

Appendix E

Fossil Fuel Emissions Estimates for North America

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E.1 Introduction

Anthropogenic carbon dioxide (CO₂) emissions from fossil fuel sources, while dominated by direct combustion for heating and energy production, can be defined to include a diverse set of industrial and agricultural processes. These include CO₂ production from cement manufacturing, gas and oil flaring, fugitive emissions, nonfuel oxidation of hydrocarbons, solid waste combustion, soil emissions, and geothermal power production. There are two general classes of global inventories: 1) those defined geographically at the nation-state scale and 2) those that generate estimates at the regular grid-cell scale (e.g., 10 km, 1 degree). The latter often are derived from the former via downscaling techniques but also may use “bottom-up” data such as emissions estimates and coordinates for power plants or airports. The available (nation-state or gridded) inventories, detailed in this appendix, cover these sectors in differing ways that cannot be reconciled directly to a common basis. In addition to their varying sectoral coverage, methodologi-

cal differences among the inventories can lead to additional sources of difference (Macknick 2014). Some of the inventories are based on fuel sales, and others on activities such as number of road miles driven. The *First State of the Carbon Cycle Report* (SOCCR1) “Part II Overview” chapter (Marland et al., 2007) provides a relevant discussion of different products and methodologies.

The varying sectoral definitions, resolutions, and methodological differences make direct comparisons challenging. For example, it is sometimes unclear whether country totals from different products include fuel usage for international marine and air transport (bunker fuels). However, the difficulties reconciling the definitions used by different products can be informative of practical uncertainty when used within atmospheric inversions or budget studies.

E.2 Emissions Estimates Considered

1. **U.S. Department of Energy Carbon Dioxide Information Analysis Center (CDIAC) Version 2017 (Boden et al., 2017) for 1751 to 2014.** Emissions included in this database are those due to fossil fuel consumption (e.g., oil, coal, and natural gas), gas flaring, and cement production. Emissions are listed by country and fuel type; bunker fuels are available separately but not included in the country totals.
2. **U.S. Energy Information Administration (EIA 2017) for 1980 to 2015.** CO₂ emissions from the consumption of energy, including emissions resulting from the consumption of petroleum, natural gas, and coal, as well as from natural gas flaring. Emissions are computed from consumption statistics for each fuel type

by applying emissions factors. Data include nonfuel use of petroleum such as asphalt for street paving and exclude emissions from geothermal power generation, cement production and other industrial processes, or municipal solid waste combustion.

3. **Fossil Fuel Data Assimilation System (FFDAS) Version 2 (Rayner et al., 2010; Asefi-Najafabady et al., 2014) for 1997 to 2012.** Emissions other than power production (which use a pointwise bottom-up dataset) are estimated using data assimilation to constrain a modified Kaya identity model. The two observed fields are space-based nightlights and population density. Country totals are then created by aggregating gridded emissions using Lloyd et al. (2016, 2017) gridded country boundaries based on the Database of Global Administrative Areas, called GADM. Version 2 of FFDAS produces estimates for electricity-production, industrial, residential, commercial, and transportation (other than domestic aviation and domestic waterborne) sectors and includes a posterior uncertainty as produced by the assimilation system and prior uncertainty estimates. These map closely to the Intergovernmental Panel on Climate Change (IPCC) 1A fuel consumption category (excepting 1A3a, civil aviation, and 1A3d, navigation).
4. **Emissions Database for Global Atmospheric Research (EDGAR) Version 4.3.2 (Janssens-Maenhout et al., 2017a) for 1970 to 2012.** Total used of all emissions listed in “CO2_excl_short-cycle_org_C” from version 4.3.2, which includes IPCC categories (see Table E.1, this page, for a partial list).
5. **Emissions Database for Global Atmospheric Research Fast Track (EDGAR FT) EDGAR Version 4.3.2 FT2016 (Janssens-Maenhout et al., 2017b; Olivier et al., 2017) for 1970 to 2016.** Sectoral coverage is described as “Transport, Other Industrial Combustion,

Table E.1. Intergovernmental Panel on Climate Change (IPCC) Source/Sink Codes and Categories

