

NACP: Urban Greenhouse Gases across the CO₂ Urban Synthesis and Analysis Network, V2

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Dataset Version: 2

Summary

This dataset provides hourly urban greenhouse gas measurements for cities in the CO₂ Urban Synthesis and Analysis (CO₂-USA) Data Synthesis Network for 2000 to 2019. Measurements include carbon dioxide (CO₂), methane (CH₄), and carbon monoxide (CO) concentrations measured at hourly intervals at multiple sites within the U.S. cities of Boston, Indianapolis, Los Angeles, Portland, Salt Lake City, San Francisco, and Washington DC/Baltimore, and Toronto, Canada.

These data expand the temporal range of greenhouse gas measurements provided in the first version of the dataset and include two additional cities.

There are 550 data files included in this dataset: 275 files in netCDF (*.nc) and 275 files in text (*.txt) formats. Also included are three companion files: scripts to load the data from netCDF files.

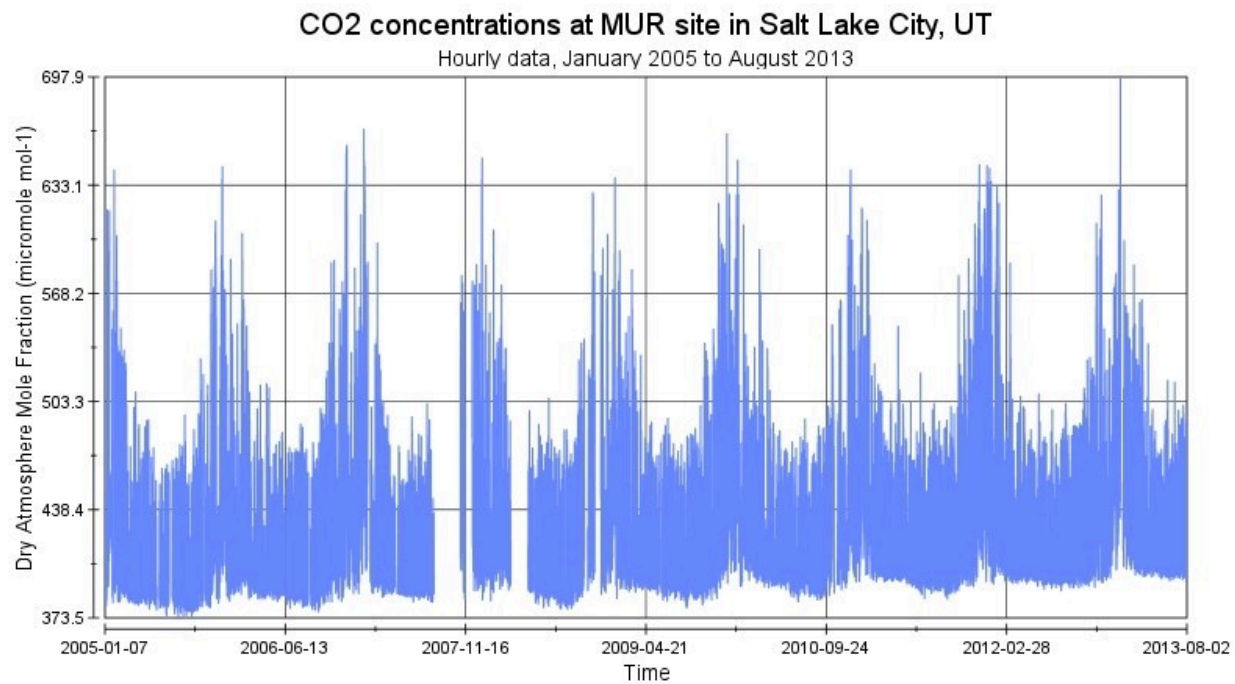


Figure 1. Carbon dioxide concentrations at the MUR site in Salt Lake City, Utah, show a pronounced seasonal pattern of higher CO₂ in the winter months. Source: salt_lake_city_co2_MUR_6m_1_hour_R0_2020-11-17.nc

Citation

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1. Dataset Overview

This dataset provides hourly urban greenhouse gas measurements for cities in the CO2 Urban Synthesis and Analysis (CO2-USA) Data Synthesis Network for 2000 to 2019. Measurements include carbon dioxide (CO₂), methane (CH₄), and carbon monoxide (CO) concentrations measured at hourly intervals at multiple sites within the U.S. cities of Boston, Indianapolis, Los Angeles, Portland, Salt Lake City, San Francisco, and Washington DC/Baltimore, and Toronto, Canada.

These data expand the temporal range of greenhouse gas measurements provided in the first version of the dataset and include two additional cities.

