CARVE: L1 Airborne Forward Looking Infrared Radiance Counts, Alaska, 2013-2015

Get Data

Documentation Revision Date: 2017-04-06

Data Set Version: V1

Summary

This data set provides earth referenced radiance counts measured by the Forward Looking Infrared (FLIR) camera aboard the CARVE aircraft between April 2013 and November 2015 for the Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE). The FLIR camera records images of the surface temperature while measuring concentrations of atmospheric carbon dioxide, methane, and ozone. Thermal images from the FLIR camera will be used to characterize land surfaces underlain by permafrost during specific phases in the freeze-thaw cycle. 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 5031 files in NetCDF (*.nc) format included in this data set.

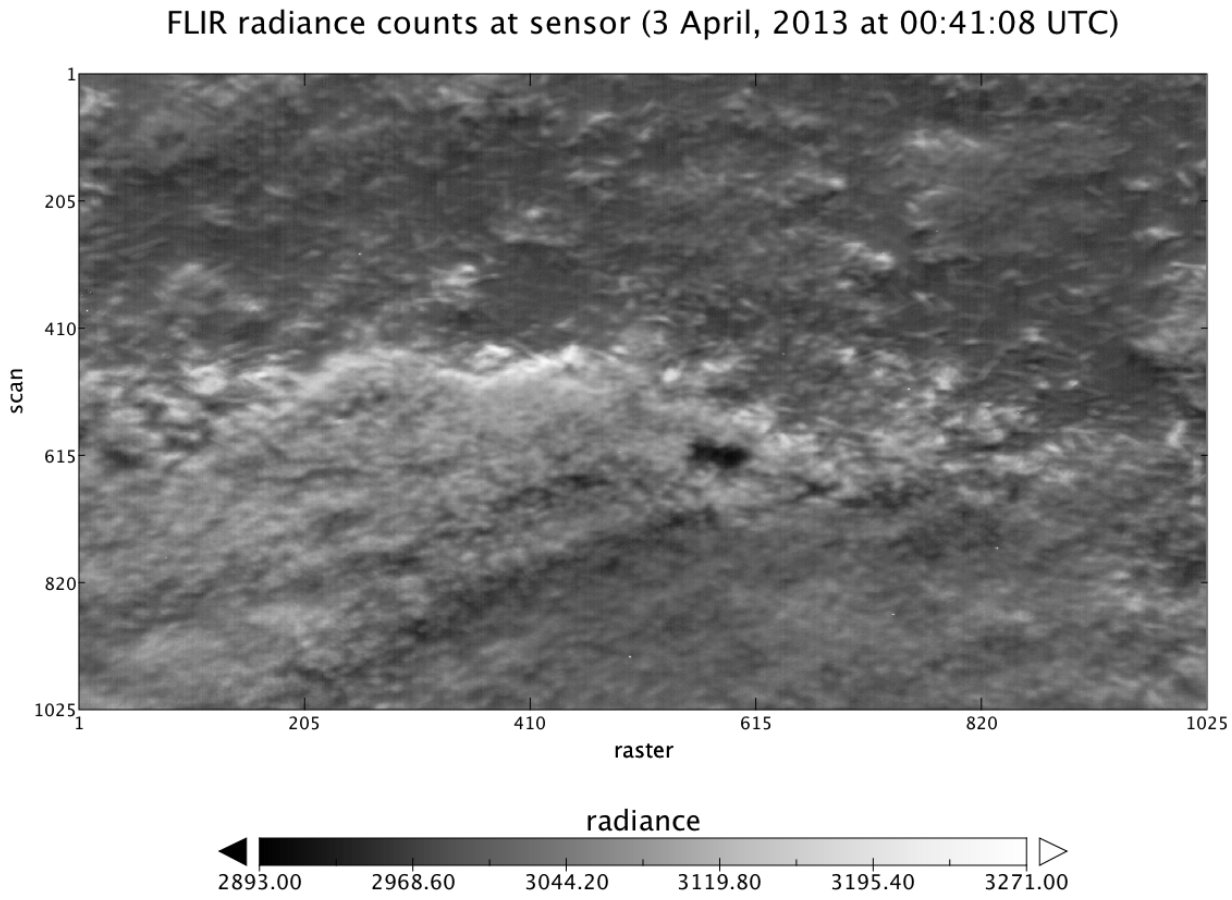

Figure 1: Infrared radiance of the land surface measured by the FLIR instrument onboard the CARVE flight on April 3, 2013.

