Supplement of Earth Syst. Sci. Data, 16, 501–523, 2024
https://doi.org/10.5194/essd-16-501-2024-supplement

Supplement of

CoCO2-MOSAIC 1.0: a global mosaic of regional, gridded, fossil, and biofuel CO_2 emission inventories

Ruben Urraca et al.

Correspondence to: Ruben Urraca (ruben.urraca-valle@ec.europa.eu)

Table of contents

1 Description of input emission inventories

1.1 Regional emission inventories integrated in CoCO2-MOSAIC 1.0

1.1.1 CAMS-REG-GHG 5.1

The Copernicus Atmosphere Monitoring Service (CAMS) has been providing consistent estimations of anthropogenic emissions over Europe since 2009, from the former TNO-MAC series to the current CAMS-GLOB-ANT and CAMS-REG inventories. CAMS datasets cover both air pollutants and greenhouse gases. The global mosaic uses CAMS-REG-GHG 5.1, which provides CH_4, CO_2ff, CO_2bf gridded emissions over Europe [30° to 72°N, -30° to 60°E] during 2000-2018 (version 5.1) (Kuenen et al., 2022). Annual CO_2 emissions are calculated at country level for each of the 209 source categories. These values are based on the emissions officially reported by European countries in their national inventories. The IIASA GAINS model is used to fill gaps or replace low quality data. EDGAR 4.3.2 emission gridmaps of (Janssens-Maenhout et al., 2019) are used in countries outside UNECE-Europe but still within the bounding box of CAMS-REG (e.g., North African countries). Emissions are spatially allocated using proxy datasets such as traffic intensity, road network, CORINE land cover, population density, or power plant list, among others, as specified in (Kuenen et al., 2022). The 209 emission categories are aggregated into the Gridded Nomenclature For Reporting (GNFR) sectors. More details on the sector classification can be found at https://www.ceip.at/reporting-instructions. CAMS-REG-GHG 5.1 is freely available at ECCAD (https://eccad3.sedoo.fr/) For CoCO2-MOSAIC 1.0, we used a specific version prepared by the CAMS team re-arranging some GNFR sectors to match better the CoCO2-MOSAIC sectors (Table S1).

Table S1: Description of CAMS-REG-GHG 5.1 sectors

Sector	Comments
A_PublicPower	
B_Industry	For this version, 1A1b and 1A1c were moved to D_Fugitives
C_OhterStationaryComb	-
D_Fugitives	-
E_Solvents	-
F1_RoadTransport_Exhaust_Gasoline	-
F2_RoadTransport_Exhaust_Diesel	-
F3_RoadTransport_Exhaust_LPG_gas	-
F4_RoadTransport_NonExhaust	-
G_Shipping	Only inland shipping
H_Aviation	Only Landing and Take-off cycles (LTO) in airports
I_OffRoad	-
J_Waste	Waste incineration with energy recovery has been already moved to

	A_PublicPower
K_AgriLivestock	Sector discarded, as it does not produce CO_2 emissions.
L_AgriOther	-

1.1.2 DACCIWA 2.0

The DACCIWA project develops an inventory of gridded anthropogenic emissions for Africa. The first version, DACCIWA 1.0 (Keita et al., 2021), provided emissions from atmospheric pollutants (BC, OC, CO, NO_X, SO_2 and NMVOCs) considering only combustion sources. Within the framework of CoCO2 Task 2.1, a new DACCIWA 2.0 inventory has been developed covering CO_2ff, CO_2bf and CH_4, and considering other anthropogenic sources (e.g., fugitive emissions) in addition to fossil fuel combustion. The inventory provides annual emissions from 2015 to 2018 at 0.1°×0.1°. Activity data come primarily from the United Nations Statistics Division (UNSTAT) database (http://data.un.org/Explorer.aspx). CO_2 emission factors derived from field measurements (Keita et al., 2018) were used for residential, commercial, road transport and open waste burning. The CH_4 emission factors from (Akagi et al., 2011), for charcoal making and solid waste burning, and from (Doumbia et al., 2019), for gas flaring, are used. The default emission factors from IPCC (2006) were used for other sources. Emissions were spatially allocated using population density, road network and African power plant network given by the Africa infrastructure (https://powerafrica.opendataforafrica.org). DACCIWA 2.0 aggregates the emissions in the same seven group of sectors that those defined for CoCO2-MOSAIC 1.0. DACCIWA 2.0 is freely available at ECCAD: https://eccad3.sedoo.fr/.

1.1.3 GEAA-AEI 3.0

The Research Group for Atmospheric and Environmental Studies (GEAA) produces the Argentine Emission Inventory (GEAA-AEI), which provides monthly gridded emissions of 12 air pollutants and GHGs (CO_2, CH_4, N_2O) from 1955 to 2020 (version 3.0) (Puliafito et al., 2021). The inventory is calculated following a bottom-up approach as follows: (i) geolocation of emission sources, (ii) identification of the activity data for each source and sector, (iii) development of a consistent monthly evolution, (iv) application of emission factors, (v) production of the raster files. GEAA-AEI 3.0 is freely available at https://doi.org/10.17632/d6xrhpmzdp.2. For this mosaic, the GEAA team prepared a specific version splitting CO_2 emissions in CO_2ff and CO_2bf, and rearranging some sectors to match better the description of the mosaic sectors (Table S2).

Table S2: Description of GEAA-AEI 3.0 sectors

Sector	Description	IPCC code	Point source
CEN	Thermal power plants	1A1a	yes
WAS	Open urban waste burning	4C	yes
IND_FUE	Industrial own fuel consumption	1A2	no
IND_PRO	Industrial production	2B, 2C	yes
COM	Commercial	1A4a	no

GOV	Governmental	1A4a	no
RES	Residential	1A4b	no
FAG	Fuel use in agriculture	1A4c	no
AVI	National aviation, only LTO (< 390m)	1A3a	no
VEH	Vehicular road transport	1A3b	no
TRE	Railroad	1A3c	no
BAR	Coastal-fluvial navigation (only national bunker)	1A3d	no

1.1.4 INEMA 1.0

The Inventario Nacional de Emisiones Antropogénicas (INEMA v1.0) (Álamos et al., 2022) is the first Chilean gridded emission inventory of anthropogenic emissions of air pollutants (NOx, SO_2, CO, VOCs, NH_3, PM10, PM2.5, and BC) and GHGs (CO_2, CH_4). INEMA provides annual gridded (0.01°×0.01°) emissions for the inventory years 2015 to 2017 disaggregated into five different sectors. In the energy, industry, and mining sectors, point emissions self-reported by Chilean industrial facilities to the Registro de Emisiones y Transporte de Contaminantes (RETC, https://retc.mma.gob.cl) are used. In residential and transport sectors, emissions are calculated as non-point sources based on firewood consumption and number of vehicles. Possibly some gas or oil use emissions are missing which especially for air pollutants are assumed to be of minor importance. The spatial allocation of residential and transport emissions is made based on population density and the road network, respectively, as described by Alamos et al. (2022). The current version of the inventory does not split CO_2ff and CO_2bf. Energy, mining and industry sectors report the sum of CO_2ff and CO_2bf, the residential sector only includes CO_2bf from firewood consumption, and the transport sector only reports CO_2ff emissions (Table S3). INEMA 1.0 is freely available at https://doi.org/10.5281/zenodo.4784286.

Table S3: Description of INEMA 1.0 sectors

Sector	CO_2	Description	IPCC code
Energy	CO_2ff + CO_2bf	RTEC point sources: production and distribution of fuels and the generation of electric energy.	1A1
Mining	CO_2ff + CO_2bf	RTEC point sources: Production and smelting of metals	2C1-4
Industry	CO_2ff + CO_2bf	RTEC point sources: remaining point sources outside the ‘Energy’ and ‘Mining’ sectors.	1A2, 2* (excluding 2C)
Residential	CO_2bf	Combustion of biomass for heating, cooking, and heating water.	1A4b
Transport	CO_2ff	Exhaust emissions from vehicles traveling on public routes nationwide in urban and interurban area. Rail, air, and sea modes are not included, nor are off-road machinery.	1A3b

1.1.5 REAS 3.2.1

The Regional Emission inventory in ASia (REAS) series provides long-term emissions from major anthropogenic air and climate pollutants over East, South and South-East Asia (E, SE and S Asia). The latest version available is REAS v3.2.1 (Kurokawa and Ohara, 2020), a long-term (1950-2015) gridded inventory that provides monthly emissions of SO_2, NO_x, CO, NMVOCs, NH_3, PM10, PM2.5, BC, OC, CO_2ff, CO_2bf.. REAS v3 is produced following a bottom-up approach. Annual activity data at country level are collected from different international and national statistics and national emission inventories. Emissions factors from research papers and from national inventories are used. Annual emissions per country are spatially allocated with proxy datasets such as HYDE 3.2.1 total population gridmaps (residential sector) or EDGAR 4.3.2 transport emission gridmaps (transport sector). The position of industry and power plant emissions was checked manually and with global databases, and large power plants were made available as point sources. Monthly emissions were estimated also using proxy datasets such as monthly energy production statistics, monthly industrial production statistics, or monthly surface temperature. Table S4 shows the sectors available for CO_2. The emissions are split in CO_2ff and CO_2bf, but some sectors only report CO_2ff emissions.

