Ground-based Observations of XCO2, XCH4, and XCO, Fairbanks, AK, 2016-2019

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Summary

This dataset provides ground-based column-averaged dry mole fractions (DMFs) of CO2 (xco2), CO (xco), CH4 (xch4), and N2O (xn2o) to supplement satellite-based observations of carbon dynamics of northern boreal ecosystems. Measurements were conducted with Bruker EM27/SUN Fourier transform spectrometers (FTS) at the University of Alaska Fairbanks (UAF) and two sites on the edges of the Tanana Flats wetlands to the south from 2016-08-04 to 2019-10-31. Single detectors were used during the first campaign at UAF in 2017, then two instruments were updated to dual detectors in early 2018 to allow retrieval of xco and xn2o. Data from additional FTS instruments, operated by Los Alamos National Laboratories (LANL), Karlsruhe Institute of Technology (KIT), and Jet Propulsion Laboratory (JPL), employed in these campaigns are included.

Observations in Fairbanks, Alaska, began in August to October 2016 using two single detectors EM27/SUN FTS, owned by LANL and KIT. In 2017, continuous observations were collected during March through October at UAF using the LANL EM27/SUN with a single detector. In 2018–2019, continuous observations were collected from April to October at UAF using the EM27/SUN owned and maintained by KIT as a part of the Collaborative Carbon Column Observing Network. In May–June 2018, three FTS instruments, including the KIT EM27 at UAF, the LANL EM27 with an upgrade to include a dual detector, and an EM27/SUN FTS owned by Caltech and the Jet Propulsion Laboratory (JPL) with a single detector were deployed.

There are five data files in comma-separated text (*.csv) format.

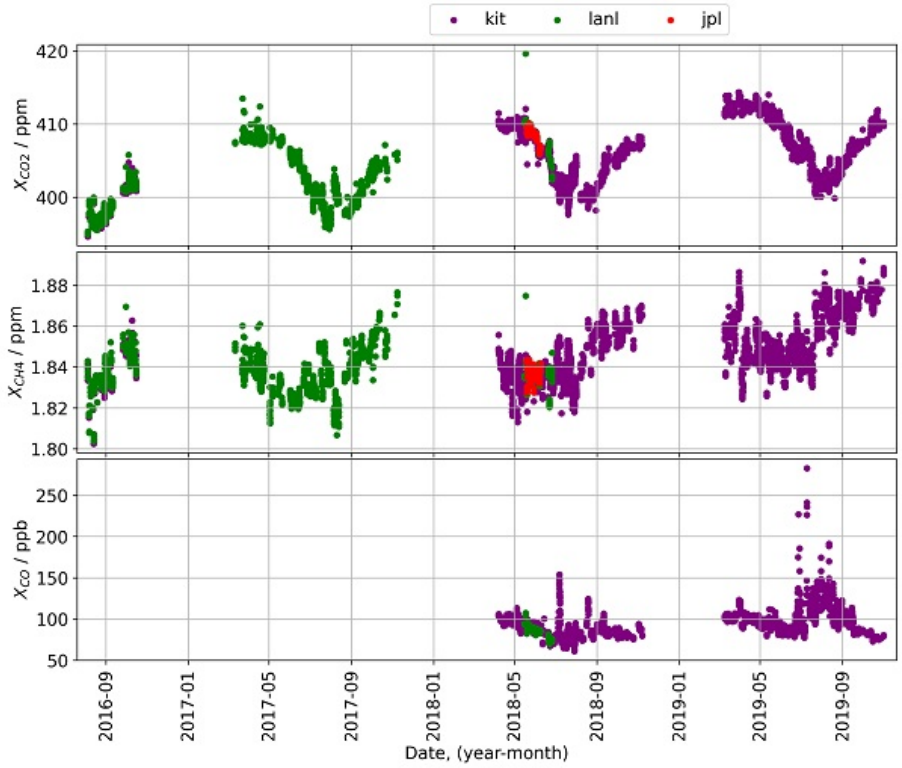

Figure 1. Time-series of ground-based column-averaged dry air mole fractions of CO2 (xco2), CH4 (xch4), and CO (xco). Plotted data represent hourly averages derived from all archived files.

