Atmospheric Chemistry

Lecture 19

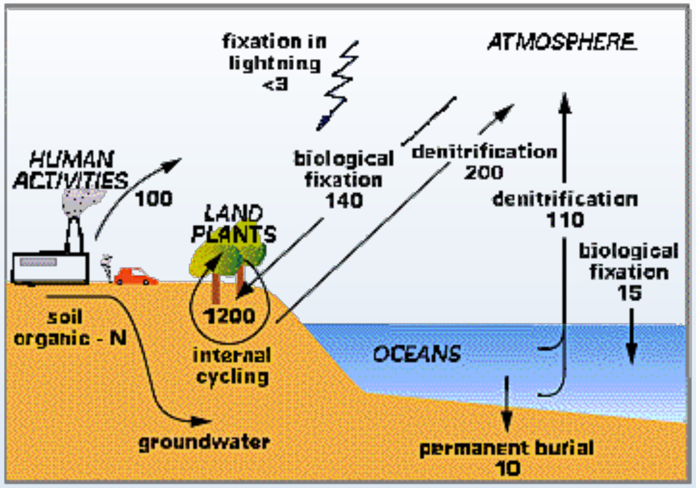
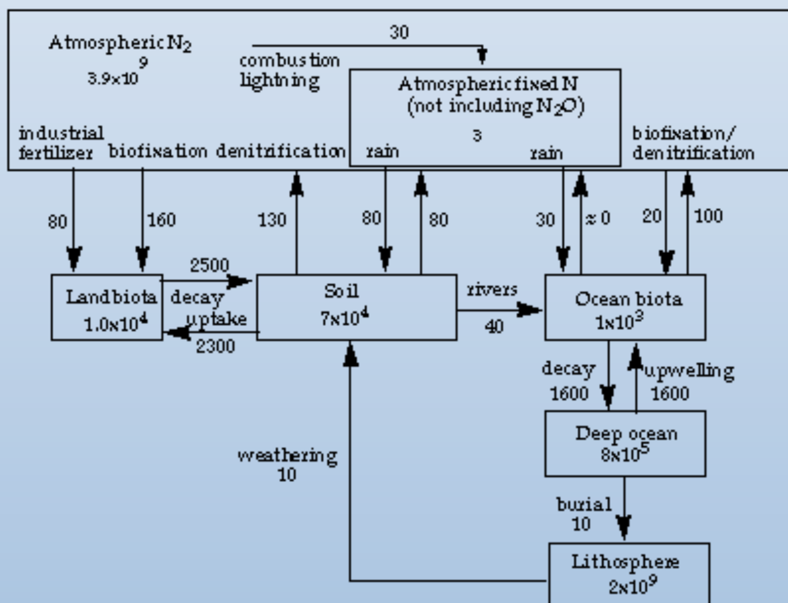


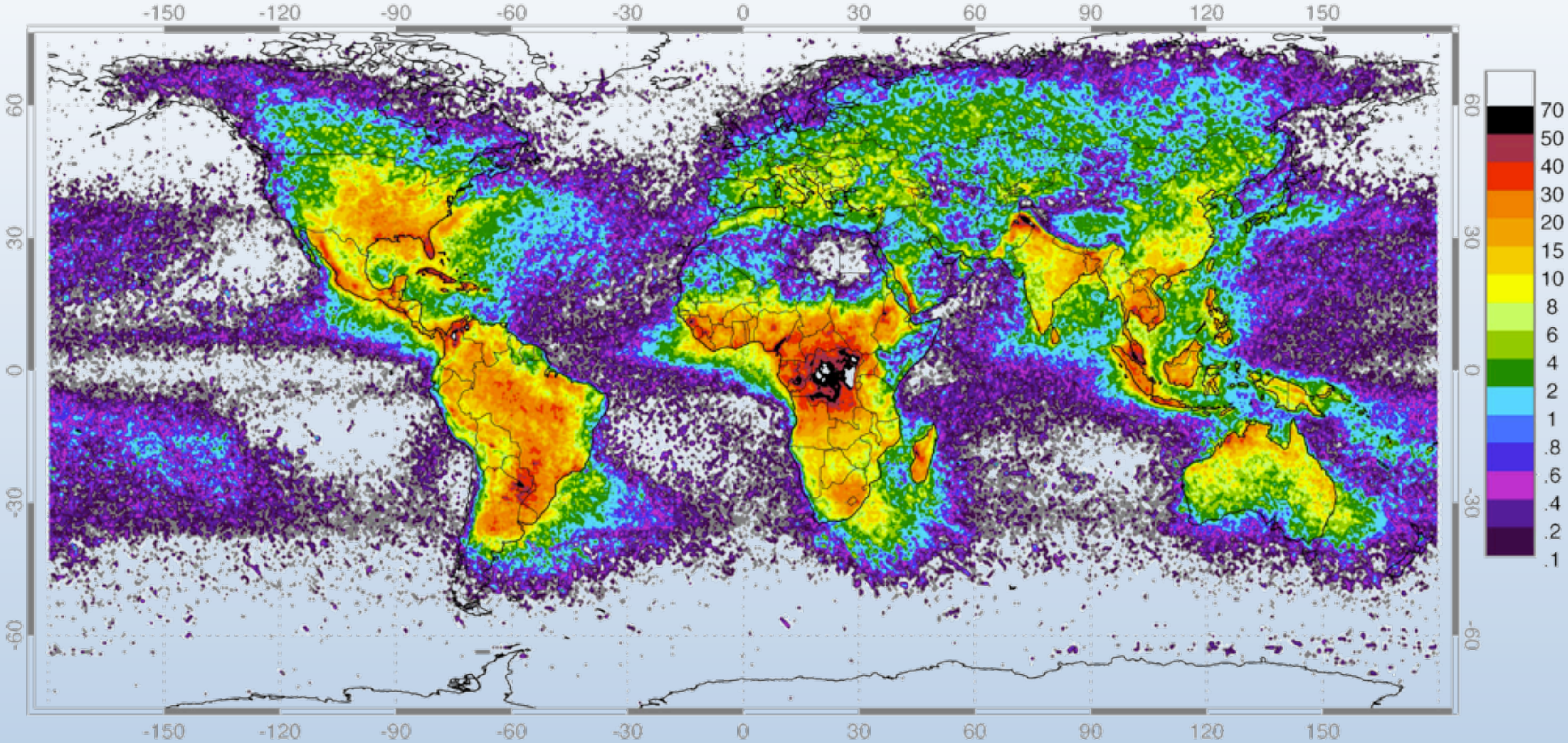
Figure 10. The Global Nitrogen Cycle



Nitrogen

- **Atmosphere: 3.9x10^{9} Tg**
  - **=1.7x10^{44} molecules**
  - **=2.8x10^{20} moles**
- **Lithosphere: 2x10^{9} Tg**
  - **=9x10^{43} molecules**
  - **=1.4x10^{20} moles**
- **Ocean: 8x10^{5} Tg**
  - **=3.4x10^{40} molecules**
  - **=6x10^{16} moles**
- **Biosphere: 1x10^{4} Tg**
  - **=4x10^{38} molecules**
  - **=7x10^{14} moles**

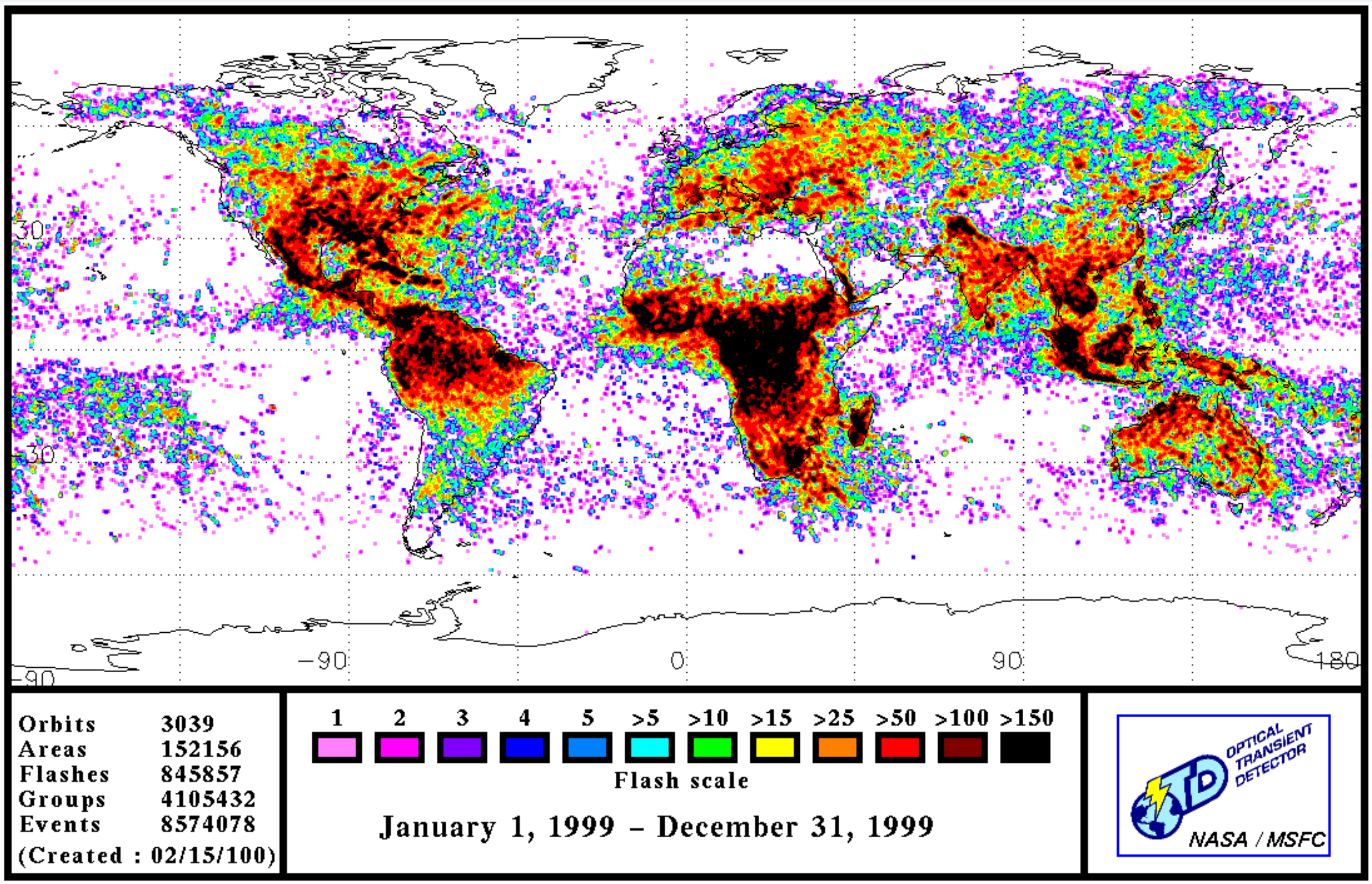
Lightning Climatology (flashes/km^2/year)



