Section S1. CEDS Update Details: CEDSv2019-12-23 relative to CEDSv2016-07-26

CEDSv2019-12-23 (Hoesly et al., 2019) was the first full public CEDS release (https://github.com/JGCRI/CEDS) and is used as the core system version in this work. An earlier version, CEDSv2016-07-26 was used to produce the CEDS-$_{Hoesly}$ inventory, as described in detail in Hoesly et al. (2018) and its supplement. Changes to the CEDS code between versions v2016-07-26 and v2019-12-23 are described in the CEDS System Release Notes on GitHub (https://github.com/JGCRI/CEDS/wiki/ Release-Notes). These updates include structural changes as well as improvements in the emissions data. The most significant improvements, which are also carried through to the CEDS$_{GBD-MAPS}$ inventory include:

- Updated residential waste burning estimates
- Fixed an error in 1960s USA SO_2 emissions and several other issues.

These updates are described in further detail in the following sections. A graphical summary of the differences between versions v2016-07-26 (CEDS$_{Hoesly}$) and v2019-12-23 is available at the CEDS repository (https://github.com/JGCRI/CEDS/ at the link "Graphs of emission differences"). Additional updates are described in the CEDS System Release Notes (https://github.com/JGCRI/CEDS/wiki/Release-Notes) and the git log of the CEDS$_{GBD-MAPS}$ system, available for download at https://github.com/emcduffie/CEDS/tree/CEDS_GBD-MAPS.

S1.1 Residential waste burning

Updates to emissions from residential open waste burning reduces emissions of all air pollutant species, particularly BC and OC emissions in lower income countries. The major change is a reduction in the assumed amount of uncollected waste that is burnt. The previous CEDS estimate was based on the 2010 value from Wiedinmyer et al. (2014) who assumed that 60% of uncollected solid waste was combusted. We conducted a literature survey, summarized below, to provide more insight into this value. We note that, for the purpose of emission estimation, the parameter we wish to know is the fraction of waste by weight that is combusted. This will be smaller than the fraction of waste that is disposed of through burning, since a significant portion of waste can be inert (e.g., ash, glass, and metals).

Reyna-Bensusan et al. (2018) examined waste disposal by surveying a "representative community" in Mexico about waste generation rates and disposal practices (Huejutla de Reyes Municipality). The Municipality has areas ranging from rural to urban and peri-urban in character. They found that in rural areas with limited access to municipal waste collection (69% had access only to a once-a-month service), 36% of household waste by weight was combusted. Commoner et al. (2000) additionally found in a survey in the Mexico state of Morelos that 14% of household waste was combusted in backyard burning, which corresponded to 52% of uncollected household waste, although only waste practices were surveyed, and waste generation rates were taken from national statistics. This is likely to overestimate the total amount of waste burnt since rural households generate half the waste per capita as compared to urban households (Reyna-Bensusan et al., 2018).

Nagpure et al. (2015) examined waste disposal using a more direct field methodology in three neighborhoods in Delhi India. The neighborhood with the lowest socio-economic status, where "field observation showed very sparse waste management facilities" had the highest rate of waste burning of ∼24% of the total generated.

For Indonesia, Meidiana and Gamse (2010) report on government statistics that imply that only 15% of uncollected waste was burnt in 2006, while 70% was burnt in 2001. It is not clear if this difference is a true difference in burning rate, or different statistical methodologies.

Data is not necessary more available in higher income countries. In the United States residential waste has long been disposed by burning in barrels ("barrel burning"), particularly in rural areas. However, "The amount of refuse that is combusted annually in the United States in residential backyard burn barrels is largely unknown (US EPA, 2006)." This same report identified seven literature sources of survey data largely developed "to estimate the barrel-burning activity in a specific state, county, or region." The "prevalence of barrel burning within the rural population [was found] to range from 12 to 40%". The EPA ultimately assumed that from 40% (1995 and 1987) to 28% (2000) of the rural population burned household refuse, the decrease reflecting a larger number of jurisdictions banning refuse burning in 2000 as compared to earlier years. EPA further assumed that 63% of the household refuse (not including yard waste) was combusted. The confidence of these estimates is rated as low. Multiplying burning prevalence by the fraction of waste burnt results in overall waste burnt fractions of 25% (1995 and 1987) and 18% (2000) for rural populations.

Overall, the fraction of residential waste that is combusted is uncertain and is likely to vary spatially and over time. For the current estimate, informed by the literature discussed above, we assume that 30% of uncollected waste is bunt, which is half the value assumed by Wiedinmyer et al. (2014), with a correspondingly lower emissions level.

With one exception the per-capita waste generation rates from Wiedinmyer et al. (2014) have been retained. For India, however, we use the value from Sharma et al. (2019), which is twice the value in Wiedinmyer et al. (2014), leaving estimates from India largely unchanged.

S1.2 Other Changes

An error in US SO_2 emissions over the 1960s caused an incorrect step-increase in emissions in 1960 in CEDSv2016-07-26. This update will not be carried through to $CEDS_{GBD\text{-}MAPS}$ as these emissions are reported from 1970 onward. An error that caused a spike in BC emissions in the Netherlands was also corrected and the consistency of Korea BC and OC emissions with the Korea national inventory was improved. These issues and their fixes are further described in the *issues* section of the CEDS GitHub repository. There are also small differences in the CEDSv2016-07-26 and CEDSv2019-12-23 emissions in the US after 2011, particularly NH_3, due to scaling to more recent EPA Trends data. Note also that the monthly seasonality profile for the gridded industrial sector emissions was removed in CEDSv2019-12-23. While there is likely some seasonality in emissions in this sector, seasonality in the CEDSv2016-07-26 data was judged to be too large.

Section S2. CEDS Update Details: $CEDS_{GBD-MAPS}$ relative to CEDSv2019-12-23

Section 2 in the Main Text describes updates to the CEDSv2019-12-23 code that are used to derive the new 1970 – 2017 $CEDS_{GBD-MAPS}$ inventory. Sections S2.1 – S2.5 below provide additional details regarding these updates. The $CEDS_{GBD-MAPS}$ source code is available at: https://github.com/emcduffie/CEDS/tree/CEDS_GBD-MAPS.

S2.1 Activity Data Updates – Additional Details

For the $CEDS_{GBD-MAPS}$ system, we have updated the inputs for activity data for both types of CEDS source categories (combustion and process) in order to enable the extension of the $CEDS_{GBD-MAPS}$ inventory out to the year 2017. We note that the distinction between CEDS combustion and process category sources is reflective of both the emission sector definition and CEDS methodology. For example, the 1A1bc_Other_transformation sector includes emissions from fuel combustion, but is treated as a process sector in CEDS due to the complexity of its processes, which include emissions from coal coke production, oil refining, and charcoal production (Hoesly et al., 2018). Other similar process sectors include emissions from the 5C_waste-incineration and 1B1_Fugitive-petr-and-gas sectors. Unlike CEDS combustion source categories, emissions from all process sectors are assigned to a single ‘process’ fuel-type, which may misallocate total emissions from biofuel, coal, and liquid oil and gas combustion to the process source category in the final fuel-specific $CEDS_{GBD-MAPS}$ products, as discussed in Sect. 4.2.

S2.1.1 Combustion Sources

For $CEDS_{GBD-MAPS}$ combustion category sources, activity data are primarily from energy consumption data, which have been updated to use the 2019 release of the World Energy Statistics from the International Energy Agency (IEA, 2019) for 40 OECD and 114 non-OECD countries and regions. For a small number of countries in Africa, Asia, and the Americas, data are only reported by the IEA at an aggregate region-level and are further disaggregated into their individual countries using historical CO_2 emissions data, as described in Hoesly et al. (2018). Historical national-level CO_2 emissions have been updated here to the most recent release from the Carbon Dioxide Information Analysis Center (CDIAC), which includes data from 1750 to 2014 (Boden et al., 2017). As IEA energy consumption data are provided at finer sectoral and fuel-type resolution than CEDS working sectors and fuels, CEDS Step 1 maps the IEA data to 52 working CEDS sectors and nine working fuel-types. Table S1 provides an example of the mapping between IEA fuels and CEDS working fuel types. Following the CEDSv2019-12-23 procedures, IEA data for residential biofuel consumption from the U.S. are replaced with renewable energy consumption data from the U.S. Energy Information Administration (EIA, 2019), which have been updated here to include the period from 1970 – 2017. In addition, $CEDS_{GBD-MAPS}$ no longer applies corrections to the IEA data for coal consumption from China, which were previously used in the CEDSv2019-12-23 system. There is, however, a known issue in the updated IEA data from China that is listed in Sect. S4 below. As described in Hoesly et al. (2018), the CEDSv2019-12-23 system additionally used coal, oil, and gas consumption data from the BP Energy Statistics product (BP, 2015) to extend available IEA data (IEA, 2015) out to the year 2014. Complete IEA data for the year 2017 are available in this work (IEA, 2019), therefore BP energy statistics are no longer used to extend emission estimates, but have been updated (BP, 2019) here as they are also used to estimate emissions from fossil fuel flaring.

Table S1. CEDS fuel-type definitions. CEDS$_{\text{GBD-MAPS}}$ fuel types, *CEDS working fuel-type definitions*, **and** IEA fuel-types

CEDS Fuels	
Coal	**Liquid Fuel + Natural Gas**
Brown coal	*Heavy Oil*
Brown coal (if no detail)	Oil shale and oil sands
Lignite	Crude/NGL/feedstocks
Peat	Crude oil
Peat products	Fuel oil
Coal Coke	Bitumen
Coke oven coke	Paraffin waxes
Hard coal	Petroleum coke
Hard coal (if no detail)	Other oil products
Anthracite	*Diesel Oil*
Coking coal	Gas/diesel oil excl. biofuels
Other bituminous coal	Lubricants
Sub-bituminous coal	Biodiesels
Patent fuel	*Light Oil*
Gas coke	Refinery stocks
Coal tar	Additives/blending components
BKB	Other hydrocarbons
Biofuel	Ethane
Biofuel	Liquefied petroleum gases (LPG)
Industrial waste	Motor gasoline excl. biofuels
Municipal waste (renewable)	Aviation gasoline
Municipal waste (non-renewable)	Gasoline type jet fuel
Primary solid biofuels	Kerosene type jet fuel excl. biofuels
Non-specified primary biofuels/waste	Other kerosene
Charcoal	Naptha
Process	White spirit & SBP
Process	Biogasoline
	Other liquid biofuels
	Bio jet kerosene
	Natural Gas
	Natural gas liquids
	Gas works gas
	Coke oven gas
	Blast furnace gas
	Other recovered gases
	Natural gas
	Refinery gas
	Biogases

S2.1.2 Process Sources

For CEDS$_{GBD-MAPS}$ process category sources, activity drivers are primarily from the UN World Population and World Urbanization Prospects, which are updated here to extend to 2017 (UN, 2019, 2018). These data are used as activity drivers for all CEDS process sources except for 5C_waste-incineration, 1B2_Fugitive-pert-and-gas, and 1B2d_Fugitive-other-energy. As described in Hoesly et al. (2018), pulp and paper consumption data (FAOSTAT, 2015) are used for default emission estimates of waste incineration (held constant here after 2014), while the latter two sectors now use a composite product that is derived from updated 2019 IEA energy statistics. World Bank data were not updated in this work (last year 2014) relative to CEDSv2019-12-23 since these data are only used to supplement population data for Kosovo. Table S2 summarizes the activity driver dataset updates that are used in CEDS$_{GBD-MAPS}$ relative to CEDSv2019-12-23. The Supplemental Information of Hoesly et al. (2018) provides a complete list of all additional CEDS input datasets, which have not been updated in this work.

Table S2. Comparison of activity driver datasets that are updated between CEDSv2019-12-23 and CEDS$_{GBD-MAPS}$ systems. For a complete list of CEDS activity drivers, see Hoesly et al. (2018).

CEDS Emission Source Category	Hoesly et al. (2018)	CEDS$_{GBD-MAPS}$
Fuel combustion	(IEA, 2015) (BP, 2015) EIA, 2(The World Bank, 2016;UN, 2014, 2015;Wiedinmyer et al., 2014)015 (biofuel from US) (Boden et al., 2016)	(IEA, 2019) (BP, 2019) (flaring estimates only) (EIA, 2019) (biofuel from US) (Boden et al., 2017)
Process	(UN, 2014, 2015) (The World Bank, 2016) (FAOSTAT, 2015)	(UN, 2019, 2018) (The World Bank, 2016) (FAOSTAT, 2015)

S2.2. Emission Factors & Inventory Input Updates – Additional Details

S2.2.1 Combustion Sources

The datasets used to calculate default emission factors (EF) for combustion sources in the CEDS$_{GBD-MAPS}$ system are largely unchanged relative to those in CEDSv2019-12-23 (see Table 2 in Hoesly et al. (2018) for a complete list). For reactive gases, combustion EFs are primarily estimated using information from the GAINS model (as released for the Energy Modeling Forum 30 (EMF30) project (Klimont et al., 2017;Stohl et al., 2015)), SPEW for BC and OC (Bond et al., 2007), and the U.S. 2011 NEI for NH_3. As described in Hoesly et al. (2018), EF calculations take into account historical changes in emission abatement strategies, while some EFs for SO_2 are also calculated explicitly using fuel sulfur content, ash retention, and country-specific percent controls (NEI, 2013). EF and emission calculations do not include information about the vertical distribution of emissions. For countries with missing contemporary sectoral or fuel-type information, EFs are extended forward to 2017 using trends from GAINS projections. The minimum allowable EFs for road transportation have also been extended to 2017, which ensures the use of realistic EFs from this sector in recent years for countries with missing data.

