Surface emissions

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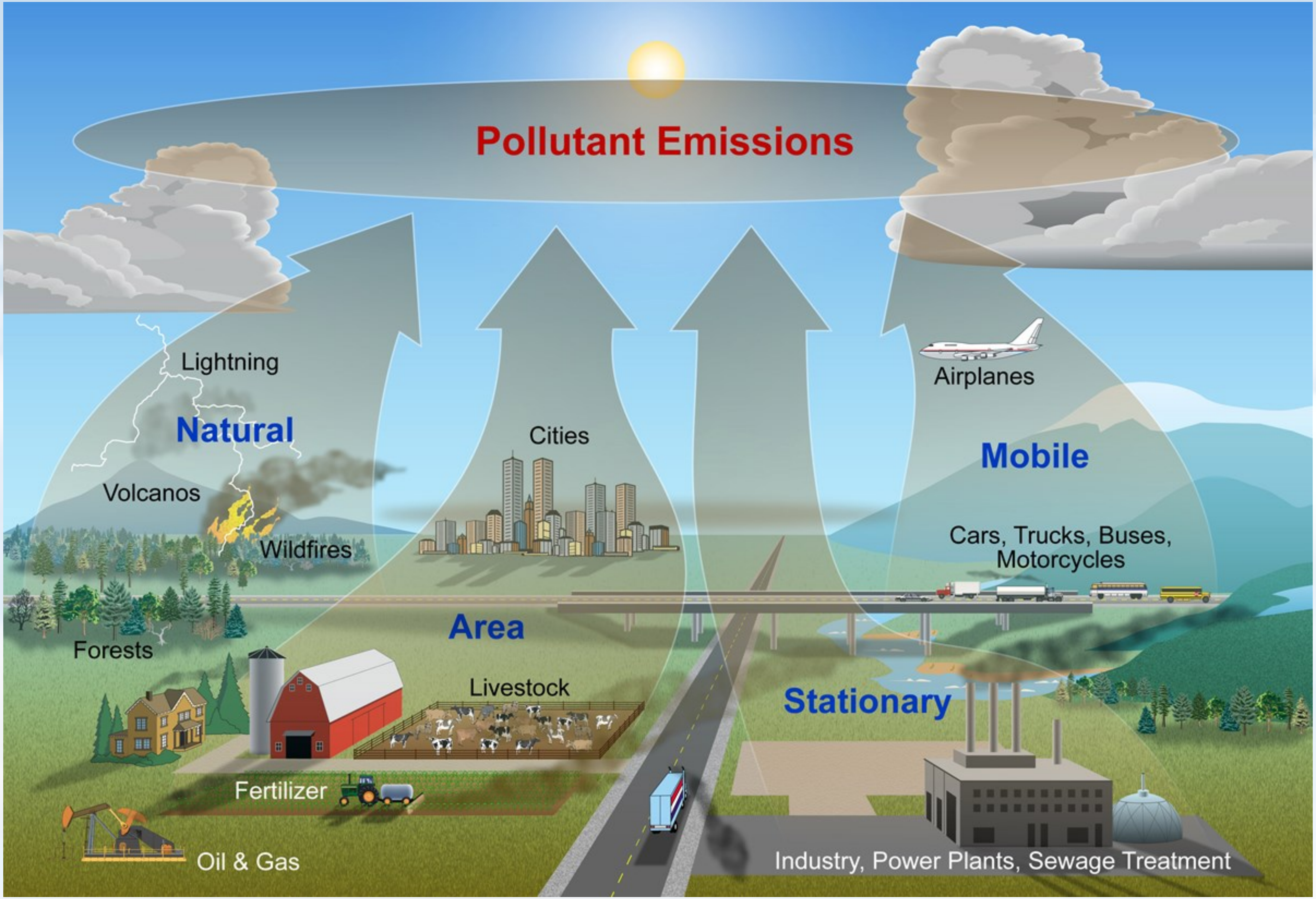
PAPILA
Prediction of Air Pollution in Latin America and the Caribbean

European Commission

Atmosphere Monitoring Service


Pollutant Emissions
Lightning
Natural
Volcanos
Wildfires
Forests
Cities
Area
Livestock
Fertilizer
Oil & Gas
Airplanes
Mobile
Cars, Trucks, Buses,
Motorcycles
Stationary
Industry, Power Plants, Sewage Treatment

Emissions Needs in Atmospheric Research

- **Analysis and forecasting of atmospheric composition, observations from campaigns**
  - wide range of chemical species
  - high spatial and temporal resolution

- **Global scale, long-range transport**
  - limited number of chemical species
  - moderate spatial and temporal resolution
  - long-term variation (a few decades)
  - need some coupling emissions/meteorological conditions

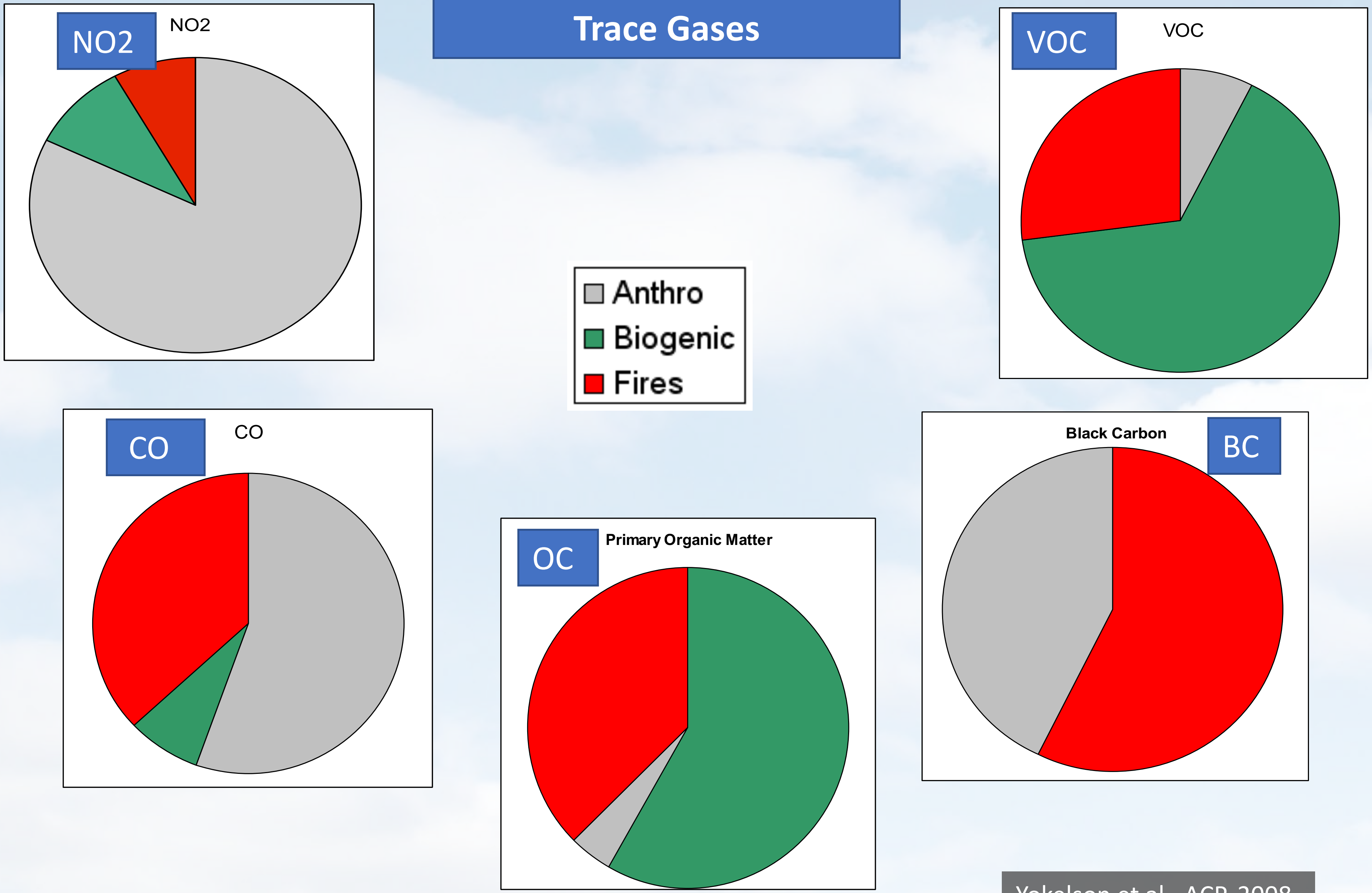
- **Climate studies: impact of climate on emissions and of emissions on climate**
  - long-lived species, aerosols and a few ozone precursors
  - emissions models or algorithms to take into account land-use and human-related changes
  - past/future realistic scenarios (decades-century)

Large diversity of sources for atmospheric pollutants

	Anthro-pogenic	Biomass burning	Biogenic/ continental	Oceanic	Photo-chemistry
CH4	Major	Significant	Major	Minor	No
CO	Major	Major	Significant	Minor	Major
NOx	Major	Significant	Major	No	Minor
VOCs	Major	Major/Sign.	Major	Minor	Major/Sign.
SO2	Major	Minor	Major	No	Minor
BC/OC	Major	Major	No	No	Minor
NH3	Major	Minor	Minor	No	No
PMs	Major	Major	Major (dust)	No	Major

NOx = nitrogen oxides ; VOCs = Volatile Organic Compounds ; BC = black carbon (soot)
OC = organic carbon ; NH3 = ammonia ; PMs = particulate matter

Global Emission Estimates: Trace Gases



Yokelson et al., ACP, 2008

Sources of air pollutants:

- Industry
- Agriculture
- Transportation
- Fires
- Soils
- Vegetation
- Oceans
- Lightning
- Volcanoes

Outline of the talk:

- Introduction
- How are emissions quantified?
- Anthropogenic emissions
- Anthropogenic emissions in Latin America
- Biogenic emissions
- Emissions from fires
- The CAMS emissions dataset
- Access to emission data
- The GEIA community

Emissions Calculation General Methodology

$$E_X = \Sigma_S \left[EF_{X,S} \bullet A_S \bullet (1 - CE_{X,S})\right]$$

Total mass emissions of compound X

Sum up all sources S

Emissions factor = mass of compound X emitted by source S per unit activity; “representative”

Activity of source S, e.g., amount of fuel burned, vehicle miles driven, etc.;

Effectiveness of control measures for compound X at source S;

Emissions from fires:

$$E_X = \Sigma_S \left[EF_X \bullet BA \bullet BD \bullet BE\right]$$

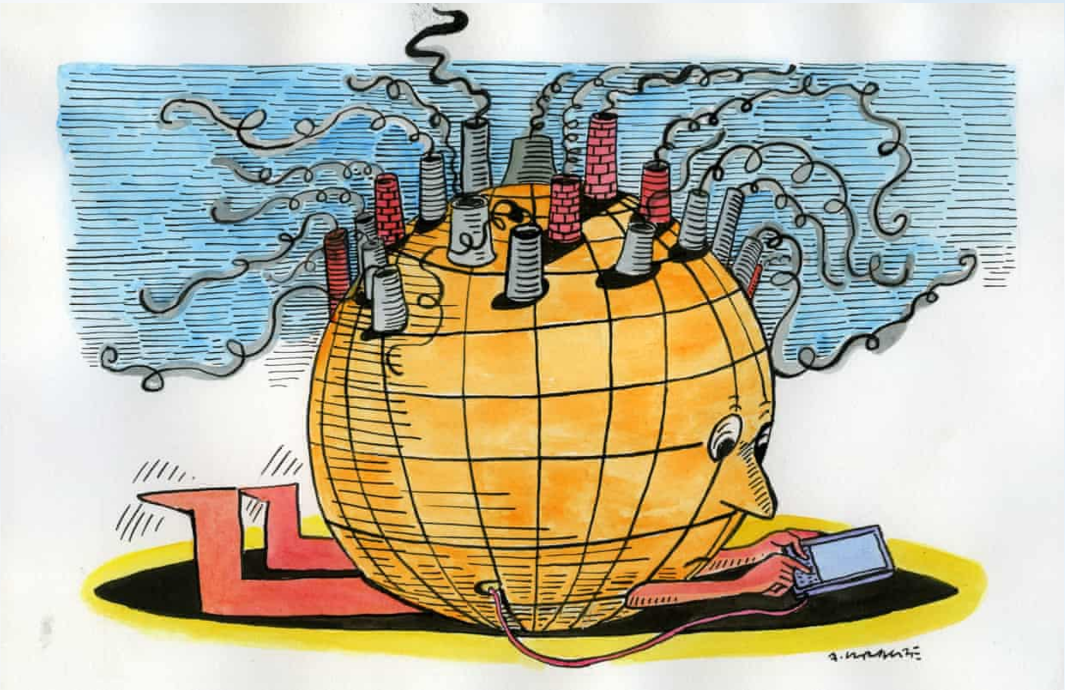
BA = Burnt Area ; BD = Biomass Density; BE = Burning Efficiency

Emissions of biogenic hydrocarbons from the vegetation:

$$E_X = \Sigma_S \left[EF_X \bullet EA \bullet EE\right]$$

EE = Escape efficiency; EA = Emission activity (depends on light, temperature, leaf age, leaf area index, soil moisture, etc.

Anthropogenic emissions



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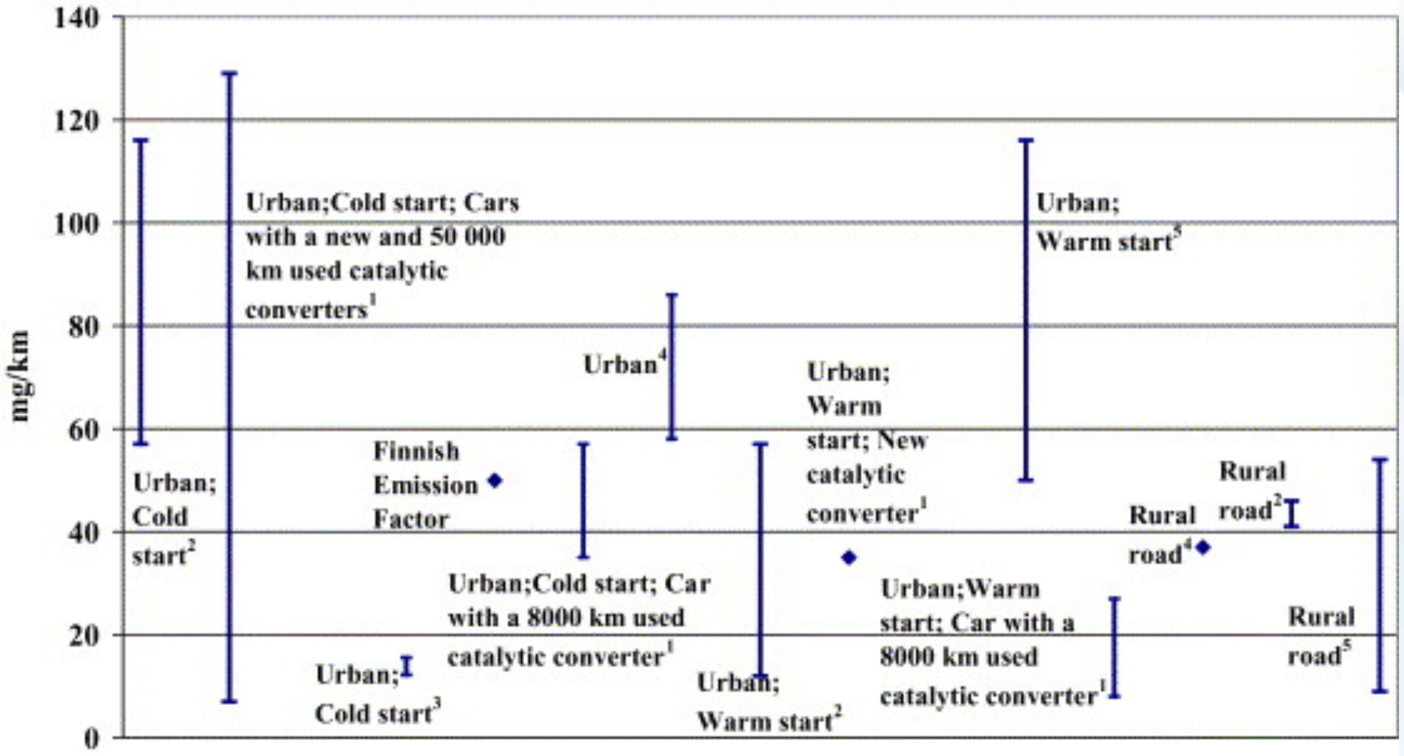
One of the main uncertainties: Emission Factors

Main reasons:

- errors in definition / interpretation of definition
- difficulty in sampling because of a wide range of conditions
- vary widely among the different processes considered

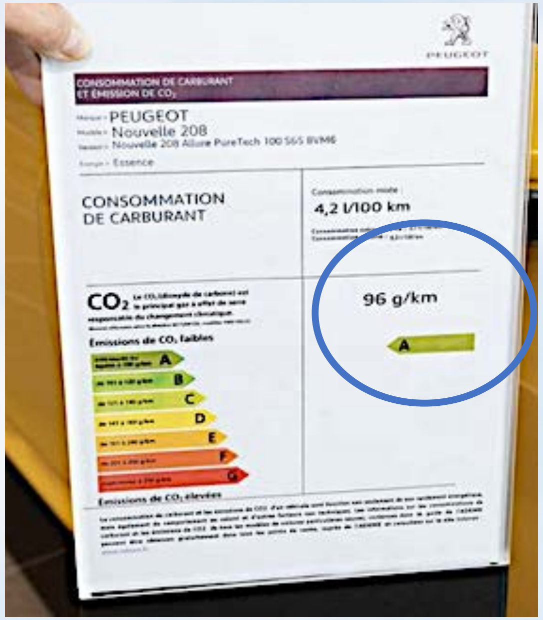


From Monni et al., 2004 (Measurement results of N_2O emission factors (mg/km) of cars with catalytic converters in different studies)

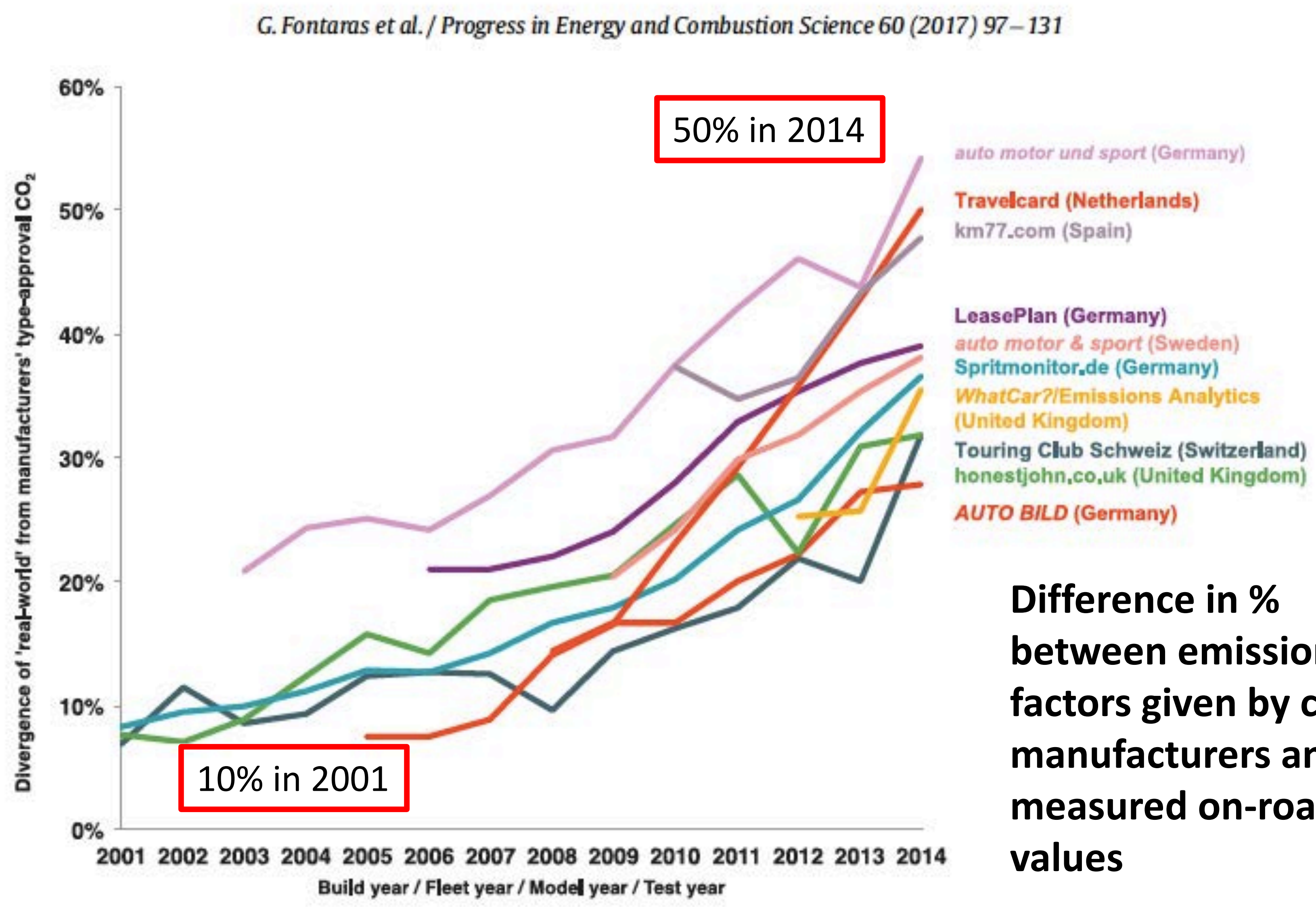
Measurement of emission factors related to traffic in different parts of the world

Measurement of emission factors for anthropogenic emissions

Automobiles emission factors: can we trust values provided by car companies?



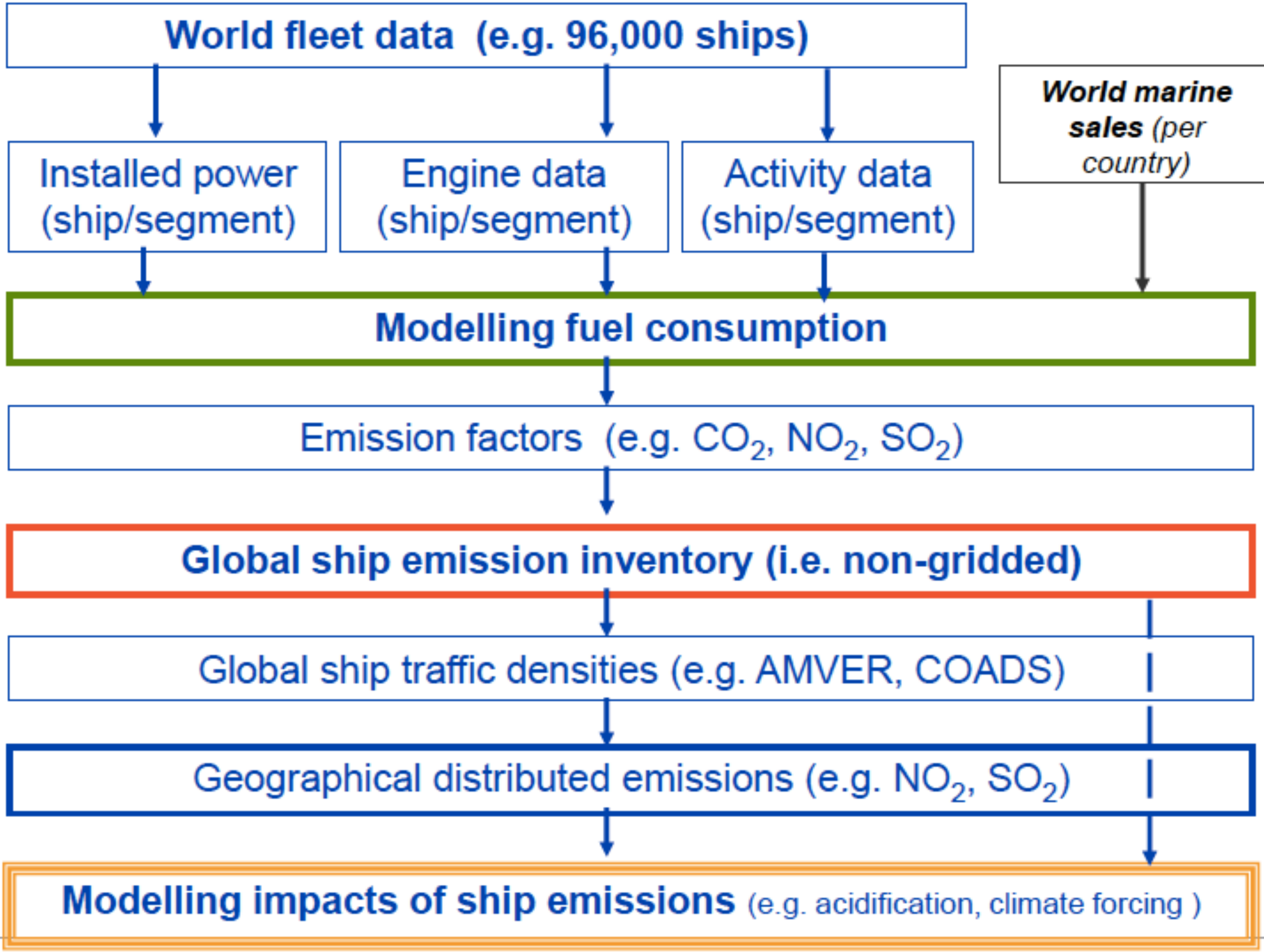
What you can see when you buy a car

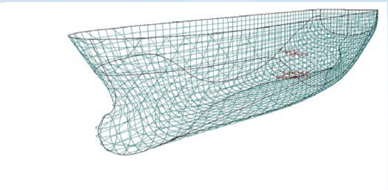


Difference in % between emission factors given by car manufacturers and measured on-road values