Project: North American Carbon Program

The North American Carbon Program (NACP) is a multidisciplinary research program designed to improve understanding of North America's carbon sources, sinks, and stocks. The central objective is to measure and understand the sources and sinks of Carbon Dioxide (CO₂), Methane (CH₄), and Carbon Monoxide (CO) in North America and adjacent oceans. The NACP is supported by a number of different federal agencies.

Related Publication

Mitchell, L.E., J.C. Lin, L.R. Hutrya, D.R. Bowling, R.C. Cohen, K.J. Davis, A. Guha, A. Karion, R.F. Keeling, J.J. Kim, N.L. Miles, C.E. Miller, S. Newman, S. Prinzivalli, A. Rice, S.J. Richardson, M. Sargent, K.R. Verhulst, F. Vogel, R.F. Weiss, J. Whetstone, and S.C. Wofsy. 2021. A multi-city urban atmospheric greenhouse gas measurement data synthesis. *Submitted* to Nature Scientific Data.

Related Datasets

Mitchell, L., J.C. Lin, L.R. Hutrya, M. Sargent, S.C. Wofsy, N.L. Miles, S.J. Richardson, K.R. Verhulst, R.M. Duren, A. Rice, R.C. Cohen, A. Shusterman, S. Newman, and A. Guha. 2019. NACP: Urban Greenhouse Gases across the CO2 Urban Synthesis and Analysis Network. ORNL DAAC, Oak Ridge, Tennessee, USA. <https://doi.org/10.3334/ORNLDAAAC/1743>

- Version 1 of this dataset. Now superseded and available only upon request.

Acknowledgments

This work was funded by the North American Carbon Program (NACP) under the NOAA Climate Program Office's Atmospheric Chemistry, Carbon Cycle, and Climate program (grant NA17OAR4310084).

2. Data Characteristics

Spatial Coverage: U.S.: Boston, Massachusetts; Indianapolis, Indiana; Los Angeles, California; Portland, Oregon; Salt Lake City, Utah; San Francisco, California; and Washington, D.C./Baltimore, Maryland; Canada: Toronto, Ontario.

Spatial Resolution: Point locations

Temporal Coverage: 2000-01-01 to 2019-12-31; sites operated for different time periods

Temporal Resolution: Hourly

Study Area: Latitude and longitude are given in decimal degrees.

Site	Westernmost Longitude	Easternmost Longitude	Northernmost Longitude	Southernmost Latitude
Full Extent	-123.0726	-70.4972	45.769	32.865

Data File Information

There are 550 data files included in this dataset: 275 files in netCDF (*.nc) and 275 files in text (*.txt) formats. A separate data file is available for each site and each of three chemical species. When available, there is a separate data file for the "background" measurements of each chemical species. The "background" time series comes from the published literature, and users are encouraged to read the relevant publication to understand how the time series was created and should be used. The text files are identical to the netCDF files, except that metadata are included as comments in the text files.

Also included are three companion files: scripts to load the data from netCDF files in Python (co2usa_load_netCDF.py), MatLab (co2usa_load_netCDF.m) and R (co2usa_load_netCDF.R) programming languages.

The data files are named <city>_<species>_<site>_<height>_<timeres>_R#_YYYY-MM-DD.ext, where

- <city> is the sampled city (Table 2),
- <species> is the chemical species ("ch4", "co", or "co2"),
- <site> is the abbreviation for the specific sampling location,
- <height> is the height of the measurement in meters,
- <timeres> is "1_hour", the temporal resolution,
 - for "background" files, this element is "background_1_hour" and there is no <site> or <height>,
- R# is the revision number,
- YYYY-MM-DD is the date of data file creation, and
- EXT is the file extension ("nc" or "txt").

Data File Details

Missing data are indicated by -9999.

Table 1. Bounding coordinates for each city. All latitudes and longitudes are given in decimal degrees. There were two sampling networks in San Francisco.

City	Number of Sites	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
Boston	8	-72.171	-70.498	43.709	41.350
Indianapolis	14	-86.740	-85.745	40.041	39.580
Los Angeles	12	-118.604	-117.257	34.609	32.867
Portland	3	-122.772	-122.603	45.769	45.497
Salt Lake City	7	-112.070	-111.837	40.794	40.481
San Francisco (BAAQMD)	4	-123.073	-121.600	38.319	37.079
San Francisco (BEACON)	65	-122.503	-121.493	38.568	37.617
Toronto	4	-80.558	-79.389	44.231	42.635
Washington/Baltimore	13	-77.530	-76.043	39.577	38.446

Table 2. Variable names and descriptions.