S2.2.2 Process Sources

For non-combustion sectors, EFs in CEDS$_{GBD-MAPS}$ Step 1 are estimated using existing emission inventories and calculated activity drivers, as described previously in Sect. 2.1. These emission estimates are primarily from the global EDGAR inventory, which has been updated in this work to use a more recent release of EDGAR (v4.3.2; EC-JRC, 2018;Crippa et al., 2018). For emissions of waste combustion, all versions of the CEDS system use country-specific EFs for 2010 from Wiedinmyer et al. (2014), along with estimates of the total mass. As described in Sect. S1.1 above, relative to CEDSv2016-07-26, assumptions for the fraction of waste burnt have been updated in both CEDSv2019-12-23 and CEDS$_{GBD-MAPS}$, along with estimates for the amount of waste generated per-capita in India (Sharma et al., 2019). Additional details on these updates can be found in the core CEDS system release notes (https://github.com/JGCRI/CEDS/wiki/Release-Notes). Similar to combustion sources, missing EFs are also extended forward and backwards in time to produce a complete time series for 1970 - 2017. Table 2 in Hoesly et al. (2018) provides a complete list of all input datasets used to estimate default process source emissions. Other than those described here, all remaining datasets are unchanged in this work relative to CEDSv2019-12-23. Despite uncertainties in contemporary EFs and default emission estimates for both source categories, many of these values are later calibrated to match contemporary regional and national-level inventories (see Sect. 2.2).

S2.3 Default CEDS Emissions Calibration Updates – Additional Details

S2.3.1 Calibration Mapping Files & Misc. Details

The first step of the calibration procedure is to aggregate emissions from common sectors and fuel-types into “scaling sectors” and “scaling fuel” groups (when fuel-specific emissions are available) for each calibration inventory. This is necessary as there are often differences in the availability and definitions of emission from source sectors and fuel-types between CEDS and the calibration inventories. Total default CEDS emissions within these aggregate groups are then calibrated to the corresponding emissions in each calibration inventory, using the scaling factors calculated from Eq. (2) in the main text. All mapping files can be found at: https://github.com/emcduffie/CEDS/tree/CEDS_GBD-MAPS/input/mappings/scaling, with specific examples described below.

The first column in each mapping file provides the sectoral names from the calibration inventory. When emissions are reported as a function of fuel type, the second column lists the fuel-types reported for each emission sector in the calibration inventory. When applicable, column three defines the aggregate scaling fuel groups. Column four defines the aggregate scaling sector groups. Columns five and six list the CEDS working sectors and working fuels that correspond to these aggregate scaling groups. Table S3 provides an example scaling mapping file for the DICE-Africa calibration inventory. Table S3 shows that the DICE-Africa inventory reports combined emissions from gas (petrol) and diesel use in cars and motorcycles. The CEDS system does not differentiate between different types of on-road sources and therefore, DICE-Africa emissions from both cars and motorcycles are mapped to the common ‘road_transport’ scaling sector, which corresponds to the CEDS 1A3b_Road sector. Similarly, the DICE-Africa inventory does not distinguish between emissions from gas and diesel fuel, therefore total CEDS road emissions from light_oil and diesel_oil combustion in the road sector are scaled to the total DICE-Africa emissions reported for cars and motorcycles.

Table S3. Example scaling mapping file for DICE-Africa in $CEDS_{GBD-MAPS}$ system.

DICE-Africa sector	DICE-Africa fuel	Scaling Fuel	Scaling Sector	CEDS Sector	CEDS Fuel
cars	gas_diesel	gas_diesel	road_transport	1A3b_Road	light_oil
		gas_diesel	road_transport	1A3b_Road	diesel_oil
motorcycles	gas_diesel	gas_diesel	road_transport		
charcoal-use	biomass	biomass	residential	1A4b_Residential	biomass
household-crop-residue-use	biomass	biomass	residential		
household-fuelwood-use	biomass	biomass	residential		
kerosene-use	light_oil	light_oil	residential	1A4b_Residential	light_oil
other-fuelwood-use[a]	biomass	n/a	n/a	n/a	n/a
adhoc-oil-refining[a]	process	n/a	n/a	n/a	n/a
generator-use[a]	gas_diesel	n/a	n/a	n/a	n/a
charcoal-production[a]	biomass	n/a	n/a	n/a	n/a
gas-flares[a]	process	n/a	n/a	n/a	n/a

[a]Suggested additions, not replacements, see Sect. S2.3.2

Relative to CEDS v2019-12-23, minor adjustments have been made to other inventory calibration mapping files in order to better reflect the overlap between $CEDS_{GBD-MAPS}$ working sectors and the updated calibration inventories. One example is the adjustment of scaling factors for agricultural NO_x emissions for the U.S. NEI and Canadian APEI inventories. In these national inventories, NO_x emissions from soils are not reported (report NH_3 emissions only). In CEDSv2019-12-23, NO_x emissions from the sum of all agricultural working sectors (3B+3D+3E+3I; including soil emissions) are calibrated to the total agricultural NO_x emissions reported in these calibration inventories, resulting in calibrated CEDS agricultural NO_x emissions that are erroneously low. In this work, $CEDS_{GBD-MAPS}$ 3D_Soil-emissions from the US and Canada are no longer scaled to these inventories and default emission estimates are used for this working sector. These updated scaling mapping files can be found at: https://github.com/emcduffie/CEDS/tree/CEDS_GBD-MAPS/input/mappings/scaling.

After the calibration procedure, $CEDS_{GBD-MAPS}$ emissions are then disaggregated back into the original 52 CEDS working sectors and 9 working fuel-types (Table 2, combustion source only) using the initial fractional contributions from each sector and fuel-type. This method allows CEDS to maintain detailed fuel and sectoral information while simultaneously calibrating total country-level emissions to authoritative inventories. This process, however, often results in total $CEDS_{GBD-MAPS}$ emissions that are higher than the individual calibration inventories, depending on the amount of overlap with each inventory. For example, Fig. (S1) shows that in China, total $CEDS_{GBD-MAPS}$ emissions for OC after 2010 are larger than those in the national calibration inventory, reported by Zheng et al. (2018). This difference is largely due to the inclusion of the waste sector in $CEDS_{GBD-MAPS}$, which is not reported in the Zheng et al. (2018) inventory. In contrast, other inventories report emissions from sources that are not included in CEDS, such as open burning on agricultural fields or road dust emissions. In these cases, these sectors are not included in the CEDS calibration procedure and are not included in the final $CEDS_{GBD-MAPS}$ inventory. In addition, sectors such as domestic shipping are not calibrated and are always set to default CEDS estimates due to large uncertainties and differences in the definitions of these sectors in individual calibration inventories.

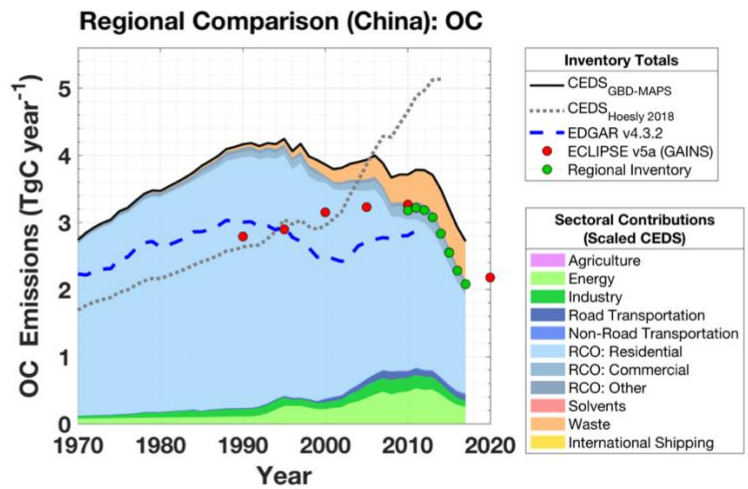

Figure S1. Inventory comparison of annual OC emissions from China. Black line) total $CEDS_{GBD-MAPS}$ emissions, colored by sectoral contributions, dashed gray line) $CEDS_{Hoesly}$ emissions, dashed blue line) EDGAR v4.3.2 emissions, red dots) ECLIPSE v5a (GAINS) inventory with 2015 and 2020 projections, green dots) calibration inventory from Zheng et al. (2018). This comparison does not include contributions from agricultural waste burning, shipping, or aviation emissions.

S2.3.2 Africa Emissions Calibration

As discussed in the main text, new calibration inventories are included in this work for emissions from India and Africa. For African countries, default $CEDS_{GBD-MAPS}$ emissions for residential and road sectors are scaled to the respective values in the DICE-Africa inventory (Marais and Wiedinmyer, 2016) for 2006 and 2013, as a function of diesel, light oil (Table S1), and biofuel use. For years between 2006 and 2013, scaling factors (SFs) from Eq. (2) in the main text are linearly interpolated within the CEDS system. These SFs are held constant before 2006 and after 2013. DICE-Africa OC emissions from cars are additionally scaled by 0.14 prior to the CEDS calibration procedure in order to correct for a previous error in the DICE-Africa OC EFs (http://wiki.seas.harvard.edu/geos-chem/index.php/DICE-Africa_anthropogenic_emissions_inventory#Scale_DICE-Africa_emissions_to_address_errors_in_inventory). Upper and lower bounds of calibration scaling factor are additionally relaxed here to limits of 1000 and 0.001 (100 and 0.01 in CEDSv2019-12-23) to ensure better agreement between DICE-Africa and $CEDS_{GBD-MAPS}$ sectoral totals. In a small number of instances, calculated scaling factors are outside this range, which may reflect differences in sectoral definitions between the two inventories or real uncertainties in the magnitude of sectoral-level emissions in Africa.

As also noted in the main text, DICE-Africa emission estimates from gas flares across Africa and ad-hoc oil refining in the Niger Delta are not included in the $CEDS_{GBD-MAPS}$ calibration procedure (Table S2). Total default $CEDS_{GBD-MAPS}$ emissions in Africa for each compound in 2013 from the 1B2_fugitive_petr_gas (gas flaring) sector are almost always larger than the respective DICE-Africa gas-flaring emissions, suggesting that emissions from this source sector may be accurately represented in default $CEDS_{GBD-MAPS}$ estimates. However, in the event that gas-flaring emissions from the DICE-Africa inventory are not accounted for in the $CEDS_{GBD-MAPS}$ default emissions, the $CEDS_{GBD-MAPS}$ 1B2_fugitive_petr_gas emissions across Africa may be underestimated by up to 28% (or up to < 0.01 Tg) for each compound in 2013 (Table S3).

In addition, DICE-Africa emissions from petrol/diesel use in residential generators, as well as fuelwood use for charcoal production and other commercial activities are not included in the $CEDS_{GBD\text{-}MAPS}$ calibration procedure. These sectors are not explicitly represented by the $CEDS_{GBD\text{-}MAPS}$ working sectors and are only expected to be represented in the $CEDS_{GBD\text{-}MAPS}$ default estimates to the extent that these sources are included in the IEA energy consumption data. Emissions from charcoal production will be allocated to the 1A1bc_Other-Transformation sector, while commercial fuelwood use would be allocated to the 1A4a_Commercial-institutional sector. In the event that these sources are not included in default $CEDS_{GBD\text{-}MAPS}$ emissions, the emissions from biofuel use in the CEDS other transformation and commercial sectors in 2013 may be underestimated by up to 100% (or up to 6 Tg) for each compound (Table S4). Similarly, residential generator use may be allocated to the 1A4b_Residential (RCO-R) and/or 1A4c_Agriculture-forestry-fishing (RCO-Other) sectors. In the event that generators are not accounted for in default estimates, CEDS emissions from light oil/diesel use in the residential sectors may be underestimated by up to 84% (or up to 0.25 Tg) for each compound (Table S4). While these maximum possible under-predictions represent large fractions of emissions from individual fuels and sectors, the sum of these potential missing emissions correspond to maximum under-predictions in total 2013 $CEDS_{GBD\text{-}MAPS}$ emissions in Africa of less than 11% (or < 10.5 Tg) for each compound (Table S3). Possible under-predictions of <11% are within typical uncertainties of bottom-up emission inventories (Sect. 4.2.2). Table S4, however, does indicate that some emissions from commercial and residential sectors in Africa may be underpredicted in $CEDS_{GBD\text{-}MAPS}$ inventory.

