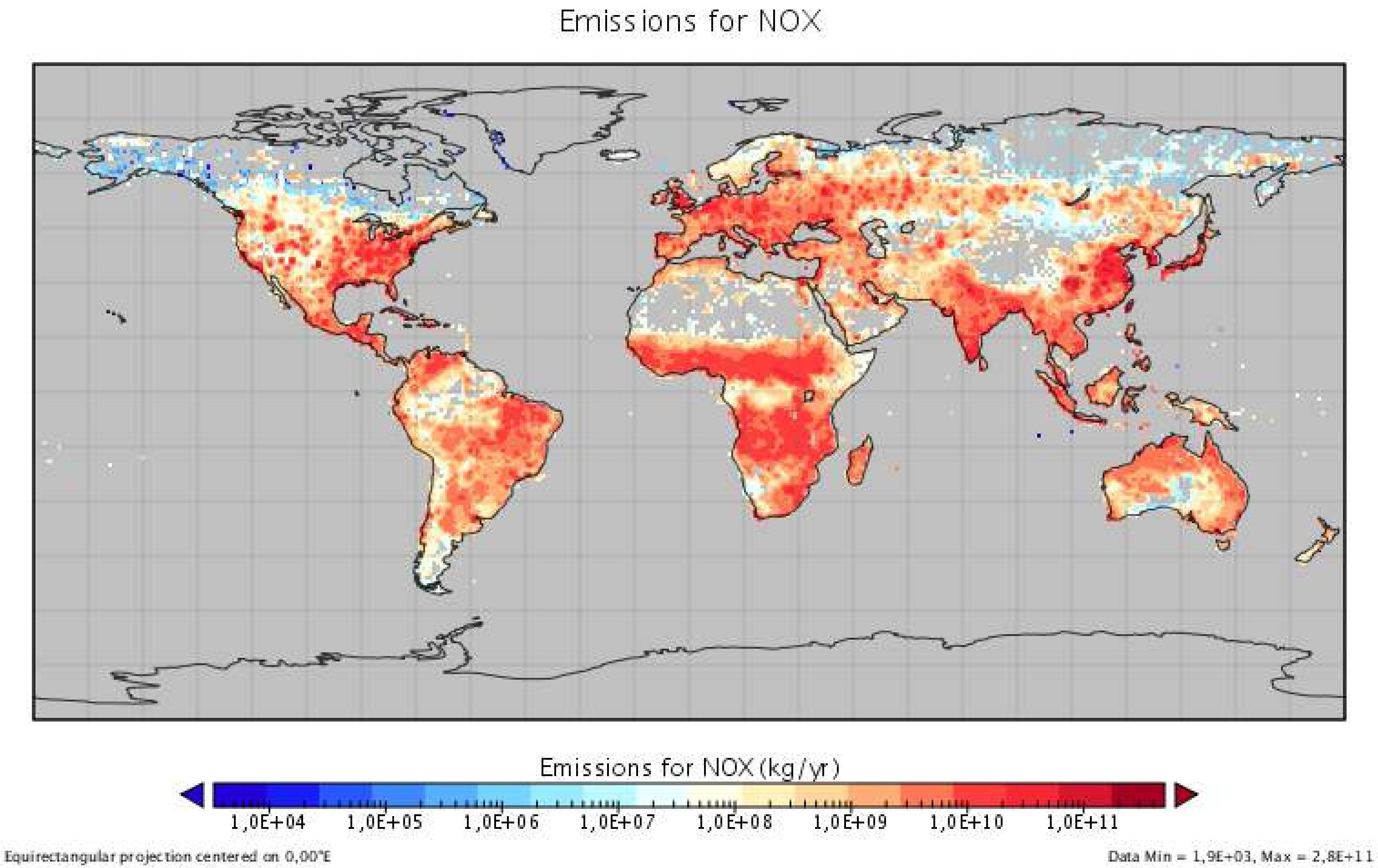
GWP, 50 years



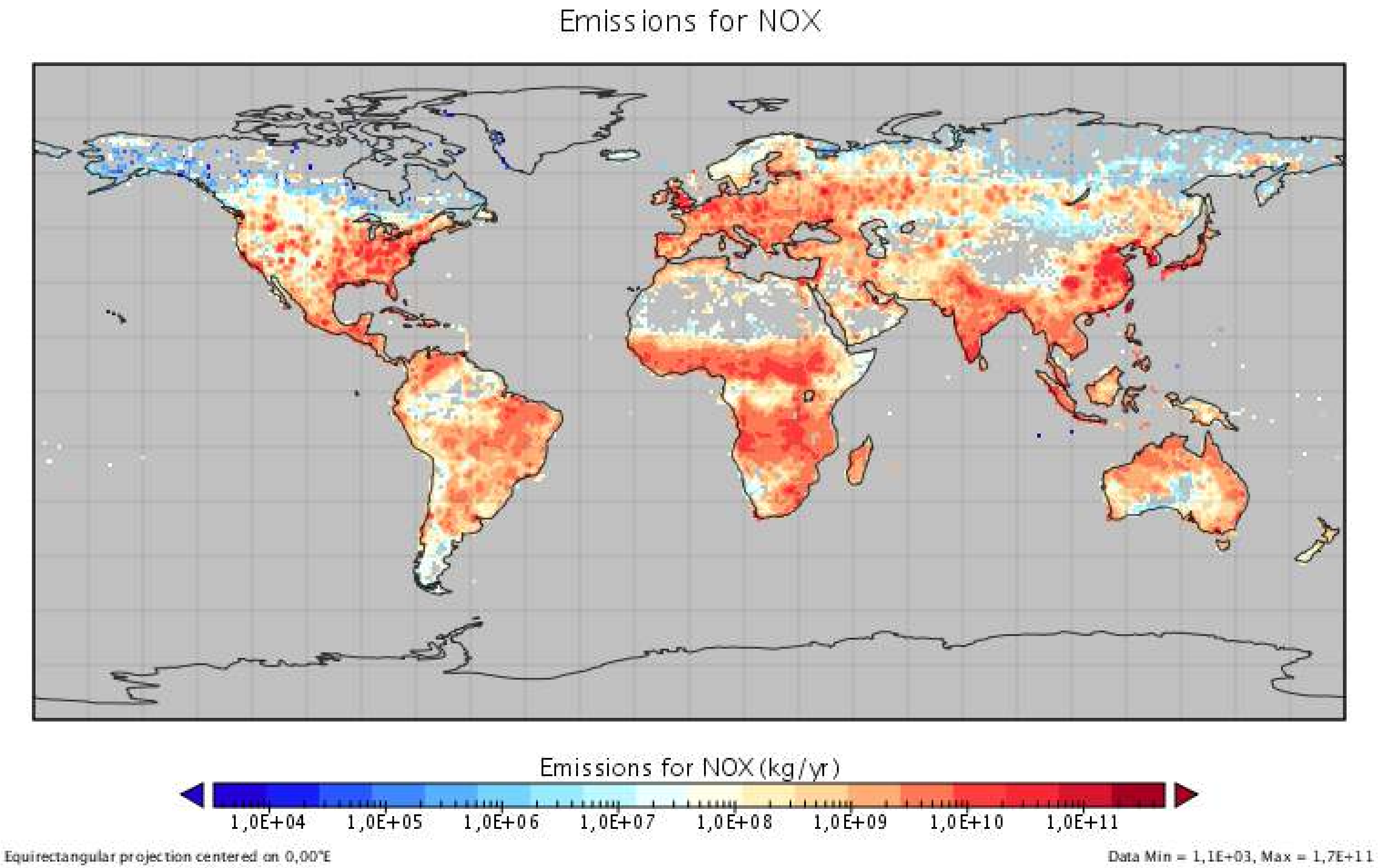
GWP, 100 years


Emissions for NOX
Emissions for NOX (kg/yr)
1,0E+04
1,0E+05
1,0E+06
1,0E+07
1,0E+08
1,0E+09
1,0E+10
1,0E+11
Equirectangular projection centered on 0,00°E
Data Min = 3,3E+03, Max = 4,9E+11

GWP, 20 years

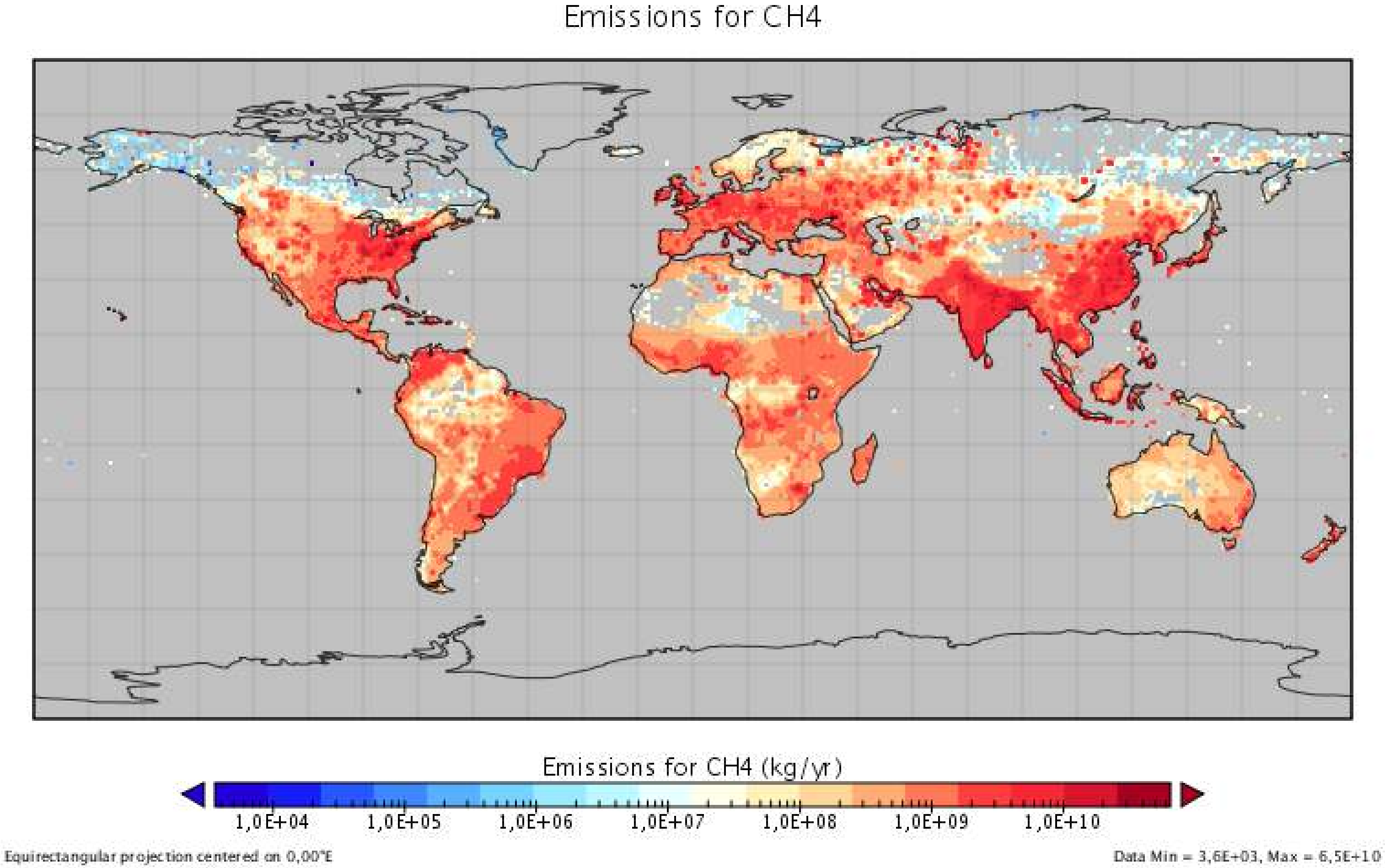

Emissions for NOX
Emissions for NOX (kg/yr)
1,0E+04
1,0E+05
1,0E+06
1,0E+07
1,0E+08
1,0E+09
1,0E+10
1,0E+11
Equirectangular projection centered on 0,00°E
Data Min = 1,9E+03, Max = 2,8E+11

GWP, 50 years

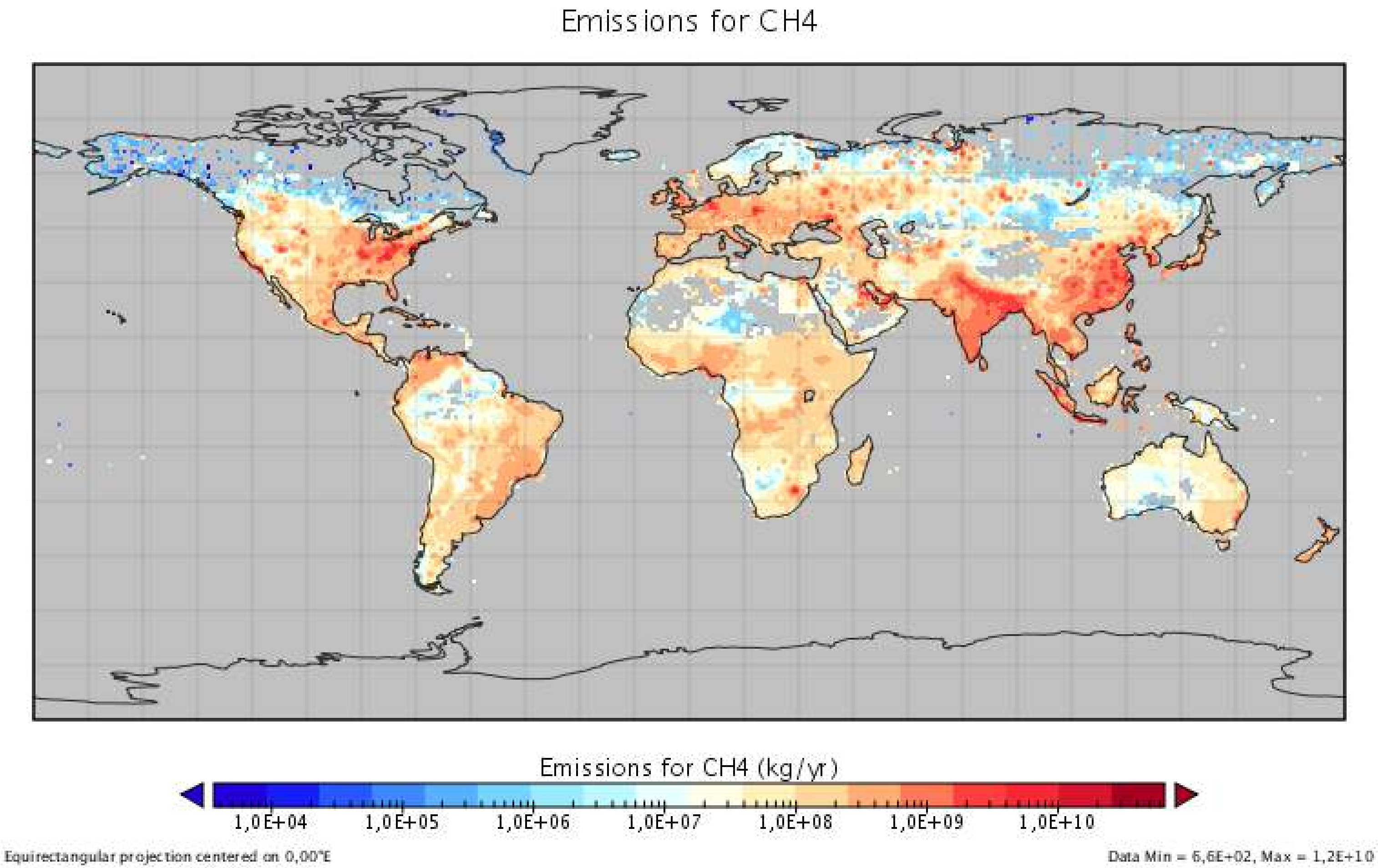


GWP, 100 years

3.6. Az egyes légszennyező anyagok GTP-vel súlyozott emisszió térképei, 20, 50, 100 év

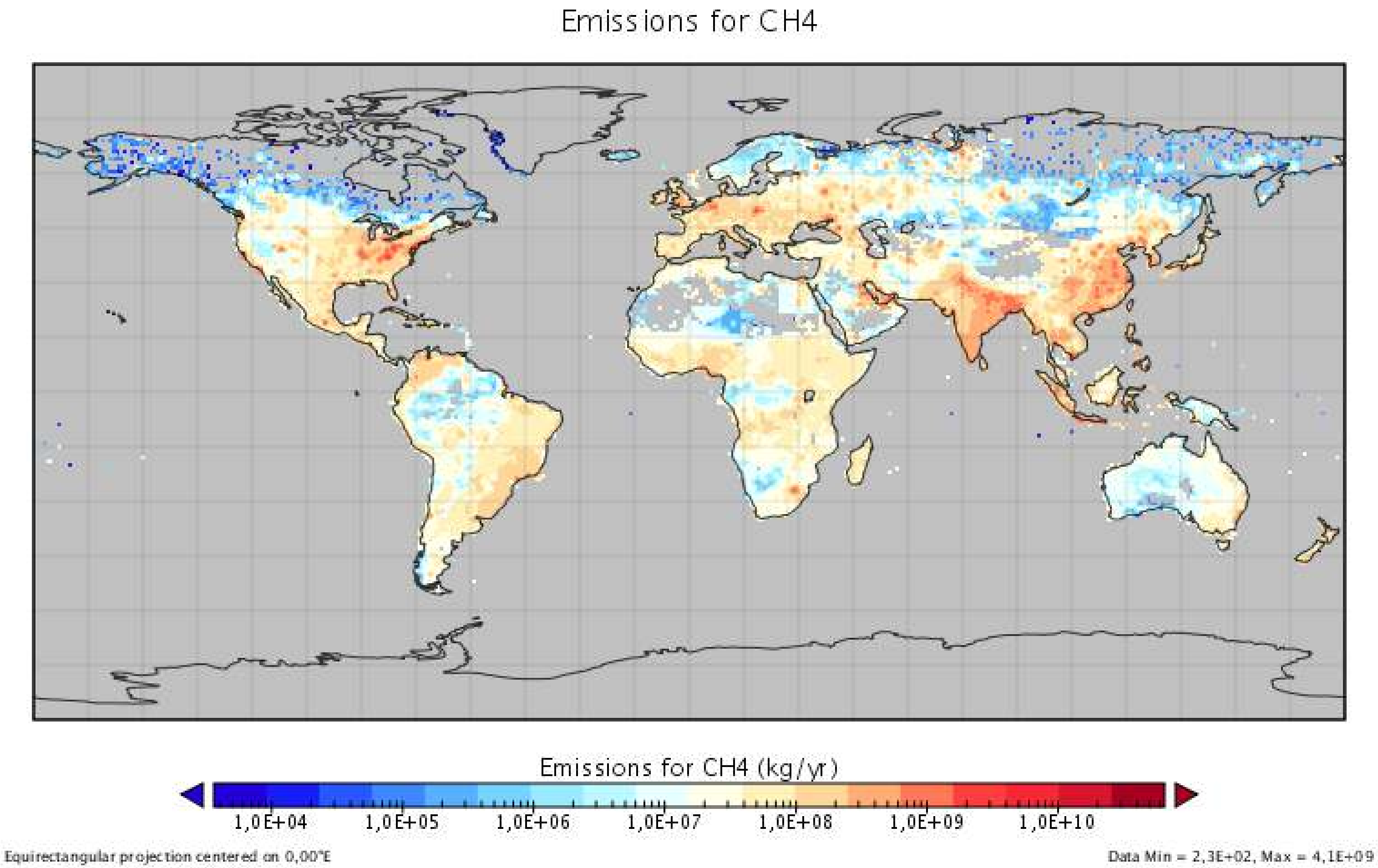


GTP, 20 years

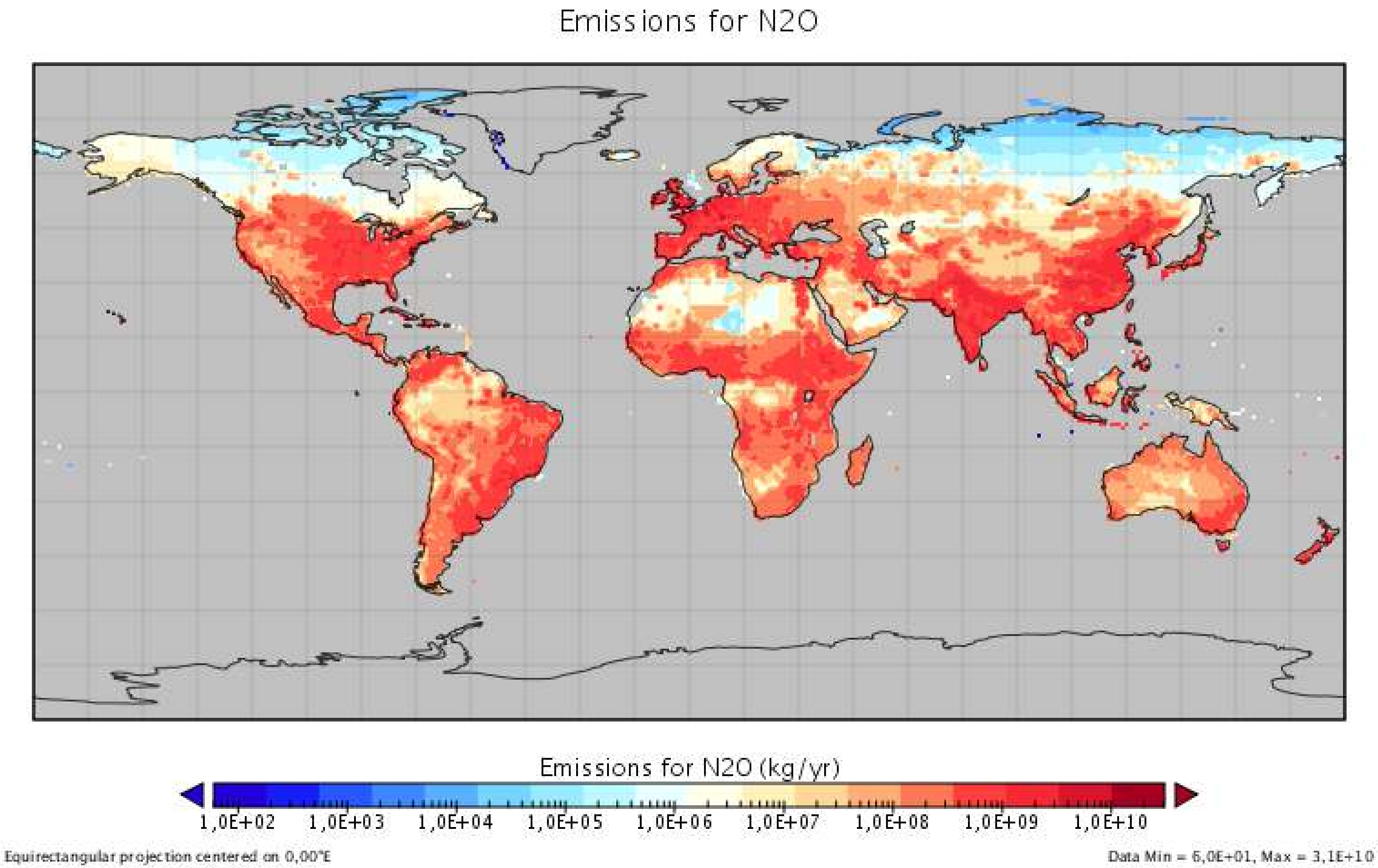


GTP, 50 years

QUANTIFY

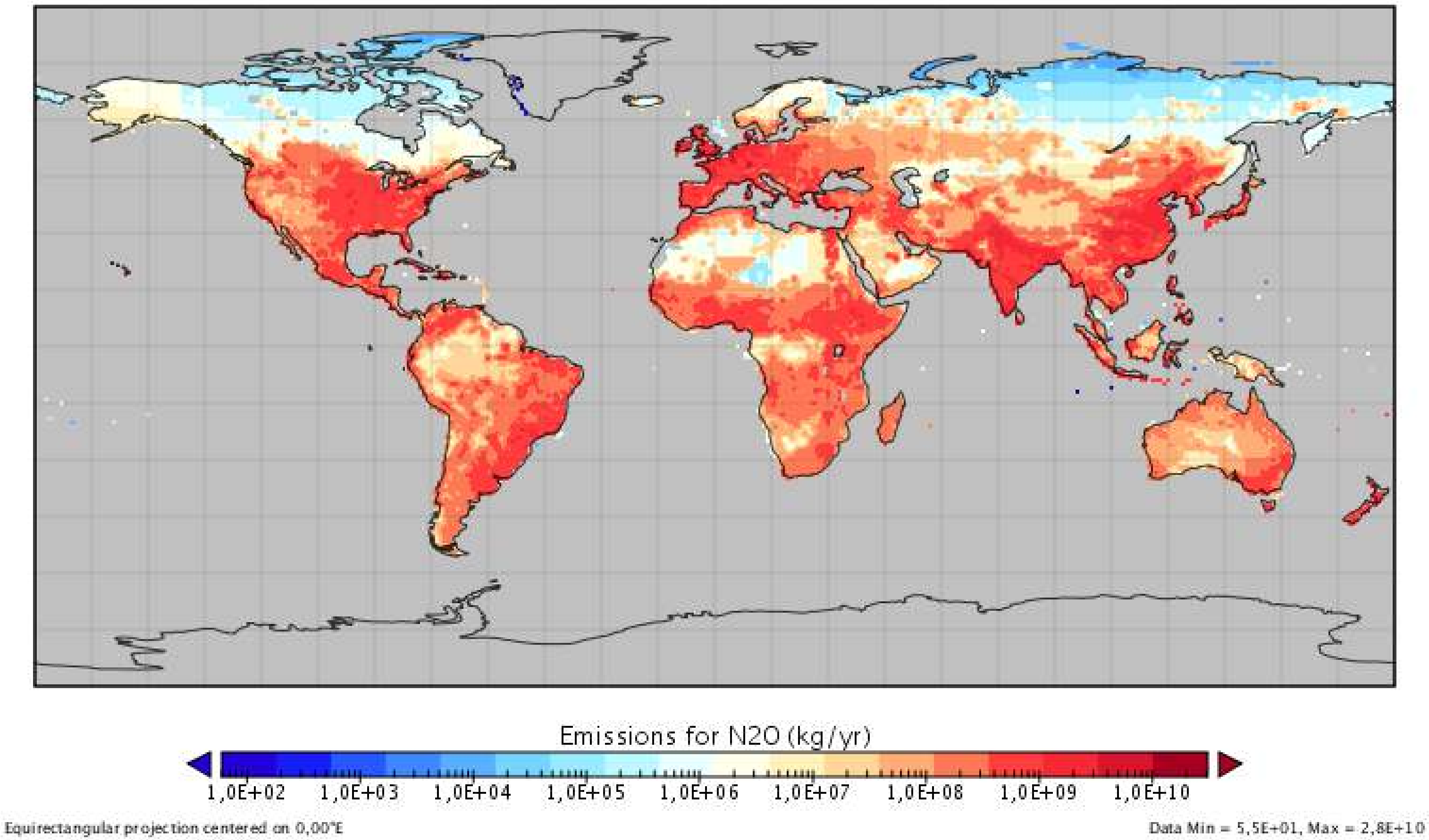


GTP, 100 years

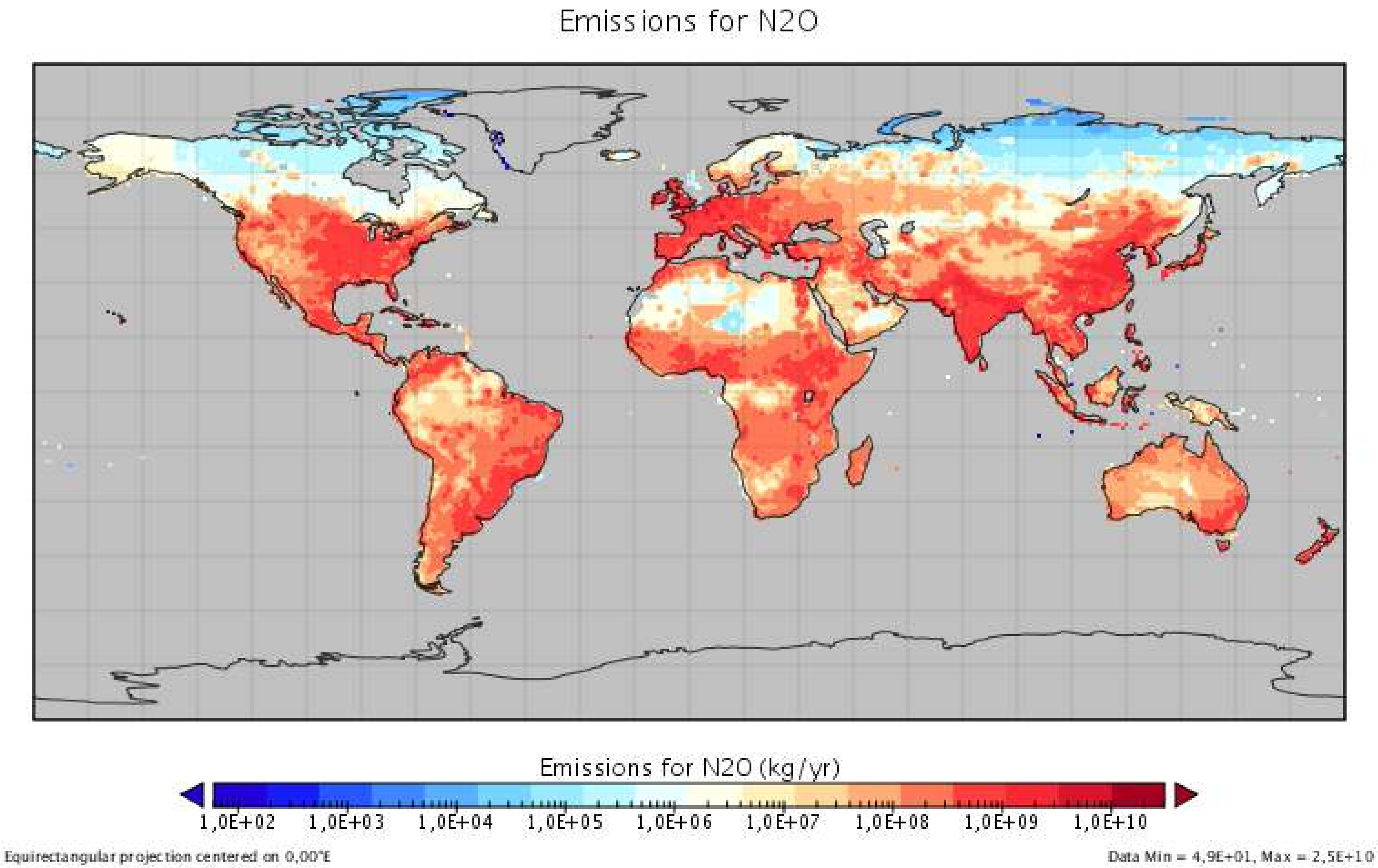

Emissions for N2O
Emissions for N2O (kg/yr)
1,0E+02
1,0E+03
1,0E+04
1,0E+05
1,0E+06
1,0E+07
1,0E+08
1,0E+09
1,0E+10
Equirectangular projection centered on 0,00°E
Data Min = 6,0E+01, Max = 3,1E+10

GTP, 20 years

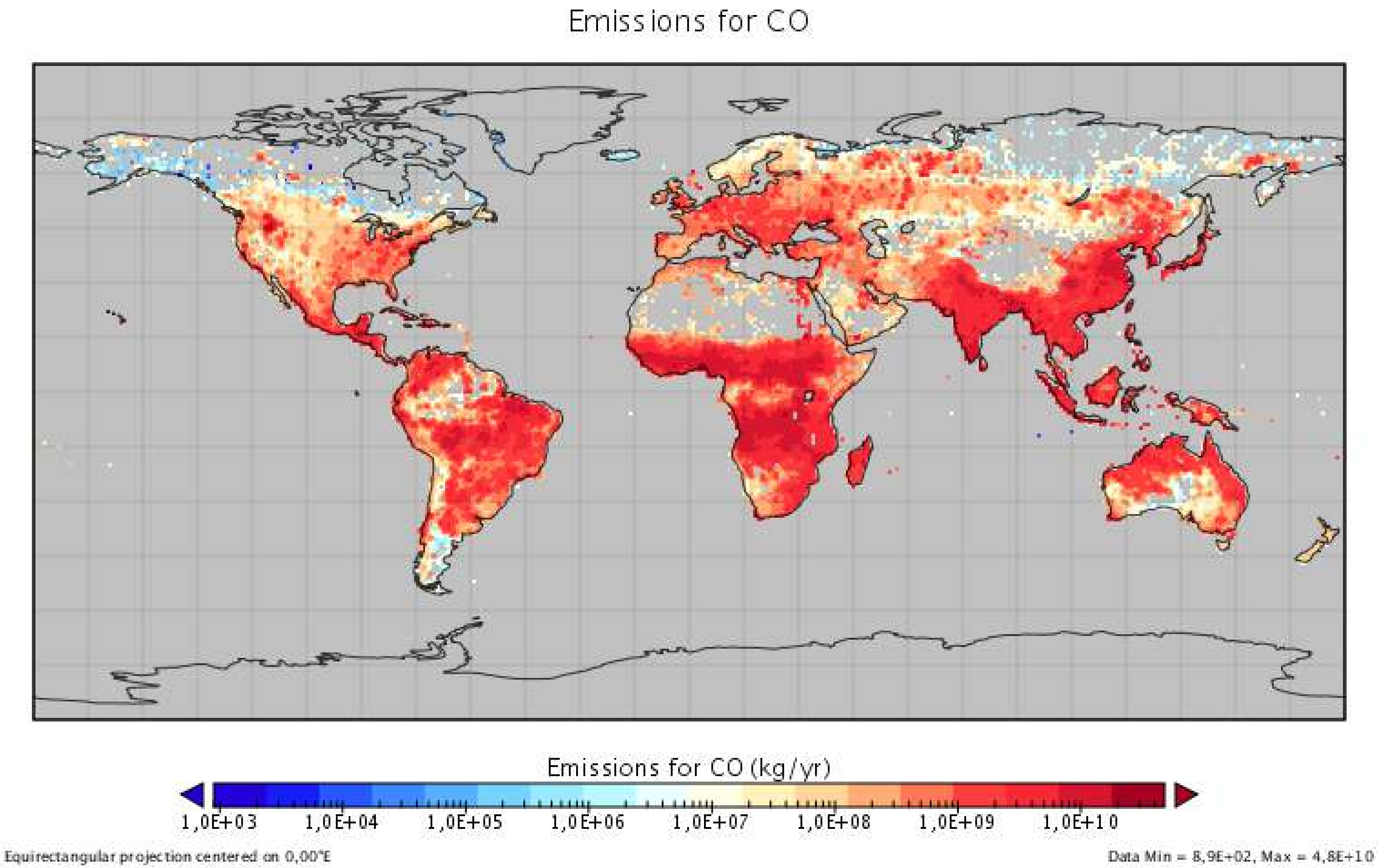
Emissions for N2O



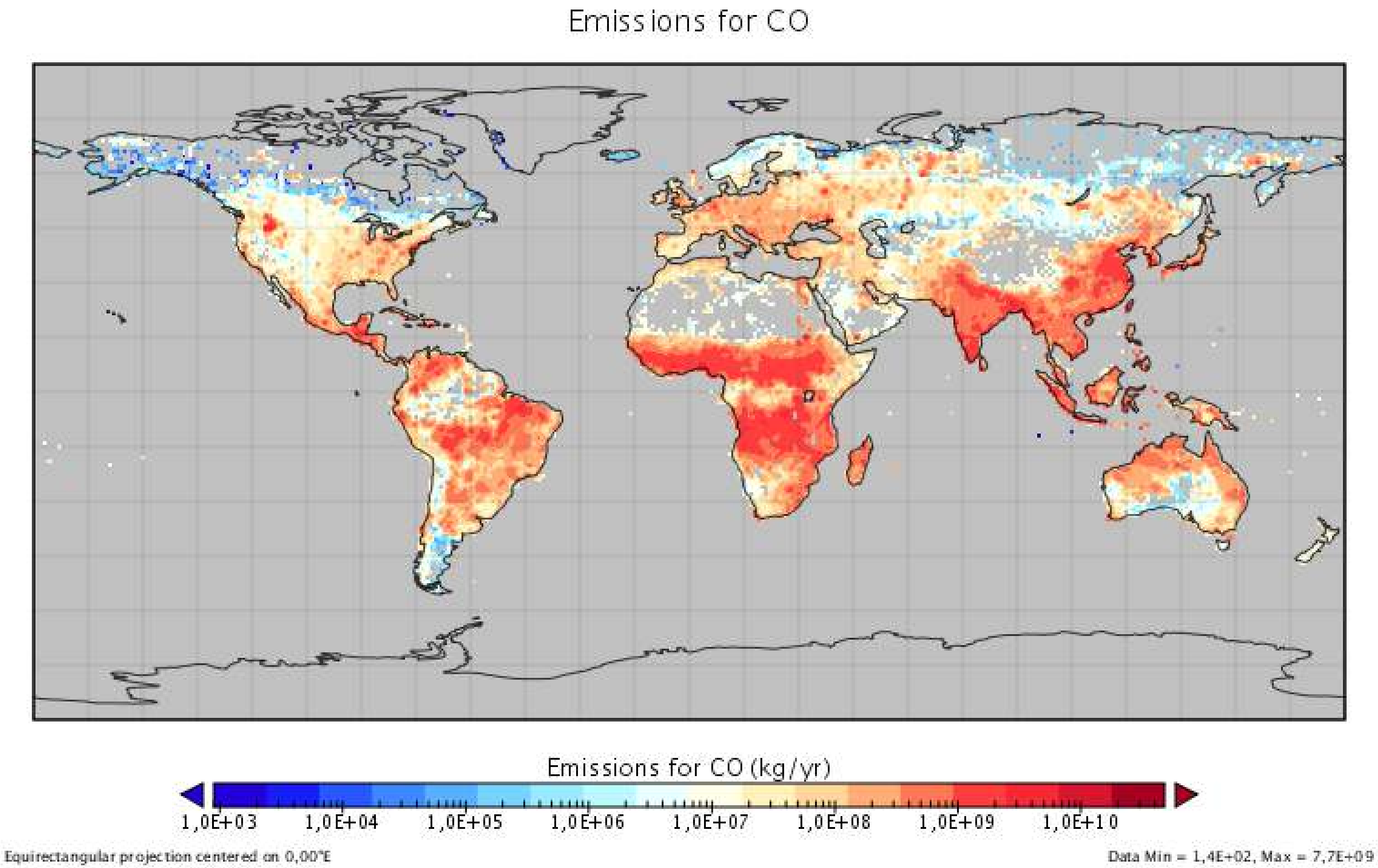
GTP, 50 years



GTP, 100 years

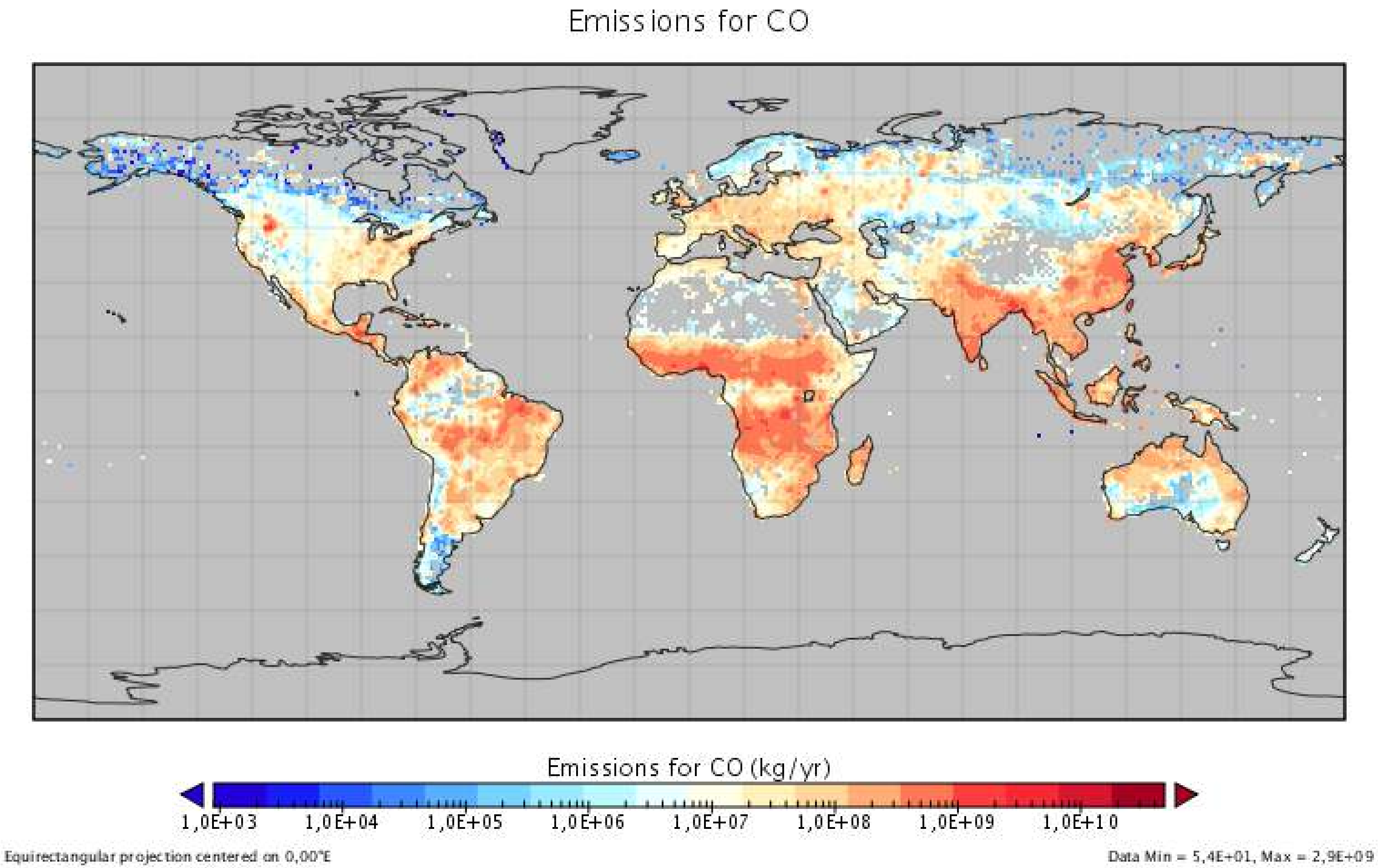

Emissions for CO
Emissions for CO (kg/yr)
1,0E+03
1,0E+04
1,0E+05
1,0E+06
1,0E+07
1,0E+08
1,0E+09
1,0E+10
Equirectangular projection centered on 0,00°E
Data Min = 8,9E+02, Max = 4,8E+10

GTP, 20 years

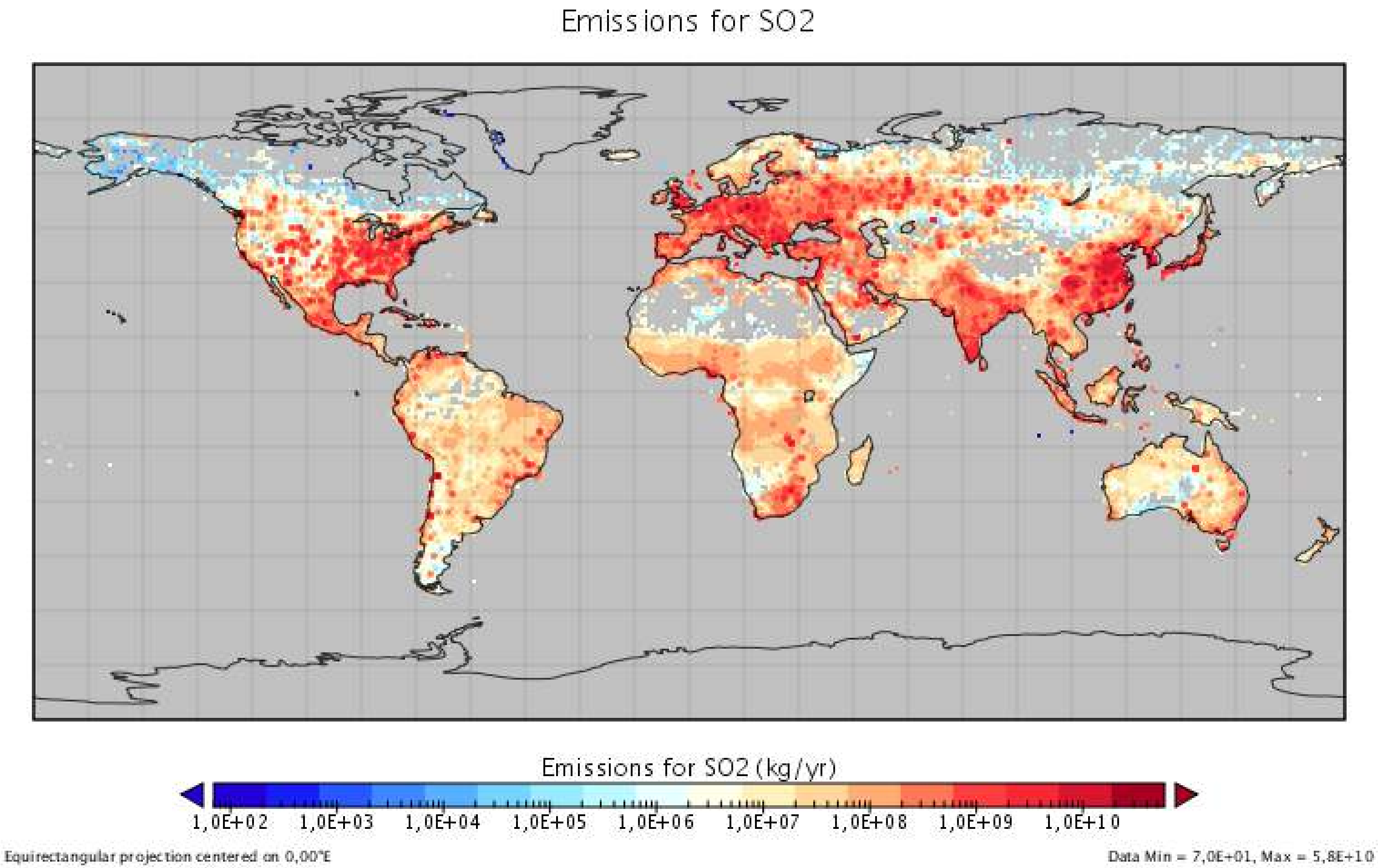


Emissions for CO
Emissions for CO (kg/yr)
1,0E+03
1,0E+04
1,0E+05
1,0E+06
1,0E+07
1,0E+08
1,0E+09
1,0E+10
Equirectangular projection centered on 0,00°E
Data Min = 1,4E+02, Max = 7,7E+09

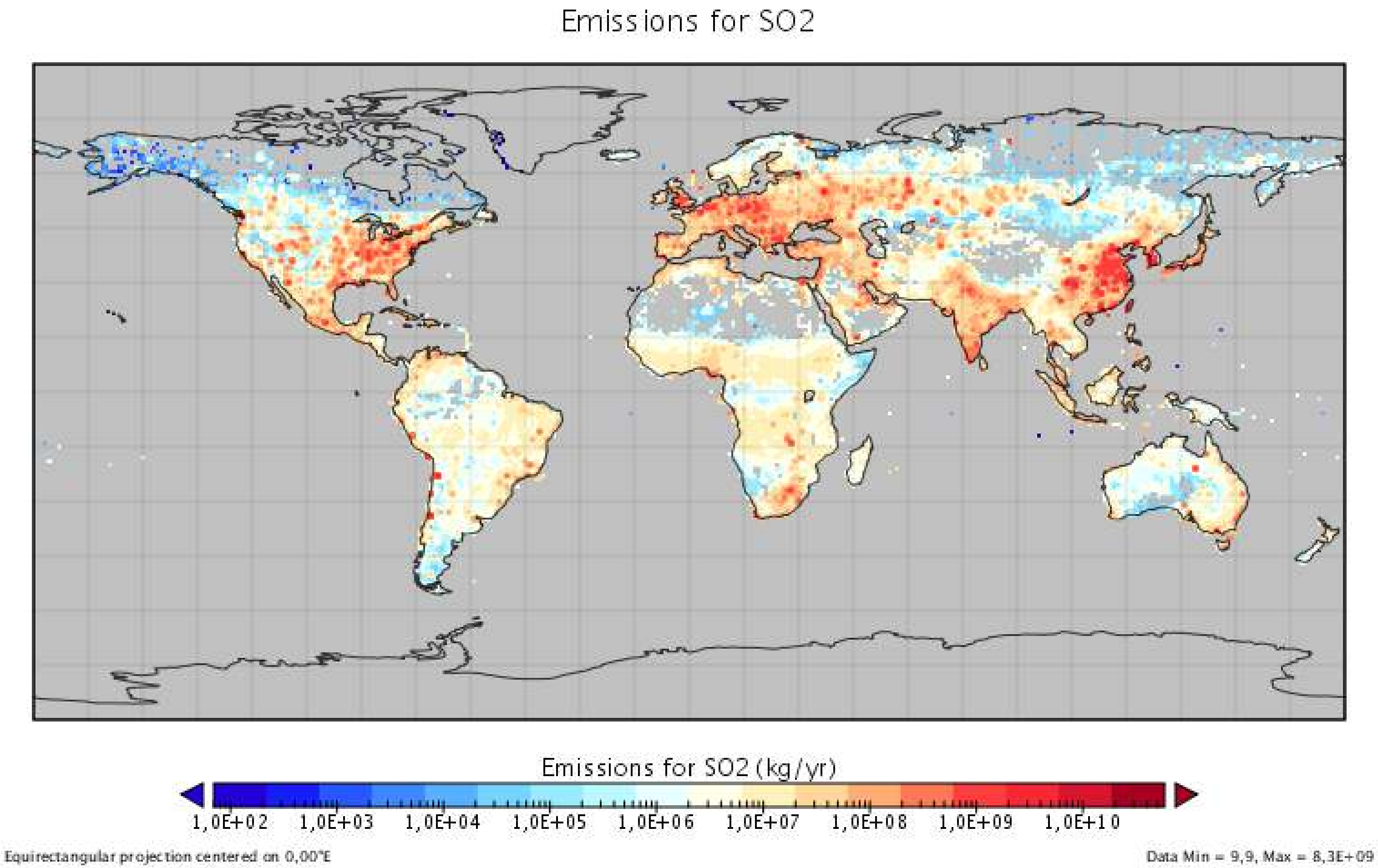
GTP, 50 years



GTP, 100 years

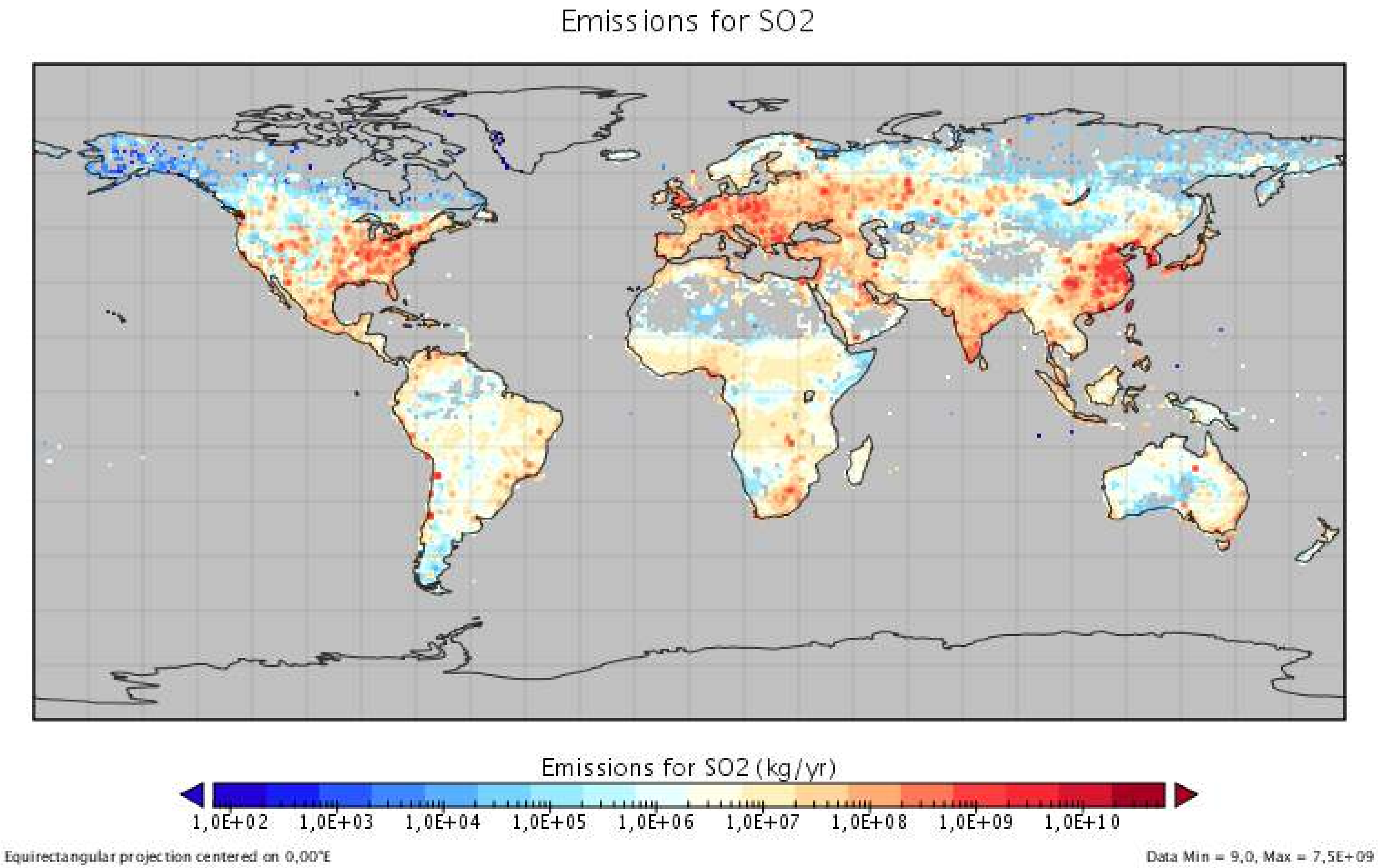

Emissions for SO2
Emissions for SO2 (kg/yr)
1,0E+02 1,0E+03 1,0E+04 1,0E+05 1,0E+06 1,0E+07 1,0E+08 1,0E+09 1,0E+10
Equirectangular projection centered on 0,00°E
Data Min = 7,0E+01, Max = 5,8E+10

GTP, 20 years

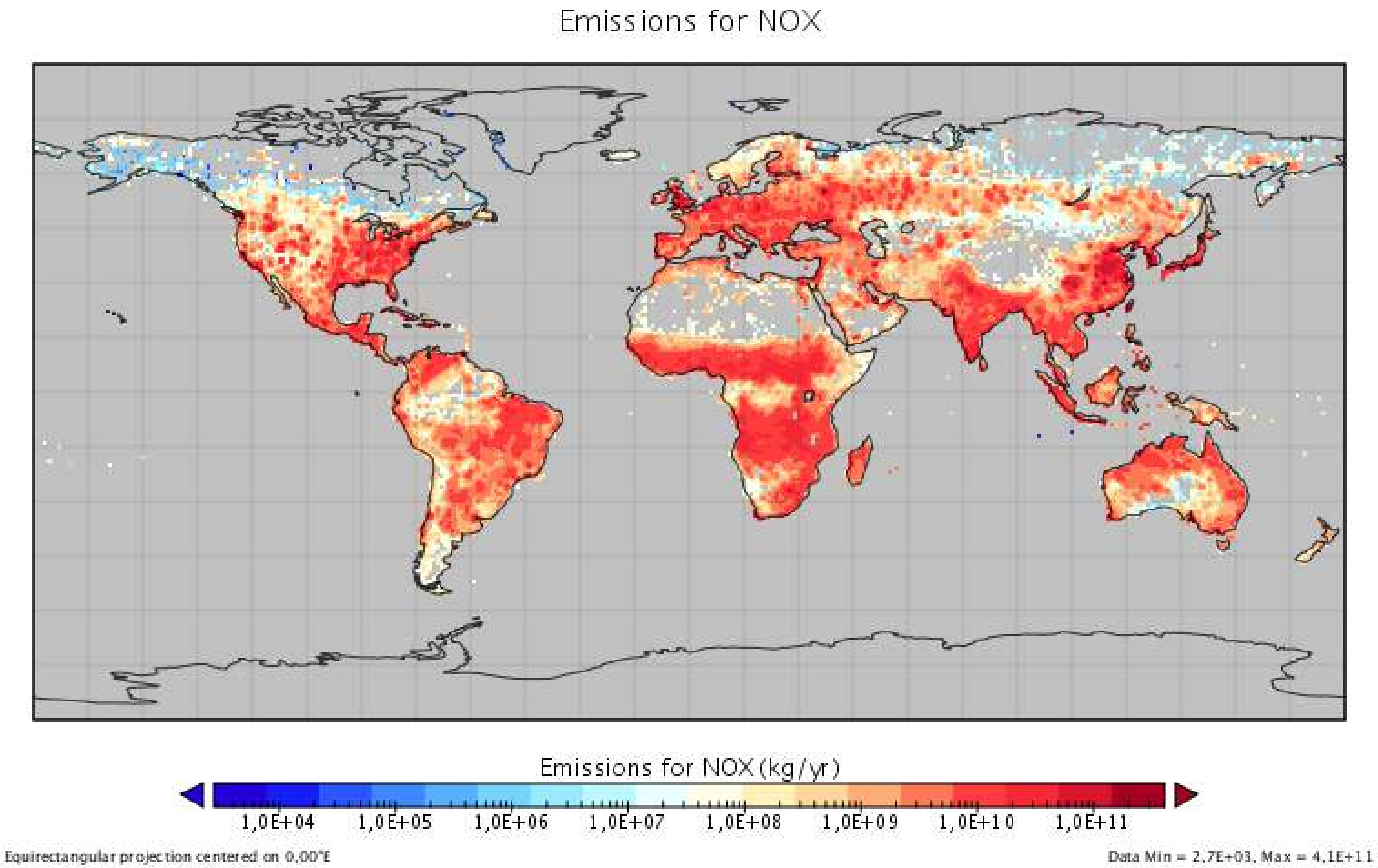


Emissions for SO2
Emissions for SO2 (kg/yr)
1,0E+02
1,0E+03
1,0E+04
1,0E+05
1,0E+06
1,0E+07
1,0E+08
1,0E+09
1,0E+10
Equirectangular projection centered on 0,00°E
Data Min = 9,9, Max = 8,3E+09

GTP, 50 years

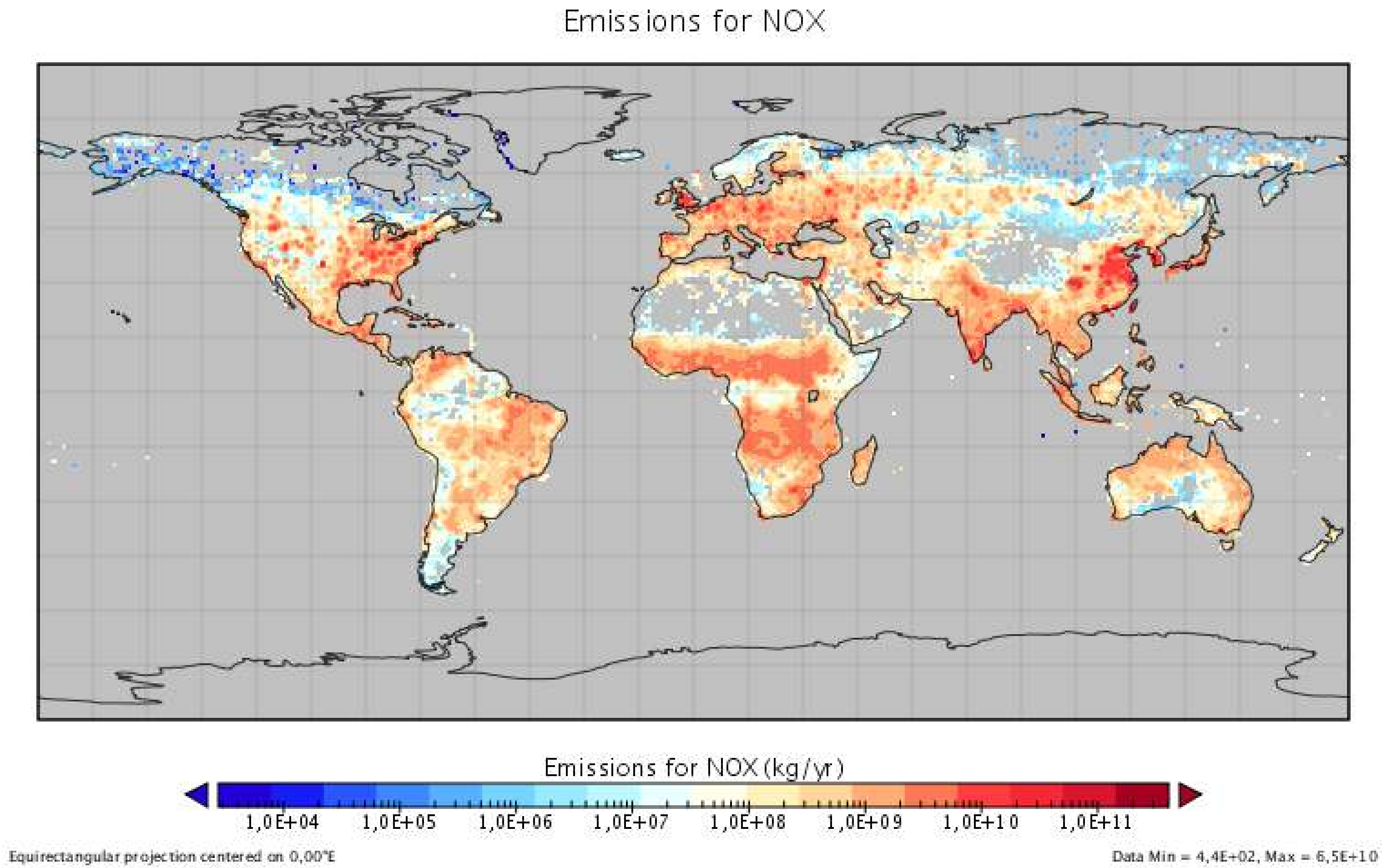


GTP, 100 years

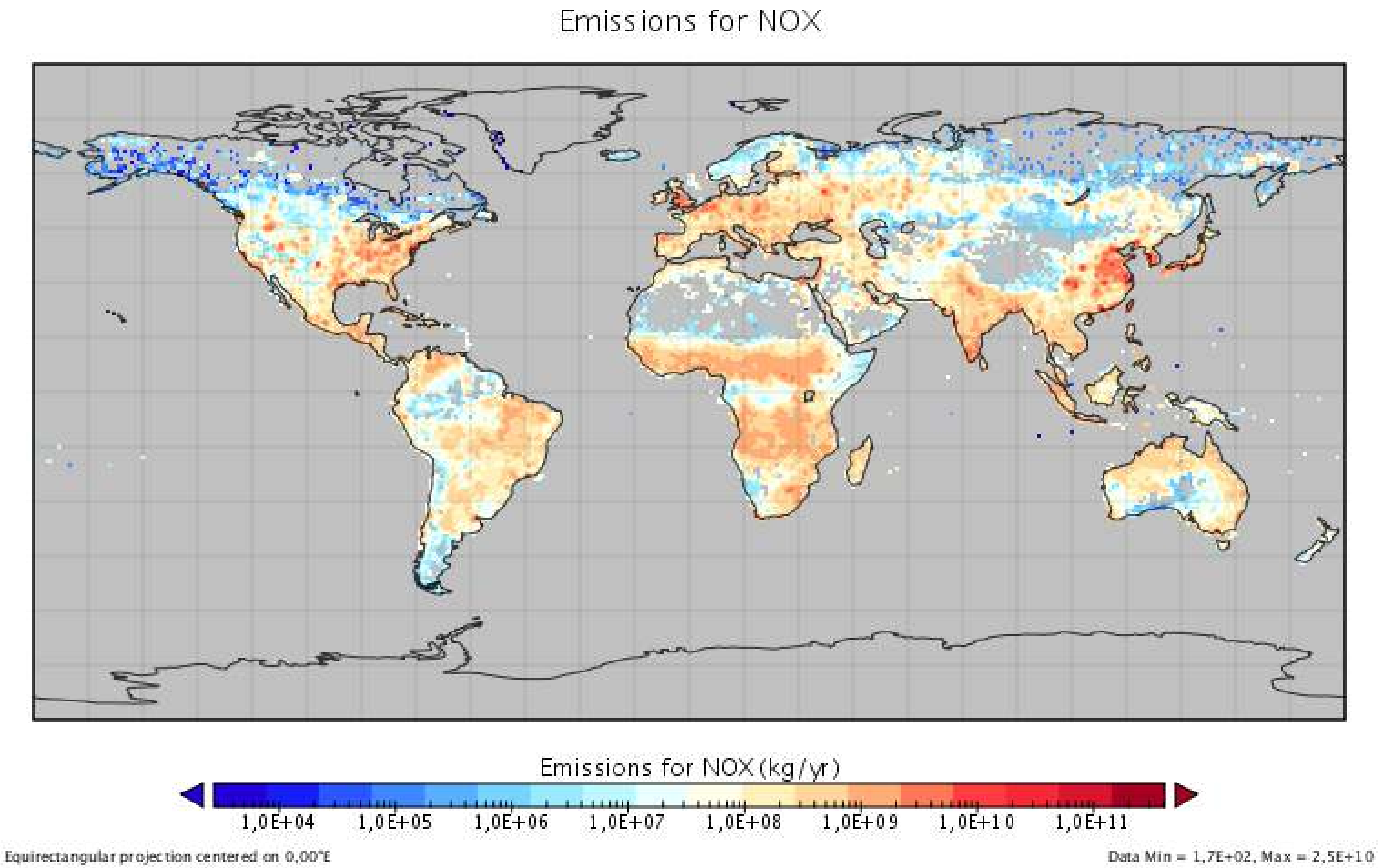


GTP, 20 years

QUANTIFY


Emissions for NOX
Emissions for NOX (kg/yr)
1,0E+04 1,0E+05 1,0E+06 1,0E+07 1,0E+08 1,0E+09 1,0E+10 1,0E+11
Equirectangular projection centered on 0,00°E
Data Min = 4,4E+02, Max = 6,5E+10

GTP, 50 years



GTP, 100 years

Emission inventories of the different transport modes

4.3. Year 2000 land transport emissions inventory

Institute: DLR Institute for Transportation Research Berlin, Germany (DLR-VS)

Version date: 15-December-2006 (final inventory), 5-January-2007 (BC, OC, primary PM1 as add-on to final inventory)

File Description:

The data are provided as comma-separated text files.

Data Description:

BC, OC and primary PM1 emissions were calculated as fractions of total primary PM (as delivered 15/12/2006), using data from Bond et al. (2004).

Bond et al.'s emission factors are not used, but rather the shares they give for BC, OC and primary PM1 as fractions of total primary PM. Total primary PM emissions were calculated based on transport volumes collected and/or estimated by Filip Vanhove (TML), emission factors estimated by Tamas Meretei (KTI) and fuel sales data from the International Energy Agency (IEA) (with some corrections).

The total primary PM emissions are part of the inventory as delivered 15/12/2006.

The emissions are calculated on an annual basis. All emissions are exhaust emissions only and are given in tonnes.

Data are provided on a basic 1° x 1° longitude/latitude grid. Ocean cells are omitted from the output.

\N stands for missing data (rail and inland waterways emissions are not yet calculated).

Reference

Bond, T.C., D.G. Streets, K.F. Yarber, S.M. Nelson, J.-H. Woo, and Z. Klimont (2004), A technology-based global inventory of black and organic carbon emissions from combustion. J. Geophys. Res., 109, D14203, doi:10.1029/2003JD003697)

Maps of GTP and GWP weighted emissions for CH_4, CO, SO_2 are presented for both freight and passenger transport origin emissions and also for emissions of their total (freight + passenger).

4.4. Year 2000 rail and inland navigation emissions inventory

Institute: DLR Transportation Studies, Berlin, Germany (DLR-VS)

Version date: 9-April-2008 (final)

File Description:

The data are provided as comma-separated text files. There are 12 data files.

Data Description:

Emission calculations are based on fuel sales data (mainly from the International Energy Agency (IEA)), and on emission factors estimated by Jens Borken and Suman Baidya.

The passenger/freight split of rail energy consumption was also estimated by Jens Borken.

IEA's energy consumption category "Domestic Navigation" includes national coastal shipping.

This domestic energy consumption was split into coastal shipping and inland navigation (=on rivers, lakes and canals) based on transport volumes.

Gridded coastal shipping was not calculated, only gridded inland navigation. Non-gridded data are available for both.

Inland navigation is assumed to be all freight transport.

The emissions are calculated on an annual basis. All emissions are exhaust emissions only.

They are given in tonnes as mass CO_2, SO_2, CO, NO_2, NMHC, CH_4, primary PM (all sizes), primary PM_1, BC, OC and N_2O.

Emissions due to electricity generation for rail are not included.

Its is assumed that in the year 2000, rail used only fossil fuels and electricity, and inland navigation used only fossil fuels.

The energy consumption is given in tonne (fossil fuels) or kWh (electricity).

Data are provided on a basic 1°x1° longitude/latitude grid. Ocean cells are omitted from the output.

A few cells in North America (mostly belonging to the Great Lakes) do not have a country code in the data (\N is given in the country column).

Maps of GTP and GWP weighted emissions for CH_4, CO, N_2O, SO_2 are presented for both freight and passenger transport origin emissions and also for emissions of their total (freight + passenger).

4.2. Annual 2000 gridded shipping emission inventory

Institute: Det Norske Veritas (DNV)

Version date of readme file: 18-November-2008

Version data of data: 08-may-2006

Temporal resolution: annual

Inventory description:

Lat = Latitude

Long = Longitude

Nobs = indicate number of **observation in each 1x1 degree grid cell**

Perc_nobs= % of total number of observations in each lat-long cell

Emission is given in tonnes per 1 degree by 1 degree grid cell for all compounds.

The coordinates of the 1x1 degree cells refer to the lower left corner.

Note that CO_2 emissions are given in mass CO_2, as well as NO_X emissions are given in mass NO_2.

File description:

The data is provided as comma separated text files.

The first row contains the field names.

The first two columns/fields gives the Latitude/Longitude position of the grid cell.

The next 10 fields/columns gives the emission in tonnes per grid cell for the 10 exhaust compounds.

Maps of GTP and GWP weighted emissions for CH_4, CO, N_2O, NO_x, SO_2 are presented.

4. Data

4.1. Gridded aviation emissions inventory for 2000

Institute: Manchester Metropolitan University

Version date: September_2008 final

Revision History: Revised horizontal grid definition to be consistent with others e.g. surface transport grids. Current version (Sept 2008) has grid cells defined by bottom left hand corner, the bottom left grid cell is now defined as -180degrees and -90degrees.

Temporal resolution: annual or monthly

Emission calculations, based on:

(1) global flight movement statistics, Official Airline Guide (OAG)

(2) data on non-scheduled air traffic, AERO2K flight database

Fuel use data, calculated from:

flight activity data, using the PIANO engine performance model on an individual flight basis.

Total fuel usage, scaled to:

the global sales data from the International Energy Agency (IEA).

The emissions, calculated on:

an annual basis and disaggregated according to a seasonal variation to create the monthly files.

All emissions are exhaust emissions only.

Spatial resolution:

1 deg x 1 deg x 610 metres (as flight levels i.e. Flight level 0 = 0 to 610m, flight level 1 = 610 to 1220 m, … , flight level 22 = 13,420 to14,030 m).

Flight levels are levels of constant pressure, and the altitude to pressure conversion is based on the ICAO standard atmosphere. The longitude/latitude values refer to the lower-left corner of the cell.

Temporal resolution:

Yearly or monthly

Annual file units:

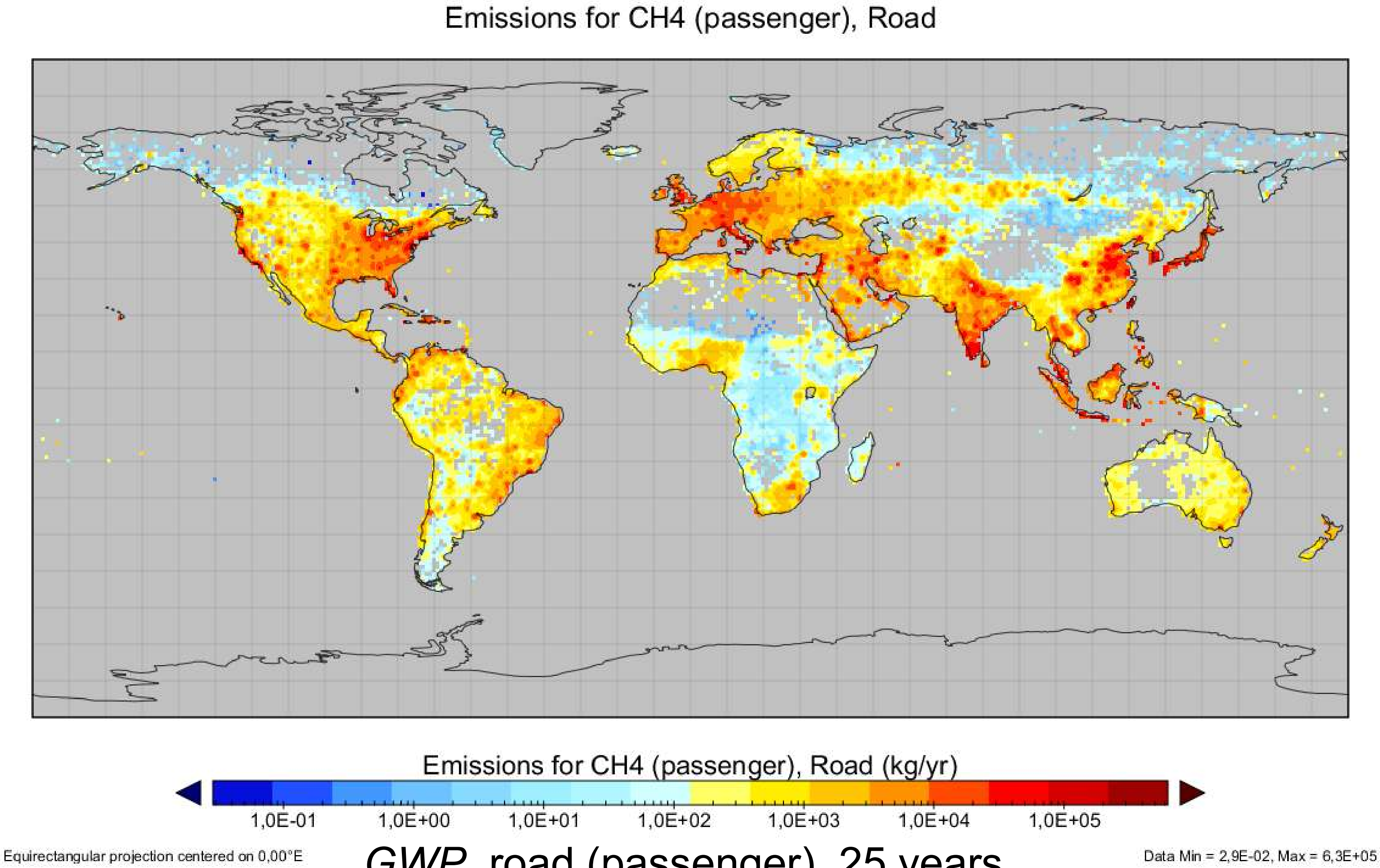
Longitude (deg), latitude (deg), level, km travelled (km/year), fuel (kg/year), NO_x (kg(NO_2)/year);

Maps of GTP and GWP weighted emissions for NO_x are presented for 23 flight levels.

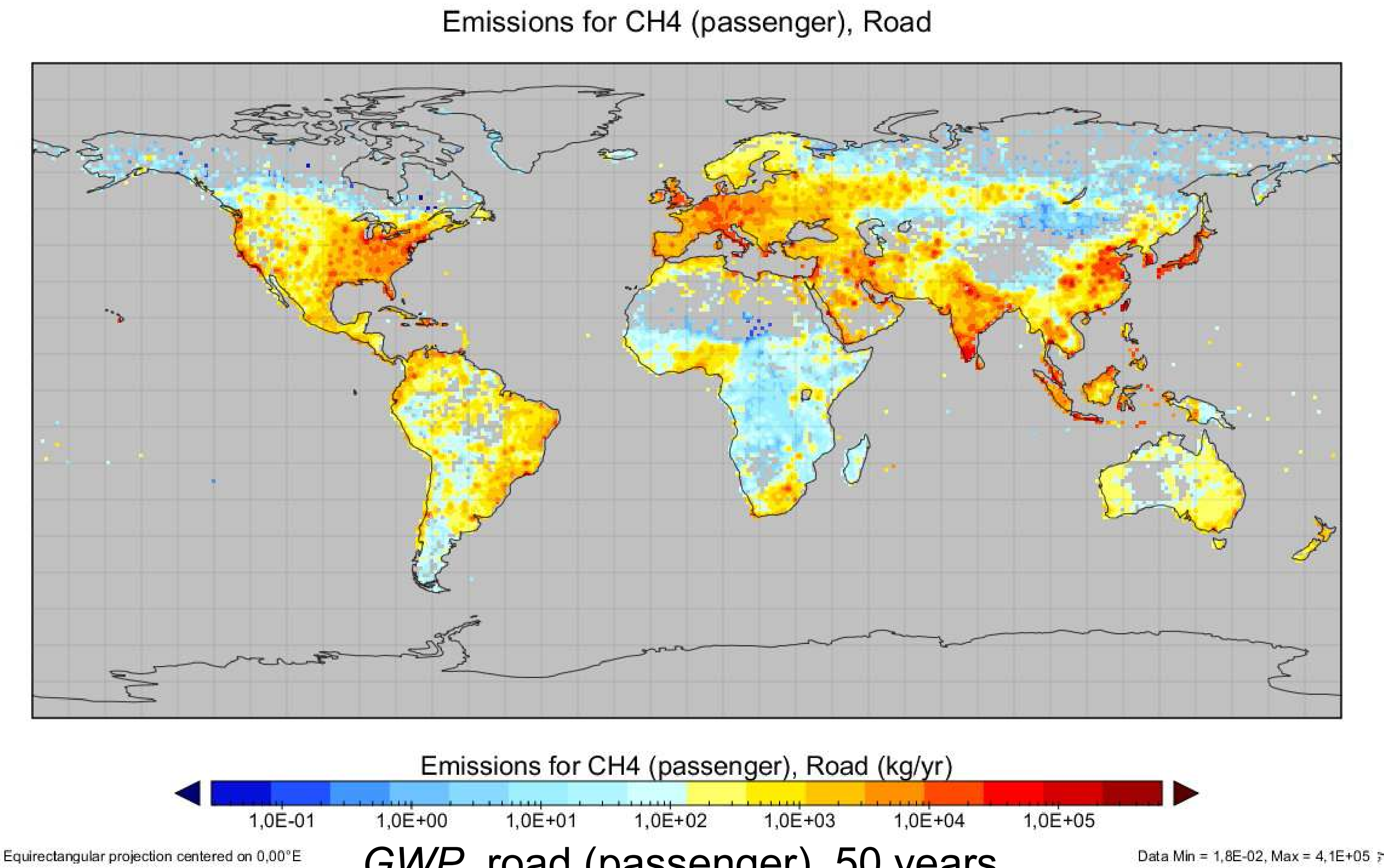
Land transport emissions

(Time horizons: 25, 50, 100 years; *GWP*, *GTP*)

5.2.3. Land transport (CH_4, CO, SO_2); time horizons: 25, 50, 100 years; *GWP*, *GTP*; road (passenger), road (freight), road (passenger+freight)



GWP, road (passenger), 25 years



GWP, road (passenger), 50 years

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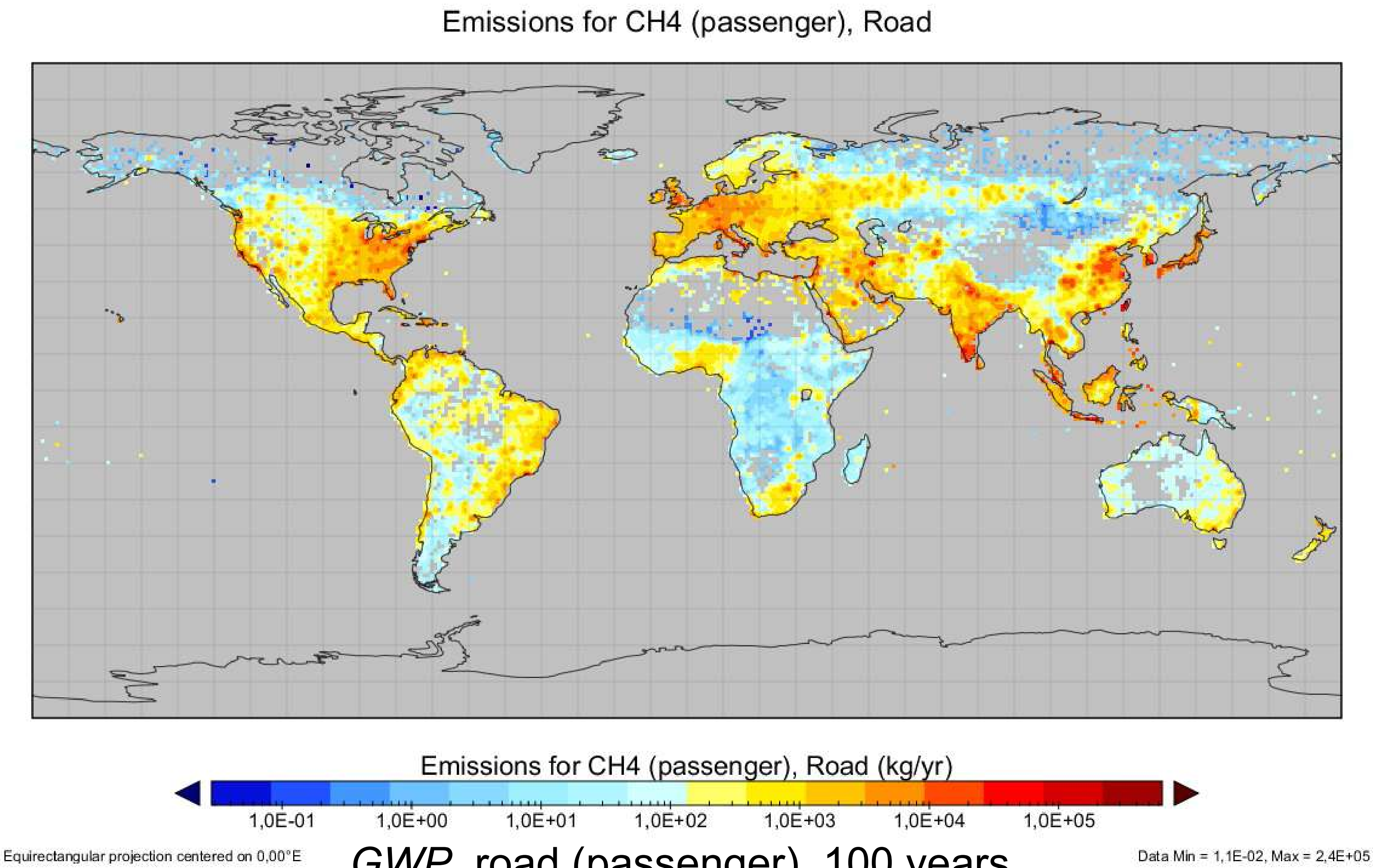


GWP, road (passenger), 100 years

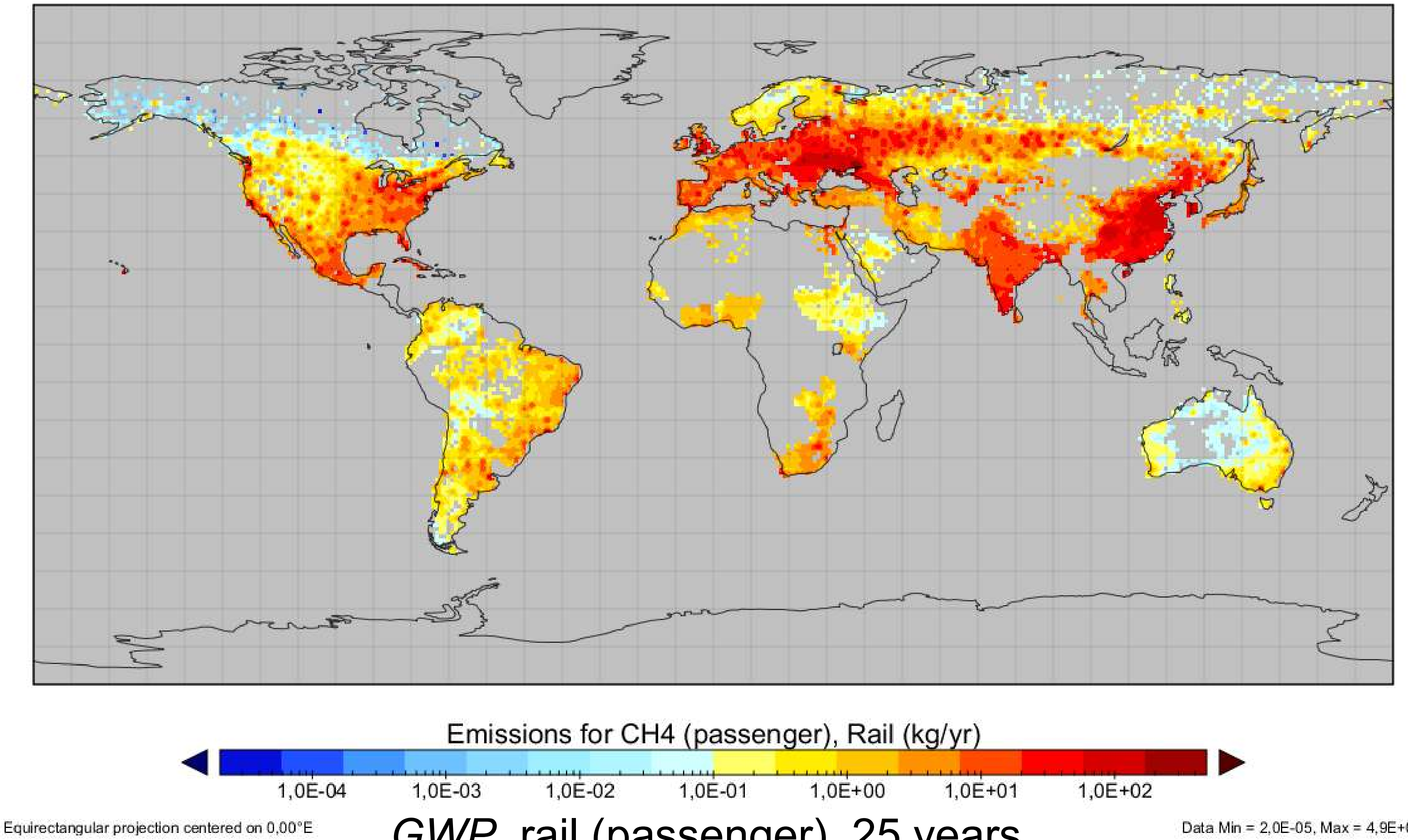
Quantify Final Meeting, 25-27 January 2010, Munich

Emissions of rail and inland navigation

(Time horizons: 25, 50, 100 years; *GWP*, *GTP*)

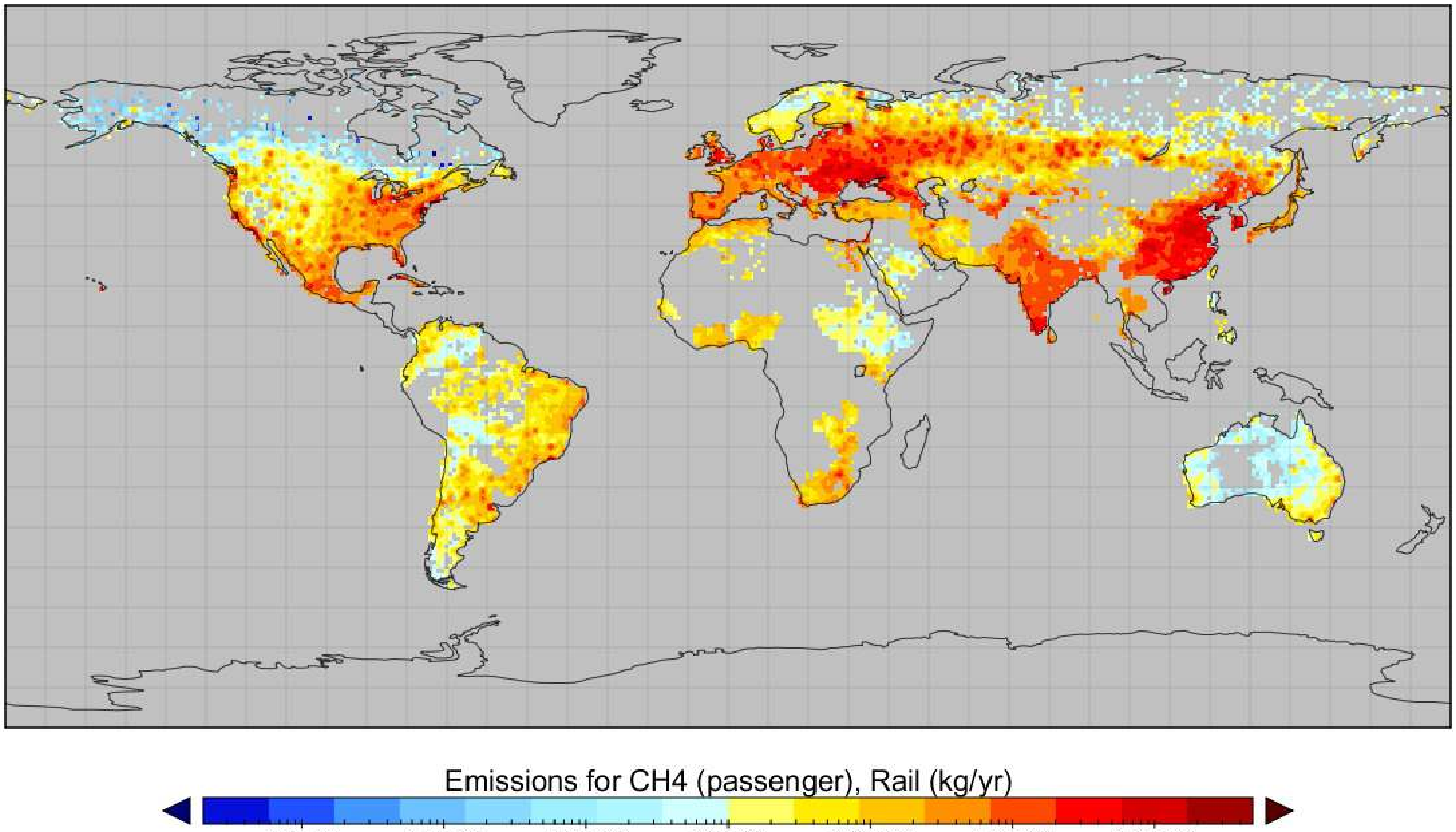
5.2.4. Rail and inland navigation (CH_4, CO, N_2O, SO_2); time horizons: 25, 50, 100 years; *GWP*, *GTP*; rail (passenger), rail (freight), rail (passenger+freight)

Emissions for CH4 (passenger), Rail



GWP, rail (passenger), 25 years

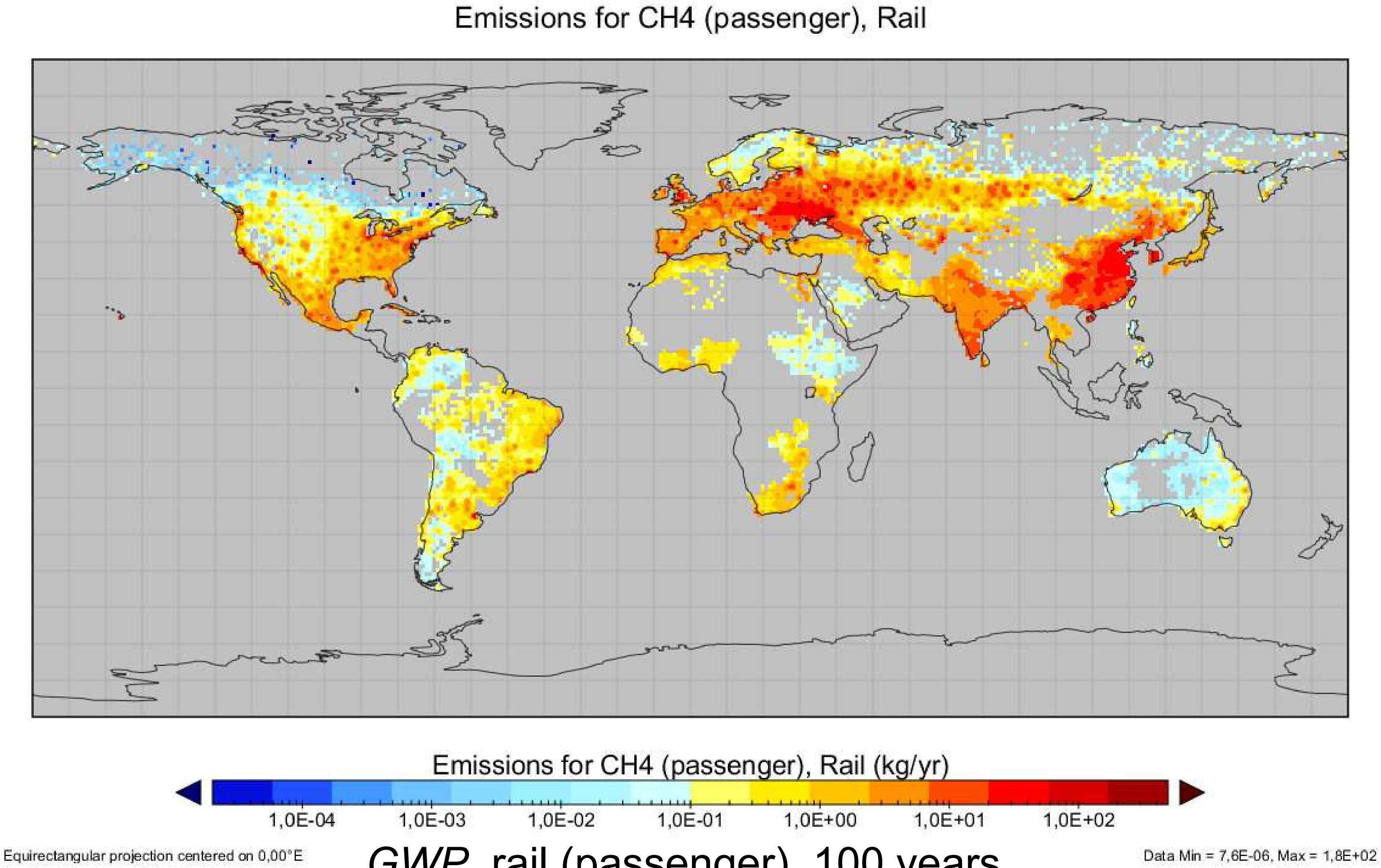
Emissions for CH4 (passenger), Rail



Equirectangular projection centered on 0,00°E

GWP, rail (passenger), 50 years

Data Min = 1,3E-05, Max = 3,2E+02



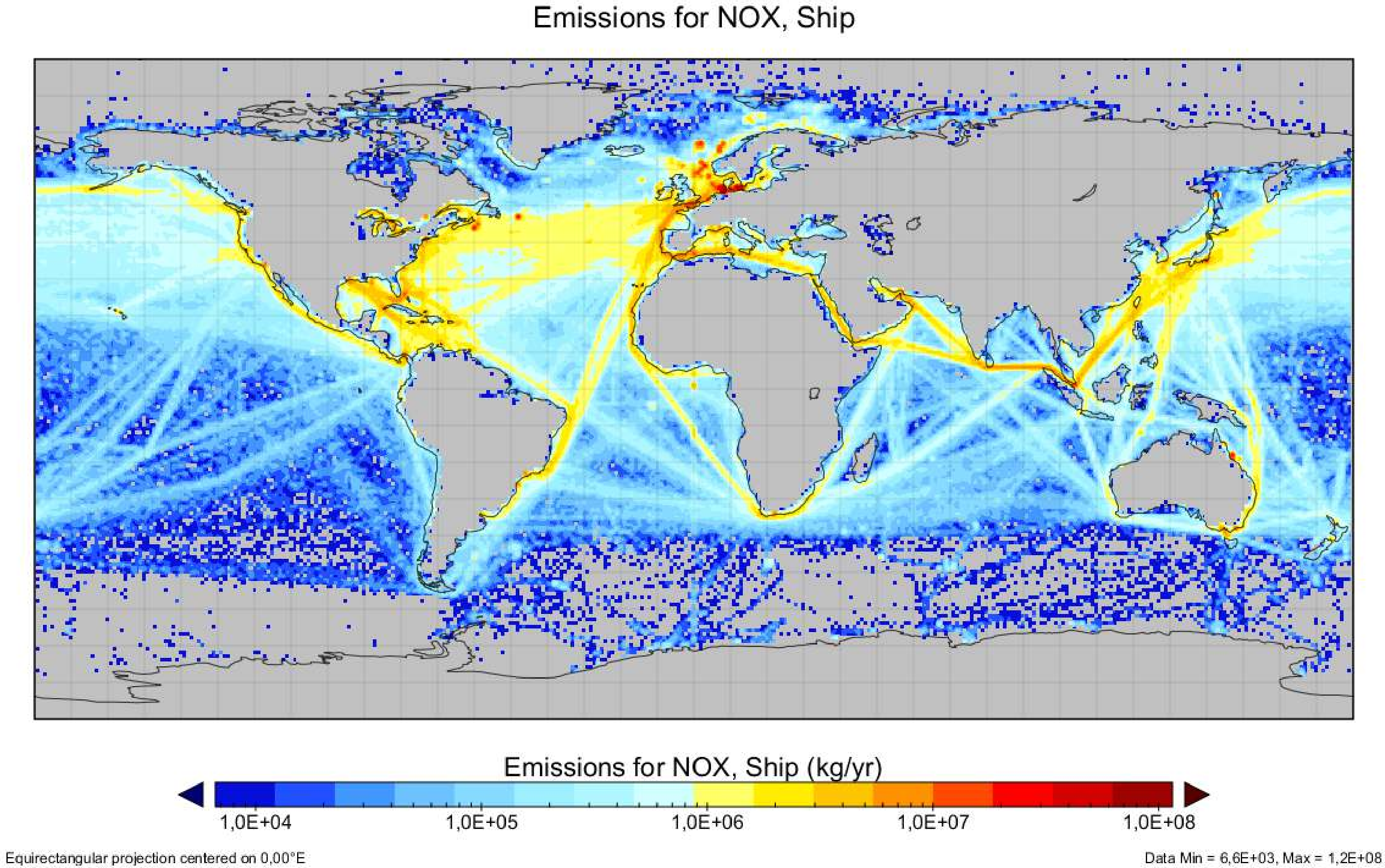
GWP, rail (passenger), 100 years

Emissions of sea shipping

(Time horizons: 25, 50, 100 years; *GWP*, *GTP*)

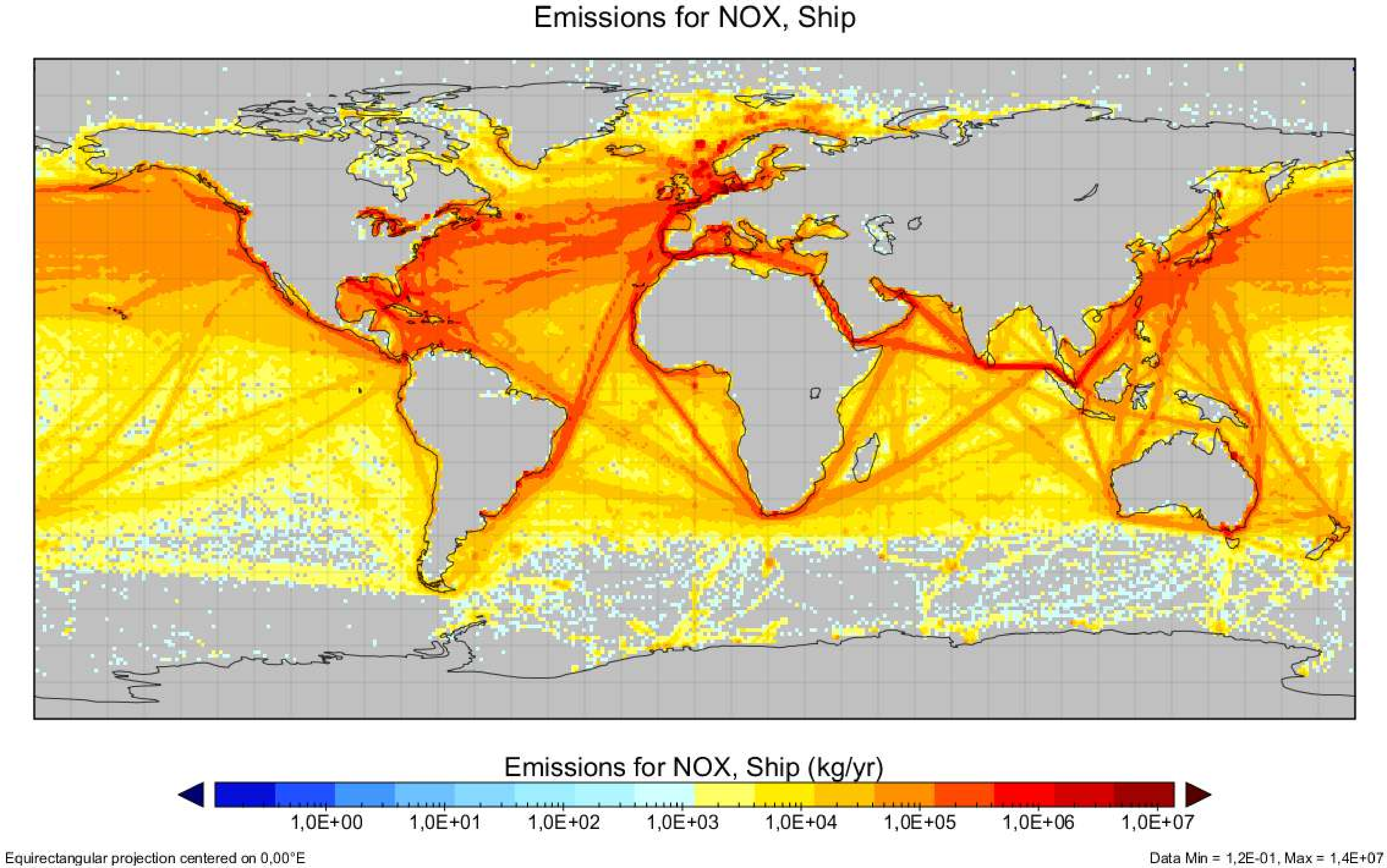
In order to make a better demonstration, emissions from ship were presented in two scales.

