The CAMS anthropogenic and natural emissions of greenhouse gases and atmospheric pollutants

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Marc Guevara, Barcelona Supercomputer Center, Barcelona, Spain

Jukka-Pekka Jalkanen, Elisa Majamaki, Finnish Meteorological Institute, Finland

Katerina Sindelarova, Charles University, Prague, Czech Republic

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Copernicus is the European earth observation program

- **Managed by the European commission**
- **Provides satellite, in-situ and model data**
- **Divided in six data services:**

Atmosphere Monitoring Service

The Copernicus atmosphere monitoring system (CAMS)

atmosphere.Copernicus.eu

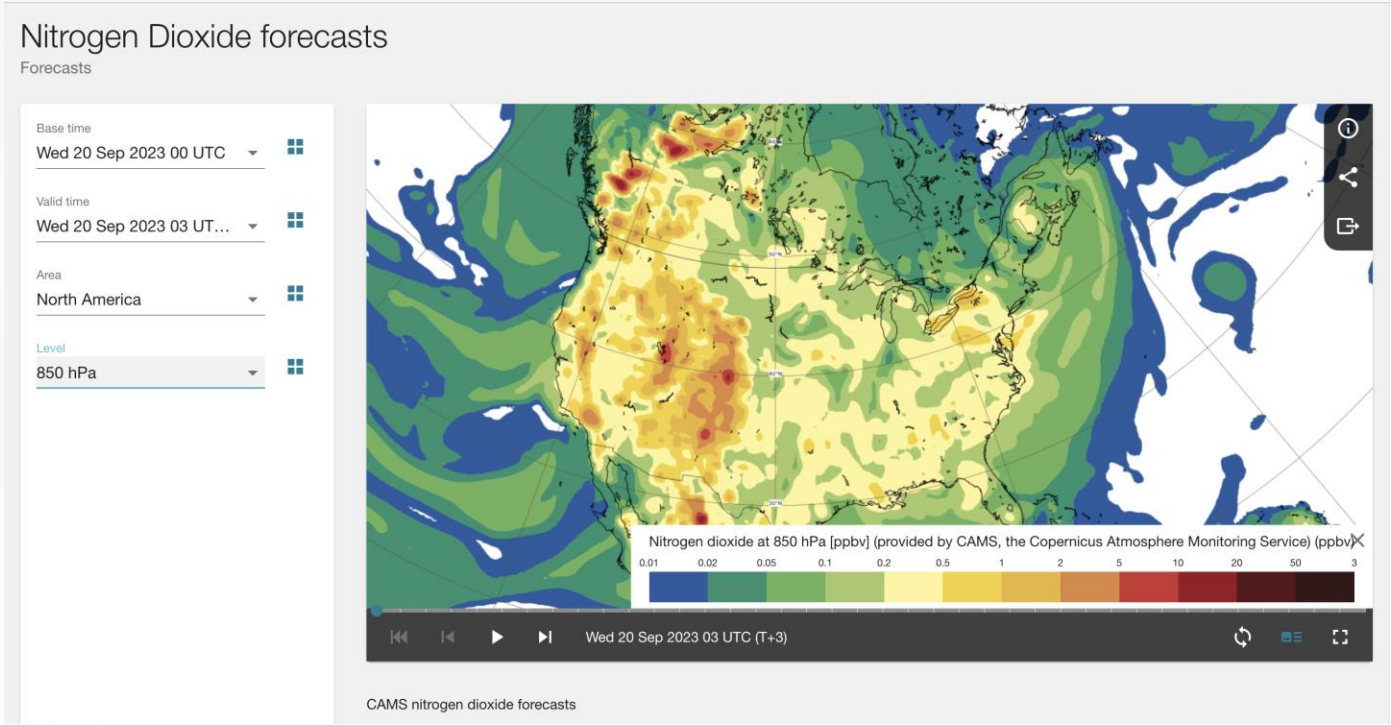
- **CAMS** is the atmosphere service of Copernicus

- It is driven by the European Center for Medium-Range Weather Forecasts (ECMWF)

- It provides **global** and **regional forecasts** and **reanalyses** for the major **air pollutants** and **greenhouse gases** for the past two decades

- All data generated by CAMS are fully public, at: https://atmosphere.copernicus.eu/data

Example of the NO_2 surface concentration forecast at 850 hPa for September 20th, as obtained from the CAMS website



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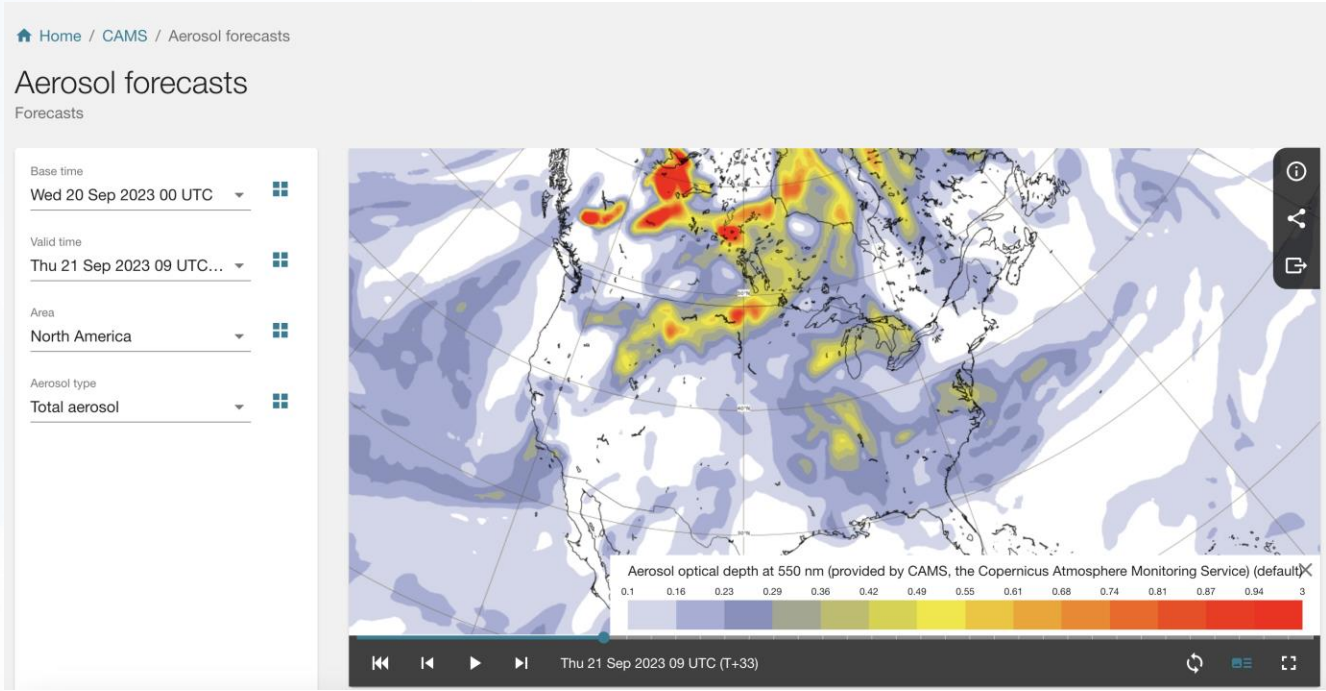
Example of the aerosol optical depth forecast for September 21st, as obtained from the CAMS website