Citation

Steiner, N., K.C. McDonald, E. Podest, C.E. Miller, and S.J. Dinardo. 2017. CARVE: L1 Airborne Forward Looking Infrared Radiance Counts, Alaska, 2013-2015. ORNL DAAC, Oak Ridge, Tennessee, USA. http://dx.doi.org/10.3334/ORNLDAAC/1428

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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 flights over the Alaskan and Canadian Arctic

Spatial Resolution: variable; ~36 cm horizontal resolution at altitude of 500 m

Temporal Coverage: 20130403 - 20151113

Temporal Resolution: 1 second to less than 1 minute

Study Area (coordinates in decimal degrees)

Site	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
Alaskan and Canadian Arctic	-168.069	-132.238	71.361	58.842

Data File Information

All FLIR Level 1 product data are stored in NetCDF (*.nc) version 4 file format. There are a total of 5031 data files. Each file provides earth referenced radiance counts captured during a portion of a CARVE flight. The number of files generated for a given day is dependent on the length of the flight. The discontinous temporal range for this product starts in April 2013 and ends in November 2015. The file naming convention is listed in Table 1. Global metadata attributes communicating information about the FLIR product and information specific to each file are described in Table 2.

Table 1. CARVE file naming convention. Example file name: *carve_FLIR_L1A_b23_20130403_000011_20160304004404124.nc*

Name element	Example value	Units
Project name	carve	
Instrument	FLIR	
Processing level	L1A	
Build ID	b23	
File date *	20130403	yyyymmdd
File number **	000011	######
Processing date and time	20160304004404124	yyyymmddhhmmss

* Data from a single flight is spread across multiple files.

** Files are numbered in order that the data were collected

Table 2. Global metadata attributes for NetCDF files

Attribute Name	Description
ancillary_file_source	List of ancillary data products used to generate the current product
build_id	Software build
collection_label	Collection label
comment	Miscellaneous information about the data or methods
conventions	Documents describing sets of discipline-specific conventions
data_start_time	Date and time of first data element in the file: yyyy-mm-ddThh:mm:ss.sssZ
data_stop_time	Date and time of last data element in the file: yyyy-mm-ddThh:mm:ss.sssZ
frequency_of_sampling	"1 second - < 1 minute"
history	Audit trail for modifications to the original data
institution	Specifies where the original data was produced

instrument	Instruments with data contained in the file
long_name	Long name of the product type
master_quality_flag	Succinct assessment of the quality of the data in the file: "Good", "Bad", or "UNK"
product_source	List of source data products used to generate the current product
production_date_time	Date and time when product was created: yyyy-mm-ddThh:mm:ss.sssZ
processing_level	Processing level of the data
references	References
sampling_interval	"Grab"
short_name	Short name of the product type
source	Method of production of original data
specification_name	The name of the document describing product contents
specification_version	Version of the document describing the product contents
title	Succinct description of data set contents

Data variables

Each file contains 14 geolocation variables and 1 science measurement variable described in Table 3. Metadata attributes for the radiance variable, including polynomial conversion coefficients for converting digital numbers to standard units, are described in Table 4.

Table 3. Data variables in each netCDF file. Fill value or missing data were set to -999.9 for all variables.

Variable	Units	Description
Geolocation measurements		
center_lat	degrees_north	Latitude of footprint center
center_lat_standard_error	degrees_north	Standard error of latitude of footprint center
center_lon	degrees_east	Longitude of footprint center
center_lon_standard_error	degrees_east	Standard error of longitude of footprint center
geolocation_qc	0: Success; 1: Error	Geolocation calculations status
heading	degree	Aircraft heading
heading_qc	0: Valid; 1: OutOfRange; 2: Error	Aircraft heading status
height	meters	Aircraft height
height_standard_error	meters	Standard error of aircraft height
pitch	degree	Aircraft pitch angle
pitch_qc	0: Valid; 1: OutOfRange; 2: Error	Aircraft pitch angle status
roll	degree	Aircraft roll angle
roll_qc	0: Valid; 1: OutOfRange; 2: Error	Aircraft roll angle status
time	seconds since 1980-01-06 0:0:0	Measurement time UTC
Science measurements		
radiance	Counts	FLIR radiance counts at sensor

Table 4. Metadata attributes for the radiance variable in the NetCDF files.