Table S4: Description of REAS 3.2.1 sectors

Sector	Description	CO_2
POWER_PLANTS_POINT	Power and heat plants as point sources.	CO_2ff
POWER_PLANTS_NON-POINT	Power and heat plants as non-point sources	CO_2ff, CO_2bf
INDUSTRY	Industry (emissions both from fuel combustion and industrial processes)	CO_2ff, CO_2bf
DOMESTIC	Residential, commerce and public services, agricultural equipment, and others (fishing is not included)	CO_2ff, CO_2bf
ROAD_TRANSPORT	Road transport (cars, buses, trucks, motorcycles, and other on-road vehicles)	CO_2ff
OTHER_TRANSPORT	Railway, and other off-road transports (navigation is not included)	CO_2ff

1.1.6 VULCAN 3.0

The Vulcan Project provides a gridded inventory of anthropogenic CO_2 emissions from fossil fuel combustion and cement production inside the USA. VULCAN 3.0 (Gurney et al., 2020) is the last version available and estimates CO_2ff emissions at 1×1km and hourly resolution from 2010 to 2015. The current VULCAN version does not include CO_2bf emissions (CO_2bf will be added in the upcoming v4.0). CO_2 emissions are estimated at the native spatial-temporal resolution of emission points, lines and polygons depending on the characteristics of the input data sources. Additional spatial and temporal distribution (downscaling, interpolation, proxy surrogates) are needed to achieve hourly resolution for six complete calendar years (2010–2015) at the spatial resolutions of a USA Census block-group or finer (e.g., points, lines) and at 10 different sectors (Table S5). The inventory includes the expanded uncertainty (coverage probability of 95%) of the CO_2 emissions at pixel level. VULCAN v3.0 is freely available at NASA's Land Process Distributed Active Archive Center (DAAC): https://doi.org/10.3334/ORNLDAAC/1741

Table S5: Description of VULCAN 3.0 sectors

Sectors	Description/Comments
Electricity production	15566 electricity production facilities, all geolocated to its physical location.
Industrial	Non-point source derived from the USA National GHG Inventory (NGHGI), spatially distributed using total building area and energy use intensity (EUI). Point sources geolocated to each individual facility.
Cement	Geolocated to each individual facility.
Commercial	Non-point source derived from USA NGHGI, spatially distributed using total building area and energy use intensity. Point sources geolocated to each individual facility.

Residential	Non-point source derived from USA NGHGI, spatially distributed using total building area and energy use intensity.
On road	Derived from USA NGHGI, distributed in space and time using traffic data.
Nonroad	Mobile sources travelling off-road except locomotives, airplanes and CMVs
Commercial Marine Vessels (CMV)	Manoeuvring, hoteling, cruise, and reduced speed zone travel and are specific to geographically located ports and shipping lanes that extend 12 nautical miles from the shoreline
Airport	Taxi & take-off/landing sequences up to 3000" (927 m).
Rail	Emissions from diesel-powered locomotives, distributed in space using freight data.

1.2 Global emission inventories used for gap-filling

1.2.1 EDGAR 6.0

EDGAR is a global gridded emission inventory providing anthropogenic emissions of GHGs (CO_2ff, CO_2bf, CH_4, N_2O, F-gases) and air pollutants from 1970 to 2018 (version 6.0) (Crippa et al., 2021). Emissions of each species are calculated at country level per sector and year using country specific activity data and emission factors. Emissions are spatially allocated using proxy datasets that may vary over time such as the location of energy and manufacturing facilities, road networks, shipping routes, human and animal population density and agricultural land use, among others. Year-to-year variations are modelled using international annual statistics. Finally, monthly profiles are derived with specific proxy data for each sector and country/region. CO_2 emissions are available separately for CO_2ff (*CO2_excl_short-cycle_org_C*) and CO_2bf (*CO2_org_short-cycle_C*) at 21 categories. EDGAR categories are the basis of the CoCO2-MOSAIC sectors and are fully described in Table 3. EDGAR 6.0 is freely available at https://edgar.jrc.ec.europa.eu/dataset_ghg60.

1.2.2 CAMS-GLOB-SHIP 3.1

CAMS-GLOB-SHIP (Jalkanen et al., 2016; Granier et al., 2019) provides shipping emissions globally from 2000 to 2018 for NO_x, SO_x, CO, CO_2, VOC, EC, OC, ash and SO_4. The emissions are estimated by combining (i) global ship activity recorded in Automatic Identification Systems (AIS), (ii) data for vessel technical description, and (iii) the Ship Traffic Emission Assessment Model (STEAM developed by the Finnish Meteorological Institute (FMI) (Jalkanen et al., 2016; Johansson et al., 2017). Shipping emissions are provided separately for sea areas and inland waters (Table S6). CAMS-GLOB-SHIP 3.1 is available at the Copernicus Atmosphere Data Store: https://ads.atmosphere.copernicus.eu/cdsapp#!/home.

Table S6 Description of CAMS-GLOB-SHIP 3.1 categories

Sector	Description
sea	Ships at sea areas
inland	Ship at inland waters

1.2.3 CAMS-GLOB-TEMPO 3.1

CAMS-TEMPO (Guevara et al., 2021) dataset provides monthly, weekly, daily, and hourly temporal profiles for air pollutants (NO_x, SO_x, NMVOC, NH_3, CO, PM10, PM2.5) and GHGs (CO_2 and CH_4). Two versions are available: CAMS-GLOB-TEMPO at global scale and CAMS-REG-TEMPO at European level, matching the spatial coverage and resolution of CAMS-GLOB-ANT and CAMS-REG inventories, respectively. The temporal profiles are normalized weight factors for each hour, day of the week, and month of the year for each sector and species. Temporal profiles can also vary spatially (per country or grid cell) and/or temporally (from year to year) depending on the input data availability for the species and the temporal resolution considered. The temporal weight factors are calculated by combining national and local statistical information linked to emission variability (e.g., electricity statistics, traffic activity) and existing meteorology-dependent parametrizations to account for the influences of sociodemographic factors and climatological conditions. For the CoCO2-MOSAIC, the monthly weight factors were used (Table S7).

Table S7: CAMS-GLOB-TEMPO 3.1 monthly factors

Sector	Spatial resolution	Year dependent	Pollutant dependent
Energy industry	Country	no	yes
Residential/commercial	Gridded	yes	no
Manufacturing industry	Country	no	no
Road transport	Gridded	no	no
Agriculture – NH3/NOx	Gridded	yes	-
Agriculture – other	Fixed	no	-

1.2.4 Gap-filling strategy

Table S8: Gap-filling missing sectors.

Inventory	Sector	Methodology
INEMA 1.0	Energy, mining & residential	CO_2ff and CO_2bf were reported together and the exact contribution of each component was not available. The INEMA team calculated the CO_2ff / CO_2bf fraction per sector and Chilean region (16 in total) based on annual emissions from the Registro de Emisiones y Transporte de Contaminantes (RETC). Then, CO_2ff and CO_2bf emissions were split by applying the regional rations at pixel level.
	Solid waste incineration	CO_2ff and CO_2bf emissions are not included. Based on EDGAR 6.0, they can be neglected (<0.1% of energy emissions).
	Residential	INEMA only reports CO_2bf from wood combustion. CO_2ff was gap-filled with EDGAR 6.0 due to its significant contribution in total settlements emissions (~30%)
	Transport	INEMA only reports CO_2ff. The contribution of CO_2bf transport emissions over Chile is less than 0.1% based on EDGAR 6.0, so CO_2bf transport emissions were neglected.
REAS 3.2.1	Solid waste incineration	CO_2ff and CO_2bf emissions not included. Based on EDGAR 6.0, they are around 3% of total energy emissions, so they were gap-filled with EDGAR 6.0 SWD_INC
	Shipping & aviation	CO_2 emissions were missing in both sectors. They were gap-filled with the global default inventory.
	Road transport	REAS only provides CO_2ff emissions for the transport sector (ROAD_TRANSPORT + OTHER_TRANSPORT). The overall contribution of CO_2bf for 'road transport' over all REAS countries is around 1%, reaching a 7% in Thailand and Philippines according to EDGAR 6.0. Thus, road transport CO_2bf emissions were gap-filled with EDGAR 6.0.
VULCAN 3.0	Solid waste incineration	CO_2ff emissions not included. Based on, EDGAR 6.0 they are negligible (<0.1% of energy emissions).
	CO_2bf (all)	CO_2bf emissions were missing in all the sectors. We gap-filled all the sectors except 'other' with EDGAR 6.0

1.3 Global emission inventories for the inter-comparison

1.3.1 CAMS-GLOB-ANT 5.3

CAMS-GLOB-ANT 5.3 provides anthropogenic emissions of CO_2ff, CO_2bf, CH_4, N_2O, CO, NO_x, SO_2, NH_3, BC, OC, NMVOCs and 24 individual VOCs globally from 2000 to 2020 (Granier et al., 2019; Soulie et al., 2023). CAMS global emissions are based on EDGAR 5.0 from 2000-2015. They are extrapolated to the current year using CEDS v2021_04_21 emissions trends during 2014-2019. The emissions are available at 17 different sectors (Table S8). The inventory includes CAMS-GLOB-SHIP 3.1 shipping emissions, and CAMS-GLOB-TEMPO 3.1 temporal profiles. The combination of CAMS-GLOB-ANT 5.3 with DACCIWA 2.0 is the so called CoCO2-PED 2018, i.e., the standard bottom-up inventory used as prior information for CoCO2 global inversions.

Table S9: Description of CAMS-GLOB-ANT 5.3 sectors for CO_2.

