The ABCflux Database: Arctic-Boreal CO2 Flux and Site Environmental Data, 1989-2020

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Documentation Revision Date: 2021-11-23

Dataset Version: 1

Summary

This Arctic-Boreal CO2 fluxes (ABCflux) dataset contains monthly aggregates of terrestrial net ecosystem CO2 exchange and its derived partitioned component fluxes: gross primary productivity (GPP) and ecosystem respiration. Over 70 supporting variables describe key site conditions (e.g., vegetation and disturbance type), micrometeorological and environmental measurements (e.g., air and soil temperatures), and flux measurement techniques. The data contained in this ABCflux dataset form a standardized monthly database of Arctic-Boreal CO2 fluxes (i.e., ABCflux Database) and include 244 sites and 6,309 monthly observations; 136 sites and 2,217 monthly observations represent tundra, and 108 sites and 4,092 observations represent the boreal biome. The data are for the period 1989 to 2020.

Flux estimates with chamber (19% of the monthly observations), snow diffusion (3%), and eddy covariance (78%) techniques are included. The largest number of observations were collected during the climatological summer (June-August; 32%). Fewer observations were available for autumn (September-October; 25%), winter (December-February; 18%), and spring (March-May; 25%).

There is one data file in comma-separated value (*.csv) format included in this dataset.

