High resolution seasonal and decadal inventory of anthropic gas-phase and particle emissions for Argentina

S. Enrique Puliafito[1,2], Tomás R. Bolaño-Ortiz[1,2], Rafael P. Fernandez[2,4,5], Lucas L. Berná[1,3], Romina M. Pascual-Flores[1,2], Josefina Urquiza[1,2], Ana I. López-Noreña[1,2,4], María F. Tames[1,2]

[1] Research Group for Atmospheric and Environmental Studies (GEAA), Mendoza Regional Faculty, National Technological University (FRM-UTN), Mendoza, M5500, Argentina
[2] National Scientific and Technical Research Council (CONICET), Mendoza, M5500, Argentina
[3] National Agency of Scientific and Technological Promotion (ANPCyT), Buenos Aires, B1675, Argentina
[4] School of Natural Sciences, National University of Cuyo (FCEN-UNCuyo), Mendoza, M5501, Argentina
[5] Institute for Interdisciplinary Science (ICB-CONICET), Mendoza, M5501, Argentina

Correspondence to: S. Enrique Puliafito (epuliafito@frm.utn.edu.ar)

Abstract. This work presents the integration of a gas-phase and particulate atmospheric emission inventory (AEI) for Argentina in high spatial resolution (0.025° × 0.025°; approx. 2.5 km × 2.5 km) considering monthly variability from 1995 to 2020. The new inventory, called GEAA-AEIv3.0M, includes the following activities: energy production, fugitive emissions from oil and gas production, industrial fuel consumption and production, transport -road, maritime and air-, agriculture, livestock production, manufacturing, residential, commercial and biomass + agricultural-waste burning. The following species, grouped by atmospheric reactivity, are considered: i) Greenhouse Gases (GHG): CO_2, CH_4 and N_2O; ii) Ozone Precursors: CO, NOx (NO + NO_2) and Non-Methane Volatile Organic Compounds (NMVOC); iii) Acidifying Gases: NH_3 and SO_2; and iv) Particulate Matter (PM): PM_{10}, $PM_{2.5}$, Total Suspended Particle (TSP) and Black-Carbon (BC). The main objective of the GEAA-AEIv3.0M high-resolution emission inventory is to provide temporal resolved emission maps to support air quality and climate modeling oriented to evaluate pollutant mitigation strategies by local governments. This is of major concern especially in countries where air quality monitoring networks are scarce, and the development of regional and seasonal emissions inventories would result in remarkable improvements in the time + space chemical prediction achieved by air quality models.

Despite distinguishing among different sectoral and activity databases as well as introducing a novel spatial distribution approach based on census radii, our high-resolution GEAA-AEIv3.0M show equivalent national-wide total emissions compared to the Third National Communication of Argentina (TNCA), which compiles annual GHG emissions from 1990 through 2014 (agreement within ± 7.5%). However, the GEAA-AEIv3.0M includes acidifying gases and PM species not considered in TNCA. ~~Spatial and temporal comparisons were also performed against EDGAR HTAPv5.0 inventory for several pollutants.~~Temporal comparisons were also performed against two international databases: Community Emissions Data System (CEDS) and EDGAR HTAPv5.0 inventories for several pollutants; for EDGAR it also includes a spatial comparison. The agreement was acceptable within less than 30% for most of the pollutants and activities, although a >90% discrepancy was obtained for methane from fuel production and fugitive emissions and >120% for biomass burning. Finally, the updated

seasonal series clearly showed the pollution reduction due to the COVID-19 lockdown during the first quarter of year 2020 with respect to same months in previous years.

Through an open access data repository, we present the GEAA-AEIv3.0M inventory, as the largest and more detailed spatial resolution dataset for the Argentine Republic, which includes monthly gridded emissions for 12 species and 15 sectors between 1995 and 2020. The datasets are available at http://dx.doi.org/10.17632/d6xrhpmzdp.2~~1~~, under a CC-BY 4 license (Puliafito et al., 2021).

1 Introduction

Many political, scientific, and professional efforts are devoted for understanding health and environmental problems. Air quality and global change are certainly two big concerns for present days (Al-Kindi et al., 2020; Haines et al., 2017). Sophisticated numerical models, chemical transport models (CTM) and general circulation climate models (GCM), are used to identify and proof the underlying physics and chemistry of these environmental and social problems; by predicting the evolution and impact of atmospheric pollutants, as well as their geochemical cycles over space and time. From there on, these models are tools for evaluating and proposing mitigation and reduction strategies (Houghton et al., 2002; IPCC, 2014; Nakicenovic et al., 2000; Ravishankara et al., 2009; Solomon et al., 2009, 2020; Thompson et al., 2019).

Air quality models (AQM) require the association of three types of basic information: meteorological data, static topography and land use data, and spatially gridded emission inventories. Meteorological boundary conditions are usually obtained from local measurements and/or global models such as the ERA Interim (European Reanalysis) and NCEP GFS (National Center for Environmental Prediction — Global Forecast System) reanalysis data. Surface terrain information can be obtained from satellite data such as those from the Shuttle Radar Topography Mission (SRTM3) (Rodriguez et al., 2005), whereas land use and surface cover data are available from the European Space Agency (ESA) map GLOBCOVER 2009 (Arino et al., 2010; Bontemps et al., 2011) and/or from regional reports (e.g., INTA, 2018). Emission data is generally obtained from national or international atmospheric emissions inventories (AEI), which are arranged with different spatial and temporal resolutions, such as, Emissions Database for Global Atmospheric Research (EDGAR) (Crippa et al., 2016; EDGAR, 2019); Evaluating the Climate and Air Quality Impacts of Short-Lived Pollutants (ECLIPSE) (Stohl et al., 2015); Community Emissions Data System (CEDS) (Hoesly et al., 2018); or the integrated assessment model Greenhouse gas – Air pollution Interactions and Synergies (GAINS) (Amann et al., 2011; Klimont et al., 2017). A comparison among GAINS, CEDS and EDGAR is presented in McDuffie et al, (2020). A review for several national inventories in China is compiled in Li et al. (2017).

Global and regional AEI require a permanent update in the spatial and temporal resolution of their data to keep track of the local socio-economic developments to improve the results of air quality models and/or global climate applications. Most inventories only present an annual account for a particular year, for example, Huneeus et al., (2020), compares time frame and available resolution of different emissions inventories for countries and cities in South America. National inventories usually include a compilation of Greenhouse Gases (GHG) to comply with international agencies requirements (i.e., UN-International

Panel for Climate Change, IPCC). Nevertheless, as these technical reports focus on total nation-wide emissions for political and governmental protocols, these standard national inventories have low spatial resolution, normally reduced to a large subnational jurisdiction (i.e, provinces, or districts) and provide low to medium information on activity details. However, good practice in air quality determination and modeling requires the use of the finest possible spatial resolution grid, fine temporal resolution and, whenever possible, technological details of the emissions sectors and activities as well. Gilliland et al. (2003) and De Meij et al. (2006) reported improved modelling results when using high spatial and temporal resolution. The finer the spatio-temporal resolution and the larger the number of species and sectors considered for the emissions, the better the air quality model performance achieved.

Local air quality models use an annual averaged static emissions inventory, whose initial constant primary sources are chemically transported with hourly dynamic meteorological data, resulting in pollution plumes that evolve following the weather conditions. Therefore, implementing a seasonal variable monthly regional emissions inventory, will result in a remarkable improvement in the chemical prediction achieved by air quality models, such as, Weather Research and Forecasting (WRF) model coupled with Chemistry (WRF-Chem) (González et al., 2018; Grell et al., 2005; Ying et al., 2009), CALPUFF (Scire et al., 2000), WRF-CALPUFF (Lee et al., 2014; Tartakovsky et al., 2013); WRF-Chimere (Ferreyra et al., 2016); AERMOD (Cimorelli et al., 2004; Kumar et al., 2006; Rood, 2014). This consideration is important, especially in cities and countries where air quality monitoring networks are scarce, as is the case for most of South American nations, including Argentina.

Atmospheric emission of short-lived climate pollutants (SLCPs), such as CH_4, black carbon (BC), CO, Non-Methane Volatile Organic Compounds (NMVOC), NOx (NO_2 + NO), SO_2 and NH_3 affect air quality, ecosystems, agricultural production, and participate in global warming with important radiative effects. In addition, knowledge of the direct emissions of CO_2 and N_2O (and the abovementioned CH_4) are important due to their dominant role as GHGs within future climate predictions. BC or soot comes from the incomplete combustion of biomass and fossil fuel being a significant constituent of fine particulate matter, an air pollutant associated with premature death and morbidity. BC has radiative effects by changing the surface albedo when it is deposited or by changing the optical properties of clouds (Myhre et al., 2009; Ramanathan et al., 2001). Methane is an important GHG with high radiative efficiency, it has natural and anthropic sources specially as a component of natural gas, an increasing energy source (Shindell et al., 2004; West et al., 2006). CH_4, CO and NOx are precursors of tropospheric ozone, also one of the SLCPs, but since O_3 is secondary produced it is usually not included within primary gas inventories (Etminan et al., 2016; UNEP-WMO, 2011). Sulfate aerosols (formed from SO_2 and NH_3), nitrate aerosols formed from NOx, NH_3, and NMVOC emissions have cooling radiative effects (Isaksen et al., 2009). Therefore, reducing SLCPs (except CH_4) would produce an improvement in air quality, but would lead to postponing climate change mitigation, requiring some trade-off between air quality and climate change (Arneth et al., 2009). As it is discussed in Stohl et al., (2015), SCLPs emissions, in contrast to long-lived CO_2, have different impacts on climate according to its geographic location and time of the year, changing their long-term climatic effect of both GHG and SCLP through multiple interactions (Jacob and Winner, 2009;

Shindell, 2015). Thus, detailed spatial and temporal AEIs will help to improve the understanding of these regional and global interdependences.

At the local and regional scale, the detail of temporal and spatial knowledge of the activity included in an AEI will determine the quality of AQM result. For example, the particulate material emitted by a thermal power plant generating electricity will depend not only on the fuel (natural gas, gas oil, or coal), but also on the given generation technology (combined cycle, turbo steam, etc.). Similarly, the increasing use of nitrogen fertilizers in agriculture in Argentina in last 20 years, has allowed the expansion of the agricultural frontier, increasing yields and cereal production, but at the same time, increasing the emissions of nitrous oxide and ammonia leading to higher SCLP emissions. In consequence, more accurate AEI will contribute evaluating the most efficient measures to reduce pollutants and to assess the economic and health impact of each activity.

This article presents a gridded emissions inventory for a dozen of SCLPs and GHG species in Argentina with high spatial resolution (0.025° × 0.025°; approx. 2.5 km × 2.5 km) and, for the first time, a monthly temporal resolution from 1995 to 2020, including many sectorial activity details compiled in several appendices. It is also a revised extended update and compendium of previously published emission inventories by Puliafito et al, (2015, 2017, 2020b, 2020a) for the years 2014 and 2016, but incorporating additional detailed activities of the manufacturing sector and the monthly temporal evolution for most of the activities and sectors considered (Table A1, App.).We will refer to this inventory as "GEAA-AEIv3.0M": GEAA Argentine High-Resolution Inventory version 3.0 with monthly resolution". ~~We compare our results with the Argentine GHG inventory for the Third National Communication of Argentina to the IPCC (TCNA, 2015), which includes annual GHG emissions from 1990 through 2014. Annual and monthly emissions of air quality pollutant such as PM and NOx are also compared to the estimations presented in the EDGAR HTAPv5.0 inventory (Crippa et al., 2016, 2020; EDGAR, 2019).~~

We compare our results with the Argentine GHG inventory for the Third National Communication of Argentina to the IPCC (TCNA, 2015), which includes annual GHG emissions from 1990 through 2014, which was updated in 2019 (TCNA, 2019), spanning from year 1990 to 2016. Annual total emissions of GHG and air quality pollutants are also compared to the estimations presented in the EDGAR HTAPv5.0 inventory (Crippa et al., 2016, 2020; EDGAR, 2019) and the Community Emissions Data System (CEDS) (Hoesly, et al. 2018; McDuffie et al, et al, 2020).

2 Material and methods

This section describes the process of preparing the GEAA-AEIv3.0M inventory: how the data from the different activities were collected, their sources and references, the methodological procedure used to estimate the emissions to the atmosphere, and how the geographical allocation of each activity was performed. Details of each sector are presented in the appendices and supplementary material, providing only representative tables and figures in the main text. Table 1a shows all sectors and activities included in the GEAA-AEIv3.0M inventory, its corresponding IPCC2006 code, the subsections where it is described, and its geographical and temporal extension. Table 1b indicates all species included for each activity with their spatial and temporal resolution. Table 2 summarizes the names of national agencies and institutions whose activity data was considered here, as well as a compendium of the main acronyms used throughout the text.

2.1 Study area and reshaping of databases

The inventory is focused on the activities performed on the continental territory and close coastal maritime area of the Argentine Republic (Figure 1a). Argentina is placed in the extreme south of South America covering 2,778,000 km^2 (IGN, 2020). Its political organization includes 24 Provinces and 524 Departments or Districts, split between rural and urban areas. Population information is available in high resolution such as localities and census fractions. All pieces of data were organized as a gridded map whose cells have a resolution of 0.025° longitude × 0.025° latitude between 53° to 73° west longitude and between 21° to 55° south latitude. An EPGS4326, WGS84 mapping is used (Figure 1a). Thus, the study area is made up of a regular grid of 1441 × 912 cells corresponding to the continental and coastal maritime sector of Argentina. Figure 1 also shows the different scales associated to the mapping process of the available information.

Depending on the spatial extent, power plants, industrial sources or refueling gas stations can easily be associated with a geographical point; residential consumption and agricultural production to an area source, whereas transport emissions (roads and railways) are associated with a line with a length that can be in the order of hundreds of meters to thousands of kilometers. For air quality modeling purposes, these different source types were reshaped into a single database in the form of grid map. The resolution of the base information determines the size of the grid cell (in this case approx. 2.5 km × 2.5 km). Area or line sources can either be included or not in a single cell. When sources sizes were greater than one cell (i.e., consumption or production are known at the District level) a proxy known data was selected to spatially disaggregate that variable (i.e., land use, population, etc.). If the variable was smaller than one cell (e.g., small census radii data in urban areas), all the sources contained in that cell were added together (Figures 1 and 2).

The activity data for each sector was obtained consulting official national organizations and reports (Table 2). These included the Statistics and Census Bureau (INDEC), the Ministry of Energy (MINEN), the Ministry of Agriculture and Livestock (MAyGN), the Animal Health Control Agency (SENASA), and the Ministry of the Environment (MINENV) through the Third National Communication of Argentina (TCNA, 2015) to the ~~IPCC~~ UNFCC, with the subsequent Biennial Updates (for 2014 and 2016).

Fuel production, processing, sales, and consumption for various sectors are available monthly from 1994 to present from public databases at MINEN. Electricity generation and fuel consumption at power plants are available monthly from 1994 to present at the energy distribution agency (CAMMESA) and the Energy Regulation Agency (ENRE). Industrial production is available mostly monthly since 1990 from the respective industrial chambers (see subsections). Transport data is available from several national transport regulation agencies (CNRT: public transport, navigation, and railroad; ANAC: domestic and international aviation).

2.2 Calculation approach

Depending on the specified detail, emission maps are constructed, in a bottom-up process, gathering activity data (i.e., fuel consumptions, number of vehicles, energy generation, etc.) or top-down approach using national aggregated activities (i.e., population, total energy consumption, gross domestic product, etc.) and then applying specific emission factors (EMEP, 2019). The activity data is organized by sectors with monthly resolution from January 1995 up to December 2019, and for some sectors they include several months in year 2020, according to the available information. The general methodology applied is based on European regulations that are compiled in the European Monitoring and Evaluation Program (EMEP) (EMEP, 2013, 2019), and has been described elsewhere (Puliafito et al., 2015, 2017, 2020b). Briefly, emissions are calculated following the general Eq. (1).

$$E(p) = \Sigma[A(i,j) * EF(i,j,p)] \quad (1)$$

where *E* is the total emission (i.e., Mg/year) for a pollutant *p*; *A* is the activity of sector *i*, for technology *j*; and *EF(i,j,p)* is the emission factor for that sector, technology, and pollutant. For example, the emissions (Mg/year) of CO (*p*), corresponding to the annual consumption of gasoline (*j*), of the private automotive sector (*i*).

The inventory was calculated by each individual sector based on the following steps: first, identifying the source of the emission in its geographical coordinates (latitude and longitude); second, assigning the specific activity that contribute to this emission to each coordinate; third, developing a consistent monthly activity evolution; fourth, applying specific emissions factors for each species, source and activity; fifth, organizing the information into a three-dimensional map (lat., long., time); and sixth, developing indices, tables, figures, and statistics.

As mentioned above, air quality models (i.e., WRF-Chem) requires fine spatial and temporal resolution (i.e., hourly information); however, the available original activity data is organized in most cases monthly. To obtain weekly and hourly profiles, whenever possible, we evaluated the temporality of each sectorial activity independently. For example, hourly and daily electricity consumption is available from energy distribution agencies, also the evolution of road transport in large cities are well known. This information allows us to produce an averaged interpolated hourly emission profile, which can later be used as proxy for other sectors (i.e., use of natural gas for heating and cooking). Conversely, other sectors such as agriculture and livestock breeding are only available on an annual basis, and only lineal interpolation may be done to obtain monthly values. Similarly, sectorial information is spatially organized into districts. So, especial care must be taken to discriminate each information into the merged gridded map. In the next methodological subsections, details are given for the spatial and temporal re-assignation.

2.3 Anthropic Emission by Activity Sector

The calculation methodology for each subsector and activity is briefly described below. The data supporting the activity for each subsector, (i.e., monthly fuel consumption, household, technology, number of livestock, etc.), and other relevant information, was compiled and made available in an external repository as is described in Data availability section.

2.3.1 Electricity production sector

The activity and consumption of the electric thermal power plants (TPP) are registered monthly in the Ministry of Energy (Minem, 2020) and in the electric distribution agency (Cammesa, 2020). The location of each power plant is well known, thus in a GIS format, these sources are represented as point sources (Figure 2a). Power plant information included the available machines and technologies, (CC: Combined cycle, TV: Turbo steam, TG: Turbo gas, DI: Diesel Engine) and the respective fuel consumption for each machine (NG: natural gas, FO: Fuel-Oil; GO: Gas oil, CM: mineral coal and BD: Biodiesel) (Figure 3a. The emission of each machine and plant is calculated according to Eq. (1), using the proper emission factors.

2.3.2 Fuel production sector

Emissions from the production and transformation of fuels were calculated from own consumption, venting, and flaring in refineries, and the production from oil and gas in wells~~.~~ Within the solid fuel production sector (1B1) we estimated the gross production of coal using the Argentine National Energy Balance-NEB. We applied two emission factors for mining and post-mining operation (18 m3 CH_4/t and 2.5 m3 CH_4/t gross production of coal, respectively according to IPCC Chap 4), which are based on mining activity in Río Turbio, Santa Cruz (-51.57°S, -72.31°E). The Ministry of Energy (Minem, 2020) maintains a monthly record of up-stream (production and extraction of gas and oil) in the wells and down-stream (fuel production, own consumption, and sales) in the refineries. Emissions were calculated from own consumption (in wells and refineries) according to the type of fuel consumed, using Eq. (1)~~. In a GIS format, each well or refinery are represented as point sources, so the emissions are in their respective coordinate. Note that each well or refinery are represented as point sources, so the emissions are in their respective coordinate within our GIS format.~~

2.3.3 Transport sector

Emissions can be calculated by applying general emission factors by type of fuel and type of commercialization (Eq. (1)) (EMEP, 2019) for a top-down national total account. However, an inventory dedicated to AQM requires the spatial (and temporal) allocation of consumption activity and emissions. We used a bottom-up approach using GIS software: where roads and railroads are represented by segments, airports, and navigation ports by points. Activity and emissions are first allocated in the respective segments, and then integrated in the respective grids, as described below.

Road transport fuel consumption for each district (Figure 2c) is available monthly for each type of fuel (gasoline, gas oil, natural gas, kerosene, and liquefied petroleum gas); and by type of commercialization (sale to the public, public transport, cargo transportation, and agricultural machinery) (data available at MINEM database, Table 2). Additionally, monthly fuel sales are also available for each refuelling gas station (RGS). Thus, we use the location and fuel sales of each commercial RGS (Figure 2d) to estimate the spatial and temporal road transport activity. Road transport fuel consumption is directly proportional to vehicle kilometres travelled (VKT) on each route. The routes are represented as segments on a GIS-type map (Figure A1, App.). These segments intersect the reference grid map (with resolution cells of 0.025° longitude × 0.025° latitude). Thus, in each cell there will be small segments that represent the route sections with their respective lengths and hierarchies. The spatial distribution of fuel consumption was carried out following (Puliafito et al., 2015) which synthetically consists of distributing the consumption of each RGS ($\mathrm{Fuel}_{\mathrm{RGS}}$) using a Gaussian function of variable width (Eq. (2)), according to the type of fuel, and location of the RGS (rural or urban). Then, applying a convolution (Eq. (3)) to calculate in each cell of the gridded map the contribution of each RGS.

$$bg(x,y) = \exp\left[-\left(\frac{x-x_m}{d}\right)^2\right] \times \exp\left[-\left(\frac{y-y_m}{d}\right)^2\right] \tag{2}$$

$$Fuel_{CONV}(x,y,k) = \frac{1}{\sum_{u,v} bg(u,v)} \iint [Fuel_{RGS}(u,v,k) \times bg(x-u, y-v)]\,du\,dv \tag{3}$$

The estimated fuel consumption of each cell ($\mathrm{Fuel}_{\mathrm{CONV}}$) is distributed proportional to the hierarchy of the routes (highways, main routes, residential and rural roads, etc.). Once the fuel consumption per cell has been obtained, the allocation of the VKT will depend on the fuel efficiency by vehicle type and fuel $R(c,k)$ and the length of each segment in the cell (Eq. (~~3~~4) and (5~~4~~)).

$$VKT_{GRID} = R(c,k) \times Fuel_{CONV}(k) \tag{4}$$

$$VKT_{GRID} = \sum_{k=1}^{K} \sum_{j=1}^{J} \sum_{i=1}^{I} h(j) \times l(i,j) \times veh(i,c,k) \tag{5}$$

Fuel efficiency is calculated at national and provincial level, according to the balance of fuel consumption and quantity and type of vehicles. Since hierarchy and length are known for each segment, then it is possible to calculate form Eq. (5) the number of vehicles per segment. Finally, the emission can be calculated using VKT and proper emission factors (Eq. (6)).

$$E_{GRID}(p) = VKT_{GRID}(c,k) \times EFc(c,k,p) = \sum_{k=1}^{K} \sum_{j=1}^{J} \sum_{i=1}^{I} veh(i,c,k) \times l(i,j) \times EFv(c,k,p) \tag{6}$$

Where *EFc* (c, k, p) is the emission factor for fuel burning (g / to m^3 of fuel consumed) and *EFv* (c, k, p) is the emission factor of each type of vehicle per kilometer traveled (g/km) according to EMEP (2019). Figure 2c shows the fuel sales at the district level; Figure 2d the distribution of the fuel sales for each refueling gas station (RGS); Figure A1 (App.) shows the calculated VKT for gasoline vehicles and the CO emissions, which is proportional to the VKT. This procedure (Eq. (2) to (5)) is then iterated comparing the estimated vehicle flows with those counted by road maintenance agencies. Changes in the hierarchy weights (*h* in Eq. 5) or gaussian function width (*d* in Eq. 2) were used to produce the convergence (Puliafito et al., 2015). Emissions from the domestic aviation sector are estimated based on the landing and take-off (LTO) activity (up to 390 m, or 1000 ft height) and the fuel consumption for cruise phase. (Figure A2e, App.) show the fuel consumption at Argentine airports. LTO emissions (E_{LTO}) and cruise phase emissions (E_{FLT}) were calculated following EMEP (2019).

$$E_{LTO}(p,a) = \sum_{k,t} N_{LTO}(a,k,t) \times EF_{LTO}(k,p) \tag{7}$$

Emissions during the cruise phase were calculated as the difference between total fuel consumption (E_{FUEL}) minus LTO emissions

$$E_{FLT}(p) = E_{FUEL} - \sum_{a} E_{LTO}(p,a) \tag{8}$$

Being *k*, type of aircraft, and *p* pollutant, *N*: number of LTOs by type of aircraft and *a*: airport in GIS format, the LTO emission were allocated over several cells over each airport according to the orientation of the runways. Cruise emissions were spatially allocated linking airports and frequencies, however for AQM these emissions are not considered since they are emitted at 9000-10000 m.

The activity data for the railway park were taken from the National Transportation Commission (CNRT) (CNRT, 2020). Fuel consumption was distributed proportionally to the length of the active railways by applying a hierarchy system distinguishing between full-operating and intermittent rail corridors. Figure A4 (App.) show the railroad (RR) network and the monthly freight and passenger activity. The railroad passenger activity in Argentina is based on a train system based in the city of Buenos Aires that comprises a long-distance service and commuter trains. Many suburban railways lines use electric traction; therefore, their respective emissions are considered in the electricity generation sector. The suburban diesel passenger railways were calculated using the transported passenger-km (PKT), the length of the tracks (LRR) commonly used and the appropriate emission factor for that type of machine.

$$E_{GRID-PR}(p) = PKT_{GRID} \times LRR \times EF_{RR}(p) \tag{9}$$

The railroad freight network is organized to export the production of grains and minerals through the fluvial ports along the main rivers, mainly at Rosario Santa Fe, Buenos Aires, and the deep-water port in Bahía Blanca. In this case, the monthly cargo movement (ton-km traveled TKT) and the fuel consumption of this subsector are known. Emissions were calculated from fuel consumption data and typical emission factors.

$$E_{GRID-RR}(p) = TKT_{GRID} \times LRR \times EF_{RR}(p) \tag{10}$$

Using GIS software, the consumption and emission of each railway subsector and company (freight, passenger, suburban rails) was allocated on segments and then integrated in their respective grid map.

Navigation subsector includes the exhaust emissions from propulsion and auxiliary engines during berthing, maneuvering in harbor and during cruise from ocean-going, in port, and inland waterway vessels. Domestic navigation in Argentina is centralized in the De La Plata, Paraná, Paraguay, and Uruguay rivers. Main active ports are Buenos Aires, La Plata, Rosario, Santa Fe, Campana, San Nicolás, Goya, Reconquista, Barranqueras, Formosa, Gualeguaychú, and Concepción del Uruguay (Figure A4 App.). A general top-down approach was employed to estimate navigation emissions, using available statistics on fuel consumption for national and international navigation, according to the general Eq. (1). Port berths and routes to and from those berths were spatially identified using existing geographic definitions of the port boundaries. GIS tools were used to describe the transit routes using navigational charts. National Port Authority (SSPYVN, 2020) provided the activity data on every port. Cruise emissions were spatially allocated proportionally across the major shipping lines also using ship movements.