Scale 1: minimum and maximum values of the scale are pollutant specific, i.e. they are different for each pollutant (e.g. NO_x emissions, *GTP*, 25 years, see figure below)



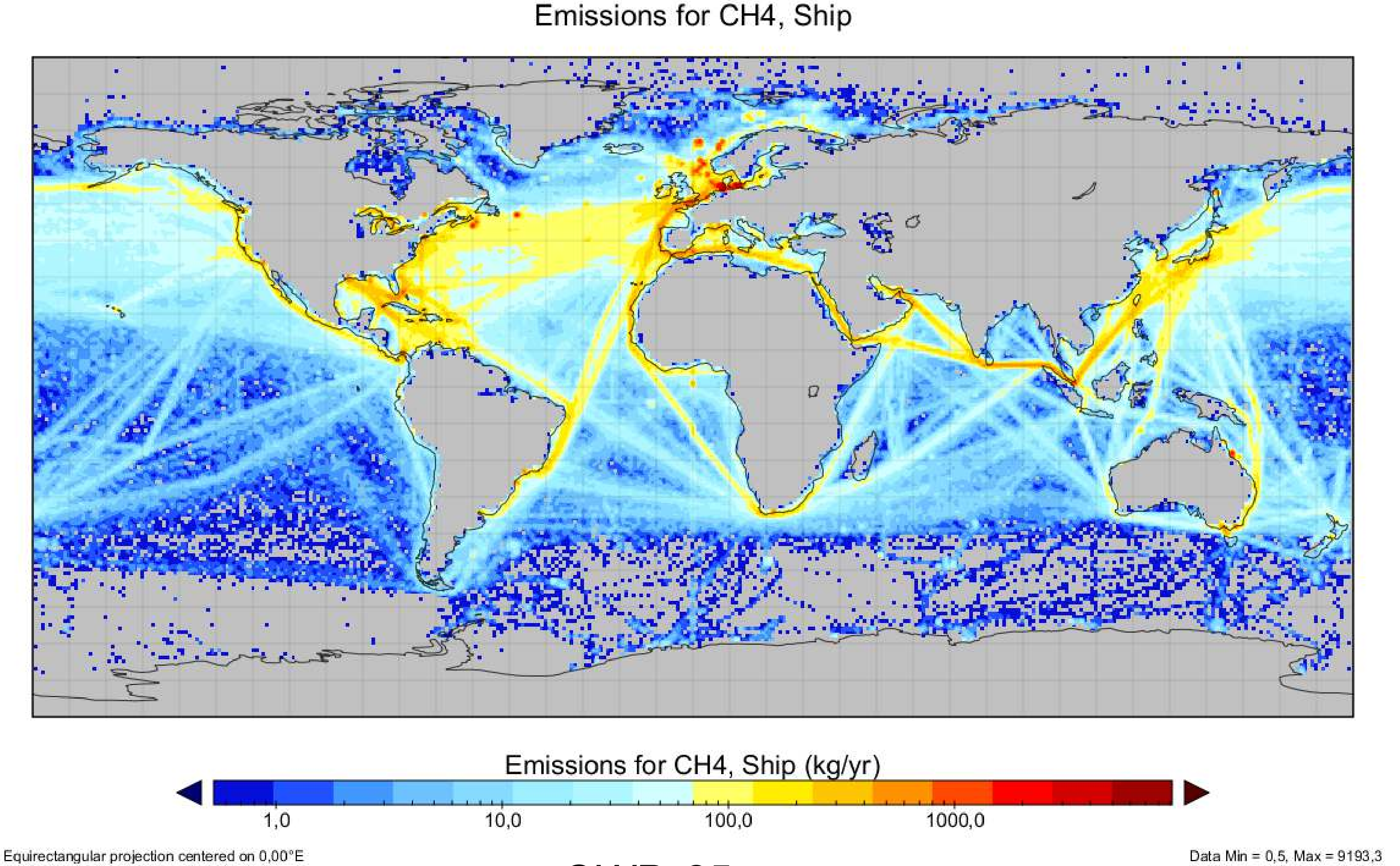
GTP, 25 years, scale 1

Scale 2: an unified scale with the same minimum and maximum values for each pollutant (e.g. NO_x emissions, *GTP*, 25 years, see figure below)

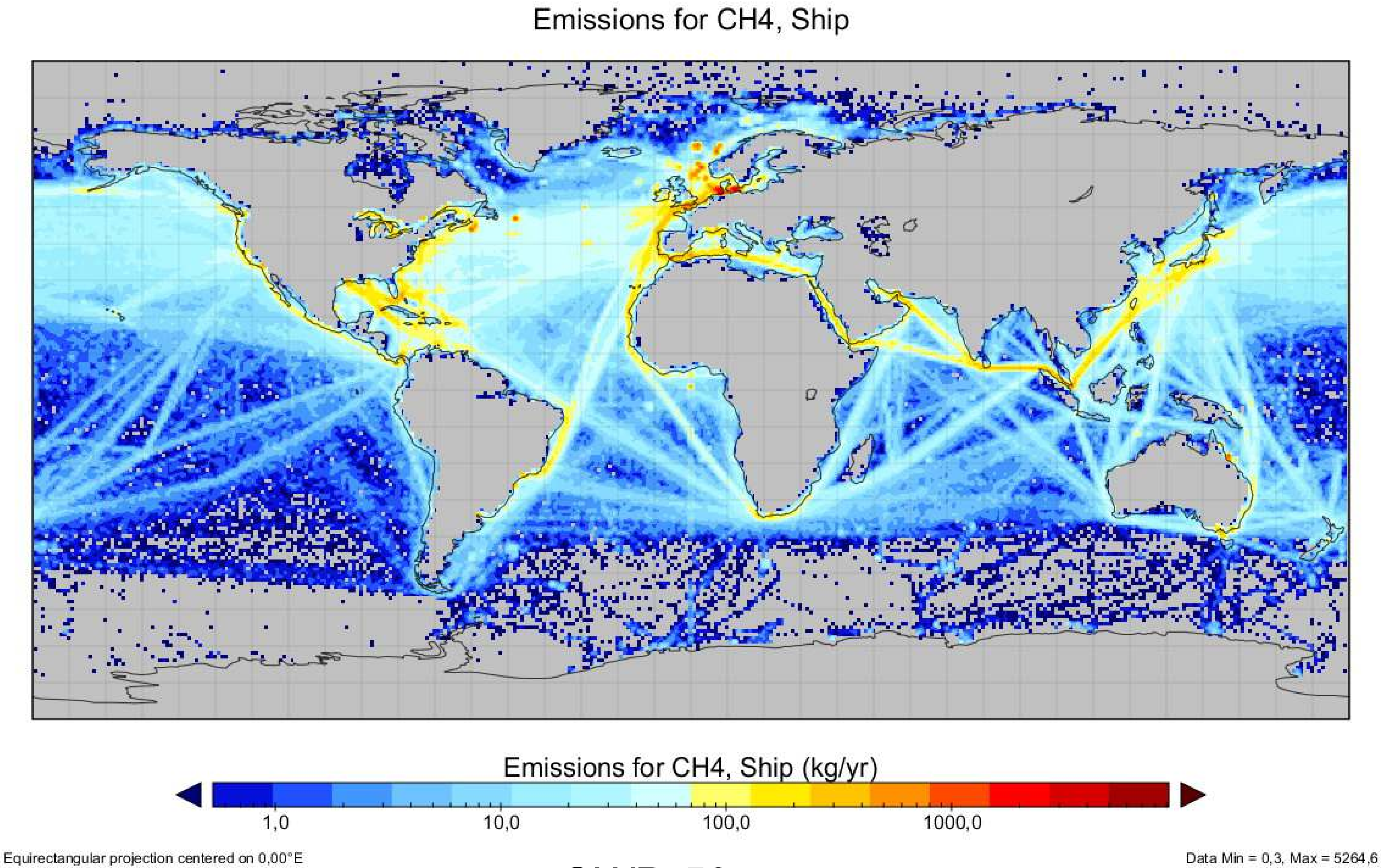


GTP, 25 years, scale 2

5.2.2. Shipping (CH_4, CO, N_2O, NO_x, SO_2; scale 1; time horizons: 25, 50, 100 years; *GWP*, *GTP*)



GWP, 25 years



GWP, 50 years

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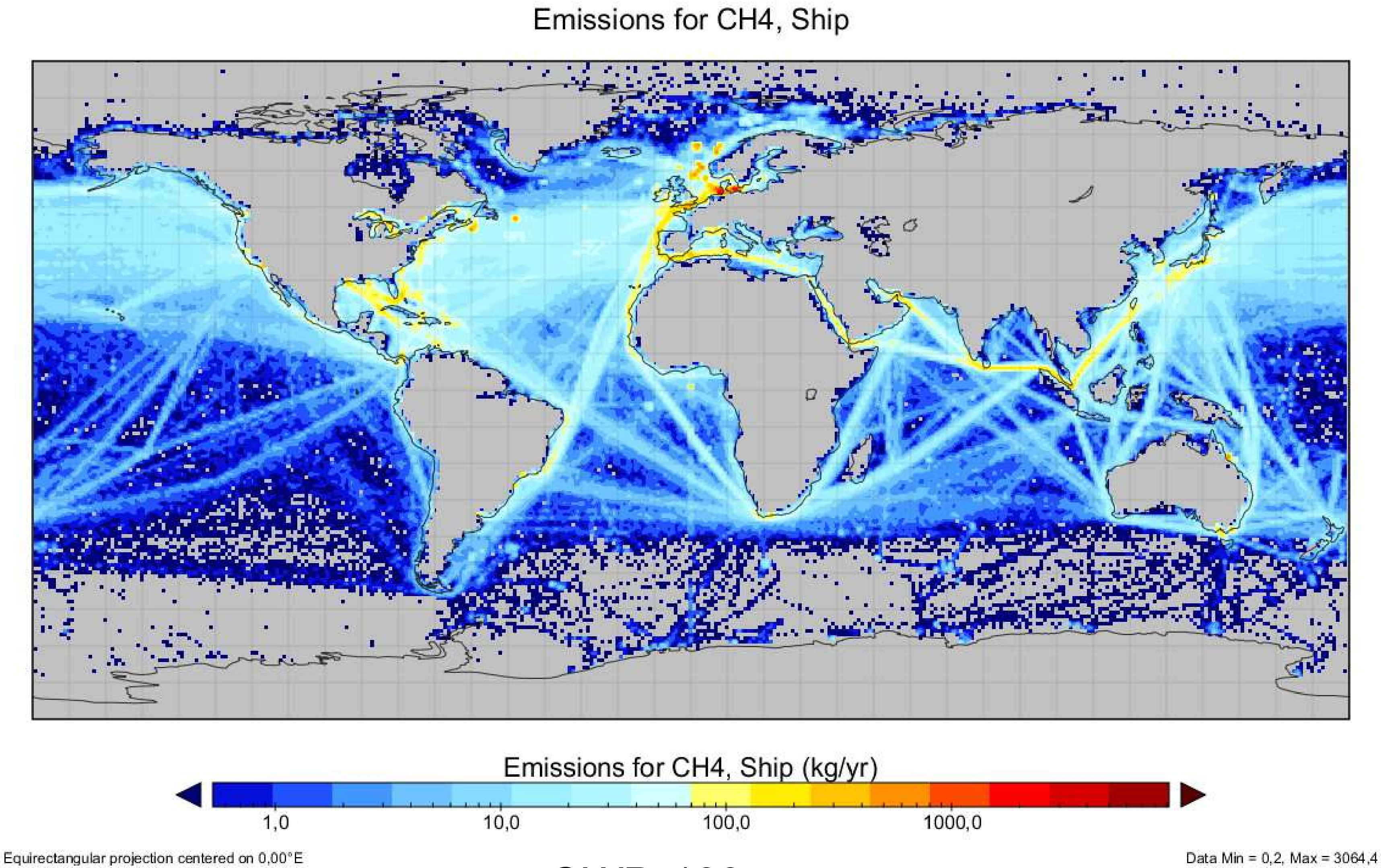


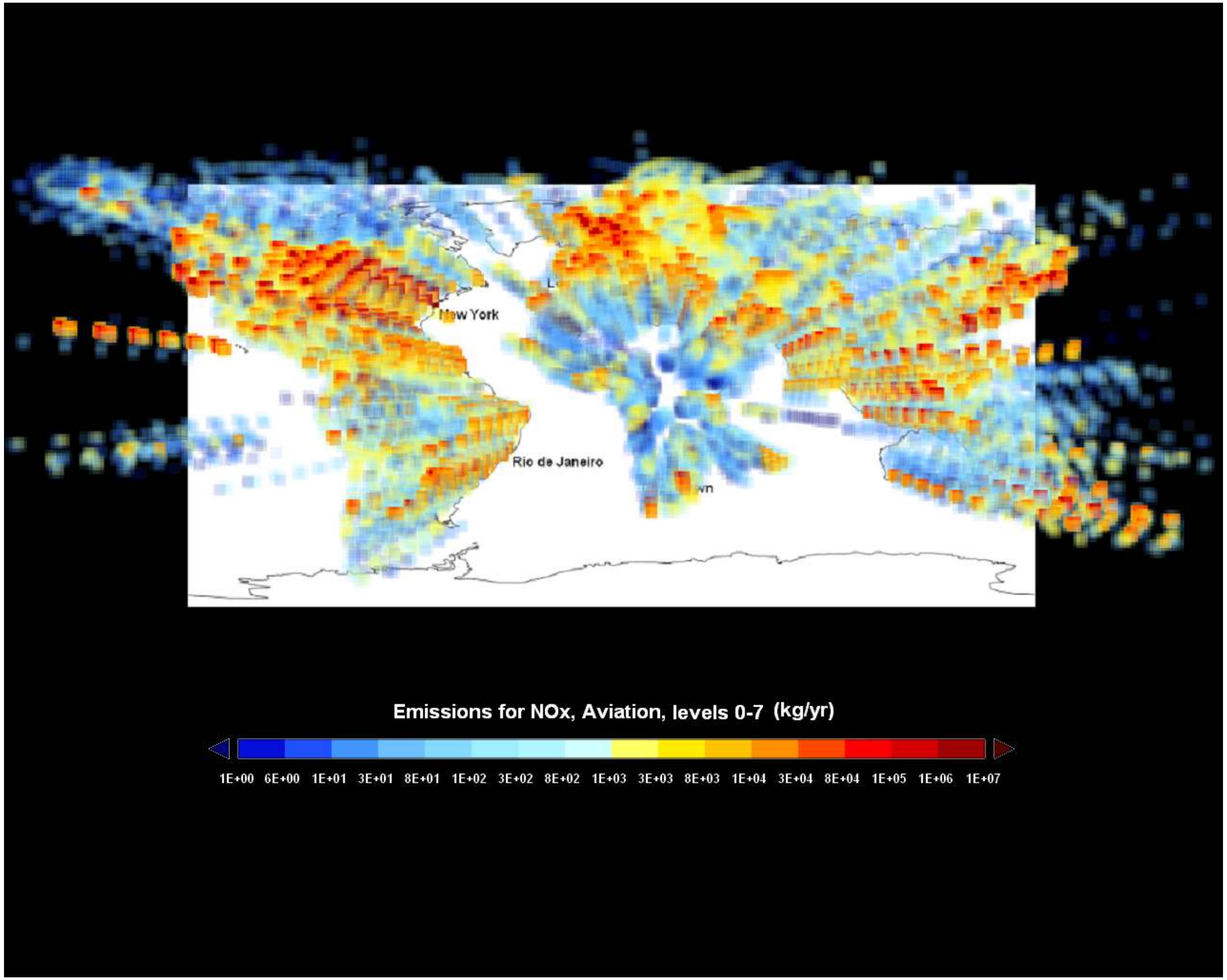
GWP, 100 years

Emissions of aviations

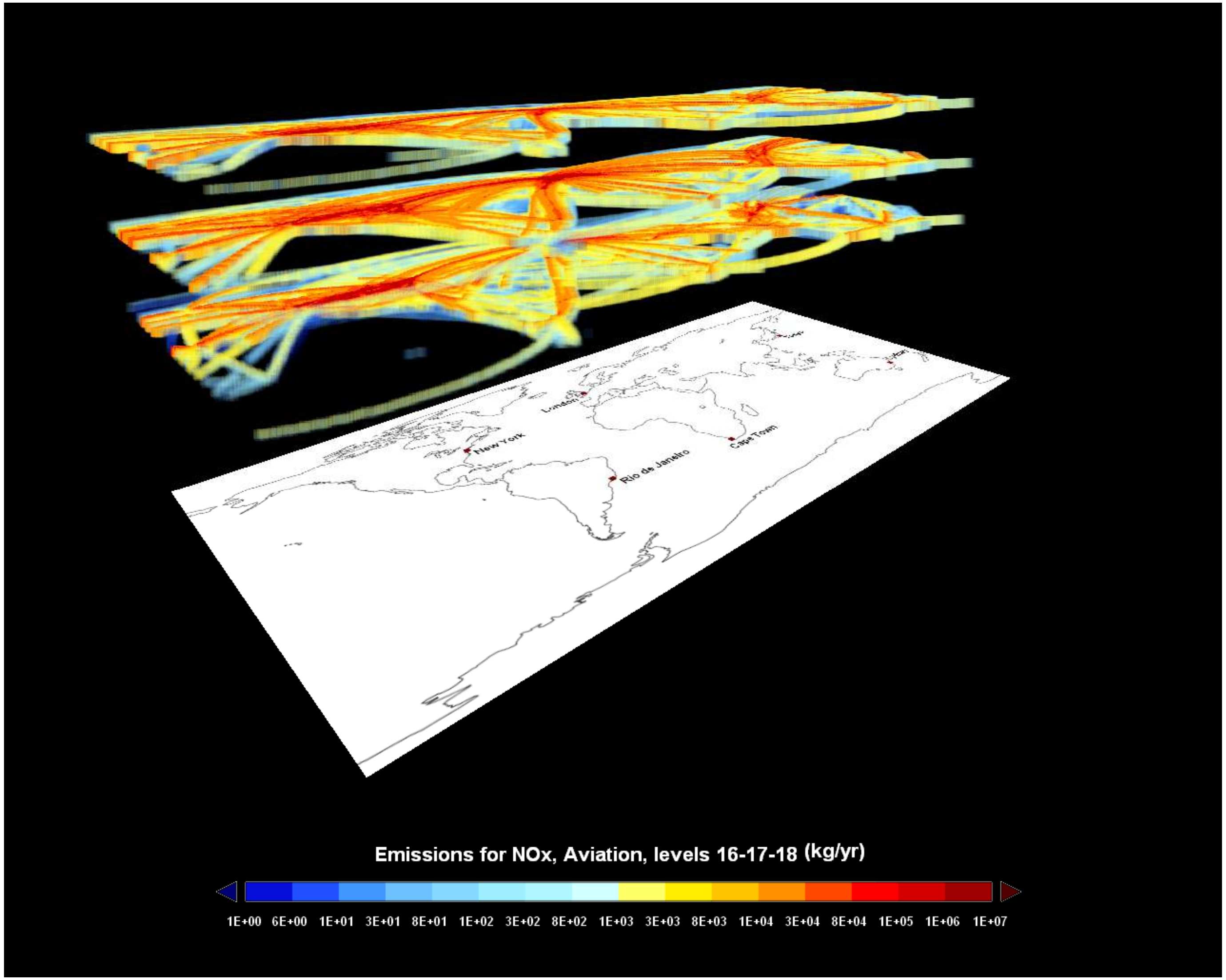
NO_x, 23 levels;

(Time horizons: 25, 50, 100 years; *GWP*, *GTP*)

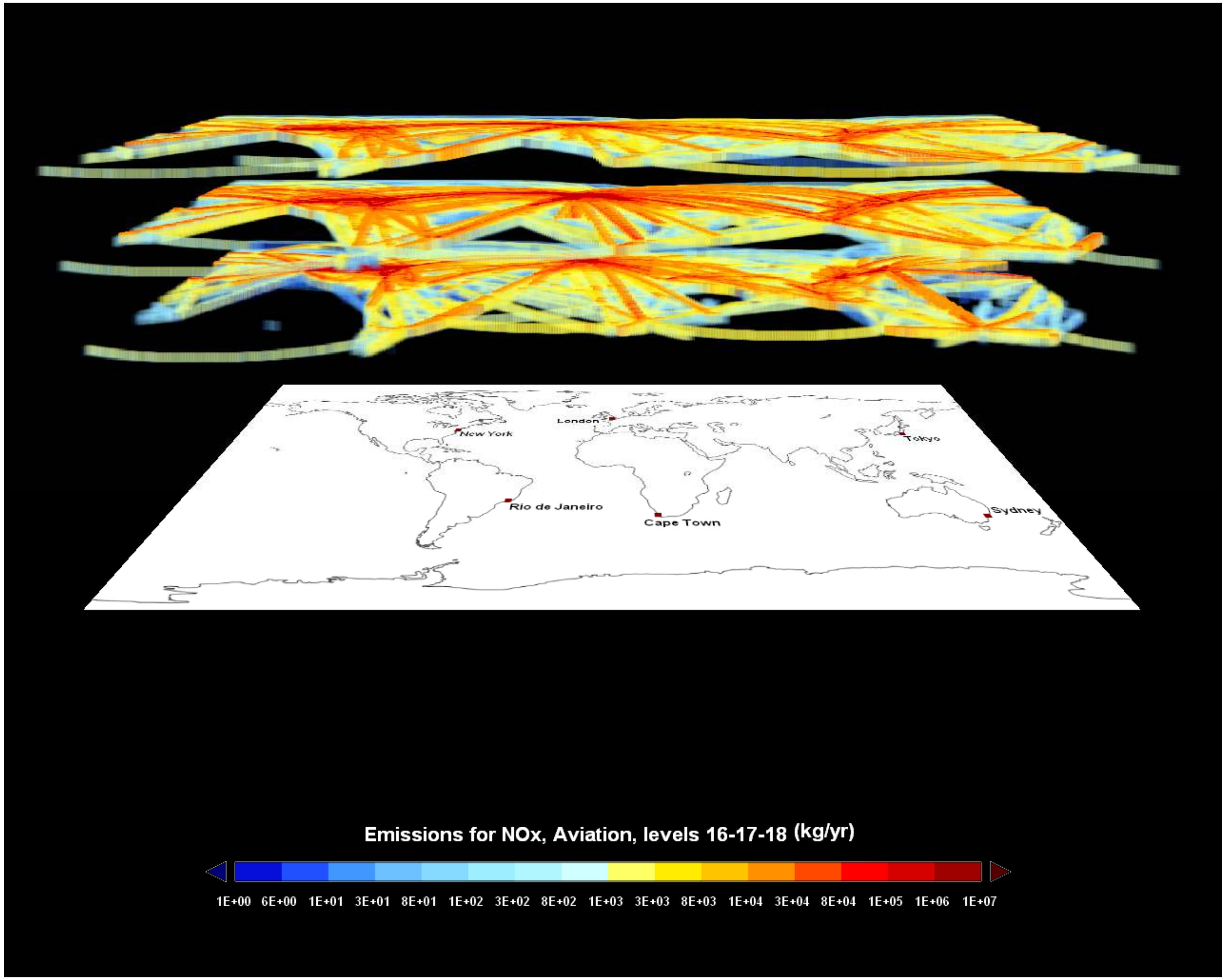
5.2.1.3. Specific presentations of original NO_x emissions of different levels



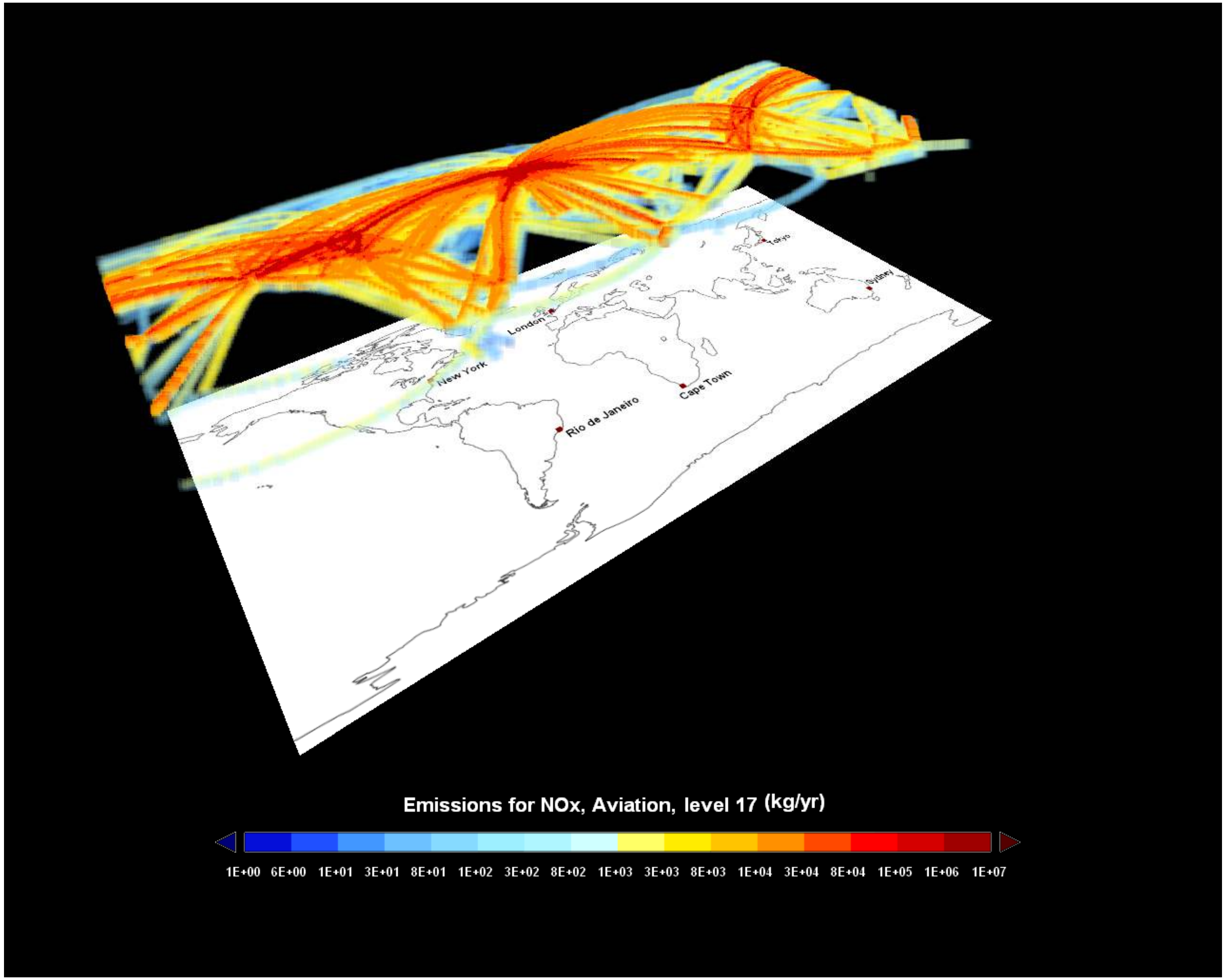
3D representation of original NO_x emissions, levels 0-7, from above



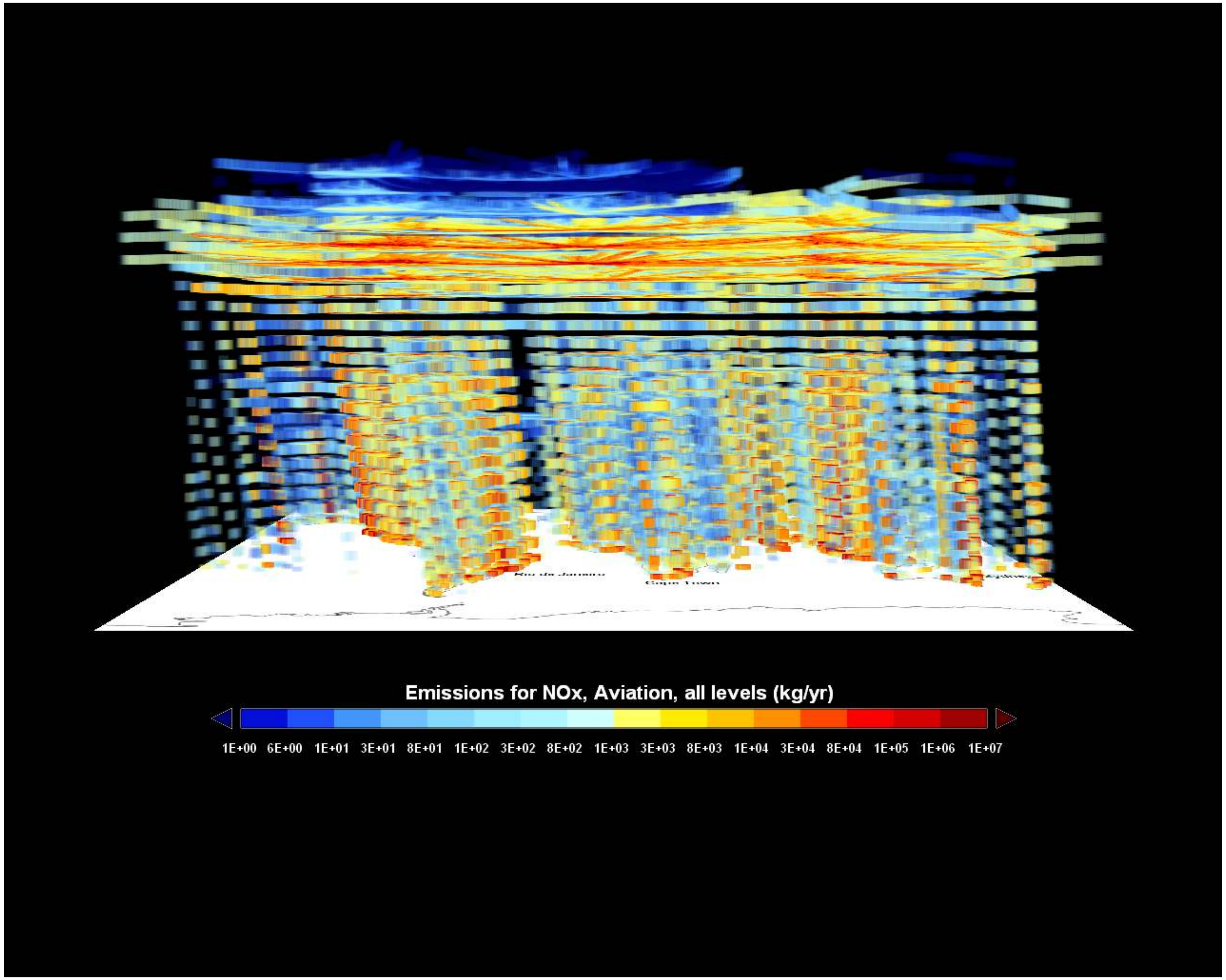
3D representation of original NO_x emissions, levels 16-17-18



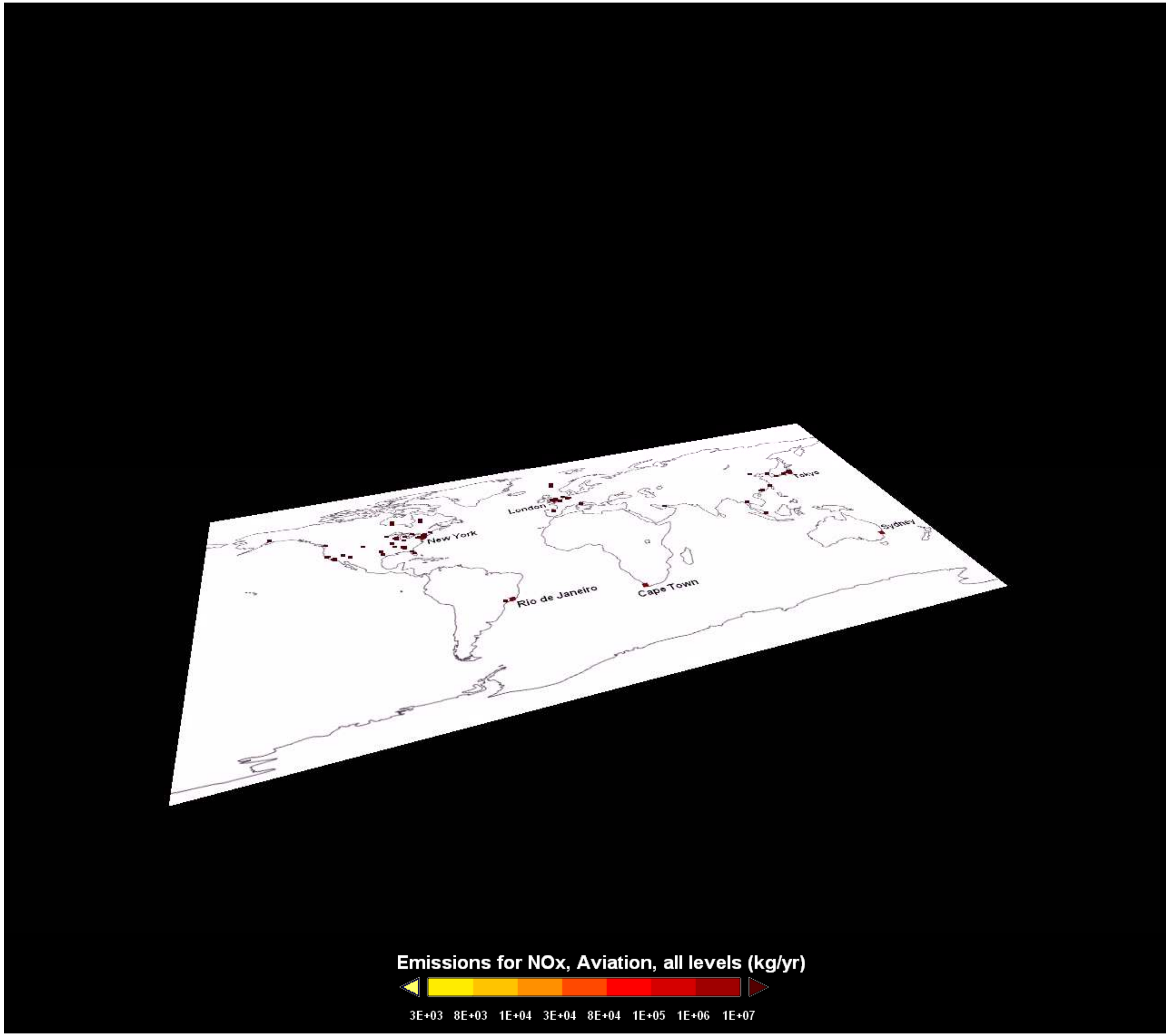
3D representation of original NO_x emissions, levels 16-17-18



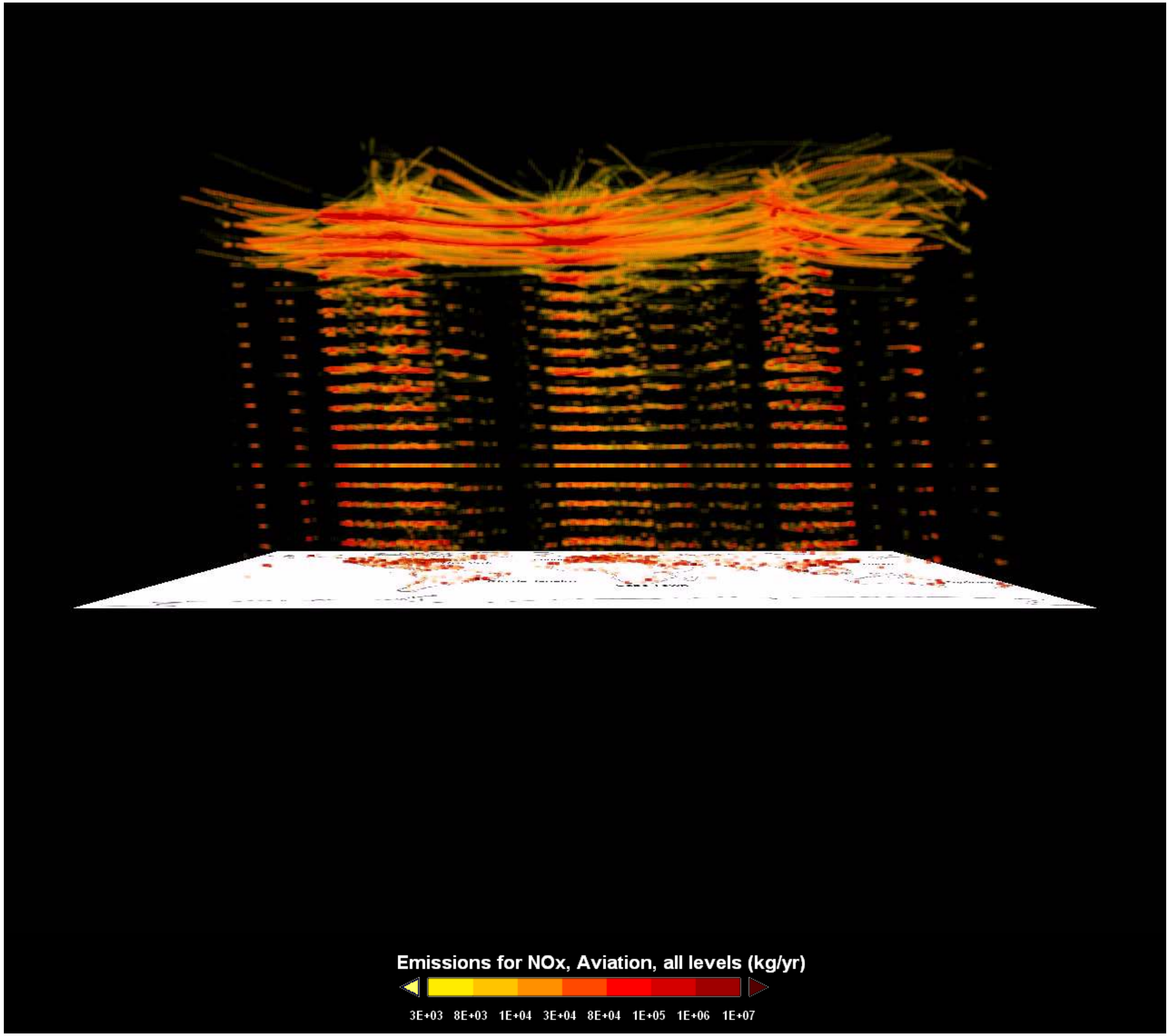
3D representation of original NO_x emissions, level 17



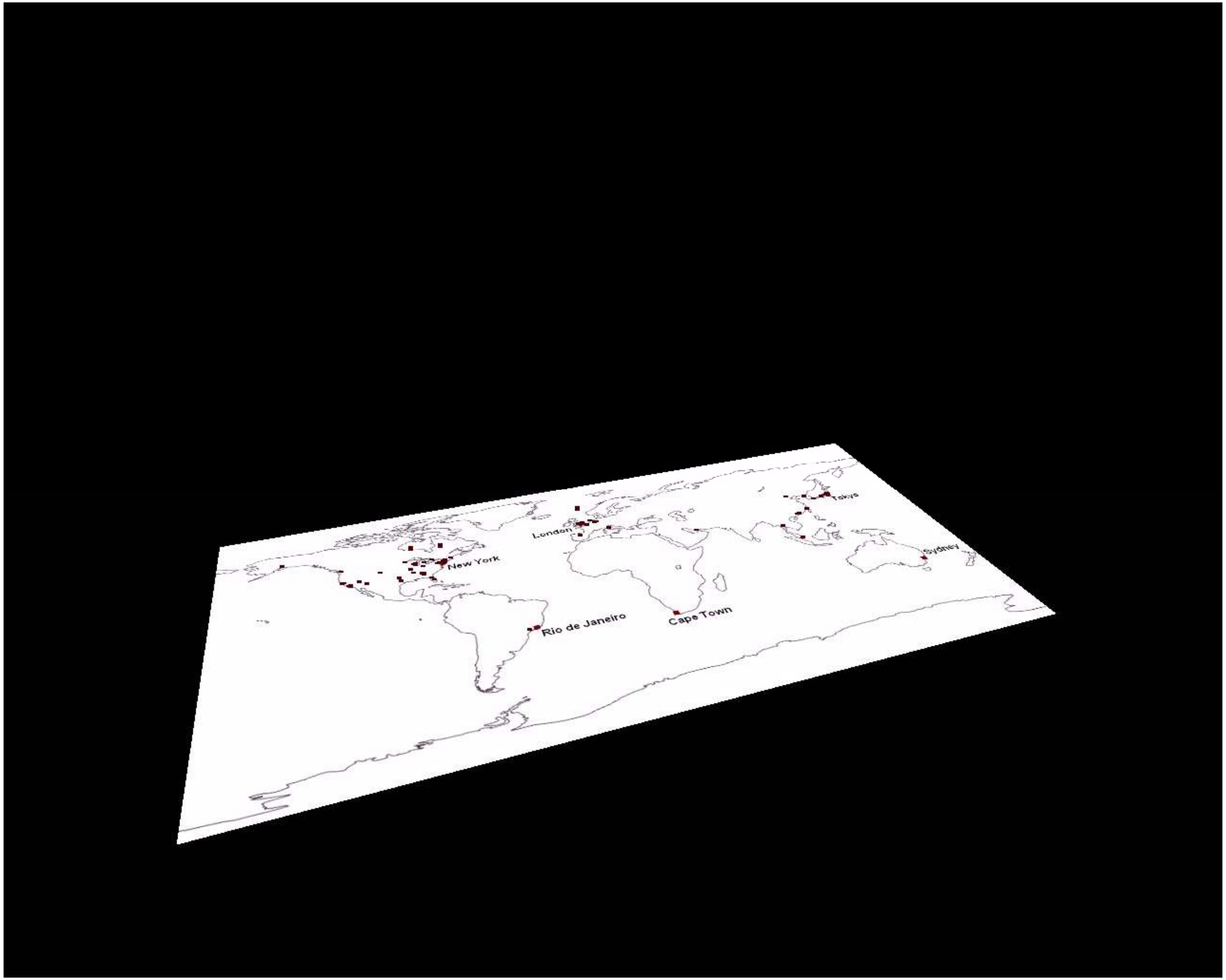
3D representation of original NO_x emissions, all levels



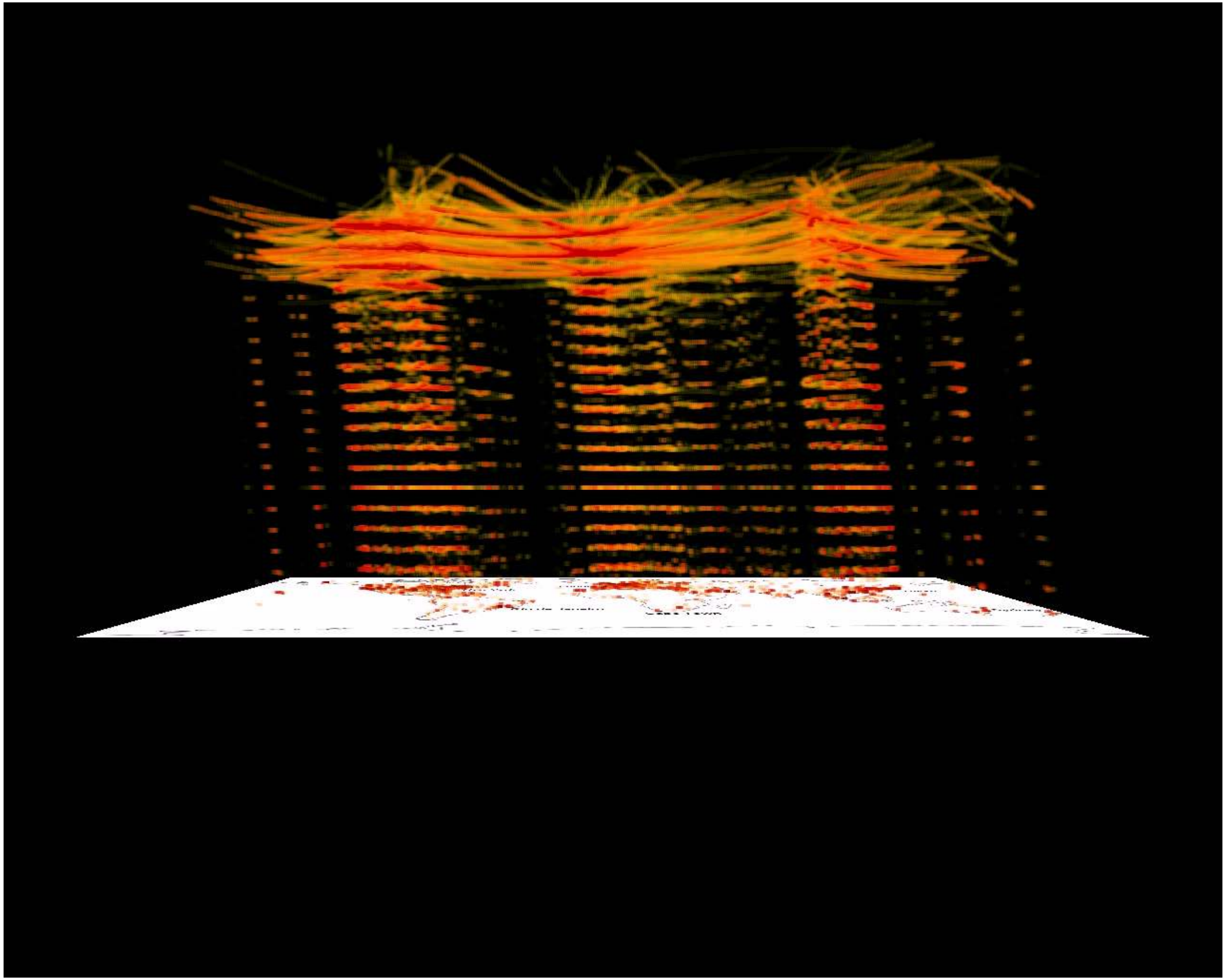
3D representation of original NO_x emissions, all levels



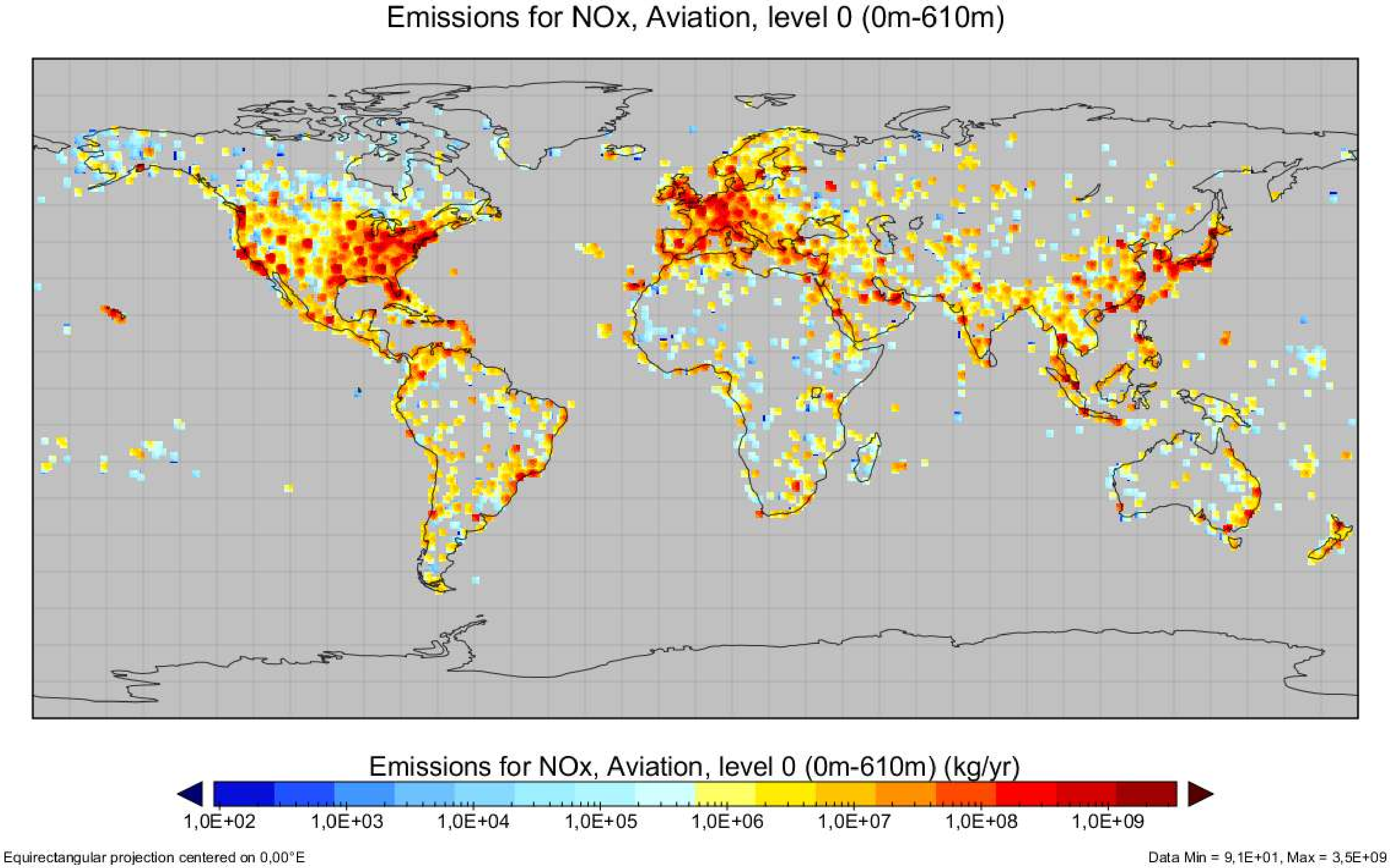
3D representation of original NO_x emissions, all levels



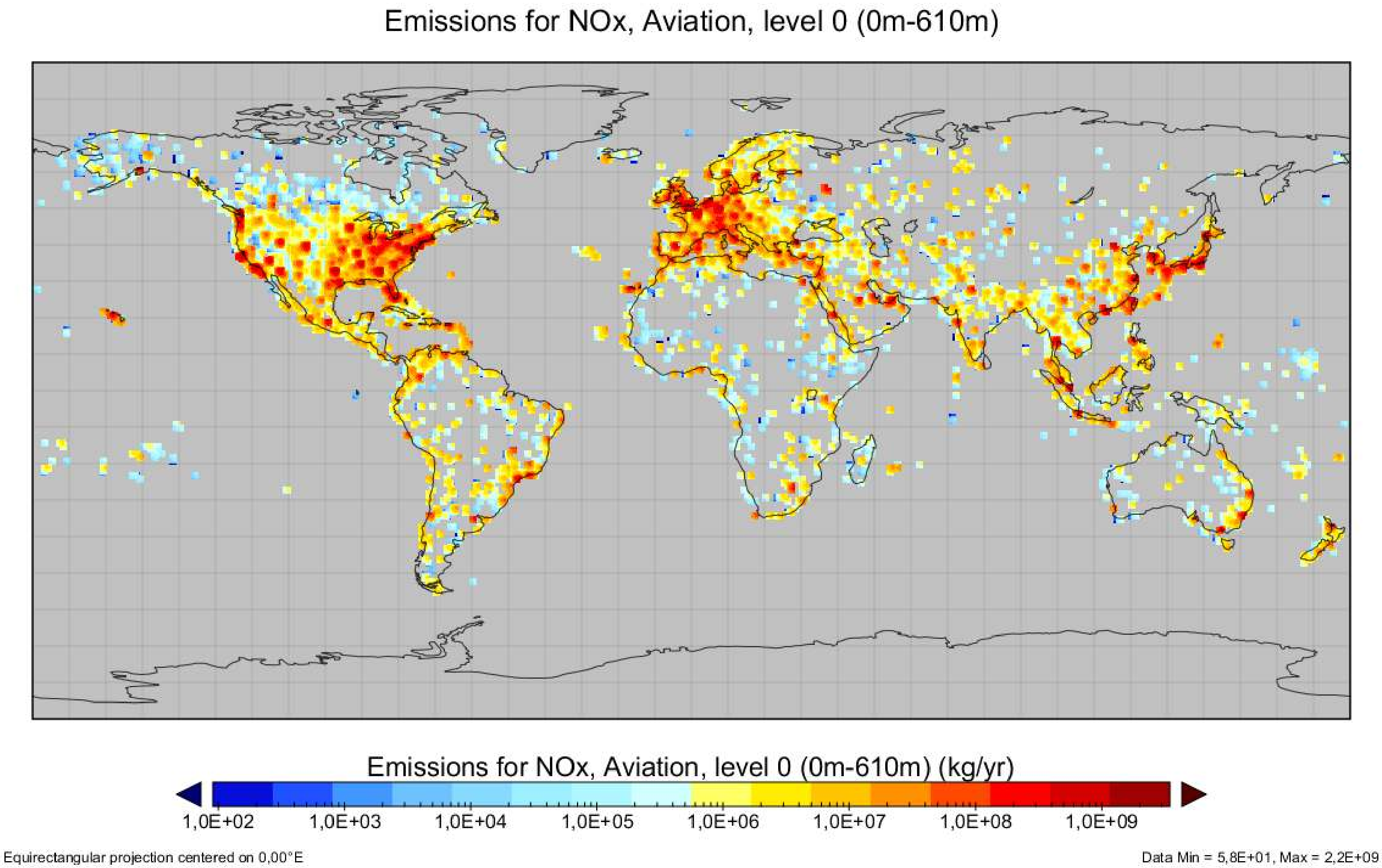
London
Tokyo
New York
Sydney
Rio de Janeiro
Cape Town



5.2.1.1. *GWP* weighted emission maps for NO_x, 25, 50, 100 years



GWP, level 0, 25 years



GWP, level 0, 50 years

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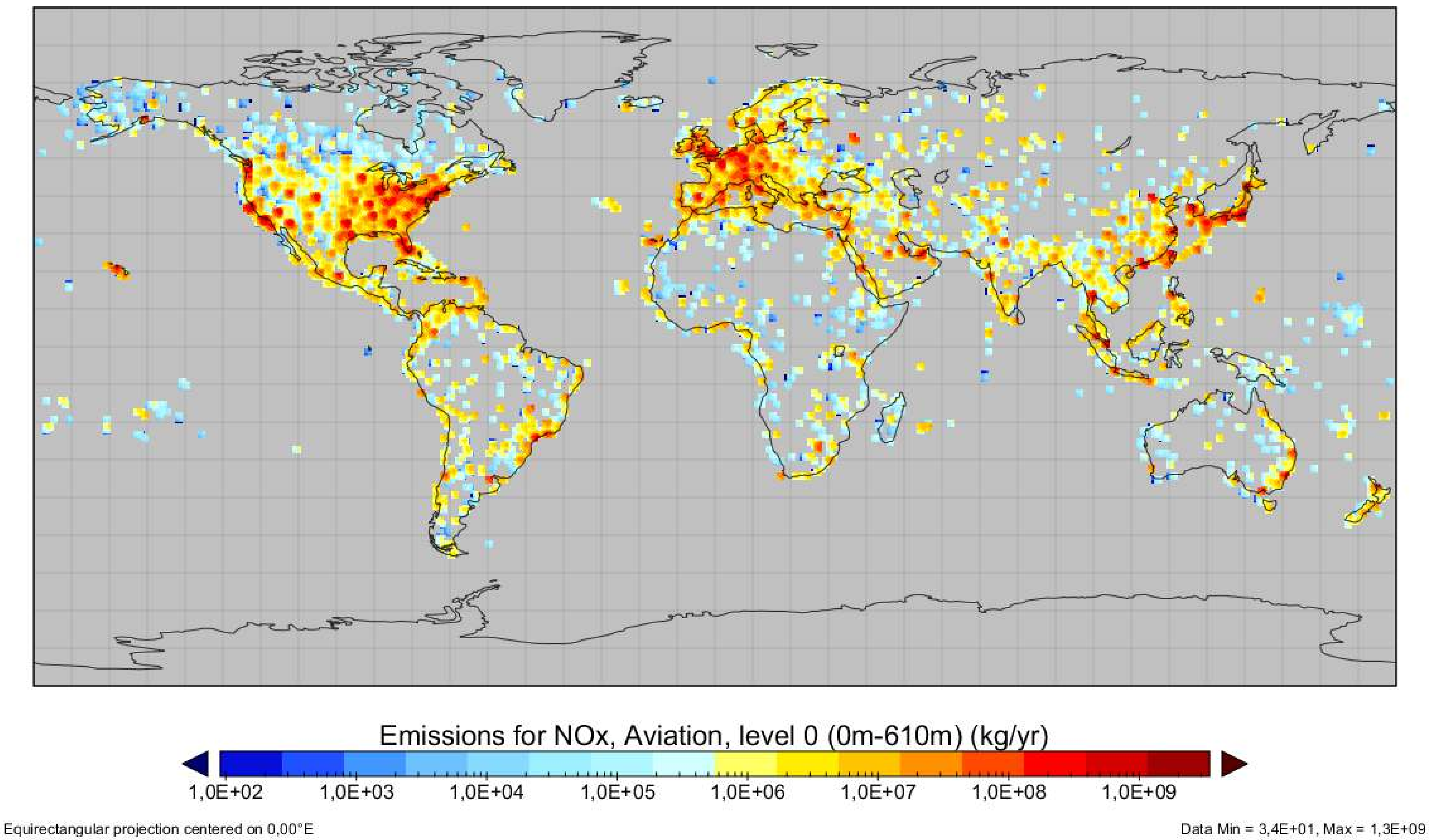
Emissions for NOx, Aviation, level 0 (0m-610m)



GWP, level 0, 100 years

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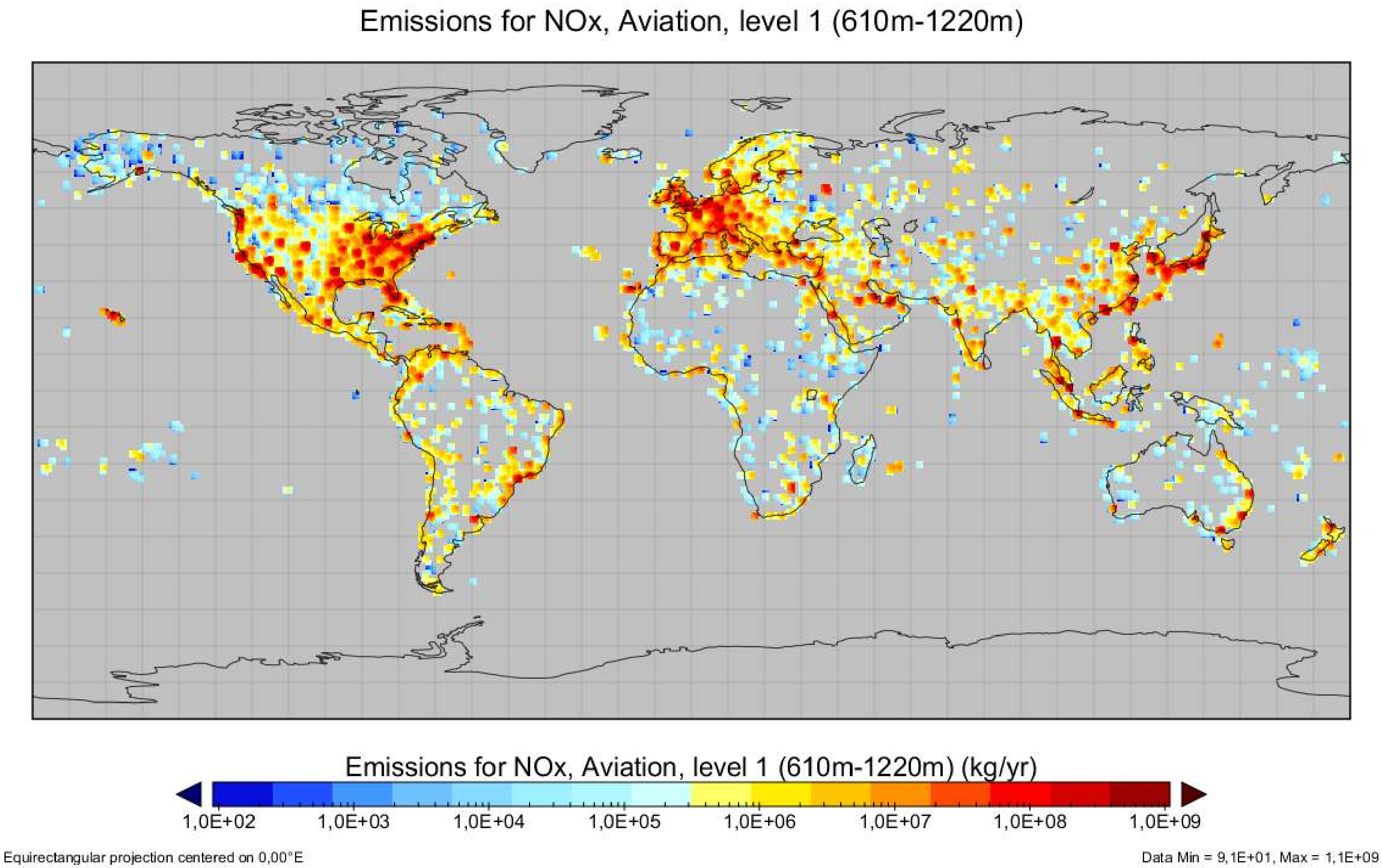
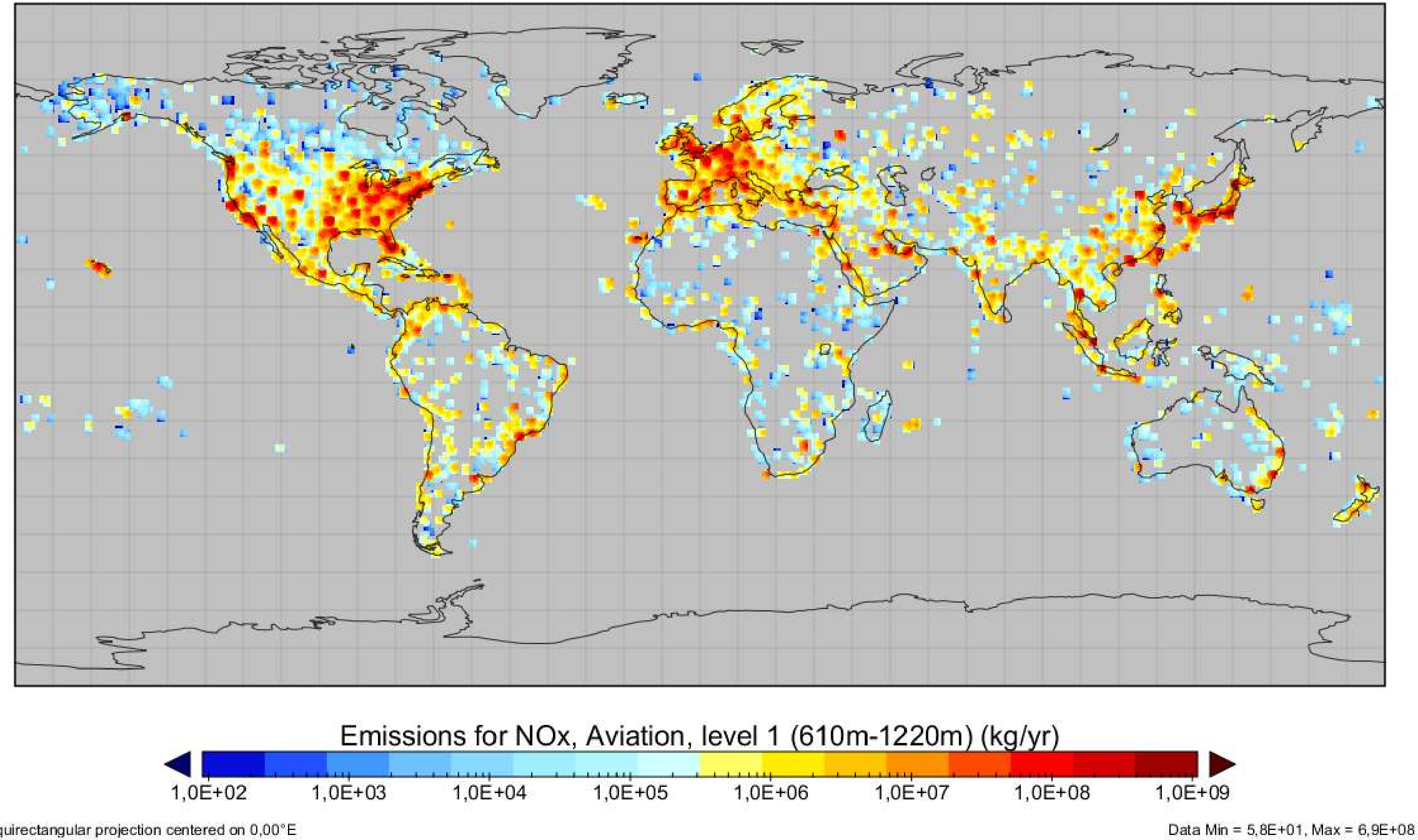


GWP, level 1, 25 years

Quantify Final Meeting, 25-27 January 2010, Munich

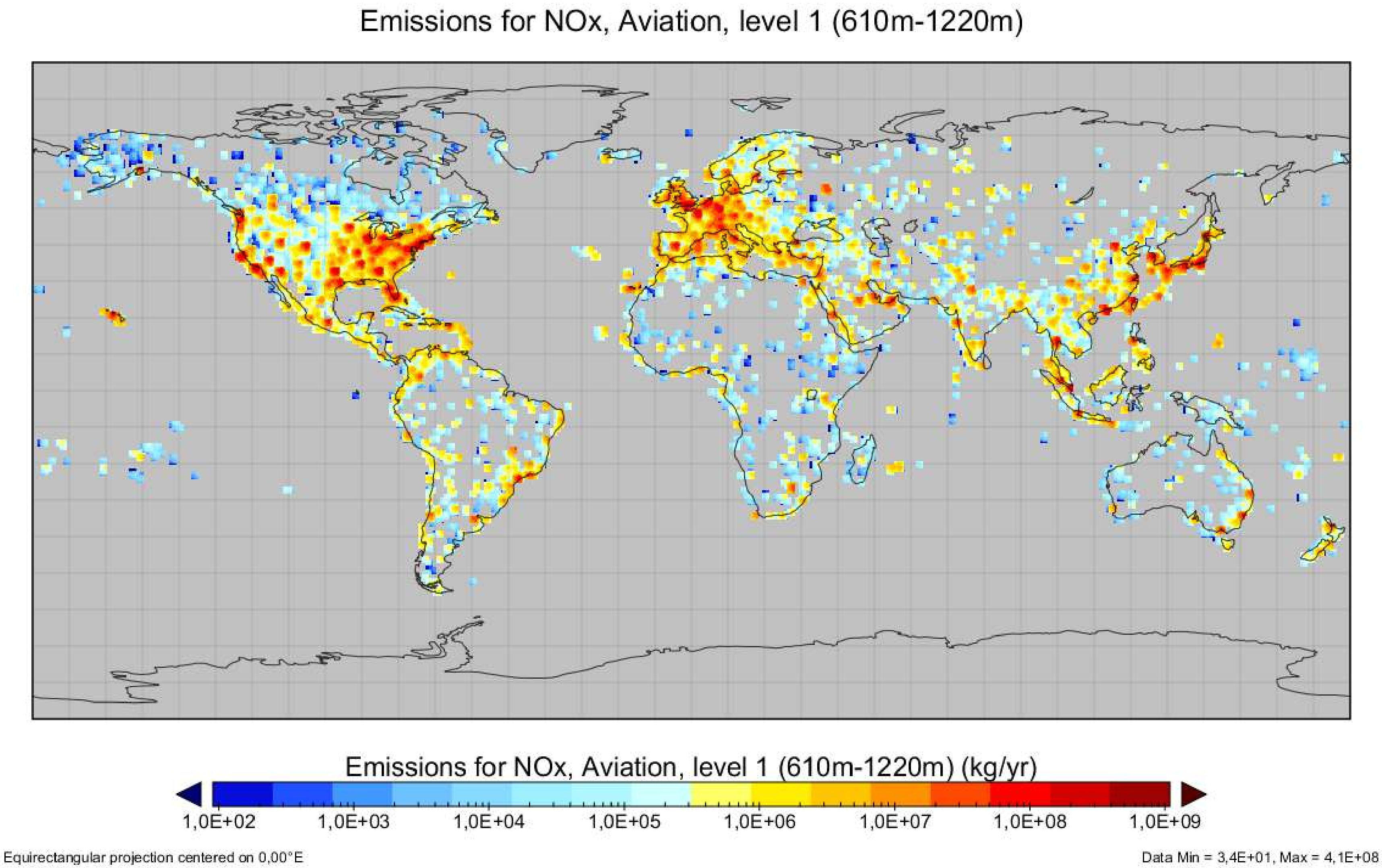
Emissions for NOx, Aviation, level 1 (610m-1220m)



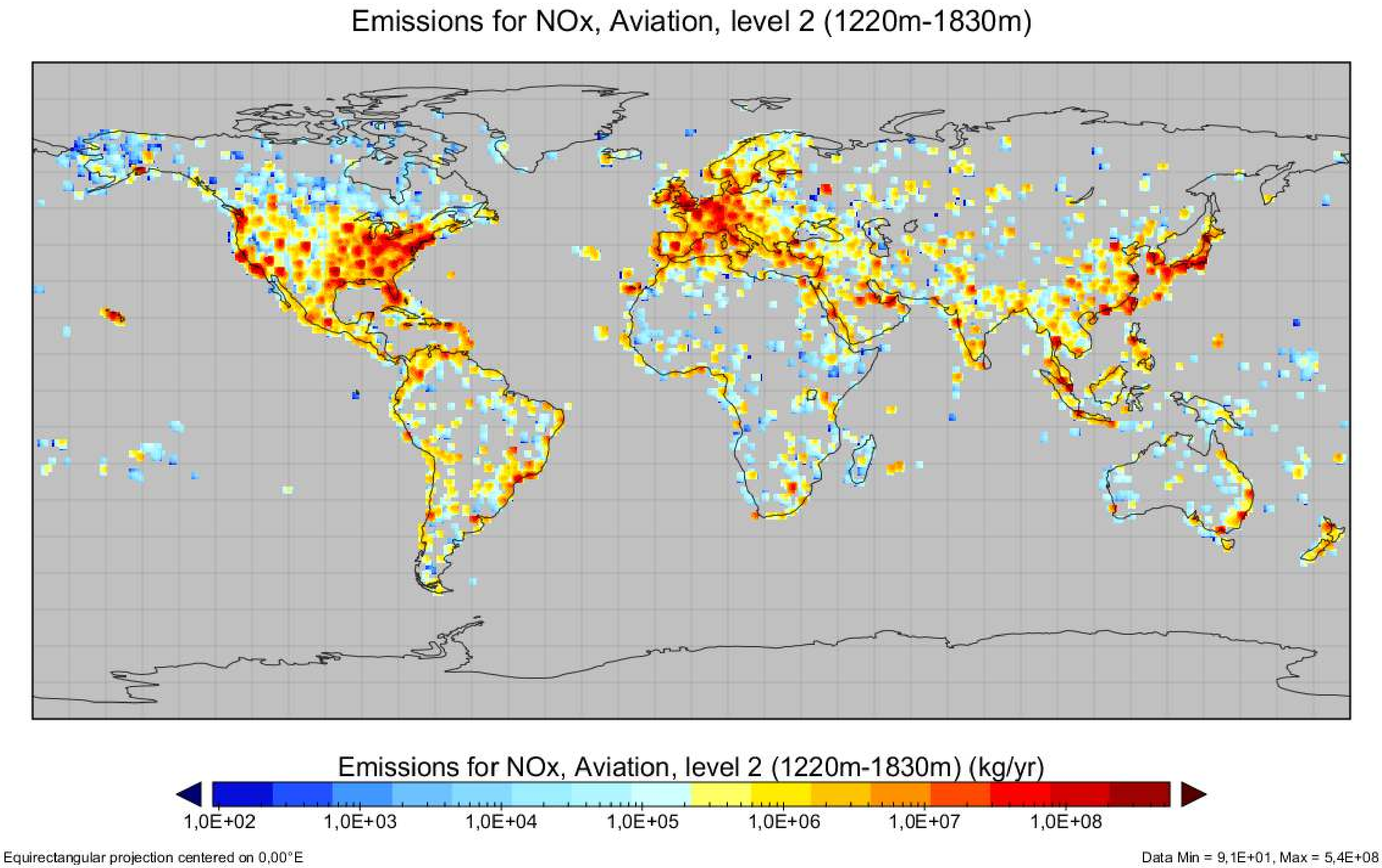
GWP, level 1, 50 years

Quantify Final Meeting, 25-27 January 2010, Munich

Emissions for NOx, Aviation, level 1 (610m-1220m)

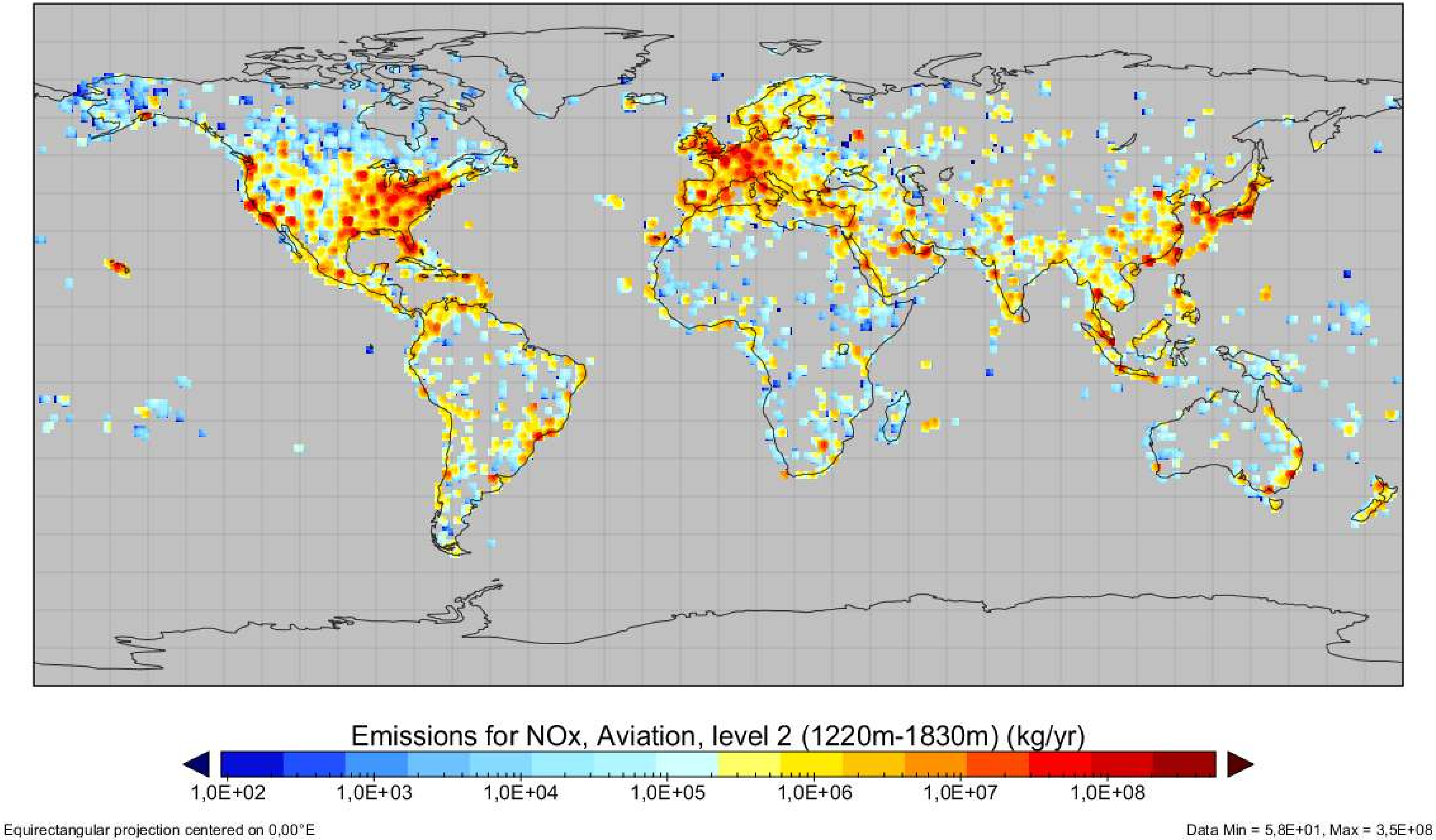


GWP, level 1, 100 years

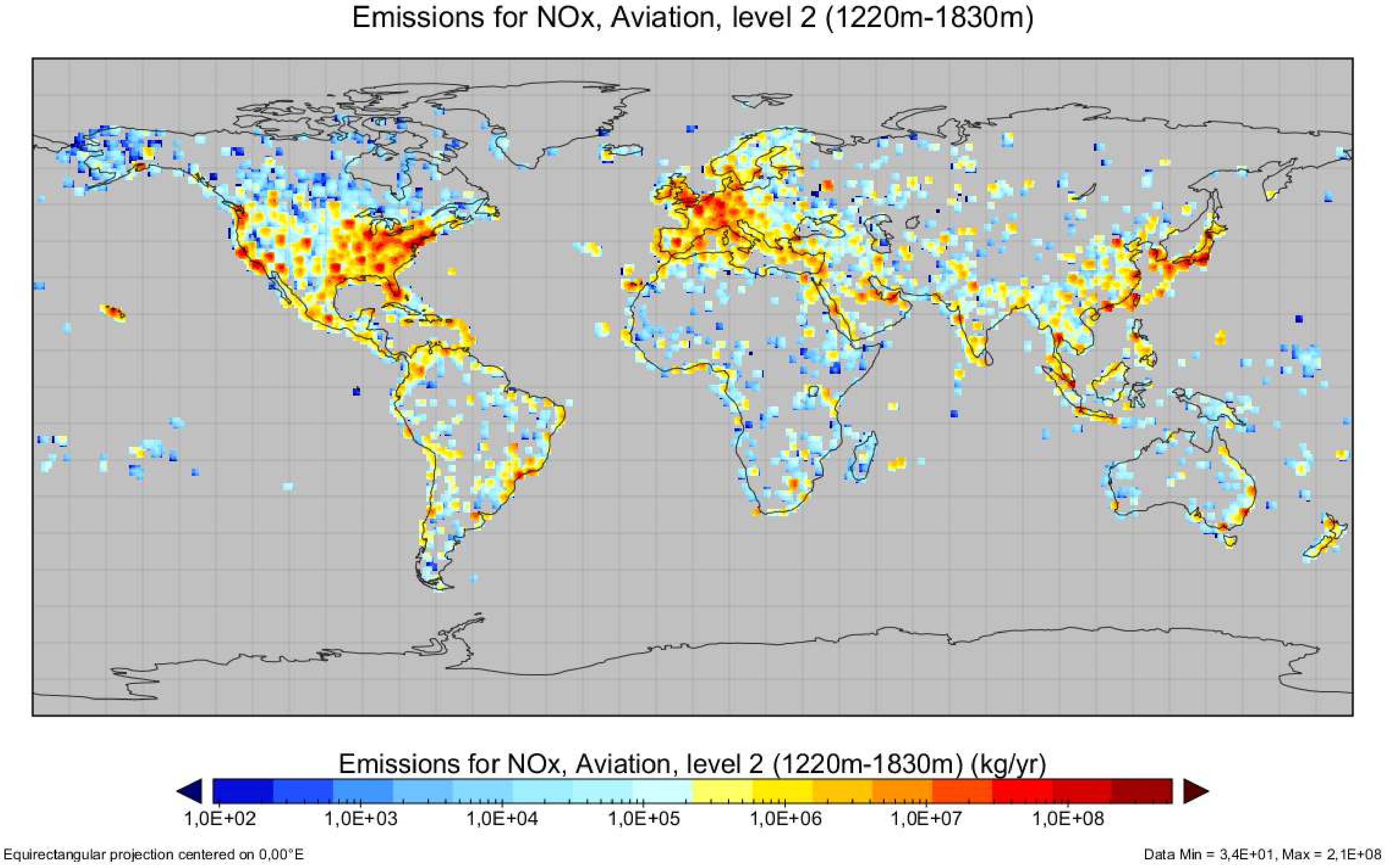


GWP, level 2, 25 years

Emissions for NOx, Aviation, level 2 (1220m-1830m)



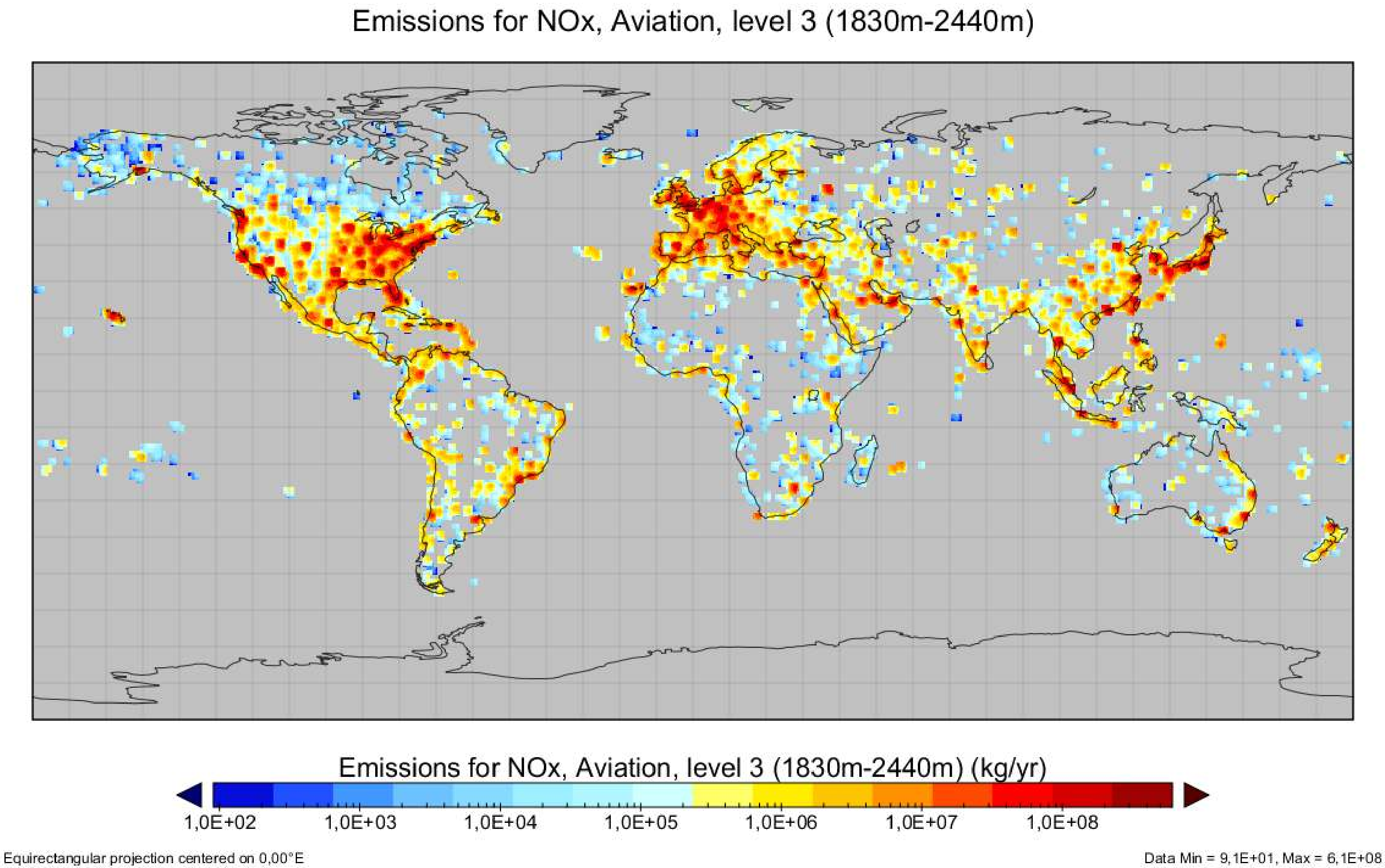
GWP, level 2, 50 years



GWP, level 2, 100 years

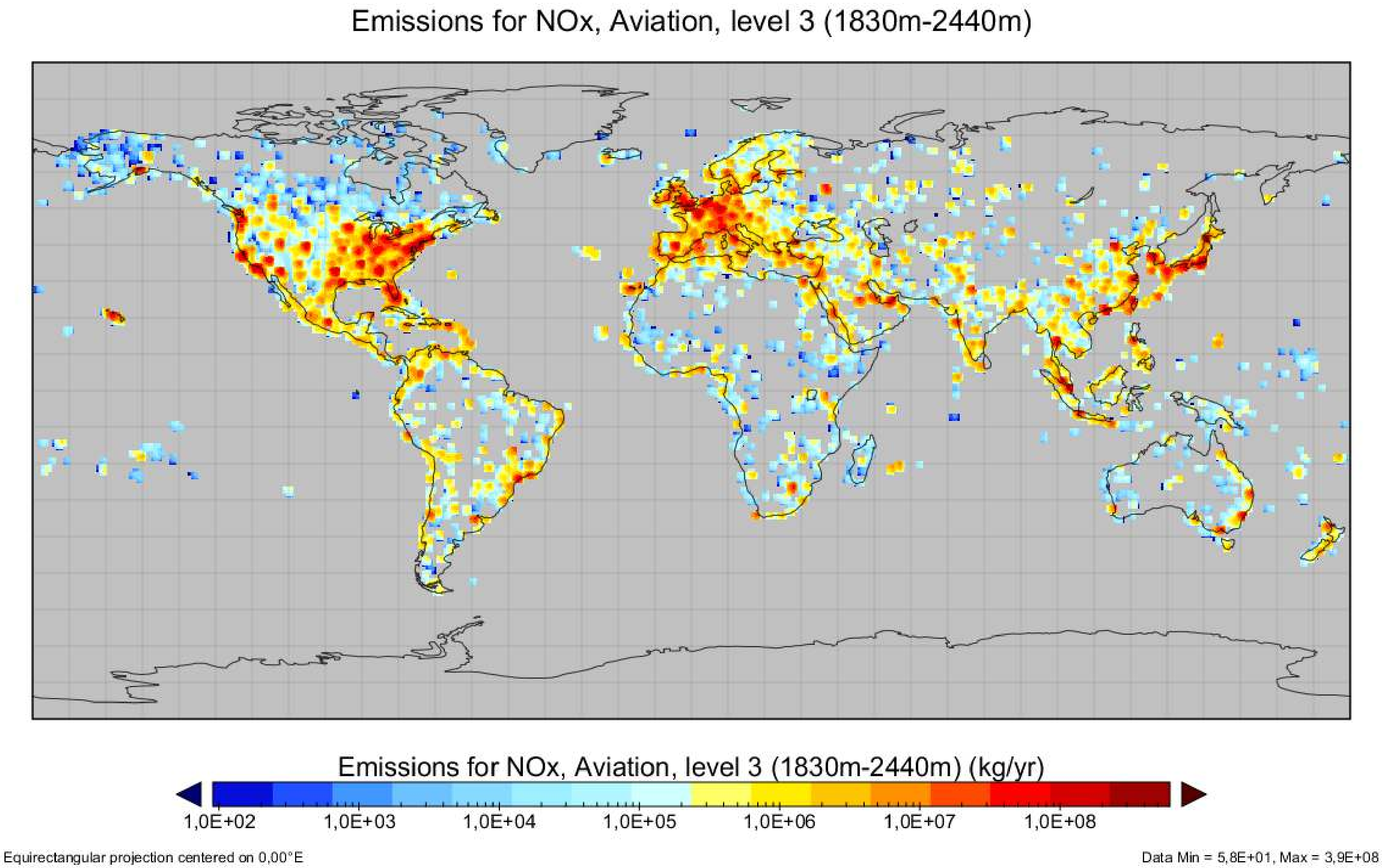
Quantify Final Meeting, 25-27 January 2010, Munich

QUANTIFY



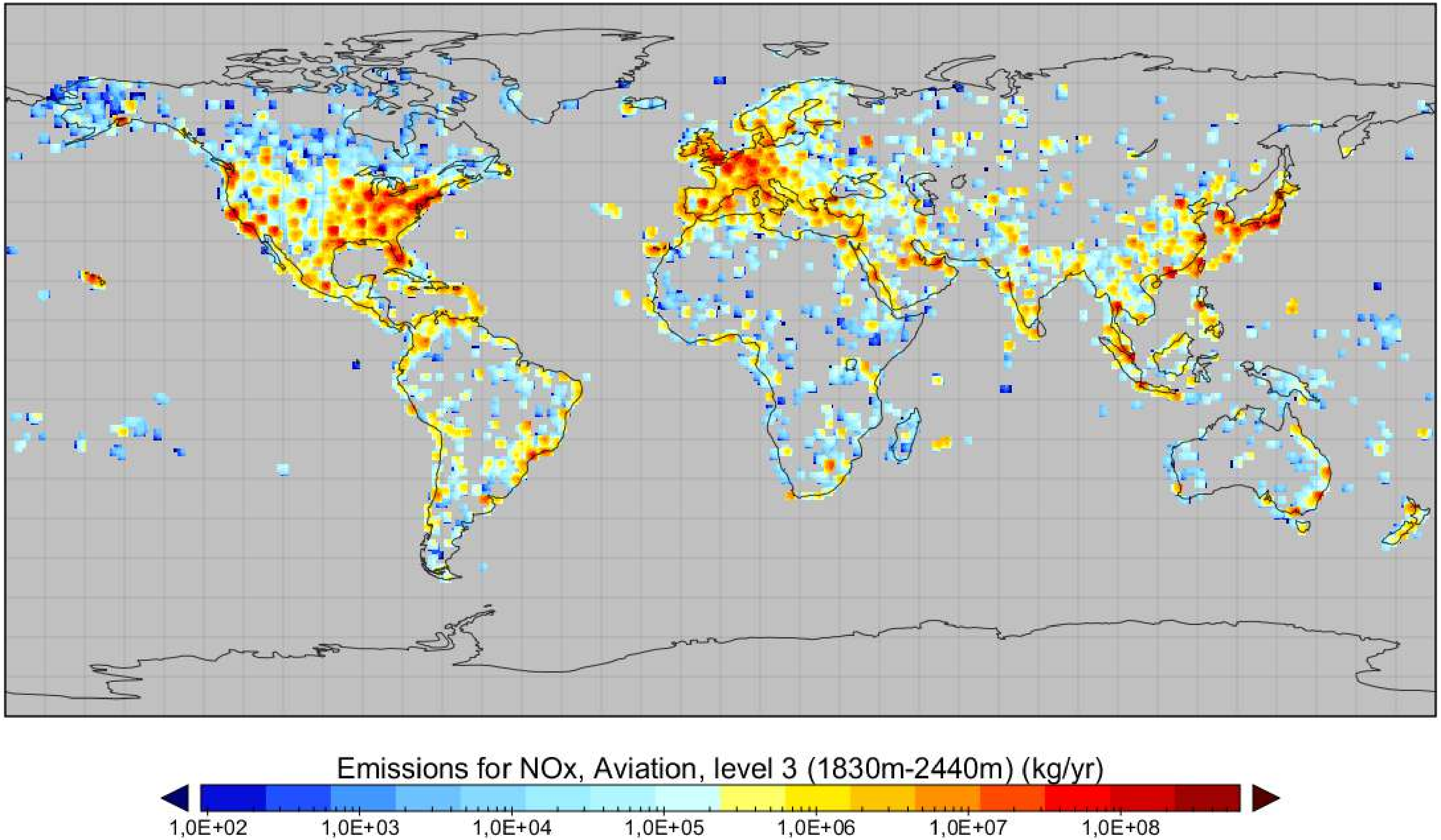
GWP, level 3, 25 years

Quantify Final Meeting, 25-27 January 2010, Munich



GWP, level 3, 50 years

Emissions for NOx, Aviation, level 3 (1830m-2440m)



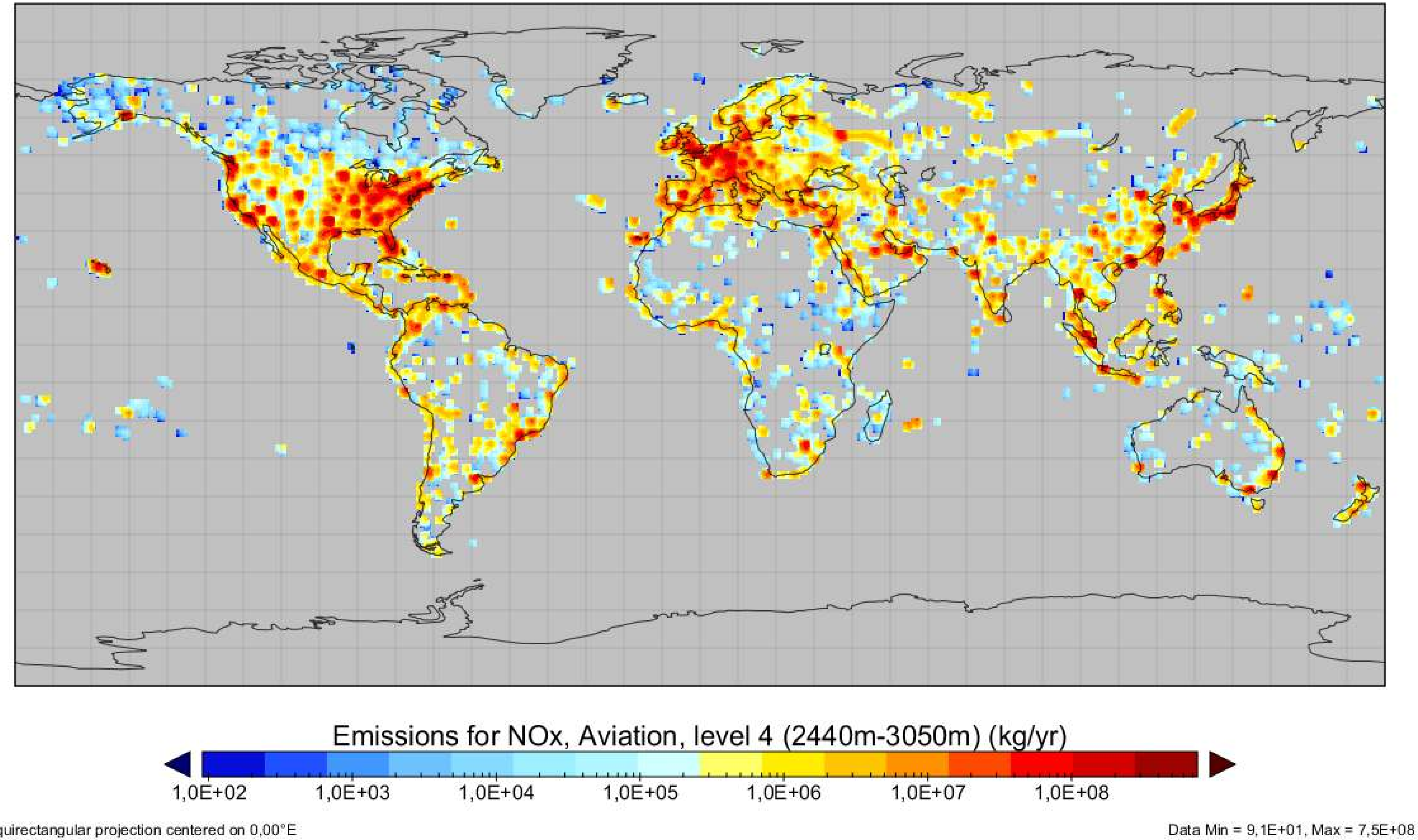
Equirectangular projection centered on 0,00°E

Data Min = 3,4E+01, Max = 2,3E+08

GWP, level 3, 100 years

Quantify Final Meeting, 25-27 January 2010, Munich

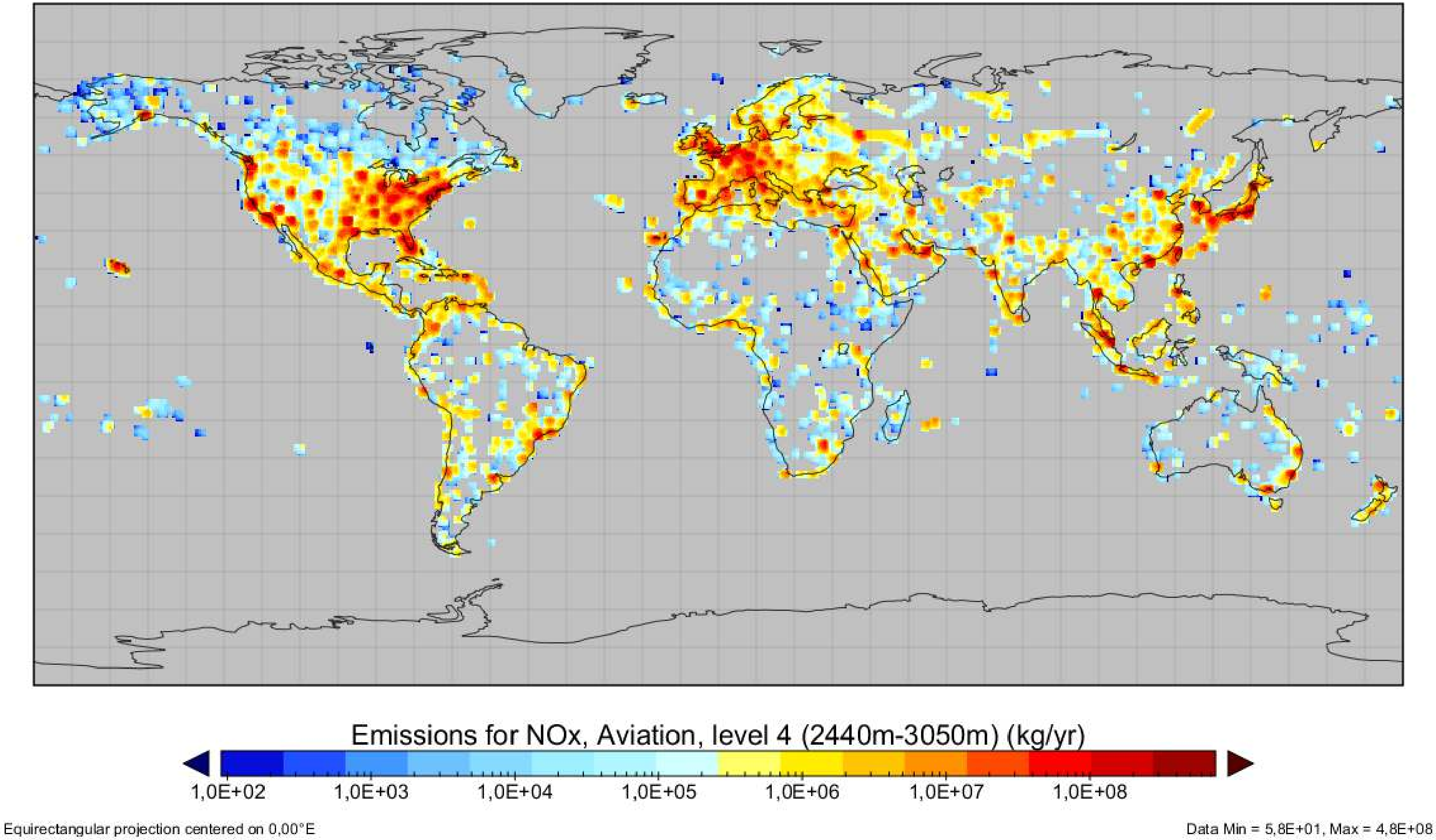
Emissions for NOx, Aviation, level 4 (2440m-3050m)



GWP, level 4, 25 years

QUANTIFY

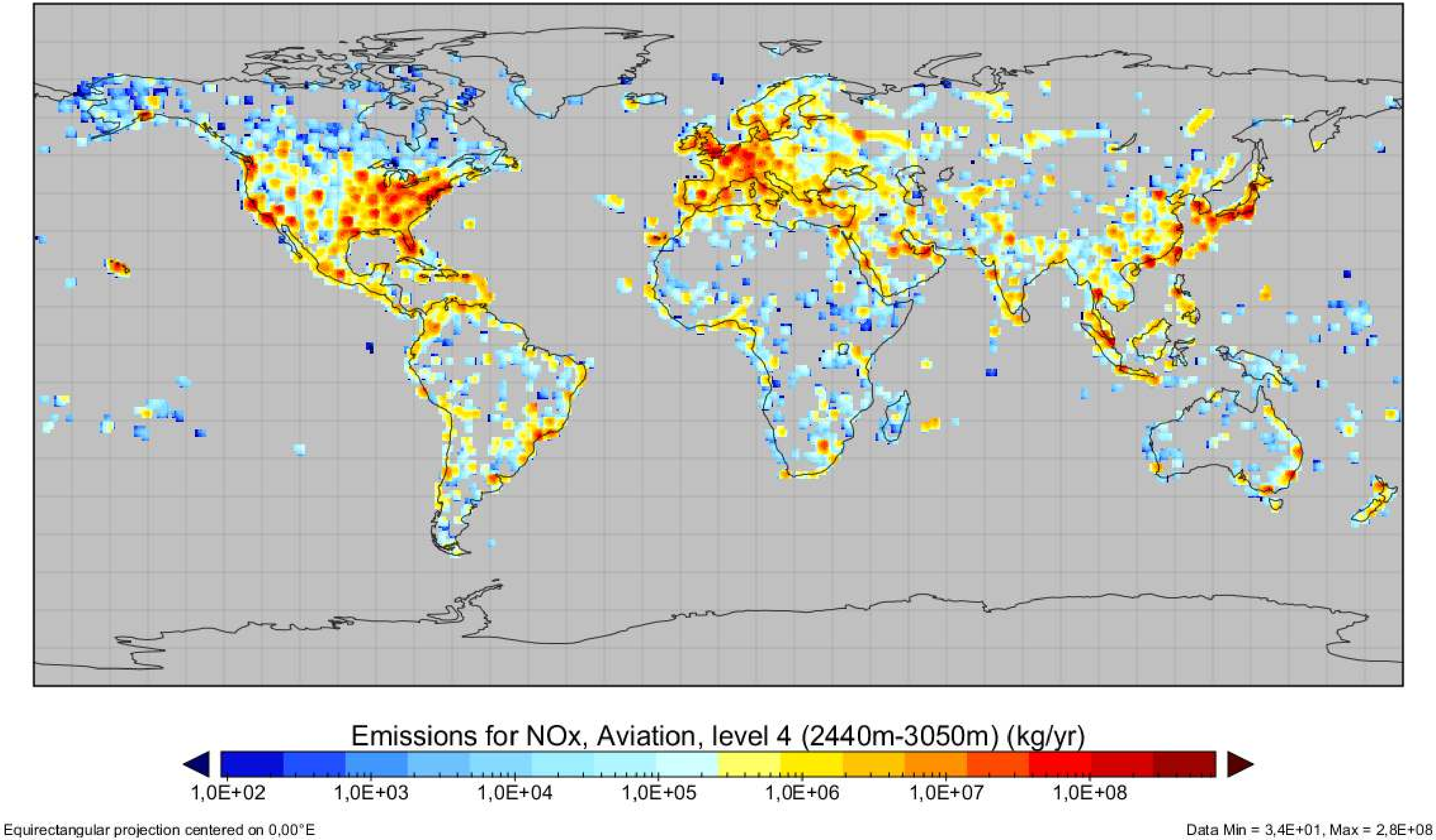
Emissions for NOx, Aviation, level 4 (2440m-3050m)



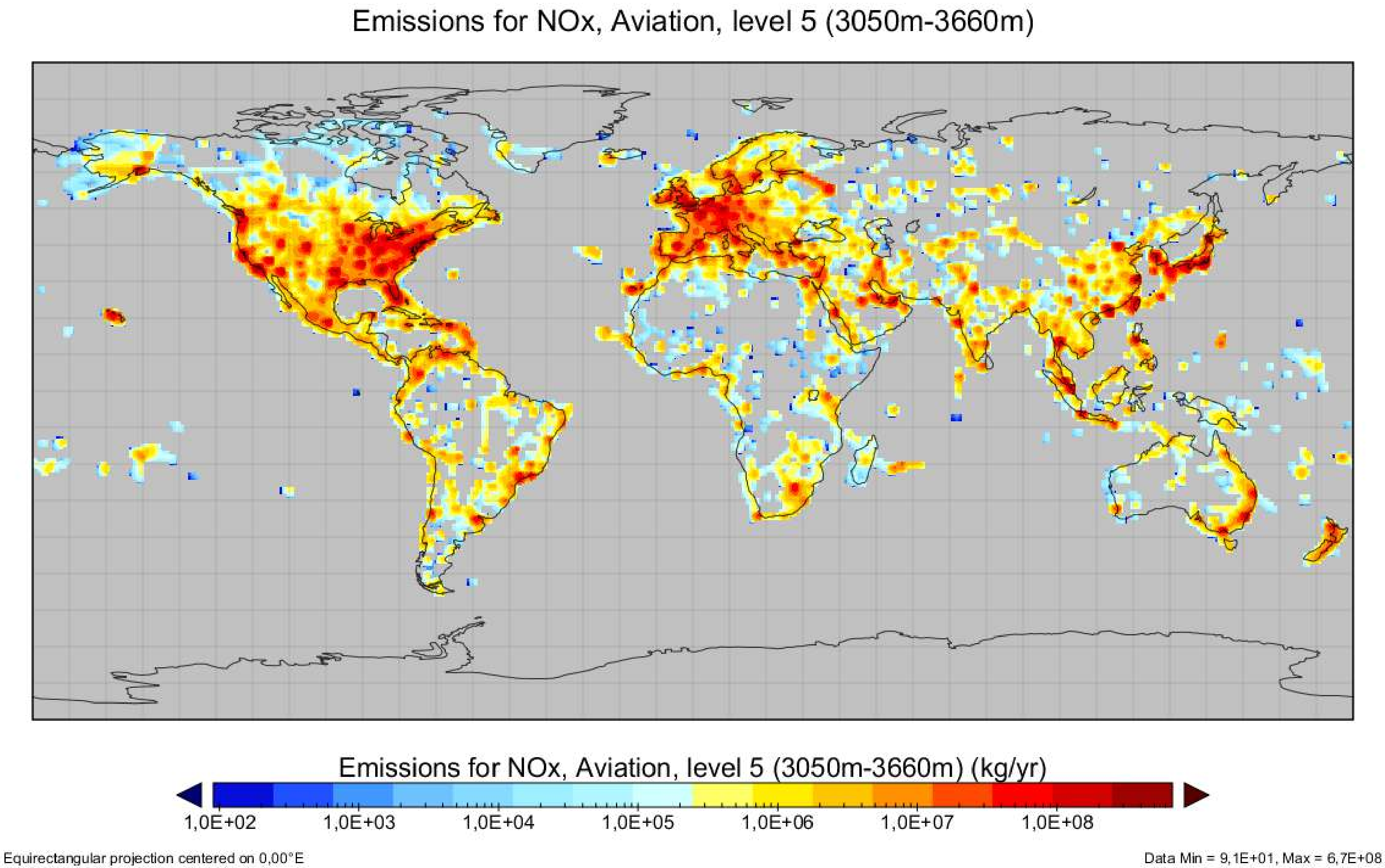
GWP, level 4, 50 years

QUANTIFY

Emissions for NOx, Aviation, level 4 (2440m-3050m)