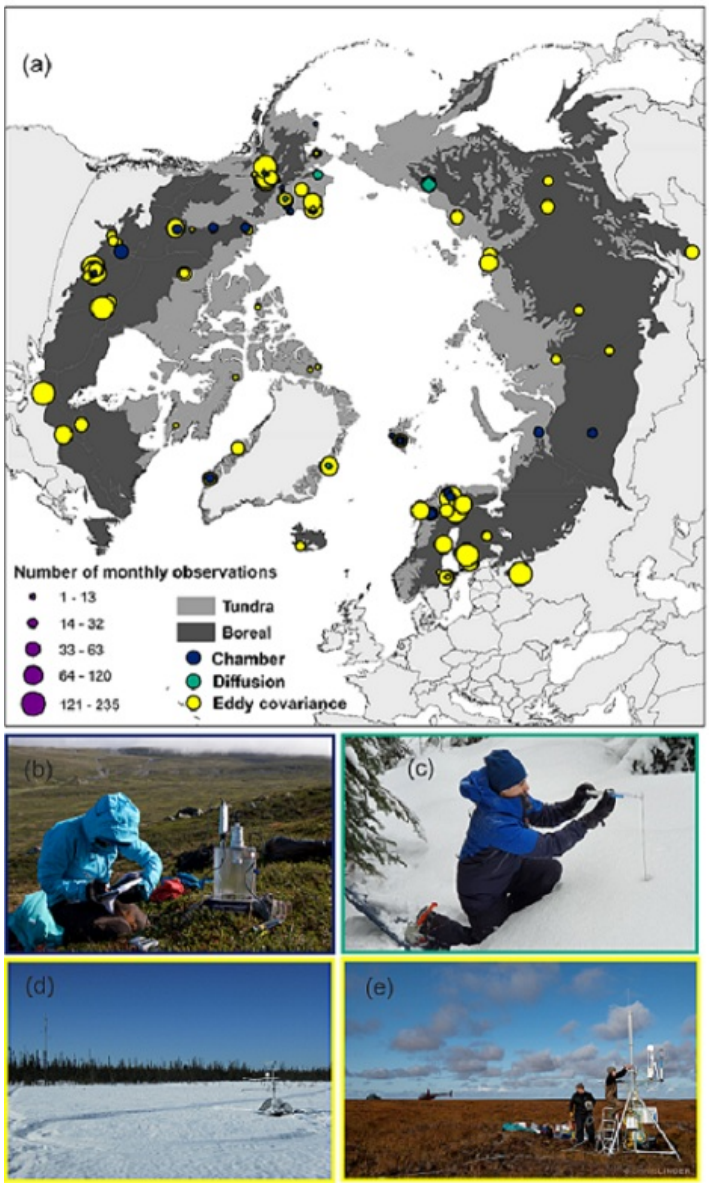

Figure 1. Map showing the distribution and measurement technique at each site (a), and examples of a manual chamber (b), diffusion measurements (c), and two eddy covariance towers in a wetland-forest and tundra ecosystem (d-e). Photographs were taken in Kilpisjärvi, Finland (July 2016), Montmorency forest, Canada (April 2021), Scotty Creek, Canada (April, 2014), and Yukon-Kuskokwim Delta, Alaska (September 2019). Image credits to: Markus Jylhä, Alex Mavrovic, Gabriel Hould Gosselin, Chris Linder, Manuel Helbig.

Citation

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Table of Contents

1. Dataset Overview

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Project: Arctic-Boreal Vulnerability Experiment

The Arctic-Boreal Vulnerability Experiment (ABoVE) is a NASA Terrestrial Ecology Program field campaign based in Alaska and western Canada between 2016 and 2021. 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 and societal implications.

Related Publication

Virkkala, A-M., S. Natali, B.M. Rogers, J.A. Watts, K. Savage, S.J. Connon, M.E. Mauritz-Tozer, T. Schuur, D.L. Peter, C. Minions, J. Nojeim, R. Commane, C.A. Emmerton, M. Goeckede, M. Helbig, D. Holl, H. Iwata, H. Kobayashi, P. Kolari, E. Lopez-Blanco, M.E. Marushchak, M. Mastepanov, L. Merbold, M. Peichl, O. Sonnentag, T. Sachs, M. Ueyama, C. Voigt, M. Aurela, J. Boike, G. Celis, N. Chae, T. Christensen, S. Bret-Harte, S. Dengel, H. Dolman, C. Edgar, B. Elberling, S.E. Euskirchen, A. Grelle, J. Hatakka, E.R. Humphreys, J. Jaerveoja, A. Kotani, L. Kutzbach, T. Laurila, A. Lohila, I. Mammarella, Y. Matsuura, G. Meyer, M.B. Nilsson, S.F. Oberbauer, S.J. Park, F.J.W. Parmentier, R. Petrov, A.S. Prokushkin, S. Zyrianov, C. Schulze, V.L. St.louis, E.S. Tuittila, J.P. Tuovinen, W. Quinton, A. Varlagin, D. Zona, and V.I. Zyryanov. 2021. The ABC flux database: Arctic-Boreal CO_2 flux observations and ancillary information aggregated to monthly time steps across terrestrial ecosystems Earth System Science Data: In review. https://doi.org/10.5194/essd-2021-233

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2. Data Characteristics

Spatial Coverage: Arctic boreal sites in Alaska, Canada, Finland, Greenland, Iceland, Mongolia, Norway, Russia, and Sweden.

> **ABoVE Reference Locations**
>
> Domain: Core ABoVE
>
> State/Territory: Alaska and Canada
>
> Grid cells (5 m): Ch079v093, Ch076v096, Ch024v013, Ch093v101, Ch048v021, Ch036v033, Ch089v059, Ch165v028, Ch039v032, Ch051v020, Ch053v017, Ch050v018, Ch048v020, Ch108v096, Ch108v095, Ch107v095, Ch105v093, Ch091v102, Ch050v007, Ch050v020, Ch052v019, Ch069v067, Ch099v023, Ch211v004, Ch041v032, Ch040v032, Ch051v019, Ch043v023, Ch042v030, Ch045v023, Ch040v028, Ch041v026, Ch047v022, Ch049v020, Ch052v018, Ch046v022, Ch094v102, Ch049v007, Ch156v057, Ch133v030, Ch011v017, Ch179v042, Ch164v110, Ch147v121, Ch048v019, Ch046v008, Ch040v029, Ch042v032, Ch092v099, Ch092v100, Ch091v101, Ch095v105, Ch069v059, Ch065v034, Ch083v090, Ch070v066, Ch064v035, Ch067v050, Ch159v102, Ch034v010, Ch078v095, Ch040v038, Ch040v037, Ch038v033, Ch042v015