Table S4. Maximum possible under-predictions in sectoral $CEDS_{GBD\text{-}MAPS}$ Africa emissions relative to DICE-Africa

DICE Sectors (Fuels)	CEDS Sectors (Fuels)	NO_x		SO_2		CO		NMVOC		NH_3		BC		OC	
		Tg[a]	%[b]	Tg[a]	%[b]	Tg[a]	%[b]	TgC[a]	%[b]	Tg[a]	%[b]	TgC[a]	%[b]	TgC[a]	%[b]
Gas Flares	1B2_fugitive_petr_gas	0.03	<0.1	-	-	<0.01	<0.1	<0.01	<0.1	-	-	<0.01	14	<0.01	28
Residential Generators (gas/diesel)	1A4b_Residential + 1A4c_Agriculture-forestry-fishing (light oil + diesel oil)	0.25	84	0.01	26	0.05	48	<0.01	2	-	-	<0.01	<0.01	<0.01	0.1
Charcoal production (fuelwood)	1A1bc_Other-transformation (process)	<0.01	16	-	-	6.0	99	2.5	99	0.03	99	<0.01	16	0.02	81
Com. Activity (fuelwood)	1A4a_Commercial-institutional (biomass)	0.09	100	0.03	88	4.5	98	2.0	99	<0.01	68	0.05	68	0.2	68
Sum of above sectors	All $CEDS_{GBD\text{-}MAPS}$ Africa Emissions	0.37	6	0.04	0.7	10.5	11	4.5	9	0.03	0.5	0.05	6.5	0.22	8

[a]Sum DICE-Africa 2013 emissions from each country within the given sector
[b]Potential underprediction in $CEDS_{GBD\text{-}MAPS}$ sectoral emissions, assuming DICE-Africa emissions are not accounted for in default CEDS estimates (i.e., 100* ($CEDS_{GBD\text{-}MAPS}$ Em. + DICE-Africa Em.)/ $CEDS_{GBD\text{-}MAPS}$ Em.)

As discussed in the main text, Fig. 3 compares the calibrated $CEDS_{GBD\text{-}MAPS}$ emissions of all compounds in Africa to those from the $CEDS_{Hoesly}$ inventory. Large differences include the reductions of NO_x and BC emissions from the on-road transport sector in $CEDS_{GBD\text{-}MAPS}$ relative to the $CEDS_{Hoesly}$ inventory. As discussed in Sect. 2.2, these reductions are largely driven by a difference in EFs used for emissions from diesel vehicles. For the on-road transport sector, the DICE-Africa inventory uses activity data from the UN energy database for total petrol/diesel use in the transport sector, which is then divided into usage for motorcycles and vehicles as described in Marais and

Wiedinmyer (2016). Vehicle activity data are not split further, and a single EF is applied to total vehicle activity data to calculate DICE-Africa emissions from all on-road cars. This DICE-Africa EFs for cars are consistent with the default CEDS EFs for on-road gasoline emissions and will be more representative of light vehicles than larger diesel trucks, which have default EFs in CEDS roughly twice as large.

S2.3.2 India Emissions Calibration

We also calibrate emissions from India to a new 2015 emissions inventory described in Venkataraman et al. (2018) (SMoG-India). Similar calibration sector and fuel definitions are defined as described above. As described in the main text, emissions for NO_x, SO_2, CO, NMVOCs, OC, and BC are available for 17 sectors and nine fuel types. Scaling mapping files can be found at: https://github.com/emcduffie/CEDS/tree/CEDS_GBD-MAPS/input/mappings/scaling. Scaling factors were calculated for the year 2015 and applied forward and back to the entire 1970 – 2017 timeseries. Due to uncertainties in the sectoral mapping and applicability of 2015 scaling factors over the entire time period, we note the potential misallocation of the SMoG-India 'Informal Industry' sector to the $CEDS_{GBD-MAPS}$ 1A2c_ind-Comb-Food-tobacco sector (rather than the 1A2g-Comb-Ind-other sector). This misallocation results in $CEDS_{GBD-MAPS}$ NO_x emissions in India possibly overpredicted by up to ~1 Tg between 1987-2014 (see also Sect. S4). While sectoral misallocations impact the magnitude of sub-sector emissions, total $CEDS_{GBD-MAPS}$ industry emissions in 2015 are equivalent to total industry emissions (information + light + heavy industry) from the SMoG-India inventory.

In addition, there are cases where default CEDS emissions for a specific sector/fuel-type combination equal 0, resulting in emissions of 0 after the calibration process. To avoid missing emissions in these instances, CEDS working fuel types are aggregated into "calibration fuels" (total coal, total liquid fuel, natural gas, and process emissions) in a similar manor to the calibration sectors (as described above in Sect. S2.3), and are later re-allocated to the CEDS working fuel types according to distributions prior to calibration. While this process may result in a slightly different fuel distribution at the most detailed level, final $CEDS_{GBD-MAPS}$ emissions (both gridded and country-level products) are aggregated into contributions from total coal, biofuel, oil and gas, and process emissions.

S2.4 Default BC and OC Emission Calibration Updates – Additional Details

Relative to CEDS v2019-12-23, BC and OC emissions are now calibrated to available regional- and national-level inventories. $CEDS_{GBD-MAPS}$ emissions for OC and BC from countries within each calibration inventory are shown in Fig. S2 and S3. These figures additionally compare these emissions to those from the $CEDS_{Hoesly}$, GAINS (ECLIPSE v5a) (Klimont et al., 2017), EDGAR v4.3.2 (Crippa et al., 2018), and calibration inventories. As described above and in the main text, regional inventories and final $CEDS_{GBD-MAPS}$ emissions may not agree depending on the level of overlap between the sectoral emissions included in each calibration inventory. For example, the national emissions from China (Zheng et al., 2018) are lower than the $CEDS_{GBD-MAPS}$ estimates due to waste emissions that are not included in the national-inventory.

It should also be noted that emissions from the metal and chemical industrial sectors in Japan are underestimated in both $CEDS_{Hoesly}$ and $CEDS_{GBD-MAPS}$ relative to the country level inventory (preliminary update from Kurokawa et al., 2013). Default CEDS emissions for these sectors are estimated to be zero in CEDS Step 1 and are therefore not scaled to the available inventory emissions. This underprediction is largest for years prior to 1995 (see

Fig. S3) and is reduced in recent years due to a decreasing fractional contribution of these sectors to total OC and BC emissions in the Kurokawa et al., 2013 inventory (40% to 28% for OC, 2% to 1.6%. for BC between 1990 and 2010). In addition, CEDS$_{\text{GBD-MAPS}}$ emissions are not scaled to EMEP emissions (EMEP, 2019) prior to 2000 due to changes in inventory reporting (Fig. S2).

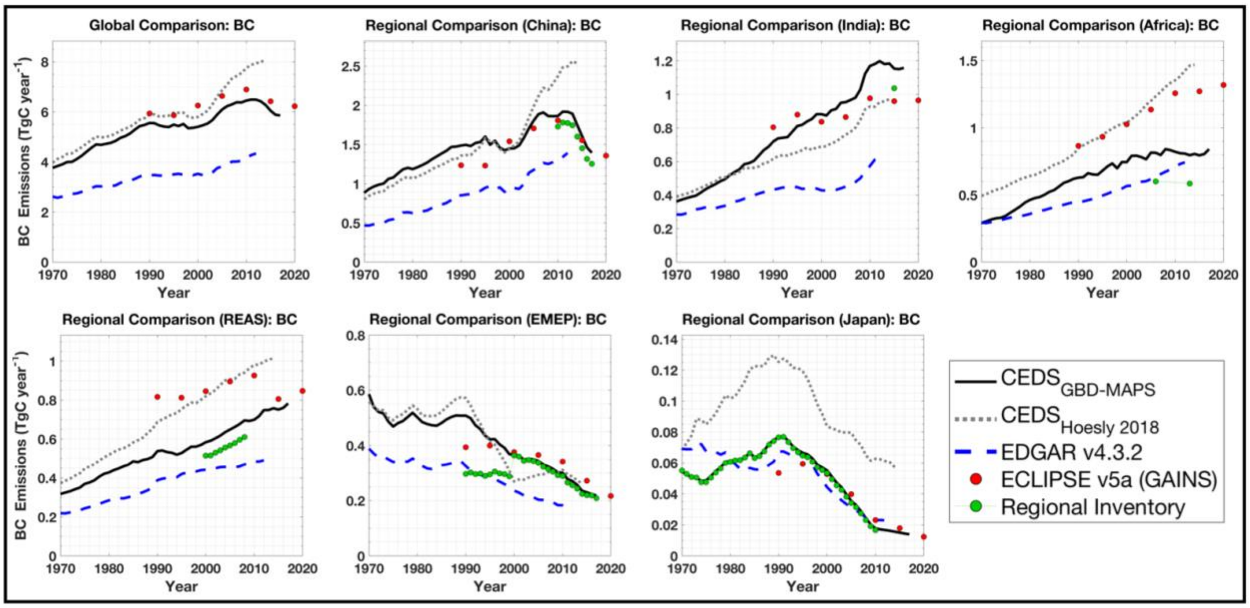

Figure S2. Time series of BC emissions from CEDS$_{\text{GBD-MAPS}}$ (black line), CEDS$_{\text{Hoesly}}$ (gray dashed line), EDGAR v4.3.2 (blue dashed line), and ECLIPSE v5a baseline current legislation (CLE) inventory from the GAINS model (red dots). Each panel shows total annual emissions from each designated country/region. GAINS values for 2015 and 2020 are emission projections. Global inventories show reported emissions from all sectors excluding open burning, shipping, and aviation. Respective regional inventories are shown by green dots/lines and include all reported emissions that are also included in regional CEDS$_{\text{GBD-MAPS}}$ emissions (e.g., do not include open burning, road dust, shipping, aviation, etc). Note: in the regional comparisons, CEDS$_{\text{GBD-MAPS}}$, CEDS$_{\text{Hoesly}}$, and EDGAR v4.3.2 emissions also include inland navigation, while GAINS v5a CLE do not include any shipping emissions. In the global comparison, all available shipping emissions (inland navigation and international shipping) are included in each inventory. REAS and EMEP member countries listed in Table S5.

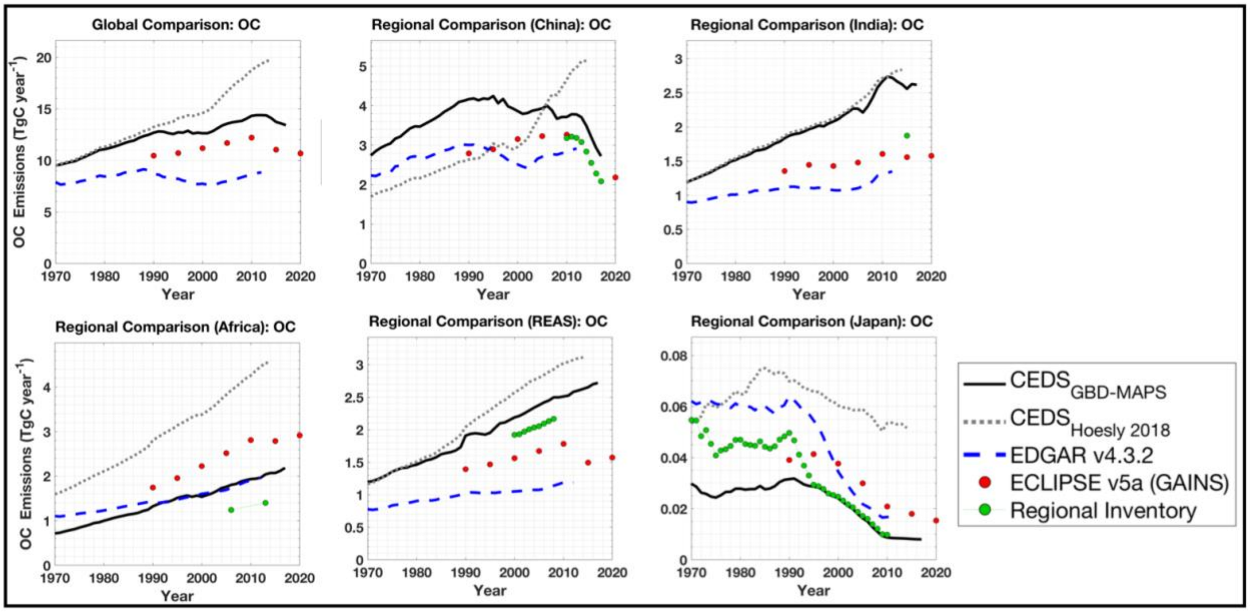

Figure S3. Same as Fig. S2, but for OC emissions.

Table S5. Countries included in REAS and EMEP regions

REAS	Afghanistan	Bhutan	Brunei Darussalam	Cambodia
	Bangladesh	Maldives	DPR Korea	Kyrgyzstan
	Indonesia	Myanmar	Kazakhstan	Mongolia
	Laos	Sri Lanka	Nepal	Singapore
	Malaysia	Turkmenistan	Pakistan	Thailand
	Tajikistan	Vietnam	Philippines	Uzbekistan
	Taiwan			
EMEP	Albania	Armenia	Belgium	Czech Republic
	Belarus	Austria	Cyprus	Estonia
	Bulgaria	Croatia	France	Germany
	Denmark	Finland	Italy	Hungary
	Georgia	Greece	Malta	Kyrgyzstan
	Iceland	Ireland	Montenegro	Latvia
	Luxembourg	Macedonia	Portugal	Netherlands
	Norway	Poland	Slovenia	Romania
	Sweden	Slovakia	Spain	Switzerland
	United Kingdom			

S2.5 Spatial Gridding & Aggregation Updates – Additional Details

Relative to CEDSv2019-12-23, CEDS emissions prior to gridding are now aggregated into 17 intermediate sectors as a function of four fuel categories: total coal (hard coal + brown coal + coal coke), solid biofuel, the sum of liquid fuel (heavy oil + light oil + diesel oil) and natural gas, and all remaining 'process' emissions.