High Resolution Full Climatology Annual Flash Rate

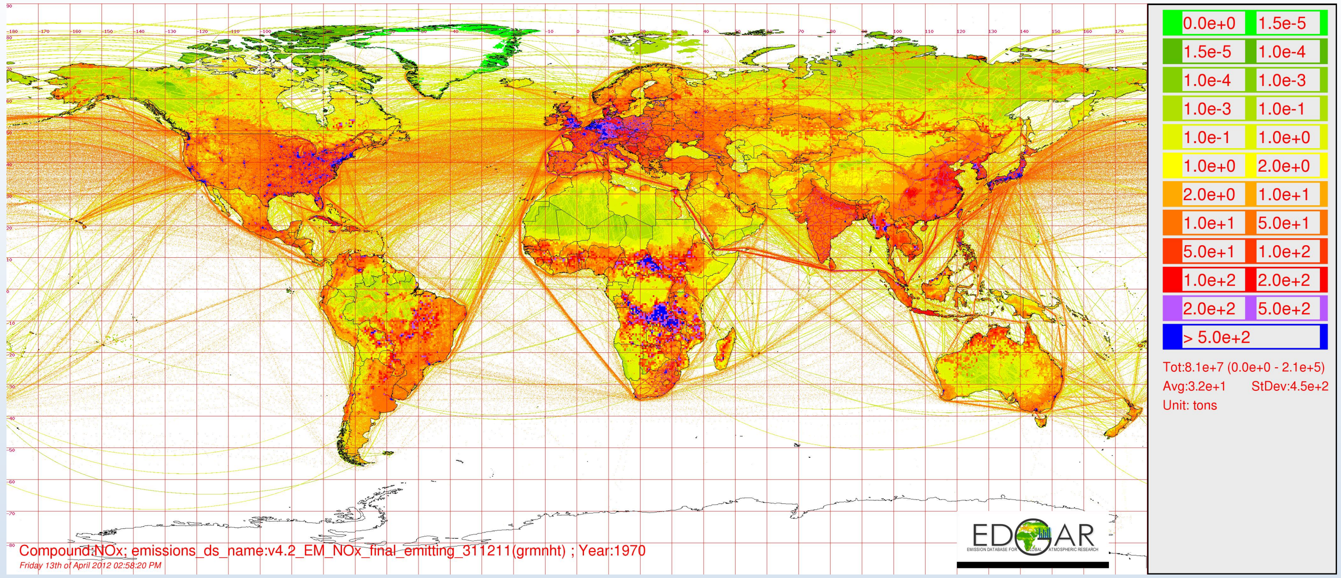
Global distribution of lightning April 1995-February 2003 from the combined observations of the NASA OTD (4/95-3/00) and LIS (1/98-2/03) instruments