Spatial Resolution: Point measurements

Temporal Coverage: 1989-12-01 to 2020-09-30

Temporal Resolution: Monthly

Study Area: All latitude and longitude are given in decimal degrees

Site	Northern Extent	Southern Extent	Eastern Extent	Western Extent
Arctic boreal sites	82.82255	48.2167	161.55	-165.62

Data file information

There is one data file in comma-separated value (*.csv) format included in this dataset. The data span from 1989 to 2020 and provide monthly aggregates, which are not actual raw observations. *GPP* and *Reco* are indirectly derived variables at eddy-covariance sites, and some flux and ancillary data can also be partly gap-filled. Positive values for NEE indicate net CO_2 loss to the atmosphere (i.e., CO_2 source) and negative numbers indicate net CO_2 uptake by the ecosystem (i.e., CO_2 sink). For consistency, *GPP* is presented as negative (uptake) values and *Reco* as positive.

Data File Details

Missing data are represented as -9999 or NA.

Table 1. Variables names and descriptions.

Variable	Units/format	Description
id		ID given to each individual monthly entry at each site
study_id		ID given to study/site entry. (PI/first author of publication)_(site name)_(tower/chamber)_(#); Eg., Schuur_EML_Tower_1. Note that there might be several chamber (or tower) Study_IDs for one site.
study_id_short		ID given to study/site entry (see details), individual chamber plots within a site not differentiated. (PI/first author of publication)_(site name)_(tower/chamber)_(#); Eg., Schuur_EML_Tower_1.
site_name		Site name as specified in data source
site_reference		A more specific name used in data source
country		Country of the study site
latitude	decimal degrees	Latitude of study site
longitude	decimal degrees	Longitude of study site
	YYYY-MM-	

start_date	DD	Start day of the measurement
end_date	YYYY-MM-DD	End day of the measurement
meas_year	YYYY	Year in which data were recorded
season		Season in which data were recorded
interval_month		Measurement month
start_day		Start day of the measurement
end_day		End day of the measurement
duration		Number of days during the measurement month
biome		Biome of the study site
veg_type		A detailed vegetation type for the study site
veg_type_short		A more general vegetation type for the site
veg_detail		Detailed vegetation description from data source/contributor
permafrost		Reported presence or absence of permafrost
disturbance		Last disturbance
disturb_year	YYYY	Year of last disturbance
disturb_severity		Relative severity of disturbance
soil_moisture_class		General descriptor of site moisture
site_activity		Describes whether the site is currently active (i.e., measurements conducted each year)
nee	g C m-2 month-1	Net ecosystem exchange (NEE) for the entire measurement interval in g C in CO_2
gpp	g C m-2 month-1	Gross primary productivity (GPP) for the entire measurement interval in g C in CO_2. Note: GPP is presented as negative (uptake) values.
reco	g C m-2 month-1	Ecosystem respiration (Reco)for the entire measurement interval in g C in CO_2
ground_nee	g C m-2 month-1	Forest floor net ecosystem exchange, measured with chambers for the entire measurement interval in g C in CO_2
ground_gpp	g C m-2 month-1	Forest floor ecosystem respiration, measured with chambers for the entire measurement interval in g C in CO_2. Note: GPP is presented as negative (uptake) values.
ground_reco	g C m-2 month-1	Forest floor gross primary productivity measured with chambers for the entire measurement interval in g C in CO_2
rsoil	g C m-2 month-1	Soil respiration measured with for the entire measurement interval in g C in CO_2
flux_method		How flux values were measured
flux_method_detail		Details related to how flux values were measured: closed- and open-path eddy covariance, mostly manual chamber measurements, mostly automated chamber measurements, a combination of chamber and cuvette measurements, diffusion measurements through the snowpack, chamber measurements on top of snow
measurement_frequency		Frequency of flux measurements. >100 characterizes high-frequency eddy covariance (and automated chamber) measurements. This is the primary variable that characterizes the frequency and gaps in monthly fluxes estimated with chambers and diffusion techniques.
diurnal_coverage		Times of day covered by flux measurements
spatial_reps_chamber		Number of spatial replicates for the chamber plot
partition_method		Method used to partition NEE into GPP and RECO
gap_fill		Gap filling method
gap_fill_perc	percent	% of nee data that was gap-filled in the measurement interval (relative to standard measurement time step)
tower_qa_qc_nee_flag	1	Overall monthly quality flag for eddy covariance aggregated observations; fraction between 0-1, indicating percentage of measured (quality flag QC = 0 in FLUXNET2015) and good-quality gap-filled data (quality flag QC = 1 in FLUXNET2015); average from daily data; 0=extensive gap-filling, 1=low gap-filling.
tower_qa_qc_source		The source for the overall quality information for the eddy covariance observations
method_error_nee	g m^{-2}	Rmse or other bootstrapped error of model fit for nee or the entire measurement interval, in g C in CO_2
method_error_technique		Technique used to quantify method errors for flux measurements

