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CARVE: L2 Atmospheric Gas Concentrations, Tower-based Flasks, Alaska, 2012-2015

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Documentation Revision Date: 2016-11-14

Data Set Version: 1

Summary

This data set provides atmospheric carbon dioxide, methane, carbon monoxide, molecular hydrogen, nitrous oxide, sulfur hexafluoride, and other trace gas mole fractions (i.e. "concentrations") from a flask sampling system at the CARVE flux tower in Fox, Alaska for the Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE). The data were derived from laboratory measurements of whole air samples collected by a Programmable Flask Package (PFP) from the top of the tower at 32 m above ground level during late evening multiple times per month since January 2012. Whole air samples collected in the PFPs were analyzed on automated systems at the NOAA Earth System Research Laboratory (ESRL) Global Monitoring Division in Boulder, CO, which also analyzes samples from the NOAA/ESRL Global Greenhouse Gas Reference Network. 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.

There are 4 data files in netCDF (*.nc) format, one for each year of samples collected at the CARVE tower, with this data set.

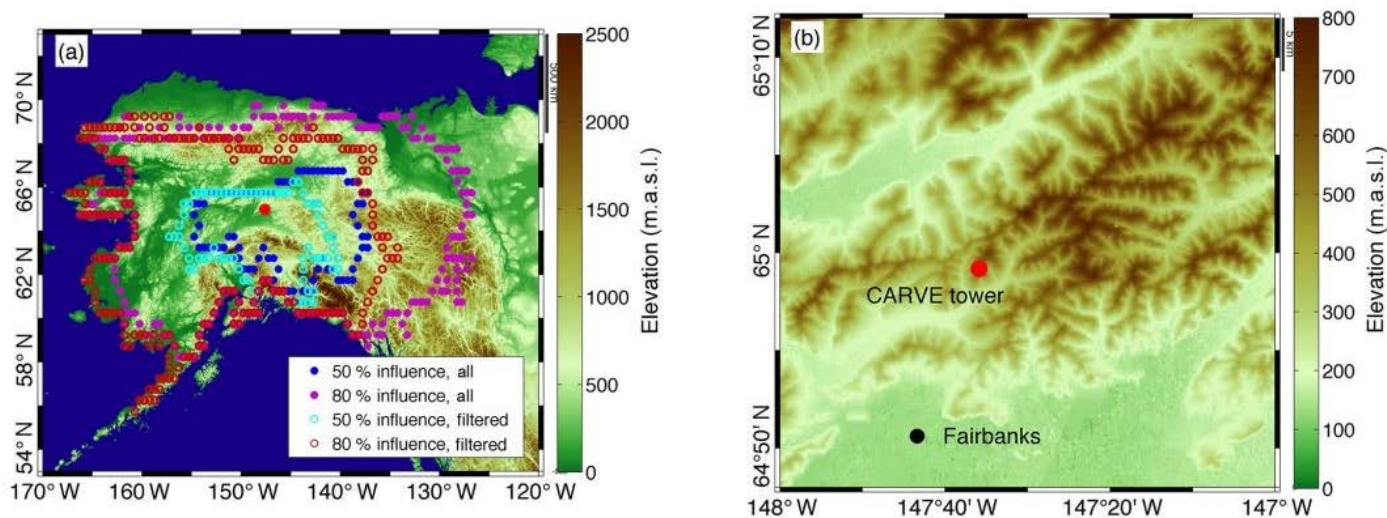


Figure 1. a) Contours show sensitivity of CO₂ and CH₄ measurements to boreal forests and lowlands of interior Alaska; b) CARVE tower (Karion et al., 2016)

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:

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

2. Data Characteristics

Spatial Coverage: CARVE tower near Fairbanks, Alaska

Spatial Resolution: Point measurements

Temporal Coverage: 20120104 - 20151205

Temporal Resolution: Air samples collected multiple times per month

Study Area (coordinates in decimal degrees)

Site	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
CARVE tower	-147.5982	-147.5982	64.9863	64.9863

Data File Information

All data are stored in NetCDF (*.nc) version 4 file format. Each file provides measurements of dry mole fractions of atmospheric CO₂, CH₄, CO, H₂, N₂O, and SF₆ and other trace gases acquired over one year of measurements.