GWP, level 4, 100 years

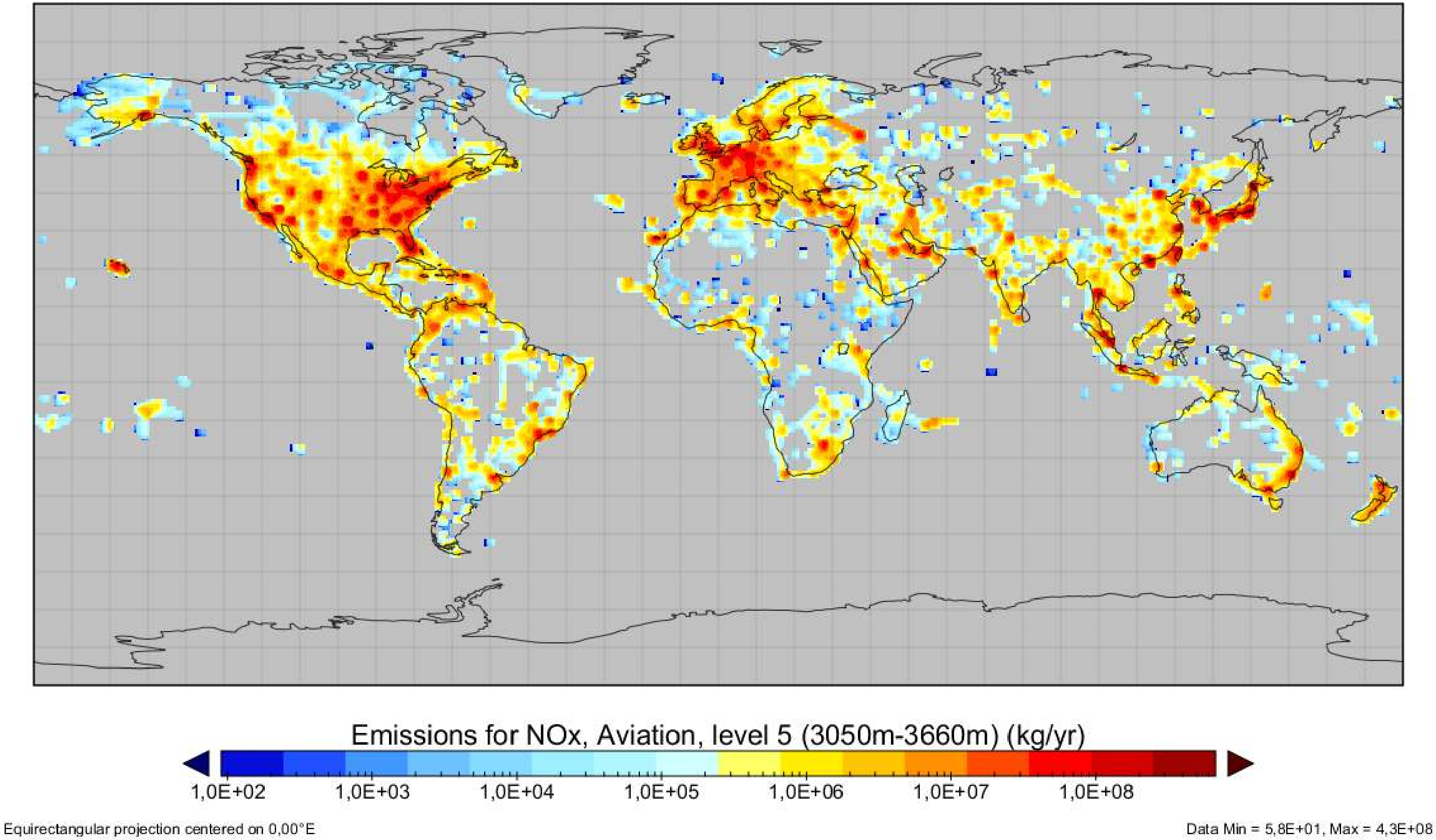


GWP, level 5, 25 years

Quantify Final Meeting, 25-27 January 2010, Munich

QUANTIFY

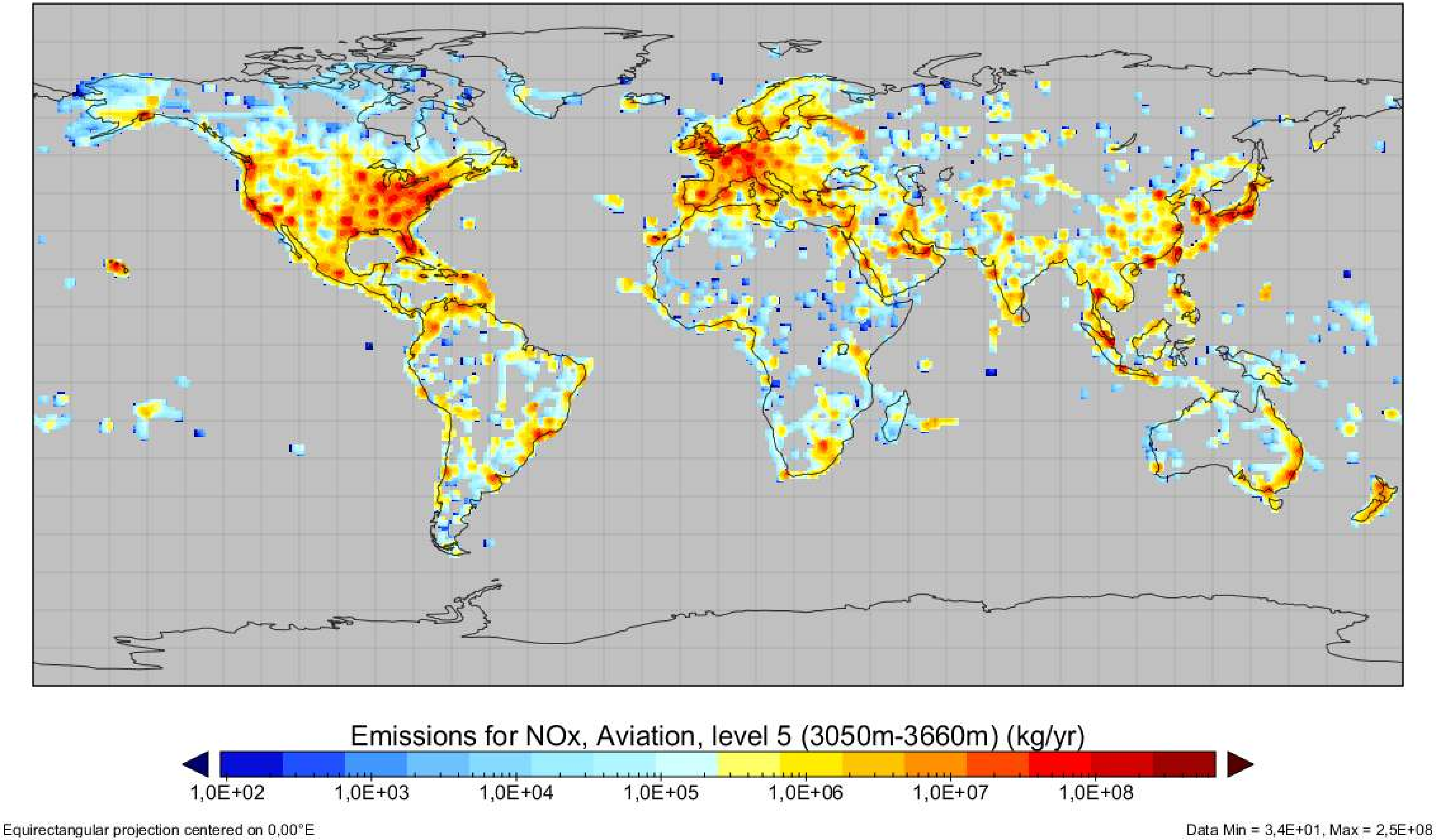
Emissions for NOx, Aviation, level 5 (3050m-3660m)



GWP, level 5, 50 years

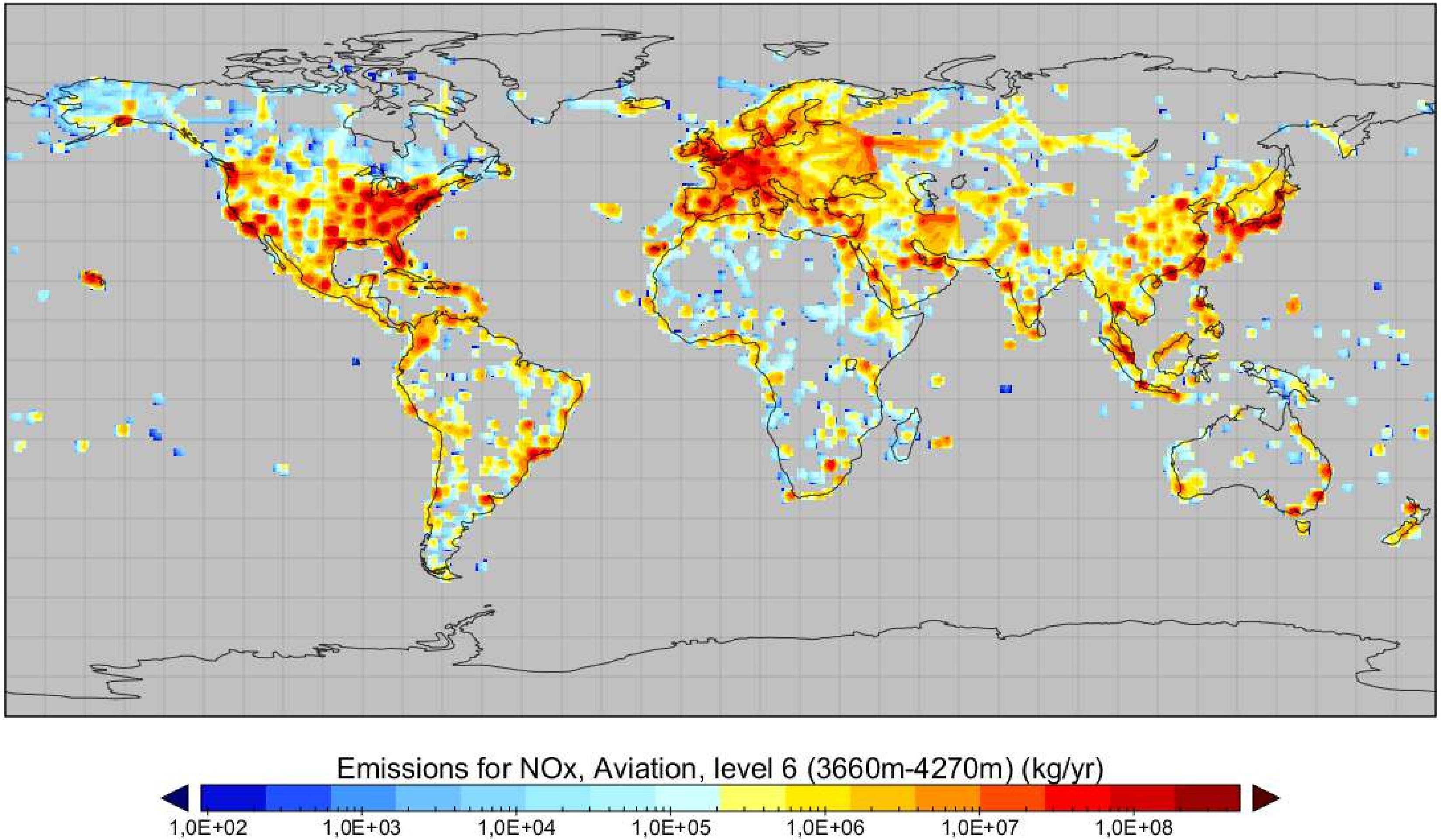
QUANTIFY

Emissions for NOx, Aviation, level 5 (3050m-3660m)



GWP, level 5, 100 years

Emissions for NOx, Aviation, level 6 (3660m-4270m)



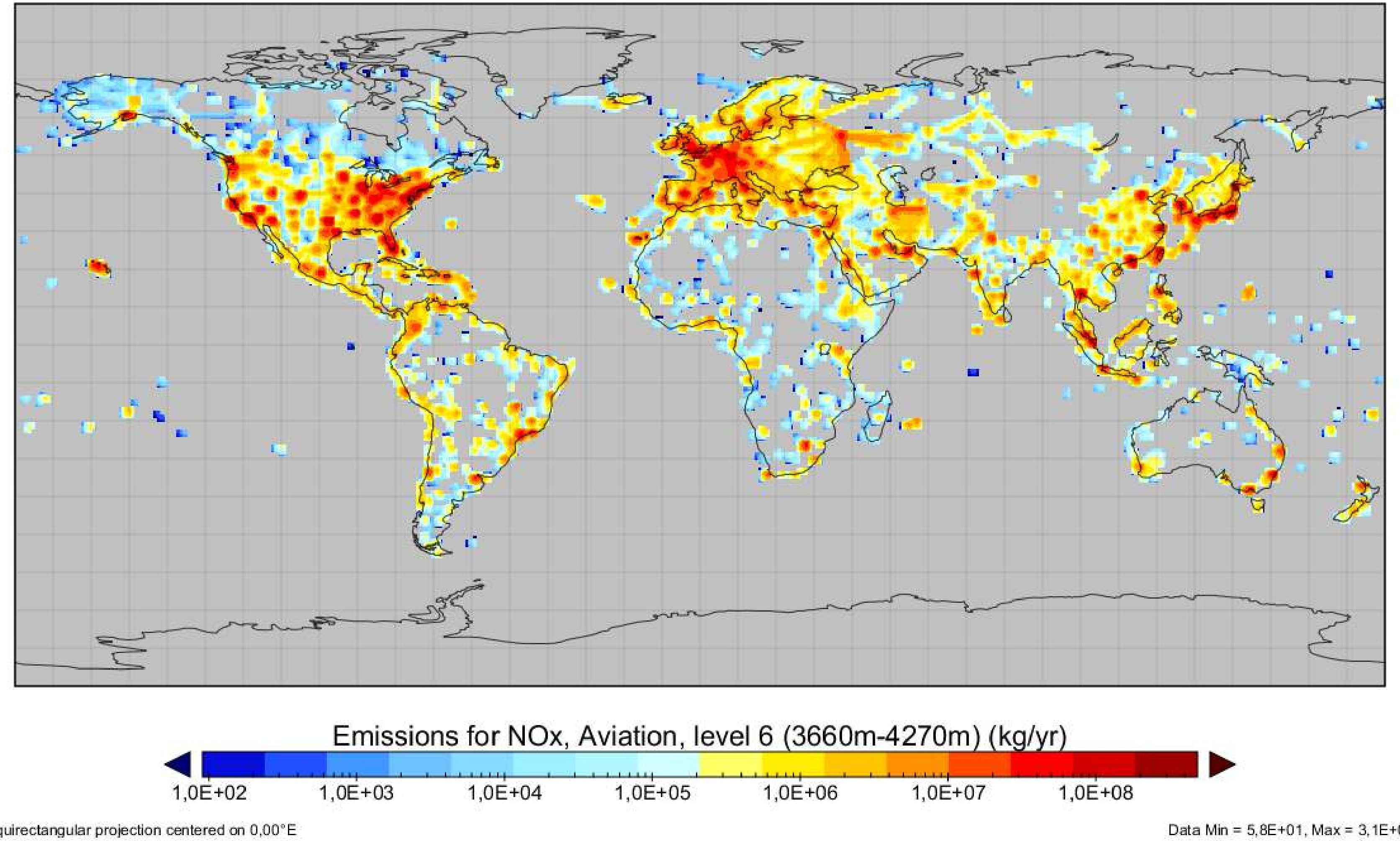
Equirectangular projection centered on 0,00°E

Data Min = 9,1E+01, Max = 4,8E+08

GWP, level 6, 25 years

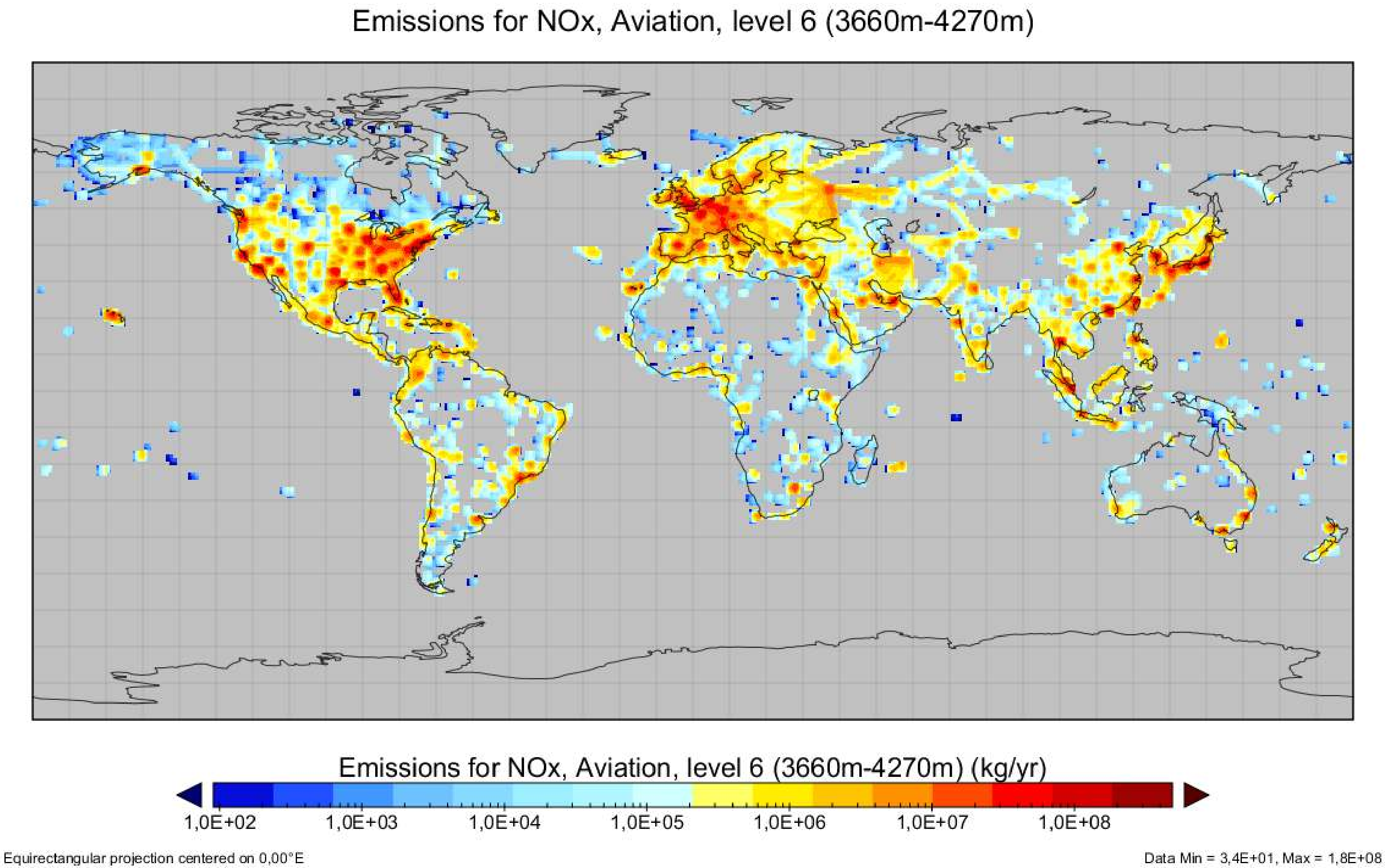
Quantify Final Meeting, 25-27 January 2010, Munich

Emissions for NOx, Aviation, level 6 (3660m-4270m)



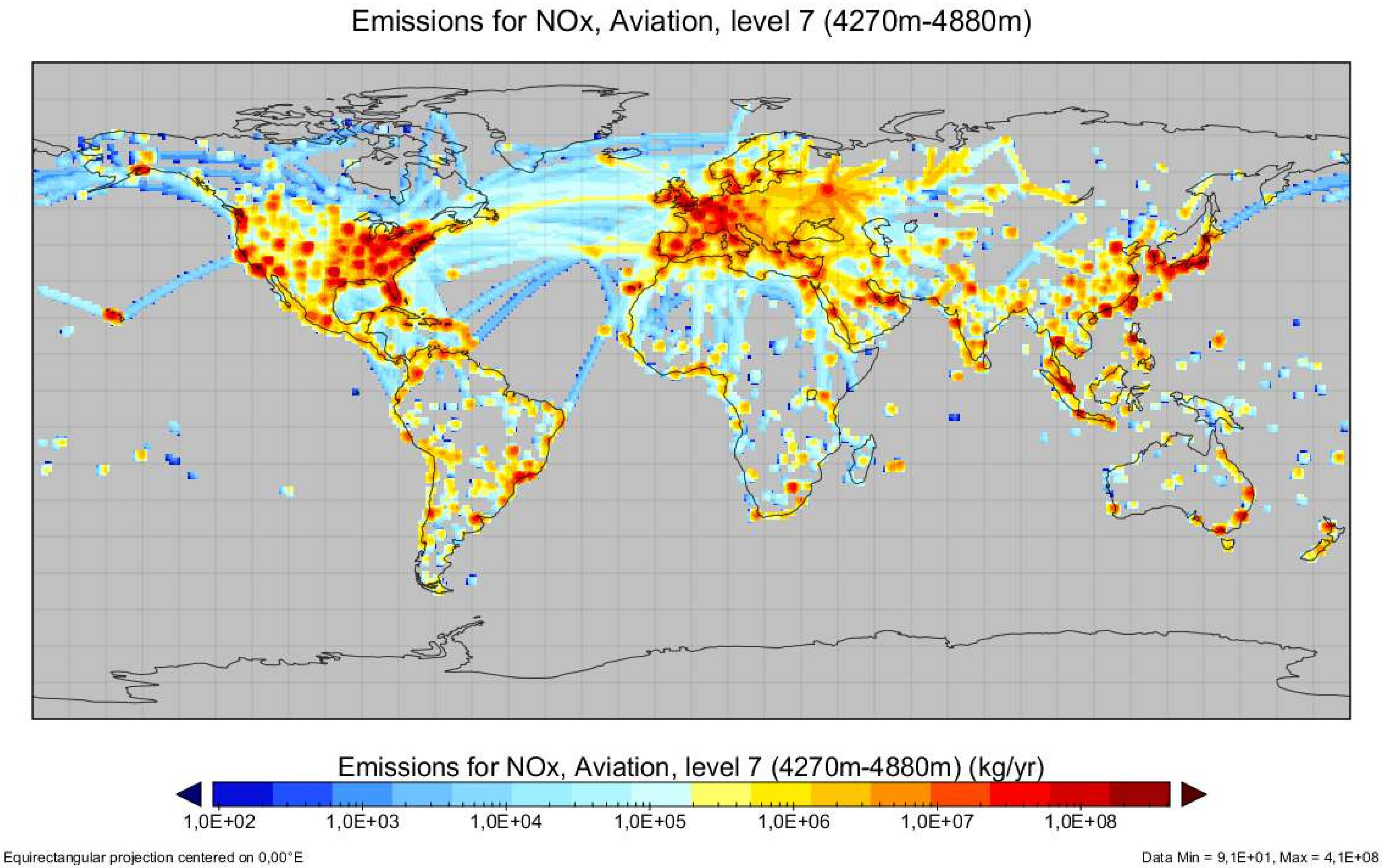
GWP, level 6, 50 years

Quantify Final Meeting, 25-27 January 2010, Munich



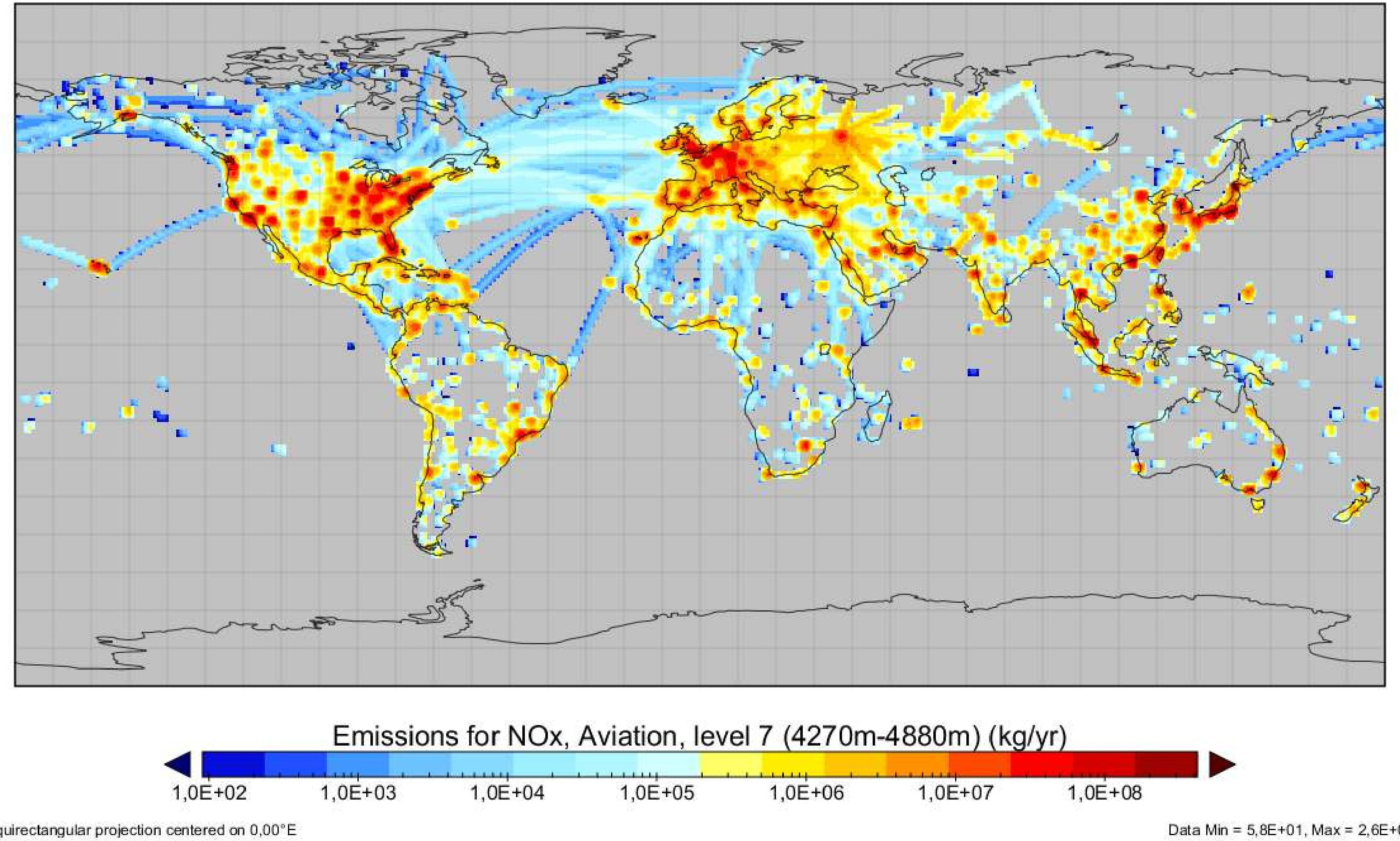
GWP, level 6, 100 years

Quantify Final Meeting, 25-27 January 2010, Munich



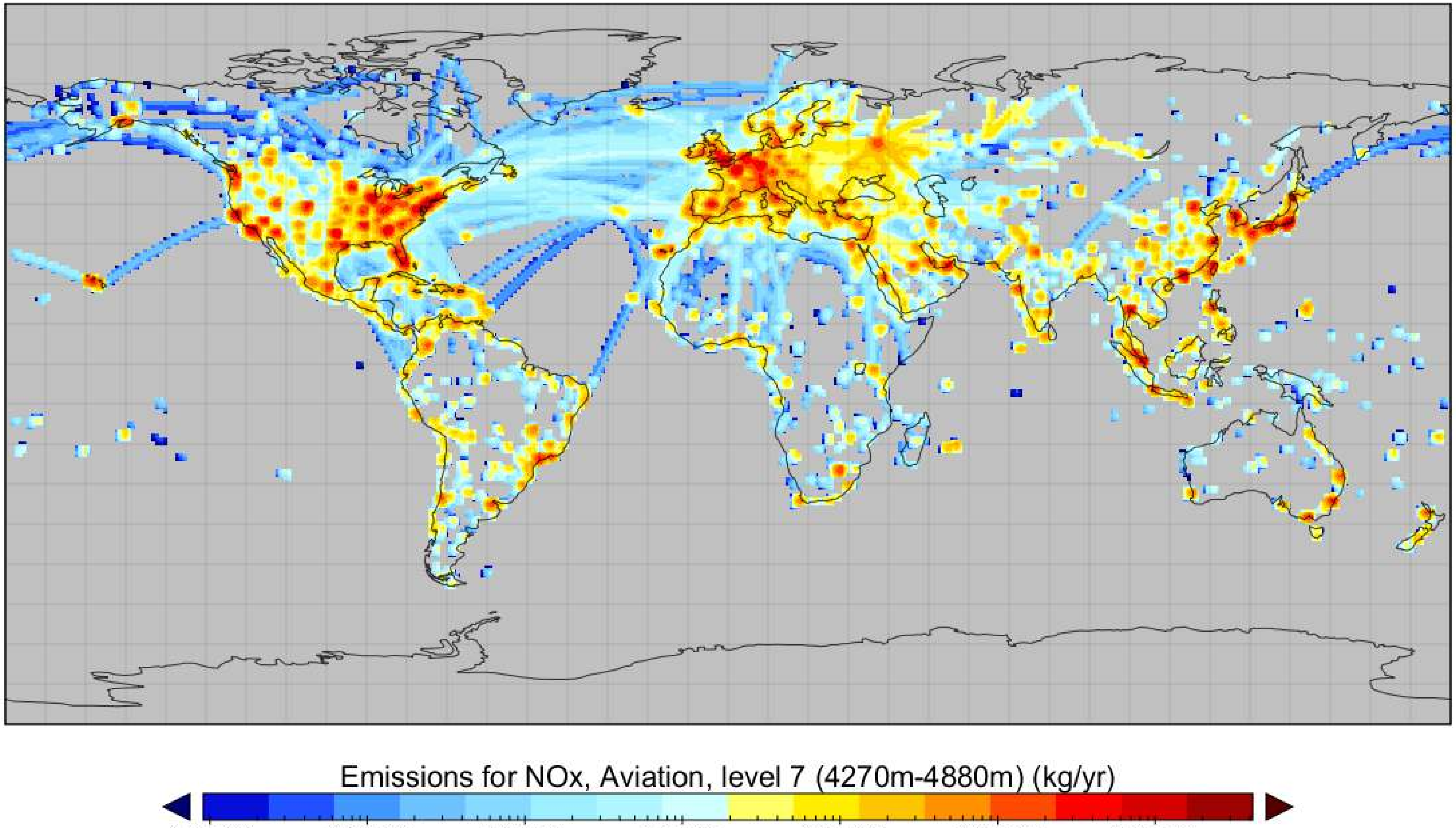
GWP, level 7, 25 years

Emissions for NOx, Aviation, level 7 (4270m-4880m)



GWP, level 7, 50 years

Emissions for NOx, Aviation, level 7 (4270m-4880m)

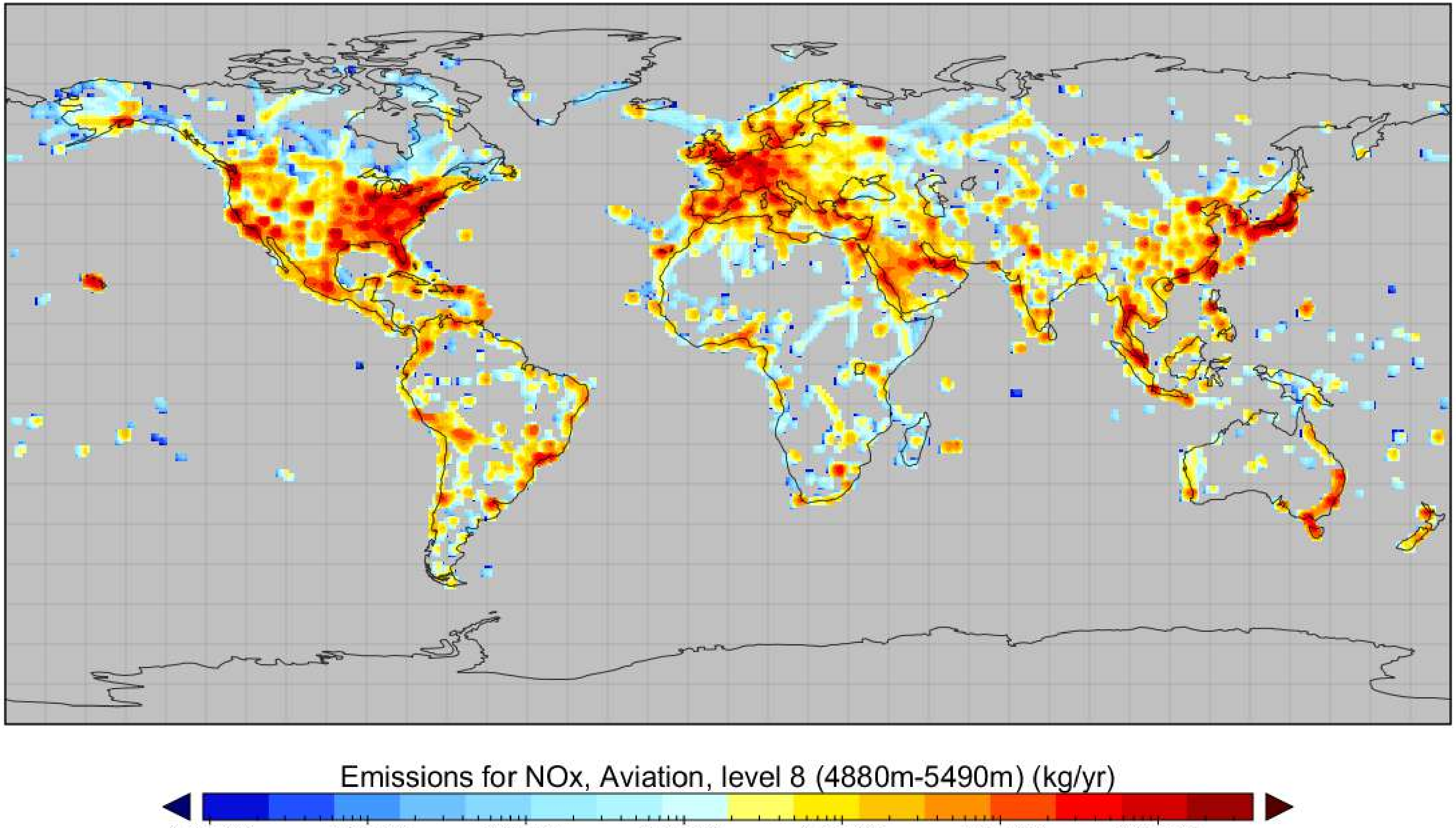


Equirectangular projection centered on 0,00°E

Data Min = 3,4E+01, Max = 1,6E+08

GWP, level 7, 100 years

Emissions for NOx, Aviation, level 8 (4880m-5490m)

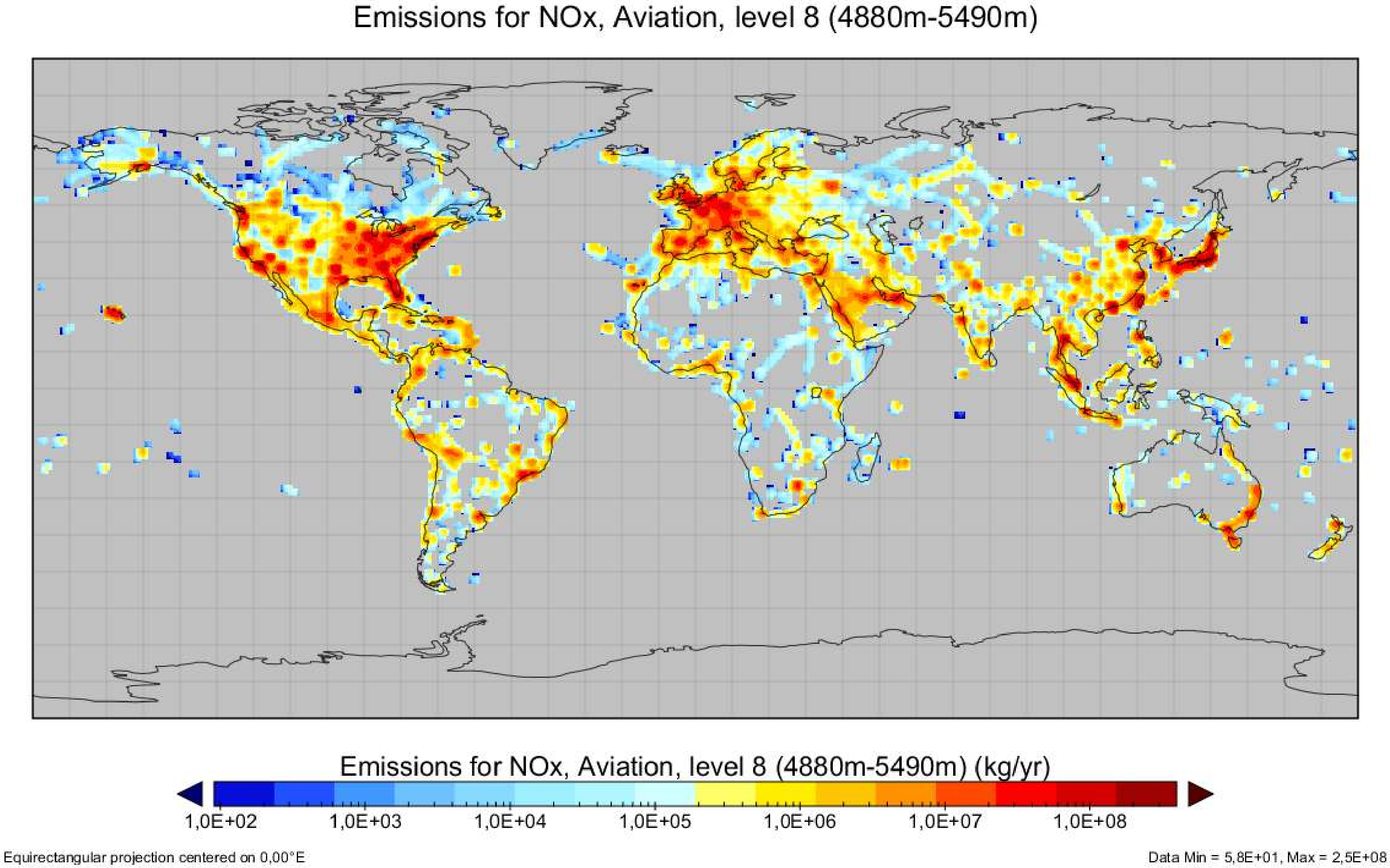


Equirectangular projection centered on 0,00°E

Data Min = 9,1E+01, Max = 4,0E+08

GWP, level 8, 25 years

Quantify Final Meeting, 25-27 January 2010, Munich

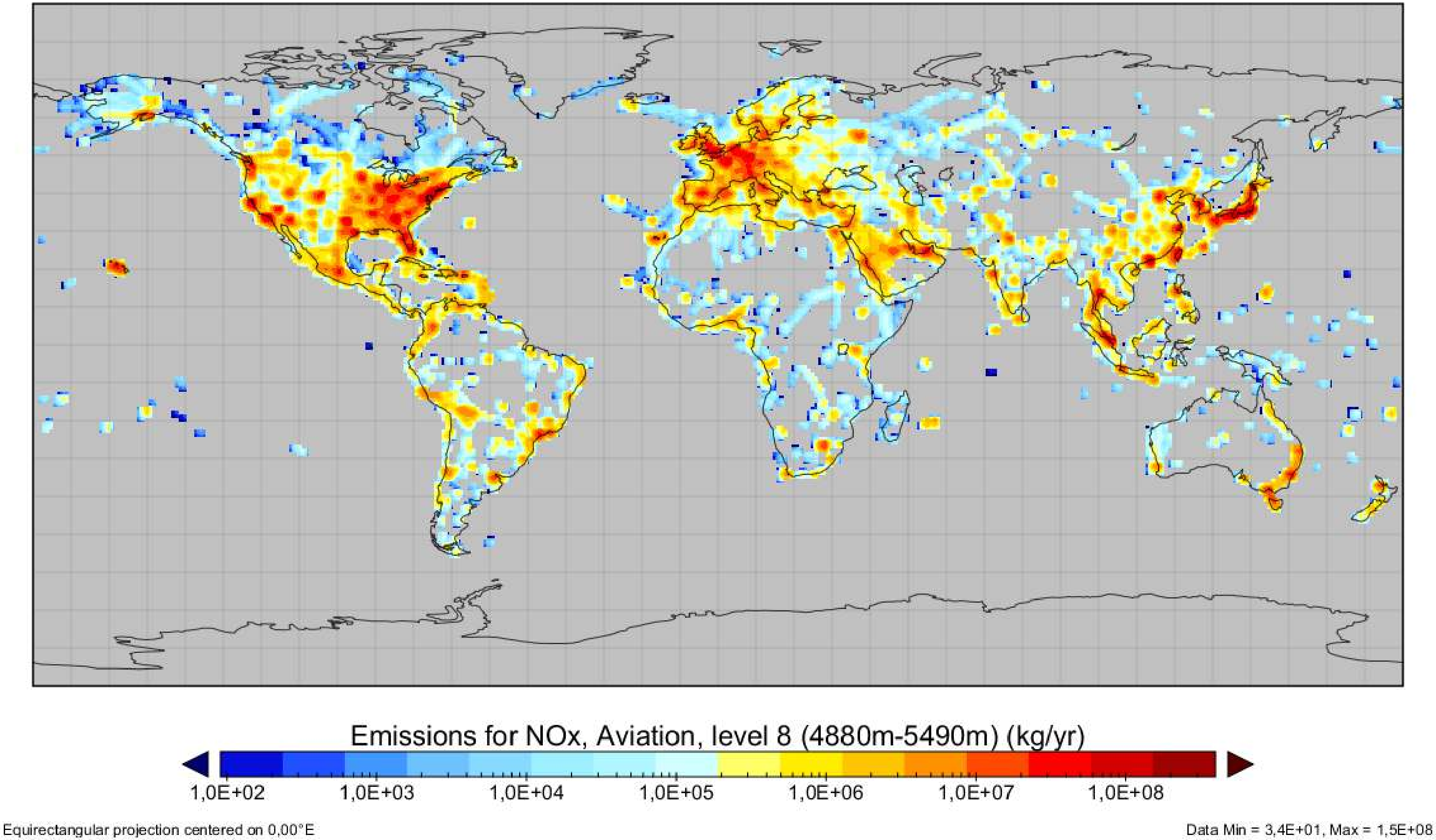


GWP, level 8, 50 years

Quantify Final Meeting, 25-27 January 2010, Munich

QUANTIFY

Emissions for NOx, Aviation, level 8 (4880m-5490m)

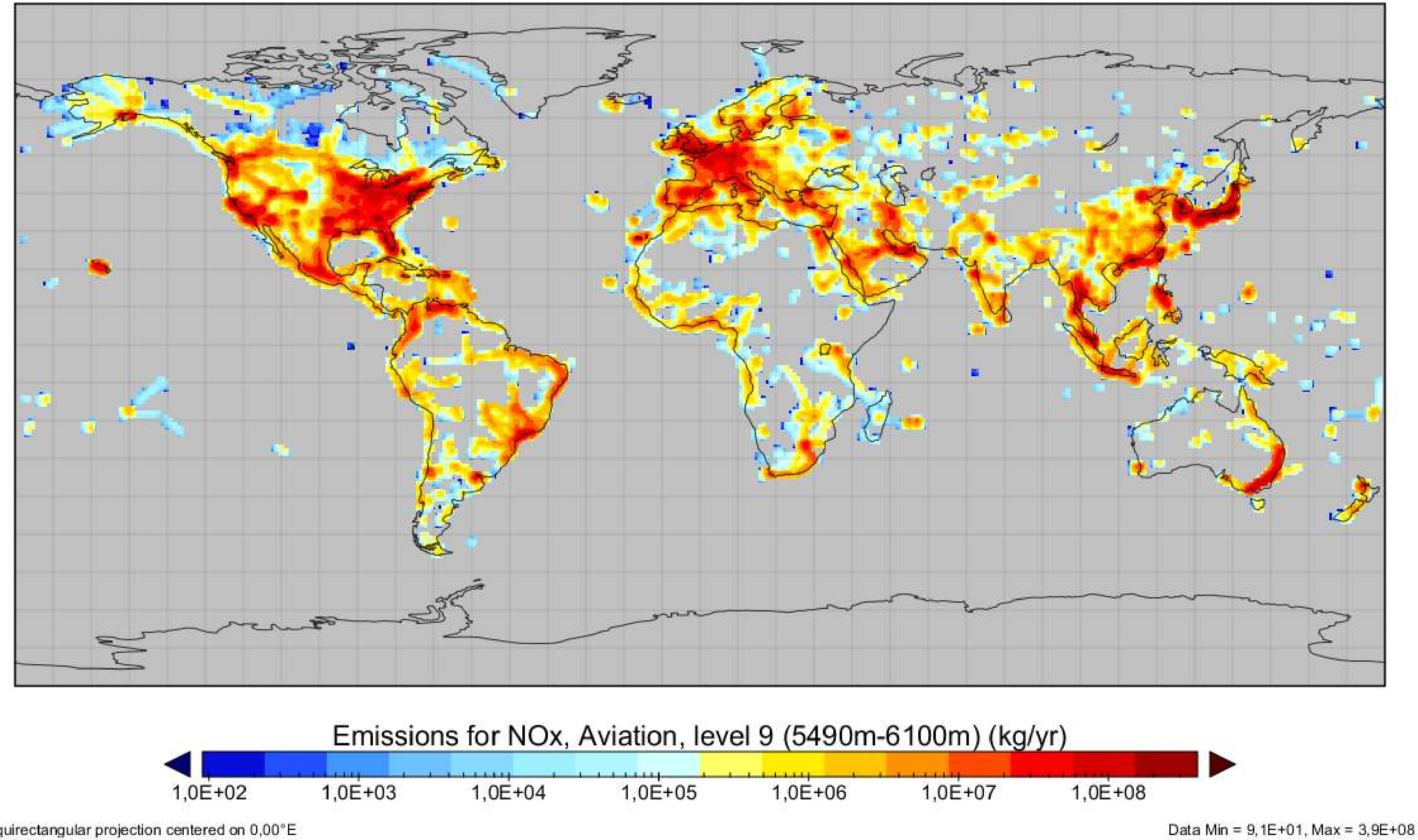


GWP, level 8, 100 years

Quantify Final Meeting, 25-27 January 2010, Munich

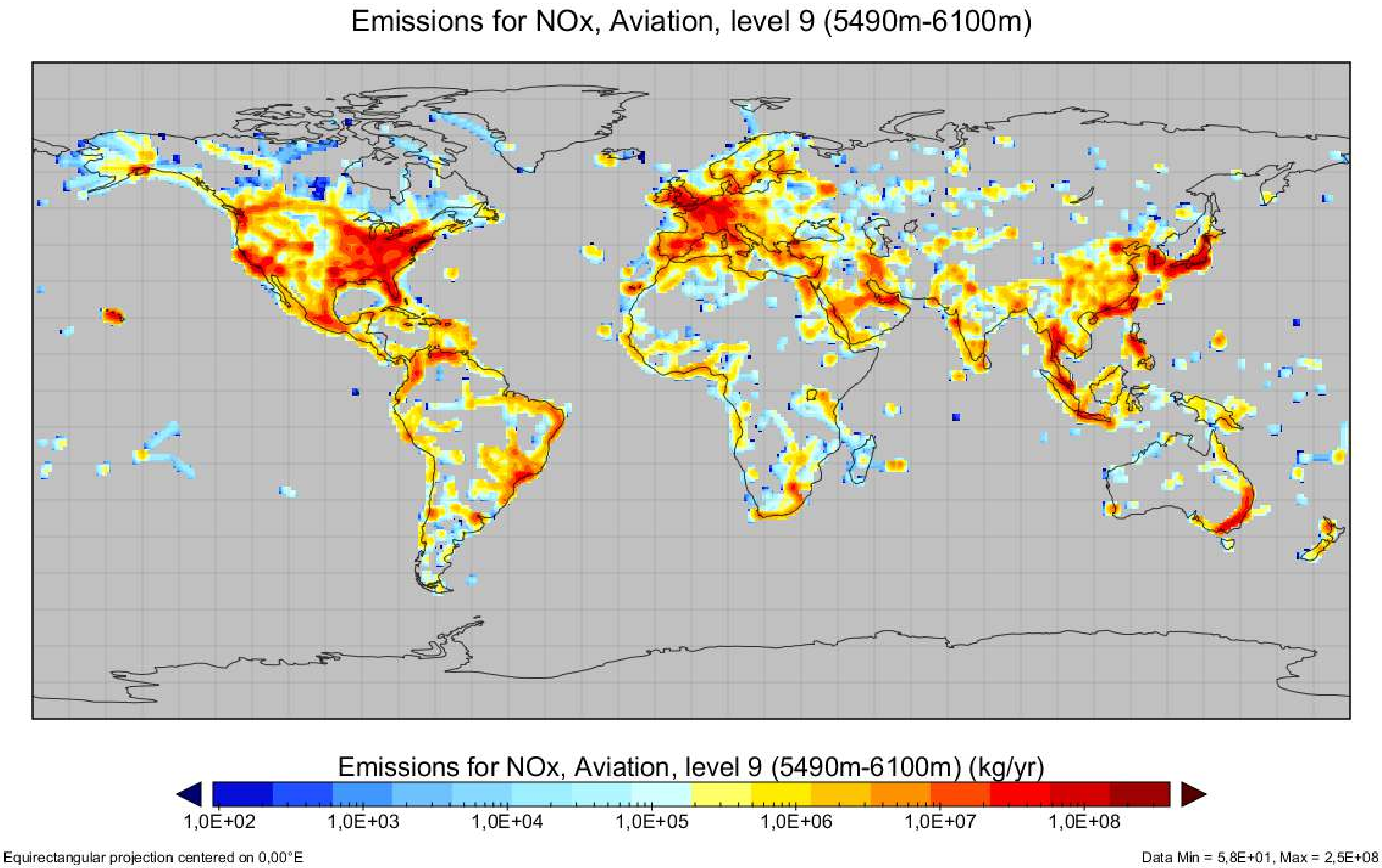
QUANTIFY

Emissions for NOx, Aviation, level 9 (5490m-6100m)



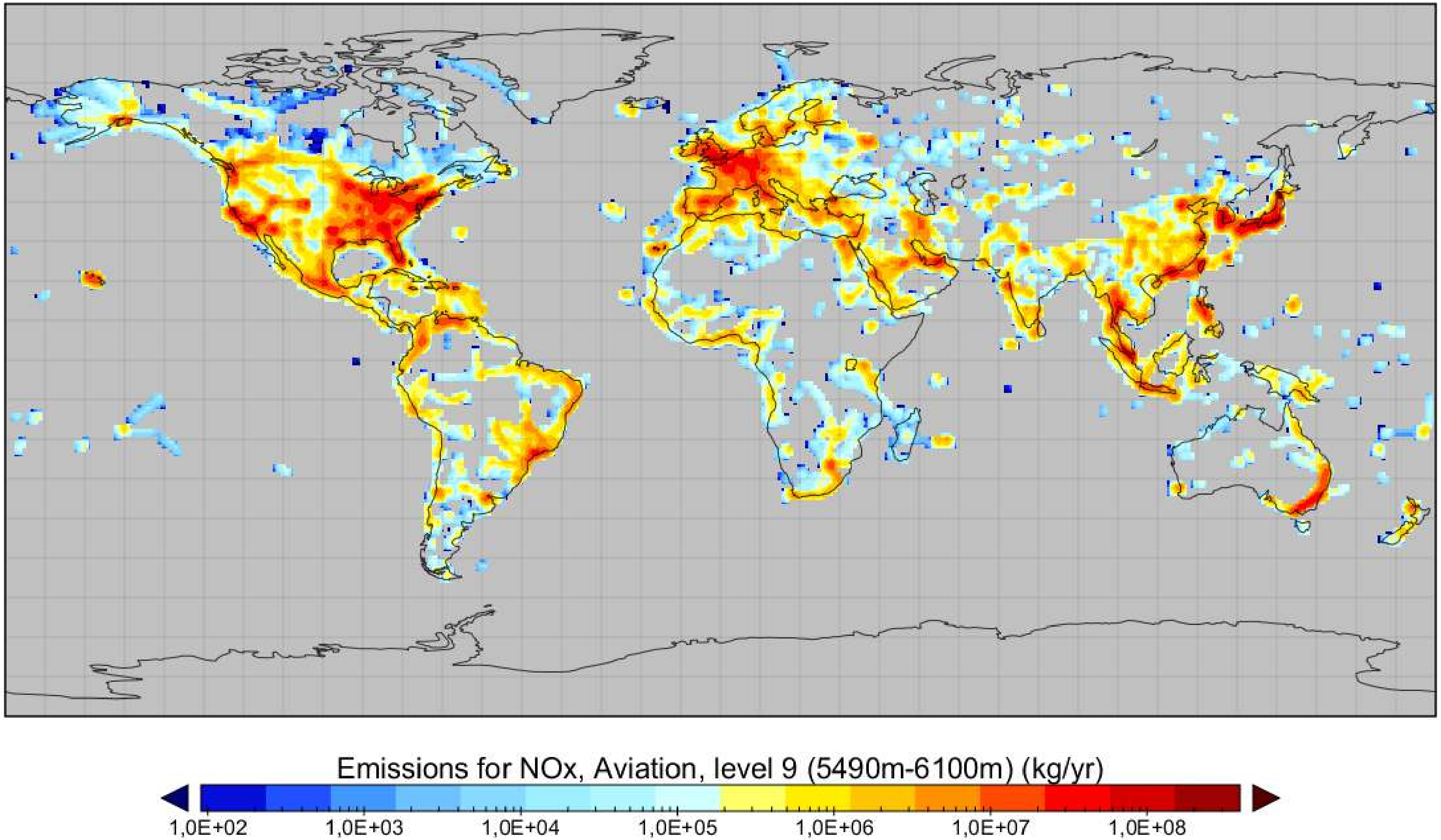
GWP, level 9, 25 years

Quantify Final Meeting, 25-27 January 2010, Munich



GWP, level 9, 50 years

Emissions for NOx, Aviation, level 9 (5490m-6100m)

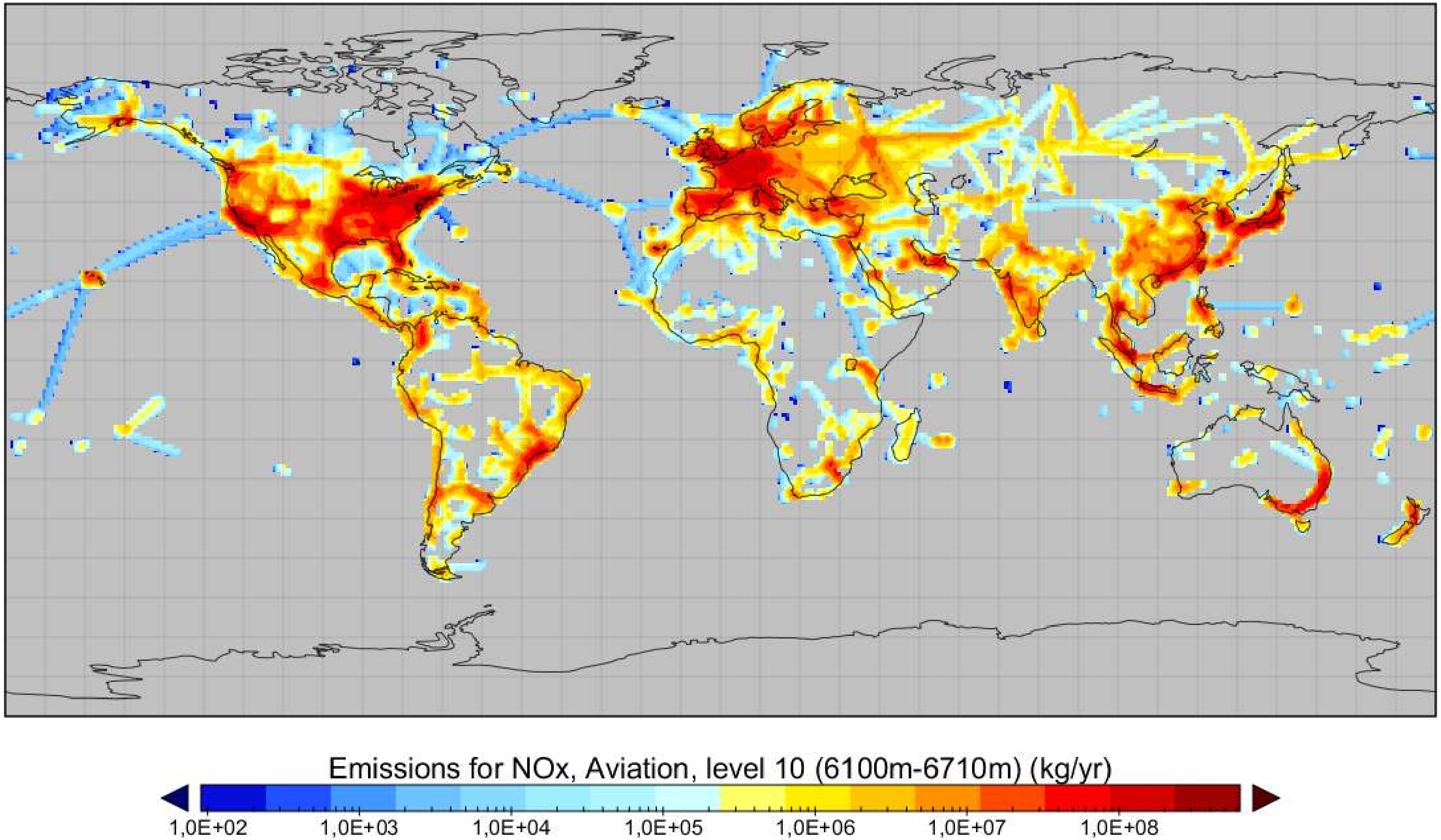


Equirectangular projection centered on 0,00°E

Data Min = 3,4E+01, Max = 1,5E+08

GWP, level 9, 100 years

Emissions for NOx, Aviation, level 10 (6100m-6710m)



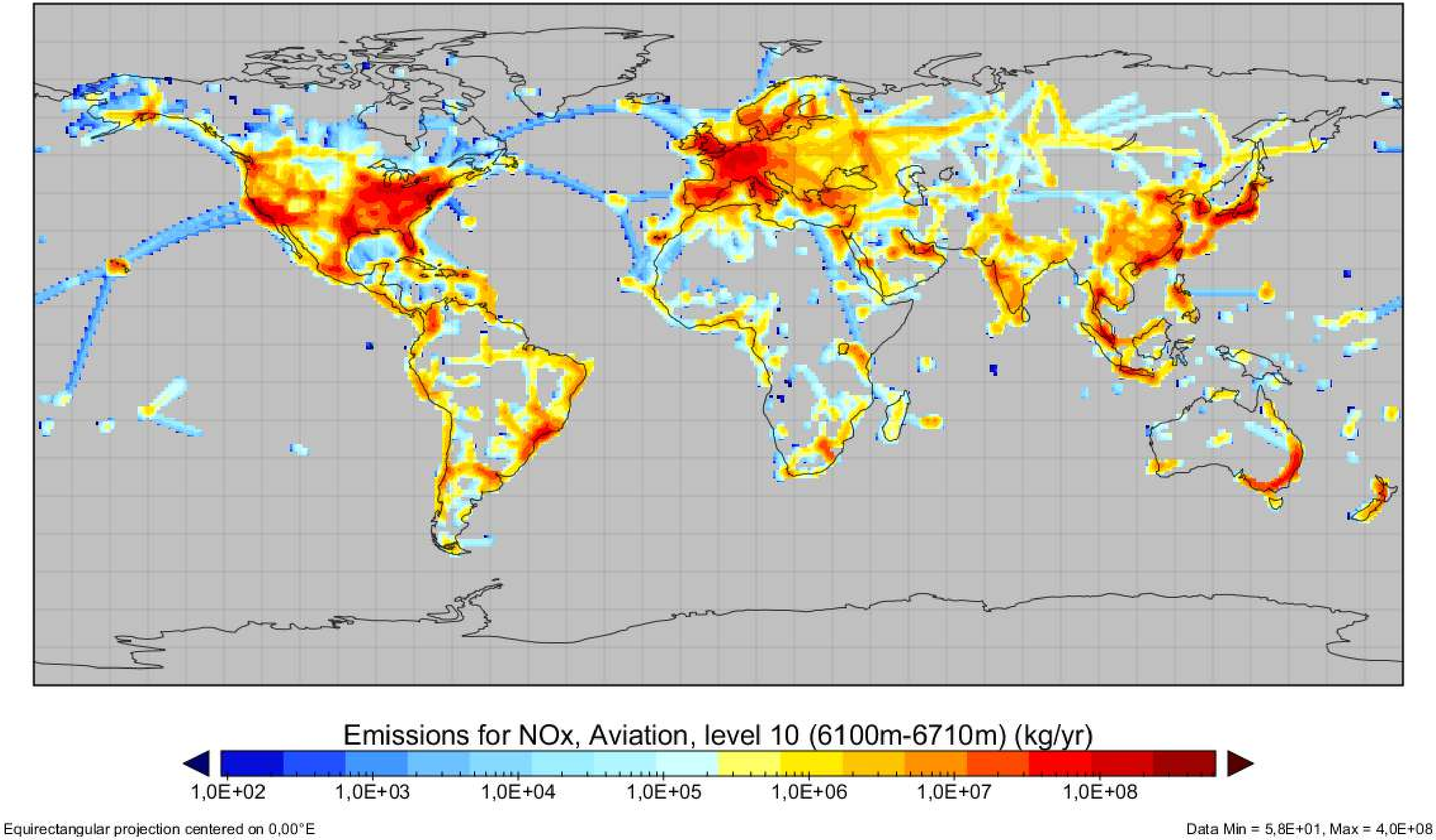
Equirectangular projection centered on 0,00°E

Data Min = 9,1E+01, Max = 6,2E+08

GWP, level 10, 25 years

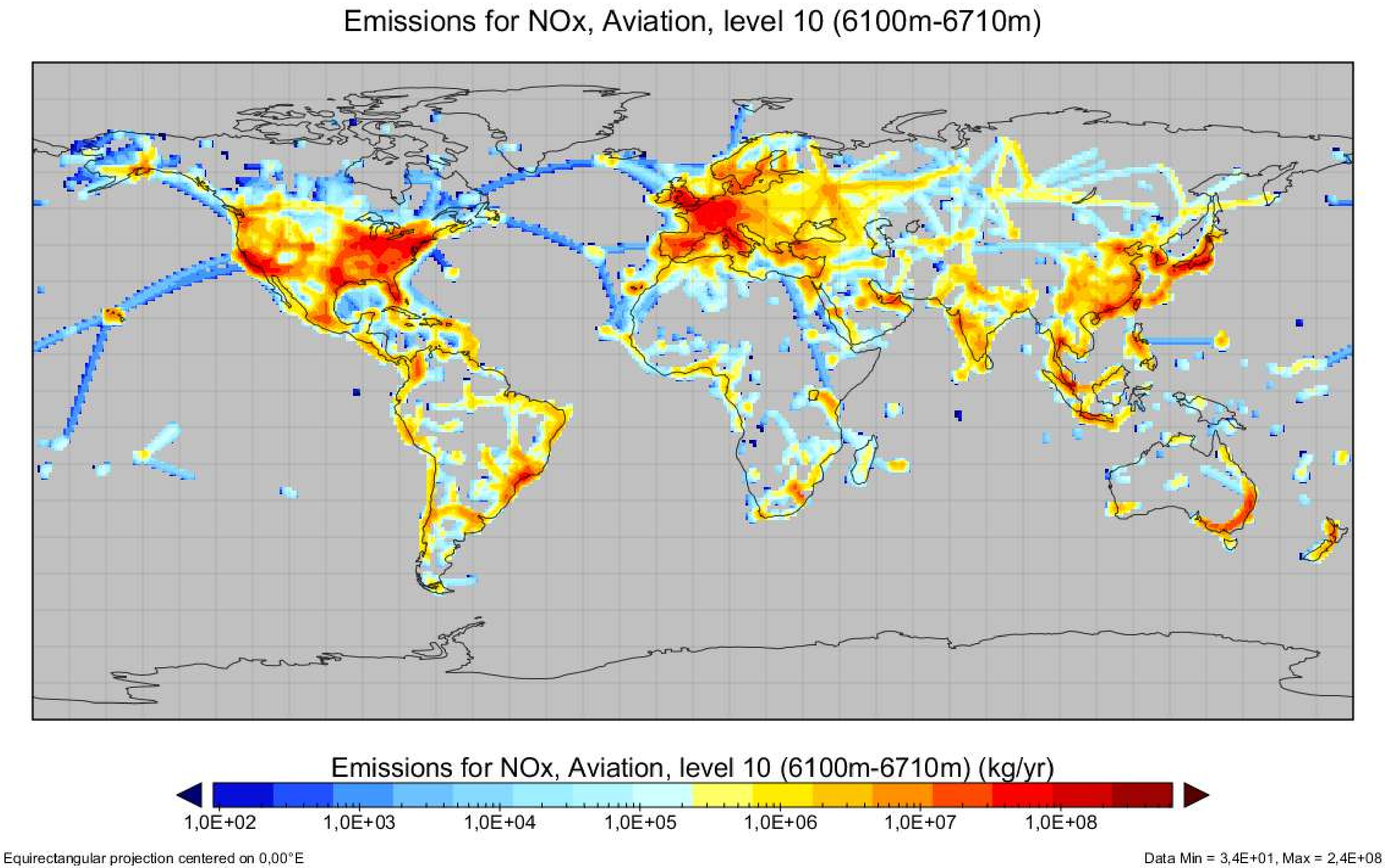
Quantify Final Meeting, 25-27 January 2010, Munich

Emissions for NOx, Aviation, level 10 (6100m-6710m)

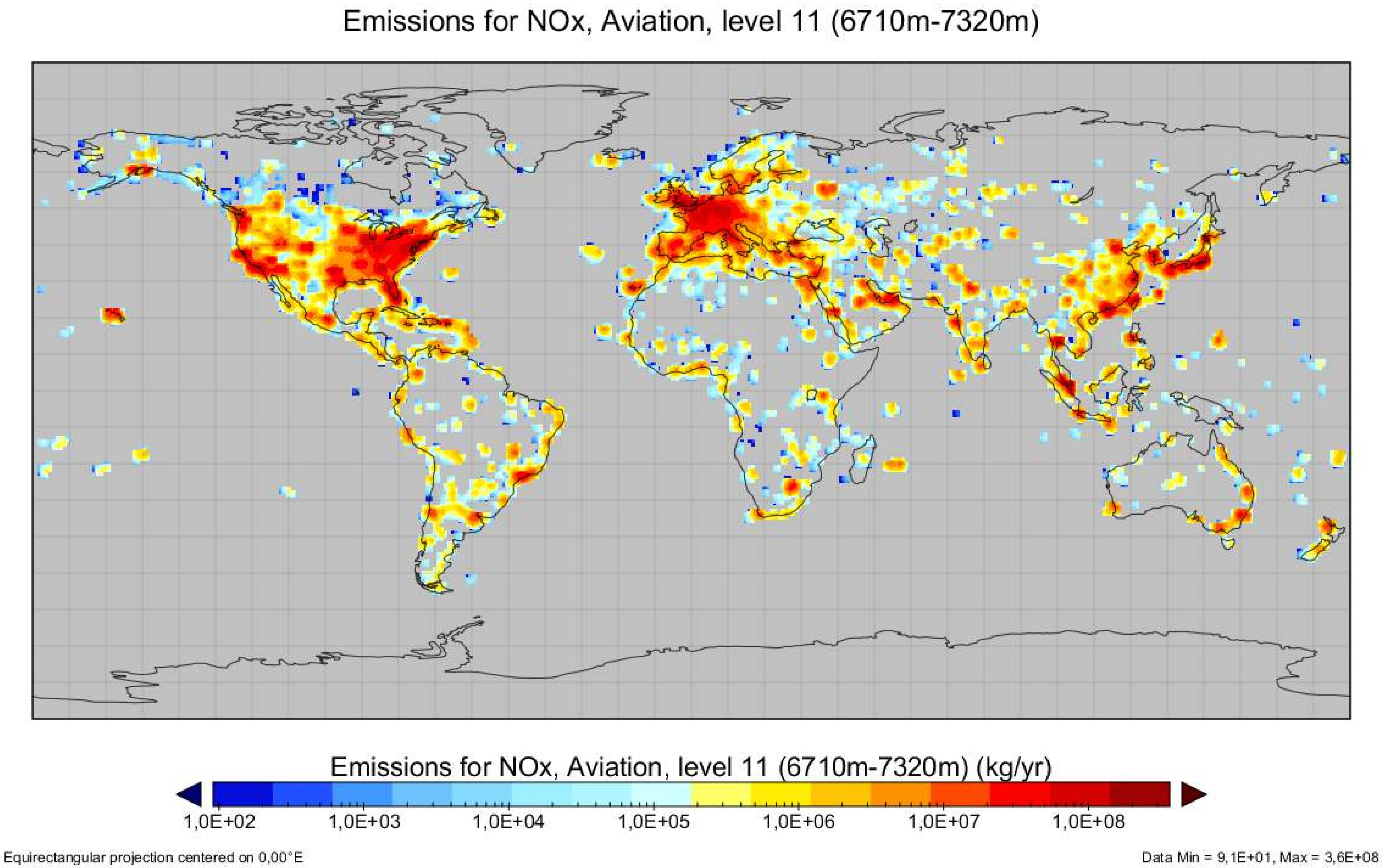


GWP, level 10, 50 years

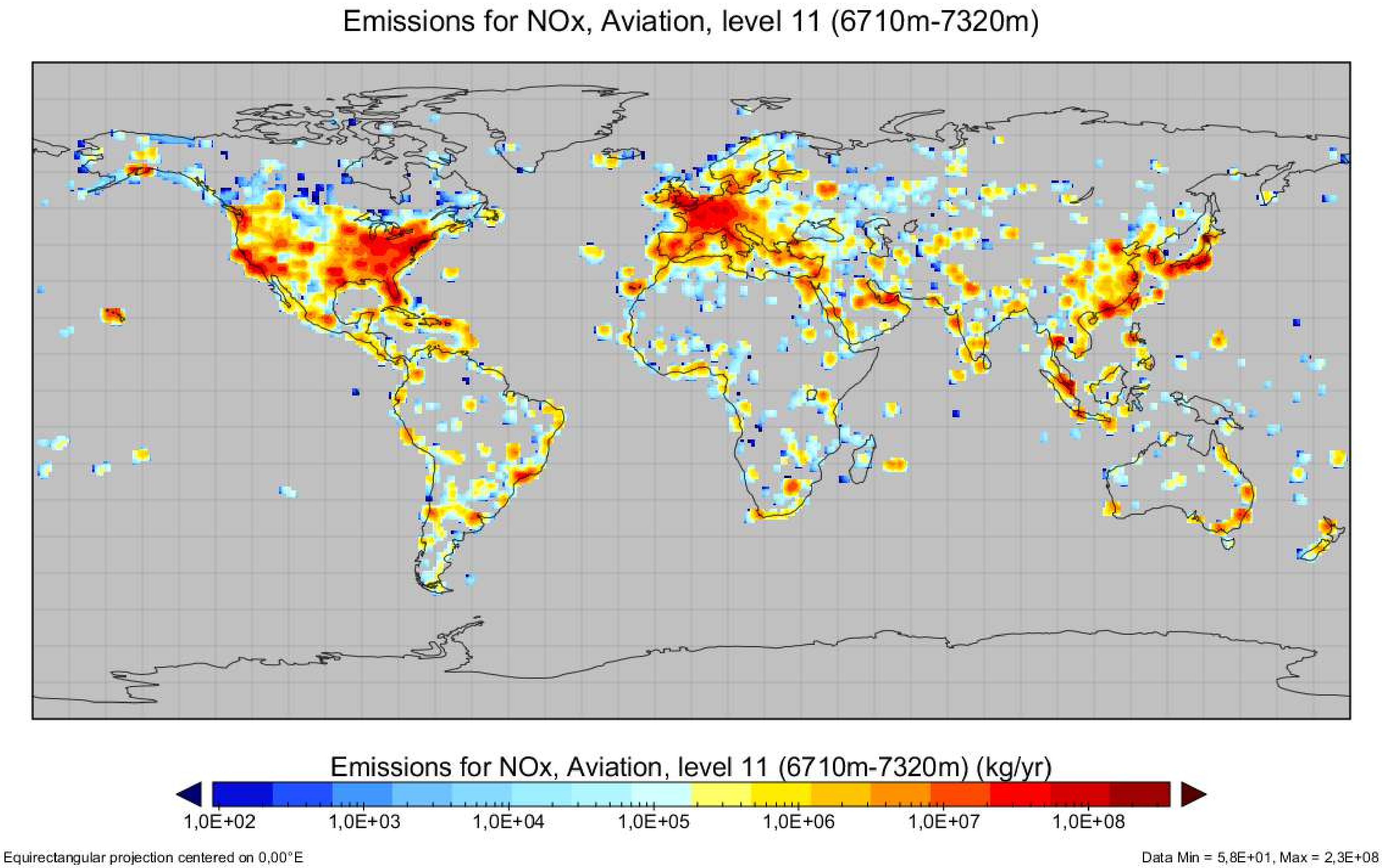
QUANTIFY



GWP, level 10, 100 years



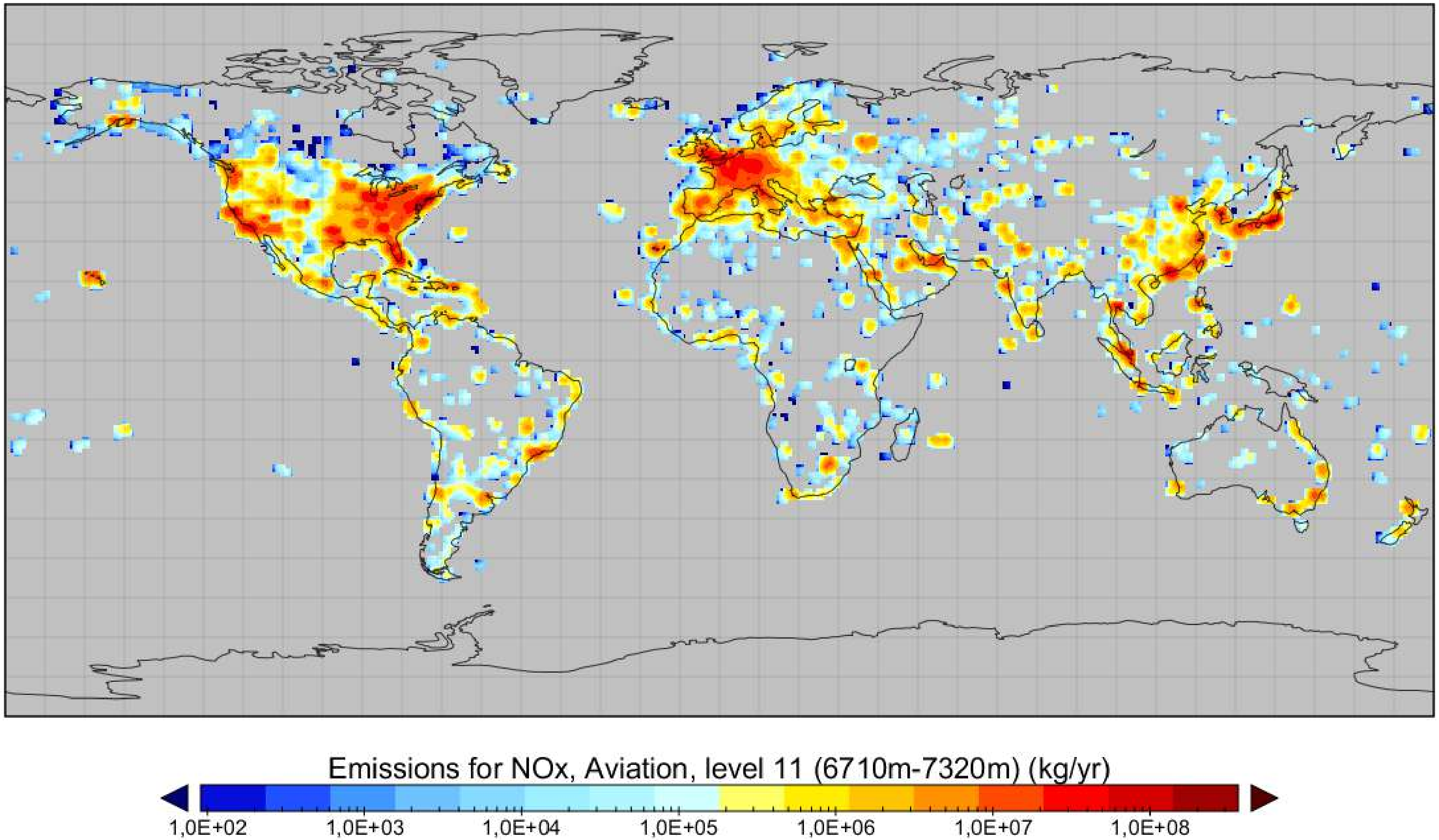
GWP, level 11, 25 years



GWP, level 11, 50 years

Quantify Final Meeting, 25-27 January 2010, Munich

Emissions for NOx, Aviation, level 11 (6710m-7320m)



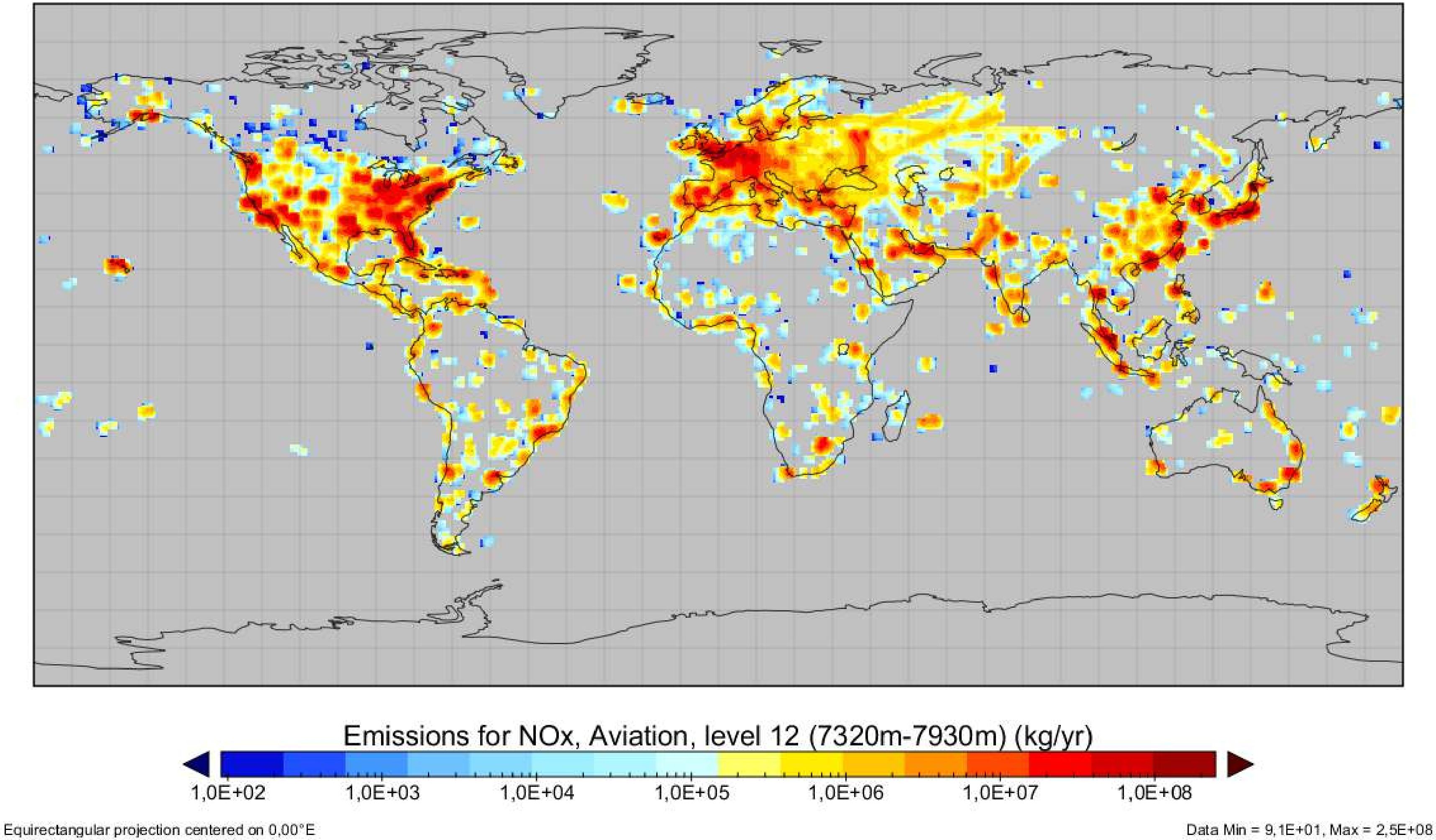
Equirectangular projection centered on 0,00°E

Data Min = 3,4E+01, Max = 1,4E+08

GWP, level 11, 100 years

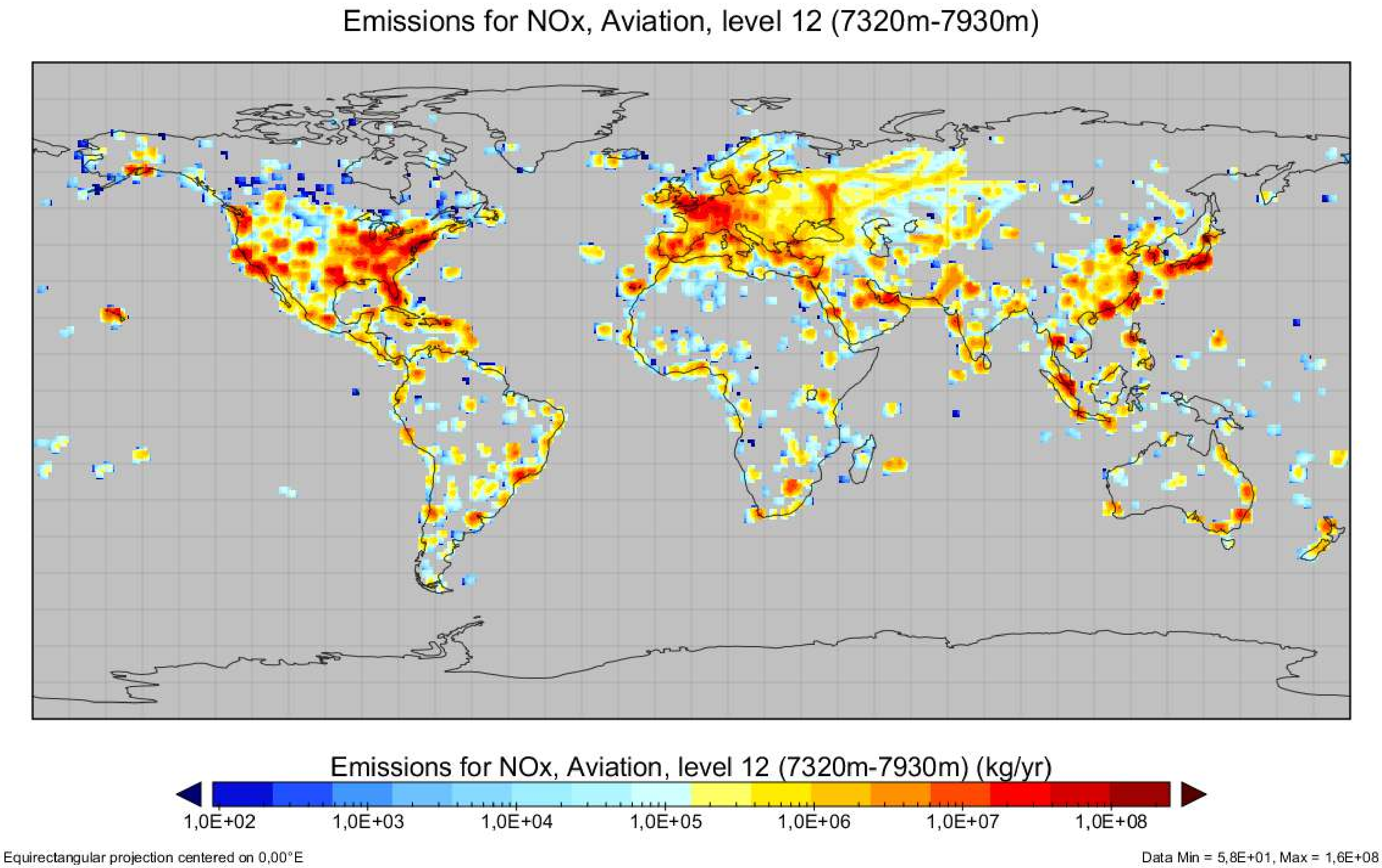
Quantify Final Meeting, 25-27 January 2010, Munich

Emissions for NOx, Aviation, level 12 (7320m-7930m)



GWP, level 12, 25 years

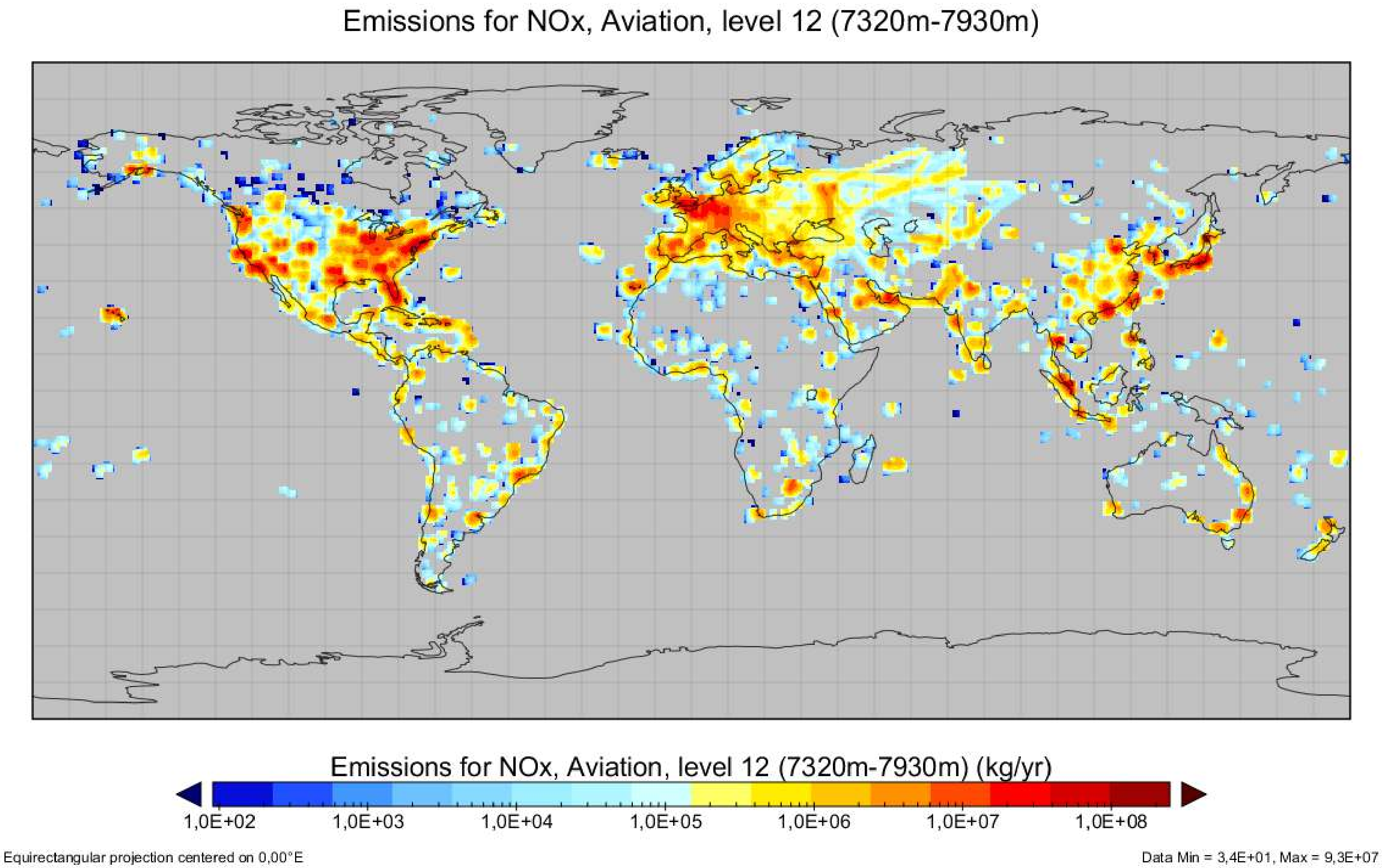
Quantify Final Meeting, 25-27 January 2010, Munich



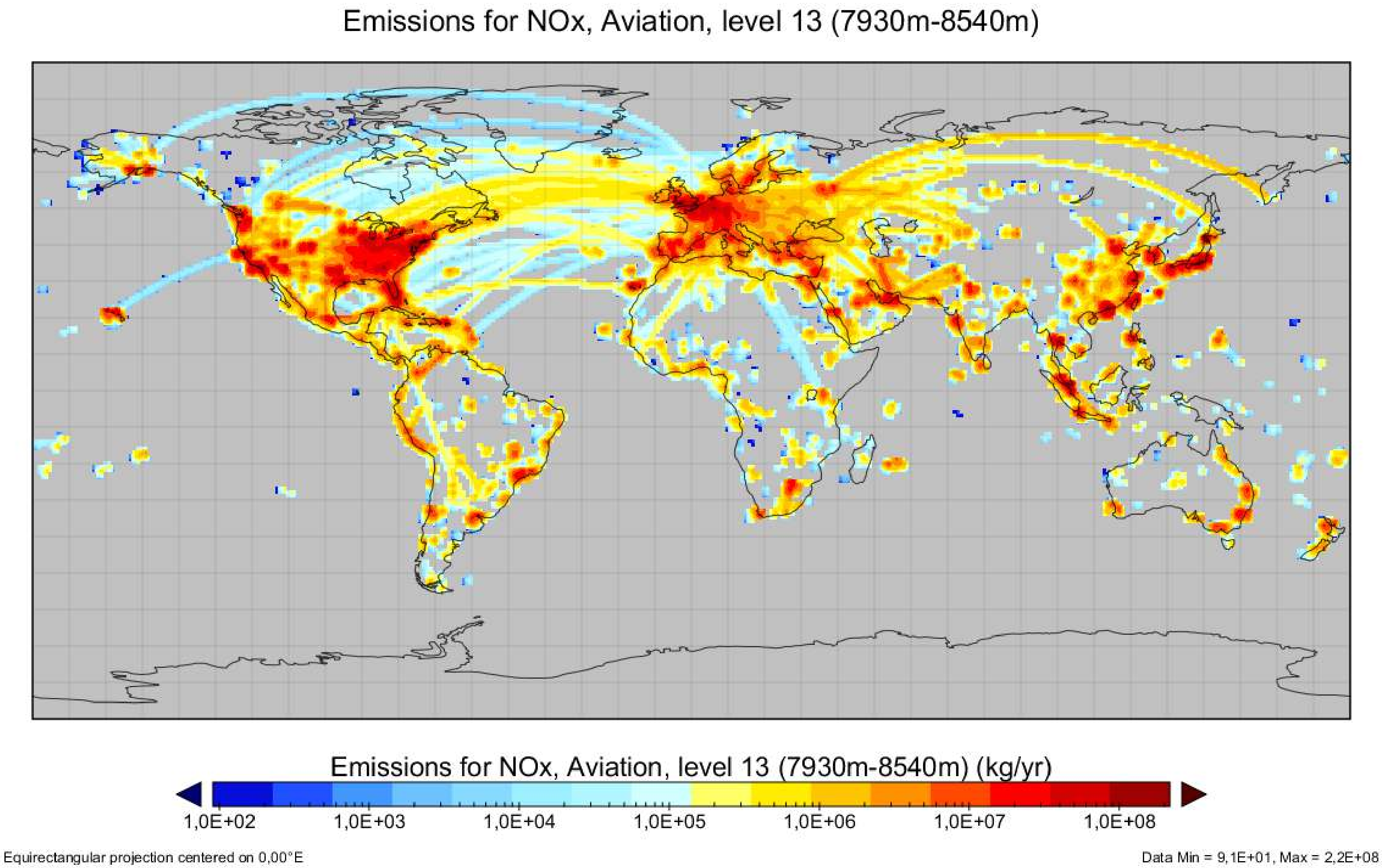
GWP, level 12, 50 years

Quantify Final Meeting, 25-27 January 2010, Munich

QUANTIFY



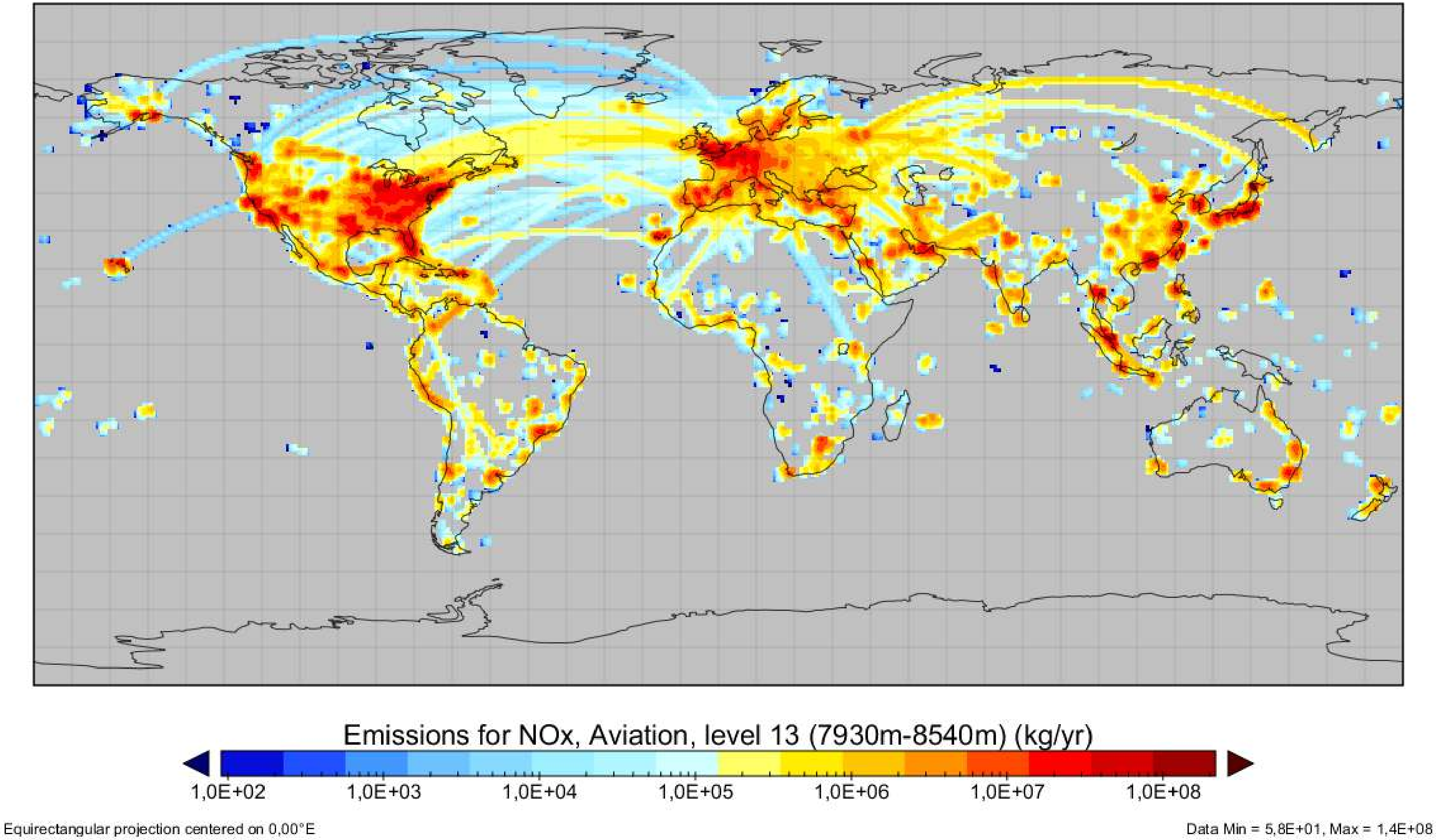
GWP, level 12, 100 years



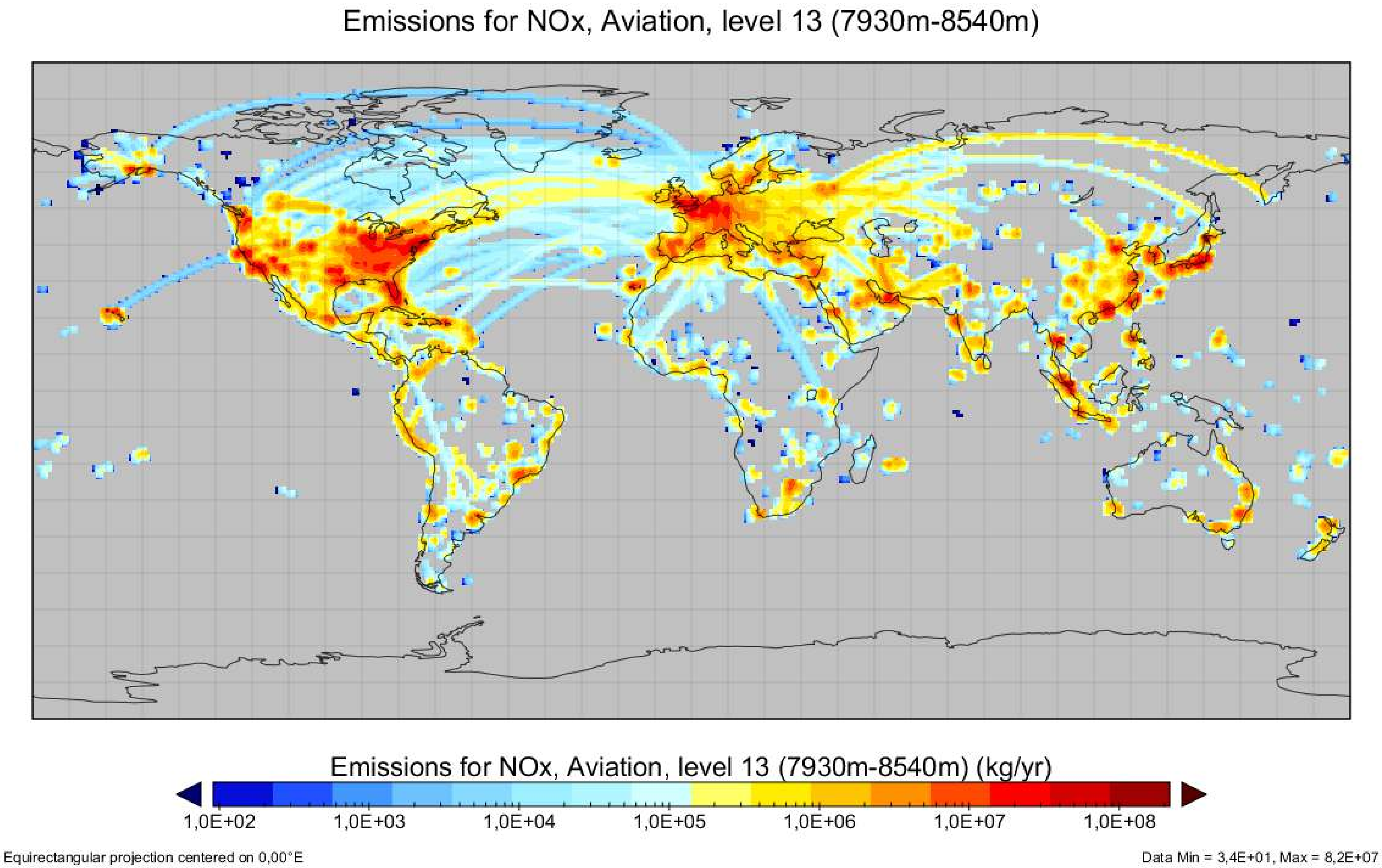
GWP, level 13, 25 years

Quantify Final Meeting, 25-27 January 2010, Munich

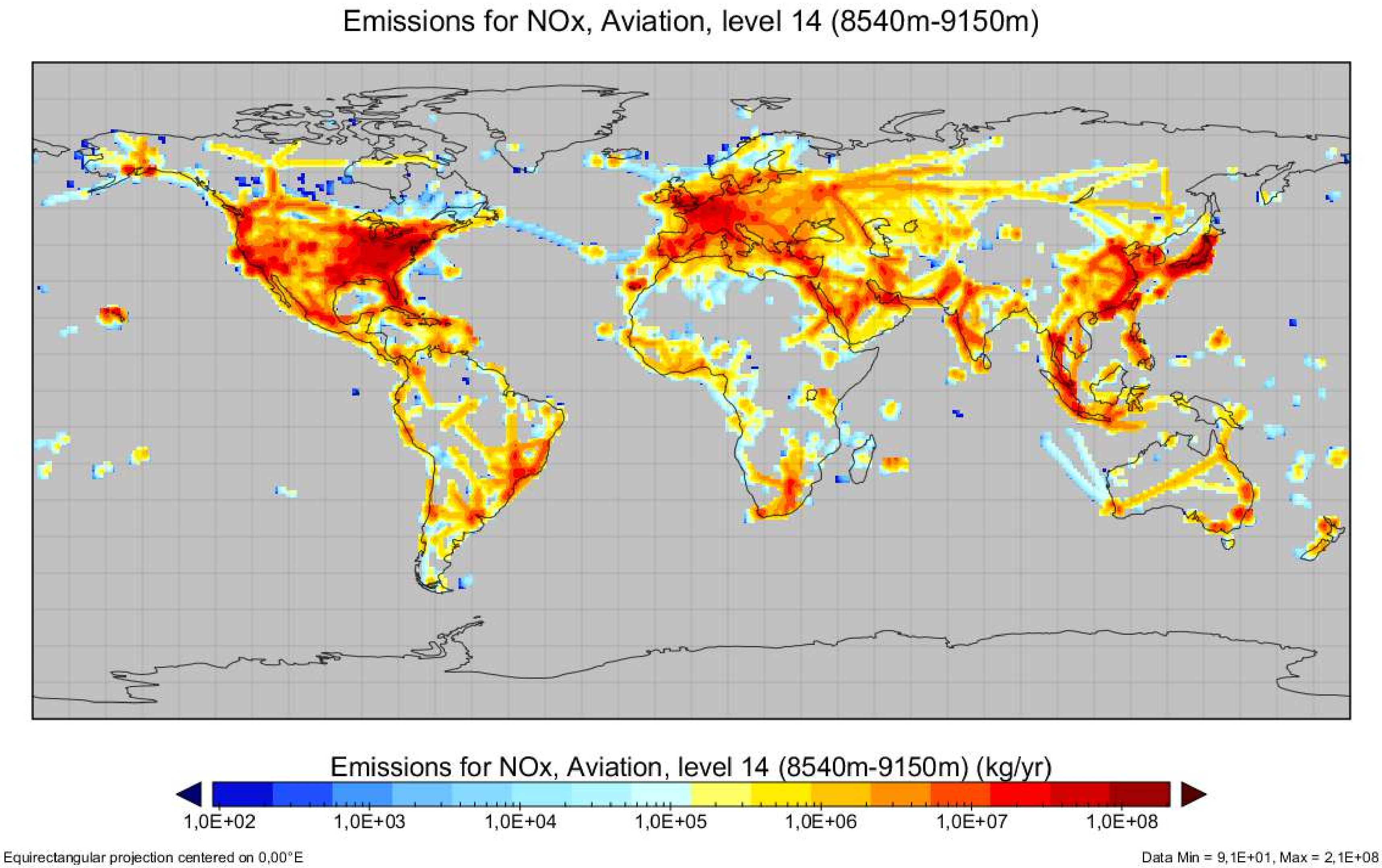
Emissions for NOx, Aviation, level 13 (7930m-8540m)