NO_x Production Estimate from Lightning

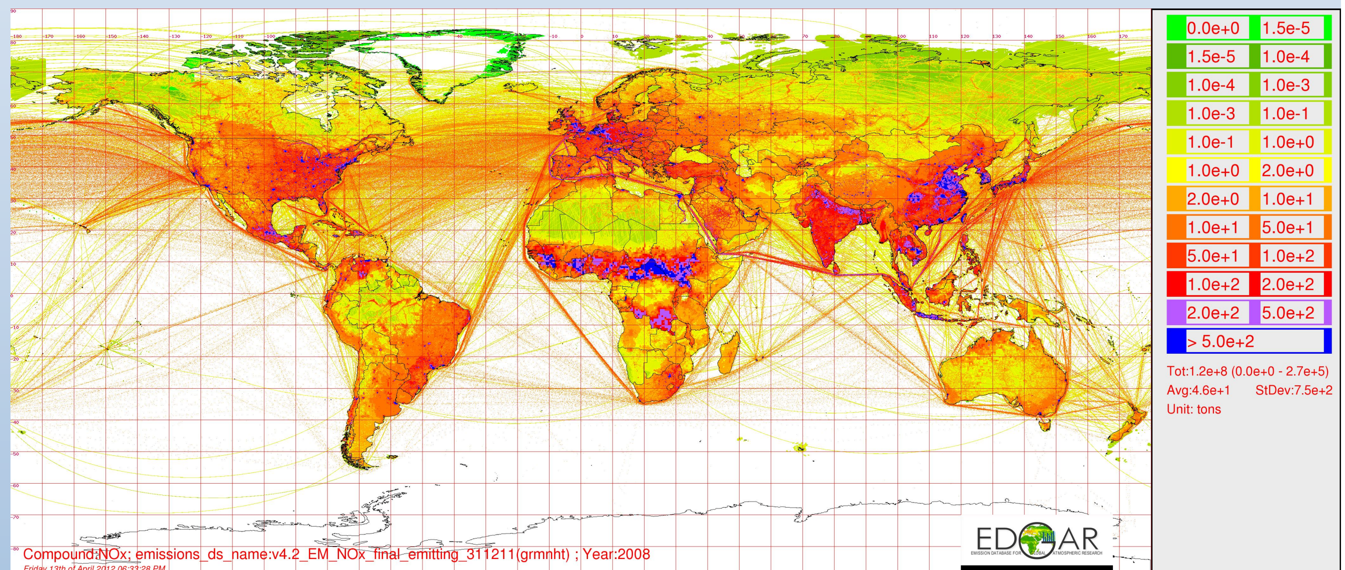


NOx Source Estimates

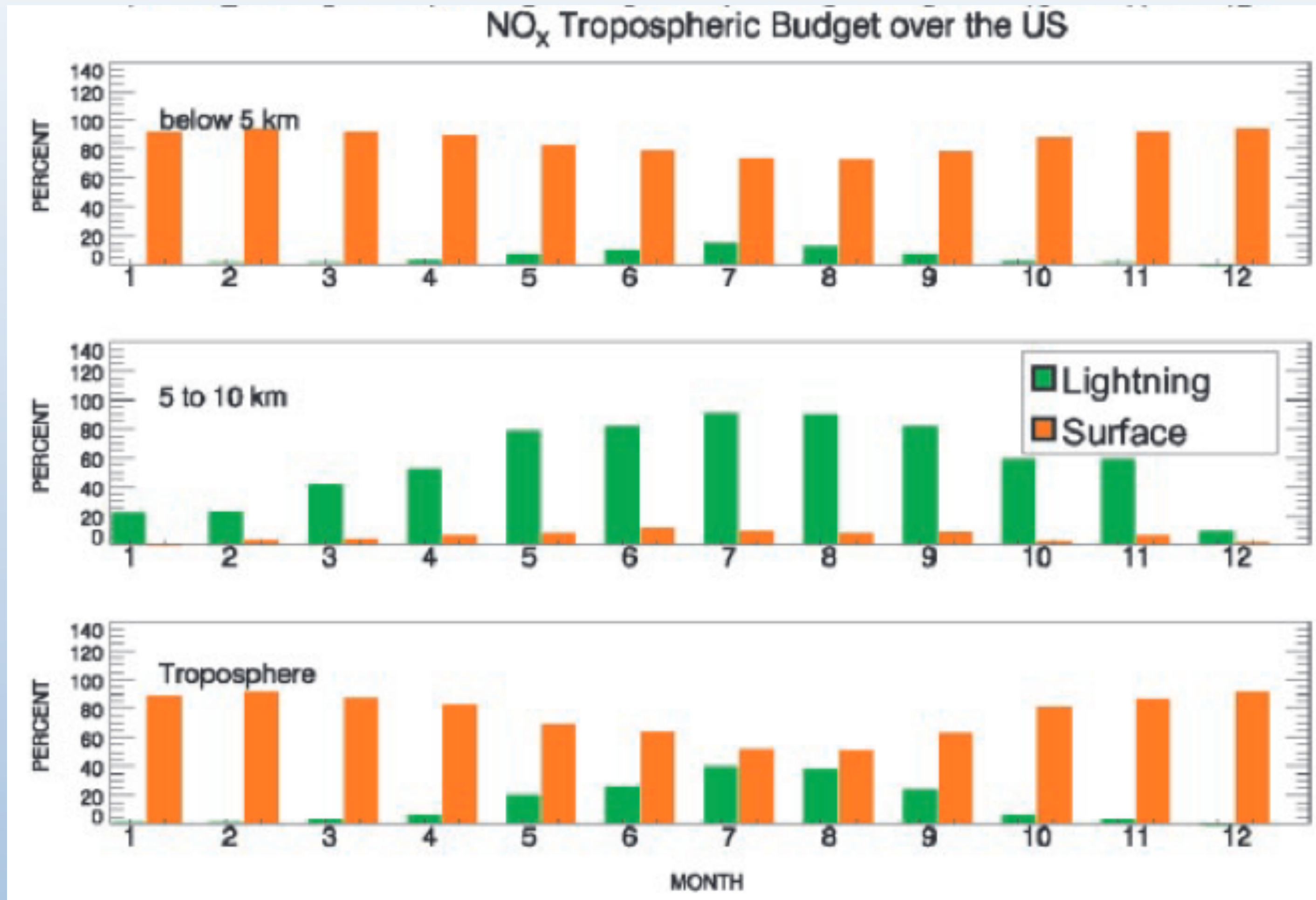
1970



2008

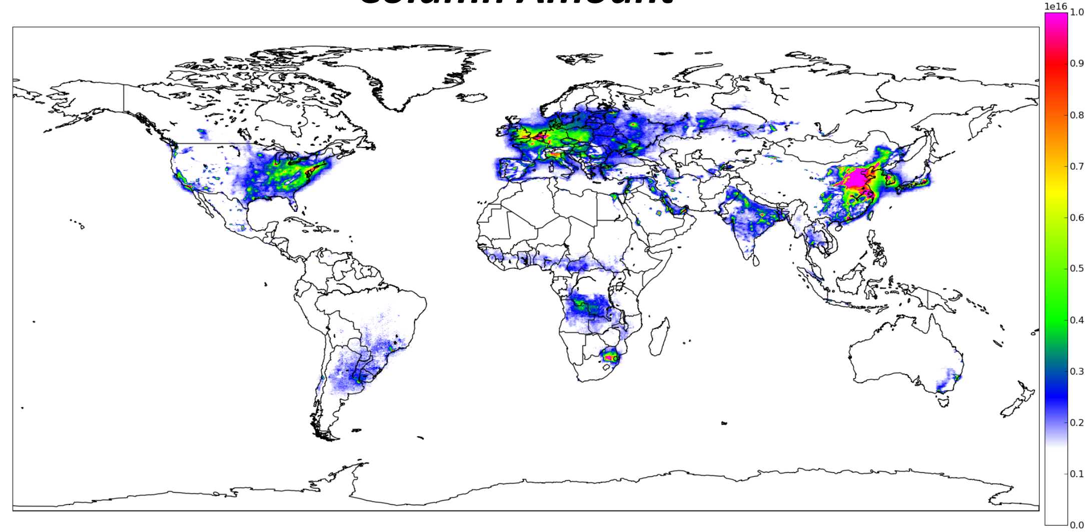


NO_x from Lightning vs NO_x from Surface Sources (Zhang et al., 2003)

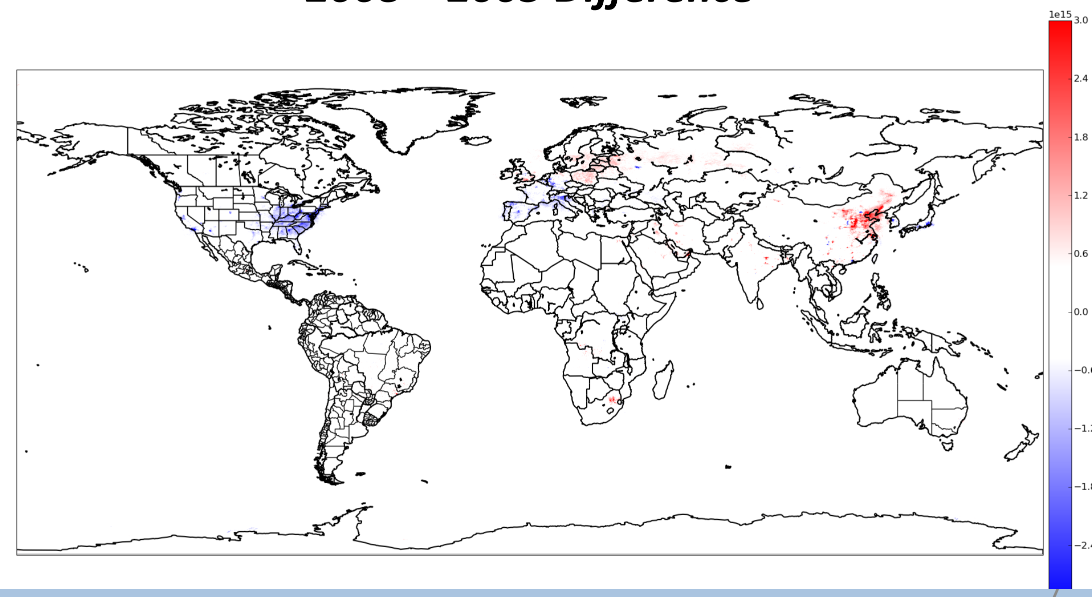


NO_2 Measurements by OMI Instrument on Aura Satellite (Global)

Column Amount

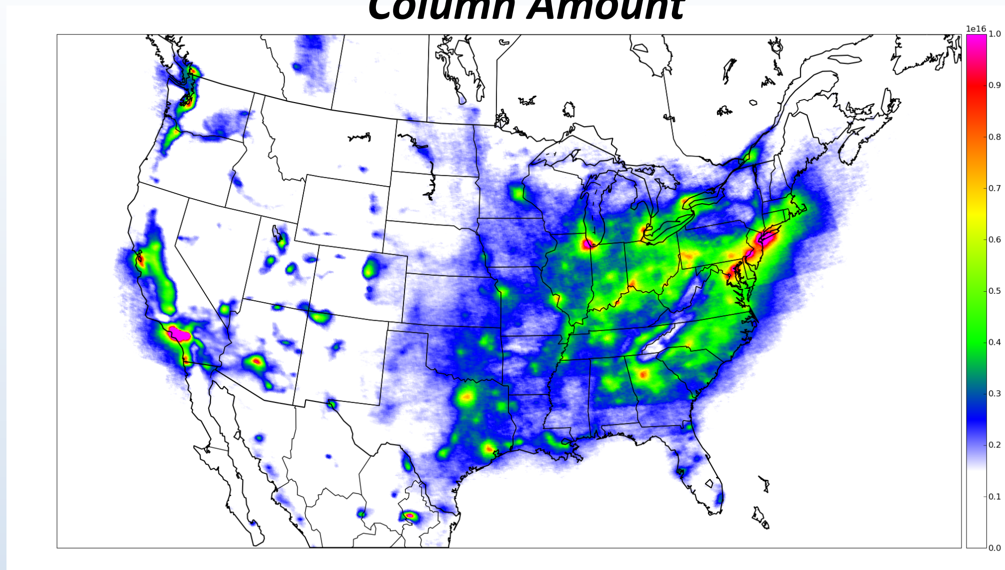


2008 – 2005 Difference

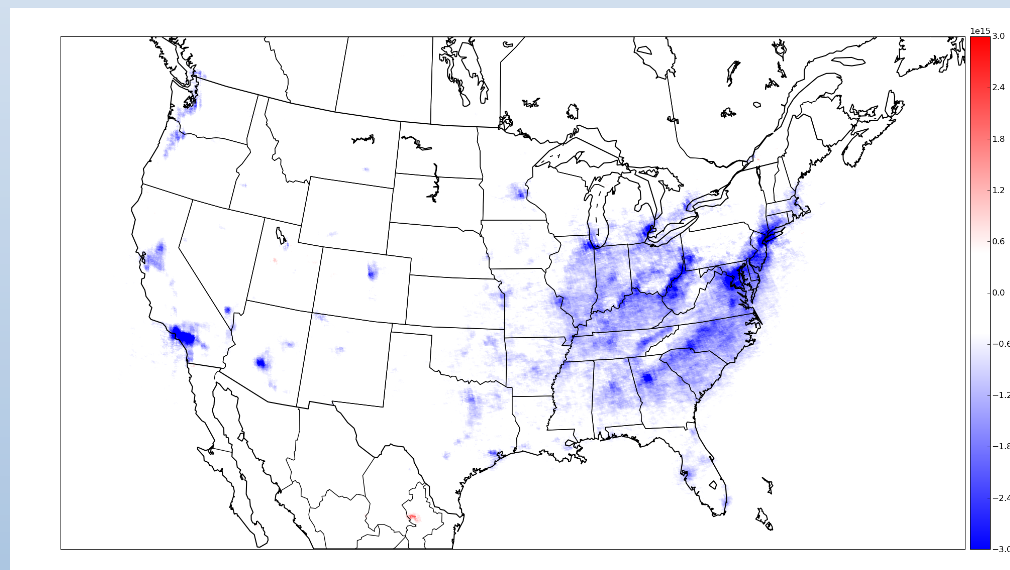


NO_2 Column Measurements by OMI Instrument on Aura Satellite (US)