All forecasts/reanalyses require comprehensive and up-to-date emission datasets

The CAMS emissions inventories (atmosphere.copernicus.eu)

- **CAMS-GLOB-ANT:** global emissions, 2000-2024, 0.1x0.1 degree; extrapolation for the most recent years (contact: CNRS - France, Claire Granier)

- **CAMS-REG:** global emissions, 2000-2020, 0.1x0.05 degree (contact: TNO - The Netherlands, Hugo Denier van der Gon)

- **CAMS-GLOB-SHIP:** ship emissions, 2000-2022, 0.1x0.1 degree (contact: Finnish Met. Institute - Finland, Jukka-Pekka Jalkanen)

- **CAMS-GLOB-TEMPO:** temporal profiles, 2000-2020, 0.1x0.1 degree (contact: Barcelona Supercomputing Center - Spain, Marc Guevara) →

- **CAMS-GLOB-BIO:** 25 biogenic VOCs + CO, 2000-2019, 0.5 degree (contact: Charles Univ. Prague- Czech Republic, Katerina Sindelarova)

- **CAMS-GLOB-SOIL:** NOx from soils, 2000-2020, 0.5x0.5 degree (contact: Met. Norway - Norway, David Simpson)

- **CAMS-GLOB-TERM:** CH4 from termites, 2000, 0.5 degree (contact: Charles University Prague – Czech Republic, Katerina Sindelarova)

- **CAMS-GLOB-OCE:** oceanic emissions DMS, OCS, halogens, 2000-2022, 0.5x0.5 deg (contact: Met. Norway - Norway, Michael Gauss)

- **CAMS-GLOB-VOLC:** SO2 from 20 volcanoes, 2000-2019, 1x1 degree (contact: Chalmers University - Sweden, Santiago Arellano)

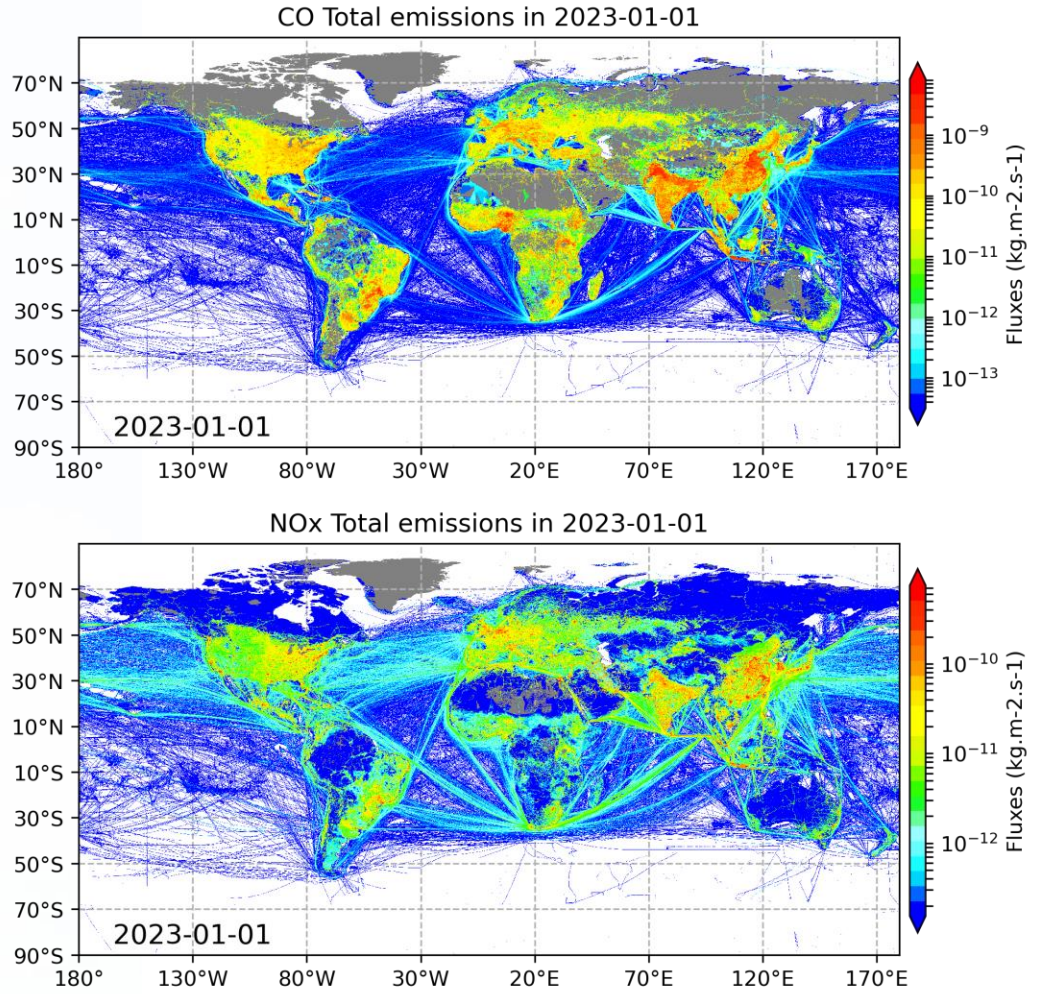
CAMS-GLOB-ANT: Global anthropogenic emissions developed at CNRS, France