2.3.4 Residential, commercial, and governmental sector

The main residential fuel used for heating and cooking in urban centers is natural gas, whose consumption is known monthly for each Province. To spatially distribute this consumption, we used information of household census and a map of census fractions from the National Statistic Office of Argentina (INDEC, 2020). This map indicates the number of households and population composition in very fine resolution for cities and broader for rural areas (Figure 1c and Figure 1d). We complemented this data with information on unsatisfied basic needs (UBN) to include differences in consumption by households (Puliafito et al., 2017).

$$Rg(x,y,k) = (Hg(x,y,k) * Rd(x,y,k))/Hd(x,y,k)$$

(11~~0~~)

*R*g being the residential consumption of fuel *k* considered in cell *(x,y)*; *Hg* is the number of households in the same cell which consume fuel *k*; *Hd* is the total number of households in district *d*, and *Rd* is the consumption of fuel *k* in district *d*. This disaggregation was performed for each type of fuel used for cooking and heating.

In less proportion, especially on rural areas, other heating and cooking fuels are used like wood, coal, and biomass. We assumed a consumption rate for cooking and heating per household of 2.7 Mg (dry basis) for those households which only use biomass, and of 0.25 Mg for the rest of the households (i.e., FAO/WISDOM project in Trossero et al., (2009)). The emissions from domestic use of fuel in each cell are calculated as follows:

$$E_{RESID}(x,y,p) = \sum_k Rg(x,y,k) \times F_{FUEL}(k,p)$$

(12~~1~~)

where $E_{RESID}(x, y, p)$ are the emissions of pollutant p, at cell grid (x, y) resulting from the use of fuel consumption k; and $F_{FUEL}(k, p)$ are proper emission factors for pollutant p and fuel type k. The emission factors from burning considered are those established by EMEP/EEA (EMEP, 2016) for natural gas stoves and heaters.

Emissions from the commercial sector (small workshops, markets, shopping centers) and government/public office sector (public buildings such as schools and hospitals) were associated with residential emissions. These specific consumptions are obtained from the classification of users of natural gas, the main fuel used that produces local emissions. Note that emissions from electricity consumption in the residential, commercial and government sectors are included in the electricity production sector.

2.3.5 Industrial sector

Emissions from the industrial sector were divided into two groups, emissions from in situ fuel combustion and emissions from the production process itself. The consumption of electrical energy from the electrical network is considered in the electricity production sector. Emissions from small manufacturing activities, which do not have significant point emissions to the atmosphere, were included as area sources in the commercial sector.

42 sectors with production-specific emissions were included, identifying more than 450 companies with their spatial location (Figure 2b). Production activity was obtained from the professional chambers of each subsector. These included the following subsector: chemical, petrochemical, refineries, food (sugar, beverages, poultry), non-metallic mining (lime, cement, glass), metallic minerals (iron, steel, aluminum), paper and cellulose (Table A3, App). Regarding fuel consumption, natural gas consumption is known by type of industry and province, for other fuels (bagasse, coal, or diesel) it was estimated from the national energy balance (Minem, 2020). Based on this information, the consumption was set proportional to the production and number of companies in each subsector and province. Electricity and natural gas consumption, and production are known for each subsector, this information was used as proxies to distribute monthly consumption at each company. For the calculation of emissions from fuel consumption, the general Eq. (1) was applied. For the emissions of each subsector, we used the emission factors proposed by EMEP (2019) or EPA AP-42 (EPA, 2016).

2.3.6 Livestock and agriculture sector

The inventory of agricultural and livestock activities in Argentina was presented in Puliafito et al. (2020a, 2020b) which considered only for year 2016 data. An ammonia inventory of Argentina for this sector was presented by Castesana et al. (2018). In this work we extended the year 2016 inventory, considering the production of livestock and agricultural activity from 1995 to 2019. To prepare this inventory, we considered the location of livestock raising, the cereal production and the use of fertilizers (Figure 4a and Figure 4c). Animal production is known annually, by type, age of the animal, and production district. The geographical distribution was made proportional to the number of productive establishments (ranches or dairy farms) by department. The emission factors depend on the type and age of the animal and the productive zone.

The production of cereals and other crops is known also annually, by type of crop within each department. The annual quantity of used fertilizers is also known by type of crop. The spatial distribution of the cultivated hectares by type of crop was made using a land use map, distributing in each department the cultivated area and type of crop in agricultural available land. The monthly emissions were simply estimated as proportional to 1/12 of the annual value since the monthly distribution was not available.

2.3.7 Burning of agricultural residues and open fires

For the location of biomass burning, crop residues burning, and other biomass fires (natural and / or man-made), we used the MCD64 collection C6 of the MODerate resolution Imaging Spectroradiometer (MODIS) sensor, aboard the (MOD14) Terra and (MYD14) Aqua satellites (Giglio et al., 2009, 2013), between 2001 and 2020. From years 1995 to 2000 we used information from national fire statistics (Environmental Ministry https://www.argentina.gob.ar/ambiente/fuego/alertatemprana/reportediario and CONAE https://www.argentina.gob.ar/ciencia/conae/aplicaciones-de-la-informacion-satelital/incendios). The MODIS collection provides two types of products: fire points (fire-events at a daily basis) and burned area (monthly averages, with percentages corresponding to different land uses). The emissions were estimated using the appropriate emission factor corresponding to the specific land use class of each burned area (Puliafito et al., 2020b).

3 Results

The present inventory is a multi-dimensional database that embraces spatial coordinates, latitude, and longitude, with a spatial resolution of 0.025ºx 0.025º (1441 x 921 cells) for the whole continental and maritime Argentine domain; a temporal resolution of 300 months from Jan 1995 to April 2020, 15 activity sectors and 12 pollutants. It is, then, possible to think of multiple ways to organize and show the results. Therefore, in this Section we will only present some representative figures and tables oriented to compare the absolute and relative contribution of each subsector to the total emission of each species, as well as to highlight the spatial and temporal variability for the whole country and within different regions. Note that the whole database has been published for its use in air quality / climate model applications in a standardized format within a free access repository as indicated in the Data availability statement. Figures 3 to 6 show selected sectors and species distribution. Figures 7 to 9 cover the results of comparing GEAA with other commonly used inventories.

The multiple appendix and supplementary information ~~provide~~ the monthly and annual emission time-series, as well as basic representative figures.

3.1 Electricity production sector

As of December 2019, Argentina had a total installed capacity of 39,704 MW, where 64.3% (25,547 MW) corresponded to sources of thermal origin; 28.5% (11,310 MW) to hydro; 5.3% renewable (2,092 MW: 1609 MW wind, 439 MW solar and 42

MW biogas: 2 MW); and 4.4% (1,755 MW) nuclear. Annual thermal generation reached in 2019 80,137 GWh, hydraulic 35,370 GWh, nuclear, 7,927 GWh, and renewables 7,812 GWh. Figure 2a show the spatial location of thermal power plants in Argentina. Annual thermal generation for 2019 was produced using mostly natural gas (17,209.2 million m^3), diesel (403.8 thousand m^3), fuel oil (185.6 Gg) and mineral coal (221.8 Gg), with an average efficiency of 1858 kcal/kWh. Figure 3a shows the total energy consumed at TPP according to the type of generation. The GHG emissions variation, in terms of CO_2 eq. (GWP100: CO_2=1; CH_4=25; N_2O=298) (Myhre et al., 2013), is shown in Figure 3b and Table 3. The monthly evolution for several pollutants is shown in Figure A2a (App.). The large variations in these emissions were associated with three important variables. a) A low frequency variation (with a maximum between May 2015 to May 2017 and minimum in Dec. 2002), corresponding to the economic activity that impacts generation and fuel consumption. b) A variation of medium frequency, corresponding to the seasonal summer / winter variation, which depends on the ambient temperature, with heavy consumption in the summer months, for example, due to the use of air conditioning. c) A third variation of greater frequency was associated with the type of fuel. An increasing proportion of natural gas use and a decrease in gas oil and coal are shown in Figure S3(Suppl. Mat). These have been reinforced in recent years due to increased natural gas production from the Vaca-Muerta basin (approx. 38.64 °S, 69.86 °W) from non-conventional wells (Minem, 2020; Rystad, 2018). Figure A2b (App.) also shows that during austral winter months TSP emissions (and SO_2) increased and those of NOx decreased. This is due to the reduction in the use of natural gas (the main residential heating fuel) and an increase in coal and fuel oil in power plants to compensate the natural gas reduction. In summertime the opposite occurs, larger use of natural gas and a reduction of fuel oil and coal results in higher NOx and lower TSP. Note that during diurnal high electricity demand (peak hours) the thermal plants may also be covered by fuel oil and gas oil. In terms of GHG, emissions from electricity production have steadily climbed around 2 % per decade, from 7.1 % in 1995 (with respect to total annual -all sectors) towards 11.7 % in 2019. NOx values have increased from 10.2 % to 14.5 % (with respect to total annual -all sectors), during the same period.

3.2 Fuel production sector

Emissions from fuel production correspond to own consumption at refineries (ROC), and extraction wells, for their own operation of the activity and transformation (FPR). ~~And f~~ugitive emissions from venting or flaring of surplus gas are also located in refineries and wells sector (FUG). Figure A2d (App.) shows the monthly variation between the years 1995 to 2020 of methane emissions reaching a monthly average of ~~27,835~~ 28,117±3,382 Mg per month for the three activities. However, the total CH_4 emission is dominated by the refinery venting and flare activity. The increase after Nov 2018 is mainly due to a growth in the production of unconventional natural gas in the Vaca-Muerta basin in the last two years (Figure A2c; App.). Figures S6 and S7 (Suppl. Mat.) also shows the activity and emissions of the extractive activity of gas and oil (up-stream) at wells from own consumption. Monthly GHG emissions (ROC+FPR+FUG) have increased from (ROC+FPR+FUG) ~~1403.20~~ 2,315.62 Gg CO_{2eq} in Dec. 1995 until reaching ~~2457.20~~ 3,344.28 Gg in Dec. 2019. Table 3 show the total annual emissions for oil and gas production for all pollutants considered. Fuel production and transformation (ROC+FPR+FUG) represented ~~6.8~~11% in 1995 and ~~10.3~~13% in 2019 of total GHG annual considered. Pollutants such as CO and NOx have an annual contribution share of~~ 1.1 % and 4.1 %~~0.2% and 3.8%, respectively, for year 1995 and 0.2% and 3.5%~~1.9 % and 5.1 %~~ for year 2019, respectively (Table 3 and Figure 5).

3.3 Transport sector

Figure A1c (App.) shows the monthly country fuel sales variation for main fuels used in the road-transport sector (ROT) from Jan 1995 to Dec 2019. Figure A1d (App.) presents the total monthly emissions of CO, NO_x and PM10 from the same activity. Table A4 (App.) show a growth of 13% in the period December ~~January ~~1995 to December 2019, for CO_2 and CO_2eq, 54 % methane, 21 % NO_x and 20 % CO and NMVOC for the same period. The main growth is due to the higher consumption of gasoline while diesel oil has only grown slightly and CNG has remained stable. However, similarly to the energy production sector, fuel consumption is strongly linked to economic activity (i.e., represented by the gross domestic product GDP as we will discuss later in Section 3.7) showing decreasing consumption from 1995 to 2002, and then climbing again. From August 2016 and on, a stagnation in gasoline consumption appears, in accordance with a retraction in national economic activity. Figure A1c and A1d (App.) also show a 52% and 63% reduction in NOx and CO ROT emissions respectively (comparing April 2020 with respect to April 2019), due to the COVID19 quarantine effect (which began on March 20, 2020) Table A5 (App.) (Bolaño-Ortiz et al., 2020). Additionally, Figure S8 (Supp. Mat.) includes monthly and annual GHG emissions (CO_2, CH_4 and N_2O) and SLCP (BC, CO, NMVOC; NOx, SO_2, NH_3) from road transport. Regarding domestic aviation (DOA), Figure A2e (App.) show monthly fuel consumption (m^3) from LTO, while Figure A2f (App.) show the respective monthly emissions (CO_2, CH_4, N_2O, NOx, CO, NMVOC, SO_2 NH_3, TSP and PM) The aviation activity has been relatively stable with increasing trend from year 2005. Year 2020 had a complete stop due to COVID-19 restrictions, only partially reestablished after Nov 2020.

Figure A3 (App.) shows the active railroad network (A3a), the average seasonal variability in RR activity (A3b), in terms of t.km for freight and passenger.km for transported passengers; and the monthly fuel consumption and amount of transported passenger (A3c). The passenger activity is centered in Buenos Aires commuting activity (> 95 %). With respect to fuel consumption (gas oil), RR freight activity represents on average 45 % and it is expected to increase as crop production and export increases. Note that following the agriculture exportation, freight RR shows a marked seasonality, where the maximum austral winter activity (June-July) is up to 40% higher than during the summer (Jan-Feb). The inter-annual increase is also seen in inland navigation since ports like Rosario, Santa Fe and Bahía Blanca are concentrating the soja-bean, wheat, and maize export. Both railroad and inland navigation activity have shown an increase of 122 % in pollutant emissions from Dec 1995 with respect to Dec 2019.

3.4 Residential, commercial, and governmental sector

Residential, commercial and government (R+C) energy consumption includes electricity (for lighting, air conditioning and partially heating), and natural gas for cooking and heating in a large part of the country (except for northeast Argentina, see Figure A3, App.). For urban areas not connected to the natural gas (NG) network, the heating energy consumption is replaced by electricity, LPG, kerosene; and in rural areas with abundant biomass available (northeast of the country),~~ the use of~~ charcoal and wood are used. According to data from radio maps and census fractions, there are 12,171,560 homes in Argentina (INDEC, 2010), of which 56% are connected to the NG network, 41% use LPG, and the remaining 3%, wood, charcoal, or kerosene. The 2019 annual consumption reached 10,680,070 (1000 m^3) of NG, 855,184 (1000 m^3) of LPG, 285,113 Mg of wood, 341,473 Mg of kerosene and 484,408 Mg of coal. The annual average per capita consumption is 268 m^3 of NG; 21.38 m^3 of LPG; 12.11 kg of charcoal, 7.1 kg of firewood, 8.5 kg of kerosene. Figure 3c shows that the annual fuel consumption of wood and LPG has decreased since 2001 and 2007, respectively, compensated by a gradual increase in the consumption of NG since 1995. Note that the residential fuel consumption shows a very strong seasonal and regional cycle (Figures 3d and Figure A3 App.) due to the large North-South extension of Argentine territory. For year 2019, NG uses represent the 80% of the total R+C annual emissions for CO_2, 14% for CH_4, 91% for NOx, 15 % CO and 7% for TSP; complementary, the use of other fuels contributes to 93% for PM_{10} and 85% of CO. (Table 3; Table A4 and A5 App.). Emissions from R+C electricity using fossil fuels are considered in the Thermal Power Plant sector.

3.5 Industrial sector

This subsection includes the monthly emissions from industrial manufacturing own fuel consumption (MFC) and emission from the production process (MOP) from January 1995 to April 2020. Note that manufacturing electricity consumption is considered in the thermal power plant sector. Table A3 (App.) shows a list of the manufacturing activities considered whereas Figure 2b shows the location of the manufacturer sector. The monthly fuel consumptions averages are: 846,380 (1000 m^3) of natural gas, blust-furnace gas, and coke-oven gas together; 13,493 Mg of LPG; 36,234 Mg of gas oil, diesel-oil, and fuel-oil; and 668,374 Mg of coal wood and biomass. Natural gas is used as main own fuel consumption followed by wood and crop residues, the later especially used in the food elaboration subsector, like sugar production, paper and wood manufacturing, due to local availability of biomass. Seasonal fluctuations, both in consumption and emissions, are due to variations in production, but it is also conditioned by less availability of natural gas during the winter months, which is derived to residential consumption. Monthly average GHG from own fuel consumption reached 2405.23 Gg per month of CO_{2eq}, while for NOx reached 5,053.27 Mg, 28,861.79 for CO and 1250.46 Mg for TSP.

The MOP included the emissions from the manufacturing own production process and included the following subsectors: 2A glass production; 2B chemistry, 2C aluminum-steel, 2D asphalt, painting, 2H paper, food, beverage. Figure 3e and Figure 3f shows the annual evolution of MOP NOx and PM_{10} emissions. Chemical industry contributes to 37.1 % of NOx emissions, followed by the food industry 36.5 %, and the steel industry with 26.4 % with respect to total MOP emissions. For PM_{10} emissions, the cement industry contributes 35.0 %, the chemical industry contributes 22.2 %, followed by the steel industry with 20.6 %, and the food industry 20.4 %, automotive painting contributes with 1.8 %.

3.6 Agricultural and livestock sector

Emissions from the agricultural livestock sector were calculated annually from 1990 to 2019. Emissions from livestock included enteric fermentation (CH_4) and manure management (CH_4, NO_2, NH_3, NOx, NMVOC, and PM). These emissions depend on the type of animal, age, type of production and the productive areas. In terms of methane emissions (i.e., CO_2eq), the bovine sector dominates Argentina's GHG emissions (30.9 %), reaching the livestock sector 95,473 Gg CO_{2eq} in 2019; (2781.09 Gg CH_4; 87.09 Gg N_2O). The historical series shows an average of 96,301 Gg CO_{2eq} between 1995 and 2019 for all livestock production (Figure 4b) with a slight decrease in 2009 by a reduction in bovine animal production. Total animal production has grown from 177 million head in 1990 to 317 million head in 2019. While bovine livestock has oscillated between 54.7 ± 3.4 million head, the largest increase was shown by the poultry sector rising its production of 30 million birds in 1990 to 232.3 million in 2019 producing a significant increase in ammonia emissions (from 6.6 Gg NH_3 in 1990 to 51.1 Gg in 2019, see Figure. 4a). Total ammonia emissions in 2019 reached 211.63 Gg for all livestock.

Emissions from the agricultural sector are signed by a strong increase in cultivated area, increased production, and increased use of fertilizers (Figure 4c). Considering the period 1990 to 2019, these numbers more than doubled from 17,700 to 37,873 kHa in cultivated area; approximately tripled from 51,457 to 172,089 Gg for cereals production; and increased at least by a factor of 15 (from 260 to 4217 Gg) for fertilizers use. Consequent to this increase of fertilizers, the largest emissions increases were for ammonia and nitrous oxide, which changed from 38.09 Mg in 1990 to 529.44 Mg in 2019 for NH_3 and from 1.58 Mg in 1990 to 21.76 Mg in 2019 for N_2O (Figure 4d).

3.7 Burning of agricultural residues and fires

For this sector, accidental and/or provoked fires from biomass burning were considered, both from agricultural residues or from other types of fires between 1995 and 2020. Figure 4e shows an average seasonal burned areas according to main land types and Figure 4f shows the evolution of $PM_{2.5}$ (Gg) emissions for the period 1995-2020, according to land type. Figure A5b (App.) shows the monthly average precipitation (1981-2018), calculated using the Climate Hazards Group Infrared Precipitations with Stations (CHIRP) database (Funk et al., 2015; Rivera et al., 2018). It clearly shows the correspondence with the land use map (Figure A5a, App.), and directly with the availability of ground fuel from biomass. Figure A5c (App.) shows the average monthly burned area (2001-2020), which shows two distinct area: North- east (rain >50 mm/month) and the semi-arid (rain > 20-50 mm/month) central-west zone of Argentina. In the northeastern area of Argentina fires predominate between August and November, associated to burning of crop residues and land changes (clearing forest for agriculture), while in the center-west of the country fire events increases during the summer months (Dec and Jan) on dry grasslands and pastures. These fires are associated to typical dry conditions in the previous winter and spring months before the raining seasons begins in late summer (Feb. and March). Figure A5c (App.) shows the emission of $PM_{2.5}$ associated to burning of biomass.

According to land type use considering the 1995-2020 period, annual burned area averages 1,064,423 million Ha, being 14.7 % forest, 27.1 % grassland, 25.6 % savanna, 22.0 % shrublands, 7.7 % cultivated areas, and the remaining 2.9% corresponds to other type of land uses.

3.8 Summary and discussions of GEAA-AEIv3.0M results

Table 3 summarizes the total annual emissions for years 1995 and 2019, while Table A4 (App.) presents a single timeframe with the monthly emissions for December 1995 and December 2019. From the point of view of the GHG emissions, the main emission sector is livestock (38.6 % and 30.9 % for 1995 and 2019, respectively), showing a 7.7% reduction trend due to decreasing bovine production (see Figure 5). Adding together thermal power plants and manufacturing own fuel production represents 16.8 % and 19.8 % of the total GHG emissions (for 1995 and 2019, respectively), followed by road transport 16.4 % and 15.7 % (1995, 2019 respectively). The residential plus commercial sectors have increased from 7.6 % to 9.8 % for the above referenced years. This is consistent with population increase, as analyzed below. In absolute values GHG have increased from 262,731.64 Gg CO_{2eq} in 1995 to 308,735.68 Gg CO_{2eq} in 2019 (17.5% increase respect to 1995). Note that GEAA-AEIv3.0M GHG inventory does not include land use changes nor sewage waste, since its focused-on air quality, and therefore these are not the total GHG numbers for Argentina; in fact, TCNA (2015) reports total CO_{2eq} of 368.295 Gg for year 2014. Most notably, the main increases are observed for NH_3 and N_2O emissions due the use of fertilizers in the agriculture (Figure 4d). Indeed, Argentina has increased its annual crop production from 51,735 to 172,089 Gg, and annual use of fertilizers from 641 to 4217 Gg (1995, 2019 respectively), while bovine production has decayed slightly from 55,921 in 1995 to 54,698 thousand heads in 2019 (Figure 4a). From a climate change perspective, reducing N_2O emissions through reducing crop production is a critical economic option, since together with livestock feeding, both activities represent the main export income for Argentina. Thus, it is not expected that the percentage contribution of N_2O to Argentine GHGs will be reduced until new nitrogen-uses efficiency of crops could be incorporated worldwide to reduce emissions (Solomon et al., 2020; UNEP, 2013).

Air quality SCLP sectorial shares are shown in Figure 5b and Figure 5d for 1995 and 2019, respectively (see also Table 3). Comparing those two years for a particular pollutant, e.g., CO, show that the dominant sectors contributing to the total emissions remain unaltered and present only minor percentage changes: road transport is the most important sector representing 69.7% and 76.0% for years 1995 and 2019, respectively, followed by open fires (11.0 % and 5.2 %) and burning of agricultural residues (2.2 % and 1.6 %, for years 1995 and 2019, respectively). Similarly, NOx, emissions are concentrated in the road transport activity, 47.6 % and 42.8 %; thermal power plants and manufacturing own fuel production, 16.7 % and 17.3 %; as well as residential & commercial, 6.8 % and 7.1 % (years 1995-2019 respectively). Fire and biomass burning represent the largest source of particulate matter (TSP) (41.3 % and 23.4 % for years 1995-2019 respectively) coming from agricultural waste, cleaning forest for agriculture and livestock feeding and natural burning of grassland. Nevertheless, it should be noted that the TSP contribution from different sectors is highly variable from year to year (Figure 4f).

The three concentrically rings presented in Figure 6 summarize the sectorial contribution to the main primary air-quality pollutants (see also Table 4): the outer ring is for PM_{10}, the middle ring for NOx and the inner ring corresponds to CO. Figure

6a show the proportion of total annual emissions with respect to urban population density. 57.0% of total PM10 emissions (70,189 Mg), 47.1 % of total NOx emissions (472,925 Mg) and 58.4% of total CO (2,391,864 Mg) are emitted in areas with low urban density (< 100 inhab./km^2), since many roads and thermal power plants are in these locations and Argentina has a vast non urbanized area (see Table 4). Note that Argentina's populations live 25.9 % in towns with less than 1000 inhab./km^2; 69.4% in urban centers between 1000 and 10000 inhab./km^2 and 4.7% in dense urban centers greater than 10000 inhab./km^2. Air quality in urban areas is dominated by road transport, residential & commercial emissions, and depending on the cities also by power plants and industrial energy consumption and production. For example, for NOx, the population is exposed to average daily emissions of: 0.5, 10.9, 72.3, 221.3 and 436.9 kg / km^2 / day for <=100; >100 and <=1000; >1000 and <=5000; >5000 and <=10000; and > 10000 inhab./km^2; respectively. However SCLP high emissions density per squared km is emitted in the denser urban area (>10000 inhab./km^2): 1,998 kg/km^2/year for PM10, 159,479 kg/km^2/year for NOx, and 462,577 kg/km^2/year for CO (Figure 6b), resulting in those urban regions to possess lower air quality standards than rural areas. Figure 6c show the proportion of the same SCLP (PM$_{10}$, NOx and CO) but as function of the sectors. These figures show, that although CO and NOx have the highest emissions density in urban centers and are dominated by road transport and power plant, maximum PM$_{10}$ is located in medium density areas (6,990 kg/km^2/year at urban density of >5000 inhab./km^2 <=10000) and are dominated by residential and road emissions. Nevertheless, in absolute numbers PM is dominated by ~~AWB and OBB~~fire produced in agriculture and forest areas, livestock feeding and refineries.

The evolution of GHG and SLCP air pollutant emissions clearly show a strong dependence to population increase and gross domestic product (GDP) changes. Figures A6 (App.) show a normalized quarterly series of GDP, de-trended population, and GHG. While population follows a linear trend (0.04% quarterly increase), GDP has a 6–8-year oscillation over the population increases, presenting local minima for Oct-2002 and Apr-2020, and local maxima for years Apr-1998 and Apr-2013. GHG variation follows the GDP changes with an extra annual seasonal variation. Note that the medium term 6–8-year oscillation as well as the annual seasonality are appreciable in the use of fossil fuels for electricity production, as described in Section 3.2. Finally, Figures A6c (App.) show the GHG/cap and GHG/GDP variations, whose trends are followed by the emission of many other pollutants (not shown). Several conclusions may be extracted from the above results. First, GHG and air quality pollutants follow mainly population increase modulated by economic activity, where Argentina's recurrent economic crisis are very visible in these timeseries. Second, GDP has fallen below population increases since 2019 aggravated by COVID-19 lock down crisis in 2020 (Bolaño-Ortiz et al, (2020); see Table A5 (App.) for monthly values for April 2019 and April 2020). Third, quarterly GHG/cap has been stable on 639 ± 65 kg/cap during the whole period, which means there have been no major enhancements in personal consumptions, but neither have been any improvement in the emissions efficiency. Fourth, GHG/GDP show a quarterly variability of 51 ± 21 g/USD, showing a slight decreasing trend from 2004 to present, since less carbon is emitted per expended USD, most probably due to technological changes (note that the sudden increase in year 2002 is produced by the reduction of GDP during the 2001-2002 economic crisis). Fifth, approximate one third of GHG emissions comes from agriculture and livestock emissions, main export activities of Argentina, another third arises from energy production (TPP) and transport (ROT+DOA+R+N), and the remaining third from the other sectors. Sixth, GHG are still coupled to GDP (and population), which means that reducing GHG emissions in Argentina can only be done, at present, at the expense of reducing activity intensity (i.e., reducing economy), as it is clearly seen in year 2020 reduction due to lock down due to COVID-19. Seventh, air pollution in urban cities is mainly produced by road transport (i.e., CO, NOx and $PM_{2.5}$) and power plants (SO_2 and NOx), and even though the largest emission densities are in large urban areas, due to the vast majority of rural areas in Argentine territory, the total national emission are originated in the less populated regions.