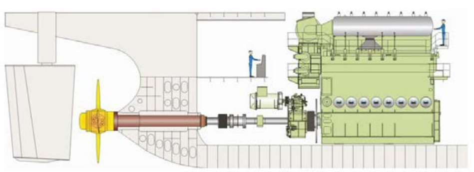
Example of emissions calculation: emissions from ships

MANAGING RISK DNV





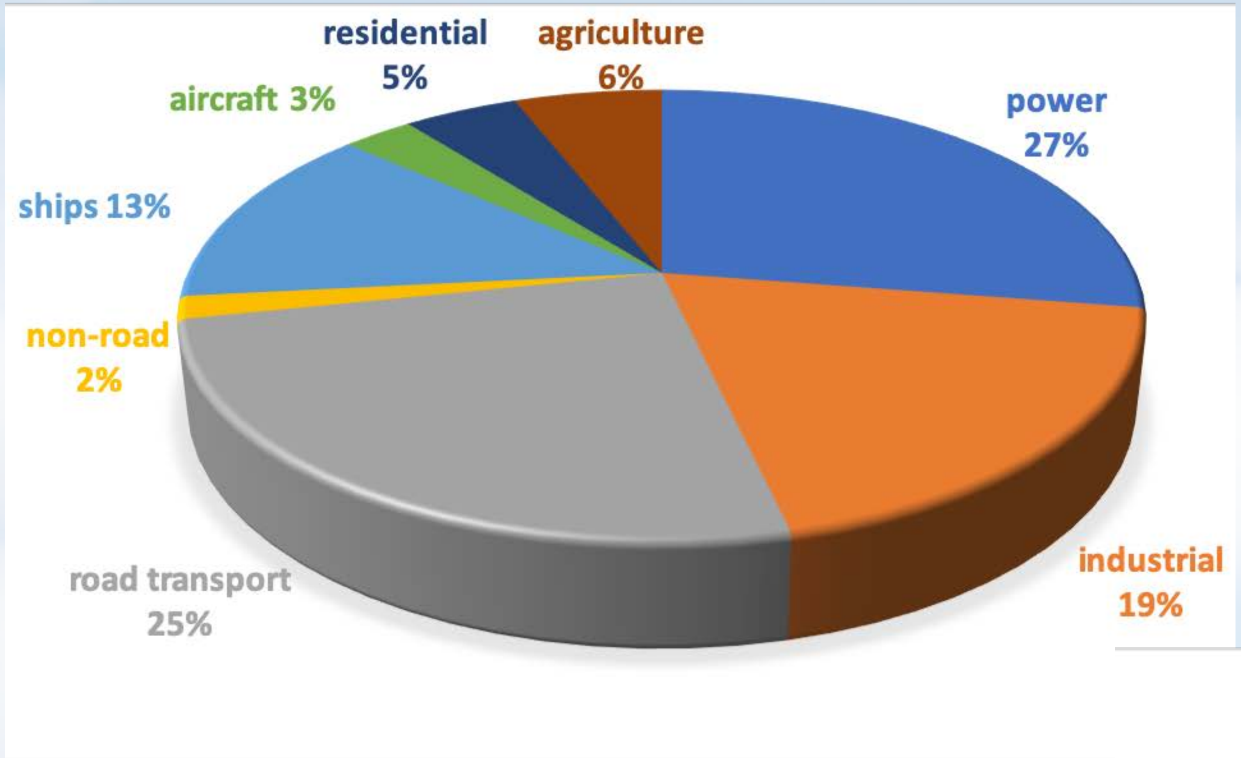
Activity



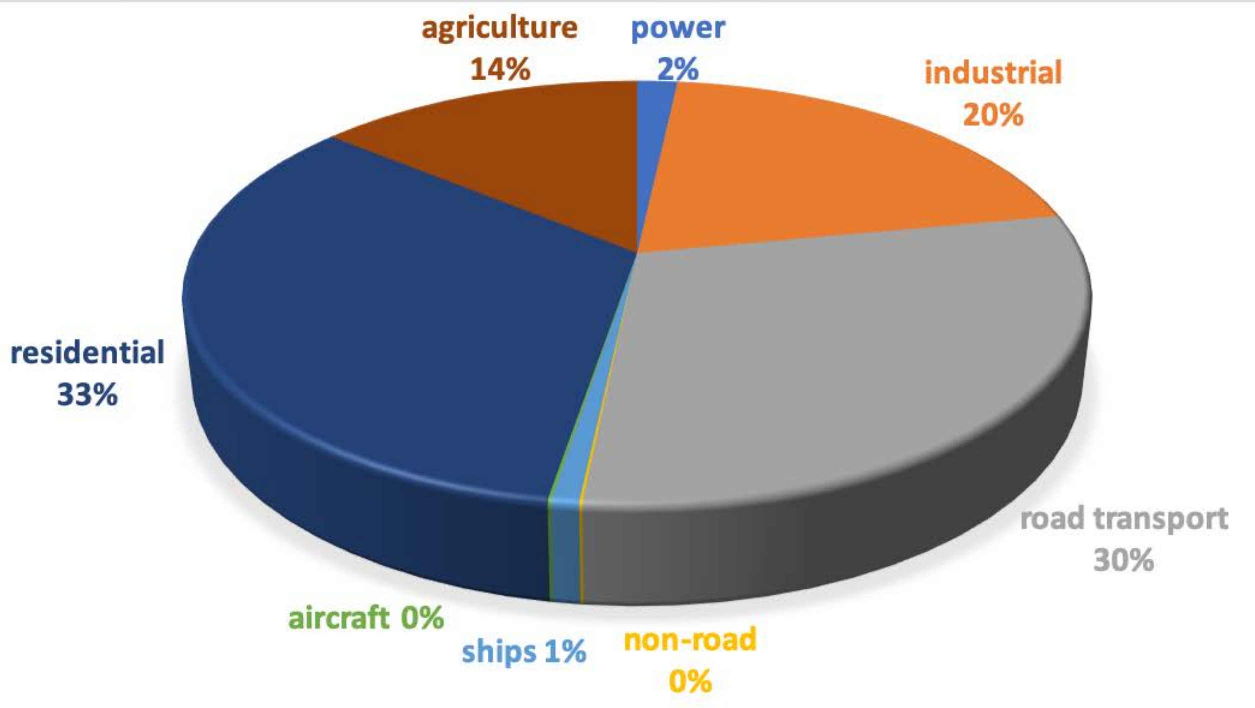
Emission factors

Gridding

Emissions have to be quantified for many different sectors: example = CO and NO_x



NOx



CO

A few anthropogenic emissions inventories commonly used:

- EDGAR inventories (Joint Research Center, Italy):
https://edgar.jrc.ec.europa.eu/
1970-2012; 0.1x0.1 degree; monthly; all compounds

- CEDS inventory for IPCC AR6 (PNNL, Pacific Northwest National Laboratory):
1750-2014; 0.5x0.5 degree; monthly; all compounds but no VOCs speciation;
http://www.globalchange.umd.edu/ceds/

- MACCity, developed in Europe (Granier et al., Climatic Change, 2011)
1960-2020; 0.5x0.5 degree, monthly; all compounds, available from ECCAD
(now replaced by the CAMS emissions; see later)

- ECLIPSE, developed at IIASA, Austria,
http://www.iiasa.ac.at/web/home/research/researchPrograms/air/ ECLIPSEv5.html
1990-2050; 0.5x0.5 degree; yearly, all compounds but no VOCs speciation

What VOCs speciation mean:

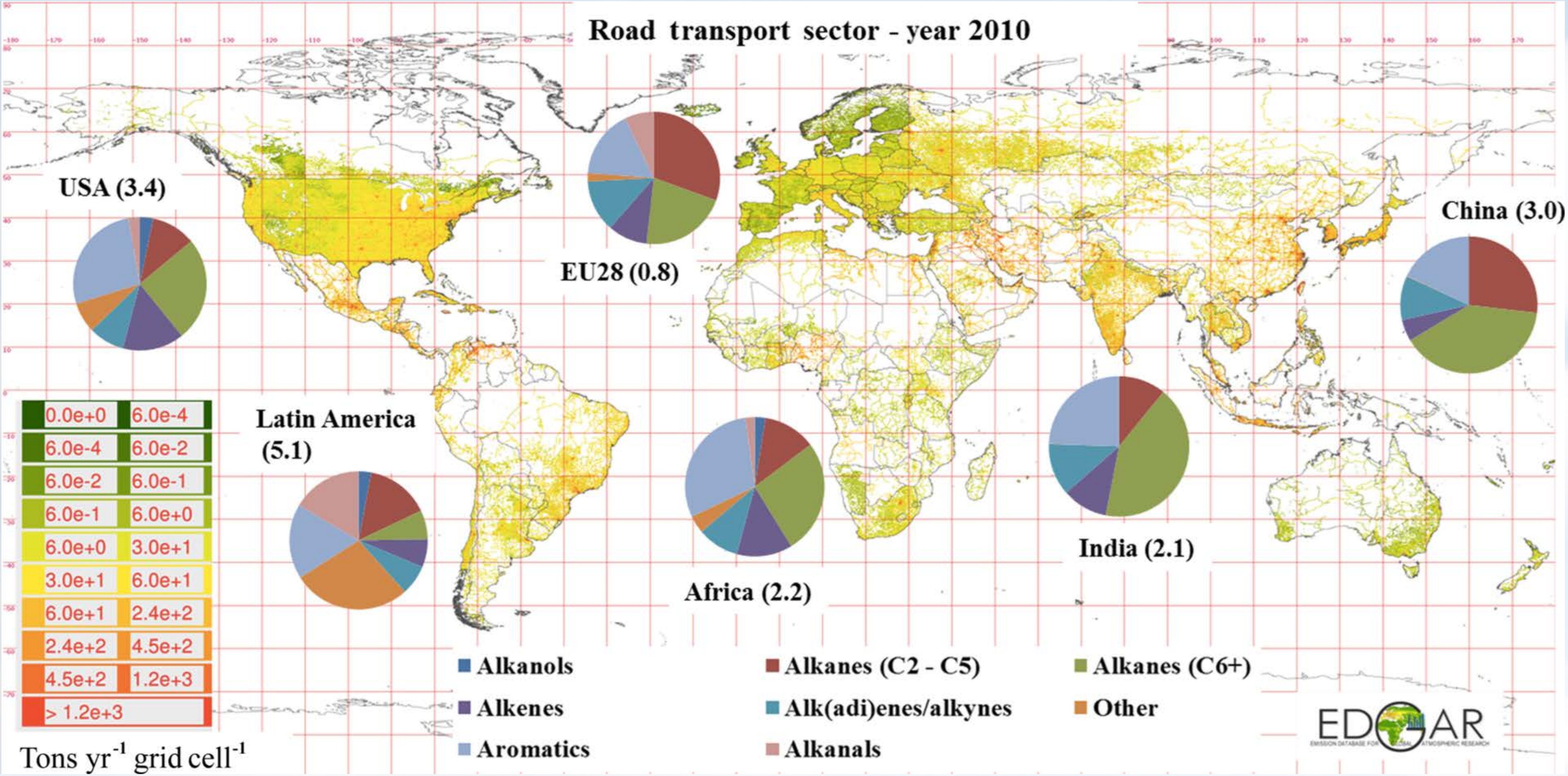
- VOCs = volatile organic compounds

- Atmospheric models include individual VOCs, such as ethane, propane, ethene, benzene, toluene, methanol, formaldehyde, etc.

- Most datasets provide surface emissions of total VOCs, without any indication of the emission of individual VOCs (speciation)

- Very few data available at the global scale. More data available at the country or city scale.

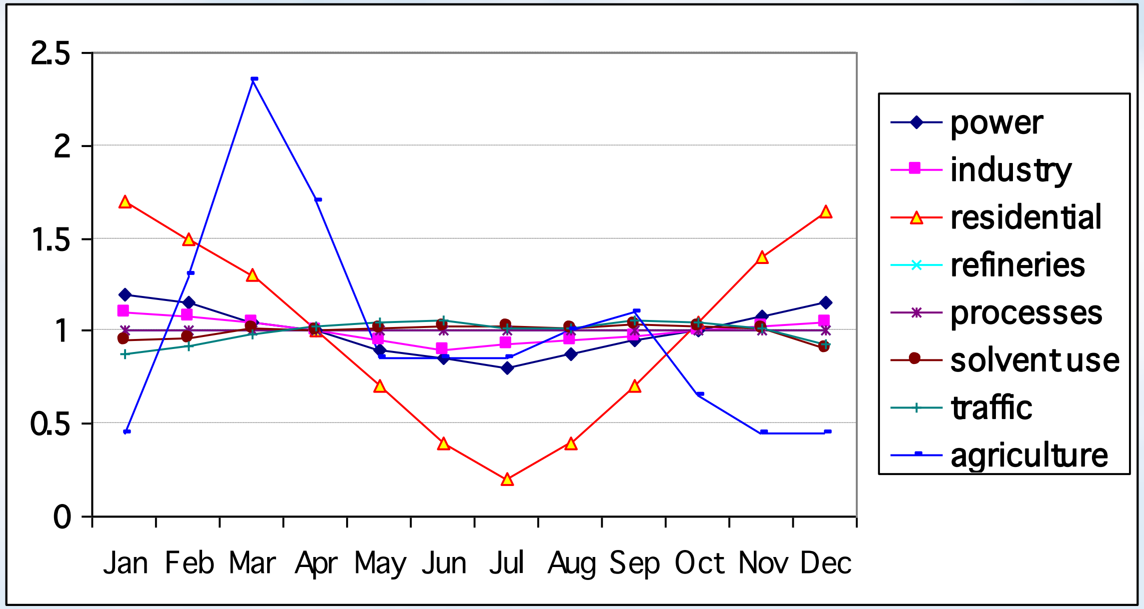
- Best available global VOCs dataset for now: EDGAR4.3.2 (Huang et al., ACP, 2017)



Road transport sector - year 2010
USA (3.4)
EU28 (0.8)
China (3.0)
Latin America (5.1)
Africa (2.2)
India (2.1)
0.0e+0 6.0e-4
6.0e-4 6.0e-2
6.0e-2 6.0e-1
6.0e-1 6.0e+0
6.0e+0 3.0e+1
3.0e+1 6.0e+1
6.0e+1 2.4e+2
2.4e+2 4.5e+2
4.5e+2 1.2e+3
> 1.2e+3
Tons yr-1 grid cell-1
Alkanols
Alkanes (C2 - C5)
Alkanes (C6+)
Alkenes
Alk(adi)enes/alkynes
Other
Aromatics
Alkanals
EDGAR
EMISSION DATABASE FOR GLOBAL ATMOSPHERIC RESEARCH

Temporal variations of the emissions: still not well known

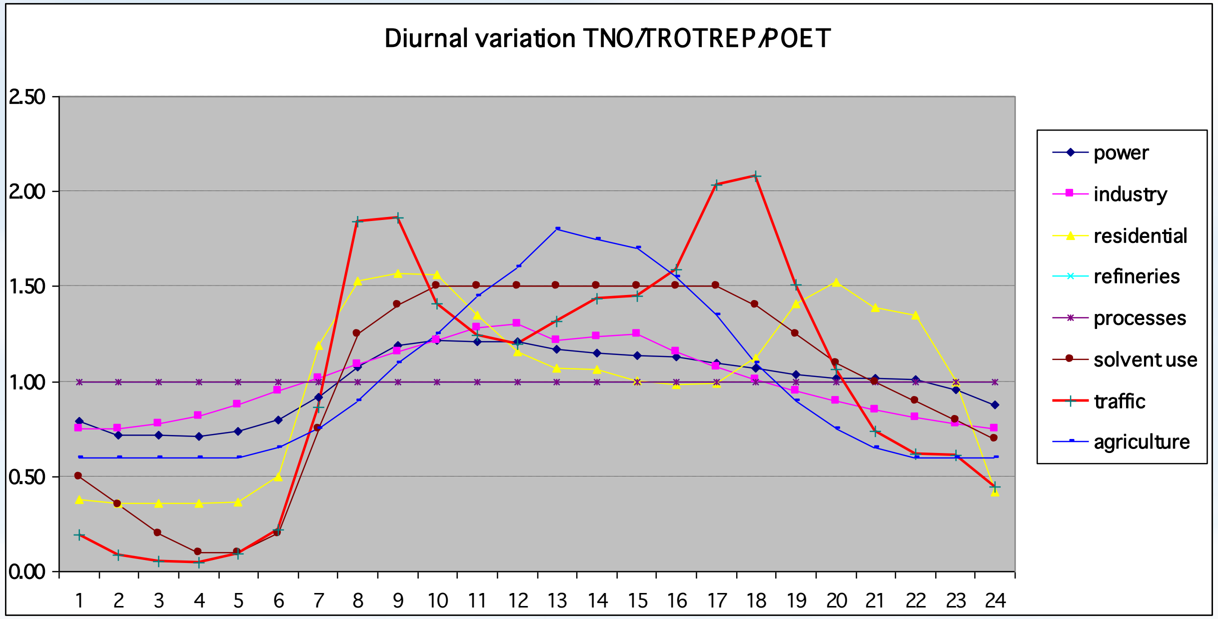
Many datasets/models use old data from TNO in the Netherlands



Seasonal

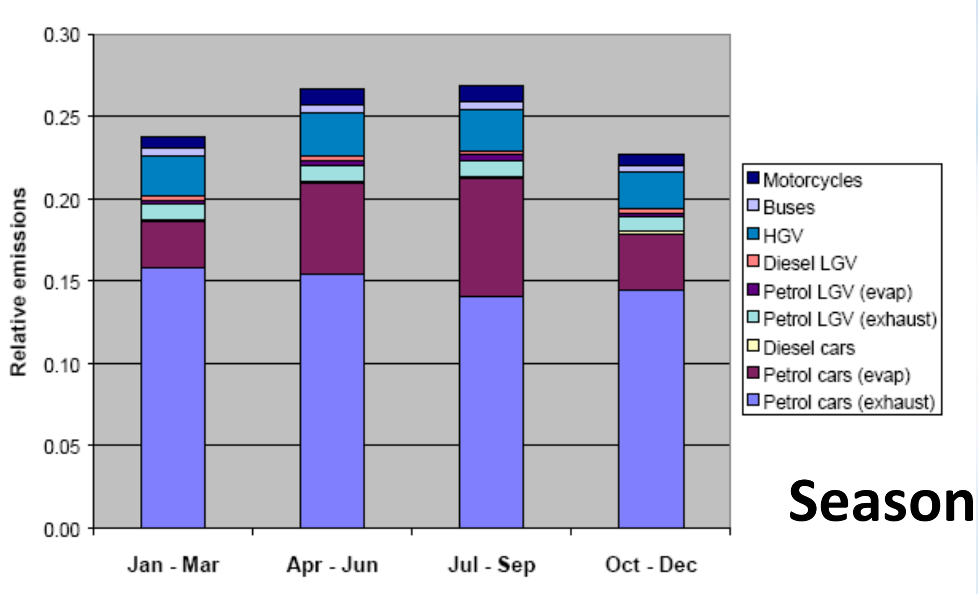
Not much details on differences between countries, species, etc.

diurnal

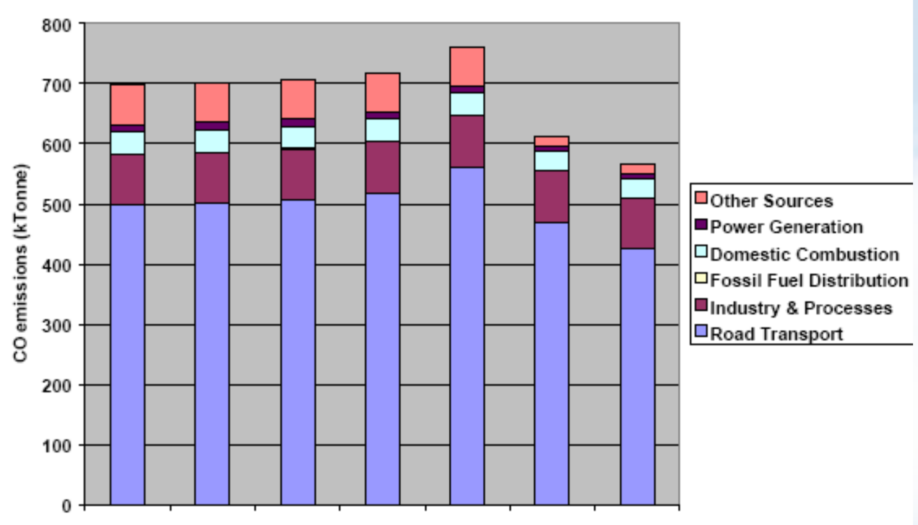


From RIVM, the Netherlands

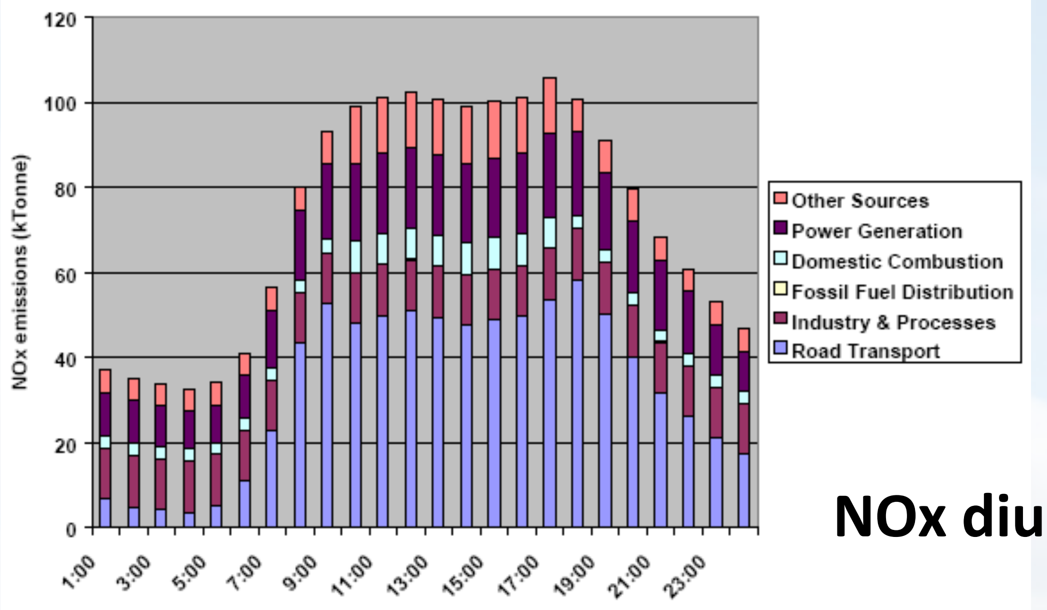
Temporal variation



Seasonal VOCs



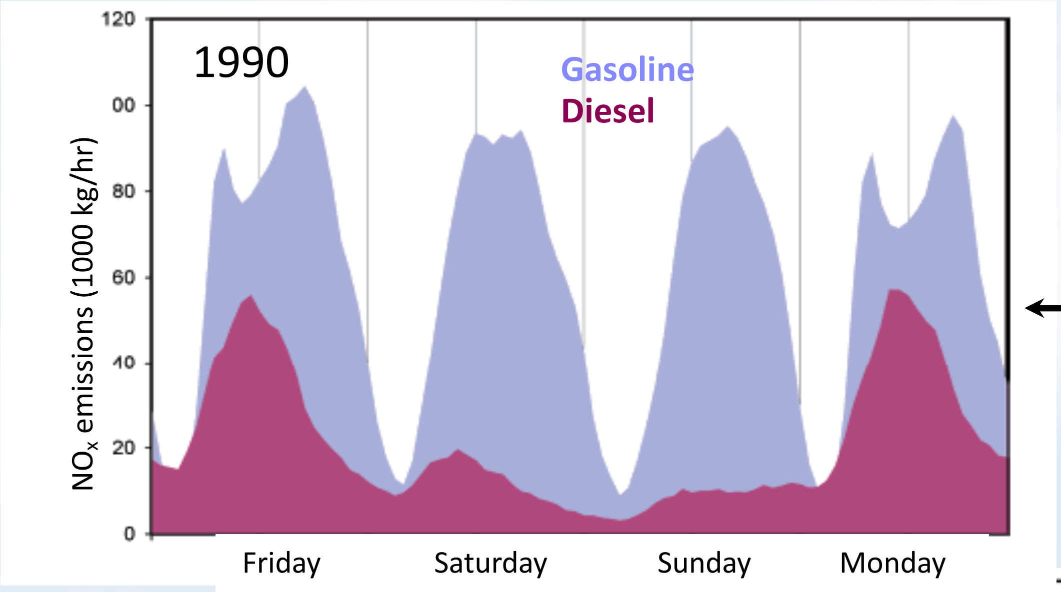
CO weekly emissions



NOx diurnal emissions

New temporal profiles developed within the CAMS project (see later)

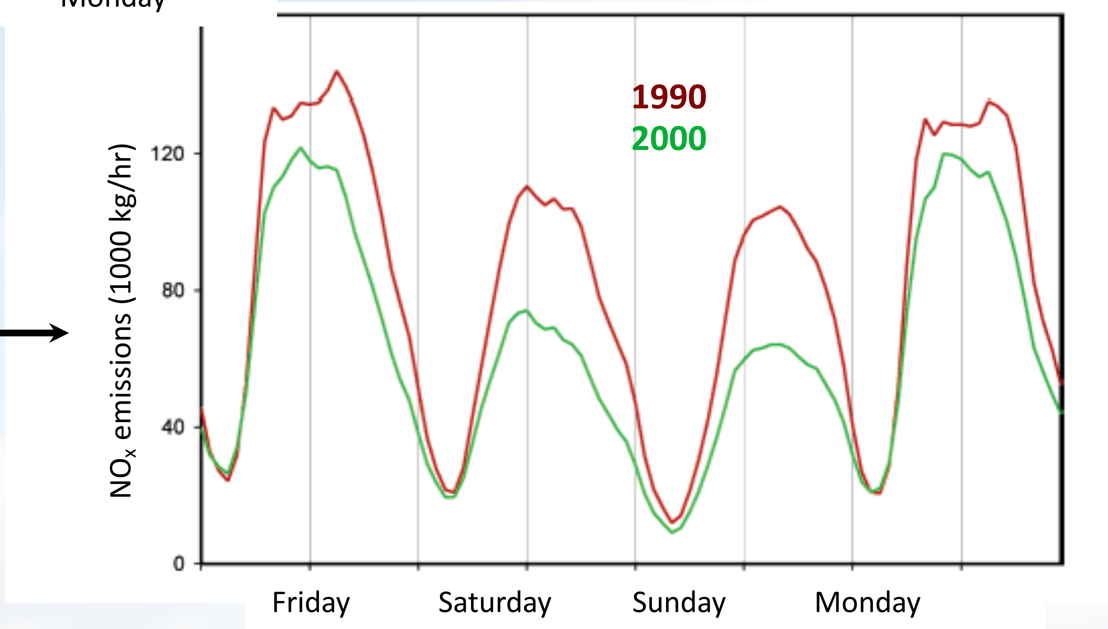
Urban Day-of-Week Variations: Surface Observations, Fuel-Based Estimates



