CARVE Modeled Gross Ecosystem CO2 Exchange and Respiration, Alaska, 2012-2014

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Documentation Revision Date: 2017-01-17

Data Set Version: V1

Summary

This data set provides 3-hourly estimates of gross ecosystem CO2 exchange (GEE) and respiration (autotrophic and heterotrophic) for the state of Alaska from 2012 to 2014. The data were generated using the Polar Vegetation Photosynthesis and Respiration Model (PolarVPRM) and are provided at ~ 1 km2 [1/4-degree (longitude) by 1/6-degree (latitude)] pixel resolution. The PolarVPRM produces high-frequency estimates of GEE of CO2 for North American biomes from remotely-sensed data sets. For Alaska, the model used meteorological inputs from the North American regional re-analysis (NARR) and inputs of fractional snow cover and land surface water index (LSWI) from the Moderate Resolution Imaging Spectroradiometer (MODIS). Land surface greenness was factored into the model from three sources: 1) Enhanced Vegetation Index (EVI) from MODIS; 2) Solar Induced Florescence (SIF) from the Orbiting Carbon Observatory 2 (OCO-2); and 3) SIF from the Global Ozone Monitoring Experiment 2 (GOME-2). Three independent estimates of GEE are included in the data set, one for each source of greenness observations.

A total of 36 NetCDF version 3 (.nc) files are contained in this data set, one per month for the period between 1 January, 2012 and 31 December, 2014.

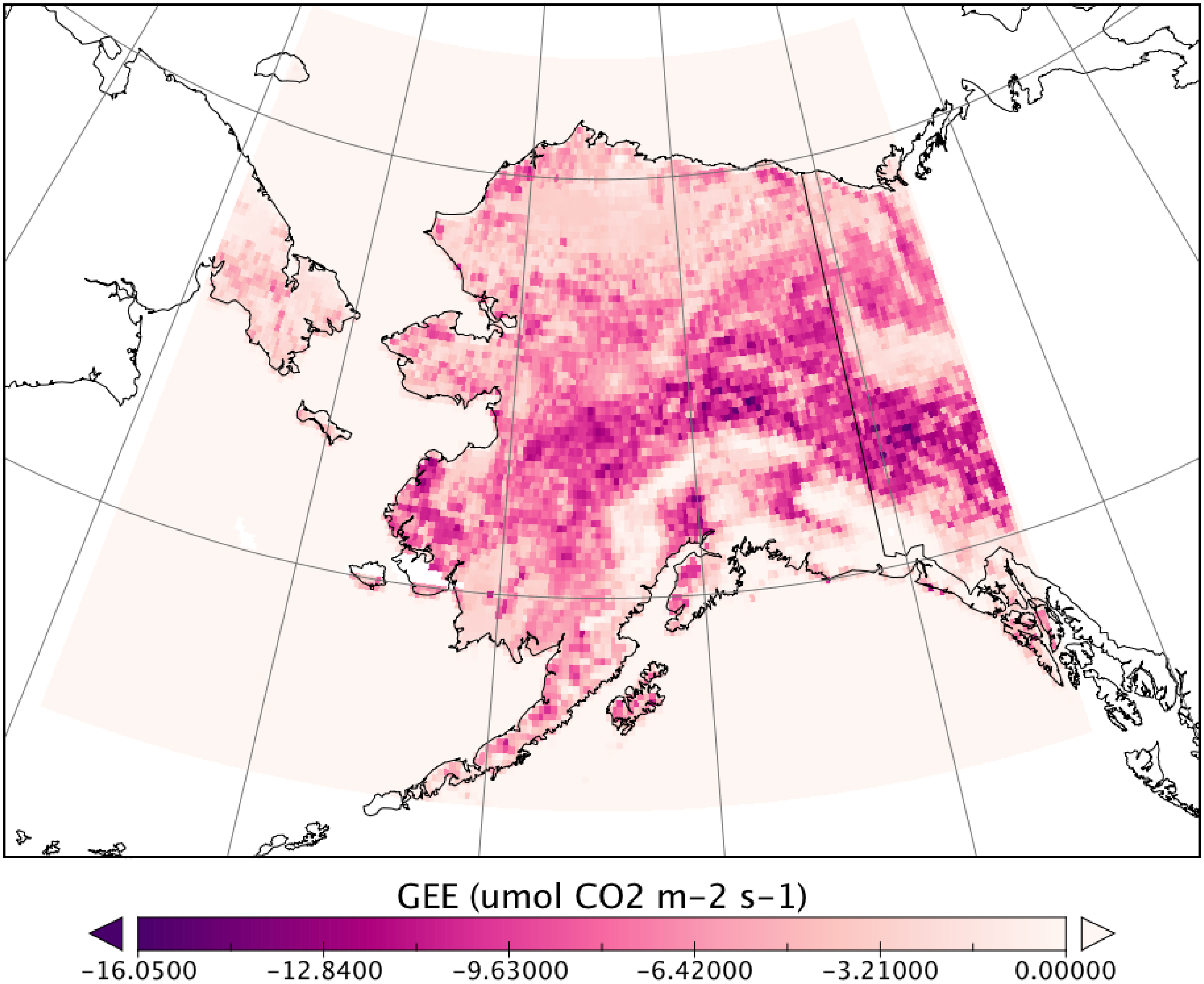

Figure 1. Gross ecosystem CO2 exchange (GEE) calculated using MODIS Enhanced Vegetation Index for 21:00 UTC, August 2, 2013. GEE typical of a mid-summer day.