Code	Category
1A1a	Public electricity and heat production
1A1bc	Other energy industries
1A2	Manufacturing industries and construction
1A3a	Domestic aviation
1A3b	Road transportation
1A3c	Rail transportation
1A3d	Inland navigation
1A3e	Other transportation
1A4	Residential and other sectors
1B1	Fugitive emissions from solid fuels
1B2	Fugitive emissions from oil and natural gas
2A1	Cement production
2A2	Lime production
2A3	Limestone and dolomite use
2A4	Soda ash production and use
2A7	Production of other minerals
2B	Production of chemicals
2C	Production of metals
2G	Nonenergy use of lubricants/waxes (carbon dioxide)
3A	Solvent and other product use: paint
3B	Solvent and other product use: degrease
3C	Solvent and other product use: chemicals
3D	Solvent and other product use: other
4D4	Other direct soil emissions
6C	Waste incineration
7A	Fossil fuel fires

Buildings, Noncombustion, Power Industry.” For unknown reasons, EDGAR FT and the standard EDGAR emissions do not agree during their common years (i.e., 2012 and before).

Table E.2. North American Fossil Fuel Carbon Dioxide Emissions^a

Year	Canada	United States	Mexico	North America
2004	150.6	1569.7	120.3	1840.6
2005	152.0	1578.9	127.2	1858.1
2006	148.3	1553.7	130.7	1832.7
2007	151.2	1578.7	131.0	1860.9
2008	153.0	1531.0	134.5	1818.5
2009	146.4	1435.4	129.8	1711.5
2010	145.8	1471.4	126.6	1743.8
2011	146.5	1442.5	132.1	1721.1
2012	141.1	1396.1	135.3	1672.5
2013	141.0	1406.9	133.7	1681.7

Notes

a) Fossil fuel emissions in teragrams of carbon (Tg C) per year from the Carbon Dioxide Information Analysis Center (Boden et al., 2017; see Section E.2, p. 839).

Table E.3. Summary Statistics on North American Fossil Fuel Carbon Dioxide Emissions^a

Quantity	Canada	United States	Mexico	North America
2004–2013 CDIAC ^b mean	147.6	1496.4	130.1	1774.1
CDIAC interannual variability (standard error of mean)	1.3	23.3	1.4	23.8
Time mean (2004–2013) of the range of the five emissions inventories in Section E.2 divided by CDIAC (percent)	30.0	5.8	14.9	5.5

Notes

a) Emissions measured in teragrams of carbon (Tg C) per year.

b) CDIAC, Carbon Dioxide Information Analysis Center.

E.3 Time Series of North American Emissions, 2004 to 2013

The CDIAC time series was chosen to represent fossil fuel emissions from Canada, the United States, and Mexico from 2004 to 2013. In part, this is due to CDIAC's long historical coverage for all three countries and its clear definition of what goes into the country totals (e.g., Marland et al., 2007). Assigning an uncertainty to the CDIAC time series is a challenge. Andres et al. (2014) discuss various ways to characterize the uncertainty of the CDIAC product and suggest that a time-average uncertainty for the United States could be about 4% (2 standard deviations).

SOCCR1 (Marland et al., 2007; p. 59) suggests $\pm 5\%$ for developed countries, concordant with International Energy Agency (IEA 2005; Marland et al., 2007) intercomparisons for developed countries (also 5%). Here, the fractional range of the five inventories listed previously is used, averaged over time, to represent the uncertainty. Note that some of these differences are driven by categorical differences in what is included, or not included, in the global inventories. The CDIAC time series is recognized as different from the mean of the five inventories. Results are shown in Table E.2 and Table E.3, this page, and Figure E.1, p. 842.

