ABoVE: TVPRM Simulated Net Ecosystem Exchange, Alaskan North Slope, 2008-2017

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Documentation Revision Date: 2022-03-17

Dataset Version: 1

Summary

This dataset includes hourly net ecosystem exchange (NEE) simulated by the Tundra Vegetation Photosynthesis and Respiration Model (TVPRM) at 30 km horizontal resolution for the Alaskan North Slope for 2008-2017. TVPRM calculates tundra NEE from air temperature, soil temperature, photosynthetically active radiation (PAR), and solar-induced chlorophyll fluorescence (SIF) using functional relationships derived from eddy covariance tower measurements. These relationships were then scaled over the region using gridded meteorology and a vegetation map. The site-level CO2 fluxes fell into two distinct ecosystem groups: inland tundra (ICS, ICT, ICH, IVO) and coastal tundra (ATQ, BES, BEO, CMDL). The expanded modeling framework allowed for the easy substitution of ecological behaviors and environmental drivers, including the choice of representative inland tundra site, coastal tundra site, vegetation map (CAVM, RasterCAVM, or ABoVE-LC), meteorological reanalysis product (NARR or ERA5), and SIF product (GOME2, GOSIF, or CSIF). Using all of these variations generated an ensemble of 288 different TVPRM simulations of regional CO2 flux and one additional simulation option with added aquatic and zero curtain fluxes (AqZC).

To simulate CO_2 fluxes for tundra ecosystems at 30 km by 30 km and hourly resolution, eddy flux tower observations were scaled up using a variety of temperature and light response behaviors and environmental drivers. The ensemble of CO_2 fluxes were evaluated using aircraft and tower measurements of CO_2 concentration to determine which of these behaviors and drivers best represent the North Slope. In TVPRM, the simulated hourly CO_2 fluxes are primarily controlled by light and heat: GPP is controlled by air temperature (Ta) and photosynthetically active radiation (PAR), with SIF used to define the seasonal cycle of photosynthetic capacity; plant respiration is controlled by air temperature (Ta); and soil respiration is controlled by near-surface soil temperature (Ts). NEE is the sum of these fluxes.

There are 2,890 data files in NetCDF version 4 (*.nc4) format included in this dataset and a companion file in R script (*.R) format.

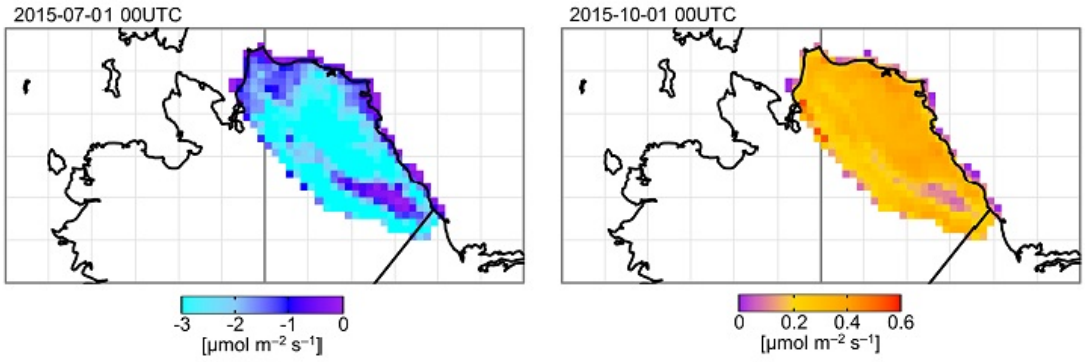

Figure 1. TVPRM net ecosystem exchange: Surface upward mass flux of carbon dioxide expressed as carbon due to emissions from natural sources for 2015-07-01 (left) and 2015-10-01 (right). The data were derived from the TVPRM model for 2015 that used "IVO" as the inland site, Barrow "CMDL" as the coastal site, "RasterCAVM" as the vegetation map, "NARR" as the meteorological product, and "GOME2" as the SIF product (as described by the source file name). Source: TVPRM_IVO_CMDL_RasterCAVM_NARR_GOME2_2015.nc4

