CARVE: L2 Atmospheric CO2, CO and CH4 Concentrations, Harvard CRDS, Alaska, 2012-2014

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Documentation Revision Date: 2016-07-26

Data Set Version: V1

Summary

This data set provides atmospheric carbon dioxide (CO2), methane (CH4), and carbon monoxide (CO) concentrations from airborne campaigns over the Alaskan and Canadian arctic for the Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE). The data were collected in situ using a four-species cavity ring-down spectrometer system (CRDS; Picarro Inc.) provided by Harvard University and are presented at 5-second intervals throughout each flight. The Harvard CRDS instrument only collected data in 2012-2014; no Harvard data are available for year 2015. Aircraft latitude, longitude, and altitude are also provided. CARVE flight campaigns took place from 2012 to 2015 between the months of March and November to enable investigation of both seasonal and inter-annual variability in atmospheric gas content. The measurements included in this data set are crucial for understanding changes in Arctic carbon cycling and the potential threats posed by thawing of Arctic permafrost.

These measurements are one part of an innovative multi-instrument remote sensing payload flown for the CARVE campaign.

There are 121 data files in netCDF (*.nc) format, one for each CARVE campaign flight in 2012-2014, with this data set.

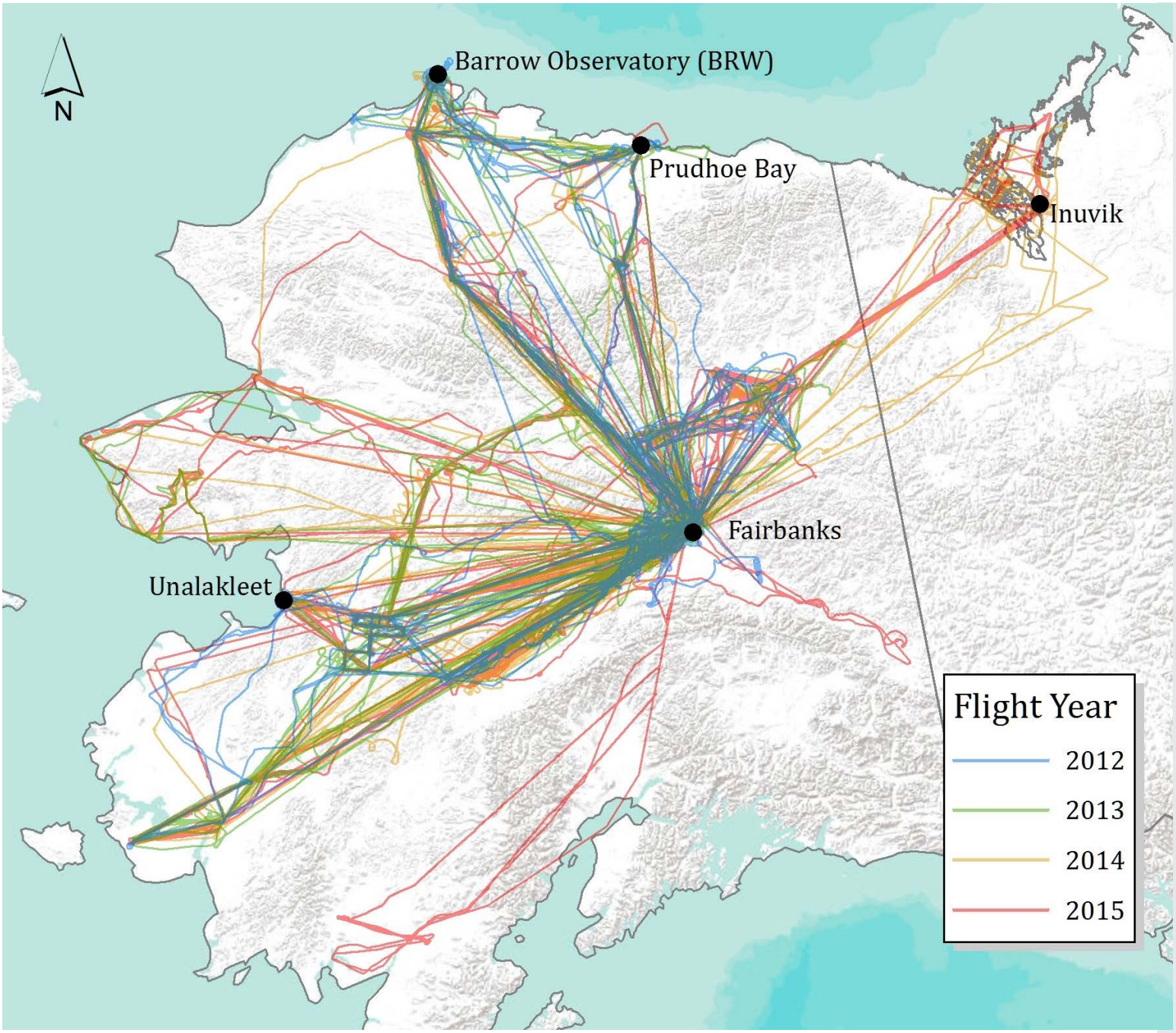

Figure 1. CARVE flights during 2012-2015 delivered atmospheric gas measurements over continuous and discontinuous permafrost regimes.

Citation

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1. Data Set Overview

Project: Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE)

The Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE) is a NASA Earth Ventures (EV-1) investigation designed to quantify correlations between atmospheric and surface state variables for Alaskan terrestrial ecosystems through intensive seasonal aircraft campaigns, ground-based observations, and analysis sustained over a 5-year mission. CARVE collected detailed measurements of greenhouse gases on local to regional scales in the Alaskan Arctic and demonstrated new remote sensing and improved modeling capabilities to quantify Arctic carbon fluxes and carbon cycle-climate processes. CARVE science fills a critical gap in Earth science knowledge and satisfies high priority objectives across NASA's Carbon Cycle and Ecosystems, Atmospheric Composition, and Climate Variability & Change focus areas as well as the Air Quality and Ecosystems elements of the Applied Sciences program. CARVE data also complements and enhances the science return from current NASA and non-NASA sensors.

Related Data:

Airborne CARVE greenhouse gas concentrations merged from both the NOAA and Harvard Picarro CRDS instruments are also available: CARVE: L2 Merged Atmospheric CO2, CO, O3 and CH4 Concentrations, Alaska, 2012-2015