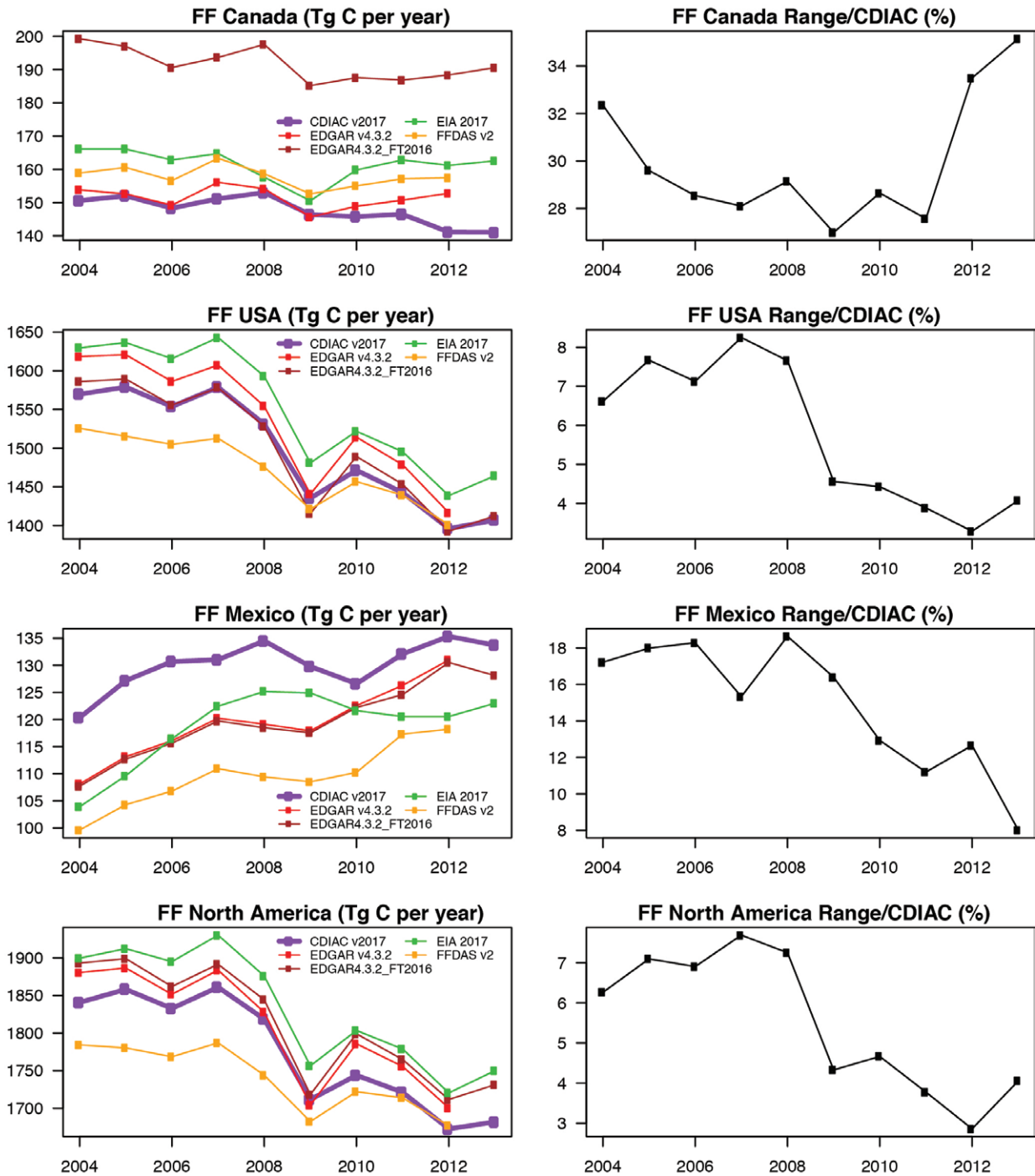


Figure E.1. Fossil Fuel Carbon Dioxide Emissions. (Left column) Data are from Canada, the United States, Mexico, and their total for North America, plotted between 2004 and 2013. (Right column) Graphs show the range of the estimates expressed as a percentage of the Carbon Dioxide Information Analysis Center (CDIAC) estimate for each year. Key: FF, fossil fuels; Tg C, teragrams of carbon; USA, United States (conterminous); EDGAR FT, Emissions Database for Global Atmospheric Research Fast Track; EIA, U.S. Energy Information Administration; FFDAS, Fossil Fuel Data Assimilation System.

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