4 Inter-comparison of GEAA-AEIv3.0M with other Emissions Inventories for Argentina

Since the present GEAA-AEIv3.0M inventory includes spatial and temporal variation, its calibration requires a double control and validation. For the temporal comparison we use the Argentina national greenhouse gas inventory (TCNA, 2015) that compiled the total annual values for Argentina between 1990 and 2014, and an updated version in 2019 (TCNA, 2019) spanning from year 1990 to 2016; the international inventories EDGAR HTAPv5.0 and CEDS. It should be noted that CEDS uses TCNA 2015 as a basis for the Argentine information (Hoesly et al, 2018), but for some species and sectors they differ slightly. There are also some differences between TCNA 2015 and TCNA 2019. Therefore, we will compare GEAA with 4 temporal series: TCNA2019, TCNA2015, CEDS and EDGAR.

Although the activity data for both studies for GEAA and TCNA (and CEDS) were taken basically from the same national sources (mostly from the National Energy Balance), the focus and methodology of each inventory varies. In TCNA activities and emissions are accumulated using a top-down approach to obtain a nation-wide annual total by sector. While in our case (GEAA-AEIv3.0M) the activities and emissions are first located in each point, line, or area with a bottom-up approach, and then the totals are calculated as the sum of all cells in the spatial grid. Therefore, the sum of the activities by sector and year may vary. ~~Likewise, we compare the annual values with the international EDGAR inventory, which~~ With respect to EDGAR, it differs especially in the use of proxy variables used for its spatial disaggregation, which has already been discussed elsewhere (Puliafito et al., 2015, 2017). A spatial comparison can also be made with the EDGAR inventory is presented in section 4.2 ~~although it has a resolution of 0.1° × 0.1°, which requires an adaptation of our higher resolution inventory (0.025° × 0.025°).~~ When comparing with other inventories, emphasis has been placed on greenhouse gases (GHG), since GHG relates to the level of agreement (or discrepancy) with the activities of each sector, since their emission factors (EF-GHG) are well established and are especially associated with energy consumption (Sato et al., 2019). On the other hand, air quality emission factors (EF-AQ, those used for NOx, CO, PM, and others) are highly variable, mainly due to uncertainties in the environmental and technological conditions considered for each activity. For example, for an on-road vehicle, the emission factors will depend on the outside temperature, engine temperature, type, and quality of fuel, idle or regime status, slope, load, age, among other factors (EMEP, 2019). So, the used average EF-AQ, will include a mixed weighted operational condition. In the same line, although electric vehicles have EF-AQ = 0, EF-GHG will still depend on how the consumed electrical energy is generated.

~~4.1 Comparison with total annual values from TCNA~~

4.1 Comparison with total annual values from TCNA, EDGAR and CEDS

Table 5 and Table A6 (App.) summarizes the total annual values for GHG emissions (CO_{2eq} Mg) for GEAA-AEIv3.0M and TCNA 2015 inventories, respectively. Note that the original TCNA report included contributions from other sectors (land use changes) not related to air quality that are not considered here.

Figure 7a shows the annual values for TCNA2019, TCNA2015, CEDS and EDGAR inventories, and Figure 7b shows the average annual differences by activity~~ Table A7 (App.)~~. In the supplementary material (file comp_geaa_ceds_edgar_tcna.xlsx, see also Supplementary material for description) we present a sectorial comparison for CO_2, CH_4, N_2O, CO, NOx, SO_2, and NMVOC among TCNA2019, TCNA2015, CEDS and EDGAR inventories. Table A7 (App.) summarizes the main results for the inventories intercomparisons. Most of the activities (1A1, 1A2, 1A1bc, 1A3a, 1A3b, 1A4abc, 2B, 2C, 3A, 3B, see Table 1a) agree within ± 27.0 % for all inventories and the considered pollutants.

~~Most of the activities (IPCC 2006: 1A1, 1A2, 1A1b, 1A1c, 1A3a, 1A3b, 1A4a-b, 2B, 2C, 3A, 3C) agree within ± 6.0 % with total differences for the sum of all sectors of 0.4 ± 3.9 %. Higher discrepancies are found in sector 1A1c (FPR 7%), 1A3c-d (R+N: 13.3%), 3C (AG: -12.5%) and (AWB -6.5%). For fuel production, the discrepancy arises from the way the activity is computed. In TCNA this is estimated from total oil and gas production, while GEAA computes emissions from own consumption at wells. Railroad and navigation activity have been updated recently (posterior to the TCNA publication) and therefore there might be differences in the estimated activities, mostly in the consumption of natural gas for domestic transport. For agriculture, and biomass burning the total differences between inventories arise from the activity data: TCNA uses national accounted fire statistics, while in GEAA, MODIS MDC64 data were used for years 2001-2020 (see Section 2.3.8). Figure A6 (App.) show annual GHG emissions comparison for the energy sector excluding refining and fugitive emissions from fuel production, resulting in a very good agreement between GEAA, TCNA and EDGAR for the main energy sector when the same aggregation scheme is applied.~~

CO_2eq in GEAA and TCNA2015 agree for the sum of all sectors within 7.1 % (Table A9, App). Higher discrepancies between GEAA and TCNA are found in N_2O profiles, and sectors 1B2 (FUG>60%), 1A3c-d (R+N: 13.3%), 3C (AG: -12.5%) and (AWB -6.5%). For fuel production, the discrepancy arises from the way the activity is computed. In Public Energy 1A1a sector, GEAA and TCNA agree within 1.5%, while EDGAR and CEDS have 16% larger CO_2 emissions and 95% higher values for CH_4. For NOx, CO, SO2 and NMVOC all profiles (GEAA-AVERAGE) agree within 10%, 32%, 10% & and 23% respectively. For Refinery own consumption (1A1bc), Manufacturing own fuel consumption (1A2), all inventories and pollutant's profile agree within 15%, but CH_4 for 1A1bc has larger dispersion (GEAA-AVERAGE : 45%). EDGAR also show high discrepancies for CH_4, CO and SO_2 for these sectors (> 60%). Transport (1A3: ROT, DOA, R+N) and Residential, Commercial, Other (1A4) sectors have also good agreement within 20% for all inventories and most pollutants. CO profiles from EDGAR shows the highest differences (59%) for 1A4 sector while CEDS presents 21% disagreement with the mean of all five profiles. Fugitive emissions (sector 1B1 and 1B2) presents the highest disagreement, in the solid fuel transformation (coal), and oil/gas production and transformation. GEAA, TCNA2015 and TCNA209 agree within 20%; CEDS and EDGAR are more than 100% higher for CH_4 and CO than GEAA. EDGAR has 2.5 times more CH_4 emissions for the fuel production sectors (1A1bc,1B1,1B2) than GEAA and TCNA (see additional discussion below).

The methane emissions from fuel production and fugitive emissions from oil and gas well needs a deeper study since a bottom-up calculation from each possible source requires in situ / airborne measurements to detect possible leakages from local facilities (Allen et al., 2013; Roscioli et al., 2015; Zavala-Araiza et al., 2014). New high-resolution satellites promise new detection capabilities (i.e., GHGSat. https://www.ghgsat.com/our-platforms/iris/).

4.2 Comparison with EDGAR database

Spatial and total annual emissions were compared to the EDGAR emissions inventory (EDGAR HTAP v5.0) for Argentina. In particular, the EDGAR monthly inventory is available only for year 2015 (Crippa et al., 2020), which was used to compare the GEAA-AEIv3.0M monthly values. Table A8 (App.) shows a summary of the statistics obtained from this comparison. For this purpose, The GEAA-AEIv3.0M inventory was adapted from a 0.025º to 0.1º spatial resolution compatible with EDGAR. Figure 8 shows the annual spatial differences between both inventories for PM10 for the transport sector (panel a), for the residential and commercial sector (panel b), as well as the annual total evolution for both sectors (Figures 8c and 8d, respectively). Figure 9 shows equivalent information as Figure 8 but for NOx.

The GEAA-AEIv3.0M vs. EDGAR HTAP v5.0 comparison shows several interesting aspects. From the spatial point of view, the residential emissions shown by EDGAR has a distribution based on the districts with surface emissions larger than the properly urbanized area, see for example, green-blue areas in north-west Argentina (Figure 8b for PM_{10}) which corresponds to a mountainous and arid area, with practically no population and only minor industry based on agricultural waste burning. The larger EDGAR emissions (negative values) for the whole district are clearly an overestimation due to not considering a high-resolution population density map, as there are no direct sources on most of this region, and most of the emissions are located on a unique location on the east-edge of the district (see red dot).

According to Janssens-Maenhout et al. (2019), EDGAR uses national and subnational administrative units as proxy population data using Gridded Population of the World, Version Three (GPWv3) provided by the Center for International Earth Science Information Network (CIESIN, 2005). This approach produces an overestimation compared to the high-resolution population density map in GEAA.

~~When appreciating the annual values, the differences of PM_{10} (and other pollutants), show similar values between the years 1995-2000, but thereafter diverges. This difference arises from a possible overestimation on the EDGAR inventory on the amount of firewood and charcoal used for heating and cooking in homes. In effect, this amount has been decreasing significantly since 2002, being replaced by an increase in the use of natural gas and LPG (Figure 3c); therefore, EDGAR trends should be corrected (Figure 8d). For estimating the residential emissions, as mention in Section 2.3.4 GEAA uses the census fractions map (INDEC, 2020) which gives fine detail of the location and amount of homes, specifying the main fuel used for cooking and heating (natural gas, wood, etc.). For NOx (Figure 9d) EDGAR overestimates GEAA values, which is seen as~~

~~mostly blue areas (negative values) in Figure 9b. Since both annual series show equivalent variations, it is most probably that the discrepancies arise from the use of different emissions factors in each inventory.~~

When appreciating the annual values, the differences of PM10 (and other pollutants), show similar values between the years 1995-2008, but thereafter diverge. Firewood, charcoal and other primary energy sources used for heating and cooking in homes have been very variable but with decreasing trend since 2003, being replaced by increasing use of natural gas and LPG (Figure 3c). While natural gas (NG) represents (on average) 56% of residential energy, kerosene + charcoal + wood + other primaries represent only 4% of energy consumption at households. However, PM10 emission factors ratio wood/NG is 600 to 700, and for NOx wood/NG is only 1.2 to 2. Then, any overestimation of wood (and other primaries) will be more visible in PM10 emissions (figure 8d) than for NOx (Figure 9d). As energy consumption inputs, EDGAR uses the International Energy Agency (IEA) World Energy Balances 2016 (Janssens-Maenhout et al., 2019), however wood and other primary energy inputs may have been overestimated, given the high variability, or they might have used a constant per capita consumption. The 40% higher values of annual residential NOx emissions in GEAA and TCNA (Figure 9d) with respect to EDGAR is produced by a higher emissions factor adopted in Argentina (TCNA) for NG emissions (150 g/GJ) compared to 51 g/GJ proposed by EMEP (EMEP2019 Table 3.3 section 1.A.4.b.i). Have we adopted 51 g/GJ as from EMEP, then we would have obtained a lower total annual NOx emissions, consistent with less primary energy use (firewood, others).

Regarding transport emissions, the spatial distribution differs in the amount of traffic and emissions per route. On the EDGAR map equivalent emissions have been attributed to primary and secondary routes (see light blue lines in Figure 8b), whereas the GEAA-AEIv3.0M distinguished among routes hierarchy (see red lines in Figure 8b). Although the annual total emissions are similar, this oversizing produces less emissions on main routes for EDGAR. It should be considered that national freight transportation by trucks in Argentina (95 % of land freights) is more important than freight transportation by trains or ships.

Table A8 (App.) show the following aspects: On the one hand, emissions from fixed sources, thermal power plants and industries) have a very similar representation between inventories (< 25 % relative difference) and little variance, which indicates that the activity is similar but with a slight difference in the used emission factors.

~~On the other hand, for the fuel production and fugitive emissions subsectors (1A1cb, 1B1 and 1B2), GEAA-AEIv3.0M has an important difference with respect to EDGAR, especially in methane emissions being EDGAR > 90 % than GEAA (for the sum of subsectors). These differences totalize 598 Gg of~~ ~~CH_4~~ ~~(or 14,970 Gg~~ ~~CO_{2eq}~~~~) per year (Figure 7 and Table 8 App.). Note that for the particular case of the 1B1 sector (fugitive emissions from coal mining), the activity data for the GEAA inventory has been estimated from the national primary energy balance, which possess large uncertainties (TCNA, 2015).~~

On the other hand, for the fuel production and fugitive emissions subsectors (1A1cb, 1B1 and 1B2), GEAA-AEIv3.0M has an important difference with respect to EDGAR, especially in methane emissions being EDGAR more than 90 % larger than GEAA (for the sum of subsectors). These differences totalize 598 Gg of CH4 (or 14,970 Gg CO2eq) per year (Figure 7 and Table 8 App.). Note that for the 1B1 sector (fugitive emissions from coal mining), the activity data for the GEAA inventory has been estimated from the national primary energy balance, which possess large uncertainties (TCNA, 2015). Although

EDGAR uses the Energy Balances from IEA, which is based on national energy balances, the amount of coal computed from CH4 emissions seems to be proportional to the total coal uses (net production + import of coal) (See Figure S18, Suppl mat). Agriculture also shows important differences (> 150%) for nitrous oxide. These differences arise from direct and indirect emissions of N_2O in manure management and managed soil, but as GEAA does not include land changes, our emissions might have been underestimated in comparison to EDGAR. Estimation of biomass burning activity (AWB, OBB) also has large uncertainties in determining burned crop residues and land fires, resulting in relative emissions differences > 120% between GEAA and EDGAR. In contrast, average CH_4 emissions have relative difference of less than 70 % for most of the sectors. Similarly, for most of SCLPs, differences range between 5 % and 65 %, with a general lower estimation of pollutants emissions for GEAA-AEIv3.0M with respect to EDGAR.

4 Conclusions

A multidimensional inventory of emissions of air pollutants to the atmosphere of Argentina for 15 activities and 12 species has been compiled. This new inventory has a monthly temporal resolution (300 months between 1995 and 2020), and a high spatial resolution of 0.025° × 0.025°. The activities included are energy production, fugitive emissions from oil and gas production, industrial own energy and production, transport -road, maritime and air-, agriculture, livestock production, residential, commercial and biomass burning. Twelve species were considered: GHG CO_2, CH_4, N_2O; ozone precursors: CO, NOx, NMVOC; acidifying gases: NH_3, SO_2; and particulate matter: PM_{10}, $PM_{2.5}$, TSP, BC.

The main objective of the emission maps is to support air quality and climate modeling, as well as to evaluate in time and space pollutant mitigation strategies. In fact, the calculated pollutant temporal series clearly showed the pollution reduction due to the COVID-19 lockdown during the first quarter of year 2020 with respect to same months in previous years. This situation gave us also the opportunity to link the pollutant emissions to economic activity, showing how Argentina's emissions are still very much coupled to population and GDP, therefore an (expected and needed) economic recovery will surely increase emissions impoverishing the air quality. In fact, 30.9 % of GHG emissions comes from livestock feeding (in rural areas), and around 60% of total SCLP emissions are emitted in rural areas (mainly both from agriculture and transport), representing altogether the main export activity of Argentina. Note than in general, emissions density is very low in most of Argentina territory, but SCLP emissions density in middle-size urban areas (pop. density > 5000 inhab./km^2) are very high due transport and power plants. Investments in technology and the promotion of de-carbonized activities for reducing and decoupling GHG, and air pollutants from GDP will require big investments and further fostering cultural changes (i.e., like bicycling in cities, changes in public transportation), which will still take many years. As it has been noted in the electricity generation, thermal power plants operate mainly with natural gas, but needs to use gas oil or coal during peak hours and in winter months, therefore, air quality improvement has less room in this sector than it could be achieved in the urban road transport sector (i.e, electric motorization).

Finally, we compared the GEAA-AEIv3.0M results against the Argentine GHG inventory of the Third National Communication of Argentina to the-UNFCC, TCNA2015 and its update TCNA2019, which compiles total country wide annual

GHG emissions from 1990 through 2016, agreeing within ± 7.5%. ~~Spatially and temporal comparison was also done with EDGAR HTAPv5.0 inventory for several pollutants. The agreement was acceptable within less than 30% for most of the pollutants and activities, although a discrepancy bigger than 90% was obtained for CH_4 arising from fuel production and > 120% for biomass burning.~~ Total annual emissions were also compared to international databases as CEDS and EDGAR for several sectoral and pollutants; spatially comparison was also done with EDGAR HTAPv5.0 inventory. The agreement with CEDS and EDGAR was acceptable within less than 30% for most of the pollutants and activities, although a discrepancy bigger than 90% was obtained for CH_4 arising from fuel production and > 120% for biomass burning.

Note that CH_4 emissions from fuel production are a permanent concern due to its big greenhouse potential effect, therefore more detailed studies will be required to unravel the differences, since top-down inventories requires a great effort to assess the actual emission chain.

Seasonal variable monthly regional emissions inventory, like GEAA-AEIv3.0M, are expected to result in a remarkable improvement in the chemical prediction achieved by air quality models, such as WRF-Chem. This consideration is important, especially in countries where air quality monitoring networks are scarce, and long-term governmental environmental programs are discontinued due to the recurrent economic crisis.

Supplement

The supplement related to this article compiles two files: A pdf file with Figure S1 to Figure S18, which show the monthly and annual variations for the different subsectors analysed. And a spreadsheets file with the comparison of total annual values for 5 inventories: GEAA, TCNA2015, TCNA2019, CEDS AND EDGAR. Both are available online.

~~The supplement related to this article compiles Figure S1 to Figure S17, which show monthly and annual variations for the different subsectors analysed, and two tables (i.e., Table S1 and Table S2), which are available online.~~

Data availability

The GEAA-AEIv3.0M inventory contains spatially distributed monthly emissions for CO_{2eq}, CO_2, CH_4, N_2O, CO, NOx, NMVOC, NH_3, SO_2, PM_{10}, $PM_{2.5}$, TSP and BC between 1995 and 2020, and includes the following subsectors: energy production, fugitive emissions from oil and gas production, industrial fuel consumption and production, transport (road, maritime and air), agriculture, livestock production, residential, commercial and biomass burning. The inventory is available as NetCDF files with a spatial resolution of 2.5 km × 2.5 km resolution, between 53° to 73° west longitude and between 21° to 55° south latitude. The files can be openly accessed through the Mendeley Datasets repository at ~~http://dx.doi.org/10.17632/d6xrhpmzdp.1~~ http://dx.doi.org/10.17632/d6xrhpmzdp.2 under a CC-BY 4 license. The main page of the repository has detailed information on the files hosted, as well as a readme.txt file with specific information to access and interpret the whole dataset.

Author contributions

S. Enrique Puliafito: Conceptualization, methodology, investigation, formal analysis, original writing & supervising; Tomás R. Bolaño-Ortiz, investigation, visualization, data organization, editing & writing; Rafael P. Fernandez: formal analysis, supervising & writing; Lucas L. Berná: data organization & investigation, Romina M. Pascual-Flores data organization & investigation, Josefina Urquiza: data organization & investigation, Ana I. López-Noreña: data organization & investigation María F. Tames: editing & writing,

Competing interests

The authors declare that they have no conflict of interest.

Acknowledgements

The authors would like to thank Universidad Tecnológica Nacional (UTN) (National Technological University) and Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) (National Council for Scientific and Technical Investigations) for supporting research activities. This work is granted by UTN IFI Projects PID 1799, 1487 and 4920, CONICET (PIP 112 201101 00673) and Agencia FONCYT (PICT 2016-1115 and 2016-0714). All data requests should be addressed to the first and corresponding author.

References

Al-Kindi, S. G., Brook, R. D., Biswal, S. and Rajagopalan, S.: Environmental determinants of cardiovascular disease: lessons learned from air pollution, Nat. Rev. Cardiol., 17(10), 656–672, doi:10.1038/s41569-020-0371-2, 2020.

Allen, D. T., Torres, V. M., Thomas, J., Sullivan, D. W., Harrison, M., Hendler, A., Herndon, S. C., Kolb, C. E., Fraser, M. P., Hill, A. D., Lamb, B. K., Miskimins, J., Sawyer, R. F. and Seinfeldi, J. H.: Measurements of methane emissions at natural gas production sites in the United States, Proc. Natl. Acad. Sci. U. S. A., 110(44), doi:10.1073/pnas.1304880110, 2013.

Amann, M., Bertok, I., Borken-Kleefeld, J., Cofala, J., Heyes, C., Höglund-Isaksson, L., Klimont, Z., Nguyen, B., Posch, M., Rafaj, P., Sandler, R., Schöpp, W., Wagner, F. and Winiwarter, W.: Cost-effective control of air quality and greenhouse gases in Europe: Modeling and policy applications, Environ. Model. Softw., doi:10.1016/j.envsoft.2011.07.012, 2011.

Arino, O., Perez, J. R., Kalogirou, V., Defourny, P. and Achard, F.: Global Land Cover Map for 2009 (GlobCover 2009), ESA Living Planet Symp., (1), 2010.

Arneth, A., Unger, N., Kulmala, M. and Andreae, M. O.: Clean the Air, Heat the Planet?, Science (80-.)., 326(5953), doi:10.1126/science.1181568, 2009.

Bolaño-Ortiz, T. R., Puliafito, S. E., Berná-Peña, L. L., Pascual-Flores, R. M., Urquiza, J. and Camargo-Caicedo, Y.: Atmospheric Emission Changes and Their Economic Impacts during the COVID-19 Pandemic Lockdown in Argentina, Sustainability, 12(20), doi:10.3390/su12208661, 2020.

Bontemps, S., Defourny, P., Bogaert, E. Van, Kalogirou, V. and Perez, J. R.: GLOBCOVER 2009 Products Description and Validation Report, ESA Bull., 136, 2011.

Cammesa: Electric distribution agency of Argentina - Cammesa, Cammesa database [online] Available from: https://portalweb.cammesa.com/memnet1/Pages/descargas.aspx (Accessed 29 December 2020), 2020.

Castesana, P. S., Dawidowski, L. E., Finster, L., Gómez, D. R. and Taboada, M. A.: Ammonia emissions from the agriculture sector in Argentina; 2000–2012, Atmos. Environ., 178, doi:10.1016/j.atmosenv.2018.02.003, 2018.

Cimorelli, A. J., Perry, S. G. and Venkatram, A.: AERMOD: Description of model formulation, Report, 44(July 2015), doi:EPA-454/R-03-004, 2004.

CNRT: National Transportation Commission (CNRT) - Argentina, Rail Transp. Stat. [online] Available from: https://www.argentina.gob.ar/transporte/cnrt/estadisticas (Accessed 21 December 2020), 2020.

Crippa, M., Janssens-Maenhout, G., Dentener, F., Guizzardi, D., Sindelarova, K., Muntean, M., Van Dingenen, R. and Granier, C.: Forty years of improvements in European air quality: Regional policy-industry interactions with global impacts, Atmos. Chem. Phys., 16(6), doi:10.5194/acp-16-3825-2016, 2016.

Crippa, M., Solazzo, E., Huang, G., Guizzardi, D., Koffi, E., Muntean, M., Schieberle, C., Friedrich, R. and Janssens-Maenhout, G.: High resolution temporal profiles in the Emissions Database for Global Atmospheric Research, Sci. Data, 7(1), 121, doi:10.1038/s41597-020-0462-2, 2020.

EDGAR: EDGAR datasets, EDGAR - Arch. datasets [online] Available from: https://edgar.jrc.ec.europa.eu/archived_datasets.php (Accessed 20 January 2021), 2019.

EMEP: EMEP/EEA Air Pollutant Emission Inventory Guidebook - 2013., 2013.

EMEP: EMEP/EEA air pollutant emission inventory guidebook - 2016 — European Environment Agency, EEA Reports, (21), doi:10.2800/247535, 2016.

EMEP: EEA Report No 13/2019., 2019.

EPA: AP-42, Compilation of Air Pollutant Emission Factors, in Pollution Control Handbook for Oil and Gas Engineering, edited by Nicholas P. Cheremisinoff., 2016.

Etminan, M., Myhre, G., Highwood, E. J. and Shine, K. P.: Radiative forcing of carbon dioxide, methane, and nitrous oxide: A significant revision of the methane radiative forcing, Geophys. Res. Lett., 43(24), doi:10.1002/2016GL071930, 2016.

FAO: Análisis del balance de energía derivada de la biomasa en Argentina - WISDOM Argentina - Informe Final, FAO Dep. For. Dendroenergía, 2009.

Ferreyra, M. F. G., Curci, G. and Lanfri, M.: First Implementation of the WRF-CHIMERE-EDGAR Modeling System Over Argentina, IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens., 9(12), doi:10.1109/JSTARS.2016.2588502, 2016.

Funk, C., Peterson, P., Landsfeld, M., Pedreros, D., Verdin, J., Shukla, S., Husak, G., Rowland, J., Harrison, L., Hoell, A. and Michaelsen, J.: The climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes, Sci. Data, 2(1), 150066, doi:10.1038/sdata.2015.66, 2015.

Giglio, L., Loboda, T., Roy, D. P., Quayle, B. and Justice, C. O.: An active-fire based burned area mapping algorithm for the MODIS sensor, Remote Sens. Environ., 113(2), doi:10.1016/j.rse.2008.10.006, 2009.

Giglio, L., Randerson, J. T. and van der Werf, G. R.: Analysis of daily, monthly, and annual burned area using the fourth-generation global fire emissions database (GFED4), J. Geophys. Res. Biogeosciences, 118(1), 317–328, doi:10.1002/jgrg.20042, 2013.

Gilliland, A. B., Dennis, R. L., Roselle, S. J. and Pierce, T. E.: Seasonal NH3 emission estimates for the eastern United States based on ammonium wet concentrations and an inverse modeling method, J. Geophys. Res. Atmos., 108(15), doi:10.1029/2002jd003063, 2003.

González, C. M., Ynoue, R. Y., Vara-Vela, A., Rojas, N. Y. and Aristizábal, B. H.: High-resolution air quality modeling in a medium-sized city in the tropical Andes: Assessment of local and global emissions in understanding ozone and PM10 dynamics, Atmos. Pollut. Res., 9(5), doi:10.1016/j.apr.2018.03.003, 2018.

Grell, G. A., Peckham, S. E., Schmitz, R., McKeen, S. A., Frost, G., Skamarock, W. C. and Eder, B.: Fully coupled "online" chemistry within the WRF model, Atmos. Environ., 39(37), 6957–6975, doi:10.1016/J.ATMOSENV.2005.04.027, 2005.

Haines, A., Amann, M., Borgford-Parnell, N., Leonard, S., Kuylenstierna, J. and Shindell, D.: Short-lived climate pollutant mitigation and the Sustainable Development Goals, Nat. Clim. Chang., 7(12), 863–869, doi:10.1038/s41558-017-0012-x, 2017.

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. I., 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(1), doi:10.5194/gmd-11-369-2018, 2018.

Houghton, J. T., Ding, Y., Griggs, D. J., Noguer, N., Linden, P. J. van der, Xiaosu, D., Maskell, K. and Johnson., C. A.: Climate change 2001: The scientific basis. Contribution of Working Group I to the Third Assessment Report of the IPCC, Q. J. R. Meteorol. Soc., 128(581), doi:10.1002/qj.200212858119, 2002.