Citation

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1. Dataset Overview

This dataset provides ground-based column-averaged dry mole fractions (DMFs) of CO_2 (*xco2*), CO (*xco*), CH_4 (*xch4*), and N_2O (*xn2o*) to supplement satellite-based observations of carbon dynamics of northern boreal ecosystems. Measurements were conducted with Bruker EM27/SUN Fourier transform spectrometers (FTS) at the University of Alaska Fairbanks (UAF) and two sites on the edges of the Tanana Flats wetlands to the south from 2016-08-04 to 2019-10-31. Single detectors were used during the first campaign at UAF in 2017, then two instruments were updated to dual detectors in early 2018 to allow retrieval of *xco* and *xn2o*. Data from additional FTS instruments, operated by Los Alamos National Laboratories (LANL), Karlsruhe Institute of Technology (KIT), and Jet Propulsion Laboratory (JPL), employed in these campaigns are included.

Observations in Fairbanks, Alaska, began in August to October 2016 using two single detectors EM27/SUN FTS, owned by LANL and KIT. In 2017, continuous observations were collected during March through October at UAF using the LANL EM27/SUN with a single detector. In 2018–2019, continuous observations were collected from April to October at UAF using the EM27/SUN owned and maintained by KIT as a part of the Collaborative Carbon Column Observing Network. In May–June 2018, three FTS instruments, including the KIT EM27 at UAF, the LANL EM27 with an upgrade to include a dual detector, and an EM27/SUN FTS owned by Caltech and the Jet Propulsion Laboratory (JPL) with a single detector were deployed.

Related Publication

Jacobs, N., W.R. Simpson, D. Wunch, C.W. O'Dell, G.B. Osterman, F. Hase, T. Blumenstock, Q. Tu, M. Frey, M.K. Dubey, H.A. Parker, R. Kivi, and P. Heikkinen. 2020. Quality controls, bias, and seasonality of CO_2 columns in the boreal forest with Orbiting Carbon Observatory-2, Total Carbon Column Observing Network, and EM27/SUN measurements. Atmospheric Measurement Techniques 13:5033–5063. https://doi.org/10.5194/amt-13-5033-2020

Acknowledgments

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2. Data Characteristics

Spatial Coverage: Fairbanks areas, Alaska, USA

Spatial Resolution: Multiple points

Temporal Coverage: 2016-08-04 to 2019-10-31

Temporal Resolution: 15 seconds, variable

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

Sites	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
Fairbanks, Alaska, and surrounding area	-149.09	-147.859	65.118	64.859

Data File Information

There are five data files in comma-separated text (*.csv) format included in this dataset. The files are named <owner>_<instrument>_<dates>.csv, where

<owner> = the instrument owner, Los Alamos National Laboratories (*lanl*), Karlsruhe Institute of Technology (*kit*), and Jet Propulsion Laboratory (*jpl*)
<instrument> = *single* or *dual* instruments deployed
<dates> = year (YYYY) and month (MM) of data collection; multiple dates may be included in the file name

Table 1. File names and descriptions.