Citation

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1. Data Set Overview

This data set includes 3-hourly estimates of gross ecosystem CO2 exchange (GEE) and respiration (autotrophic and heterotrophic) at 1/4-degree (longitude) by 1/6-degree (latitude) pixel resolution (~1 km^2; latitude dependent) for the state of Alaska from 2012 to 2014. The data were generated using the Polar Vegetation Photosynthesis and Respiration Model (PolarVPRM), a formulation of the Vegetation Photosynthesis and Respiration Model (VPRM;

Mahadevan et al., 2008) that uses polar-specific vegetation classes to account for high-latitude influences on GEE.

Meteorological inputs are taken from the North American regional re-analysis (NARR), and inputs of fractional snow cover and land surface water index (LSWI) from the Moderate Resolution Imaging Spectroradiometer (MODIS). Land surface greenness is factored into the model from one of three sources: 1) Enhanced Vegetation Index (EVI) from MODIS; 2) Solar Induced Florescence (SIF) from the Orbiting Carbon Observatory 2 (OCO-2); or, 3) SIF from the Global Ozone Monitoring Experiment 2 (GOME-2). Three different estimates of GEE are included in the data set, one for each source of greenness observations.

This project was partially funded by the National Science and Engineering Research Council (NSERC) through the Vanier Canada Graduate Scholarship.

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 Publication:

Luus, K.A., R. Commane, N.C. Parazoo, J. S. Benmergui, S. E. Euskirchen, C. Frankenberg, J. Joiner, J. Lindaas, C.E. Miller, W.C. Oechel, D. Zona, S. Wofsy, and J.C. Lin. 2017. Tundra photosynthesis captured by satellite-observed solar-induced chlorophyll fluorescence. Geophysical Research Letters. http://dx.doi.org/10.1002/2016GL070842

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This project was partially funded by the National Science and Engineering Research Council (NSERC) through the Vanier Canada Graduate Scholarship.

2. Data Characteristics

Spatial Coverage: Alaska

Spatial Resolution: 1/4-degree longitude by 1/6-degree latitude pixel resolution

Temporal Coverage: The data covers the period 20120101 to 20141231.

Temporal Resolution: 3-hourly

Spatial Extent: All latitudes and longitudes given in decimal degrees

Site (Region)	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
Alaska	-179	-134	73	55

Data File Information:

There are 36 data files in NetCDF v3 format (.nc), each containing the 3-hourly GEE and respiration estimates for a single month between 2012 and 2014. The number of days in the month represented by a given NetCDF determines the number of timestamps contained within the file [e.g. January has 31 days; (31 days x 24 hours) / 3-hourly_timestamp_interval = 248 timestamps].

File naming convention:

PolarVPRM-AlaskanNEE-3hrly-YYYY-MM.nc

Where: YYYY-MM indicates the year and month represented by the data.

Variable names and decsription:

All GEE and respiration CO_2 quantities are in micromoles per square meter per second (µmol/m^2/second).

Variable Name	Units	Description
dayOfMonth		Day of month
dayOfYearFrac		Fractional day of year

Feedback

GEE_GOME2_SIF	μmol/m^2/second	Gross Ecosystem CO2 Exchange= -1*GPP, calculated using GOME-2 SIF. Negative GEE indicates carbon uptake by vegetation.
GEE_MODIS_EVI	μmol/m^2/second	Gross Ecosystem CO2 Exchange= -1*GPP, calculated using MODIS EVI. Negative GEE indicates carbon uptake by vegetation.
GEE_OCO2_SIF	μmol/m^2/second	Gross Ecosystem CO2 Exchange= -1*GPP, calculated using OCO-2 SIF. Negative GEE indicates carbon uptake by vegetation.
hour		Starting time of the timestep (3-hourly, UTC)
latitude	decimal degrees	Latitude
longitude	decimal degrees	Longitude
RESP	umol/m^2/second	Respiration CO2= Autotrophic + Heterotrophic respitration
tstep		Timestep
vegclasses		Eight (8) vegetation classes: 1) evergreen forest; 2) deciduous forest; 3) mixed forest; 4) shrubs; 5) graminoid tundra; 6) shrub tundra; 7) wetland; and 8) water. Aggregated from the Circumpolar Arctic Vegetation Map (CAVM; Walker et al., 2005; 2016) & Synergistic Land Cover Product (SYNMAP; Jung et al., 2006):
VEGF	%	Fractional cover by 8 vegetation classes as aggregated from the Circumpolar Arctic Vegetation Map (CAVM; Walker et al., 2016) & Synergistic Land Cover Product (SYNMAP; Jung et al., 2006)