Table 1: CARVE file naming convention. Example file name: `carve_GroundFlask_L2_b23_20111231_20160807222152.nc`

Name element	Example value	Units
Project name	<i>carve</i>	
Instrument	<i>GroundFlask</i>	
Processing level	<i>L2</i>	
Build ID	<i>b23</i>	
Flight date	<i>20111231</i>	<i>yyyymmdd</i>
Processing date and time	<i>20150727184306</i>	<i>yyyymmddhhmmss</i>

Data variables

Each file contains 14 geolocation variables and 69 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.

Variable name	Description	Units
Geolocation and ancillary measurements		
center_lat	latitude	degrees North
center_lat_standard_error	latitude standard error	degrees North
center_lon	longitude	degrees East
center_lon_standard_error	longitude standard error	degrees East
height	height of sample 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
elevation	surface elevation	meters
event_number	NOAA database event number	
intake_height	sample intake height	meters
flask_id	sample container ID	
sample_method	sample collection method	
site_code	sample site code	
Science measurements		
benz	benzene (C ₆ H ₆)	parts per trillion (ppt) **
brfm	bromoform (CHBr ₃)	ppt
c2f6	hexafluoroethane (CF ₃ CF ₃)	ppt

c2h2	ethyne (acetylene; C ₂ H ₂)	ppt
c2h4	ethene (ethylene; C ₂ H ₄)	ppt
c2h6	ethane (C ₂ H ₆)	ppt
c3h6	propene (propylene; C ₃ H ₆)	ppt
c3h8	propane (C ₃ H ₈)	ppt
ccl4	carbon tetrachloride (tetrachloromethane; CCl ₄)	ppt
cf4	carbon tetrafluoride (tetrafluoromethane; CF ₄)	ppt
ch2brcl	bromochloromethane (CH ₂ BrCl)	ppt
ch3i	methyl iodide (CH ₃ I)	ppt
ch4	methane (CH ₄)	parts per billion (ppb) **
chl3	chloroform (CHCl ₃)	ppt
co	carbon monoxide (CO)	ppb
co2	carbon dioxide (CO ₂)	parts per million (ppm) **
co2c13	d ¹³ C of CO ₂	ppm
co2c14	D ¹⁴ C of CO ₂	ppm
co2o18	d ¹⁸ O of CO ₂	ppm
cs2	carbon disulfide (CS ₂)	ppt
dibr	dibromomethane (CH ₂ Br ₂)	ppt
di3cl	dichloromethane (CH ₂ Cl ₂)	ppt
f112	CFC-112 (CCl ₃ CClF ₂)	ppt

f113	CFC-113 (CCl ₂ FCClF ₂)	ppt
f114	CFC-114 and CFC-114a (ClF ₂ CCF ₂ Cl)	ppt
f115	CFC-115 (CClF ₂ CF ₃)	ppt
f11a	CFC-11 (ion 101; CCl ₃ F)	ppt
f11b	CFC-11 (ion 103; CCl ₃ F)	ppt
f124	HCFC-124 (CHClF ₂ CF ₃)	ppt
f125	HFC-125 (CHF ₂ CF ₃)	ppt
f13	CFC-13 (CClF ₃)	ppt
f134	HFC-134 (CHF ₂ CHF ₂)	ppt
f134a	HFC-134a (CH ₂ FCF ₃)	ppt
f141b	HCFC-141b (CH ₃ CCl ₂ F)	ppt
f142b	HCFC-142b (CH ₃ CF ₂ Cl)	ppt
f143a	HFC-143a (CH ₃ CF ₃)	ppt
f152a	HFC-152a (CH ₃ CHF ₂)	ppt
f160	chloroethane (CH ₃ CH ₂ Cl)	ppt
f227e	HFC-227ea (CF ₃ CHFCF ₃)	ppt
f23	HFC-23 (CHF ₃)	ppt
f236fa	HFC-236fa (CF ₃ CH ₂ CF ₃)	ppt
f32	HFC-32 (CH ₂ F ₂)	ppt
f365m	HFC-365mfc (CH ₃ CF ₂ CH ₂ CF ₃)	ppt
fc12	CFC-12 (CCl ₂ F ₂)	ppt
h1211	bromochlorodifluoromethane (halon 1211; CBrClF ₂)	ppt

