THE COPERNICUS ATMOSPHERE MONITORING SERVICE (CAMS) EMISSIONS OF GREENHOUSE GASES AND AIR POLLUTANTS

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Abstract: We describe several inventories of emissions of air pollutants and greenhouse gases developed in order to drive the Copernicus Atmosphere Monitoring Service (CAMS) atmospheric models, which provide global and regional air quality forecasts and reanalyses. A global inventory of anthropogenic emissions of air pollutants (including 25 speciated VOCs) and greenhouse gases, as well as a regional inventory of European emissions, have been developed. Global and regional temporal profiles of emissions, based on weather patterns, are also available. The CAMS emissions inventories also include ship emissions based on automatic ships identification systems and adjustment factors to account for COVID-19 lockdowns. Emissions of various compounds from natural sources, i.e. volcanoes, vegetation and soils have also been developed.

Keywords: CAMS, Air pollutants, GHG, Emissions

Résumé : Nous décrivons ici plusieurs inventaires d'émissions de polluants atmosphériques et de gaz à effet de serre développés comme données d'entrée pour les modèles atmosphériques du Service Atmosphérique de Copernicus (Copernicus Atmosphere Monitoring Service: CAMS), qui fournit des prédictions et réanalyses de la qualité de l'air à des échelles globales et régionales. Un inventaire global d'émissions anthropiques de polluants atmosphériques (comprenant 25 VOCs individuels) et de gaz à effet de serre, ainsi qu'un inventaire régional d'émissions européennes, ont étés développés. Des profils temporels d'émissions, basés sur les conditions météorologiques sont également disponibles. Les inventaires d'émissions de CAMS incluent aussi des émissions dues aux bateaux, sur la base du système automatique d'identification de bateaux et des facteurs d'ajustement pour prendre en compte les effets des confinements liés au COVID-19. Des émissions de plusieurs composés issues de sources naturelles, i.e. les volcans, la végétation et les sols ont aussi été développées.

Mots-clefs : CAMS, Polluants atmosphériques, Gaz à effet de serre, Émissions

Introduction

Copernicus, the European Union's Earth observation program (copernicus.eu) includes several services, including the Copernicus Atmosphere Monitoring Service (CAMS, atmosphere.copernicus.eu), CAMS provides regional and global forecasts and reanalysis of the distribution of the major air pollutants and greenhouse gases. Several inventories of emissions were developed to be used as input for these simulations/reanalyses. This paper summarizes the methodology of the development of those inventories, a few results and information on the access to the datasets.

1. Global anthropogenic emissions: CAMS-GLOB-ANT

CAMS-GLOB-ANT is a global inventory of anthropogenic emissions of the main atmospheric pollutants and greenhouse gases: NOx, SO_2, black carbon (BC), organic carbon (OC), NH_3, non-methane volatile organic compounds (NMVOCs) with 25 speciated individual VOCs, CO_2 (excluding/including short cycle), CH_4, N_2O. CAMS-GLOB-ANT provides emissions on a monthly basis at a 0.1x0.1 degree resolution for the 2000-2022 period. 19 sectors of emissions are taken in account.

1.1. General methodology

CAMS-GLOB-ANT is based on a combination of two emissions inventories: EDGARv5 and CEDS.

The EDGAR (Emission Database for Global Atmospheric Research: data.jrc.ec.europa.eu/collection/edgar) inventories provides yearly gridded data for the major atmospheric pollutants and greenhouse gases. We have used version 5 of the EDGAR emissions which are available up to 2015 and version EDGARv4.3.2 for individual VOCs emissions, which are provided up to 2012.

We have also used the CEDS (Community Emissions Data System: www.globalchange.umd.edu/ceds) emissions, which were developed in support of the simulations performed for the 6th IPCC assessment (www.ipcc.ch/report/ar6/wg1/). We have used the version described in McDuffie et al. (2020) and the country data available in the corresponding repository (zenodo.org/record/3754964#.YhSpr98o8_U), which provides total emissions per country and sector up to 2019.

