CARVE: Net Ecosystem CO2 Exchange and Regional Carbon Budgets for Alaska, 2012-2014

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Documentation Revision Date: 2017-05-05

Data Set Version: V1

Summary

This data set provides estimates of 3-hourly net ecosystem CO2 exchange (NEE) at 0.5-degree resolution over the state of Alaska for 2012-2014. The NEE estimates are the output are from Geostatistical Inverse Modeling of a subset of CARVE aircraft CO2 data, WRF-STILT footprints, and PVPRM-SIF data from flux towers (CRV: located in Fox, AK and BRW: located just outside Barrow, AK). Daily mean NEE is also provided as calculated for all of Alaska and for four sub-regions (0.5-degree resolution) that were defined across Alaska, based on general landcover type: North Slope Tundra, South and West Tundra, Boreal Forests, and Mixed (all other). Also provided are derived annual carbon budgets for (1) all of Alaska with defined contributions from biogenic, fossil fuel, and biomass burning sources and (2) annual biogenic carbon budgets for the four landcover-type regions of Alaska. Provided for completeness are the CARVE aircraft atmospheric measurement data used in estimating NEE.

This data set includes 9 files in total. The 3-hourly net ecosystem exchange (NEE) is in netCDF (*.nc) format. There are four tabular data files in comma-separated (*.csv) format containing daily mean NEE, carbon budgets, and CO2 column profiles from CARVE flights. Four maps of the regional landcover types are provided in geotiff (*.tif) format.