A full list of CARVE data products is available at: https://carve.ornl.gov/dataproducts.html

2. Data Characteristics

Spatial Coverage: CARVE flights over the Alaskan and Canadian Arctic

Spatial Resolution: Point measurements

Temporal Coverage: Periodic flights occurred during the growing seasons (approx. March – November) of 2012 through 2014.

Temporal Resolution: All measurements were aggregated to 5-second intervals for distribution with this data set.

Study Area (coordinates in decimal degrees)

Site	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
Alaska and Canadian Arctic	-168.11	-131.75	71.56	60.21

Data File Information

All data are stored in NetCDF (*.nc) version 4 file format. Each file provides measurements of dry mole fractions of atmospheric CO_2, CH_4, and CO acquired during a single flight. No H2O concentration measurements were made so H2O and the corresponding QC layer contain fill values of 0.

Table 1. CARVE file naming convention. Example file name: carve_AtmosISGA_L2_H_b23_20120523_20150712233810.nc

Name element	Example value	Units
Project name	*carve*	
Instrument	*AtmosISGA*	
Processing level	*L2*	
Investigator group	*H*	*Harvard University group*
Build ID	*b23*	
Flight date	*20120523*	*yyyymmdd*
Processing date and time	20150712233810	*yyyymmddhhmmss*

Data variables

Each file contains 8 geolocation variables and 8 science measurement variables described in Table 2.

Table 2. Data variables in each netCDF file. Fill value or missing data were set to -999.9 for all variables. H2O values were set to 0.

Variable name	**Description**	**Units**
Geolocation measurements		
center_lat	latitude	Decimal degrees North
center_lat_standard_error	latitude standard_error	Decimal degrees North
center_lon	longitude	Decimal degrees east
center_lon_standard_error	longitude standard error	Decimal degrees east
height	height of aircraft above ground	Meters
height_standard_error	height standard error	Meters
geolocation_qc	geolocation status flag	0 = Success, 1 = Error
time	time	seconds since 1980-1-6 0:0:0 UTC
Science Measurements		
co	Carbon monoxide dry mole fraction measurements at 5-second intervals	parts per billion (1x10^-9)
co_qc	QC flag for carbon monoxide measurements	see Table 3
co2	Carbon dioxide dry mole fraction measurements at 5-second intervals	parts per million (1x10^-6)
co2_qc	QC flag for carbon dioxide measurements	see Table 3
ch4	Methane dry mole fraction measurements at 5-second intervals	parts per billion (1x10^-9)

ch4_qc	QC flag for methane measurements	see Table 3
h2o *	Water vapor concentration at 5-second intervals	percent (1x10^-2)
h2o_qc *	QC flag for water vapor measurements	see Table 3

* Sample air was dried in two stages prior to measurement, first with a nafion dryer, then followed by a dry ice trap. Hence, no water data are reported for the Harvard University L2 product. This field is included in the data file for consistency with the NOAA CRDS data.