h1301	bromotrifluoromethane (halon 1301; CF ₃ Br)	ppt
h2	hydrogen (H ₂)	ppb
h2402	dibromotetrafluoroethane (halon 2402; CBrF ₂ CBrF ₂)	ppt
hf133a	HCFC-133a (CH ₂ ClCF ₃)	ppt
hf21	HCFC-21 (CHCl ₂ F)	ppt
hf22	HCFC-22 (CHF ₂ Cl)	ppt
ic4h10	i-butane (i-C ₄ H ₁₀)	ppt
ic5h12	i-pentane (i-C ₅ H ₁₂)	ppt
mcfa	methyl chloroform (ion 97; CH ₃ CCl ₃)	ppt
mebr	methyl bromide (CH ₃ Br)	ppt
mecl	methyl chloride (CH ₃ Cl)	ppt
n2o	nitrous oxide (N ₂ O)	ppb
nc4h10	n-butane (n-C ₄ H ₁₀)	ppt
nc5h12	n-pentane (n-C ₅ H ₁₂)	ppt
nc6h14	n-hexane (n-C ₆ H ₁₄)	ppt
nf3	nitrogen trifluoride (NF ₃)	ppt
ocs	carbonyl sulfide (COS)	ppt
p218	perfluoropropane (C ₃ F ₈)	ppt
pce	tetrachloroethylene (C ₂ Cl ₄)	ppt
sf6_ccgg	sulfur hexafluoride (SF ₆)	ppt
sf6_hats	sulfur hexafluoride (SF ₆)	ppt

so2f2	sulfuryl fluoride (SO ₂ F ₂)	ppt
tce	trichloroethylene (C ₂ HCl ₃)	ppt
tol	toluene (C ₇ H ₈)	ppt

* Values for geolocation variables do not change (-147.6 E, 65 N)

** parts per million – ppm – micromol of gas per mol of dry air – 10⁻⁶

parts per billion – ppb – nanomol of gas per mol of dry air – 10⁻⁹

parts per trillion – ppt – picomol of gas per mol of dry air – 10⁻¹²

The netcdf files also include a QC flag for each analyte. For example, the benzene ratio QC flag is “benz_ratio_status”. The flag values are the same for all analytes and are provided in Table 3.

Table 3. QC flag value descriptions

QC Flag	Flag Meaning	Description
1	Valid	
2	Preliminary	Sample measurement is preliminary and has not yet been carefully examined by the PI
3	Deselected	Sample measurement is likely valid but does not meet selection criteria determined by the goals of the CARVE investigation
4	Rejected	Obvious problems during collection or analysis

Calibration:

All measurements are reported as dry air mole fractions on their respective World Meteorological Organization (WMO) standard scales:

- WMO X2014A CO standard scale (see Novelli et al., 1991)
- WMO X2007 CO₂ standard scale (see Zhao and Tans, 2006)
- WMO 2004A CH₄ standard scale (see Dlugokencky et al., 2005)
- WMO 2004 CMDL H₂ standard scale (Novelli et al., 1999)
- WMO 2006A N₂O standard scale (Hall et al., 2007)
- WMO 2014 SF₆ standard scale (Hall et al., 2007)

3. Application and Derivation

These data files contain dry mole fractions of CO, CO₂, CH₄, H₂, N₂O, and SF₆ measured from whole air samples collected at the CARVE tower site between 2012 and 2015. These measurements provide context for aircraft observations obtained during the CARVE project.

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

Table 4. Repeatability of gas detection was determined as 1 standard deviation of ~20 aliquots of natural air measured from a standard cylinder.