Sector	Name	IPCC sector
ags	Agricultural soils	Agricultural soils
ene	Power generation	Energy industry
fef	Fugitives	Fuel exploitation
ind	Industrial process	Iron and Steel production Aluminium, magnesium and steel production Non-energy use of fuel Non-metallic mineral processes
ref	Refineries	Oil refineries and transportation
res	Residential and other sectors	Residential and other sectors
shp	Ships	Ships
slv	Solvents	Solvents production and application
swd	Solid waste and waste water	Waste incineration
tnr	Off road transportation	Non-road ground transportation
tro	Road transportation	Road transportation

1.3.2 CEDS v2021_04_21

The Community Emissions Data System (CEDS) produces consistent estimates of global air emissions species (BC, CH_4, CO, CO_2, N_2O, NH_3, NMVOC, NO_x, OC, SO_2, VOCs) over the industrial era (1750-present). CEDS emissions are obtained with the bottom-up approach described at (Hoesly et al., 2018; McDuffie et al., 2020). First, the default emissions are estimated at country level per year, compound and sector (55 in total). Sectors are classified into (i) fuel combustion and (ii) process sources. In fuel-combustion sources, nine fuels are defined. Activity data is collected from international bodies, mainly International Energy Agency (IEA) energy statistics, and ODIAC emission factors are applied for CO_2. For process sources, EDGAR emissions are directly taken. However, the implicit emissions factors are estimated to extend the emissions spatially and temporally by using activity data such as HYDE or UN population datasets, or pulp and paper consumption. Second, the default emissions at country level are scaled to match the total emissions of national inventories. Third, the emissions are disaggregated spatially, using mainly EDGAR 5.0 spatial proxies, and temporally, using ECLIPSE monthly weight factors for all sectors except for shipping (EDGAR based). Finally, the emissions are aggregated into the nine final sectors (Table S9). The last release (CEDS_v2021_04_21) provides gridded emissions at 0.5˚×0.5˚ and 0.1˚×0.1˚ (produced by downscaling the 0.5˚×0.5˚dataset using EDGAR as spatial proxies). Aviation emissions are only available in the 0.5˚×0.5˚ dataset. Both datasets include only CO_2ff emissions.

CEDS_v2021_04_21 is available at: https://data.pnnl.gov/dataset/CEDS-4-21-21

Table S10: Description of CEDS v2021_04_21 sectors. (c) and (p) stand for combustion and process sector, respectively.

Sector	Description & NFR14 code	Sector	Description & NFR14 code
0: Agriculture	Agriculture • 3B_Manure-management (p) • 3D_Soil-emissions (p) • 3I_Agriculture-other (p) • 3D_Rice-Cultivation (p) • 3E_Enteric-fermentation (p)	4: Residential, commercial, other	Res., Comm., Other – Residential • 1A4b_Residential (c) Res., Comm., Other – Commercial • 1A4a_Commercial-institutional (c) Res., Comm., Other – Other • 1A4c_Agriculture-forestry-fishing (c)
1: Energy	Electricity and heat production • 1A1a_Electricity-public (c) • 1A1a_Electricity-autoproducer (c) • 1A1a_Heat-production (c) Fuel Production & Transformation • 1A1bc_Other-transformation (p) • 1B1_Fugitive-solid-fuels (p) Oil and Gas Fugitive/Flaring • 1B2_Fugitive-petr-and-gas (p) Fuel Production and Transformation c • 1B2d_Fugitive-other-energy (p) Fossil Fuel Fires • 7A_Fossil-fuel-fires (p)	5: Solvents production and application	Solvents production and application • 2D_Degreasing-Cleaning (p) • 2D3_Other-product-use (p) • 2D_Paint-application (p) • 2D3_ Chemical-products-manufacture-processing (p)
2: Industry	Industrial combustion • 1A2a_Ind-Comb-Iron-steel (c) • 1A2b_Ind-Comb-Non-ferrous-metals (c) • 1A2c_Ind-Comb-Chemicals (c) • 1A2d_Ind-Comb-Pulp-paper (c) • 1A2e_Ind-Comb-Food-tobacco (c)	6: Waste	Waste • 5A_Solid-waste-disposal (p) • 5E_Other-waste-handling (p) • 5C_Waste-incineration (p) • 5D_Wastewater-handling (p)

	• 1A2f_Ind-Comb-Non-metallic-minerals (c) • 1A2g_Ind-Comb-Construction (c) • 1A2g_Ind-Comb-transpequip (c) • 1A2g_Ind-Comb-machinery (c) • 1A2g_Ind-Comb-mining-quarrying • 1A2g_Ind-Comb-wood-products • 1A2g_Ind-Comb-textile-leather • 1A2g_Ind-Comb-other (c) • 1A5_Other-unspecified (c) Industrial process and product use • 2A1_Cement-production (p) • 2A2_Lime-production (p) • 2A6_Other-minerals (p) • 2B_Chemical-industry (p) • 2C_Metal-production (p) • 2H_Pulp-and-paper-food-beverage-wood (p) • 2L_Other-process-emissions (p) • 6A_Other-in-total (p)		
3: Transportation	Road transportation • 1A3b_Road (c) Non-road Transportation • 1A3c_Rail (c) • 1A3dii_Domestic-navigation (c) • 1A3eii_Other-transp (c)	7: International shipping	International shipping • 1A3di_International-shipping (c) Tanker Loading • 1A3di_Oil_Tanker_Loading (p)

1.3.3 ODIAC v2020b

The Open-source Data Inventory for Anthropogenic CO_2 (ODIAC) version 2020b provides CO_2ff emissions at 1˚×1˚ and 1/120˚×1/120˚ (~1 km) resolution (Oda et al., 2018). ODIAC emissions are based on CDIAC CO_2ff national emissions by fuel type. First, CDIAC emissions are mapped into the extended ODIAC emission categories: point, non-point sources, cement production, and international aviation and marine bunkers. Then CDIAC national emissions are disaggregated spatially and temporally. The spatial disaggregation is based on (i) power plant profiles from the CARMA database, for point sources, (ii) DMSP night-time light data, for non-point sources and cement production, (iii) night-time light-based gas flare maps, for gas flaring, and (iv) aircraft and ship fleet track, for international aviation & marine bunker. Finally, emissions are temporally disaggregated using CDIAC monthly gridded emissions. ODIAC are not disaggregated per sectors except for international aviation and marine bunker emissions, which are provided separately and only at 1˚×1˚. ODIAC inventories are available at https://db.cger.nies.go.jp/dataset/ODIAC/

1.3.4 CAMS-GLOB-AIR 1.1

CAMS-GLOB-AIR 1.1 (Granier et al., 2019) provides aircraft emissions (national and international) of different species including CO_2 at 0.5˚×0.5˚ for 25 altitude levels (from 305m to 14.945m). CAMS-GLOB-AIR 1.1 emissions are the same as CEDS aircraft emissions described in (Hoesly et al., 2018) up to 2014. Since then, they are extrapolated using the trends calculated for the period 2012-2014.

2 IEA definition of biofuel

IEA definition to identify what belongs to the second category of "biofuel" that generate CO2bf:

Biofuels: Biofuels cover bioethanol, biodiesel, bio-methanol, bio-dimethylether, bio-oil. Liquid biofuels are mainly biodiesel and bioethanol/ETBE used as transport fuels. They can be made from new or used vegetable oils and may be blended with or replace petroleum-based fuels. The natural plant feedstock includes soya, sunflower, and oil seed rape oils. Under some circumstances, used vegetable oils may also be used as feedstock for the process.

Biogas: A gas composed principally of methane and carbon dioxide produced by anaerobic digestion of biomass, comprising

- Landfill gas, formed by the digestion of landfilled wastes.
- Sewage sludge gas, produced from the anaerobic fermentation of sewage sludge.
- Other biogas, such as biogas produced from the anaerobic fermentation of animal slurries and of wastes in abattoirs, breweries, and other agro-food industries.

Black liquor: This is a recycled by-product formed during the pulping of wood in the paper making industry. In this process, lignin in the wood is separated from cellulose, with the latter forming the paper fibres. Black liquor is the combination of the lignin residue with water and the chemicals used for the extraction of the lignin and is burned in a recovery boiler. The boiler produces steam and electricity and recovers the inorganic chemicals for recycling throughout the process.

Peat (and peat briquettes): Combustible soft, porous, or compressed, fossil sedimentary deposit of vegetal origin with high water content (up to 90% in the raw state), easily cut, of light to dark brown colour. Only peat used for energy purposes should be reported.

Solid biomass: Covers organic, non-fossil material of biological origin which maybe used as fuel for heat production or electricity generation. It comprises:

- Charcoal: Covers the solid residue of the destructive distillation and pyrolysis of wood and other vegetal material
- Wood, wood wastes, other solid wastes: Covers purpose-grown energy crops (poplar, willow, etc.), a multitude of woody materials generated by an industrial process (wood/paper industry in particular) or provided directly by forestry and agriculture (firewood, wood chips, bark, sawdust, shavings, chips, black liquor, etc.) as well as wastes such as straw, rice husks, nut shells, poultry litter, crushed grape dregs, etc. Combustion is the preferred technology for these solid wastes. The quantity of fuel used should be reported on a net calorific value basis.

3 CoCO2-MOSAIC 1.0 description

3.1 File structure and format description

```
CoCO2-MOSAIC-v1.0
    |- CoCO2-MOSAIC-v1.0_01x01_1M_2015_CO2ff.nc
    |- CoCO2-MOSAIC-v1.0_01x01_1M_2015_CO2bf.nc
    |- CoCO2-MOSAIC-v1.0_01x01_1M_2015_CO2ff_AIR.nc
    |- metadata.csv
```

Figure S1: File structure (example for 2015 files)

Table S11: Summary of the main CoCO2-MOSAIC 1.0 file

Product family	anthropogenic emissions
Species	CO2ff, CO2bf
Spatial coverage	global
Temporal coverage	2015, 2016, 2017, 2018
Spatial resolution	0.1° × 0.1°
Temporal resolution	monthly
Sectors	energy_s energy_a manufacturing settlements transport aviation other
Source inventories	0: default inventory (EDGAR v6.0/CAMS-GLOB-SHIP v3.1) 1: CAMS-REG-GHG v5.1 2: DACCIWA v2.0 3: GEAA-AEI v3.0 4: INEMA v1.0 5: REAS v3.2.1 6: VULCAN v3.0
Data format	NetCDF

Table S12: Description of the NetCDF data layers of the main file (CO_2ff and CO_2bf emissions)

Layer	Dimensions	Units	Data type	Fill value	Description
mask_country	[lat, lon]	-	int16	-	Country ISO numeric code (3-digit). Regions defined under conflict by EUROSTAT 2020 don't have an ISO Code, so a 4-digit code was assigned (see metadata.csv)
mask_inventory	[lat, lon]	-	int8	-	Numerical ID of the inventory. Attributes. - *flag_value*: inventory numerical ID - *flag_meaning*: inventory name - *flag_year*: inventory year
cell_area	[lat, lon]	m^2	float64	-	Area of each grid cell.
energy_s	[time, lat, lon]	$kg/m^2/s$	float32	-1e30	Emission flux in the energy_s sector.
energy_a	[time, lat, lon]	$kg/m^2/s$	float32	-1e30	Emission flux in the energy_a sector.
manufacturing	[time, lat, lon]	$kg/m^2/s$	float32	-1e30	Emission flux in the manufacturing sector.
settlements	[time, lat, lon]	$kg/m^2/s$	float32	-1e30	Emission flux in the settlements sector.
transport	[time, lat, lon]	$kg/m^2/s$	float32	-1e30	Emission flux in the transport sector.
aviation	[time, lat, lon]	$kg/m^2/s$	float32	-1e30	Emission flux in the aviation sector.
other	[time, lat, lon]	$kg/m^2/s$	float32	-1e30	Emission flux in the other sector.