Most recent version: CAMS-GLOB-ANT_v6.1: 2000-2024

Global anthropogenic emissions inventory

- Major air pollutants and greenhouse gases
- 25 speciated VOCs emissions
- 15 activity sectors
- 0.1x0.1 degree spatial resolution
- Monthly temporal resolution
- Based on the EDGAR versions 6 and 7 emissions developed at JRC (Italy) and CEDS, developed at PNNL, USA
- Extrapolation to get the emissions for the most recent years

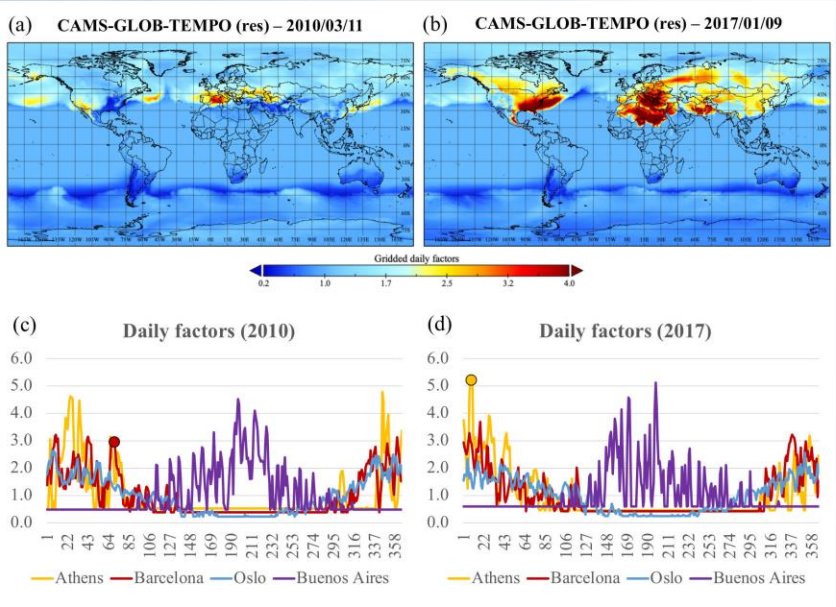
Details in Soulie et al., https://doi.org/10.5194/essd-2023-306, Earth Syst. Sci. Data, in review, 2023



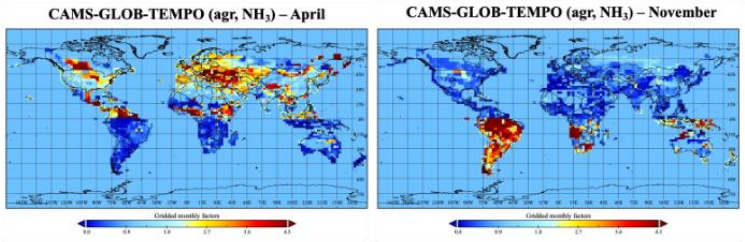
CAMS-GLOB-TEMPO: temporal profiles of emissions (developed at Barcelona Supercomputing Center, Spain)

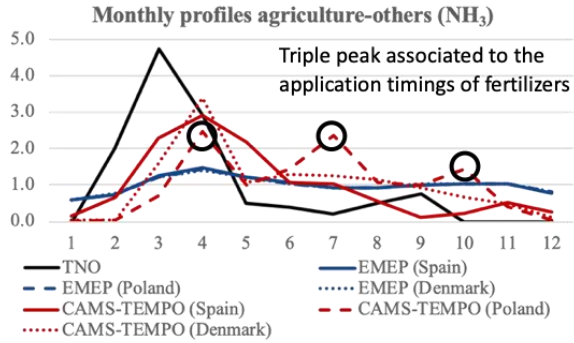
- Gridded temporal profiles, 0.1x0.1 degree resolution, monthly/weekly/daily profiles
- Consideration of **year & pollutant-dependency, sociodemographic and meteorological influences; Sectoral coverage**: energy & manufacturing industry, residential/commercial combustion, road transport, agriculture (livestock, fertilizers and agricultural waste burning), aviation, shipping
- Details in Guevara et al. (2021), https://doi.org/10.5194/essd-13-367-2021