California statewide NO_x emissions from motor vehicles based on roadside monitoring, traffic counts, and fuel use

Weekend-weekday differences resulting from traffic patterns

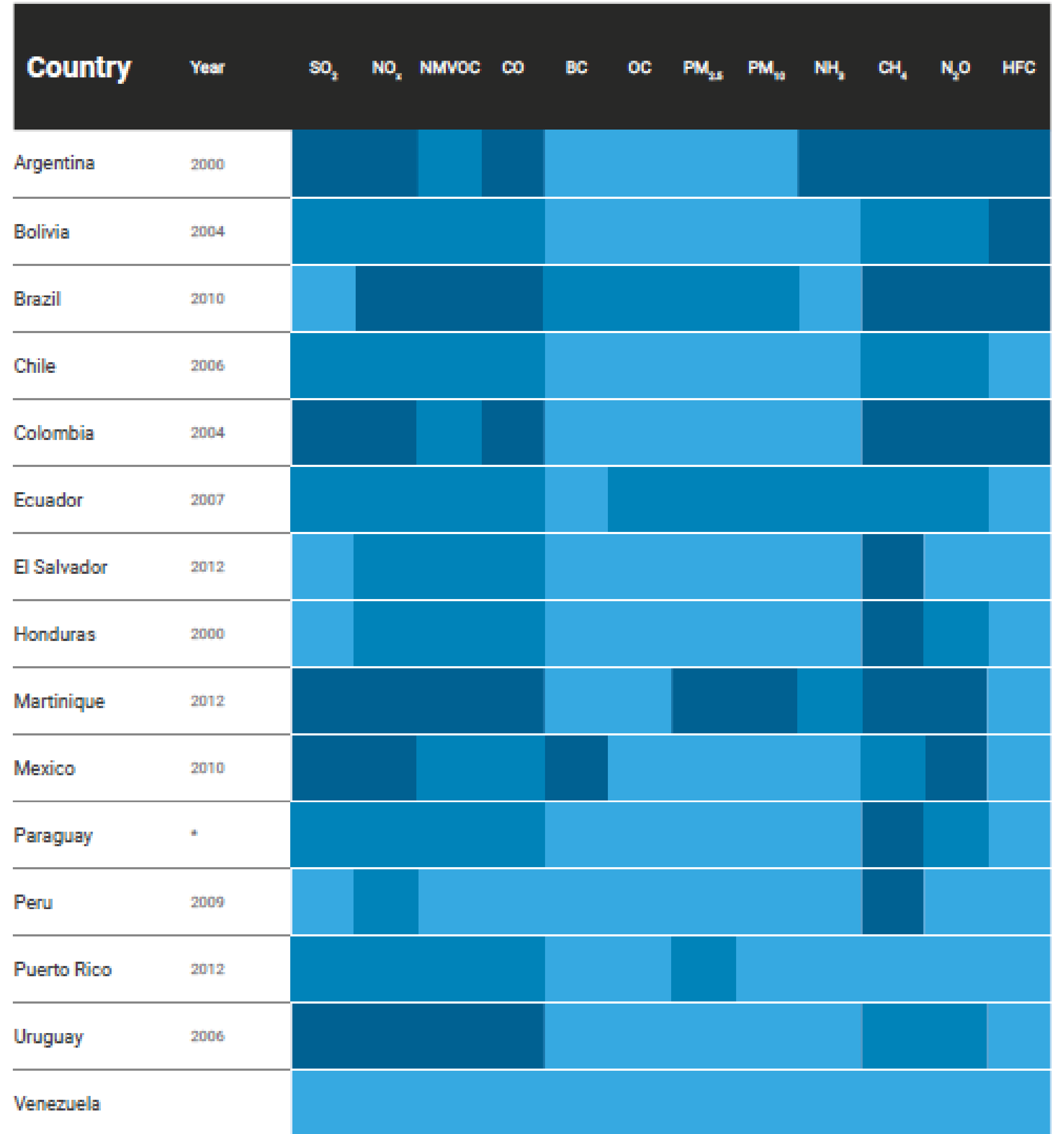
1990 - 2000 change in weekend-weekday difference:
cleaner gasoline vehicles



Harley et al., *Environ. Sci. Technol.,* 2005

Anthropogenic emissions in Latin America

Availability and completeness of national emissions data in LAC

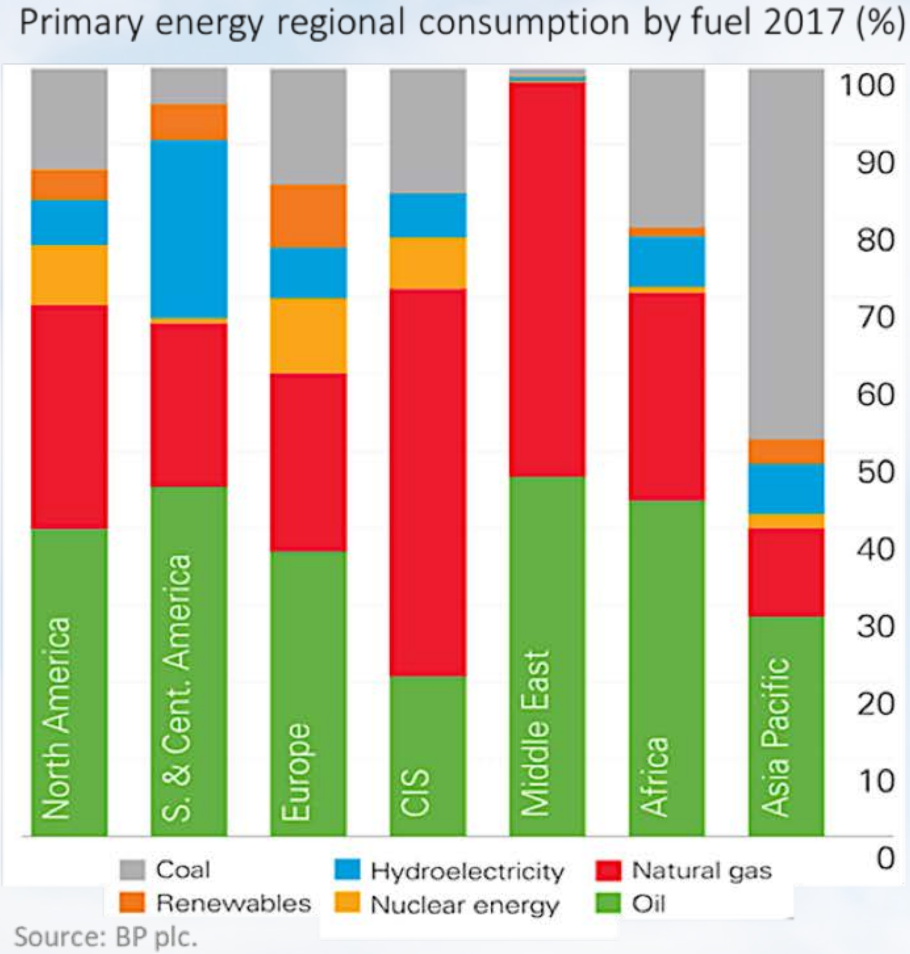


- National inventory provided and complete
- National inventory incomplete
- National inventory not provided

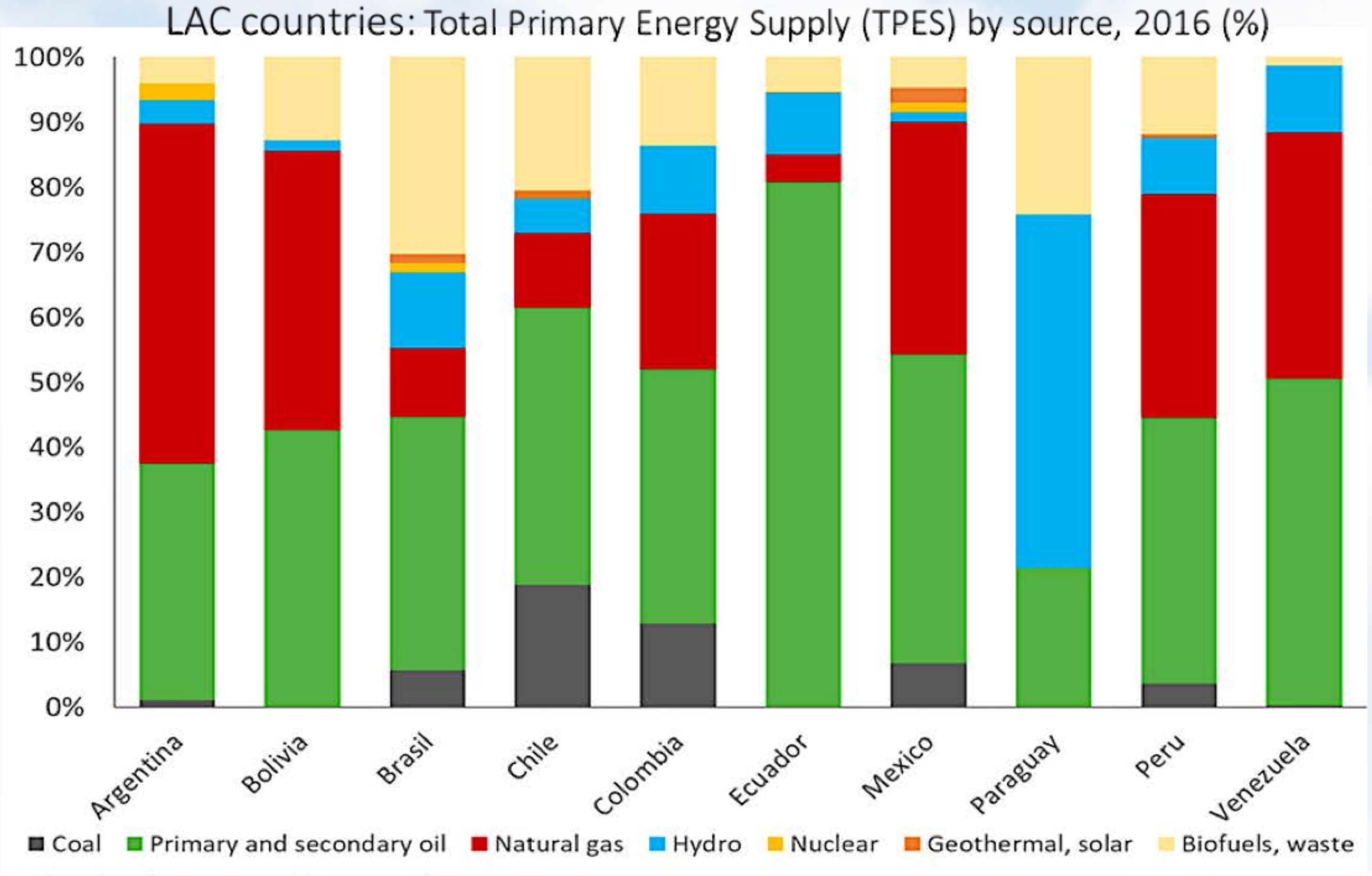
- Not all sectors (residential combustion, agriculture)
- NH_3 in Brazil
- Data for PM are very scarce
- Harmonization and systematization
- Spatial and temporal disaggregation

From Paula Castesana, CNEA, Argentina

Differences between Latin America countries



Source: BP plc.



Based on data from IEA World Energy Balances 2018

- Old fleet
- Motorcycles
- CNG, LPG, ethanol

CO

PM

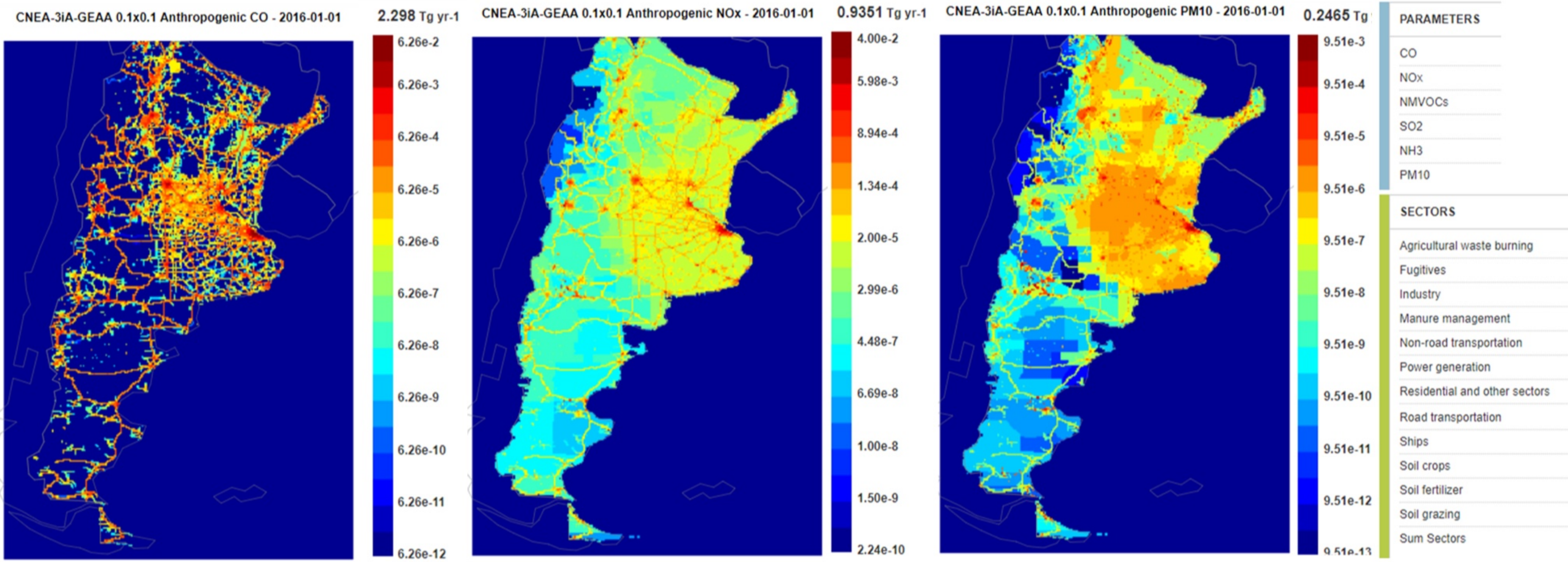
VOCs

SO_2

NO_x

Anthropogenic emission inventories of Argentina

Argentina – local inventory:
Spatial resolution: 0.1° x 0.1° (coverage: Argentina)
Temporal coverage: Yearly (2016)

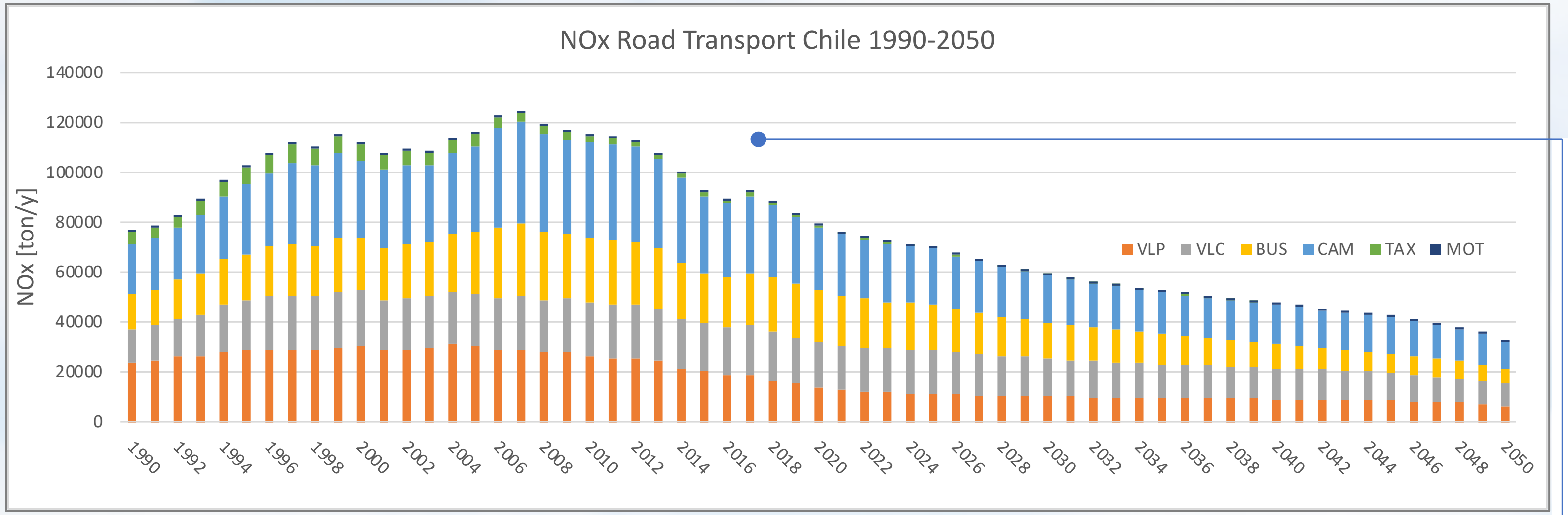


From Paula Castesana, CNEA

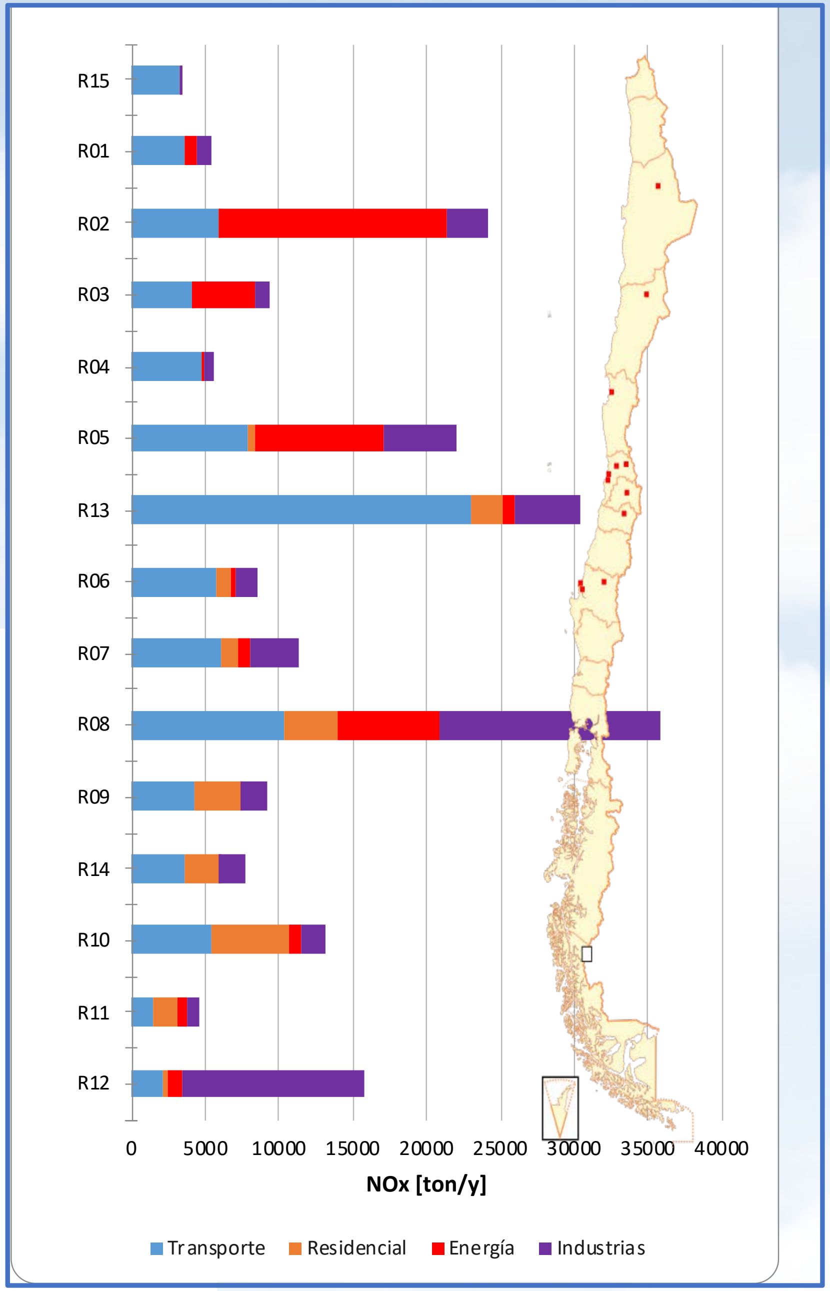
Castesana, P.; Dawidowski, L.; Finster, L.; Gómez, D.; Taboada, M. (2018). Ammonia emissions from the agriculture sector in Argentina; 2000–2012. Atmospheric Environment, 178, 293–304.

Puliafito, S.; Allende, D.; Castesana, P.; Ruggeri, F.; (2017). High-resolution atmospheric emission inventory of the argentine energy sector. Comparison with EDGAR global emission database. Heliyon, 3 (12), e00489.

Current PAPILA research Chile & Colombia (From Mauricio Osses and Nestor Rojas)