Table 3. QC flag value descriptions

QC Flag	Flag Meaning	Description
0	Valid	
1	OutOfRange	CO, CO_2, or CH_4 mole fractions are above or below the laboratory standards used to calibrate the instrument.
2	CavityAnomaly	Variation in cavity pressure is beyond 139.5-140.5 torr or the cavity temperature is beyond 44.98-45.02 C.
3	Suspected Leak	Used to indicate system leaks or calibration problems. For these flight dates, it is recommended to use the merged atmospheric gas data instead.

Known data gaps:

Instrument had not yet equilibrated on 20120724 (DOY=205).

Suspected system leak affected CO2 on 20120918 (DOY=261).

The wavelength monitor was unstable (April 2013, DOY=91-95), resulting in very noisy data. A new wavelength monitor and lower-vibration inlet valve were installed in time for the first May flight and the remaining data are much less noisy.

The calibration system was not enabled until mid-way through the flight on 20130709 (DOY=189). These data were calibrated using the mean calibration for the second half of the flight.

Calibration system was not enabled on 20140812 (DOY=223). Calibration applied was the mean of 20140811 and 20140813 calibrations.

Calibration:

CO2, CH4, and CO measurements are reported on their respective world Meteorological Organization (WMO) standard scales:

- NOAA 2007 CO2 standard scale (see Zhao and Tans, 2006)
- NOAA 2004 CH4 standard scale (see Dlugokencky et al., 2005)
- NOAA 2004 CO standard scale (see Novelli et al., 1991)

3. Application and Derivation

These data files contain high-frequency atmospheric CO_2, CH_4, and CO content observations for CARVE flights during March– November of 2012 to 2014. The CARVE project was designed to collect detailed measurements of important greenhouse gases on local to regional scales in the Alaskan arctic and demonstrate new remote sensing and improved modeling capabilities to quantify Arctic carbon fluxes and carbon cycle-climate processes. The CARVE data provide insights into Arctic carbon cycling that may be useful in numerous applications.

4. Quality Assessment

Continuous measurements from the Harvard CRDS instrument were calibrated against on-board standard gas samples once every 30 minutes by an automated system.

Table 4. Laboratory uncertainty standards from calibration of CRDS instrument. These values represent the maximum and minimum concentrations of standard

gases used to calibrate the instrument in the given year. These values are for the user's reference since the line absorption is expected to remain fairly linear.

Gas	2012	2013	2014
CO (ppb)	46 – 203	40 – 204	39.6 – 243.2
CO2 (ppm)	387.43 – 414.43	375.9 – 418.9	374.5 – 417.1
CH4 (ppb)	1736.1 – 2284.3	1700.5 – 2294.1	1696.4 – 2286.3

Allan variance analyses of the Picarro signals against calibrated gas samples demonstrated excellent performance. Measured precisions (1 std) for 2.5-second integration times are 0.012 ppm for CO2, 0.118 ppb for CH4, and 2.319 ppb for CO. This outstanding performance provides CARVE with high sensitivity to rapid changes in atmospheric concentrations of these gases.

5. Data Acquisition, Materials, and Methods

CARVE Flights

These data represent one part of the data collected by the Carbon in Arctic Reservoirs Vulnerability Experiment (Miller et al, 2012). A C-23 Sherpa aircraft made frequent flights out of Fairbanks, Alaska between March and November over multiple years, observing the spring thaw, summer draw-down, and fall refreeze of the Arctic growing season. Flights concentrate observations on three study domains: the North Slope, the interior, and the Yukon River valley. North Slope flights cover regions of tundra and continuous permafrost and were anchored by flux towers in Barrow, Atqasuk, and Ivotuk. Flights to Prudhoe Bay characterize the CO2 and CH4 emissions from oil and natural gas processing plants. Flights over interior Alaska sample discontinuous permafrost, boreal forests, and wetlands. A complete list of CARVE flights can be found at: https://carve.ornl.gov/flights.html. Flight paths and atmospheric gas concentrations for CARVE surveys can be visualized through the CARVE Flight Data Visualization Tool (http://carve.ornl.gov/visualize).