3.2 Country mask

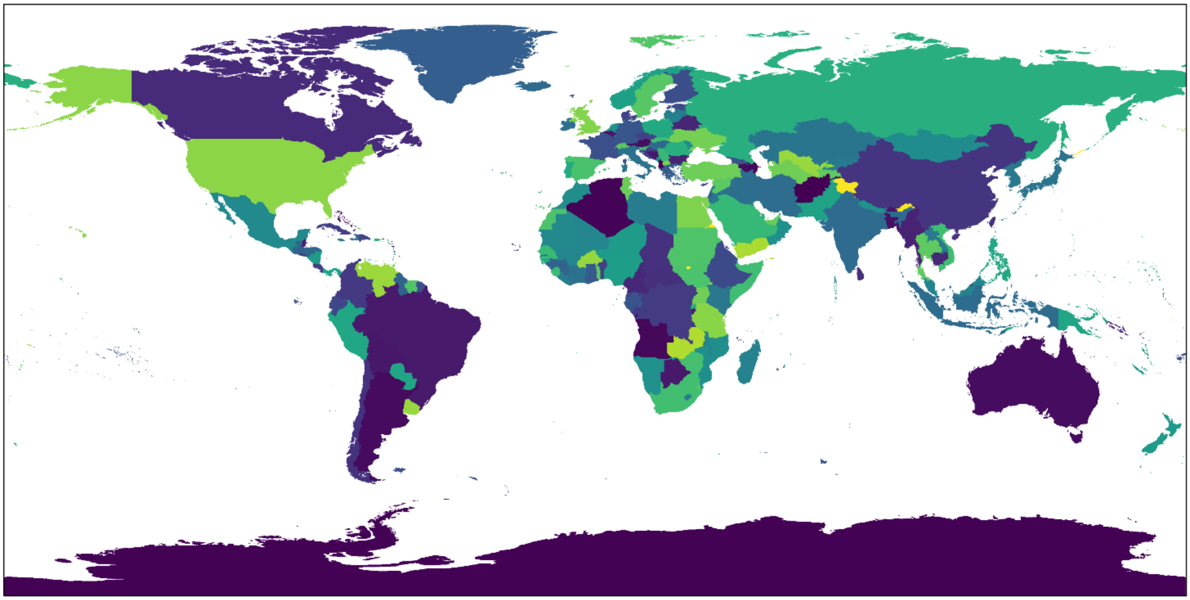


Figure S2: Country mask of CoCO2-MOSAIC 1.0 (*mask_country*)

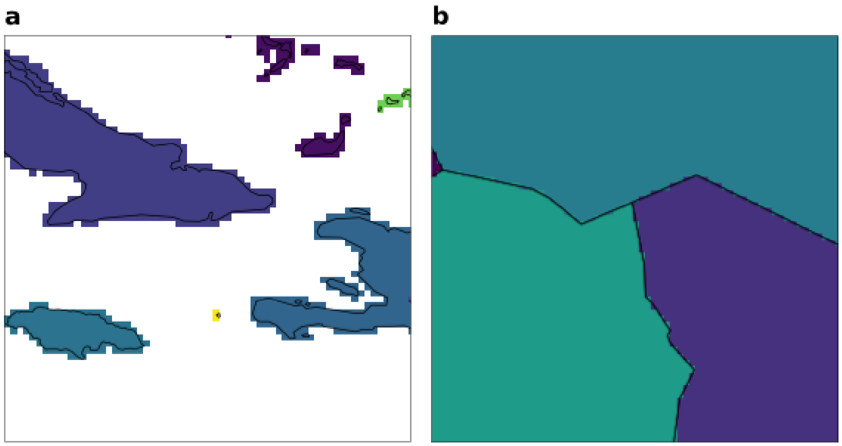


Figure S3 Masking procedure applied at (a) coastal pixels and (b) borders between countries.

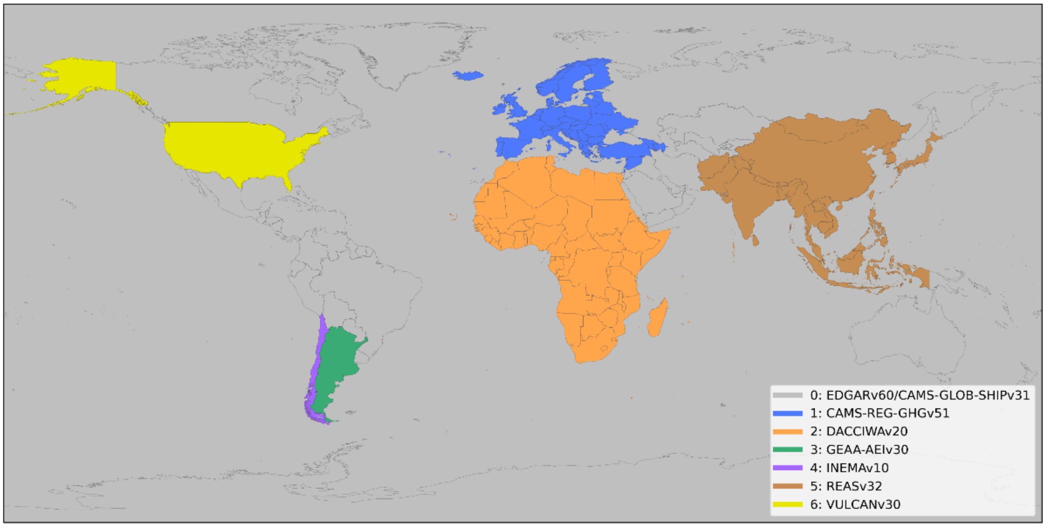


Figure S4 Inventory mask of CoCO2-MOSAIC 1.0.

Table S13: Description of countries covered by each regional inventory

Inventory ID	**Inventory name**	**Countries**
1	CAMS-REG-GHG 5.1	ALB, ARM, AUT, AZE, BEL, BGR, BIH, BLR, CHE, CYP, CZE, DEU, DNK, ESP, EST, FIN, FRA, GBR, GEO, GRC, HRV, HUN, IRL, ISL, ITA, KOS, LTU, LUX, LVA, MDA, MKD, MLT, MNE, NLD, NOR, POL, PRT, ROU, SRB, SVK, SVN, SWE, TUR, UKR, LBN, PSE, SYR
2	DACCIWA 2.0	DZA, AGO, BEN, BWA, BFA, BDI, CMR, CPV, CAF, TCD, COM, COG, COD, CIV, DJI, EGY, GNQ, ERI, ETH, GAB, GMB, GHA, GIN, GNB, KEN, LSO, LBR, LBY, MDG, MLI, MWI, MRT, MUS, MYT, MAR, MOZ, NAM, NER, NGA, REU, RWA, STP, SEN, SYC, SLE, SOM, ZAF, SSD, SDN, SWZ, TZA, TGO, TUN, UGA, ESH, ZMB, ZWE, XF, XG, XO, XU, XV
3	GEAA-AEI 3.0	ARG
4	IENEMA 1.0	CHL
5	REAS 3.2.1	MNG, KOR, PRK, JPN, CHN, PHL, IDN, TWN, BRN, SGP, MYS, IND, KHM, VNM, LAO, THA, MMR, BTN, BGD, NPL, LKA, MDV, PAK, AFG, TLS, XH, XA, XB, XC, XD, XE, XM, XN
6	VULCAN 1.0	USA
0	EDGAR 6.0 (default)	All countries not covered by regional inventories, and sea pixels. Sea pixels are masked as -1 in mask_country.