Citation

Schiferl, L., and R. Commane. 2022. ABoVE: TVPRM Simulated Net Ecosystem Exchange, Alaskan North Slope, 2008-2017. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1920

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1. Dataset Overview

This dataset includes hourly net ecosystem exchange (NEE) simulated by the Tundra Vegetation Photosynthesis and Respiration Model (TVPRM) at 30 km horizontal resolution for the Alaskan North Slope for 2008–2017. TVPRM calculates tundra NEE from air temperature, soil temperature, photosynthetically active radiation (PAR), and solar-induced chlorophyll fluorescence (SIF) using functional relationships derived from eddy covariance tower measurements. These relationships were then scaled over the region using gridded meteorology and a vegetation map. The site-level CO_2 fluxes fell into two distinct ecosystem groups: inland tundra (ICS, ICT, ICH, IVO) and coastal tundra (ATQ, BES, BEO, CMDL). The expanded modeling framework allowed for the easy substitution of ecological behaviors and environmental drivers, including the choice of representative inland tundra site, coastal tundra site, vegetation map (CAVM, RasterCAVM, or ABoVE-LC), meteorological reanalysis product (NARR or ERA5), and SIF product (GOME2, GOSIF, or CSIF). Using all of these variations generated an ensemble of 288 different TVPRM simulations of regional CO_2 flux and one additional simulation option with added aquatic and zero curtain fluxes (AqZC).

To simulate CO_2 fluxes for tundra ecosystems at 30 km by 30 km and hourly resolution, eddy flux tower observations were scaled up using a variety of temperature and light response behaviors and environmental drivers. The ensemble of CO_2 fluxes were evaluated using aircraft and tower measurements of CO_2 concentration to determine which of these behaviors and drivers best represent the North Slope. In TVPRM, the simulated hourly CO_2 fluxes are primarily controlled by light and heat: GPP is controlled by air temperature (Ta) and photosynthetically active radiation (PAR), with SIF used to define the seasonal cycle of photosynthetic capacity; plant respiration is controlled by air temperature (Ta); and soil respiration is controlled by near-surface soil temperature (Ts). NEE is the sum of these fluxes.

Project: Arctic-Boreal Vulnerability Experiment

The Arctic-Boreal Vulnerability Experiment (ABoVE) is a NASA Terrestrial Ecology Program field campaign being conducted in Alaska and western Canada, for 8 to 10 years, starting in 2015. Research for ABoVE links field-based, process-level studies with geospatial data products derived from airborne and satellite sensors, providing a foundation for improving the analysis, and modeling capabilities needed to understand and predict ecosystem responses to, and societal implications of, climate change in the Arctic and Boreal regions.

Related Publication

Schiferl, L. D., J. D. Watts, E. J. L. Larson, K. A. Arndt, S. C. Biraud, E. S. Euskirchen, J. M. Henderson, K. McKain, M. E. Mountain, J. W. Munger, W. C. Oechel, C. Sweeney, Y. Yi, D. Zona, and R. Commane. 2022. Multi-scale observations indicate unfrozen soils and inland waters drive dormant season carbon dioxide losses across the Alaska North Slope. In process.

Acknowledgments

This work was funded by NASA's ABoVE program (grant NNX17AC61A).

2. Data Characteristics

Spatial Coverage: Alaska's North Slope, U.S.

> **ABoVE Reference Locations**
>
> Domain: Core
>
> State/Territory: Alaska
>
> Grid cells: Ah000v000 and Ah001v00

Spatial Resolution: 30 km

Temporal Coverage: 2008-01-01 to 2017-12-31

Temporal Resolution: Hourly

Site Boundaries: Latitude and longitude are given in decimal degrees.