File Name	Description
kit_single_201608_201610.csv	Column-averaged dry mole fractions of CO_2 (*xco2*) and CH_4 (*xch4*) collected at Fairbanks and on the edges of the Tanana Flats wetlands to the south, starting in August 2016 using the Bruker EM27/SUN FTS. In this dataset, *xco2* and *xch4* were retrieved using GGG2014 coupled with the EM27/SUN GGG interferogram processing suite.
kit_dual_201804_201910.csv	Column-averaged dry mole fractions of CO_2 (*xco2*), CH_4 (*xch4*), and CO (*xco*) collected April 2018 to October 2019 at Fairbanks with an upgrade to include a dual detector for retrieving *xco*.
lanl_single_201608-201610_201703-201711.csv	Column-averaged dry mole fractions of CO_2 (*xco2*) and CH4 (*xch4*) collected August to October 2016 at Fairbanks using two EM27/SUN FTS, owned by LANL and KIT, each with a single detector for retrieving *xco2* and *xch4*.
lanl_dual_201805-201806.csv	Column-averaged dry mole fractions of CO_2 (*xco2*), CO (*xch4*), and CH_4 (*xco*) collected at Fairbanks during May and June 2018 using the EM27/SUN FTS, including the KIT EM27 at Fairbanks, and the LANL EM27 with an upgrade to include a dual detector.
jpl_single_201805-201806.csv	Column-averaged dry mole fractions of CO_2 (*xco2*) and CH_4 (*xch4*) collected May to June 2018 using an EM27/SUN FTS owned by Caltech and JPL with a single detector for retrieving *xco2* and *xch4*.

Table 2. Variables in the data files. **Note**: N_2O, H_2O, and HDO are provided but are not the primary data products and have undergone only very limited vetting to verify their precision and accuracy.

Variable	Units	Description

spectrum		Spectrum
date	YYYY-MM-DD	Date of observation
year	YYYY	Year of observation
day	DDD	Day of year of observation
hour		Fractional UT Hour
latitude	Decimal degrees	Latitude
longitude	Decimal degrees	Longitude
zobs	km	Geometric altitude
zmin	km	Pressure altitude
asza	degrees	Solar Zenith Angle
azim	degrees	Solar Azimuth Angle
osds	ppm	Observer-Sun Doppler Stretch
opd	cm	Optical path difference
fovi	rad	Internal Field of View
graw	cm-1	Spectral Point Spacing
internal_temp	Degrees C	Internal temperature
internal_pressure	mbar	Internal pressure
external_temp	C	External temperature
external_pressure	hPa	External pressure
external_humidity	%	External humidity
sia	AU	Solar Intensity (Average) was -2.0 9999
fvsi	%	Fractional Variation in Solar Intensity
xair	ppm	Calculated as: 0.2095*Column air/column dry air
xair_error	ppm	One-sigma precision
xh2o	ppm	Column_h2o/column dry air
xh2o_error	ppm	One-sigma precision
xhdo	ppm	Calculated as: 0.2095*Column_h2o/column dry air
xhdo_error	ppm	One-sigma precision
xco	ppb	Calculated as: 0.2095*Column hdo/column dry air (not provided in single detector files)
xco_error	ppb	One-sigma precision
xn2o	ppb	Calculated as: 0.2095*Column co/column dry air
xn2o_error	ppb	One-sigma precision
xch4	ppm	Calculated as: 0.2095*Column ch4/column dry air
xch4_error	ppm	One-sigma precision
xco2	ppm	Calculated as: 0.2095*Column co2/column dry air
xco2_error	ppm	One-sigma precision

Table 3. Air mass correction factors.

Retrieved Gas	**Airmass-Dependent Correction Factors**
xco2	-0.0068 0.0050
xch4	0.0053 0.0080
xn2o	0.0039 0.0100
xco	-0.0483 0.1000
xh2o	-0.0000 0.0000
Retrieved Gas	**Airmass-Independent/In-Situ Correction Factors**
xco2	0.9898 0.0010
xch4	0.9765 0.0020

xn2o	0.9638 0.0100
xco	1.0672 0.0200
xh2o	1.0183 0.0100

3. Application and Derivation

Regional-scale observations of atmospheric CO_2, CH_4, and CO are necessary for closing gaps in the carbon budget across the ABoVE domain and on continental and global scales. Ground-based column-averaged dry air mole fractions of these greenhouse gases complement aircraft and tall tower observations, and they can be used for satellite and model validation (Jacobs et al., 2020).