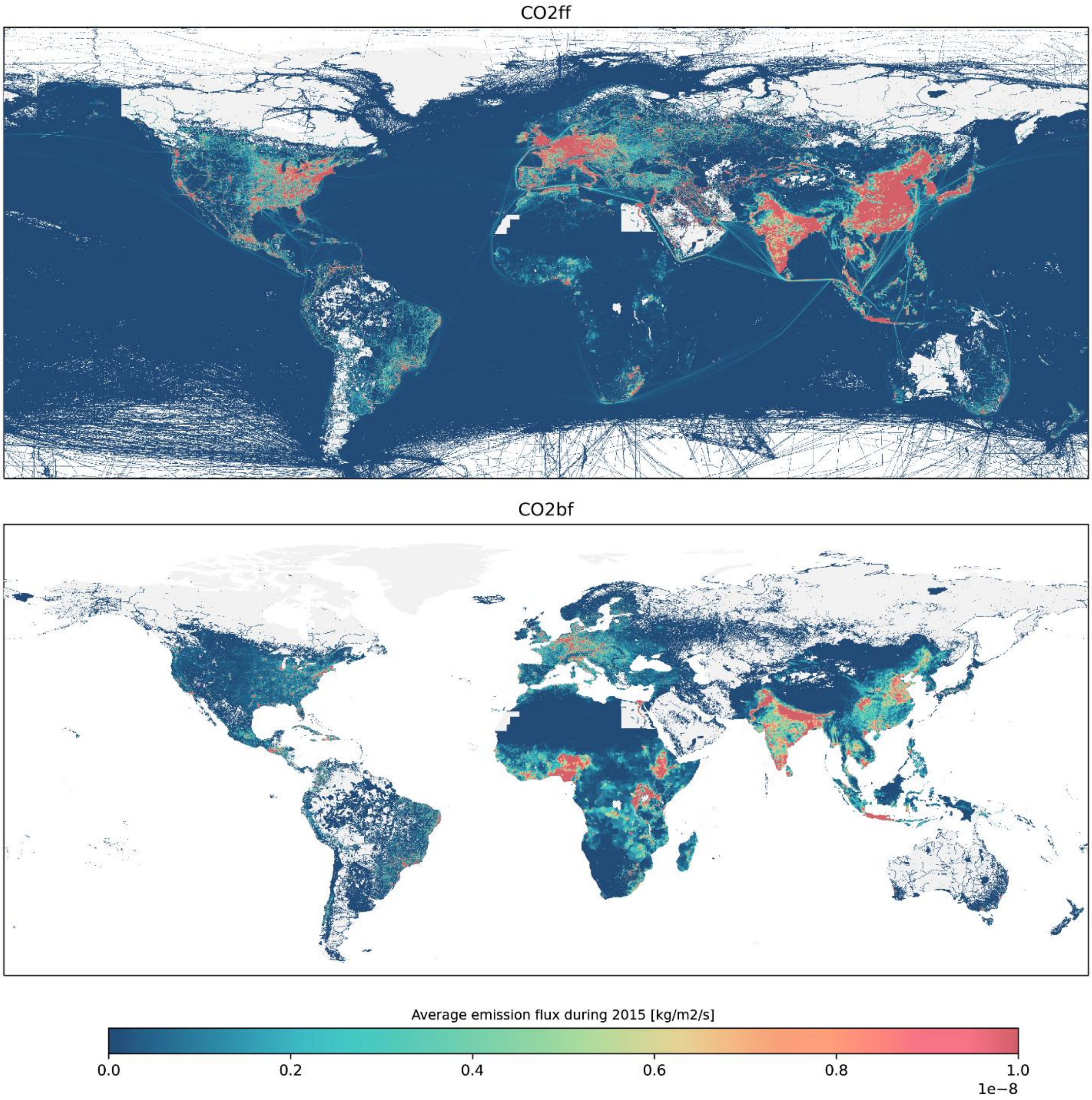


Figure S5 Average flux of CO_2ff and CO_2bf anthropogenic emissions during 2015 based on CoCO2-MOSAIC 1.0

290

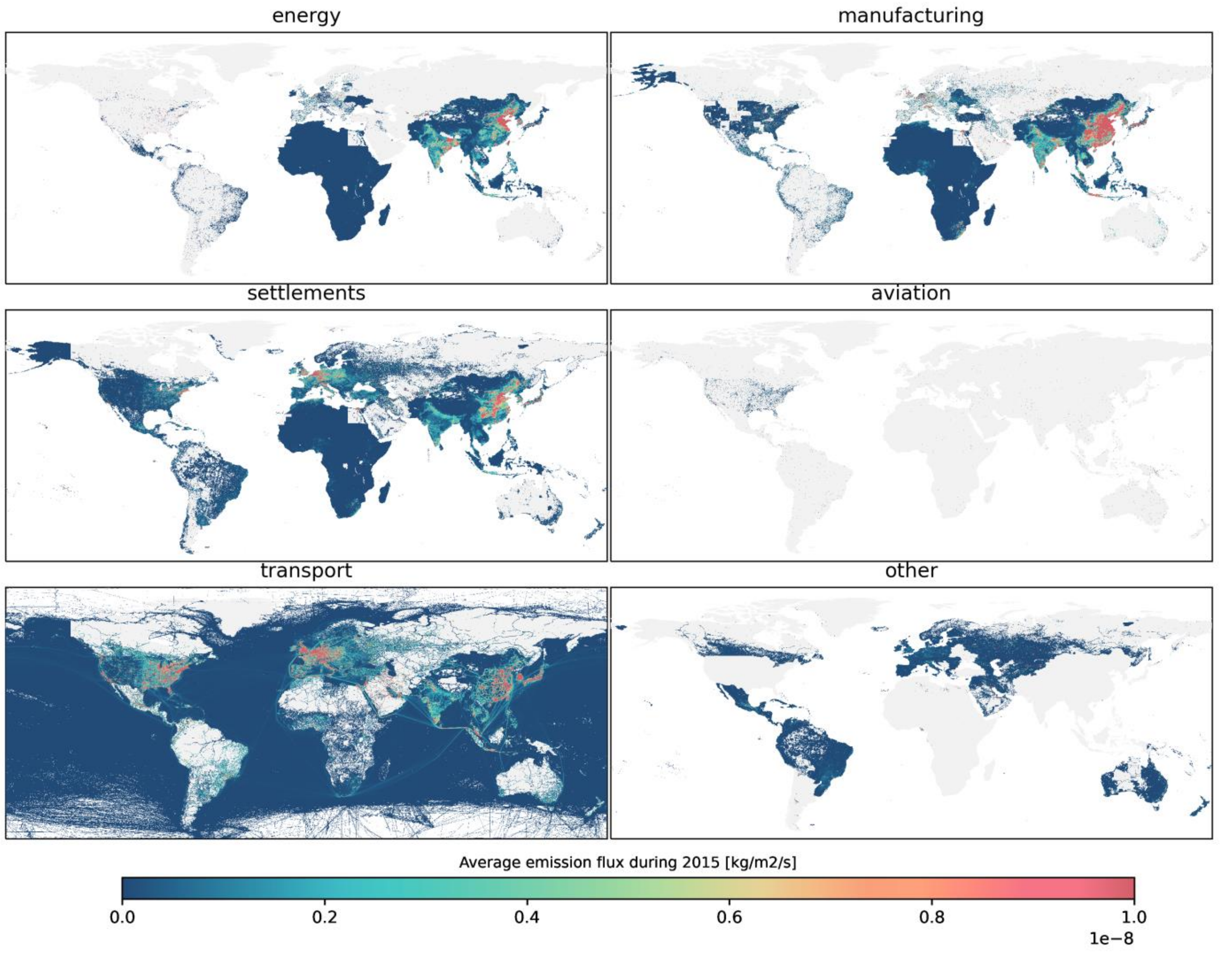


Figure S6 Average flux of CO_2ff anthropogenic emissions during 2015 per sector based on CoCO2-MOSAIC 1.0.

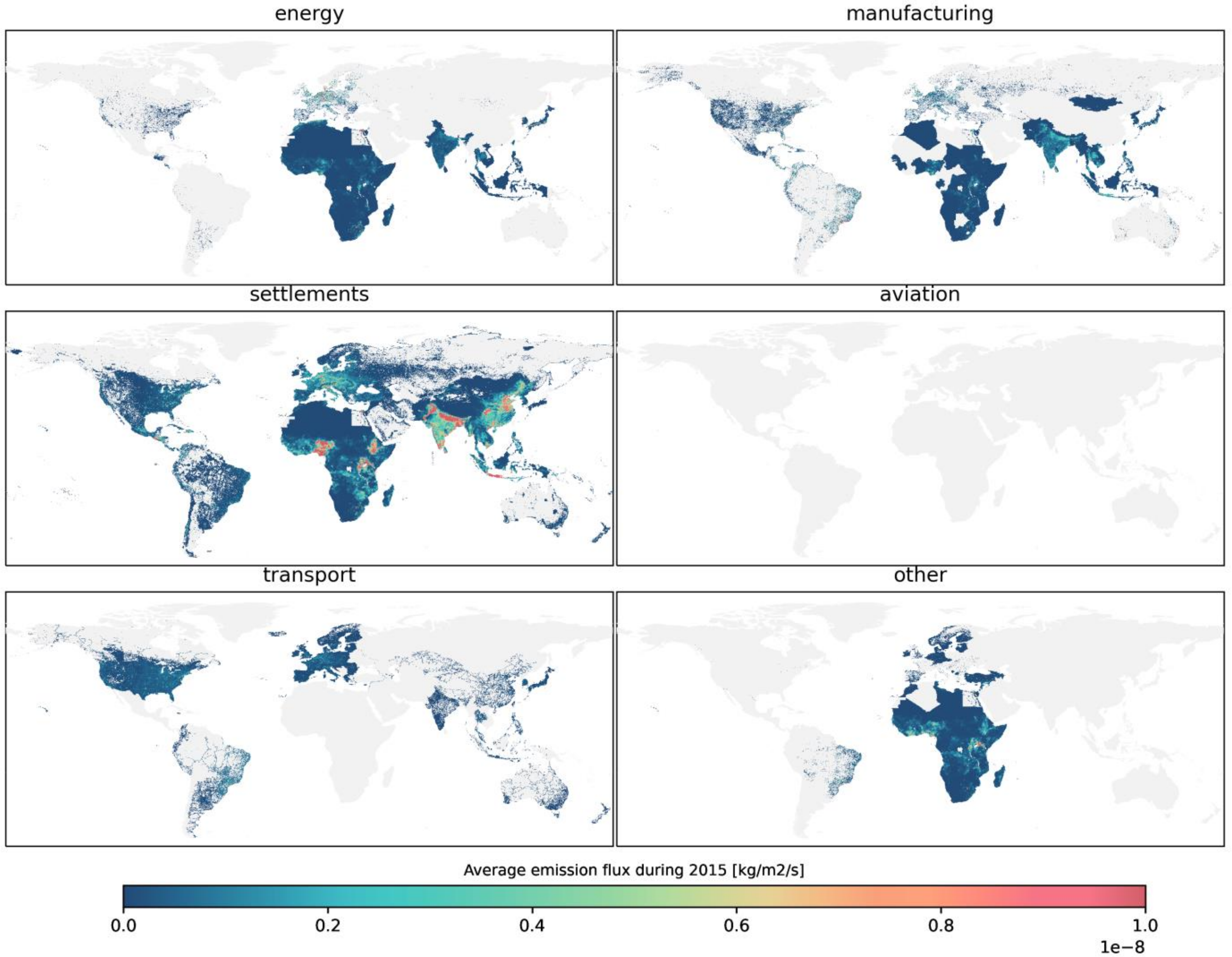
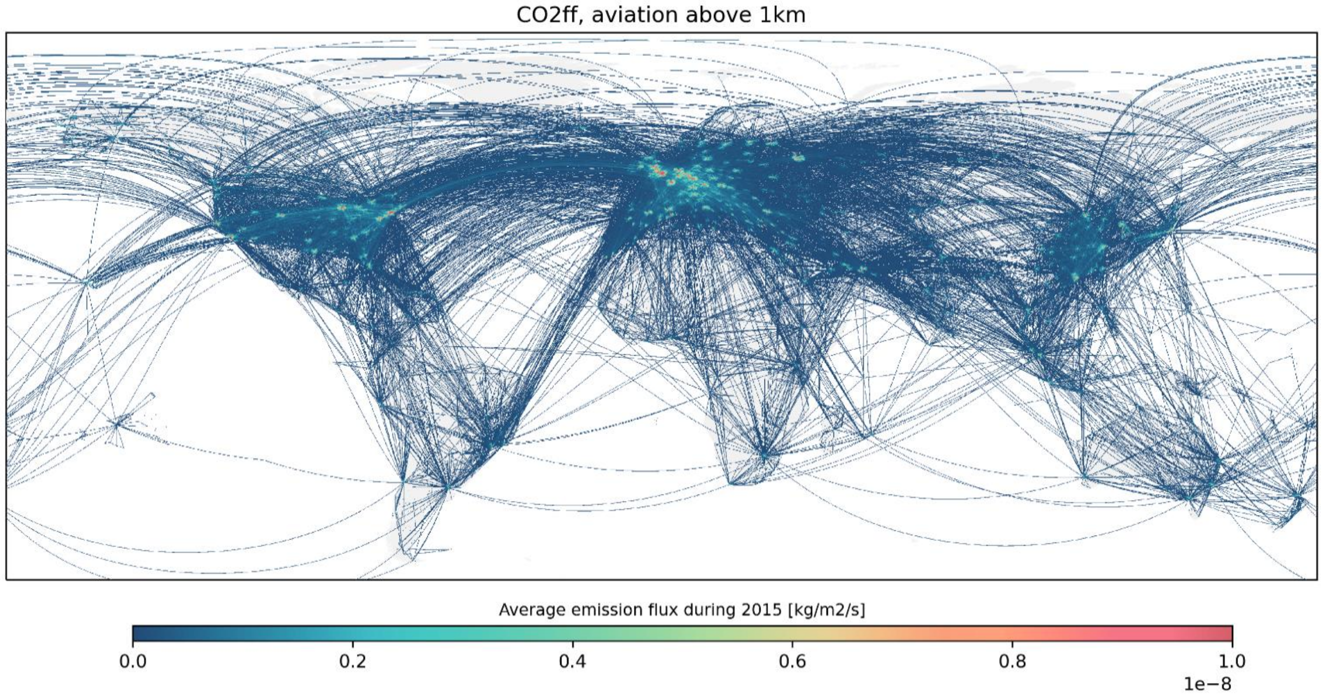