Residential combustion: Influence of temperature



Fertilizers: Influence of meteorology + crop calendars



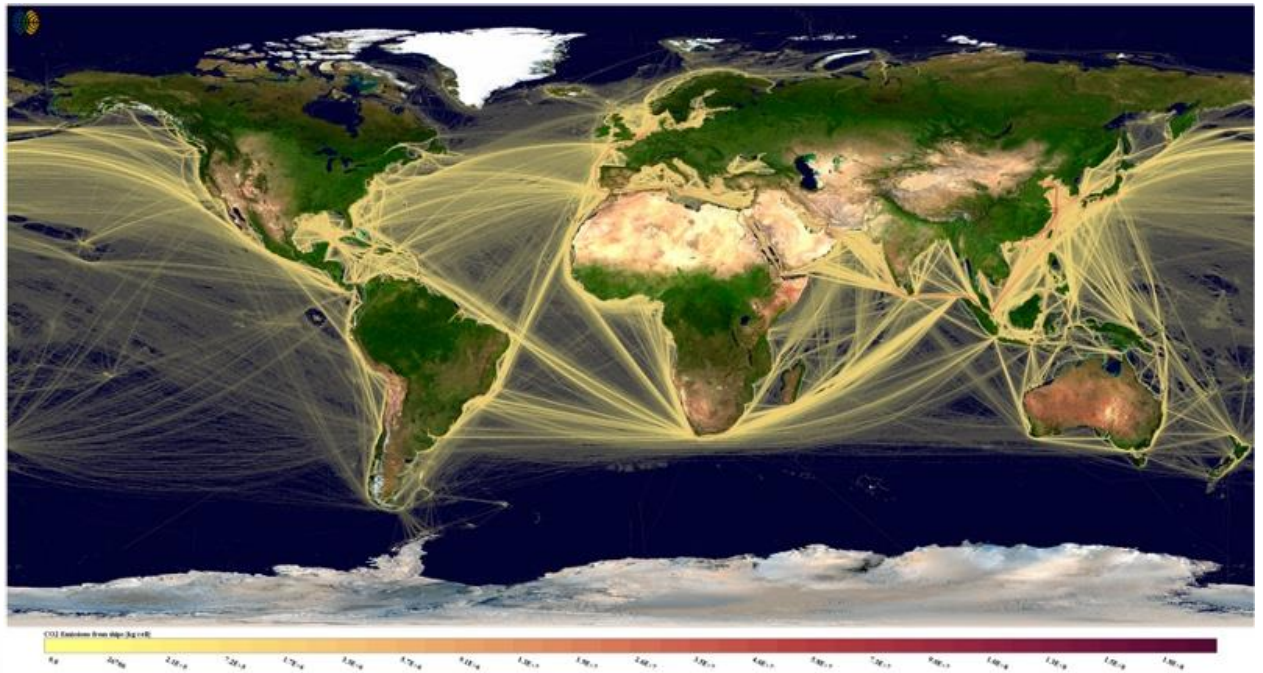


CAMS-GLOB-SHIP: Emissions from shipping (developed at the Finnish Meteorological Institute, Finland)

Global timeseries of ship emissions for many chemical species

- Use of the STEAM v4.2.5 ship emission model
- Uses AIS (Automatic Identification System) data, i.e. location, speed, etc. for the 2014-2022 data (back casting 2000-2013)

Includes:
- Updated emission factors
- Daily 0.1 deg grids with International/ Domestic split
- Inclusion of ambient effects from Copernicus Marine/Atmosphere: Wind, Waves, Ice cover, Sea currents



CAMS-REG - Anthropogenic emissions in Europe (done at TNO, The Netherlands)

Official reported GHG emissions (UNFCCC NIR – CRF)

Official reported Air Pollutant emissions (EMEP CEIP)

Other emission datasets IIASA GAINS & JRC EDGAR

TNO internal estimates Bottom-up checks

- Small combustion (wood)
- Non-international shipping
- Agricultural waste burning
- Etc.

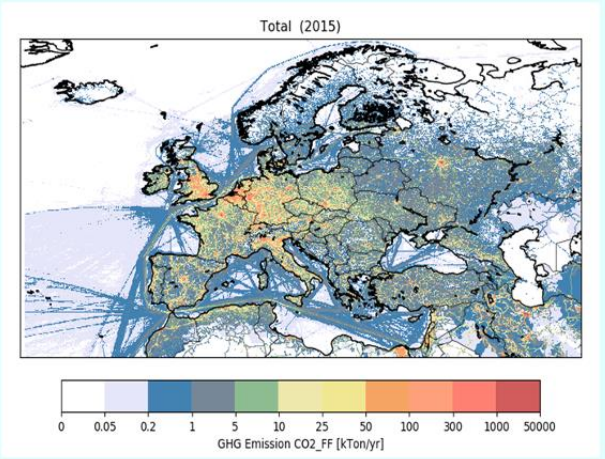
80+ subsectors: aggregated NFR with fuel splits

CAMS / TNO emissions by subsector

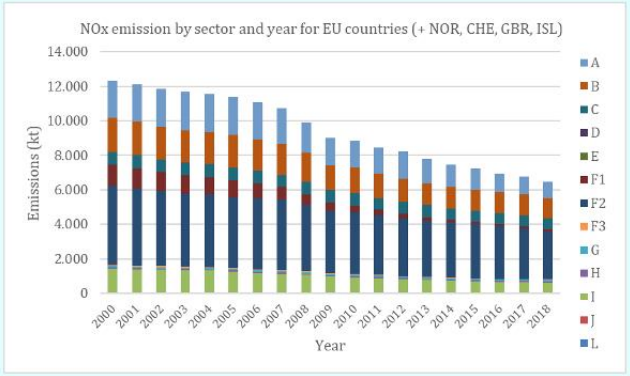
Shipping grids *(CAMS - FMI)*

Spatial proxies

- Population
- Road transport
- Animal densities
- E-PRTR, etc. etc.