GWP, level 13, 50 years

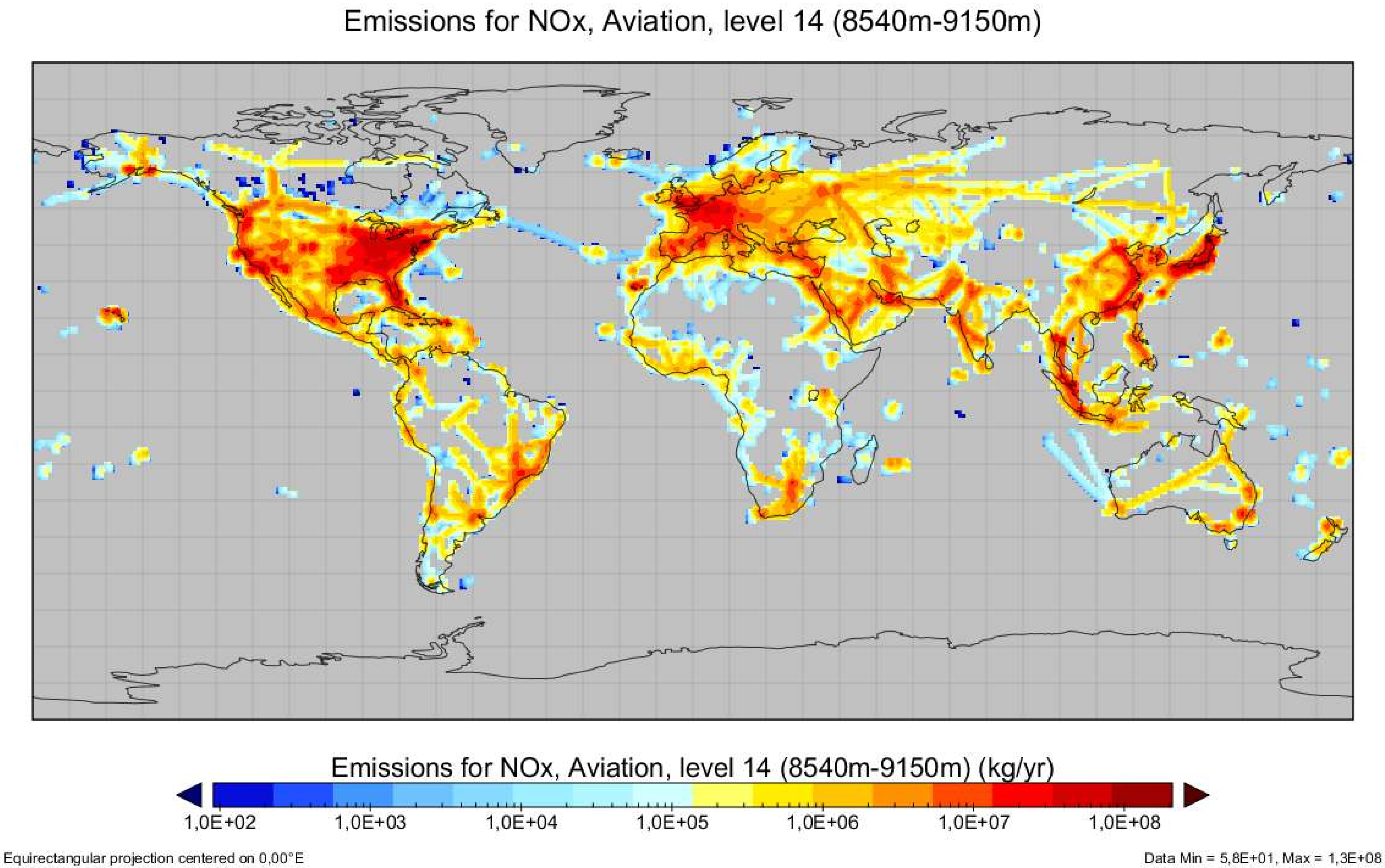


GWP, level 13, 100 years



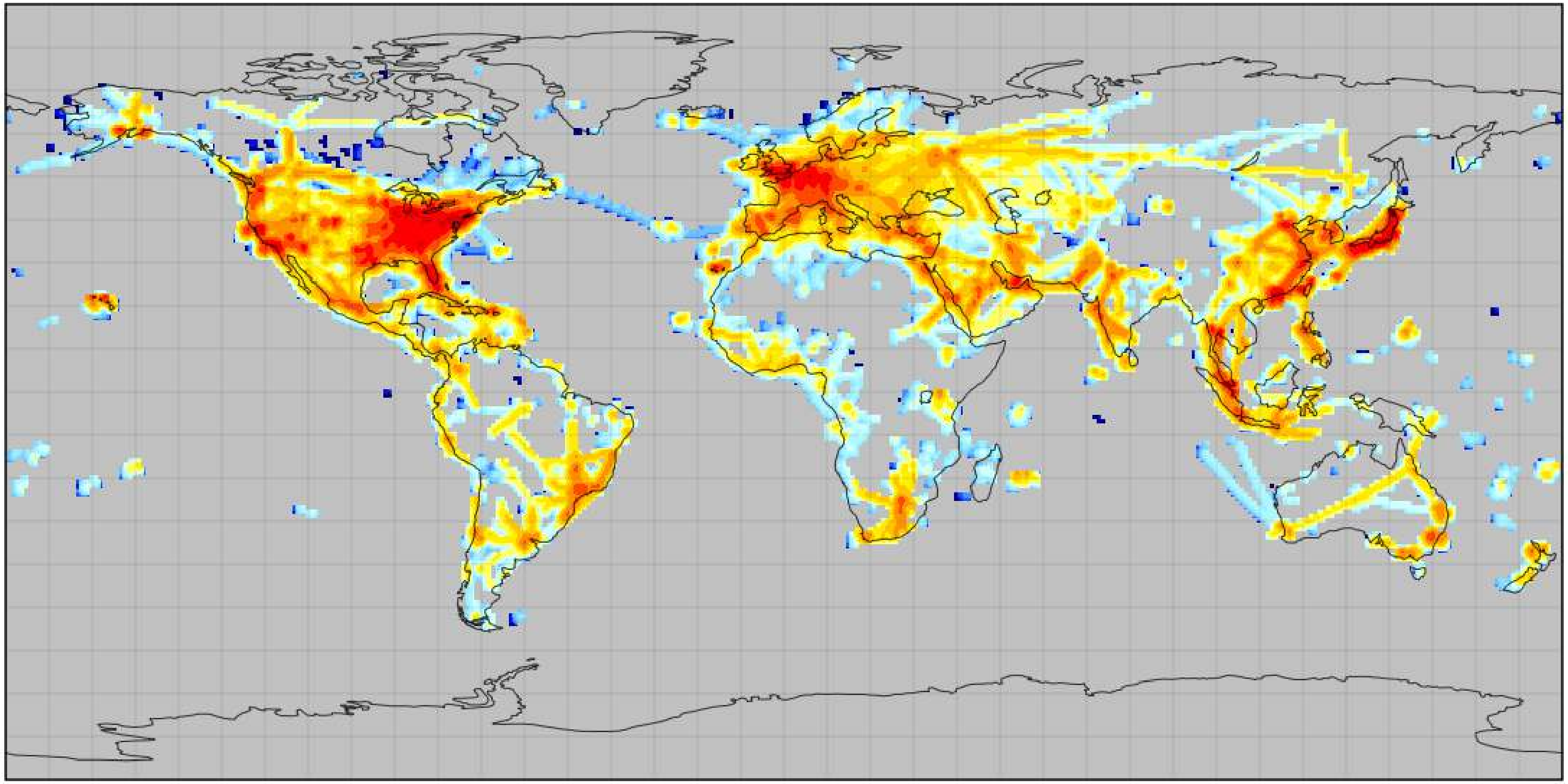
GWP, level 14, 25 years

Quantify Final Meeting, 25-27 January 2010, Munich



GWP, level 14, 50 years

Emissions for NOx, Aviation, level 14 (8540m-9150m)



Emissions for NOx, Aviation, level 14 (8540m-9150m) (kg/yr)

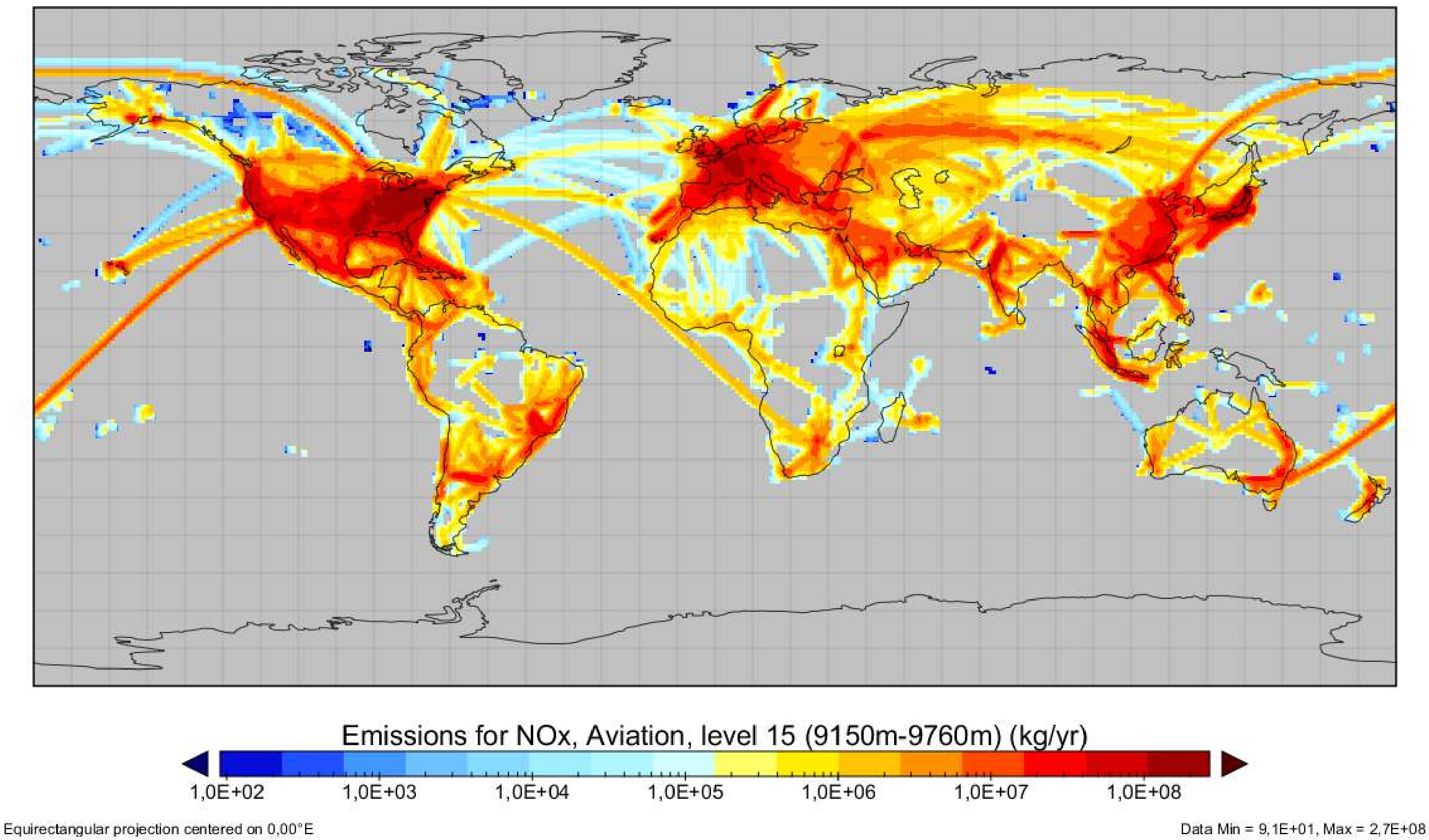
1,0E+02 1,0E+03 1,0E+04 1,0E+05 1,0E+06 1,0E+07 1,0E+08

Equirectangular projection centered on 0,00°E

Data Min = 3,4E+01, Max = 7,9E+07

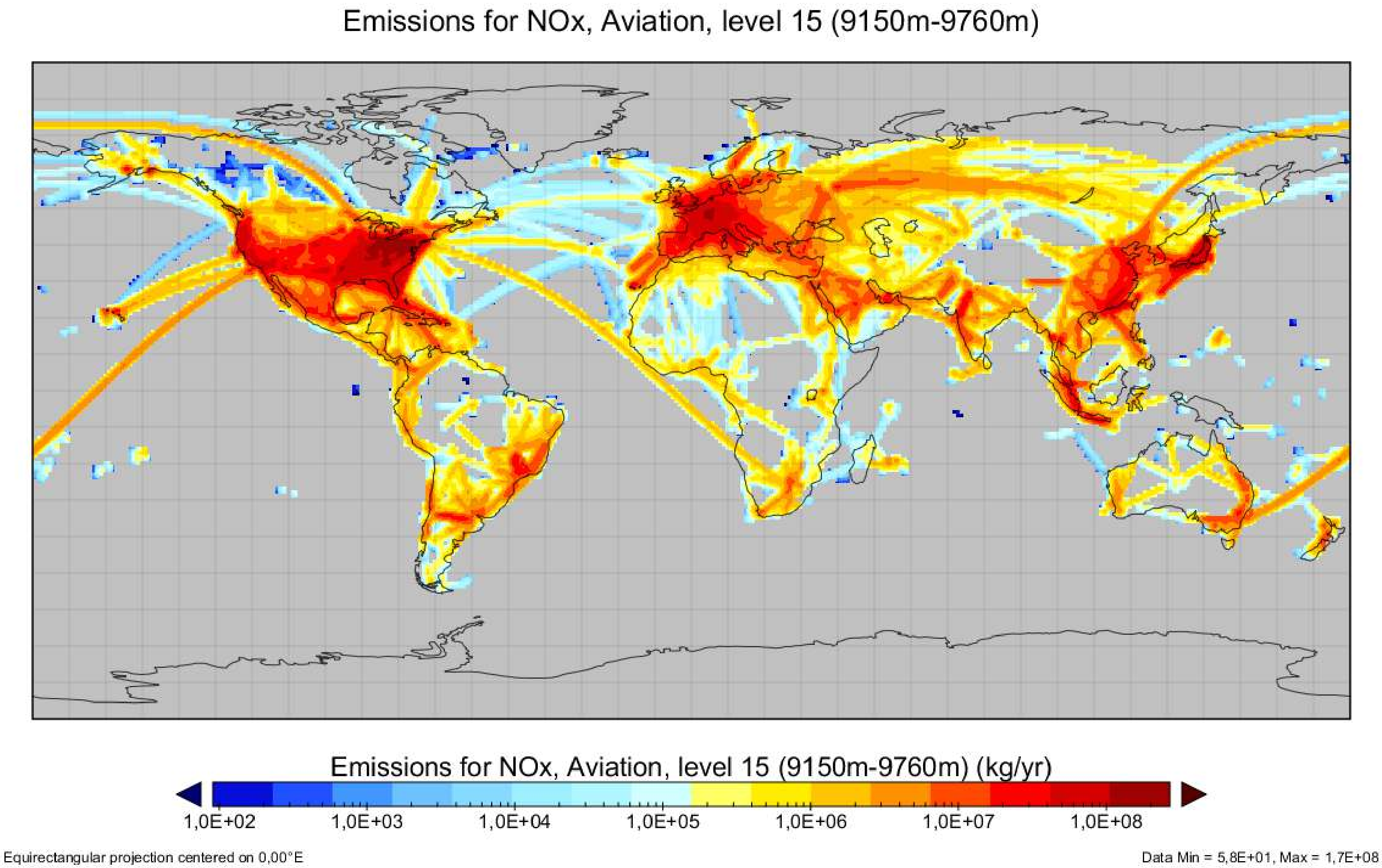
GWP, level 14, 100 years

Emissions for NOx, Aviation, level 15 (9150m-9760m)



GWP, level 15, 25 years

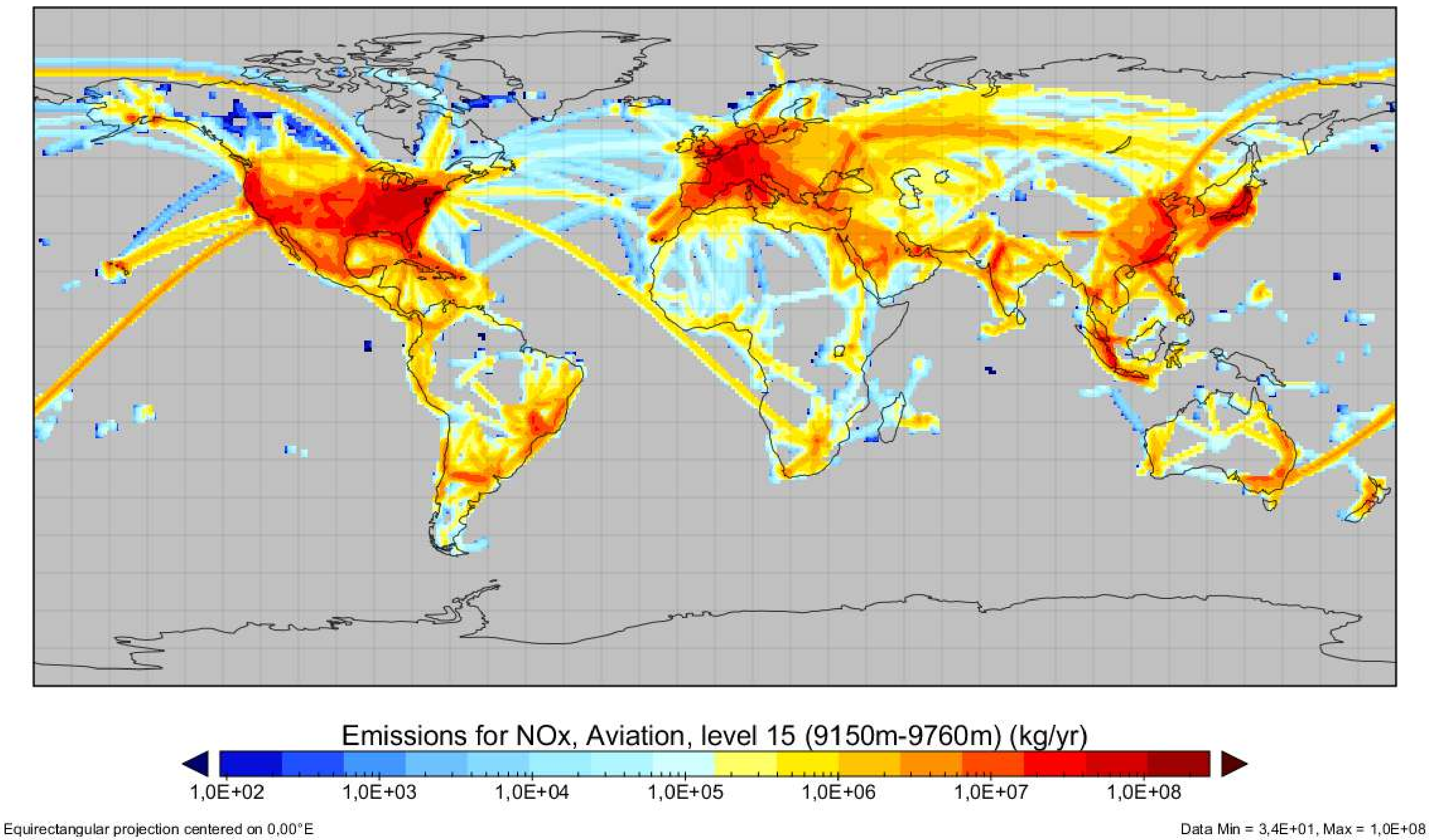
Quantify Final Meeting, 25-27 January 2010, Munich



GWP, level 15, 50 years

Quantify Final Meeting, 25-27 January 2010, Munich

Emissions for NOx, Aviation, level 15 (9150m-9760m)

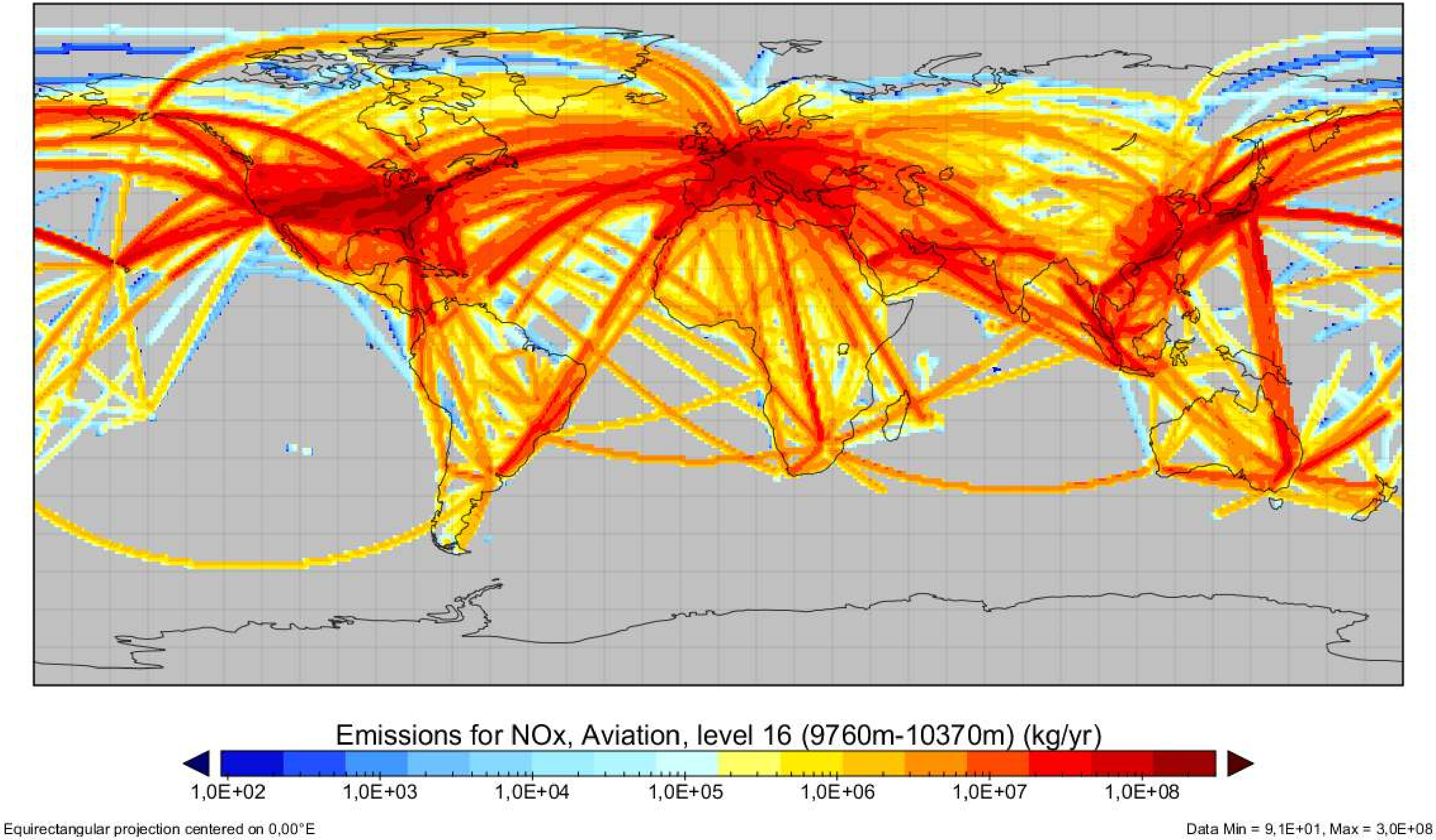


GWP, level 15, 100 years

Quantify Final Meeting, 25-27 January 2010, Munich

QUANTIFY

Emissions for NOx, Aviation, level 16 (9760m-10370m)

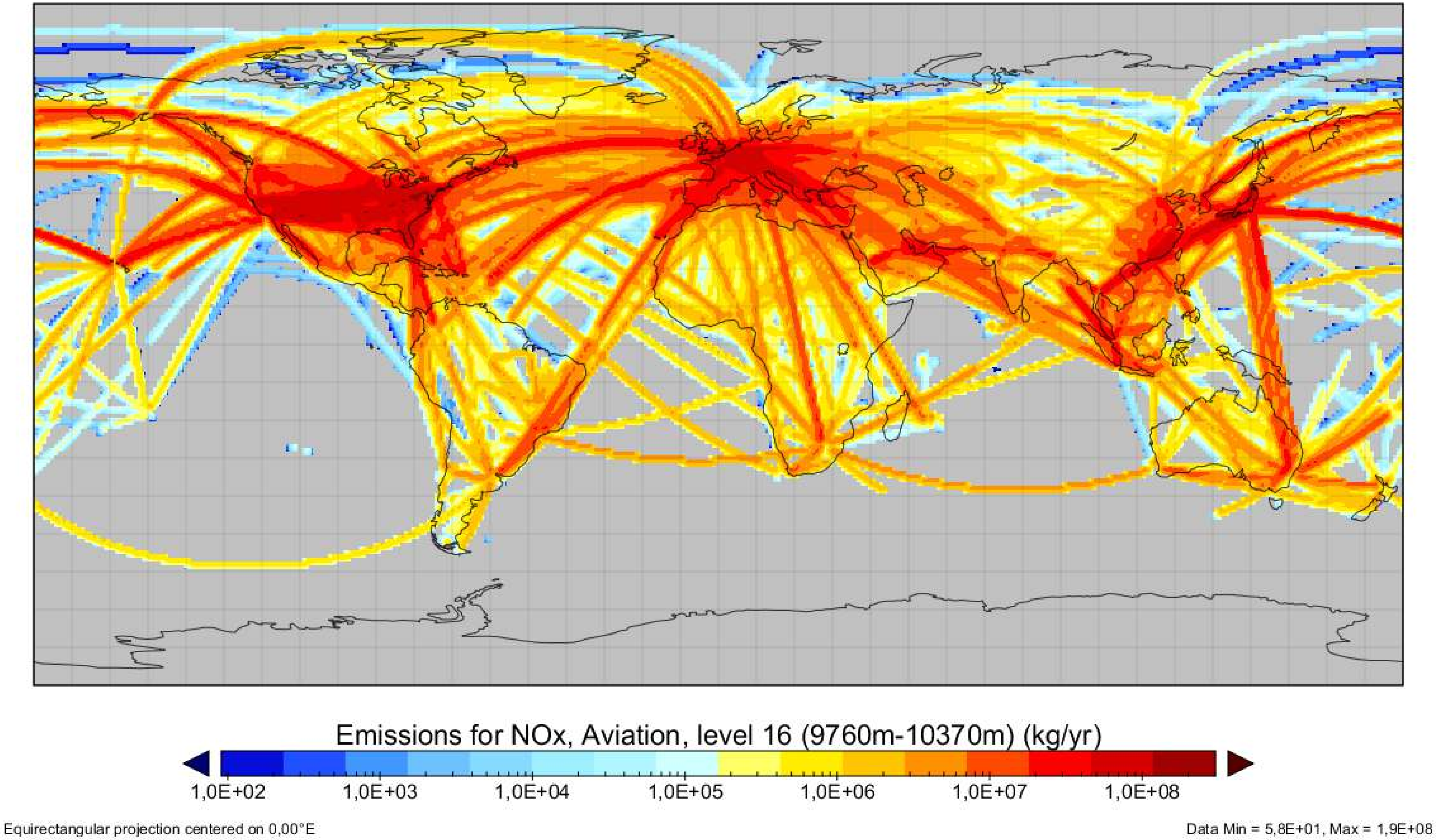


GWP, level 16, 25 years

Quantify Final Meeting, 25-27 January 2010, Munich

QUANTIFY

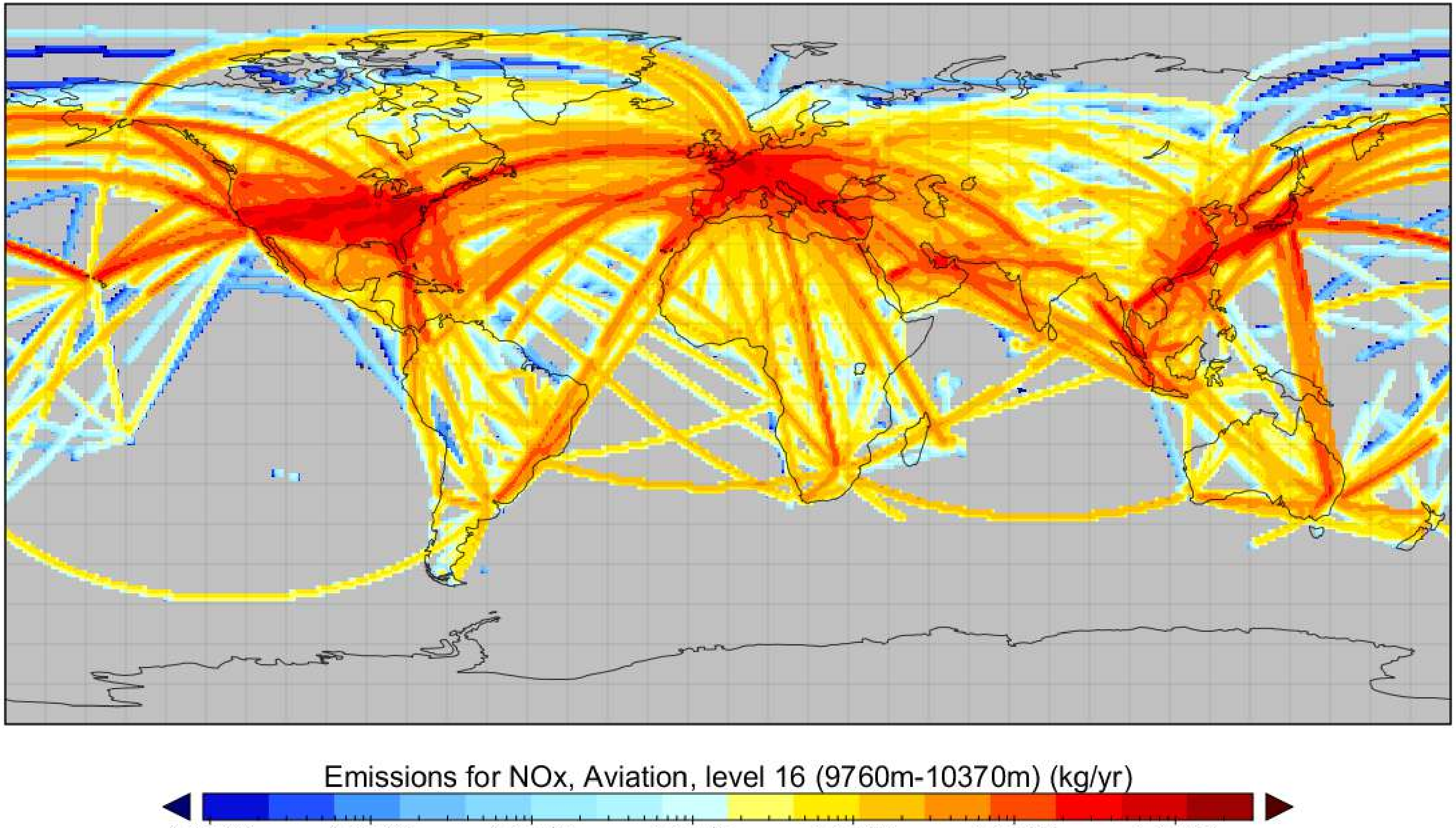
Emissions for NOx, Aviation, level 16 (9760m-10370m)



GWP, level 16, 50 years

Quantify Final Meeting, 25-27 January 2010, Munich

Emissions for NOx, Aviation, level 16 (9760m-10370m)

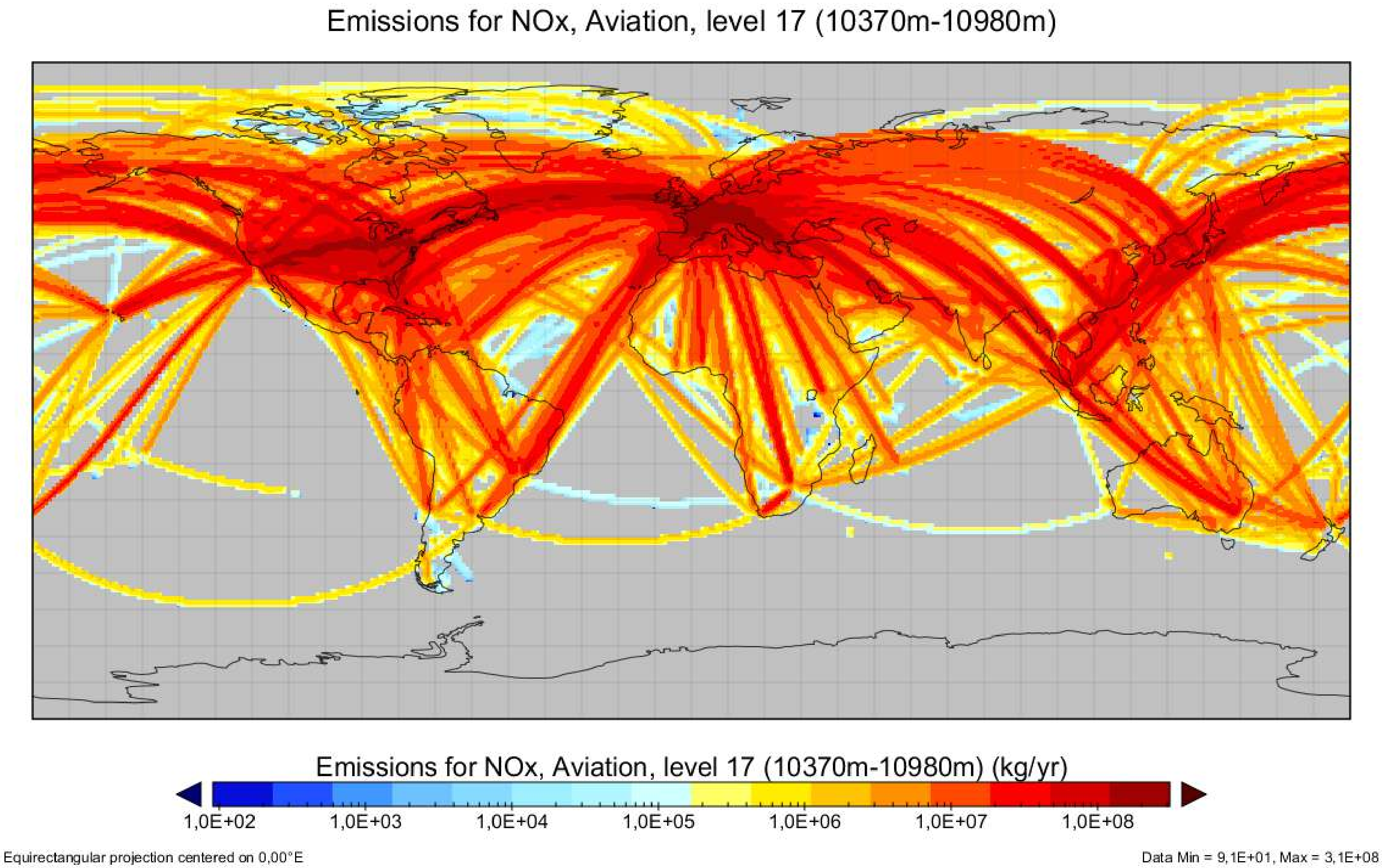


Equirectangular projection centered on 0,00°E

Data Min = 3,4E+01, Max = 1,1E+08

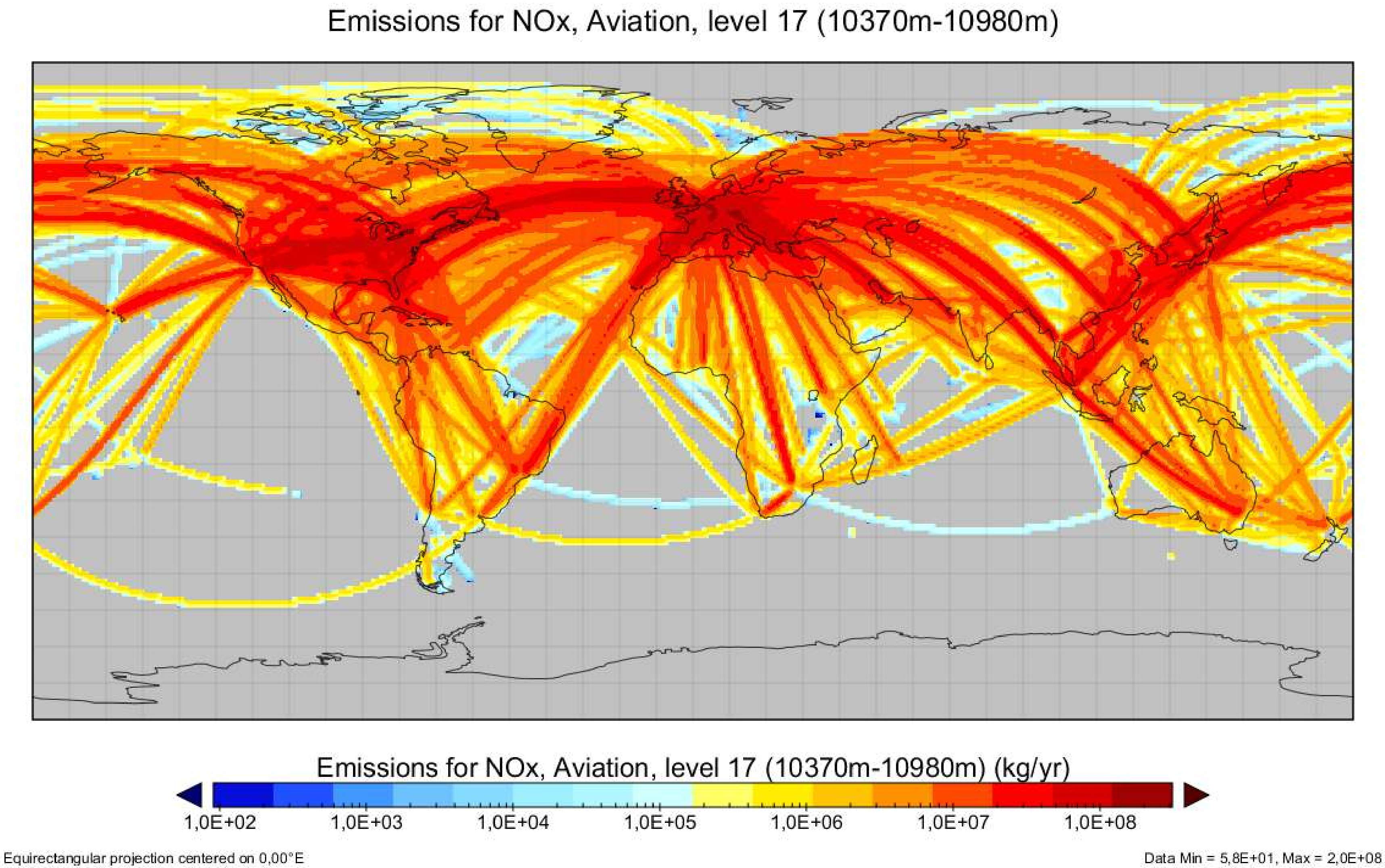
GWP, level 16, 100 years

Quantify Final Meeting, 25-27 January 2010, Munich

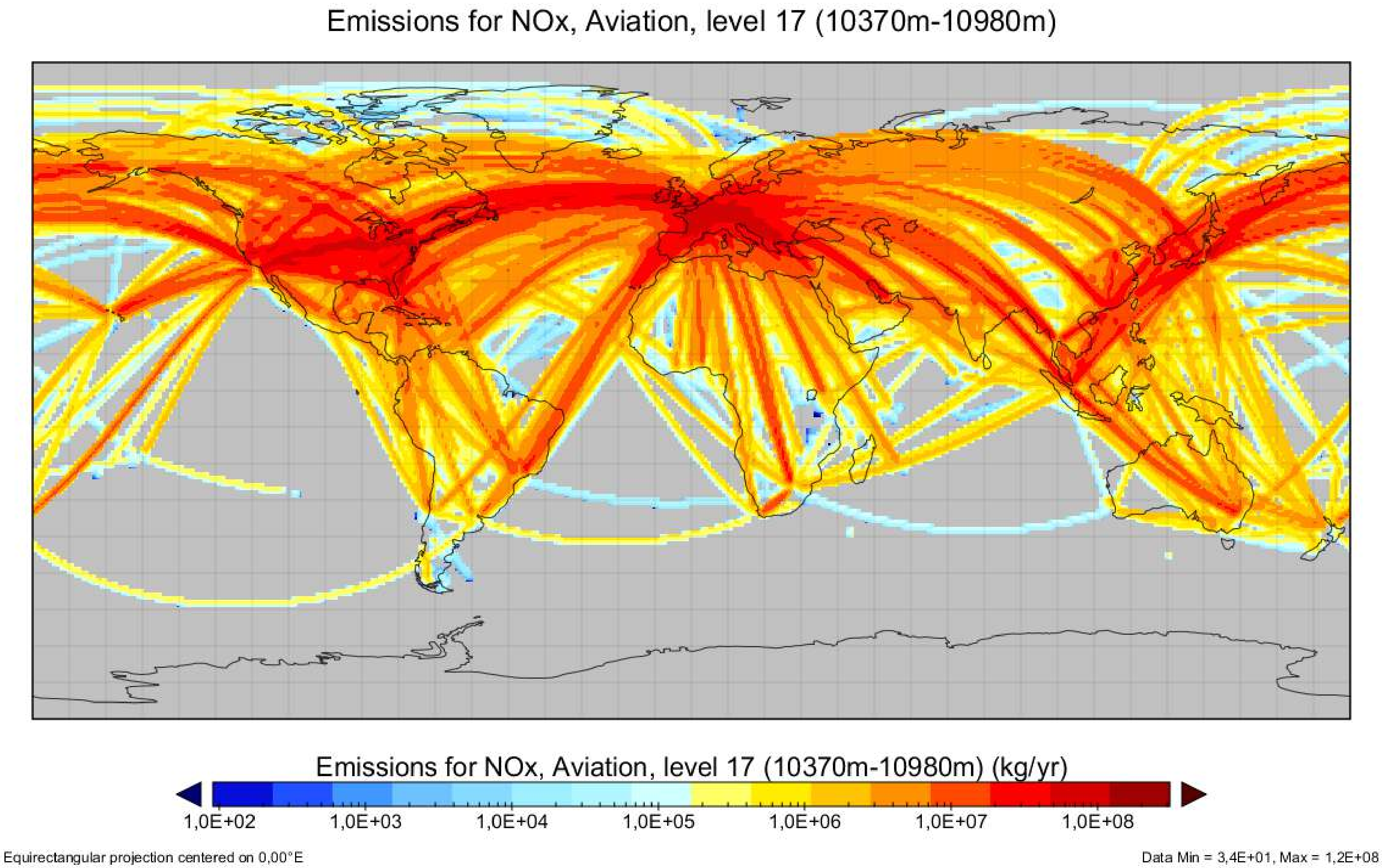


GWP, level 17, 25 years

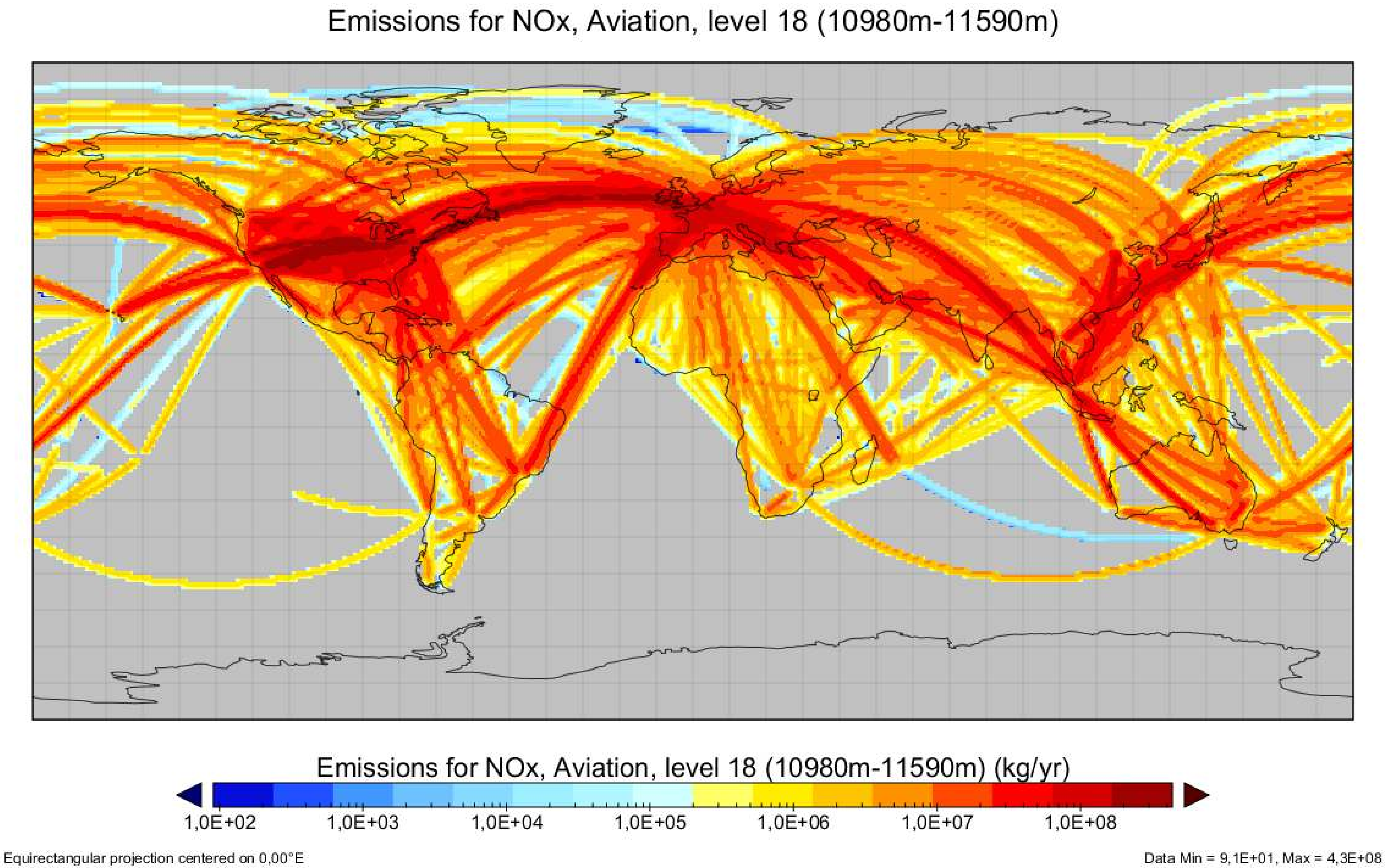
Quantify Final Meeting, 25-27 January 2010, Munich



GWP, level 17, 50 years

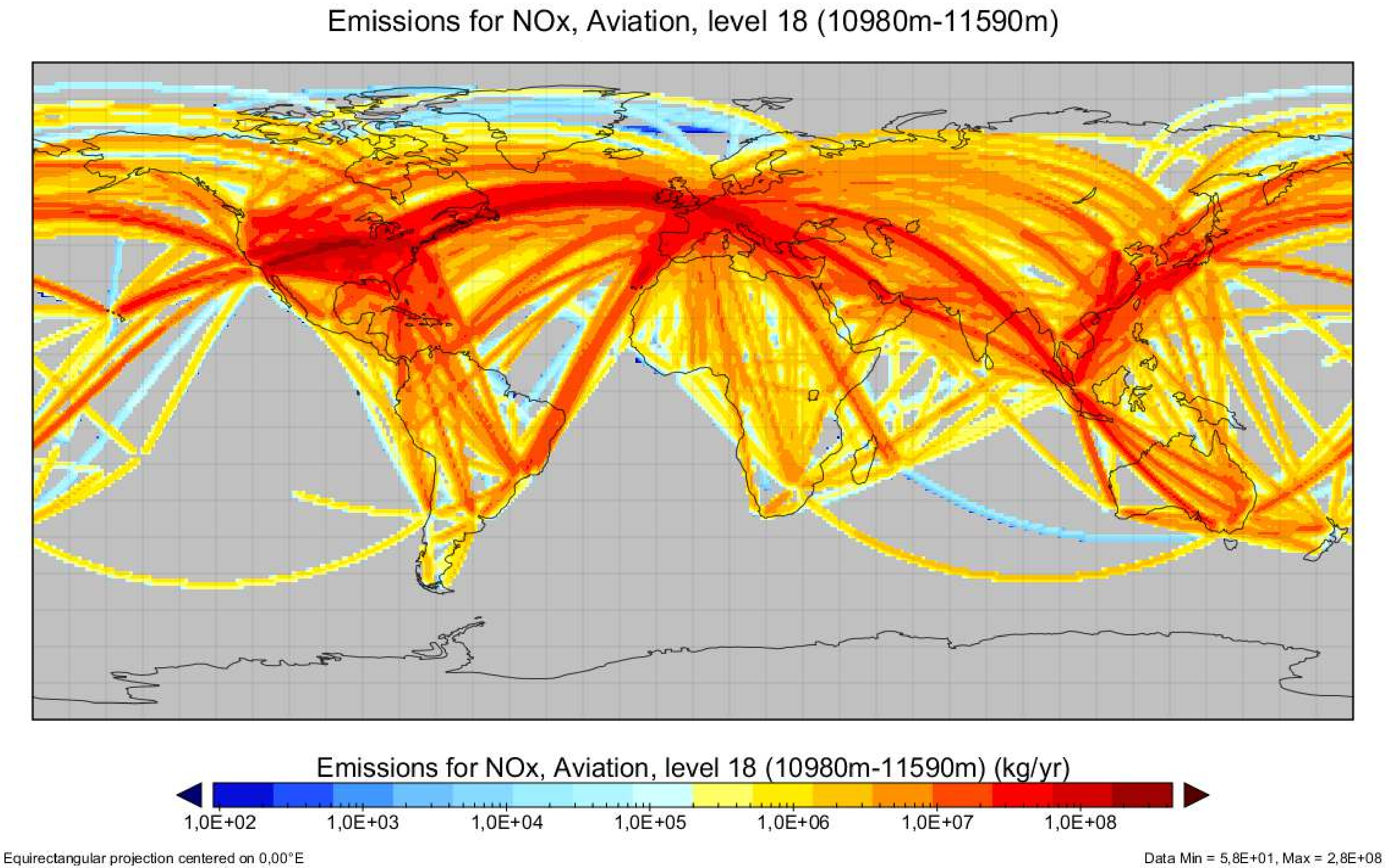


GWP, level 17, 100 years



GWP, level 18, 25 years

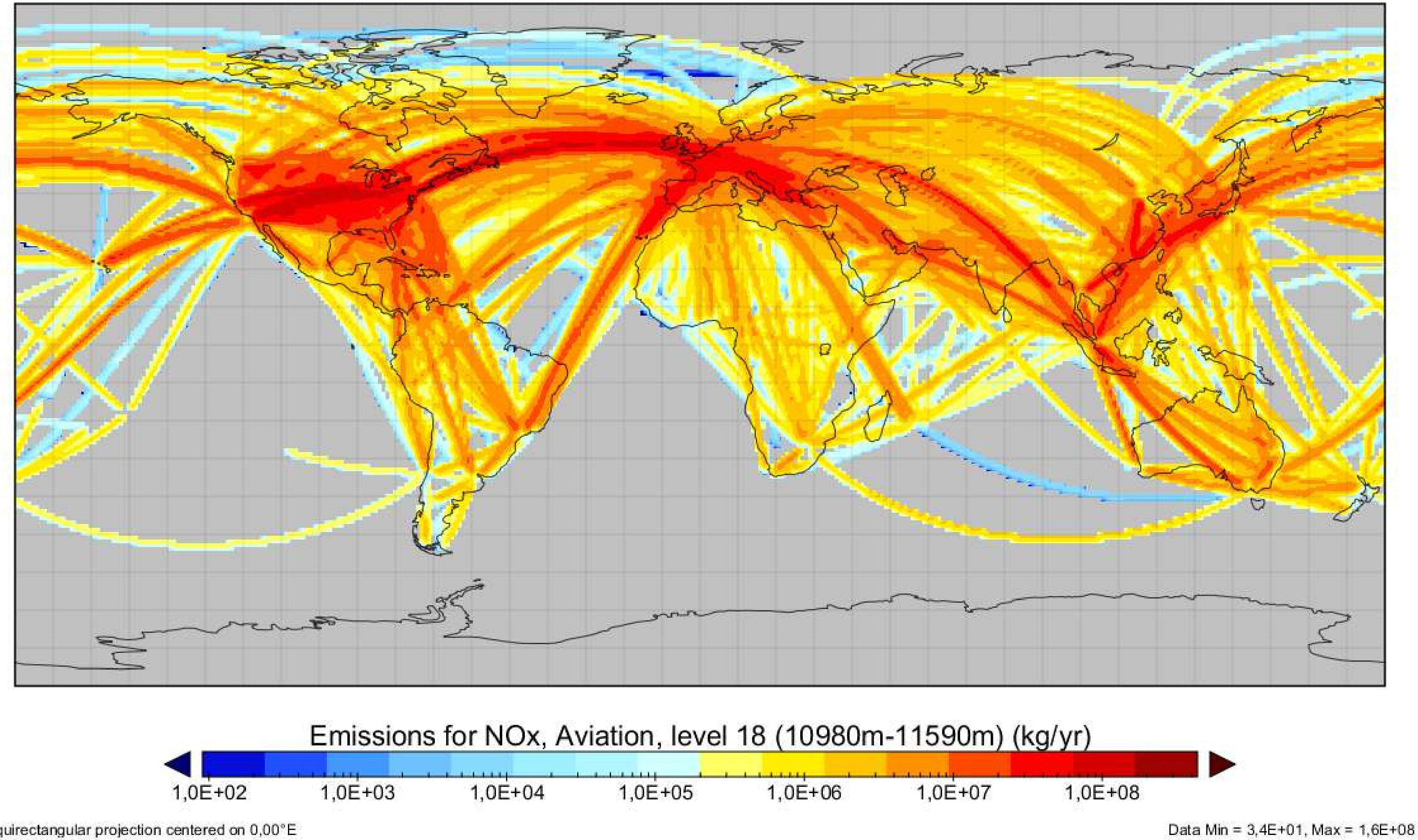
Quantify Final Meeting, 25-27 January 2010, Munich



GWP, level 18, 50 years

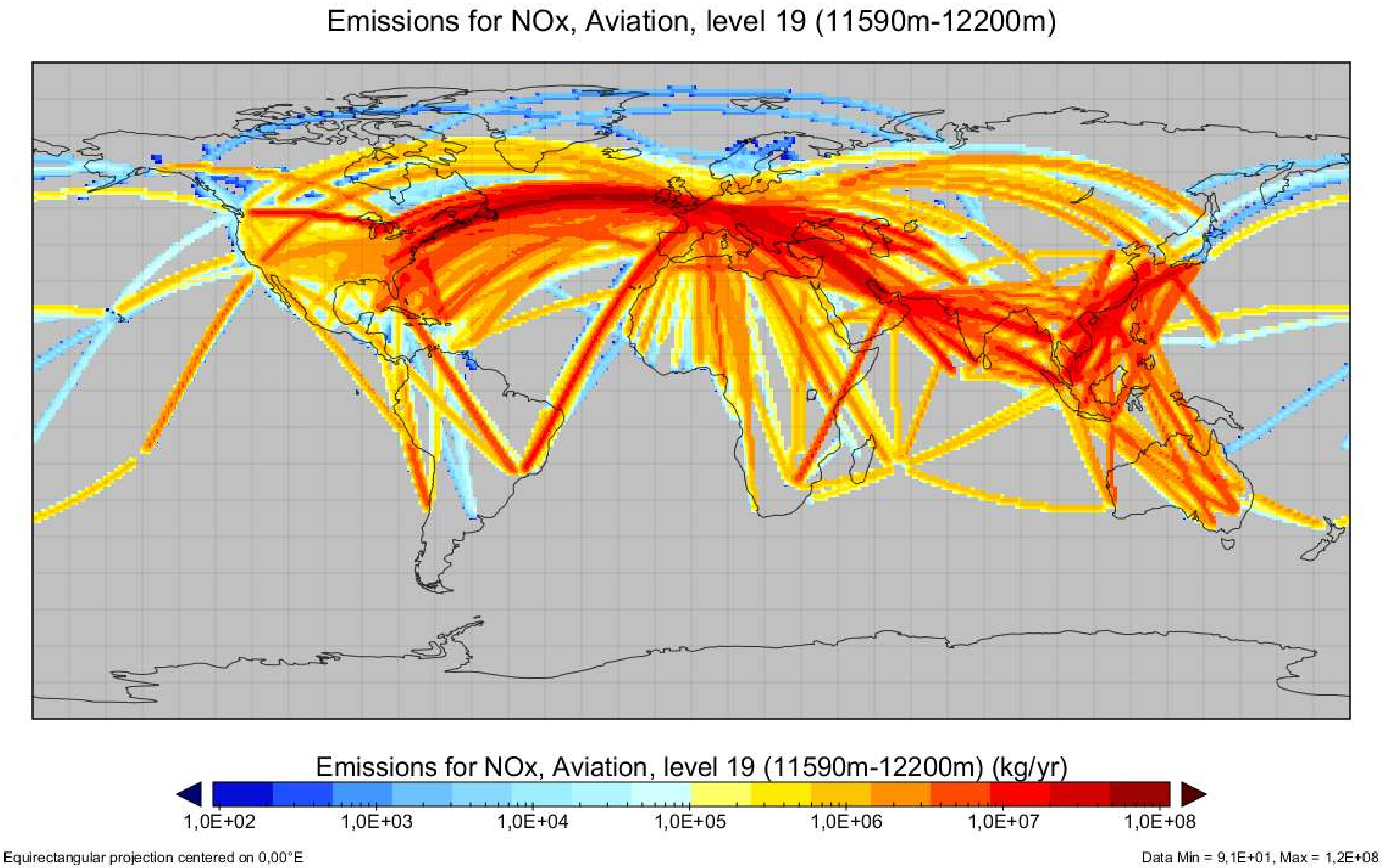
Quantify Final Meeting, 25-27 January 2010, Munich

Emissions for NOx, Aviation, level 18 (10980m-11590m)



GWP, level 18, 100 years

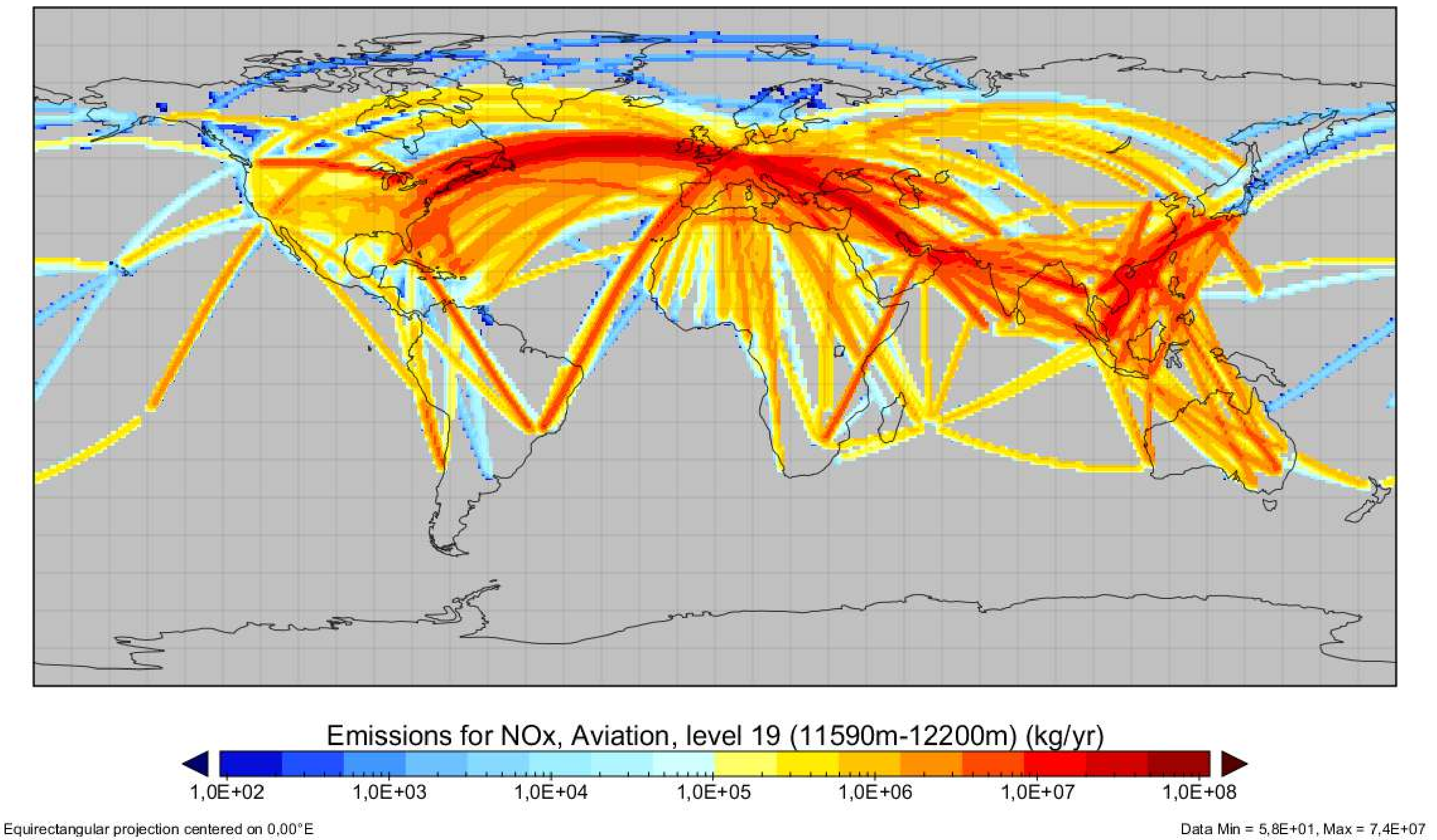
Quantify Final Meeting, 25-27 January 2010, Munich



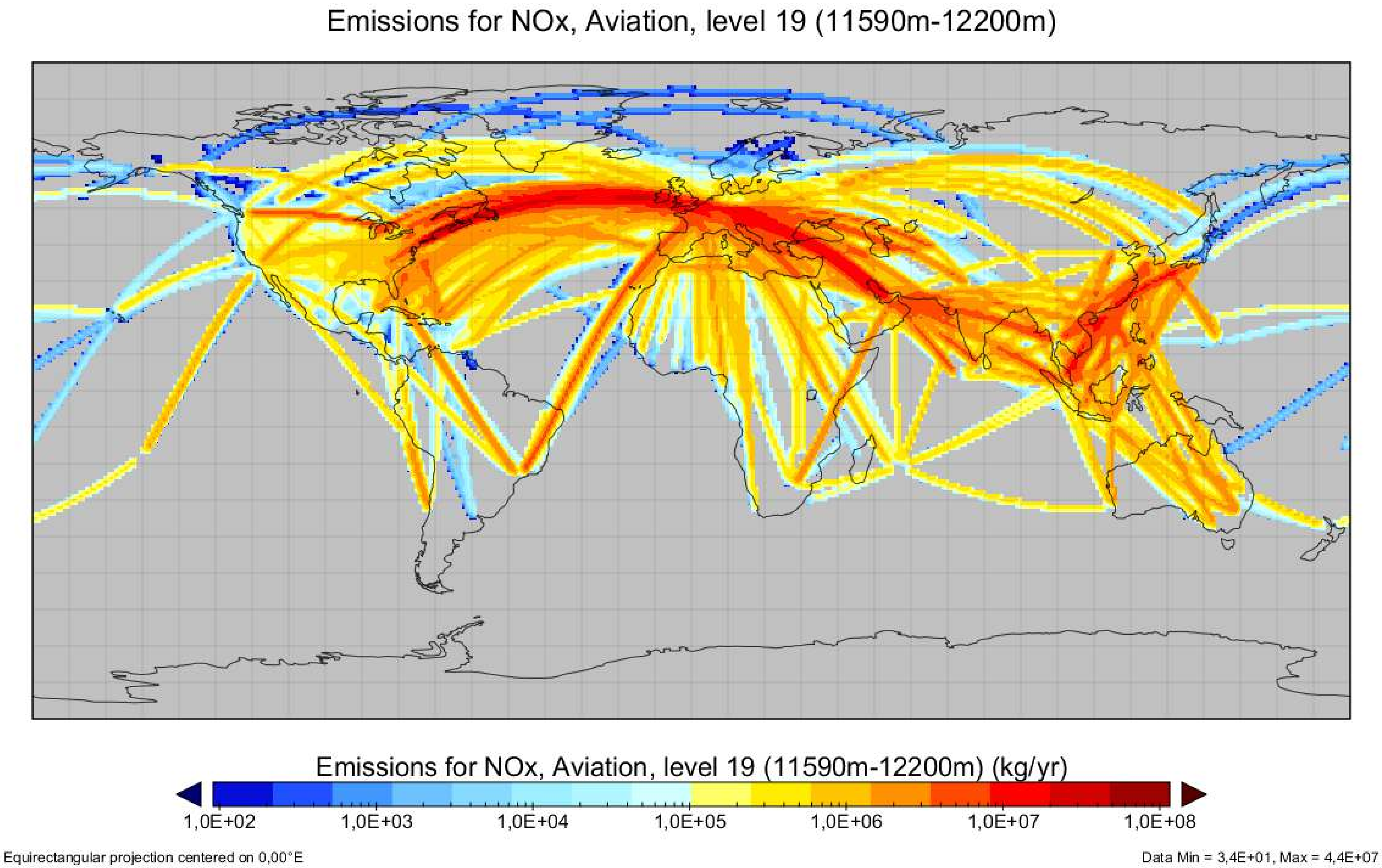
GWP, level 19, 25 years

Quantify Final Meeting, 25-27 January 2010, Munich

Emissions for NOx, Aviation, level 19 (11590m-12200m)



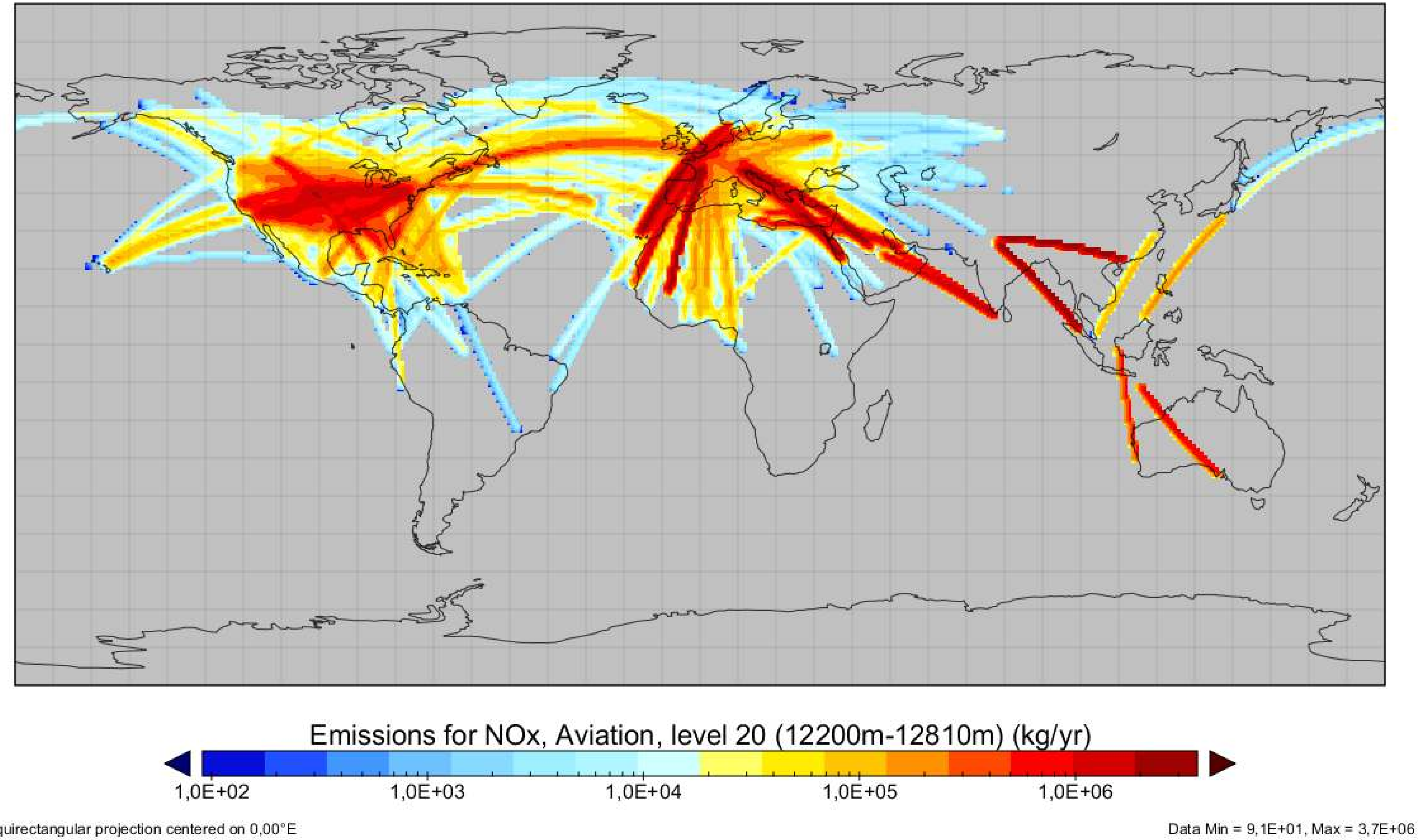
GWP, level 19, 50 years



GWP, level 19, 100 years

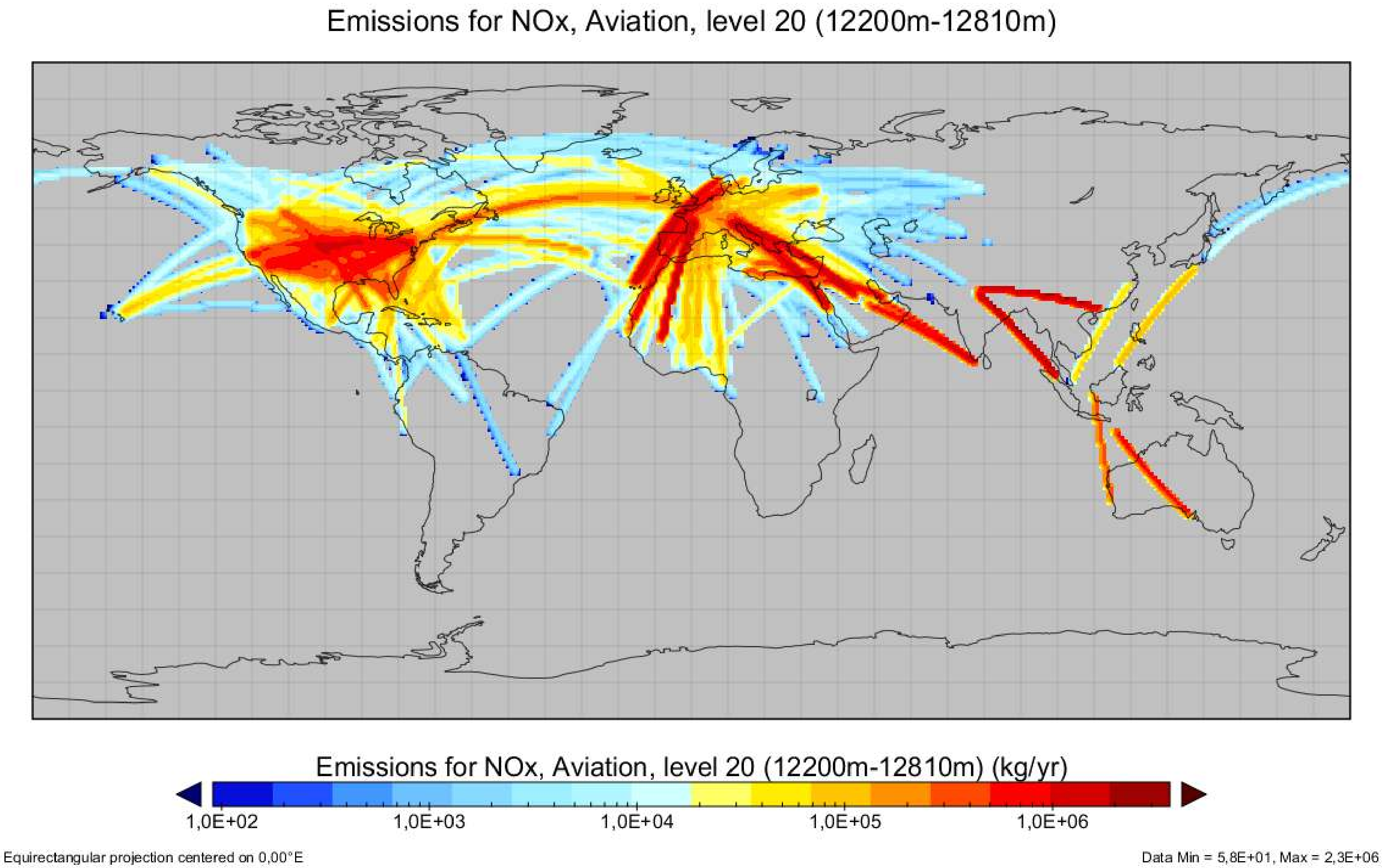
Quantify Final Meeting, 25-27 January 2010, Munich

Emissions for NOx, Aviation, level 20 (12200m-12810m)



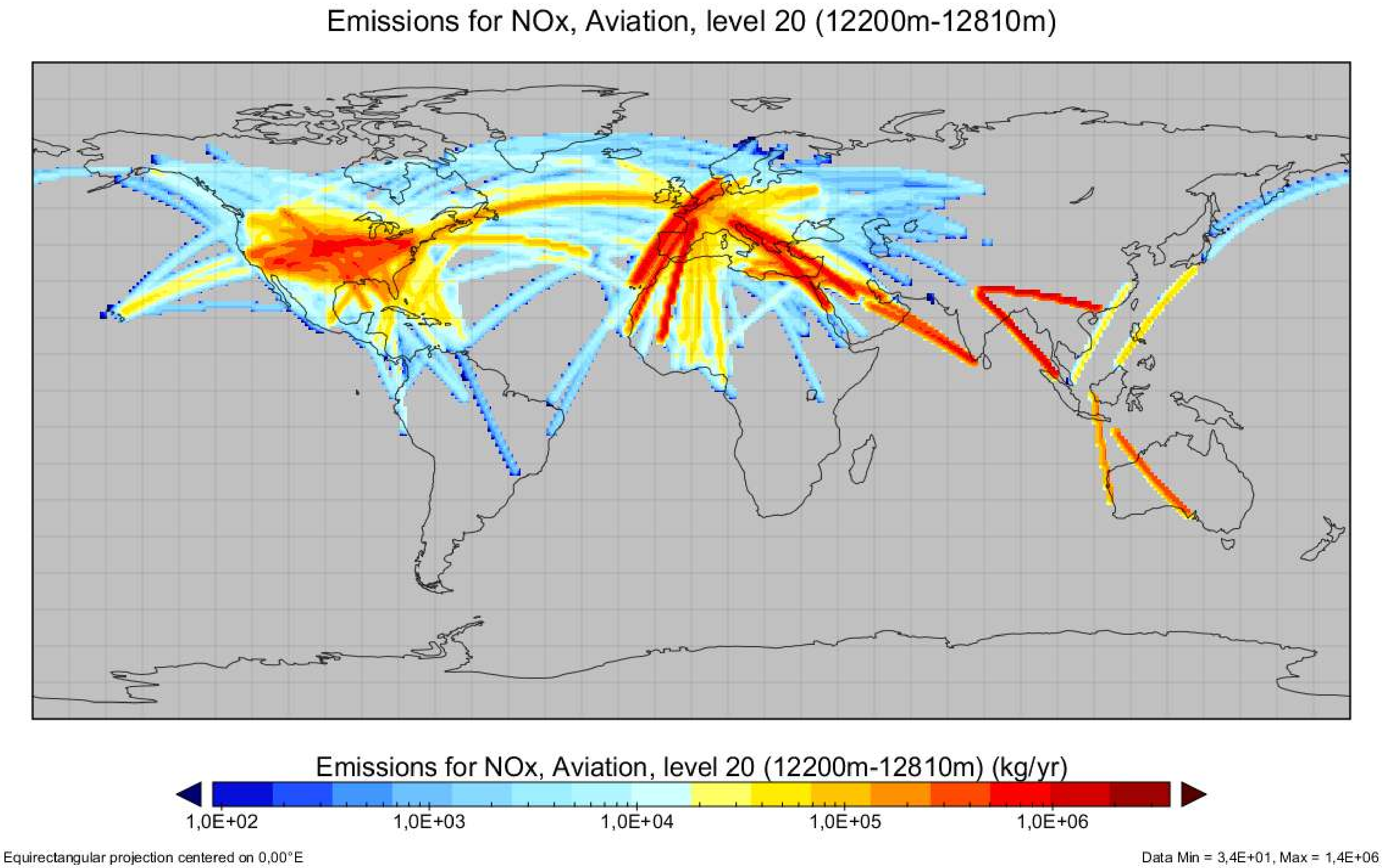
GWP, level 20, 25 years

Quantify Final Meeting, 25-27 January 2010, Munich



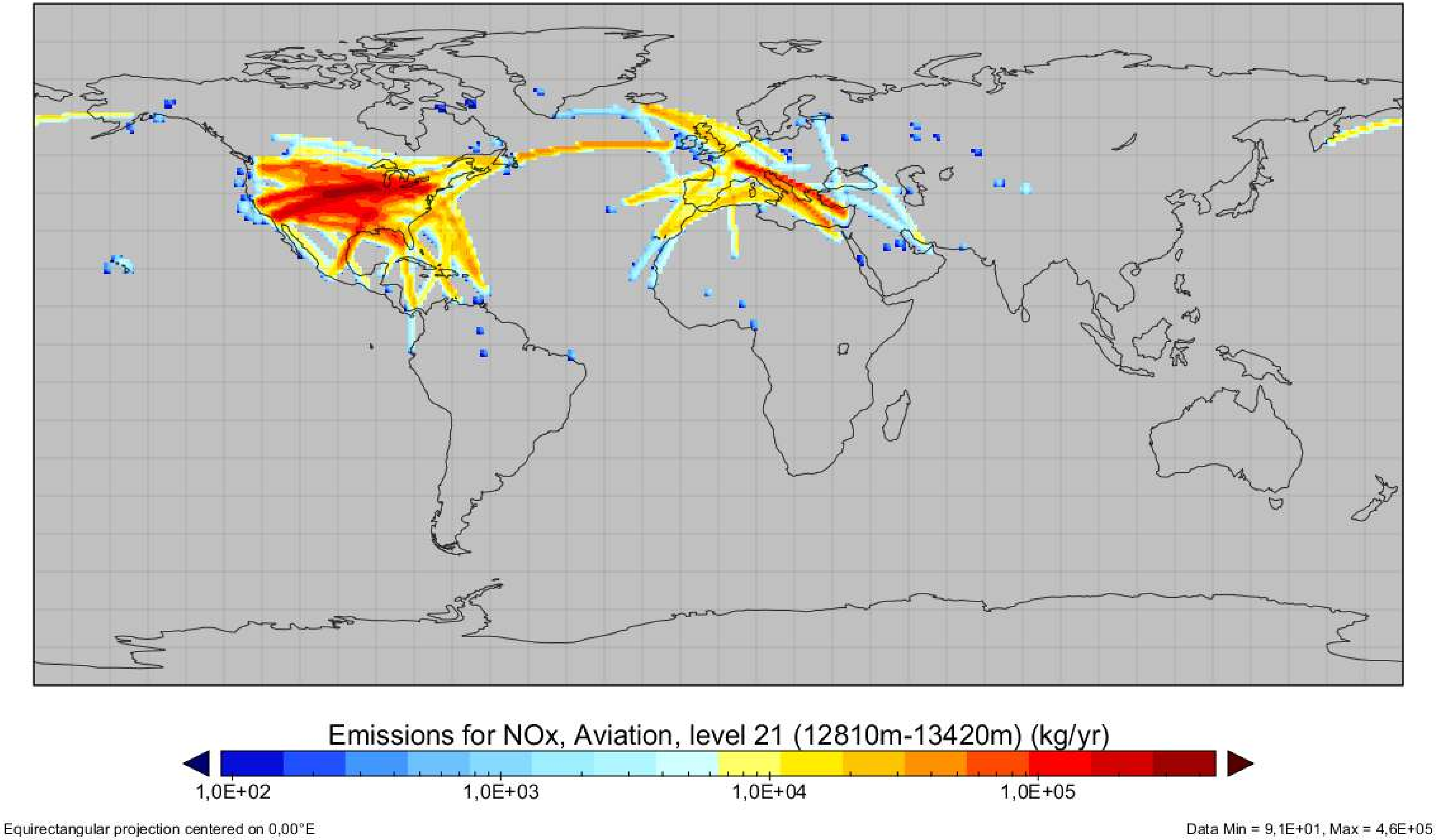
GWP, level 20, 50 years

Quantify Final Meeting, 25-27 January 2010, Munich



GWP, level 20, 100 years

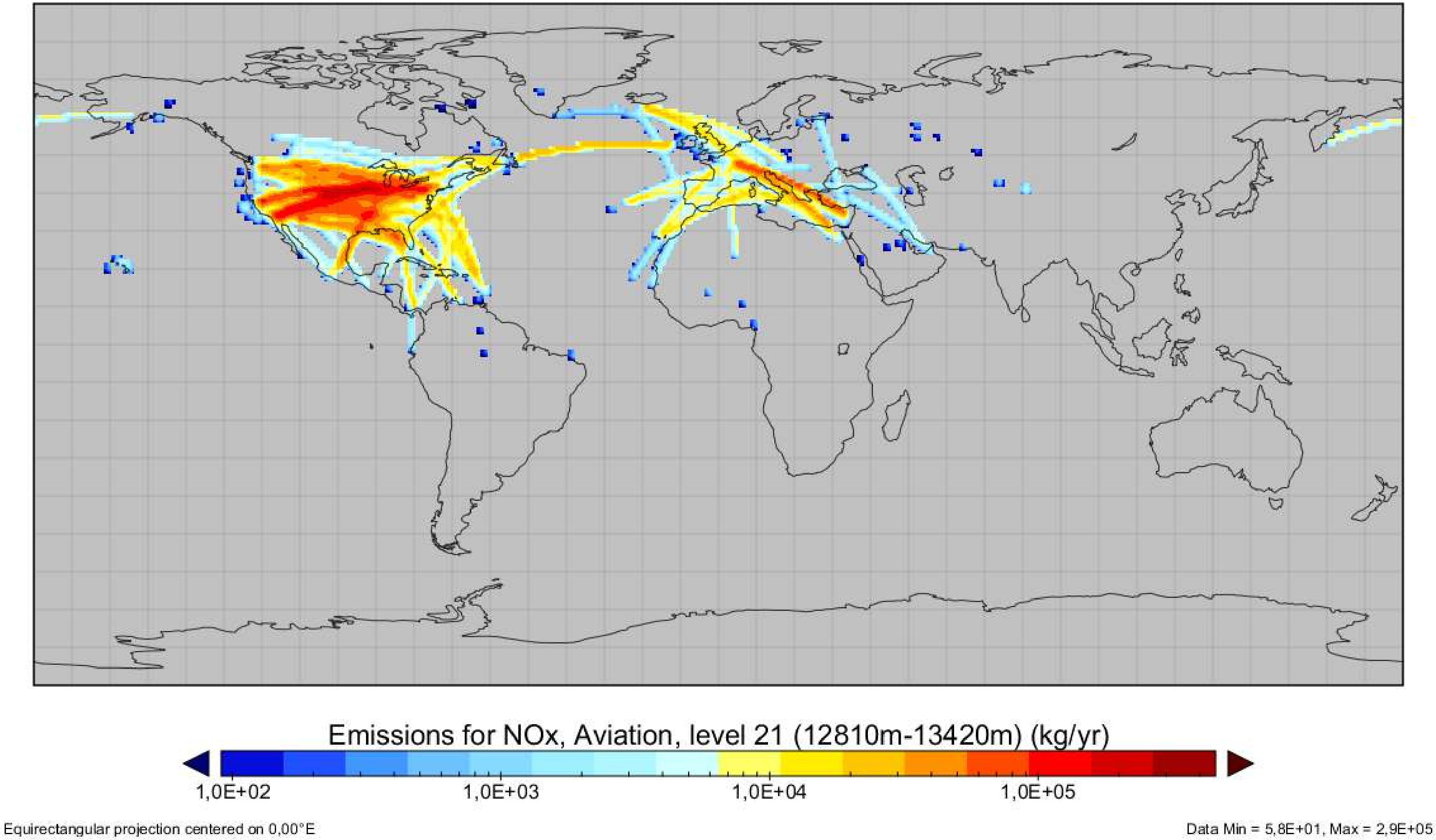
Emissions for NOx, Aviation, level 21 (12810m-13420m)



GWP, level 21, 25 years

Quantify Final Meeting, 25-27 January 2010, Munich

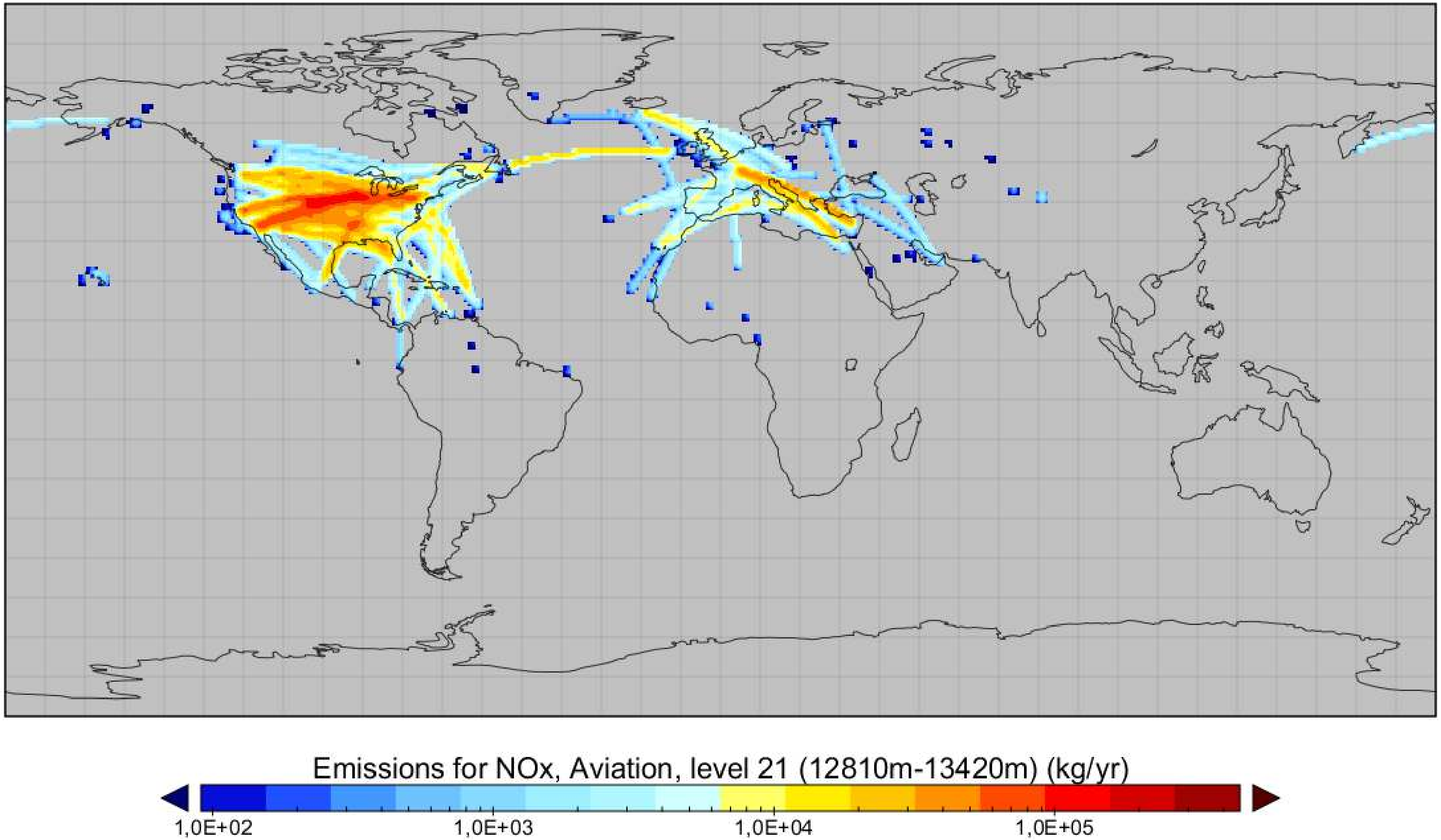
Emissions for NOx, Aviation, level 21 (12810m-13420m)



GWP, level 21, 50 years

Quantify Final Meeting, 25-27 January 2010, Munich

Emissions for NOx, Aviation, level 21 (12810m-13420m)



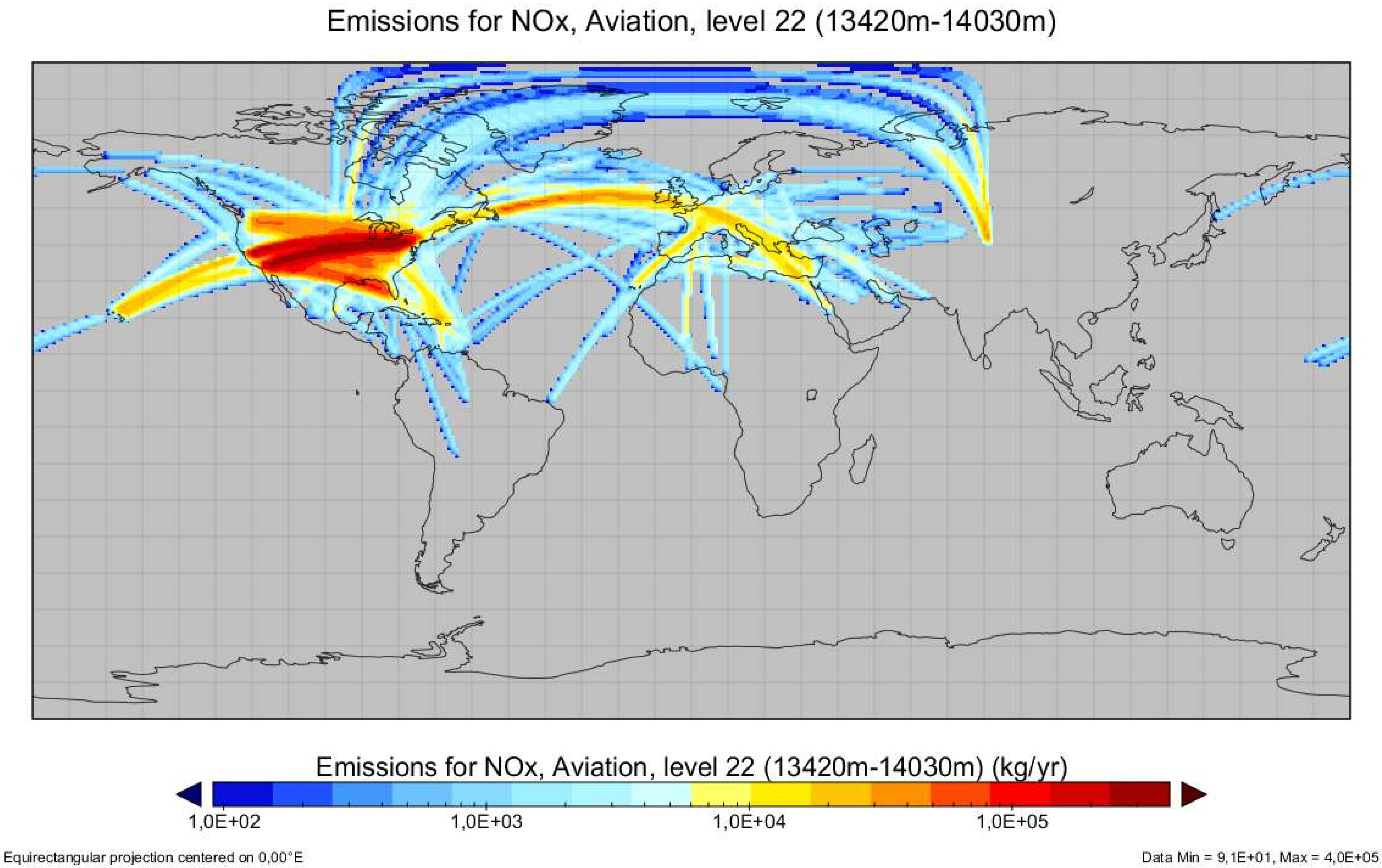
Equirectangular projection centered on 0,00°E

Data Min = 3,4E+01, Max = 1,7E+05

GWP, level 21, 100 years

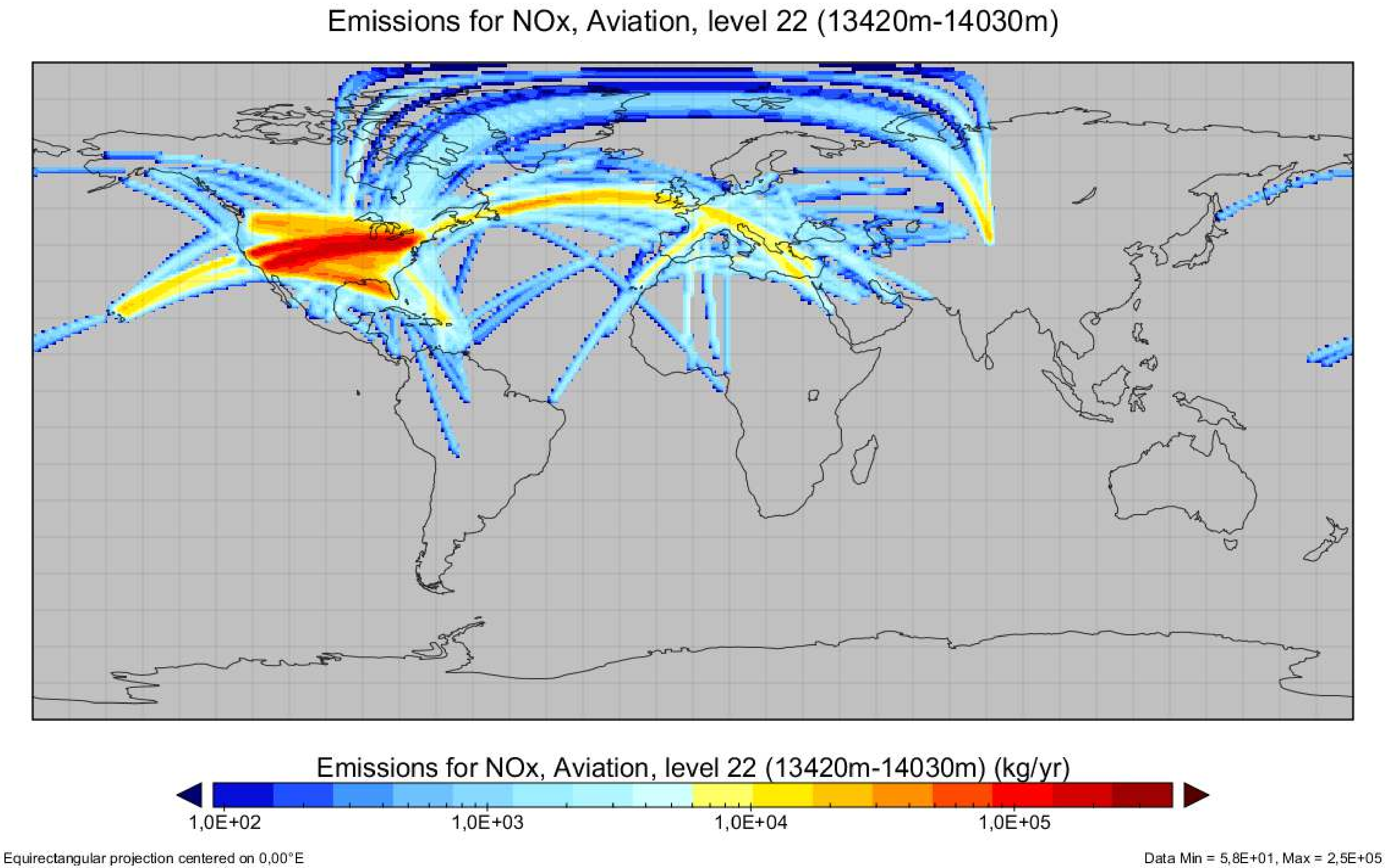
Quantify Final Meeting, 25-27 January 2010, Munich

QUANTIFY



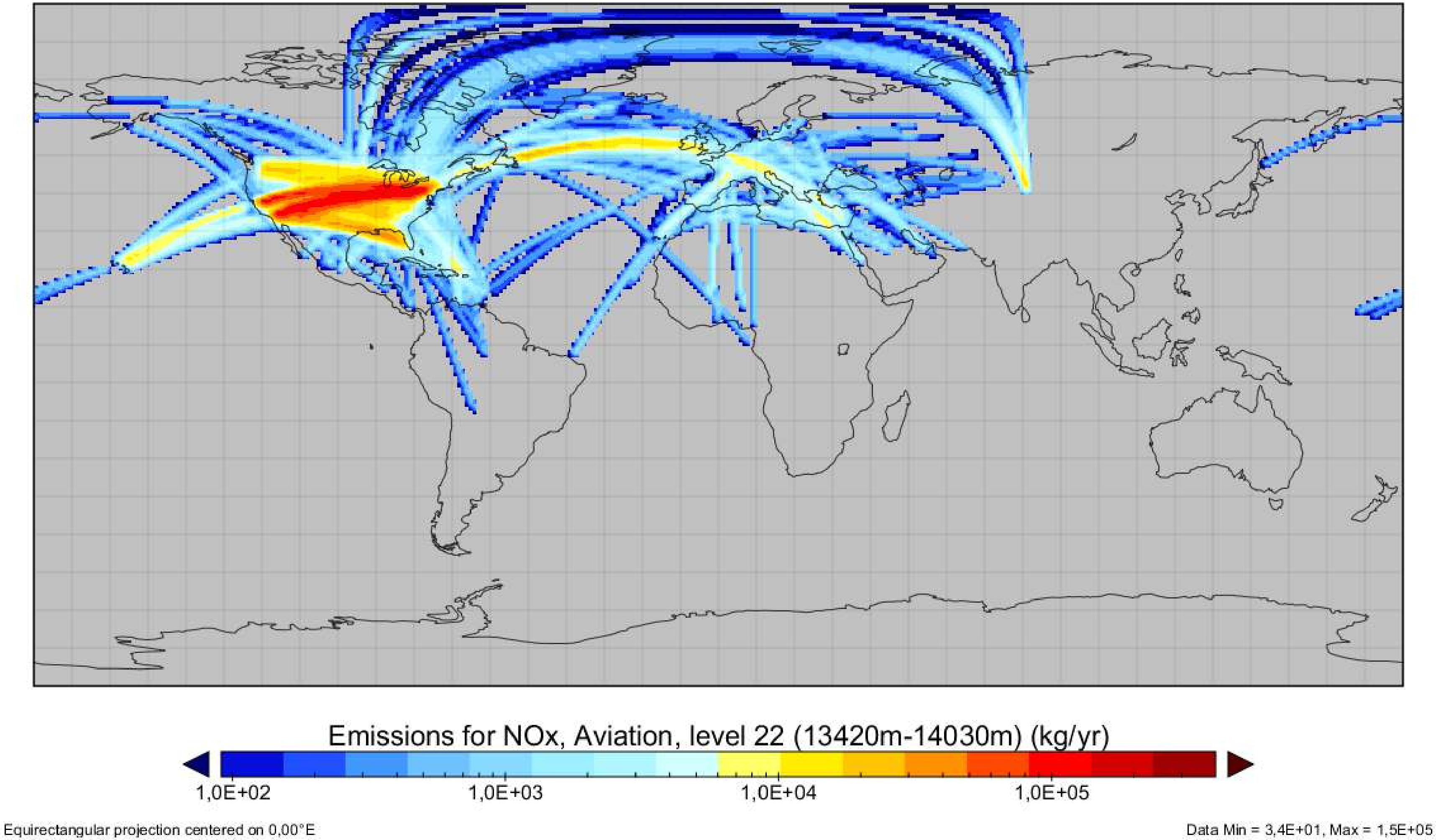
GWP, level 22, 25 years

Quantify Final Meeting, 25-27 January 2010, Munich



GWP, level 22, 50 years

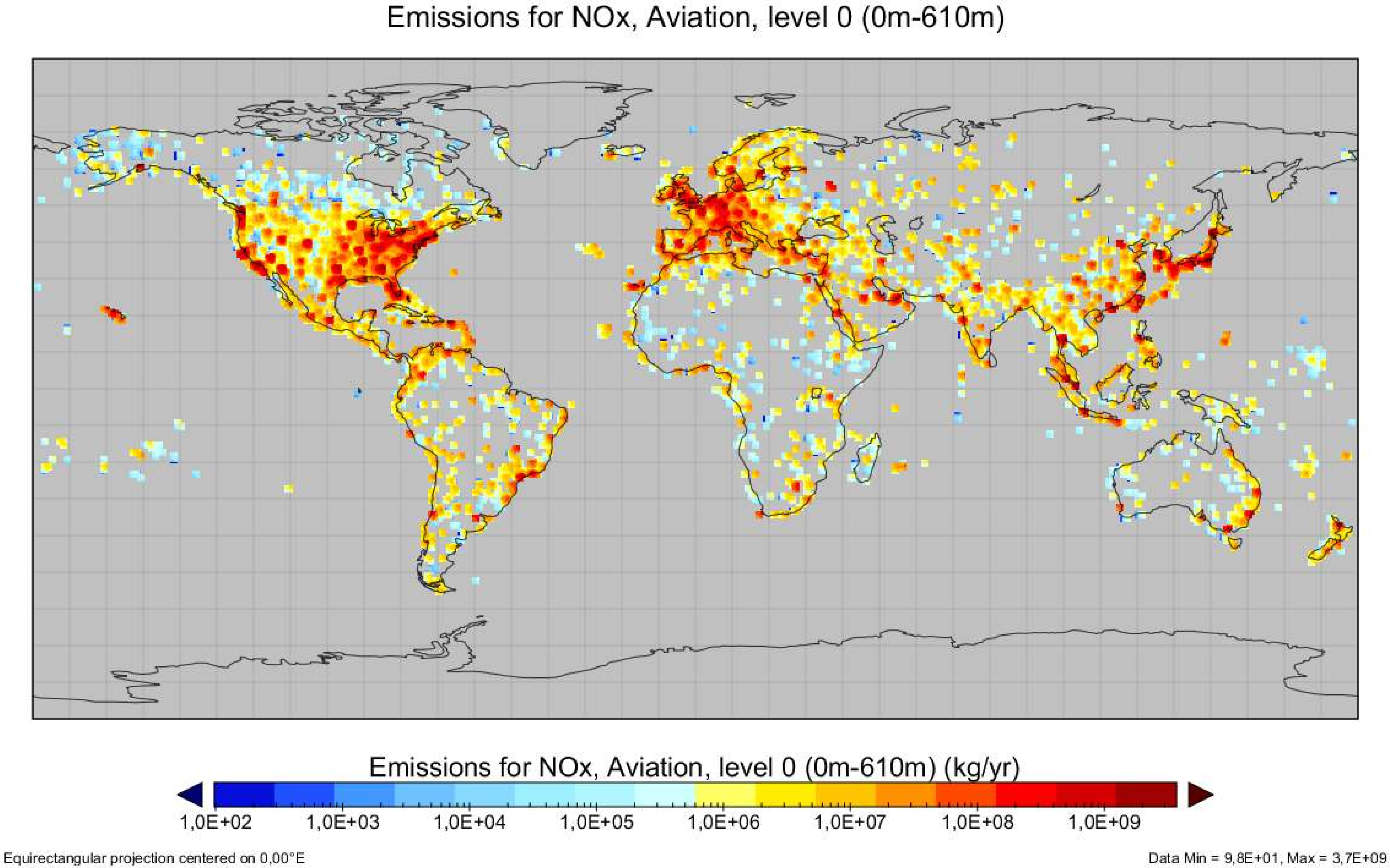
Emissions for NOx, Aviation, level 22 (13420m-14030m)