Figure S7 Average flux of CO_2bf anthropogenic emissions during 2015 per sector based on CoCO2-MOSAIC 1.0



295 **Figure S8 Average flux of CO_2ff anthropogenic emissions above 1km height during 2015 based on CoCO2-MOSAIC 1.0**

4 Additional figures and tables for the inter-comparison

Table S14: Total CO_2ff emissions [Mt] in 2015 per region and globally. Only land pixels are included. In both cases, aviation emissions are excluded.

Region	Inventory	energy	manufacturing	settlements	transport	other	total
Europe CAMS-REG-GHG 5.1	COCO2-MOSAIC 1.0	1451	859	682	1143	233	4368
	CAMS-GLOB-ANT 5.3	1523	818	726	1079	295	4441
	EDGAR 6.0	1542	833	731	1079	302	4486
	CEDS v2021_04_21	1654	766	699	1065	24	4208
	ODIAC 2020b	-	-	-	-	-	4292
Africa DACCIWA 2.0	COCO2-MOSAIC 1.0	529	233	126	276	59	1224
	CAMS-GLOB-ANT 5.3	481	247	116	309	163	1317
	EDGAR 6.0	471	250	116	331	169	1336
	CEDS v2021_04_21	642	242	97	328	6	1315
	ODIAC 2020b	-	-	-	-	-	1314
Argentina GEAA-AEI 3.0	COCO2-MOSAIC 1.0	47	32	40	49	16	184
	CAMS-GLOB-ANT 5.3	54	40	39	45	30	208
	EDGAR 6.0	55	40	39	45	29	208
	CEDS v2021_04_21	74	40	39	43	1	198
	ODIAC 2020b	-	-	-	-	-	197
Chile INEMA 1.0	COCO2-MOSAIC 1.0	33	8	5	23	0	70
	CAMS-GLOB-ANT 5.3	33	18	6	23	3	83
	EDGAR 6.0	33	17	5	24	3	83
	CEDS v2021_04_21	32	17	5	24	0	78
	ODIAC 2020b	-	-	-	-	-	84
E, SE, and S Asia REAS 3.2	COCO2-MOSAIC 1.0	6396	7293	1250	1838	0	16776
	CAMS-GLOB-ANT 5.3	7088	5915	1172	1757	917	16849
	EDGAR 6.0	6937	5975	1199	1768	941	16820
	CEDS v2021_04_21	7395	5349	1054	1753	40	15591
	ODIAC 2020b	-	-	-	-	-	15997
USA VULCAN 3.0	COCO2-MOSAIC 1.0	2087	881	575	2002	2	5547
	CAMS-GLOB-ANT 5.3	1976	549	574	1580	364	5043
	EDGAR 6.0	1981	570	561	1534	361	5006
	CEDS v2021_04_21	2241	540	552	1490	26	4849
	ODIAC 2020b	-	-	-	-	-	5204
Other regions EDGAR 6.0	COCO2-MOSAIC 1.0	2416	1516	661	1452	815	6860
	CAMS-GLOB-ANT 5.3	2384	1452	649	1452	825	6762
	EDGAR 6.0	2416	1516	661	1463	815	6871
	CEDS v2021_04_21	3052	1535	615	1390	22	6613
	ODIAC 2020b	-	-	-	-	-	6858
All regions	**COCO2-MOSAIC 1.0**	**12958**	**10823**	**3339**	**7499**	**1125**	**35028**
	CAMS-GLOB-ANT 5.3	**13570**	**9046**	**3284**	**6962**	**2673**	**34703**
	EDGAR 6.0	**13442**	**9207**	**3314**	**6840**	**2694**	**34811**
	CEDS v2021_04_21	**15158**	**8494**	**3063**	**6821**	**118**	**32851**
	ODIAC 2020b	**-**	**-**	**-**	**-**	**-**	**33945**

Table S15: Total CO_2bf emissions [Mt] in 2015 per region and globally. Only land pixels are included. In both cases, aviation emissions are excluded.

Region	Inventory	energy	manufacturing	settlements	transport	other	total
Europe CAMS-REG-GHG 5.1	COCO2-MOSAIC 1.0	184	111	279	43	18	635
	CAMS-GLOB-ANT 5.3	205	93	242	43	2	585
	EDGAR 6.0	206	100	243	43	2	594
Africa DACCIWA 2.0	COCO2-MOSAIC 1.0	244	105	1294	0	431	2074
	CAMS-GLOB-ANT 5.3	3	84	1244	0	0	1332
	EDGAR 6.0	4	129	1091	0	0	1224
Argentina GEAA-AEI 3.0	COCO2-MOSAIC 1.0	0	8	1	3	0	13
	CAMS-GLOB-ANT 5.3	3	4	3	3	0	12
	EDGAR 6.0	3	18	2	3	0	26
Chile INEMA 1.0	COCO2-MOSAIC 1.0	0	2	14	0	0	16
	CAMS-GLOB-ANT 5.3	15	8	7	0	0	30
	EDGAR 6.0	15	8	7	0	0	30
E, SE, and S Asia REAS 3.2	COCO2-MOSAIC 1.0	97	219	1473	18	0	1807
	CAMS-GLOB-ANT 5.3	201	252	1559	18	0	2030
	EDGAR 6.0	193	791	1425	18	0	2428
USA VULCAN 3.0	COCO2-MOSAIC 1.0	69	151	89	106	0	416
	CAMS-GLOB-ANT 5.3	70	121	86	98	0	374
	EDGAR 6.0	69	151	89	106	0	417
Other regions EDGAR 6.0	COCO2-MOSAIC 1.0	80	562	179	65	55	941
	CAMS-GLOB-ANT 5.3	82	211	185	65	55	598
	EDGAR 6.0	80	562	179	65	55	941
All regions	**COCO2-MOSAIC 1.0**	**675**	**1158**	**3330**	**235**	**505**	**5903**
	CAMS-GLOB-ANT 5.3	**581**	**773**	**3326**	**228**	**57**	**4962**
	EDGAR 6.0	**570**	**1761**	**3037**	**236**	**57**	**5660**