Column Amount

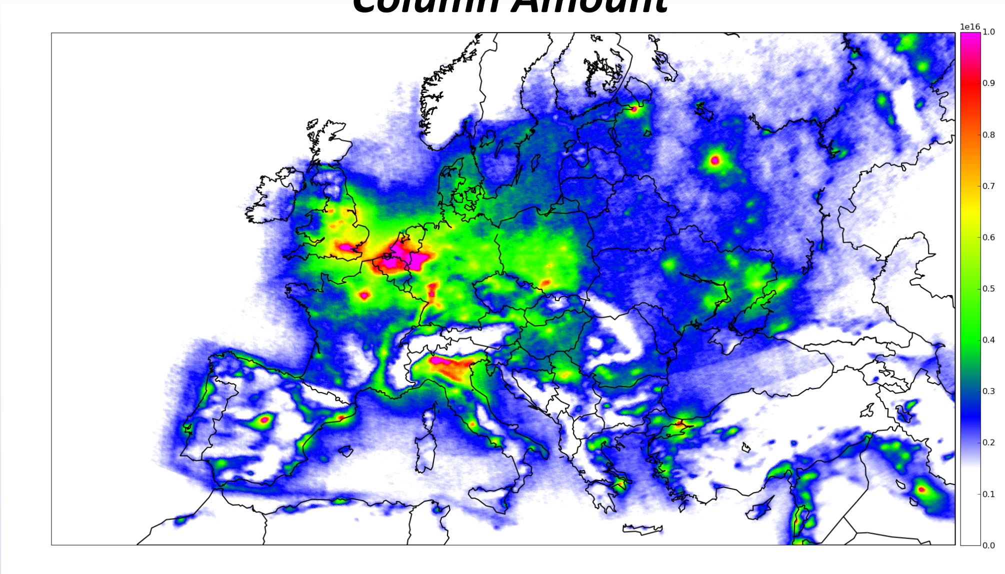


2008 – 2005 Difference

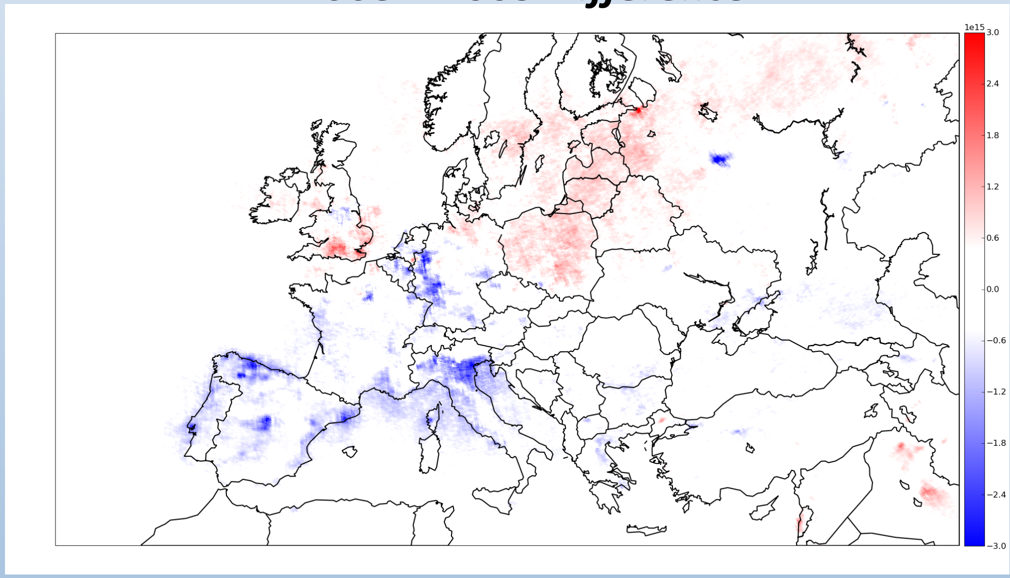


Europe

Column Amount

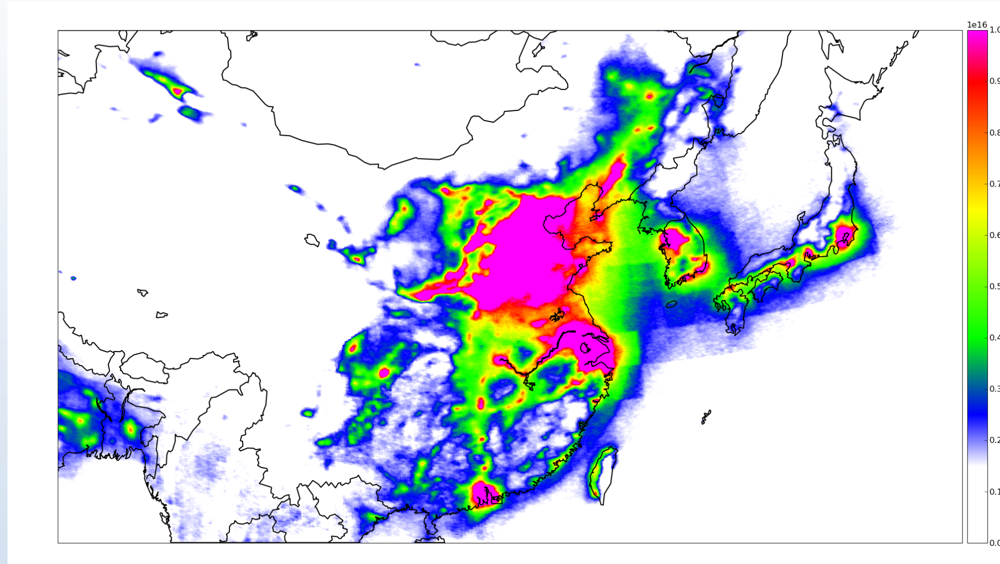


2008 – 2005 Difference

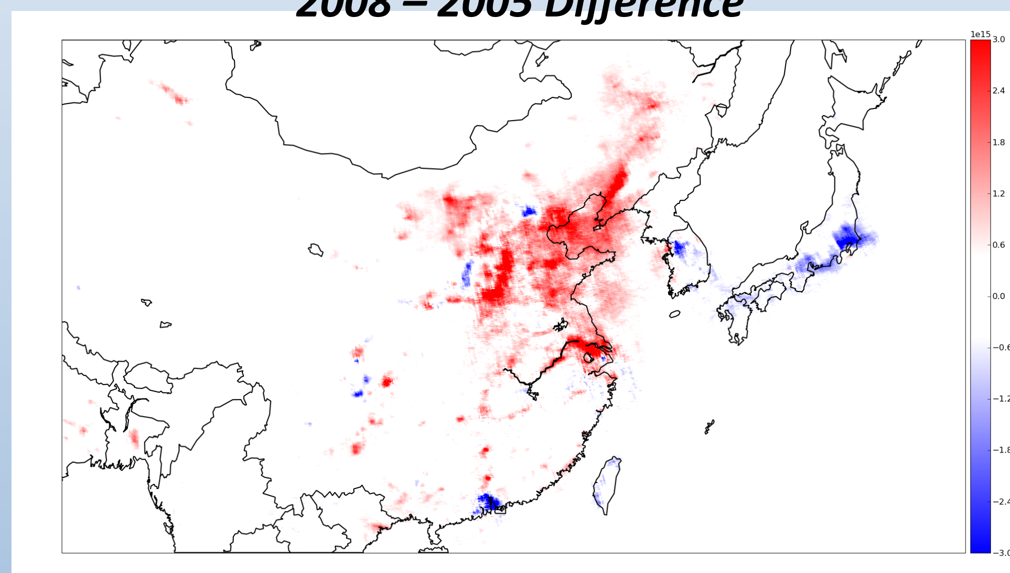


Asia

Column Amount

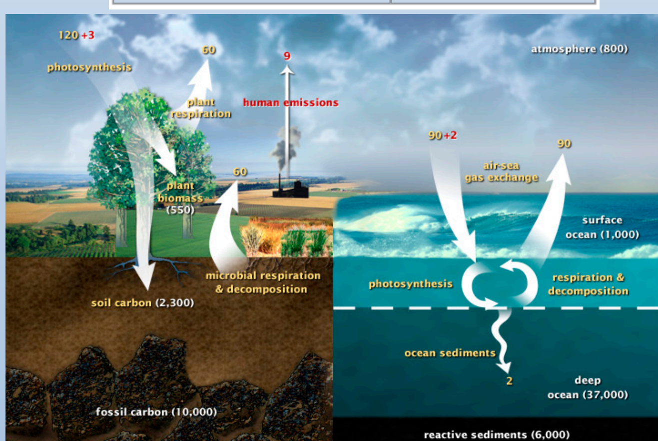


2008 – 2005 Difference



Carbon pools in the major reservoirs on earth.[2]