Huneeus, N., Denier van der Gon, H., Castesana, P., Menares, C., Granier, C., Granier, L., Alonso, M., de Fatima Andrade, M., Dawidowski, L., Gallardo, L., Gomez, D., Klimont, Z., Janssens-Maenhout, G., Osses, M., Puliafito, S. E., Rojas, N., Ccoyllo, O. S.-, Tolvett, S. and Ynoue, R. Y.: Evaluation of anthropogenic air pollutant emission inventories for South America at national and city scale, Atmos. Environ., 235, 117606, doi:https://doi.org/10.1016/j.atmosenv.2020.117606, 2020.

IGN: National Geographic Institute of the Argentine Republic, Polit. Div. Surf. Popul. ARGENTINA [online] Available from: https://www.ign.gob.ar/NuestrasActividades/Geografia/DatosArgentina/DivisionPolitica (Accessed 26 December 2020), 2020.

INDEC: Population projections by province in Argentina, Popul. Proj. by Prov. Argentina [online] Available from: https://www.indec.gob.ar/indec/web/Nivel4-Tema-2-24-85 (Accessed 15 December 2020), 2020.

IPCC: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change., 2014.

Isaksen, I. S. A., Granier, C., Myhre, G., Berntsen, T. K., Dalsøren, S. B., Gauss, M., Klimont, Z., Benestad, R., Bousquet, P., Collins, W., Cox, T., Eyring, V., Fowler, D., Fuzzi, S., Jöckel, P., Laj, P., Lohmann, U., Maione, M., Monks, P., Prevot, A. S. H., Raes, F., Richter, A., Rognerud, B., Schulz, M., Shindell, D., Stevenson, D. S., Storelvmo, T., Wang, W.-C., van Weele, M., Wild, M. and Wuebbles, D.: Atmospheric composition change: Climate–Chemistry interactions, Atmos. Environ., 43(33), 5138–5192, doi:https://doi.org/10.1016/j.atmosenv.2009.08.003, 2009.

Jacob, D. J. and Winner, D. A.: Effect of climate change on air quality, Atmos. Environ., 43(1), 51–63, doi:https://doi.org/10.1016/j.atmosenv.2008.09.051, 2009.

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(3), 959–1002, doi:10.5194/essd-11-959-2019, 2019.

Klimont, Z., Kupiainen, K., Heyes, C., Purohit, P., Cofala, J., Rafaj, P., Borken-Kleefeld, J. and Schöpp, W.: Global anthropogenic emissions of particulate matter including black carbon, Atmos. Chem. Phys., 17(14), doi:10.5194/acp-17-8681-2017, 2017.

Kumar, A., Dixit, S., Varadarajan, C., Vijayan, A. and Masuraha, A.: Evaluation of the AERMOD dispersion model as a function of atmospheric stability for an urban area, Environ. Prog., 25(2), doi:10.1002/ep.10129, 2006.

Lee, H. D., Yoo, J. W., Kang, M. K., Kang, J. S., Jung, J. H. and Oh, K. J.: Evaluation of concentrations and source contribution of PM10 and SO2 emitted from industrial complexes in Ulsan, Korea: Interfacing of the WRF-CALPUFF modeling tools, Atmos. Pollut. Res., 5(4), doi:10.5094/APR.2014.076, 2014.

Li, M., Liu, H., Geng, G., Hong, C., Liu, F., Song, Y., Tong, D., Zheng, B., Cui, H., Man, H., Zhang, Q. and He, K.: Anthropogenic emission inventories in China: A review, Natl. Sci. Rev., 4(6), doi:10.1093/nsr/nwx150, 2017.

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(4), doi:10.5194/essd-12-3413-2020, 2020.

De Meij, A., Krol, M., Dentener, F., Vignati, E., Cuvelier, C. and Thunis, P.: The sensitivity of aerosol in Europe to two different emission inventories and temporal distribution of emissions, Atmos. Chem. Phys., 6(12), doi:10.5194/acp-6-4287-2006, 2006.

Minem: Ministry of Energy - Argentina, Open database from Argentine Minist. Energy [online] Available from: http://datos.minem.gob.ar/dataset?groups=comercializacion-de-los-hidrocarburos (Accessed 27 December 2020), 2020.

Myhre, G., Berglen, T. F., Johnsrud, M., Hoyle, C. R., Berntsen, T. K., Christopher, S. A., Fahey, D. W., Isaksen, I. S. A., Jones, T. A., Kahn, R. A., Loeb, N., Quinn, P., Remer, L., Schwarz, J. P. and Yttri, K. E.: Modelled radiative forcing of the direct aerosol effect with multi-observation evaluation, Atmos. Chem. Phys., 9(4), doi:10.5194/acp-9-1365-2009, 2009.

Myhre, G., Shindell, D., Bréon, F.-M. F.-M., Collins, W., Fuglestvedt, J., Huang, J., Koch, D., Lamarque, J.-F. J.-F., Lee, D., Mendoza, B., Nakajima, T., Robock, A., Stephens, G., Takemura, T., Zhan, H. and Zhang, H.: Anthropogenic and Natural Radiative Forcing: Supplementary Material, Clim. Chang. 2013 Phys. Sci. Basis. Contrib. Work. Gr. I to Fifth Assess. Rep. Intergov. Panel Clim. Chang. Phys. Sci. Basis. Contrib. Work. Gr. I to Fifth Assess. Rep., doi:10.1017/

CBO9781107415324.018, 2013.

Nakicenovic, N., J, A., Davis G and de Vries B, Fenhann J, Gaffin S, Gregory K, Grübler A, Jung TY, Kram T, La Rovere EL, Michaelis L, Mori S, Morita T, Pepper W, Pitcher H, Price L, Raihi K, Roehrl A, Rogner H-H, Sankovski A, Schlesinger M, Shukla P, Smith S, Swart R, van Rooijen S, Victor, D. Z.: IPCC Special Report on Emissions Scenarios, Cambridge, UK., 2000.

Puliafito, S. E., Allende, D., Pinto, S. and Castesana, P.: High resolution inventory of GHG emissions of the road transport sector in Argentina, Atmos. Environ., 101, doi:10.1016/j.atmosenv.2014.11.040, 2015.

Puliafito, S. E., Allende, D. G., Castesana, P. S. and Ruggeri, M. F.: High-resolution atmospheric emission inventory of the argentine energy sector. Comparison with edgar global emission database, Heliyon, 3(12), doi:10.1016/j.heliyon.2017.e00489, 2017.

Puliafito, S. E., Bolaño-Ortiz, T. R., Berná Peña, L. L. and Pascual-Flores, R. M.: Dataset supporting the estimation and analysis of high spatial resolution inventories of atmospheric emissions from several sectors in Argentina, Data Br., 29, 105281, doi:10.1016/j.dib.2020.105281, 2020a.

Puliafito, S. E., Bolaño-Ortiz, T., Berná, L. and Pascual Flores, R.: High resolution inventory of atmospheric emissions from livestock production, agriculture, and biomass burning sectors of Argentina, Atmos. Environ., 223, 117248, doi:10.1016/j.atmosenv.2019.117248, 2020b.

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.: Mendeley Data, Data High Resolut. Seas. Decad. Invent. Anthr. gas-phase Part. Emiss. Argentina [online] Available from: http://dx.doi.org/10.17632/d6xrhpmzdp.2, 2021.

Ramanathan, V., Crutzen, P. J., Kiehl, J. T. and Rosenfeld, D.: Atmosphere: Aerosols, climate, and the hydrological cycle, Science (80-.)., 294(5549), doi:10.1126/science.1064034, 2001.

Ravishankara, A. R., Daniel, J. S. and Portmann, R. W.: Nitrous Oxide (N<sub>2</sub>O): The Dominant Ozone-Depleting Substance Emitted in the 21st Century, Science (80-.)., 326(5949), 123 LP – 125, doi:10.1126/science.1176985, 2009.

Rivera, J. A., Marianetti, G. and Hinrichs, S.: Validation of CHIRPS precipitation dataset along the Central Andes of Argentina, Atmos. Res., 213, 437–449, doi:10.1016/J.ATMOSRES.2018.06.023, 2018.

Rodriguez, E., Morris, C. S., Belz, J. E., Chapin, E. C., Martin, J. M., Daffer, W. and Hensley, S.: An assessment of the SRTM topographic products, 2005.

Rood, A. S.: Performance evaluation of AERMOD, CALPUFF, and legacy air dispersion models using the Winter Validation Tracer Study dataset, Atmos. Environ., 89, 707–720, doi:https://doi.org/10.1016/j.atmosenv.2014.02.054, 2014.

Roscioli, J. R., Yacovitch, T. I., Floerchinger, C., Mitchell, A. L., Tkacik, D. S., Subramanian, R., Martinez, D. M., Vaughn, T. L., Williams, L., Zimmerle, D., Robinson, A. L., Herndon, S. C. and Marchese, A. J.: Measurements of methane emissions from natural gas gathering facilities and processing plants: Measurement methods, Atmos. Meas. Tech., 8(5), doi:10.5194/amt-8-2017-2015, 2015.

Rystad: Rystad energy, Will vast potential Argentina's Vaca Muerta shale Play ever be unlocked? [online] Available from: https://www.rystadenergy.com/newsevents/news/press-releases/Will-the-vast-potential-of-Argentinas-Vaca-Muerta-shale-play-ever-be-unlocked/ (Accessed 24 November 2020), 2018.

Sato, A., Vitullo, M. and Gschwantner, T.: Chapyer 8 Settlements - 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, in Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA., 2019.

Scire, J. S., Strimaitis, D. G. and Yamartino, R. J.: A User's Guide for the CALPUFF Dispersion Model, Earth Tech. Inc, (January), 2000.

Shindell, D. T.: The social cost of atmospheric release, Clim. Change, 130(2), doi:10.1007/s10584-015-1343-0, 2015.

Shindell, D. T., Walter, B. P. and Faluvegi, G.: Impacts of climate change on methane emissions from wetlands, Geophys. Res. Lett., 31(21), doi:10.1029/2004GL021009, 2004.

Solomon, S., Plattner, G.-K., Knutti, R. and Friedlingstein, P.: Irreversible climate change due to carbon dioxide emissions, Proc. Natl. Acad. Sci., 106(6), 1704 LP – 1709, doi:10.1073/pnas.0812721106, 2009.

Solomon, S., Alcamo, J. and Ravishankara, A. R.: Unfinished business after five decades of ozone-layer science and policy, Nat. Commun., 11(1), 4272, doi:10.1038/s41467-020-18052-0, 2020.

SSPYVN: National Port Authority (SSPYVN) - Argentina, Load. Stat. data [online] Available from: https://www.argentina.gob.ar/puertos-vias-navegables-y-marina-mercante/estadisticas-de-carga (Accessed 29 December

2020), 2020.

Stohl, A., Aamaas, B., Amann, M., Baker, L. H., Bellouin, N., Berntsen, T. K., Boucher, O., Cherian, R., Collins, W., Daskalakis, N., Dusinska, M., Eckhardt, S., Fuglestvedt, J. S., Harju, M., Heyes, C., Hodnebrog, Hao, J., Im, U., Kanakidou, M., Klimont, Z., Kupiainen, K., Law, K. S., Lund, M. T., Maas, R., MacIntosh, C. R., Myhre, G., Myriokefalitakis, S., Olivié, D., Quaas, J., Quennehen, B., Raut, J. C., Rumbold, S. T., Samset, B. H., Schulz, M., Seland, Shine, K. P., Skeie, R. B., Wang, S., Yttri, K. E. and Zhu, T.: Evaluating the climate and air quality impacts of short-lived pollutants, Atmos. Chem. Phys., 15(18), doi:10.5194/acp-15-10529-2015, 2015.

Tartakovsky, D., Broday, D. M. and Stern, E.: Evaluation of AERMOD and CALPUFF for predicting ambient concentrations of total suspended particulate matter (TSP) emissions from a quarry in complex terrain, Environ. Pollut., 179, doi:10.1016/j.envpol.2013.04.023, 2013.

TCNA: Third National Communication of Argentina to the IPCC, City of Buenos Aires. [online] Available from: https://unfccc.int/documents/67499, 2015.

Thompson, R. L., Lassaletta, L., Patra, P. K., Wilson, C., Wells, K. C., Gressent, A., Koffi, E. N., Chipperfield, M. P., Winiwarter, W., Davidson, E. A., Tian, H. and Canadell, J. G.: Acceleration of global N2O emissions seen from two decades of atmospheric inversion, Nat. Clim. Chang., 9(12), 993–998, doi:10.1038/s41558-019-0613-7, 2019.

UNEP-WMO: Integrated Assessment of Black Carbon and Tropospheric Ozone, United Nations Environ. Program. (UNEP), Nairobi, Kenya., (UNEP/GC.26/INF/20), 2011.

UNEP: United Nations Environment Programme, Nairobi, Kenia., 2013.

West, J. J., Fiore, A. M., Horowitz, L. W. and Mauzerall, D. L.: Global health benefits of mitigating ozone pollution with methane emission controls, Proc. Natl. Acad. Sci. U. S. A., 103(11), doi:10.1073/pnas.0600201103, 2006.

Ying, Z., Tie, X. and Li, G.: Sensitivity of ozone concentrations to diurnal variations of surface emissions in Mexico City: A WRF/Chem modeling study, Atmos. Environ., 43(4), doi:10.1016/j.atmosenv.2008.10.044, 2009.

Zavala-Araiza, D., Sullivan, D. W. and Allen, D. T.: Atmospheric hydrocarbon emissions and concentrations in the barnett shale natural gas production region, Environ. Sci. Technol., 48(9), doi:10.1021/es405770h, 2014.

FIGURES

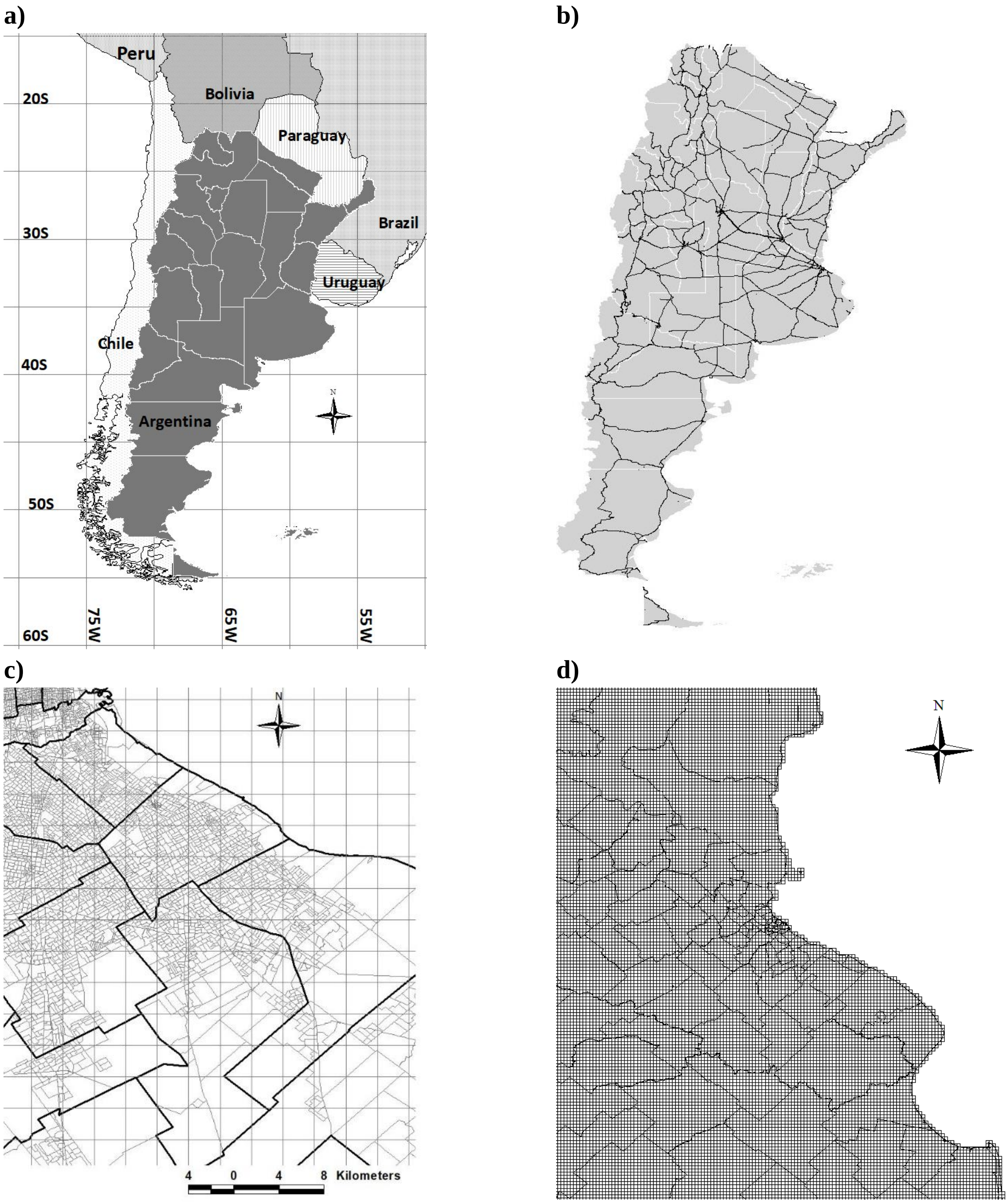

Figure 1. Spatial coverage and scales used in this inventory: a) Geographical location of Argentina in South America (provinces in white outline); b) main roads; c) districts (black outline) and censal fractions (grey outline); d) spatial gird with districts in background.

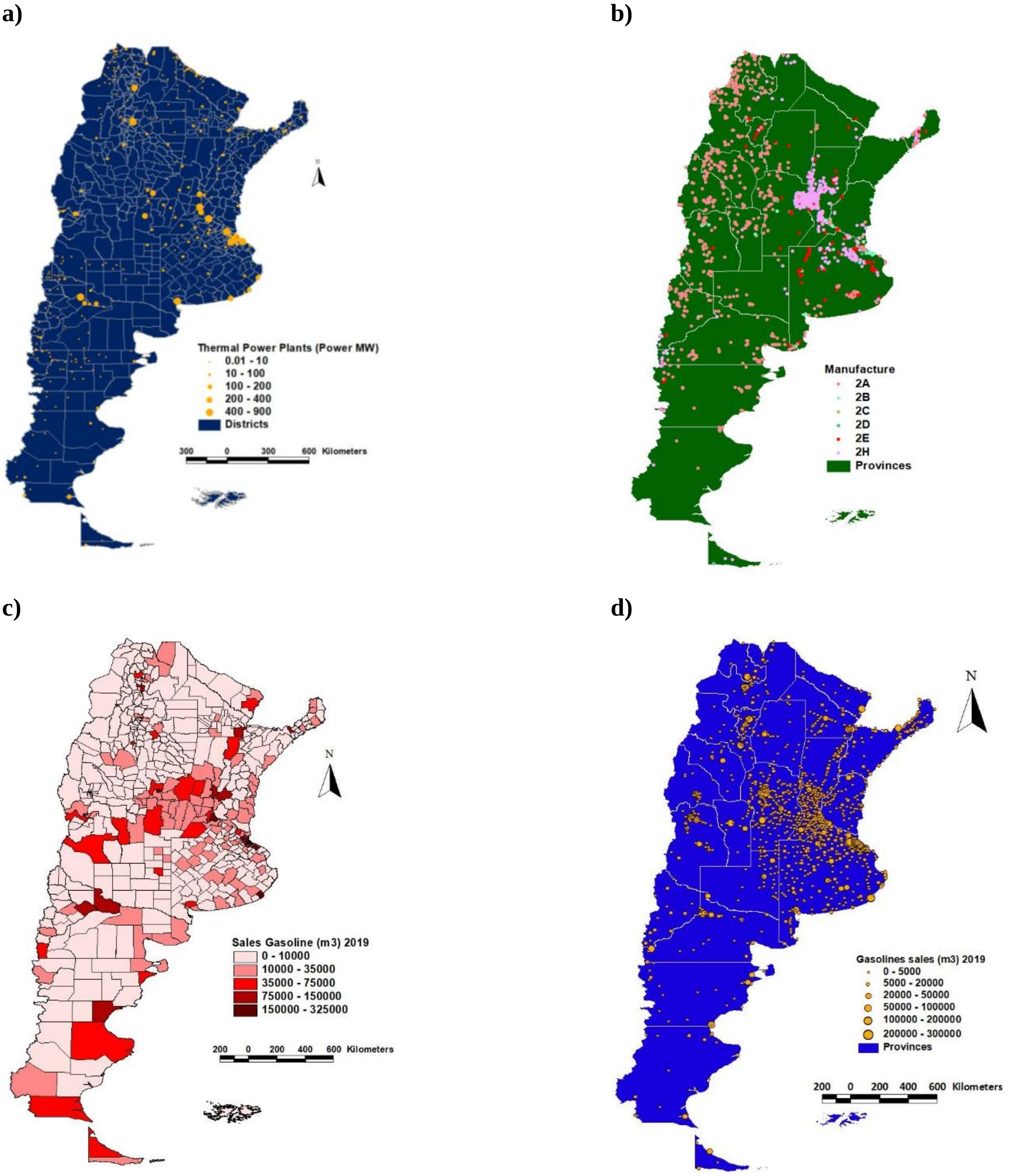

Figure 2. Location of point sources: a) thermal power plants (districts in white outline); b) manufacturing industries (provinces in white outline). Manuf. code. 2A: cement, calcium, glass, mining; 2B: chemical; 2C: steel, iron, aluminium; 2D: car-painting; 2E. other non-specified, 2H: paper, food, beverages (see Table A3 App.); c) District distribution of annual gasoline sales for year 2019; d) Location of refuelling gas stations and their individual yearly gasoline sales.

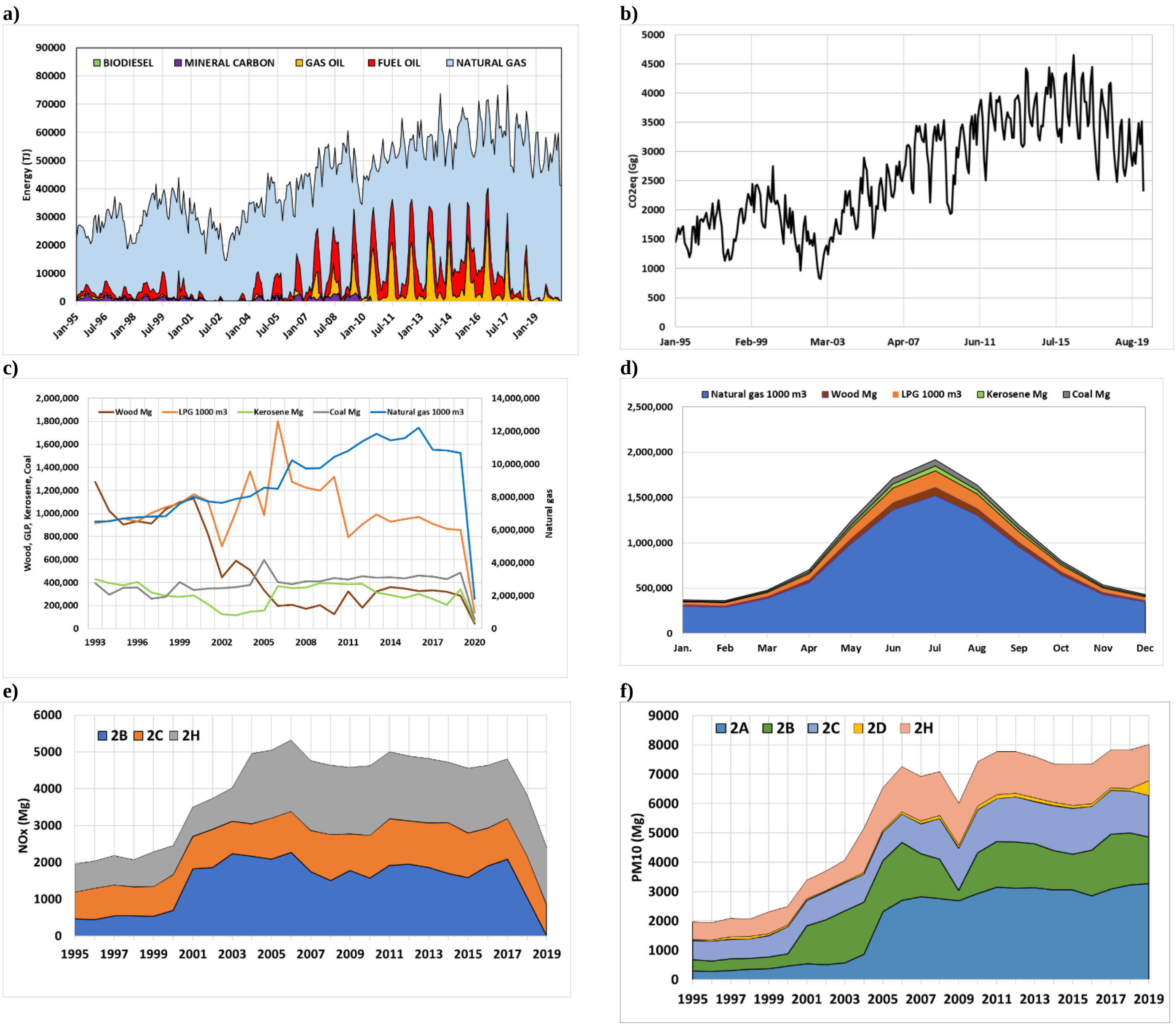

Figure 3. a) Evolution of monthly energy consumption by thermal power plants; b) GHG emissions evolution (in terms of CO2eq-Gg) from energy consumption at thermal power plants; c) Monthly fuel consumption for residential & commercial sector; d) Seasonal average fuel consumption for residential & commercial sector for the period 1995-2019. e) Annual NOx emissions (in t) from manufacturing activities: f) Annual PM10 emissions (in t) for manufacturing activities. Ref. manuf. codes: 2A: cement, calcium, glass, mining; 2B: chemical; 2C: steel, iron, aluminium; 2D: car-painting; 2H: paper, food, beverages (see Table A3, App.).

a) **b)**

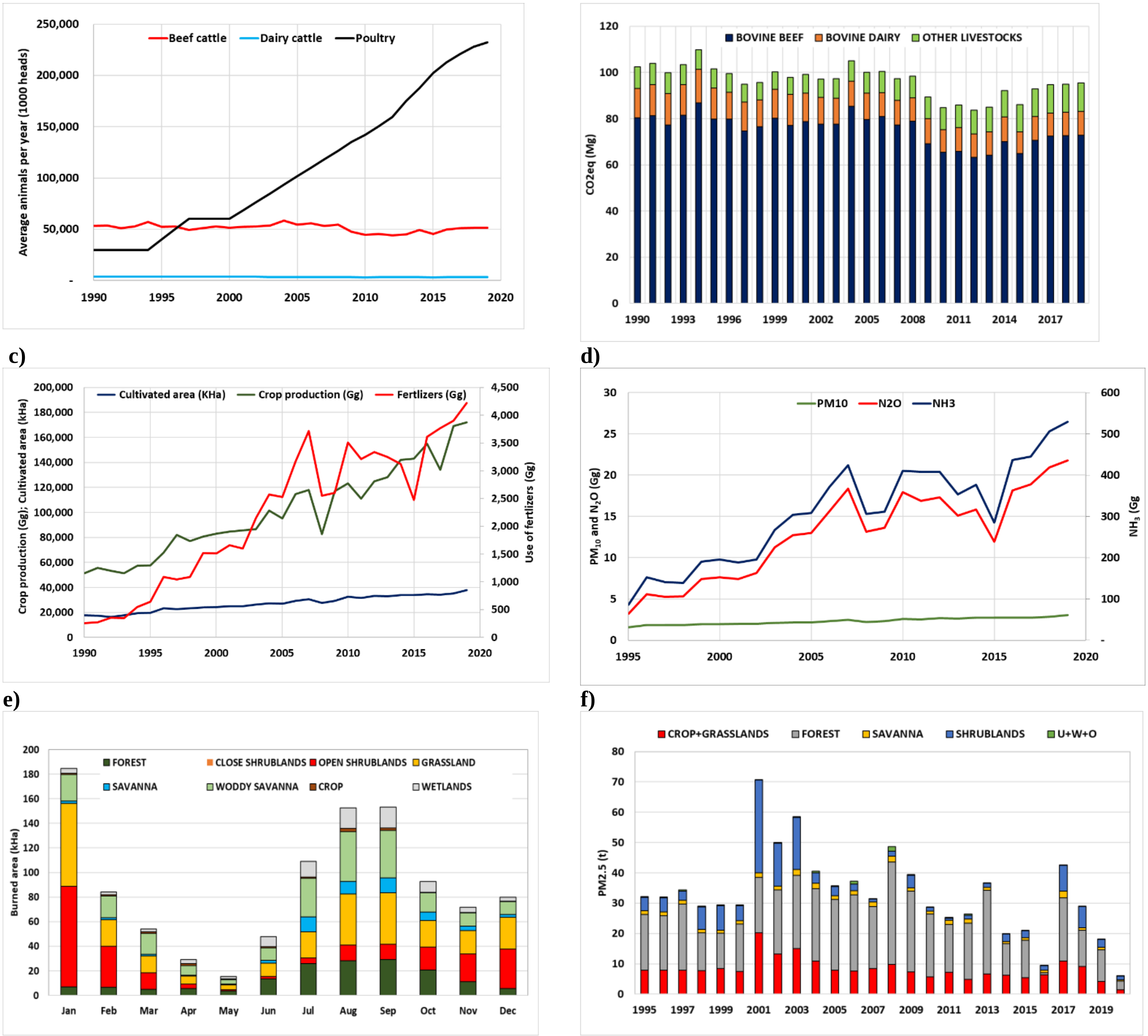

Figure 4. a) Annual animal production for three brides: Bovine, dairy and poultry; b) Annual evolution of GHG (in Gg) from for three brides: Bovine (beef production), Bovine (dairy production), other livestock's brides; c) Annual evolution of main agriculture indices: Crop production (Gg), cultivated area (kHa) and Use of fertilizers (Gg); d) annual emissions of N_2O, NH_3 and PM_{10} from fertilizers uses and arable lands; e) average stational burned area in kHa for the period 1995-2020, according to land type; f) annual emissions evolution of $PM_{2.5}$ (kt) for the period 1995-2020, according to land type.