310

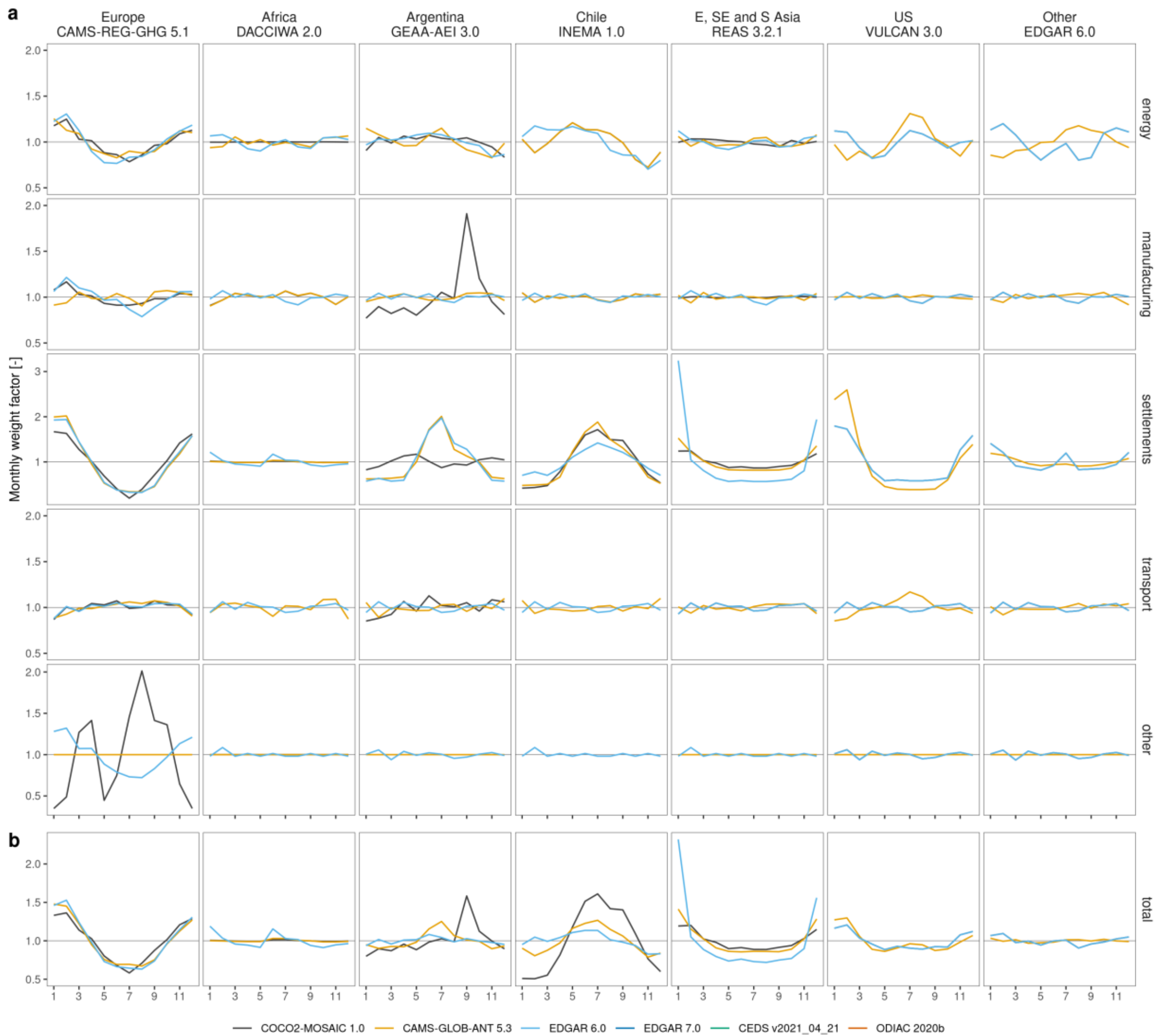


Figure S9 Monthly CO_2bf weight factors per sector and region. Monthly factors are calculated with the total monthly emissions per region and sector (monthly factor = total monthly emissions per region / total annual emissions per region). Note that the settlement sector has a different scale due to its larger seasonality.

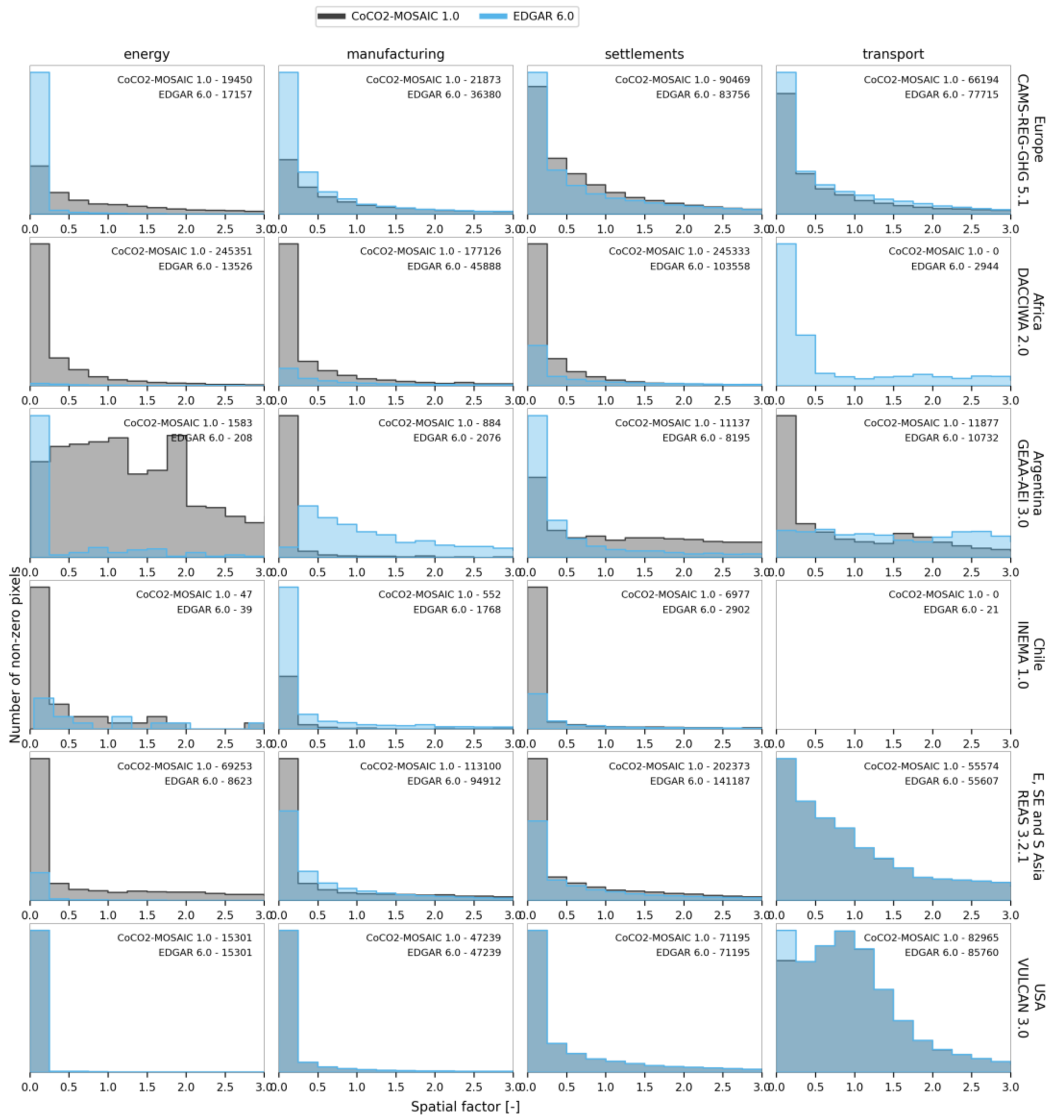


Figure S10 Histogram of annual CO_2bf spatial weight factor (pixel emission flux / average emission flux in the region) during 2015 per region and sector. The annotation shows the number of pixels with non-zero emissions. Pixels with zero emissions are excluded from the histograms.

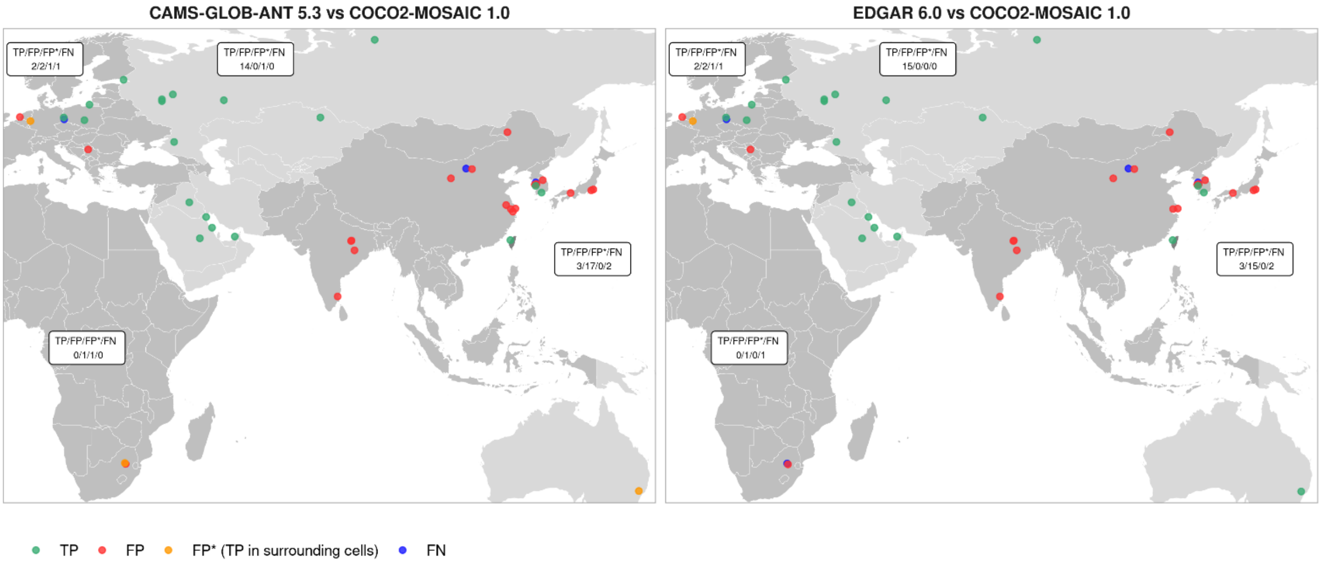


Figure S11 Comparison of the location of super-emitting pixels from the global inventories (test datasets) against those from CoCO2-MOSAIC 1.0 (reference dataset). TP = true positive, FP = false positive, FP* = false positive, with a TP in the surrounding pixels, FN = false negative.