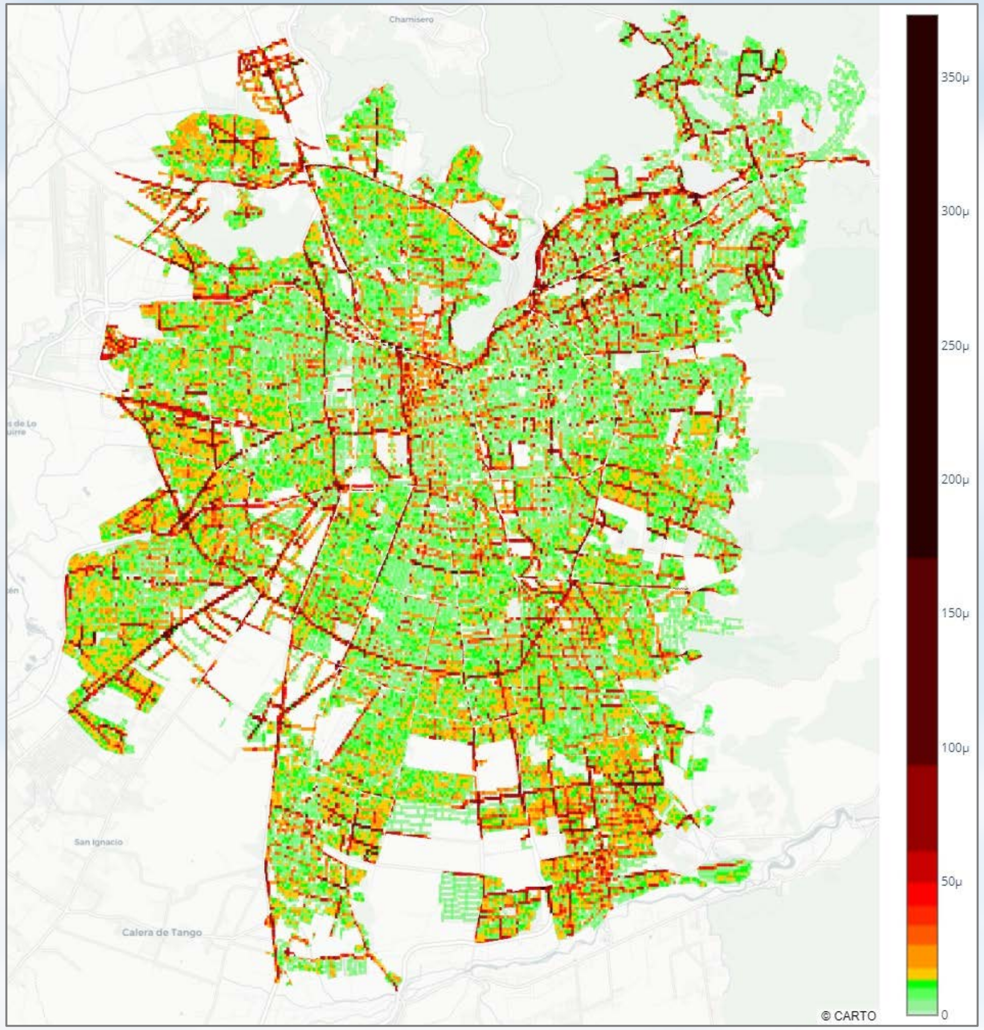


Past and future NOx road emission trends in Chile

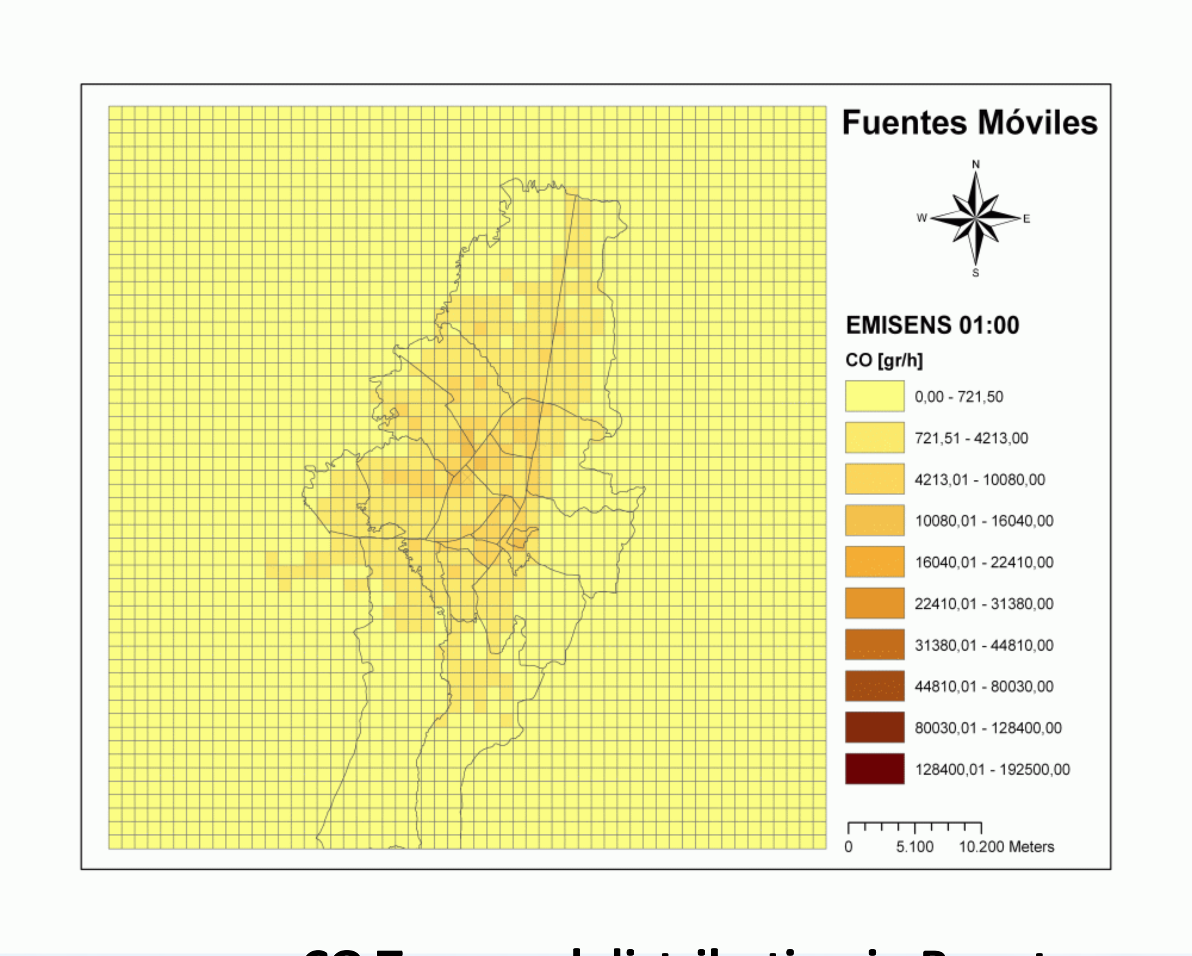


2017 NOx emissions in regions of Chile
Comparison among different sources

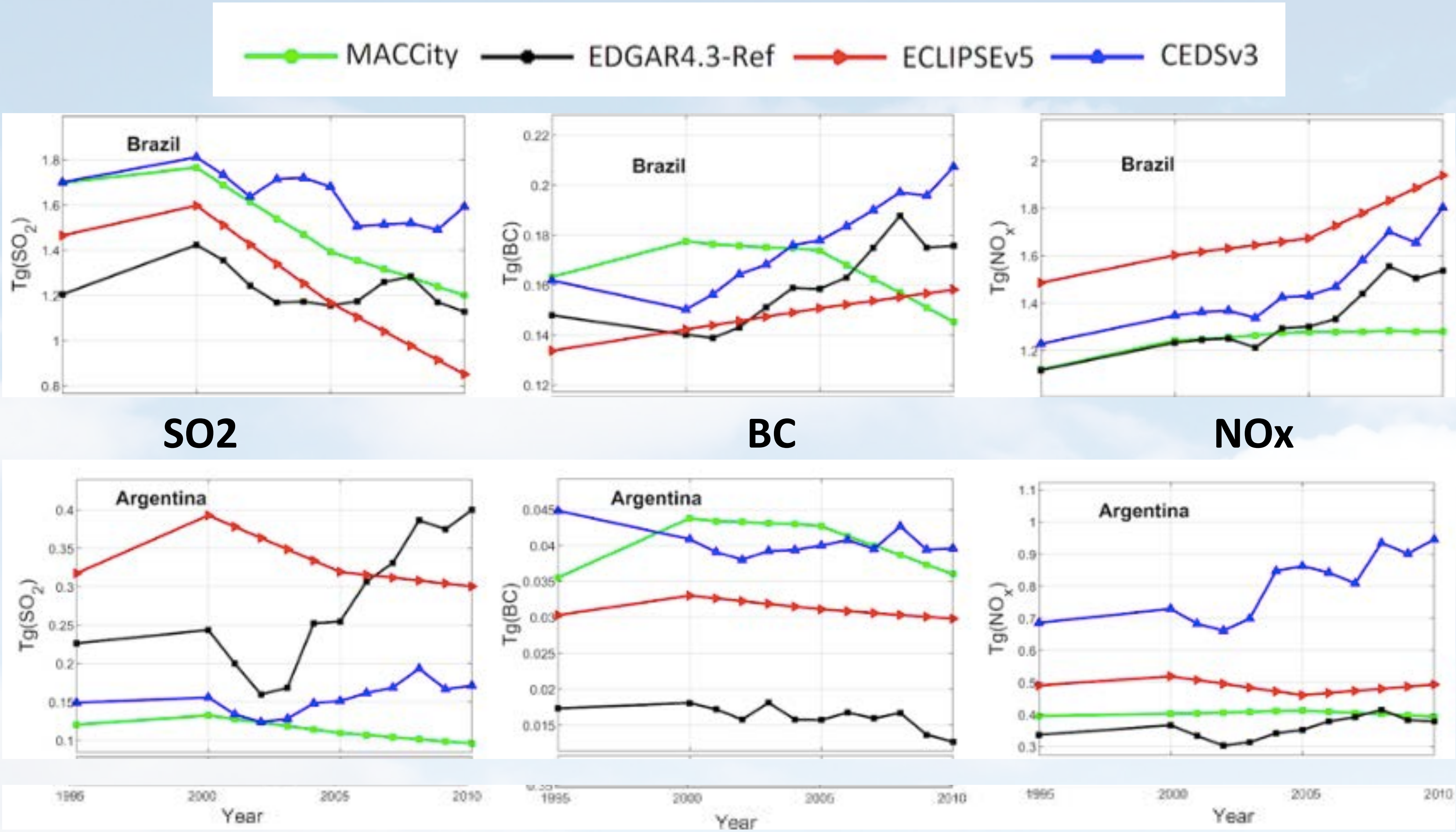
Current PAPILA research Chile & Colombia



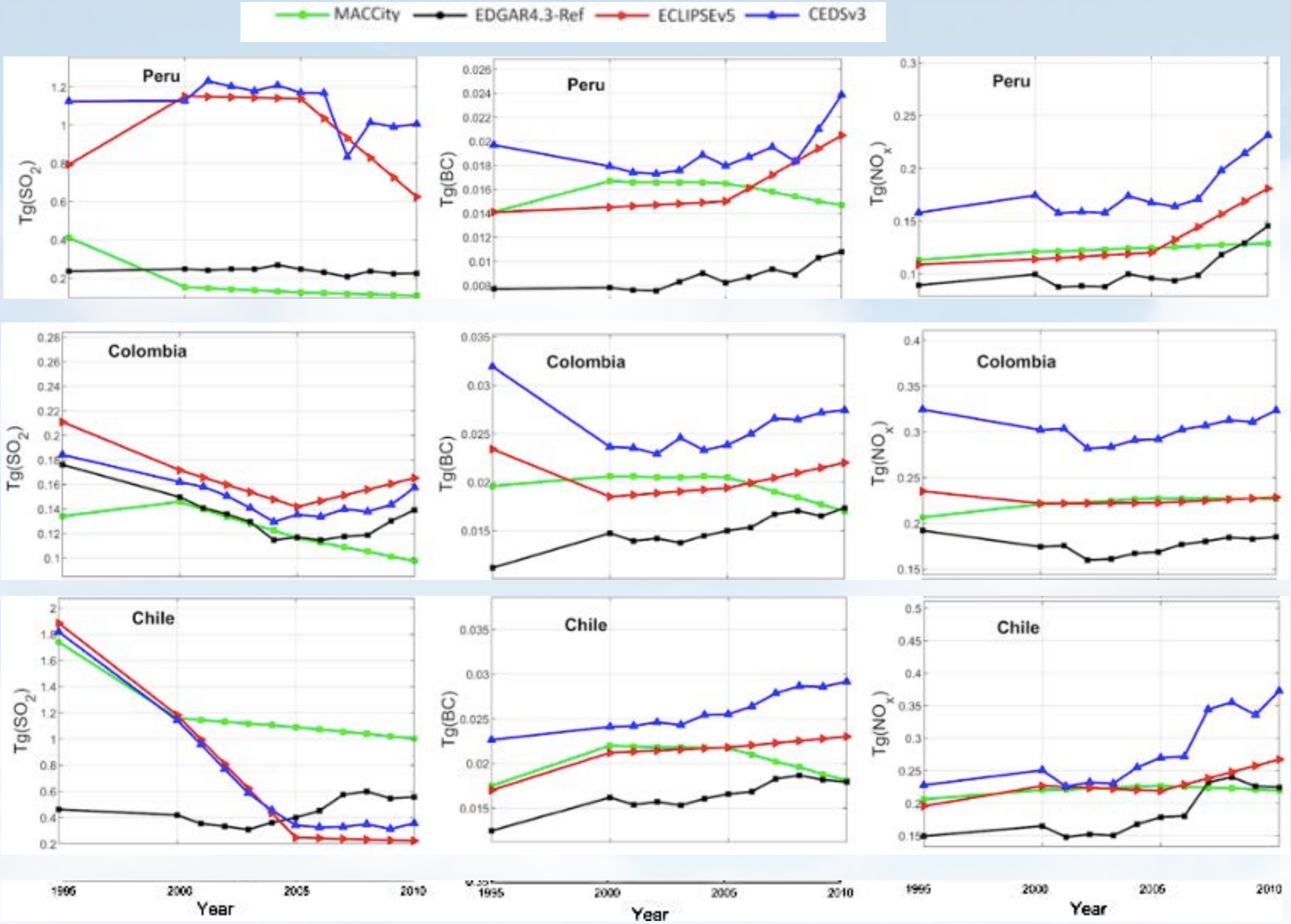
NOx road transport: high resolution spatial distribution
At 200x200 meters (Santiago)



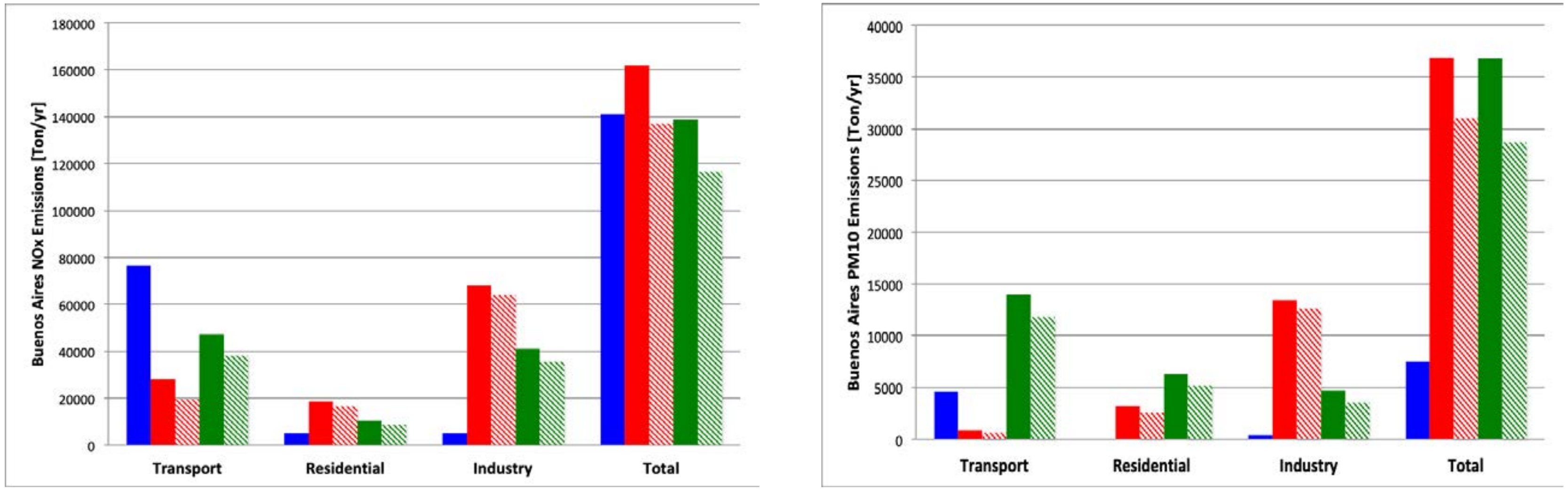
CO Temporal distribution in Bogota
year, month, day, hour



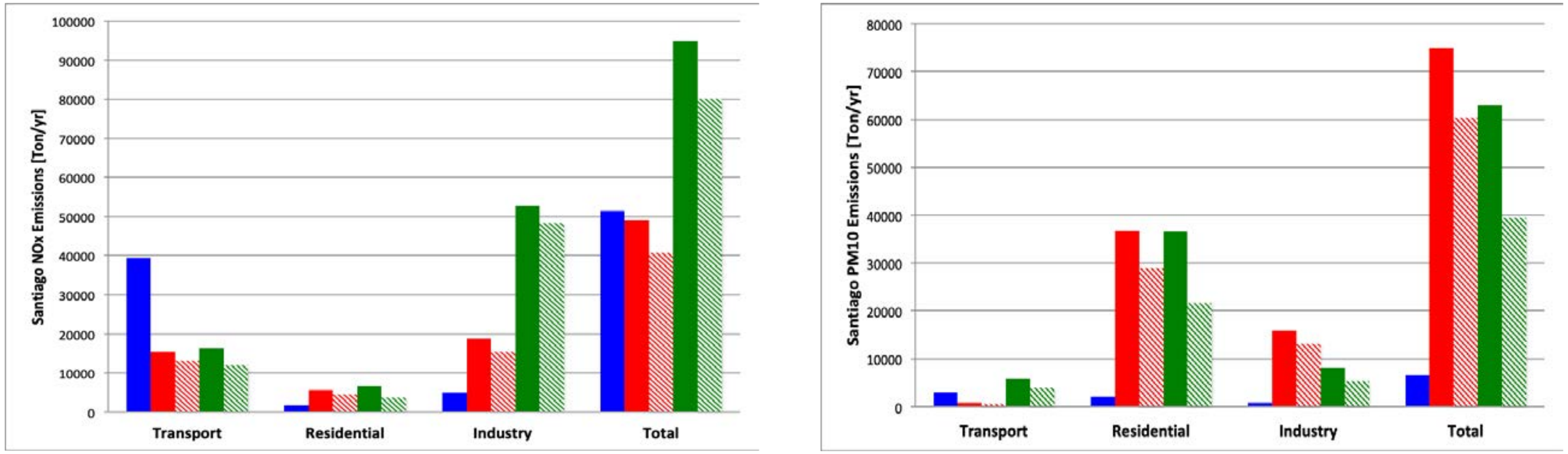
From Huneeus et al., submitted to Atmos. Env.: 19 authors from Chile, Argentina, Brazil, Peru, Colombia + USA and Europe



MACCity
EDGAR4.3-Ref
ECLIPSEv5
CEDSv3
Peru
Colombia
Chile
Tg(SO2)
Tg(BC)
Tg(NOx)
Year



Buenos Aires: NOx (left) and PM10 (right)



Santiago: NOx (left) and PM10 (right)

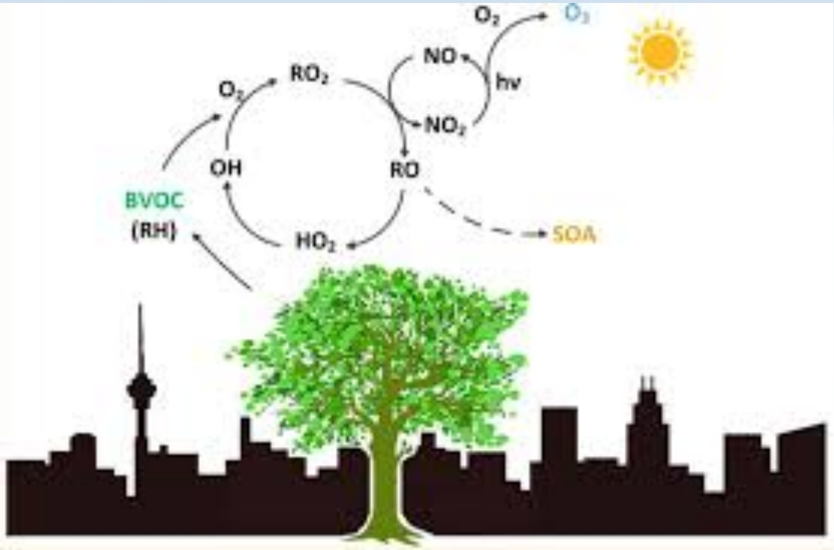
Blue: local inventory

Red: EDGAR

Green: ECLIPSE

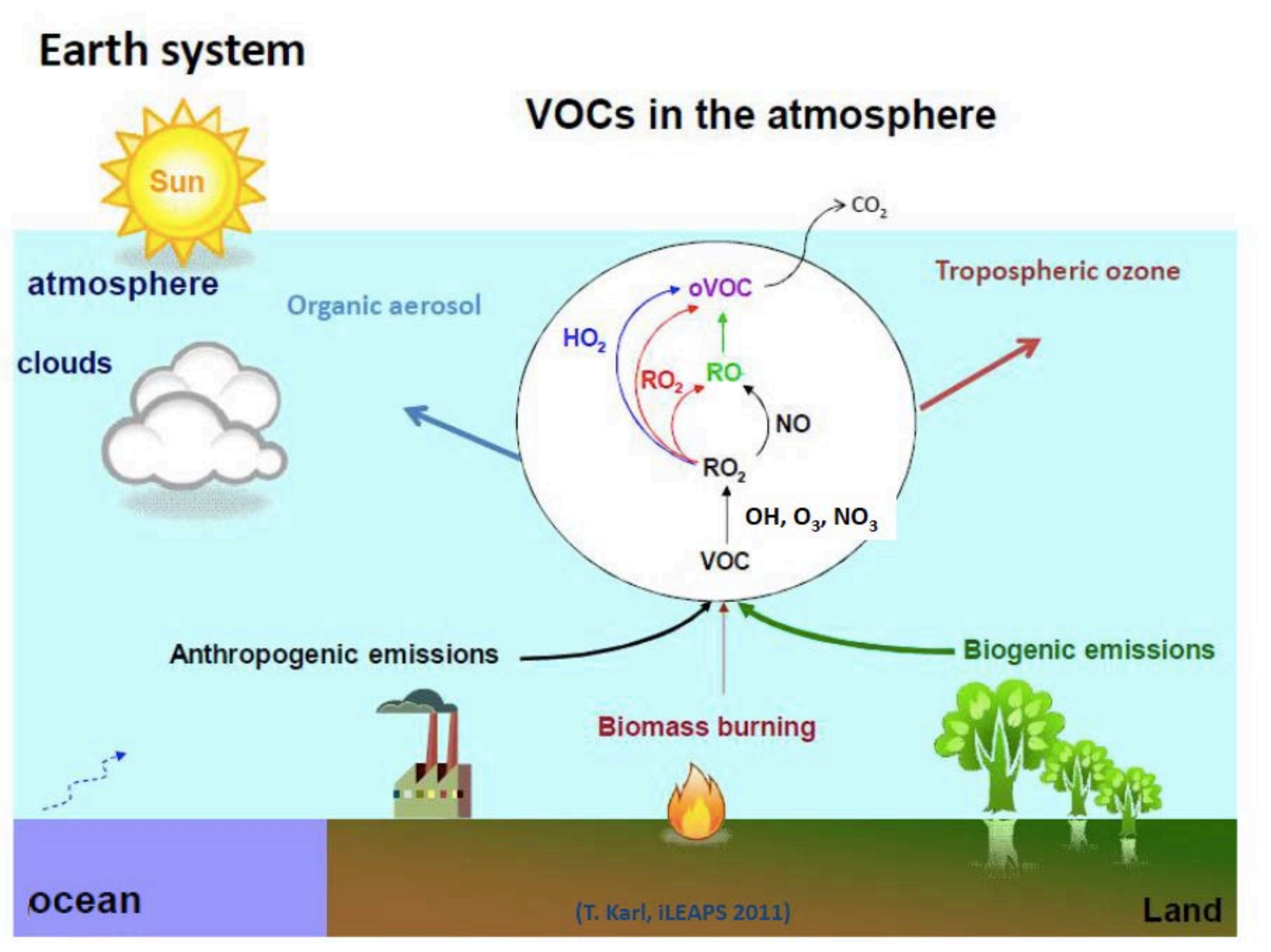
From Huneeus et al., 2019

Biogenic Emissions

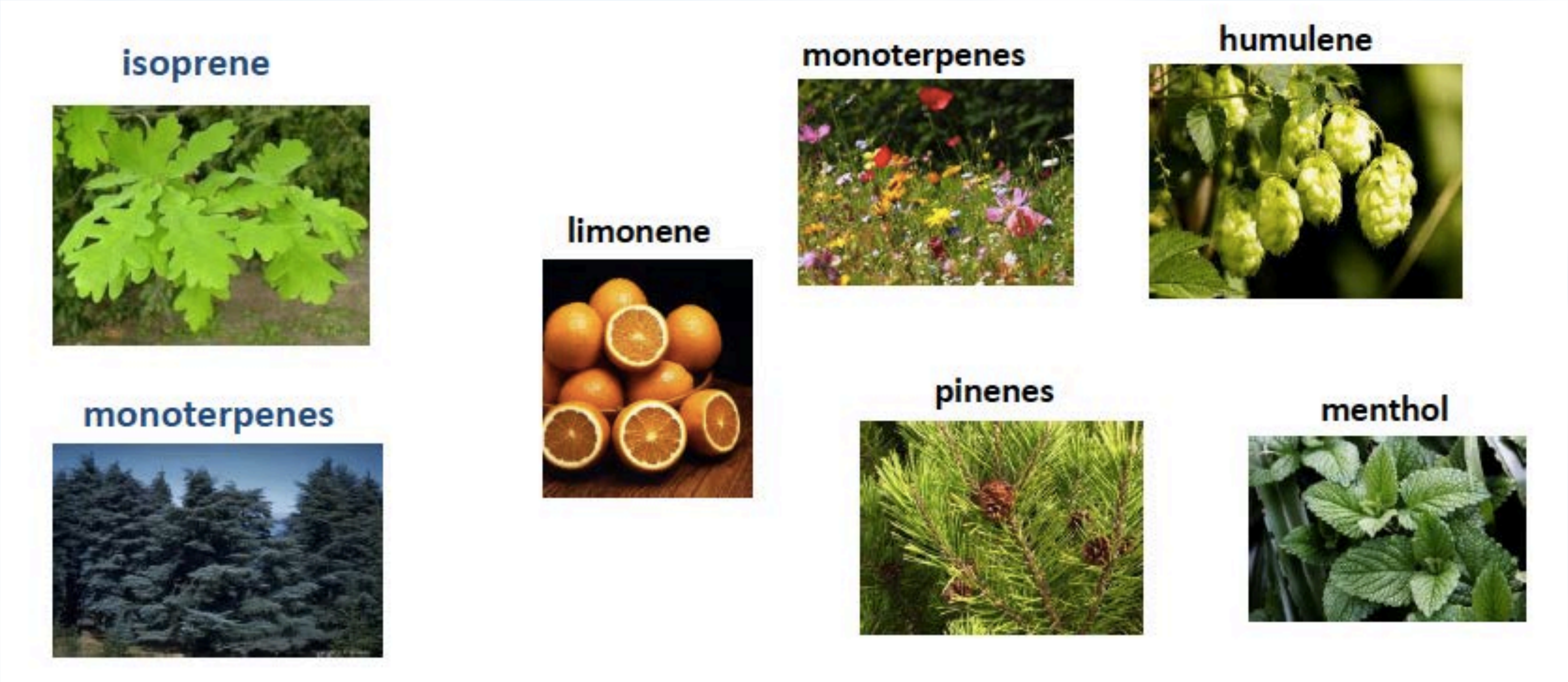


This part uses a lot of the work done by Katerina Sindelarova and Jana Doubalova at the Charles University in Prague