To develop the current version of the CAMS-GLOB-ANT inventory, the EDGArv5 gridded data were extrapolated from 2015 to 2022 by multiplying the emissions for each year starting in 2015 by a factor calculated from the CEDS country data, using the following formula: $e_{t+1} = q.e_t$, where e_t is the emissions on year t and q the growth factor: q = $q = \frac{c_{2019}}{mean(c_{2014 \rightarrow 2019})} \frac{c_{2019}}{mean(c_{2014 \rightarrow 2019})}$ with c_t being the CEDS emissions at year t. This growth factor q is calculated for each country and sectors. The emissions are then gridded on the EDGARv5/CAMS grid (0.1x0.1 degree) and used to extrapolate the emissions up to 2022.

EDGARv5, CEDS and CAMS sectors do not match exactly, so a sector conversion is made before calculating the growth factors for EDGARv5/CEDS sectors correspondence and another conversion is made with the extrapolated data to match CAMS sectors. In some cases, the sectors available in EDGAR and CAMS data are not available in the CEDS data, so the growth factors are calculated using the last years (2013-2015) of EDGAR's emissions.

For now, the CAMS-GLOB-ANT emission do not take into account the changes in emissions related to the COVID-19 lockdowns in 2020. A separate dataset providing adjustment factors for the lockdowns has been developed, it is called: CONFORM (COvid-19 adjustmeNt Factors fOR eMissions) and is described in Doumbia et al. (2021)

An example of the NOx emissions in July 2021 from version 5.3 of the CAMS-GLOB-ANT inventory is shown in Figure 1.

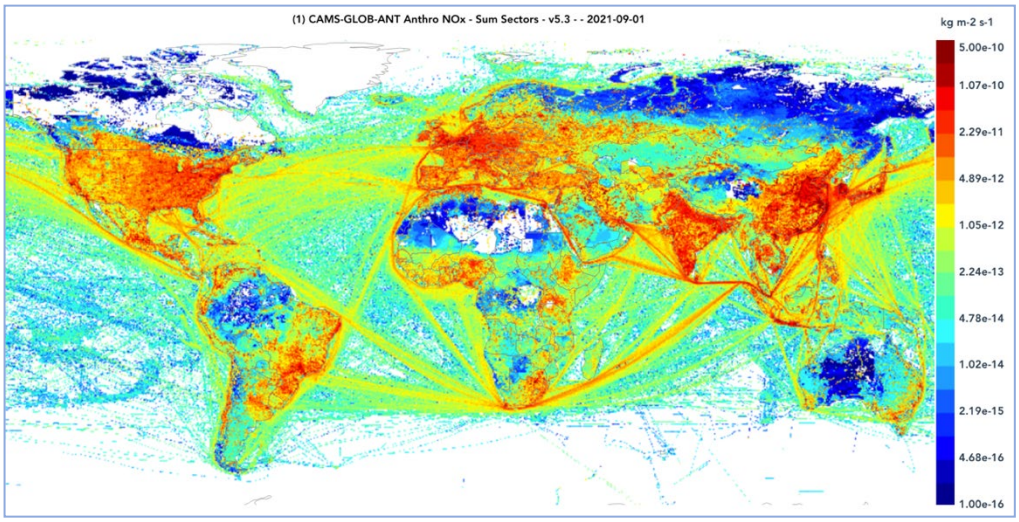

figure 1: NOx emissions (in kg/m2/s) in July 2021 as given by version 5.3 of CAMS-GLOB-ANT

1.2. Individual VOCs

No individual VOCs emissions are present in CEDS or EDGAR inventories. We have used a previous version of EDGAR (EDGARv4.3.2), which provides the emissions of individual VOCs up to 2021. To extrapolate the emissions of each individual VOCs up to 2022, we have applied the growth factor of the total NMVOCs species.

1.3. Temporal variation, ship and aircraft emissions

Aircraft emissions are provided by CAMS-GLOB-AIR. These emissions are based on the CEDS aircraft emission data as described in Hoesly et al. (2018). For the years up to 2014, the emissions are the same as in CEDS. After 2014, we extrapolate in time using the trends calculated for the period 2012-2014. For the speciation of VOCs, the emissions are based on the weights defined by EDGAR for landing and take off (for the first two levels of the atmosphere corresponding to 0.305 km and 0.915 km), and for exhaust (corresponding to the rest of the levels up to 14.945 km). The emission for each individual VOC is calculated by multiplying these weights by the emissions for total VOCs.

The monthly time-step of CAMS-GLOB-ANT was implemented using temporal profiles given by the CAMS-GLOB-TEMPO dataset as described in Section 3. Ships emissions are described in Section 4.