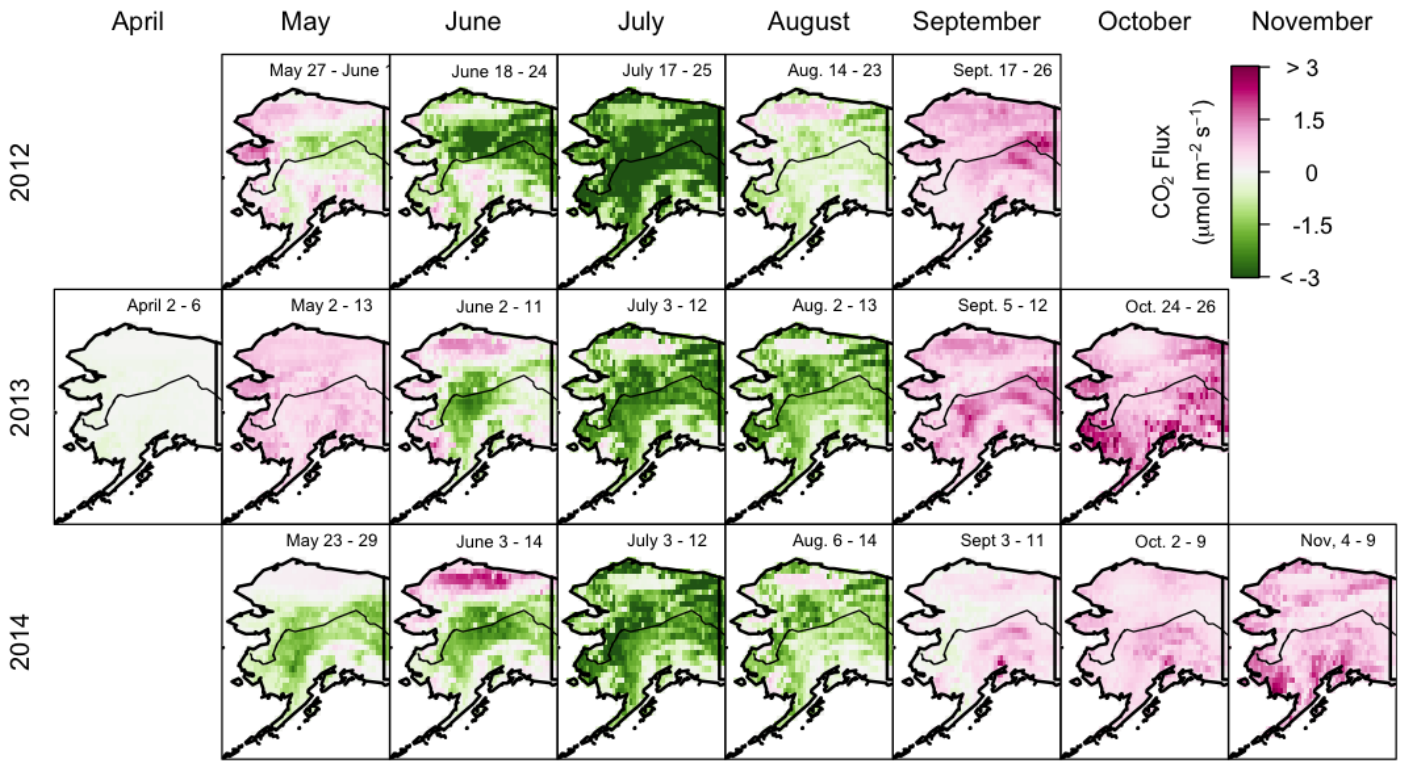

Figure 1. Optimized biogenic net CO2 flux for Alaska 2012-2014. The date of each measurement period is shown at the top of each map. From Commane et al. (2017)

Citation

Commane, R., J. Benmergui, J.O.W. Lindaas, S. Miller, K.A. Luus, R.Y-W. Chang, B.C. Daube, S. Euskirchen, J. Henderson, A. Karion, J.B. Miller, N.C. Parazoo, J.T. Randerson, C. Sweeney, P. Tans, K. Thoning, S. Veraverbeke, C.E. Miller, and S.C. Wofsy. 2017. CARVE: Net Ecosystem CO2 Exchange and Regional Carbon Budgets for Alaska, 2012-2014. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1389

Table of Contents

1. Data Set Overview

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Project: Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE)

Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE) is collecting detailed measurements of important greenhouse gases on local to regional scales in the Alaskan Arctic and demonstrating new remote sensing and improved modeling capabilities to quantify Arctic carbon fluxes and carbon cycle-climate processes. Ultimately, CARVE will provide an integrated set of data that will provide unprecedented experimental insights into Arctic carbon cycling.

Related Data Set:

Luus, K.A., and J.C. Lin. 2017. CARVE Modeled Gross Ecosystem CO2 Exchange and Respiration, Alaska, 2012-2014. ORNL DAAC, Oak Ridge, Tennessee, USA. http://dx.doi.org/10.3334/ORNLDAAC/1314

Related Publication:

Commane, R., Lindaas, J.O.W., Benmergui, J., Luus, K.A., Chang, R.Y-W. , Daube, B.C., Euskirchen, S., Henderson, J., Karion, A., Miller, J.B., Miller, S., Parazoo, N.C., Randerson, J.T., Sweeney, C., Tans, P., Thoning, K., Veraverbeke, S., Miller, C.E., and Wofsy, S.C., 2017. Carbon dioxide sources from Alaska driven by increasing early winter respiration from Arctic tundra. *Proceedings of the National Academy of Sciences*.

Acknowledgements:

This project was funded by the National Oceanic and Atmospheric Administration (NOAA), NASA Grants NNX13AK83G, NNXNNX15AG91G and 1444889 (through JPL), the NSF AON program (#1503912) and the USGS Climate Research and Development Program.

2. Data Characteristics

Spatial Coverage: Alaska

Spatial Resolution: 0.5- x 0.5-degree

Temporal Coverage: 20120101-20141231

Temporal Resolution: 3-hourly

Study Area (All latitudes and longitudes are given in decimal degrees)

Site	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
Alaska	-169	-120	74.5	50

Data File Information

This data set includes one file in netCDF (*.nc) format containing 3-hourly net ecosystem exchange (NEE), four binary maps of land cover in geotiff (*.tif) format, and four tabular data files in comma-separated (*.csv) format containing mean daily NEE, carbon budgets, and CO2 column profiles from CARVE flights.

Table 1. File names and descriptions

File name	Description
oNEE.nc	3-hourly aircraft-optimized CO2 flux (net ecosystem exchange) for the Alaska domain
Daily_Mean_Aircraft_Optimized_NEE_AK.csv	daily mean aircraft-optimized CO2 flux for the Alaska domain
Annual_Carbon_Budget_Region.csv	annual biogenic carbon budget by region
Annual_Total_Carbon_Budget_AK.csv	annual carbon budget by source
CO2_Data_Profiles_CARVE_Flights.csv	CO2 air column profiles from CARVE flights
Forest_Interior_AK.tif	forested land coverage map of interior Alaska
Tundra_Cover_North_Slope.tif	tundra coverage map of the North Slope

Tundra_Cover_Yukon_Kuskokwim.tif	tundra coverage map of the Yukon-Kuskokwim Delta
Mixed_Landcover_AK.tif	mixed land cover map of the Alaska domain

Spatial Data Files

The netCDF (*oNEE.nc*) provides aircraft-optimized CO2 flux (net ecosystem exchange) data in 3-hourly intervals. Data fields within the netCDF file are described in Table 2.