Gridded European regional emission product (time series)



2000-2019; 0.05x0.1 degree spatial resolution

More details in Kuenen et al., Earth Syst. Sci. Data, 2022 (https://doi.org/10.5194/essd-14-491-2022)

CAMS-GLOB-BIO: Global gridded inventory of biogenic VOC emissions from vegetation developed at the Charles University (Czech Republic)

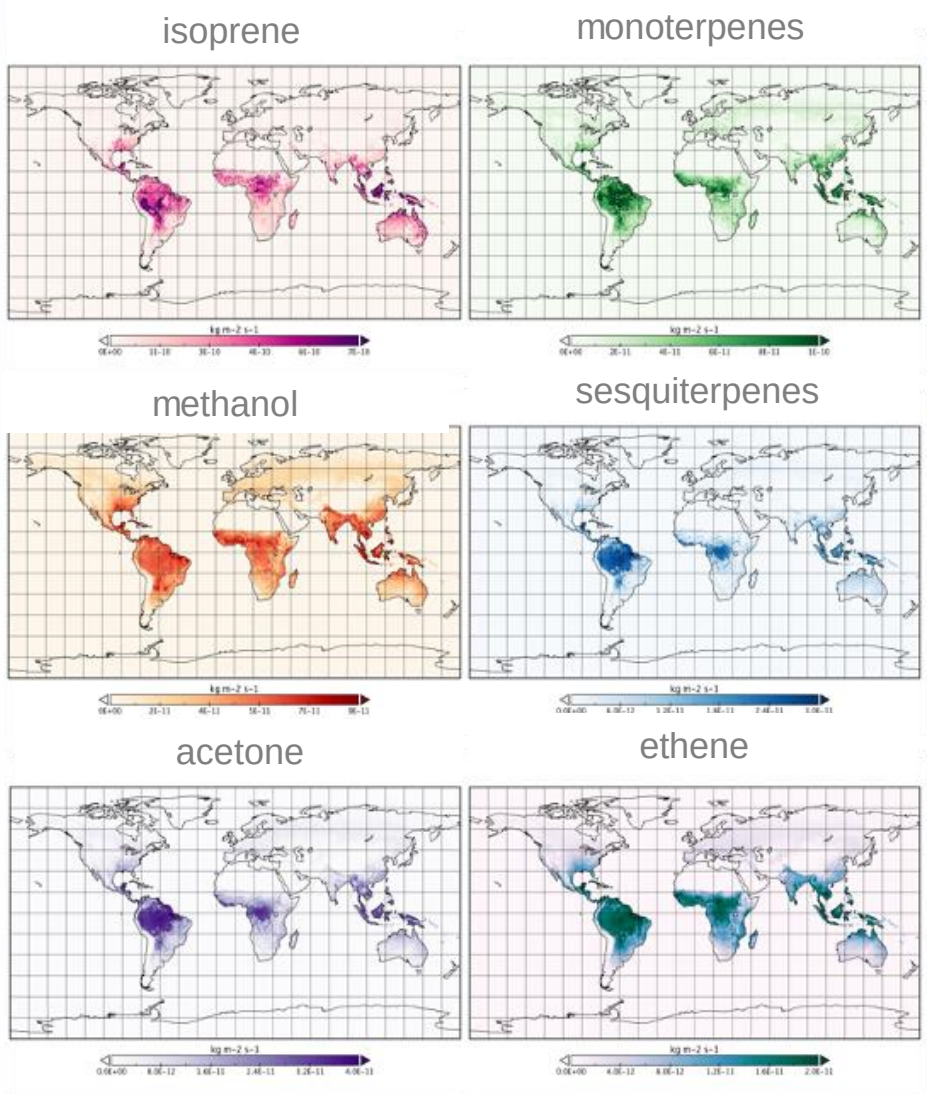
Emissions calculated by the MEGANv2.1 model and ECMWF meteorology

Monthly mean emissions and monthly averaged daily profiles of 25 VOC species/chem. groups for 2000 – 2022 on a 0.25x0.25 deg. grid

- **CAMS-GLOB-BIOv3.1**
  - driven by ERA5, includes update of isoprene emission factors in Europe based on the EMEP model data
- **CAMS-GLOB-BIOv3.0**
  - driven by ERA5 and by annually changing land cover from the ESA-CCI dataset
- **CAMS-GLOB-BIOv1.2**
  - driven by ERA-Interim meteorology

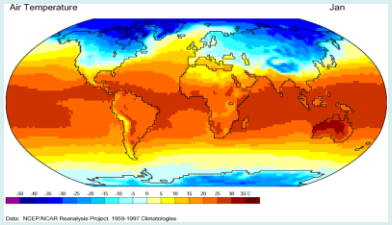
More details in Sindelarova et al.
ESSD, 2022, https://doi.org/10.5194/essd-14-251-2022

CAMS-GLOB-BIOv3.1
annual mean emissions [kg m^{-2} s^{-1}]



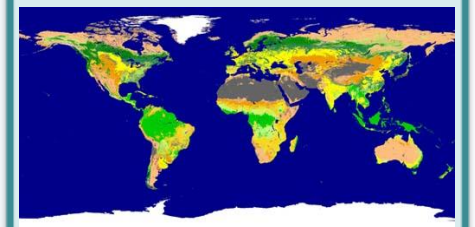
CAMS Biogenic Emissions (Sindelarova et al., ESSD 2022)

Meteorological fields

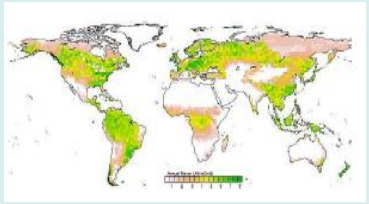


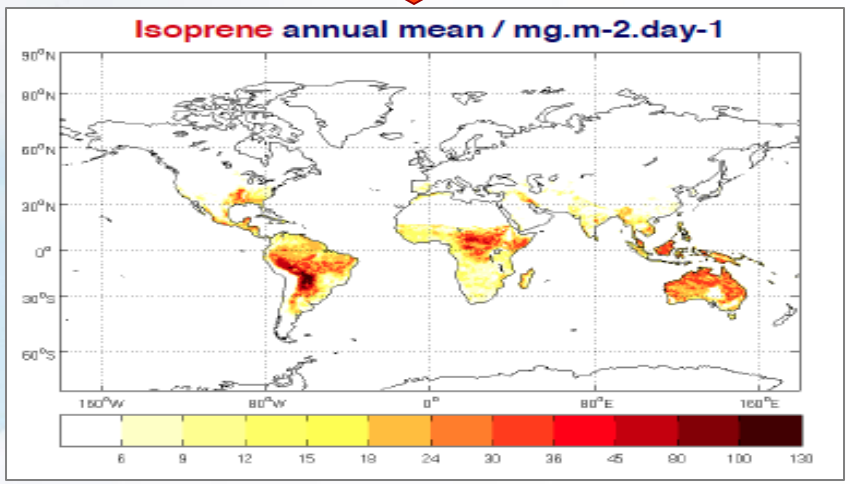
Emission potentials

Ecosystem distribution



Biomass density





time resolution	monthly means – 2000-2022
spatial coverage	global
spatial resolution	0.5° x 0.5°