GWP, level 22, 100 years

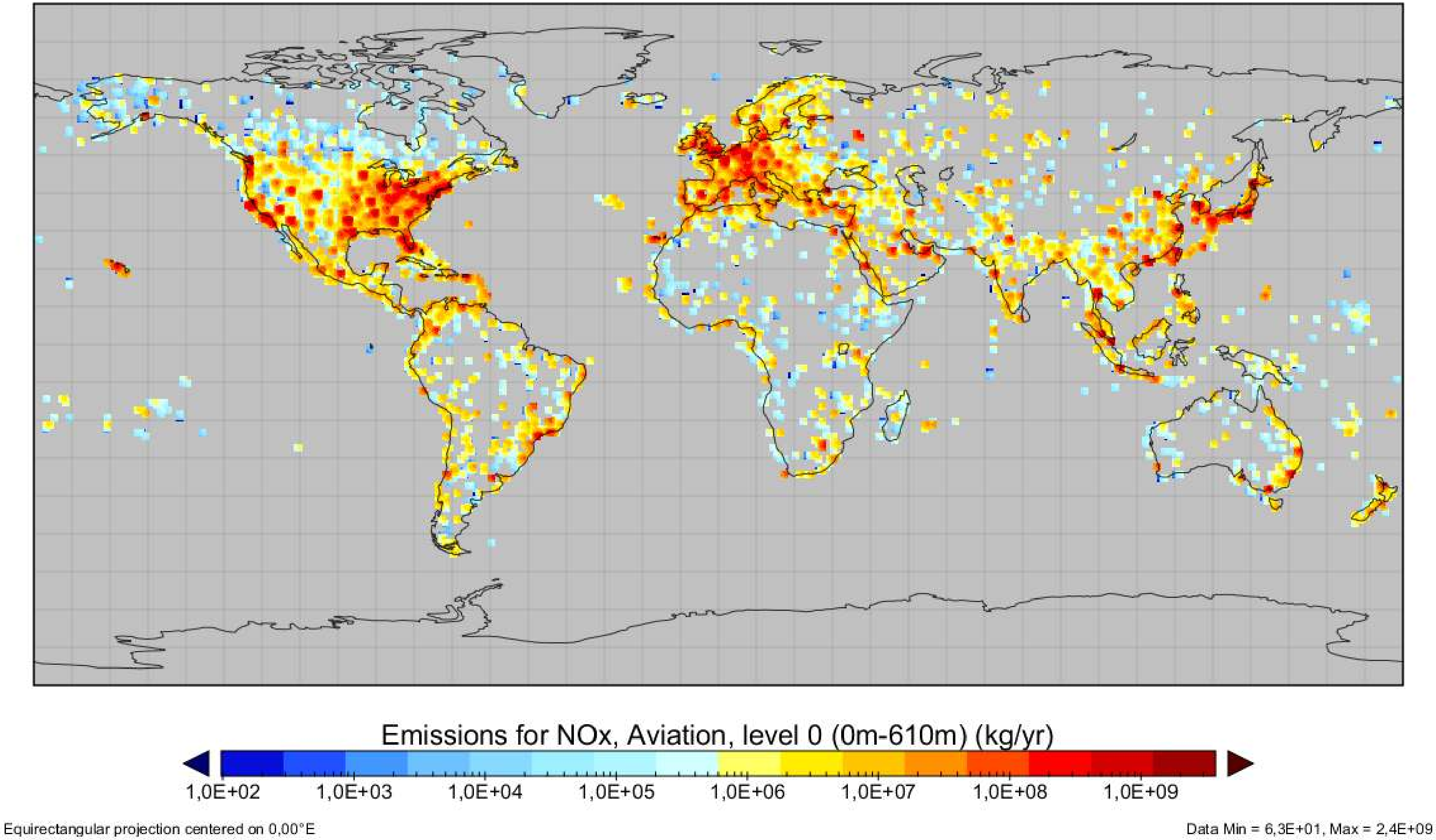
Quantify Final Meeting, 25-27 January 2010, Munich

5.2.1.2. GTP weighted emission maps for NOx, 25, 50, 100 years



GTP, level 0, 25 years

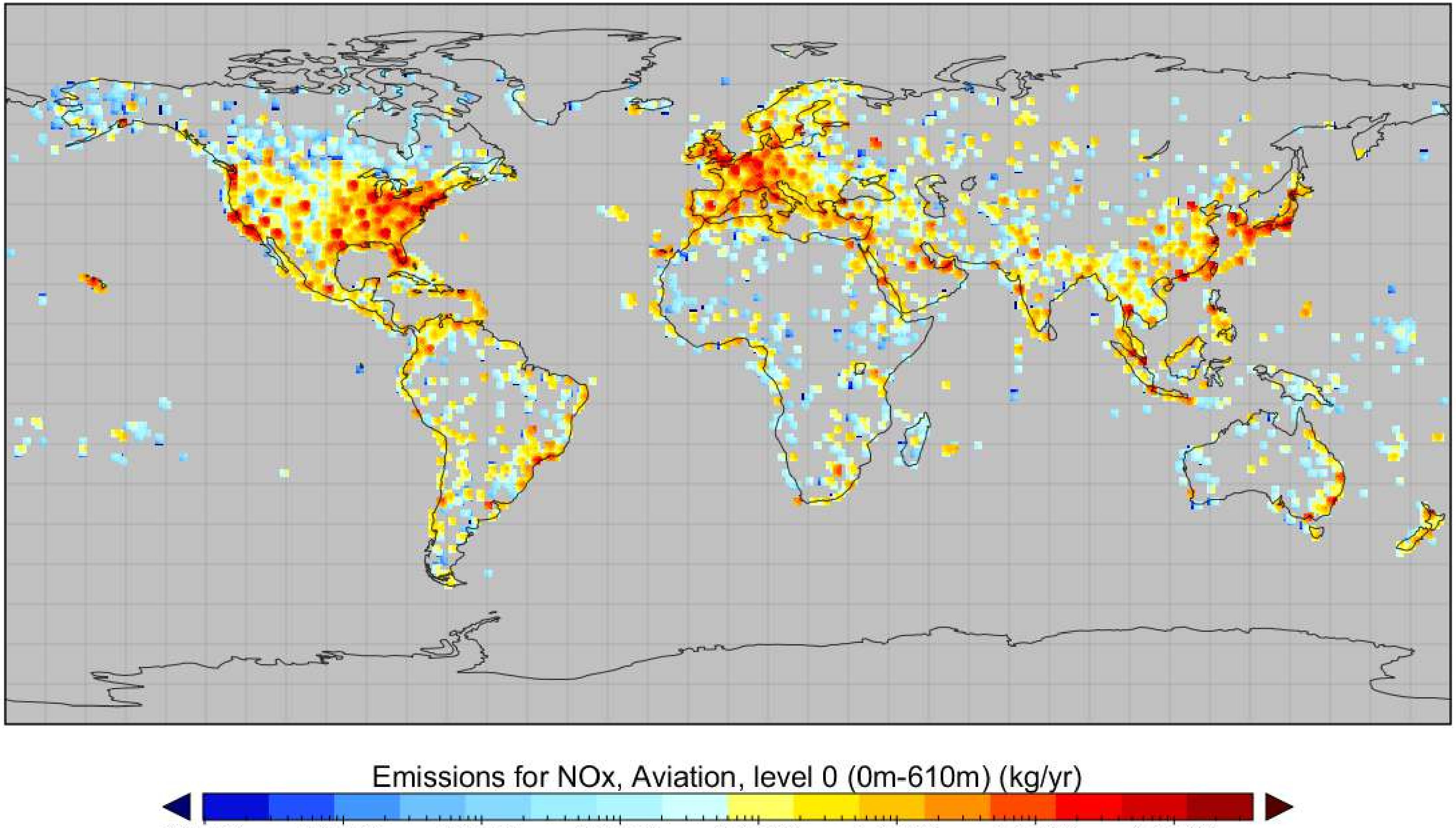
Emissions for NOx, Aviation, level 0 (0m-610m)



GTP, level 0, 50 years

Quantify Final Meeting, 25-27 January 2010, Munich

Emissions for NOx, Aviation, level 0 (0m-610m)



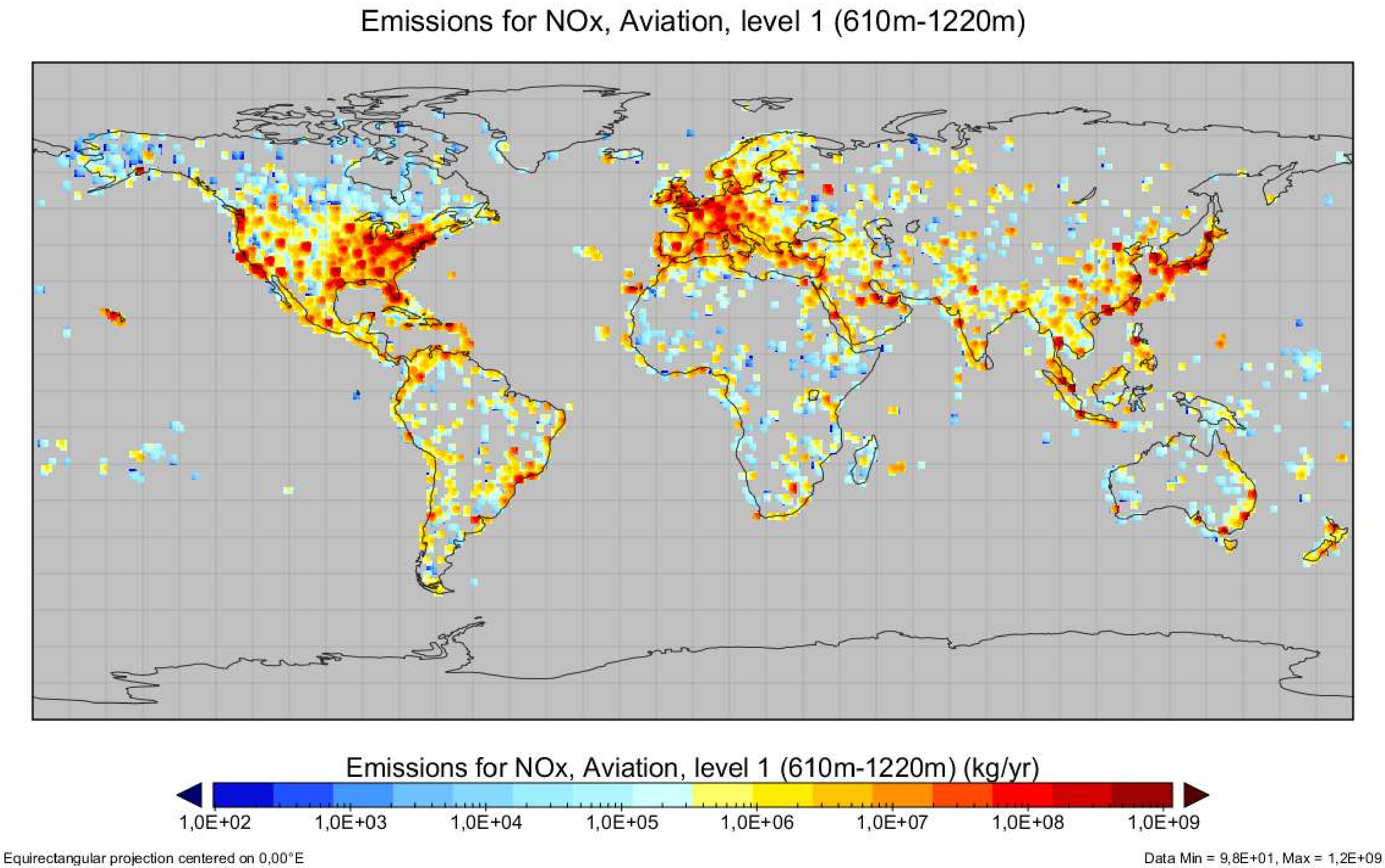
Equirectangular projection centered on 0,00°E

Data Min = 3,6E+01, Max = 1,4E+09

GTP, level 0, 100 years

Quantify Final Meeting, 25-27 January 2010, Munich

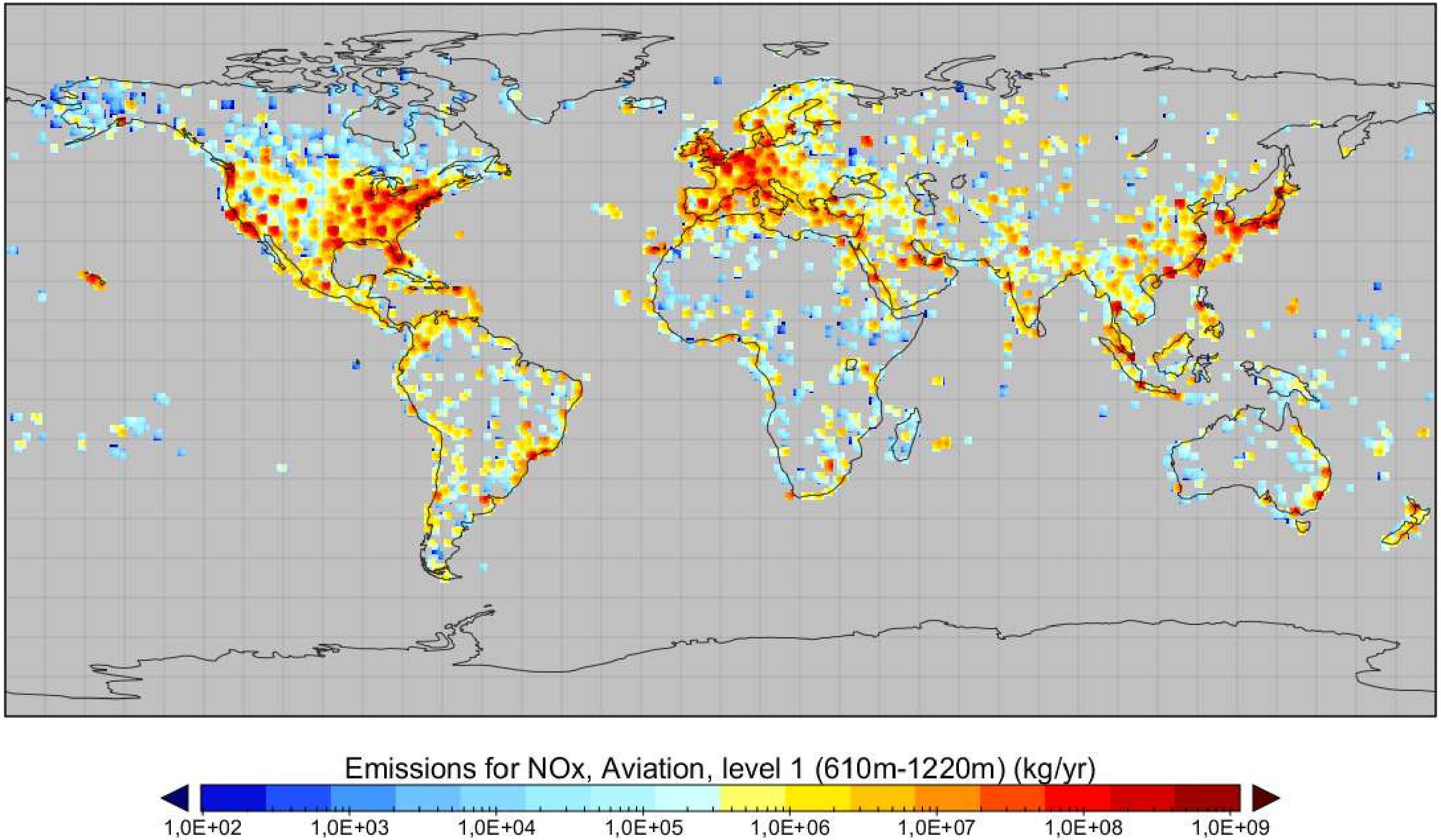
QUANTIFY



GTP, level 1, 25 years

Quantify Final Meeting, 25-27 January 2010, Munich

Emissions for NOx, Aviation, level 1 (610m-1220m)



Equirectangular projection centered on 0,00°E

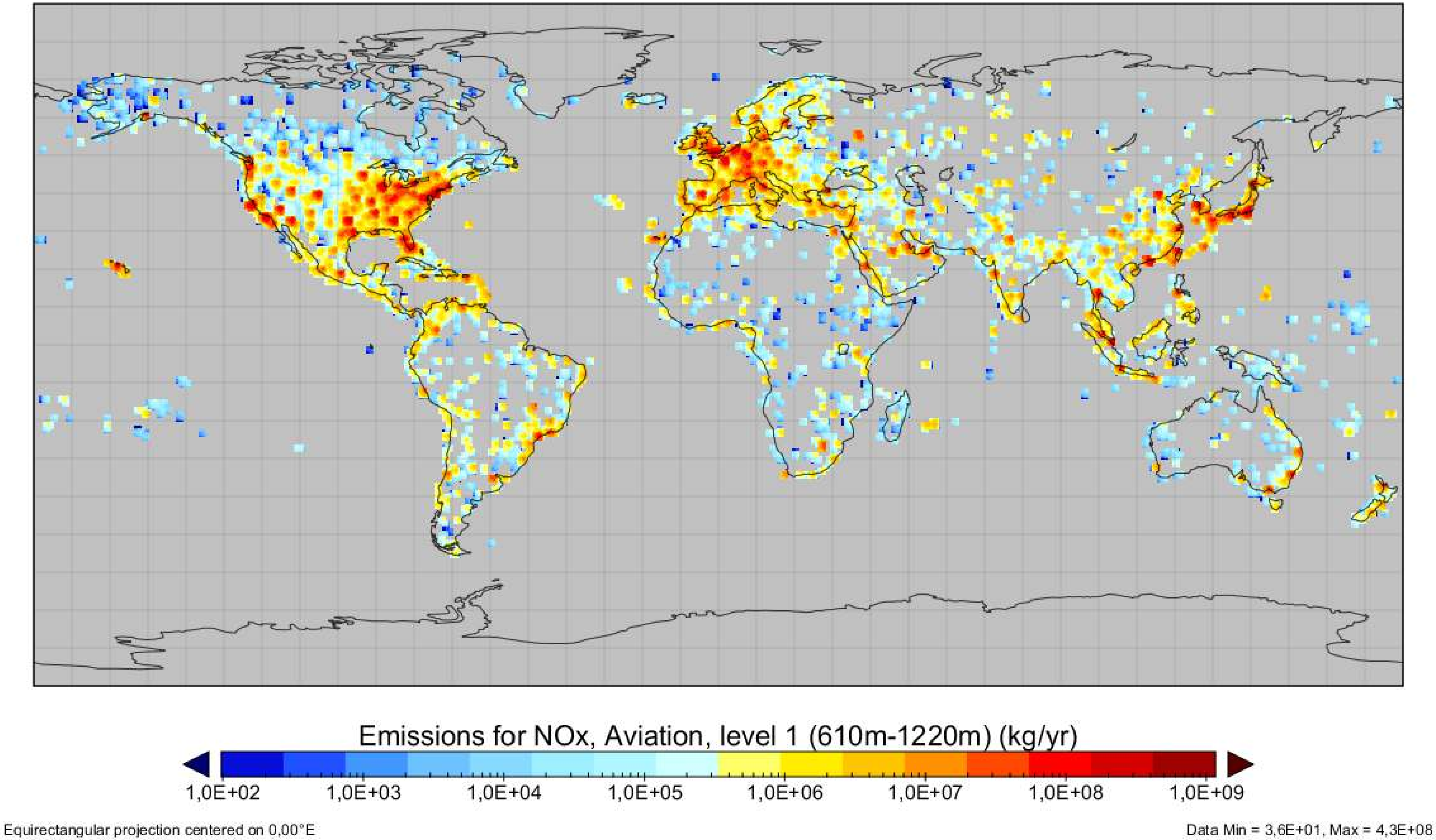
Data Min = 6,3E+01, Max = 7,5E+08

GTP, level 1, 50 years

Quantify Final Meeting, 25-27 January 2010, Munich

QUANTIFY

Emissions for NOx, Aviation, level 1 (610m-1220m)

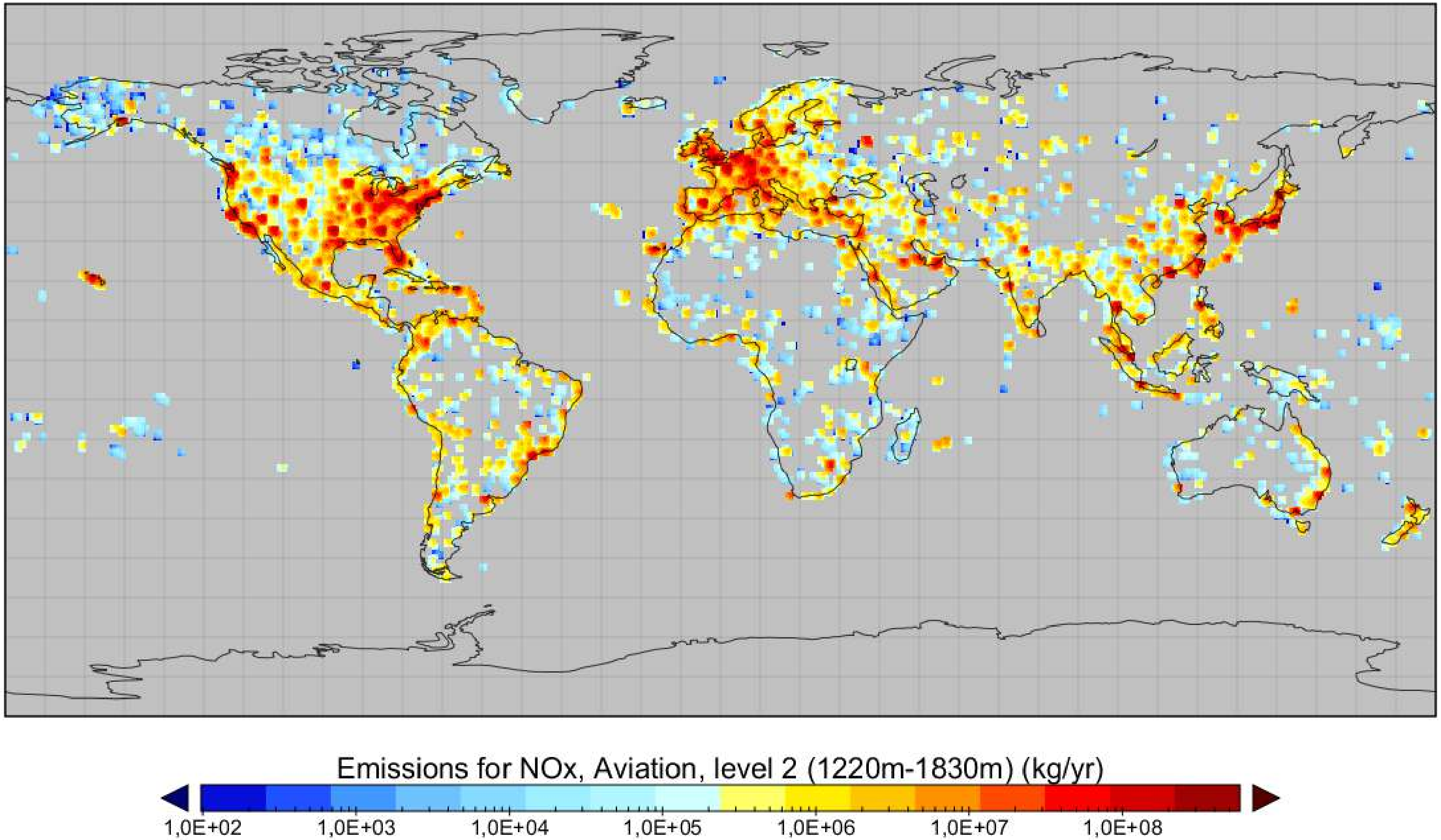


GTP, level 1, 100 years

Quantify Final Meeting, 25-27 January 2010, Munich

QUANTIFY

Emissions for NOx, Aviation, level 2 (1220m-1830m)



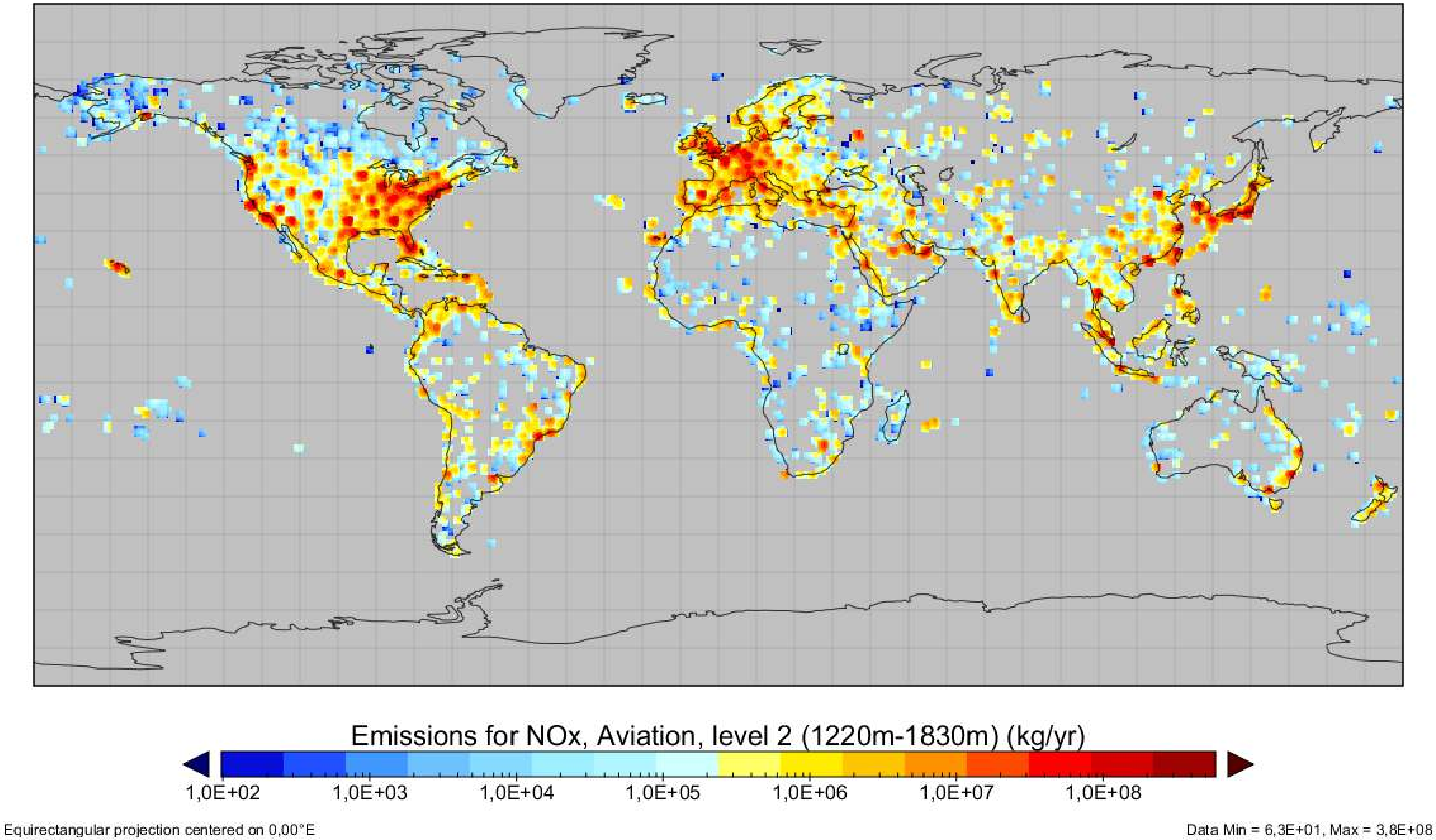
Equirectangular projection centered on 0,00°E

Data Min = 9,8E+01, Max = 5,8E+08

GTP, level 2, 25 years

Quantify Final Meeting, 25-27 January 2010, Munich

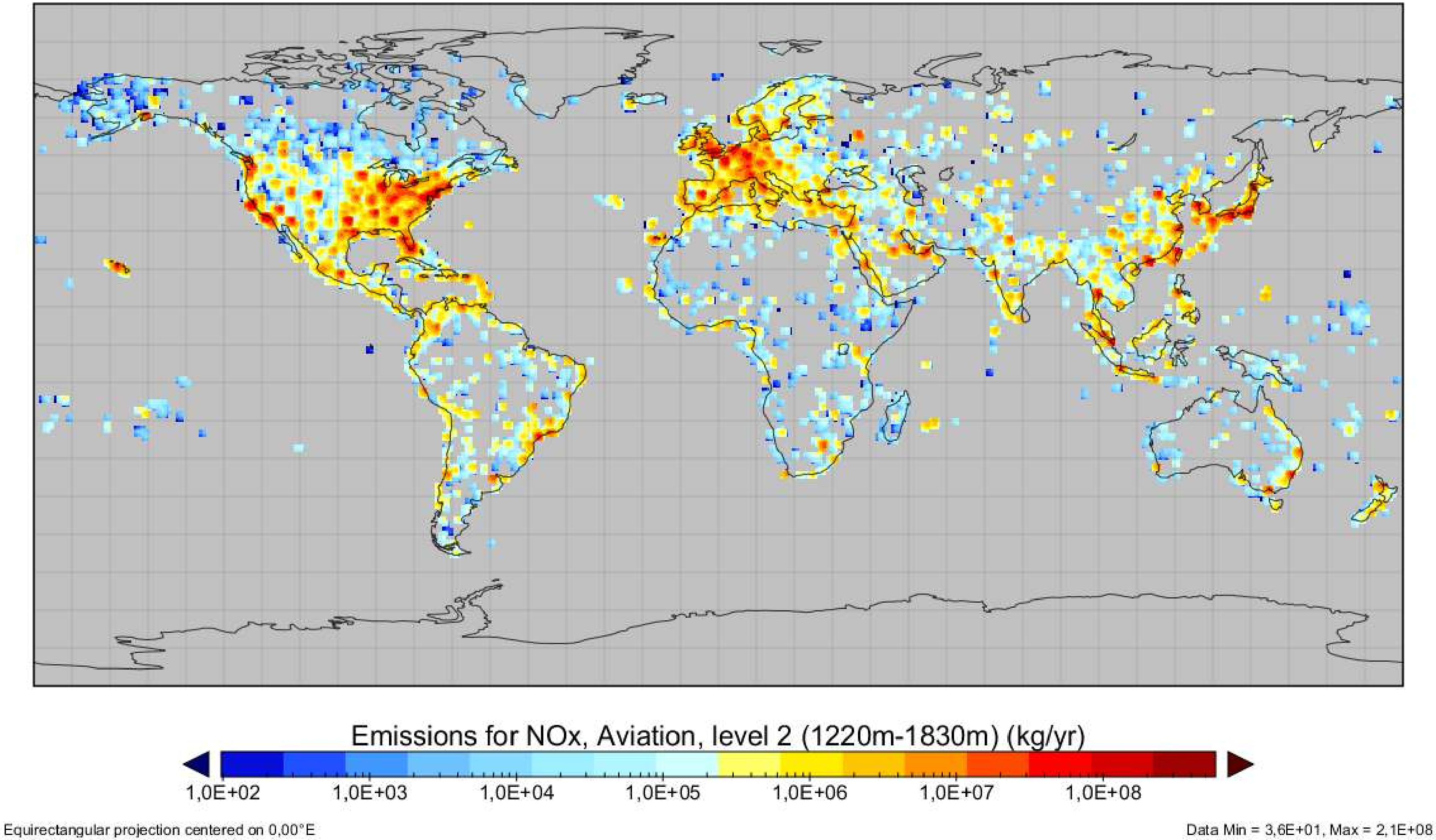
Emissions for NOx, Aviation, level 2 (1220m-1830m)



GTP, level 2, 50 years

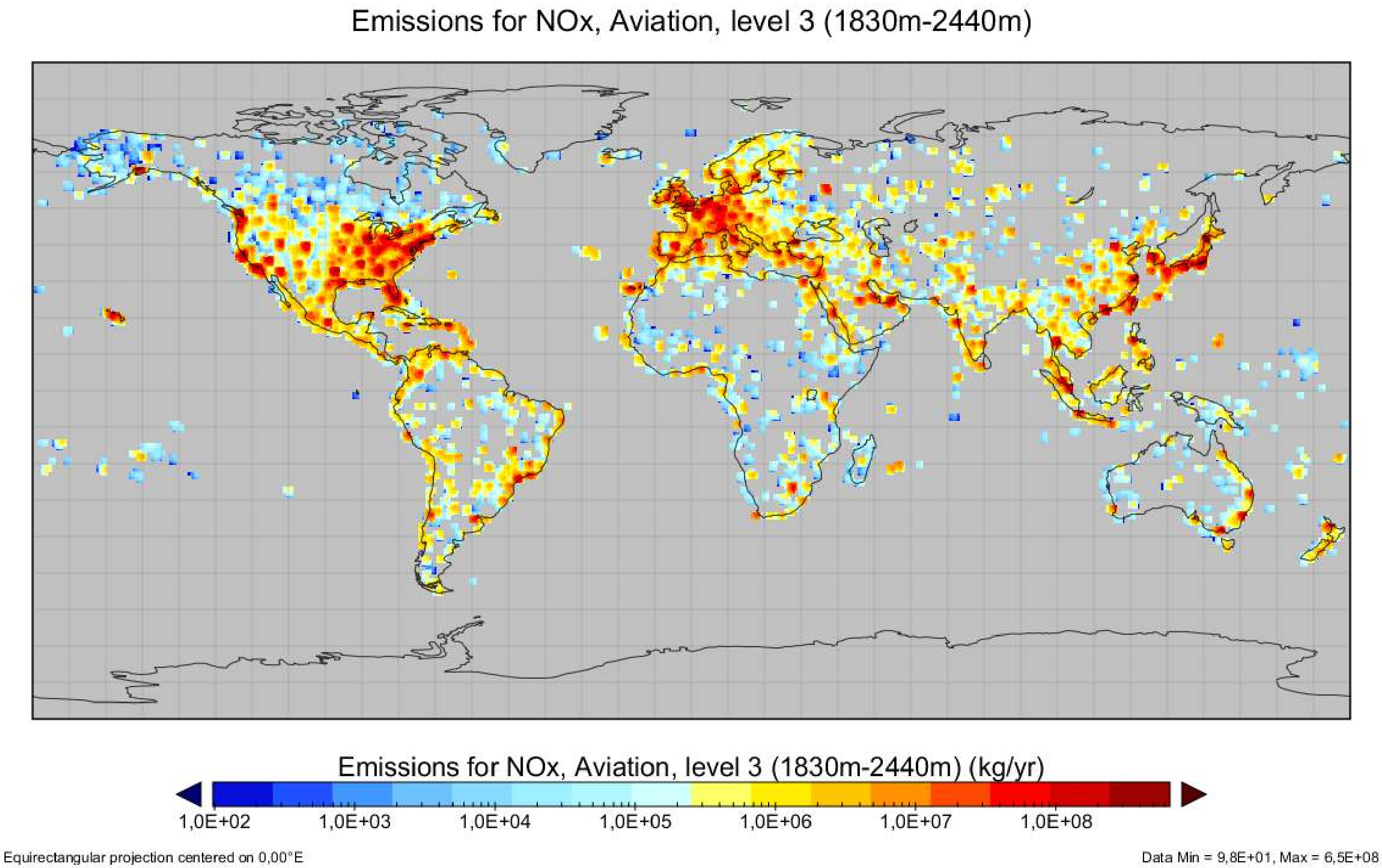
Quantify Final Meeting, 25-27 January 2010, Munich

Emissions for NOx, Aviation, level 2 (1220m-1830m)



GTP, level 2, 100 years

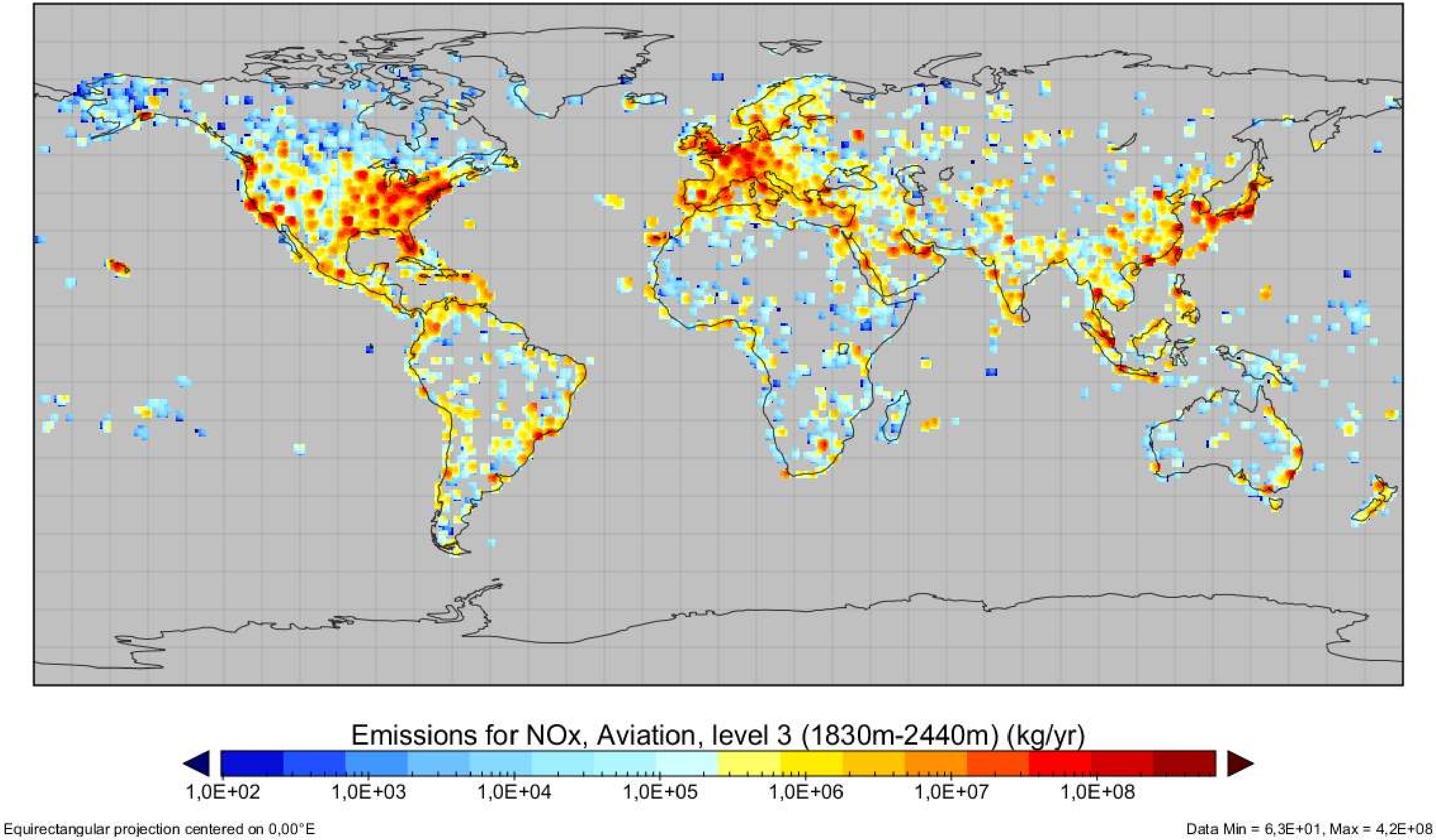
Quantify Final Meeting, 25-27 January 2010, Munich



GTP, level 3, 25 years

QUANTIFY

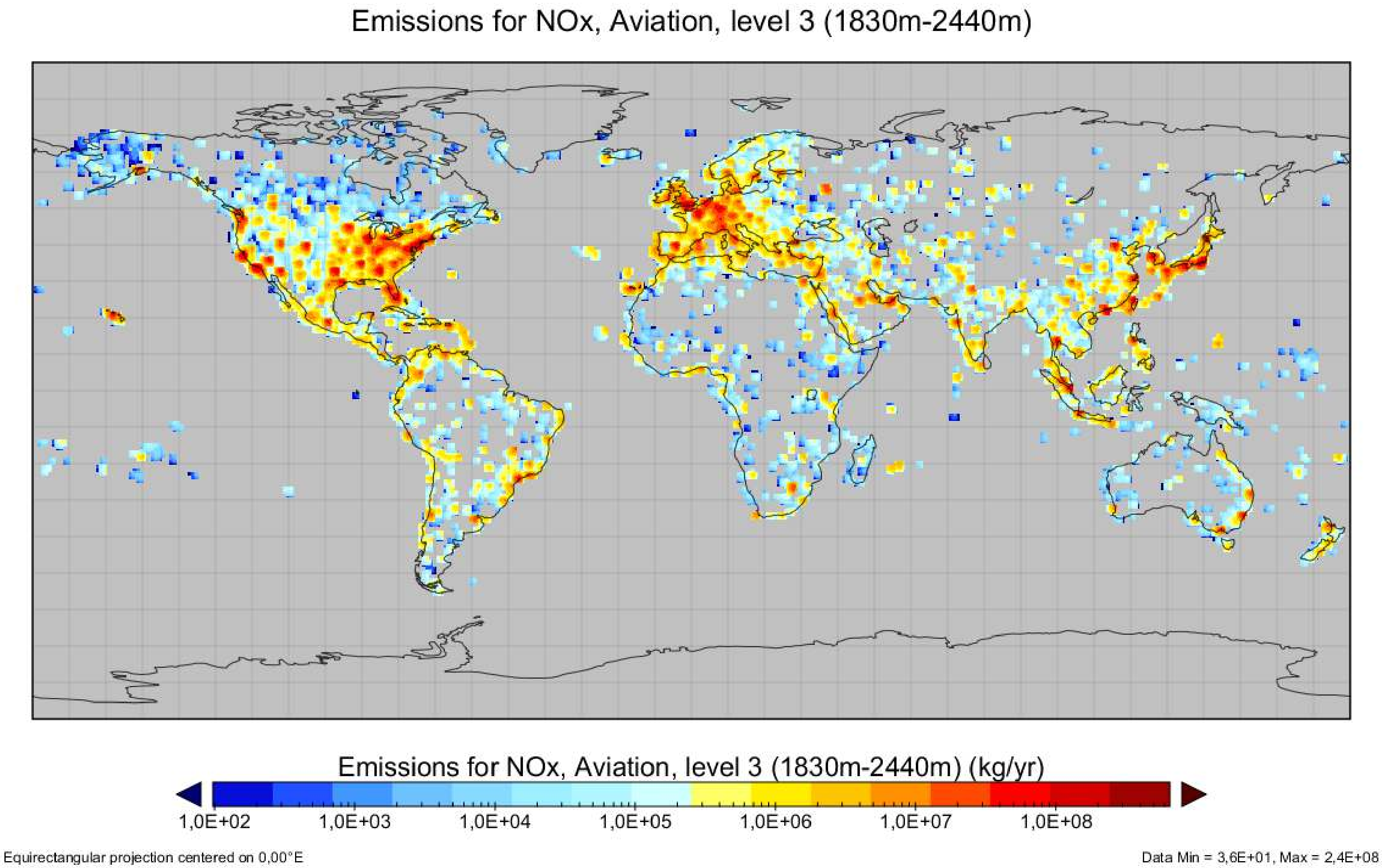
Emissions for NOx, Aviation, level 3 (1830m-2440m)



GTP, level 3, 50 years

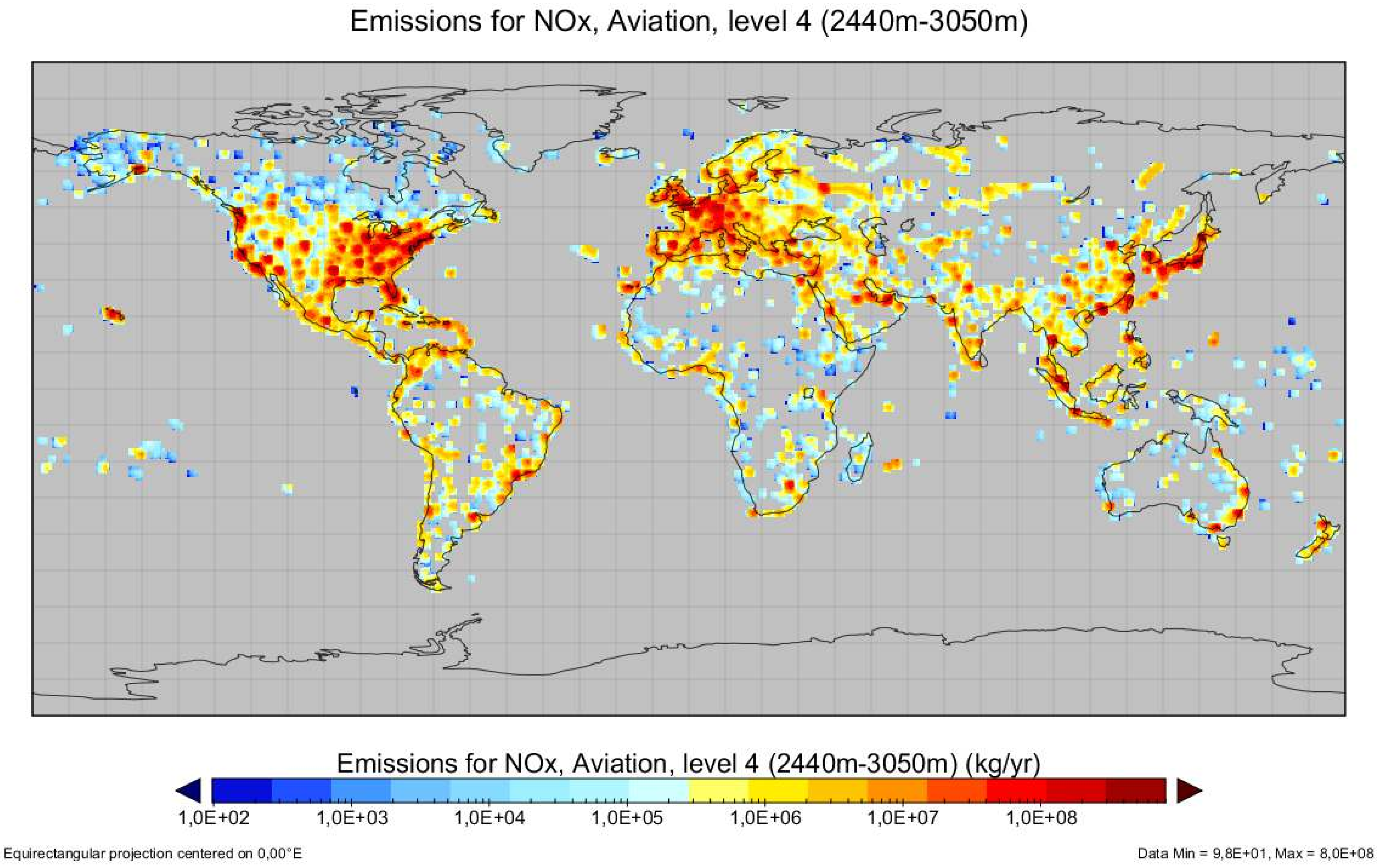
Quantify Final Meeting, 25-27 January 2010, Munich

QUANTIFY



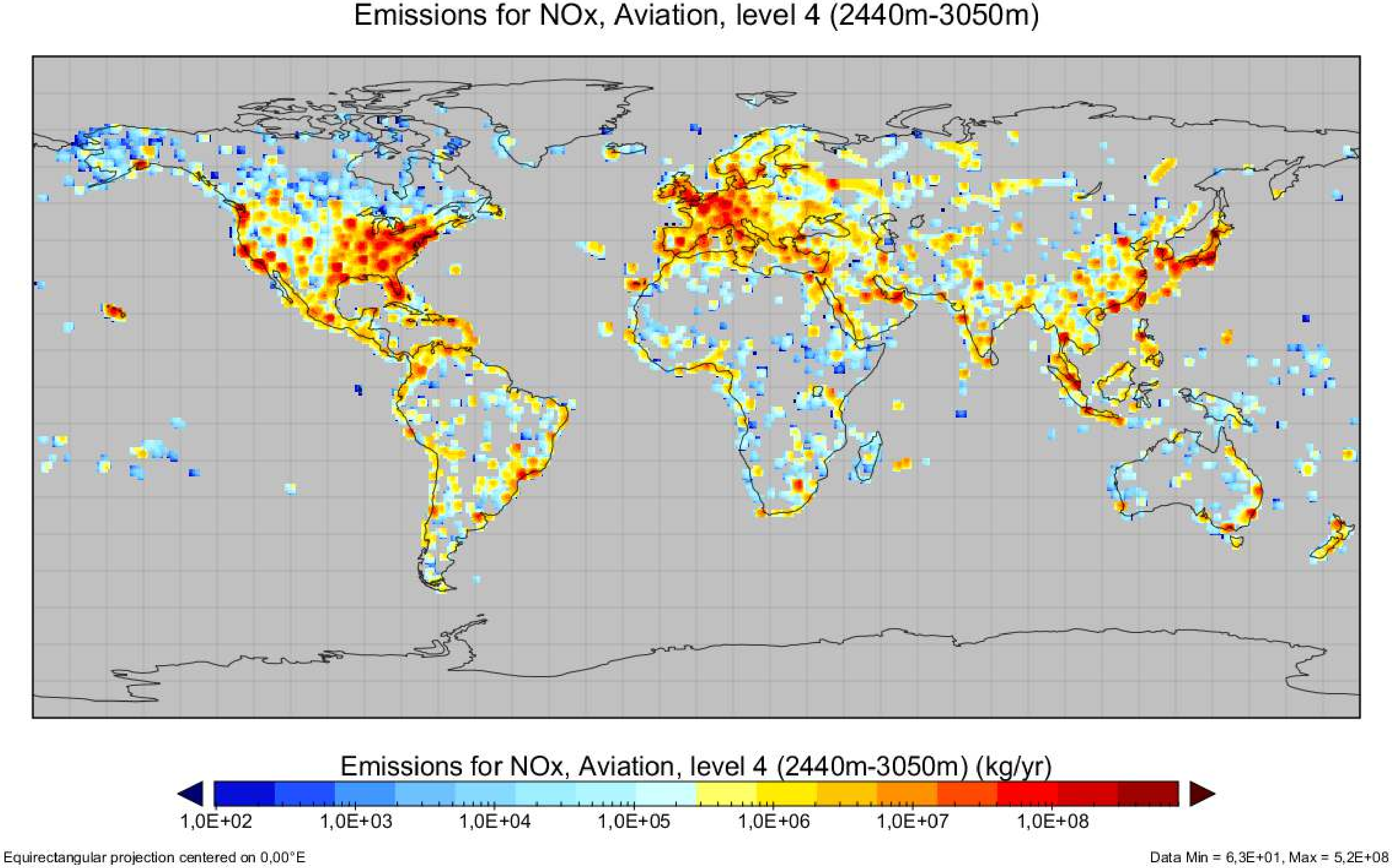
GTP, level 3, 100 years

Quantify Final Meeting, 25-27 January 2010, Munich



GTP, level 4, 25 years

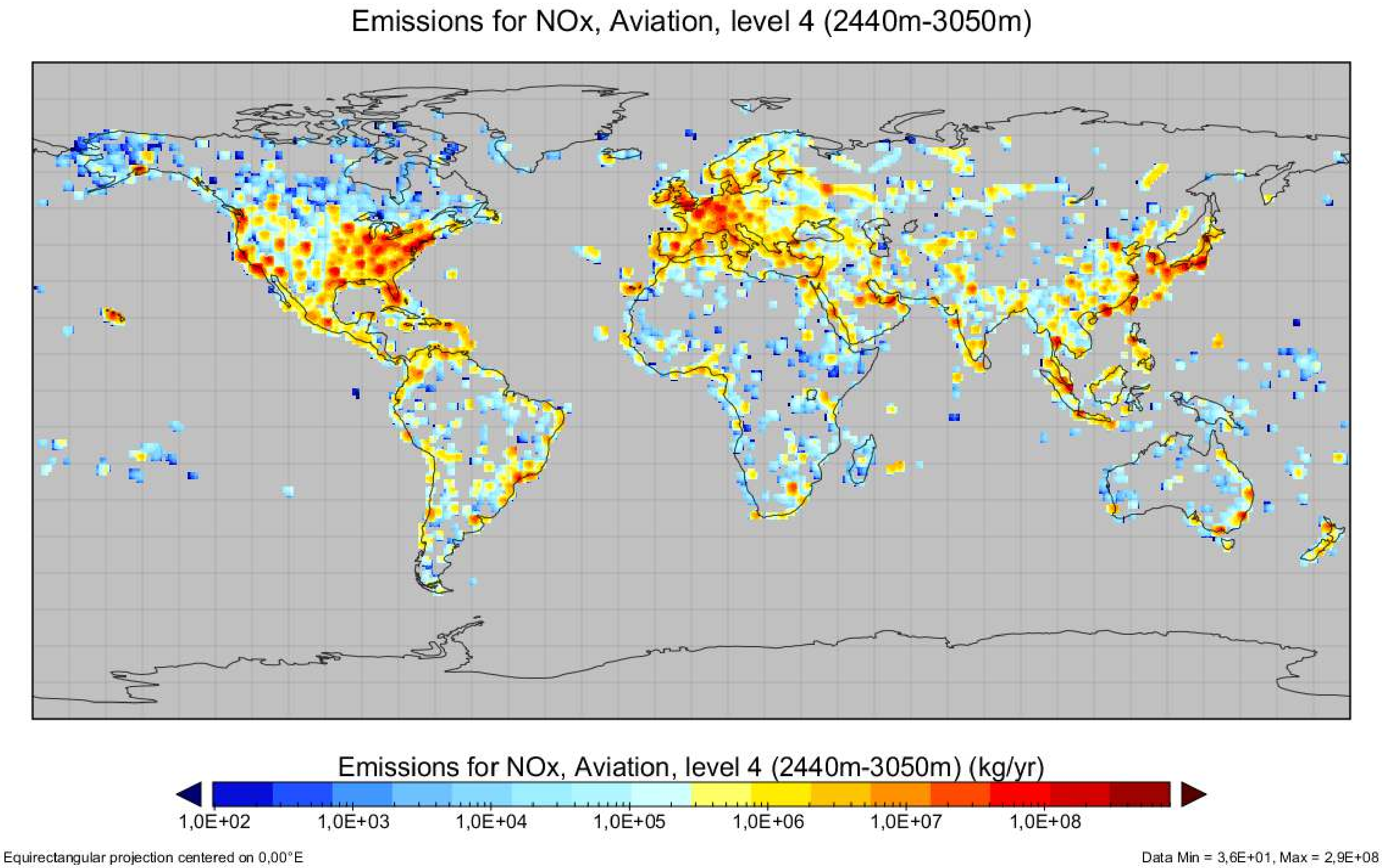
Quantify Final Meeting, 25-27 January 2010, Munich



GTP, level 4, 50 years

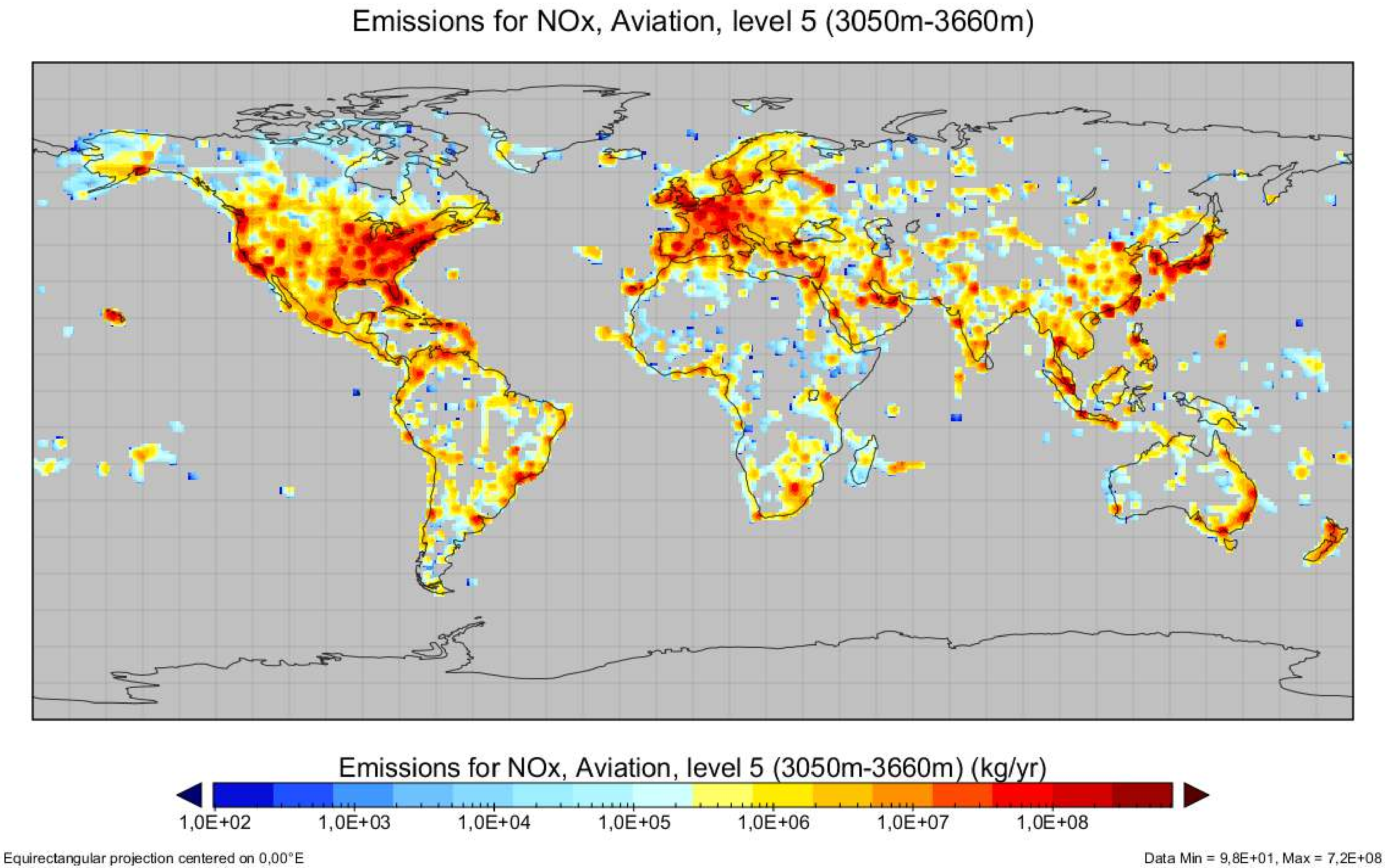
Quantify Final Meeting, 25-27 January 2010, Munich

QUANTIFY



GTP, level 4, 100 years

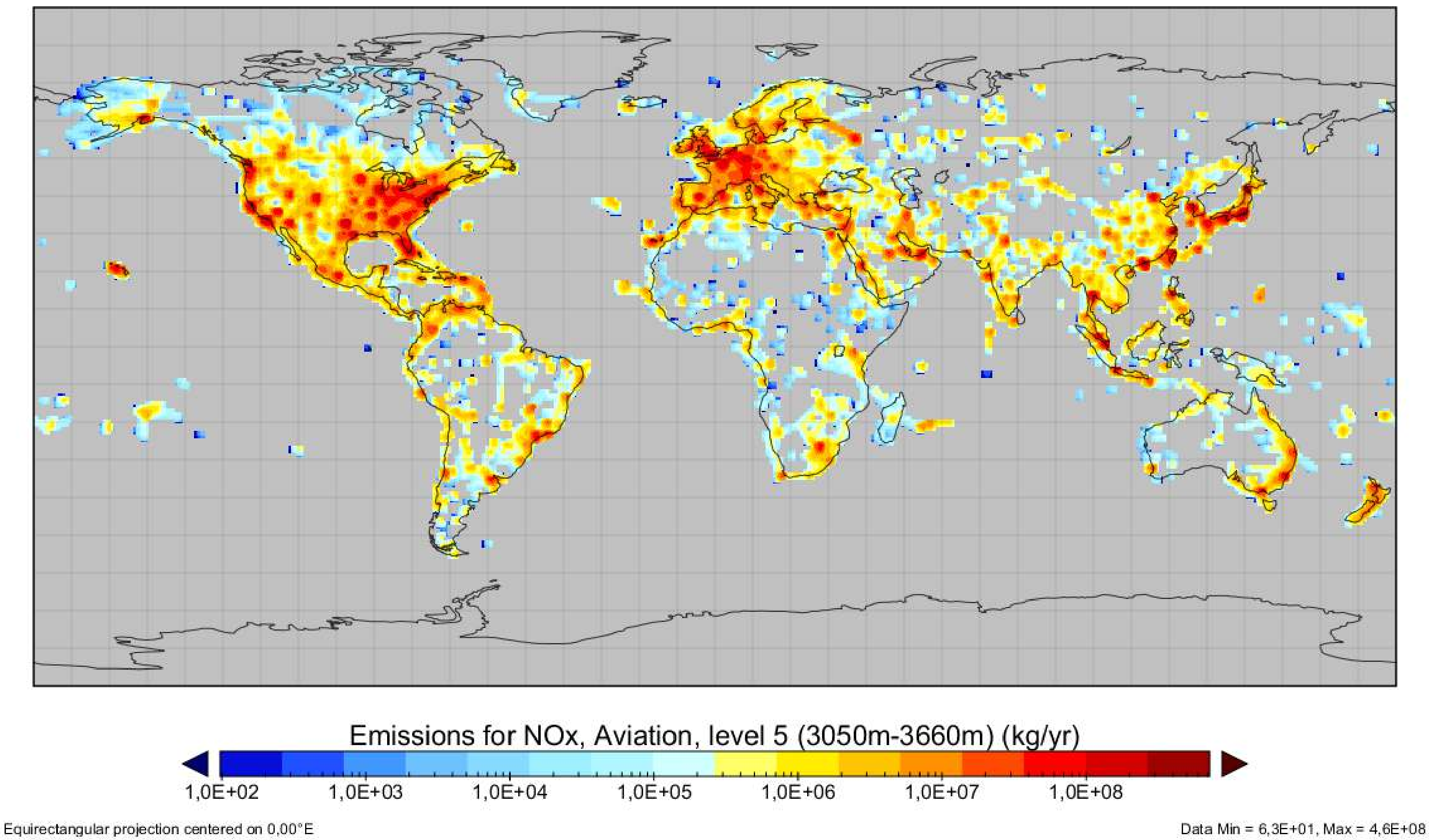
Quantify Final Meeting, 25-27 January 2010, Munich



GTP, level 5, 25 years

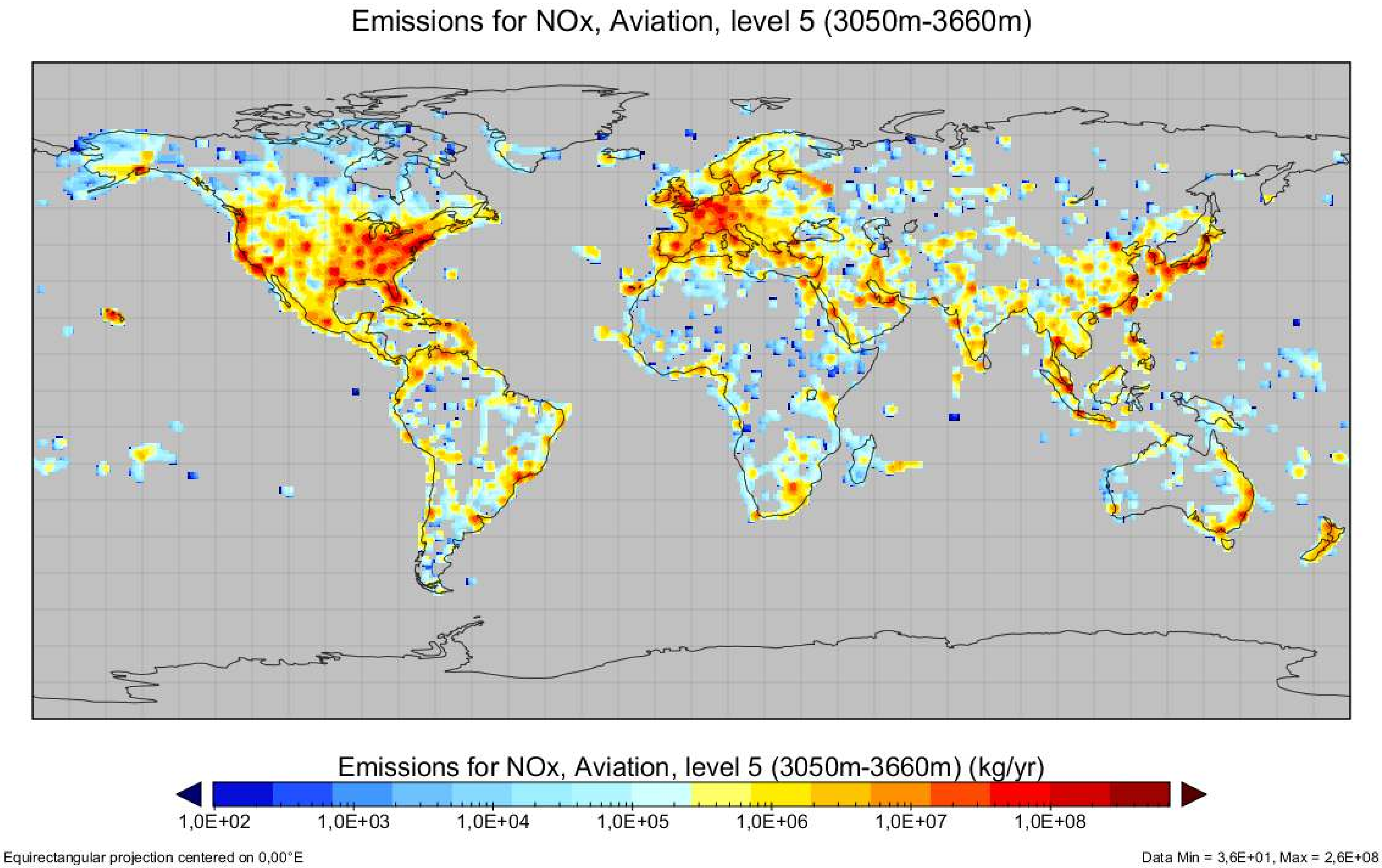
Quantify Final Meeting, 25-27 January 2010, Munich

Emissions for NOx, Aviation, level 5 (3050m-3660m)



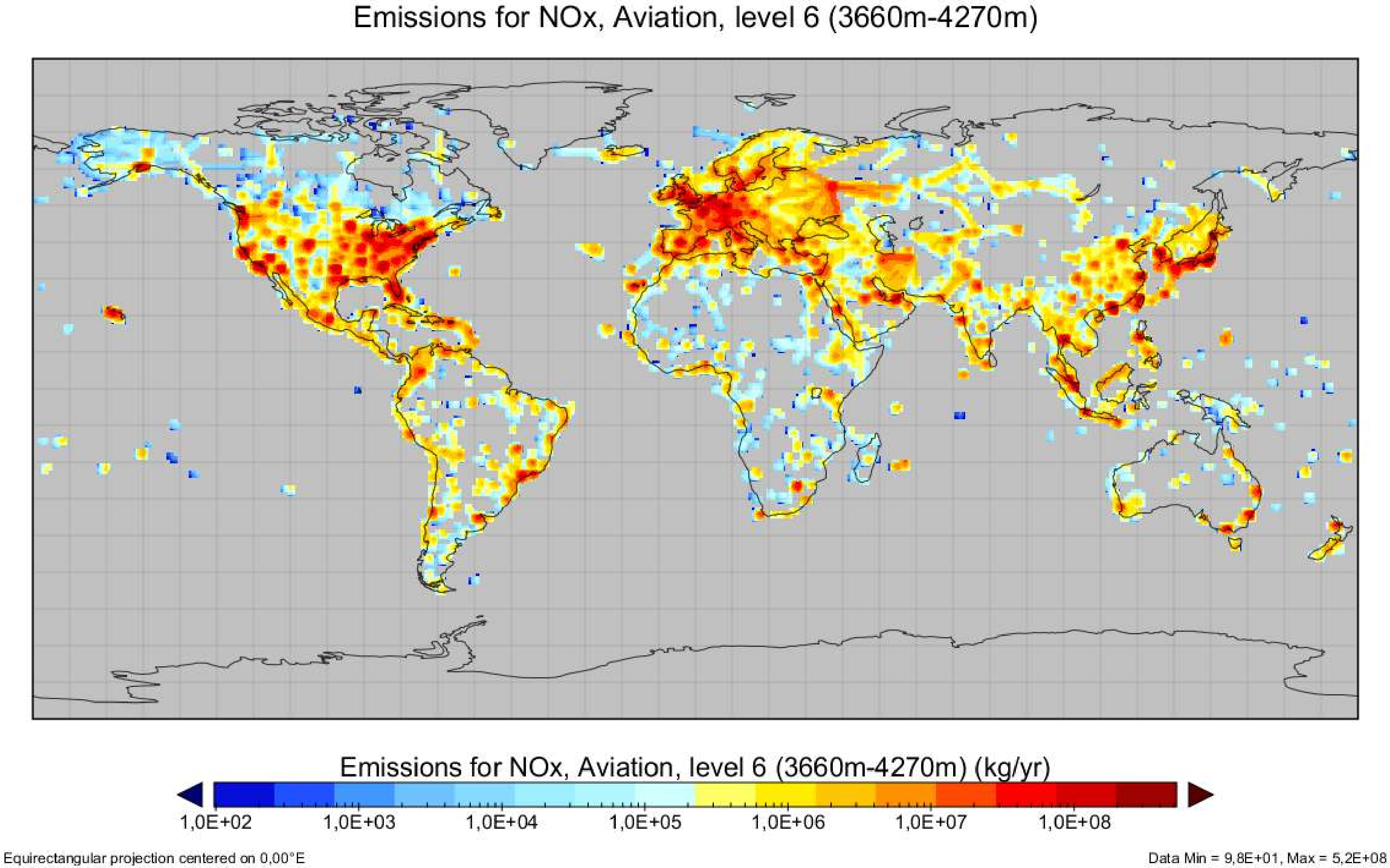
GTP, level 5, 50 years

Quantify Final Meeting, 25-27 January 2010, Munich



GTP, level 5, 100 years

Quantify Final Meeting, 25-27 January 2010, Munich

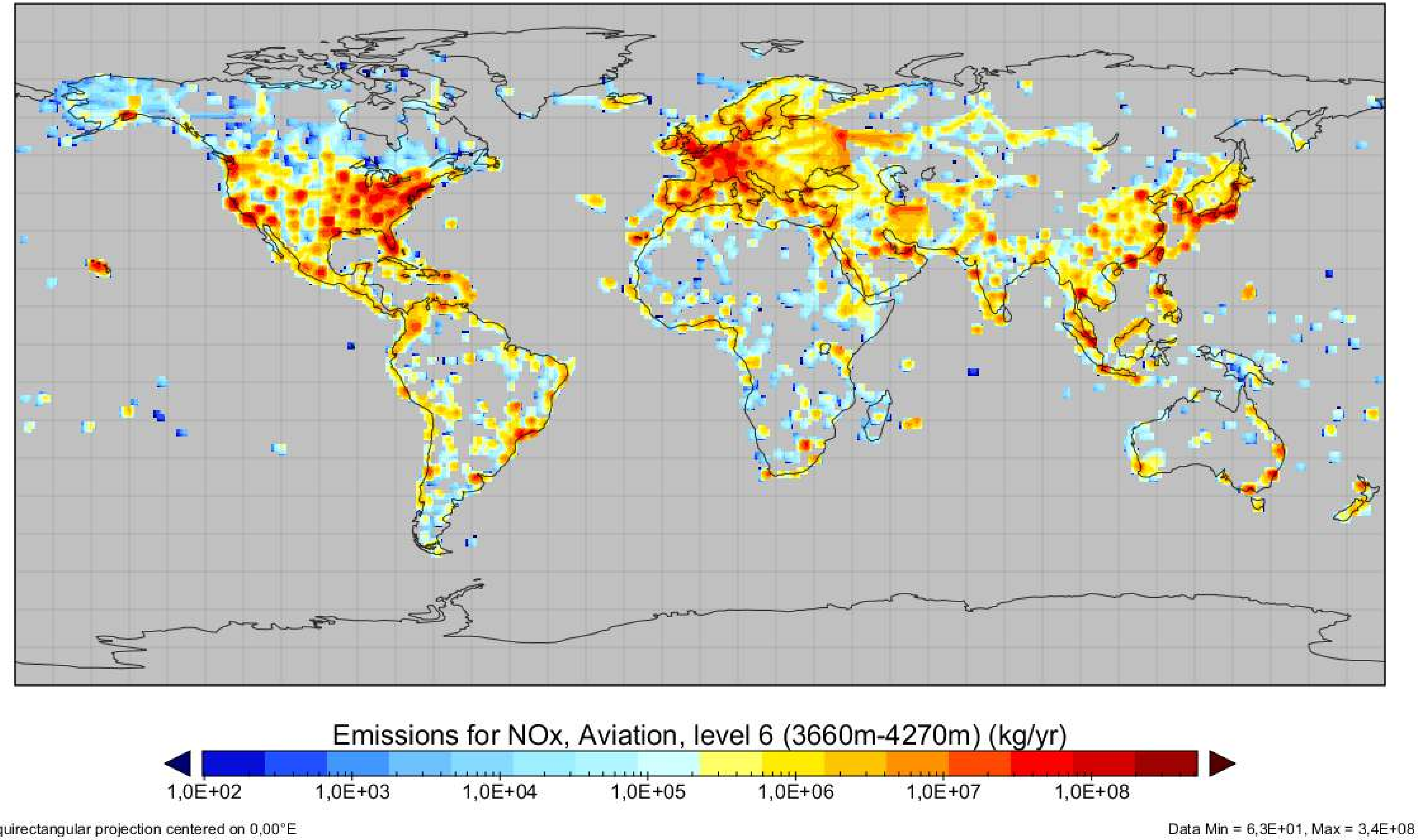


GTP, level 6, 25 years

Quantify Final Meeting, 25-27 January 2010, Munich

QUANTIFY

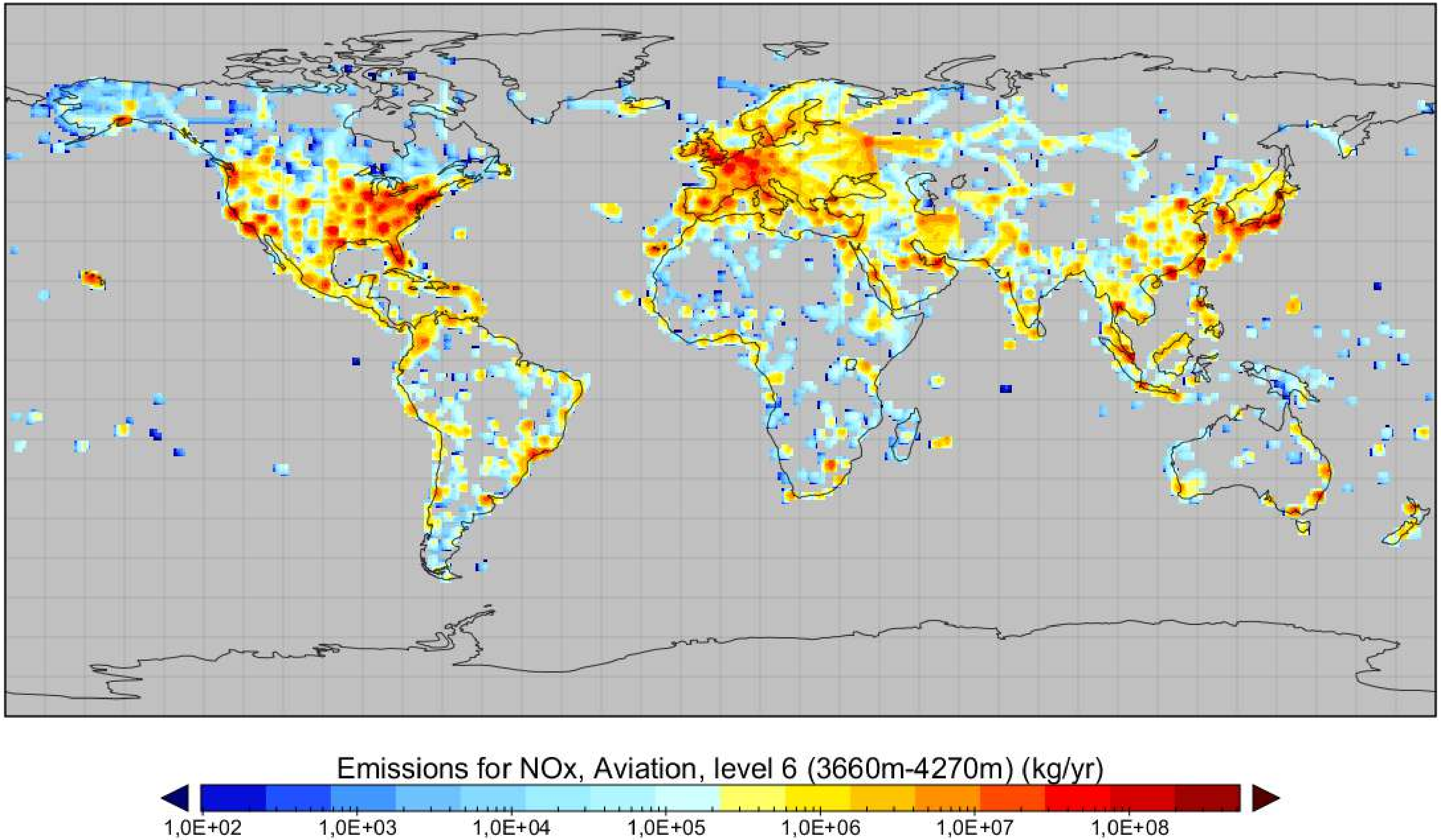
Emissions for NOx, Aviation, level 6 (3660m-4270m)



GTP, level 6, 50 years

Quantify Final Meeting, 25-27 January 2010, Munich

Emissions for NOx, Aviation, level 6 (3660m-4270m)

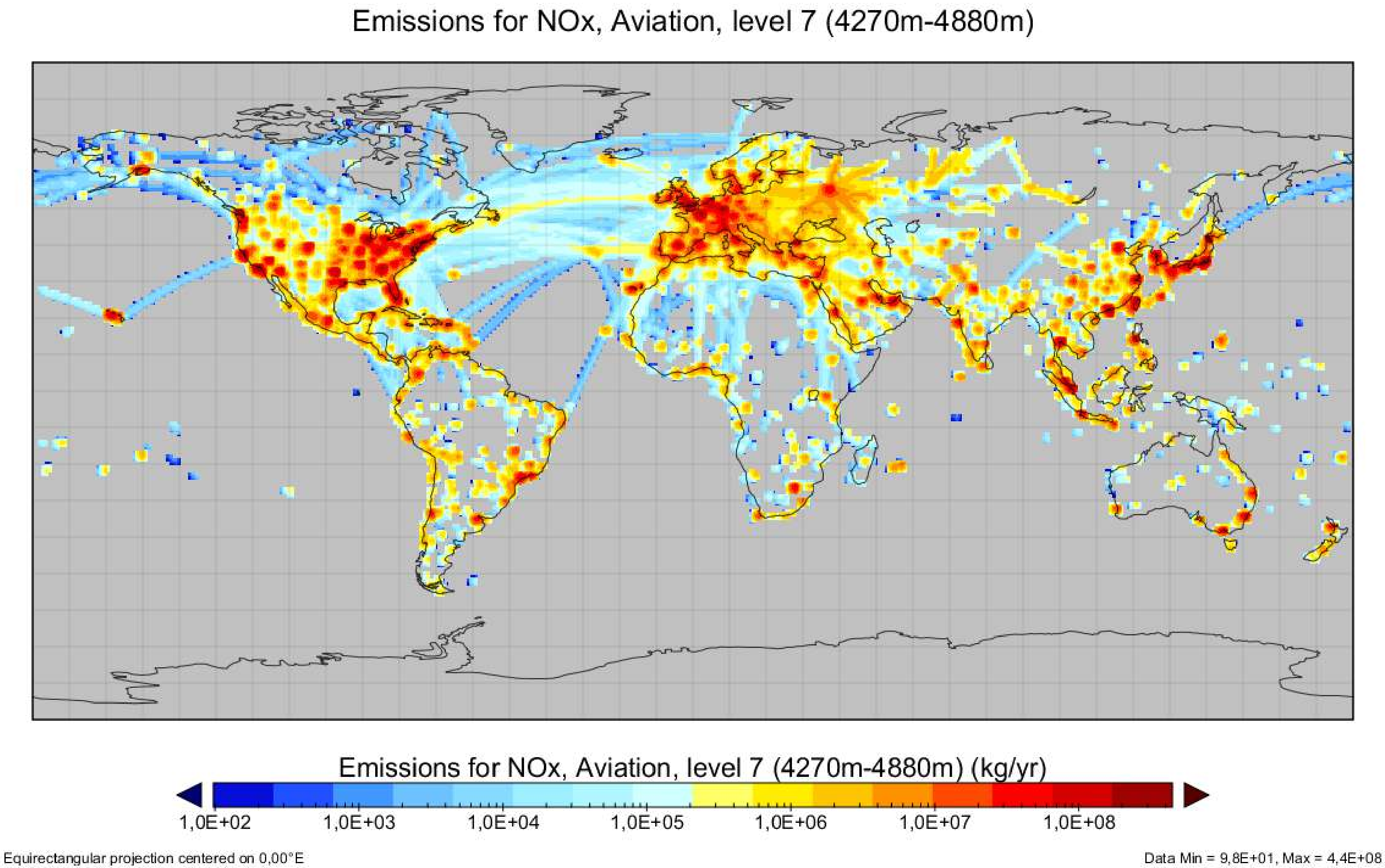


Equirectangular projection centered on 0,00°E

Data Min = 3,6E+01, Max = 1,9E+08

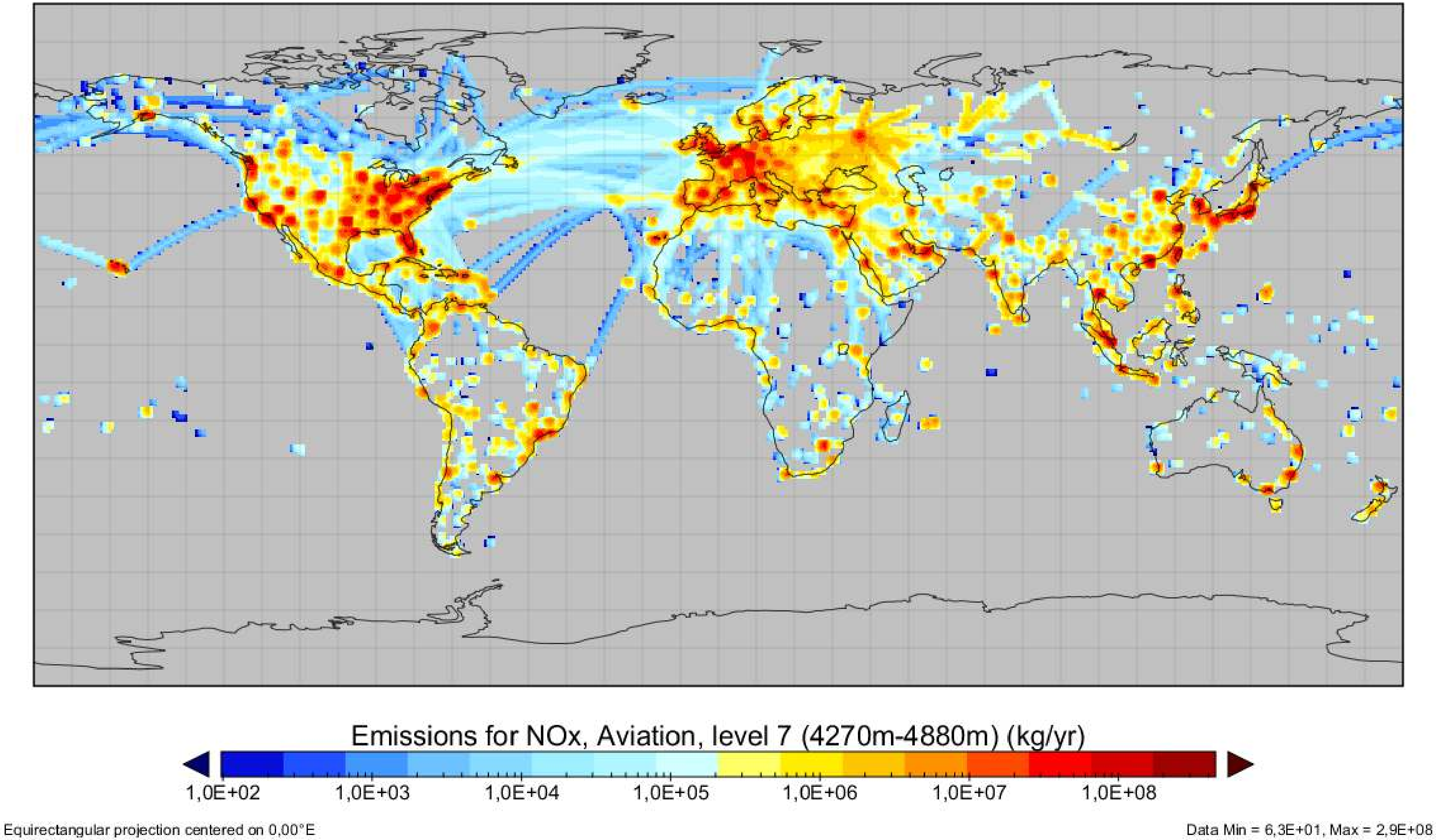
GTP, level 6, 100 years

Quantify Final Meeting, 25-27 January 2010, Munich

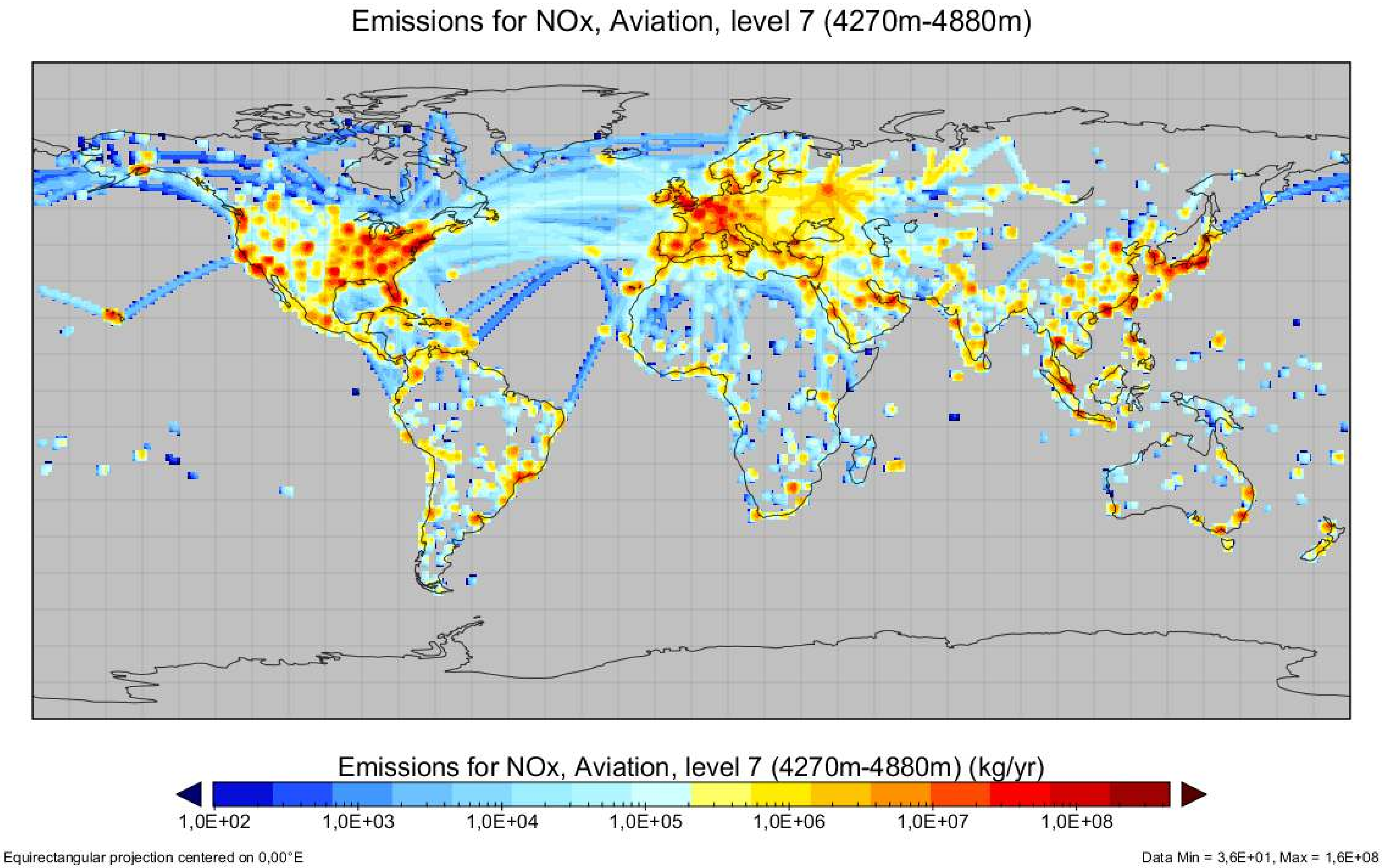


GTP, level 7, 25 years

Emissions for NOx, Aviation, level 7 (4270m-4880m)



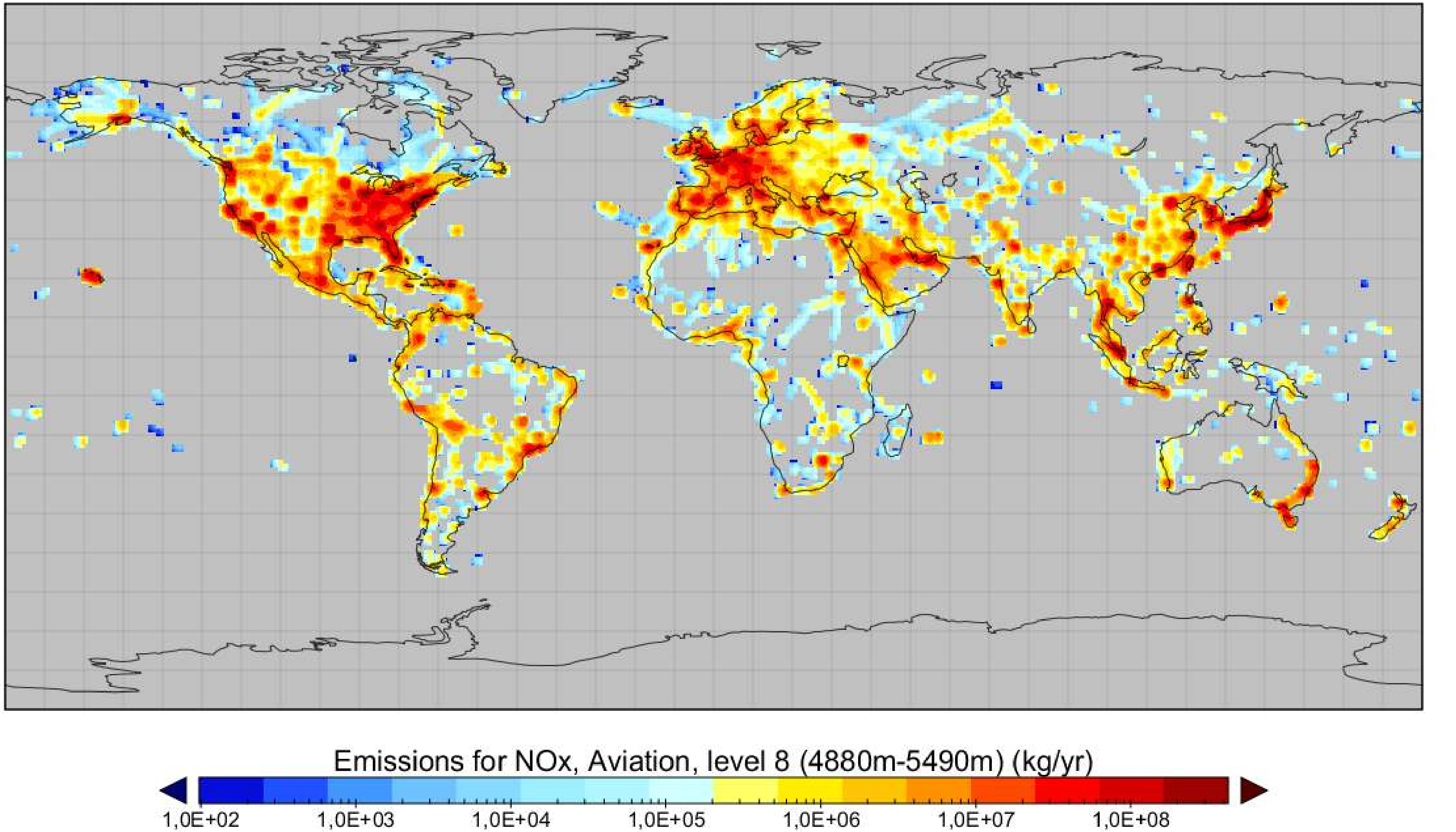
GTP, level 7, 50 years



GTP, level 7, 100 years

Quantify Final Meeting, 25-27 January 2010, Munich

Emissions for NOx, Aviation, level 8 (4880m-5490m)

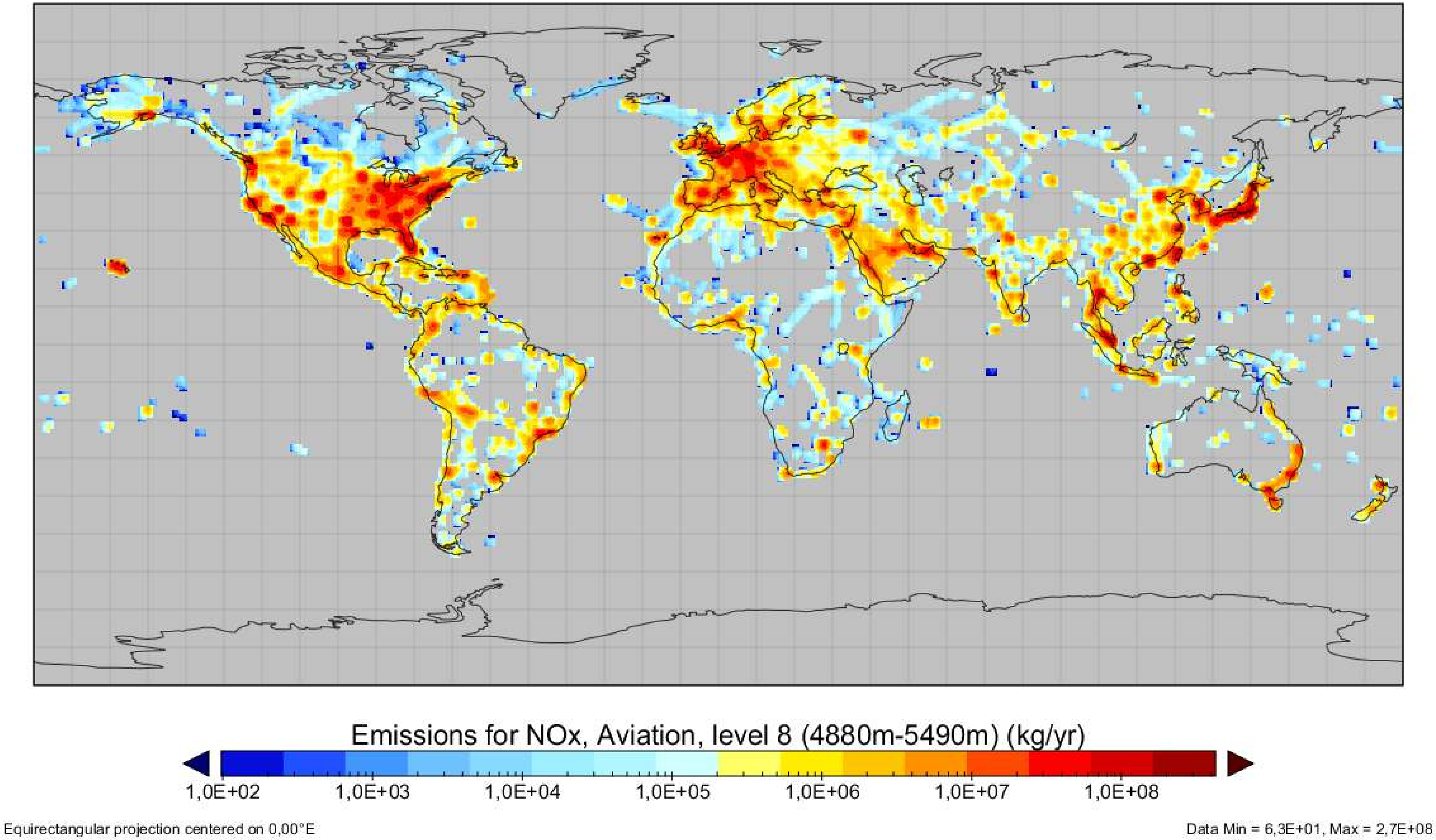


GTP, level 8, 25 years

Quantify Final Meeting, 25-27 January 2010, Munich

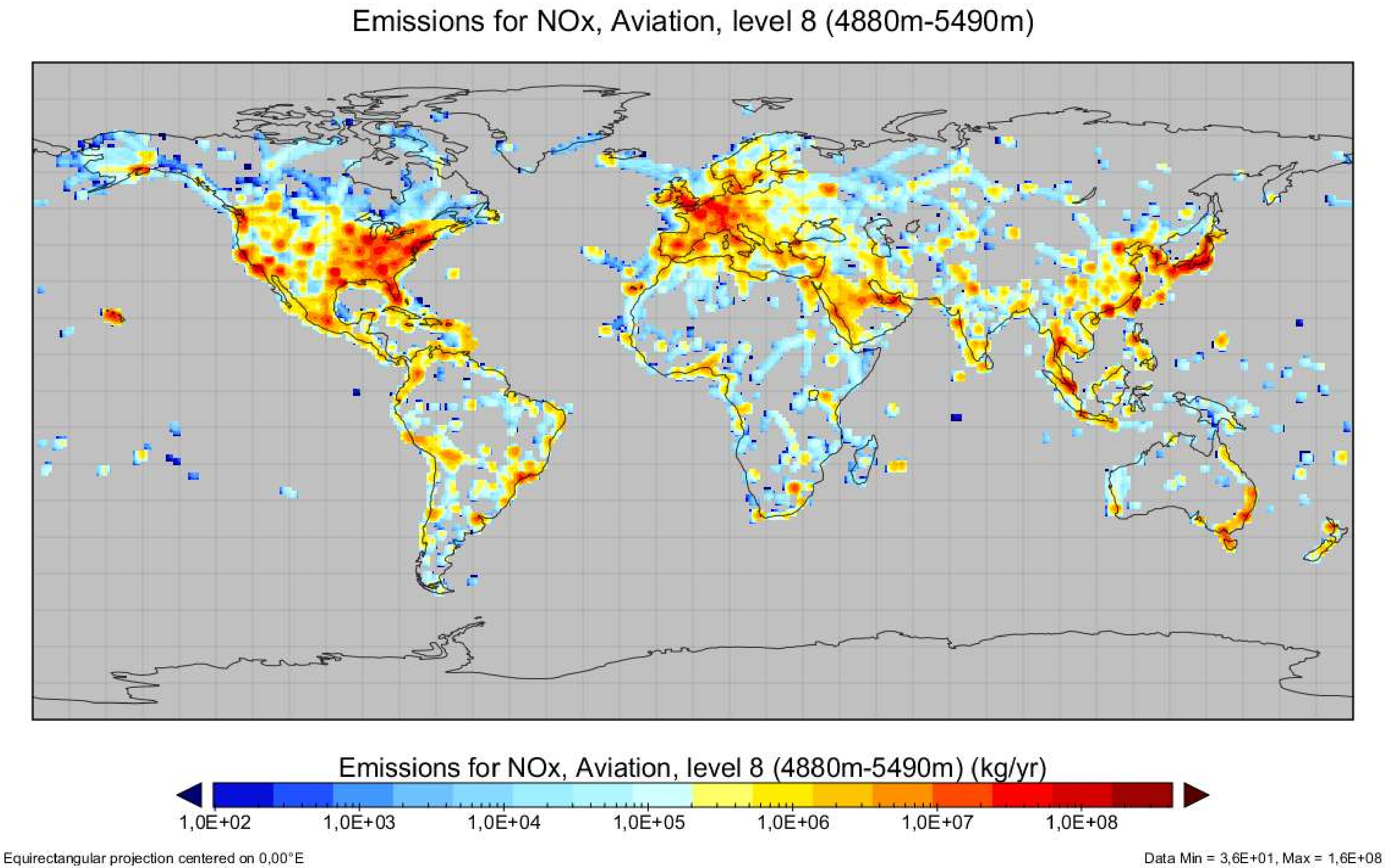
QUANTIFY

Emissions for NOx, Aviation, level 8 (4880m-5490m)