CEDS Step 5 then spatially allocates total country-level emission estimates on to a 0.5°×0.5° global grid to facilitate their use in earth system models. The procedure for spatially allocating CEDS total country-level emissions is largely unchanged between CEDSv2019-12-23 and $\text{CEDS}_{\text{GBD-MAPS}}$. This process uses normalized spatial distribution proxies that are compound- and sector-specific. In CEDSv2019-12-23, proxy distribution data are primarily from gridded EDGAR emissions (v4.2 and v4.3) (EC-JRC/PBL, 2012, 2016) and HYDE population (Klein Goldewijk et al., 2011) (primarily for historical extension prior to 1970 and waste emissions). In CEDSv2019-12-23, gridding proxies are then held constant after 2008 or 2010 (ROAD transportation only). For the $\text{CEDS}_{\text{GBD-MAPS}}$

inventory, we have updated the compound- and sector-specific normalized spatial proxies for 1970 – 2012 to use the most recent release of the EDGAR inventory (v4.3.2) (Table S6). Spatial proxies are then held constant for all years after 2012. These updates extend many of the latest spatial proxies from 2008 to 2012 but may still introduce uncertainty in the gridded $\text{CEDS}_{\text{GBD-MAPS}}$ products between 2013 and 2017 for sectoral emissions that have experienced large changes in their normalized spatial distributions within large countries (Sect. 4.2.4). The same sector-specific gridding proxy is also applied to emissions from each fuel group within each sector. This process may introduce additional uncertainties into the gridded $\text{CEDS}_{\text{GBD-MAPS}}$ products as discussed in Sect. 4.2. These uncertainties do not impact the final country-level $\text{CEDS}_{\text{GBD-MAPS}}$ products because they are not gridded.

As further described in Hoesly et al. (2018), sectors that do not have congruent emissions between CEDS and EDGAR v4.3.2 inventories use population data from HYDE (Klein Goldewijk et al., 2011) and Gridded Population of the World (GPW) (Doxsey-Whitfield et al., 2015) products as backup spatial proxies. Supplemental Table S6 provides a complete list of gridding proxies as a function of sector. All sectors that do not use EDGAR data use the same spatial proxies as in CEDSv2019-12-23. For example, emissions from the waste sector are gridded using yearly estimates of population, which have not been updated relative to CEDSv2019-12-23 and are therefore held constant after the year 2015.

Table S6. Gridding proxies used for spatial allocation, listed by sector.

CEDS final sectors	**CEDS intermediate gridding sectors**	**Spatial Proxy**[a]	**Years**[b]
Agriculture (AGR)	Agriculture	EDGAR v4.3.2 AGR	1970 – 2012
International Shipping (SHP)	International Shipping	ECLIPSE and additional data[c]	1990, 1995, 2000, 2005, 2010, 2015
	International Shipping (tanker loading)	ECLIPSE and additional data[c]	1996
On-Road Transportation (ROAD)	On-Road Transportation	EDGARv4.3.2 ROAD	2010
Non-Road Transportation (NRTR)	Non-Road Transportation	EDGAR v4.3.2 NRTR	1970 - 2012
Residential, Commercial, Other - Residential (RCOR)	Residential, Commercial, Other - Residential	EDGAR v4.3.2 RCO	1970 – 2012
Residential, Commercial, Other - Commercial (RCOC)	Residential, Commercial, Other - Commercial	EDGAR v4.3.2 RCO	1970 – 2012
Residential, Commercial, Other - Other (RCOO)	Residential, Commercial, Other - Other	EDGAR v4.3.2 RCO	1970 – 2012
Energy (ENE)	Oil and gas fugitive/flaring	ECLIPSE FLR[c]	1970 – 2015
	Electricity and heat production	EDGAR v4.3.2 ELEC	1970 – 2012
	Fuel production and transformation	EDGAR v4.3.2 ETRN	1970 – 2012
	Fossil Fuel Fires	EDGAR v4.3.2 FFFI	1970 - 2012
Waste (WST)	Waste	HYDE population, GPW v4 (modified rural population)[c]	1970 – 2015
Industry (IND)	Industrial Combustion	EDGAR v4.3.2 INDC	1970 – 2012
	Industrial process and product use	EDGAR v4.3.2 INPU	1970 – 2012
Solvent production and application (SLV)	Solvent production and application (SLV)	EDGAR v4.3.2 SLV	1970 - 2012

[a]All species and sectors use population as a backup proxy.
[b]Spatial proxies held constant for years not listed. For example, EDGAR v4.3.2 proxies from 2012 are used for years 2012-2017. All sectors use population as a backup proxy (2016-2017 use 2015 population).
[c]Not updated relative $\text{CEDS}_{\text{Hoesly}}$ inventory.

After the gridding procedure, the 17 intermediate sectors are then aggregated into 11 final sectors, by effectively splitting the original CEDSv2019-12-23 emissions from the TRA sector into 'On-Road' and 'Non-Road/Other' contributions and splitting the original RCO sector into individual contributions from the Residential, Commercial, and Other sectors. Table 2 contains a complete breakdown of the definitions of CEDS working, intermediate gridding, and final sectors. Figure S4 illustrates the level of detail available in this new $CEDS_{GBD\text{-}MAPS}$ inventory by illustrating global BC emissions in 2017 from 1) all source sectors, 2) the residential sector only, 3) residential biofuel-use only, and 4) residential coal-use only.

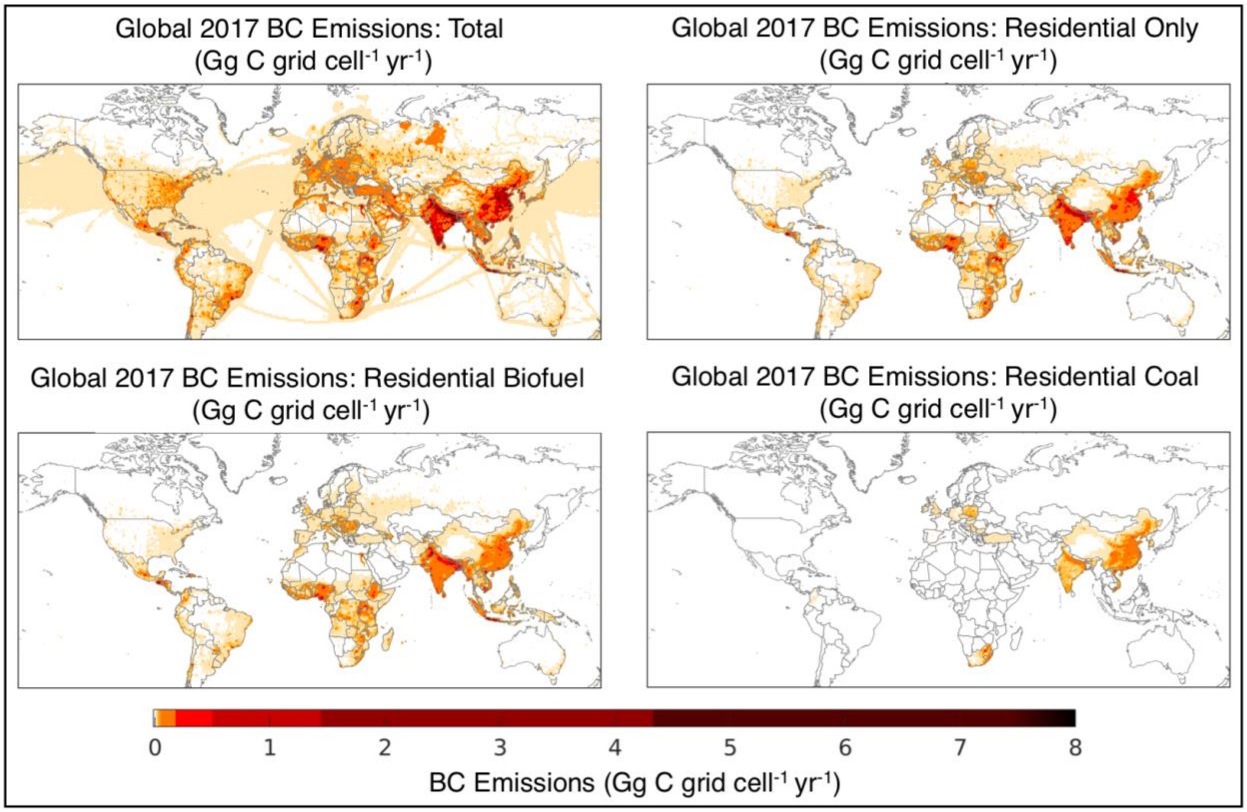

Figure S4. Map of global BC emissions for 2017 from (top left) all sectors, (top right) residential emissions only, (bottom left) residential biofuel only, and (bottom right) residential coal only.

Section S3. Supplemental Results

Table S7. Fractional sectoral and fuel-type contributions to 2017 global emissions of each compound. Sectoral contributions in bold sum to 100% for each compound (i.e., AGR + ENE +… SHP =100%). Fractional contributions of fuel-types within each sector sum to 100% for each compound (i.e., ENE coal + ENE biofuel + ENE Oil+Gas + ENE Process =100%).

Sector	Fuel-Type	NO_x	CO	SO_2	NH_3	NMVOC	BC	OC
AGR	**Total**	**5%**	**-**	**-**	**75%**	**-**	**-**	**-**
AGR	Coal	-	-	-	-	-	-	-
AGR	Biofuel	-	-	-	-	-	-	-
AGR	Oil + Gas	-	-	-	-	-	-	-
AGR	Process	100	-	-	100	-	-	-
ENE	**Total**	**22%**	**11%**	**42%**	**2%**	**36%**	**10%**	**8%**
ENE	Coal	46	10	63	4	<1	3	7
ENE	Biofuel	3	2	<1	3	<1	15	53
ENE	Oil + Gas	35	8	18	6	<1	2	<1
ENE	Process	16	80	19	87	99	80	40
IND	**Total**	**15%**	**14%**	**36%**	**2%**	**6%**	**12%**	**10%**
IND	Coal	49	36	38	5	25	47	17
IND	Biofuel	10	11	1	39	25	24	78
IND	Oil + Gas	36	5	25	11	9	29	5
IND	Process	5	48	36	45	41	-	-
ROAD	**Total**	**23%**	**32%**	**2%**	**1%**	**17%**	**20%**	**7%**
ROAD	Coal	-	-	-	-	-	-	-
ROAD	Biofuel	-	-	-	-	-	-	-
ROAD	Oil + Gas	100	100	100	100	100	100	100
ROAD	Process	-	-	-	-	-	-	-
NRTR	**Total**	**6%**	**1%**	**1%**	**<1%**	**1%**	**1%**	**<1%**
NRTR	Coal	<1	<1	<1	<1	<1	<1	<1
NRTR	Biofuel	-	-	-	-	-	-	-
NRTR	Oil + Gas	100	100	100	100	100	100	100
NRTR	Process	<1	<1	<1	<1	<1	<1	<1
RCOR	**Total**	**3%**	**35%**	**4%**	**6%**	**18%**	**38%**	**54%**
RCOR	Coal	9	13	68	<1	2	13	8
RCOR	Biofuel	57	86	22	96	97	70	92
RCOR	Oil + Gas	34	1	10	3	1	17	<1
RCOR	Process	-	-	-	-	-	-	-
RCOC	**Total**	**1%**	**<1%**	**2%**	**<1%**	**<1%**	**5%**	**4%**
RCOC	Coal	-	47	68	23	16	45	38
RCOC	Biofuel	-	12	1	28	29	28	54
RCOC	Oil + Gas	100	41	31	49	55	27	8
RCOC	Process	-	-	-	-	-	-	-
RCOO	**Total**	**3%**	**3%**	**1%**	**<1%**	**1%**	**6%**	**2%**
RCOO	Coal	2	10	36	12	4	13	22
RCOO	Biofuel	1	21	1	11	23	10	48
RCOO	Oil + Gas	97	69	63	77	73	77	30
RCOO	Process	-	-	-	-	-	-	-
SLV	**Total**	**-**	**-**	**-**	**<1%**	**17%**	**-**	**-**
SLV	Coal	-	-	-	-	-	-	-
SLV	Biofuel	-	-	-	-	-	-	-
SLV	Oil + Gas	-	-	-	-	-	-	-
SLV	Process	-	-	-	100	100	-	-
WST	**Total**	**2%**	**3%**	**<1%**	**14%**	**2%**	**5%**	**13%**
WST	Coal	-	-	-	-	-	-	-
WST	Biofuel	-	-	-	-	-	-	-
WST	Oil + Gas	-	-	-	-	-	-	-
WST	Process	100	100	100	100	100	100	100
SHP	**Total**	**20%**	**<1%**	**12%**	**<1%**	**2%**	**3%**	**1%**
SHP	Coal	-	-	-	-	-	-	-
SHP	Biofuel	-	-	-	-	-	-	-
SHP	Oil + Gas	100	100	100	100	27	100	100
SHP	Process	-	-	-	-	73	-	-

Table S8. Region/Country definitions for main text Fig. 8 and supplemental Fig. S6-S19