Site	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
Alaska's North Slope	-177.4690	-128.5915	77.2626	56.0894

Data File Information

There are 2,890 data files in NetCDF version 4 (*.nc4) format included in this dataset; one file per year for the period 2008–2017 containing hourly NEE data. Also included is the companion file TVPRM_NEE_read_plot.R, which is an R script describing how to read and plot the data from the data files. The data files are an ensemble of ecological behaviors and environmental drivers, including the choice of representative inland tundra site, coastal tundra site, meteorological reanalysis product (NARR or ERA5), vegetation map (CAVM, RasterCAVM, or ABoVE-LC), and SIF product (GOME2, GOSIF, or CSIF), which generated 288 different TVPRM simulations of regional CO_2 flux. An additional simulation option using aquatic and zero curtain fluxes (AqZC) was also provided.

2,880 data files are named TVPRM_<inlandsite>_<coastalsite>_<vegmap>_<met>_<SIF>_YYYY.nc4 and 10 data files are named TVPRM_IVO_CMDL_ABoVE-LC_NARR_CSIF_AqZC_YYYY.nc4, where

- <inlandsite> is the inland site: ICS, ICT, ICH, IVO (Table 2),
- <coastalsite> is the coastal site: ATQ, BES, BEO, CMDL (Table 2),
- <vegmap> is the vegetation map: CAVM, RasterCAVM, ABoVE-LC (Table 3),
- <met> is the meteorological product: NARR, ERA5 (Table 4),
- <SIF> is the SIF products: GOME2, GOSIF, CSIF (Table 5), and
- YYYY is the year: 2008-2017.

Data File Details

Missing values are represented by -9999. The Coordinate Reference System is “Canada Albers Equal Area Conic” (ESRI:102001). The proj.4 string is "+proj=aea +lat_1=50 +lat_2=70 +lat_0=40 +lon_0=-96 +x_0=0 +y_0=0 +ellps=GRS80 +units=m +no_defs".

Table 1. Variable names and descriptions.

Variable	Units	Description
NEE	umol m-2 s-1	net ecosystem exchange; surface upward mass flux of carbon dioxide expressed as carbon due to emission from natural sources

lat	degrees_north	latitude
lon	degrees_east	longitude
time_bnds	hours since 2008-01-01 00:00:00	time bounds; start and end time for each timestamp
time	hours since 2008-01-01 00:00:00	middle of each hour
crs		coordinate reference system or projection; albers conical equal area
x	m	x coordinate of projection
y	m	y coordinate of projection

Table 2. Site names and descriptions.

Site ID	Name	Ecosystem	TVPRM Group	Vegetation
ATQ	Atqasuk	Wet polygonized tundra	coastal	Water sedge, dwarf shrub
BES	Barrow Biocomplexity Experiment, South	Wetland tundra	coastal	Sedge, moss
BEO	Barrow Environmental Observatory	Wet polygonized tundra	coastal	Graminoid grass, sedge
CMDL	Barrow Climate Monitoring and Diagnostics Laboratory	Moist tundra	coastal	Graminoid grass, lichen
IVO	Ivotuk	Tussock tundra	inland	Tussock-forming sedge, moss
ICS	Imnavait Creek Wet Sedge	Wet sedge tundra	inland	Water sedge, dwarf deciduous shrub, moss
ICH	Imnavait Creek Heath Tundra	Dry heath tundra	inland	Dwarf evergreen shrub, deciduous shrub, lichen
ICT	Imnavait Creek Tussock Tundra	Moist acidic tussock tundra	inland	Tussock-forming sedge, deciduous dwarf shrub, evergreen dwarf shrub

Table 3. Vegetation map names and descriptions.