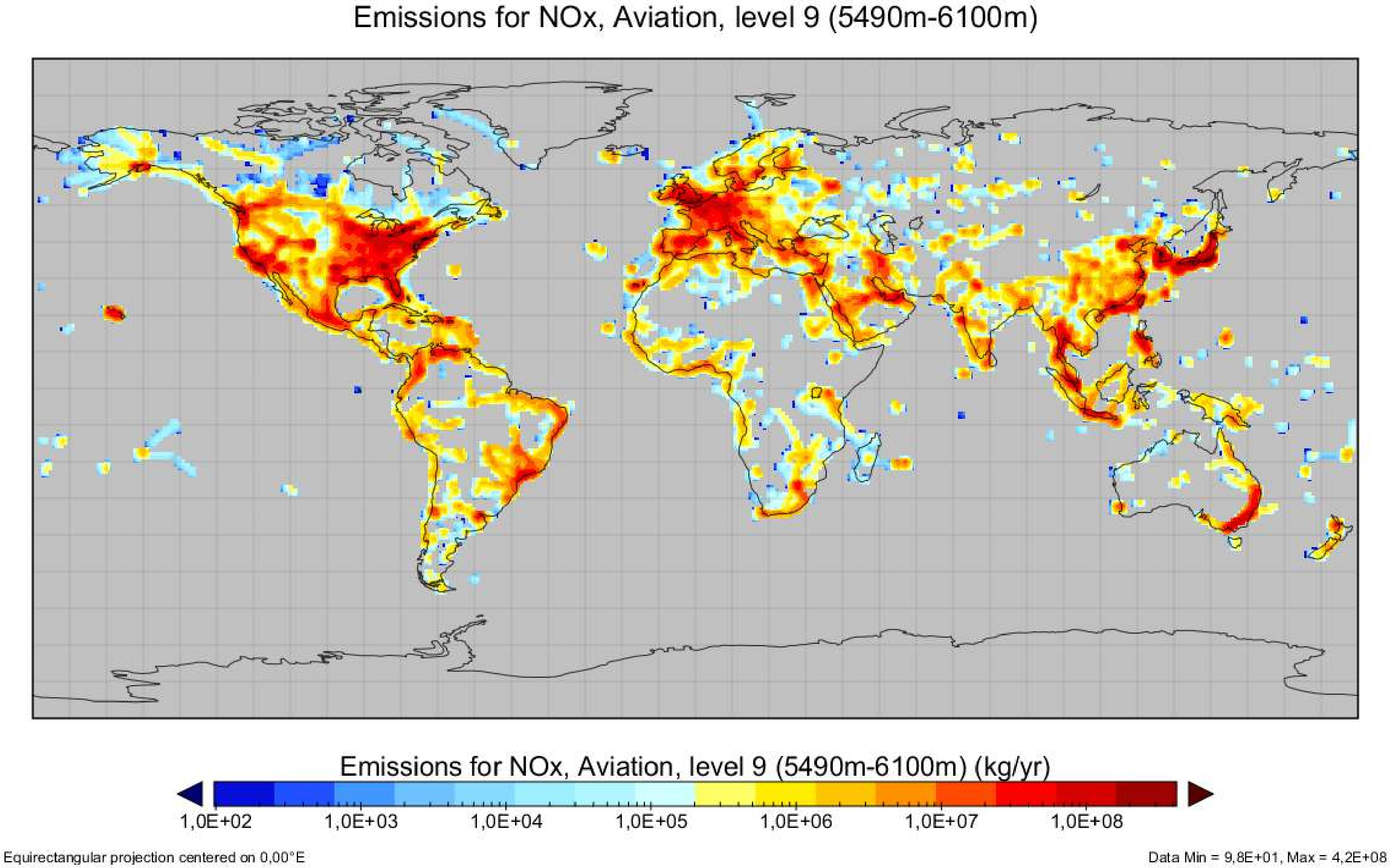


GTP, level 8, 50 years

QUANTIFY

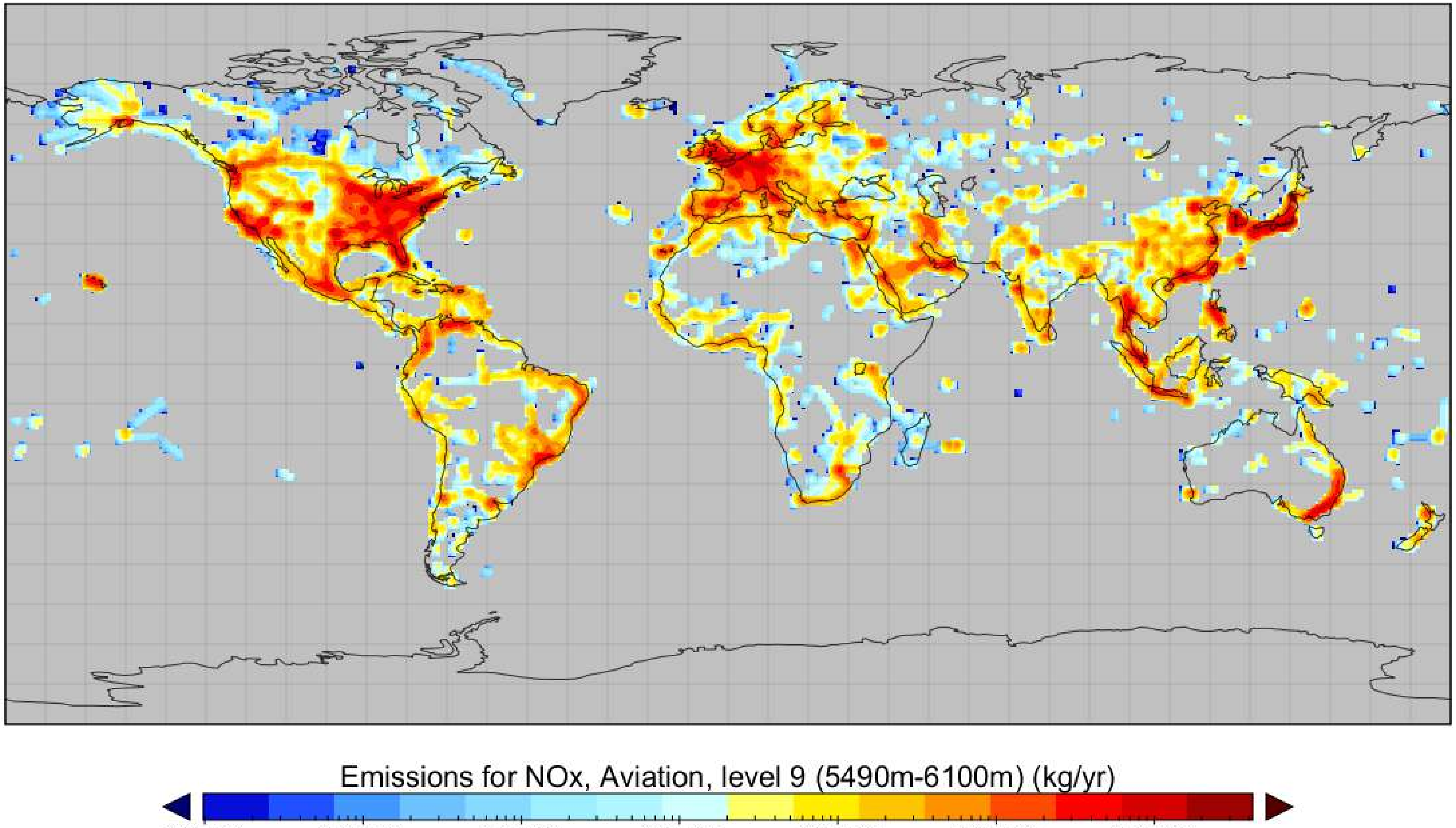


GTP, level 8, 100 years



GTP, level 9, 25 years

Emissions for NOx, Aviation, level 9 (5490m-6100m)

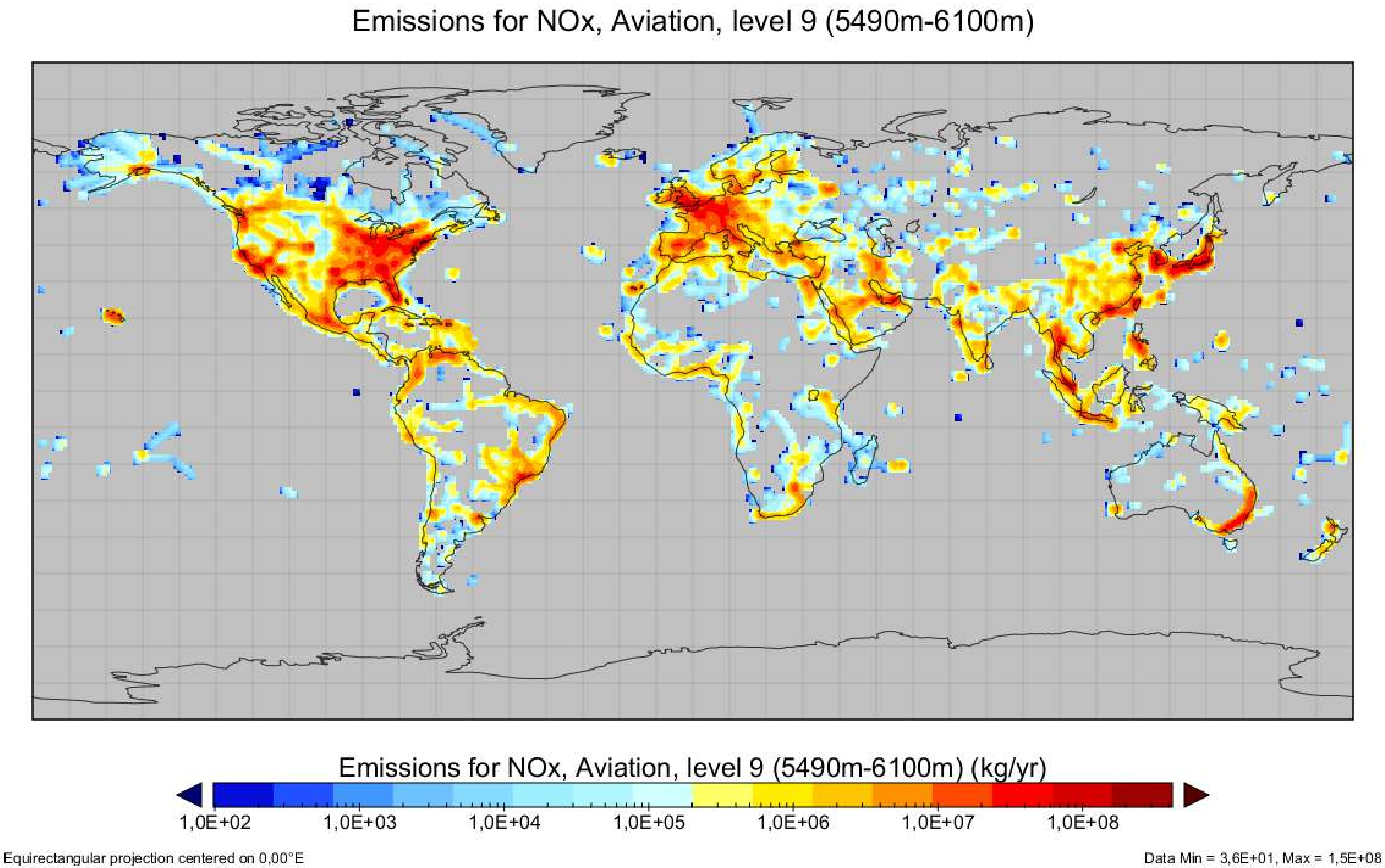


Equirectangular projection centered on 0,00°E

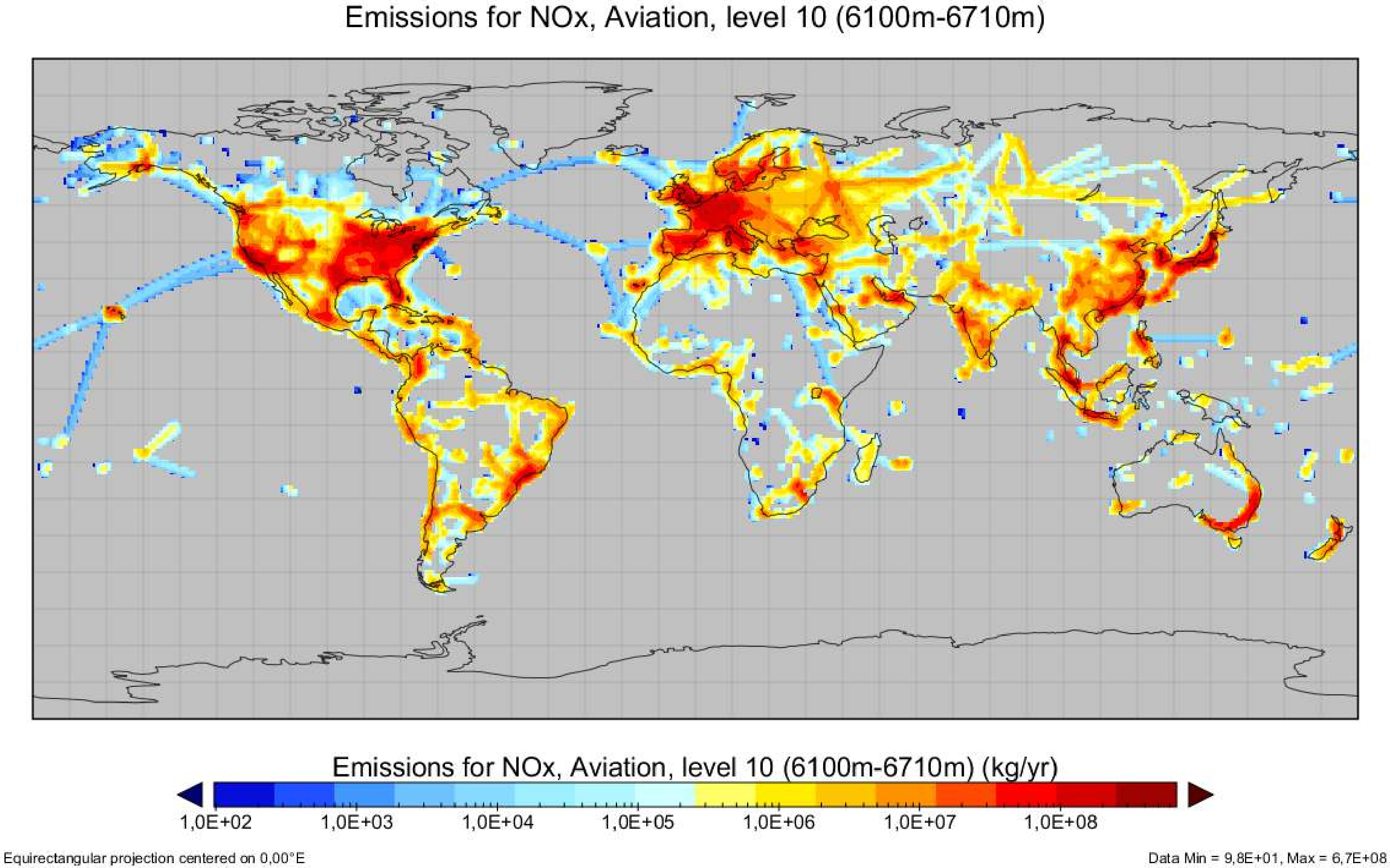
Data Min = 6,3E+01, Max = 2,7E+08

GTP, level 9, 50 years

Quantify Final Meeting, 25-27 January 2010, Munich

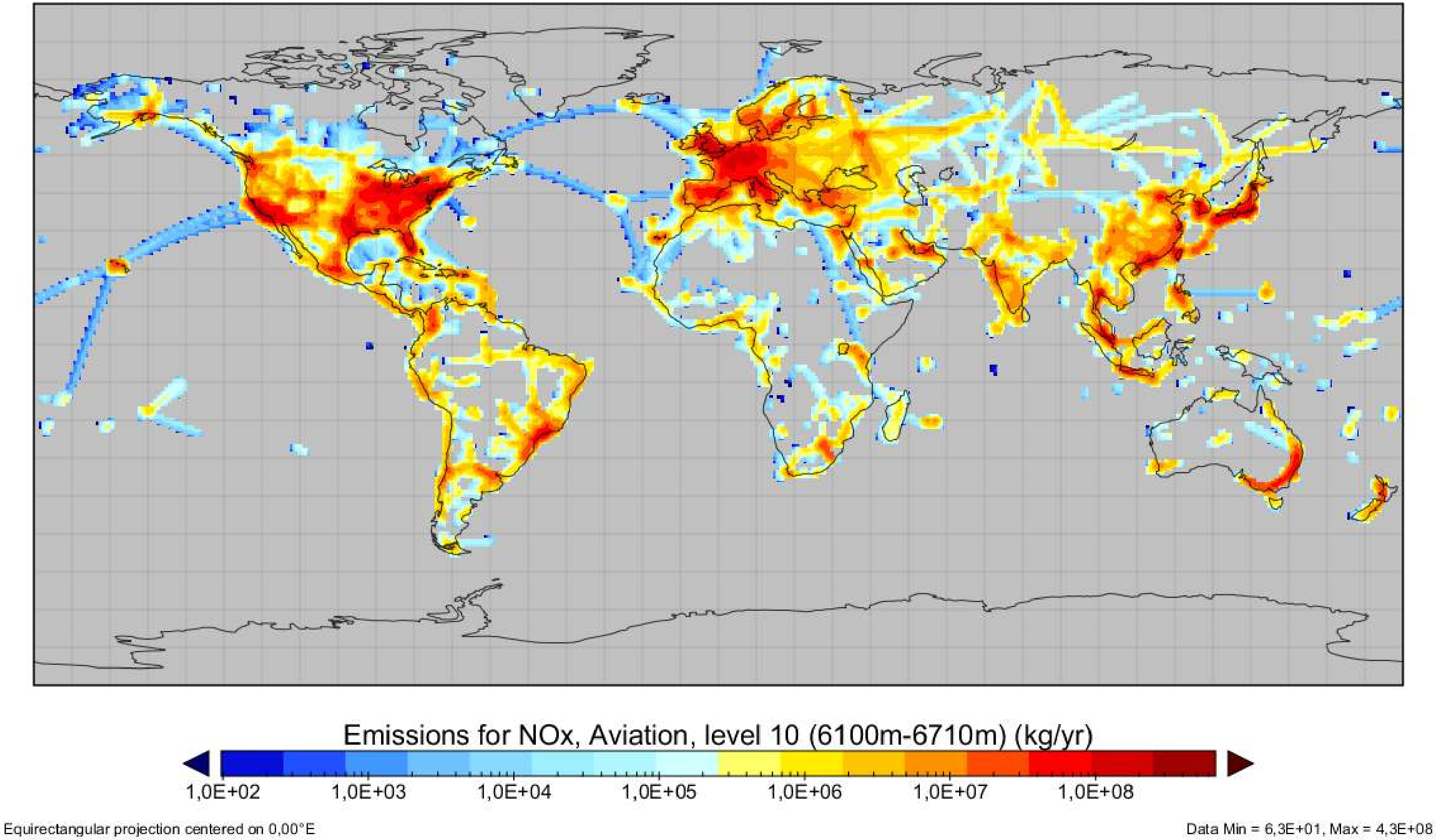


GTP, level 9, 100 years



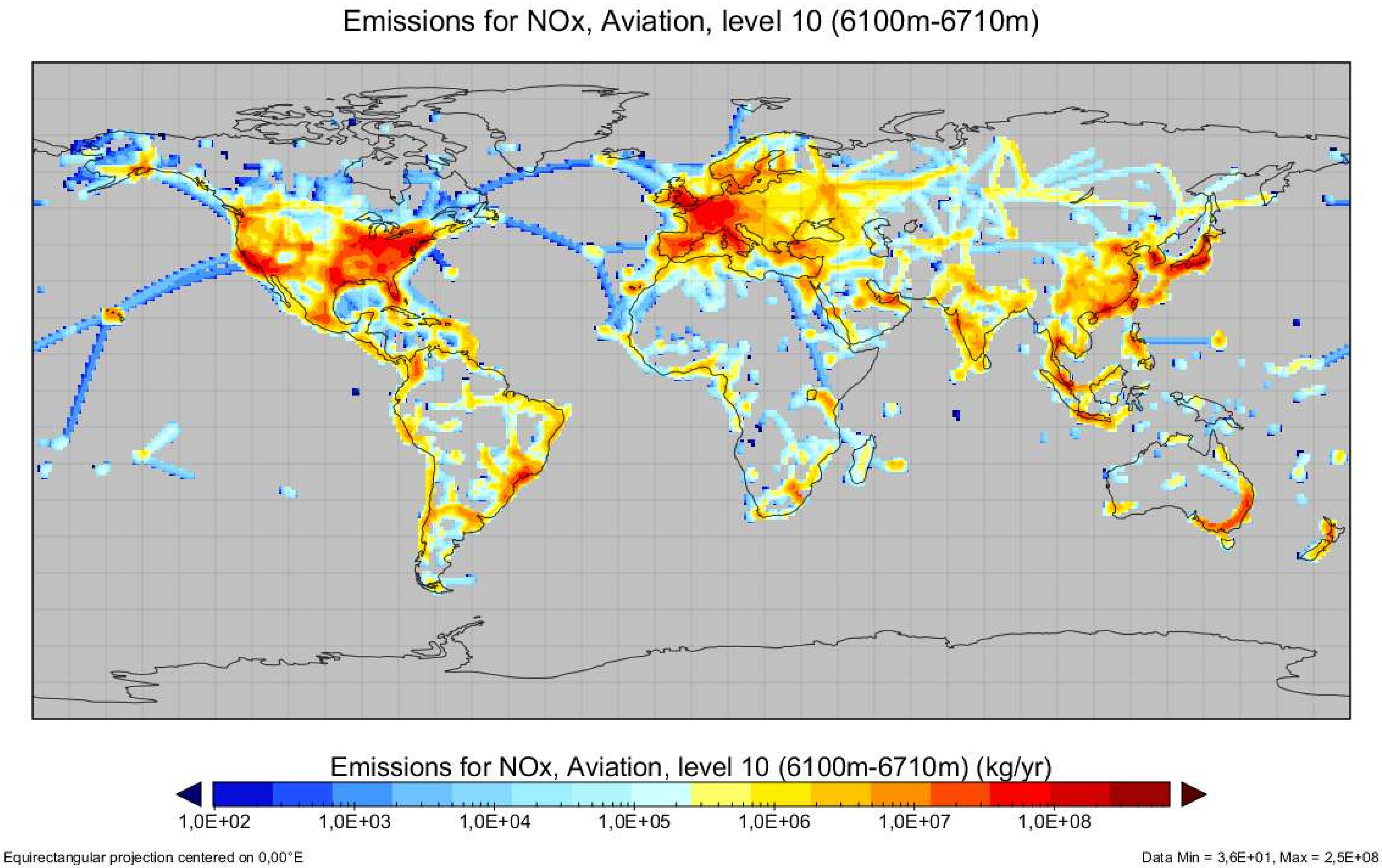
GTP, level 10, 25 years

Emissions for NOx, Aviation, level 10 (6100m-6710m)

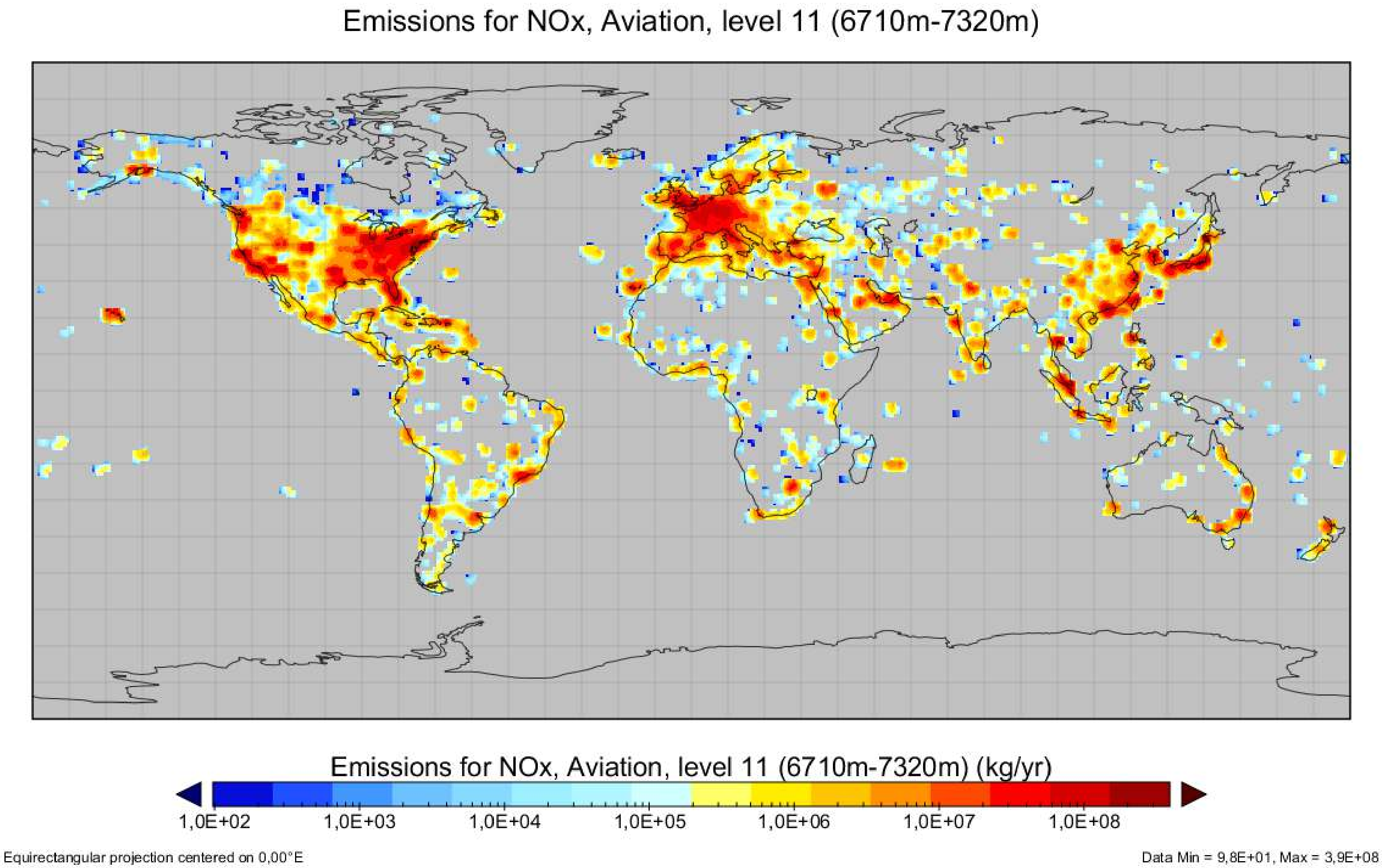


GTP, level 10, 50 years

Quantify Final Meeting, 25-27 January 2010, Munich

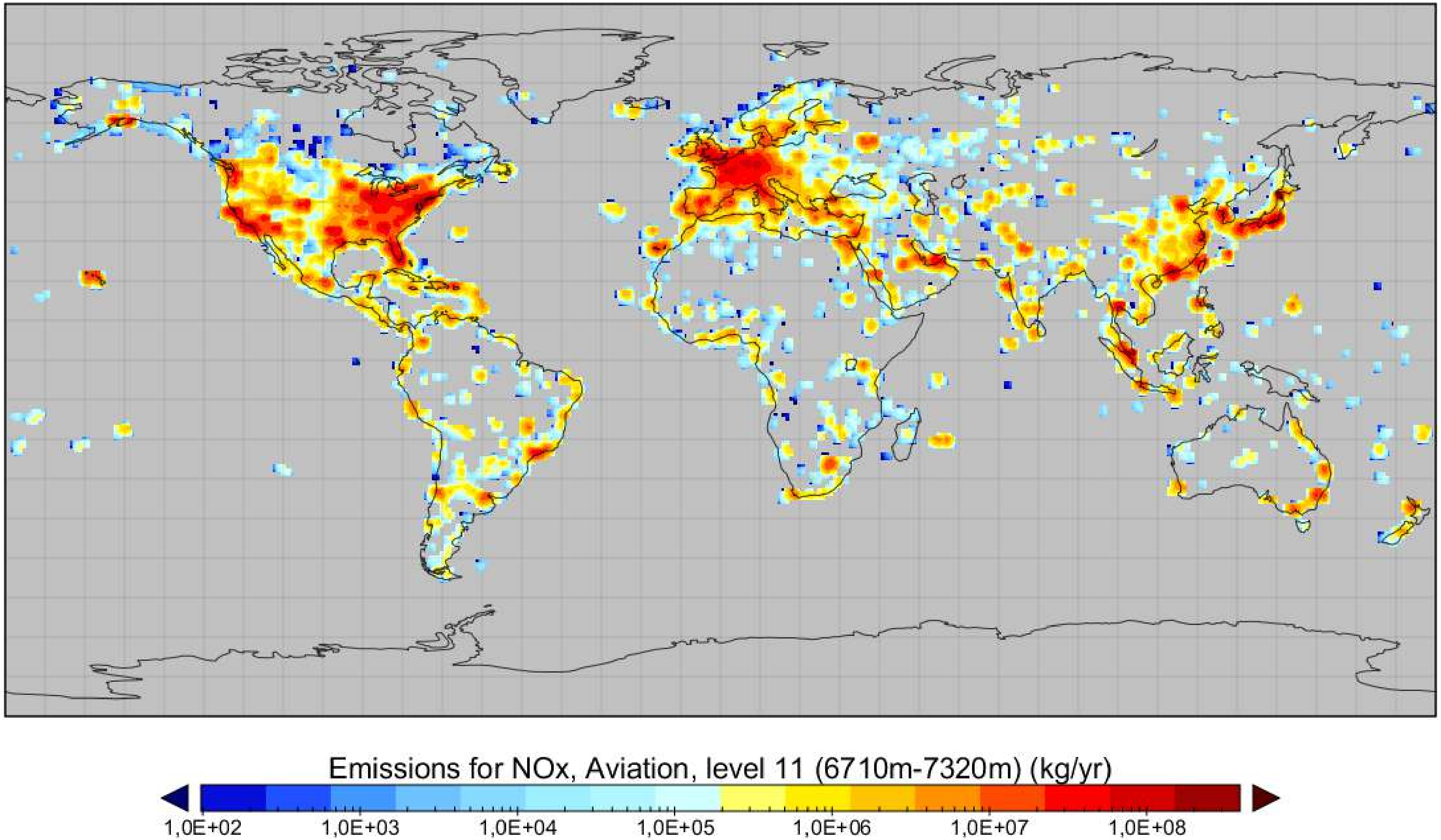


GTP, level 10, 100 years



GTP, level 11, 25 years

Emissions for NOx, Aviation, level 11 (6710m-7320m)

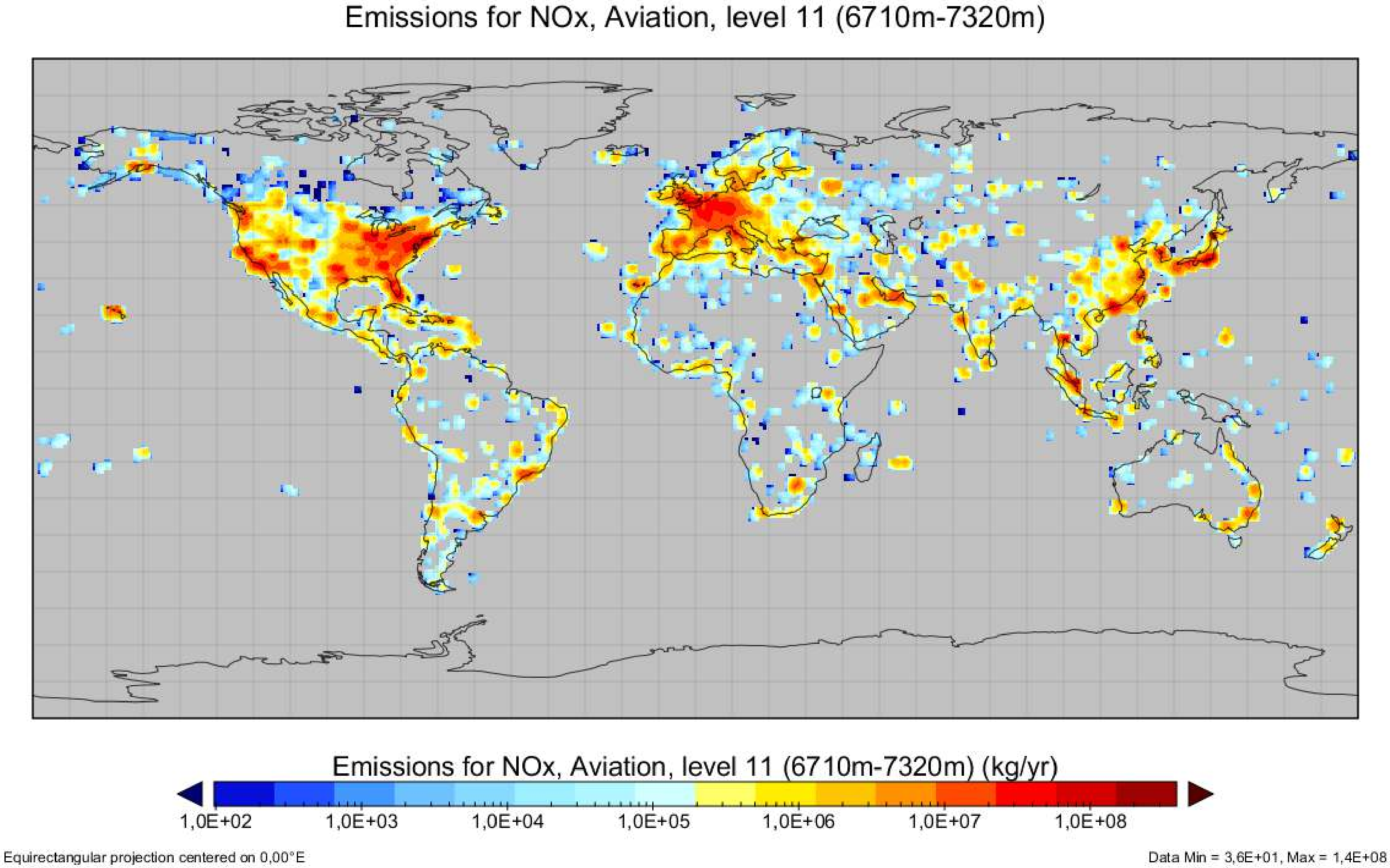


Equirectangular projection centered on 0,00°E

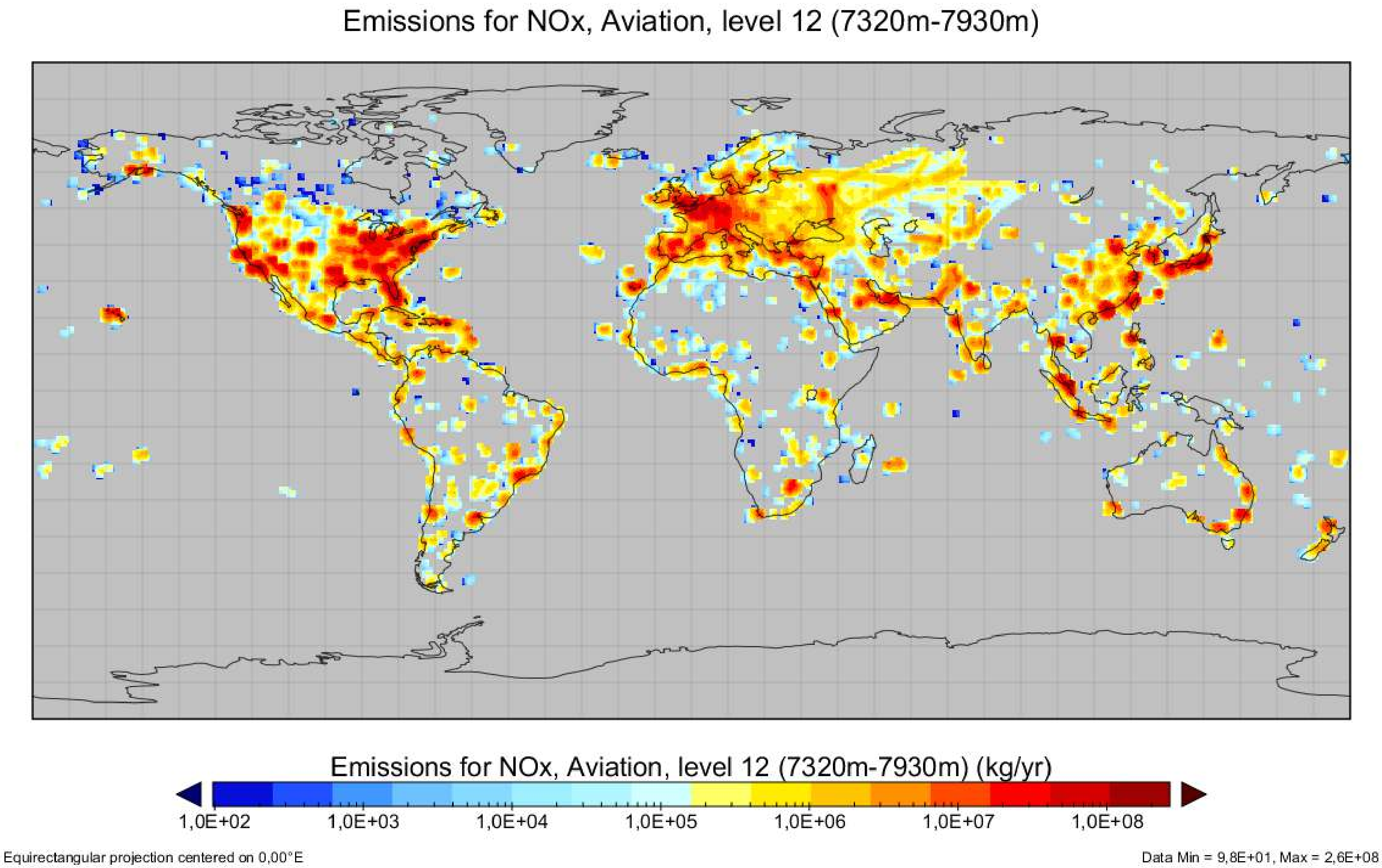
Data Min = 6,3E+01, Max = 2,5E+08

GTP, level 11, 50 years

Quantify Final Meeting, 25-27 January 2010, Munich

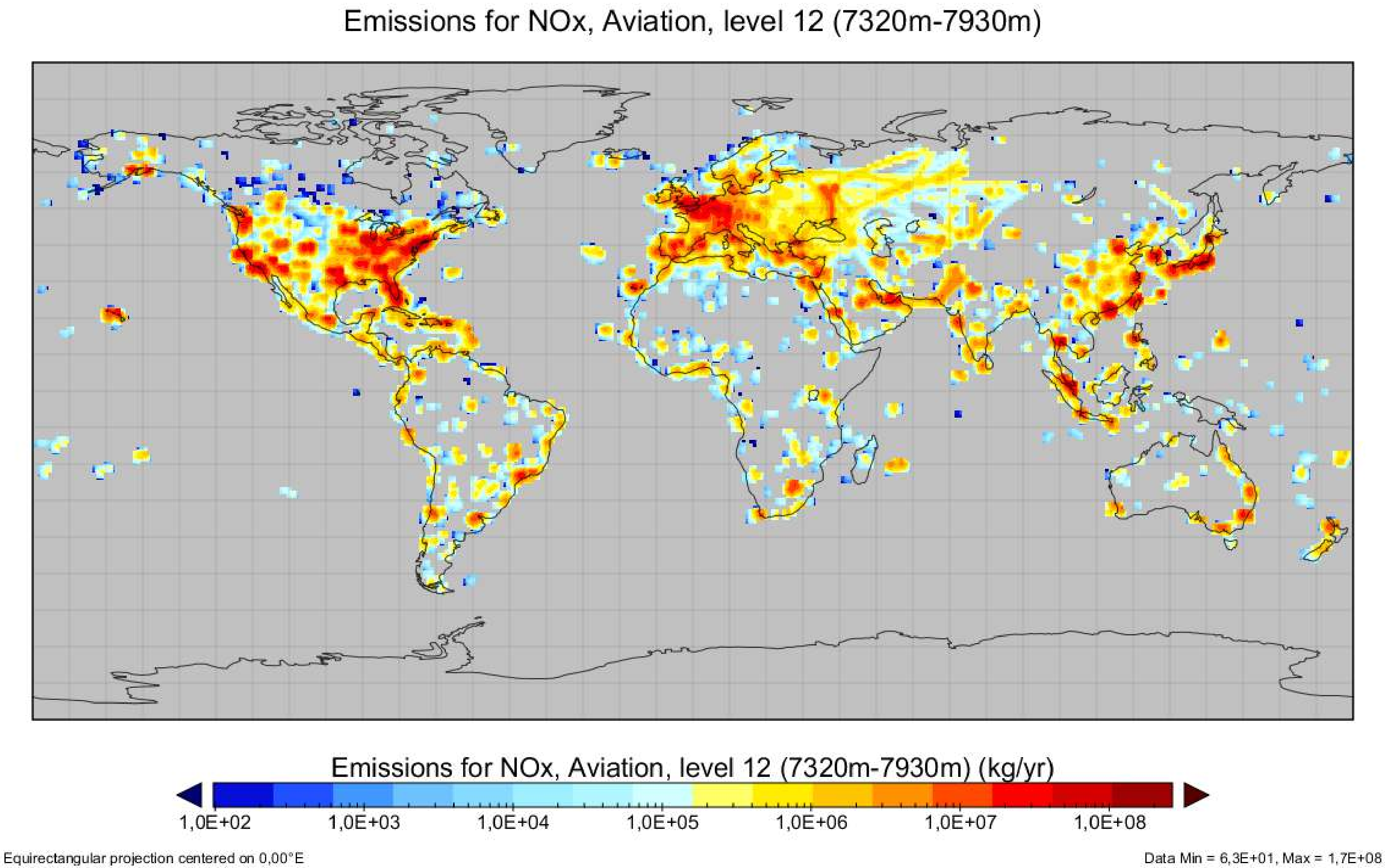


GTP, level 11, 100 years



GTP, level 12, 25 years

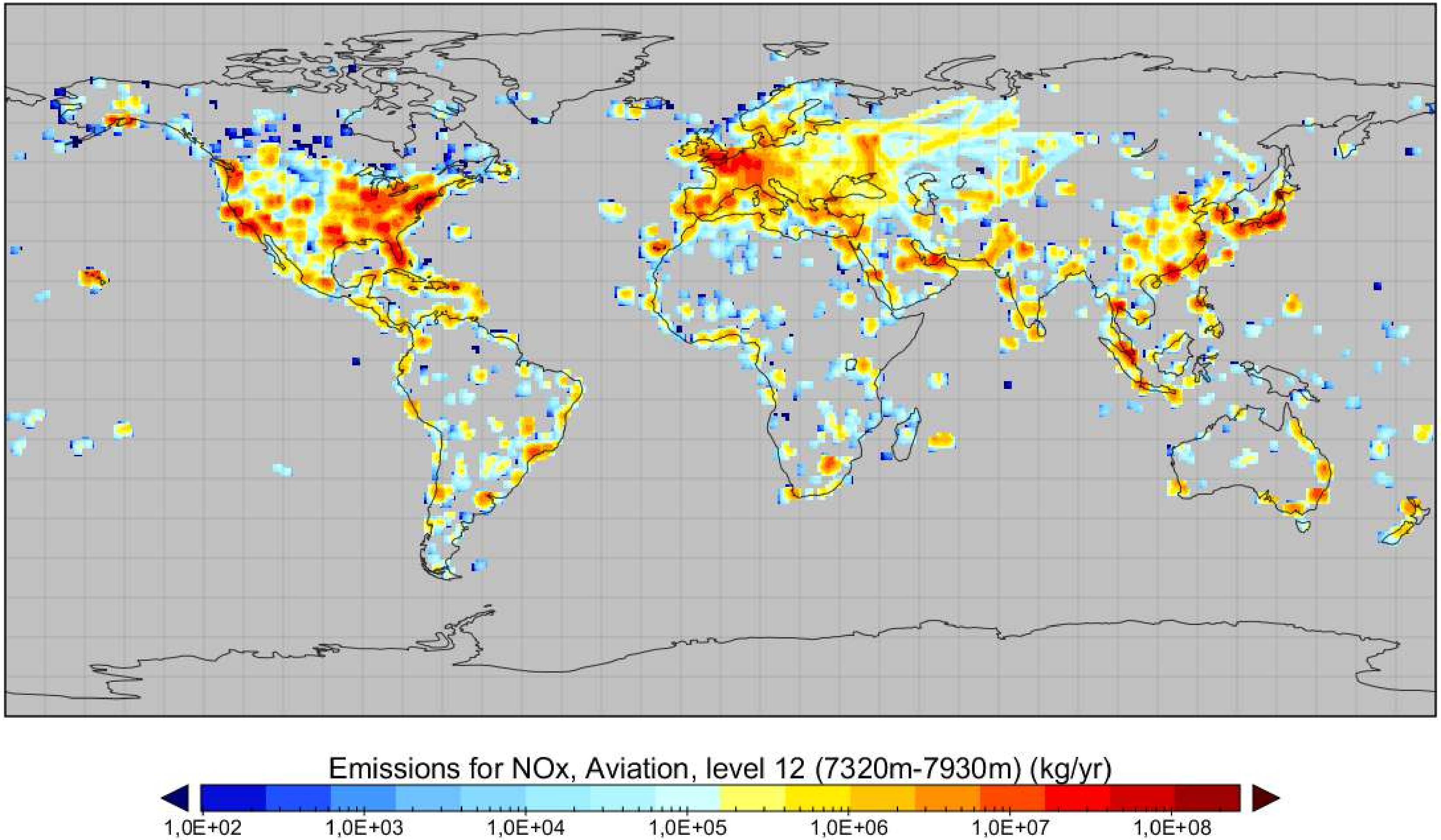
Quantify Final Meeting, 25-27 January 2010, Munich



GTP, level 12, 50 years

Quantify Final Meeting, 25-27 January 2010, Munich

Emissions for NOx, Aviation, level 12 (7320m-7930m)



Equirectangular projection centered on 0,00°E

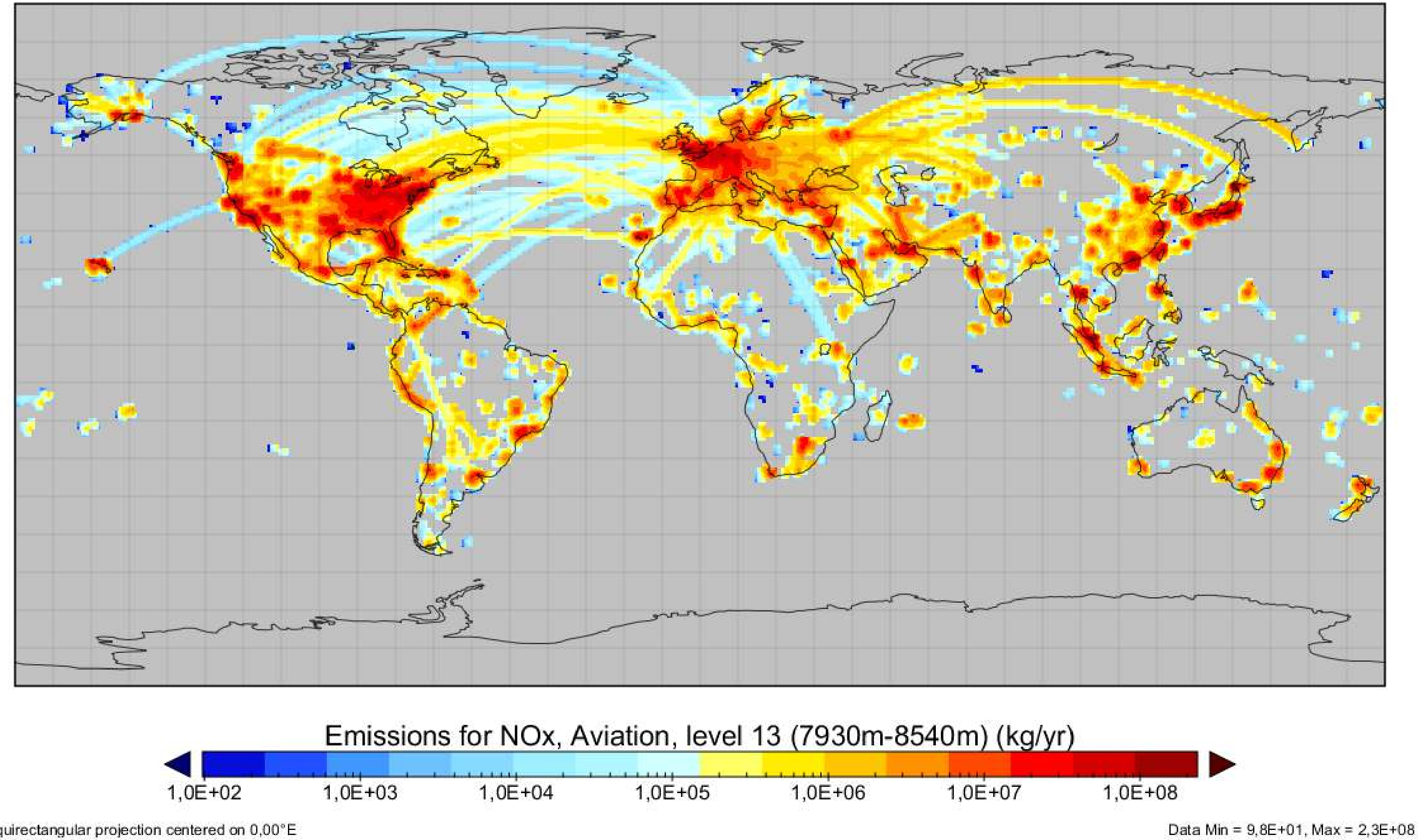
Data Min = 3,6E+01, Max = 9,7E+07

GTP, level 12, 100 years

Quantify Final Meeting, 25-27 January 2010, Munich

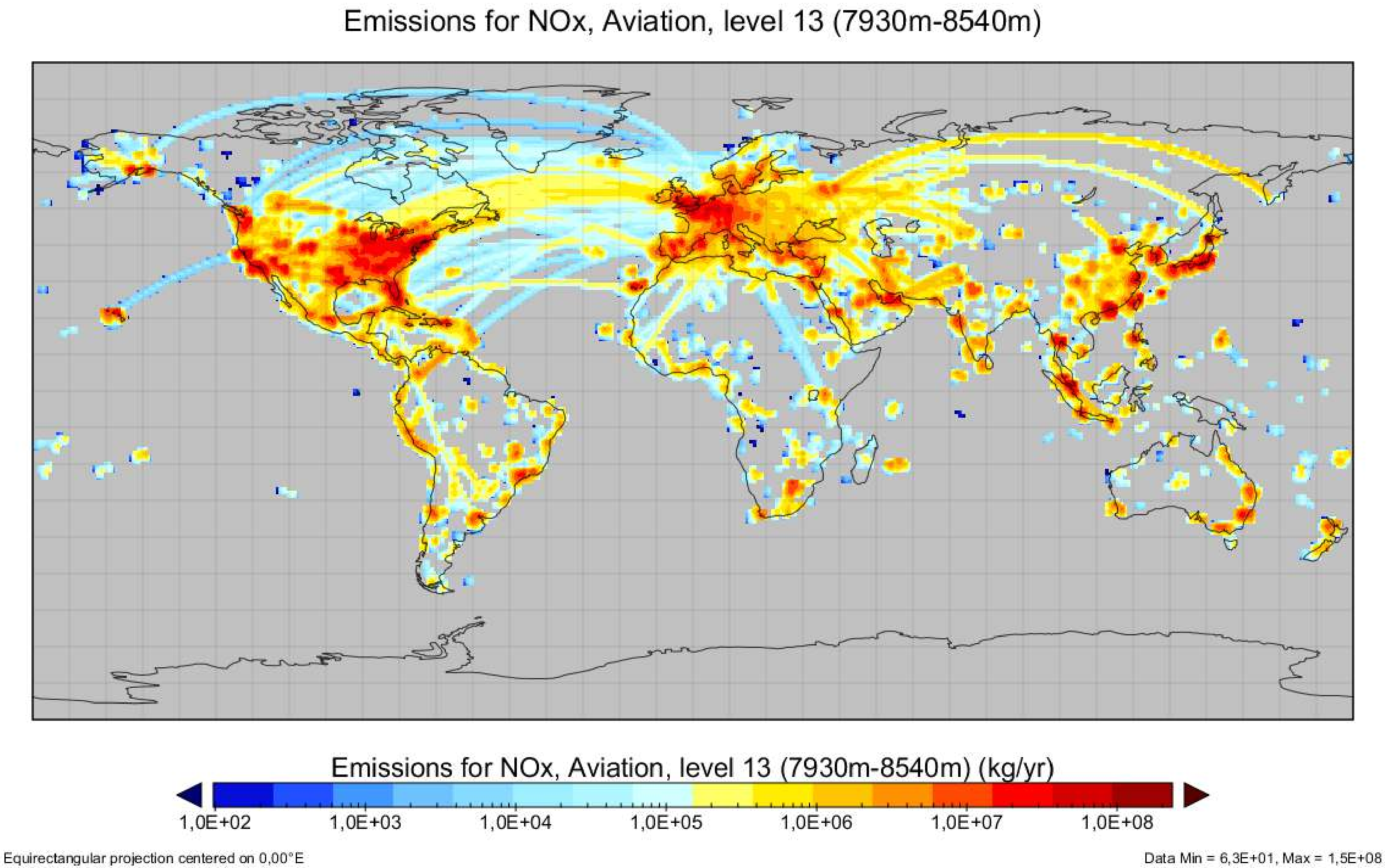
QUANTIFY

Emissions for NOx, Aviation, level 13 (7930m-8540m)



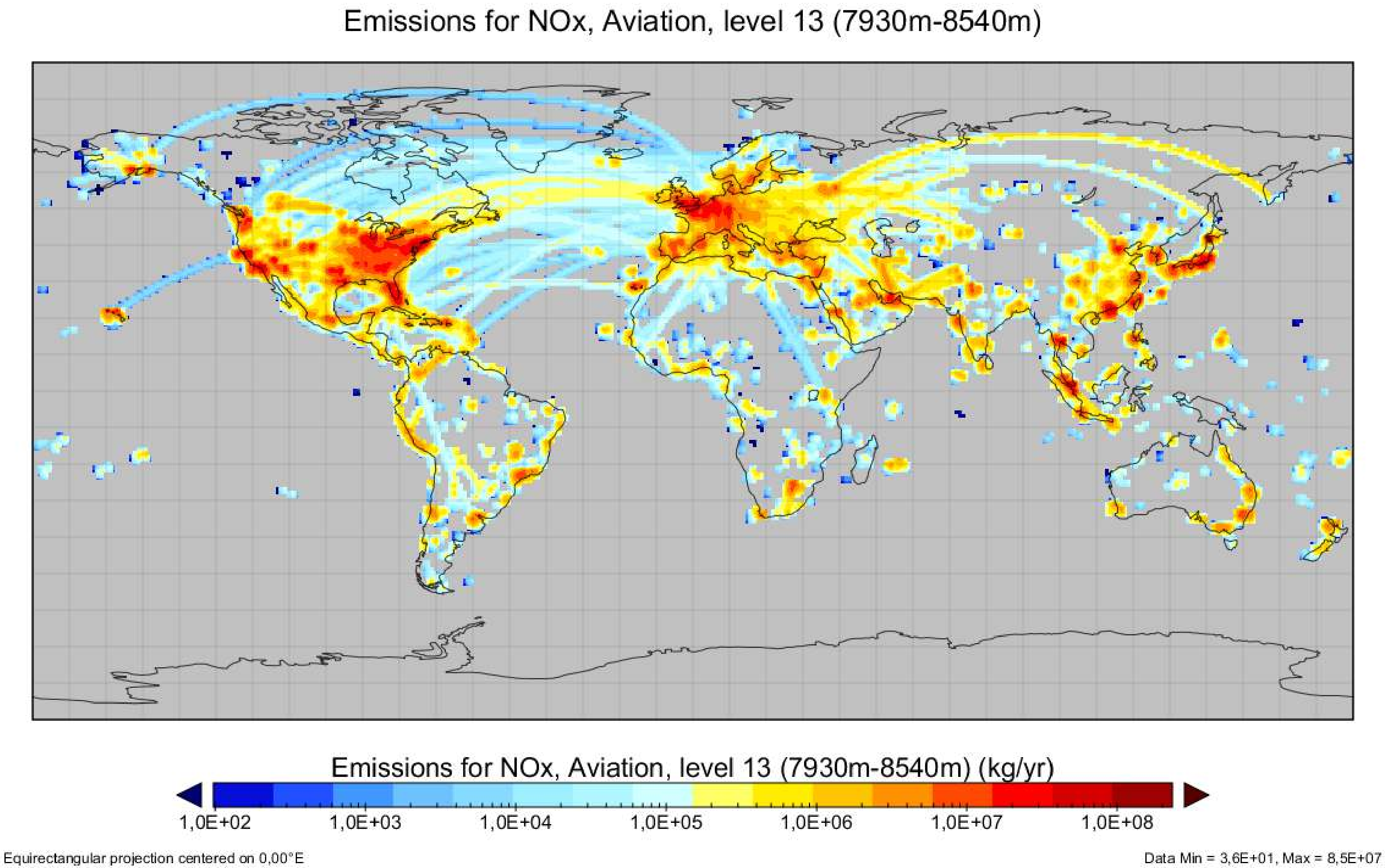
GTP, level 13, 25 years

Quantify Final Meeting, 25-27 January 2010, Munich

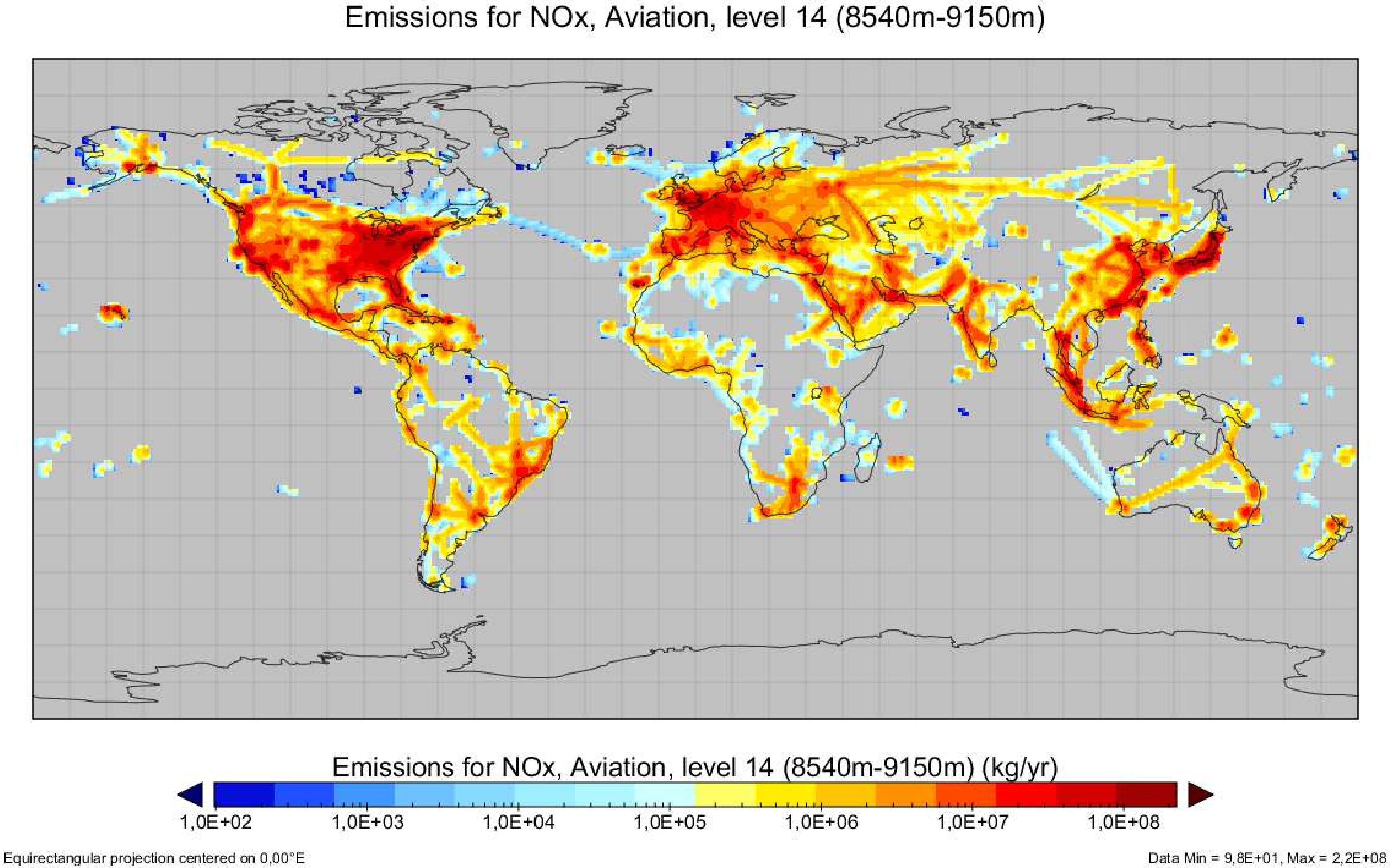


GTP, level 13, 50 years

Quantify Final Meeting, 25-27 January 2010, Munich

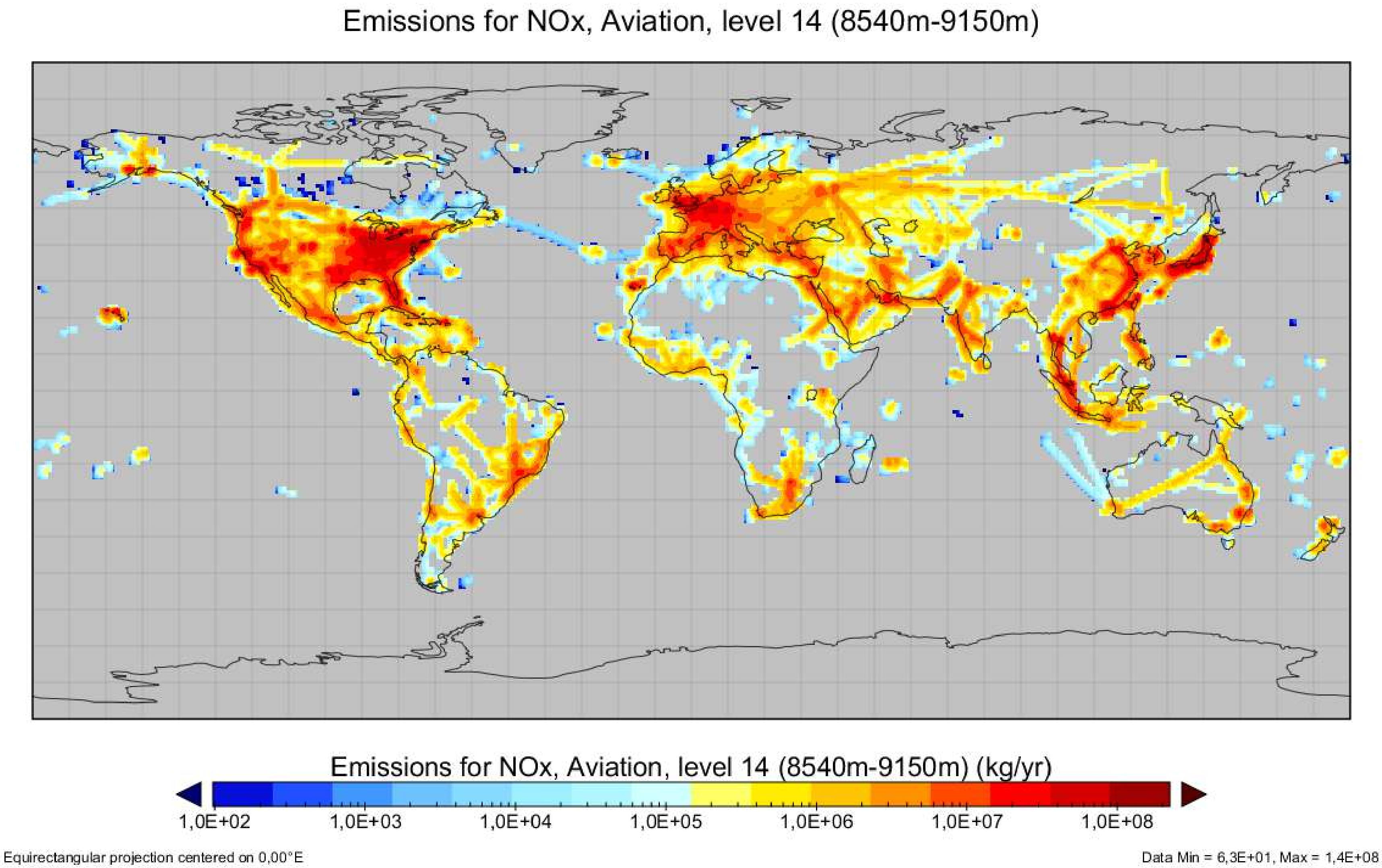


GTP, level 13, 100 years



GTP, level 14, 25 years

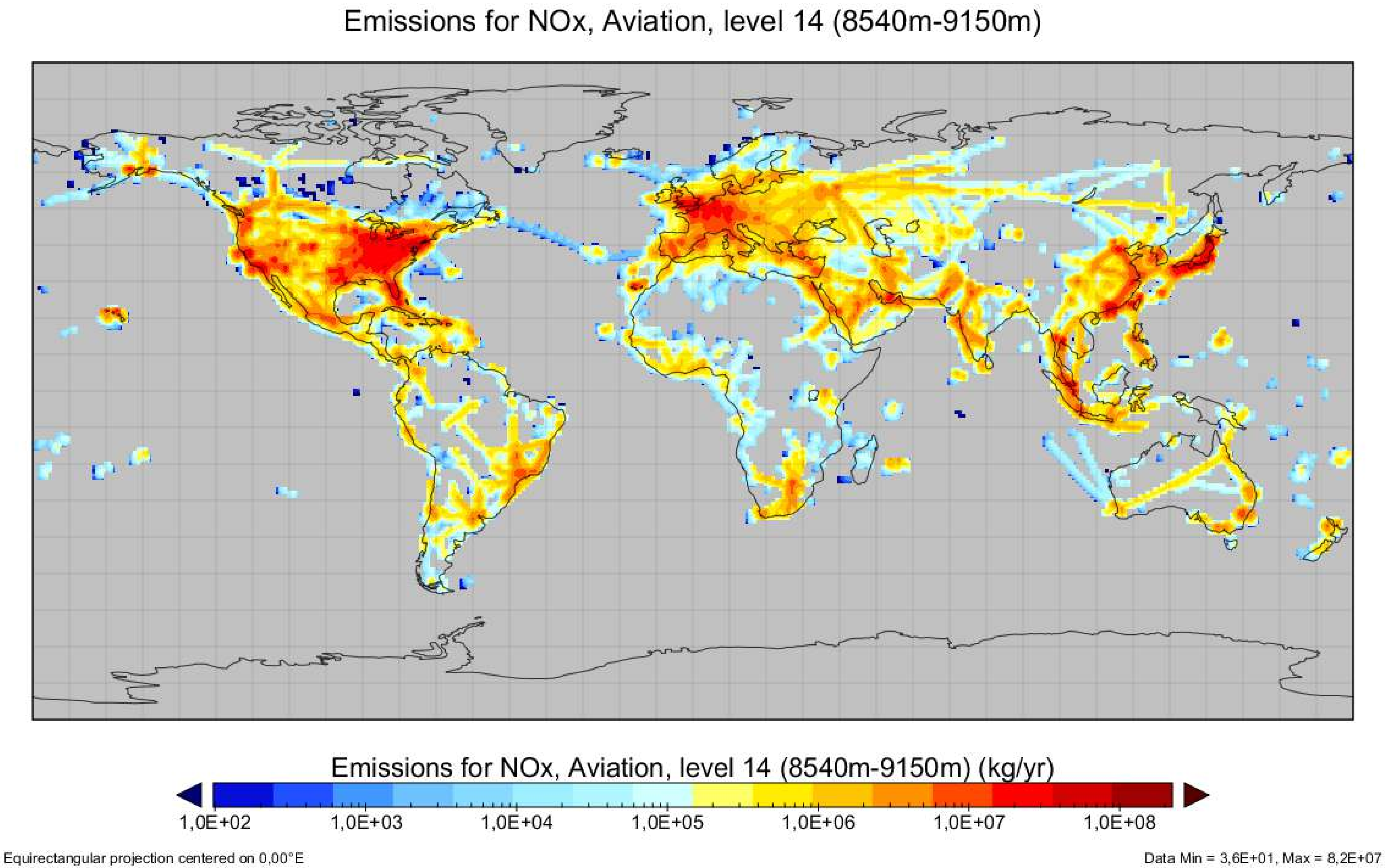
Quantify Final Meeting, 25-27 January 2010, Munich



GTP, level 14, 50 years

Quantify Final Meeting, 25-27 January 2010, Munich

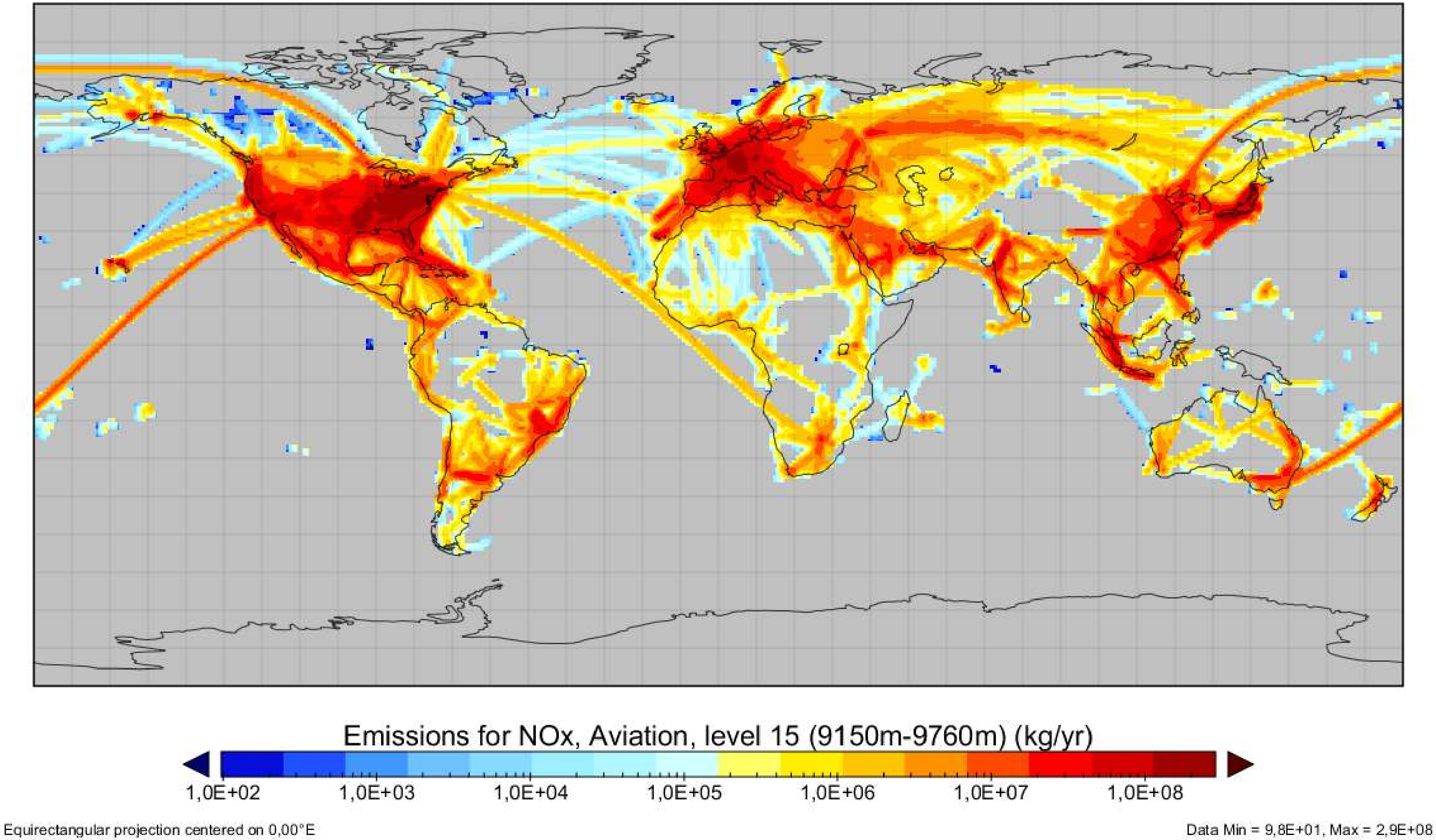
QUANTIFY



GTP, level 14, 100 years

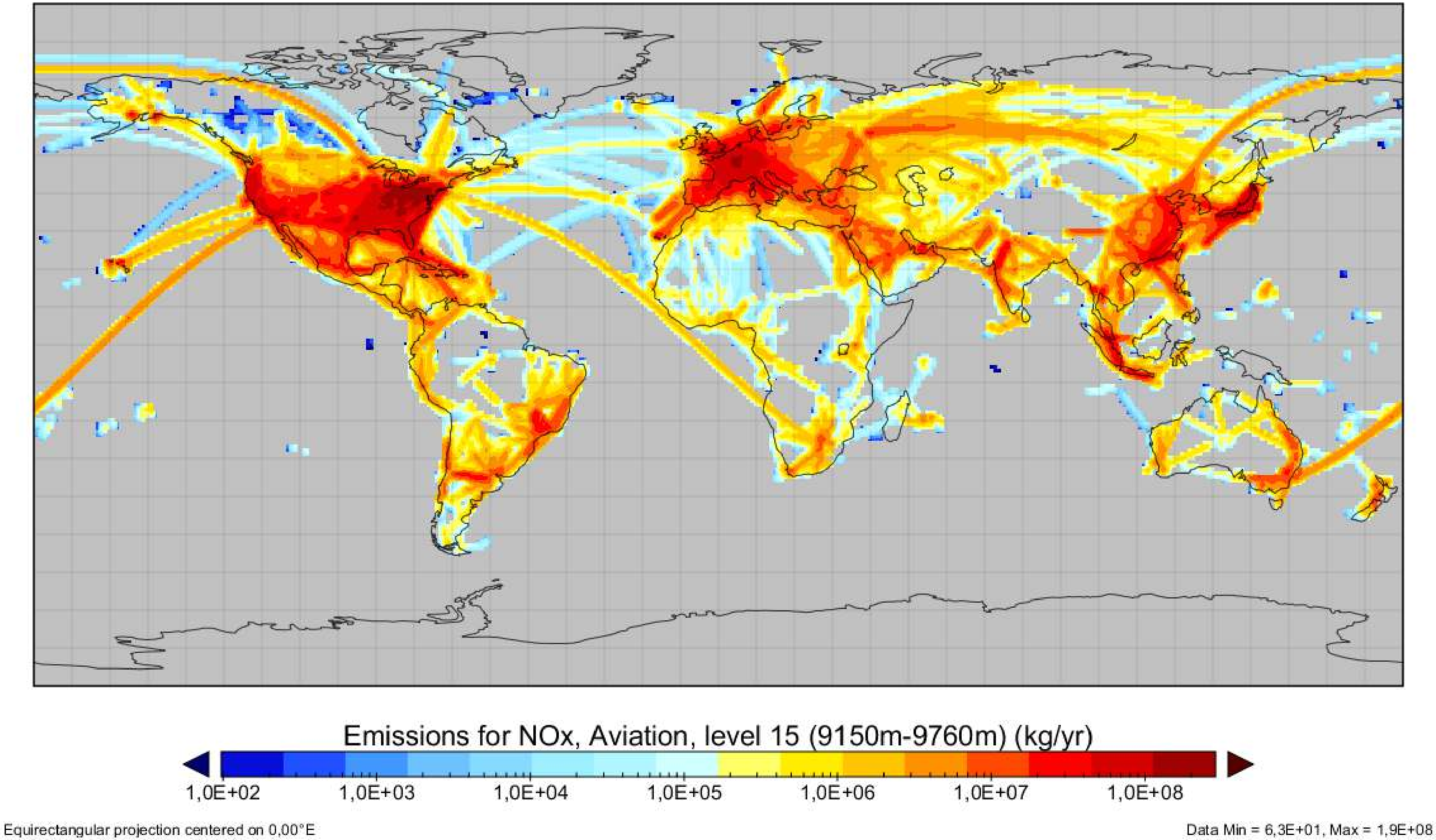
Quantify Final Meeting, 25-27 January 2010, Munich

Emissions for NOx, Aviation, level 15 (9150m-9760m)



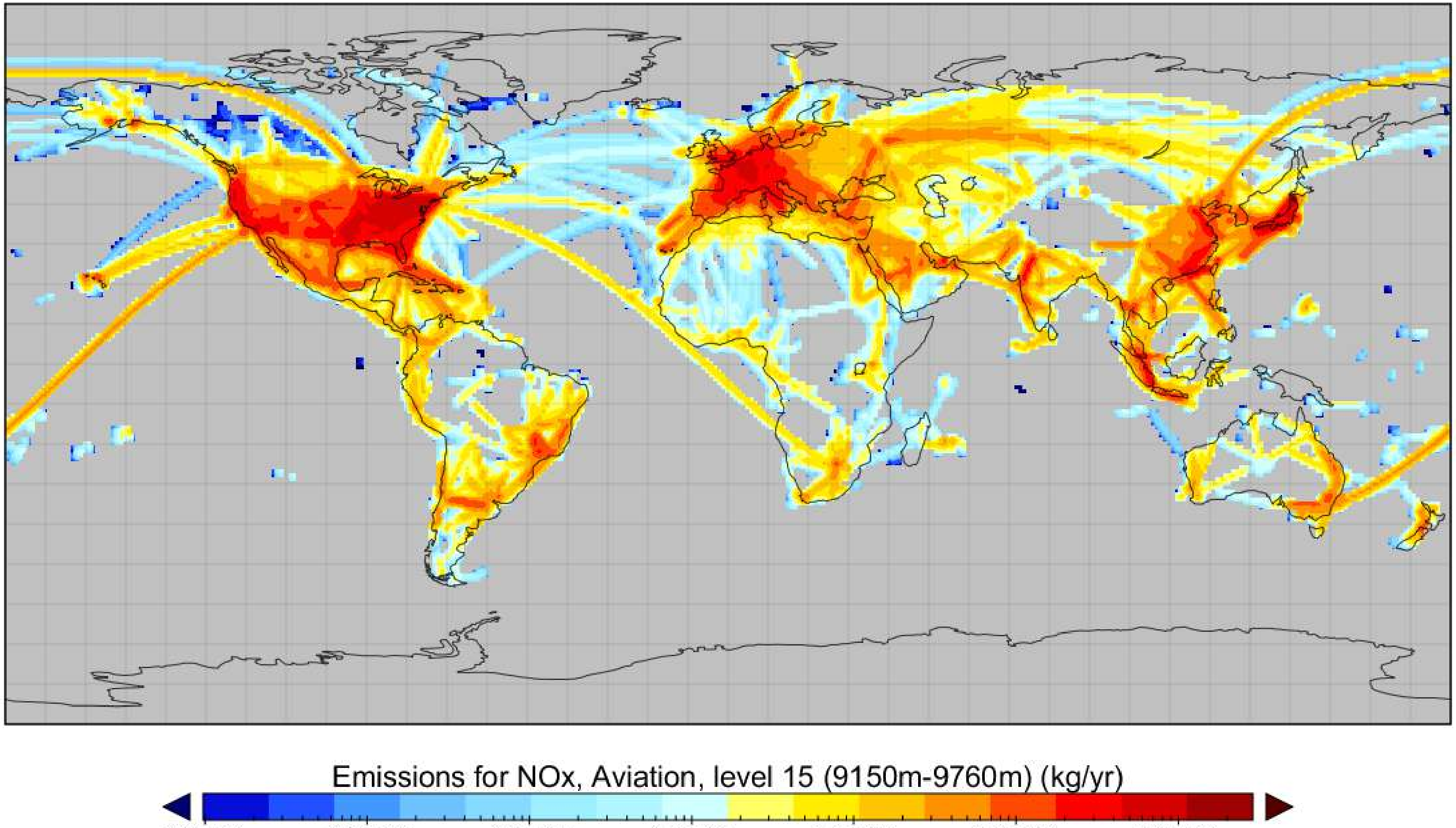
GTP, level 15, 25 years

Emissions for NOx, Aviation, level 15 (9150m-9760m)



GTP, level 15, 50 years

Emissions for NOx, Aviation, level 15 (9150m-9760m)



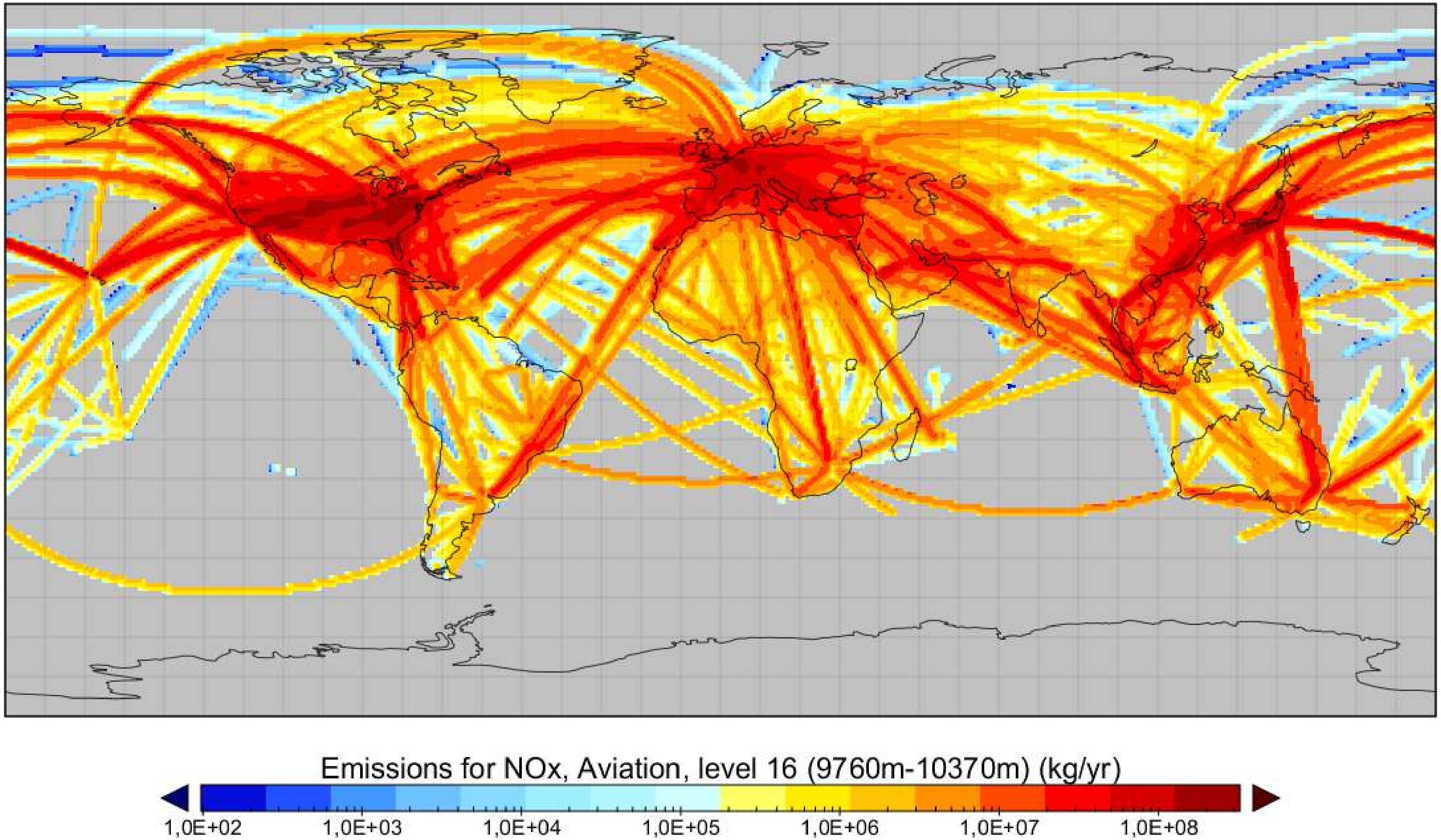
Equirectangular projection centered on 0,00°E

Data Min = 3,6E+01, Max = 1,1E+08

GTP, level 15, 100 years

Quantify Final Meeting, 25-27 January 2010, Munich

Emissions for NOx, Aviation, level 16 (9760m-10370m)



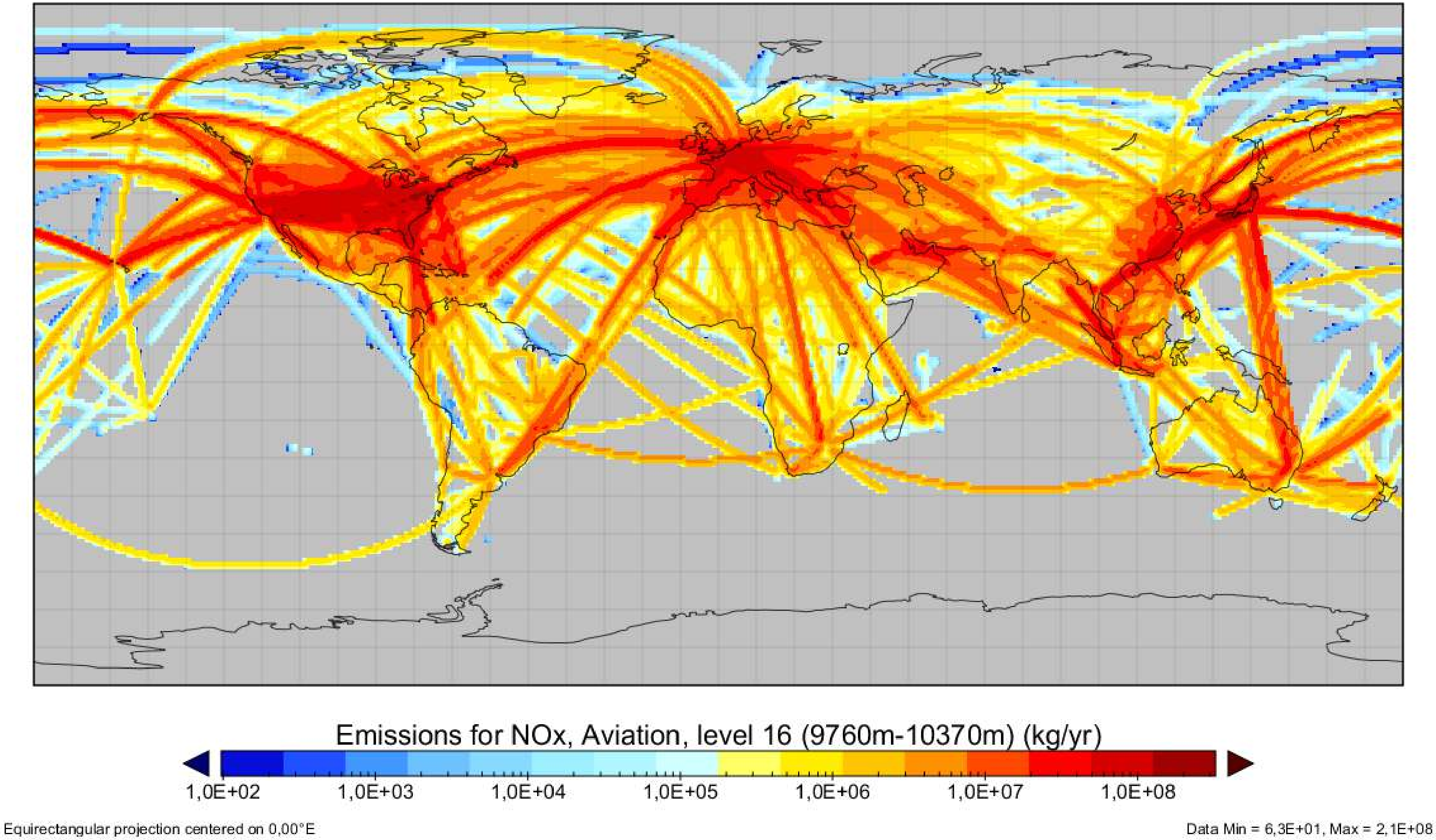
Equirectangular projection centered on 0,00°E

Data Min = 9,8E+01, Max = 3,2E+08

GTP, level 16, 25 years

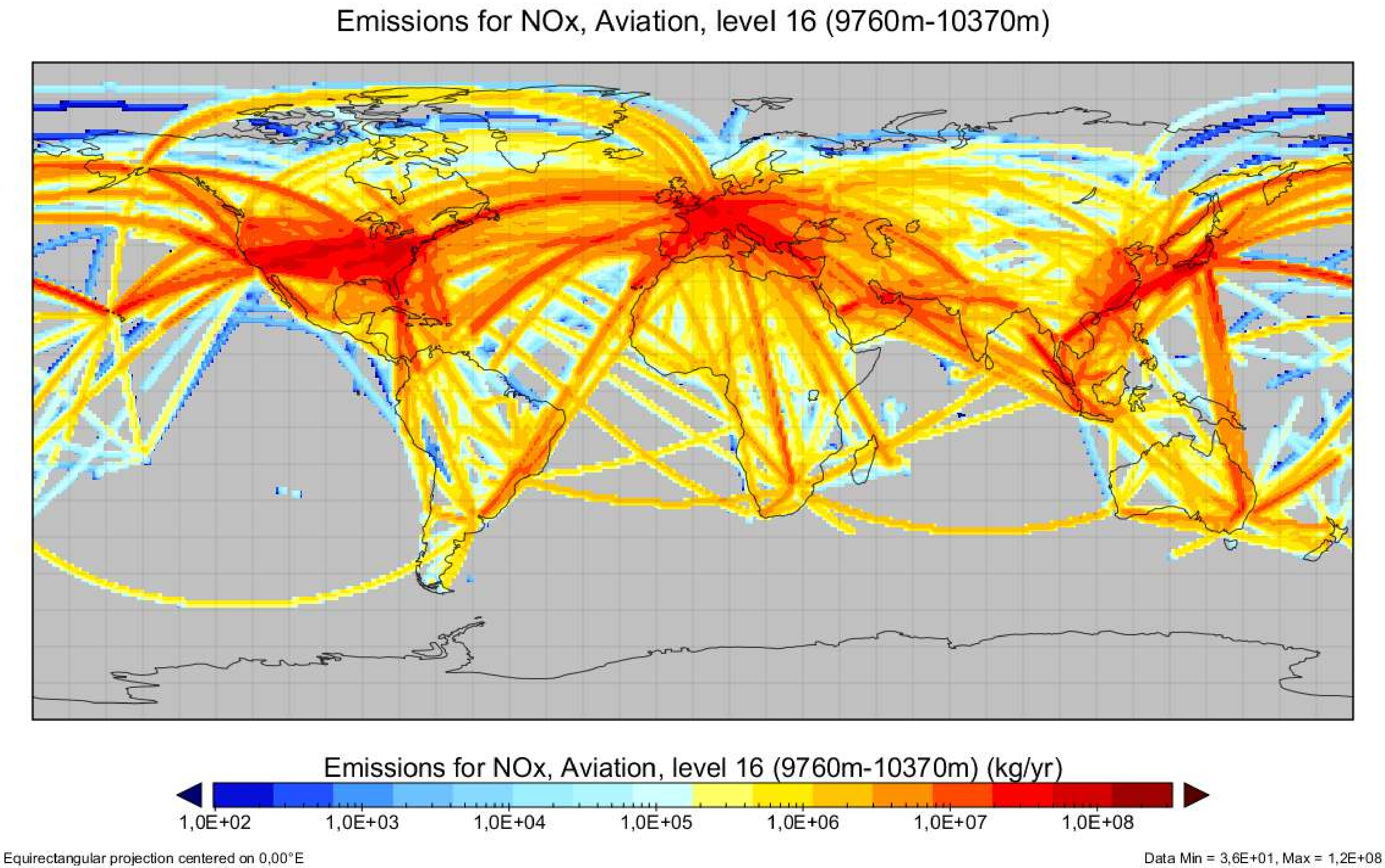
Quantify Final Meeting, 25-27 January 2010, Munich

Emissions for NOx, Aviation, level 16 (9760m-10370m)



GTP, level 16, 50 years

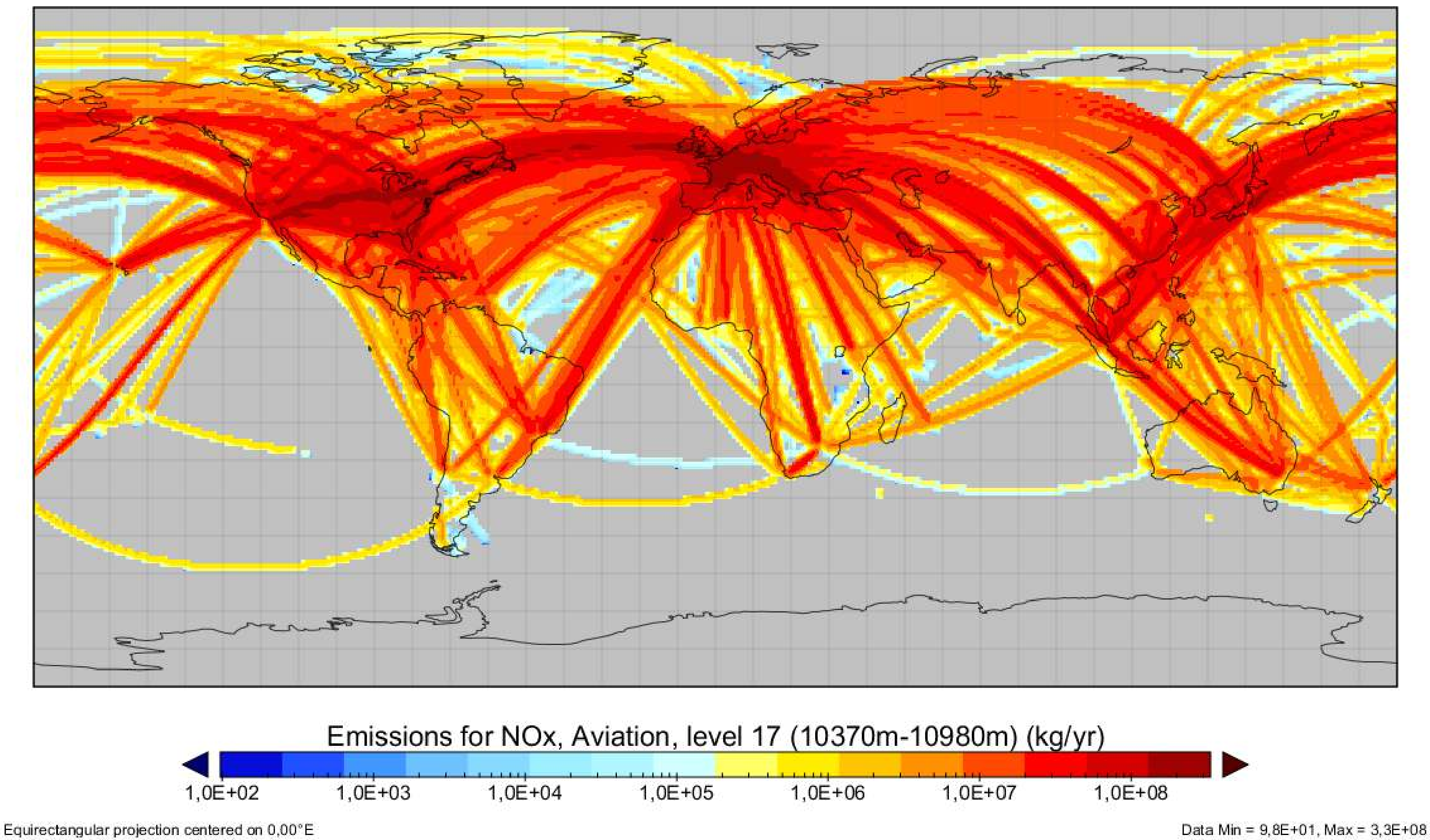
Quantify Final Meeting, 25-27 January 2010, Munich



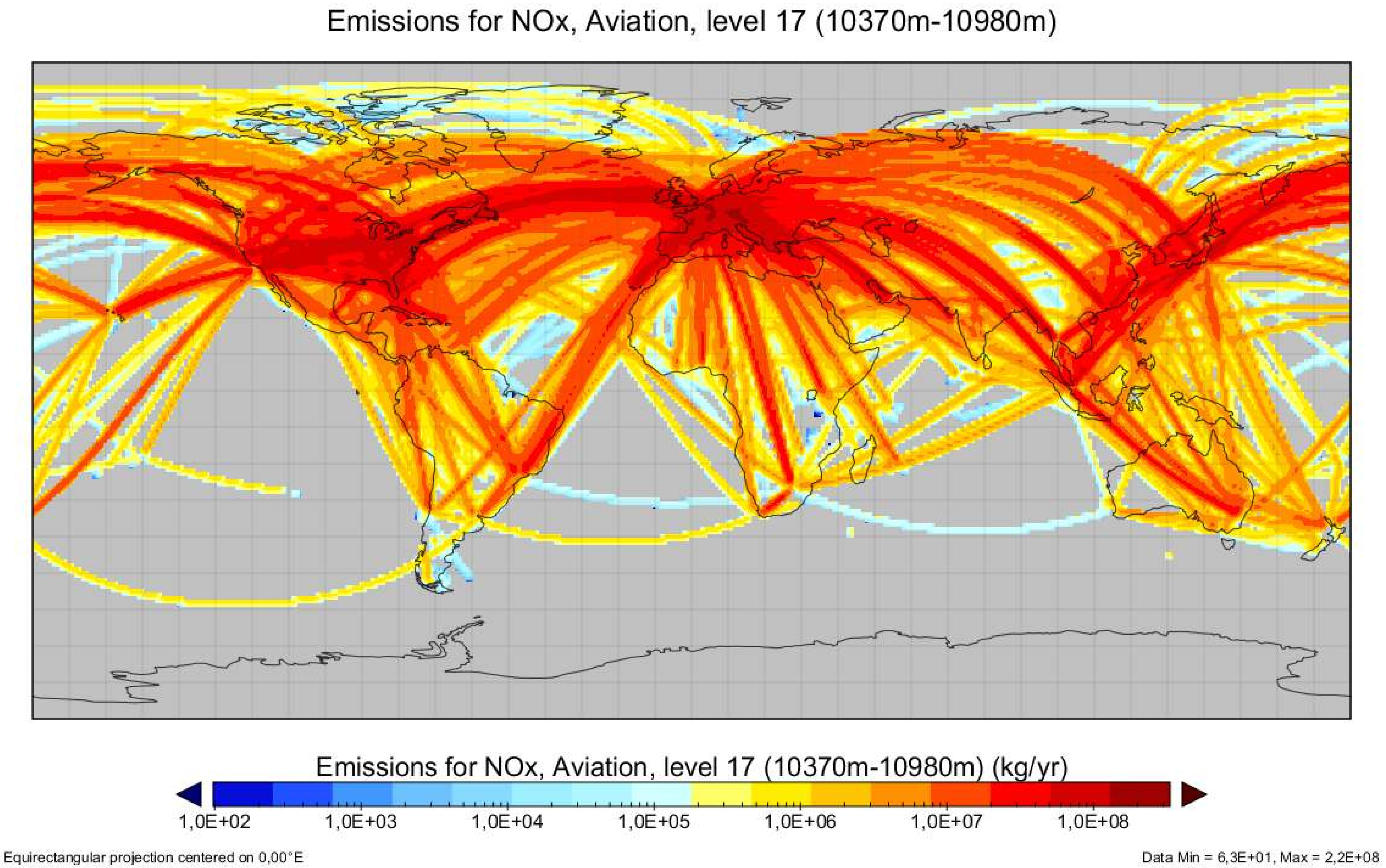
GTP, level 16, 100 years

Quantify Final Meeting, 25-27 January 2010, Munich

Emissions for NOx, Aviation, level 17 (10370m-10980m)



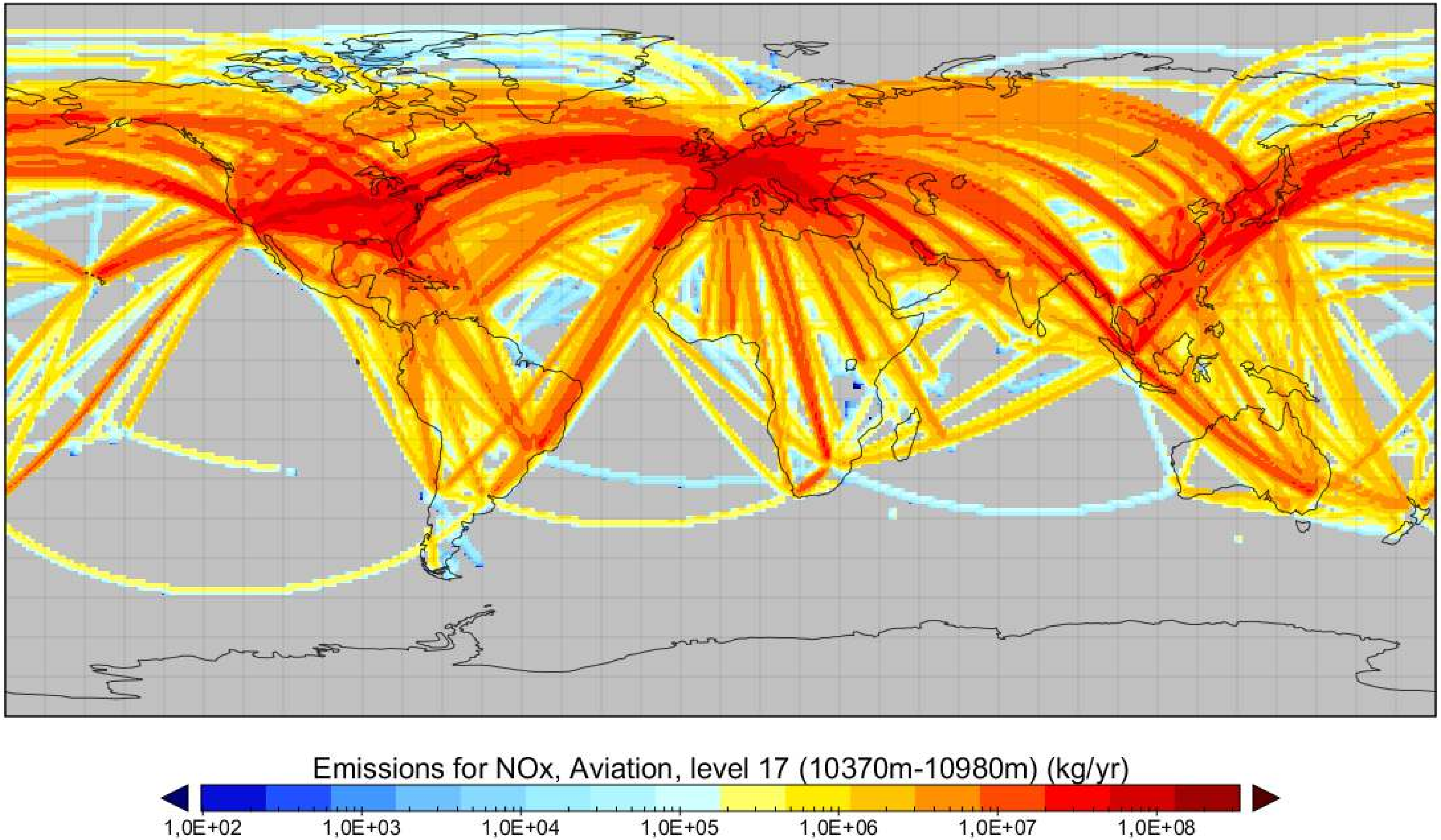
GTP, level 17, 25 years



GTP, level 17, 50 years

Quantify Final Meeting, 25-27 January 2010, Munich

Emissions for NOx, Aviation, level 17 (10370m-10980m)