Region/Country	Member Countries			
Africa	Algeria	Angola	Burundi	Benin
	Burkina Faso	Botswana	Central African Republic	Cote d'Iviore
	Cameroon	Chad	Congo	Comoros
	Cape Verde	DR Congo	Djibouti	Egypt
	Eritrea	Ethiopia	Gabon	Ghana
	Guinea	Gambia	Guinea-Bissau	Equatorial Guinea
	Kenya	Liberia	Libya	Lesotho
	Madagascar	Malawi	Mali	Mauritania
	Mauritius	Morocco	Mozambique	Namibia
	Niger	Nigeria	Reunion	Rwanda
	Sao Tome and Principe	Senegal	Seychelles	Sierra Leone
	Somalia	South Africa	South Sudan	Sudan
	Tunisia	Swaziland	Tanzania	Togo
	Zimbabwe	Uganda	Western Sahara	Zambia
China	China			
Europe	Albania	Austria	Belgium	Bosnia
	Bulgaria	Croatia	Cyprus	Czech Republic
	Denmark	Finland	France	Germany
	Gibraltar	Greece	Greenland	Hungary
	Iceland	Ireland	Italy	Liechtenstein
	Luxembourg	Macedonia	Malta	Netherlands
	Norway	Poland	Portugal	Romania
	Serbia and Montenegro	Slovakia	Slovenia	Spain
	Sweden	Switzerland	Turkey	United Kingdom
Former Soviet Union	Armenia	Azerbaijan	Belarus	Estonia
	Georgia	Kazakhstan	Kyrgyzstan	Latvia
	Lithuania	Moldova	Tajikistan	Turkmenistan
	Russia	Ukraine	Uzbekistan	
India	India			
Latin America	Antigua and Barbuda	Argentina	Aruba	Bahamas
	Barbados	Belize	Bermuda	Bolivia
	Brazil	British Virgin Islands	Cayman Islands	Chile
	Colombia	Costa Rica	Cuba	Curacao
	Dominica	Dominican Republic	Ecuador	El Salvador
	Faeroe Islands	Falkland Islands	French Guiana	Grenada
	Guadeloupe	Guatemala	Jamaica	Guyana
	Honduras	Haiti	Netherland Antilles	Martinique
	Mexico	Montserrat	Peru	Nicaragua
	Panama	Paraguay	Sint Maarten	Saint Kitts and Nevis
	Saint Lucia	St Pierre and Miquelon	St Vincent and Grenadines	Suriname
	Trinidad and Tobago	Turks and Caicos Islands	US Virgin Islands	Uruguay
	Venezuela			
North America	United States	Canada	Puerto Rico	
Other Asia/ Pacific/ Middle East	Afghanistan	American Samoa	Australia	Bahrain
	Bangladesh	Bhutan	Brunei Darussalam	Cambodia
	Chinese Taipei	Cook Islands	DPR Korea	Micronesia
	Fiji	French Polynesia	Guam	Hong Kong
	Indonesia	Iraq	Islamic Republic of Iran	Israel
	Japan	Jordan	Kiribati	Kuwait
	Laos	Lebanon	Oman	Macao
	Malaysia	Maldives	Marshall Islands	Mongolia
	Montenegro	Myanmar	Nepal	New Caledonia
	New Zealand	Niue	Pakistan	Palau
	Palestine	Papua New Guinea	Philippines	Qatar
	Republic of Korea	Samoa	Saudi Arabia	Singapore
	Soloman Islands	Sri Lanka	Syria	Thailand
	Timor-Leste	Tokelau	Tongo	United Arab Emirates
	Vanuatu	Vietnam	Wallis and Futuna Islands	Yemen

To supplement the results presented in Sect. 3, Fig. S5 provides time series of the contributions of each source sector to global emissions, for each compound. Figures S6-S11 additionally show time series of sectoral emissions of each compound in dominant source regions, including North America, Europe, China, India, Africa, and the Other Asia/Pacific/Middle East region (Table S8). To highlight the fuel-type information in the $CEDS_{GBD\text{-}MAPS}$ inventory, Fig. S12 also illustrates global emissions of each compound as a function of fuel-group and sector, while Fig. S12-S19 illustrate the fuel-type contributions to emissions from the 9 world regions listed above. Figures S21 and S22 provide an additional comparison of $CEDS_{GBD\text{-}MAPS}$ global sectoral emissions to sectoral emissions reported from the EDGAR v4.3.2 and GAINS (ECLIPSE v5a) inventories.

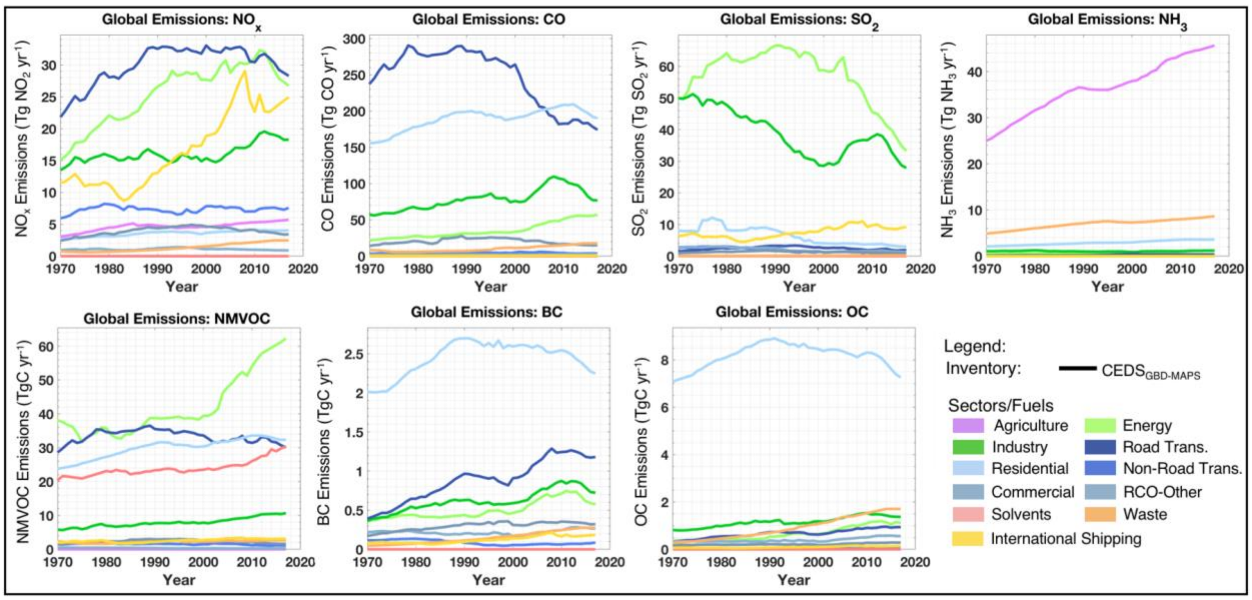

Figure S5. Time series of global emissions for each compound as a function of emission sector (all fuel types shown).

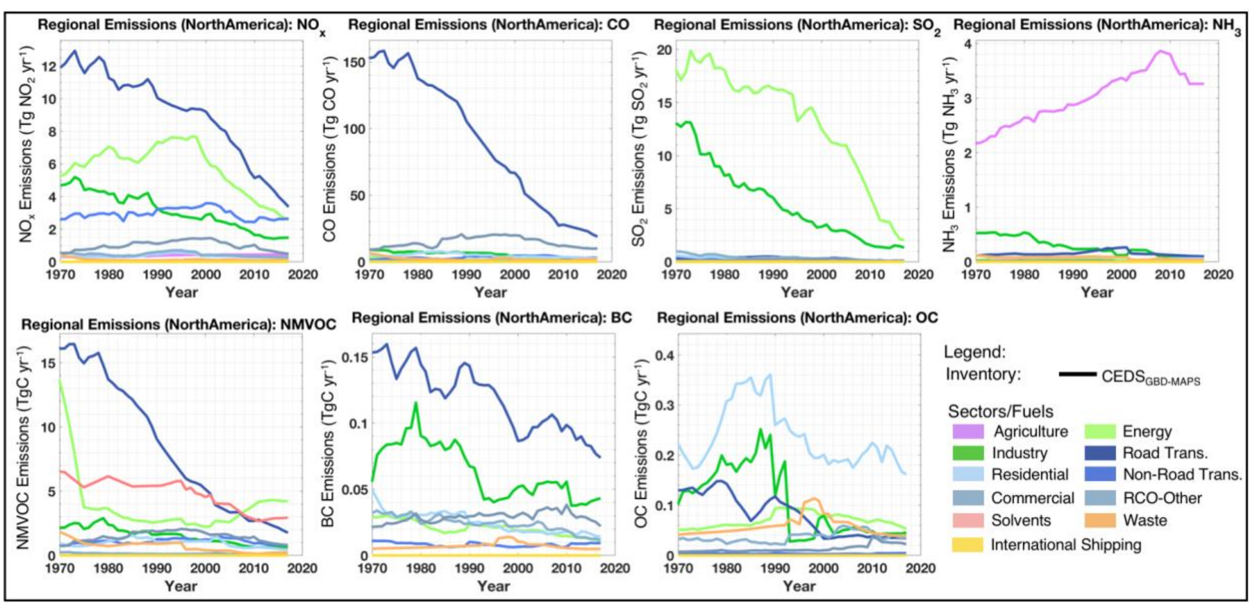

Figure S6. Time series of emissions in North America, as a function of emission sector (all fuel types shown).

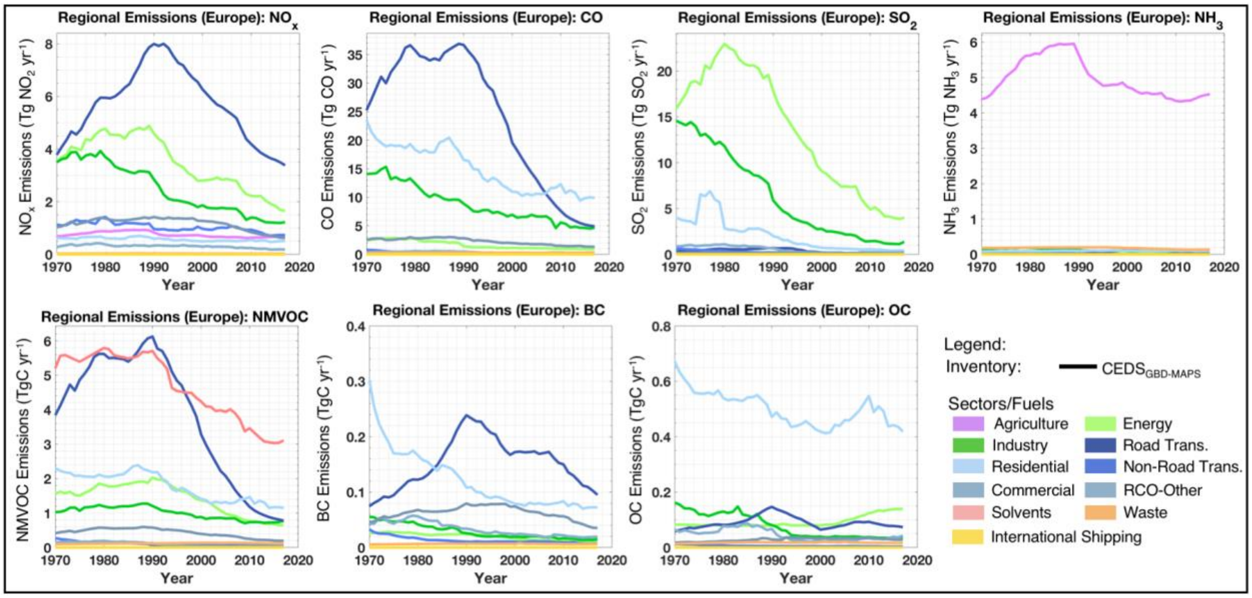

Figure S7. Time series of emissions in Europe, as a function of emission sector (all fuel types shown).

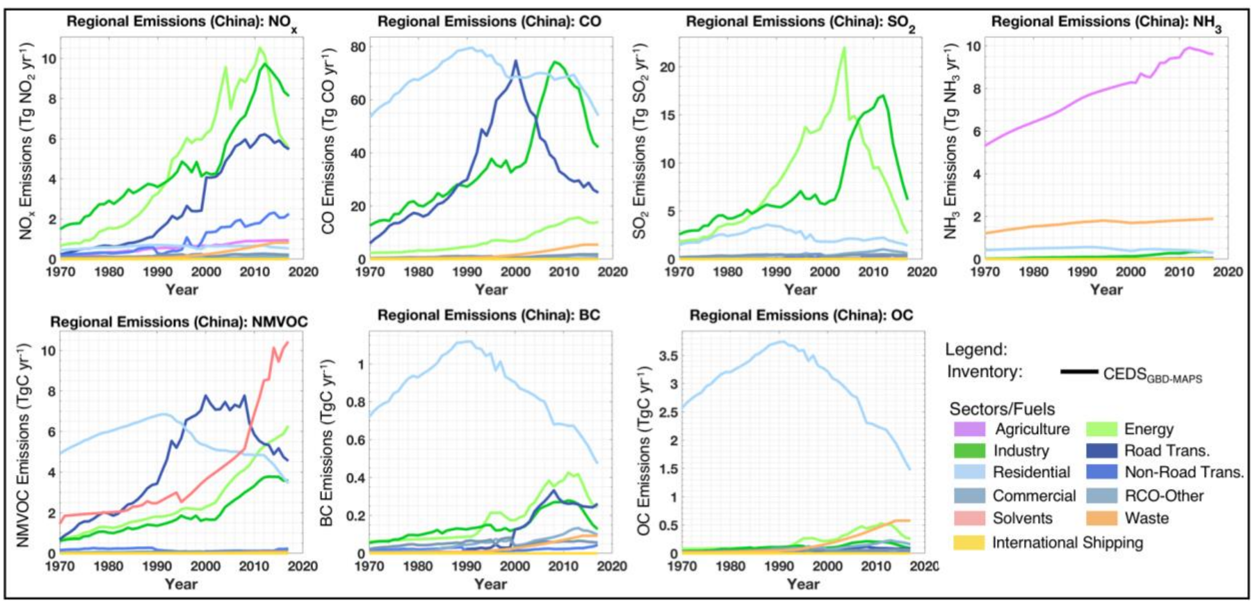

Figure S8. Time series of emissions in China, as a function of emission sector (all fuel types shown).