2. European anthropogenic emissions: CAMS-REG

The CAMS-REG anthropogenic emissions (Kuenen et al., 2022) are inventories providing air pollutants and greenhouse gases regional emissions for the European domain. The emissions are given for the 2000-2017 period with a 0.05x0.1 grid resolution. The emissions are based on 2017 national emissions reporting combined with other sources. The main air pollutants are included: NO_x, SO_2, NMVOCs, NH_3, CO, PM_{10} and $PM_{2.5}$, and also CH_4. To stay as close as possible to the emissions as officially reported and used in policy assessment, the inventory uses the officially reported emission data by European countries to the UN Framework Convention on Climate Change, the Convention on Long-Range Transboundary Air Pollution and the EU National Emission Ceilings Directive as the basis where possible. Emissions are collected at the high sectoral level, distinguishing around 250 different sector–fuel combinations, whereafter a consistent spatial distribution is applied for Europe. Along with the resulting annual emission maps, profiles for splitting particulate matter (PM) and NMVOCs into individual components are provided, as well as information on the height profile by sector and temporal disaggregation down to the hourly level to support modelling activities.

3. Temporal profiles: CAMS-GLOB-TEMPO

CAMS-GLOB-TEMPO (Guevara et al., 2021) provides gridded monthly, daily, weekly and hourly weight factors for atmospheric chemistry modelling for the 2000-2017 period. CAMS-GLOB-TEMPO includes temporal profiles for the main air pollutants (NO_x; SO_x; NMVOCs; NH_3; CO; PM_{10}; and $PM_{2.5}$) and the greenhouse gases (CO_2 and CH_4) for each of the following anthropogenic source categories: energy industry (power plants), residential combustion, manufacturing industry, transport (road traffic and air traffic in airports) and agricultural activities (fertilizer use and livestock), ships emissions from CAMS-GLOB-SHIP (see below). The temporal factors take in account weather variations impacts on emissions (from residential heating for example) and human activities, electricity production, traffic counts variations.

4. Ship emissions: CAMS-GLOB-SHIP

CAMS-GLOB-SHIP provides daily emissions from ships, at the global and regional (Europe) scale. The emissions are computed with the Ship Traffic Emissions Assessment Model (STEAM3, Johansson et al., 2017), which combines real-time ship activity data from the Automatic Identification System (AIS) and vessel technical data. The emissions are available with a daily timestep on 0.1x0.1 or 0.005.01 (Europe) degree resolution grids for the 2000-2020 period. It should be noted that the coverage of inland shipping data may be poor, because the use and coverage of AIS in inland waterways is incomplete. For deep sea shipping AIS is mandatory, but for inland shipping it is voluntary.

5. Natural emissions: CAMS-GLOB-OCE, CAMS-GLOB-SOIL, CAMS-GLOB-BIO, CAMS-GLOB-VOLC and CAMS-GLOB-TERM

Within CAMS, natural emissions inventories have also been developed, which provide the emissions of several compounds emitted by the oceans, soils, vegetation and volcanoes.

CAMS-GLOB-OCE provides natural emissions of dimethyl sulfide (DMS), halogens carbonyl sulfide (OCS) and carbonyl disulfide (CS2) from oceans. The methodology and the emissions of OCS and CS2 are described in Lennartz et al. (2021). The CAMS dataset includes the emissions of OCS, DMS and Halogens (bromoform (CHBr3), methyl iodide (CH3I), dibromomethane (CH2Br2)). The emissions are provided with a spatial resolution of 0.5x0.5 or 1x1 degree and cover the 2000 to 2020 period.

CAMS-GLOB-SOIL (Simpson and Darras, 2021) is an inventory of NO emissions from soils, comprising gridded monthly data and the corresponding 3-hourly weight factors, suitable for atmospheric chemistry modelling. Data are provided globally at 0.5° × 0.5°degree horizontal resolution, and with over the period 2000–2018. Emissions are provided as total values and also with separate data for soil NO emissions from background biome values, and those induced by fertilizers/manure, pulsing effects, and atmospheric deposition, so that users can include, exclude or modify each component if wanted.