The CARVE aircraft carried a remote sensing and atmospheric sampling payload consisting of the following instruments: a passive/active L-band system (PALS), a Fourier transform spectrometer (FTS), and an in situ gas analyzer suite (ISGAS) with a gas analyzer and flask sampling system (see https://carve.ornl.gov/documentation.html). All instruments were controlled by a master computer system (Data Acquisition and Distribution System, DADS). Data were logged and UTC time stamped at 1 second intervals. DADS also recorded GPS data (Lat, Lon, elevation), aircraft pitch, roll, and yaw, as well as basic meteorological data from onboard instruments.

In situ gas analyzer

This data set includes continuous, in situ measurements from the gas analyzer, a cavity ring-down spectroscopy (CRDS) instrument (Picarro Inc.) used for rapid measurement of trace gas mole fractions (Crosson, 2008). Gas measurements from samples collected with the flask system are distributed as a separate CARVE data set. CRDS is a technique for measuring quantities of gaseous substances based on the rate of light intensity decay following laser illumination of a highly-reflective containment cavity. A CRDS system measures the time constant of decay to 1/*e* of its initial intensity, its *ring-down time*, in order to calculate the concentration of the absorbing gas mixture within the cavity. These data were gathered using a four-species CRDS system (Picarro model G2401, SN CFKBDS2010).

CO_2, CH_4, and CO were recorded at 2.5 to 5-second intervals for the duration of each flight, and aggregated to 5-second temporal resolution for distribution in this data set. CO and CH4 dry mole fractions are reported in parts per billion (ppb) and CO2 dry mole fractions in parts per million (ppm). Records with invalid measurements are assigned a default mole fraction (-999.9). Sample air was dried in two stages prior to measurement, first with a nafion dryer, then followed by a dry ice trap. Hence, no water data are reported.

The CRDS instruments were calibrated in the laboratory each year before and after each seasonal deployment, with a series of four or five standard reference tanks (World Meteorological Organization; Novelli et al., 1991; Zhao and Tans, 2006; Dlugokencky et al., 2005) at NOAA/ESRL. Drift between laboratory calibrations in March and December of the same year for each of the two gas analyzers was found to be < 3 ppb CO, <= 0.05 ppm CO2, and < 2 ppb CH4 for the ambient range of mole fractions. Similar results have been shown for CO2 in other Picarro CRDS analyzers (Richardson et al., 2012). Flight measurements for all species were initially corrected using this linear calibration prior to analysis of the on-board standards. On-board standards were performed using a set of NOAA-calibrated reference tanks that were routinely sampled during flights (approximately every 30 minutes).

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:

- E-mail: uso@daac.ornl.gov
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7. References

Crosson, E.R. (2008). A cavity ring-down analyzer for measuring atmospheric levels of methane, carbon dioxide, and water vapor, Appl. Phys. B-Lasers O., 92: 403-408. doi: 10.1007/s00340-008-3135y, 2008.

Dlugokencky, E.J., R.C. Myers, P.M. Lang, K.A. Masarie, A.M. Crotwell, K.W. Thoning, B.D. Hall, J.W. Elkins, and L.P. Steele (2005). Conversion of NOAA CMDL atmospheric dry air methane mole fractions to gravimetrically-prepared standard scale, J. Geophys. Res., 110, D18306 doi: 10.1029/2005JD006035.

Miller, C.E., Dinardo, S.J. et al. (2012). CARVE: The Carbon in Arctic Reservoirs Vulnerability Experiment., *2012 IEEE Aerospace Conference*. doi: 10.1109/AERO.2012.6187026

Novelli, P. C., Elkins, J. W., and Steele, L. P. (1991). The development and evaluation of a gravimetric reference scale for measurements of atmospheric carbon monoxide, J. Geophys. Res.-Atmos., 96, 13109–13121, doi:10.1029/91jd01108

Richardson, S.J., N.L. Miles, K.J. Davis, E.R. Crosson, C.W. Rella, and A.E. Andrews (2012). Field Testing of Cavity Ring-Down Spectroscopy Analyzers Measuring Carbon dioxide and Water Vapor, J. atmos. Ocean. Tech., 29, 397-406. doi: 10.1175/jtech-d-11-00063.1.

Zhao, C., and P.P. Tans (2006). Estimating uncertainty of the WMO Mole Fraction Scale for carbon dioxide in air, J. Geophys. Res. 111, D08S09, doi: 10.1029/2005JD006003.