Attribute Name	Description
long_name	Variable long name
_FillValue	Null data fill value
MinCounts	Minimum radiance value [digital number]

MaxCounts	Maximum radiance value [digital number]
MinRadiance	Minimum radiance value [W/(sr*cm^2)]
MaxRadiance	Maximum radiance value [W/(sr*cm^2)]
valid_min	Minimum valid radiance value [digital number]
valid_max	Maximum valid radiance value [digital number]
BandpassLow	Minimum integration wavelength [nm]
BandpassHigh	Maximum integration wavelength [nm]
units	Radiance units
C0	zero-degree polynomial conversion coefficient [DN to W/(sr*cm^2)]
C1	first-degree polynomial conversion coefficient [DN to W/(sr*cm^2)]
C2	second-degree polynomial conversion coefficient [DN to W/(sr*cm^2)]
C3	third-degree polynomial conversion coefficient [DN to W/(sr*cm^2)]
C4	fourth-degree polynomial conversion coefficient [DN to W/(sr*cm^2)]
C5	fifth-degree polynomial conversion coefficient [DN to W/(sr*cm^2)]
C6	sixth-degree polynomial conversion coefficient [DN to W/(sr*cm^2)]
radiance_coefficients	non-zero radiance conversion polynomial coefficients
AtmA1	For internal use only
AtmA2	For internal use only
AtmB1	For internal use only
AtmX	For internal use only
PolynomialOrder	For internal use only
B	For internal use only
R	For internal use only
F	For internal use only
BGValue	For internal use only
FrameRate	For internal use only
MinTemperature	For internal use only
MaxTemperature	For internal use only
TempC0	For internal use only
TempC1	For internal use only
TempC2	For internal use only
IntegrationTime	For internal use only

3. Application and Derivation

The FLIR instrument was operated during the spring, summer, and fall seasons during clear sky conditions targeting ecosystem components that influence the carbon cycle. Thermal images from the FLIR camera aboard the CARVE aircraft may be used to study the role of seasonal freeze/thaw (F/T) processes in the carbon cycle, an important component to carbon and methane exchange with the atmosphere. Measurements of the temperature and the freeze-thaw state of various landscape components, including the soil and vegetation, may be combined with measurements of atmospheric gas concentrations to better understand the role of surface processes in the exchange of greenhouse gases with the atmosphere in the Alaskan arctic.

4. Quality Assessment

Each NetCDF file contains a global attribute *MasterQualityFlag* that provides a summary indication of the data quality of the whole file. Values are set

to: *Good* - all lower-level quality assessments passed; *Bad* - some or all lower-level quality assessments were not passed; or *UNK* - quality is unknown.

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).