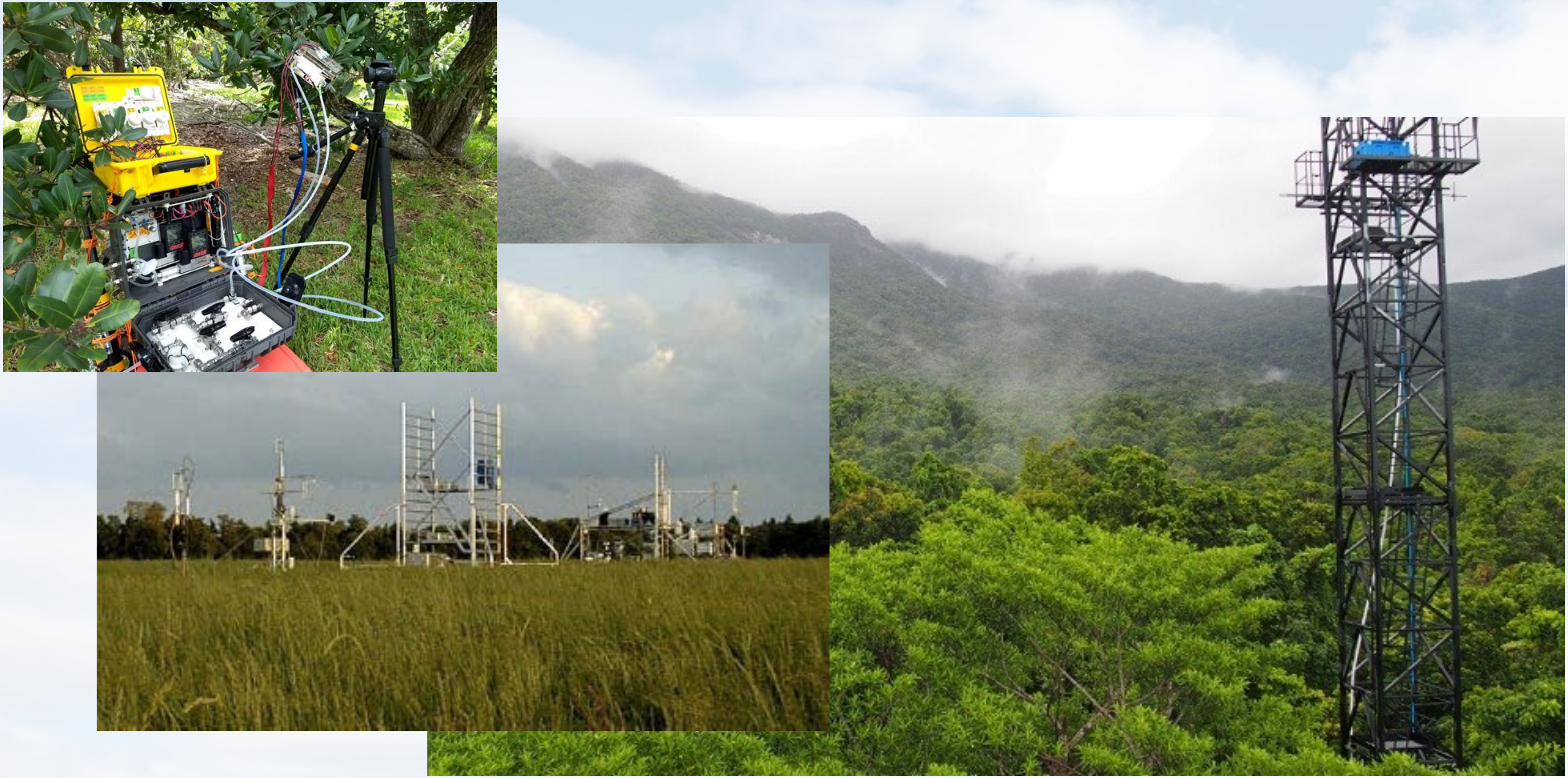
Biogenic emissions = VOCs emissions released by the vegetation

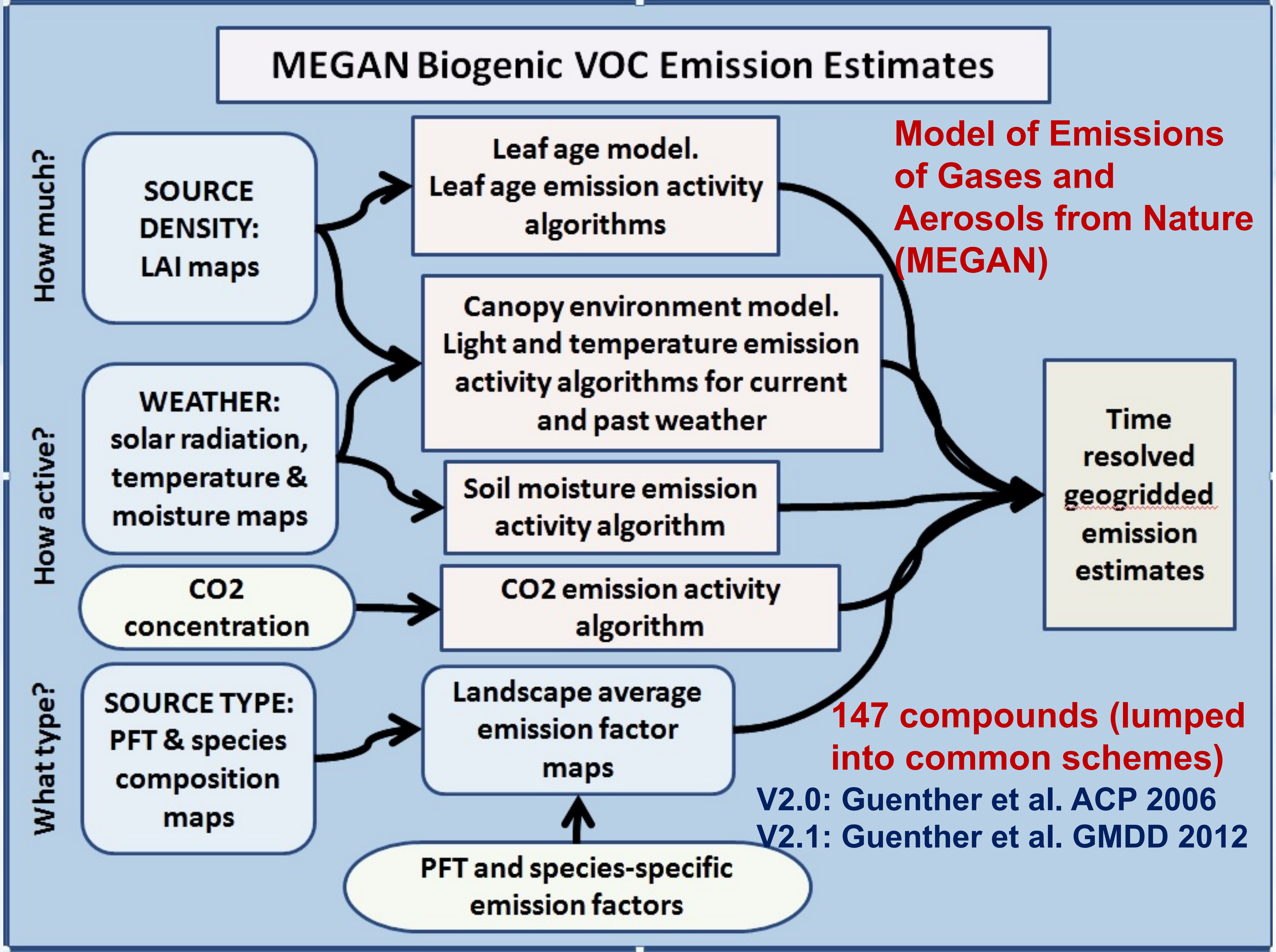


Many VOCs (volatile organic compounds) are emitted by the vegetation : a few of them



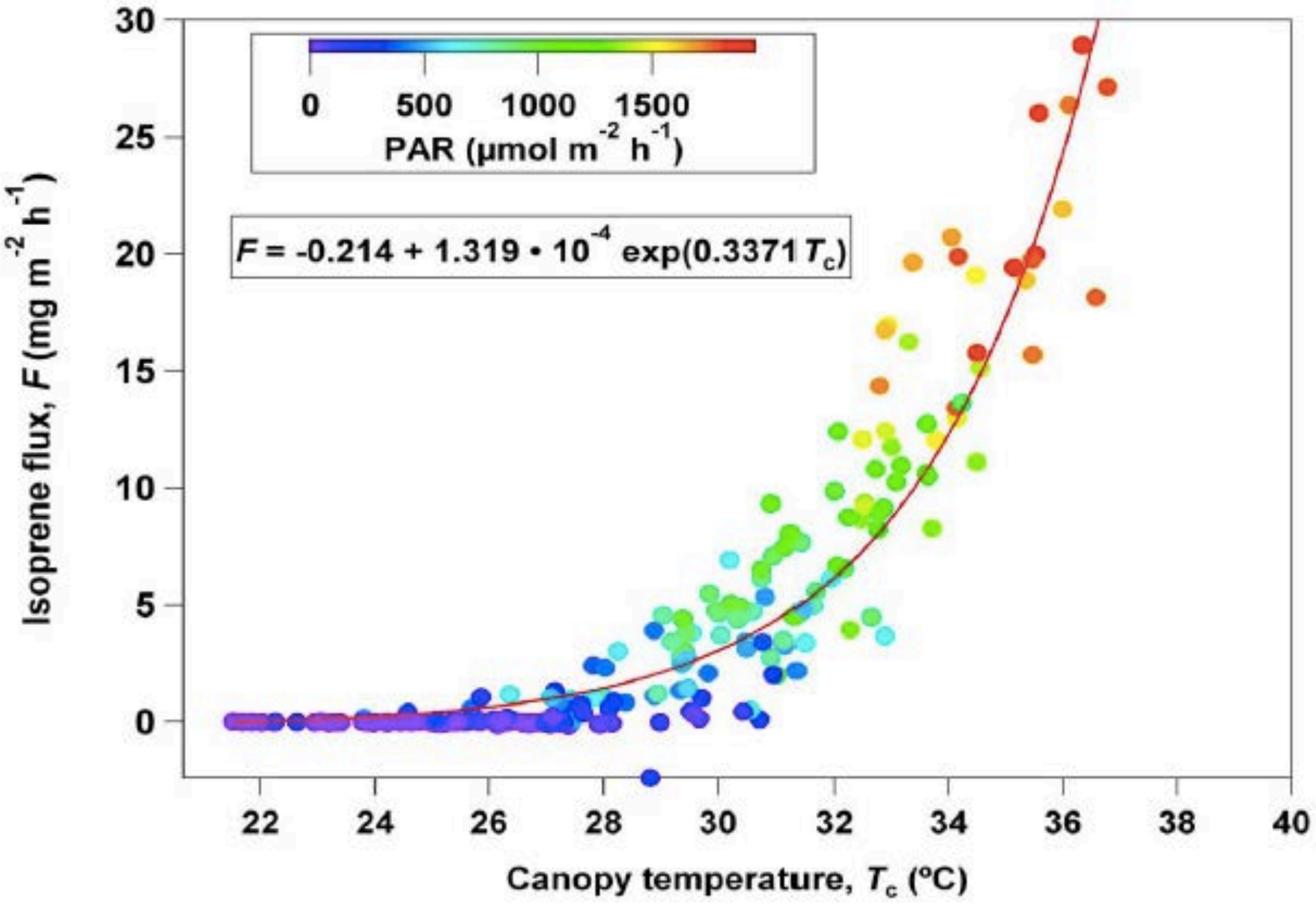
Observations of the emissions from the vegetation

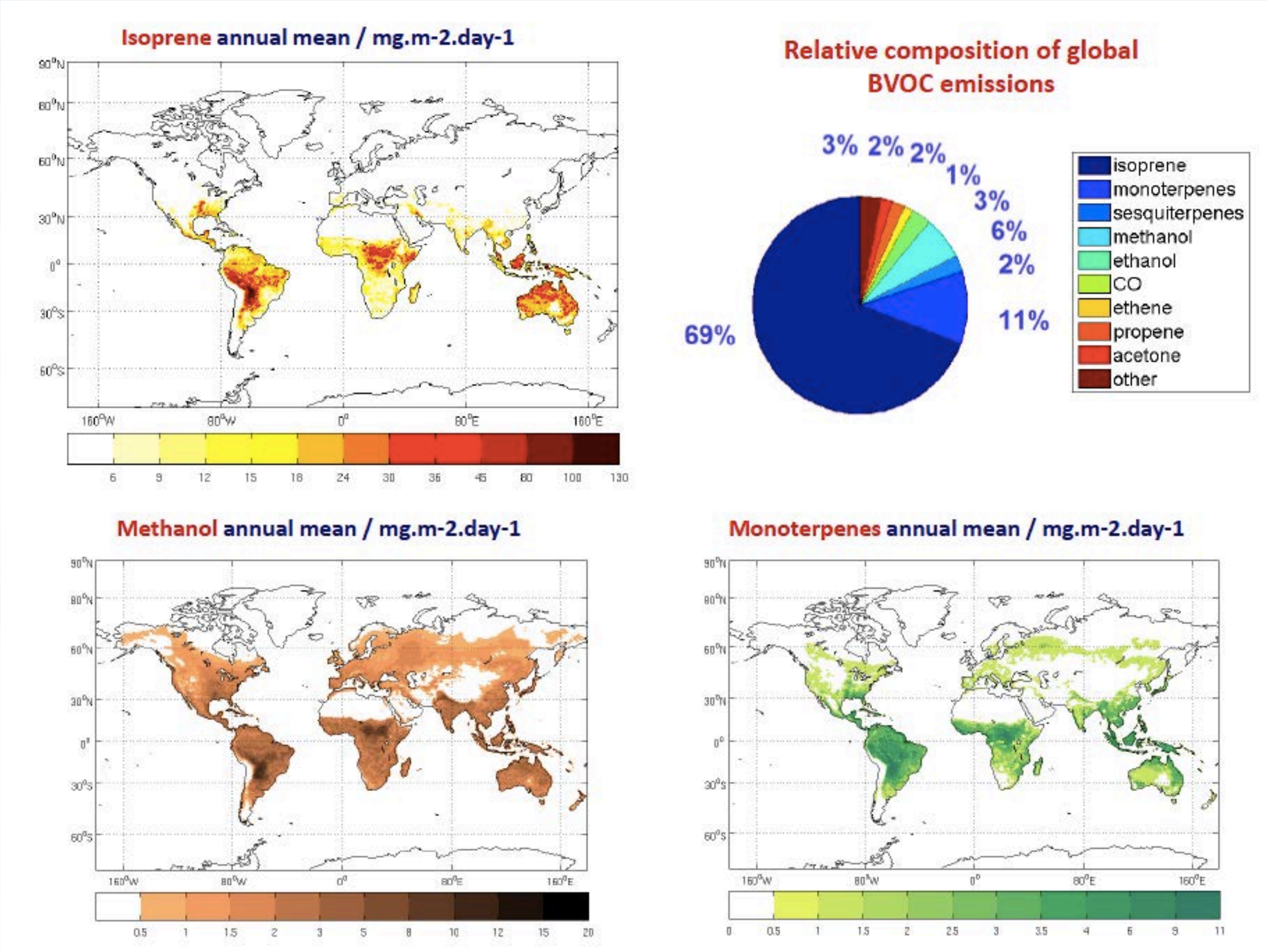




MEGAN Biogenic VOC Emission Estimates
How much?
How active?
What type?
SOURCE DENSITY: LAI maps
Leaf age model. Leaf age emission activity algorithms
Canopy environment model. Light and temperature emission activity algorithms for current and past weather
WEATHER: solar radiation, temperature & moisture maps
Soil moisture emission activity algorithm
CO2 concentration
CO2 emission activity algorithm
SOURCE TYPE: PFT & species composition maps
Landscape average emission factor maps
PFT and species-specific emission factors
Time resolved geogridded emission estimates
Model of Emissions of Gases and Aerosols from Nature (MEGAN)
147 compounds (lumped into common schemes)
V2.0: Guenther et al. ACP 2006
V2.1: Guenther et al. GMDD 2012

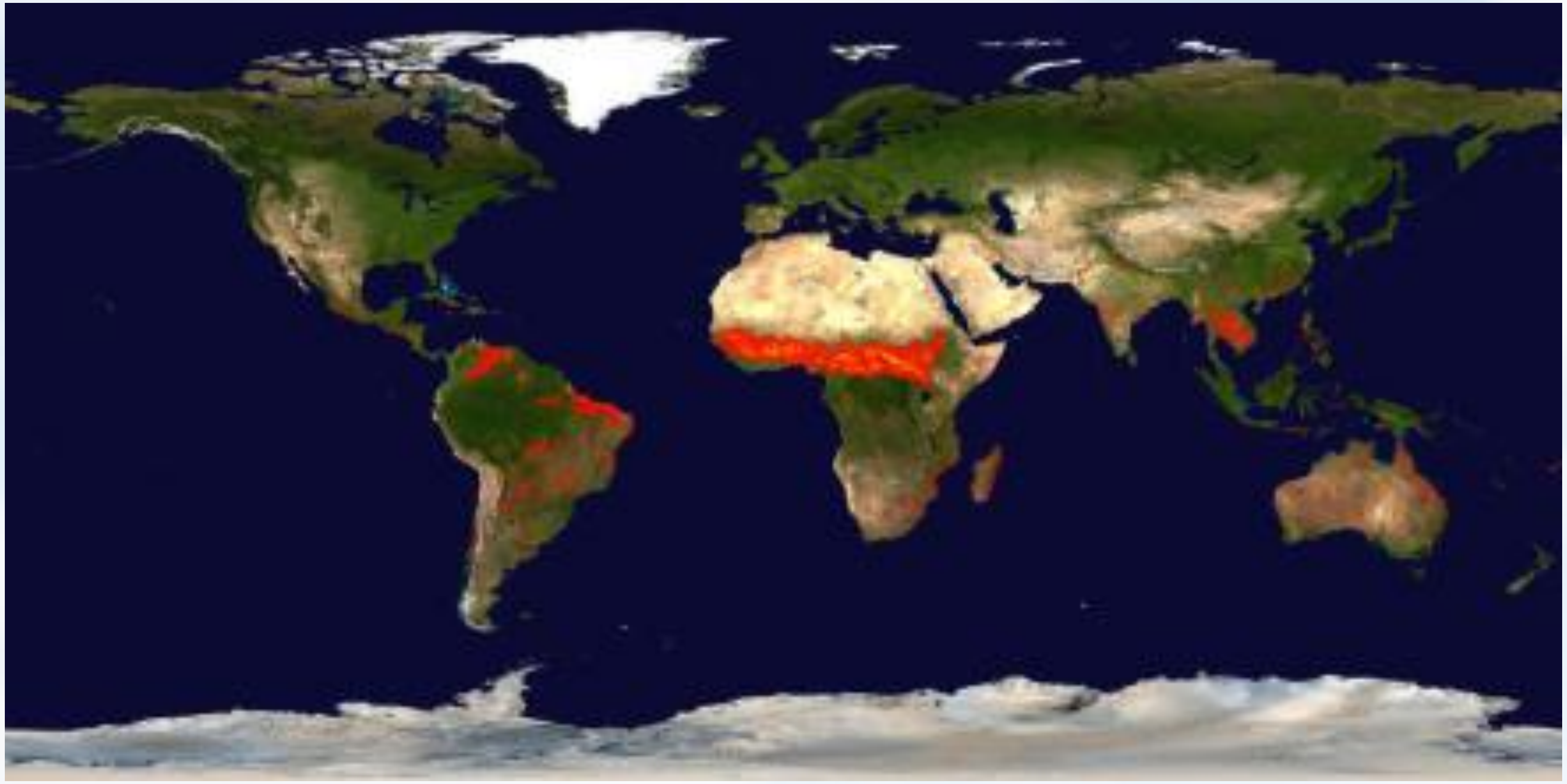
Effects of temperature and radiation on isoprene emission





From Katerina Sindelarova and Jana Doubalova, Czech Rep.

Fire Emissions



What is Biomass burning:

Burning of living and dead vegetation

It includes:

- **human-initiated burning of vegetation for land clearing and land-use change**
- **Natural, lightning-induced fires.**

about 90% of fires are related to human activities with only a small percentage of natural fires contributing to the total amount of vegetation burned.

Most recent fire inventories are using satellite data

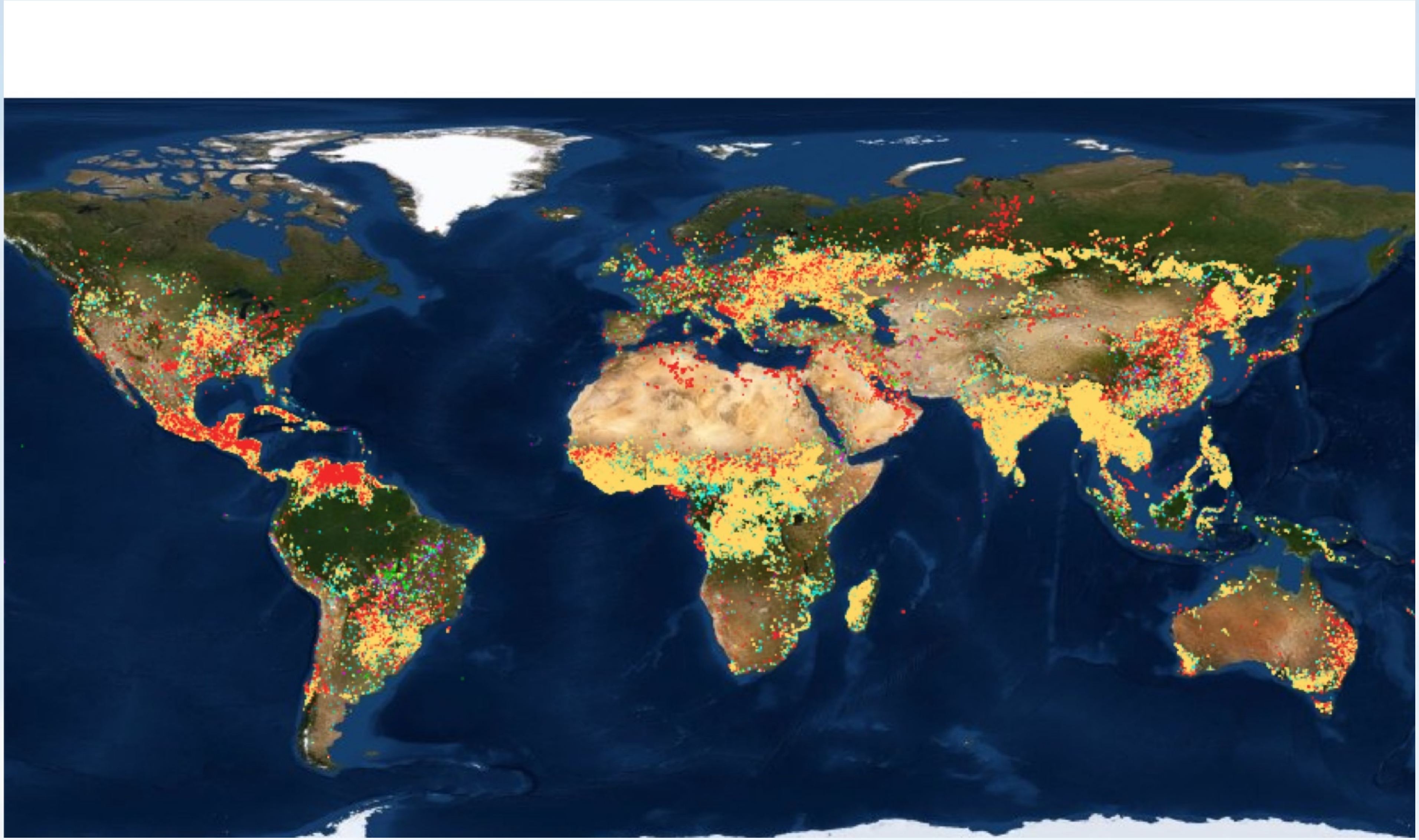
- **Active fires** = fires actively burning at the overpass time of the satellite; detection mostly based on temperature (also called hot spots)

- **Burned areas** = areas affected by fire within a certain time interval; detection based on the effects of fire on vegetation (removal of photosintetic activity, charcoal on the ground, exposed soil).