Vegetation Map ID	Map Name	Map Resolution	Year	Map Classification Details
CAVM	Circumpolar Arctic Vegetation Map	14 km polygons, 8 km linear features	satellite data from 1993 and 1995, developed in 2003	15 classification units based on plant growth forms, roughly separated by summer temperature and soil moisture. Polygon classification from a combination of satellite, vegetation, temperature, topographic, and geologic data.
RasterCAVM	Raster version of CAVM	1 km spatial	satellite data as in CAVM, additional data from 2000–2009	Classification as in CAVM, redistributed at a higher resolution based on unsupervised classification using satellite and elevation data.
ABoVE-LC	Landsat-derived Annual Dominant Land Cover across ABoVE Core Domain	30 m spatial	2014	15 classification units based on semi-supervised classification using satellite, climate, and topographic data.

Table 4. Meteorology product and descriptions.

Met ID	Product Name	Product Resolution	Product Variable used in TVPRM		
			Air Temperature (Ta)	Near-surface Soil Temp. (Ts)	PAR
NARR	NOAA North American Regional Reanalysis	~30 km spatial, 3 hourly temporal	air.2m	tsoil (10 cm)	dswrf
ERA5	ECMWF Reanalysis, fifth generation	~31 km spatial, hourly temporal	t2m	stl2 (7–28 cm)	ssrd

Table 5. SIF product names and descriptions.

SIF ID	Product Name	Product Resolution	Product Details
GOME-2	Interpolated GOME-2 SIF (created for this study) [GOME-2: Global Ozone Monitoring Experiment- 2]	0.01° latitudinal, daily temporal	Discrete GOME-2 SIF v27 retrievals, normalized by solar zenith angle, averaged by center point into overlapping 0.5° latitudinal bins across the North Slope domain. Temporal interpolation within each bin and latitudinal interpolation across bins are applied using loess fit smoothing.
	Global 'OCO-2'		

GOSIF	SIF [OCO-2: Orbiting Carbon Observatory-2]	0.05° spatial, 8 day temporal	Aggregated OCO-2 soundings combined with MODIS enhanced vegetation index and MERRA-2 PAR, vapor pressure deficit, and air temperature to create a higher resolution gridded SIF product using multivariate linear regression.
CSIF	Contiguous SIF	0.05° spatial, 4 day temporal	Aggregated OCO-2 soundings combined with MODIS surface reflectance to create a higher resolution gridded SIF product using a neural network.

3. Application and Derivation

Each TVPRM configuration is a combination of tundra ecosystem behaviors and scaling drivers with the potential to represent the spatially and temporally varying Alaskan North Slope NEE. This dataset presents results from all configuration options given the assumption that tundra ecosystems behave as observed at a particular eddy flux site and can be extrapolated in space and time using particular scaling drivers.

4. Quality Assessment

The multiple configuration options available represent the uncertainty and variability in quantifying the North Slope NEE based on various ecological function relationships and scaling assumptions.

5. Data Acquisition, Materials, and Methods

The Tundra Vegetation Photosynthesis and Respiration Model (TVPRM) was developed to simulate CO_2 fluxes in the Alaskan North Slope tundra. In TVPRM, the simulated hourly CO_2 fluxes are primarily controlled by light and heat: Gross primary production (GPP) is controlled by air temperature (Ta) and photosynthetically active radiation (PAR), with solar-induced fluorescence (SIF) used to define the seasonal cycle of photosynthetic capacity; plant respiration is controlled by air temperature (Ta); and soil respiration is controlled by near-surface soil temperature (Ts). Net ecosystem exchange (NEE) is the sum of these fluxes. Parameter values (αs, βs, αa, βa, λ, PAR0) for the relationships used by TVPRM are determined using year-round eddy covariance flux tower observations of CO_2 flux from eight sites in various tundra ecosystems throughout the North Slope.