high_freq_availability		Availability of high-frequency data
aggregation_method		Method used to aggregate data to measurement interval
instrumentation		Description of instrumentation used
tower_version		Version number of the eddy covariance dataset from the extraction source
tower_data_restriction		Tower data restrictions: No, CC by 4.0, Tier 1, or Tier 2
tower_corrections		Details related to processing corrections employed, including time, duration, and thresholds for u* and heat corrections
spatial_variation_technique		Spatial techniques used by researchers, for example, growing seasons, subhabitats, etc.
light_response_method_chamber		Details related to how the varying light response conditions were considered in chamber measurements
par_cutoff	umol par m^{-2} $second^{-1}$	Photosynthetically active radiation (PAR) level used to define night-time data and apply partitioning method
precip_int	mm	Mean precipitation during measurement interval
tair_int	degrees C	Mean air temperature during measurement interval
tsoil	degrees C	Mean soil temperature during measurement interval
soil_moisture	percent	Mean soil moisture during the measurement interval (% by volume)
thaw_depth	cm	Mean thaw depth during the measurement interval
tsoil_depth	cm	Depth of soil temperature measurement below surface
moisture_depth	cm	Depth of soil moisture measurement below surface
alt	cm	Active layer thickness (cm; maximum thaw depth), will change annually
water_table_depth	cm	Mean water table depth during the measurement interval (cm); positive is below the surface, negative is above (inundated)
snow_depth	cm	Mean snow depth during the measurement interval
vapor_pressure_deficit	pa	Mean vapor pressure deficit during the measurement interval
evapotranspiration	mm	Total evapotranspiration during the measurement interval
par	w m^{-2}	Mean photosynthetically active radiation (PAR) during measurement interval
par_ppfd	µmol m2 s	Mean photosynthetically active radiation during measurement interval (measured in photosynthetic photon flux density, ppfd; micromol m-2 s-1)
precip_annual	mm	Mean annual precipitation from site or nearby weather station as a general site descriptor. This should describe the longer-term climate for the site rather than a few years of study
tair_annual	degrees C	Mean annual air temperature from site or nearby weather station as a general site descriptor. This value describes the longer-term climate for the site rather than a few years of study.
t_precip_source_yrs		Data source and years used to calculate mean annual temperature/precipitation
elevation	m	Elevation above sea level
lai		Leaf area index
sol_depth	cm	Soil organic layer depth
soil_perc_carbon	percent	Soil carbon percentage
perc_c_depth	cm	Depth at which soil carbon % was measured
c_density	kg m^{-2}	Soil carbon per unit area
c_density_depth	cm	Depth to which soil organic carbon per unit area was estimated (cm)
agb	kg m^{-2}	Above ground biomass in kg carbon
agb_type		Types of above ground vegetation included in the agb measurement
soil_type		General soil type, including source (e.g., USDA, CSSC, NCSCD)
soil_type_detail		Detailed soil type description, if available
other_data		Other types of data from the data source that may be relevant
notes_site_info		Any other relevant information
notes_time_variant		Any other relevant information
citation		Journal article, data citation, and/or other source (online repository, pi submitted, etc.).
citation_data_overlap		Another citation for the site
data_contributor_or_author		Data contributor(s) or primary author(s) associated with data set or publication