Table S16: Absolute and relative expanded (95%) uncertainty per sector.

Sector	Emissions [Mt]	U [Gt]	u [%]
energy_s	799	[-0.04, 0.01]	[-4.5, 1.2]
energy_a	12159	[-0.39, 0.42]	[-3.2, 3.4]
manufacturing	10824	[-0.70, 1.08]	[-6.5, 10.0]
settlements	3340	[-0.13, 0.15]	[-3.9, 4.3]
transport	7500	[-0.31, 0.46]	[-4.2, 6.1]
aviation	148	[-0.00, 0.01]	[-2.1, 4.1]
aviation above 1km	768	[-0.38, 0.77]	[-50.1, 100.1]
other	1127	[-0.11, 0.48]	[-9.4, 42.8]
TOTAL	**35896.34**	**[-0.88, 1.34]**	**[-2.4, 3.7]**

5 Analysis of the discrepancies on the geo-location of super-emitters

- Europe: All the super-emitters identified by CAMS-REG-GHG 5.1 contain a power plant. Contrary, CAMS-GLOB-ANT 5.3 and EDGAR 6.0 have the same false positive in Serbia [20.25E, 44.65N]. This is likely a geolocation error in the inventories as satellite images do not show any power plant and the closest power facility is at [20.4E, 44.8N].
- Africa: each inventory points out different super-emitters. DACCIWA 2.0 identifies one super-emitter at [28.95W, 26.05S] corresponding to the Kendal coal station. EDGAR 6.0 shows a different super-emitter at [29.15W, 26.25S] that contains two different coal stations (Kriel and Matla). CAMS-GLOB-ANT 5.3 shows a third different super-emitter at [28.95W, 25.95S] (Kusile coal station), and a false positive at [29.15W, 26.15S] just one pixel below the EDGAR 6.0 super-emitter and a likely geolocation error.
- E, SE, E Asia: All REAS super-emitters contain a power plant, whereas EDGAR 6.0 and CAMS-GLOB-ANT 5.3 have 5 and 6 false positives, respectively. Most of them are in South Korea and have a power plant in the surroundings pixels, so the chances of geo-location errors are again high.

6 References

Akagi, S. K., Yokelson, R. J., Wiedinmyer, C., Alvarado, M. J., Reid, J. S., Karl, T., Crounse, J. D., and Wennberg, P. O.: Emission factors for open and domestic biomass burning for use in atmospheric models, Atmos. Chem. Phys., 11, 4039–4072, https://doi.org/10.5194/acp-11-4039-2011, 2011.

Álamos, N., Huneeus, N., Opazo, M., Osses, M., Puja, S., Pantoja, N., Denier van der Gon, H., Schueftan, A., Reyes, R., and Calvo, R.: High-resolution inventory of atmospheric emissions from transport, industrial, energy, mining and residential activities in Chile, Earth Syst. Sci. Data, 14, 361–379, https://doi.org/10.5194/essd-14-361-2022, 2022.

Crippa, M., Guizzardi, D., Muntean, M., Schaaf, E., Lo Vullo, E., Solazzo, E., Monforti-Ferrario, F., Olivier, J., and Vignatti, E.: EDGAR v6.0 Greenhouse Gas Emissions. , 2021.

Doumbia, E. H. T., Liousse, C., Keita, S., Granier, L., Granier, C., Elvidge, C. D., Elguindi, N., and Law, K.: Flaring emissions in Africa: Distribution, evolution and comparison with current inventories, Atmos. Environ., 199, 423–434, https://doi.org/10.1016/j.atmosenv.2018.11.006, 2019.

Granier, C., Darras, S., Denier van der Gon, H., Doubalova, J., Elguinidi, N., Galle, B., Gauss, M., Guevara, M., Jalkanen, J.-P., Kuenen, J., Liousse, C., Quack, B., Simpson, D., and Sindelarova, K.: The Copernicus Atmosphere Monitoring Service global and regional emissions, 2019.

Guevara, M., Jorba, O., Tena, C., Denier van der Gon, H., Kuenen, J., Elguindi, N., Darras, S., Granier, C., and Pérez García-Pando, C.: Copernicus Atmosphere Monitoring Service TEMPOral profiles (CAMS-TEMPO): global and European emission temporal profile maps for atmospheric chemistry modelling, Earth Syst. Sci. Data, 13, 367–404, https://doi.org/10.5194/essd-13-367-2021, 2021.

Gurney, K. R., Liang, J., Patarasuk, R., Song, Y., Huang, J., and Roest, G.: The Vulcan Version 3.0 High-Resolution Fossil Fuel CO_2 Emissions for the United States, J. Geophys. Res. Atmos., 125, https://doi.org/10.1029/2020JD032974, 2020.

Hoesly, R. M., Smith, S. J., Feng, L., Klimont, Z., Janssens-Maenhout, G., Pitkanen, T., Seibert, J. J., Vu, L., Andres, R. J., Bolt, R. M., Bond, T. C., Dawidowski, L., Kholod, N., Kurokawa, J., Li, M., Liu, L., Lu, Z., Moura, M. C. P., O'Rourke, P. R., and Zhang, Q.: Historical (1750–2014) anthropogenic emissions of reactive gases and aerosols from the Community Emissions Data System (CEDS), Geosci. Model Dev., 11, 369–408, https://doi.org/10.5194/gmd-11-369-2018, 2018.

Jalkanen, J.-P., Johansson, L., and Kukkonen, J.: A comprehensive inventory of ship traffic exhaust emissions in the European sea areas in 2011, Atmos. Chem. Phys., 16, 71–84, https://doi.org/10.5194/acp-16-71-2016, 2016.

Janssens-Maenhout, G., Crippa, M., Guizzardi, D., Muntean, M., Schaaf, E., Dentener, F., Bergamaschi, P., Pagliari, V., Olivier, J. G. J., Peters, J. A. H. W., van Aardenne, J. A., Monni, S., Doering, U., Petrescu, A. M. R., Solazzo, E., and Oreggioni, G. D.: EDGAR v4.3.2 Global Atlas of the three major greenhouse gas emissions for the period 1970–2012, Earth Syst. Sci. Data, 11, 959–1002, https://doi.org/10.5194/essd-11-959-2019, 2019.

Johansson, L., Jalkanen, J.-P., and Kukkonen, J.: Global assessment of shipping emissions in 2015 on a high spatial and temporal resolution, Atmos. Environ., 167, 403–415, https://doi.org/10.1016/j.atmosenv.2017.08.042, 2017.

Keita, S., Liousse, C., Yoboué, V., Dominutti, P., Guinot, B., Assamoi, E.-M., Borbon, A., Haslett, S. L., Bouvier, L., Colomb, A., Coe, H., Akpo, A., Adon, J., Bahino, J., Doumbia, M., Djossou, J., Galy-Lacaux, C., Gardrat, E., Gnamien, S., Léon, J. F., Ossohou, M., N'Datchoh, E. T., and Roblou, L.: Particle and VOC emission factor measurements for anthropogenic sources in West Africa, Atmos. Chem. Phys., 18, 7691–7708, https://doi.org/10.5194/acp-18-7691-2018, 2018.

Keita, S., Liousse, C., Assamoi, E.-M., Doumbia, T., N'Datchoh, E. T., Gnamien, S., Elguindi, N., Granier, C., and Yoboué, V.: African anthropogenic emissions inventory for gases and particles from 1990 to 2015, Earth Syst. Sci. Data, 13, 3691–3705, https://doi.org/10.5194/essd-13-3691-2021, 2021.

Kuenen, J., Dellaert, S., Visschedijk, A., Jalkanen, J.-P., Super, I., and Denier van der Gon, H.: CAMS-REG-v4: a state-of-the-art high-resolution European emission inventory for air quality modelling, Earth Syst. Sci. Data, 14, 491–515, https://doi.org/10.5194/essd-14-491-2022, 2022.

Kurokawa, J. and Ohara, T.: Long-term historical trends in air pollutant emissions in Asia: Regional Emission inventory in ASia (REAS) version 3, Atmos. Chem. Phys., 20, 12761–12793, https://doi.org/10.5194/acp-20-12761-2020, 2020.

McDuffie, E. E., Smith, S. J., O'Rourke, P., Tibrewal, K., Venkataraman, C., Marais, E. A., Zheng, B., Crippa, M., Brauer, M., and Martin, R. V.: A global anthropogenic emission inventory of atmospheric pollutants from sector- and fuel-specific sources (1970–2017): an application of the Community Emissions Data System (CEDS), Earth Syst. Sci. Data, 12, 3413–3442, https://doi.org/10.5194/essd-12-3413-2020, 2020.

Oda, T., Maksyutov, S., and Andres, R. J.: The Open-source Data Inventory for Anthropogenic

CO₂, version 2016 (ODIAC2016): a global monthly fossil fuel CO₂ gridded emissions data product for tracer transport simulations and surface flux inversions, Earth Syst. Sci. Data, 10, 87–107, https://doi.org/10.5194/essd-10-87-2018, 2018.

Puliafito, S. E., Bolaño-Ortiz, T. R., Fernandez, R. P., Berná, L. L., Pascual-Flores, R. M., Urquiza, J., López-Noreña, A. I., and Tames, M. F.: High-resolution seasonal and decadal inventory of anthropogenic gas-phase and particle emissions for Argentina, Earth Syst. Sci. Data, 13, 5027–5069, https://doi.org/10.5194/essd-13-5027-2021, 2021.

Soulie, A., Granier, C., Darras, S., Doumbia, T., Guevara, M., Jalkanen, J., Keita, S., and Liousse, C.: Global Anthropogenic Emissions (CAMS-GLOB-ANT) for Air Quality Forecasting and Reanalyses for the Copernicus Atmosphere Monitoring Service, Earth Syst. Sci. Data (to be Submitt., 2023.