List of modeled species

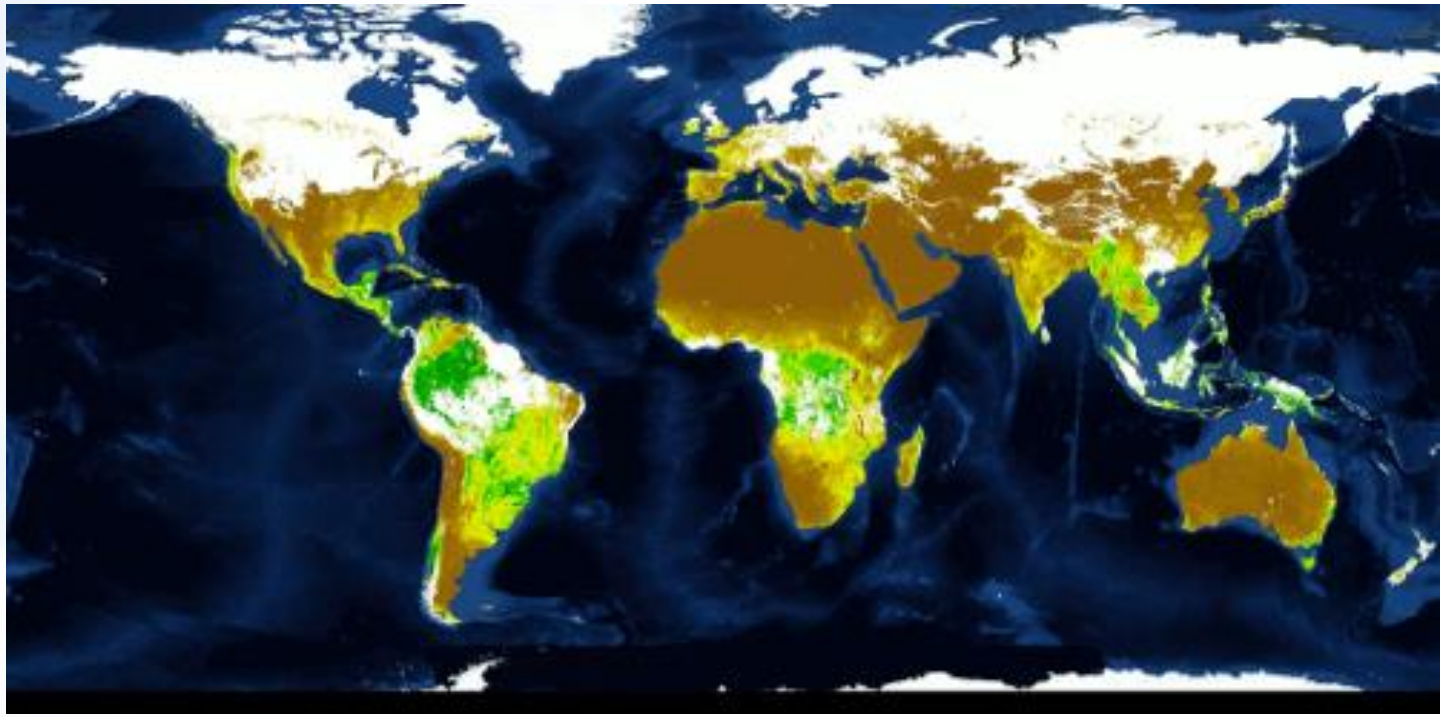
isoprene
α-pinene
β-pinene
other monoterpenes
sesquiterpenes
CO
hydrogen cyanide
ethane
propane
butane and higher alkanes
ethene
propene
butene and higher alkenes
methanol
ethanol
formaldehyde
acetaldehyde
other aldehydes
acetone
other ketones
formic acid
acetic acid
toluene

Satellite-derived values of Leaf Area Index

- Leaf area index is an essential parameter in modelling BVOC emissions providing information on vegetation seasonality

- The animation shows the status of the vegetation (the Leaf Area Index) over the entire globe changing from winter to summer in the period from January 2011 till February 2012. The images have a temporal frequency of 10 days.