Variable	Units	Description
ch4 co co2	ch4, co: nmol mol ⁻¹ co2: μmol mol ⁻¹	average of the greenhouse gas (ch4, co, or co2) mole fraction measurements during each 1 hour time period
elevation	m	elevation above sea level at the station location
inlet_height	m	height of the sample inlet above ground level
lat	degrees north	latitude of sample location
lon	degrees east	longitude of sample location
n	count	number of measurements in the hour
std_dev	ch4, co: nmol mol ⁻¹ co2: μmol mol ⁻¹	standard deviation of the greenhouse gas mole fraction measurements in the hour
time	seconds	sample time in number of seconds since 1970-01-01 00:00:00 in UTC; time denotes the end of the 1-hour sample period
time_string	character	sample date/time in ISO 8601 format (UTC)
uncertainty	ch4, co: nmol mol ⁻¹ co2: μmol mol ⁻¹	measurement uncertainty determined by the data provider

The following information can also be found within each of the data files:

- Title of the dataset
- Summary
- Keywords
- References
- Date created
- Fair use data policy
- Data provider name, affiliation, contact information, and email
- Compilation originator name, affiliation, contact information, and email
- Temporal resolution of the data
- Data start and stop dates
- Instruments used in the data collection
- Calibration scale of the chemical species

3. Application and Derivation

Cities have emerged as leaders in U.S. efforts to reduce greenhouse gas (GHG) emissions, but the scientific knowledge to quantitatively track emissions and assess the efficacy of mitigation is lacking. As the global population increasingly resides in urban regions, scientific knowledge about *how much*, *where*, and *why* a particular city emits carbon becomes increasingly important. These cooperative data products are made freely available to the public and scientific community to advance the study of urban carbon cycling and associated air pollutants.

Urban GHG measurements are commonly compared to 'background' values, the mole fraction of GHG in the air flowing into the city. The difference between the observed and the background mole fractions measures how fluxes within the city altered the atmospheric composition of the urban airshed. Background values from the published literature are provided for Boston (CO₂, CH₄) Indianapolis (CO₂, CH₄, CO), and Salt Lake City (CO₂) in data files with 'background' in the filename. The background data are different from the other measurements in the dataset; refer to the *references* attribute in the file header for information about how the background dataset was constructed.

4. Quality Assessment

Several approaches were used to validate greenhouse gas measurements in each city. At a minimum, the research teams in every city calibrated their measurements with working calibration standards in the form of high-pressure gas cylinders that have known mole fractions and are tied to World Meteorological Organization calibration standards. Calibration frequency varied across cities and sites from hourly to daily intervals, with the timing being dependent on several factors that could impact instrument drift (e.g., whether or not the instrument is in a temperature-controlled setting).

The BEACO2N network in San Francisco used a modified approach with their low-cost sensor network design (Shusterman et al. 2016). That network had a dedicated site with typical calibrations and then used a whole-network calibration approach to correct for site-specific instrument drift. In addition to regular calibrations, some cities have conducted "round-robin" calibration tests where one or more calibration cylinders were used to test instruments at sites across a city, or between laboratories in different cities.

Measurement uncertainties, as determined by the data providers, are provided in the "uncertainty" variable of the data files.

5. Data Acquisition, Materials, and Methods

CO₂-USA Network

The CO₂ Urban Synthesis and Analysis (CO₂-USA) network was established to build a collaborative network of urban carbon cycle researchers to facilitate data sharing, create analysis frameworks to enable cross-city synthesis analyses, and enable new collaborations tackling objectives that are difficult to address in isolation (Fig. 2). One of the principal objectives of the CO₂-USA project was to develop a harmonized synthesis dataset of atmospheric dry-air mole fraction urban greenhouse gas (GHG) measurements that is readily usable, traceable to international calibration standards, and accessible to a large community: researchers, urban stakeholders, and the public. This collaborative network aims to exchange information on community standards and common measurements, facilitate data sharing, and create analysis frameworks and cross-city syntheses to catalyze a new generation of researchers and enable new collaborations tackling important objectives that are difficult to address in isolation.