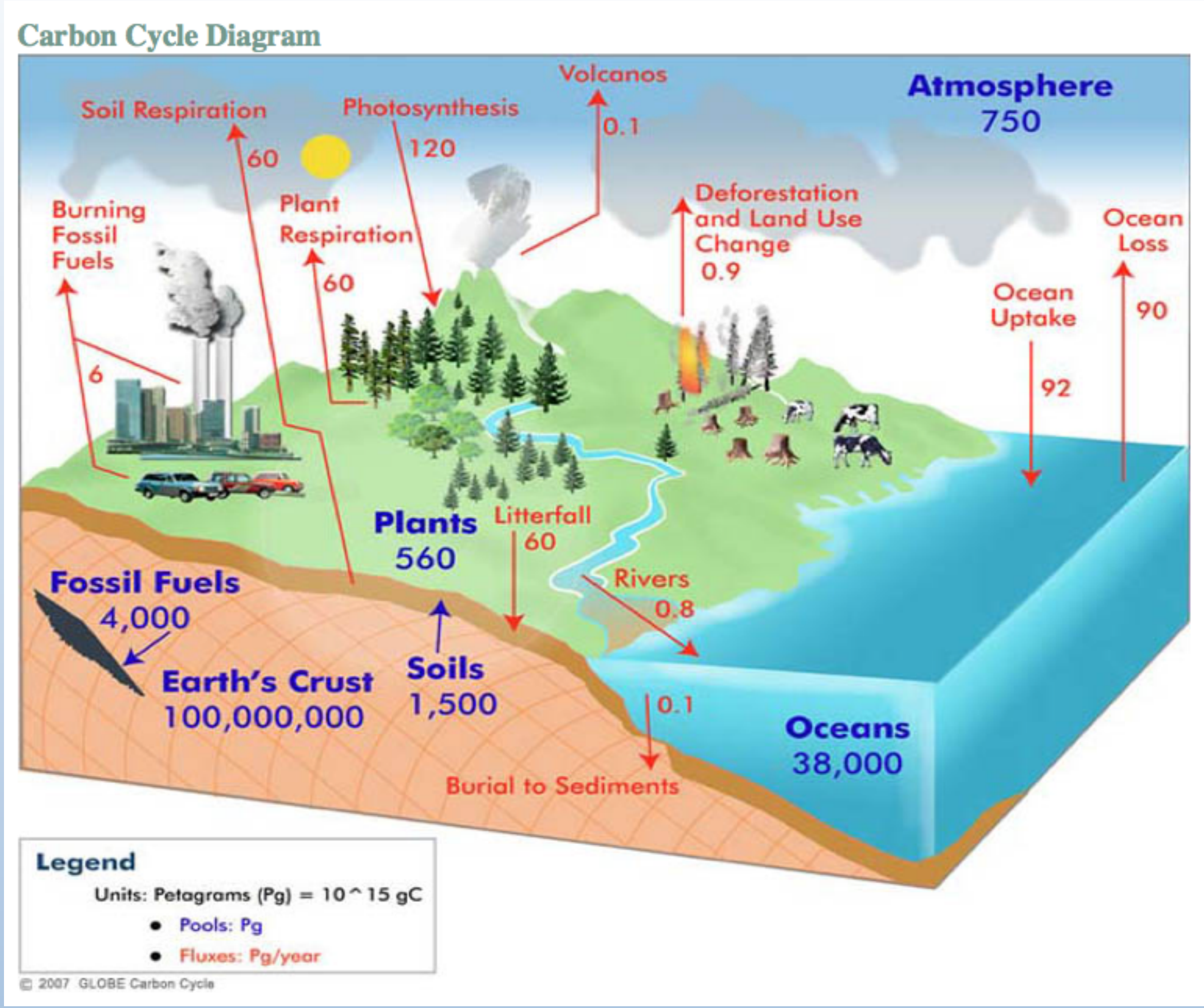
Pool	Quantity (gigatons)
Atmosphere	720
Oceans (total)	38,400
Total inorganic	*37,400*
Total organic	1,000
Surface layer	670
Deep layer	36,730
Lithosphere	
Sedimentary carbonates	> 60,000,000
Kerogens	15,000,000
Terrestrial biosphere (total)	2,000
Living biomass	600 - 1,000
Dead biomass	1,200
Aquatic biosphere	1 - 2
Fossil fuels (total)	4,130
Coal	3,510
Oil	230
Gas	140
Other (peat)	250



Carbon

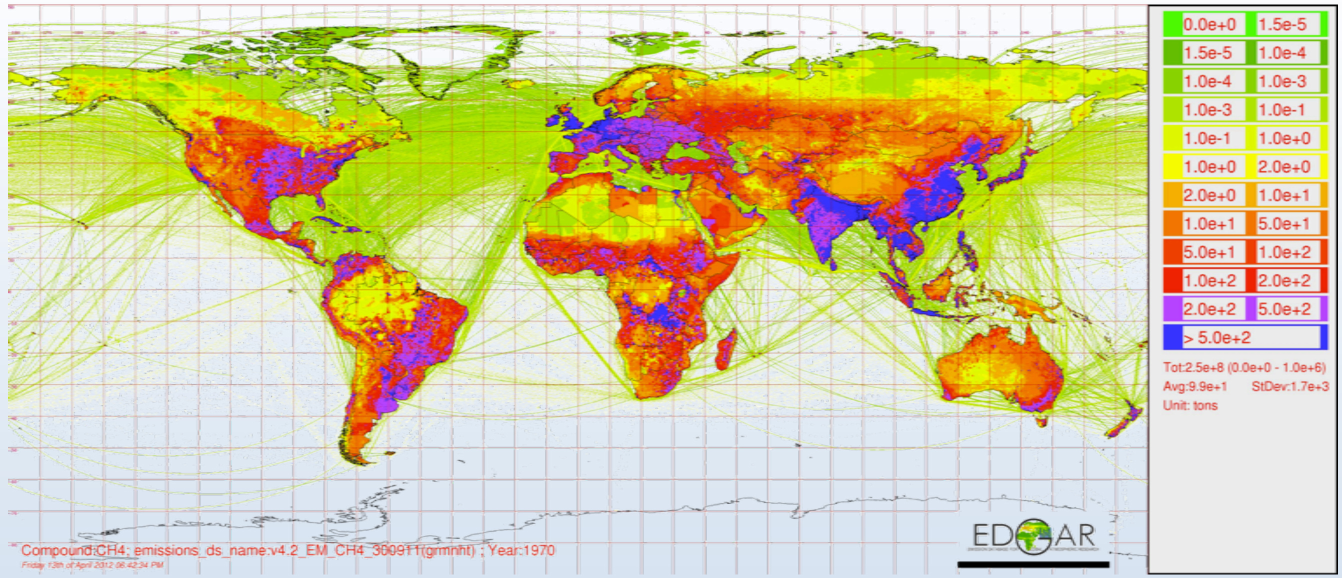
- **Atmosphere: 8.3x10^{5} Tg (390 ppbv)**
  = 4.1x10^{40} atoms
  = 7x10^{16} moles C
- **Oceans: 3.8x10^{7} Tg**
  = 2x10^{42} atoms
  = 3x10^{18} moles C
- **Lithosphere: 7x10^{10} Tg**
  = 3.5x10^{45} atoms
  = 6x10^{21} moles C
- **Biosphere: 2x10^{6} Tg**
  = 1x10^{41} atoms
  = 2x10^{17} moles C
- **Fossil Fuels: 4x10^{6} Tg**
  = 2x10^{41} atoms
  =4x10^{17} moles C