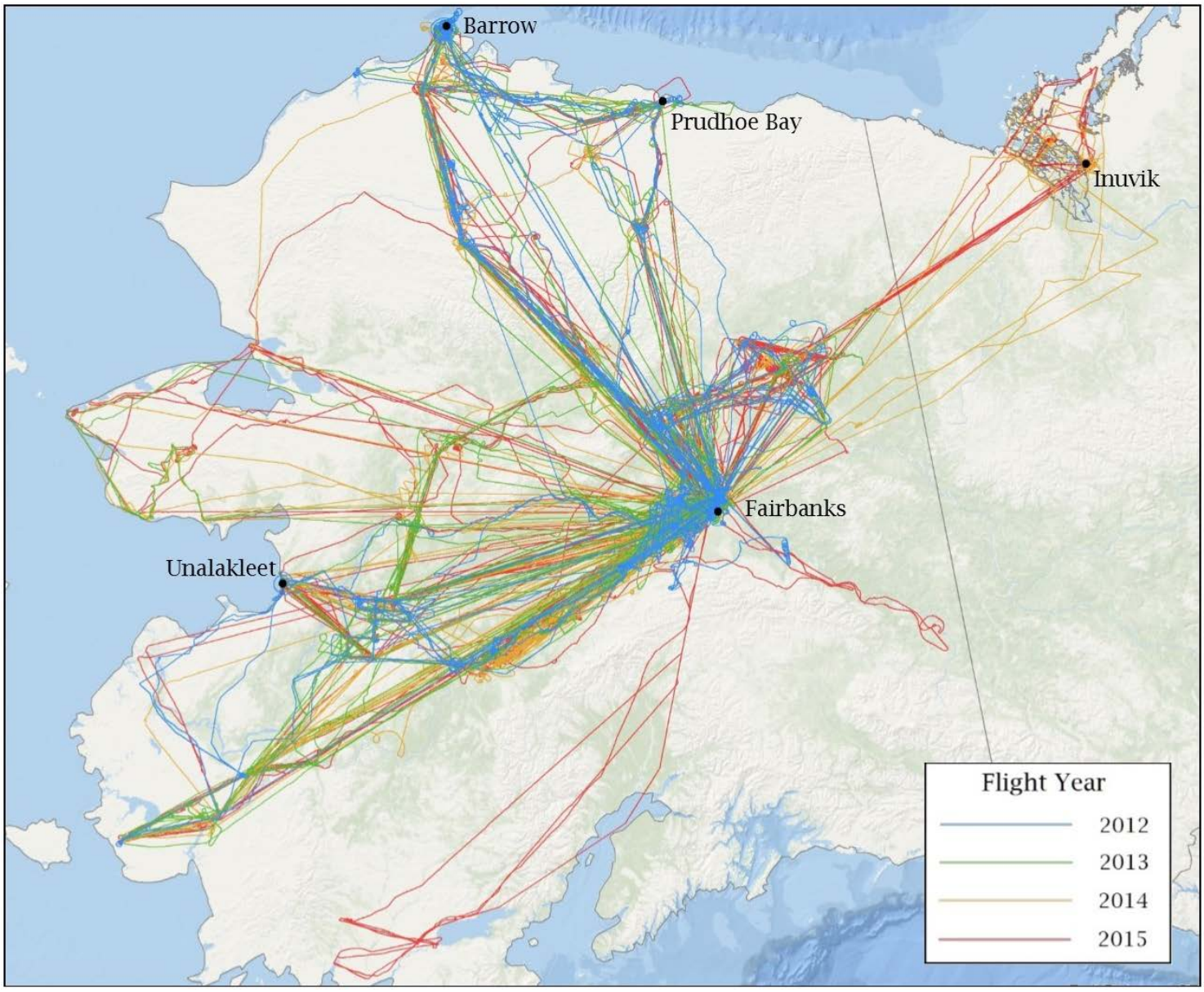

Figure 2. CARVE flights during 2012-2015 delivered measurements over continuous and discontinuous permafrost regimes.

The CARVE aircraft carried a remote sensing and atmospheric sampling payload consisting of the following instruments: 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). DADS also recorded GPS data (Lat, Lon, altitude), aircraft pitch, roll, and yaw, as well as basic meteorological data from onboard instruments.

Forward-Looking Infrared Camera

The nadir-pointed FLIR-SC8200 camera on board the CARVE aircraft is used to measure upwelling mid-infrared spectral radiance at 3-5 microns at a rate

of 1 frame per second. The instantaneous field of view (IFOV) of the FLIR instrument allows for a pixel resolution of ~36 cm from a height of 500 m. These high-resolution observations allow for the discrimination of individual landscape components such as soil, vegetation and surface water features in the image footprint.

To convert radiance counts into standard units, for a pixel in column, *x*, row, *y*, use the following equation:

$$L_{x,y} = \sum_{i=0}^{6} C_i Q_{x,y}$$

Here, $Q_{x,y}$, is radiance in counts, C_i, is the i^{th} degree polynomial conversion coefficient and, $L_{x,y}$, is mid-infrared radiance at the sensor in watts per steradian per centimeter squared (W sr^{-1} cm^{-2}).

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
- Telephone: +1 (865) 241-3952

7. References

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