email		Primary author email
orcid		Personal digital identifier: https://orcid.org/
data_availability		Current availability of data: data available in a published paper, in an open online data repository, in an already published synthesis, or user contributed
data_maturity		Current maturity of data
extraction_source		Data source
dataentry_person		The person(s) who added the data to the database

3. Application and Derivation

ABCflux can be used in a wide array of empirical, remote sensing, and modeling studies to improve understanding of the regional and temporal variability in CO_2 fluxes, and to better estimate the terrestrial Arctic Boreal Zone CO_2 budget (Virkkala et al., 2021).

4. Quality Assessment

The data were screened for poor-quality, potential unit and sign convention issues, and inaccurate coordinates. Source data downloaded from different repositories were processed and quality checked using quality flags associated with monthly data supplied by the repository processing pipeline (Virkkala et al., 2021). Note that GPP is sometimes positive because the gap-filling and partitioning approach is based on a model which does not always predict periods with 0 GPP correctly.

5. Data Acquisition, Materials, and Methods

The ABCflux database is a standardized monthly database of compiled *in-situ* measured terrestrial ecosystem-level CO_2 fluxes from sites in the Arctic Boreal Zone (ABZ) aggregated to monthly time periods (g C m^{-2} $month^{-1}$). The database includes 94 variables: 16 are flux measurements and associated metadata (e.g., NEE, measurement date, and duration), 21 describe flux measurement methods (e.g., measurement frequency, gap-filling method), 49 describe site conditions (e.g., soil moisture, air temperature, vegetation type), and 8 describe the extraction source (e.g., primary author or site PI, citation, data maturity). Sixty-one variables are considered static and thus do not vary with repeated measurements at a site (e.g., site name, coordinates, vegetation type), while 33 variables are considered dynamic and vary monthly (e.g., soil temperature). There are 244 sites and 6,309 monthly observations; 136 sites and 2,217 monthly observations represent tundra, and 108 sites and 4092 observations represent the boreal biome. Flux estimates with chamber (19% of the monthly observations), snow diffusion (3%), and eddy covariance (78%) techniques are included. The largest number of observations were collected during the climatological summer (June-August; 32%), and fewer observations were available for autumn (September-October; 25%), winter (December-February; 18%), and spring (March-May; 25 %).

Data sources

Potential CO_2 flux studies and sites from prior synthesis efforts were identified (Belshe et al., 2013; McGuire et al., 2012; Virkkala et al., 2018; Natali et al., 2019; Virkkala et al., 2021), including a search of citations within and of the studies included in these prior syntheses. A literature search was also conducted to ensure that the database included the most recent publications. Studies were included that reported at least NEE, presented at a monthly or finer temporal resolution, and had supporting data describing the sites. Eddy covariance and supporting environmental data products were downloaded from AmeriFlux (Novick et al., 2018), Fluxnet2015 (Pastorello et al., 2020), EuroFlux database cluster (ICOS, Carbon Extreme, Carbo Africa, GHG Europe, Carbo Italy, INGOS) (Paris et al., 2012; Valentini, 2003), and the Station for Measuring Ecosystem-Atmosphere Relations (Hari et al., 2013).