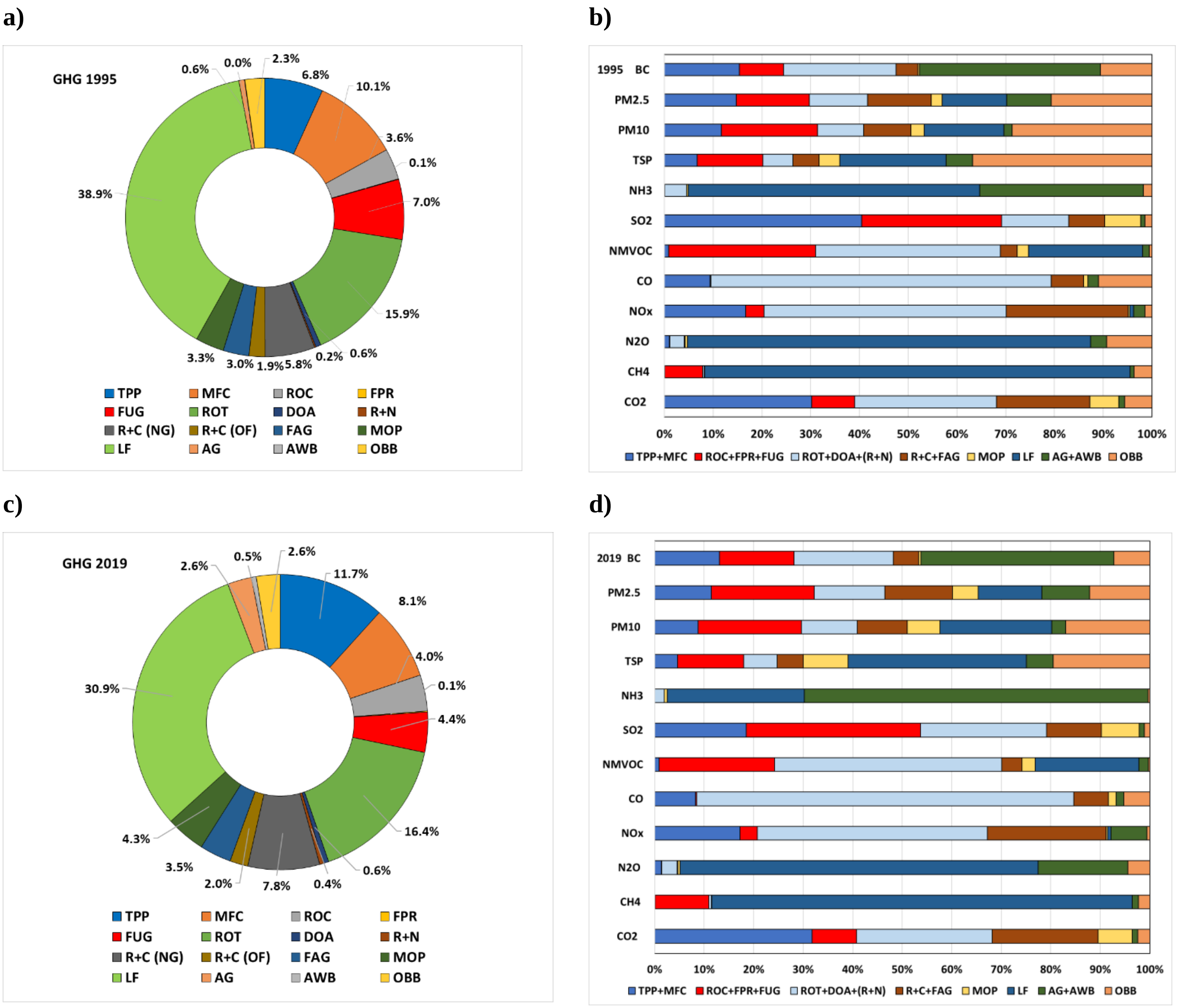

Figure 5. GHG participation by activity for Argentina years 1995 (a) and 2019 (c), (see Table 3); and sectoral SLCP pollutant contribution share of emissions for Argentina: b) year 1995, b) year 2019. Reference codes are provided in Table 1a.

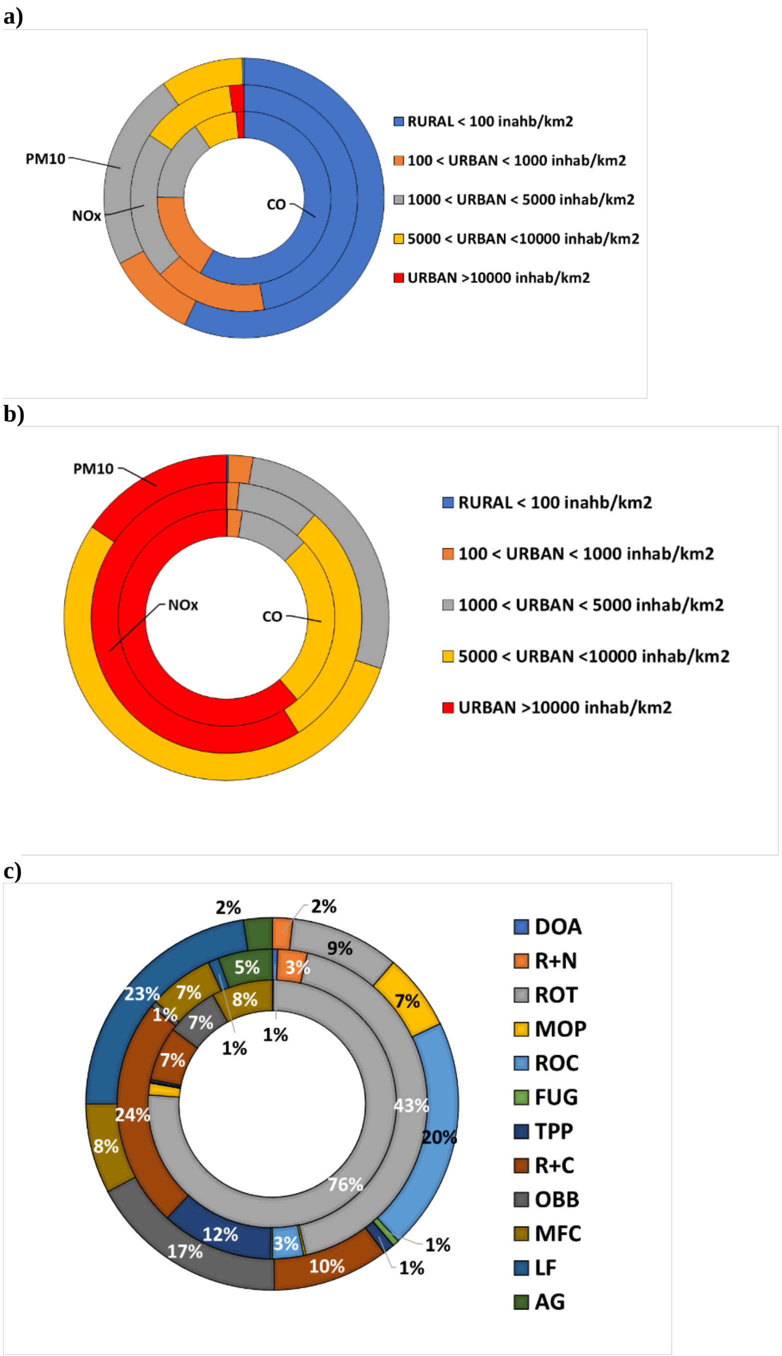

Figure 6. Annual PM10 (outer ring), NOx (middle ring) and CO (inner ring) emissions distribution according to different classifications: a) total emissions with respect to population density; b) emissions density (kg/km^2/year) with respect to urban density, c) total sectoral contribution (see Table 4). Reference codes are provided in Table 1a

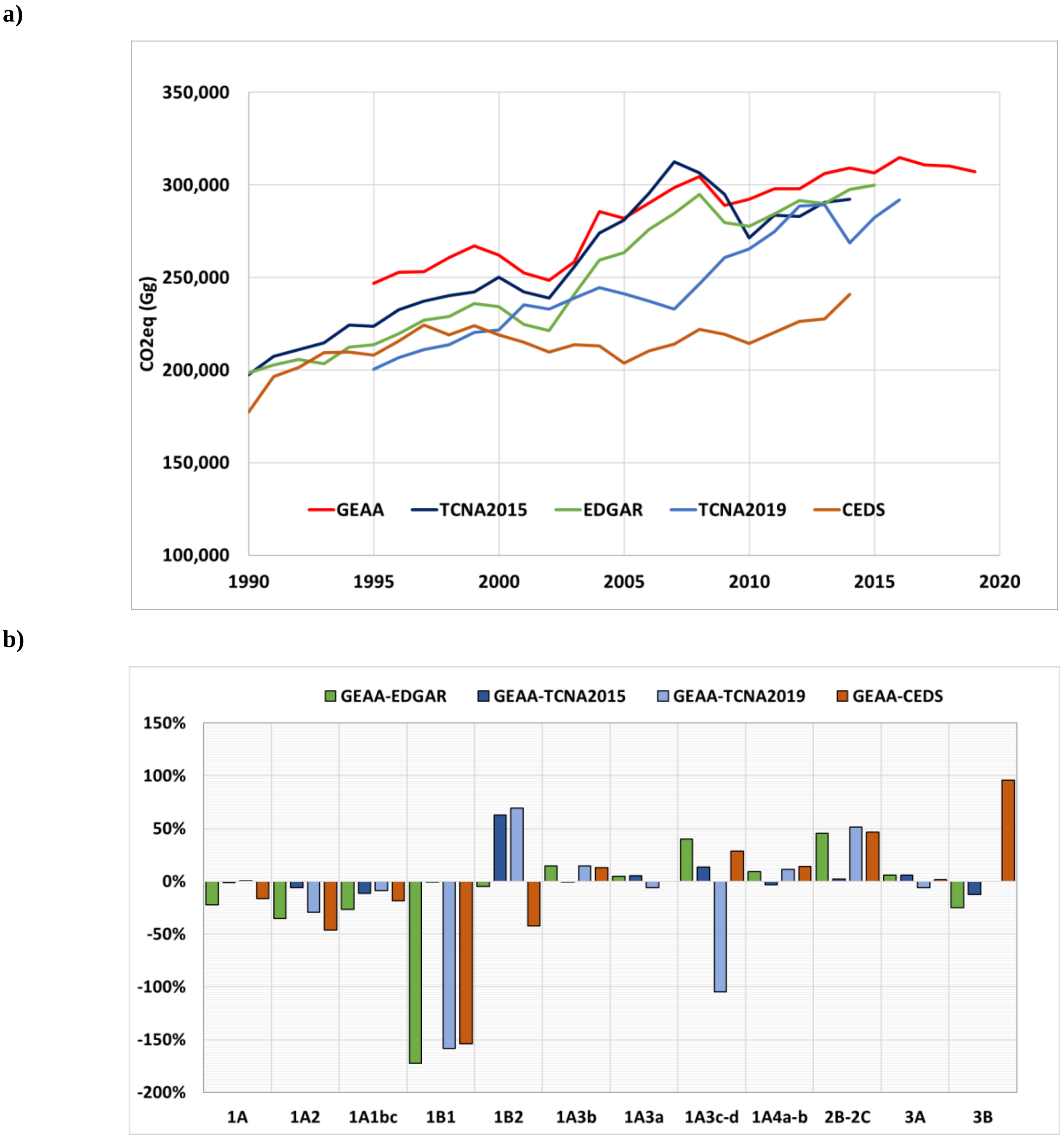

Figure 7. a) Evolution of total annual CO_2eq-Gg emissions for GEAA (red), TCNA2015 (blue); TCNA2019 (light-blue); EDGAR (green) and CEDS (brown), inventories for Argentina years 1990-2019. (Table 5 and Tables A5 App.); b) Percentage difference in GHG emissions [(GEAA – inventory)/GEAA] for years 1995 through 2016, for the considered activities (see also Tables A6 and A7 App.). Note that CEDS does not provides N2O profiles. GHG are calculated as (CO2eq = CO2 + CH4*25 + N2O*298).

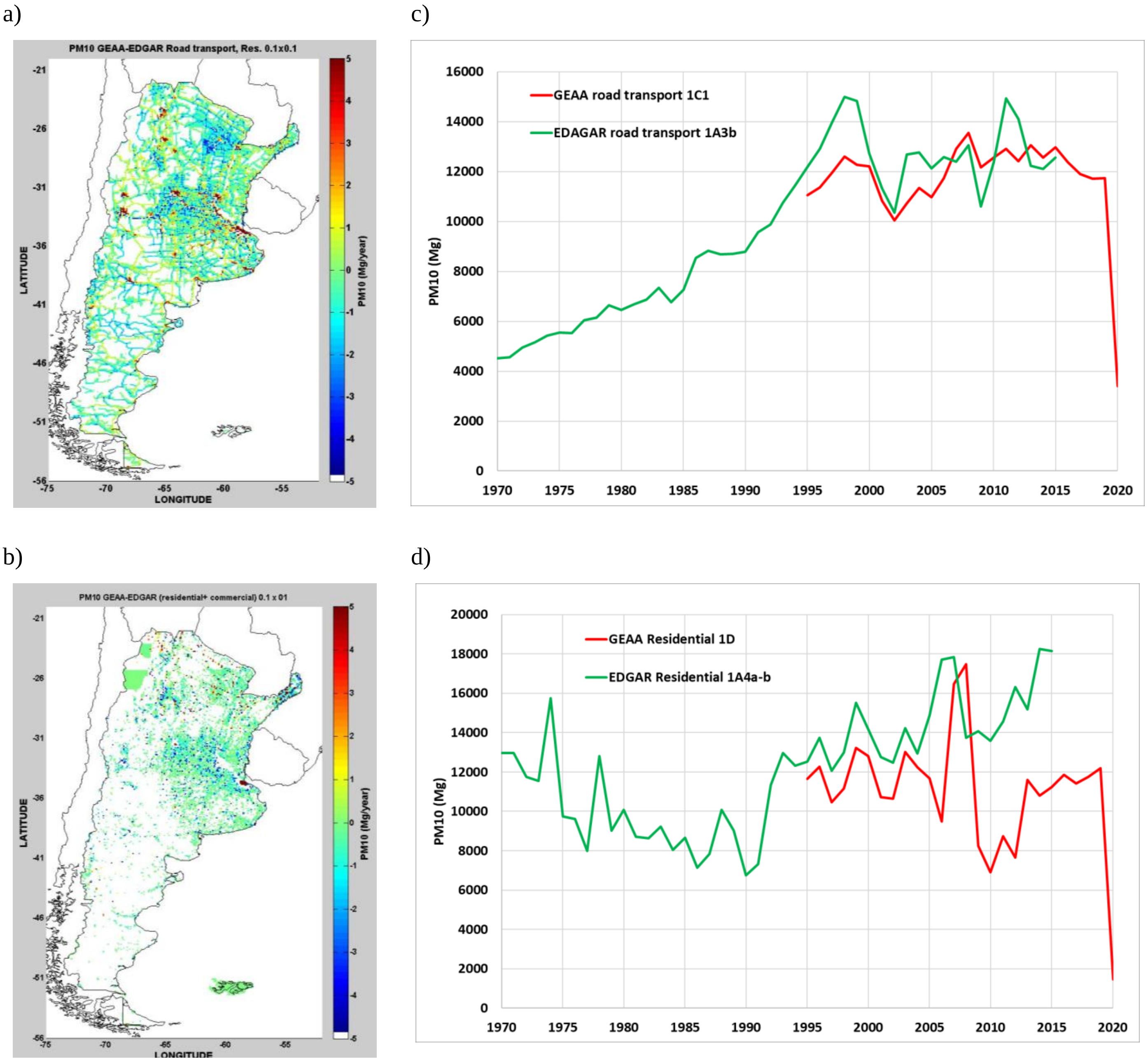

Figure 8: GEAA and EDGAR annual PM_{10} emissions from road transport sector: a) differences (t/year/cell); c) annual series. GEAA and EDGAR annual PM10 emissions from residential + commercial activities: b) differences (t/year/cell); d) annual series. Maps are represented at 0.1×0.1 resolution for year 2015.

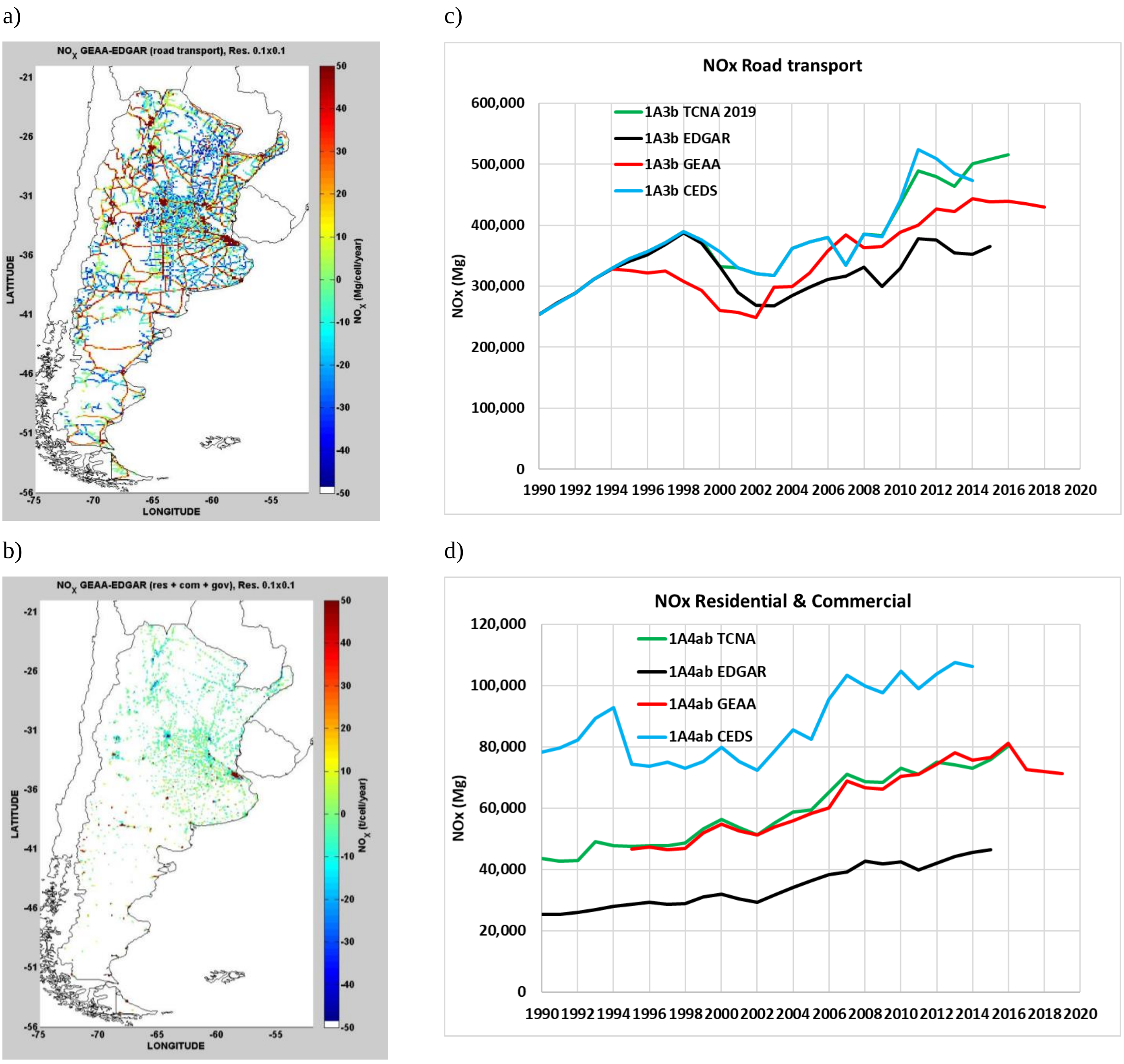

Figure 9: GEAA and EDGAR annual NOx emissions from road transport sector: a) differences (GEAA-EDGAR) in Mg/year/cell); c) annual series. GEAA and EDGAR annual NOx emissions from residential + commercial activities: b) differences (Mg/year/cell); d) annual series. Maps are represented at 0.1×0.1 resolution for year 2015. CEDS (light blue) and TCNA (green) profiles are also include for comparison.

Tables

Table 1a. Sectors, activities, classification codes and resolution considered in GEAA-AEIv3.0M inventory

Sector and Activities	Acronym	IPCC code	Text Section	Period / Resolution	Spatial coverage /resolution
Fuel Combustion				**1995-2020 Monthly**	**National 0.025° x 0.025°**
Power and heat production	TPP	1A1a	2.3.1 / 3.1		
Manufacture own energy production	MFC	1A1b	2.3.5 / 3.4		
Fuel Production and transformation		1A1b	2.3.2 / 3.2		
refinery own consumption,	ROC	1A1c	2.3.2 / 3.2		
oil and gas extraction at wells,	FPR	1Ab2	2.3.2 / 3.2		
fugitive emissions, venting, and flaring	FUG				
Road transportation	ROT	1A3b	2.3.3 / 3.3		
Domestic aviation	DOA	1A3a	2.3.3 / 3.3		
Railroad and navigation	R+N	1A3c, d	2.3.3 / 3.3		
Residential Commercial and Public offices combustion	R+C	1A4a, b 1A4c	2.3.4 / 3.4		
Fuel use in Agriculture	FAG				
Manufacture Processes (non-combustion)				**1995-2020 Monthly**	**National 0.025° x 0.025°**
Production of minerals, chemicals, and metals, pulp/paper/food/drink	MOP	2B + 2C	2.3.5 / 3.5		
Agriculture and livestock feeding				**1995-2020 Yearly**	**National 0.025° x 0.025°**
Enteric fermentation, Manure management and Feeding and manure deposited on pasture	LF	4A + 4B	2.3.6 / 3.6		
Rice cultivation, Fertilizer application and Crop residues	AG	4C + 3C3	2.3.6 / 3.6		
Fires				**1995-2020 Monthly**	**National 0.025° x 0.025°**
Biomass & Savanna burning and Fires from LULC	OBB		2.3.7 / 3.7		
Agricultural waste burning	AWB	4F	2.3.6 / 3.6		

Table 1b. Sectors, activities, and pollutants considered in GEAA-AEIv3.0M inventory.