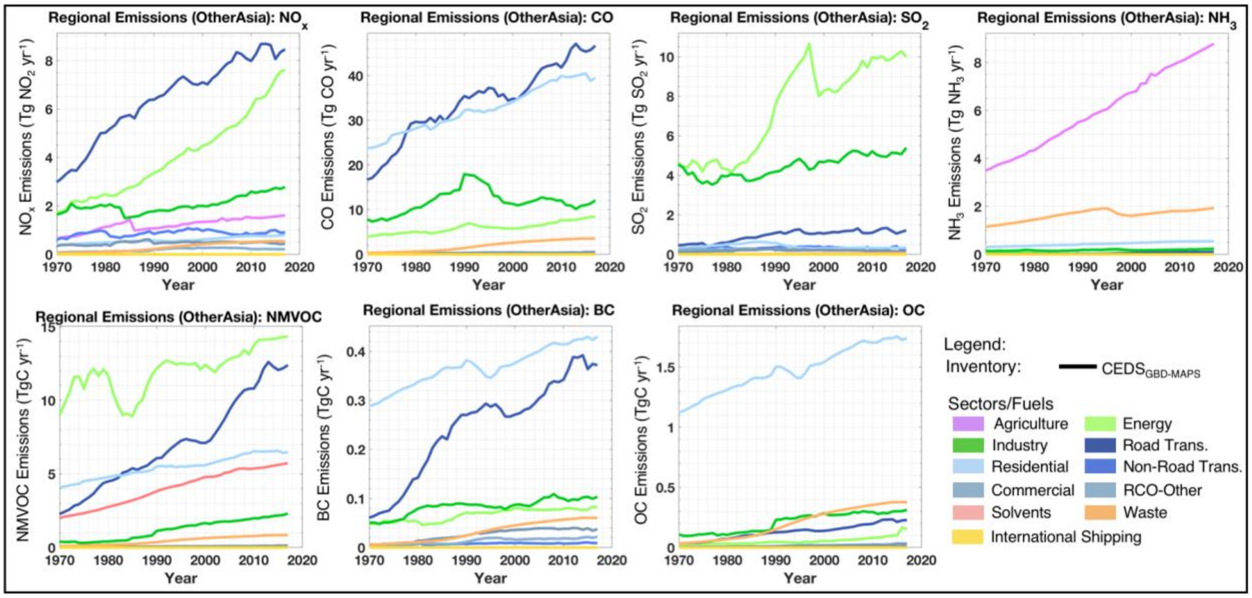

Figure S9. Time series of emissions in the Other Asia/Pacific/Middle East region (Table S8), as a function of emission sector (all fuel types shown).

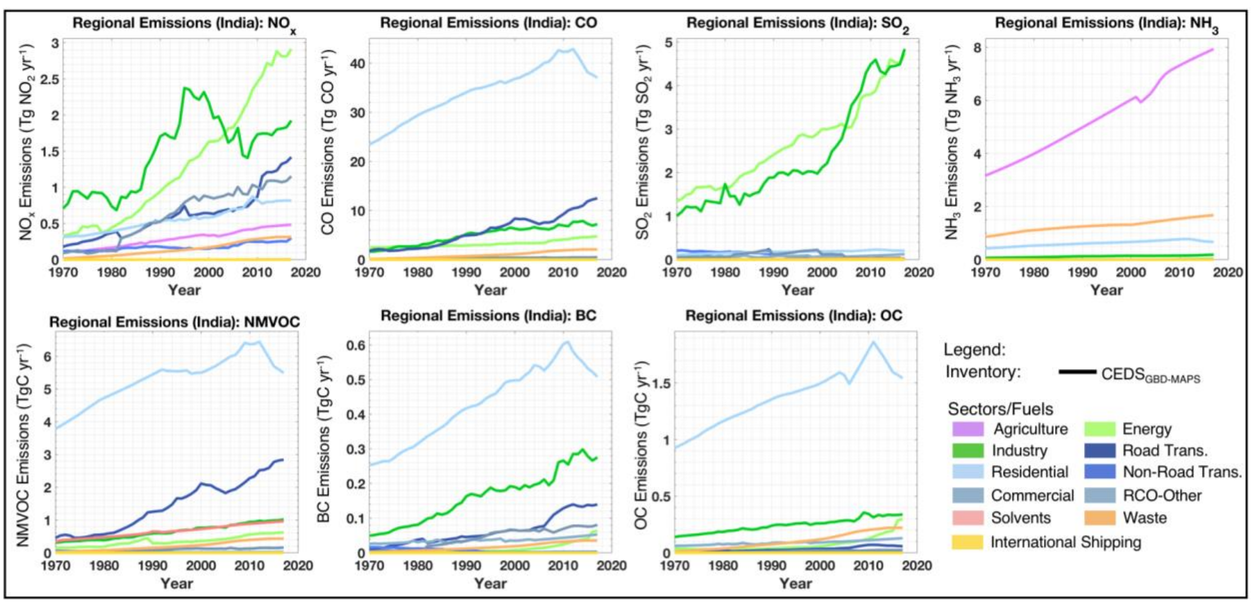

Figure S10. Time series of emissions in India, as a function of emission sector (all fuel types shown).

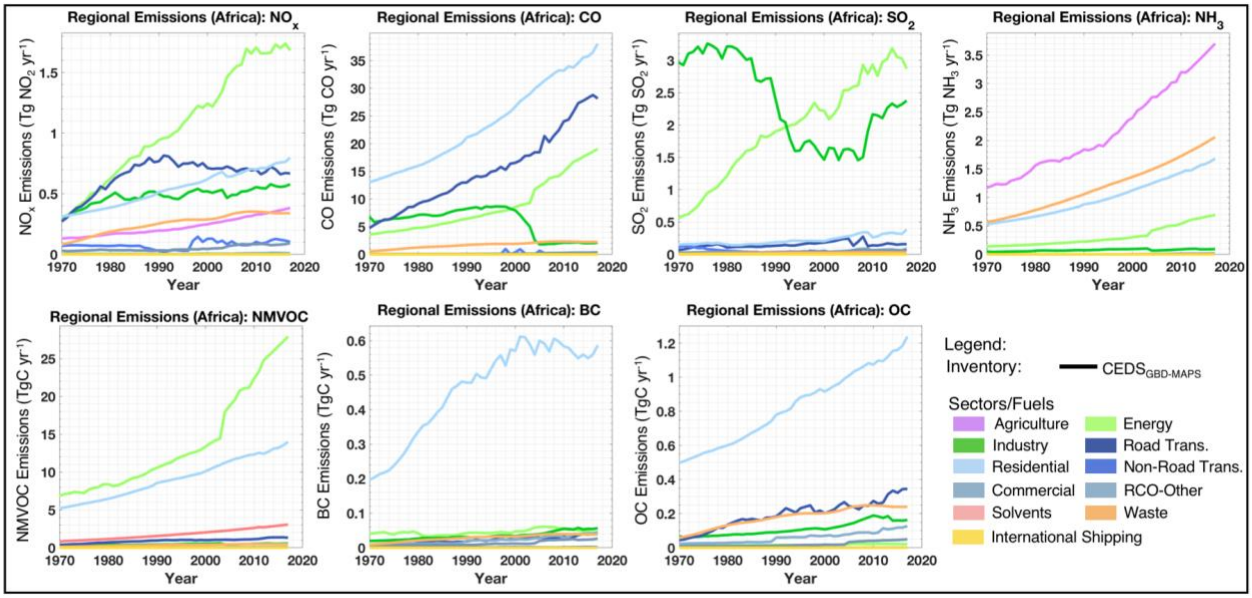

Figure S11. Time series of emissions in Africa, as a function of emission sector (all fuel types shown).

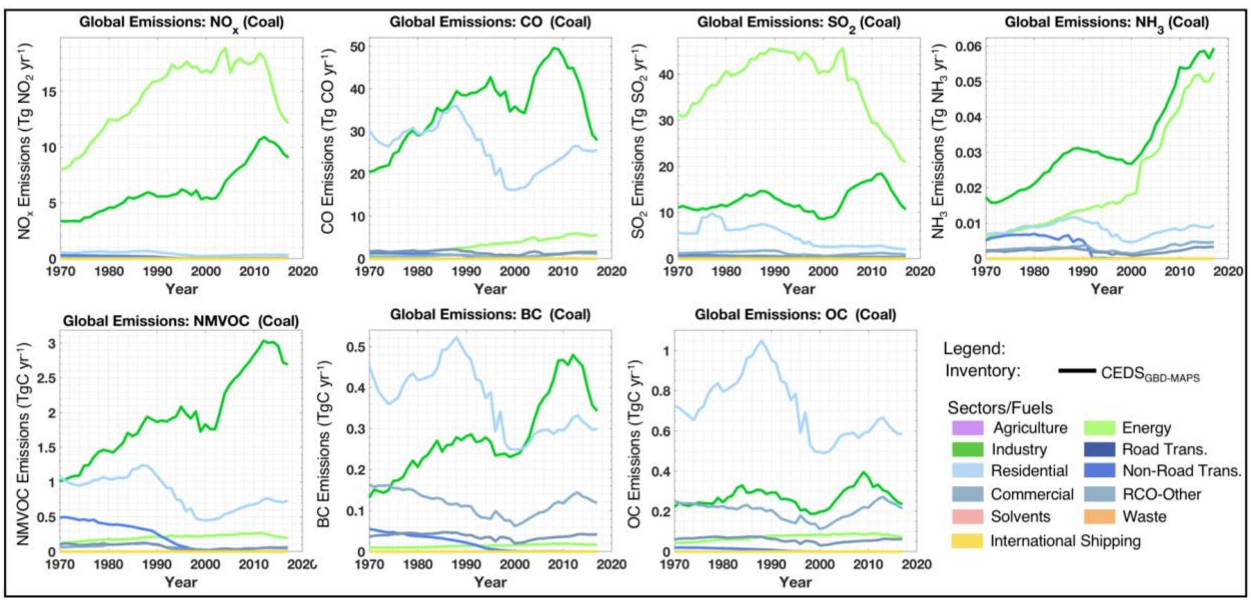

Figure S12. Time series of global sectoral emissions associated with coal combustion.

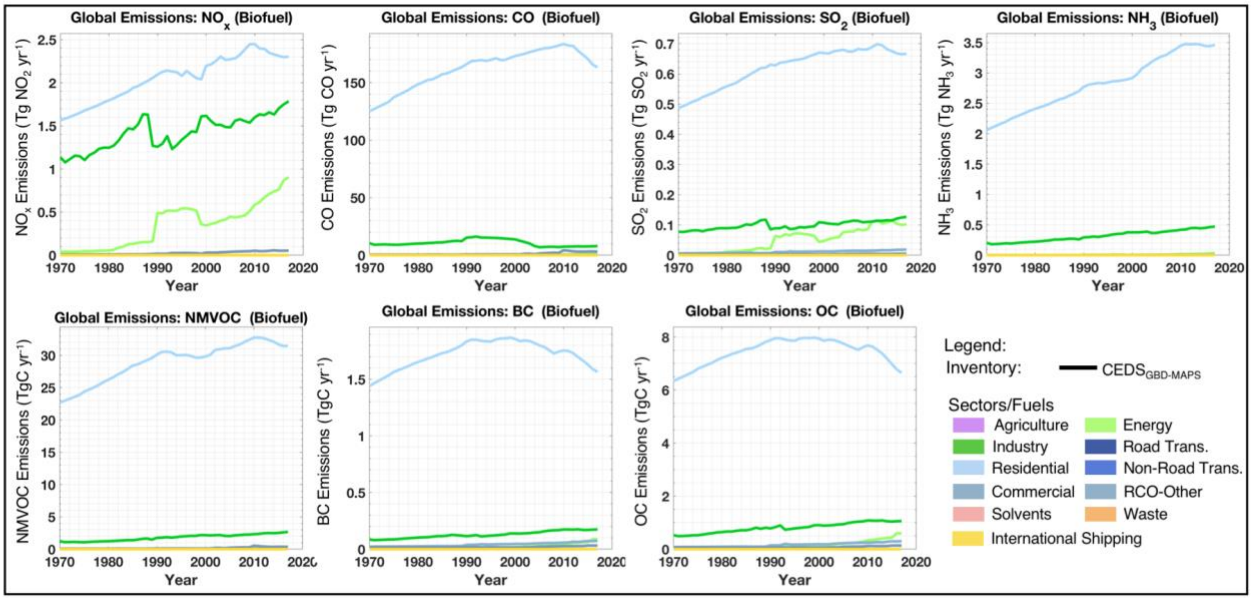

Figure S13. Time series of global sectoral emissions associated with solid biofuel combustion.