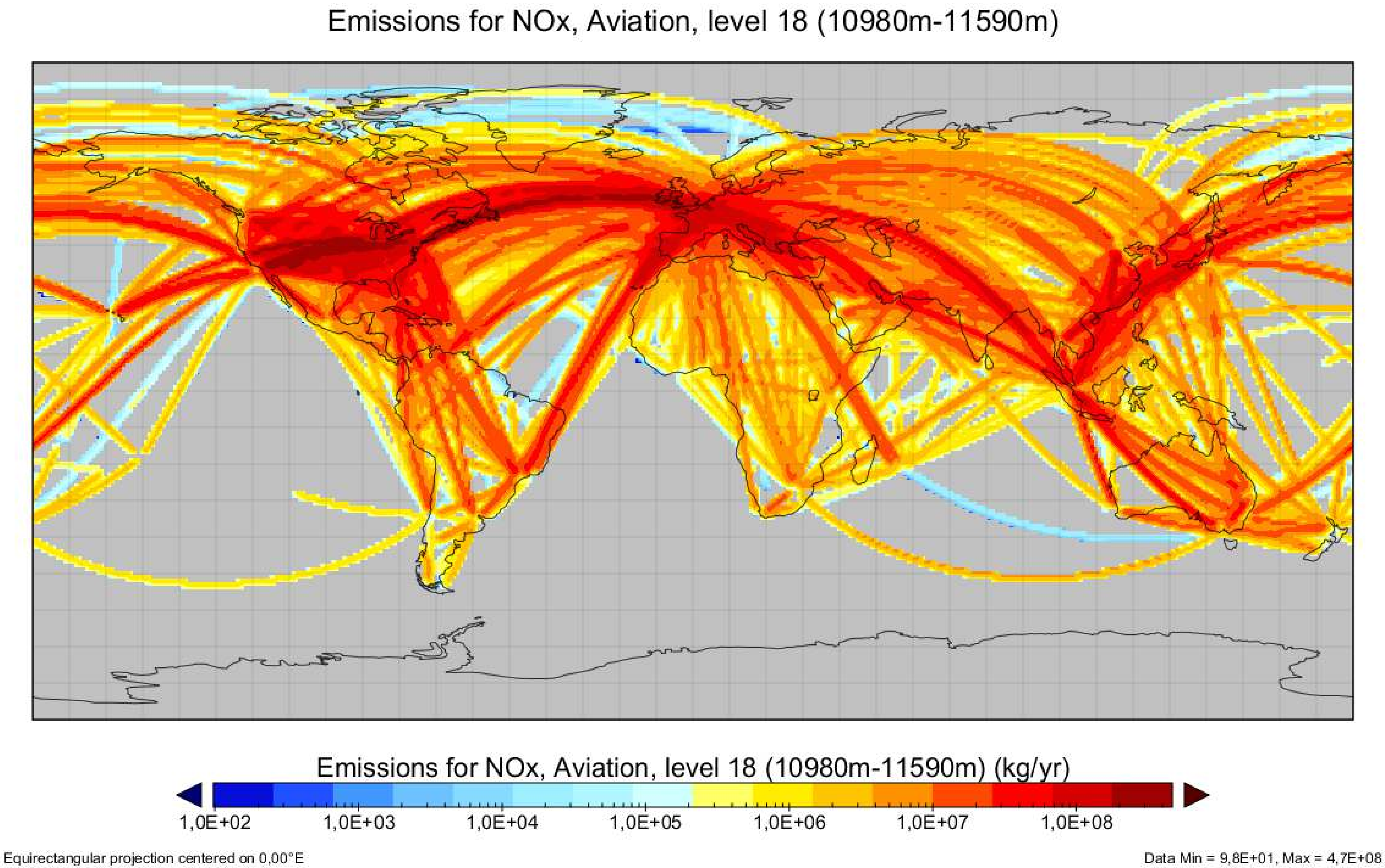


Equirectangular projection centered on 0,00°E

Data Min = 3,6E+01, Max = 1,2E+08

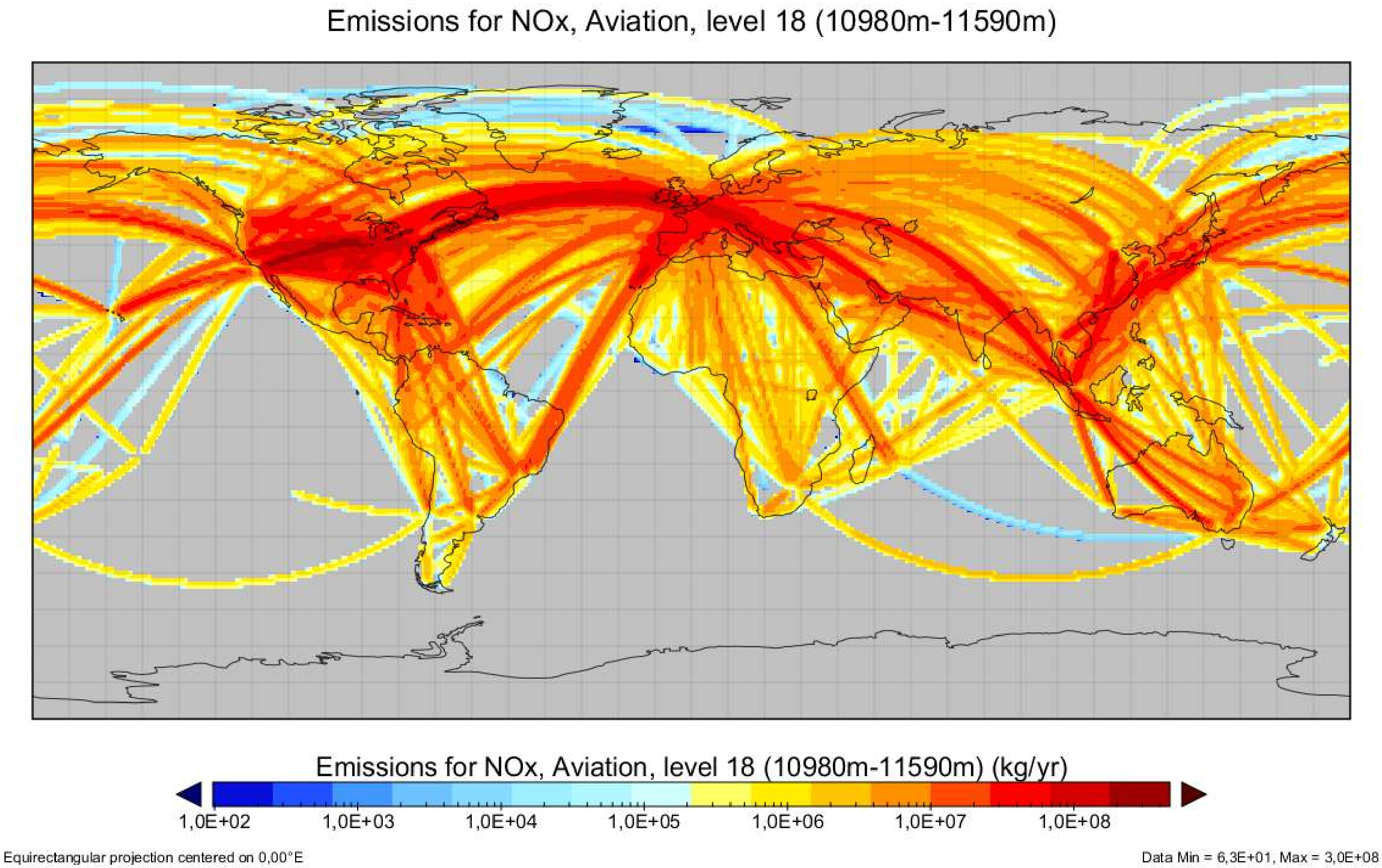
GTP, level 17, 100 years

Quantify Final Meeting, 25-27 January 2010, Munich



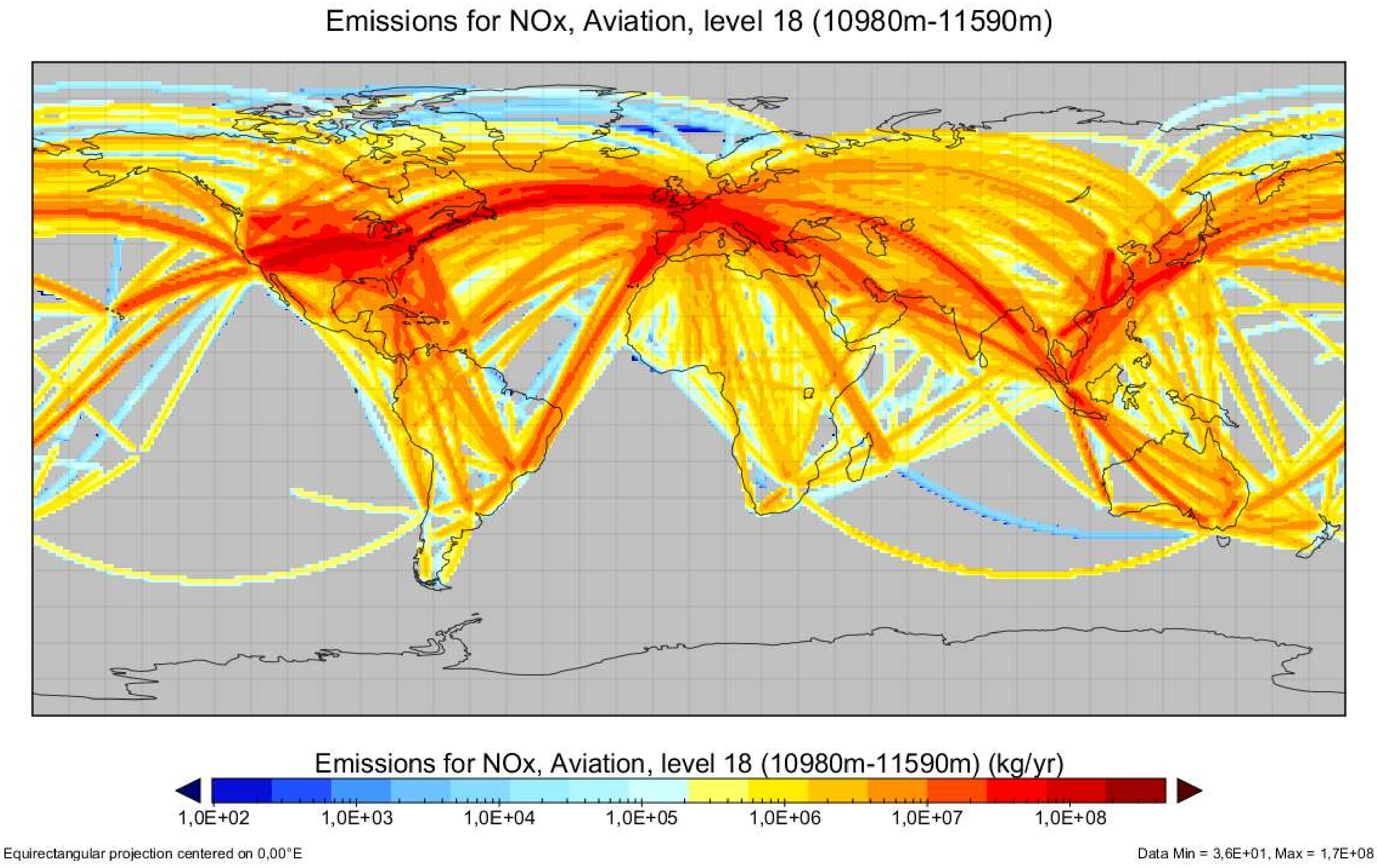
GTP, level 18, 25 years

Quantify Final Meeting, 25-27 January 2010, Munich



GTP, level 18, 50 years

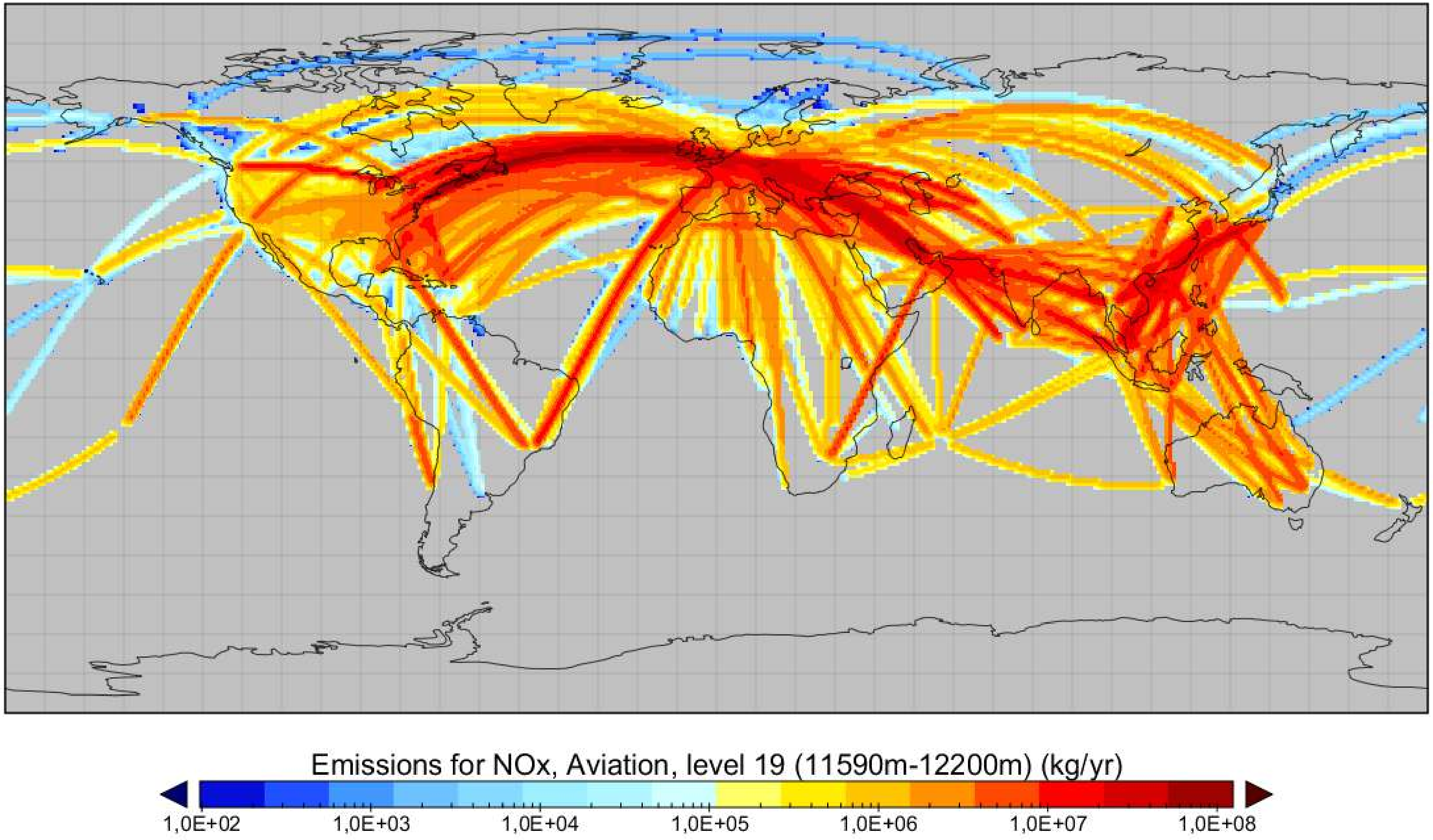
Quantify Final Meeting, 25-27 January 2010, Munich



GTP, level 18, 100 years

Quantify Final Meeting, 25-27 January 2010, Munich

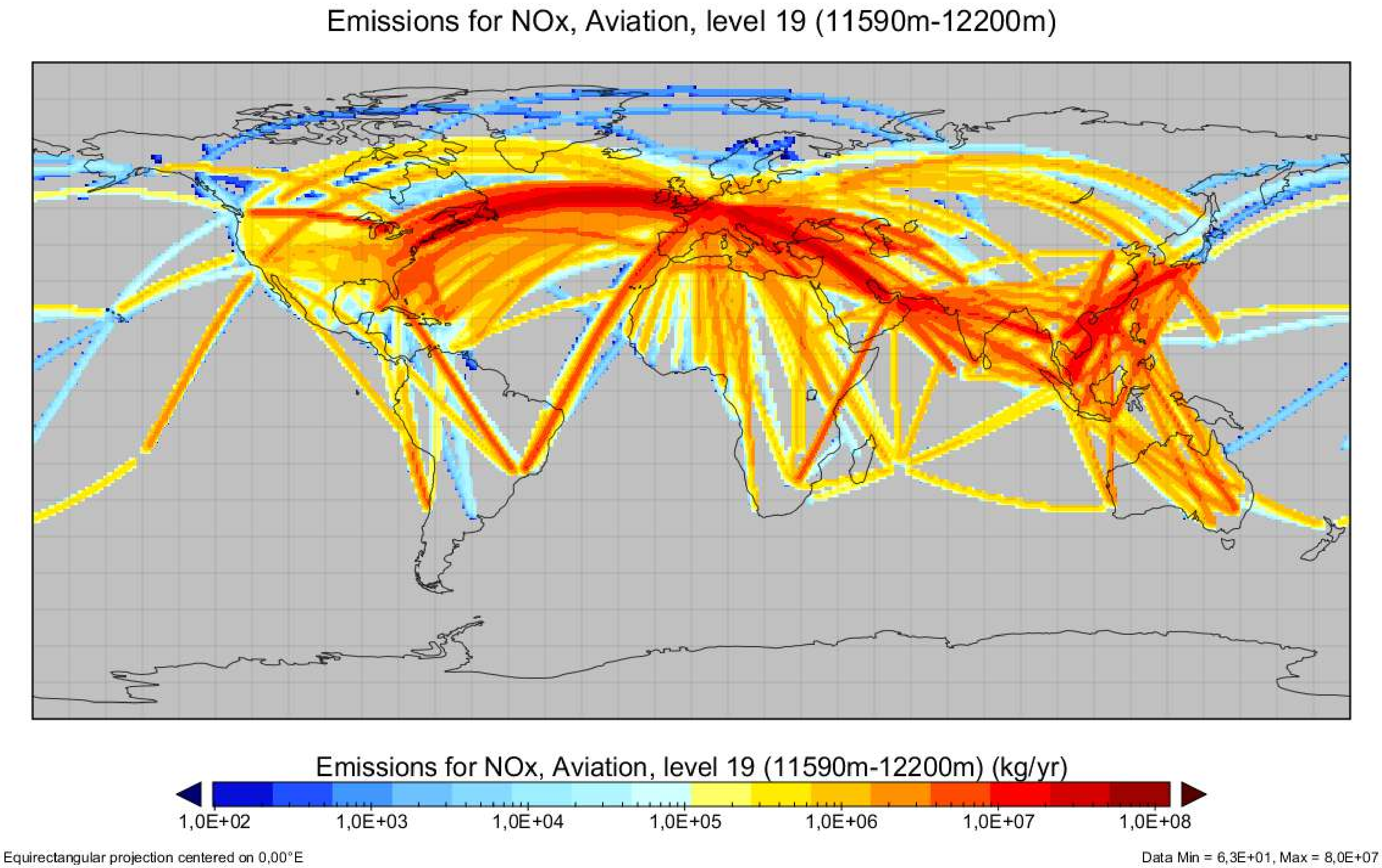
Emissions for NOx, Aviation, level 19 (11590m-12200m)



Equirectangular projection centered on 0,00°E

Data Min = 9,8E+01, Max = 1,2E+08

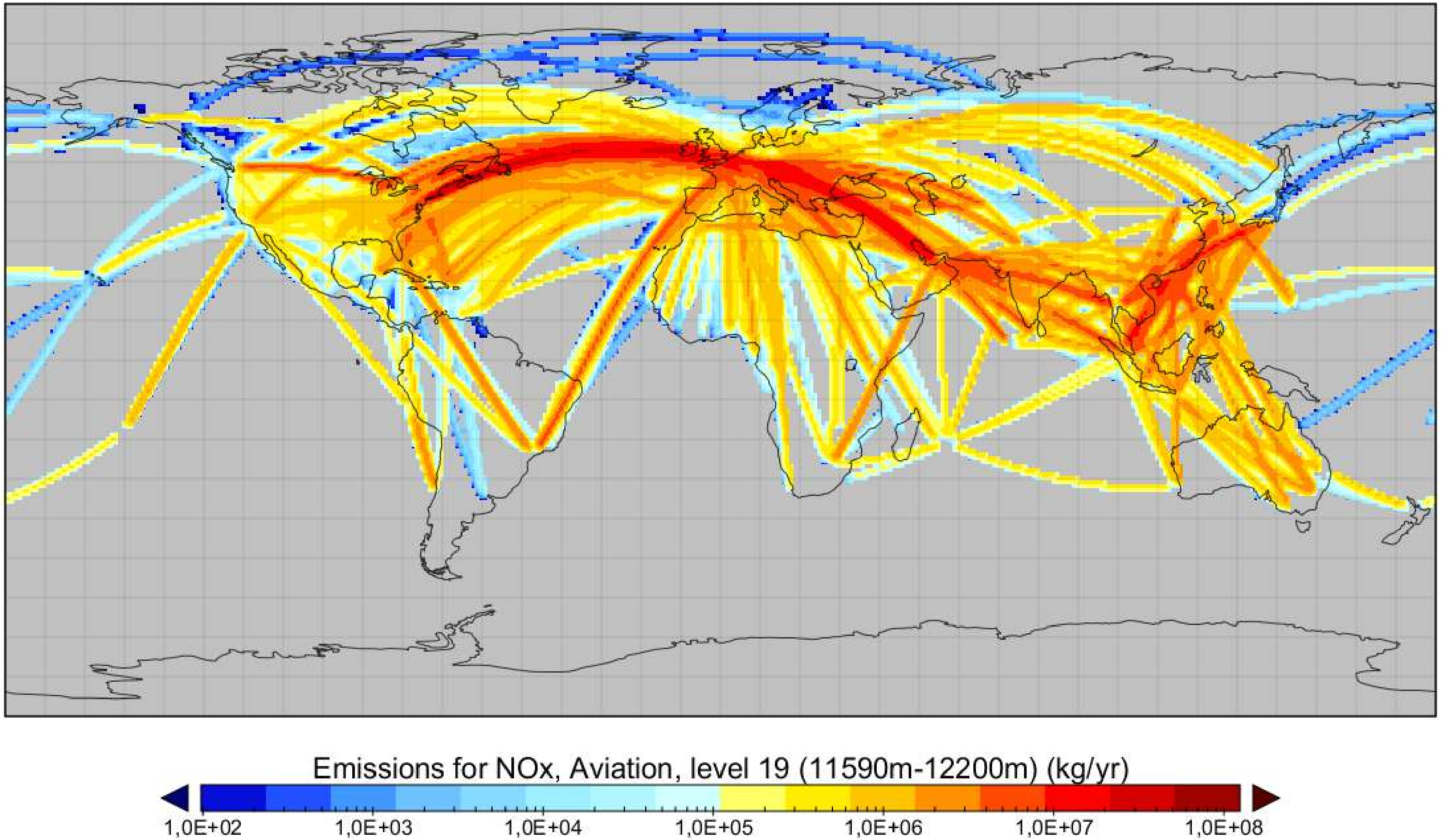
GTP, level 19, 25 years



GTP, level 19, 50 years

Quantify Final Meeting, 25-27 January 2010, Munich

Emissions for NOx, Aviation, level 19 (11590m-12200m)



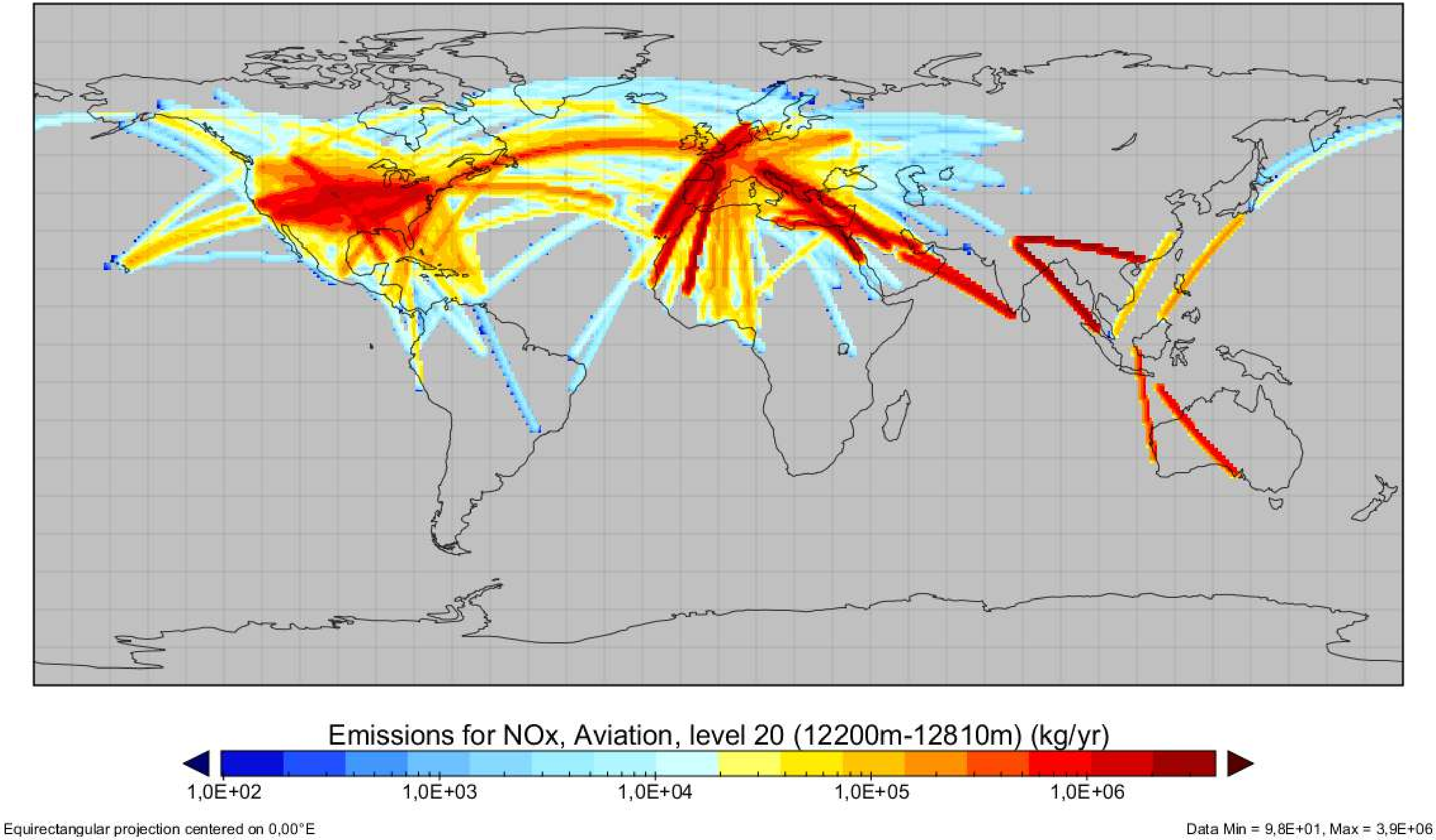
Equirectangular projection centered on 0,00°E

Data Min = 3,6E+01, Max = 4,6E+07

GTP, level 19, 100 years

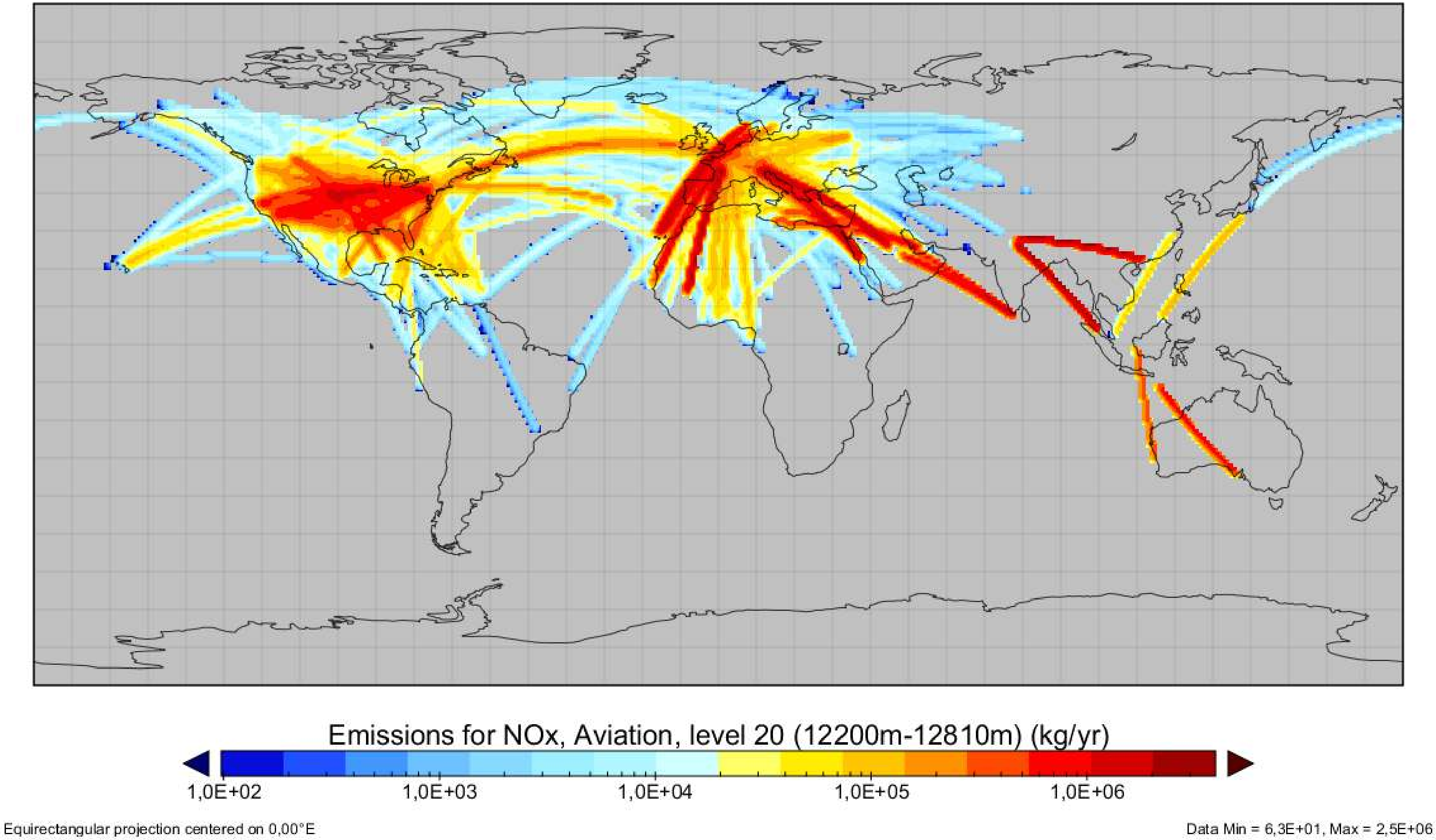
Quantify Final Meeting, 25-27 January 2010, Munich

Emissions for NOx, Aviation, level 20 (12200m-12810m)



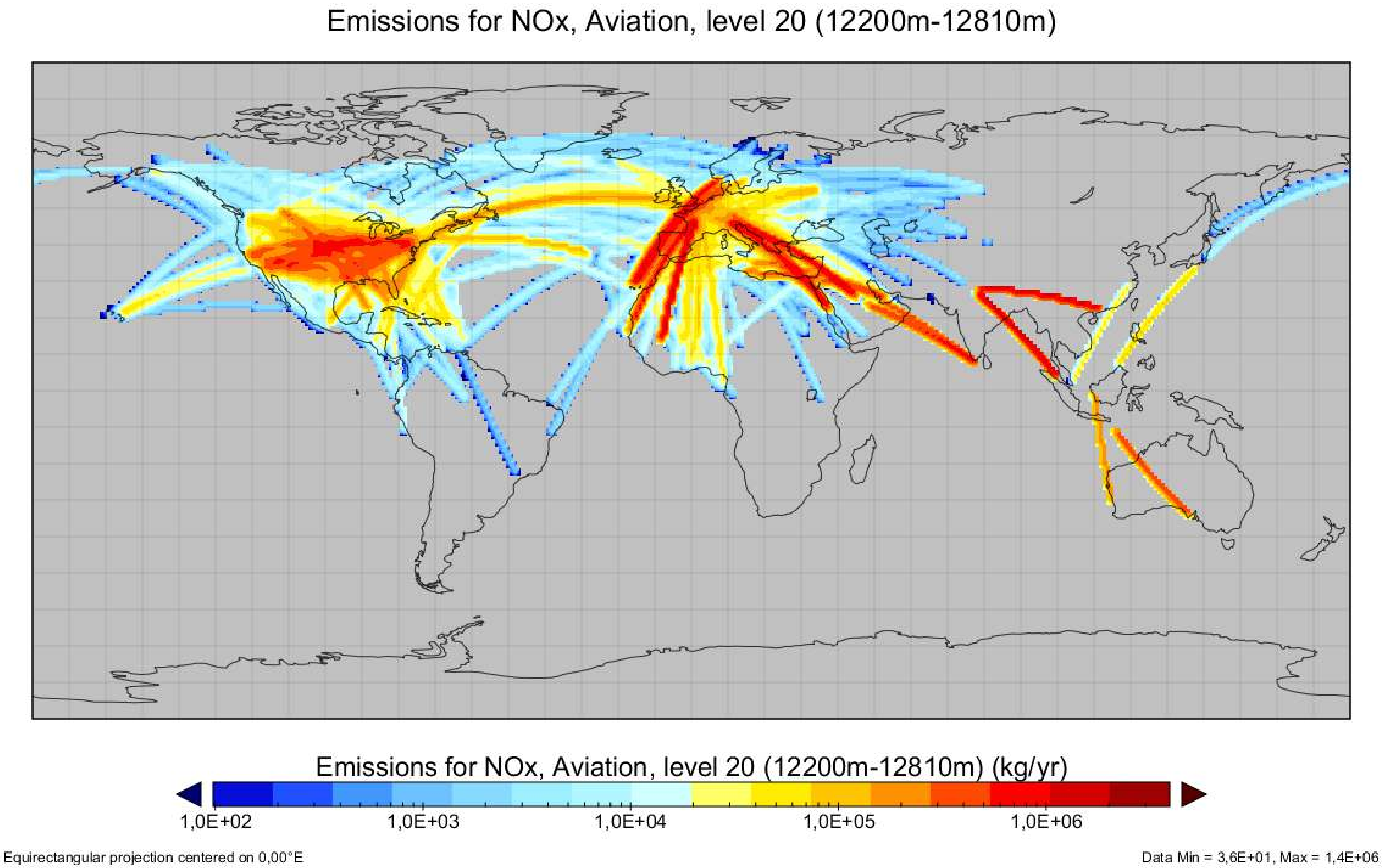
GTP, level 20, 25 years

Emissions for NOx, Aviation, level 20 (12200m-12810m)



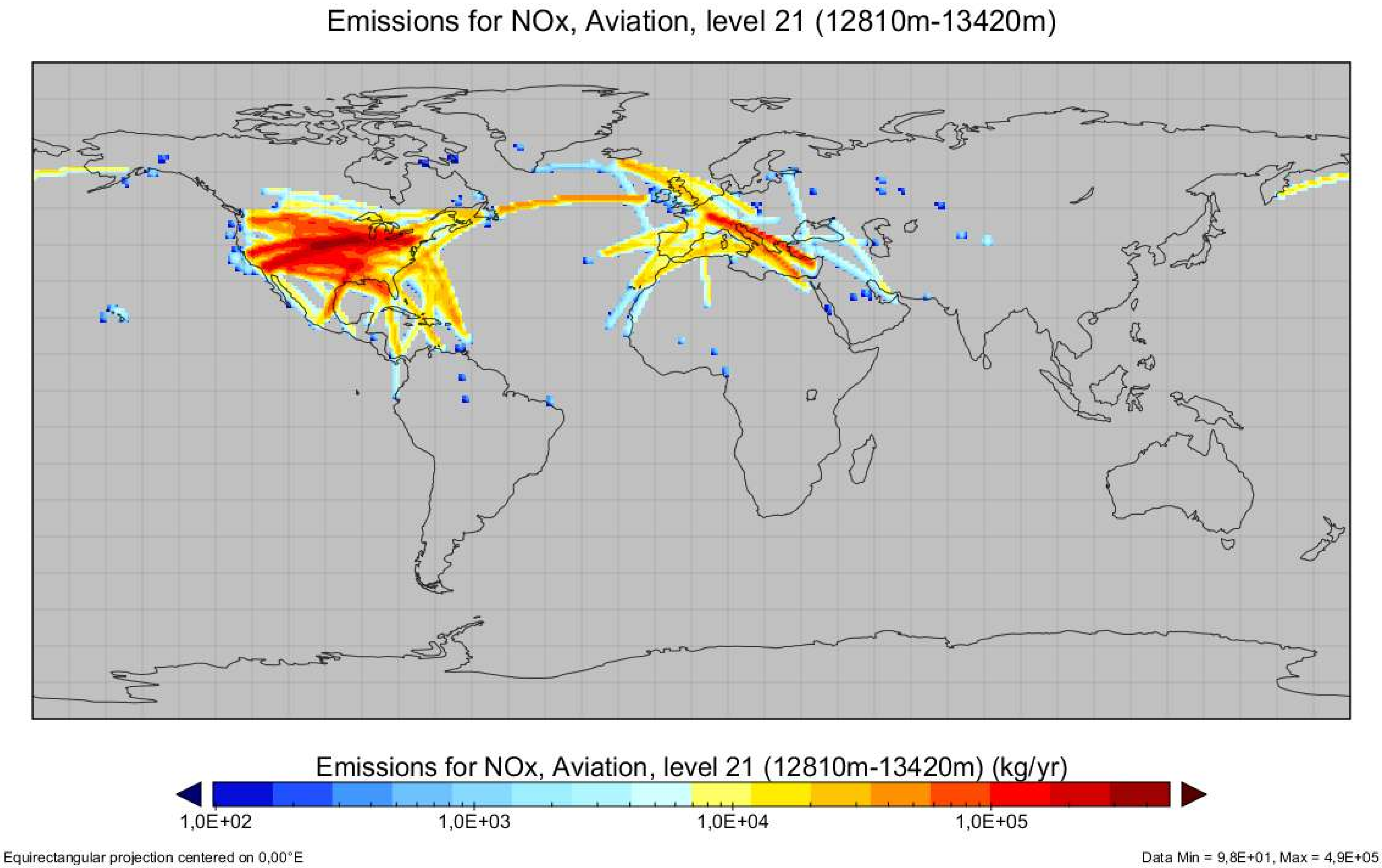
GTP, level 20, 50 years

Quantify Final Meeting, 25-27 January 2010, Munich



GTP, level 20, 100 years

Quantify Final Meeting, 25-27 January 2010, Munich

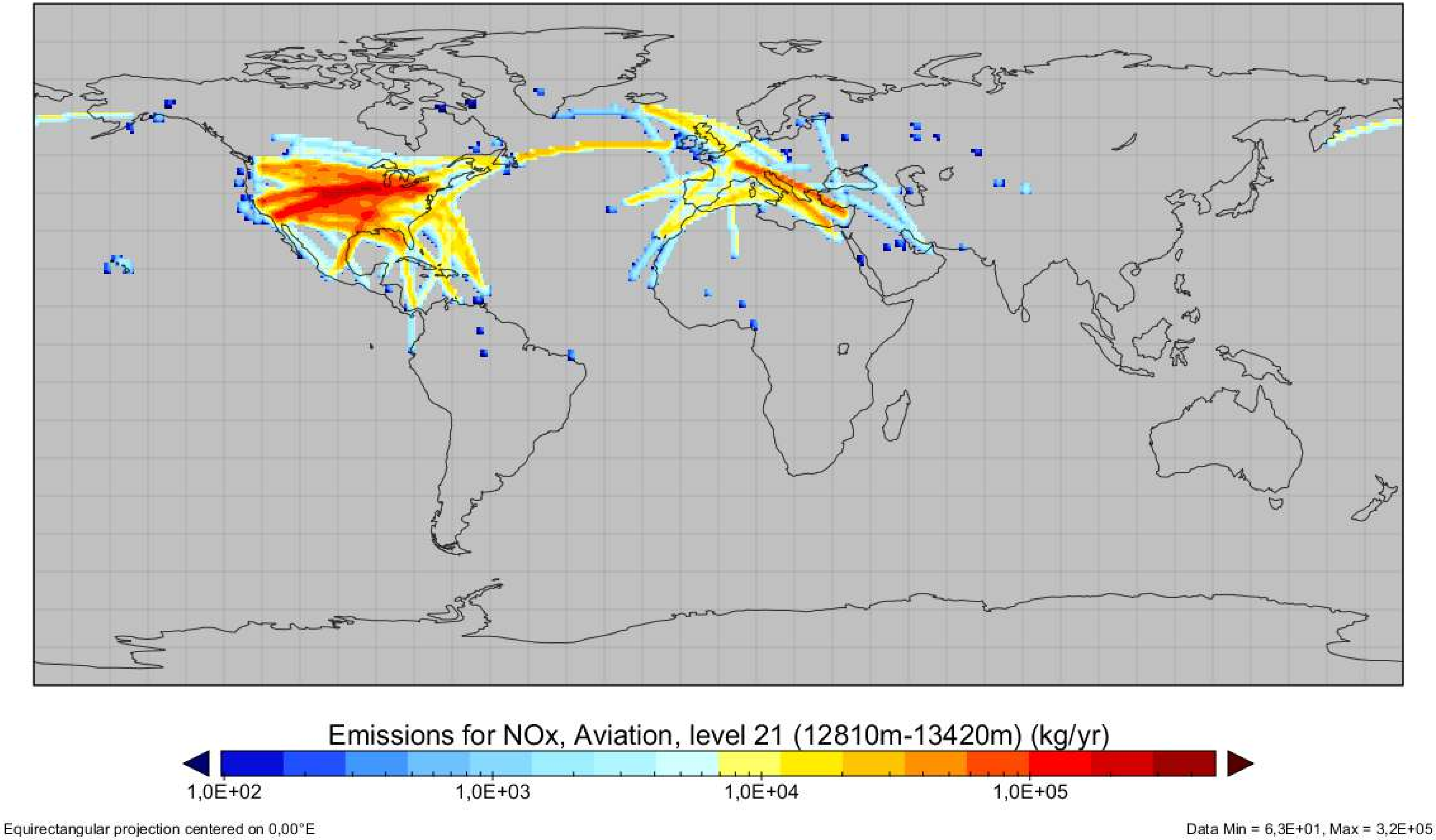


GTP, level 21, 25 years

Quantify Final Meeting, 25-27 January 2010, Munich

QUANTIFY

Emissions for NOx, Aviation, level 21 (12810m-13420m)

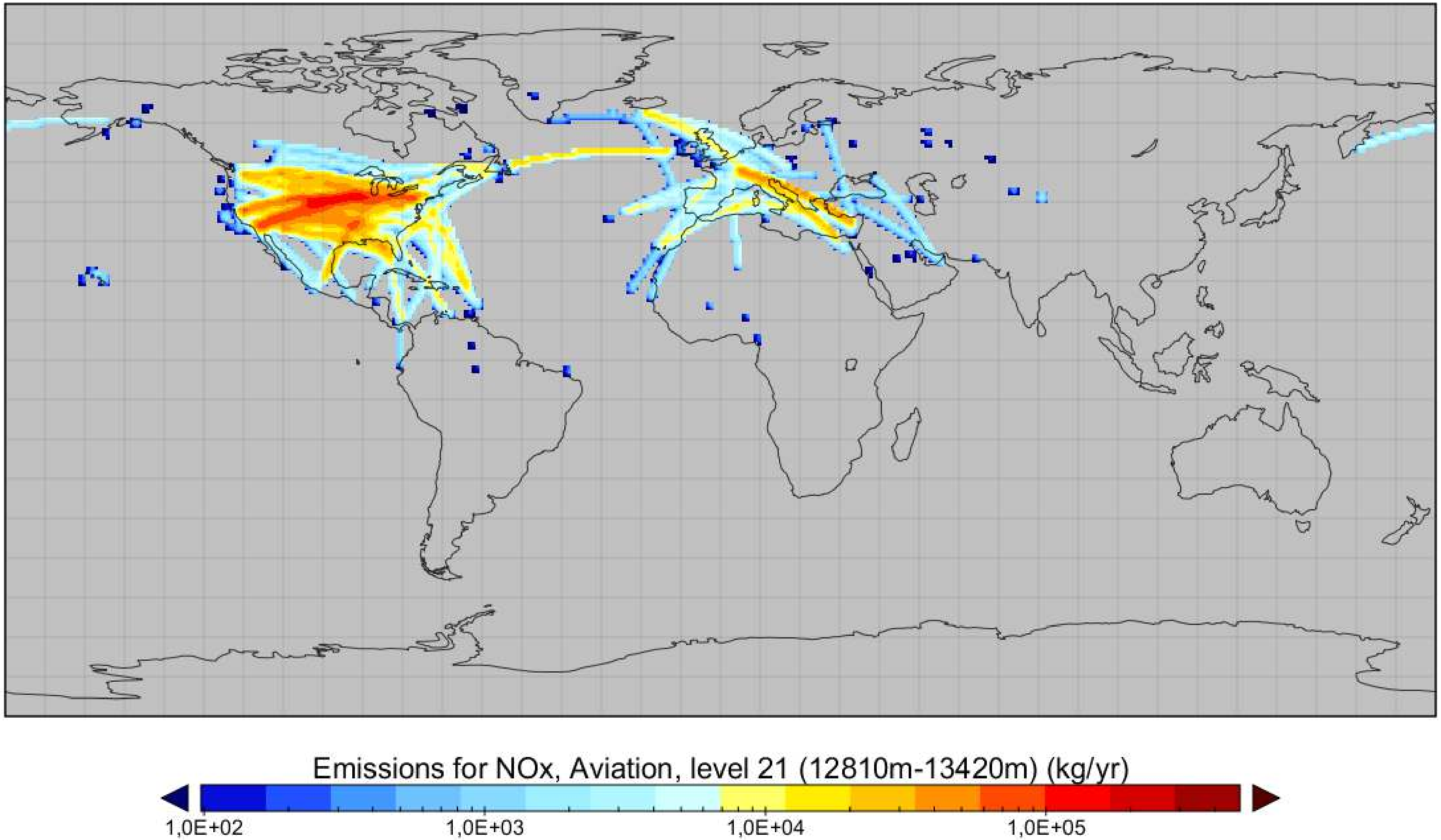


GTP, level 21, 50 years

Quantify Final Meeting, 25-27 January 2010, Munich

QUANTIFY

Emissions for NOx, Aviation, level 21 (12810m-13420m)



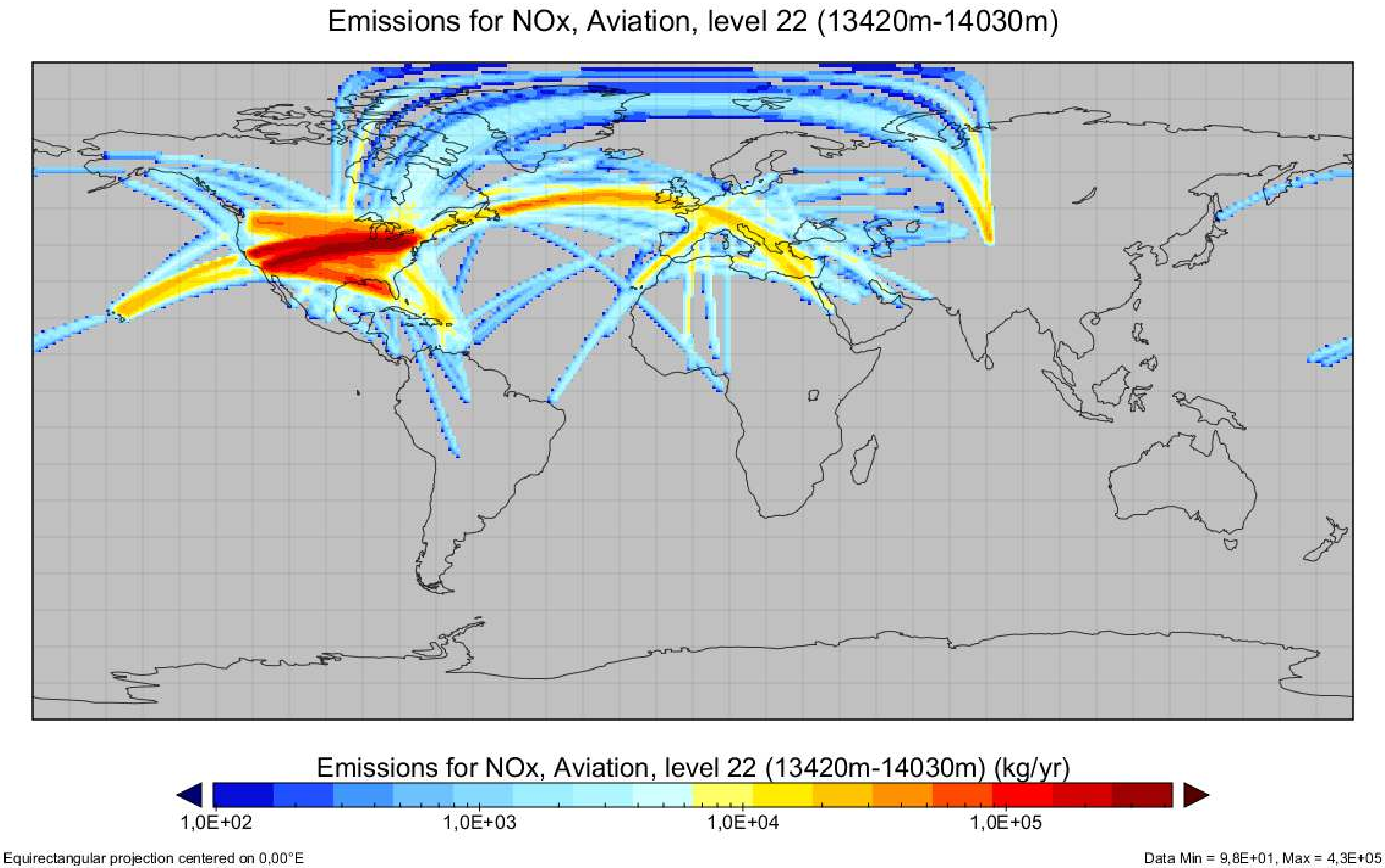
Equirectangular projection centered on 0,00°E

Data Min = 3,6E+01, Max = 1,8E+05

GTP, level 21, 100 years

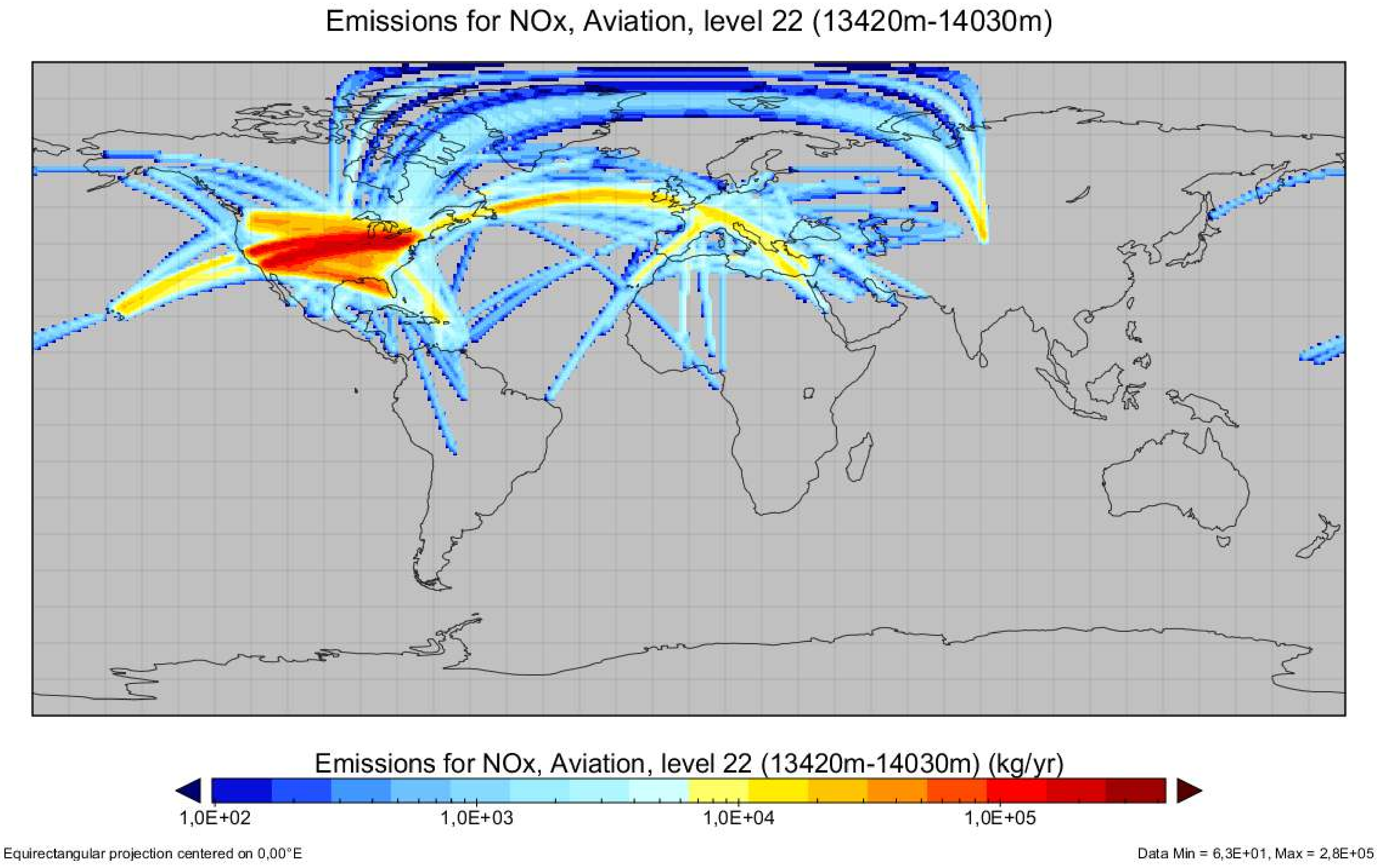
Quantify Final Meeting, 25-27 January 2010, Munich

QUANTIFY



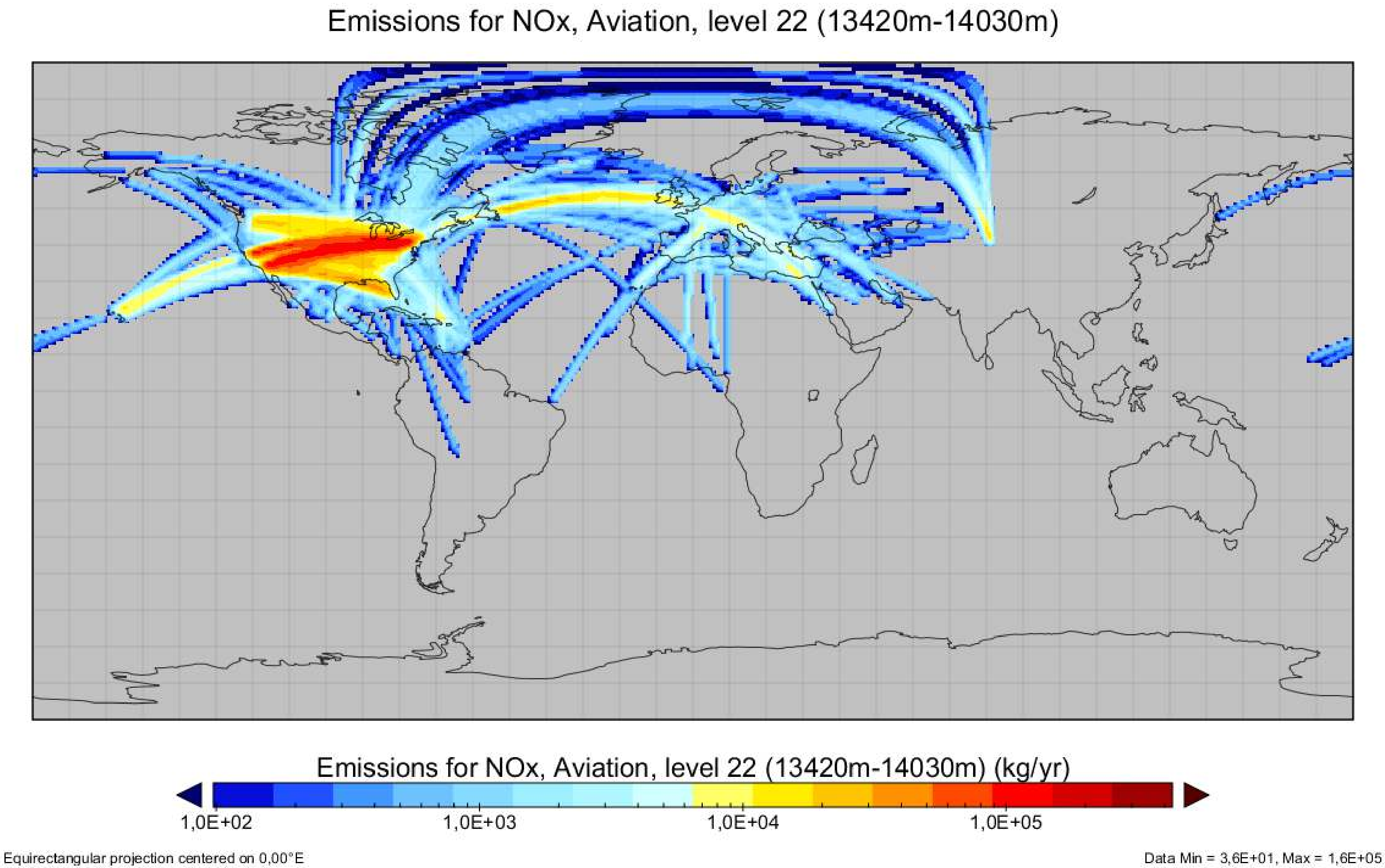
GTP, level 22, 25 years

Quantify Final Meeting, 25-27 January 2010, Munich



GTP, level 22, 50 years

Quantify Final Meeting, 25-27 January 2010, Munich



GTP, level 22, 100 years

Quantify Final Meeting, 25-27 January 2010, Munich

- ✓ The emissions are reduced by increasing time horizon;
- ✓ The main corridors exhibit outstanding emissions;
- ✓ The density of air traffic is indicated by different colours (blue = low level density; red = high level density);
- ✓ The largest air traffic (red and shades) are observed over North-America, Europe and East Asia;
- ✓ The density of air traffic is different at the different levels;

3. History of air pollution

3.1. Environmental pollution in ancient times

- 3.1.1. Regional and hemispheric-scale atmospheric lead pollution
- 3.1.2. Regional and hemispheric-scale atmospheric copper pollution

3.2. Deforestation

3.3. Atmospheric environment from ancient times to the present, based in literary sources

3.4. Environmental awareness in ancient Israel

3.5. Air pollution in medieval cities

3.6. Attempts to control air pollution

3.7. The smoke and fog in London

- 3.7.1. AThe big smog and what happened afterwards

3.8. Scientific milestones in the management of air quality

Air pollution is as old as mankind….

www.bampfa.berkeley.edu/.../info_3.html

The Chinese ink is made of soot, produced by oil or wood combustion.

www.acornplanet.com/hui_inkstick.shtml

Indian cave paintings

www.kamat.com/kalranga/rockpain/

www.cartoonstock.com/directory/f/first_fire.asp

Cave dwellers used fire for cooking and heating, which polluted the air.


Th oldest pollution source in the history of mankind

„Lead is so abundant in the terrestrial layers that its mining higher than a certain amount was forbidden.”

Plinius: Natural History (on Britain), A.D. 77

3.1. Enviromental pollution in ancient times

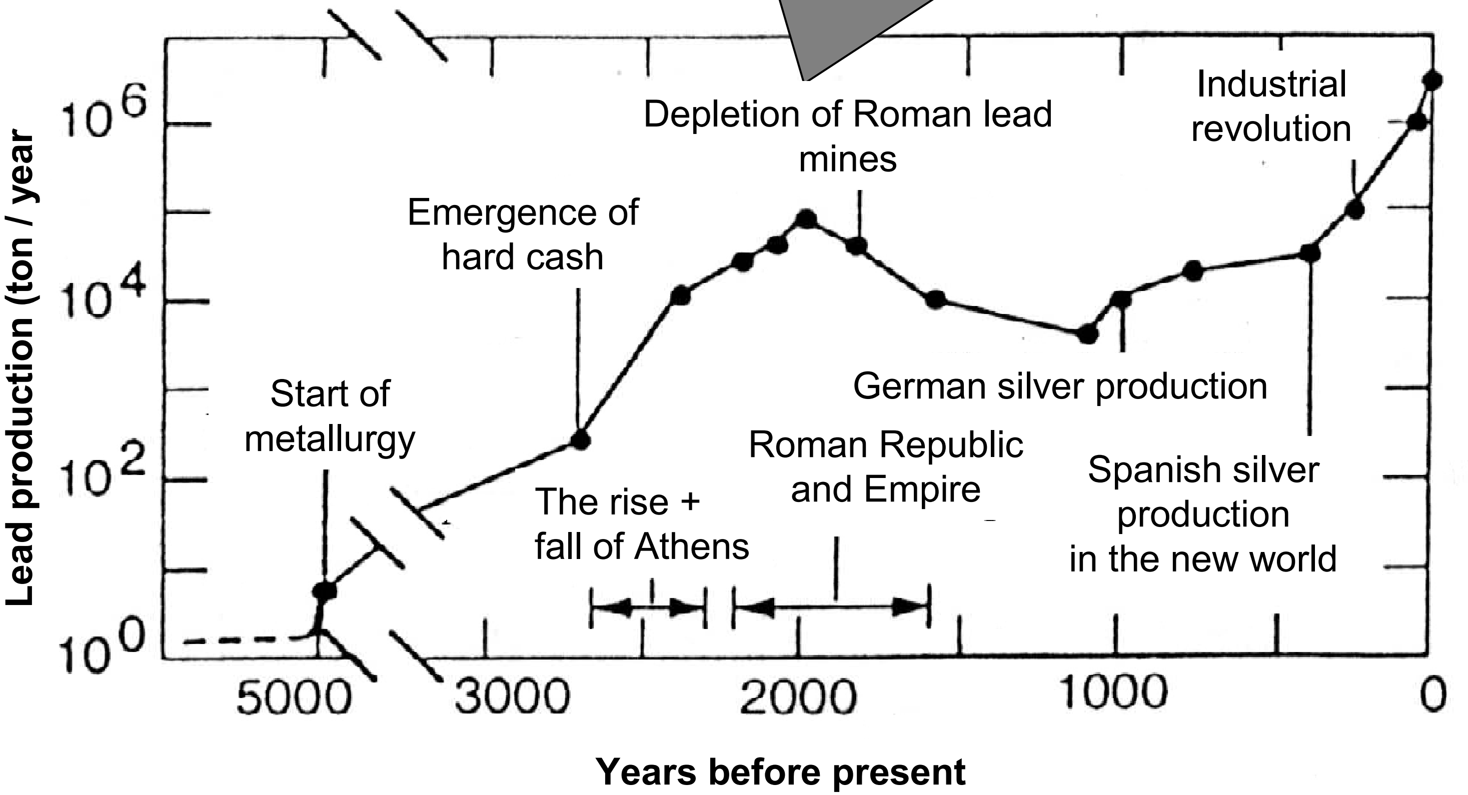
3.1.1. Regional and hemispheric-scale atmospheric lead pollution

- In the golden age of the Roman Empire (about 2000 years ago) approx. 5% of the maximum processed 80,000 tons lead per year is was released into the atmosphere (Hong et al., 1994a)

  → local and regonal air pollution in Europe (e.g. lacustrine sediments in southern Sweeden (Renberg et al., 1994), or the Arctic troposphere, Hong et al., 1994a);

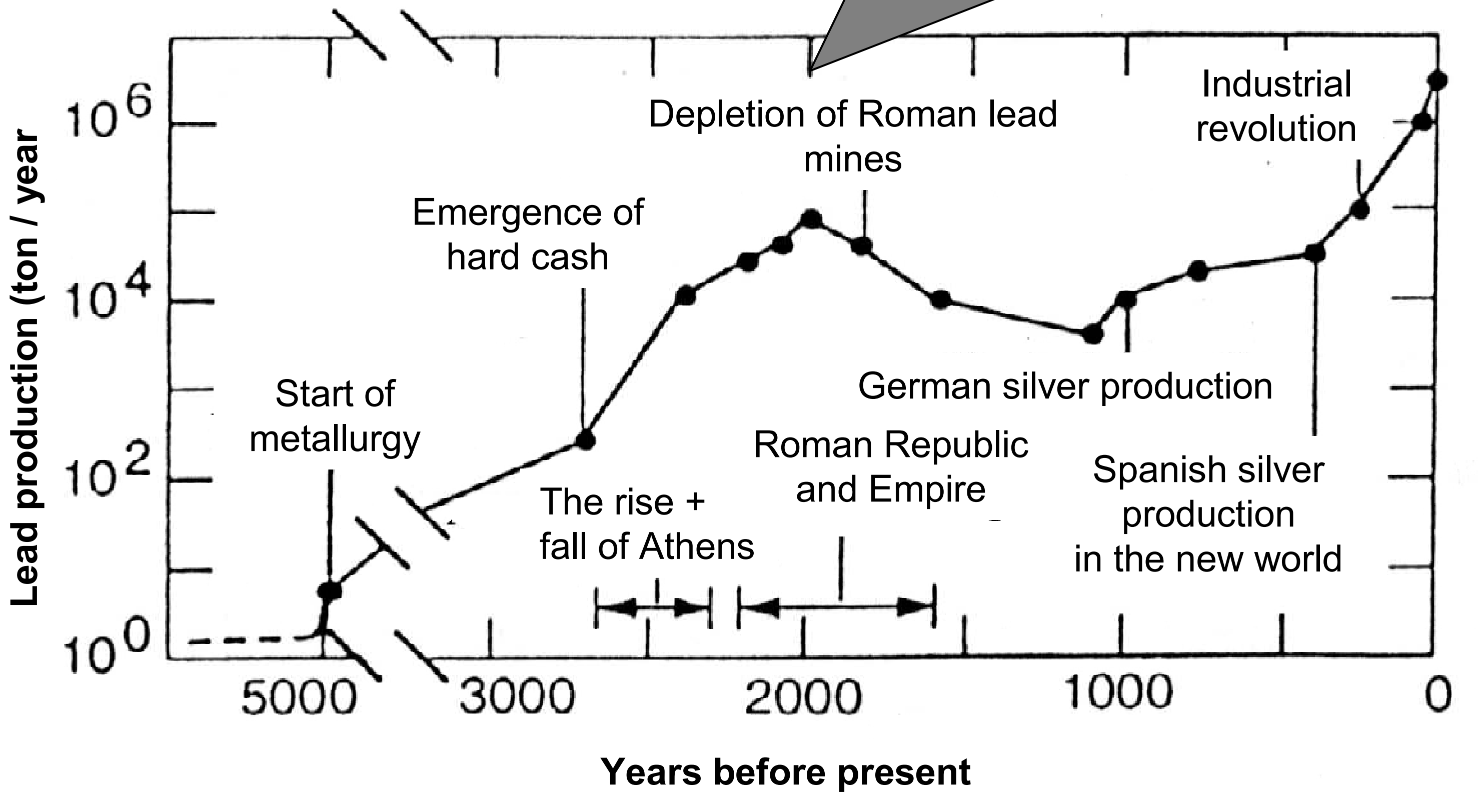
- About 70% of lead content of the Greenland ice sheet in the period B.C. 150 – A.D. 50 comes from Rio Tinto mines (SW Spain) (Rosman et. al., 1993). It was mined by Romans in the period B.C. 205 – A.D. 410.

In the golden age of the Roman Empire (about 2000 years ago) - approx. 5% of the maximum processed 80,000 tons lead per year got into the atmosphere (Hong et. 1994a).



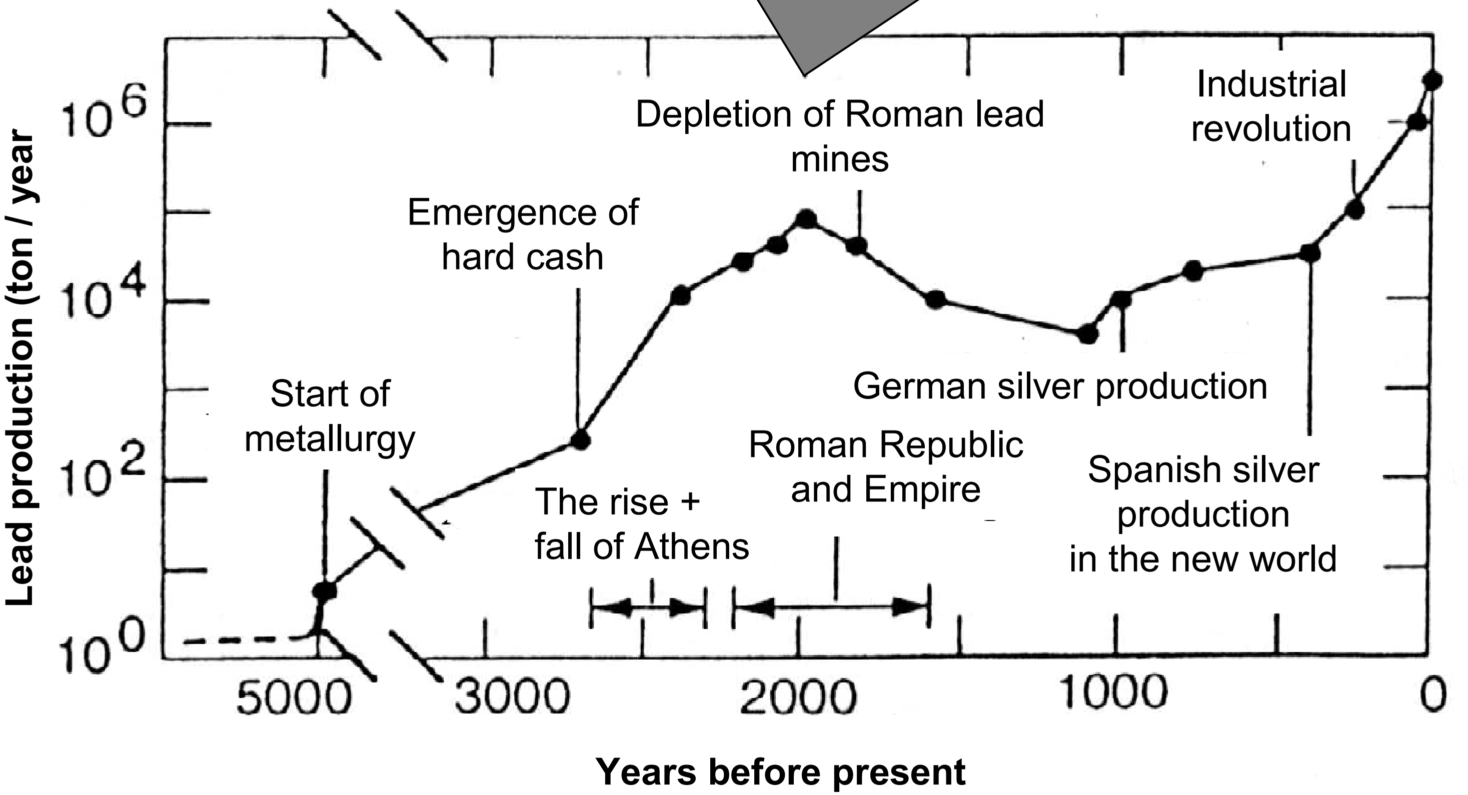
Lead production of the world in ancient times

After the fall of the Roman Empire, atmospheric lead concentrations dropped dramatically, dropped to the background concentration levels 7,760 years ago (Hong et. 1994a).



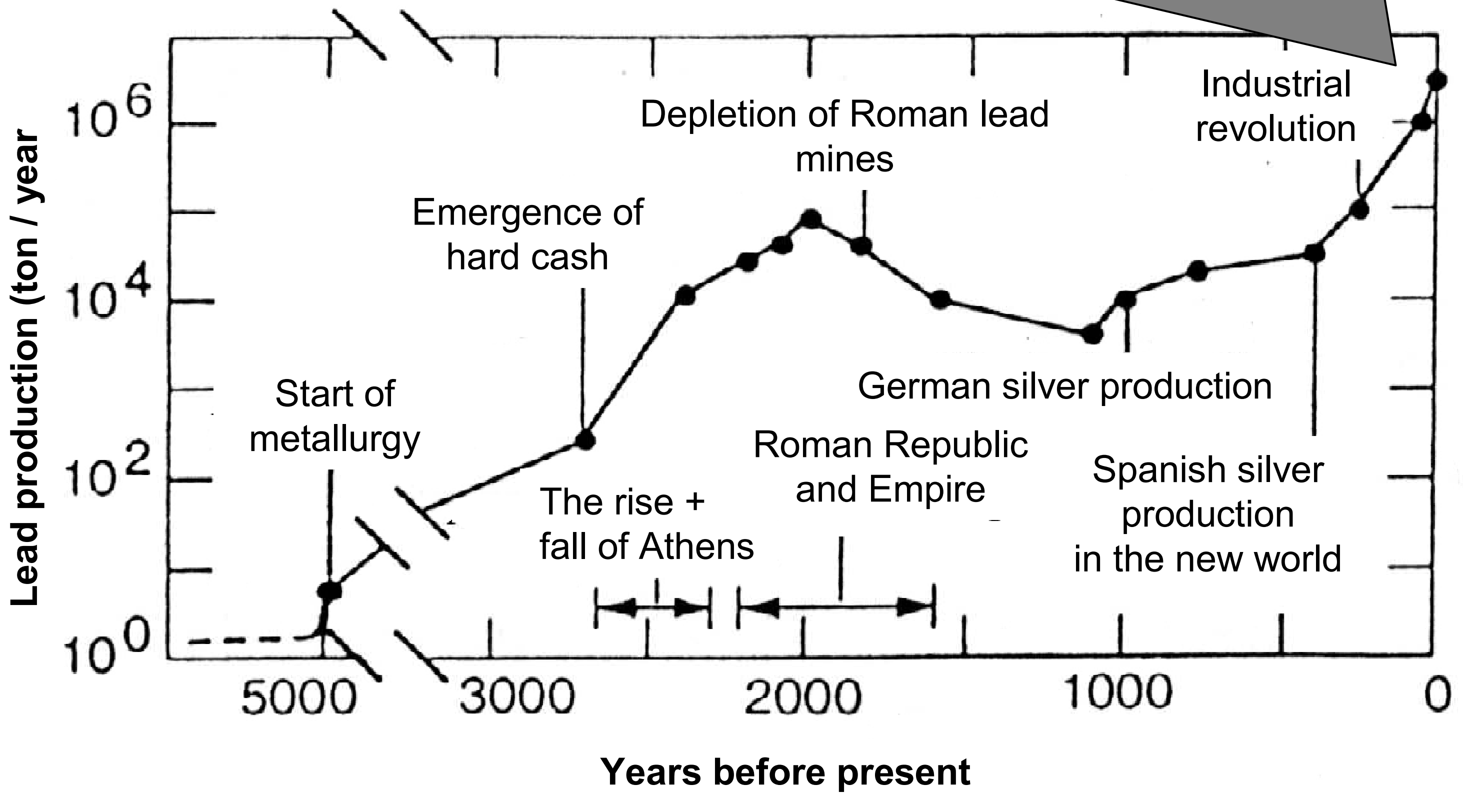
Lead production of the world in ancient times

Then, in the Middle Ages and the Renaissance period it started to rise again, and 470 years ago it reached twice of the recognized the value of the age of the Roman Empire (Boutron, 1995).



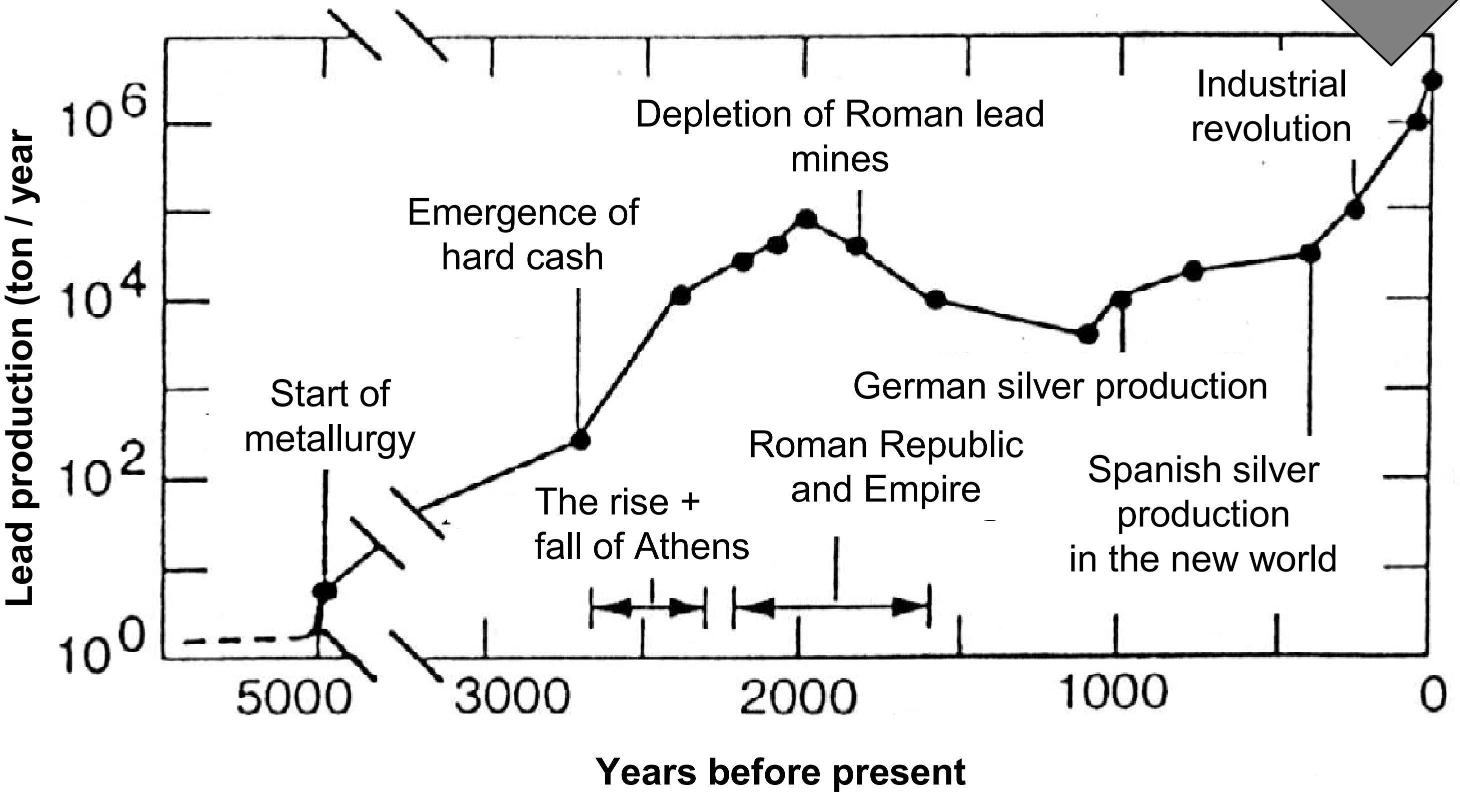
Lead production of the world in ancient times

Then, there was a continuous rise even after the Industrial Revolution and since the 1930s until approx. 1960 the Greenland ice and snow samples indicated a rapid growth. This was due to fuels containing lead anti-knock additives, which were first used in 1923 (Nriagu, 1990).



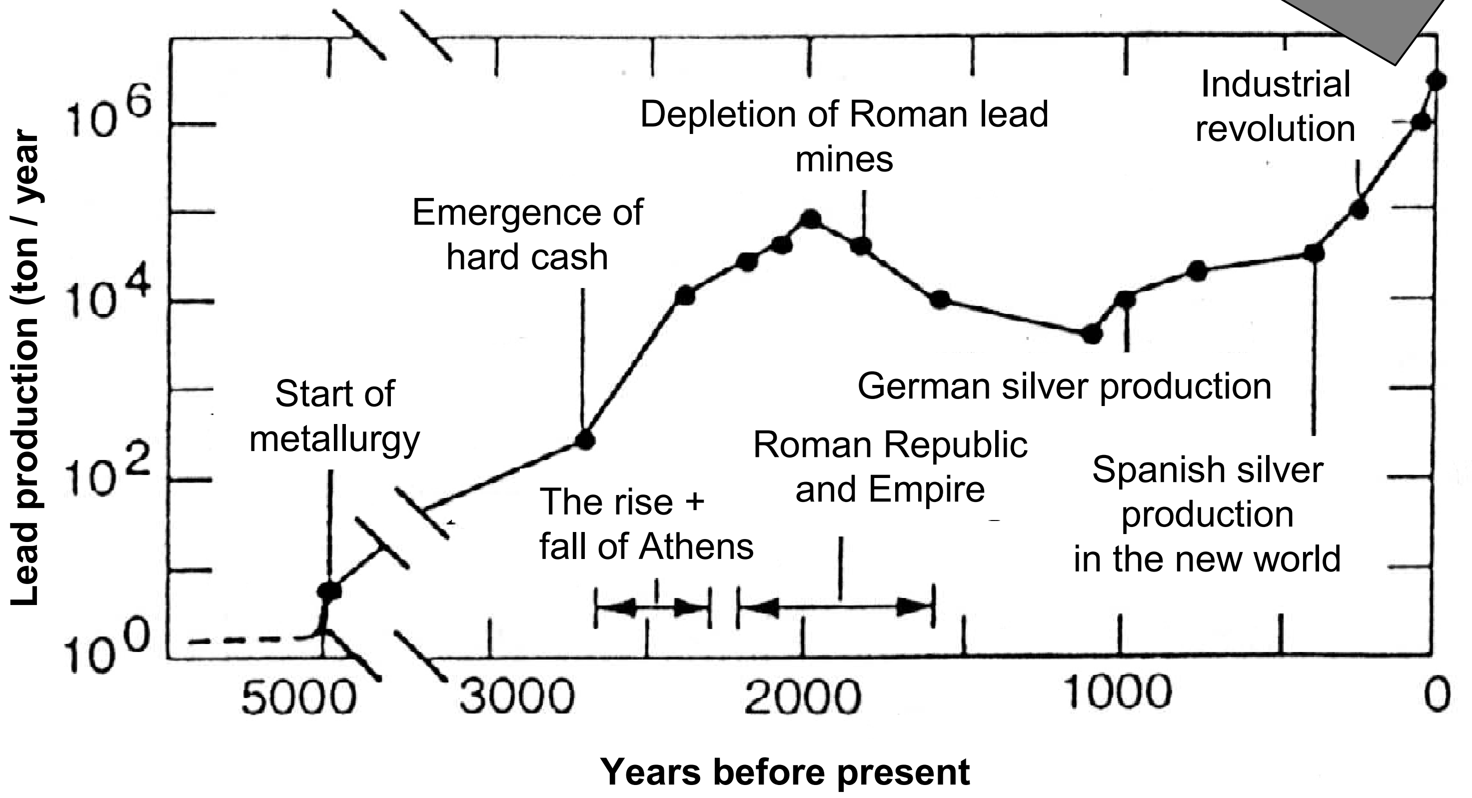
Lead production of the world in ancient times

On the global scale, in the 1970s, 2/3 of lead additives were used by US, 70% of which got directly to the atmosphere through motor vehicle exhaust gases.



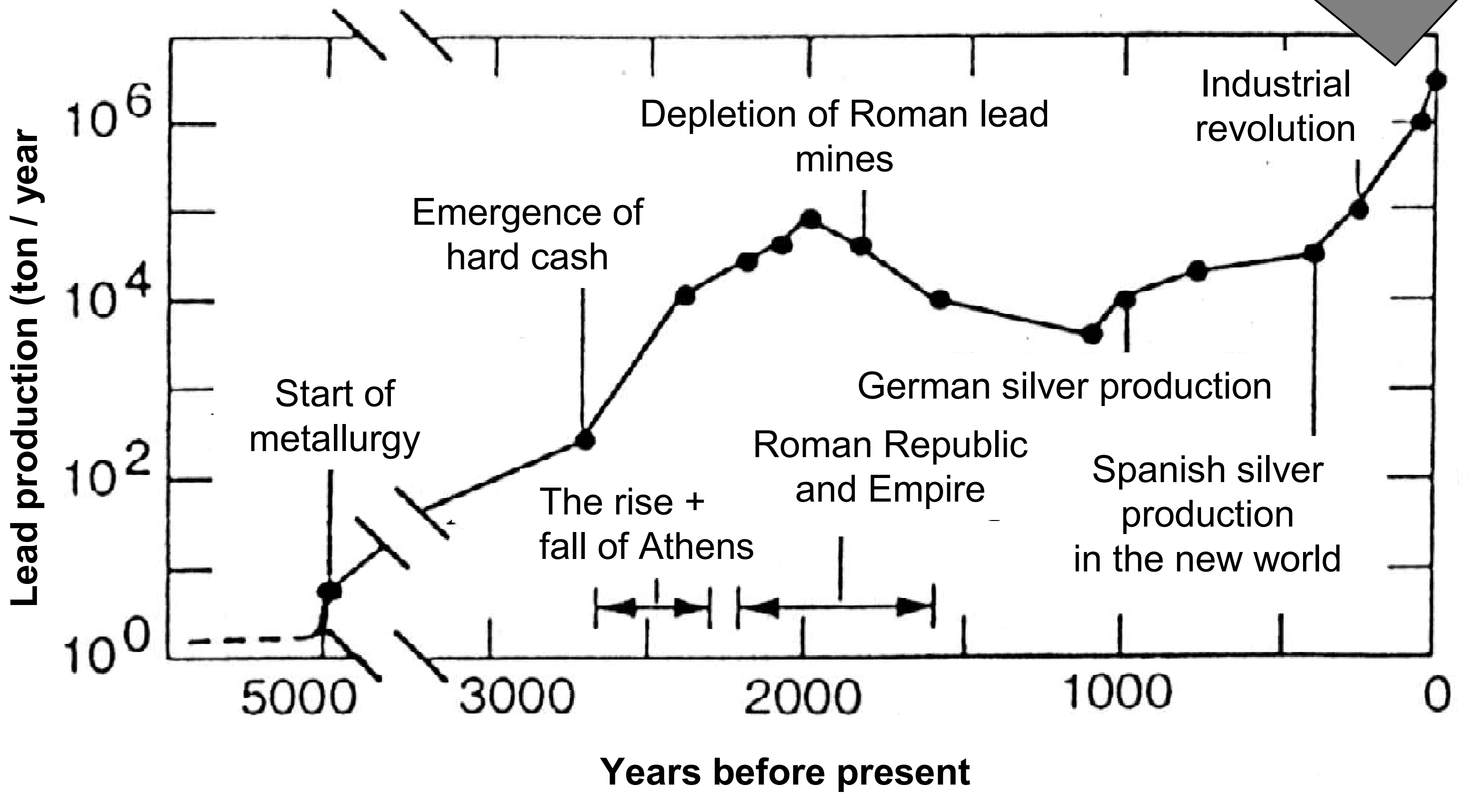
Lead production of the world in ancient times

Atmospheric lead concentrations, observed in the 1960s, were approx. 200 times higher than the natural values. This is one of the severe - ever recorded - global-scale environmental pollution on Earth (Boutron, 1995).



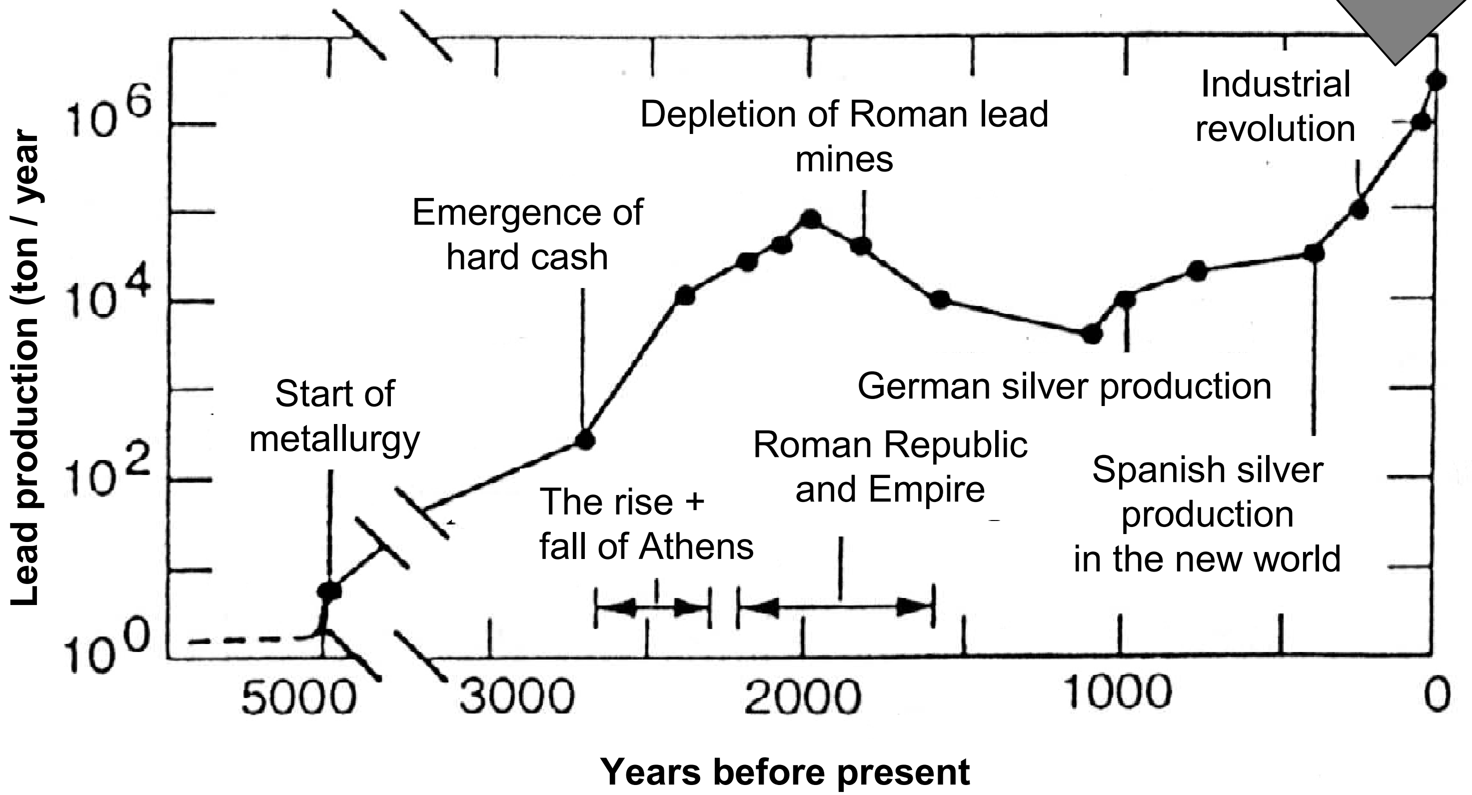
Lead production of the world in ancient times

Recently, gasoline sold in the United States entirely, while gasoline sold in Europe in increasing ratio are of lead-free (Nriagu, 1990).



Lead production of the world in ancient times

In the most recent period, Eurasia is responsible for 75% of atmospheric lead concentrations (al Rosman et. 1993).



Lead production of the world in ancient times

„Clay plumbing is healthier since from a lead tube white lead precipitates, what is said to be harmful to the body.”
[white lead = lead carbonate ($PbCO_3$)]
Vitruvius

- During the Greco-Roman period in the troposphere over Greenland, a significant part of the four-fold increase in the concentration of lead came from lead / silver mining and -procession. During the Roman Empire around 40% of the world lead production came from Spain, Central Europe, Britain, Greece and Asia Minor (Nriagu, 1983a).

- Atmospheric lead pollution has been detected over the Antarctic since the beginning of the 20th century. A significant part of the here-detected lead of anthropogenic origin came from South America (Boutron, 1995; Makra, 2003).

„Copper is gold."

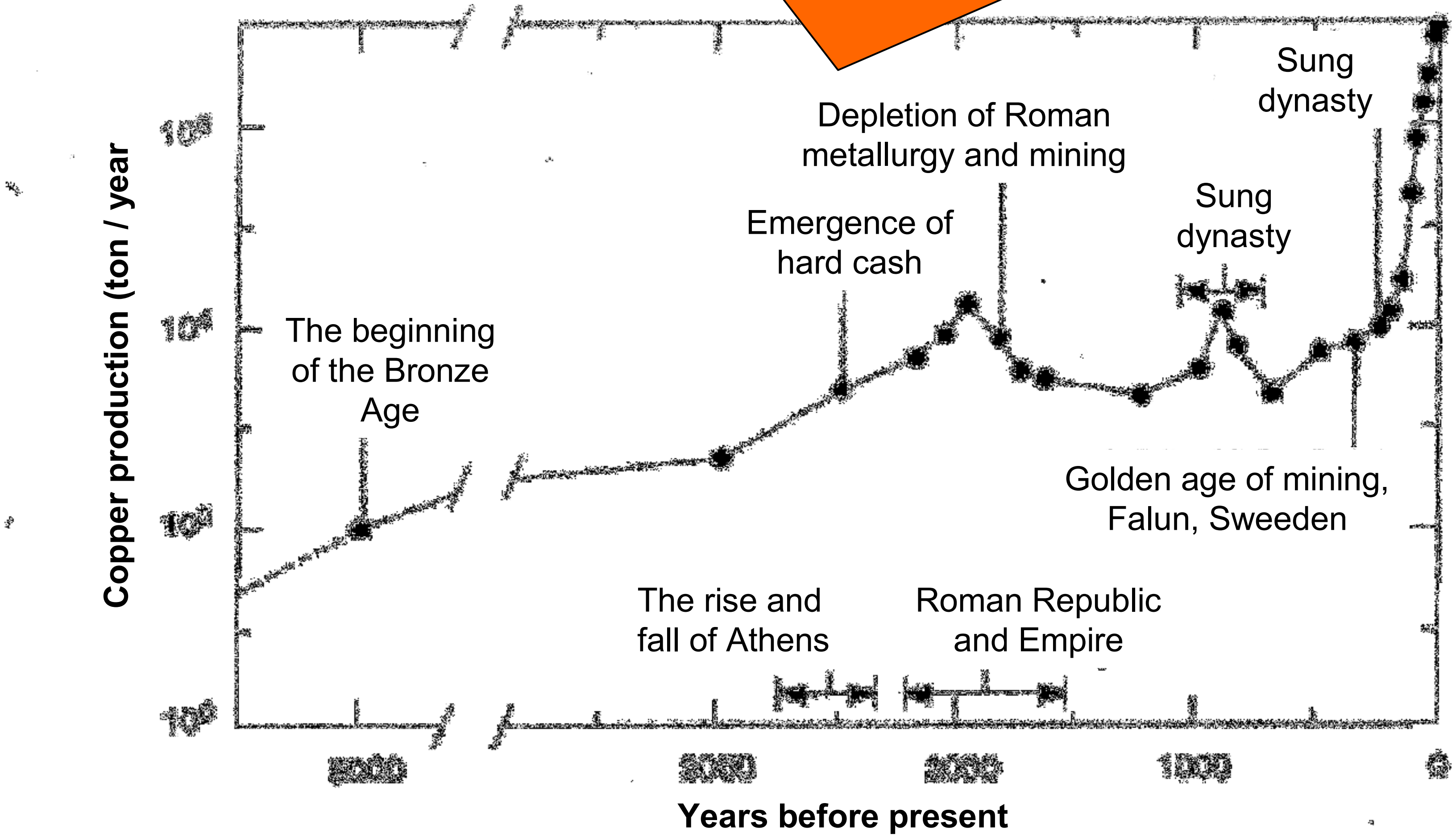
Chinese proverb

3.1.2. Regional and hemispheric-scale atmospheric copper pollution

- Before the start of the anthropogenic copper consumption - approx. 7000 years before - the total amount of atmospheric copper came from natural sources.

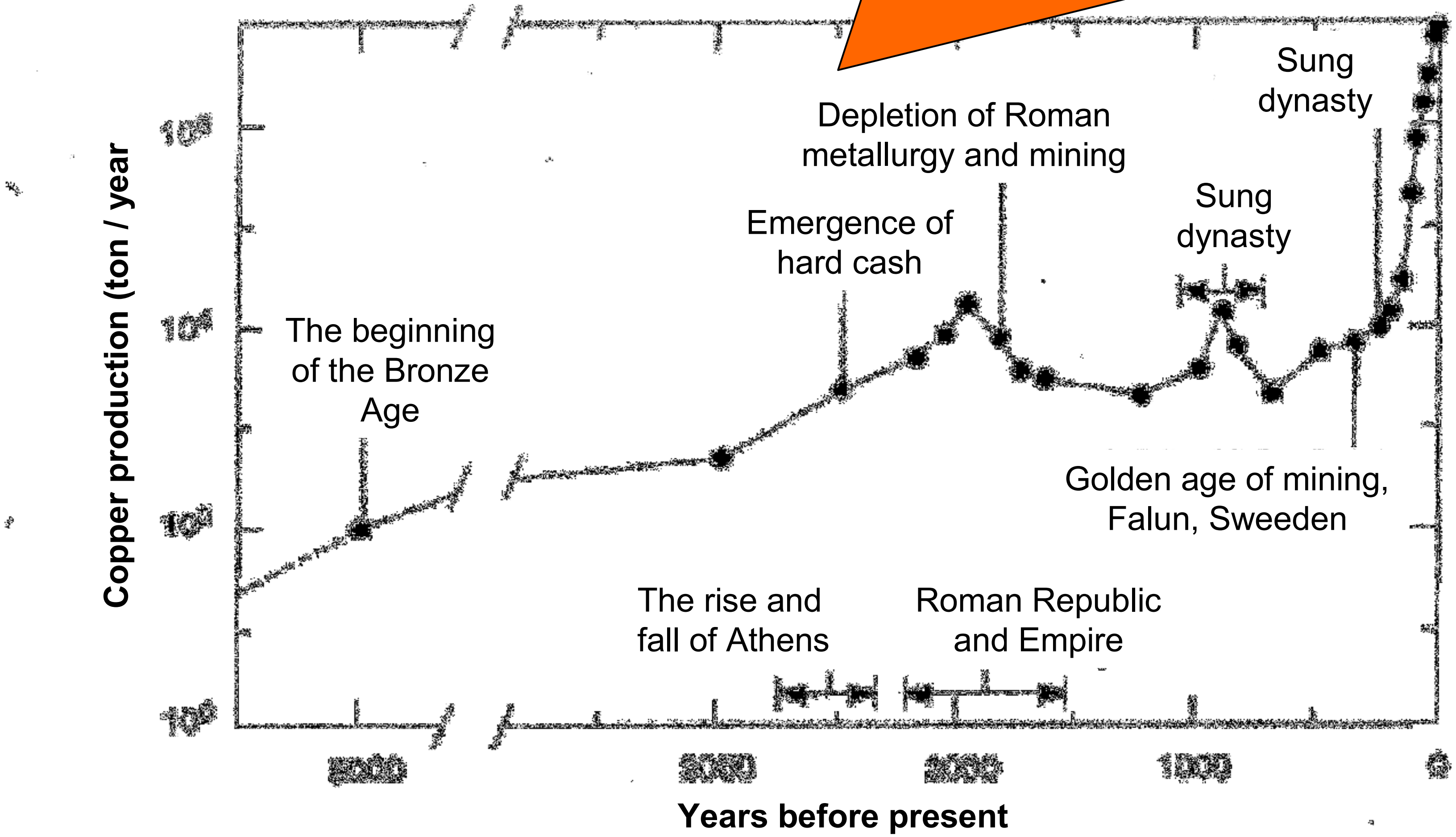
- Atmospheric emissions related to production in the context of major technological modifications significantly changed in the past 7000 years. In ancient times because of the primitive melting processes the emission factor was around 15%. It was 15%. Initially, several steps of the processing of sulphide ore several steps (roasting, smelting, oxidation, cleaning) were implemented in open furnaces. Emissions have been ignored until the Industrial Revolution. Advanced metallurgical furnaces and new processes have been spread only afterwards (Makra, 2003).

From the period 2500 years ago, copper concentration in the atmosphere has increased, which is a consequence of a large scale copper pollution occurred in the northern hemisphere (Hong et. al., 1996b).



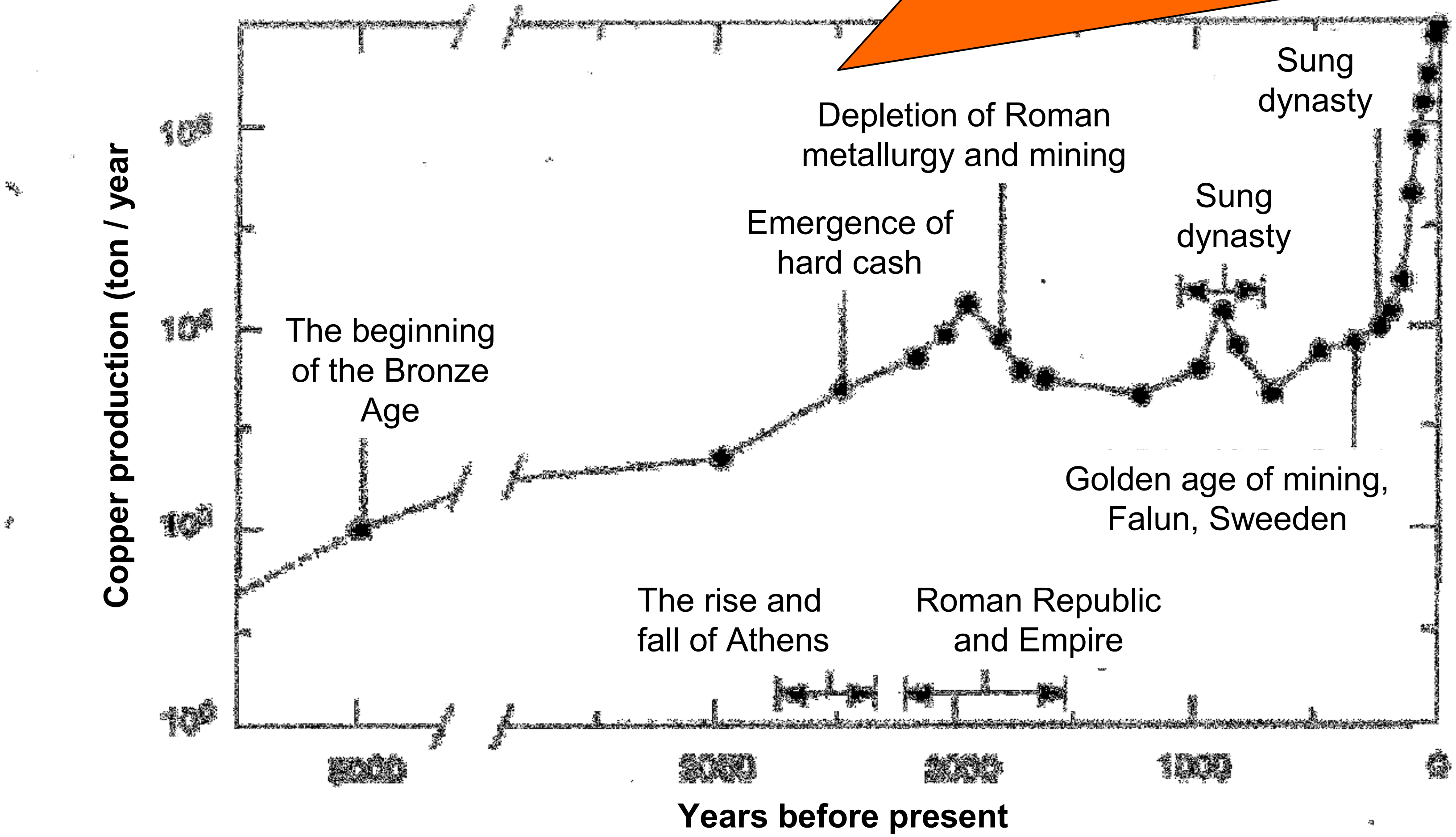
Copper production of the world in ancient times

From the mid-19th century, metal processing decreased to five-steps ⇒ emission factor has decreased substantially. In the 20th century, this factor was only 1%, and by introducing further changes this value decreased to 0.25% (Honget al., 1996a; 1996b).



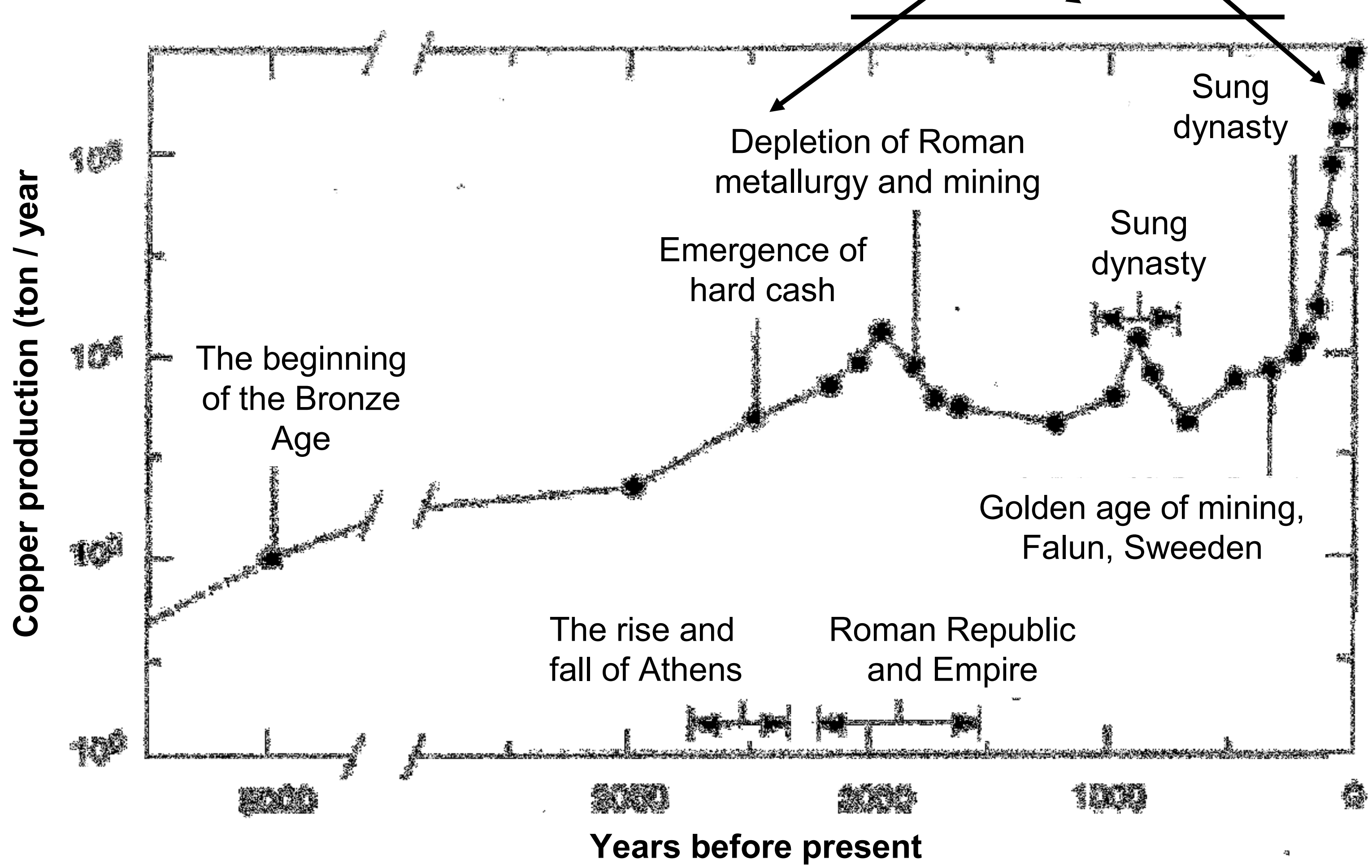
Copper production of the world in ancient times

Ca / Al ratio has increased since the age of the Roman Empire in the ice samples ⇒ significant copper pollution has occurred over the Arctic troposphere. **Cause:** processing at high temperature → small particle aerosol → it can easily access from the mid-latitudes to the Arctic region (in Roman times: primarily Spain, in the Middle Ages: China).