Sector and Activities	CO2	CH4	N2O	CO	NH3	NOx	SO2	NMVCOC	TSP	PM10	PM2.5	BC
Fuel Combustion:												
Power and heat production	x	x	x	x		x	x	x	x	x	x	x
Fuel Production (incl. fugitive emissions, venting, and flaring)	x	x	x	x	x	x	x	x	x	x	x	x
Road transportation	x	x	x	x	x	x	x	x	x	x	x	x
Domestic aviation	x	x	x	x		x	x	x	x	x	x	x
Railroad and navigation	x	x	x	x	x	x	x	x	x	x	x	x
Residential Commercial and Public offices combustion	x	x	x	x	x	x	x	x	x	x	x	x
Fuel use in agriculture	x	x	x	x		x	x	x	x	x	x	x
Industrial Processes (non-combustion):												
Production of minerals, chemicals, and metals, pulp/paper/food/drink	x	x	x	x	x	x	x	x	x	x	x	x
Agriculture and livestock feeding:												
Enteric fermentation, Manure management and Feeding and manure deposited on pasture	x	x	x	x	x	x	x	x	x	x	x	x
Rice cultivation, Fertilizer application and Crop residues	x	x	x	x	x	x	x	x	x	x	x	x
Fires:												
Biomass & Savanna burning and Fires from LULC	x	x	x	x	x	x	x	x	x	x	x	x
Agricultural waste burning	x	x	x	x	x	x	x	x	x	x	x	x

Table 2. Acronyms used in this text

Acronym [&]	Definition	Web page / observation
	National Agencies in Argentina	
ANAC	Argentine Aviation Regulation Agency	https://www.argentina.gob.ar/anac
CAMMESA	National Electricity Administration Agency	https://portalweb.cammesa.com/default.aspx
CNRT	National Transport Regulation Agency	https://www.argentina.gob.ar/transporte/cnrt
MINEM	Energy data base at the Ministry for Energy	https://www.argentina.gob.ar/economia/energia/datos-y-estadisticas
INDEC	Statistics and Census Bureau	https://www.indec.gob.ar/
MAyGN	Ministry of Agriculture and Livestock	https://www.magyp.gob.ar/datosabiertos/
SENASA	Animal Health Control Agency	https://www.argentina.gob.ar/senasa
INTA	National Agricultural Research Institute	https://www.argentina.gob.ar/inta
	Models, software, inventories, and international databases	
GHG	Greenhouse Gases	
GWP100	Global Potential Warming for 100 years	CH4: 28; N2O: 298
IPCC	Intergovernmental Panel on Climate Change	https://archive.ipcc.ch/index.htm
AQM	Air quality models	
AEI	Atmospheric Emissions Inventory	
GEAA-AEIV2.5	High Resolution Atmospheric Emissions Inventory for Argentina	This study and Puliafito et al, (2015,2017,2020)
TCNA	Third Argentine National Greenhouse Gases Inventory	https://www.argentina.gob.ar/ambiente/cambio-climatico/tercer-informe-bienal
WRF-Chem	Weather Research and Forecasting with Chemistry	Grell et al, (2005) https://www2.acom.ucar.edu/wrf-chem
EDGAR-HTAP	Emissions Database for Global Atmospheric Research – Hemispheric Transport of Air Pollution	https://edgar.jrc.ec.europa.eu/htap.php
EMEP	European Monitoring and Evaluation Program Guidebook	https://www.eea.europa.eu/publications/emep-eea-guidebook-2019
EMEP	European Monitoring and Evaluation Program Guidebook	https://www.eea.europa.eu/publications/emep-eea-guidebook-2019
MODIS	MODerate resolution Imaging Spectroradiometer	https://modis.gsfc.nasa.gov/
GIS	Geographical Information System	Software for spatial database handling

[&] **additional acronyms are compiled in Table A2, Appen.**

Table 3. Summary of annual emissions for years 2019 and 1995 for Argentina

ACTIVITY	CO2 Gg	CH4 Mg	N2O Mg	NOx Mg	CO Mg	NMVOC Mg	SO2 Mg	NH3 Mg	TSP Mg	PM10 Mg	PM2.5 Mg	BC Mg
TPP 2019	35,678.88	1,607.55	1,325.56	116,846.07	14,528.58	3,575.67	12,290.06	151.21	1,399.47	1,257.11	1,043.70	149.47
TPP 1995	17,553.66	356.50	626.42	58,675.49	6,321.52	1,593.15	36,196.60	86.17	1,139.47	872.60	594.73	156.66
MFC 2019	24,992.33	2,208.53	295.41	56,366.47	324,412.57	5,385.40	2,733.86	-	10,133.40	9,588.97	9,045.70	2,447.42
MFC 1995	26,250.01	2,824.24	396.77	56,264.14	310,726.15	6,358.39	5,514.90	-	14,358.78	13,417.68	12,263.79	3,347.67
ROC 2019	12,205.23	253.29	33.58	32,535.64	3,647.96	1,167.81	5,793.80	-	32,542.81	24,951.48	17,573.11	2,778.22
ROC 1995	9,338.78	238.06	28.42	24,339.37	2,655.09	735.52	8,744.05	-	30,455.98	23,655.15	12,680.67	1,942.33
FPR 2019	323.26	16.34	20.53	1,649.30	361.00	200.58	5,809.89	-	472.37	472.37	472.37	109.01
FPR 1995	161.45	7.96	12.30	847.79	181.20	116.81	7,579.97	-	239.57	239.57	239.57	55.29
FUG 2019	4,690.45	355,047.46	29.17	597.41	3,080.42	225,773.26	16,958.86	213.20	217.96	212.81	207.17	102.24
FUG 1995	3,221.52	274,263.50	22.90	815.68	4,095.64	269,081.98	13,283.92	167.00	225.25	200.77	173.86	82.17
ROT 2019	49,113.18	15,479.65	3,665.54	429,428.25	3,115,081.40	445,859.47	13,305.08	13,632.44	14,670.69	11,736.55	10,562.89	2,676.82
ROT 1995	40,256.52	9,451.45	2,908.92	328,342.02	2,369,115.10	337,757.03	12,371.08	10,519.94	13,814.63	11,051.70	9,946.53	4,974.70
DOA 2019	1,778.89	12.44	49.76	6,219.91	2,487.96	1,243.98	22.14	1,128.29	19.90	12.44	0.56	0.72
DOA 1995	1,547.02	10.82	43.27	5,409.16	2,163.66	1,081.83	19.26	981.22	17.31	10.82	0.49	0.56
R+N 2019	1,307.21	119.02	33.30	30,815.96	3,350.27	1,283.33	7,345.94	3.04	2,198.82	2,192.28	1,985.79	1,290.77
R+N 1995	411.51	38.61	10.48	8,674.78	1,180.56	478.38	1,854.75	0.96	513.66	508.55	463.77	301.45
R+C 2019	30,209.84	3,072.56	133.47	71,282.30	147,318.96	11,637.59	3,169.54	-	12,812.68	12,185.51	11,783.56	963.73
R+C 1995	19,989.81	2,171.80	113.91	46,604.97	119,634.45	10,352.82	3,788.44	-	12,154.73	11,651.83	11,199.15	980.65
FAG 2019	10,647.49	425.12	84.68	169,183.27	140,726.22	28,283.82	5,795.20	-	273.63	227.12	193.05	63.71
FAG 1995	7,773.42	314.71	62.94	125,885.35	104,904.46	20,980.89	3,805.84	-	199.32	165.43	140.62	46.40
MOP 2019	13,150.74	116.27	562.25	2,399.50	62,061.61	25,880.67	6,256.51	4,015.92	22,565.27	8,155.49	4,580.94	90.16
MOP 1995	8,506.78	257.58	463.68	1,996.66	29,614.58	20,754.96	7,600.02	976.95	9,865.09	3,361.22	1,987.79	69.96
LF 2019	-	2,781,099.06	87,068.47	6,673.93	-	204,075.53	-	211,634.17	89,789.65	27,806.44	11,327.39	-
LF 1995	-	3,084,156.16	81,859.67	5,530.74	-	209,738.66	-	154,913.12	50,213.95	19,964.21	11,541.43	-
AG 2019	645.99	39,646.34	21,760.71	67,825.59	-	15,169.70	-	529,442.66	3,792.42	3,033.94	2,275.45	-
AG 1995	83.24	26,291.25	3,205.65	9,991.65	-	7,930.75	-	86,602.95	1,982.69	1,586.15	1,189.61	-
AWB 2019	1,551.18	3,327.46	68.51	5,186.92	65,961.93	3,914.65	831.36	439.70	9,623.73	479.19	6,161.53	7,726.41
AWB 1995	1,731.25	3,713.72	76.46	5,789.04	73,619.08	4,369.08	913.36	490.74	10,558.49	524.62	6,759.89	8,478.19
OBB 2019	4,627.87	74,128.96	5,336.02	6,083.67	214,146.38	2,679.91	874.61	2,631.45	48,672.18	20,918.91	10,720.87	1,440.13
OBB 1995	8,079.03	128,727.05	9,185.10	10,059.21	372,831.42	4,602.62	1,476.97	4,610.87	84,698.39	35,006.35	18,020.96	2,411.27
TOT. 2019	190,922.53	3,274,899.83	120,466.95	1,003,094.18	4,097,165.27	976,031.73	81,186.87	763,292.08	249,173.89	123,224.49	87,933.46	19,838.80
TOT. 1995	144,904.02	3,524,712.57	99,016.90	689,226.05	3,397,042.91	895,445.94	103,149.16	259,349.91	230,383.15	122,186.83	87,199.82	22,847.31

Ref (see Table 1a): TPP: Power Plants, MFC: Manufacturing own fuel consumption, ROC: Refinery own consumption, FPR: Fuel production, FUG: Fugitive, venting and flare, ROT: Road transport, DOA. Domestic Aviation, R+N: Railroad and navigation, R+C: Residential and commercial, FAG: Fuel use in agriculture, MOP: Manufacturing own process, LF: Livestock feeding, AG: Agriculture, AWB: Agriculture waste burning, OBB. Open biomass burning.

Table 4. Emission distribution of CO and NOx according to population density for year 2019.

Density (d) inhab /km2	RURAL d < 100	URBAN VERY LOW 100 < d < 1000	URBAN LOW 1000 < d < 5000	URBAN MEDIUM 5000 < d <10000	URBAN HIGH d >10000	TOTAL
N.of cells	445,917.00	6,508.00	1,285.00	269.00	21.00	454,000.00
AREA (km^2)	2,786,981.25	40,675.00	8,031.25	1,681.25	131.25	2,837,500.00
Popul. 2019	659,690	11,010,333	18,590,350	12,658,283	2,115,971	45,034,627
% Pop.	1.5%	24.4%	41.3%	28.1%	4.7%	100.0%
			CO (Mg/year)			
DOA	939.49	382.50	362.07	803.90	-	2,487.96
R+N	1,519.50	856.40	637.30	293.39	43.69	3,350.27
ROT	1,891,902.61	504,092.42	418,483.32	248,576.30	52,026.75	3,115,081.40
MOP	4,037.09	2,366.40	55,431.16	226.96	-	62,061.61
ROC	274.77	408.66	2,488.22	476.32	-	3,647.96
FUG	127.57	657.48	2,037.21	619.16	-	3,441.42
TPP	7,659.52	3,415.03	1,004.07	2,449.97	-	14,528.58
R+C	7,482.69	122,122.84	100,543.83	49,410.28	8,485.55	288,045.19
OBB	271,743.78	5,518.57	2,295.39	550.57	-	280,108.31
MFC	206,177.34	47,437.49	45,502.24	25,138.23	157.27	324,412.57
AG	-	-	-	-	-	-
total	**2,391,864.34**	**687,257.80**	**628,784.82**	**328,545.06**	**60,713.26**	**4,097,165.27**
			NOX (Mg/year)			
DOA	3,062.42	638.05	703.51	1,815.92	-	6,219.91
R+N	13,964.98	7,884.30	5,862.93	2,702.03	401.72	30,815.96
ROT	271,442.41	69,834.64	52,841.31	29,604.42	5,705.48	429,428.25
MOP	855.57	536.36	948.55	59.02	-	2,399.50
ROC	2,441.80	3,606.38	22,189.13	4,298.32	-	32,535.64
FUG	2,062.70	117.60	50.93	15.48	-	2,246.70
TPP	61,421.78	29,418.21	7,265.37	18,740.70	-	116,846.07
R+C	1,181.68	39,165.14	110,402.61	74,925.87	14,790.28	240,465.58
LF	5,943.46	631.22	92.73	6.52	-	6,673.93
AG	67,825.59	-	-	-	-	67,825.59
OBB	10,882.44	254.92	106.81	26.41	-	11,270.58
MFC	31,840.49	9,344.20	11,524.93	3,622.73	34.13	56,366.47
total	**472,925.33**	**161,431.02**	**211,988.82**	**135,817.42**	**20,931.60**	**1,003,094.18**

The total Argentine population, surface extension, total emission and emission density are classified according to the mean urban density within each cell.

Ref (see Table 1a): PP: Power Plants, MFC: Manufacturing own fuel consumption, ROC: Refinery own consumption, FPR: Fuel production, FUG: Fugitive, venting and flare, ROT: Road transport, DOA. Domestic Aviation, R+N: Railroad and navigation, R+C (NG): Residential and commercial (natural gas), R+C (OF) Residential and commercial (other fuels), FAG: Fuel use in agriculture, MOP: Manufacturing own process, LF: Livestock feeding, AG: Agriculture, AWB: Agriculture waste burning, OBB. Open biomass burning.

Table 5. GEAA-AEIv3.0M inventory: annual GHG emissions values (CO2eq-Gg) for Argentina

GEAA	TPP	MFC	ROC	FPR	FUG	ROT	DOA	R+N	R+C	MOP	LF	AG	AWB	OBB
1,995	17,749.25	18,024.89	9,353.21	165.32	18,184.30	41,359.67	1,560.18	415.60	27,797.39	8,651.39	101,498.09	1,695.80	115.63	5,955.34
1,996	20,826.95	18,493.91	9,643.63	177.89	18,799.09	41,807.13	1,367.99	441.06	28,539.23	10,205.50	99,446.99	2,573.35	112.54	5,929.80
1,997	19,262.39	20,579.40	12,621.84	193.34	20,839.63	42,543.93	1,298.71	455.59	27,748.90	9,779.01	94,889.85	2,605.04	124.31	6,300.14
1,998	20,721.15	21,245.05	13,587.82	221.14	22,348.66	43,878.61	1,501.11	488.51	27,521.44	10,676.77	95,701.14	2,463.19	137.69	5,441.60
1,999	25,112.72	19,497.20	10,797.78	217.49	22,574.52	42,084.17	1,668.87	467.98	29,781.25	10,760.03	100,296.06	3,446.39	131.03	5,424.73
2,000	24,837.23	19,078.08	9,529.70	226.27	21,364.44	40,900.27	1,496.43	461.73	30,577.03	11,828.29	97,815.89	3,502.92	121.34	5,419.34
2,001	18,663.59	18,293.31	9,822.28	233.23	23,438.00	36,373.21	1,232.84	613.28	29,321.45	11,691.38	99,192.43	3,508.62	122.61	12,628.66
2,002	15,752.08	19,958.15	11,508.66	239.91	22,709.20	35,117.90	1,061.34	425.57	28,484.88	12,555.16	97,176.91	3,553.81	117.99	8,805.61
2,003	17,931.58	20,919.28	12,953.60	250.16	24,409.70	35,351.22	1,002.70	551.27	31,207.62	12,147.16	97,348.52	4,306.07	133.46	10,690.27
2,004	24,019.60	21,736.17	10,971.60	245.77	24,301.76	40,308.29	1,140.46	753.33	38,384.08	13,746.51	105,015.93	5,012.78	128.42	7,611.06
2,005	26,831.51	21,790.57	10,182.71	248.49	23,536.45	38,917.27	1,165.37	792.22	39,201.41	14,514.90	100,023.34	4,650.46	134.97	6,443.59
2,006	28,635.29	23,209.38	10,674.46	256.49	24,053.83	41,986.89	1,061.69	895.38	37,485.78	15,845.14	100,422.99	5,471.65	146.62	7,113.35
2,007	33,097.09	23,541.34	11,150.99	282.57	24,954.74	46,734.03	1,123.93	544.59	37,435.83	15,917.05	97,298.78	6,581.49	143.39	5,779.05
2,008	37,396.18	23,525.38	10,939.15	305.56	24,218.39	49,840.10	1,239.22	540.22	37,639.75	15,464.60	98,494.27	4,882.03	142.49	9,526.25
2,009	34,571.68	21,457.59	12,689.37	321.57	23,190.67	46,221.94	1,277.76	513.63	41,515.36	13,012.09	89,388.62	4,777.49	133.41	7,002.68
2,010	36,908.13	22,824.46	12,167.45	310.18	23,577.74	46,971.09	1,413.33	1,669.57	40,857.43	15,014.81	84,718.60	6,615.52	116.99	5,084.54
2,011	41,508.00	23,583.76	11,469.80	308.42	23,085.63	49,243.13	1,400.63	2,094.96	38,074.76	16,199.11	85,809.80	6,113.89	117.58	4,842.19
2,012	44,362.83	19,629.01	12,228.66	310.68	23,578.77	49,563.61	1,400.28	1,970.54	39,716.60	15,791.57	83,684.63	6,351.81	112.44	5,070.32
2,013	44,483.29	20,094.33	12,167.58	310.01	23,553.45	52,138.47	1,427.47	1,590.85	44,813.13	16,415.74	84,983.24	5,561.22	95.37	6,411.52
2,014	44,550.34	17,277.11	12,057.86	320.89	23,243.00	51,271.14	1,479.39	1,591.88	43,316.26	16,749.46	92,146.92	5,890.00	100.09	3,619.45
2,015	47,110.08	17,204.82	12,267.69	337.38	24,198.48	53,703.80	1,410.44	1,633.40	44,251.88	15,050.95	86,008.21	4,600.55	88.66	3,899.49
2,016	48,010.62	15,175.80	12,435.98	353.86	24,091.19	52,378.63	1,505.14	1,636.37	45,977.49	14,895.51	92,918.38	6,886.05	90.64	2,034.04
2,017	43,482.46	16,557.00	12,451.73	340.35	23,706.77	51,637.09	1,589.45	1,405.43	42,654.35	16,071.67	94,683.67	6,784.85	103.72	8,128.27
2,018	41,406.62	17,483.46	13,467.61	333.15	23,453.19	51,033.57	1,704.82	1,496.32	40,876.34	16,332.22	94,930.79	7,582.61	107.13	5,297.25
2,019	36,114.09	18,950.36	12,221.57	329.78	27,708.33	50,592.50	1,794.03	1,320.11	40,905.26	13,321.19	95,473.88	8,121.84	103.60	3,443.36
2,020	14,687.61	6,967.85	5,452.56	272.91	19,565.56	13,819.76	291.27	284.23	15,518.47	325.96	--	--	--	1,304.43

Ref: (Table 1a) TPP: Power Plants, MFC: Manufacturing own fuel consumption, ROC: Refinery own consumption, FPR: Fuel production, FUG: Fugitive, venting and flare, ROT: Road transport, DOA. Domestic Aviation, R+N: Railroad and navigation, R+C Residential and commercial and others, MOP: Manufacturing own process, LF: Livestock feeding, AG: Agriculture, AWB: Agriculture waste burning, OBB. Open biomass burning.

APPENDIX

TABLES

Table A1. Argentine inventories developed at the Group for Atmospheric and Environmental Studies (GEAA)

Name	Sectors	Species	Extension/ Temporal /Resolution	Reference
GEAA-AEIv1.0A	Road transport sector	CO_2, CH_4, CO, NOx, NMVOC, TSP, PM_{10}, $PM_{2.5}$	Argentina, annual 2014, 9 × 9 km	Puliafito et al., (2015)
GEAA-AEIv2.0A	Public electricity and heat production, oil refining, fugitive emissions from oil and gas production, domestic aviation, road transport, rail and inland navigation, residential sector, cement production	CO_2, CH_4, N_2O, CO, NOx, NMVOC, TSP, PM_{10}, $PM_{2.5}$	Argentina, annual 2016, 0.025° × 0.025°	Puliafito et al., (2017)
GEAA-AEIv3.0A	Public electricity and heat production, oil refining, fugitive emissions from oil and gas production, domestic aviation, road transport, rail and inland navigation, residential sector, cement production, agriculture, livestock production, biomass burning.	CO_2, CH_4, N_2O, CO, NOx, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC	Argentina, annual, 2016, 0.025° × 0.025°	Puliafito et al., (2020a, 2020b)

5

Table A2. Other acronyms used in this text

Acronym	Definition	Web page / observation
	Fuels and technology considered in power plants	
CC	Combined cycle	Power plant technology
TV	Turbo steam	Power plant technology
TG	Turbo gas	Power plant technology
DI	Diesel Engine	Power plant technology
NG	Natural Gas	Fuel
FO	Heavy fuel oil	Fuel
GO	Gasoil	Fuel
CM	Mineral coal, carbon, charcoal	Fuel
BD	Biodiesel	Fuel

Acronym	Definition	Web page / observation
	Transport variables	
RGS	Refueling Gas Stations	Loading fuel stations for vehicles
VKT	Vehicle kilometer transported (v-km)	Passenger transport index
TKT	Ton kilometer transported (t-km)	Freight transport index
PKT	Passenger kilometer transported (p-km)	Public transport index
LTO	Landing and take-off	Aviation index
FO	Heavy fuel oil	Fuel for navigation
CNG	Compressed natural Gas	Fuel
NA	Gasoline	Fuel
GO	Gasoil	Fuel
AK	Kerosene for aviation	Jet fuel for aviation
AG	Gasoline for aviation	Fuel for aviation

Table A3. List of industrial activities

Number	Code	Activity	Number	Code	Activity
1	2.C.1	steel-iron	24	2.B.10	pet
2	2.C.3	aluminium	25	2.B.10	polyethylene high density
3	2.B.4	benzoic acid	26	2.B.10	polyethylene
4	2.B.4	acetaldehiyde	27	2.B.10	polypropylene
5	2.B.4	acetic acid	28	2.B.10	ammonium sulphate
6	2.B.4	ethyl acetate	29	2.B.7	carbon sulfide
7	2.B.4	acetone	30	2.B.4	toluene
8	2.B.4	n-butyl acetate	31	2.B.10	urea
9	2.B.2	nitric acid	32	2.H.1	paper-bisulfite
10	2.B.4	salicylic acid	33	2.H.1	paper-kraft
11	2.B.4	alcohol	34	2.H.1	paper-pulp
12	2.B.1	ammonia	35	2.H.2	vegetable oil
13	2.B.4	aromatics-btx	36	2.H.2	food-poultry
14	2.D.3	asphalt	37	2.H.2	sugar
15	2.D.3	asphalt roof	38	2.H.2	Beverage
16	2.D.3	asphalt roads	39	2.A.2	calcium lime
17	2.B.10	sulfuric acid	40	2.A.1	cement
18	2.B.2	benzene	41	2.D.3	car painting
19	2.B.7	sodium carbonate	42	2.B.5	calcium carbide
20	2.B.10	chlorine	43	2.A.3	glass
21	2.B.10	ethylene	44	2.A.2	calcium lime
22	2.B.10	nylon	45	2.A.1	cement
23	2.B.10	other-chemical			

Table A5. Impact of COVID-19 lockdown on Argentine emissions: Summary of monthly emissions for April 2020 and April 2019

ACTIVITY	CO2 Gg	CH4 Mg	N2O Mg	NOx Mg	CO Mg	NMVOC Mg	SO2 Mg	NH3 Mg	TSP Mg	PM10 Mg	PM2.5 Mg	BC Mg
TPP 2019	2,530.77	116.50	95.10	7,771.41	1,076.04	1,793.39	30.22	10.20	84.93	80.61	70.39	5.64
TPP 2020	2,283.65	105.11	85.86	6,945.82	973.79	1,622.99	20.38	9.18	76.44	72.55	63.35	4.72
MFC 2019	2,093.32	181.19	24.26	4,744.00	27,105.62	444.18	231.72	-	831.10	785.91	739.35	199.83
MFC 2020	1,798.00	148.91	19.89	4,097.13	23,207.05	369.41	192.49	-	675.23	638.86	601.50	162.11
ROC 2019	978.86	20.61	2.74	2,613.18	288.87	94.15	500.51	-	2,657.90	2,041.85	1,400.41	226.99
ROC 2020	377.30	7.39	0.97	1,004.66	2,368.31	35.90	20.31	-	935.38	711.20	557.05	81.96
FPR 2019	25.98	1.31	1.73	133.52	29.05	16.79	655.63	-	38.11	38.11	38.11	8.79
FPR 2020	25.32	1.27	1.69	130.19	28.32	16.40	649.15	-	37.15	37.15	37.15	8.57
FUG 2019	366.10	27,433.58	2.25	66.03	337.74	22,672.10	1,306.81	16.43	16.46	16.45	16.44	8.00
FUG 2020	282.16	18,951.76	1.51	64.42	330.79	20,533.41	877.53	11.03	11.58	11.57	11.56	5.49
ROT 2019	4,041.20	1,247.94	296.17	34,981.68	160,653.89	35,763.14	1,119.41	1,070.96	1,253.78	1,003.03	902.72	240.59
ROT 2020	2,258.54	496.35	131.63	16,620.72	60,076.25	13,588.16	796.19	467.55	957.93	766.35	689.71	184.77
DOA 2019	150.08	1.05	4.20	524.77	209.91	104.95	95.19	1.87	1.68	1.05	0.05	0.15
DOA 2020	-	-	-	-	-	-	-	-	-	-	-	-
R+N 2019	115.04	10.49	2.93	296.29	2,700.24	0.27	113.80	641.24	191.46	190.85	172.91	112.39
R+N 2020	76.93	6.89	1.96	184.70	1,915.03	0.18	68.16	477.60	147.06	146.98	132.83	86.34
R+C 2019	2,390.18	127.73	4.26	6,386.31	2,128.77	212.88	12.77	-	93.67	93.67	93.67	5.06
R+C 2020	1,554.96	264.68	6.87	3,532.67	7,601.99	621.99	118.59	-	564.49	529.84	516.43	38.24
FAG 2019	887.29	35.43	7.06	14,098.61	11,727.19	2,356.99	482.93	-	22.80	18.93	16.09	5.31
FAG 2020	885.46	35.40	7.05	14,094.25	11,725.73	2,355.53	482.81	-	22.75	18.88	16.05	5.30
TOT. 2019	**13,578.83**	**29,175.82**	**440.71**	**71,615.79**	**206,257.31**	**63,458.84**	**4,549.00**	**1,740.69**	**5,191.90**	**4,270.45**	**3,450.13**	**812.76**
TOT. 2020	**9,542.32**	**20,017.75**	**257.45**	**46,674.56**	**108,227.26**	**39,143.97**	**3,225.63**	**965.36**	**3,428.02**	**2,933.38**	**2,625.64**	**577.50**
(20-19)/19	**-42.3%**	**-45.7%**	**-71.2%**	**-53.4%**	**-90.6%**	**-62.1%**	**-41.0%**	**-80.3%**	**-51.5%**	**-45.6%**	**-31.4%**	**-40.7%**

Ref: TPP: Power Plants, MFC: Manufacturing own fuel consumption, ROC: Refinery own consumption, FPR: Fuel production, FUG: Fugitive, venting and flare, ROT: Road transport, DOA. Domestic Aviation, R+N: Railroad and navigation, R+C: Residential and commercial, FAG: Fuel use in agriculture.