Carbon Fluxes and Reservoirs

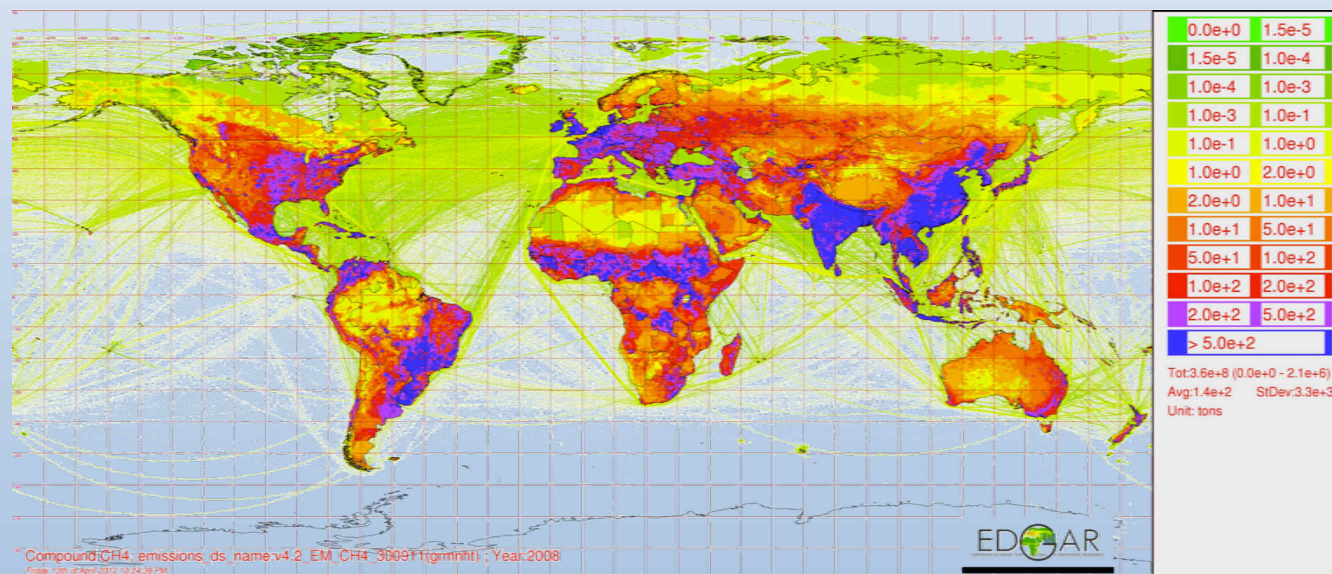


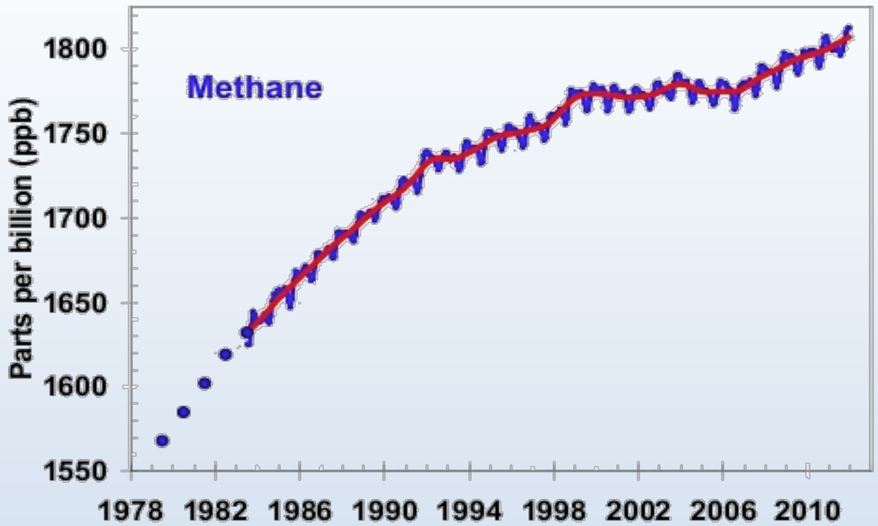
CH_4 Source Estimates

1970

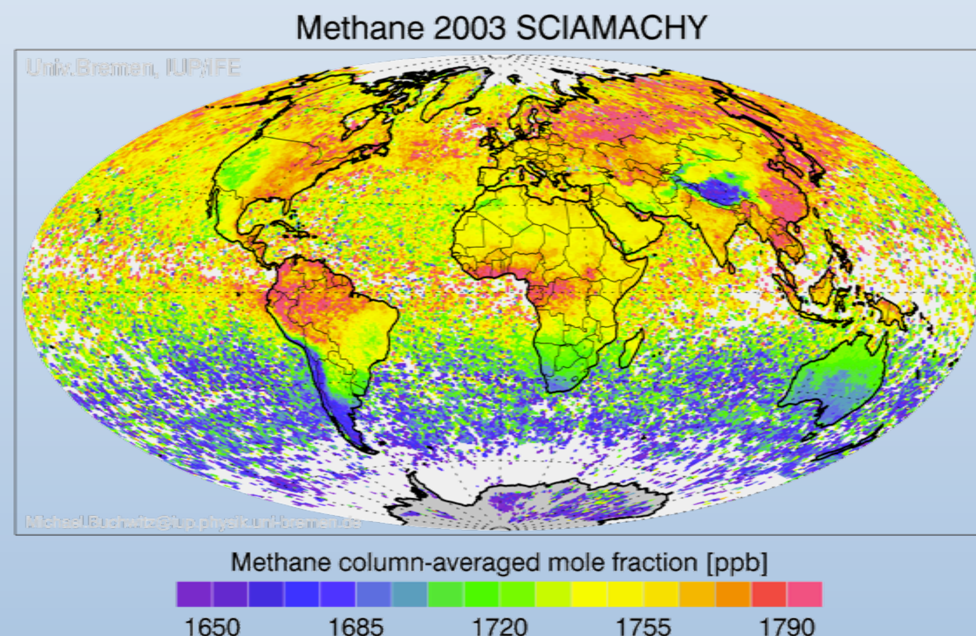


2008

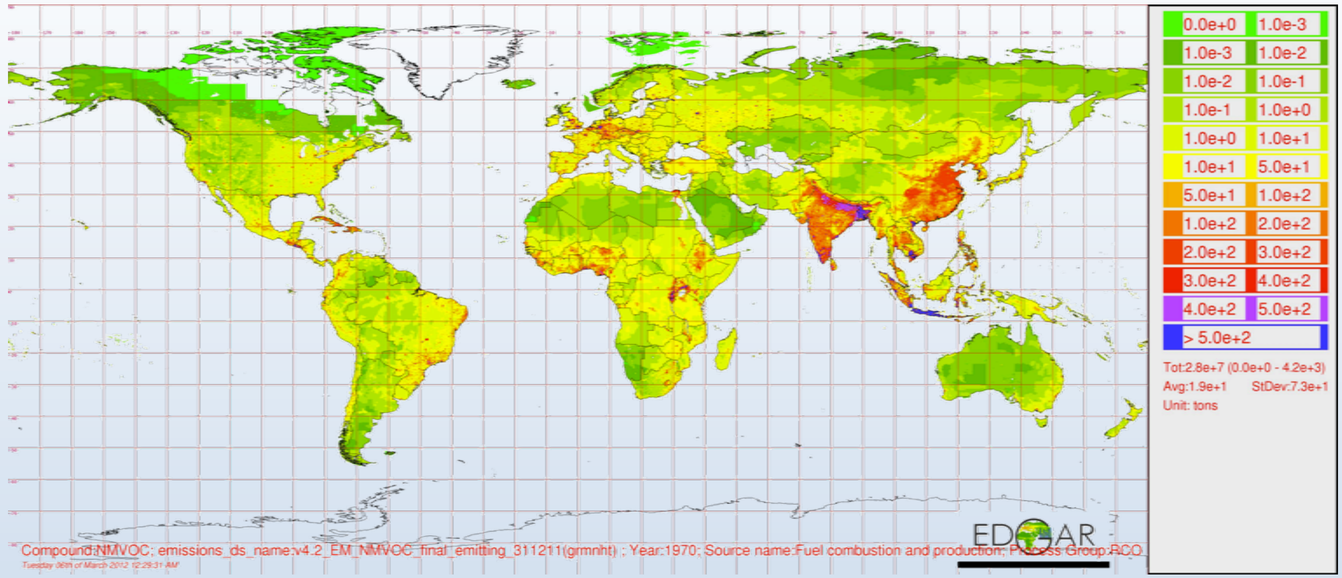


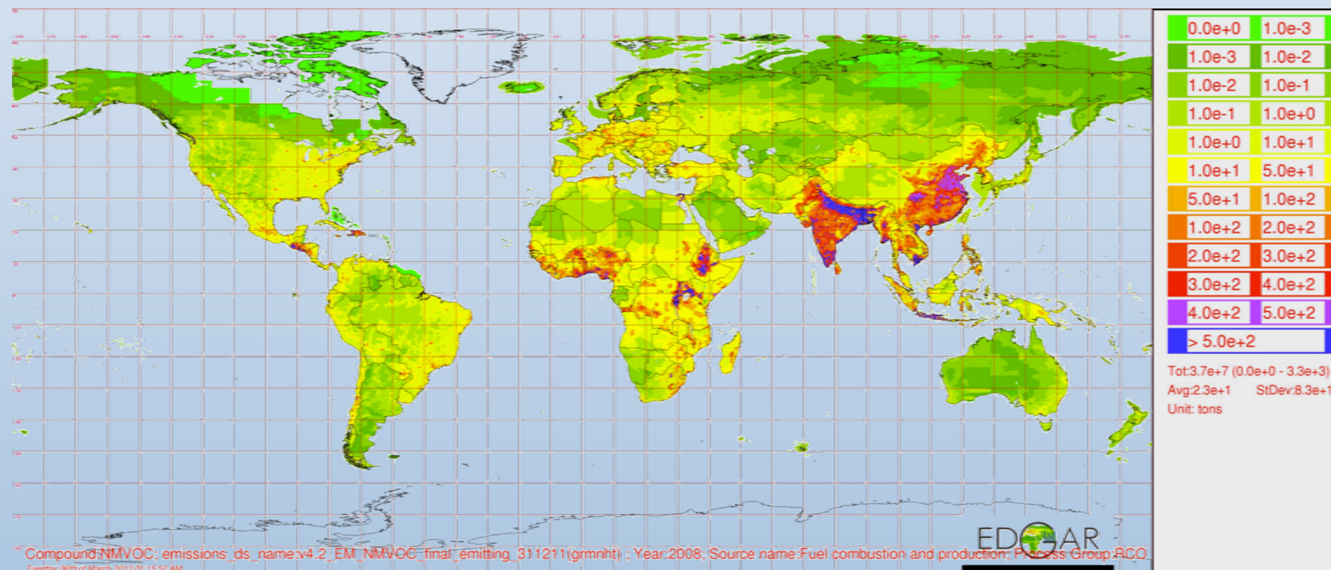


Methane Measurements

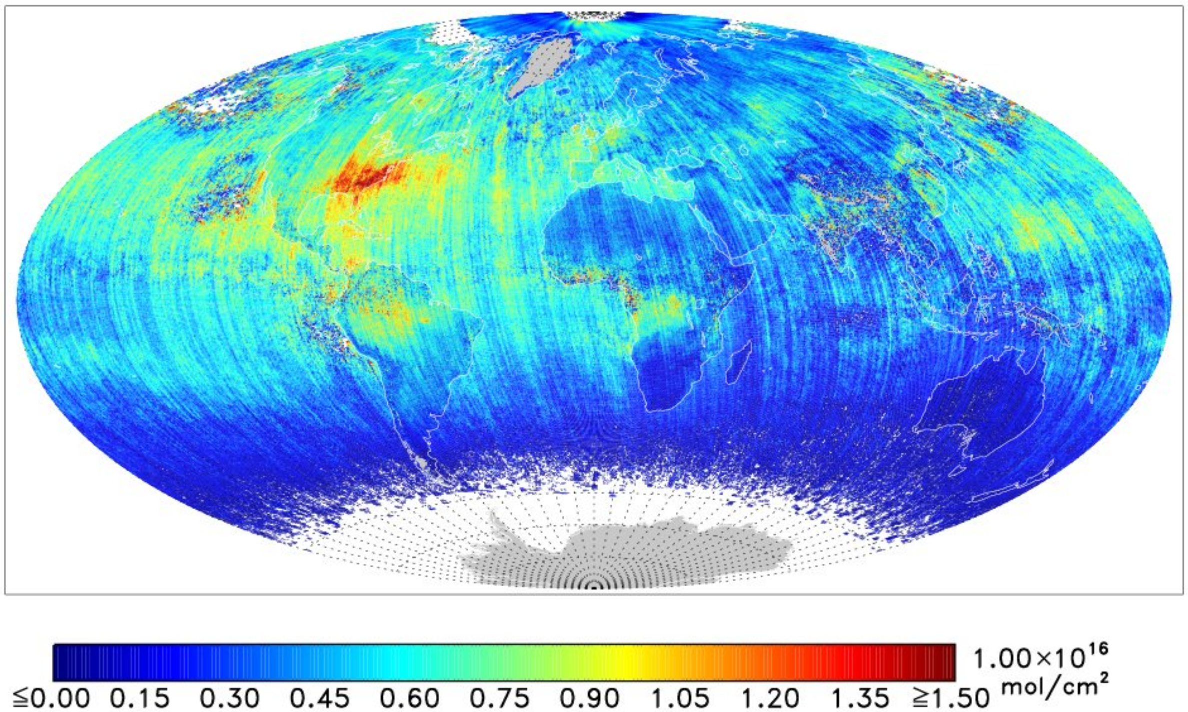


VOC Emission Estimates (non-methane)





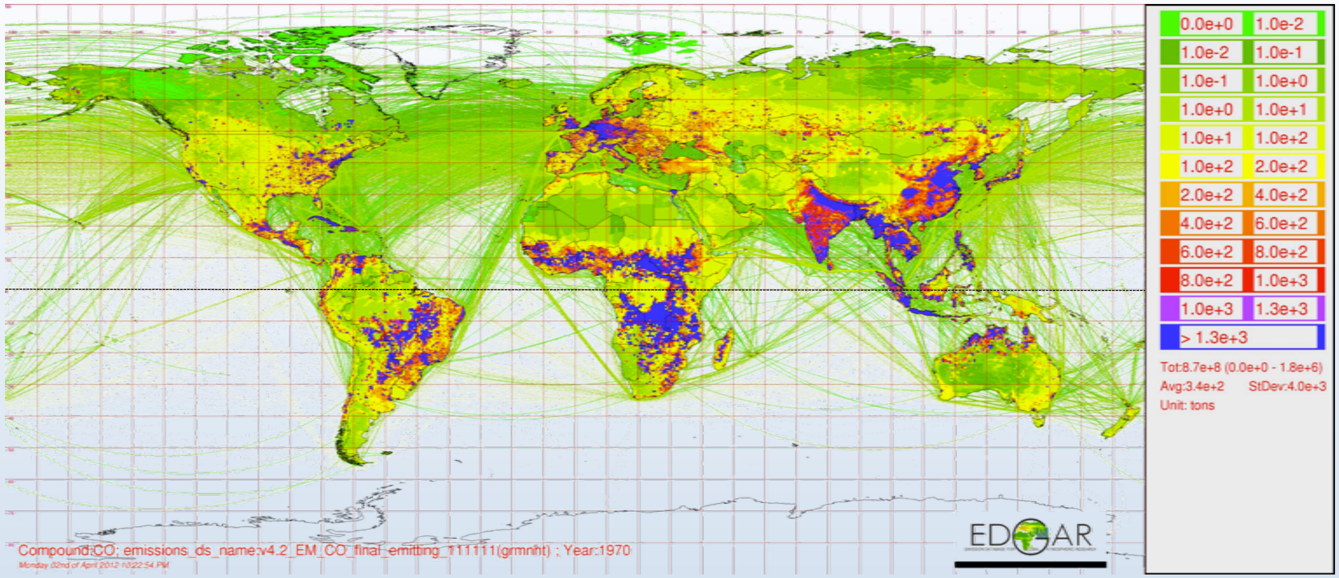