Table 2. Data fields in *oNEE.nc*

Data field	Units	Description
oNEE	umol (micromole) m-2 s-1	aircraft-optimized CO2 flux (net ecosystem exchange)
latitude	degrees_north	latitude of grid cell
longitude	degrees_east	longitude of grid cell
time	days since 2012-01-01 00:00:00.0 UTC	3-hourly time steps measured in days since 2012-01-01

GeoTIFF Files

The four geotiff files included in this data set provided the spatial coverage for which net biogenic carbon budgets were calculated: *Forest_Interior_AK.tif* – boreal forests of interior Alaska; *Tundra_Cover_North_Slope.tif* – North Slope tundra; *Tundra_Cover_Yukon_Kuskokwim.tif* – Yukon-Kuskokwim Delta of south-west Alaska and the Seward Peninsula; and *Mixed_Landcover_AK.tif* – mixed areas or areas of Alaska not included in other regions. Biogenic carbon budgets were calculated from the aircraft-optimized CO2 fluxes for 2012, 2013, and 2014. Spatial data properties for the geotiff files are described below.

Spatial Data Properties

Spatial Representation Type: Raster

Number of Bands: 1

Raster Format: GeoTIFF

Projection: Geographic (WGS 1984)

Angular Unit: Degree (0.0174532925199433)

Prime Meridian: Greenwich (0.0)

Datum: D_WGS_1984

Spheroid: WGS_1984

Semimajor Axis: 6378137.0

Semiminor Axis: 6356752.314245179

Inverse Flattening: 298.257223563

Tabular Data Files

Annual_Carbon_Budget_Region.csv and *Annual_Total_Carbon_Budget_AK.csv* provide the annual carbon budget by region and source, respectively. Rows in *Annual_Carbon_Budget_Region.csv* give the carbon budget in TgC yr-1 for the area of coverage provided in the corresponding geotiff: “NS” – *tundra.NS.tif;* “YK” – *tundra.YK.tif;* “IA” – *forest.IA.tif;* and “Other” – *mixed.tif*. Rows in *Annual_Total_Carbon_Budget_AK.csv* give the carbon budget in TgC yr-1 for three sources influencing CO2 concentrations: biogenic, biomass burning, and fossil fuel. Each file contains one column per year for the

years 2012, 2013, and 2014.

Tabular data file structure for the remaining files are described in Tables 3 and 4.

Table 3. Column names, units, and descriptions in *Daily_Mean_Aircraft_Optimized_NEE_AK.csv*

Column Name	Units	Description
Date	YYYYMMDD	Date
DOY		Day of Year (Jan 1 = Day 0)
days_since_1Jan2012		days since January 1 2012
oNEE_mean	umol m-2 s-1	Mean aircraft optimized NEE for Alaska domain with interpolation between aircraft measurement periods
sd	umol m-2 s-1	Standard deviation of aircraft optimized NEE within the Alaska domain
CI975	umol m-2 s-1	95% confidence interval (upper limit) of aircraft optimized NEE within the Alaska domain
CI025	umol m-2 s-1	95% confidence interval (lower limit) of aircraft optimized NEE within the Alaska domain
PVPRMv9	umol m-2 s-1	Mean NEE calculated from Polar-Vegetative Photosynthesis and Respiration Model
oNEE_raw	umol m-2 s-1	Mean aircraft optimized NEE for Alaska domain for airborne measurement periods only
oNEE_mean_NS	umol m-2 s-1	Mean aircraft optimized NEE for Alaska domain with interpolation between aircraft measurement periods for Alaskan North Slope
sd_NS	umol m-2 s-1	Standard deviation of aircraft optimized NEE within the Alaska domain for Alaskan North Slope
CI975_NS	umol m-2 s-1	95% confidence interval (upper limit) of aircraft optimized NEE within the Alaska domain for Alaskan North Slope
CI025_NS	umol m-2 s-1	95% confidence interval (lower limit) of aircraft optimized NEE within the Alaska domain for Alaskan North Slope
PVPRMv9_NS	umol m-2 s-1	Mean NEE calculated from Polar-Vegetative Photosynthesis and Respiration Model for Alaskan North Slope
oNEE_raw_NS	umol m-2 s-1	Mean aircraft optimized NEE for Alaska domain for airborne measurement periods only for Alaskan North Slope
oNEE_mean_YK	umol m-2 s-1	Mean aircraft optimized NEE for Alaska domain with interpolation between aircraft measurement periods for Alaskan Yukon-Kuskokwim Delta and Seward Penninsula
sd_YK	umol m-2 s-1	Standard deviation of aircraft optimized NEE within the Alaska domain for Alaskan Yukon-Kuskokwim Delta and Seward Penninsula
CI975_YK	umol m-2 s-1	95% confidence interval (upper limit) of aircraft optimized NEE within the Alaska domain for Alaskan Yukon-Kuskokwim Delta and Seward Penninsula
CI025_YK	umol m-2 s-1	95% confidence interval (lower limit) of aircraft optimized NEE within the Alaska domain for Alaskan Yukon-Kuskokwim Delta and Seward Penninsula
PVPRMv9_YK	umol m-2 s-1	Mean NEE calculated from Polar-Vegetative Photosynthesis and Respiration Model for Alaskan Yukon-Kuskokwim Delta and Seward Penninsula
oNEE_raw_YK	umol m-2 s-1	Mean aircraft optimized NEE for Alaska domain for airborne measurement periods only for Alaskan Yukon-Kuskokwim Delta and Seward Penninsula
oNEE_mean_IA	umol m-2 s-1	Mean aircraft optimized NEE for Alaska domain with interpolation between aircraft measurement periods for interior Alaska
sd_IA	umol m-2 s-1	Standard deviation of aircraft optimized NEE within the Alaska domain for interior Alaska
CI975_IA	umol m-2 s-1	95% confidence interval (upper limit) of aircraft optimized NEE within the Alaska domain for interior Alaska
CI025_IA	umol m-2 s-1	95% confidence interval (lower limit) of aircraft optimized NEE within the Alaska domain for interior Alaska
PVPRMv9_IA	umol m-2 s-1	Mean NEE calculated from Polar-Vegetative Photosynthesis and Respiration Model for interior Alaska