- **Fire radiative energy** = radiant heat output from a fire. Several instruments are on board a geostationary satellites

Fires from a NASA composite (FIRMS)

on April 15



https://firms.modaps.eosdis.nasa.gov

Measurements of emission factors

Species	Savanna and grassland			Tropical forest			Temperate forest			Boreal forest			Peat Fires			Agricultural residues (open)		
	average	std.dev.	N	average	std.dev.	N	average	std.dev.	N	average	std.dev.	N	average	std.dev.	N	average	std.dev.	N
MCE	0.94	0.02	48	0.91	0.03	15	0.90	0.05	45	0.89	0.04	21	0.79	0.02	5	0.92	0.06	30
CO_2	1660	90	31	1620	70	9	1570	130	39	1530	140	14	1550	130	5	1420	240	25
CO	69	21	49	105	40	15	113	50	46	121	47	22	250	23	5	74	50	34
CH_4	2.5	1.0	47	6.2	2.0	13	5.2	2.8	36	5.5	2.5	20	9.3	1.5	5	5.5	5.7	17
Total non-methane hydrocarbons	3.5	1.2	13	5.6	1.5	4	13.4	11.8	13	6.0	2.9	8	*19*	-	*0*	5.8	5.1	11
C_2H_2	0.32	0.29	28	0.35	0.39	6	0.31	0.09	20	0.28	0.13	12	0.11	0.05	3	0.29	0.24	10
C_2H_4	0.85	0.38	25	1.11	0.24	5	1.12	0.30	20	1.54	0.66	7	1.47	0.72	3	0.96	0.52	12
C_2H_6	0.41	0.32	28	0.88	0.23	7	0.69	0.57	20	0.97	0.37	14	1.85	1.5-2.2	2	0.65	0.46	10
C_3H_4	0.071	0.111	8	0.013	-	1	0.05	0.02	7	0.062	0.031	3	0.006	-	1	0.17	0.01-0.34	2
C_3H_6	0.46	0.45	26	0.86	0.41	5	0.63	0.40	19	0.67	0.45	7	1.14	1.07-1.21	2	0.41	0.26	15
C_3H_8	0.13	0.18	20	0.53	0.15-0.91	2	0.27	0.19	14	0.29	0.10	8	0.99	-	1	0.17	0.07	9
1-Butene	0.082	0.049	13	0.073	0.020-0.125	2	0.12	0.061	9	0.16	0.143	4	0.46	0.18-0.74	2	0.083	0.043	8
i-Butene	0.041	0.019	6	0.109	-	1	0.086	0.074	9	0.052	0.032	3	0.31	-	1	0.079	0.040	3
trans-2-Butene	0.020	0.012	11	0.033	0.016-0.050	2	0.037	0.031	9	0.030	0.018	3	0.078	-	1	0.036	0.014	6
cis-2-Butene	0.017	0.010	11	0.031	0.020-0.042	2	0.038	0.039	9	0.023	0.016	3	0.062	-	1	0.027	0.010	6
Butadiene	0.095	0.057	13	*0.15*	-	*0*	0.125	0.068	12	0.089	0.030	4	0.22	0.19-0.26	2	0.16	0.24	10
n-Butane	0.021	0.011	14	0.041	-	1	0.081	0.060	11	0.111	0.059	7	0.32	-	1	0.043	0.029	7
i-Butane	0.007	0.005	13	0.015	-	1	0.031	0.026	11	0.052	0.051	6	0.090	-	1	0.016	0.017	7
1-Pentene	0.022	0.009	6	0.058	-	1	0.048	0.024	7	0.046	0.025	3	0.110	-	1	0.015	0.011	5
2-Pentenes	0.014	0.020	4	*0.026*	-	*0*	0.043	0.023	5	0.011	0.006-0.016	2	0.062	-	1	0.023	0.005	4
n-Pentane	0.007	0.008	11	0.014	-	1	0.034	0.026	10	0.050	0.015	6	0.24	-	1	0.042	0.057	7
2-Methyl-butenes	0.025	0.037	7	0.075	-	1	0.056	0.045	6	*0.051*	-	*0*	0.125	-	1	0.026	0.013	5
2-Methyl-butane	0.008	0.009	10	0.008	-	1	0.017	0.011	8	0.032	0.016	6	0.123	-	1	0.019	0.014	5
n-Pentadienes	0.048	-	1	*0.042*	-	*0*	0.035	0.016	4	*0.049*	-	*0*	*0.10*	-	*0*	*0.030*	-	*0*
Isoprene	0.101	0.158	10	0.22	0.016-0.42	2	0.10	0.05	9	0.074	-	1	0.52	0.05-0.98	2	0.17	0.26	7
Cyclopentene	0.019	0.016	4	*0.022*	-	*0*	0.041	0.019	5	*0.03*	-	*0*	0.025	-	1	0.007	0.002	3
Cyclopentadiene	0.026	-	1	*0.036*	-	*0*	0.027	0.025-0.029	2	*0.041*	-	*0*	0.010	-	1	0.001	-	1
4-Methyl-1-pentene	0.049	-	1	0.049	-	1	*0.041*	-	*0*	*0.044*	-	*0*	*0.09*	-	*0*	0.005	0.007	4
2-Methyl-1-pentene	0.018	0.032	4	*0.037*	-	*0*	0.058	0.027	3	*0.043*	-	*0*	0.11	-	1	*0.026*	-	*0*
1-Hexene	0.043	0.018	6	0.065	-	1	0.084	0.022	3	0.109	-	1	*0.14*	-	*0*	0.012	0.005	3
Hexadienes	0.006	-	1	*0.007*	-	*0*	0.006	0.006-0.006	2	*0.008*	-	*0*	*0.017*	-	*0*	*0.005*	-	*0*
n-Hexane	0.018	0.028	10	*0.032*	-	*0*	0.032	0.040	10	0.054	0.035	3	0.14	-	1	0.032	0.059	4
Isohexanes	0.019	0.028	3	*0.048*	-	*0*	0.026	0.038	8	0.013	0.008-0.018	2	0.054	-	1	0.067	0.115	4
Heptanes	0.016	0.019	6	*0.024*	-	*0*	0.029	0.026	8	0.021	0.018-0.024	2	0.112	-	1	0.031	0.033	4
Octenes	0.021	0.027	3	0.012	-	1	0.036	0.023	5	*0.021*	-	*0*	0.065	-	1	0.003	-	1
Terpenes	0.104	0.096	5	*0.15*	-	*0*	1.17	1.95	9	1.53	-	1	0.08	0.005-0.16	2	0.029	0.031	3
Benzene	0.33	0.22	18	0.38	0.05	4	0.39	0.20	16	0.57	0.21	7	0.87	0.78-0.95	2	0.28	0.20	15
Toluene	0.20	0.14	16	0.23	0.04	4	0.25	0.17	15	0.35	0.11	6	0.45	0.37-0.52	2	0.16	0.10	15
Xylenes	0.086	0.077	8	0.086	0.049	3	0.16	0.090	9	0.11	0.016	3	0.23	-	1	0.09	0.11	9
Ethylbenzene	0.022	0.010	8	0.043	0.034	3	0.041	0.018	10	0.038	0.011	3	0.042	-	1	0.045	0.049	7
Styrene	0.056	0.029	6	*0.028*	-	*0*	0.066	0.028	8	*0.13*	-	*0*	0.055	0.027-0.082	2	0.043	0.029	6
PAHs	0.012	0.016	4	*0.14*	-	*0*	0.017	0.019	6	0.72	-	1	*0.39*	-	*0*	0.033	0.017	4
Methanol	1.35	0.47	14	2.8	0.5	4	2.2	0.9	19	2.33	1.45	13	2.5	0.4	3	2.6	1.4	8
Ethanol	0.036	0.017-0.055	2	*0.067*	-	*0*	0.076	0.089	7	0.058	0.063	3	*0.16*	-	*0*	*0.05*	-	*0*
1-Propanol	0.025	-	1	*0.038*	-	*0*	*0.041*	-	*0*	*0.044*	-	*0*	*0.090*	-	*0*	*0.027*	-	*0*
2-Propanol	*0.08*	-	*0*	*0.12*	-	*0*	*0.13*	-	*0*	*0.14*	-	*0*	*0.29*	-	*0*	*0.09*	-	*0*
Butanols	0.11	0.008-0.21	2	0.009	-	1	0.064	0.029-0.098	2	*0.072*	-	*0*	*0.15*	-	*0*	0.011	-	1
Cyclopentanol	0.033	-	1	0.032	-	1	*0.038*	-	*0*	*0.040*	-	*0*	*0.083*	-	*0*	0.016	-	1
Phenol	0.43	0.19	7	0.23	0.006-0.45	2	0.25	0.09	3	*0.63*	-	*0*	0.47	0.42-0.51	2	0.50	0.49	4
Formaldehyde	1.23	0.65	16	2.40	0.63	3	2.08	0.70	15	1.75	0.40	4	1.07	0.44	3	1.8	0.7	7
Acetaldehyde	0.84	0.65	9	2.26	1.55-2.97	2	1.07	0.62	13	0.81	0.23	4	1.16	0.70-1.63	2	1.7	1.2	4
Hydroxyacetaldehyde (glycolaldeh.)	0.21	0.18	5	*0.42*	-	*0*	0.39	-	1	*0.48*	-	*0*	0.11	-	1	3.2	2.3-4.1	2
Glyoxal	*0.40*	-	*0*	*0.60*	-	*0*	*0.65*	-	*0*	*0.69*	-	*0*	*1.4*	-	*0*	0.23	-	1
Methylglyoxal	0.40	0.15-0.64	2	*0.52*	-	*0*	0.27	-	1	*0.61*	-	*0*	0.23	-	1	0.55	-	1
Acrolein (Propenal)	0.48	0.25	6	0.65	-	1	0.34	0.13	7	0.33	-	1	0.27	-	1	0.65	0.45	4
Propanal	0.053	0.009-0.097	2	0.10	-	1	0.087	0.040	4	0.24	-	1	*0.33*	-	*0*	0.18	-	1
Butanals	0.11	0.054-0.220	2	0.13	0.073-0.18	2	0.11	0.07	5	*0.16*	-	*0*	0.02	-	1	0.17	0.02-0.32	2
Methacrolein	*0.11*	-	*0*	0.15	-	1	0.14	0.18	5	0.11	0.12	3	*0.38*	-	*0*	0.28	-	1
Crotonaldehyde	*0.25*	-	*0*	0.24	-	1	*0.40*	-	*0*	*0.43*	-	*0*	*0.88*	-	*0*	0.42	-	1

Important uncertainty for the determination of the emissions from fires = emission factors

Compilation of average values published regularly but large spread of values

Andreae et al., ACP, 2019

	savanna and grassland	Tropic. Forest	Temp. Forest	Boreal Forest	Peat fires	Agriculture
CO	69 ± 21	105 ± 40	113 ± 50	121 ± 47	250 ± 23	74 ± 50
NOx as NO	2.5 ± 1.3	2.8 ± 1.3	3.0 ± 1.8	1.18 ± 0.86	1.2 ± 0.9	2.6 ± 1.1

	savanna and grassland			Tropic. Forest			Temp. Forest			Boreal Forest			Peat fires			Agriculture		
MCE	0.94	0.02	48	0.91	0.03	15	0.90	0.05	45	0.89	0.04	21	0.79	0.02	5	0.92	0.06	30
CO_2	1660	90	31	1620	70	9	1570	130	39	1530	140	14	1550	130	5	1420	240	25
CO	69	21	49	105	40	15	113	50	46	121	47	22	250	23	5	74	50	34
C_2H_2	0.85	0.38	25	1.11	0.24	5	1.12	0.30	20	1.34	0.66	7	1.47	0.72	3	0.96	0.32	12
C_2H_4	0.41	0.32	28	0.88	0.23	7	0.69	0.57	20	0.97	0.37	14	1.85	1.5-2.2	2	0.65	0.46	10
C_3H_4	0.071	0.111	8	0.013	-	1	0.05	0.02	7	0.062	0.031	3	0.006	-	1	0.17	0.01-0.34	2
C_3H_6	0.46	0.45	26	0.86	0.41	5	0.63	0.40	19	0.67	0.45	7	1.14	1.07-1.21	2	0.41	0.26	15
C_3H_8	0.13	0.18	20	0.53	0.15-0.91	2	0.27	0.19	14	0.29	0.10	8	0.99	-	1	0.17	0.07	9
1-Butene	0.082	0.049	13	0.073	0.020-0.125	2	0.12	0.061	9	0.16	0.143	4	0.46	0.18-0.74	2	0.083	0.043	8
i-Butene	0.041	0.019	6	0.109	-	1	0.086	0.074	9	0.052	0.032	3	0.31	-	1	0.079	0.040	3
trans-2-Butene	0.020	0.012	11	0.033	0.016-0.050	2	0.037	0.031	9	0.030	0.018	3	0.078	-	1	0.036	0.014	6
cis-2-Butene	0.017	0.010	11	0.031	0.020-0.042	2	0.038	0.039	9	0.023	0.016	3	0.062	-	1	0.027	0.010	6
Butadiene	0.095	0.057	13	0.15	-	0	0.125	0.068	12	0.089	0.030	4	0.22	0.19-0.26	2	0.16	0.24	10
n-Butane	0.021	0.011	14	0.041	-	1	0.081	0.060	11	0.111	0.059	7	0.32	-	1	0.043	0.029	7
i-Butane	0.007	0.005	13	0.015	-	1	0.031	0.026	11	0.052	0.051	6	0.090	-	1	0.016	0.017	7
1-Pentene	0.022	0.009	6	0.058	-	1	0.048	0.024	7	0.046	0.025	3	0.110	-	1	0.015	0.011	5
2-Pentenes	0.014	0.020	4	0.026	-	0	0.043	0.023	5	0.011	0.006-0.016	2	0.062	-	1	0.023	0.005	4
n-Pentane	0.007	0.008	11	0.014	-	1	0.034	0.026	10	0.050	0.015	6	0.24	-	1	0.042	0.057	7
2-Methyl-butenes	0.025	0.037	7	0.075	-	1	0.056	0.045	6	0.051	-	0	0.125	-	1	0.026	0.013	5
2-Methyl-butane	0.008	0.009	10	0.008	-	1	0.017	0.011	8	0.032	0.016	6	0.123	-	1	0.019	0.014	5
n-Pentadienes	0.048	-	1	0.042	-	0	0.035	0.016	4	0.049	-	0	0.10	-	0	0.030	-	0
Isoprene	0.101	0.158	10	0.22	0.016-0.42	2	0.10	0.05	9	0.074	-	1	0.52	0.05-0.98	2	0.17	0.26	7
Cyclopentene	0.019	0.016	4	0.022	-	0	0.041	0.019	5	0.03	-	0	0.025	-	1	0.007	0.002	3
Cyclopentadiene	0.026	-	1	0.036	-	0	0.027	0.025-0.029	2	0.041	-	0	0.010	-	1	0.001	-	1
4-Methyl-1-pentene	0.049	-	1	0.049	-	1	0.041	-	0	0.044	-	0	0.09	-	0	0.005	0.007	4
2-Methyl-1-pentene	0.018	0.032	4	0.037	-	0	0.058	0.027	3	0.043	-	0	0.11	-	1	0.026	-	0
1-Hexene	0.043	0.018	6	0.065	-	1	0.084	0.022	3	0.109	-	1	0.14	-	0	0.012	0.005	3
Hexadienes	0.006	-	1	0.007	-	0	0.006	0.006-0.006	2	0.008	-	0	0.017	-	0	0.005	-	0
n-Hexane	0.018	0.028	10	0.032	-	0	0.032	0.040	10	0.054	0.035	3	0.14	-	1	0.032	0.059	4
Isohexanes	0.019	0.028	3	0.048	-	0	0.026	0.038	8	0.013	0.008-0.018	2	0.054	-	1	0.067	0.115	4
Heptanes	0.016	0.019	6	0.024	-	0	0.029	0.026	8	0.021	0.018-0.024	2	0.112	-	1	0.031	0.033	4
Octenes	0.021	0.027	3	0.012	-	1	0.036	0.023	5	0.021	-	0	0.065	-	1	0.003	-	1
Terpenes	0.104	0.096	5	0.15	-	0	1.17	1.95	9	1.53	-	1	0.08	0.005-0.16	2	0.029	0.031	3
Benzene	0.33	0.22	18	0.38	0.05	4	0.39	0.20	16	0.57	0.21	7	0.87	0.78-0.95	2	0.28	0.20	15
Toluene	0.20	0.14	16	0.23	0.04	4	0.25	0.17	15	0.35	0.11	6	0.45	0.37-0.52	2	0.16	0.10	15
Xylenes	0.086	0.077	8	0.086	0.049	3	0.16	0.090	9	0.11	0.016	3	0.23	-	1	0.09	0.11	9
Ethylbenzene	0.022	0.010	8	0.043	0.034	3	0.041	0.018	10	0.038	0.011	3	0.042	-	1	0.045	0.049	7
Styrene	0.056	0.029	6	0.028	-	0	0.066	0.028	8	0.13	-	0	0.055	0.027-0.082	2	0.043	0.029	6
PAHs	0.012	0.016	4	0.14	-	0	0.017	0.019	6	0.72	-	1	0.39	-	0	0.033	0.017	4
Methanol	1.35	0.47	14	2.8	0.5	4	2.2	0.9	19	2.33	1.45	13	2.5	0.4	3	2.6	1.4	8
Ethanol	0.036	0.017-0.055	2	0.067	-	0	0.076	0.089	7	0.058	0.063	3	0.16	-	0	0.05	-	0
1-Propanol	0.025	-	1	0.038	-	0	0.041	-	0	0.044	-	0	0.080	-	0	0.027	-	0
2-Propanol	0.08	-	0	0.12	-	0	0.13	-	0	0.14	-	0	0.29	-	0	0.09	-	0
Butanols	0.11	0.008-0.21	2	0.009	-	1	0.064	0.029-0.098	2	0.072	-	0	0.15	-	0	0.011	-	1
Cyclopentanol	0.033	-	1	0.032	-	1	0.038	-	0	0.040	-	0	0.083	-	0	0.016	-	1
Phenol	0.43	0.19	7	0.23	0.006-0.45	2	0.25	0.09	3	0.63	-	0	0.47	0.42-0.51	2	0.50	0.49	4
Formaldehyde	1.23	0.65	16	2.40	0.63	3	2.08	0.70	15	1.75	0.40	4	1.07	0.44	3	1.8	0.7	7
Acetaldehyde	0.84	0.65	9	2.26	1.55-2.97	2	1.07	0.62	13	0.81	0.23	4	1.16	0.70-1.63	2	1.7	1.2	4
Hydroxyacetaldehyde (glycolaldeh.)	0.21	0.18	5	0.42	-	0	0.39	-	1	0.48	-	0	0.11	-	1	3.2	2.3-4.1	2
Glyoxal	0.40	-	0	0.60	-	0	0.65	-	0	0.69	-	0	1.4	-	0	0.23	-	1
Methylglyoxal	0.40	0.15-0.64	2	0.52	-	0	0.27	-	1	0.61	-	0	0.23	-	1	0.55	-	1
Acrolein (Propenal)	0.48	0.25	6	0.65	-	1	0.34	0.13	7	0.33	-	1	0.27	-	1	0.65	0.45	4

Emission factors are given in gram species per kilogram dry matter burned

Andreae et al., 2019

One issue: these averages EF do not take into account the different stages of the fires

A few biomass burning emissions inventories commonly used:

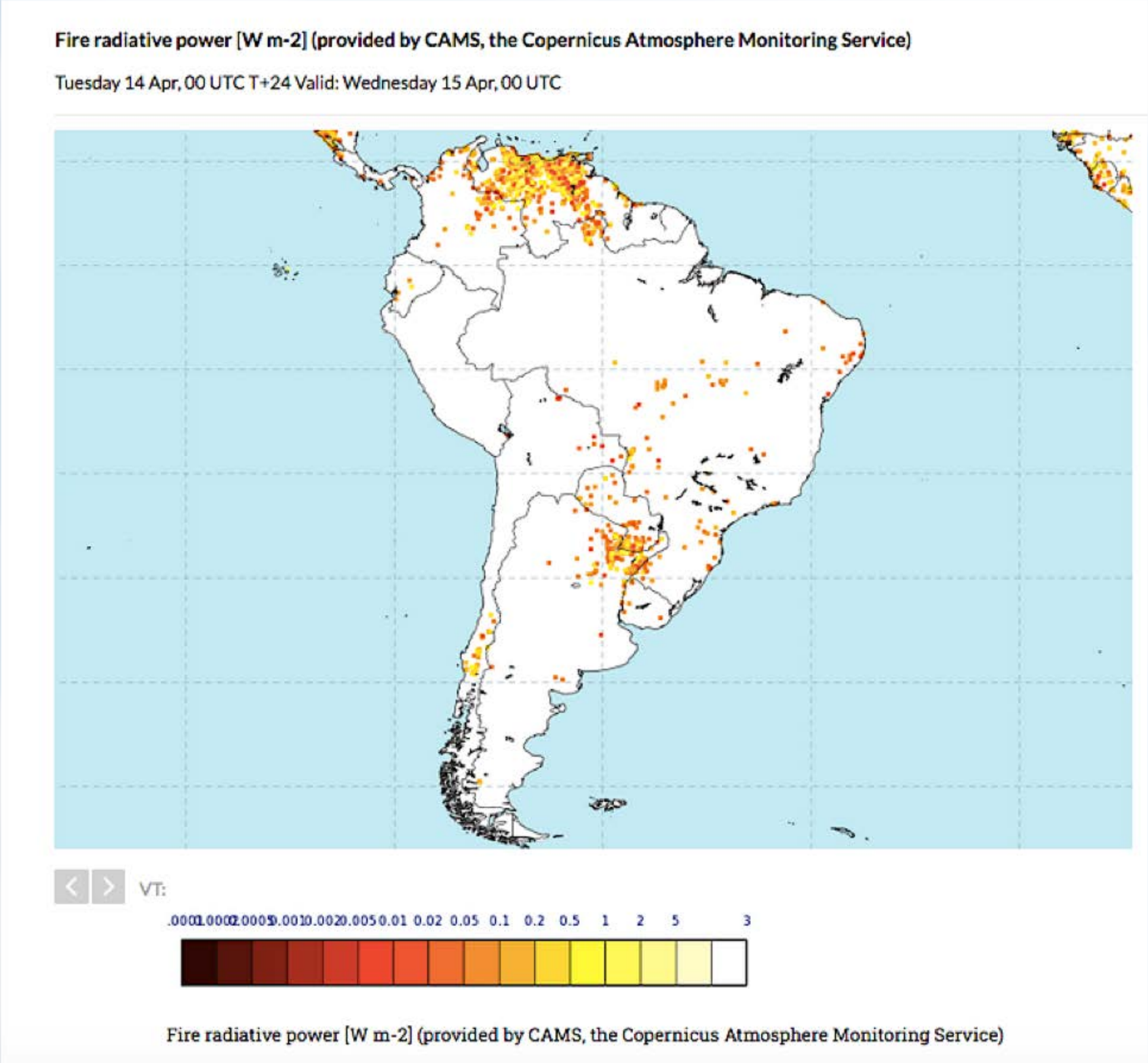
- GFED inventories (Global Fire Emissions Database):
https://www.globalfiredata.org/
1997-2019; 0.25x0.25 degree; monthly; carbon emissions

- FINN inventory from NCAR:
2012-now; 1x1 km2; daily; ready for use in NCAR global/regional models;
https://www2.acom.ucar.edu/modeling/finn-fire-inventory-ncar

- GFAS, developed at ECMWF (European Meteorological Center):
https://atmosphere.copernicus.eu/global-fire-emissions
2003-now; operational; 0.1x0.1 degree, daily

And many others based on different satellite products (active fires, burned areas, fire radiative energy, etc.)

Radiative energy from fires on April 15
All data available on the CAMS Global Fire Assimilation System: https://apps.ecmwf.int/datasets/data/cams-gfas/

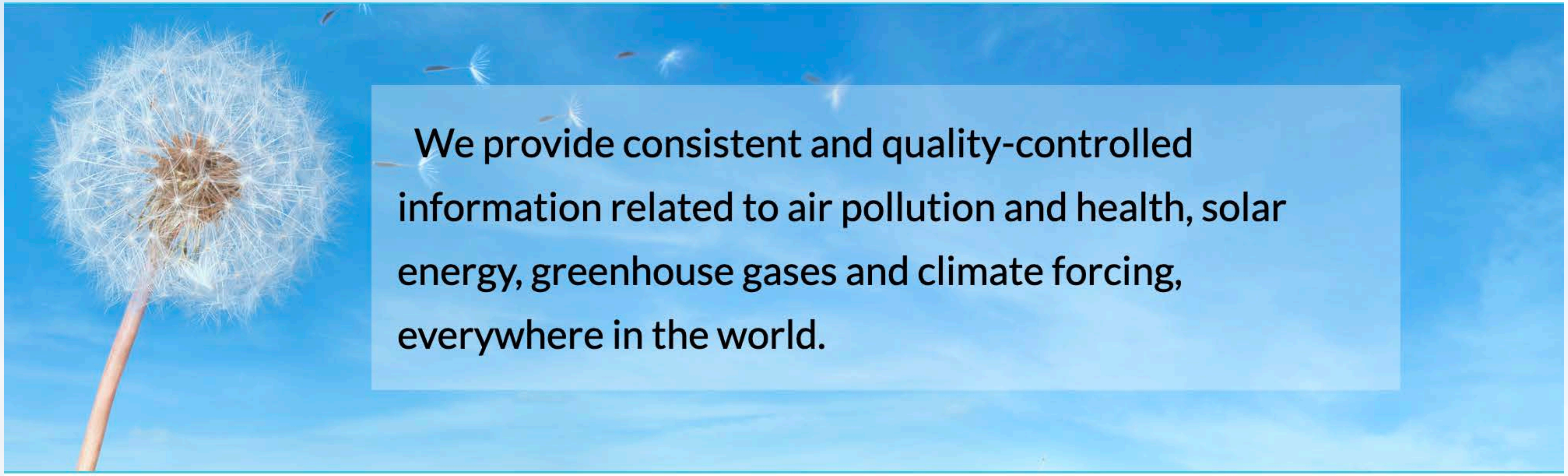


A new set of emissions as part of the European Copernicus Atmospheric Monitoring Service (CAMS)

CAMS ➔ operational air quality forecasting system at the regional and global scales

https://atmosphere.copernicus.eu/

All datasets/model results publicly available



CAMS emissions

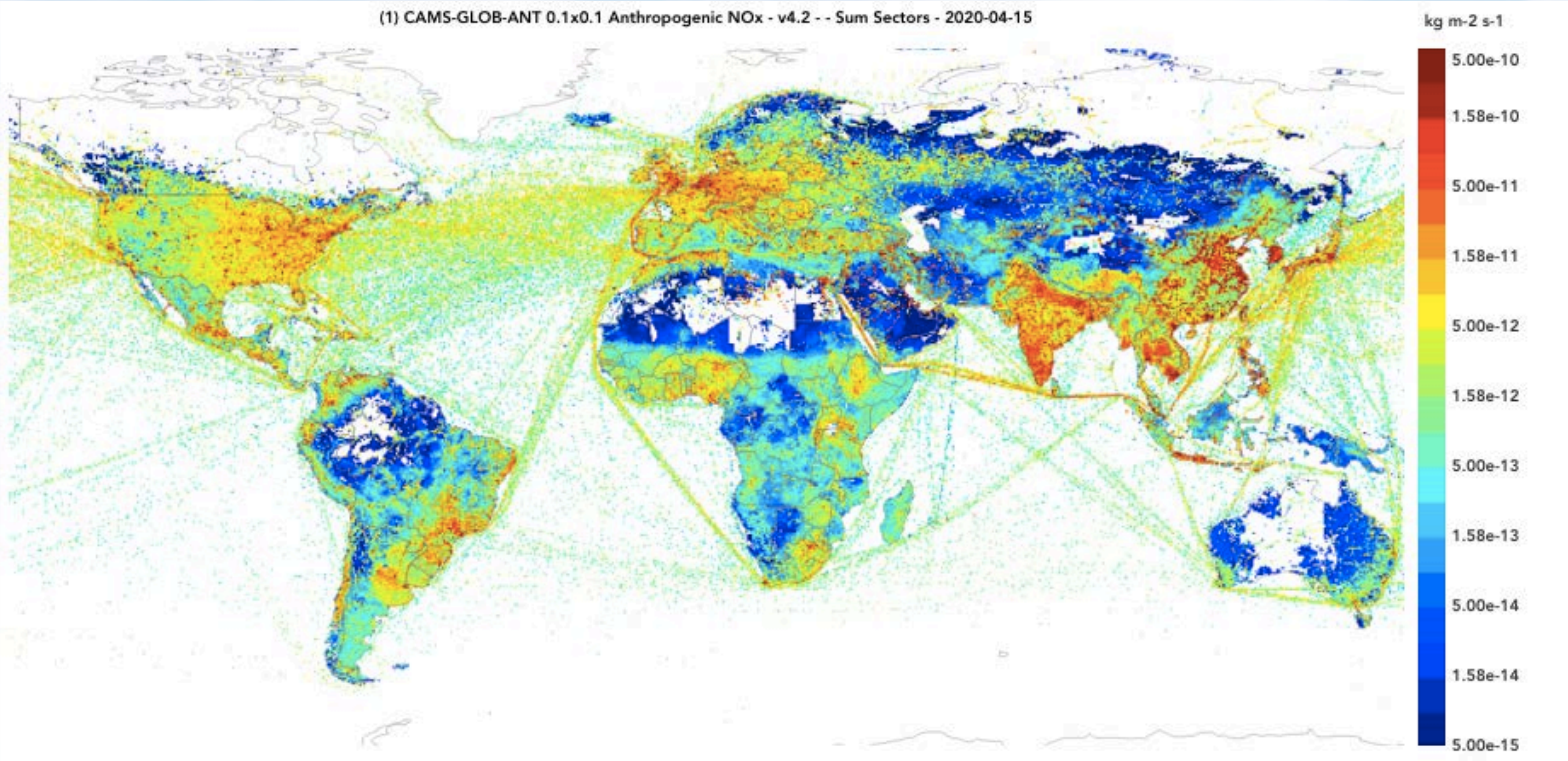
- CAMS-GLOB-ANT: global emissions, 2000-2020, 0.1x0.1 degree
- CAMS-REG: European emissions, 2000-2017, 0.05x0.1 degree
- CAMS-GLOB-SHIP: ship emissions, 2000-2018, 0.1x0.1 degree
- CAMS-GLOB-BIO: 25 biogenic VOCs + CO, 2000-2018, 0.5 degree
- CAMS-GLOB-SOIL: NOx from soils, 2000-2015, 0.5x0.5 degree
- CAMS-GLOB-TERM: CH4 from termites, 2000, 0.5 degree
- CAMS-GLOB-OCE: oceanic emissions DMS, OCS, halogens, 2000-2018, 0.5x0.5 deg.
- CAMS-GLOB-VOLC: SO2 from 20 volcanoes, 2000-2019, 1x1 degree