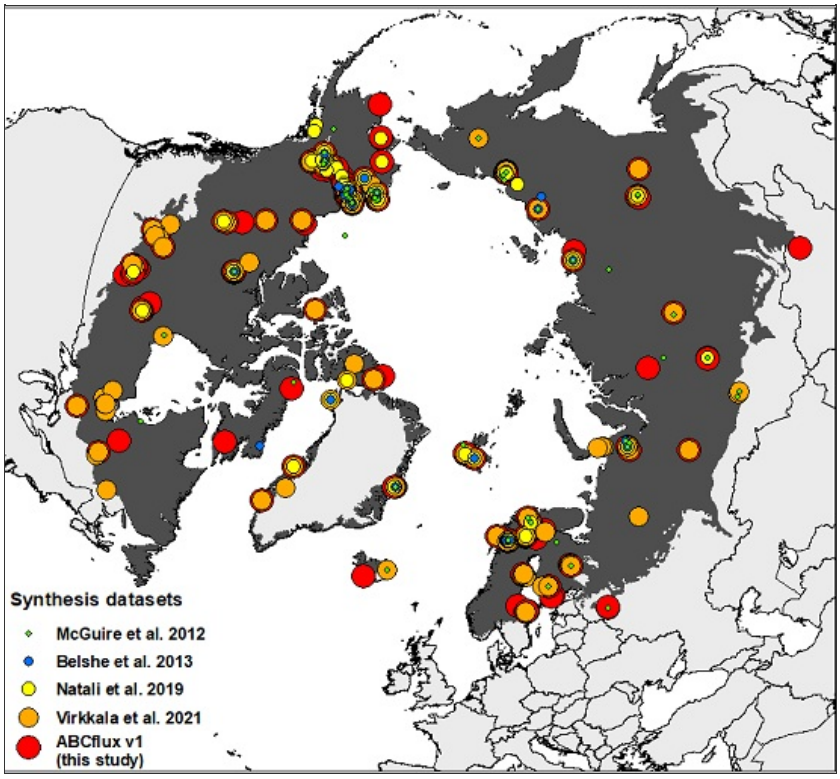

Figure 2. The flux site distribution in syntheses focused on compiling fluxes from high latitudes (McGuire et al. 2012, Belshe et al. 2013, Natali et al. 2019, Virkkala et al. 2021 and this study (ABCflux)). The Arctic-Boreal Zone is highlighted in dark grey; countries are shown in the background. Based on the unique latitude-longitude coordinate combinations in the tundra, there were 136 tundra sites in ABCflux, 104 tundra sites in Virkkala et al. 2021, 68 tundra sites in Natali et al., 2019, 34 tundra sites in Belshe et al. 2013, and 66 tundra sites in McGuire et al., 2012. Observations that were included in previous studies but not in ABCflux represent fluxes aggregated over seasonal, not monthly periods.

The data were summed to monthly time steps. Although the three flux measurement techniques primarily measure net ecosystem exchange (NEE), chamber and eddy covariance techniques can also be used to estimate GPP (the photosynthetic flux) and Reco (comprising emissions from autotrophic

and heterotrophic respiration), which are also included in the database. Source GPP, Reco, or NEE datasets that were not gap filled were not aggregated. Flux measurement techniques were recorded (e.g., measurement frequency, instrumentation, gap filling, and partitioning method, number of spatial replicates for chamber measurements, flux data quality), wherever possible.

Additional Data

A community call was solicited in 2018 through a CO_2 flux synthesis workshop (Parmentier et al., 2019, Reconciling historical and contemporary trends in terrestrial carbon exchange of the northern permafrost-zone, 2021), whereby the network of Arctic Boreal Zone flux researchers were contacted and invited to contribute their most current unpublished data. This call resulted in an additional 39 sites and 1,372 monthly observations (see variable *extraction_source*).

Refer to Virkkala et al. (2021) for additional information.

6. Data Access

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

The ABCflux Database: Arctic-Boreal CO2 Flux and Site Environmental Data, 1989-2020

Contact for Data Center Access Information:

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

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