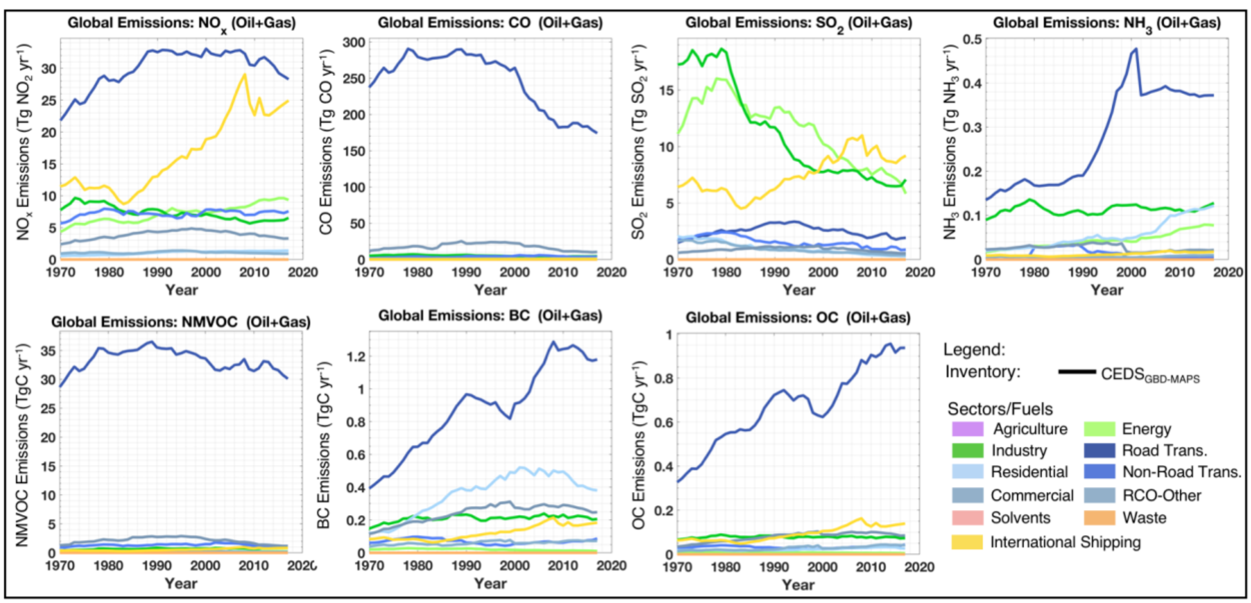

Figure S14. Timeseries of global sectoral emissions associated with the combustion of liquid oil and natural gas.

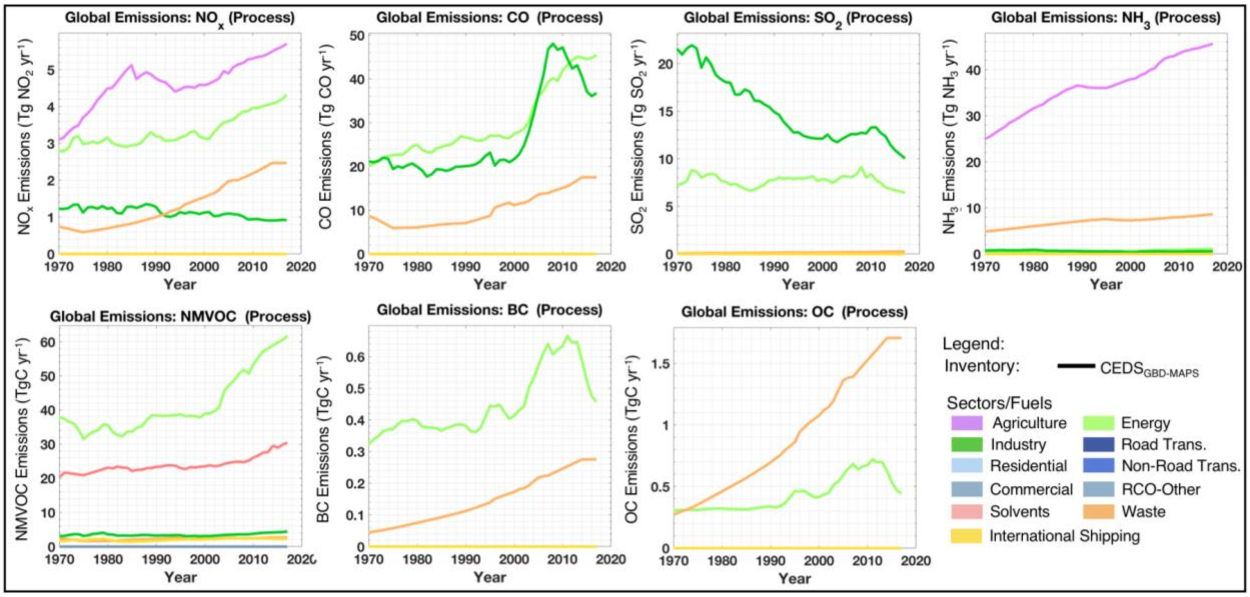

Figure S15. Timeseries of global sectoral emissions associated with CEDS process-level emission sources (Table 2)

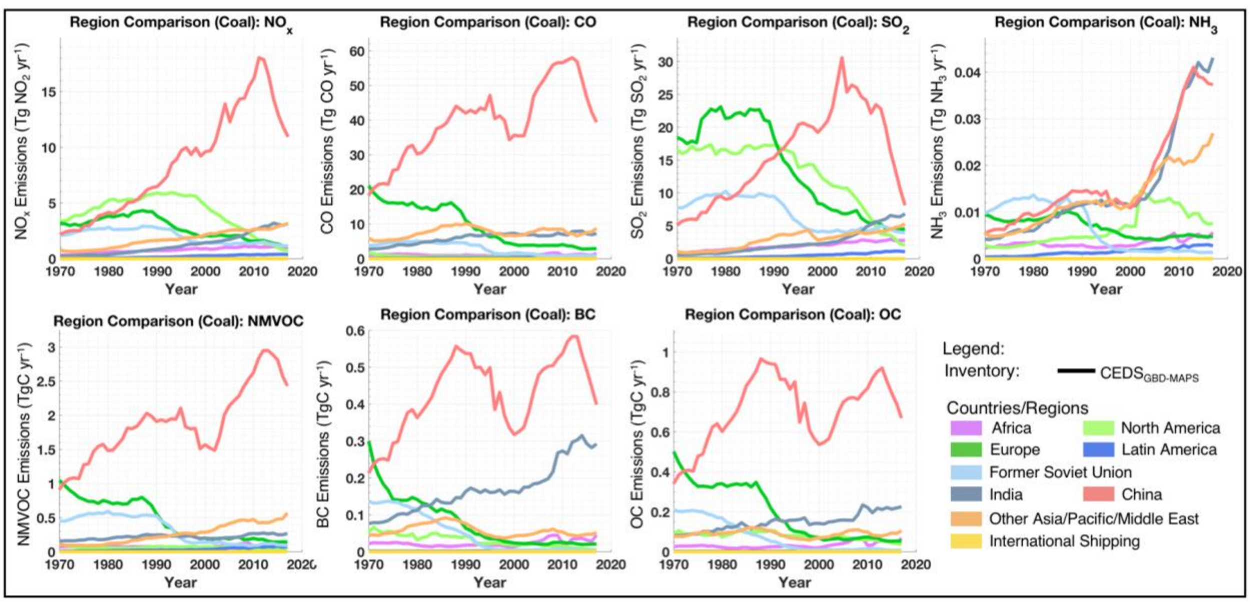

Figure S16. Timeseries of emissions associated with coal combustion, split into contributions from 9 world countries/regions (from coal combustion in all sectors).

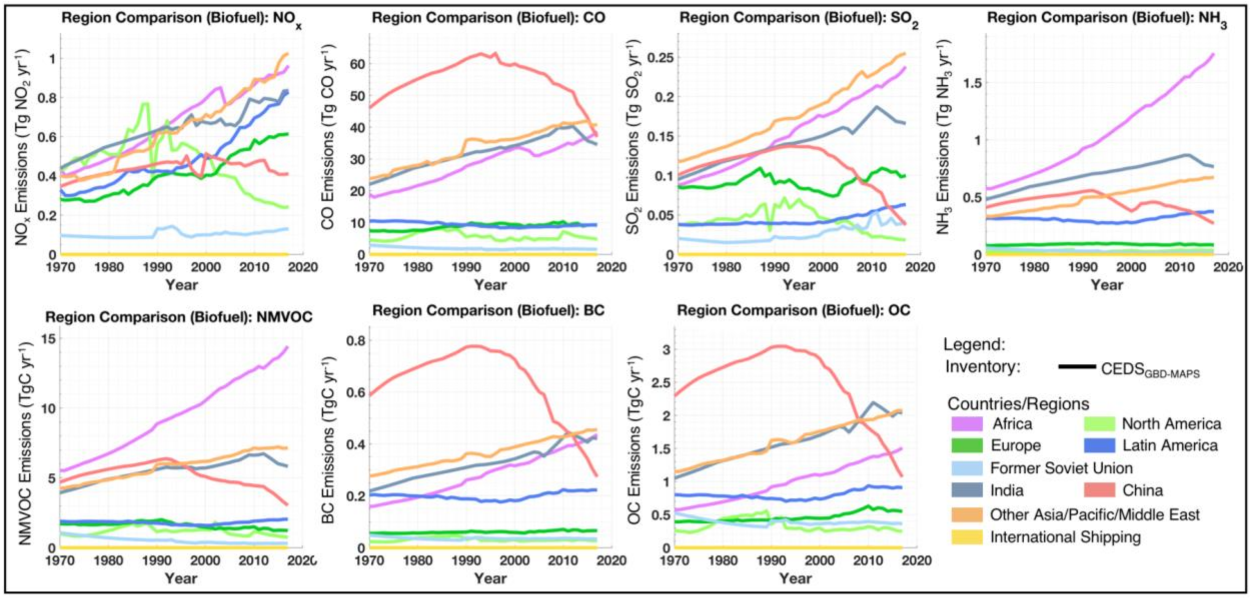

Figure S17. Timeseries of emissions associated with solid biofuel combustion, split into contributions from 9 world countries/regions (from biofuel combustion in all sectors).

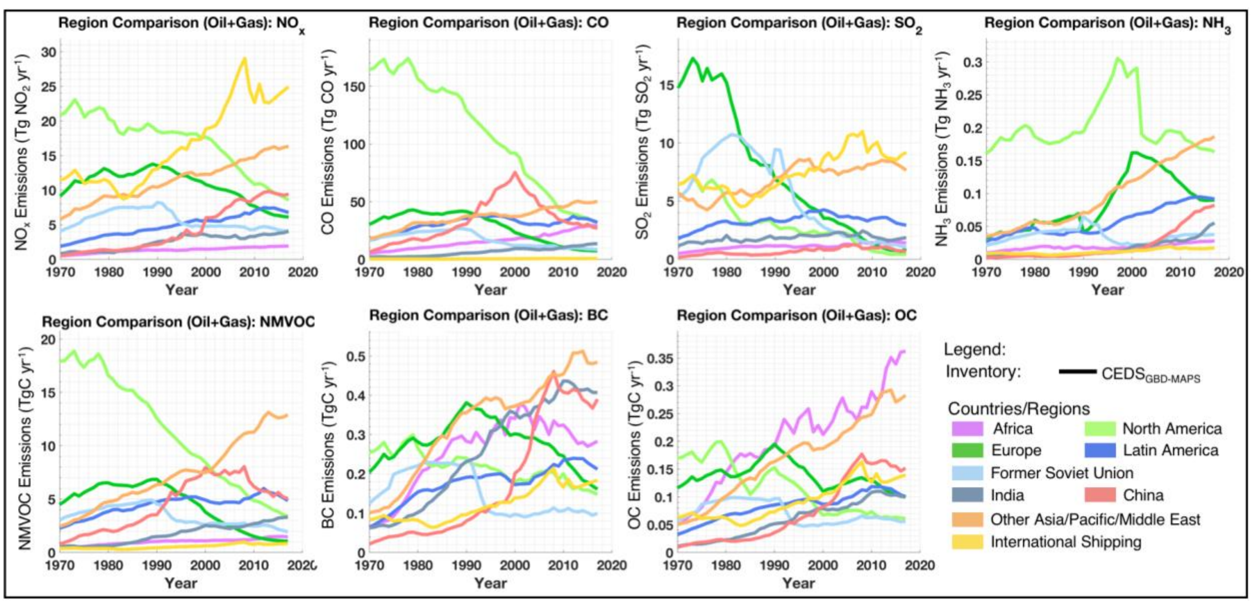

Figure S18. Timeseries of emissions associated with the combustion of liquid oil and natural gas, split into contributions from 9 world countries/regions.