CAMS Global anthropogenic emissions: CAMS-GLOB-ANT_v4.2

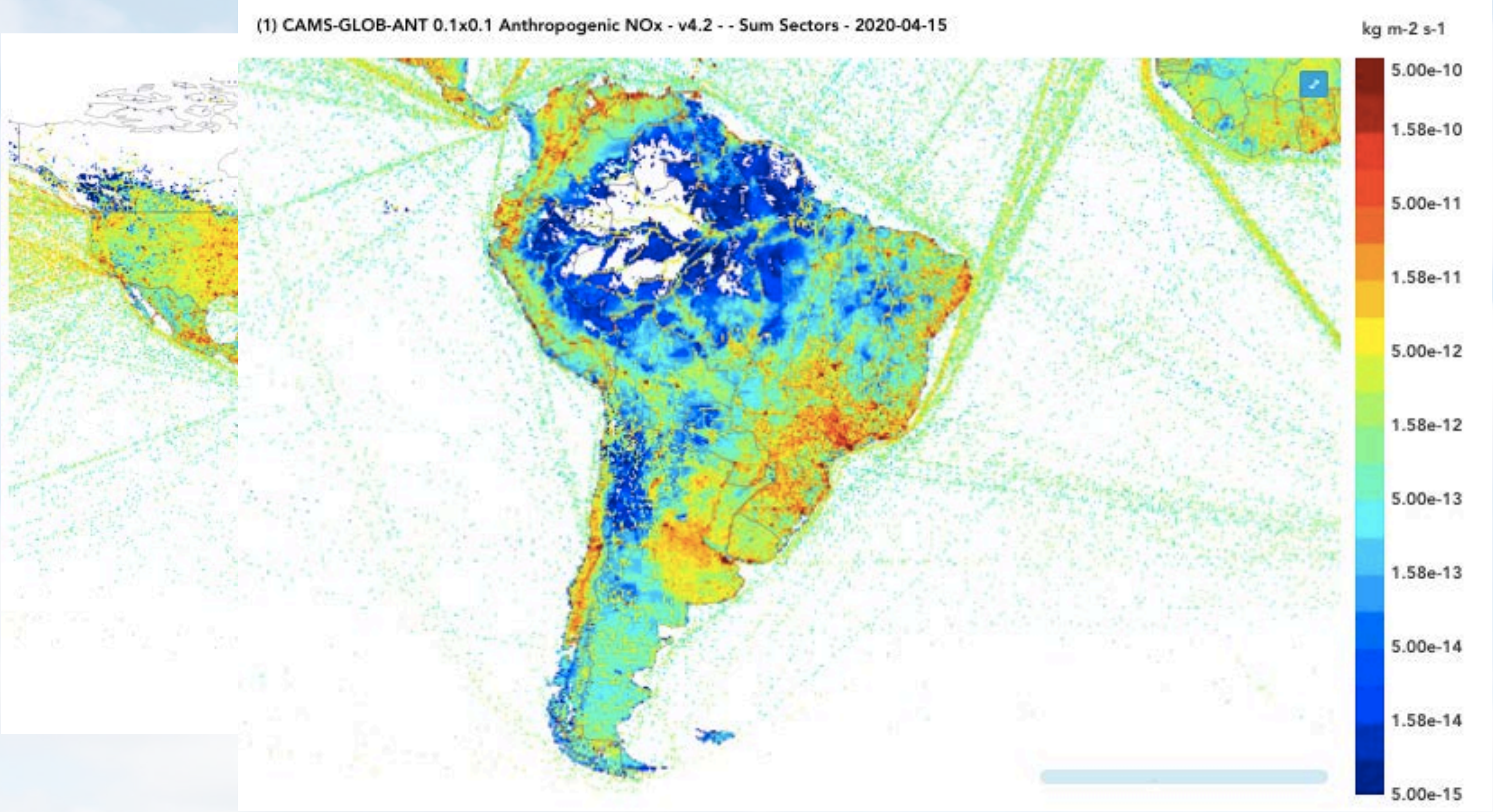
- Based on the EDGAR inventory developed by the EU Joint Research Center (JRC, Italy) and the CEDS dataset developed for the IPCC AR6 report (CEDS)
- 2000-2019, monthly averages
- 0.1x0.1 degree spatial resolution
- Emissions for CH_4, CO, NO_x, SO_2, NMVOCs, SO_2, NH_3, BC, OC and 25 individual VOCs
- Sectors harmonized with the regional EU emissions

Developed at Laboratoire d'Aerologie, Toulouse, France (Nellie Elguindi, Sabine Darras, Claire Granier)

Example of CAMS emissions: version v4.2 – NOx in April 2020

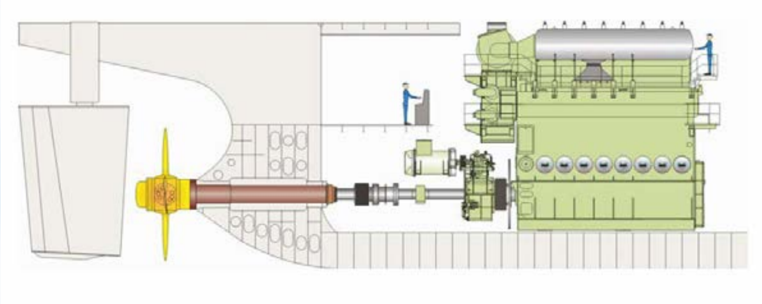


Example of CAMS emissions: version v4.2 – NOx in April 2020

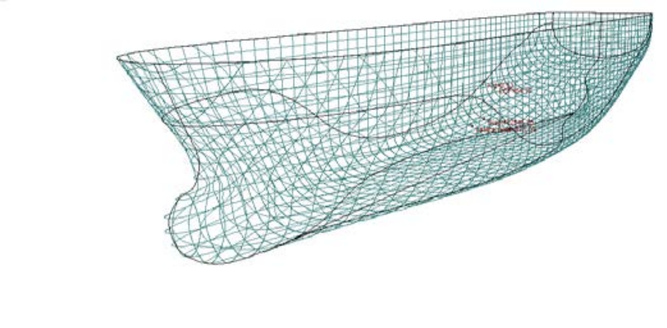


CAMS Global/European ship emissions: CAMS-GLOB-SHIP_v2.1

- **Ship emissions more and more important: in many countries, road emissions decreasing, and almost no regulations in ship emissions (except in SECA countries in Nothern Europe)**



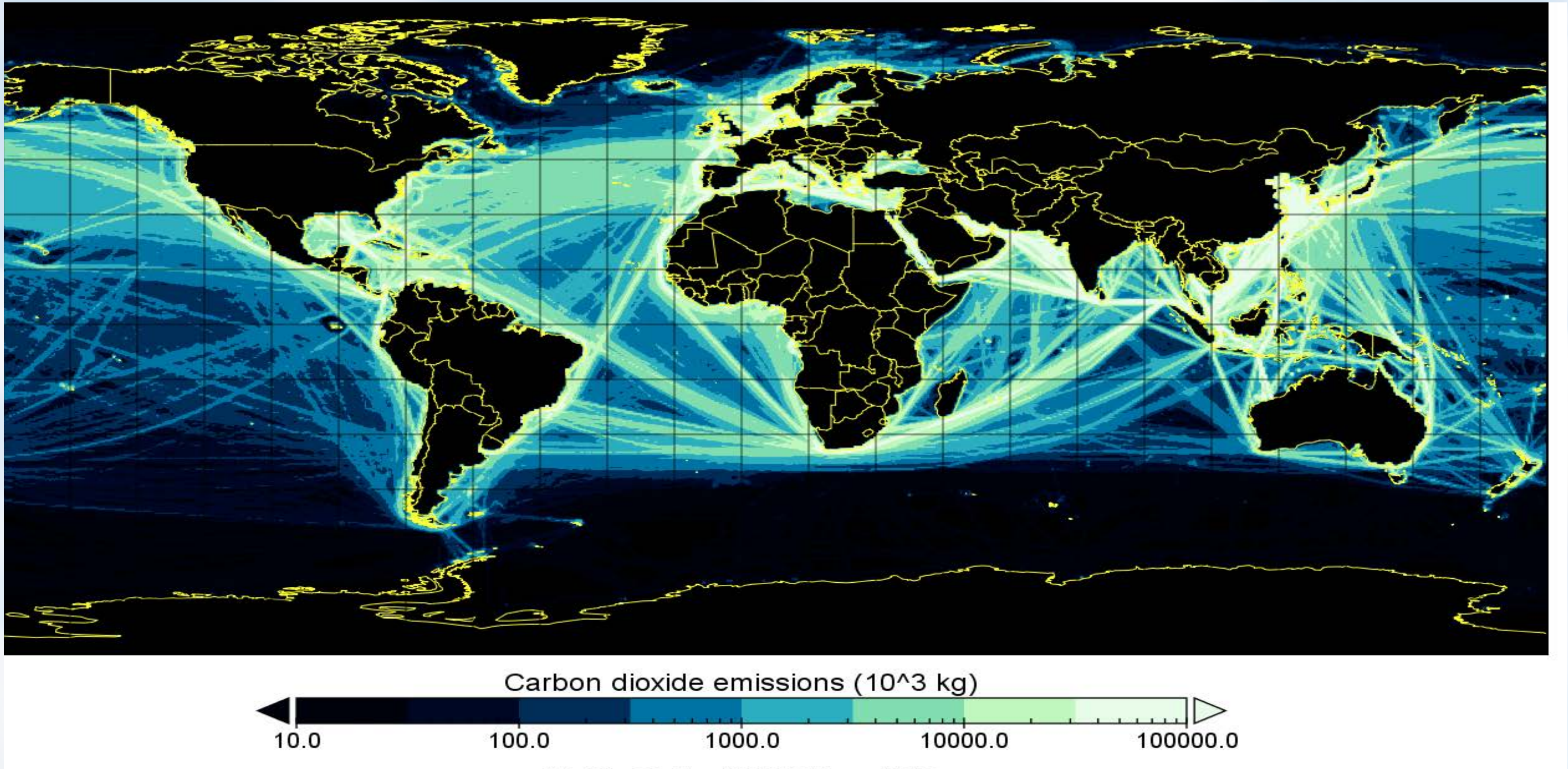
- **FMI (Finland) has developed a very detailed model called STEAM, which calculate global and regional datasets based on realistic vessel traffic**



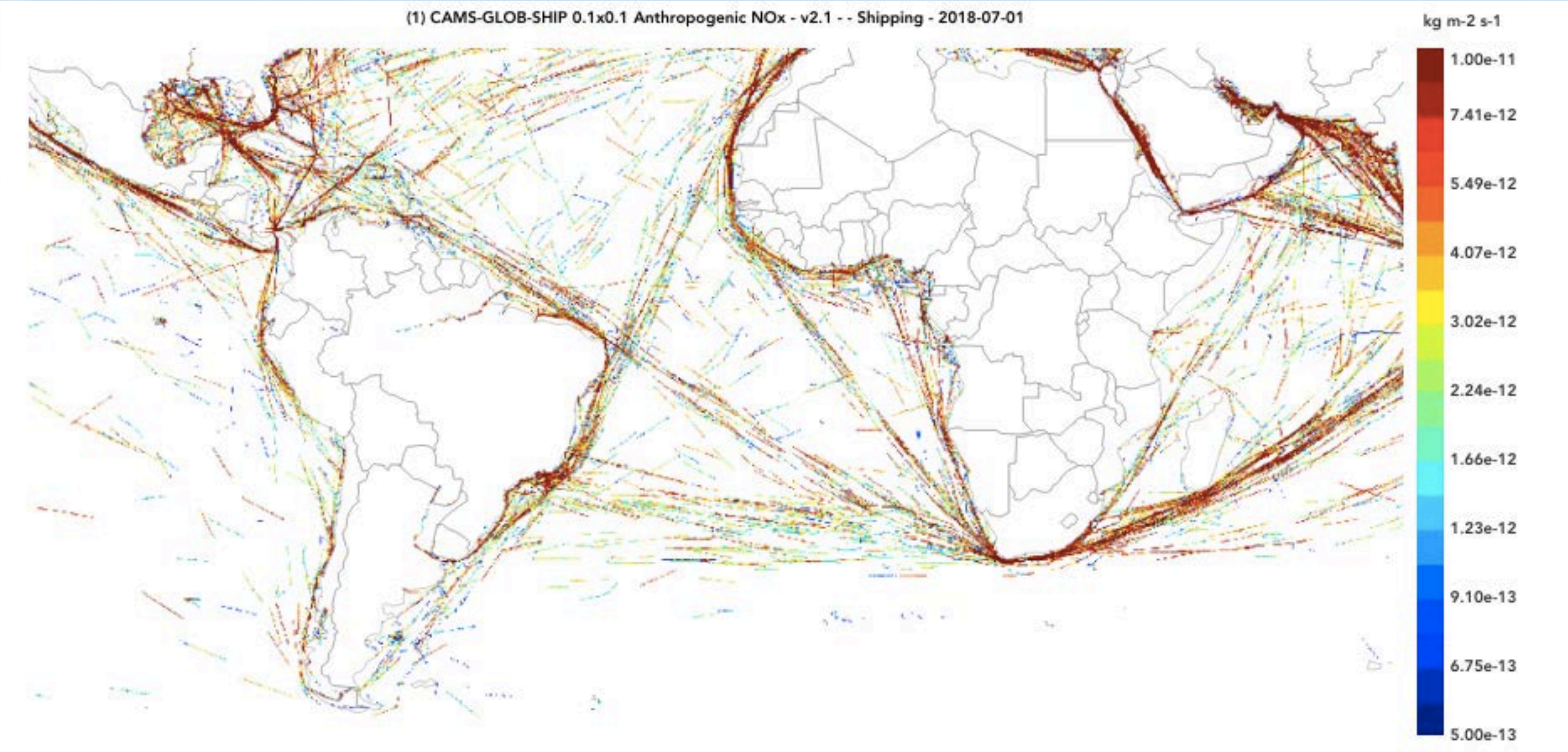
- **Localisation of ships with AIS (Automatic Identification System) + Technical description of the global fleet**

Developed at the Finnish Meteorological Office by Jukka-Pekka Jalkanen and colleagues

CAMS Global/European ship emissions: CAMS-GLOB-SHIP_v2.1



Emissions are provided at a 0.25x0.25 degree for 2000-2018, on a daily basis

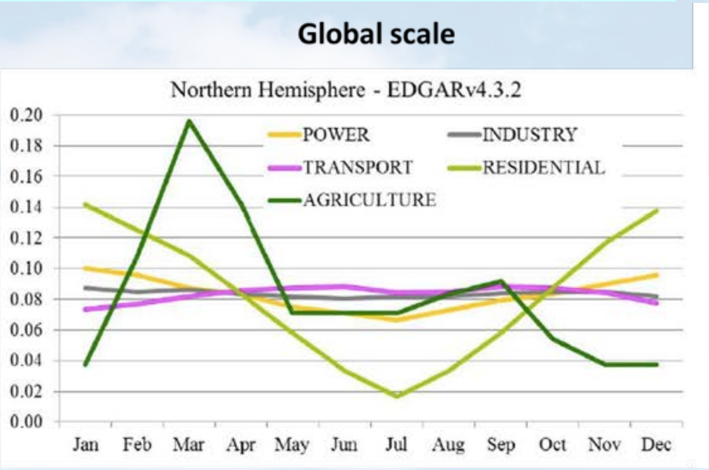


NOx ship emissions on July 1st, 2018

Daily mean

CAMS Temporal profiles: CAMS-GLOB-TEMPO_v2.1

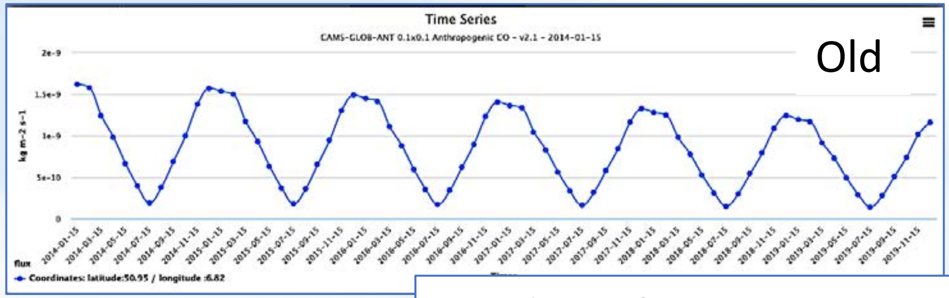
Emissions generally available as monthly averages, based on old temporal profiles



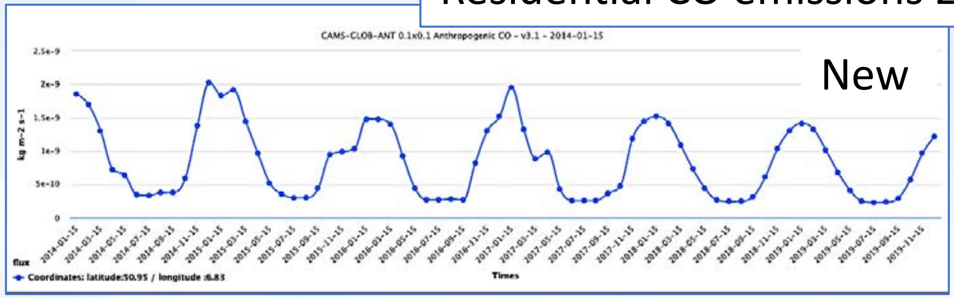
New developments at Barcelona Supercomputing Center by Marc Guevara and colleagues

New monthly, daily and weekly temporal profiles have veen developed, based on observations and data collected in different world countries

Residential temporal profiles depend on the meteorology



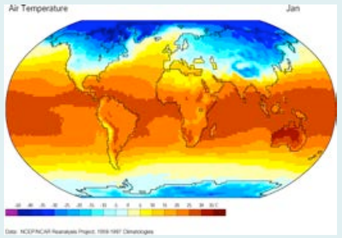
Residential CO emissions 2014-2019



Biogenic emissions : CAMS-GLOB-BIO_v2.1

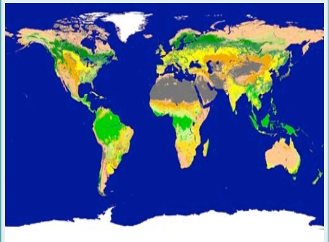
Developed at the Charles University (Czech Republic) using the MEGAN model by Katerina Sindelarova and Jana Doubalova

Meteorological fields

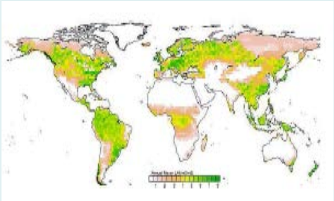


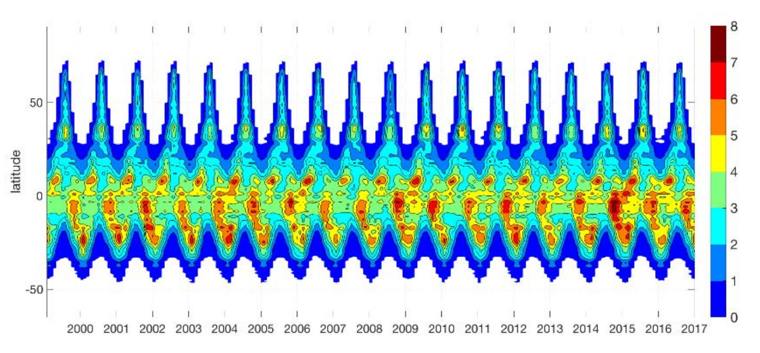
Emission potentials

Ecosystem distribution



Biomass density



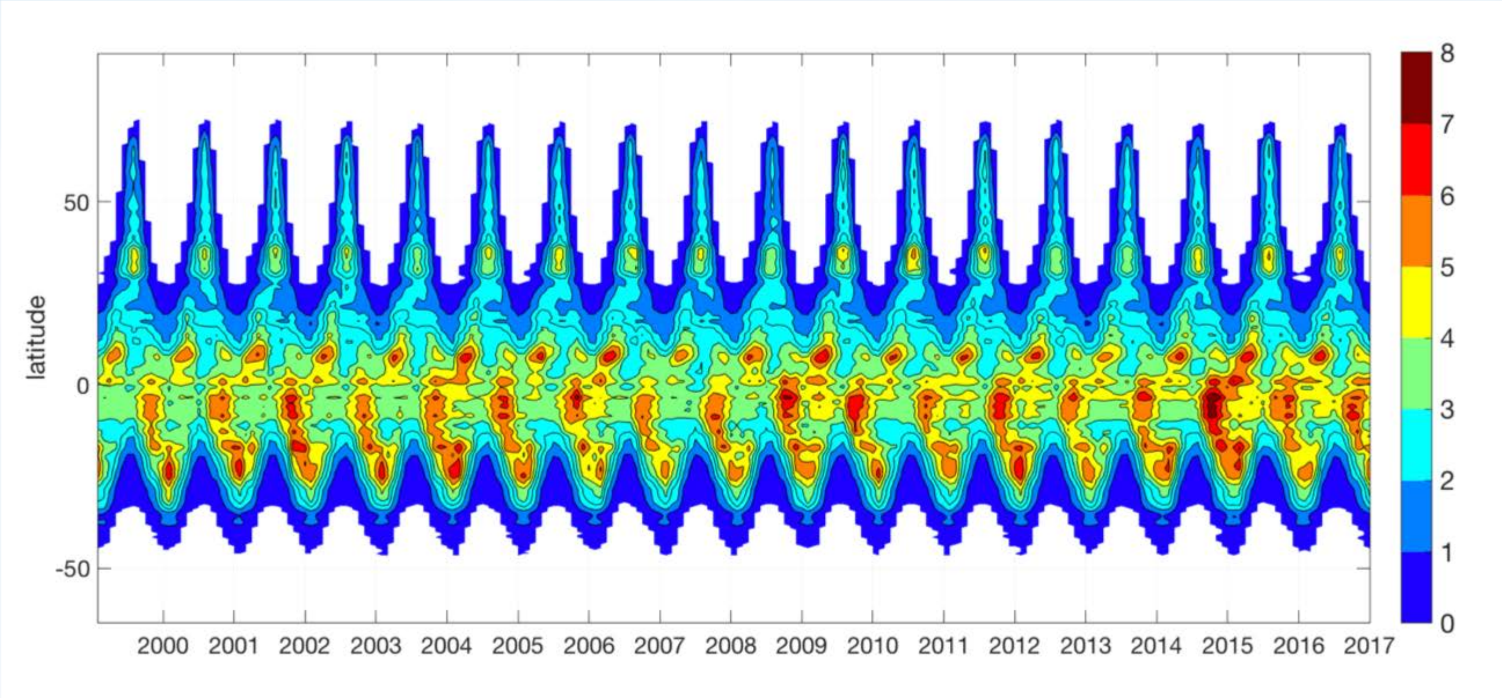


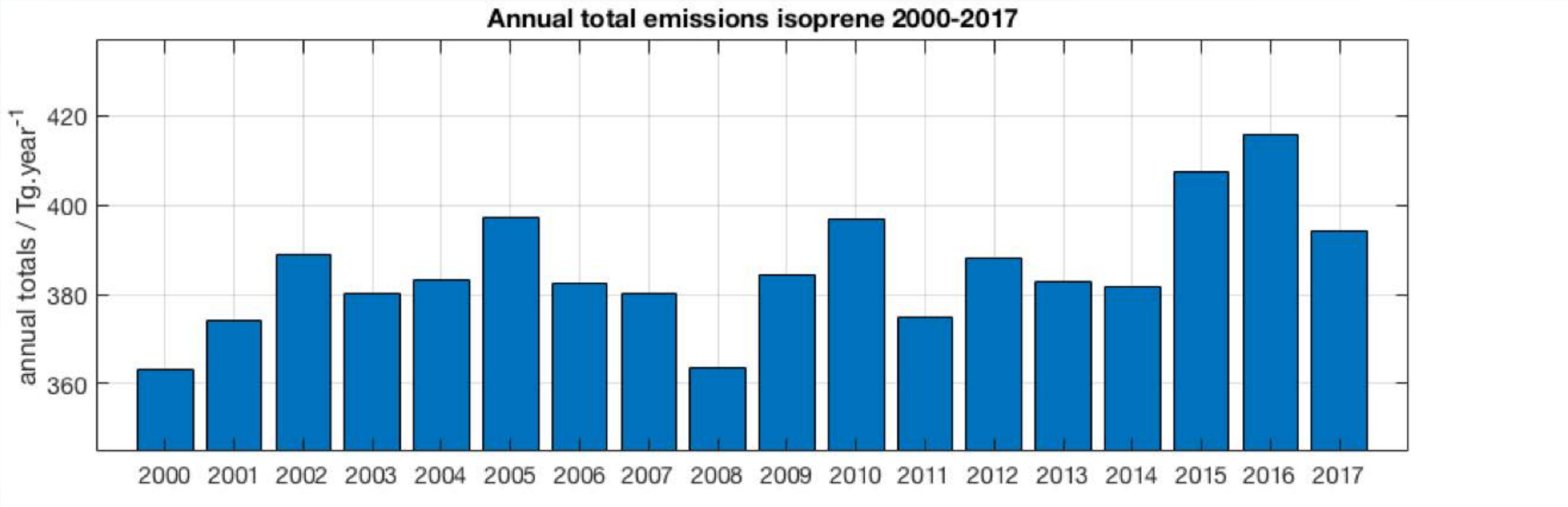
List of modeled species

Isoprene; α-pinene; β-pinene
other monoterpenes
Sesquiterpenes; CO
hydrogen cyanide
Ethane; propane
butane and higher alkanes
Ethene; propene
butene and higher alkenes
Methanol; ethanol
Formaldehyde; acetaldehyde
other aldehydes
Acetone; other ketones
formic acid; acetic acid
toluene

time resolution: monthly means ; **spatial coverage:** global
spatial resolution: 0.5° x 0.5 ° ; **Time period:** 2000-2017