OMI Measurements of Formaldehyde (CH_2O)



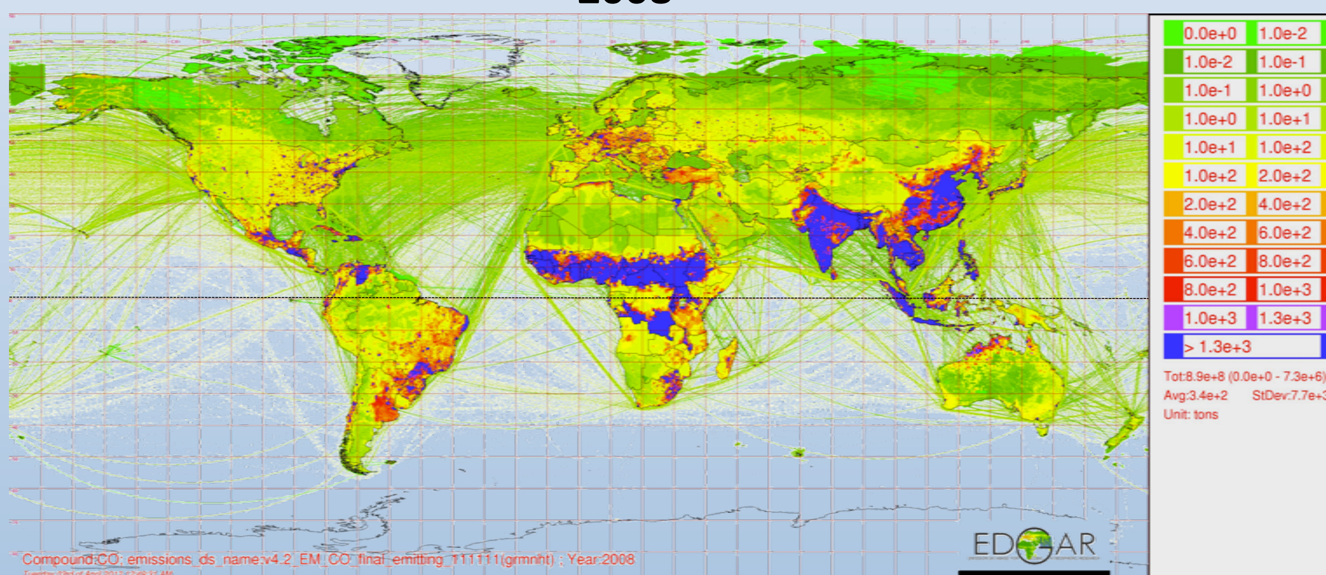
Average OMI HCHO geometric vertical columns for the month of July 2005. Only ground pixels with a cloud cover of 20% or less has been included. Note that this image is not corrected for the stripes. Level-2 products are effected by residual errors in the dark current correction of the level-1b radiance and irradiance products, which is manifested as along-track stripes.