Table A4 Summary of pollutants emissions for Argentina during December 2019 and December 1995

ACTIVITY	CO2 Gg	CH4 Mg	N2O Mg	NOx Mg	CO Mg	NMVOC Mg	SO2 Mg	NH3 Mg	TSP Mg	PM10 Mg	PM2.5 Mg	BC Mg
TPP 2019	35,678.88	1,607.55	1,325.56	116,846.07	14,528.58	3,575.67	12,290.06	151.21	1,399.47	1,257.11	1,043.70	149.47
TPP 1995	17,553.66	356.50	626.42	58,675.49	6,321.52	1,593.15	36,196.60	86.17	1,139.47	872.60	594.73	156.66
MFC 2019	24,992.33	2,208.53	295.41	56,366.47	324,412.57	5,385.40	2,733.86	-	10,133.40	9,588.97	9,045.70	2,447.42
MFC 1995	26,250.01	2,824.24	396.77	56,264.14	310,726.15	6,358.39	5,514.90	-	14,358.78	13,417.68	12,263.79	3,347.67
ROC 2019	12,205.23	253.29	33.58	32,535.64	3,647.96	1,167.81	5,793.80	-	32,542.81	24,951.48	17,573.11	2,778.22
ROC 1995	9,338.78	238.06	28.42	24,339.37	2,655.09	735.52	8,744.05	-	30,455.98	23,655.15	12,680.67	1,942.33
FPR 2019	323.26	16.34	20.53	1,649.30	361.00	200.58	5,809.89	-	472.37	472.37	472.37	109.01
FPR 1995	161.45	7.96	12.30	847.79	181.20	116.81	7,579.97	-	239.57	239.57	239.57	55.29
FUG 2019	4,690.45	355,047.46	29.17	597.41	3,080.42	225,773.26	16,958.86	213.20	217.96	212.81	207.17	102.24
FUG 1995	3,221.52	274,263.50	22.90	815.68	4,095.64	269,081.98	13,283.92	167.00	225.25	200.77	173.86	82.17
ROT 2019	49,113.18	15,479.65	3,665.54	429,428.25	3,115,081.40	445,859.47	13,305.08	13,632.44	14,670.69	11,736.55	10,562.89	2,676.82
ROT 1995	40,256.52	9,451.45	2,908.92	328,342.02	2,369,115.10	337,757.03	12,371.08	10,519.94	13,814.63	11,051.70	9,946.53	4,974.70
DOA 2019	1,778.89	12.44	49.76	6,219.91	2,487.96	1,243.98	22.14	1,128.29	19.90	12.44	0.56	0.72
DOA 1995	1,547.02	10.82	43.27	5,409.16	2,163.66	1,081.83	19.26	981.22	17.31	10.82	0.49	0.56
R+N 2019	1,307.21	119.02	33.30	30,815.96	3,350.27	1,283.33	7,345.94	3.04	2,198.82	2,192.28	1,985.79	1,290.77
R+N 1995	411.51	38.61	10.48	8,674.78	1,180.56	478.38	1,854.75	0.96	513.66	508.55	463.77	301.45
R+C 2019	30,209.84	3,072.56	133.47	71,282.30	147,318.96	11,637.59	3,169.54	-	12,812.68	12,185.51	11,783.56	963.73
R+C 1995	19,989.81	2,171.80	113.91	46,604.97	119,634.45	10,352.82	3,788.44	-	12,154.73	11,651.83	11,199.15	980.65
FAG 2019	10,647.49	425.12	84.68	169,183.27	140,726.22	28,283.82	5,795.20	-	273.63	227.12	193.05	63.71
FAG 1995	7,773.42	314.71	62.94	125,885.35	104,904.46	20,980.89	3,805.84	-	199.32	165.43	140.62	46.40
MOP 2019	13,150.74	116.27	562.25	2,399.50	62,061.61	25,880.67	6,256.51	4,015.92	22,565.27	8,155.49	4,580.94	90.16
MOP 1995	8,506.78	257.58	463.68	1,996.66	29,614.58	20,754.96	7,600.02	976.95	9,865.09	3,361.22	1,987.79	69.96
LF 2019	-	2,781,099.06	87,068.47	6,673.93	-	204,075.53	-	211,634.17	89,789.65	27,806.44	11,327.39	-
LF 1995	-	3,084,156.16	81,859.67	5,530.74	-	209,738.66	-	154,913.12	50,213.95	19,964.21	11,541.43	-
AG 2019	645.99	39,646.34	21,760.71	67,825.59	-	15,169.70	-	529,442.66	3,792.42	3,033.94	2,275.45	-
AG 1995	83.24	26,291.25	3,205.65	9,991.65	-	7,930.75	-	86,602.95	1,982.69	1,586.15	1,189.61	-
AWB 2019	1,551.18	3,327.46	68.51	5,186.92	65,961.93	3,914.65	831.36	439.70	9,623.73	479.19	6,161.53	7,726.41
AWB 1995	1,731.25	3,713.72	76.46	5,789.04	73,619.08	4,369.08	913.36	490.74	10,558.49	524.62	6,759.89	8,478.19
OBB 2019	4,627.87	74,128.96	5,336.02	6,083.67	214,146.38	2,679.91	874.61	2,631.45	48,672.18	20,918.91	10,720.87	1,440.13
OBB 1995	8,079.03	128,727.05	9,185.10	10,059.21	372,831.42	4,602.62	1,476.97	4,610.87	84,698.39	35,006.35	18,020.96	2,411.27
TOT. 2019	**190,922.53**	**3,276,560.06**	**120,466.95**	**1,003,094.18**	**4,097,165.27**	**976,131.41**	**81,186.87**	**763,292.08**	**249,184.98**	**123,230.60**	**87,934.08**	**19,838.80**
TOT. 1995	**144,904.02**	**3,532,823.42**	**99,016.90**	**689,226.05**	**3,397,042.91**	**895,932.89**	**103,149.16**	**259,349.91**	**230,437.33**	**122,216.66**	**87,202.87**	**22,847.31**

Ref: TPP: Power Plants, MFC: Manufacturing own fuel consumption, ROC: Refinery own consumption, FPR: Fuel production, FUG: Fugitive, venting and flare, ROT: Road transport, DOA. Domestic Aviation, R+N: Railroad and navigation, R+C: Residential and commercial, FAG: Fuel use in agriculture, MOP: Manufacturing own process, LF: Livestock feeding, AG: Agriculture, AWB: Agriculture waste burning, OBB. Open biomass burning.

Comparison of total annual values for 5 inventories: GEAA, TCNA2015, TCNA2019, CEDS AND EDGAR

In this Section we compare the total annual values for Argentina for the period 1995 through 2015 for several national and international databases. We include the present work GEAA-AEIv3.0M with the Third National Communication of Argentina to the IPCC (TCNA, 2015), which includes annual GHG emissions from 1990 through 2014 and the recent update TCNA 2019 (which spans from year 1990 to 2016). Annual total emissions of GHG and air quality pollutants are also compared to the estimations presented in the EDGAR HTAPv5.0 inventory (Crippa et al., 2016, 2020; EDGAR, 2019) and the Community Emissions Data System (CEDS) (Hoesly, et al. 2018; McDuffie et al, et al, 2020). We selected those sectors and pollutants that are present in at least 3 inventories. PM10, PM25 are only present in EDGAR (Table A10). These contaminants were discussed in the main text.

The supplementary file “comp_geaa_ceds_edgar_tcna.xlxs”, contains detailed information for each inventory and their comparison. It includes tables and figures, according to Table A6. Tables A7 through Table A10 retrieves some of the main results of the comparisons.

Table A6. Index of supplementary file comp_geaa_ceds_edgar_tcna.xlxs

Page 1	Summary table for all species and sectors
Page 2	Summary tables for CO2 all sectors and inventories
Page 3	Tables and Figures for CO2 all sectors and inventories
Page 4	Summary tables for CH4 all sectors and inventories
Page 5	Tables and Figures for CH4C all sectors and inventories
Page 6	Summary tables for N2O all sectors and inventories
Page 7	Tables and Figures for N2O all sectors and inventories
Page 8	Summary tables for CO all sectors and inventories
Page 9	Tables and Figures for CO all sectors and inventories
Page 10	Summary tables for NOX all sectors and inventories
Page 11	Tables and Figures for NOX all sectors and inventories
Page 12	Summary tables for NMVOC all sectors and inventories
Page 13	Tables and Figures for NMVOC all sectors and inventories
Page 14	Summary tables for SO2 all sectors and inventories
Page 15	Tables and Figures for SO2 all sectors and inventories
Page 16	Summary tables for NH3 all sectors and inventories
Page 17	Tables and Figures for NH3 all sectors and inventories
Page 18	Comparison of CO2 eq between GEAA and EDGAR
Page 19	Comparison of PM10 between GEAA and EDGAR
Page 20	Comparison of PM2.5 between GEAA and EDGAR

Table A7. Comparison of total annual values for 5 inventories: GEAA, TCNA2015, TCNA2019, CEDS and EDGAR, years 1995-2015

SECTOR	POLLUTANT	CO2		CH4		N2O		NOX		CO		NMVOC		SO2	
		mad	sd	mad	sd	mad	sd	mad	sd	mad	sd	mad	sd	mad	sd
1A1a	GEAA-TCNA2019	1.0%	1.2%	10.8%	16.0%	166.8%	132.3%	18.8%	11.4%	5.3%	4.5%	8.2%	9.1%	29.5%	9.0%
1A1a	GEAA-TCNA2015	1.5%	1.9%	7.3%	13.2%	178.9%	108.8%	12.1%	12.4%	5.9%	4.7%	7.9%	11.5%	31.8%	36.5%
1A1a	GEAA-CEDS	16.8%	6.9%	62.3%	35.1%			9.5%	13.7%	35.6%	8.2%	23.8%	11.3%	21.4%	27.4%
1A1a	GEAA-EDGAR	23.9%	5.4%	75.7%	33.2%	197.2%	74.0%	15.5%	7.3%	128.0%	8.3%	22.5%	20.3%	162.7%	35.9%
1A1a	GEAA-AVERAGE	8.6%	2.5%	28.5%	13.2%	136.9%	78.8%	10.2%	7.8%	32.3%	4.2%	10.1%	8.7%	23.1%	11.7%
1A1bc	GEAA-TCNA2019	17.2%	16.9%	10.3%	12.4%	9.8%	11.7%	15.9%	14.4%	15.7%	10.6%	9.3%	12.9%	28.7%	36.7%
1A1bc	GEAA-TCNA2015	9.7%	11.4%	5.8%	8.2%	14.5%	19.5%	11.9%	13.6%	11.5%	8.5%	6.8%	11.2%	24.6%	35.3%
1A1bc	GEAA-CEDS	22.1%	16.6%	95.4%	22.9%			12.8%	12.6%	12.8%	8.0%	6.9%	10.5%	29.0%	35.7%
1A1bc	GEAA-EDGAR	28.8%	10.6%	113.9%	15.6%	14.3%	12.1%	71.0%	12.5%	168.4%	10.8%	95.3%	35.3%	186.8%	34.6%
1A1bc	GEAA-AVERAGE	15.0%	10.0%	44.1%	10.7%	7.0%	7.9%	10.5%	9.1%	43.4%	6.7%	19.9%	11.2%	29.4%	20.6%
1A4abc	GEAA-TCNA2019	12.3%	12.2%	96.3%	17.6%	15.8%	18.4%	4.7%	9.4%	11.5%	10.7%	7.7%	11.5%	5.8%	8.5%
1A4abc	GEAA-TCNA2015	6.5%	3.5%	6.4%	3.0%	12.0%	16.6%	2.4%	6.2%	10.1%	8.3%	4.3%	7.4%	9.5%	12.3%
1A4abc	GEAA-CEDS	13.9%	5.4%	51.4%	28.3%			15.7%	8.1%	21.3%	9.0%	7.5%	9.8%	34.1%	12.6%
1A4abc	GEAA-EDGAR	13.4%	5.0%	83.8%	13.4%	14.4%	13.2%	97.4%	8.5%	58.6%	8.2%	44.9%	10.8%	138.4%	20.9%
1A4abc	GEAA-AVERAGE	9.5%	4.5%	49.3%	5.8%	9.6%	9.9%	17.6%	9.6%	6.4%	8.6%	10.9%	8.0%	36.0%	8.5%
1A2	GEAA-TCNA2019	18.9%	19.2%	85.4%	12.5%	83.9%	15.9%	3.9%	5.2%	10.3%	13.7%	5.0%	5.9%	4.2%	4.5%
1A2	GEAA-TCNA2015	26.4%	5.6%	7.2%	10.3%	6.9%	10.2%	2.5%	3.5%	5.7%	8.2%	3.5%	3.2%	4.5%	5.9%
1A2	GEAA-CEDS	12.8%	10.8%	15.2%	15.4%			4.2%	5.6%	6.0%	7.9%	4.0%	4.1%	3.8%	4.6%
1A2	GEAA-EDGAR	8.9%	12.2%	22.5%	23.3%	20.2%	22.4%	91.0%	13.9%	62.0%	19.9%	268.1%	43.1%	363.2%	34.3%
1A2	GEAA-AVERAGE	10.0%	11.0%	23.1%	6.4%	19.4%	4.4%	20.2%	4.7%	11.2%	6.1%	54.4%	6.4%	77.1%	5.1%
1A3bc	GEAA-TCNA2019	15.4%	6.8%	13.8%	5.0%	37.6%	13.1%	13.1%	7.6%	14.3%	16.3%	17.0%	16.2%	37.7%	15.7%
1A3bc	GEAA-TCNA2015	10.4%	8.7%	5.4%	5.7%	12.7%	13.6%	12.0%	8.7%	18.5%	20.0%	12.0%	16.8%	29.8%	16.6%
1A3bc	GEAA-CEDS	11.4%	4.2%	29.4%	27.1%			10.5%	7.9%	15.6%	15.7%	13.4%	15.5%	18.4%	21.4%
1A3bc	GEAA-EDGAR	14.2%	5.2%	3.4%	3.8%	84.0%	10.9%	9.9%	11.4%	15.5%	13.9%	10.1%	11.3%	44.6%	59.0%
1A3bc	GEAA-AVERAGE	10.7%	3.7%	5.8%	6.5%	29.8%	10.6%	7.6%	6.6%	7.1%	10.4%	9.9%	10.0%	19.3%	18.9%

Ref.: mad: Mean absolute differences from two inventories for years 1995-2015. sd.: Standard deviation of two inventories for years 1995-2015. GEAA-AVERAGE: Differences between GEAA profile and the average of all inventories profile. TCNA2015 (1995-2014); CEDS (1995-2014).

Table A7. **Comparison of total annual values for 5 inventories: GEAA, TCNA2015, TCNA2019, CEDS and EDGAR, years 1995-2015, cont.**

SECTOR	POLLUTANT	CO2		CH4		N2O		NOX		CO		NMVOC		SO2	
		mad	**sd**	**mad**	**sd**	**mad**	**sd**	**mad**	**sd**	**mad**	**sd**	**mad**	**sd**	**mad**	**sd**
1B1-2	GEAA-TCNA2019	19.2%	18.8%	6.6%	6.3%	16.9%	18.5%	26.9%	19.2%	2.2%	1.9%	56.6%	25.7%	12.7%	12.7%
1B1-2	GEAA-TCNA2015	16.9%	13.8%	2.2%	2.9%	14.1%	16.0%	19.5%	16.9%	2.0%	2.1%	46.9%	27.4%	11.7%	13.0%
1B1-2	GEAA-CEDS	87.1%	36.6%	134.5%	16.8%			23.2%	23.3%	222.4%	16.2%	22.9%	35.8%	12.5%	12.4%
1B1-2	GEAA-EDGAR	67.3%	53.2%	93.5%	22.9%	61.4%	25.3%	81.5%	65.2%	232.3%	22.2%	23.6%	25.6%	119.0%	16.0%
1B1-2	GEAA-AVERAGE	28.0%	22.3%	45.8%	7.2%	19.1%	12.8%	28.4%	22.2%	94.0%	2.1%	27.6%	21.6%	19.3%	16.0%
2A-H	GEAA-TCNA2019	3.9%	5.8%	202.3%	68.9%										
2A-H	GEAA-TCNA2015	74.3%	7.7%												
2A-H	GEAA-CEDS	45.7%	11.0%	30.9%	24.0%			73.9%	31.8%	41.4%	22.9%	17.8%	24.9%	196.5%	84.0%
2A-H	GEAA-EDGAR	154.9%	17.9%	34.5%	20.2%	54.6%	24.5%	83.4%	26.7%	6.9%	8.7%	154.9%	22.8%	16.1%	23.6%
2A-H	GEAA-AVERAGE	85.6%	1.7%	81.9%	2.2%	56.2%	42.1%	44.7%	36.6%	36.5%	17.1%	51.3%	15.7%	53.0%	36.6%

Ref.: mad: Mean absolute differences from two inventories for years 1995-2015. sd.: Standard deviation of two inventories for years 1995-2015. GEAA-AVERAGE: Differences between GEAA profile and the average of all inventories profile. TCNA2015 (1995-2014); CEDS (1995-2014).

Table A8. TCNA 2015 inventory: annual GHG emissions (CO2eq) for Argentina

	Thermal	Industry	Refineries	Oil and gas wells		Transport		
Year	power plants 1A	Own generation 1A2	Own consumption 1A1b	Fuel production 1A1c	Fugitive 1B2	road 1A3b	aviation 1A3a	RR+Nav 1A3c-d
1990	15,706.88	16,501.02	9,269.17	3,447.89	6,950.76	25,507.58	815.39	288.37
1991	19,136.44	16,768.11	10,901.54	4,892.44	7,408.33	29,461.89	733.85	330.67
1992	18,017.77	17,352.62	10,659.80	3,694.22	7,750.94	32,019.02	884.85	328.63
1993	18,015.32	16,740.70	10,289.13	3,474.92	8,309.04	32,737.29	948.27	344.06
1994	17,628.19	20,018.24	9,023.33	3,740.68	8,866.12	35,737.92	1,951.31	363.93
1995	18,166.10	19,449.54	9,102.76	4,080.22	9,564.93	36,945.09	1,514.86	338.02
1996	21,285.91	19,873.51	9,524.50	5,085.91	10,516.06	39,232.40	1,314.52	661.29
1997	19,134.48	21,989.22	11,828.70	6,910.75	11,067.24	41,133.64	1,250.39	610.85
1998	21,058.34	21,275.85	13,295.01	8,668.25	11,319.03	41,052.62	1,454.38	660.72
1999	25,361.58	19,713.04	11,113.80	6,853.12	11,751.22	40,063.34	1,625.74	525.97
2000	24,930.20	19,833.80	11,372.46	7,270.08	12,002.19	42,946.45	1,456.41	554.78
2001	18,588.23	19,715.11	11,363.35	7,466.04	12,324.69	39,290.91	1,221.01	537.51
2002	15,629.79	19,228.19	12,045.22	7,869.93	11,878.26	36,005.43	1,051.15	367.43
2003	19,294.77	21,491.67	12,629.12	8,040.06	12,695.49	36,180.78	993.08	413.59
2004	24,327.20	23,400.78	12,906.03	8,478.70	12,913.57	39,735.19	1,129.51	488.02
2005	26,647.44	22,467.38	12,080.06	8,123.95	12,774.80	41,411.57	1,154.19	528.46
2006	29,569.33	25,295.68	12,529.30	8,182.17	12,910.18	44,517.82	1,051.50	609.38
2007	34,148.97	27,087.89	13,781.99	8,977.27	12,887.55	47,496.82	1,113.14	418.64
2008	37,551.54	24,402.58	14,938.58	9,757.38	12,828.71	48,113.19	1,227.32	403.06
2009	34,574.48	23,556.89	15,451.87	10,271.38	12,134.80	48,806.22	1,265.50	403.63
2010	37,231.26	23,094.29	15,944.78	10,060.11	11,871.86	49,949.26	1,072.06	1,267.85
2011	42,719.05	24,455.59	15,401.95	9,978.06	11,785.01	51,675.56	1,029.39	1,672.33
2012	45,839.43	21,296.52	15,557.41	10,015.44	11,492.12	49,547.25	1,123.33	1,619.72
2013	45,387.65	21,873.91	15,876.59	10,002.27	11,146.36	52,200.96	1,425.95	1,264.30
2014	42,862.29	20,911.32	15,477.85	10,093.15	11,178.27	54,278.65	1,424.71	1,225.31

- All values are expressed in Gigagram (Gg)

Table A8. TCNA 2015 inventory: annual GHG emissions (CO2eq) for Argentina (cont)

Year	Residential R+C+G 1A4a-b	Industry process 2B-2C	Livestock 3A	Agriculture 3C	AWB 3C	Open Fire 4D	TOTAL CO2eq
1990	24,517.72	9,540.84	87,636.74	349.19	212.30	11,169.89	197,453.73
1991	24,720.74	8,378.34	88,594.13	463.43	186.93	11,271.16	207,248.02
1992	25,140.64	8,303.30	89,722.18	529.82	146.92	11,342.06	210,977.93
1993	26,223.75	8,912.40	90,799.21	1,282.76	134.26	11,443.96	214,834.65
1994	26,742.26	9,721.20	91,952.85	1,883.75	133.34	7,415.99	224,217.00
1995	27,148.36	9,328.91	89,756.38	2,105.59	137.81	7,669.22	223,710.37
1996	28,071.42	9,836.97	88,821.63	3,248.31	132.77	7,163.02	232,683.63
1997	28,671.85	10,826.80	87,426.72	3,150.95	133.77	5,200.40	237,382.10
1998	29,365.26	10,418.14	86,637.43	3,276.85	127.27	6,473.43	240,118.89
1999	30,813.07	10,039.09	87,100.90	3,902.55	123.16	5,087.66	242,294.36
2000	31,740.68	10,885.59	90,383.24	3,801.71	115.26	11,855.40	250,161.47
2001	32,065.79	10,576.84	92,194.44	4,001.92	107.31	16,481.77	242,123.13
2002	30,385.11	11,208.32	97,328.20	3,775.15	105.59	10,447.44	239,063.64
2003	31,773.64	12,198.88	103,077.81	4,886.99	106.57	11,451.45	255,793.80
2004	34,189.58	13,146.01	105,890.70	5,634.71	105.42	4,966.31	273,923.78
2005	37,339.45	14,491.42	106,500.77	5,336.95	110.22	5,947.75	280,932.86
2006	38,947.71	15,127.06	108,307.50	6,397.94	105.65	5,548.83	295,454.24
2007	43,609.29	15,764.48	108,912.19	7,209.60	98.65	4,828.97	312,602.88
2008	41,330.10	15,117.25	105,199.48	5,242.94	97.31	5,579.43	306,559.03
2009	40,661.47	12,766.63	100,433.97	4,887.72	98.70	6,485.02	295,095.93
2010	41,853.22	15,038.69	67,294.02	6,567.54	95.44	5,202.85	271,323.15
2011	42,581.64	16,209.16	68,960.22	7,136.69	91.84	4,398.59	283,778.11
2012	42,563.09	15,384.33	72,408.78	6,109.88	89.43	3,525.62	283,094.35
2013	44,474.53	16,378.75	74,069.66	6,540.19	86.17	3,609.97	290,780.21
2014	46,118.80	16,578.47	75,076.70	7,141.45	212.30	3,987.29	292,425.83

Table A9. Comparison total annual values GEAA and TCNA 2015 from 1995 through 2014

SECTOR	TPP	MFC	ROC	FPR	FUG	ROT	DOA	R+N	R+C
1995	-2.3%	30.5%	4.5%	16.8%	61.1%	11.3%	2.9%	20.6%	2.4%
1996	-2.2%	30.6%	3.1%	2.7%	55.5%	6.4%	4.0%	-40.0%	1.7%
1997	0.7%	30.9%	8.0%	-19.1%	60.6%	3.4%	3.8%	-29.1%	-3.3%
1998	-1.6%	40.4%	3.8%	-27.4%	65.0%	6.7%	3.2%	-30.0%	-6.5%
1999	-1.0%	42.1%	-0.9%	-7.1%	62.0%	4.9%	2.6%	-11.7%	-3.4%
2000	-0.4%	38.3%	-15.3%	-8.3%	55.1%	-4.9%	2.7%	-18.3%	-3.7%
2001	0.4%	34.3%	-12.2%	-7.2%	61.3%	-7.7%	1.0%	13.2%	-8.9%
2002	0.8%	43.1%	-2.5%	-9.4%	61.9%	-2.5%	1.0%	14.7%	-6.5%
2003	-7.3%	33.4%	4.4%	-7.2%	62.4%	-2.3%	1.0%	28.5%	-1.8%
2004	-1.3%	26.4%	-14.0%	-13.7%	60.3%	1.4%	1.0%	42.7%	11.6%
2005	0.7%	31.4%	-14.6%	-7.3%	58.5%	-6.2%	1.0%	39.9%	4.9%
2006	-3.2%	27.3%	-13.6%	-4.5%	59.8%	-5.9%	1.0%	38.0%	-3.8%
2007	-3.1%	22.0%	-18.6%	-4.2%	63.5%	-1.6%	1.0%	26.2%	-15.2%
2008	-0.4%	30.5%	-28.2%	-5.3%	61.2%	3.5%	1.0%	29.1%	-9.3%
2009	0.0%	29.8%	-17.2%	-5.1%	62.4%	-5.4%	1.0%	24.0%	2.1%
2010	-0.9%	36.0%	-24.4%	-7.7%	66.0%	-6.1%	27.5%	27.4%	-2.4%
2011	-2.9%	30.2%	-26.7%	-7.4%	64.6%	-4.8%	30.6%	22.4%	-11.2%
2012	-3.3%	29.9%	-21.5%	-6.9%	68.6%	0.0%	21.9%	19.5%	-6.9%
2013	-2.0%	25.1%	-24.0%	-7.0%	71.2%	-0.1%	0.1%	22.9%	0.8%
2014	-3.9%	13.8%	-22.3%	-4.3%	69.9%	-5.7%	3.8%	26.0%	-6.3%
Average	**-1.27%**	**31.3%**	**-0.79%**	**-6.97%**	**62.55%**	**-0.79%**	**5.59%**	**13.30%**	**-3.30%**

SECTOR	MOP	LF	AG	AWB	OBB	Total
1995	-7.5%	12.3%	-21.6%	-17.5%	-25.2%	12.0%
1996	3.7%	11.3%	-23.2%	-16.5%	-18.8%	10.6%
1997	-10.2%	8.2%	-19.0%	-7.3%	19.1%	10.2%
1998	2.5%	9.9%	-28.4%	7.9%	-17.3%	11.5%
1999	6.9%	14.1%	-12.4%	6.2%	6.4%	13.3%
2000	8.3%	7.9%	-8.2%	5.1%	-74.5%	5.6%
2001	10.0%	7.3%	-13.1%	13.3%	-26.5%	5.9%
2002	11.3%	-0.2%	-6.0%	11.1%	-17.1%	6.8%
2003	-0.4%	-5.7%	-12.6%	22.4%	-6.9%	3.9%
2004	4.5%	-0.8%	-11.7%	19.7%	42.1%	7.9%
2005	0.2%	-6.3%	-13.7%	20.2%	8.0%	3.5%
2006	4.6%	-7.6%	-15.6%	32.5%	24.7%	2.0%
2007	1.0%	-11.3%	-9.1%	37.0%	17.9%	-0.9%
2008	2.3%	-6.6%	-7.1%	37.7%	52.3%	3.6%
2009	1.9%	-11.6%	-2.3%	29.9%	7.7%	1.5%
2010	-0.2%	22.9%	0.7%	20.3%	-2.3%	10.9%
2011	-0.1%	21.8%	-15.4%	24.6%	9.6%	8.3%
2012	2.6%	14.4%	3.9%	22.8%	35.9%	8.7%
2013	0.2%	13.7%	-16.2%	10.1%	55.9%	8.9%
2014	1.0%	20.4%	-19.2%	3.3%	-9.7%	7.7%
Average	**2.13%**	**5.71%**	**-12.51%**	**14.1%**	**4.1%**	**7.1%**

- The percentage difference has been computed as (GEAA – TCNA) / GEAA * 100.%

Ref: TPP (1A1): Power Plants, MFC (1A2): Manufacturing own fuel consumption, ROC (1A1b): Refinery own consumption, FPR (1A1c): Fuel production, FUG (1B2): Fugitive, venting and flare, ROT (1A3b): Road transport, DOA(1A3a). Domestic Aviation, R+N (1A3c-d): Railroad and navigation, R+C (NG) (1A4a-b): Residential and commercial, MOP (2B-2C): Manufacturing own process, LF (3A): Livestock feeding, AG (3C): Agriculture, AWB: Agriculture waste burning, OBB (4D). Open biomass burning.