Evolution of isoprene emissions from the CAMS dataset



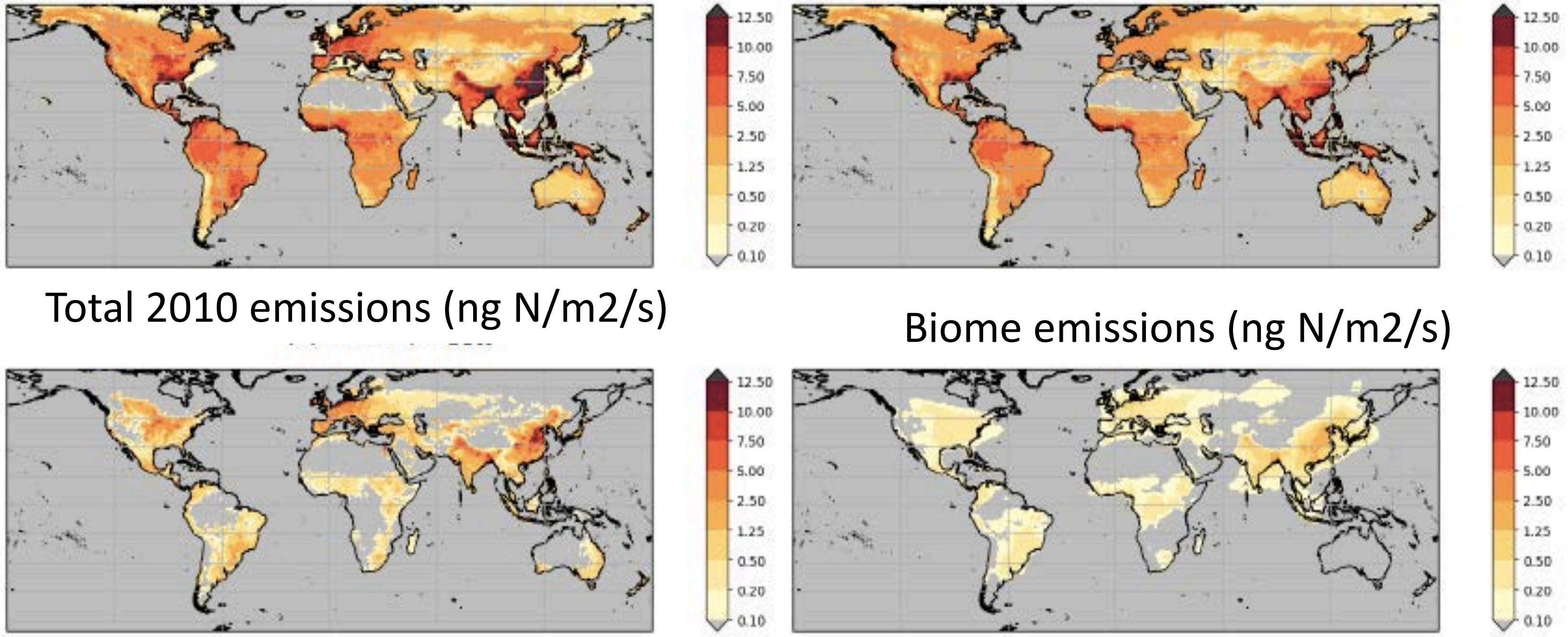


Soil NOx emissions: CAMS-GLOB-SOIL_v1

Different approaches have been tested, many based on Yienger and Levy (1995) or on Hudman and al. (ACP, 2012)

New version based on Yienger and Levy ➔ CAMS-GLOB-SOIL

2000-2015; 0.5x0.5 degree resolution; monthly averages



Total 2010 emissions (ng N/m2/s)

Biome emissions (ng N/m2/s)

Fertilizer emissions

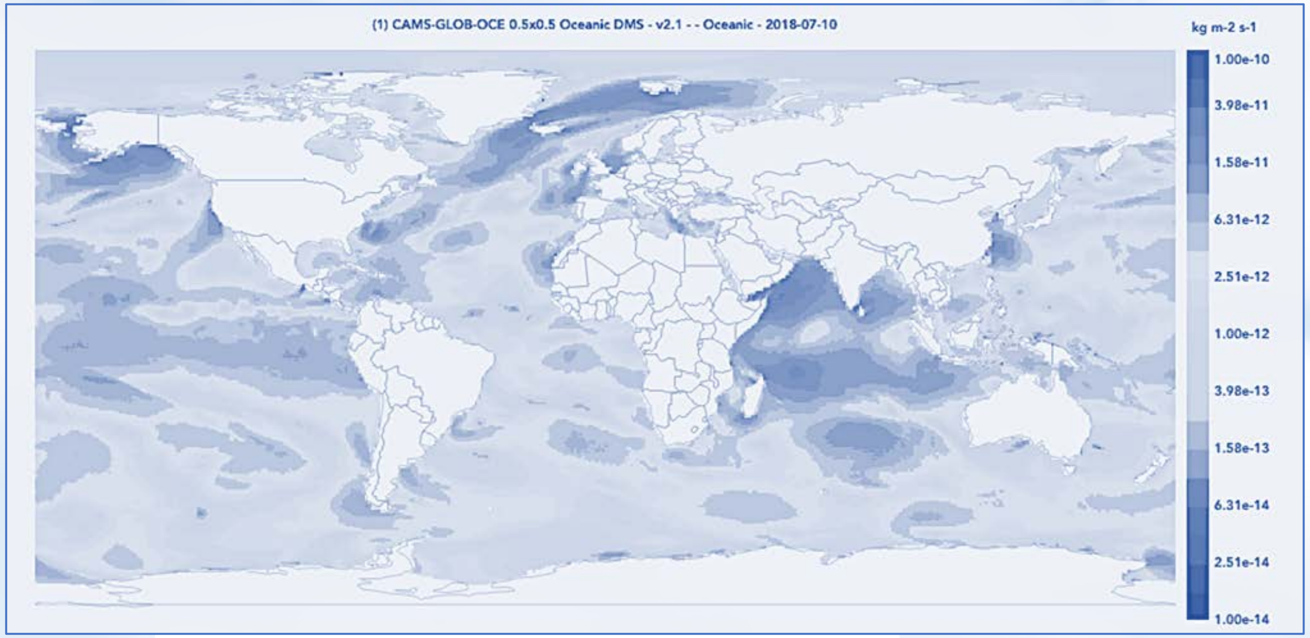
Deposition induced emissions

Developed at the Norwegian Meteorological office by David Simpson

Oceanic emissions: CAMS-GLOB-OCE_v2.1

Emissions of DMS, OCS and halogens ($CHBr_3$, CH_3I, CH_2Br_2) from the oceans have been developed by Met Norway in Oslo and GEOMAR in Kiel
→ CAMS-GLOB-OCE

The emissions are based on a climatologies of DMS, OCS and halogens concentrations in sea water measured in different oceans
+ ECMWF meteorology



DMS emissions on July 10, 2018

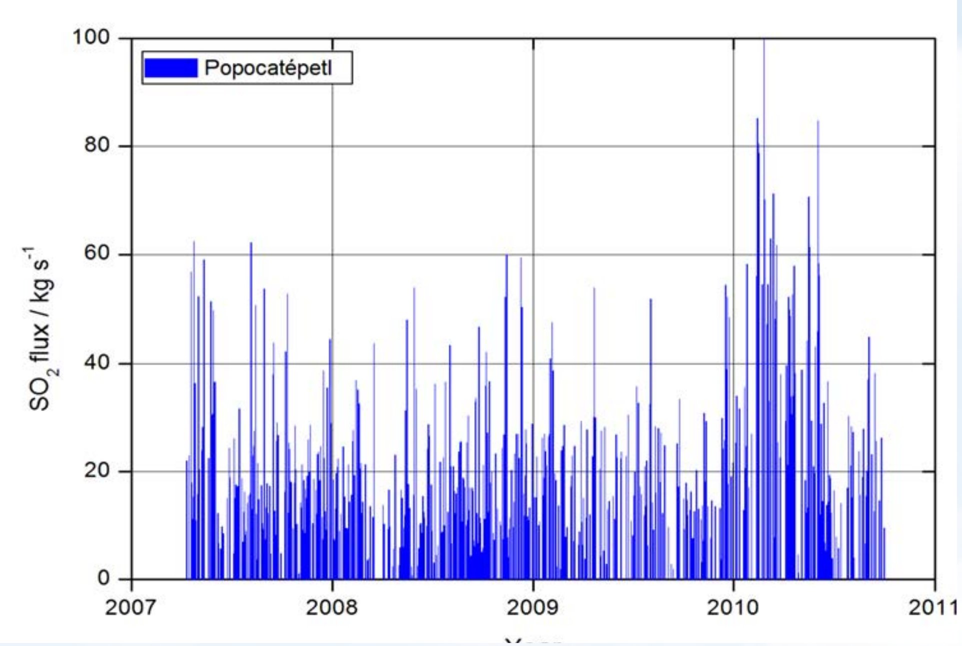
Time period and spatial/temporal resolution:
DMS: 2000-2015, 0.5x0.5 degree, daily
OCS: average for 2002-2014, 1x1 degree, monthly
Halogens: 2000-2015, 0.5x0.5, daily

Developed by Michael Gauss and colleagues at the Norwegian Meteorological office + GEOMAR in Kiel, Germany

Volcanic emissions: CAMS-GLOB-VOLC_v2.1

SO2 emissions from continuously degassing volcanoes
Use of observations from the NOVAC network: novac-community.org

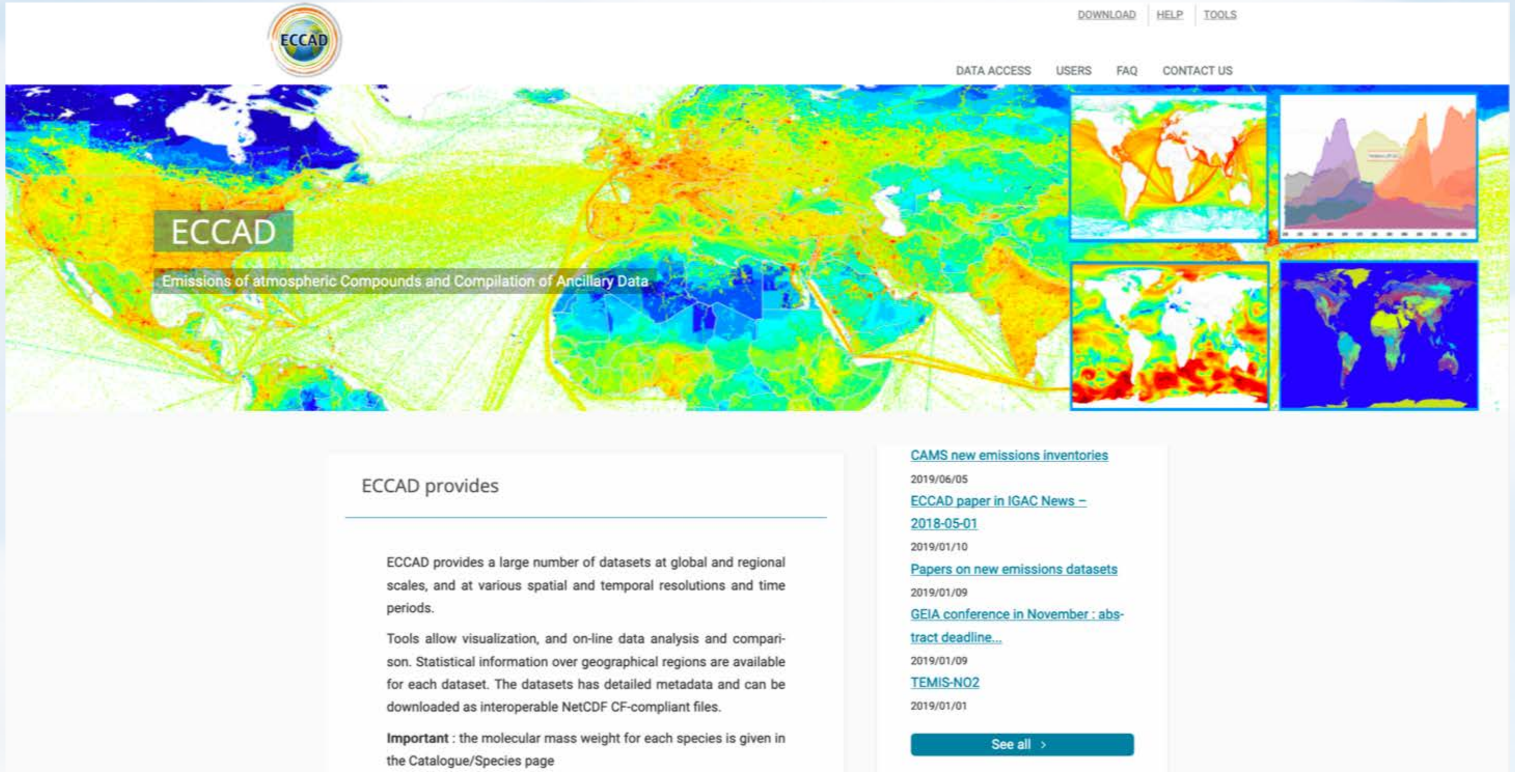
Emissions developed by Bo Galle and Santiago Arellano at the Chalmers University in Sweden



2007-2011 emissions from Popocatépetl, Mexico

Most of the datasets mentioned here are publicly available

Access: ECCAD database (Emissions of Chenical Coumpounds & Compilation of Ancillary Data)



http://eccad.aeris-data.fr/

The ECCAD database is developed by Sabine Darras and Hung Le Vu at the Midi-Pyrenees Observatory in Toulouse, France

CAMS emissions and others in ECCAD

All the CAMS-GLOB-xx mentioned in the talk are publicly available

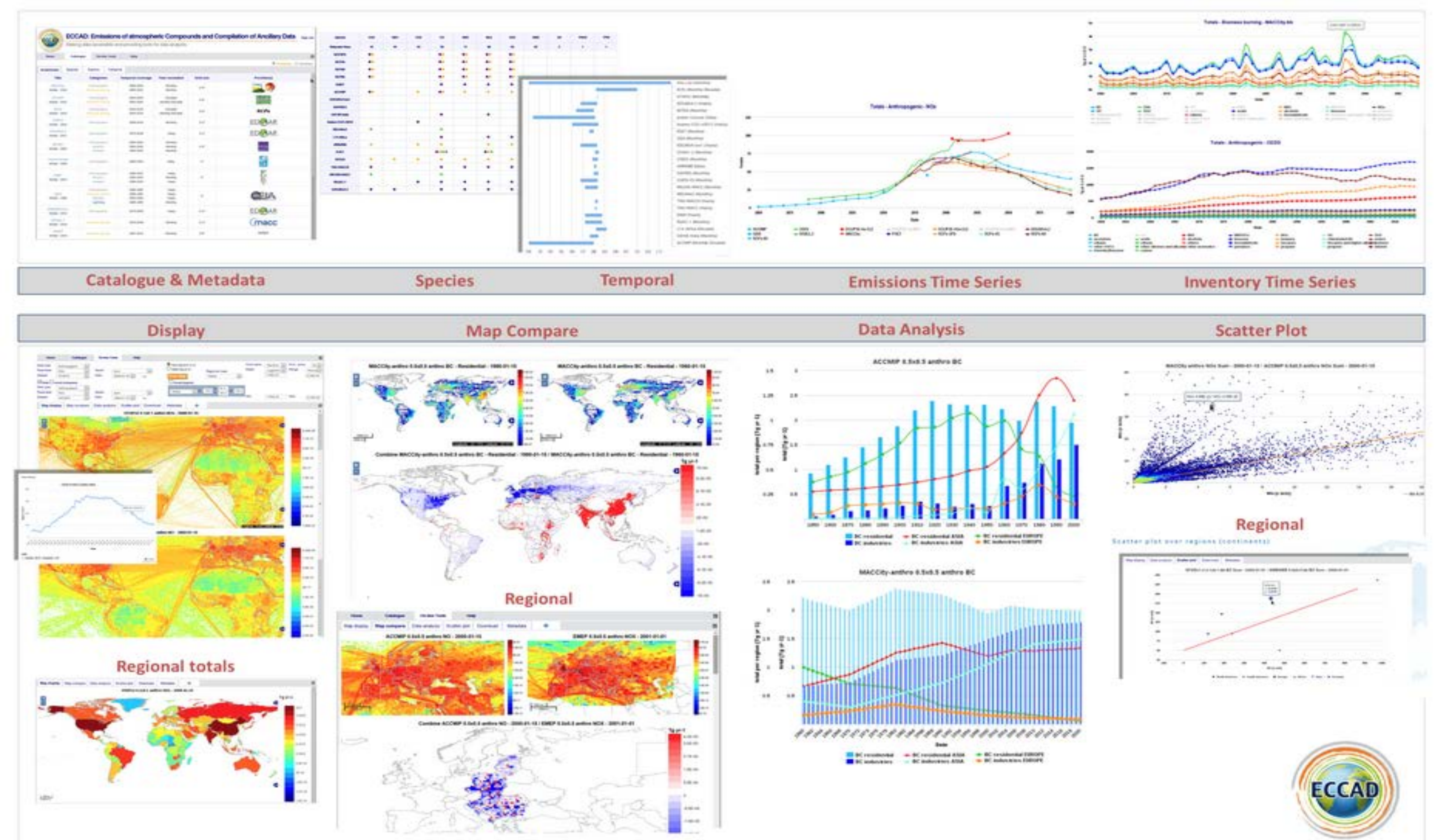
Documentation/methodology/results:

Reference: Granier et al., The Copernicus Atmospheric Monitoring Service global and regional emissions, ECMWF/CAMS report, *DOI: 10.24380/d0bn-kx16*, 2019.
(Updated version available in May/June)

ECCAD :

- → Detailed metadata with complete reference
- → User-friendly tools to visualize and analyse emissions
- → Download of emissions data
- → Possibility of hosting data with restricted access while the data are being checked and analysed

Example of ECCAD tools



Global Emissions InitiAtive

Gregory Frost
GEIA Co-Chair
NOAA/Earth System Research Laboratory, Boulder, CO, USA

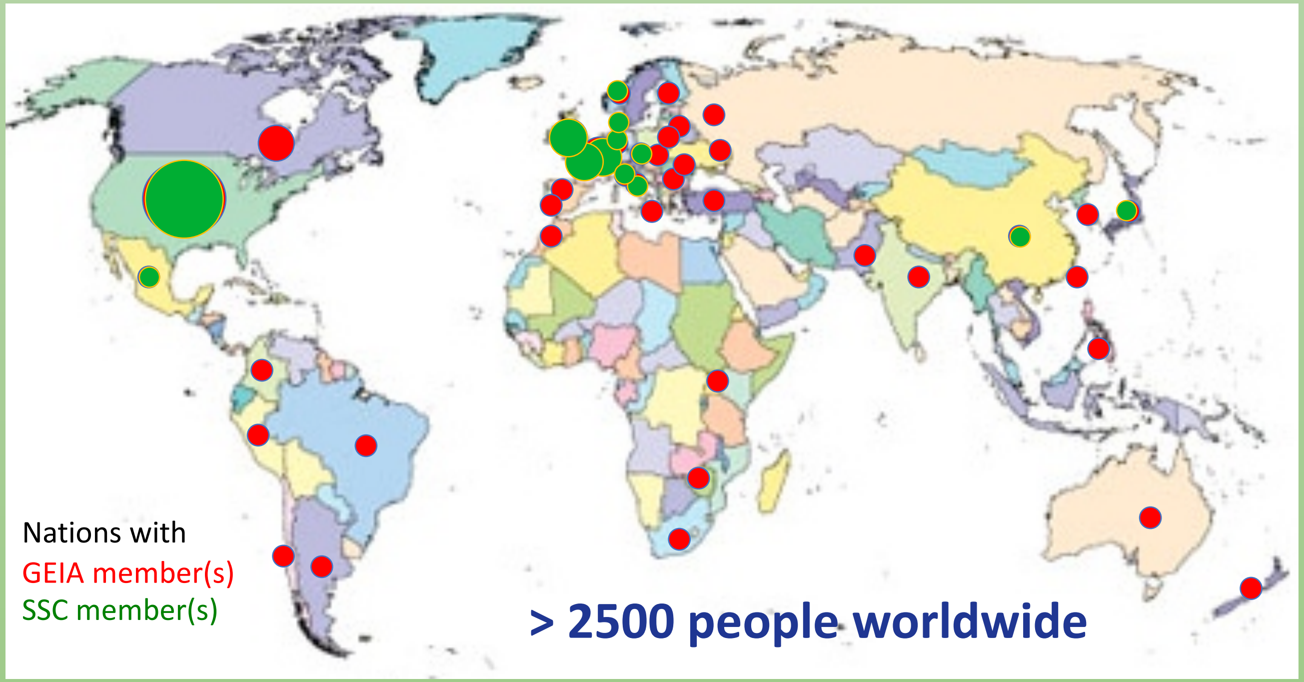
Leonor Tarrasón
GEIA Co-Chair
Norwegian Institute for Air Research, Kjeller, Norway

Claire Granier
GEIA Database Manager

Paulette Middleton
GEIA Network Manager
Panorama Pathways, Boulder, CO, USA

- Founded in 1990
- Community initiative
- Bridging science and policy
- Bringing together people, data, and tools
- Creating and communicating emissions information
- Key forum for emissions knowledge
- Serving stakeholders in rapidly evolving global society

Network



GEIA Community

Scientific Steering Committee

Alexander Baklanov (*Switzerland*)
Beatriz Cardenas (*Mexico*)
Hugo Denier van der Gon (*The Netherlands*)
Gregory Frost[1] (*USA*)
Claire Granier[2] (*France, USA*)
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Paulette Middleton[3] (*USA*)
Ute Skiba (*UK*)
Allison Steiner *(USA)*
Leonor Tarrasón[1] (*Norway*)
Erika von Schneidemesser (*Germany*)
Yuxuan Wang (*China*)

[1] ***Co-Chair*** [2] ***Database Manager*** [3] ***Network Manager***

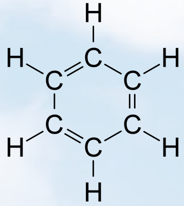
GEIA Working Groups

China Emissions WG

Contacts: Kebin He, Qiang Zhang, Yuxuan Wang

- Improving scientific basis for Chinese emissions
- Sharing results between Chinese research groups

VOC Emissions WG



Contacts: Erika von Schneidemesser, Hugo Denier van der Gon

- Improving global understanding of VOC emissions
- Evaluating megacity VOC emissions speciation and sources

Latin America/Caribbean (LAC) Emissions WG

Contacts: Nicolas Huneeus, Laura Dawidowski, Néstor Rojas

- Developing and evaluating LAC-specific emissions information
- Creating LAC regional emissions database and inventory

Urban Emissions WG

Contacts: Leonor Tarrasón

- Leveraging techniques for urban emissions characterization
- Building capacity in megacities around the world

African Emissions WG

Contacts: Cathy Liousse, Mogesh Naidoo, Sekou Keita

- Create African emission databases at the country/city scales
- Create a network of African experts with local experts and decision makers

GEIA 19th GEIA Conference

GEIA's efforts to accelerate societal transformations

- Advancing emissions science
- Accelerating societal transformations
- Latest research on all emissions sectors
  - Energy and renewables
  - Transportation
  - Agriculture
  - Natural sources
  - Wildfires
- Mitigation efforts
- Impacts of changing emissions
- Highlights from GEIA's Working Groups
- Solicit community input on GEIA's future

Conference in Santiago, Chile
➔ Now a virtual conference

Details at: geiacenter.org

Talks as video, posters as PDF or videos + webinars/discussions

Summary

- High quality emissions information is critical to understand the atmosphere and make good decisions about how to manage it
- Bottom-up inventories are integral to these efforts, but there are challenges associated with these complex datasets
- There are significant disagreements between different global and regional bottom-up inventories ; identifying the causes of these differences and the uncertainties in these datasets is difficult because of lack of information
- Many publicly available inventories are accessible through the ECCAD database
- GEIA seeks to bring together people, data and tools to provide the best information on emissions

Thank you for your attention

And thanks to all colleagues who sent me pictures and slides

Questions, comments:
Send me an email: claire.granier@noaa.gov