The site-level CO_2 fluxes fell into two distinct ecosystem groups: inland tundra (ICS, ICT, ICH, IVO) and coastal tundra (ATQ, BES, BEO, CMDL; Table 2). The expanded modeling framework allowed for the easy substitution of ecological behaviors and environmental drivers, including the choice of representative inland tundra site, coastal tundra site, vegetation map (CAVM, RasterCAVM, or ABoVE-LC; Table 3), meteorological reanalysis product (NARR or ERA5; Table 4), and SIF product (GOME2, GOSIF, or CSIF; Table 5). Notable changes since the CARVE Polar Vegetation Photosynthesis and Respiration Model (PVPRM) include the use of additional site-years of CO_2 flux observations (with increased data coverage over winter), more inclusive data filtering methods, and much higher temporal and spatial resolution SIF datasets.

Determining Variable Parameters Using Observed NEE

The variable parameters (αs, βs, αa, βa, λ, PAR0) were calculated for each 365-day period using a moving window (i.e., day 1=365, day 2=366, day 3=367, etc.) The moving window method accounted for variability in both day-to-day data availability and year-to-year ecosystem response to environmental drivers. The NEE in the dataset used one set of parameters for each "met+SIF" combination. The median value for each variable parameter from the set of valid 365-day periods was used in the site-level NEE evaluation and regional scaling as follows:

1. Linear regression of observed NEE against Ts to determine αs and βs and calculate Rsoil.
2. Linear regression of observed NEE against Ta to determine αa and βa and calculate Rplant.
3. Nonlinear fitting of observed NEE against PAR, SIF, and Ta to determine λ and PAR0 and calculate GPP.

Each 365-day period must have had valid data (i.e., observed NEE, reanalyzed Ta, Ts, and PAR, and derived SIF) for 70% of potential growing days and 50% of potential non-growing days in order to calculate variable parameters. This requirement most often failed because of gaps in observed NEE. To mitigate unrealistic observed non-growing season uptake outside of noise prior to Step 1, non-growing season half-hourly observed NEE values during 24-hour periods were removed when 50% of half-hours have observed NEE and both 50% and the mean of those observed NEE values were negative. For each step, data were removed when NEE values were outside of three standard deviations of the mean.

The eddy flux data used to determine the parameters was available only for 2013–2017. It was assumed that the data were constant for the time period of 2008–2017.

Table 6. Sources of flux observations, meteorology, SIF data, and vegetation maps.

Data Type	Source
ICS, ICT, and ICH eddy flux tower observations	http://aon.iab.uaf.edu/data
IVO, ATQ, BES, BEO, and CMDL eddy flux tower observations	https://doi.org/10.18739/A2X34MS1B
NARR meteorology	https://psl.noaa.gov/data/gridded/data.narr.html
ERA5 meteorology	https://www.ecmwf.int/en/forecasts/dataset/ecmwf-reanalysis-v5
GOME-2 SIF	https://avdc.gsfc.nasa.gov/pub/data/satellite/MetOp/GOME_F/
GOSIF	https://globalecology.unh.edu/data/GOSIF.html
CSIF	https://figshare.com/articles/dataset/CSIF/6387494
CAVM vegetation map	https://www.geobotany.uaf.edu/cavm/
RasterCAVM vegetation map	https://doi.org/10.17632/c4xj5rv6kv.1
ABoVE-LC vegetation map	https://doi.org/10.3334/ORNLDAAC/1691

6. Data Access

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

ABoVE: TVPRM Simulated Net Ecosystem Exchange, Alaskan North Slope, 2008-2017

Contact for Data Center Access Information:

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- Telephone: +1 (865) 241-3952

7. References

Schiferl, L. D., J. D. Watts, E. J. L. Larson, K. A. Arndt, S. C. Biraud, E. S. Euskirchen, J. M. Henderson, K. McKain, M. E. Mountain, J. W. Munger, W. C. Oechel, C. Sweeney, Y. Yi, D. Zona, and R. Commane. 2022. Multi-scale observations indicate unfrozen soils and inland waters drive dormant season carbon dioxide losses across the Alaska North Slope. In process.