Gas	Average Repeatability
CO	UV resonance fluorescence: +/- 0.4 ppb (Gerbig et al., 1999)

CO2	+/- 0.03 ppm (Conway et al., 1994)
CH4	+/- 1.2 ppb (Dlugokencky et al., 1994)
H2	+/- 0.4 ppb (Novelli et al., 1999)
N2O	+/- 0.26 ppb (Dlugokencky et al., 2009)
SF6	+/- 0.03 ppt (Dlugokencky et al., 2009)

5. Data Acquisition, Materials, and Methods

CARVE research tower

A stationary, tower-based greenhouse gas measurement site, the CARVE tower (NOAA site code CRV), was established in 2011 to give year-round context for the intensive aircraft observations performed throughout the CARVE project. The measurements contained in this data set are from the flask sampling system at the top (32 m.a.g.l.) of CARVE tower in Fox, Alaska (17 km north of Fairbanks; 64.9863 N, 147.5982 W, 611 m.a.s.l.). The tower site was chosen for its high elevation compared to the immediate surrounding mean ground level and its relatively large region of influence to provide temporal and spatial context for CARVE aircraft measurements in interior Alaska.

The surrounding land cover is composed of deciduous and evergreen forest, shrub or scrub, some scattered areas of woody wetlands, mainly south of the Chena River south of Fairbanks, and medium and low intensity developed land in and immediately around Fairbanks (Homer et al., 2015). The tower is located on a ridge, and measurements from the tower represent a wide region of interior Alaska, as indicated by surface influence fields generated from the WRF-STILT modeling framework (Henderson et al., 2015), which show that the tower's influence region encompasses a substantial part of Alaska (Fig. 1a).

Flask air sampling system

This data set includes measurements from discrete air samples captured by the flask sampling system atop the CARVE tower. The two air-sampling devices, the Programmable Flask Package (PFP) and Programmable Compressor Package (PCP) systems, are used routinely on aircraft as part of the NOAA/ESRL Global Monitoring Division's Global Greenhouse Gas Reference Network (Sweeney et al., 2013).



Figure 2. Flask sampling system Left: Programmable Flash Package (PFP) containing 12 flasks. Right: Programmable Compressor Package (PCP) containing pumps for pressurizing the flasks. (Image courtesy: <http://www.esrl.noaa.gov/gmd/ccgg/aircraft/sampling.html>)

A typical sampling routine uses one PCP and one or more PFP(s) that are pre-programmed with a sampling plan dictating the interval for filling each flask. For each sample, the inlet line and compression manifold are flushed with about 5 liters of ambient air. Valves on both ends of the current flask are then opened and the flask is flushed with about 10 more liters of ambient air to displace the dry, low CO₂ fill gas with which the flasks are shipped. The sample flush air is measured by a mass flow meter to ensure that a sufficient volume passes through the manifold and flask before the downstream valve is closed and pressurization begins. Sample flush volumes and fill pressures during sampling are recorded by the data logger, along with ambient temperature, pressure, and relative humidity. GPS position and time stamp are also recorded with each sample.

Gas detection

- Quantities of CO₂ in flask air samples were detected using a non-dispersive infrared analyzer and reported in parts per million (micromol CO₂ per mol dry air, i.e. ppm). Because detector response is non-linear in the range of atmospheric levels, ambient samples are bracketed during analysis by a set of reference standards used to calibrate detector response.
- CH₄ was isolated from constituent gases through gas chromatography and quantified with flame ionization detection. Measurements are reported in parts per billion (ppb).
- CO was determined by either resonance fluorescence at ~150 nm with a precision of ±0.4 ppb, or by UV absorption spectroscopy with precision ~1 ppb (Novelli et al., 1998) and reported in ppb.
- H₂ was isolated using gas chromatography, and detected using pulsed-discharge He ionization, providing a precision of ±0.4 ppb for H₂ (Novelli et al., 2009). H₂ quantities are reported in ppb.
- The N₂O and SF₆ sample components were isolated using gas chromatography and quantified with electron capture detection. N₂O and SF₆ are reported in ppb and parts per trillion (ppt), respectively.

6. Data Access

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

[CARVE: L2 Atmospheric Gas Concentrations, Tower-based Flasks, Alaska, 2012-2015](http://www.esrl.noaa.gov/gmd/ccgg/aircraft/sampling.html)

Contact for Data Center Access Information:

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