LAI product from Copernicus Global Land Service



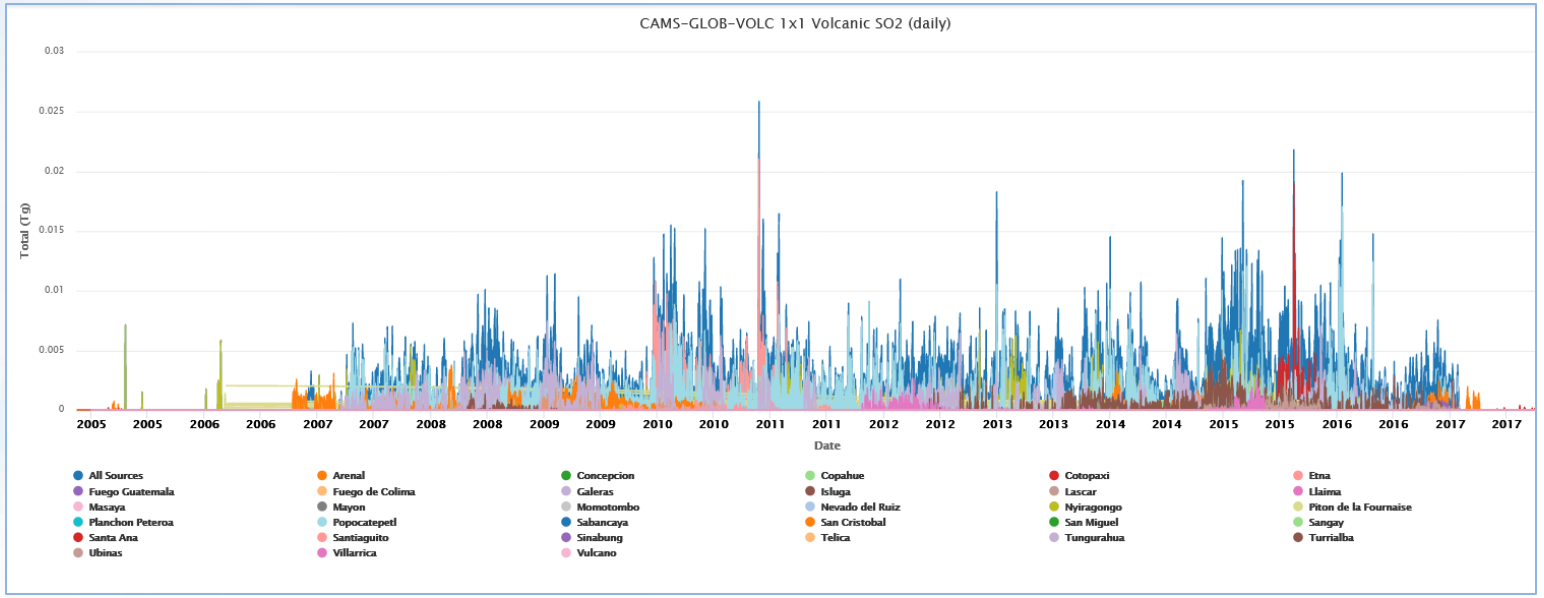
https://land.copernicus.eu/global/products/lai

Copernicus
Europe's eyes on Earth

CAMS-GLOB-VOLC: SO2 emissions from continuously degassing volcanoes (developed at Chalmers University, Sweden)

Timeseries of SO2 emissions for 36 continuously degassing volcanoes

- 2005-2019; daily, spatial resolution 1 degree
- Derived from observations using ground based remote sensing (NOVAC volcanoes network: novac-community.org)
- Statistics of gas flux, plume height, plume velocity, cloud cover
- Meteorological data from ECMWF/ERA-interim and ECMWF/ERA5



More information in Arellano et al., Earth Syst. Sci. Data, 2021, https://doi.org/10.5194/essd-13-1167-2021

CAMS-GLOB-OCE: oceanic emissions
Developed at Met-Norway

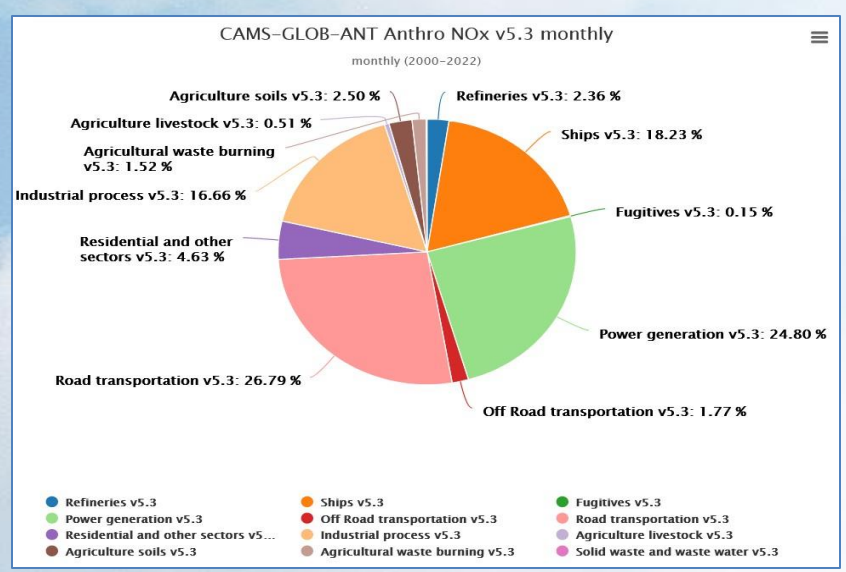
Oceanic emissions based on local observations

- **Dimethyl sulphide (DMS) and halogenated species (CHBr3 - bromoform, CH_2Br_2 - dibromomethane, and CH_3I - methyl iodide/iodomethane)**
  - version 3.1; 2000-2022 for DMS, 2000-2019 for halogenated species
  - temporal resolution daily, spatial resolution 0.5x0.5 deg
  - based on CDS product "ERA5 hourly data on single levels from 1979 to present", water concentrations and flux formulas from the literature (see Lana et al. (2013) for DMS; Ziska et al. (2013) for halogenated species)