oNEE_raw_IA	umol m-2 s-1	Mean aircraft optimized NEE for Alaska domain for airborne measurement periods only for interior Alaska

Table 4. Column names, units, and descriptions in *CO2_Data_Profiles_CARVE_Flights.csv*

Column Name	Units	Description
Year		Year
Date		Date in yyyymmdd
Time		Time in hh:mm:ss
DOY		Day of Year (Jan 1 = Day 0)
Lat		Latitude
Lon		Longitude
Altitude_magl	meters	Mean Altitude above ground level
CO2_mean	ppm	Mean CO2 concentration
CO2_sd	ppm	Standard deviation of carbon dioxide
CO_mean	ppb	Mean carbon monoxide
CO_sd	ppb	Standard deviation of carbon monoxide
Temperature	DegC	Temperature
Pressure	mbar	Pressure
Altitude_GPS_masl	meters	Altitude above mean seal level
H2O	%	Water vapor
O3_mean	ppb	Mean Ozone
O3_sd	ppb	Standard deviation of Ozone
prfl_number		Profile number
STILT_FP	umol m-2 s-1	Total footprint
STILT		Stilt File name

3. Application and Derivation

This data set has been used to assess carbon fluxes and carbon-climate feedbacks in arctic and boreal Alaska by combining and comparing several complementary approaches which in turn will help to gain a more complete understanding of the Alaskan carbon budget and new insight into how arctic carbon fluxes may respond to future climate change (Commane et al., 2017).

4. Quality Assessment

Calculation of the additive flux correction was required to match the modeled to observed column enhancements, within a given measurement period. The "column difference" calculated for each flight period is defined as the difference between the modeled and observed integrated CO2 columns.To represent the spatial distribution of the additive flux correction an inverse model was applied to the column difference for each two week flight period. The column differences vary between -0.25 to +0.45 mol m-2. The goal of the inverse framework is to find an optimal model of the additive flux correction that accounts for the spatial variations of the column differences for each flight period, leading to a spatially explicit, optimal estimate for the CO2 fluxes and annual budget for Alaska (Commane et al., 2017).

5. Data Acquisition, Materials, and Methods

NEE Derivation

According to Commane et. al., 2017, mean CO2 mole fractions were calculated from altitude profiles of CO2 concentration measured across Alaska during the Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE) flights, spanning April-November in 2012-2014. For each aircraft integrated CO2 column, a high resolution transport model was coupled with a data-driven CO2 flux estimate to predict atmospheric CO2 enhancements associated with

Alaskan land surface biogenic fluxes, and then the modeled integrated CO2 column was calculated. Profiles with carbon monoxide mole fractions exceeding 150 ppb were removed to exclude the influence of biomass burning and fossil fuel combustion.