CO Source Estimates

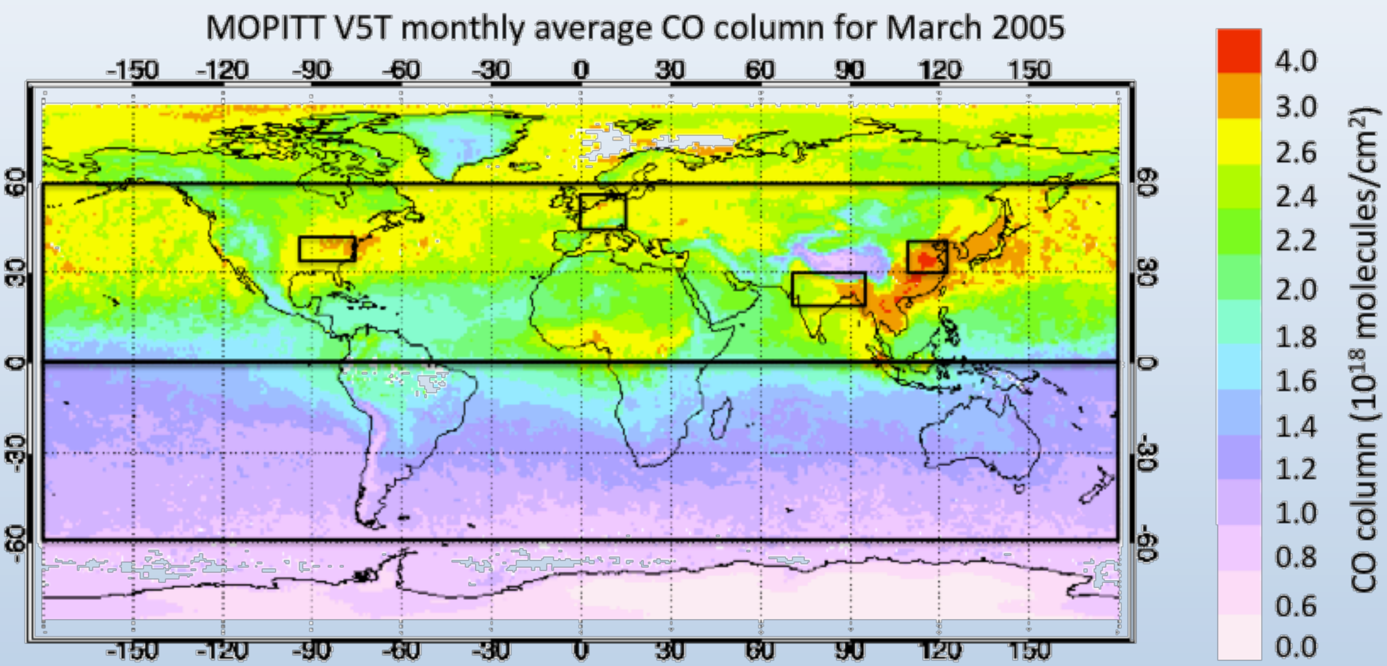
1970



2008

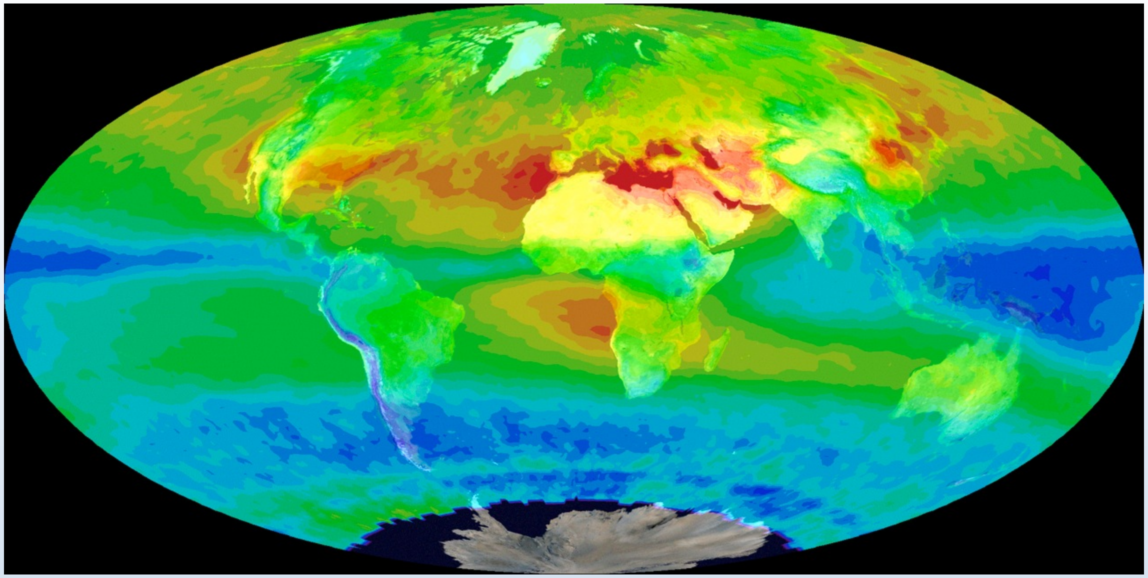


Carbon Monoxide Column Measurements

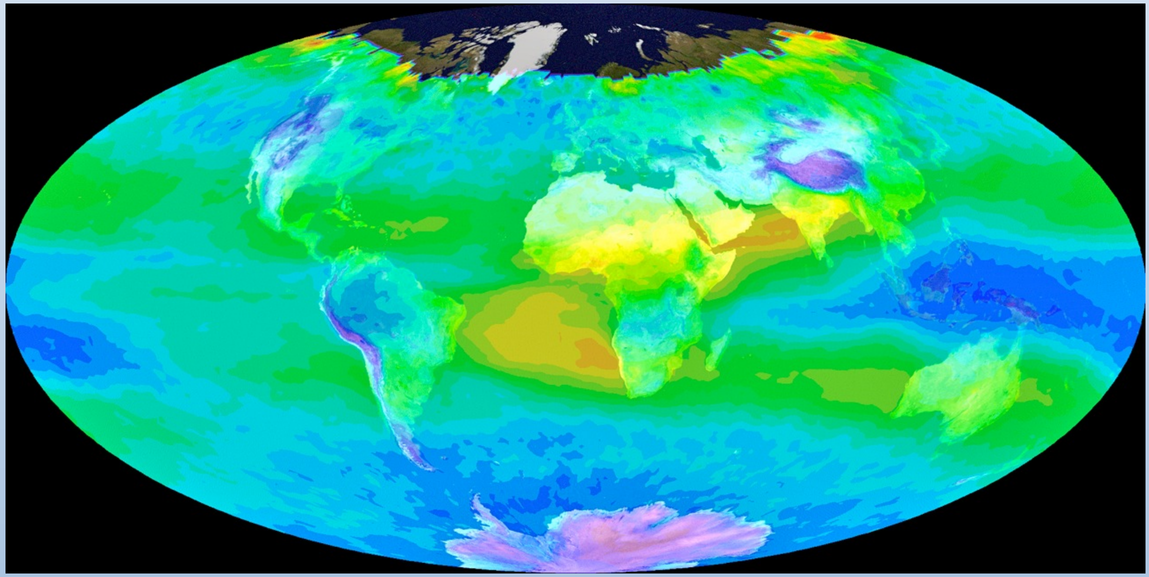


Column Tropospheric Ozone Deduced from Satellite measurements

Northern Summer



Southern Summer



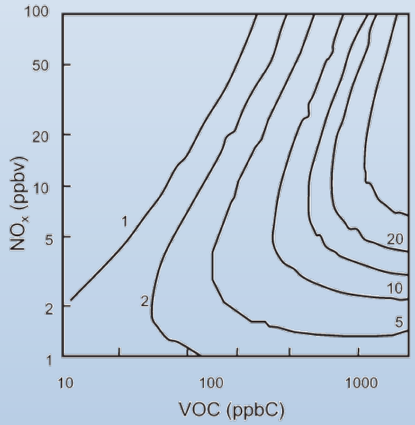


Fig. 10 Isopleths giving net rate of ozone production (ppb h^{-1}) as a function of VOC (ppbC) and NO_x (ppbv) for mean summer daytime meteorology and clear skies under urban conditions.[16]

Oxygen

- **Biosphere: $2.5x10^7$ Tg**
  - $= 4.5x10^{41}$ O atoms
  - $= 8X10^{17}$ moles O_2
- **Lithosphere: $2.5x10^{11}$ Tg**
  - $= 8x10^{21}$ moles O
  - $= 4.5x10^{45}$ O atoms
- **Atmosphere: $1.2x10^9$ Tg**
  - $= 2x10^{43}$ molecules of O_2 or $4x10^{43}$ O atoms
  - $= 3.8x10^{19}$ moles O_2
- **Ocean: $1.2x10^{12}$ Tg (H_2O)**
  - $= 4.6x10^{46}$ O atoms
  - $= 8x10^{22}$ moles of O

Table 2: Annual gain and loss of atmospheric oxygen (Units of 10^{10} kg O_2 per year)

Photosynthesis (land)	16,500
Photosynthesis (ocean)	13,500
Photolysis of N_2O	1.3
Photolysis of H_2O	0.03
Total Gains	~ 30,000
Losses - Respiration and Decay	
Aerobic Respiration	23,000
Microbial Oxidation	5,100
Combustion of Fossil Fuel (anthropogenic)	1,200
Photochemical Oxidation	600
Fixation of N_2 by Lightning	12
Fixation of N_2 by Industry (anthropogenic)	10
Oxidation of Volcanic Gases	5
Losses - Weathering	
Chemical Weathering	50
Surface Reaction of O_3	12
Total Losses	~ 30,000

Table 1: Major reservoirs involved in the oxygen cycle

Reservoir	Capacity (kg O_2)	Flux In/Out (kg O_2 per year)	Residence Time (years)
Atmosphere	$1.4 * 10^{18}$	$30,000 * 10^{10}$	4,500
Biosphere	$1.6 * 10^{16}$	$30,000 * 10^{10}$	50
Lithosphere	$2.9 * 10^{20}$	$60 * 10^{10}$	500,000,000

Oxygen Cycle Reservoirs & Flux