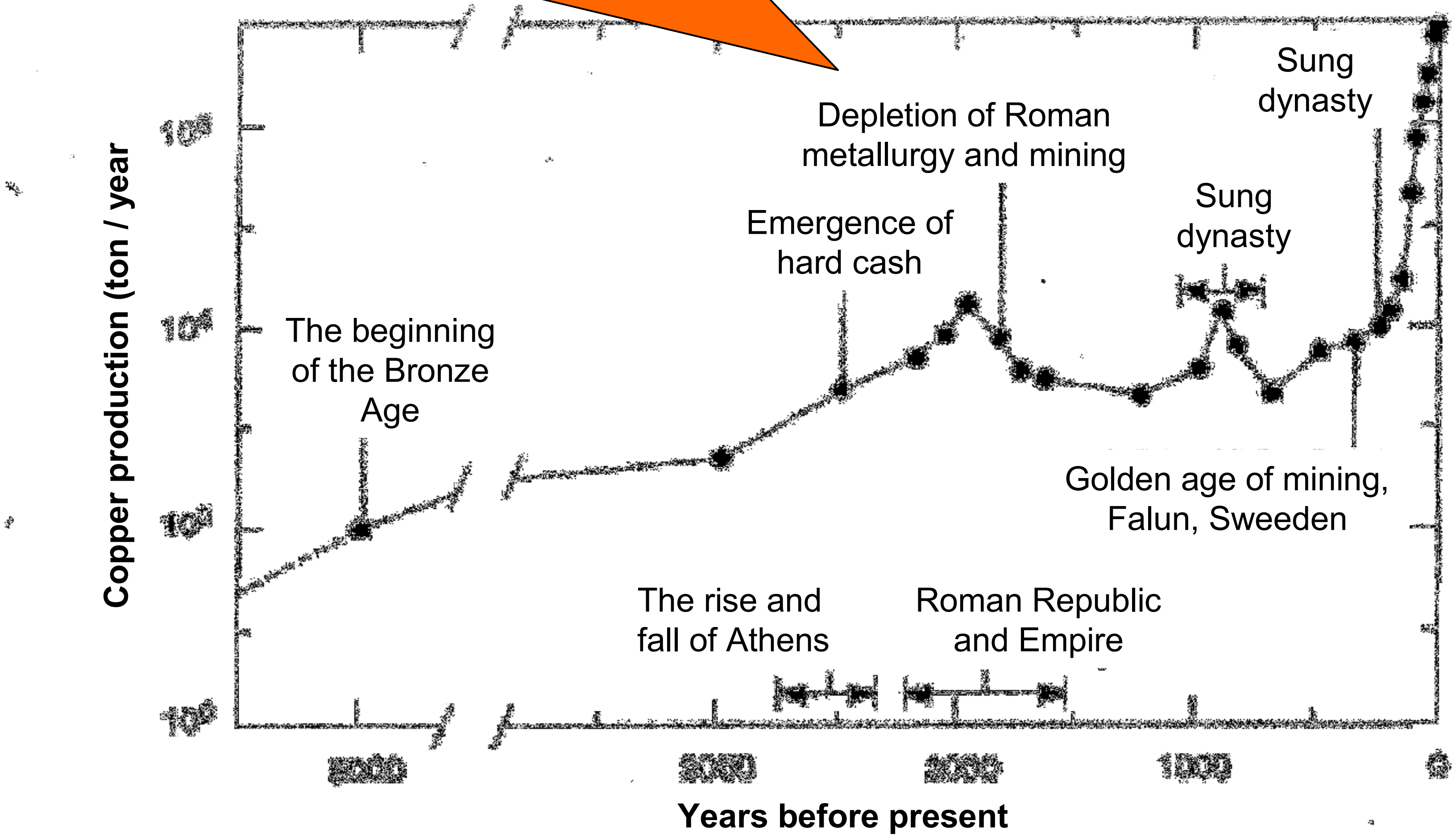
Copper production of the world in ancient times

Cu / Al ratio detected ice samples is small **until the period of about 2500 years ago**, is medium **from the Roman times until the Industrial Revolution**, and suddenly rising **close to the present time**.



Copper production of the world in ancient times

Data from Roman age show a large variability. Reason: production of copper occurred in short periods, depending on how much copper was needed (Hong et. al., 1996b).



Copper production of the world in ancient times

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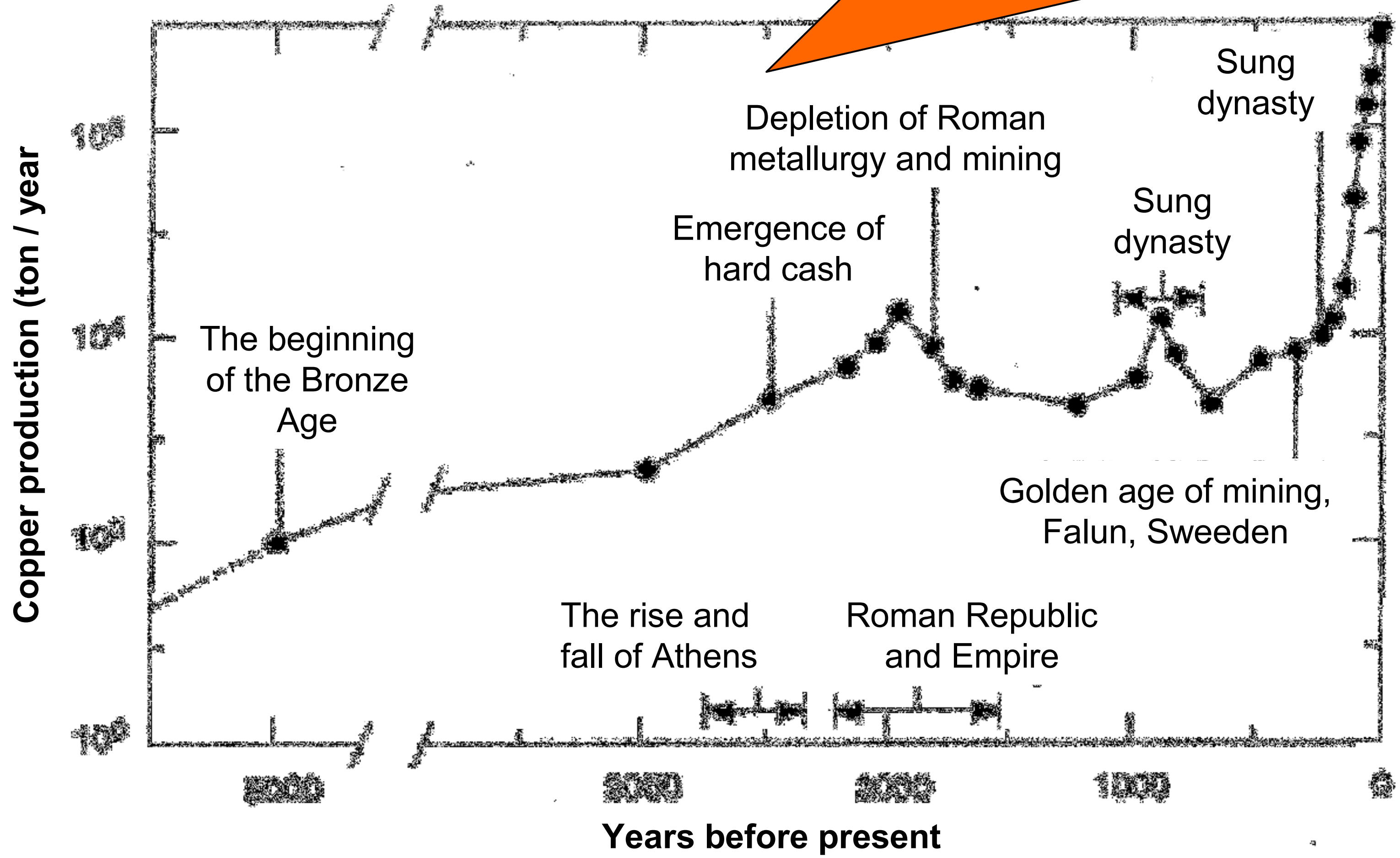
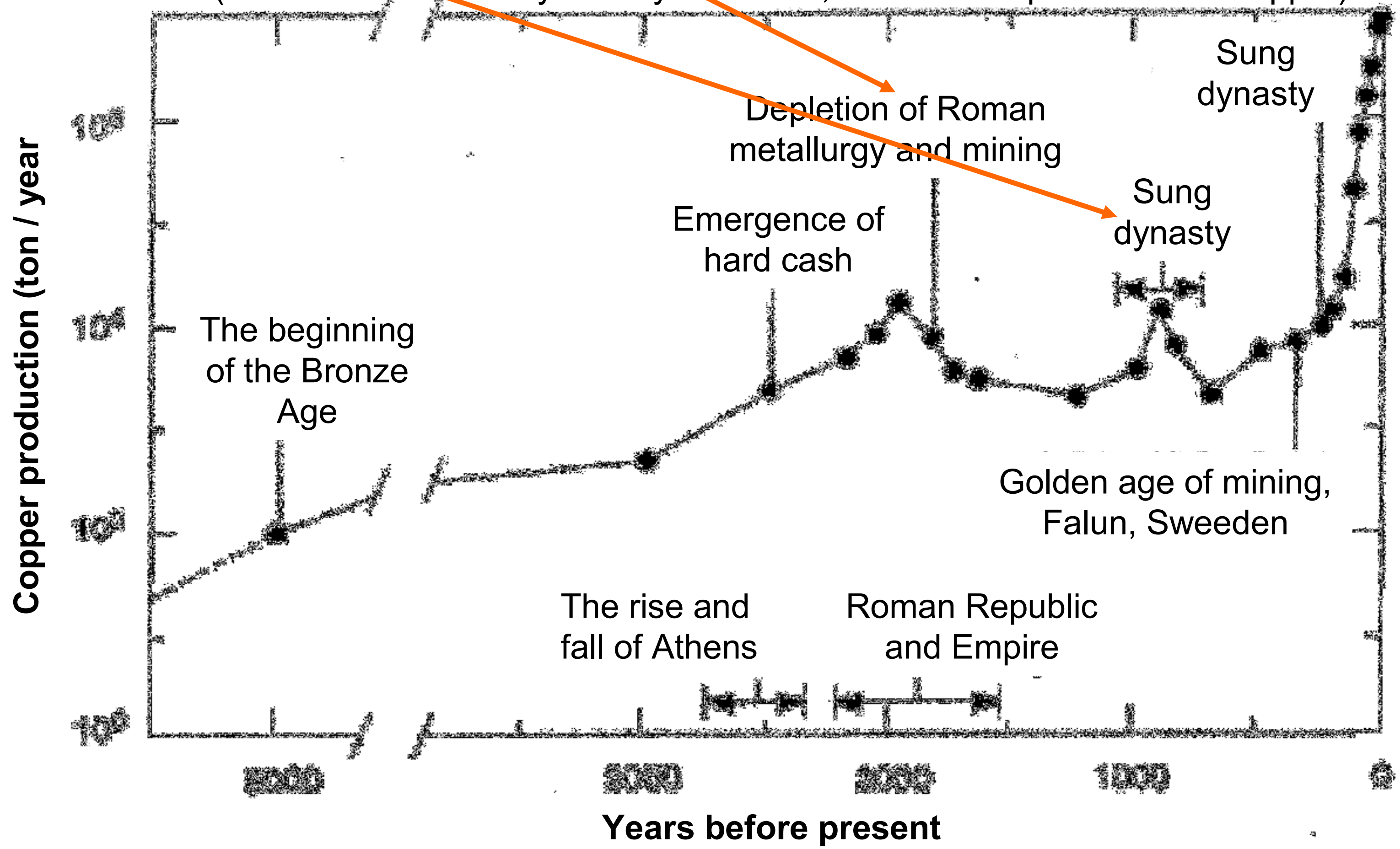


Copper production of the world in ancient times

- In accordance with the Greenland ice samples (production data vs. emission factors) copper emission culminated twice in the atmosphere prior to the Industrial Revolution (Makra, 2003):

  1) Golden age of the Roman Empire, ≈ 2,000 years ago, 2,300 t / yr → spread of coins in the ancient Mediterranean;

  2) the Northern Song Dynasty (A.D. 960-1279) flourished, A.D. 1,080 in China, 2,100 t / year (the Chinese economy heavily marketed, boosted the production of copper).



Copper production of the world in ancient times

„The best time for tree planting was 20 years ago. The second best time is now.”

Chinese proverb

3.2. Deforestation

- Platon: *„Kritias”* – evidence of forest degradation at Attica peninsula;

„This happened 9000 years ago: After a long time the land of Attica that had once been so productive - destroyed as a result of deforestation: floods are common, in the high-altitude areas winter rain washed away the soil that has already gone. As a result, Athens now looks like a small island, the skeleton of a patient's body, where there is hardly any meat. In the old days the land was unspoiled, soil-covered mountains were found even at the higher elevations, and what we call scrubs, richly covered the land. There was plenty of forest in the mountains, but by now one can hardly see its trace. Some of the mountains, can only sustain bees; not so long ago, roof beams of our biggest buildings came from these mountains and these beams are still in place. And there were a lot of other, well-kept, tall trees, which gave plenty of food for the beasts.”

<u>Can be this description justifyied?</u> – No.

„ A civilization can flourish when people plant trees, under which they will never sit down.”

Greek proverb

- However:

  1) The Mediterranean was colder / wetter in the Neolithic than today ⇒ favorable conditions for the perennial vegetation

  2) summers getting dryer in later age ⇒ forest degradation (nothing to do with human activity)

- Summer rainfall shortage → scrubby vegetation, shrubs

  ⇒ sheep and goats

- **Recent view:** Turks are responsible for the destruction of Greek forests;

  ↑

  ↓

- **Reality:** more forest has been destroyed in the Greek declaration of independence. When the declaration of independence (in 1821) and afterwards about 40% of Greece was covered with forests. By 2000 this area has shrunk to 14%; however, a significant part of this is degraded coppice / shrub (Makra, 2002a; Makra and Brimblecombe, 2004).

„Waste is a resource in a wrong place."
Chinese proverb

3.3. Atmospheric environment from ancient times to the present, based on literary sources

- atmospheric environment: There are no direct data in the literature;
- 1) Solon, BC 6th century, * Athens: first legislative approach of air pollution: he regulated that smiths could work only beyond residential areas ⇒ reduction of noise and air pollution.

- [*BC 4th century, population of Athens was approx. 40-50,000 people. Since as many people lived in the city for several centuries before, Athens - along with Rome - was supposed to be by far the most urbanized settlement in the ancient world.]

- 2) A work of Thukudides → an anthropogenic air pollution episode: during the Peloponnesos War - when the Peloponnesos troops besieged the city of Plataies (430 B.C.) - the attacking army covered the city walls with trees surrounded by tar and sulphur and then lit them. Thus a significant amount of smoke and sulphur dioxide formed.

  → goal: forcing the residents to surrender Plataies city;

- Urbanization and environmental problems were associated later in the ancient world. Vitruvius (75-26 B.C., age of Caesar Augustus) described climate and weather conditions of the Roman cities (reference: smoke pollution, Horace poems (65-68 B.C.).

„ As I left depressing air of Rome, stifling kitchen odours, emanating and swirling smoke from chimneys with toxic vapours and soot, made me feel better.”

a detail from the letter of Seneca written to Lucilius, A.D. 61

- Air pollution problems of the classic big cities:

  1) Horace mentions – "Roman buildings are becoming blacker from smoke" (this is a problem in many ancient cities).

  2) Seneca - teacher of Emperor Nero - was ill all his life, and his doctor often advised him to leave Rome.

  Letter of Seneca to Lucilius, A.D. 61: – he has to leave the depressing smoke of Rome and odours of kitchens to help them feel better.

  Corpus Iuris Civilis Justinianei (527-565):

  „Aerem corrumpere non licet” („Do not pollute the air.”) (Makra, 2002a; Makra and Brimblecombe, 2004)

„ Do not destroy anything aimlessly, which can cause pleasure anyone.”

Talmud

3.4. Environmental awareness in ancient Israel

- Environment is a natural element of the Jewish religion;

  [e.g. Jewish forbade clearing the trees around the city, their watering was compulsary, they had to take care of the environment and they were not allowed to live a luxury life (it is also a kind of wasting).]

  – laws of the Talmud on the maintenance of the overall environmental quality of life laws of the Talmud on the maintenance of the overall environmental quality of life:

  (i) it is prohibitid to open a shop in a courtyard of a house, or if the noise of the customers disturbs the peace of the neighbours.

  (ii) dovecotes must be at least 50 cubits from the city walls (1 cubit ≈ 45 cm) away so that pigeon dirt not harm the city's vegetable gardens.

  (iii) Threshing floors can only be a certain distance of the city to exempt the city from air pollution caused by chaff.

- 5th book of Moses id the base of Jewish ecology. This includes inter alia:

  (a) The soldier must not carry out their job (toilet) in the camp.
  (b) It is prohibited to build latrines close to a residential home because they exudes stench.
  (c) It is prohibited to open up sewers in the summer.
  (d) If someone is suffering from sewage of anybody else, he (she) may claim compensation as well.
  (e) The waste water can not be let out near the allotments, as it reduces crop yields.

The nature for Jews is a natural and fundamental thing, and they admit that one should live now, as it is written in the Bible, the Torah and the Talmud.

(a) The biblical cities were surrounded by a greenery in a modern sense that stretched to a distance of 1,000 cubits from the city walls.
(b) Olive and vine were forbidden to use on temple altars, because these trees produce large amounts of fumes when combustion.

- Even in Jerusalem, the holiest city, strict environmental regulations were introduced:

(

(i) The dung heaps are fully banned from the city.
(ii) tanneries should be installed at least 60 cubits from the city, because they are very smelly.
(iii) The tanneries can be built only to the eastern side of the city (in Israel the north and west winds are most common $\Rightarrow$ so stench will not come back to the city.
(iv) The mills can be built only 50 cubits from the city (from mills a large amount of dust comes into the air, and it's harmful to the human body if inhaled.)
(v) Wheat powder is harmful not only for humans, but it takes bad to arable lands, as well. Thus, if possible, mills should be built far away even from cultivated lands.
(vi) Garbage should be thrown only beyond the city area, incinerators and kilns should only be operated beyond the city, at least 50 cubits from the city wall, as it emits a lot of smoke, and attracts pests and rodents.

- Tosefta book of the law includes:

  (a) In drinking water one must not wash.

  (b) Lid should be put to all wells so that snakes, insects and evil spirits not attack the water.

  (c) Do not dig sewage pit near neighbours.
- Noise pollution

  (i) Mills are not allowed to isntall near the city. (Operation of the mill stones can cause high noise and vibration.)

  (ii) Operation of a single large school (with 50 pupils) nera a residential area depends on the inhabitants. (Namely, children can cause great noise that my disturb local people.)
- What is the reason that the ancient Jews dealt so much with the environment, and that environmental sensitivity was then pushed into the background?

The Jews had no their own land for a long time $\Rightarrow$ they did not feel themselves close to the nature.

Their is an old Jewish saying: *„The Jews deal better with their environment than the dirty Romans.”* (Makra, 2002a; Makra and Brimblecombe, 2004)

3.5. Air pollution in medieval cities

- Early societies

  combustion and heating – key role in forming air pollution, → firstly air pollution of interiors

  old cities

  small area, great population density

  (a) easier protection against external threats,

  (b) easy movement of people and goods transport within the city limits,

  ⇒ smoke (from blacksmith workshops, breweries, and other energy-intensive manufactures) during descending air flows accumulates between the houses.

  Medieval European cities:

  → high buildings,

  → densely populated narrow streets between houses and canyons ⇒ they keep smoke and mist;

- Medieval England

  (a) low energy-intensive industries (eg. bakeries, brick incinerators and smelters)

  (b) industrial energy demand in cities may have had probably smaller than household demand, which has increased significantly in winter.

  energy use in the Middle Ages

  → building materials (clay pots, tiles, glass, iron, steel and lime)

  (1) *iron smelting* – in the forests, near the wood source, and remote from urban population– to avoid pollution – may have happened,

  (2) *lime burning* - produced much higher quntatity compared to the production of iron smelting;

  utilized for

  (2a) preparing mortar and

  (2b) agricultural purposes;

- Lime produced by burning limestone ($CaCO_3$) in furnace at a high temperature. This cuts carbon dioxide and lime (CaO) is formed (1). When mixed with water to form a binder, hydrated lime [$Ca(OH)_2$] is formed (2):

$$CaCO_3 \rightarrow CaO + CO_2 \qquad (1)$$

$$CaO + H_2O \rightarrow Ca(OH)_2 \qquad (2)$$

Limestone had been traditionally burned by oak tree.

1253 (construction of Westminster): – III. Henry purchased <u>oak tree as fuel</u>,

1264: – III. Henry purchased <u>coal as fuel</u> :

„to Mayor of London, July 23, 1264,

Modified attorney: a shipload of marine carbon ("sea-coal") and four millstones should be delivered for the king, to the city of London without delay and promptly to Windsor castle, and there to be transferred to the captain of ghe castle."

- Origin of marine carbon (carbon Marus) (typical Hungarian translation: coal): it was delivered to major ports of England across the sea in the 13th century.

  Coal had to appear in London already in the early 13th century.

  Reason:

  1228: a central London street name:

  Sacoles Lane (Sacoles ≈ Sea-coal). The memory of it is still preserved by two London street name: Lane and Old Seacoal Lan and Seacoal Lane.

- The earliest documented occurrence associated with air pollution in England:

  Nottingham, summer, 1257: Queen Eleanor (III. Henry's wife) visited the Nottingham castle restoration process. She found the air so stinky from coal smoke that left to the Tutbury castle in order to save her health.

„I do not dare to laugh, because I fear that if I open my mouth, inhale bad air.”

William Shakespeare

Why did the medieval thinking assumed that the smell of sulphur from coal combustion is bad for human health?

Bad smell has long been associated with unhealthy air.

(a) unhealthy odours from the marshes were called "miasma" (named by ancient Greeks). Recent meaning of the word: toxic / infectious air.

Fears about marshes in the Middle Ages:

(1) Winchester Cathedral was needed to build further away from the planned location, because of the near constant stench emanating from a swamp;

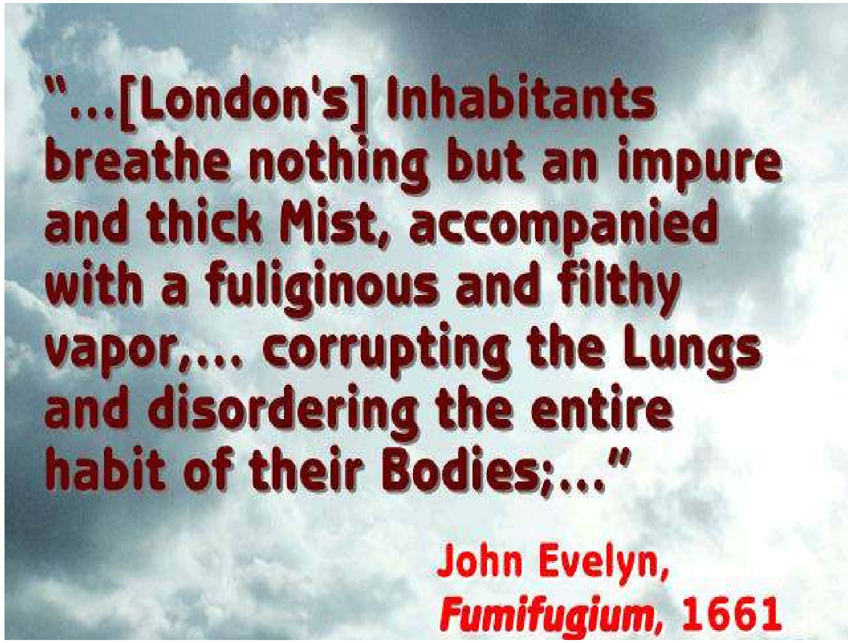
(2) the Fleet River in London was so smelly that the White Frairs monks and some of their companions had died because of the bad air (Makra, 2002a; Makra and Brimblecombe, 2004);

3.6. Attempts to control air pollution

Notable dates / events:

- 1273: England have banned the use of pulverized coal – the first known attempt in England to address air quality;
- 1285: a committee was set up in medieval London for investigating the high degree air pollution from coal combustion;
- A note from the 13th century: a carbon trader was tortured and then hanged for causing smoke;
- 1306: a statement issued the ban using coal ↔ two weeks later it was legally announced that this declaration invalid;
- 1377: the importance of the height of chimney, was recognized in the spread of air pollution; from then the minimum heights of chimneys were regulate in London,
- ⇒ air pollution decreased somewhat in the immediate vicinity of the pollution source ↔ overall air quality has deteriorated in the surrounding areas;

- IV. Henry (ruled: 1399-1413) has set up a carbon management,
- III. Richárd (ruled: 1483-1485) heavily taxed coal consumption,
- 1661: II. Károly (ruled: 1660-1685) gave a mandate to investigate smoke, and a body entrusted a proposal to monitor polluters,
- 1661: the first serious work was published in the area of air pollution;



- John Evelyn: *„Fumifugium”* or *„The trouble of the air and the dispersed smoke of London: and some medicine recommending respectfully”*.
- Air pollution control efforts of the courts and the parliament had a limited impact in the medieval London.
  - (i) based on seasonal frequency distribution of air pollution incidents / complaints, air pollution in London was clearly a summer problem,
  - (ii) $\Rightarrow$ burning of coal did not happen for the purpose of domestic heating, as heating should produce winter peak – as today;

- In the medieval London, the main source of air pollution (based on complaints found in documents from the 13th century), is lime-burning

  Reason:

  coal demand of lime needed for constructions: thousands t / y ↔ coal requirement of a simple charcoal forge: 1 t / y;

  lime-burning culminated in the summer.

  Reason:

  construction projects – due to the short days and cold winters - were concentrated in the summer,

  Lime production in the 13th century showed the same seasonal distribution as complaints related to air pollution;

- In connection with the air pollution, Londoners

  (a) sued the main polluters,

  (b) they also turned to the authorities with their complaints;

  Reason:

  They recognized that air pollution can damage not only their health, but also their property.

  Example:

  14th century, London: – a submission to the Court of Unpleasant Cases:

„Thomas Yonge and his wife, Alice complains to forge chimney to 12 feet (1 foot ≈ 30.5 cm) lower than it should be, and when from large iron pieces called "Osmond" breastplates, spears and other weapons are made, the roar of jackhammers shakes the house stones and rammed earth partition walls, so that they are close to collapse and bother people for their day and night, and ruin the wine and the beer cellars, and the smell of coal smoke penetrates in their rooms and kitchens, so that only for a fraction of their houses may be issued."

- The defense of Blacksmiths and arms manufacturers (≈ a the defensive of today's craftsmen).

  „We are honest merchants, and we must continue our craft around the city freely, making our houses for the job. The workshop has for long been on the property, and the houses, which enters the smoke, were only recently built."

- Blacksmiths used very few coal, but their work

  (a) was noisy,

  (b) was dirty,

  (c) they worked until late at night;

  ⇒ they have been exposed major attacks

- Around the success of early attempts to regulate air pollution of London there is a lot of uncertainty ↔ effective steps:

  (a) the Municipality has banned the use of coal,

  (b) construction of tall chimneys were encouraged;

„The sky is so polluted that only a storm can purify it.”
William Shakespeare

The advantage of tall chimneys: stronger winds can carry away the pollutants emitted by them with a better chance → the smoke can be diluted;

- Air pollution control in the medieval England

  (a) limiting the burning of coal (a group of blacksmiths in London suggested in the 13th century),

  (b) according to a reguation, brick incinerators in Beverley, regarding to the damage caused to orchards, have to be settled to a certain distance beyond the city limit;

  (c) 1307: regulation of lime kiln working with hard coal (for brick incinerators, forges and smelters it did not apply).

Regulations and laws brought at the end of the 13th century and early 14th century had little effect.

- Regulation of coal use in lime works could not stay for long time → 1329: lime-burning occurred again with charcoal.

  Until the mid-14th century, air pollution in London has been free from complaints.

  Reason:

  (a) they could use more wood for heating,

  (b) city dwellers could accustom to the smell of coal smoke (due to the very general lime burning);

  Until the age of Elizabeth, lime burning remains one of the most important uses of coal – Shakespeare complains about the smell of lime works (Makra, 2002a; Makra and Brimblecombe, 2004).

3.7. The smoke and fog in London

- It seemed that due to the laws of *„Reduction of Smoke Inconvenience”* only a matter of time, and air pollution problem of London would be solved.

  <u>**Problem:**</u>

  The magistrate authorities were reluctant to impose environmental fines, that would deter polluters.

  <u>**Reason:**</u>

  The city leaders feared that the factory owners in this case significantly reduce their production.

- In London in the late 19th century, there was no air pollution monitoring network $\Rightarrow$ no one knew the degre of air pollution.
- 1869-1870: R.A. Smith took first precipitation samples and analyzed them.

Isolated measurements

⇒ (a) improvement of air quality,

(b) other long-term changes??? ...

Huge chimneys London:

Result: black smoke emissions declined slightly,

Problem:

(i) the frequency of the fog increased,

(ii) the thickness of the fog increased,

(iii) atmospheric haze become more frequent;

Notes in association with the London fog

(1) in the first half of the 17th century, the fog was not at all uncommon, but it surely occurred naturally [Thomas Harriot, astronomer (1560-1621)],

(2) At the end of the 17th century, in weather notes of astronomer John Gadbury some very thick and enduring London fogs are referred to as "very smelly fogs";

Frequent mention of London fogs suggests that the city was much foggier than usual. This could be a result of a more stable air circulating system, which could have prevented the dissolution of mists in this stage of the little ice age.

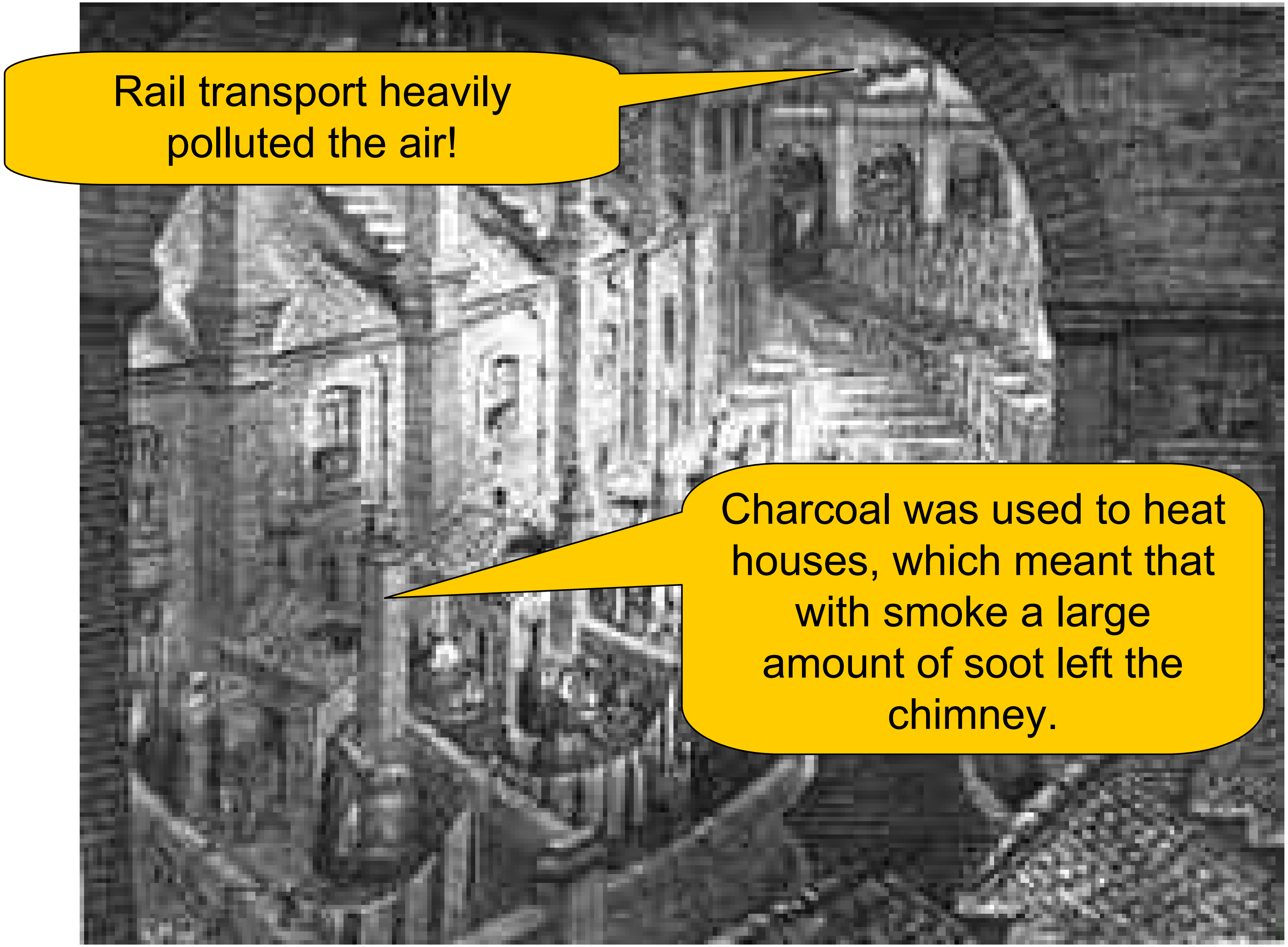
1680-as évek: H.R. Bentham, German visitor reported in his travel diary on the climate of London prone to fog.

(3) The 19th century fogs were thicker, and more frequent and had a different colour than in the past. Then people began to suspect that the fog is related to air pollution.

- In Victorian England

(a) Mossman analyzed a 200-year long dataset $\Rightarrow$ a frightening increase was experienced in the frequency of fog during the study period,

(b) Brodie detected a definite upward trend between 1870-1890;


Rail transport heavily polluted the air!
Charcoal was used to heat houses, which meant that with smoke a large amount of soot left the chimney.

.

- The 1880s: "Fog and Smoke Commission" → goal: to reduce smoke,

  (a) regarding emissions from factories, existing emission control should be tightened;

  (b) introduction of restrictions is not a solution in relation to household heating; instead examples of distribution of good heating;

  Example:

  [A proposal: Welsh girls should be sent to the downtown who show us how to fire the harder coal (anthracite).]

- Fog and tourism

  First the visitors were disappointed when they could not enjoy the view of the capital because of the fog.

  End of 17th century: German travelers took the reputation of London fog ⇒

  19th century: many people were even more disappointed, when they did not meet with this "fame" of London.

1888: Poet James Russell Lowell (US Secretary) wrote the following letter when visiting England:

„For Miss Sedgwick

October 3, 1888

Radnor Place, 2,

We are at the beginning of the foggy time of year, today we have yellow fog, which always brightens me, so ingeniously transforms things. There is something mysterious in it, which flatters the self-esteem, which lets you belong to a unique layer, which can do to wrap into the golden mantle of loneliness. And at the same time very picturesque sight. Even the flys are bordered by a halo of gold, and all the people on the street are like images of fading frescoes. Even the gray and even black fog are new and unknown world, which attracts the mortals who bored with the usual landscapes."

The foggy season began late fall and lasted until the end of the winter, but in the situation was the worst in November.

The cold and the fog was a popular background of the events of detective novels.

Frederick Marryat, author of the book *"Children of new forest"*, writes: *"November is the month of misanthropy and suicides, too."*

A French proverb says: *"In October the English shoots pheasant, in November shoots himself."*

”There is no sun, no moon …

There are no leaves, no birds, –
NOVEMBER”

(Thomas Hood)

- Since the November mists were thicker and more durable ⇒ they had probably much greater effect. Very dense fogs, even in the 20th century records, have the highest frequency in November.

  There was a close relationship between onset of fogs and frequency of cases of depression in the winter months. The gloom come upon the city. It was so dark that the houses had to turn the lights on during daylight hours.

AP

- New terms were cretaed: pl. *„daylight darkness”*, *„*high fog”*.

  [*high fog: those periods during the day when there was no fog on the surface. In this case, sometimes the Sun did not look at all – although it was very dark but – lights of the buildings could be seen yet a few miles away.]

- Calendar of one of the most serious London smog event

  January 16, 1955: daytime darkness covers the city.

  Air pressure / weather of the day:

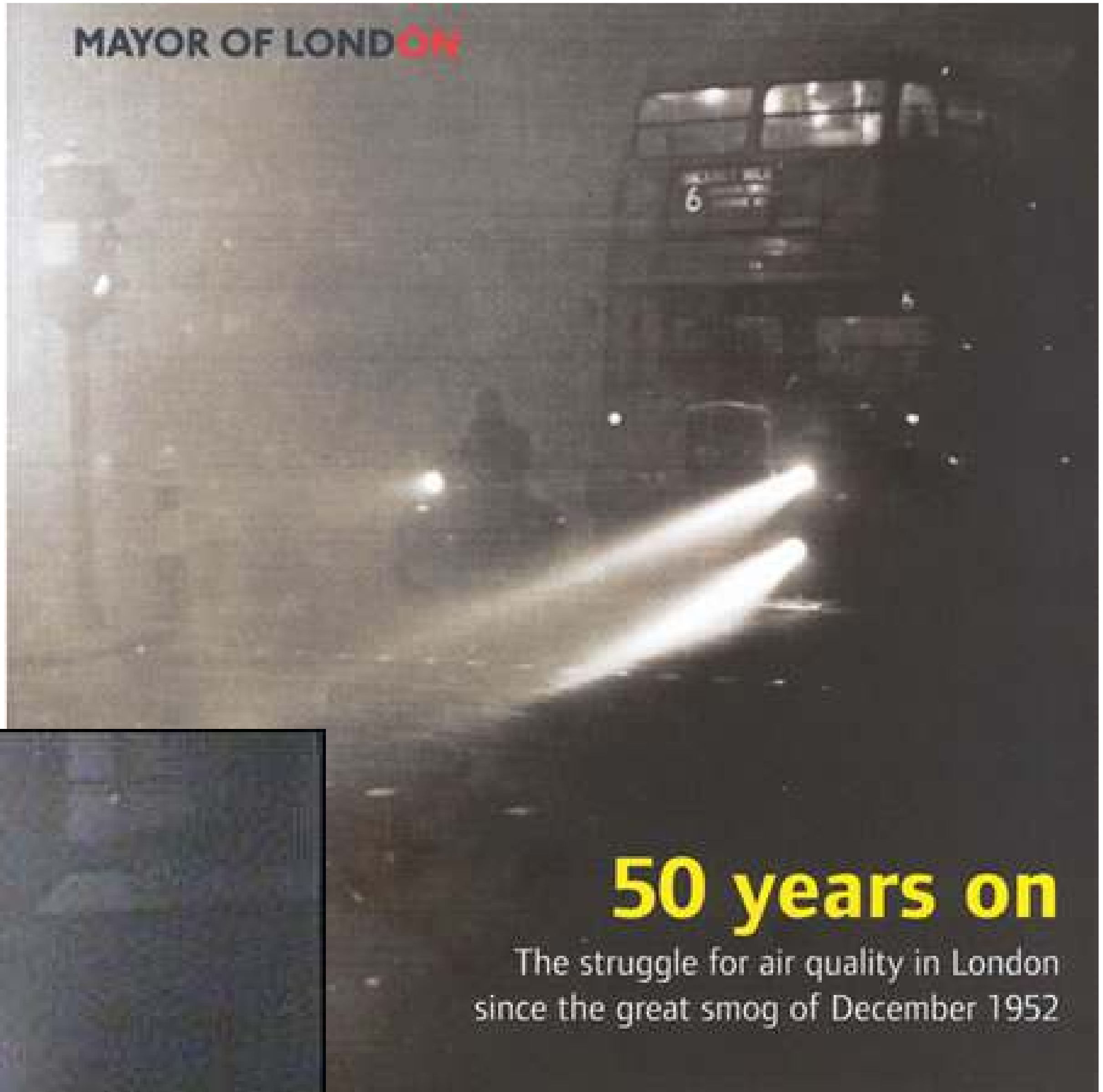
  deep depression, with very active fronts and dense clouds. There was fog and temperature inversion in the lower layers of the atmosphere. The morning light showed that the wind drove the smoke toward northeast from London. The smoke did not dissipate, as the inversion prevented vertical mixing. The thickness of the initial smoke layer was of approx. 175 m. It had just reached the Chilterns, when a cold front crossed its path. The air containing smoke rose in the powerful convergence zone before the front. This upwelling accumulated the polluted air into a more than 1 km thick vertical column. According to flight observations, this cloud Around noon the smoke layer has been heavily accumulated over the Chilterns. A short time later, wind direction has turned and wind gradually strengthened. The wind took this air with the very thick column of smoke and cloud back over London.

  Strength of illumination

  on a sunny January day in London it is ≈ 36 kilolux, which reduces to approx. 7 kilolux on a heavily overcast day in January. On the study day, at 13^{15} the strengh of illumination decreased from 7 kilolux to 0,03 kiloluxra. During 6 minutes almost complete darkness was in the city! According to the Londoners it seemed as if the world had come to the end.

Piccadilly at noon, January 16, 1955

Other effects of the fog (apart from depression and tourism):
(1) increased lighting costs,
(2) disruptions in transport,
(3) the number of accidents increased,
(4) during long-term fogs sanitation costs increased (in this case there was a strong soot deposition).).



The disturbing effect of fog on traffic

November 11, 1667, London:

Anthony Woods writes on a big fog when *"horses ran to each other, carts, horse-drawn carriages, etc. collided."*

December 8-14, 1873, the Victorian London:

– complete traffic chaos.

It was such a thick fog that - not seeing even on the banks of the Thames further on the tip of their nose - at least 15 people sank in the northern docks.

London, December 5, 1952. 10^{30} a.m.

Particle concentration: 3.000 $\mu g \cdot m^{-3}$

Source: National Archives

Effect of foggy periods on mortality trends
1873: in foggy periods, 700 more people died in London as it could have been normally expected.

Persistently foggy periods continued even in the 20th century. Among them, the most extreme is the *"Great Smog"* in 1952. (Table 1).

SO_2 daily threshold (EU)= 125 $\mu g \cdot m^{-3}$; PM_{10} daily threshold (EU)= 50 $\mu g \cdot m^{-3}$;

Table 1
The major London smogs

year	month	duration (day)	mortality excess	maximum daily SO_2 concentration, $\mu g\ m^{-3}$	maximum daily smoke concentration, $\mu g\ m^{-3}$
1873	December	3	270-1000		(a)
1880	January	4	700-1100		
1882	February				
1891	December				(b)
1892	December	3	≈ 1000		
1948	November	6	≈ 300		
1952	December	5	4000	3700	4460
1956	January		480	2800	1700
1957	December		300-800	2800	3000
1962	December	4	340-700	4100	1900
1975	December	3	(c)		500-600
1982	November			560	

(a) smoke concentration in early fogs was 800 $\mu g\ m^{-3}$, or higher.
(b) the deposition of soot in this fog was 9.4 $g\ m^{-2}$.
(c) statistically non-significant.

The effect of the fog on animals

Animals also suffered from fog. A significant portion of cattle that came to the 1873 World's Fair and placed at Islington were destroyed, but wild animals also suffered from fog.

The visibility did not exceed 500 m for a week.

The fog of London, and detective stories

Book was not published not that did not mentioned fog. In the book of Conan Doyle titles "The number four", Sherlock Holmes, Watson and Miss Morstan go to Upper Norwood on a misty September evening, but by the time they get there, the fog was disbanded (Makra, 2002b; Makra and Brimblecombe, 2005).

London City: visibility was less than 50 m-nél for 48 hours.

- In the special literature there is no proper explanation for the colour of the fog. Descriptions mention most often the yellow fog.

The beginning of the 19th century, Byron: *„A greyish-brown dome descends over London”*

„… A mighty mass of brick, and smoke, and shipping,
Dirty and dusky, but as wide as eye
Could reach, with here and there a sail just skipping
In sight, then lost amidst the forestry
Of masts; a wilderness of steeples peeping
On tiptoe through their sea-coal canopy;
A huge, dun cupola, like a foolscap crown
On a fool's head—and there is London Town! .”

Lord George Gordon Byron: Don Juan, part
http://www.gutenberg.org/files/21700/21700-8.txt

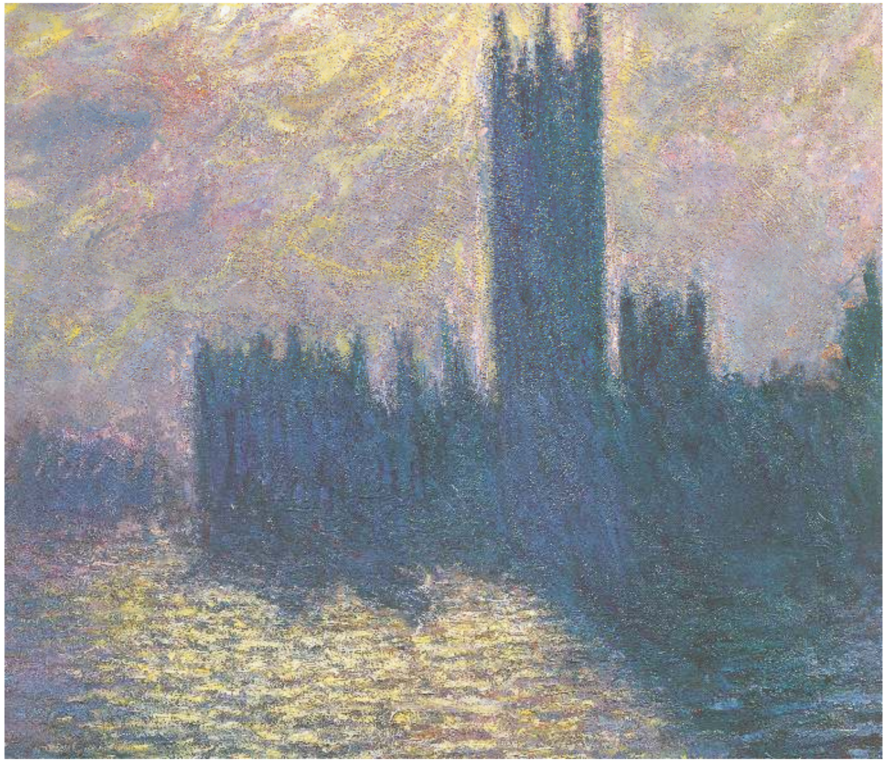
1840s: thick yellow fog in London. <u>The probable cause of the yellow fog:</u>
(a) In an atmosphere - above the fog layer - fine smoke particles absorb blue light in the visible range in such a way that the fog appears in yellow in the surface.
(b) yellow fog at night: most likely caused by light shop-windows and the gas lamps.

We can read in a book of Conan Doyle (*"Adventures of Bruce-Partington"*) (in which detective Sherlock Holmes investigates, who has a friend, Watson) that a fog settled in London in November 1895. On the fourth day of fog Watson writes: *"oily, heavy, brown material is swirling around us in the air, which is condensed into droplets on glass window."* This assumes that the droplets may have contained coloured components.

• The best story dealing with the parallel of air pollution and the destruction of London is the book of Barr, titled *"Nemesis of London".* The book was made after a depressing foggy period → a chillingly prophetic vision: the author assumes a direct link between air pollution and the destruction of the city. He describes that almost all population of London drown in the mist that covers the city.

• Apocalyptic work of Conan Doyle: *„The dangerous zone"*. He writes that mankind will die out when the Earth passes through the zone of an "anesthetic" gas.

The dense fog and smoke led to the formation of particles and oxides of sulphur simultaneously in the air of London



www.ibiblio.org/wm/paint/auth/monet/parliament/

Claude Monet:
The Thames below Westminster (1904)

The doomsday vision of 19th-century arts

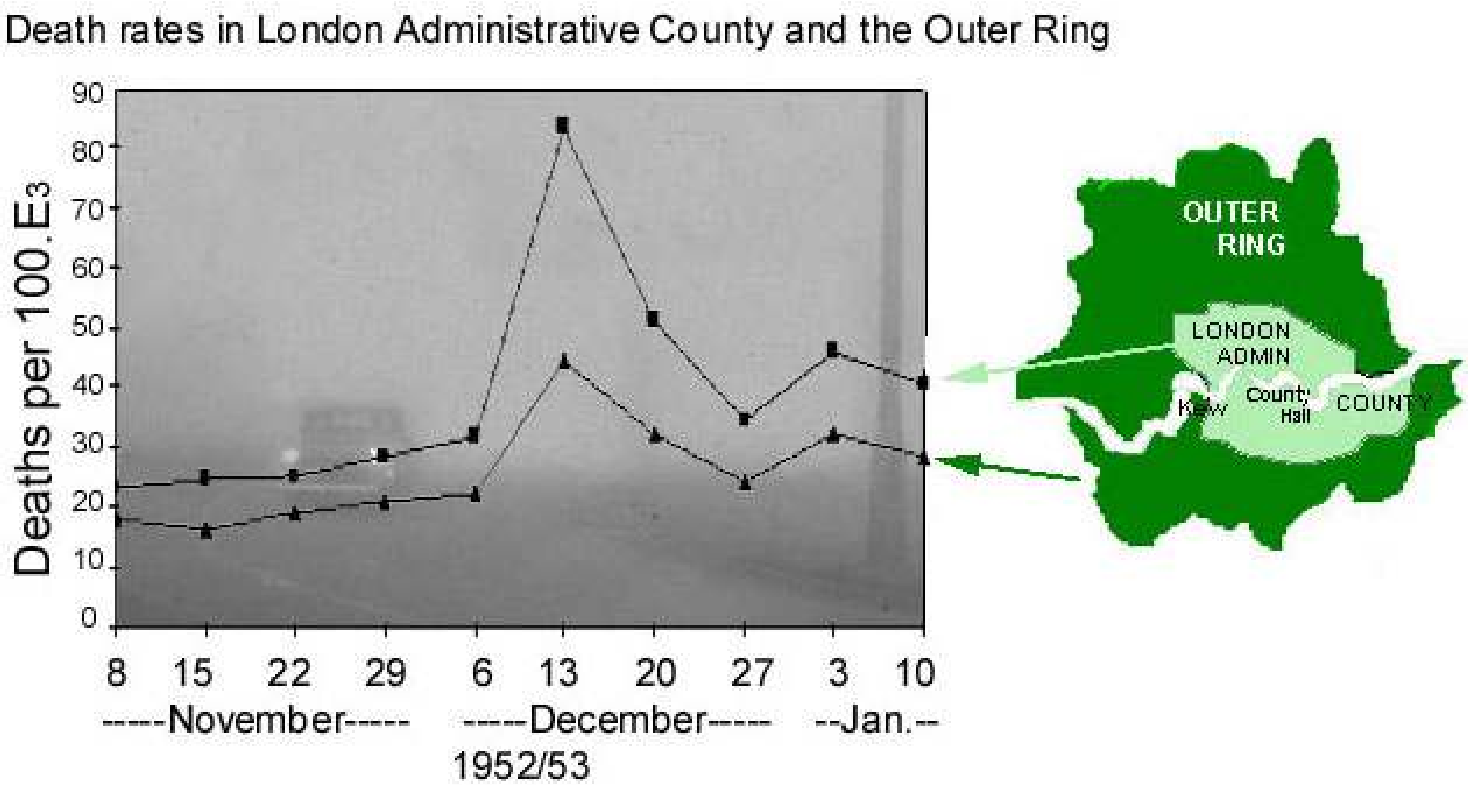
(a) Monet was in London at the beginning if his career, and it seemed that he was not at all disturbed by the fog → his painting "The Thames below Westminster" (National Gallery, London). Monet pointedly visited London in the winter to prepare a series of Thames.

(b) In the titles of paintings of a number of impressionists - eg. Pissarro - even the word "mist" is also included.

(c) Chiang Ye, Chinese writer - who often went to London in the 1930s – in his book titled "A quiet traveler in London" wrote on fog, and found that fog provided help him unfolding of his style of oriental inspiration (Makra, 2002b; Brimblecombe and Makra, 2005).

3.7.1. The big smog and what happened afterwards

- In the week ending on December 13, 4500 people died as a result of the smog.
- From December 1952 to March 1953 13,500 more people died in London than usual.
- 1853: Charles Dickens writes of the smog in detail in his book, titled *"Bleak House"*.



Prolonged contact of the polluted air or with various materials brought new problems to the surface.

Example:

(1) One of the pillars of the Charing Cross railway station collapsed.

Reason:

The material of the column contained 9% iron sulphate ($FeSO_4$) (reaction of iron and sulphuric coal smoke).

environment.yale.edu/.../
london_smog_1952.html

(2) Stone and brick buildings of London were destroyed faster at the turn of the 19-20th century than ever before. The thick dark smoke covered the cities coated the windows and deposited in the homes.

(3) The outer surfaces of the buildings were painted dark. In the homes dark wallpaper was the fashion and cleaning of curtains was a constant problem. Popularity of silver bowls and cutlery declined.

Reason:

(a) erosive / bleaching effect of urban air on their surfaces;
(b) it was rare for any who have ever polished them;

The "Great Smog" □ 4 to 8 December 1952.
It was a relatively good time before the smog week. Every day a light breeze was blowing, the sun was shining for moments, but on December 4, Thursday, weather conditions suddenly began to deteriorate. The wind weakened, the air became more humid and the sky dingy. A slow-moving anticyclone stopped over in London. Thursday evening it became apparent that a very large fog will descend on London. On Friday a decidedly Dickensian image was sitting on the city:

"Night at noon." The London Piccadilly Circus at noon, a very serious smog during the winter 1955.
Source: *When Smoke Ran Like Water,* Devra Davis, Perseus Books

„… fog everywhere, fog up the river where it flows among green aits and meadows – fog down the river, where it rolls defiled among the tiers of shipping and the waterside pollutions of a great (and dirty) city. Fog on the Essex marshes, fog on the Kentish heights. Fog creeping into the cabooses of collier-brigs; fog lying out on the yards, and hovering in the rigging of great ships; fog drooping on the gun-whales of barges and small boats. Fog in the eyes and throats of ancient Greenwich pensioners, wheezing by the firesides of their wards; fog in the stem and bowl of the afternoon pipe of the wrathful skipper, down in his close cabin; fog cruelly pinching the toes and fingers of his shivering little prentice boy o the deck ."

Central London at the time of the murder smog, in December 1952. At this time visibility was less than 30 feet (1 foot = 31.6 cm). During the smog people saw neither their hands, nor their feet, and the buses traveled so that policemen went before them, who lit lamp. Surce: *When Smoke Ran Like Water,* Devra Davis, Perseus Books

According to many people, the fog was thicker on that Friday morning, than ever. It has become even thicker during the day. In the afternoon people have felt bad, they felt suffocating odour in the air. Those who were then in the open, found their skin and clothes dirty after a very short time. Friday night the number of patients treated with respiratory complaints has doubled, and the anticyclone completely stalled. Meanwhile, millions of chimneys poured smoke into the stagnant, foggy air.

On Saturday, the fog strengthened further. Visibility gradually reduced almost to zero, and the traffic completely stopped. Londoners continued to suffer, many people died. On Sunday nothing changes happened, the number of deaths has continued to grow. The rescuers were unable to carry out their duties. It is doubtful whether many people surveyed the nature of tragedy. A Victorian man knew that this fog can kill you, but in the 20th century it was already unknown. By Monday morning, the weather improved slightly, transport gradually started again, even though there were huge delays. By Tuesday, the "Great Smog" disappeared.

What happened – how did the smog take place?

*Changes in smoke and sulphur dioxide concentrations were compared with mortality. The maximum daily concentration of smoke (5 December) and sulphur dioxide amounted to 4460 $\mu g \cdot m^{-3}$ and 3700 $\mu g \cdot m^{-3}$, respectively; however, in some short periods significantly higher values may have occurred. In the four-hour average of the densest smoke incredibly high 14.000 $\mu g \cdot m^{-3}$ smoke concentration was measured. The air conditioning system of the National Gallery in London several times
1 □m.
clogged due to the large amount of solid material accumulated in the air (Makra, 2002b; Brimblecombe and Makra, 2005).

[*The disperse system, wherein the dispersion medium is gas, and the dispersed material, that is the dispersed part is solid, is called smoke. Smoke particles of the dispersed material are combustion products of fuels; their size is smaller than 1 μm.]

This smog was no longer possible to ignore.
1953: formation of the Beaver Committee
1955: the government submitted to the parliament a draft regulation of air pollution.
1956. július 5: Clean Air Act :
(a) for the first time regulated sources of industrial and household pollutants
(b) limited the emission of smoke,
(c) prohibited the emission of black smoke;

District governments → smoke-free zones; industrial plants → high chimneys + high efficiency filters. Household emissions (90% of the total smoke) substantially decreased compared to the 1970s.

London air had cleared dramatically. Many small cities are sometimes more smoky than London**.**

Fashionable smog masks, London, 1950s

Source: DL Davis.
When Smoke Ran Like Water (2002)

Reasons

Heavy smog episodes were quite frequent in London over the past two centuries.

Key factors

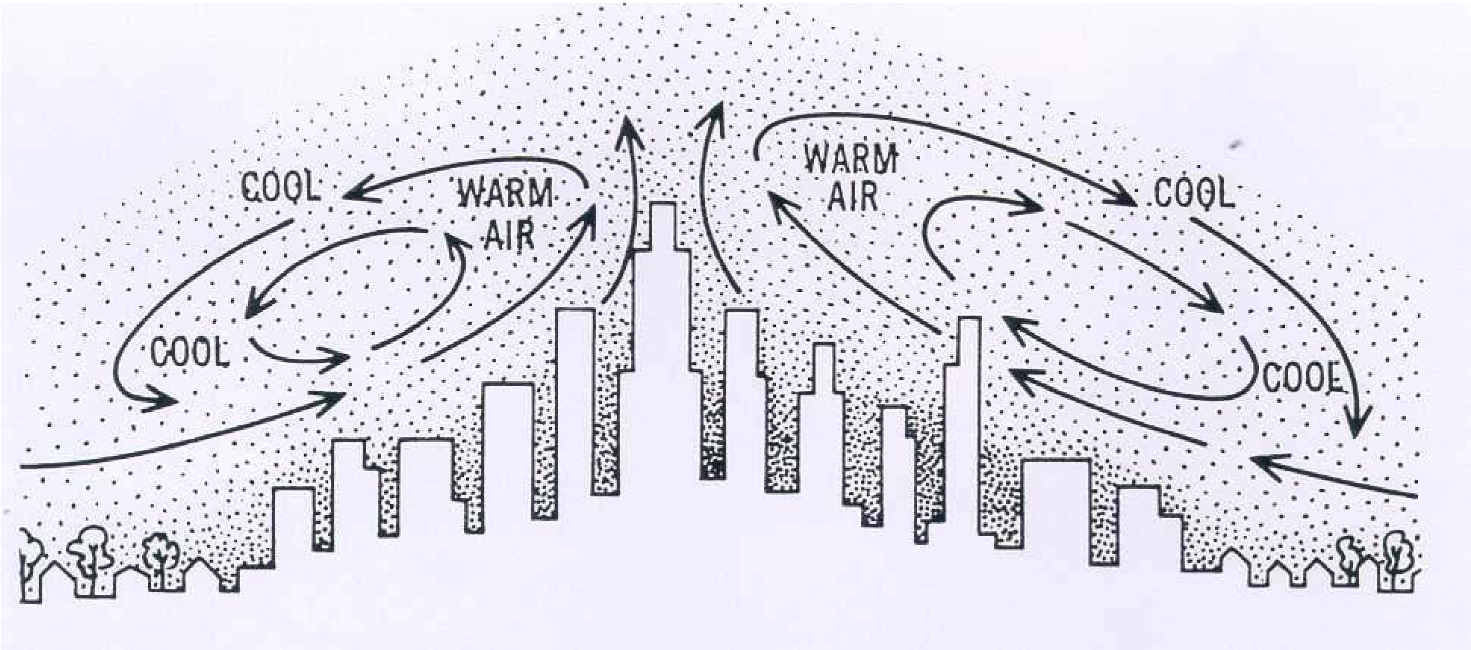
- persistent anticyclonic weather situation
- fog
- temperature inversion
- vehicle exhaust emissions
- household heating
- smoke from factory chimneys
- smoke from coal combustion

1873: 700 dead
1911: 1.150 dead
1952: > 4.000 dead

– The latter incident prompted the parliament to bringing the Clean Air Act into force in 1956.

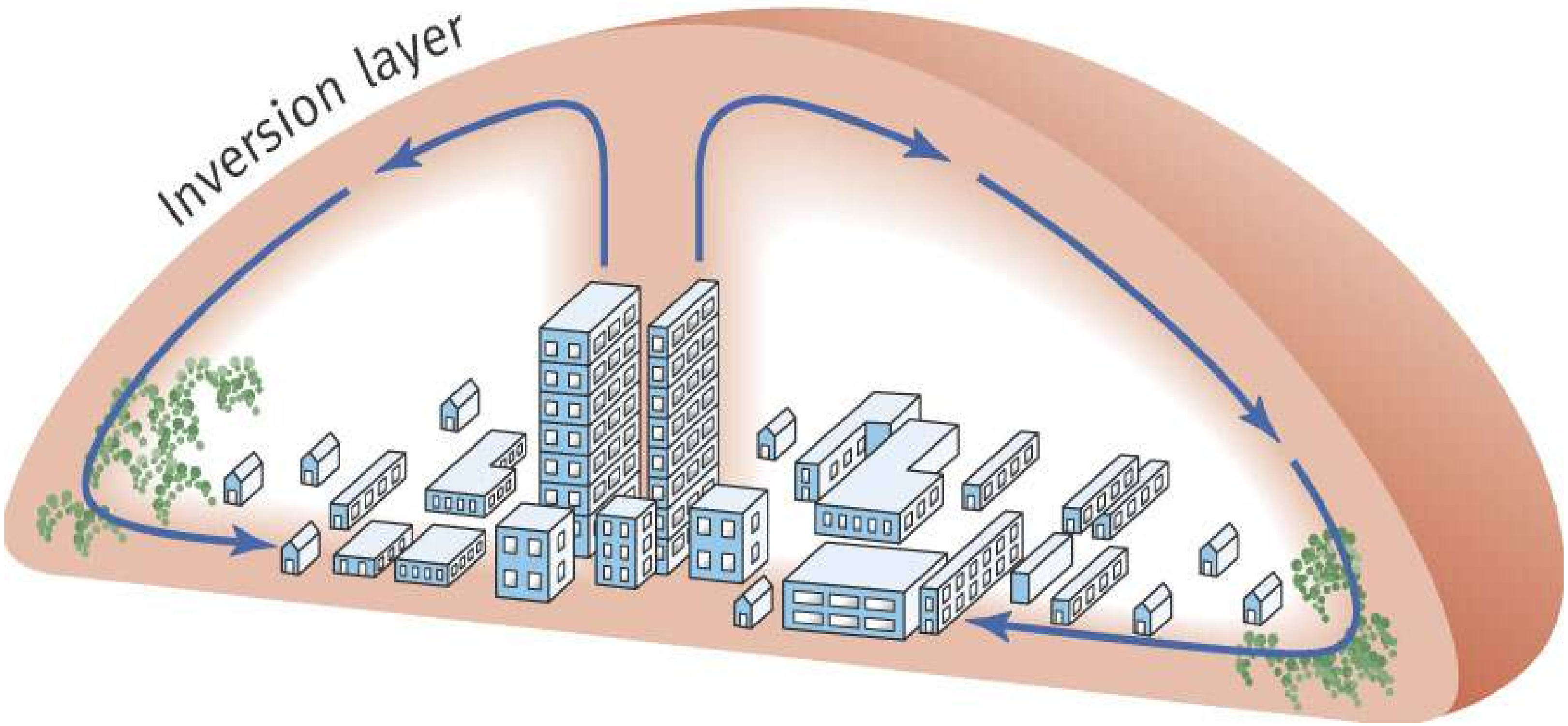
LOCAL EFFECTS

- Land - sea relationship (water warms and cools more slowly, so winds are blowing daytime to the land, while at night the toward the sea)
- Air cooled on hillsides results in winds blowing toward the valley
- In the settlements, many concrete and asphalt absorbs a lot of heat, at night heat island is formed over the city (steady air circulation)



Urban thermal inversion

(warm air over the cold, retains air pollutants)



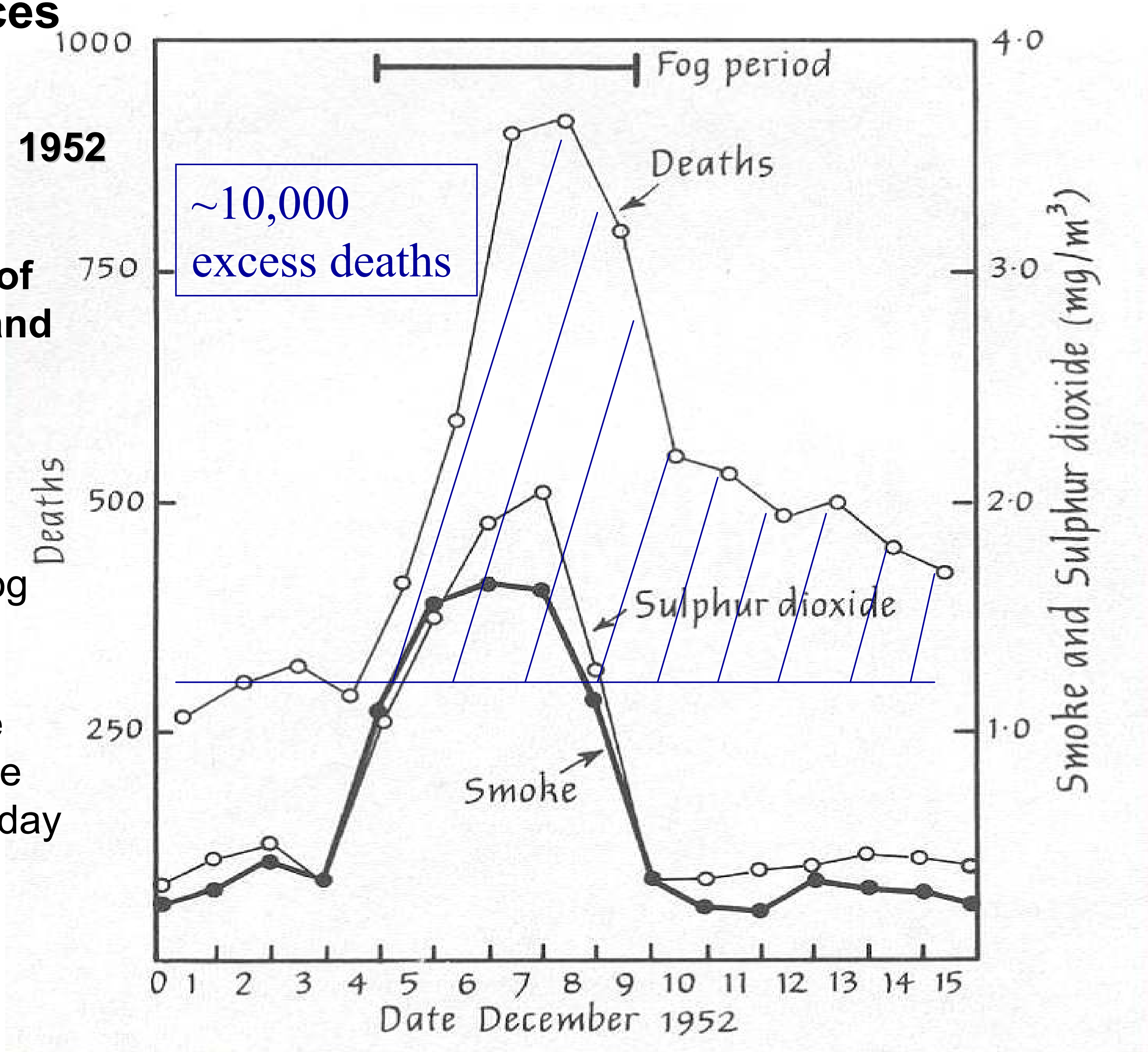
Consequences

London smog, 1952

concentration of air pollutants and the number of death cases

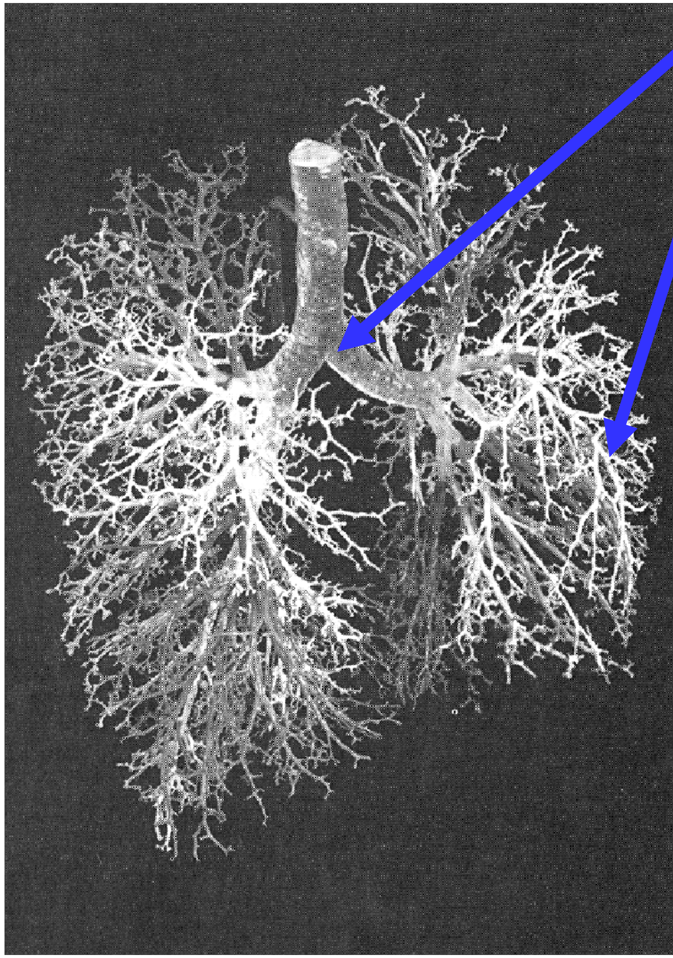
- 4.703 died in the London smog in two weeks.

- The death rate culminated in the 8th and the 9th day with 900 deaths daily.



Healths effects

- Pneumonia
- Bronchitis
- Tuberculosis
- Heart disease
- Asthma
- Respiratory diseases
- Cardio-vascular diseases



Conducting air
- trachea
- bronchi (the first 10 branches; c-shaped cartilage is in their wall)
- bronchioles (after the branch 10; no c-shaped cartilage in their wall)

Gas exchange
- respiratory bronchioles (branches of the last bronchioles)
- alveoli (where gas exchange takes place)

3.8. Scientific milestones in the management of air quality

- 18-19th century: development of the physical sciences and mathematics → important advancement of knowledge in the atmospheric transport of pollutants;

(a) 1855: A. Fick set up a one-dimensional diffusion equation,

(b) 1882: Reynolds has published the first major study on the turbulence theory, in which he defined the so-called *Reynolds number,

(c) 1894: Reynolds illustrated undoubtedly diffusion and viscosity caused by the turbulence,

[*Reynolds number: Reynolds number ratio of inertial force to viscous force in the flow field.

→ Inertial force: a force that will take place if any (in the simplest case) mass point of mass *m* is examined in an accelerated movement reference system compared to the inertia system, using the basic dynamic equation.

→ Inertia system: a reference system, in which the law of inertia is valid.

→ Viscosity force (internal friction): shear force inside the body against deformation. According to viscosity force, change of the shape of any solid, liquid, or vapour-phase body, displacement of their individual layers on each other requires work.]

(d) 1912-1914: studies of the researchers by the Mellon Institute of the University of Pittsburg assumed that air pollution is harmful to health,

(e) 1915: G.I. Taylor in his work titled „Vorticity in the atmosphere" introduced the concept of mixing path,

(f) 1917: A.E. Wells recognized the role of the chimney height – as an important factor – in reduction of ground-level air pollution concentrations;

(g) 20th century: arrangements for the management of air quality (e.g. for checking air pollution – first of all, reducing smoke and smell) have appeared ;

(h) 1918: J.S. Owen published his work titled *„Measurement of air pollution”*;

(i) 1926: Owen and Shaw together published the first comprehensive work on the problems of urban air pollution, titled *"Smoke problem of big cities"*.

At that time the main sources of anthropogenic emissions were as follows:

(1) industrial activities,

(2) electrical energy,

(3) household heating;

– solid fuels were burned; the emissions were not regulated;

Early control efforts:

(1) aimed at regainig specific emitted plant materials (e.g. acids),

(2) to reduce smoke emissions;

<u>Understanding dispersion of air pollutants:</u>

the very first experiments were based on observations of bursts of anti-aircraft guns bullets;

(j) 1920: Richardson used photographs of a time shift to study the diffusion of smoke,

(k) 1921: G.I. Taylor introduced the Fick's diffusion transfer theory and the concept of homogeneous turbulence,

(l) 1935: G.I. Taylor introduced the concept of homogeneous and isotropic turbulence,

(m) 1923: O.F.T. Roberts made a proposal to resolve Fick's diffusion equation in the case of instantaneous point sources,

(n) 1923: Schmidt dealt with the theory of three-dimensional diffusion problem,

(o) Later Bosanquet and Pearson developed a diffusion model based on point source,

(p) 1925: Richardson and Proctor received diffusion data from great distances using balloons,

(q) 1937: Rotschke Rotschke correlated typical daily changes of air pollutants with periodic variability of atmospheric stability;

After World War II the problems related to air pollution in cities continued to increase;

(r) 1941: Kolmogorov introduced a similarity hypothesis of small-scale turbulence, which later became the basis for development of theories on local structure of turbulence and their applications,

(s) from the end of 1940: electronic computers → high development of

(*) computer modeling of the atmosphere and air pollutants,

(**) research into the field of atmospheric turbulent diffusion;

(t) 1959: Monin applied similarity principles for a single source diffusion, furthermore Gaussian equation of Sutton based on point source was extended to high sources,

(u) 1949: through Batchelor, the mathematical theory of turbulence diffusion renewed,

(v) parameters of σ_y and σ_x (standard deviation of horizontal/vertical distribution of smoke concentration) some years later were incorporated into the diffusion equation,

(z) 1958: Machta developed the first usable model for global scale diffusions.

(x) 1960s: science and technology are developing

$\Rightarrow$ (*) substantial progress in the field of air pollution meteorology,

(**) environmental awareness increases,

public demand $\Rightarrow$ political force to study the problems of air pollution, and to regulate the phenomenon;

$\Rightarrow$ (*) the relevant legislation evolves

(**) the first simplified air quality control systems are introduced;

„The new US citizen enjoys the busy streets, the smog-covered skies, are choking industrial acids, surfeit from screeching noise of the wheels, from row houses, while the city itself wither and die over time.”

John Steinbeck

Air pollution history in the United States

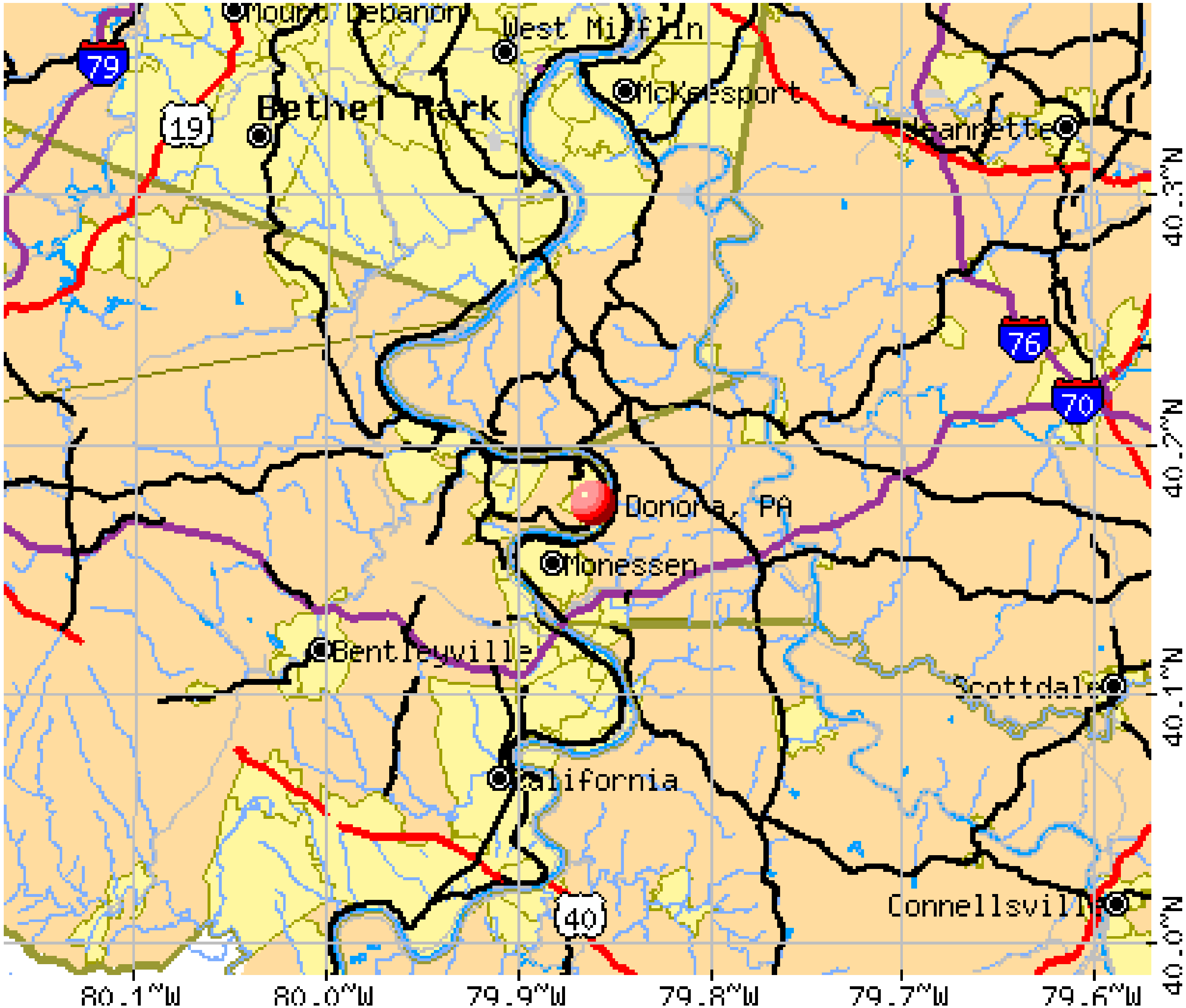
1870 - : In the US, air quality has deteriorated rapidly after the Industrial Revolution. The basic problem was coal burning in the central part of the country and the Midwest.

1943: In the US, the first serious air pollution episode described as smog happened in Los Angeles. The visibility was reduced just a block away. Symptoms of this phenomenon were: itchy eyes, shortness of breath and nausea.

The event was described as a gas attack, and the near butadiene plant blamed.

Protests at Pasadena City Hall on November 9, 1954, following fifteen days of smog in October.

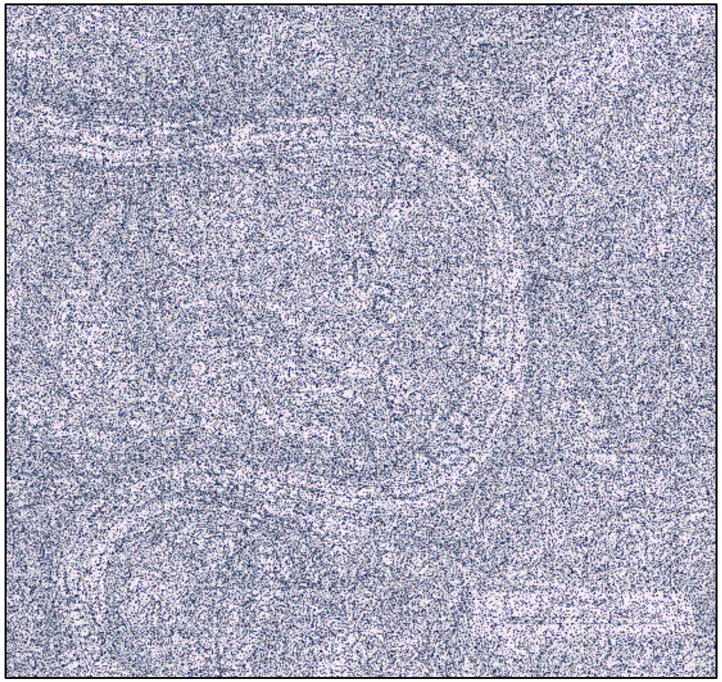
Donora, PA - 1948

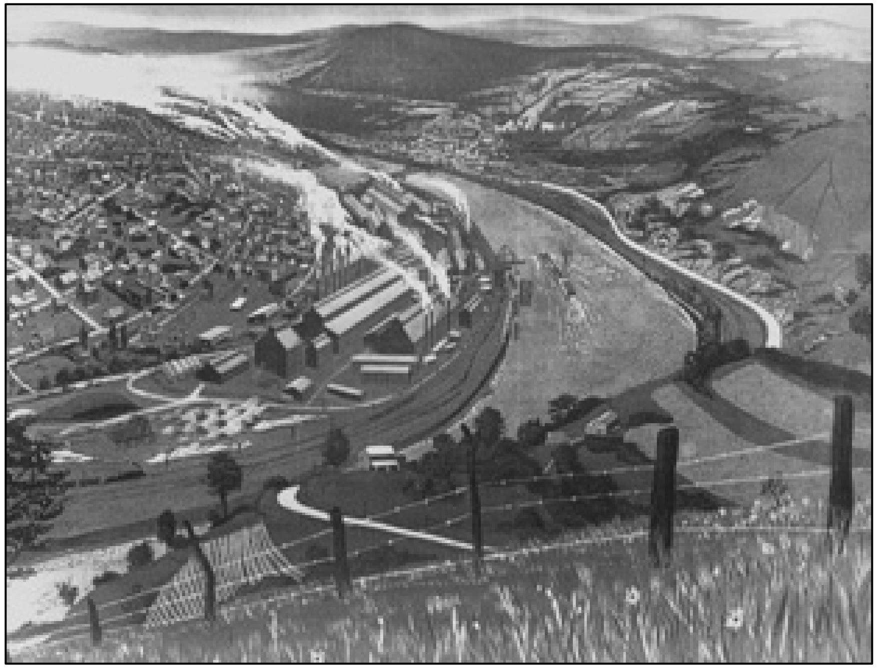


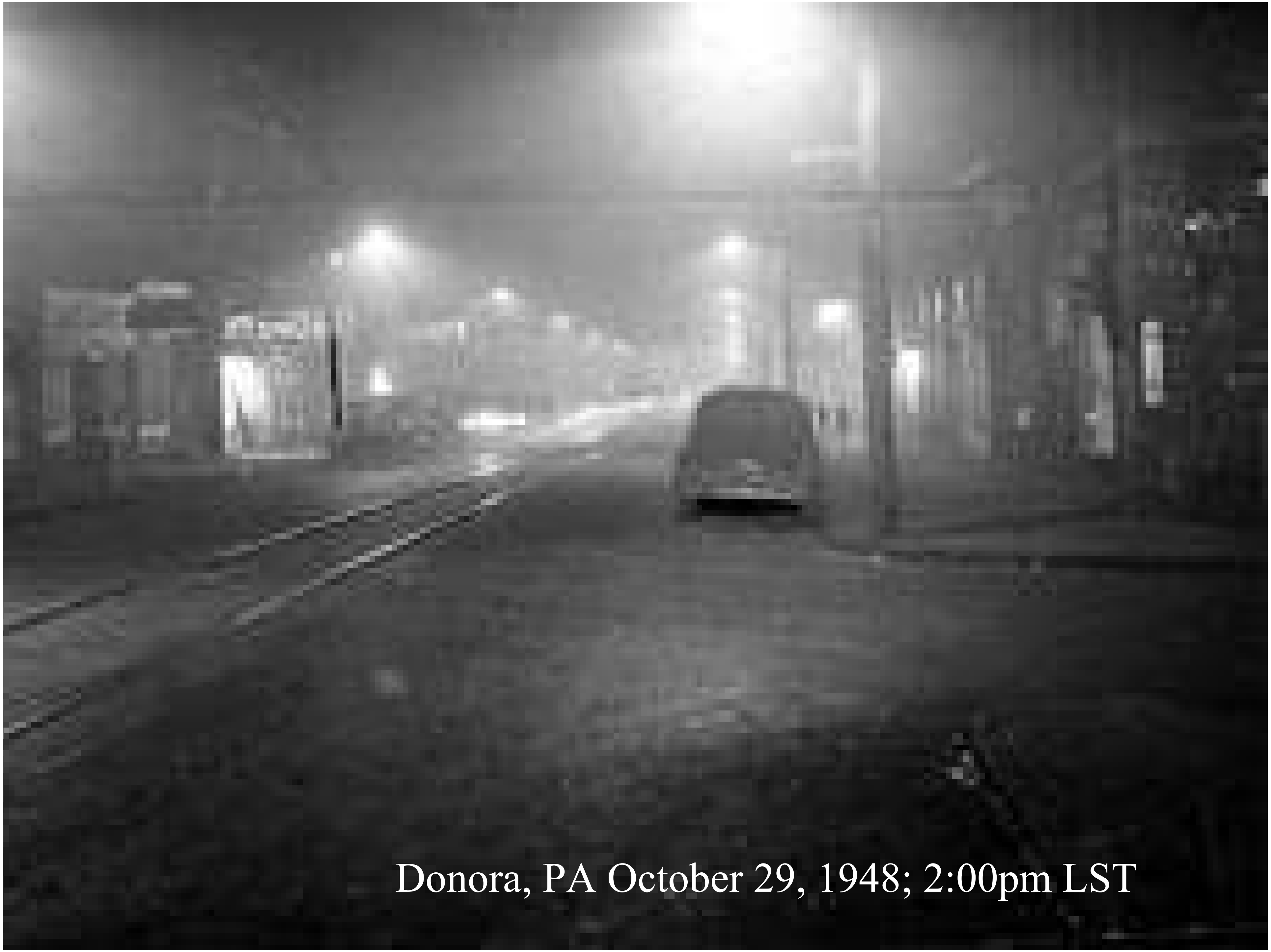
location:

West-Pennsylvania, Valley of Monongahela-River

Donora PA, 1948







Donora, PA October 29, 1948; 2:00pm LST

Donora (PA) smog, 1948

2:00 PM LST, Oct 29, 1948

www.oceanservice.noaa.gov/.../supp_pol02c.html

lhncbc.nlm.nih.gov/.../safe_donora.html

Other severe air pollution episodes in the US before 1970:

St. Louis - **1939**, for one week lighting was needed daytime in public areas;

LA - **1943**, visibility reduced to three blocks away;

Donora, Pennsylvania - **1948**, 20 dead and 5.190 people (half of the city's population) patient;

LA - **1954**, due to heavy smog in October stopped almost all the factories and the schools were closed;

NYC - **1953**, cca. 200 dead; **1963**, 405 dead; **1965**, 65 dead; **1966**, 168 dead.

After introducing Clean Air Act did air polution decrease?

1966 On the day of thanksgiving, there was a huge smog in New York, which was due to transport, industry, power plants and domestic heating based on coal burning. Owing to persistent anticyclonic conditions and temperature inversions polluted air has accumulated.

Smog warnings were assigned in the area of three states. Car owners were asked to stay at home. The incinerators have stopped. The heavy smog had 168 deaths.

Credit: Neal Boenzi/NYT Pictures

1966: New York City buried under a sea of smog.

1960s and 1970s:

In American big cities, rapidly growing industrial production and car use has led to a heavy smog.

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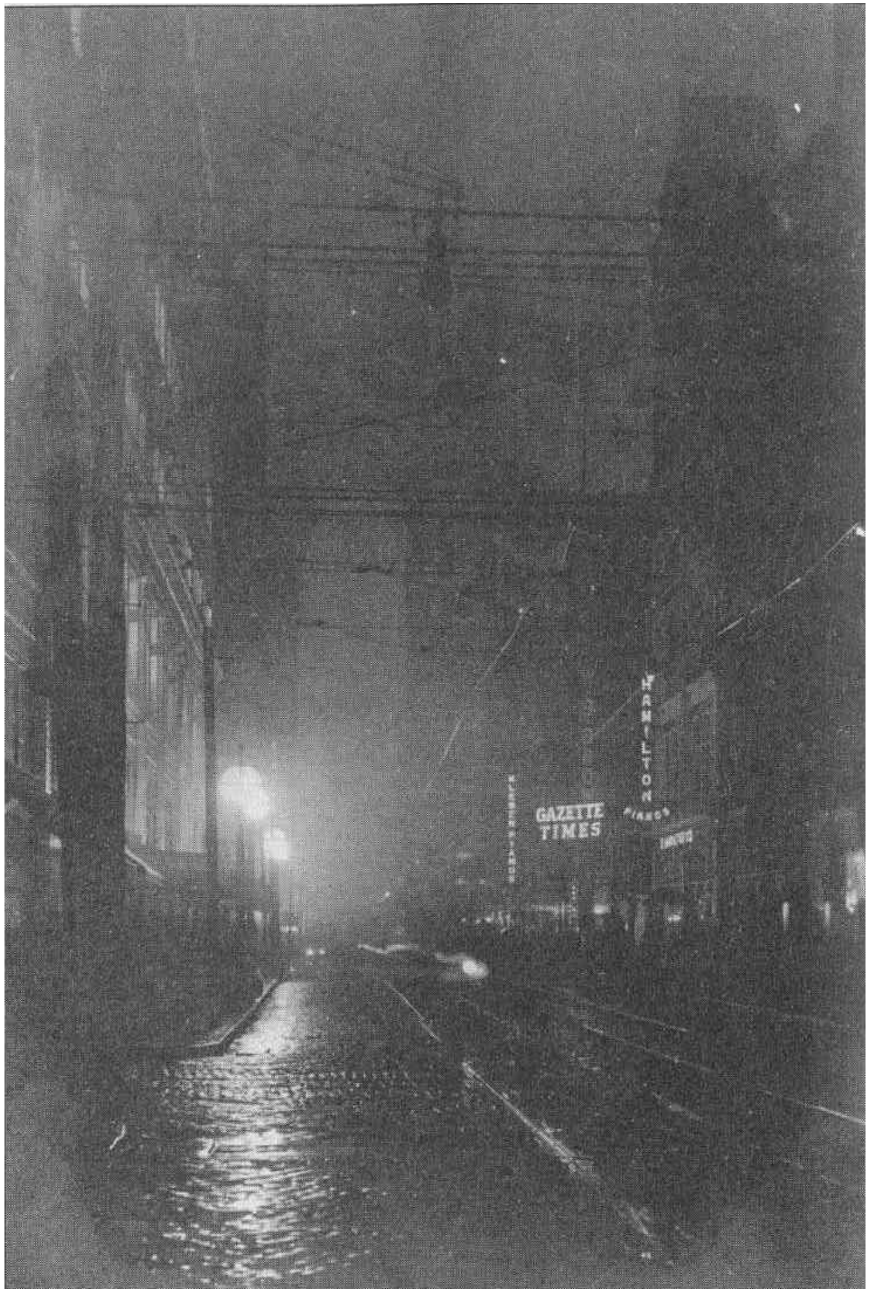

Pittsburg, 1913, 15^{00}.

A very serious smoggy day.

Source: Courtesy Carnegie Library of Pittsburg.

Regulations

1955 Act to control air pollution

1960 Air Pollution potential - the first forecasts

1963 National Air Pollution Authority - Clean Air Act

Air Quality Agreement

Air Quality Designation regions

A regional approach to air pollution control

1970 Turning Point …(change in social attitudes)

- National Environmental Policy Agreement (január 1.)
- The first "Earth Day" (April 22)
- Establishment of the Environmental Protection Agency (July 9)
- **Clean Air Act (1970)**
  - National Air Quality Standards

1987 Standards for particulate matter (PM_{10})

- **Clean Air Act (1990)**

2002 New PM Standards ($PM_{2.5}$)

A Few Well-Known Air Pollution Episodes Around the Globe in the 20th Century.

Region affected	*Date*	*Cause*	*Pollutant*	*Effects*
Meuse valley, Belgium	December 1930	Temperature inversion	SO_2	63 deaths
Los Angeles, USA	July 1943	Low wind circulation	smog	unknown
Donora, PA, USA	October 1948	Weather inversion	SO_2	20 deaths
London, England	December 1952	Subsidence inversion	SO_2, smog	3,000 excess deaths
New York City, USA	December 1962	Shallow inversion	SO_2	269 excess deaths
Bhopal, India	December 1984	Accident	methyl iso-cyanate	> 2,000 deaths
Chernobyl, Ukraine	April 1986	Accident	Radioact i-vity	31 immediate deaths, > 30,000 ill
Lake Nyos, Africa	April 1986	Natural	CO_2	1,700 deaths
Kuala Lampur, Malaysia	September 1997	Forest fire	CO, soot	Unknown

Concentrations of Principal Air Pollutants in Megacities in the Developing World.

Country / City	SO_2, $\mu g/m^3$	TSP (PM-10), $\mu g/m^3$	CO, $\mu g/m^3$	NO_x, $\mu g/m^3$	Pb, $\mu g/m^3$
China:					
Beijing (1997)	75	377	NA	122	NA
National average (1997)	3 to 248	32 to 741		4 to 140 (1995 data)	
Mexico:					
Mexico City (1996)	244 to 482	218 to 442	90,000 to 140,000	295 to 619	NA
India:					
New Delhi (1987)	40 to 90	700 to 1400	NA	45 to 65	0.37 to 4.6
WHO guideline (1999)	500 (10 min) 125 (24 hr) 50 (1 yr)	200 to 250	100,000 (15 min) 60,000 (30 min) 30,000 (1 hr) 10,000 (8 hr)	200 (1 hr) 40 (1 yr)	0.5 (1 hr)
NAAQS (USA)	1,300 (3hr) 365 (24 hr) 80 (1 yr)	150 (24 hr) 50 (1 yr)	40,000 (1 hr) 10,000 (8 hr)	100 (1 yr)	1.5 (quarterly avg.)

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4. *Air Pollution Aspects of Three Indian Cities, Vol. I. Delhi*, National Environmental Engineering Research Institute, Nagpur, India (1991).
5. F Guzman: Air pollution in Mexico Cityu, The Mexico City Workshop, Integrated Program on Urban, Regional and Global Air pollution, MIT, Massachusetts, September (1999). http://eaps.mit.edu/megacities/workshop_99/mexico.html.
6. Air Pollution: Mexico City. http://www.ess.co.at/GAIA/cases/mex. Environmental Software and Services, GmbH, Gumpoldskirchen, Austria.

Major air pollution episodes

1952	London smog; Minamata (metil-higany)
1957	Rocky Flats (plutonium)
1967	Torrey Canyon (oil pollution)
1968	Ozone hole, first announcement
1974	Flixborough (explosion)
1976	Seveso (dioxin) Introduction of Eu-law
1978	Amoco Cadiz (oil pollution)
1979	Three Miles Island (Harrisburg) nuclear pollution
1983	Castilio de Beliver (250.000 t oil spilled out)

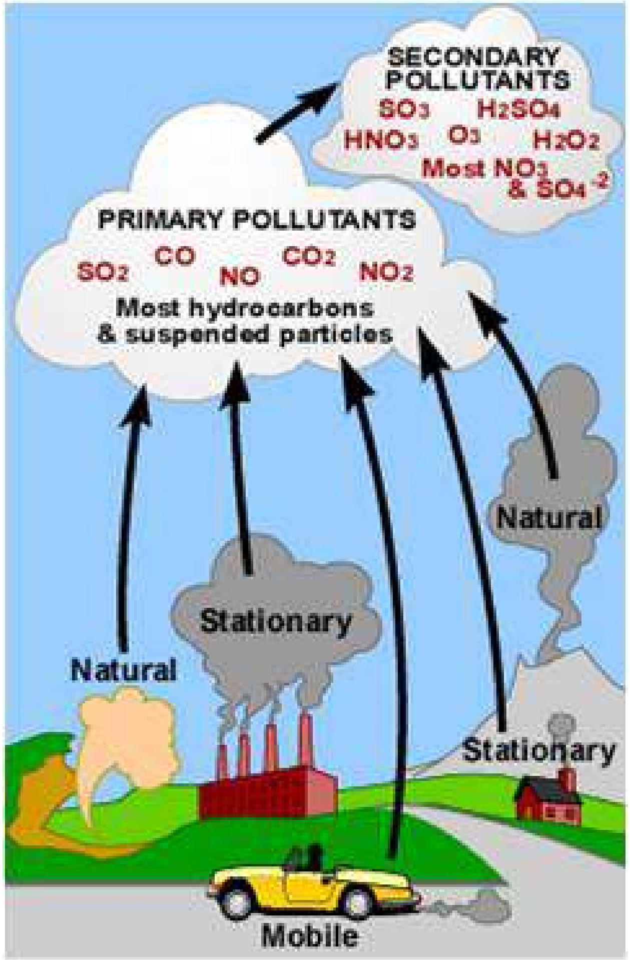
Major air pollution episodes

1984	Ixhuatepec (Mexico), gas explosion
1984	Bhopal (MIC, > 10.000 dead), chemical pollution
1986	Csernobil (31 - > 1.000.000), radioactive pollution
1986	Basel (Schweizerhalle, Rhine), chemical pollution + fire
1988	Piper Alpha, oil rig, fire and explosion
1989	Exxon Valdez (PWS, Alaska), 40.000 t oil spilled out
1992	Guadalajara, olaj in sewage pipes + explosion
1995	Essequibo (Guayana), 8 million liter cyanide spilled out of a gold mine
1997	Indonesia, regional smog due to forest fire

Types of air pollutants

<u>Primary</u>: They can get directly into the atmosphere from chimney or other surface sources. E.g.: SO_2, CO_2. Their impact is direct, and can be traced back to the pollutants emitted.

<u>Secondary</u>: From primary air pollutants novel compounds are formed in the atmosphere. These secondary air pollutants. Pl.: photochemical air pollutants **(ozone),** acid rain, smog. Their impact can be direct or indirect.



Primary air pollutants

They can get into the atmosphere directly:

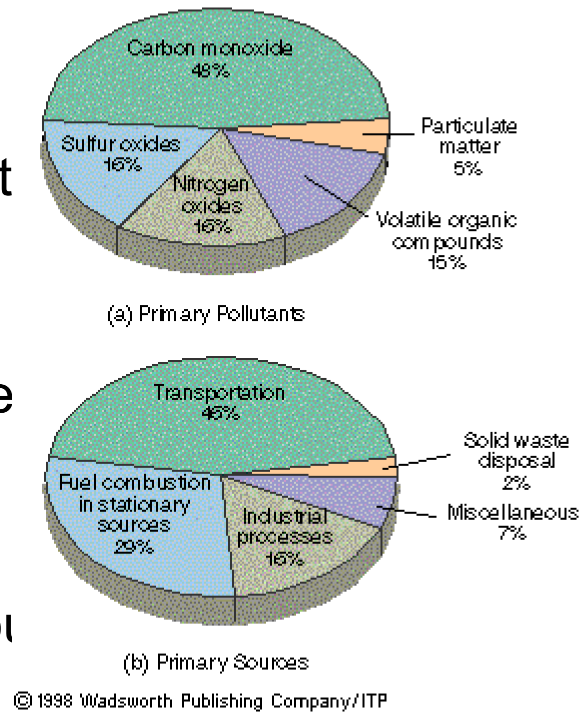
Carbon-monoxide (CO)

- A colorless, odorless, poisonous gas
- It is generated due to incomplete combust (especially in engines of old cars)
- Cause headache,

sleepiness, tiredness that lead to death slee

Nitrogen oxides (NO_x, NO)

- NO – nitrogen-monoxide
- They are released to the atmosphere throu cars or industrial activity.



Primary air pollutants

Sulphur oxides (SO_x)

- SO_2 – sulphur-dioxide
- gets into the atmosphere to a large extent through coal burning
- responsible for acid rain problem

Volatile organic compounds (VOC-k)

- highly reactive organic compounds
- gets into the atmosphere through incomplete combustion and industrial sources

Particulate matter (dust, ash, salt particles)

- they have significant role in froming respiratory diseases.

Secondary air pollutants

They are generated in the atmosphere from primary air pollutants, through chemical and photochemical reactions.

sulphuric acid (H_2SO_4):
May cause respiratory diseases.

nitrogen-dioxide (NO_2):
Makes the air yellowish brown.

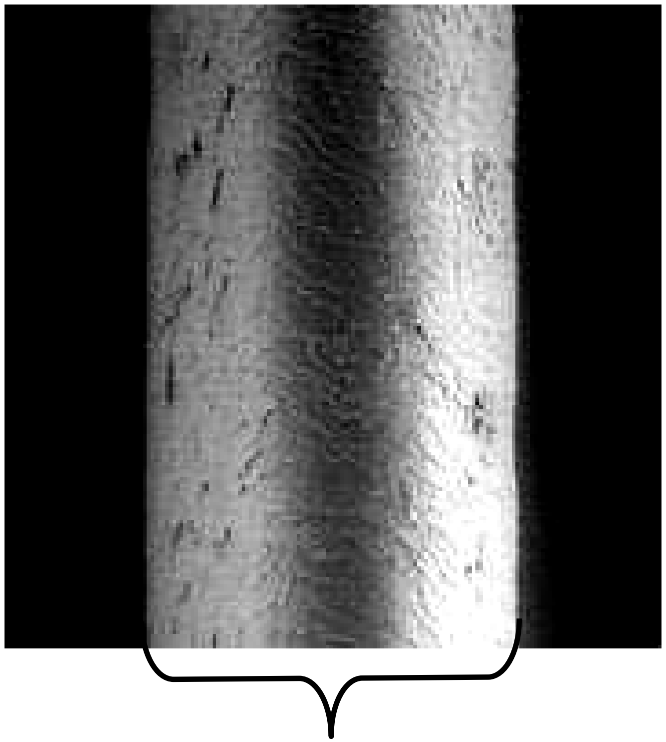
ozone (O_3):
A colorless gas, odour is sweet.
Oxidiser, attacks the lung tissue and rubber products, etc.
Irritating to eyes.

Particles from combustion

- They can be linked with most health problems.
- Its size is tenth of a micrometer, spreading quickly enters enclosed spaces as well.
- More tiny particles can be linked together and can get deep into the lungs.
- Symbol and designation: $PM_{2.5}$

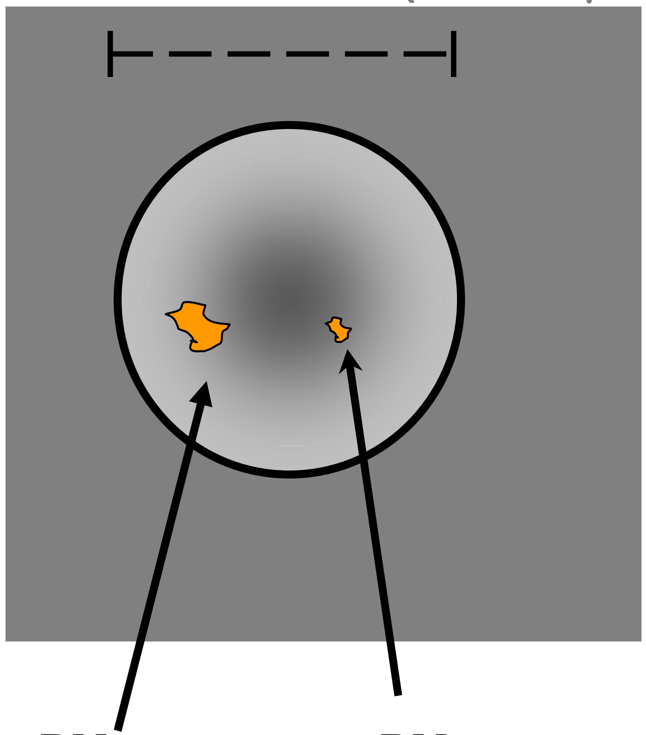
Particles

- They are a mixture of small, liquid and gaseous particles.



Human hair (diameter: 70 μm)

Diameter of hair (d = 70 μm)



M. Lipsett, California Office of Environmental Health Hazard Assessment

Size is important!

- Fine and ultrafine particles behave like gas:
  - they penetrate from outside air into enclosed spaces;
  - they penetrate deep into the lungs.
- A Fine particles have a higher cumulated surface.
- They bind to toxic combustion products, metals and toxic substances in the air, and carry them deep into the lungs.

We finished for today, goodbye!

ямарваа нэг зүйлийн гэгээлэг талыг нь үргэлж олж харцгаая

өнөөдөртөө ингээд дуусгацгаая, баяртай

让我们总是从光明的一面来看待事物吧！

今天的课程到此结束，谢谢！

دعونا ننظر دائما إلى الجانب المشرق من الأشياء!

انتهينا لهذا اليوم، وداعا!