3. Application and Derivation

The data can be used to calculate 3-hourly estimates of net ecosystem exchange (NEE) of CO_2 as the sum of respiration and GEE. Examining trends in NEE and its drivers may provide insights into how the North American high-latitude carbon cycle responds to changing environmental conditions. For example, analysis of model output by PolarVPRM for the period from 2001-2012 indicated that warming air temperatures and drought stress in forests increased growing season rates of respiration, and decreased rates of net carbon uptake by vegetation when air temperatures exceeded optimal temperatures for photosynthesis. Concurrent increases in growing season length at Arctic tundra sites allowed for increases in photosynthetic uptake over time by tundra vegetation. PolarVPRM estimated that the North American high-latitude region changed from a carbon source (2001-2004) to a carbon sink (2005-2010) and again to a source (2011-2012) in response to changing environmental conditions (Luus et al, 2017).

Data produced by the PolarVPRM is also currently being used to scale up circumpolar eddy co-variance observations of NEE, and as *a priori* estimates of Alaskan NEE for Lagrangian modeling of aircraft CO_2 concentration observations as part of the CARVE project.

4. Quality Assessment

A comprehensive error analysis of PolarVPRM was conducted using a first-order Taylor expansion based approach (Lin et al., 2011). The model was validated against eddy co-variance (EC) observations from nine North American sites, of which three were used in model calibration. Comparison of NEE from PolarVPRM and three other models to NEE from EC observations indicated that PolarVPRM displayed the strongest statistical agreement. Details of the uncertainty analysis are presented in Luus et al. (2017).

5. Data Acquisition, Materials, and Methods

The PolarVPRM presents a high-latitude formulation of the Vegetation Photosynthesis and Respiration Model (VPRM; Mahadevan et al., 2008) that uses remote sensing observations to calculate terrestrial biospheric carbon exchange, net ecosystem exchange (*NEE*), as the sum of respiration (*R*) and gross ecosystem exchange (*GEE*):

$NEE = GEE + R$

Gross ecosystem exchange

GEE, the photosynthetic uptake of carbon by vegetation, is calculated according to remote sensing-based estimates of incoming shortwave radiation (SW), air temperature (T_{air}), land surface water index (*LSWI*), and estimates of the fraction of photosynthetically active radiation absorbed by photosynthetically active vegetation ($FAPAR_{PAV}$). SW is expressed as photosynthetically active radiation (*PAR***),** where *PAR* = 1.98 x SW (Lin et al., 2011). *LSWI* is derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) surface reflectance product (MOD09). $FAPAR_{PAV}$ is estimated from the MODIS Enhanced Vegetation Index (EVI; MOD13).

GEE is limited during snow season when EVI is decreased and when air temperatures are sub-optimal. These limits are implemented through the use of dimensionless scaling variables T_{scale} and P_{scale}. *LSWI* is also implemented as a limitation on *GEE* (W_{scale}) for forested regions north of 55°N.

$P_{scale} = (1 + LSWI) / 2$

$W_{scale} = (1 + LSWI) / (1 + LSWI_{max})$

$T_{scale} = (T_{air} – T_{min})(T_{air} – T_{max}) / ((T_{air} – T_{min})(T_{air} – T_{max}) – (T_{air} – T_{opt})^2)$

$GEE = -1 * (\lambda * T_{scale} * W_{scale} * P_{scale}) * FAPAR_{PAV} * (1 / (1 + (PAR / PAR_0))) * PAR$

- λ refers to the theoretical maximum light-use efficiency at low-light levels, but functions in practice as a combined light-use efficiency and scaling parameter.
- PAR_0 is the half-saturation value of *PAR*.
- For all vegetation classes, T_{max} = 40°C and T_{min} = 0°C. For non-arctic vegetation classes, T_{opt} = 20°C. For barren/wetland regions, T_{opt} = 10°C; and over shrub tundra and graminoid tundra, T_{opt} = 15°C.
- $LSWI_{max}$ refers to the maximum annual pixel-specific *LSWI*.

Respiration

During growing season, respiration (*R*) is more heavily influenced by above-ground than below-ground temperatures. So, PolarVPRM simulates *R* as a function of air temperature.

The snow and growing seasons are defined according to MODIS observations of fractional snow cover area (*SCA*). Snow season (*SCA* ≥ 50%) respiration is calculated as linear function of soil temperature, and growing season respiration (*SCA* < 50%) is calculated as a piecewise linear function of air temperature:

When $SCA < 50\%$, $R = \alpha * T_{air} + \beta$, and, when $SCA \geq 50\%$, $R = \alpha * T_{soil} + \beta$.

Regression coefficients α and β describe the linear association between growing season respiration and air temperature.

For more information and detailed model description see Luus et al. (2017).

6. Data Access

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

CARVE Modeled Gross Ecosystem CO2 Exchange and Respiration, Alaska, 2012-2014

Contact for Data Center Access Information:

- E-mail: uso@daac.ornl.gov
- Telephone: +1 (865) 241-3952

7. References

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