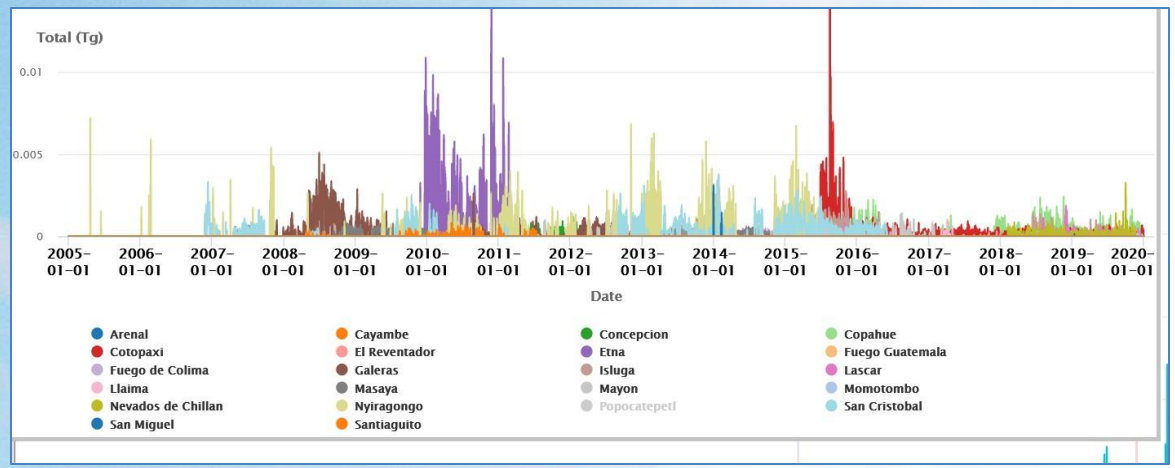
- **Carbonyl sulfide (OCS)**
  - version 1.1
  - temporal resolution monthly, spatial resolution 1x1 deg
  - representative of the period 2002-2014, based on Lennartz et al. (2017)

More details in Lennartz et al, Earth Syst. Sci. Data, 2021 (https://doi.org/10.5194/essd-13-2095-2021)

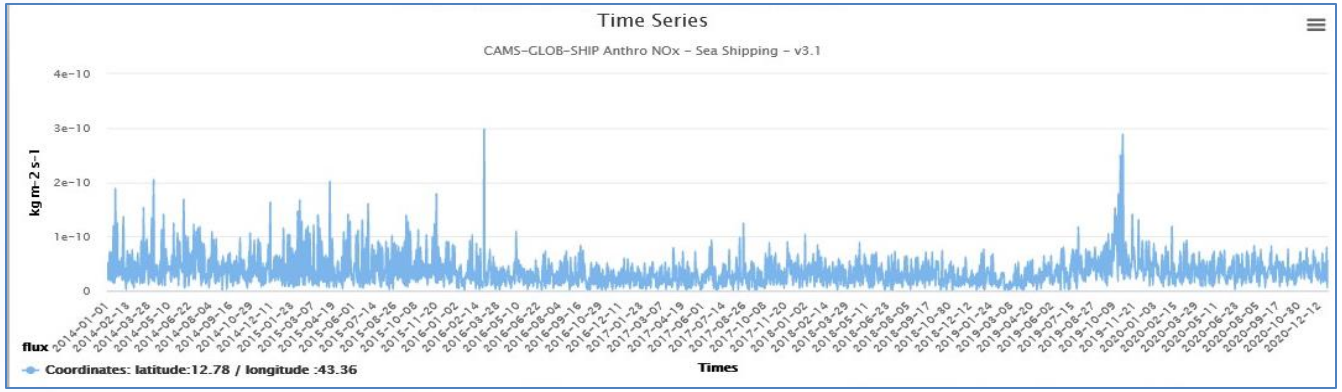
Examples of the analyses of the CAMS emissions done with the ECCAD database (eccad.sedoo.fr) (talk on Sept, 28 at 8:20)



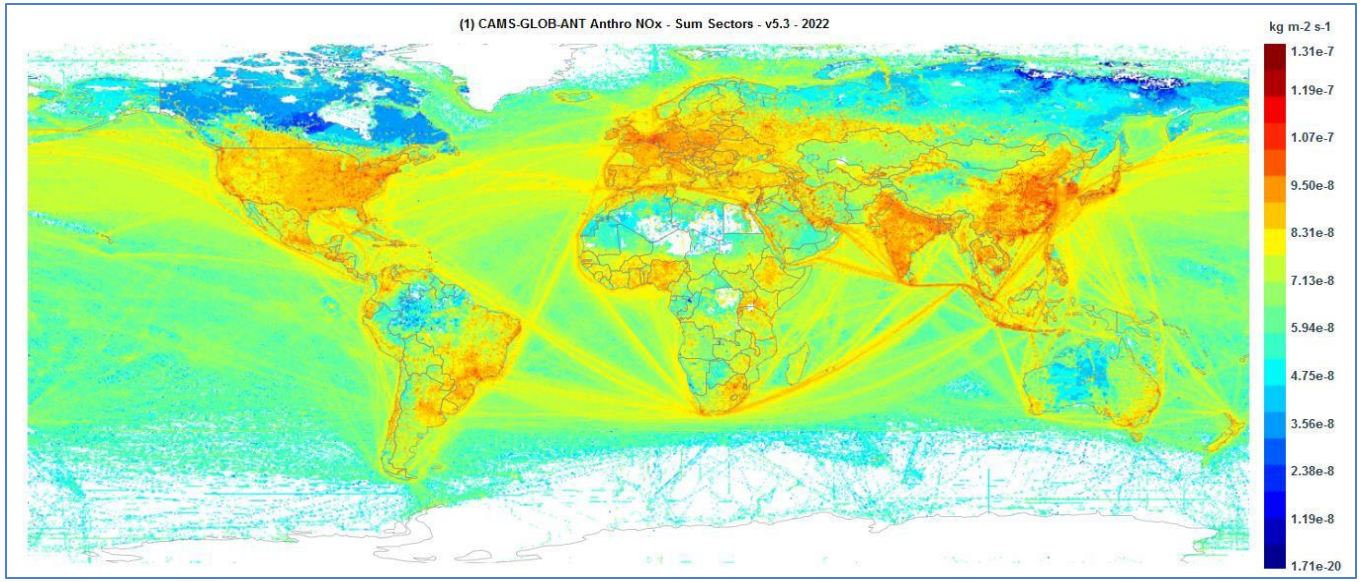
Contribution from each sector to the NOx emissions



Daily SO2 emissions from volcanoes from 2005 to 2020



Daily NOx emissions from ships in the Suez Canal in 2014



NOx anthropogenic emissions in 2022

More information on the CAMS emissions:

Email: Claire.granier@noaa.gov