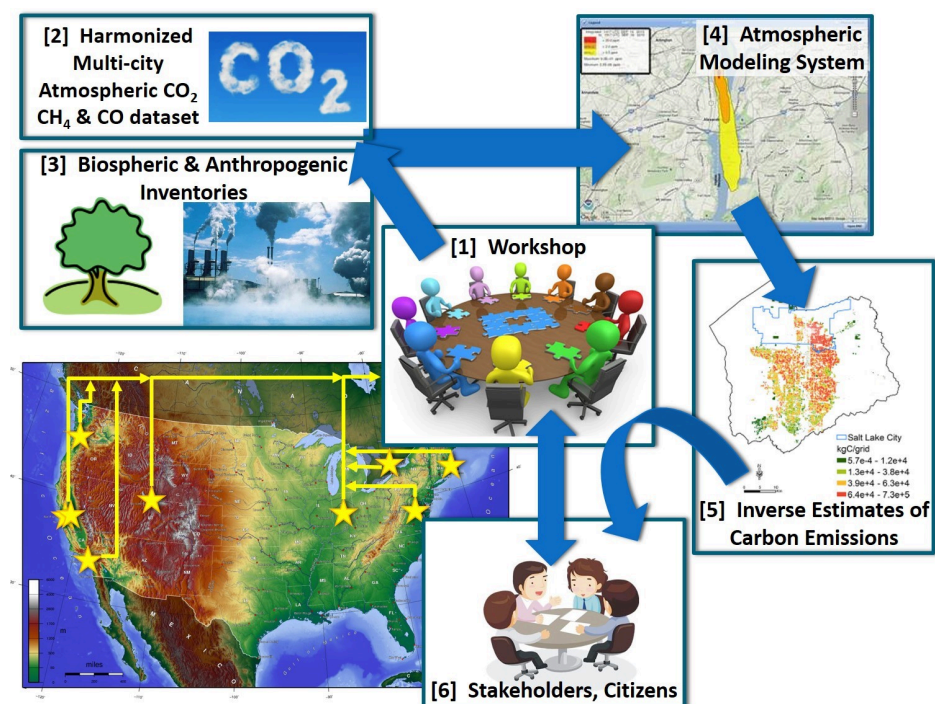


Figure 2. Schematic of the CO₂-USA project showing the eight cities currently in the CO₂-USA network (there are two measurement networks in San Francisco).

Specifically, the CO₂-USA synthesis effort seeks to:

- Quantify & understand similarities/differences in CO₂ and CH₄ fluxes across cities;
- Develop harmonized CO₂ and CH₄ mixing ratio datasets that are readily useable, traceable, and accessible by the research community and the public;
- Construct an atmospheric modeling system that is scalable and transferable between cities;
- Compare & understand similarities/differences between anthropogenic emission inventories;
- Improve estimates of biospheric fluxes across cities;
- Foster a community of urban carbon cycle researchers and generate collaborative studies;
- Engage stakeholders to link them with data, syntheses, and insights into urban emissions.

More information about the CO2-USA project can be found on [the project webpage](#).

Data Collection & Compilation

Urban GHG monitoring projects are underway in many cities, including Los Angeles (Feng et al., 2016; Verhulst et al., 2016), Indianapolis (Lauvaux et al., 2016), Salt Lake City (McKain et al., 2012; Bares et al., 2019), Paris (Staufer et al., 2016), Washington, DC (Mueller et al., 2017), and Boston (McKain et al., 2015; Sargent et al., 2018; Karion et al., 2020). These observational networks provide an opportunity for top-down assessments of GHG emissions using high-precision atmospheric measurements that are highly comparable both within the network and between networks and offer long-term stability.

Data providers collected GHG dry-air mole fraction measurements including CO₂, CH₄, and CO using a variety of instrumentation, experimental setups, and site configurations. All measurements were made using spectroscopy-based instrumentation. Each of these instruments also measures water vapor to correct for the spectroscopic absorption and dilution of water vapor. Each reports the mole fraction of the target GHG species on a dry-air mole fraction basis. Experimental setups varied across cities and sites within cities, but most sites had a gas analyzer, calibration tanks containing reference gas mixtures, a data logger, and tubing to an external inlet.

The temporal frequency of the native measurements varied across cities, so data providers calculated and reported hourly averages using the "floored hour." For example, data from 08:00 to 08:59 were averaged and reported as the hour of 08:00 UTC. In addition, the standard deviation and number of measurements within the hour were reported where possible.

Code used to compile and work with this data product is maintained on the GitHub repository https://github.com/uataq/co2usa_data_synthesis. The repository also includes scripts to load the data from the netCDF files have been written in the Python, R and Matlab programming languages (which have been included as companion files to this dataset). A [Python script](#) for loading the data and making plots is available.

6. References

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7. Dataset Revisions

Version	Dataset Title and Description	Published
1	NACP: Urban Greenhouse Gases across the CO2 Urban Synthesis and Analysis Network This initial version includes data from 2000-01-01 to 2019-05-14 for sites in six cities. This version is superseded and available only by request.	2019-10-31
2	NACP: Urban Greenhouse Gases across the CO2 Urban Synthesis and Analysis Network, V2 This version expands the temporal range of measurements to 2019-12-31 and adds data for two additional cities.	2021-11-30