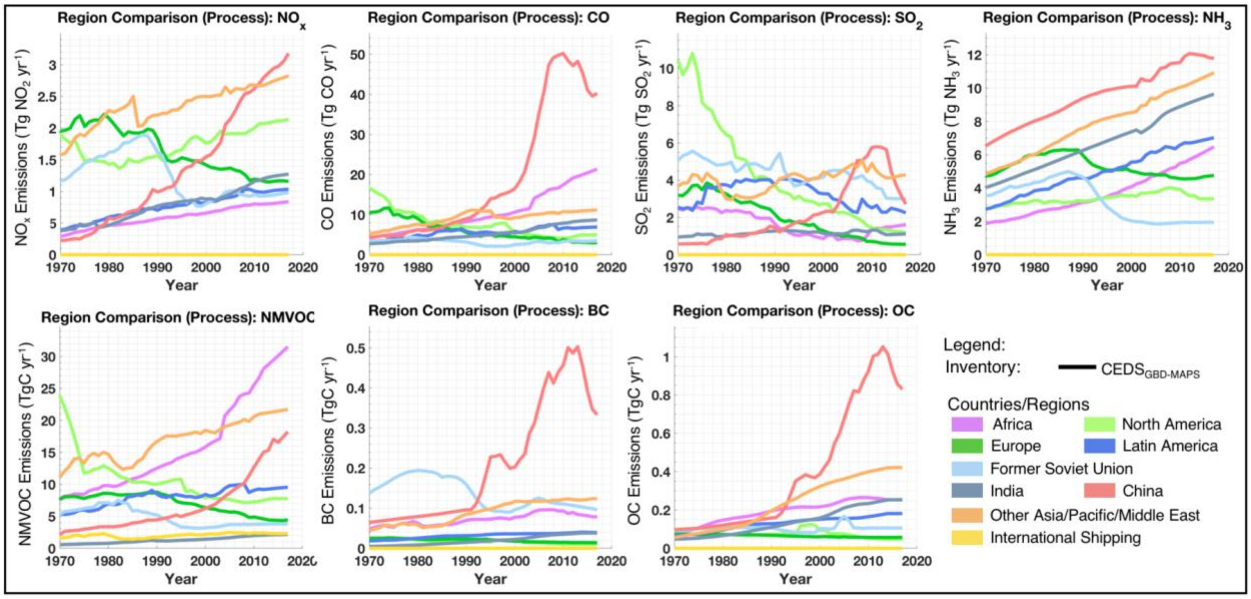

Figure S19. Timeseries of emissions from CEDS process-level sources (Table 2), split into contributions from 9 world countries/regions.

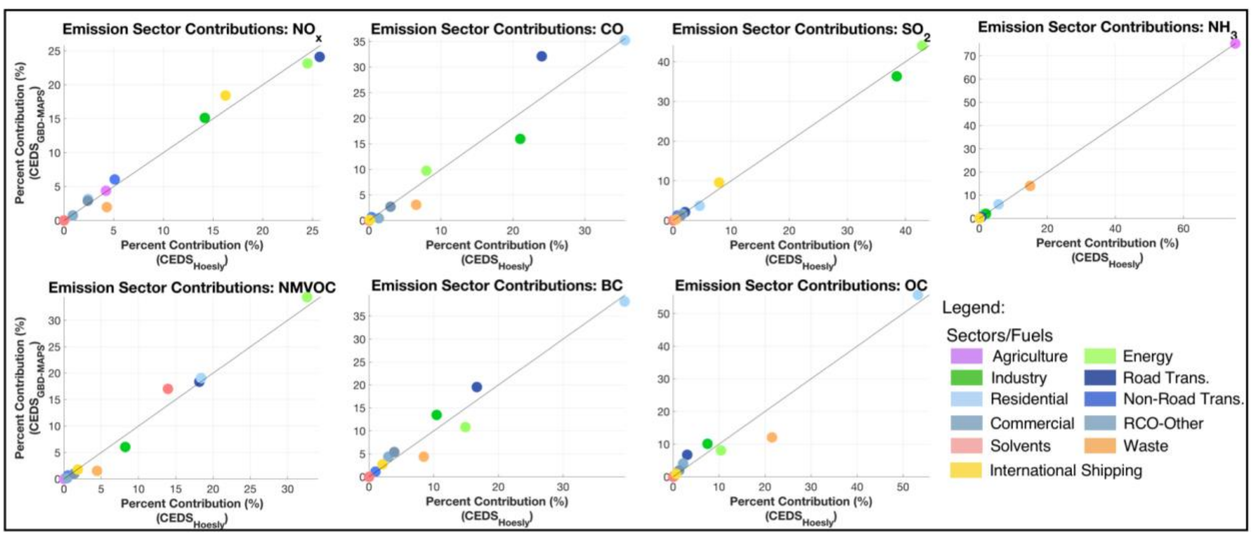

Figure S20. Comparison of CEDS sectoral fractional contributions in the $CEDS_{GBD\text{-}MAPS}$ (y-axis) and $CEDS_{Hoesly}$ (x-axis) inventories. Fractional contributions are calculated from global total emissions from all fuel types (= Sector X/ Total global emissions). Black line in the 1:1 line. Points are colored by sector.

Table S9. Mapping between EDGAR v4.3.2, ECLIPSE v5a (GAINS), and CEDS$_{GBD-MAPS}$ sectors for Fig. S21-S22

Aggregate Figure Sectors	CEDS$_{GBD-MAPS}$ Final Sectors	EDGAR v4.3.2 Reported Sectors	ECLIPSE v5a (gridded data) sectors
Agriculture	AGR	4A – Enteric fermentation 4B – Manure management 4C – Rice cultivation 4D1/4D2/4D4 – Direct soil emissions	Agriculture – livestock and arable land operations (AGR)
Energy	ENE	1A1a – Public electricity and heat production 1A1bc/1A5 – Other energy industries 1B1 – Fugitive solid fuels 1B2 – Fugitive oil and gas 7A – Fossil fuel fires	Energy – power plants, energy production/ conversion, fossil fuel distribution (ENE)
Industry	IND	1A2 – Manufacturing and Construction 2A1 – Cement Production 2A2 – Lime Production 2A4 – Soda Ash Production 2A7 – Other mineral production 2B – Other Chemical Production 2C – Metal Production 2D – Pulp/paper/food/drink Production	Industrial combustion (IND)
On-road + Non-Road Transportation	ROAD NRTR	1A3b – Road transportation 1A3c – Rail transportation 1A3d – Inland navigation 1A3e – Other transportation	Transport – on-road and non-road (TRA)
Residential + Commercial + Other	RCOR RCOC RCOO	1A4 – Residential and other sectors	Residential and commercial combustion (DOM)
Solvent Use	SLV	6A – Solid waste disposal on land 6B – Wastewater handling 6C – Waste incineration 6D – Other waste handling	Solvent use (SLV)
Waste	WST	3A – Solvent and other product use: paint 3B - Solvent and other product use: degrease 3C - Solvent and other product use: chemicals 3D - Solvent and other product use: other	Waste disposal, including burning (WST)
International Shipping	SHP	1C2 – International shipping	International shipping (SHP)

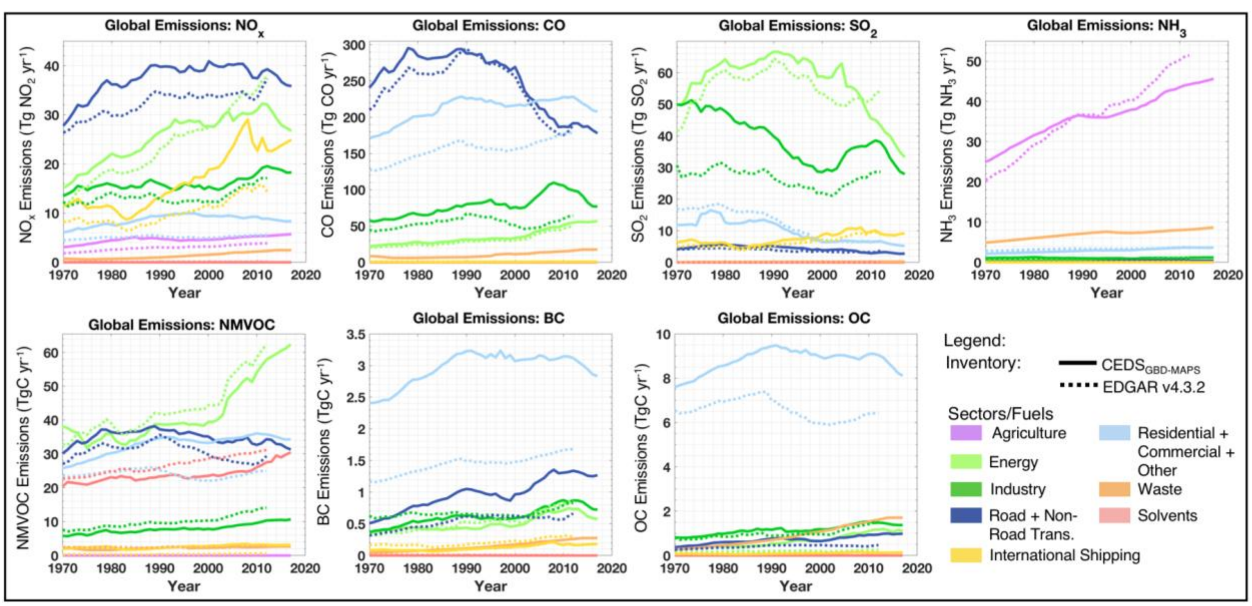

Figure S21. Comparison of sectoral global emissions in CEDS$_{GBD-MAPS}$ and EDGARv4.3.2 inventories. CEDS$_{GBD-MAPS}$ emissions are shown by solid lines, EDGARv4.3.2 data are shown by dashed lines. Sectoral mappings are in Table S9.

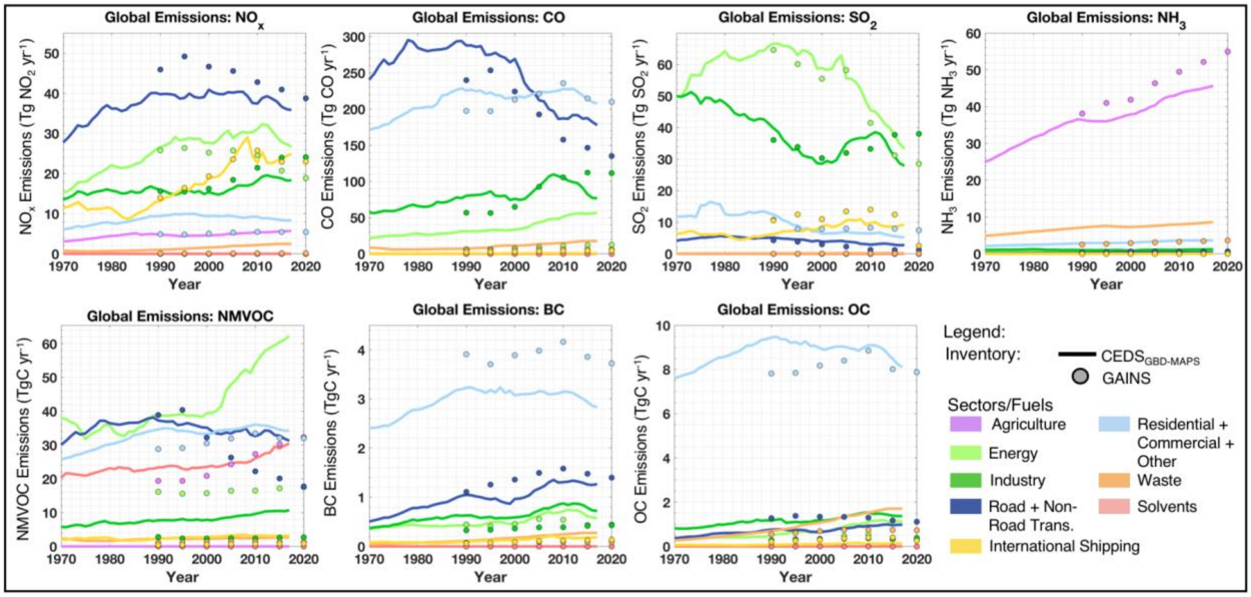

Figure S22. Comparison of sectoral global emissions in CEDS$_{GBD\text{-}MAPS}$ and GAINS inventories. CEDS$_{GBD\text{-}MAPS}$ emissions are shown by solid lines, GAINS data are shown by dashed lines. Sectoral mappings are in Table S9.

Section S4. Known Inventory Issues

This list is up to date as the submission of the ESSD discussion paper describing the CEDS$_{GBD\text{-}MAPS}$ system and the associated data. These issues are in addition to known issues already recognized from the core CEDSv2019-12-23 system (https://github.com/JGCRI/CEDS/issues). New issues after this point will be listed using the issues tracking system on the GitHub repository for both the core CEDS and CEDS$_{GBD\text{-}MAPS}$ systems at: https://github.com/JGCRI/CEDS/issues and https://github.com/emcduffie/CEDS/issues.

- SO_2 and NO_x emissions from the energy sector in China are too large between 1978 and 2004. This issue results from an issue in the underlying IEA energy data, which manifests in the spikes in SO_2 and NO_x energy emissions in 2004 that are visible in Fig. S8. This issue may result in up to a 10 Tg overprediction in SO_2 emissions from the energy sector in 2004, which decrease to a maximum possible overprediction of 0.3 Tg by 1978. For NO_x emissions, the maximum overprediction is 4 Tg in 2004, which decreases to 0.1 Tg by 1978.
- As discussed in Sect. S2.3, industrial emissions of NO_x in India may be overpredicted by up to 1 Tg between 1987 and 2014. This results from the potential misallocation of the SMoG-India 'Informal Industry' sector to the CEDS$_{GBD\text{-}MAPS}$ 1A2c_ind-Comb-Food-tobacco sector, rather than the 1A2g-Comb-Ind-other sector.
- Industry emissions of NO_x and SO_2 in China may not account for emissions from metal smelting due to uncertainties in the MEIC sectoral calibration mapping files for industry sector emissions.
- Residential emissions of SO_2 from the combustion of coal may be over-predicted by up to 4 Tg between 1972 – 1980 (Fig. S12). This sudden increase in emissions from this sector is associated with the CEDS$_{GBD\text{-}MAPS}$ procedures and not the underlying IEA energy data.

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