The influence of land surface fluxes for each of the 231 vertical profiles was calculated using the high-resolution WRF-STILT transport model. The proportion of particles located in the lower half of the planetary boundary layer determined the influence of surface fluxes on the measured mole fractions. The two-dimensional WRF-STILT footprint was calculated for each particle at 3-hour intervals on a 0.5- by 0.5-degree grid over the 10-day travel period of the particles. Ecosystem fluxes of CO2 were calculated using the Polar Vegetation Photosynthesis and Respiration Model (PVPRM) and enhanced by convolution with the land surface influence functions calculated from WRF-STILT.

Additive corrections to PVPRM CO2 fluxes were obtained for each two-week aircraft measurement period using a geostatistical inverse model (GIM) to minimize the differences between modeled and observed column CO2 enhancements. PVPRM fluxes and additive flux corrections (interpolated between two-week flight periods) were used to calculate regional-scale CO2 fluxes for Alaska during 2012-2014. The time-series of aircraft-optimized biogenic CO2 flux after additive correction is depicted in Figure 1.

Definition of Regions

Biogenic carbon budgets were calculated for four Alaska sub-regions: North Slope Tundra (Tundra_Cover_North_Slope.tif), South and West Tundra (Tundra_Cover_Yukon_Kuskokwim.tif), Boreal Forests (Forest_Interior_AK.tif), and Mixed (Mixed_Landcover_AK.tif). North Slope Tundra included grid cells with 60% or more tundra north of 67°N. South & West Tundra included grid cells with 60% or more tundra south of 67°N. Forests represented areas of at least 40% Alaska's forest cover. "Mixed" represents everything else not classified in the other regions. North Slope Tundra, South and West Tundra and Forests represent ~80% of the total area of Alaska.

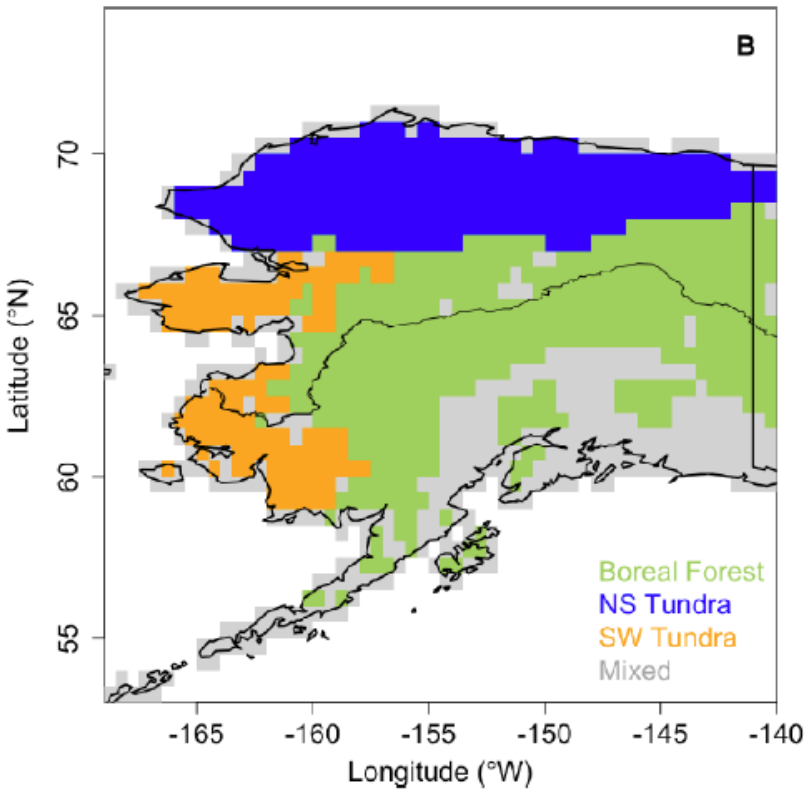

Figure 2: Map of the regional areas within Alaska

6. Data Access

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

CARVE: Net Ecosystem CO2 Exchange and Regional Carbon Budgets for Alaska, 2012-2014

Contact for Data Center Access Information:

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7. References

Commane, R., Lindaas, J.O.W., Benmergui, J., Luus, K.A., Chang, R.Y-W. , Daube, B.C., Euskirchen, S., Henderson, J., Karion, A., Miller, J.B., Miller, S., Parazoo, N.C., Randerson, J.T., Sweeney, C., Tans, P., Thoning, K., Veraverbeke, S., Miller, C.E., and Wofsy, S.C., 2017. Carbon dioxide sources from Alaska driven by increasing early winter respiration from Arctic tundra. *Proceedings of the National Academy of Sciences*.