Table A10. Comparison total annual values GEAA and EDGAR from 1995 through 2015 for PM

1995-2015	**GEAA-EDGAR**	**PM10**		**PM2.5**	
Stat./ sector		Mean	Std. Dev.	Mean	Std. Dev.
TPP	1A1a	-274.37%	116.86%	-154.72%	71.43%
MFC	1A2	-166.03%	62.86%	-94.77%	41.98%
ROC/FPR	1A1bc	98.37%	0.99%	97.80%	2.10%
FUG	1B2	91.90%	8.61%	92.43%	8.05%
ROT	1A3b	-6.23%	9.69%	-18.01%	10.77%
DOA	1A3a	-428.53%	47.80%	-745.30%	76.89%
R+N	1A3c-d	-237.50%	202.99%	-231.82%	194.61%
R+C	1A4a-b	-36.21%	35.34%	13.67%	22.23%
MOP	2B-2C	-110.66%	47.89%	-67.56%	34.65%
LF	3A	67.19%	3.46%	89.16%	1.27%
AG	3C	76.79%	4.72%	80.46%	4.50%
OBB	4D	-91.27%	95.85%	-287.63%	248.76%
Total		**-40.15%**	**29.01%**	**-68.61%**	**32.50%**

- The percentage difference has been computed as (GEAA – EDGAR) / GEAA * 100.%

Ref: PP: Power Plants, MFC: Manufacturing own fuel consumption, ROC: Refinery own consumption, FPR: Fuel production, FUG: Fugitive, venting and flare, ROT: Road transport, DOA. Domestic Aviation, R+N: Railroad and navigation, R+C (NG): Residential and commercial (natural gas), R+C (OF) Residential and commercial (other fuels), FAG: Fuel use in agriculture, MOP: Manufacturing own process, LF: Livestock feeding, AG: Agriculture, AWB: Agriculture waste burning, OBB. Open biomass burning.

FIGURES

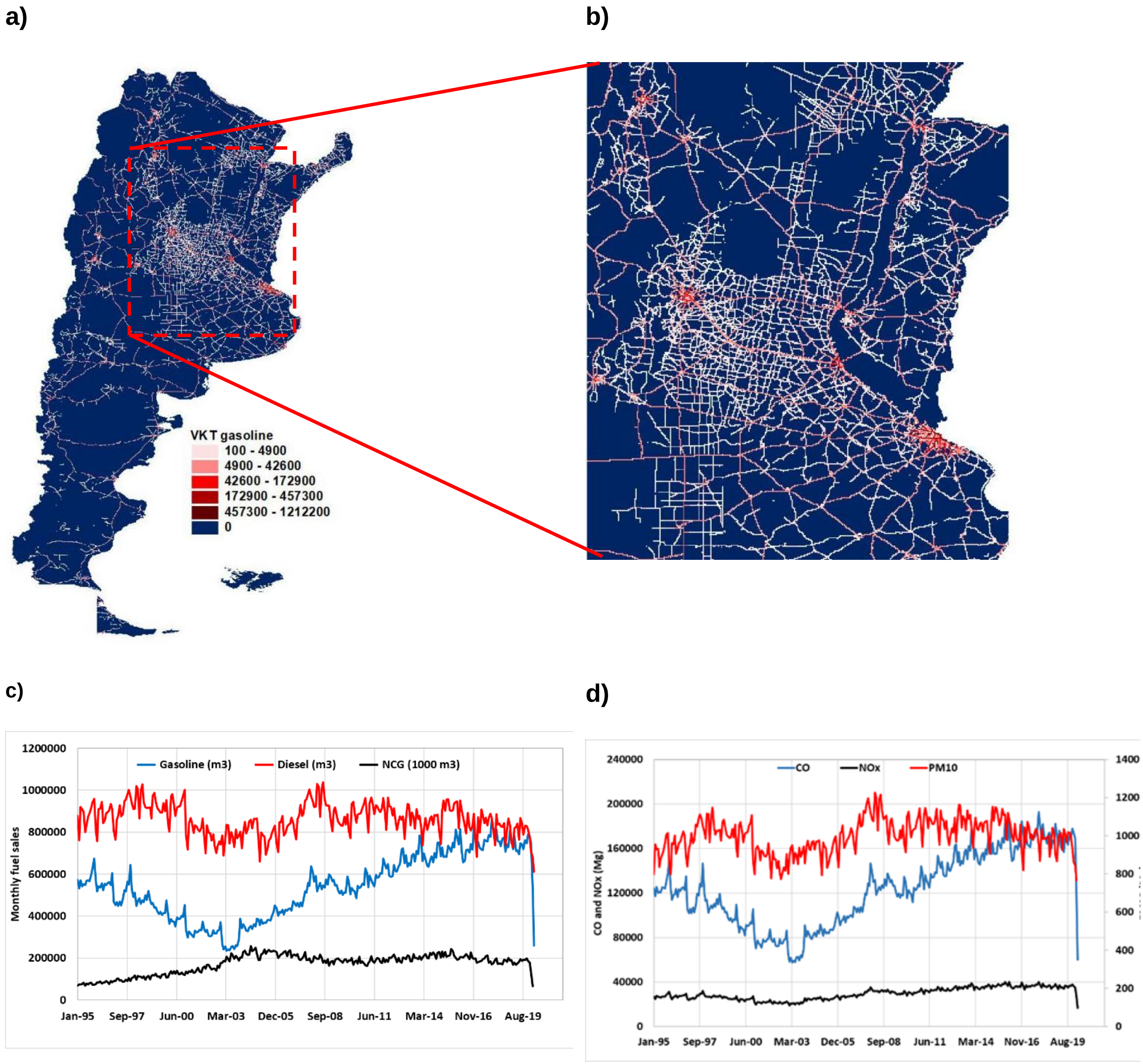

Figure A1. Calculated VKT for gasoline vehicles; b) Calculated VKT for gasoline vehicles at central area of Argentina. c) Monthly fuel sales: Gasoline blue line); Gas oil (red line); Compressed natural gas (CNG) (black line); d) Monthly emissions (in Mg) from road transport between January-1995 through April 2020; CO (blue line) and NOx (black line) left axis, PM10 (red line) right axis.

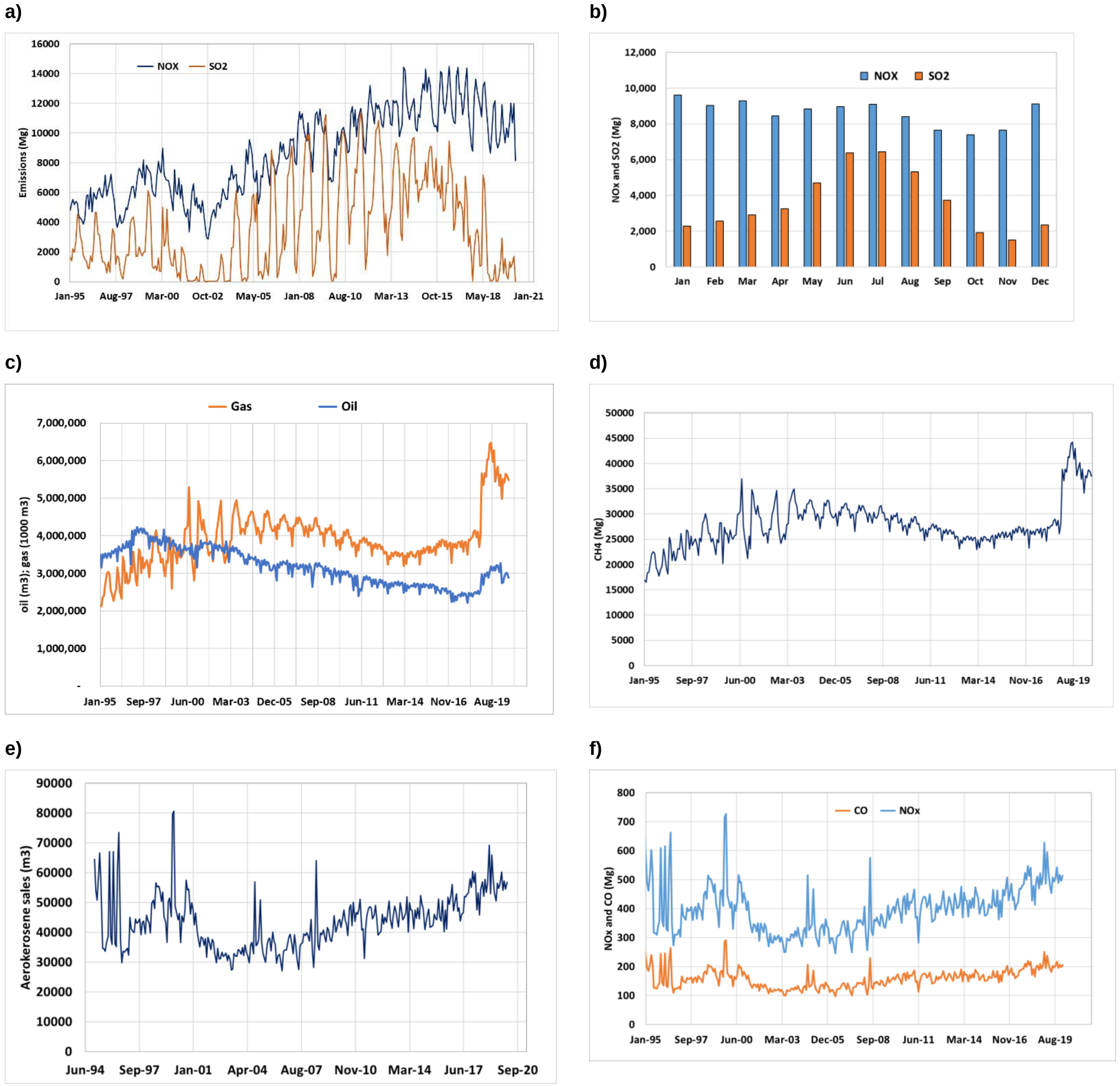

Figure A2. a) Monthly NOx and SO_2 emissions (Mg) from thermal power plants; b) average seasonal NOx and SO_2 emissions 1995-2019 (Mg) from thermal power plants; c) Monthly oil (m^3) and gas production (1000 m^3); d) Monthly methane emissions (Mg) from fuel production. e) Monthly aerokerosene sales at airports (m^3) for domestic and international flights; f) Monthly CO and NOx emissions from aviation.

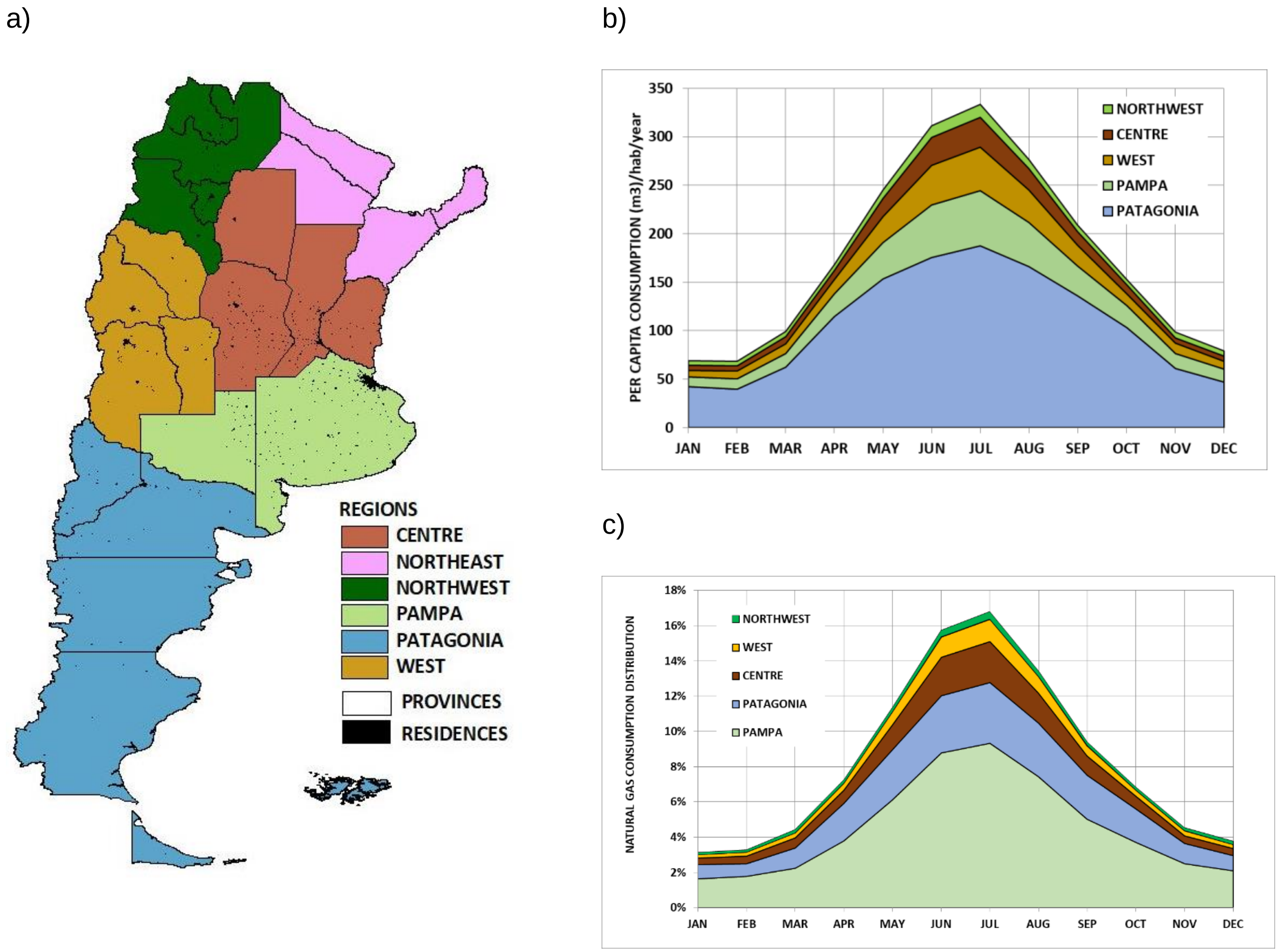

Figure A3. a) Regions and provinces with natural gas consumption at homes, b) Per capita annual natural gas consumptions, c) regional and seasonal distribution of natural gas consumptions per region (% of total annual consumption).

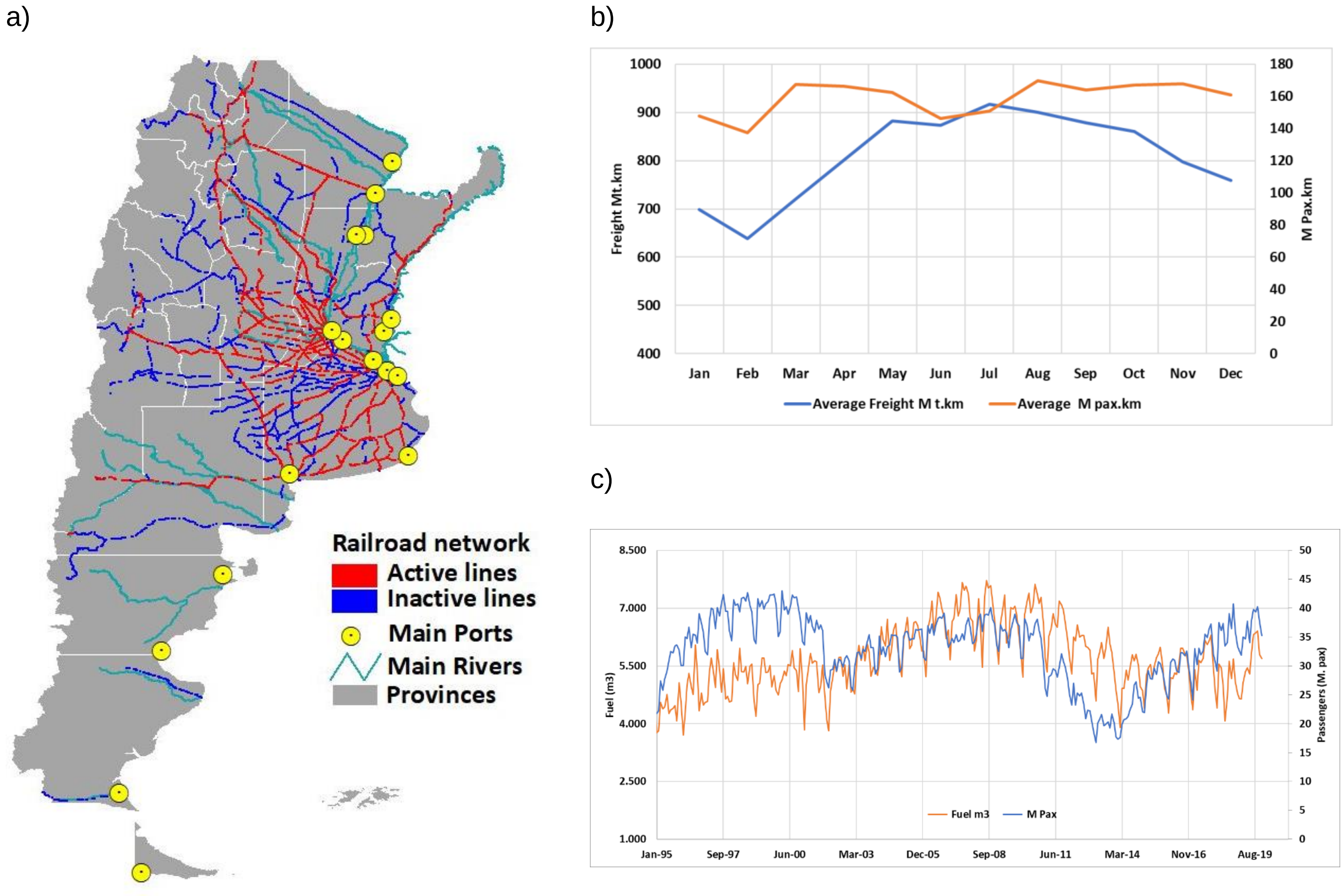

Figure A4. a) Railroad network and navigation ports, b) seasonal railroad freight (Million t. per km) and passenger activity (Million passengers per km), c) Monthly railroad activity and fuel consumption (m^3) and passenger activity (Million passengers per km).

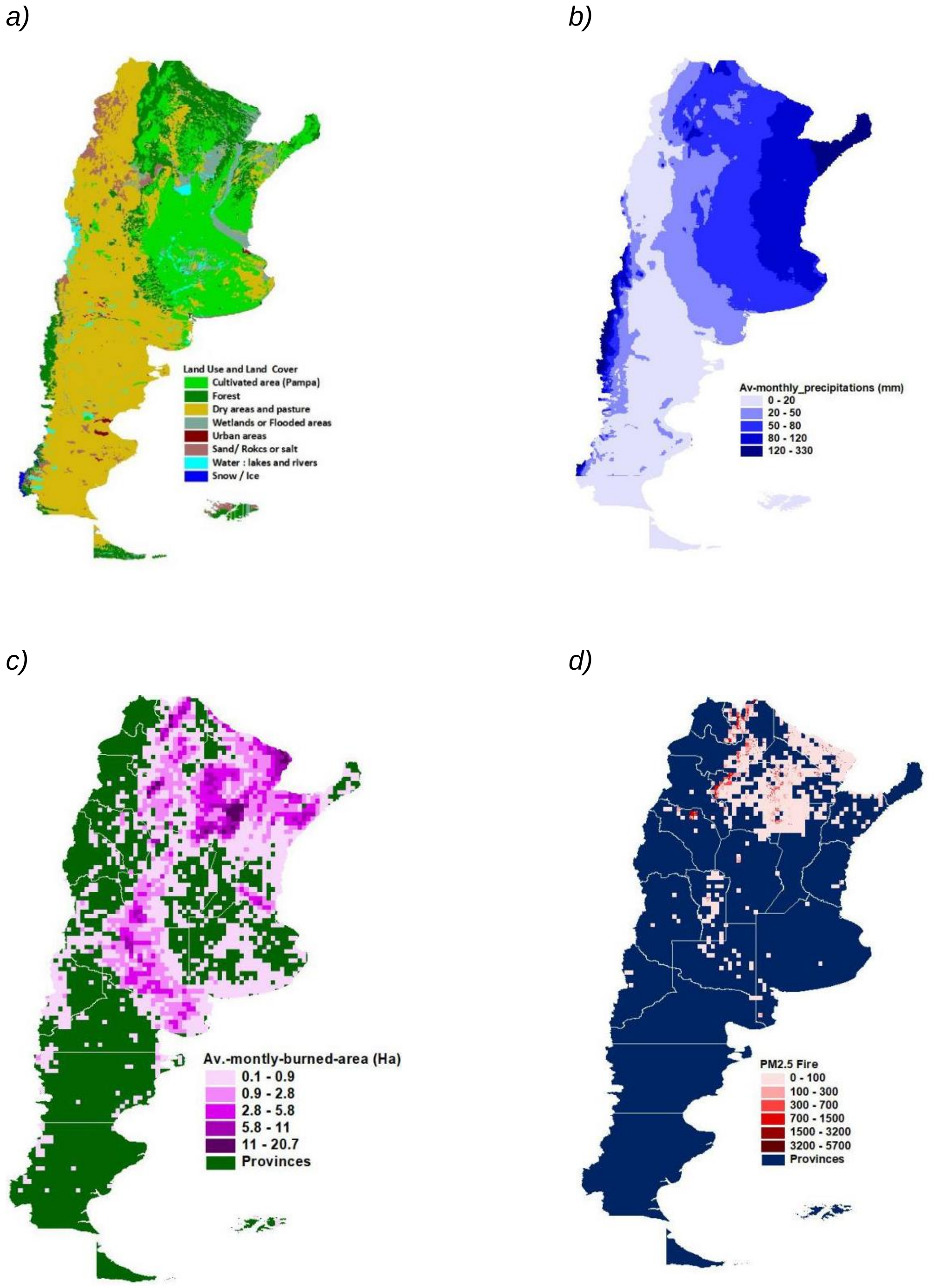

Figure A5. a) Land types for Argentina; b) monthly average precipitation (mm/cell); c) monthly average burned area (ha/cell); d) PM2.5 emissions in (kg/cell) for Sept. 2017.

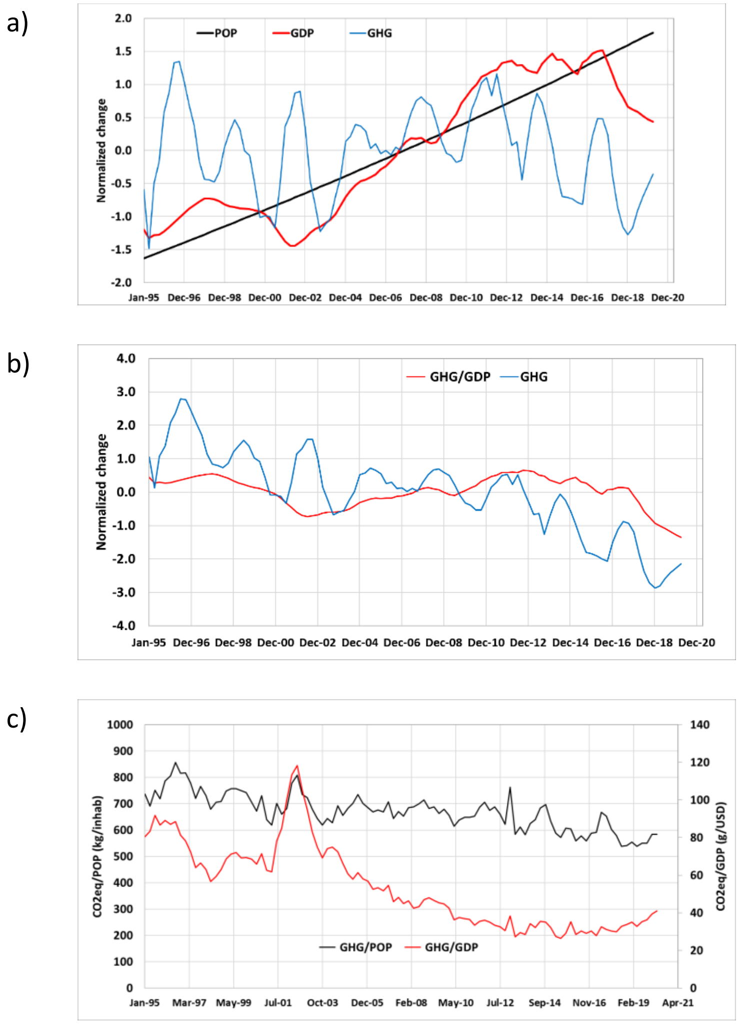

Figure A6. Normalized Change in a) Population, Gross Domestic Product and GHG in terms of CO2eq between 1995 and 2020; b) Population de-trended GDP and GHG. c) De-trended GHG/cap and GHG/GDP. The normalized function is obtained by subtracting the function mean value and divided by its standard deviation.

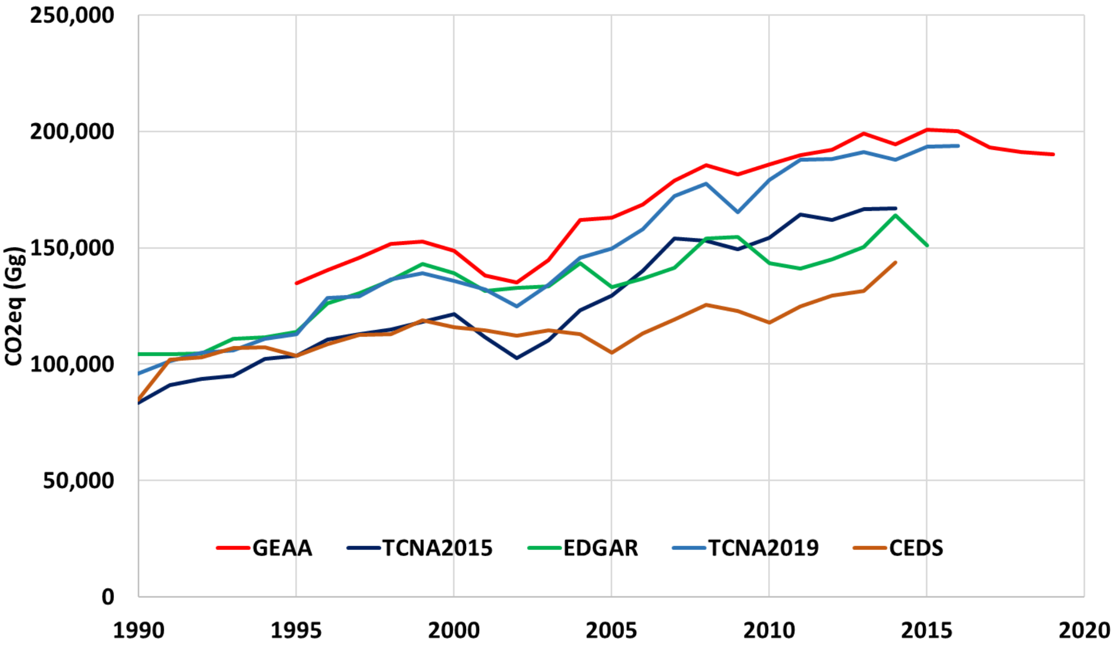

Figure A7. Comparison of annual GHG emissions for the energy sector between the different inventories considered in this work (see Table A7.).