CAMS-GLOB-BIO (Sindelarova et al., 2022) provides high-resolution global emission inventories of the main biogenic volatile organic compounds (BVOCs) species including isoprene, monoterpenes, sesquiterpenes, methanol, acetone and ethene. Emissions on a monthly and daily basis were calculated by the Model of Emission of Gases and Aerosols from Nature (MEGANv2.1) driven by meteorological reanalyses of the European Centre for Medium-Range Weather Forecasts (ECMWF) for the period of 2000–2019 using ERA5 (both 0.25◦ × 0.25◦ horizontal spatial resolution) meteorology. Furthermore, European isoprene emission potential data were updated using high-resolution land cover maps and detailed information of tree species composition and emission factors from the EMEP MSC-W model system.

Figure 2 displays the global emissions of isoprene for the 2000-2019 period.

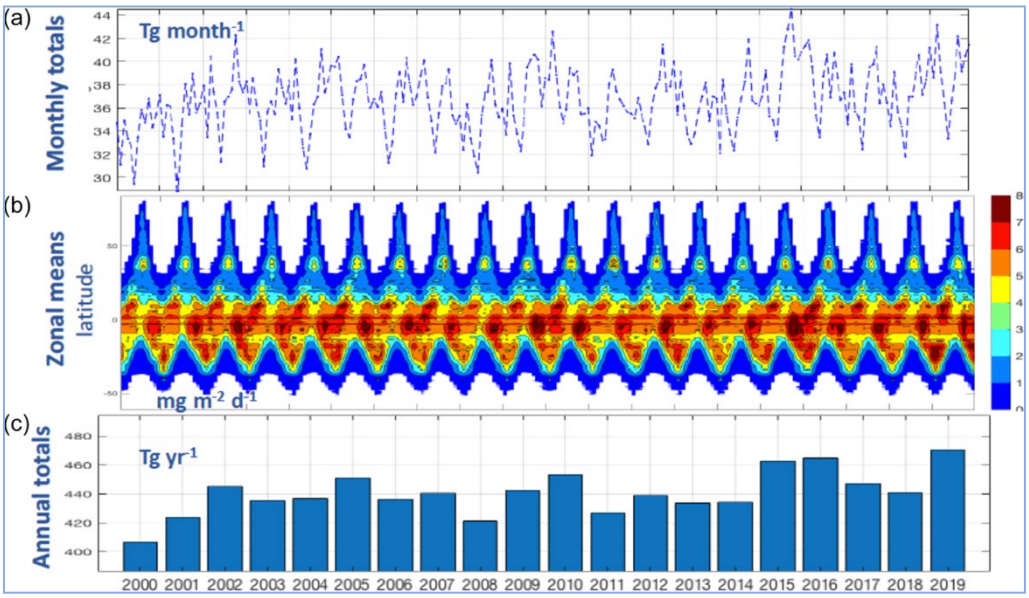

figure 2 : Global monthly totals (a), zonal means (b) and global annual totals (c) of the isoprene emissions for the period of 2000–2019 in the CAMS-GLOB-BIOv3.1 inventory (from Sindelarova et al., 2022)

CAMS-GLOB-VOLC (Arellano et al., 2021) provides the emissions of SO2 from constant degassing volcanoes, based on the compilation of results of homogenized post-analysis of measurements of SO_2 flux and plume parameters obtained during the period March 2005 to January 2017 of 32 volcanoes from the NOVAC (Network for Observation of Volcanic and Atmospheric Change: novac-community.org) network.

CAMS-GLOB-TERM provides emissions of methane from termites. The emissions of CH4 from termite nests were estimated based on the methodology by Sanderson (1996). 11 ecosystems from the Olson vegetation database (Olson et al., 1989) were identified as termite habitats. Each of these ecosystems was assigned termite biomass per m^2 and CH4 emission flux per g of termite and hour. Long-term monthly means of precipitation were used to introduce seasonality based on the observations. More details can be found in Granier et al. (2019).

Conclusion and availability of the emissions data

The Copernicus Atmosphere Monitoring Service provides, in addition of models/reanalysis data, various open-access emissions datasets that can be really useful for a lot of research activities and for modeling. The data are consistent and were carefully checked and evaluated.

The emissions are publicly available on the ECCAD (Emissions of atmospheric Compounds and Compilation of Ancillary Data: ecad.aeris-data.fr). The ECCAD database will be described in details in the conference in the paper by Darras et al.

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