4. Quality Assessment

The dry column-average CO_2 DMF (column CO_2/column O_2) can be affected by three main sources of error.

1. Measurement precision: The standard deviation of column CO_2/column O_2 during a one-hour period was <0.1% under clear sky conditions and approximately 0.2% under partly cloudy conditions. The repeatability of the measurement was not a significant source of error.
2. Spectroscopic errors: The absolute accuracy of the CO_2, CH_4, and CO retrievals were calibrated by comparison to integrated aircraft profiles resulting in the previously reported Airmass-Independent Correction Factors. The standard deviation of the fitting residuals was approximately 0.1%. The aircraft profiles were performed with the sun at air mass 1.1 to 2.0 (SZA 25 to 60 degrees) and the column-averaged CO_2 DMF was calibrated for these values. However, additional systematic errors may be present at higher air masses due to errors in spectroscopy.
3. Systematic instrumental changes over time: These were mitigated by calibrations and instrument maintenance performed by Frank Hase and colleagues at the Karlsruhe Institute of Technology (KIT) every one to two years.

Refer to Jacobs et al. (2020) for details.

5. Data Acquisition, Materials, and Methods

Ground-based measurements of column-averaged dry mole fractions (DMF) of CO_2 (*xco2*), CO (*xco*), CH_4 (*xch4*), and N_2O (*xn2o*) were collected in the vicinity of Fairbanks, Alaska, USA. Measurement sites included the University of Alaska Fairbanks (UAF) and on the edges of the Tanana Flats wetlands south of UAF using Bruker EM27/SUN Fourier transform spectrometers (FTS),

- In August–October 2016, observations in Fairbanks began using two EM27/SUN FTS, owned by Los Alamos National Laboratories (LANL) and Karlsruhe Institute of Technology (KIT), each with a single detector for retrieving *xco2* and *xch4*.
- In March - October 2017, continuous observations were collected at UAF using the LANL EM27/SUN with a single detector.
- In 2018 and 2019, continuous observations were collected during April through October at UAF using the EM27/SUN owned by KIT as a part of the Collaborative Carbon Column Observing Network (COCCON; https://www.imk-asf.kit.edu/english/COCCON.php).
- In May–June 2018, three EM27/SUN FTS, including the KIT EM27 at UAF, the LANL EM27, and an EM27/SUN FTS owned by the Jet Propulsion Laboratory (JPL) with a single detector were deployed.

The Bruker EM27/SUN FTS was developed by KIT in collaboration with Bruker Optics (Gisi et al., 2012; Hase et al., 2016) to be a compact, mobile solar-viewing FTS designed for field deployment and has a resolution of 0.5 cm^{-1}. Columns of gases were retrieved for multiple bands or micro-windows and the average of those individual band retrievals were calculated to obtain the dry mole fractions (DMF) of CO_2, CO, CH_4, and N_2O.

Regular characterization of the Instrument Line Shape (ILS) for each EM27/SUN spectrometer was used to monitor instrument performance over time. Retrieval methods for EM27/SUN retrievals of *xco2* were used by implementing the GGG2014 retrieval algorithm (Wunch et al., 2015) coupled with the EM27/SUN GGG interferogram processing suite (EGI) (Hedelius and Wennberg, 2017). N_2O, H_2O, and HDO are included in this dataset but are not the primary data products; these measurements have undergone only very limited vetting to verify their precision and accuracy.

Quality controls applied to EM27/SUN retrievals follow those outlined by Hedelius et al. (2016) including an upper bound on sun zenith angle (*sza*) at 82 degrees and an upper bound on CO_2 retrieval error at 5 ppm. In addition, a lower bound is set on the average solar intensity (*sia*) in EM27/SUN retrievals at 90 AU.

Refer to Jacobs et al. (2020) for details.

6. Data Access

These data are available through the Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

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Contact for Data Center Access Information:

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