

ACT-America: Profile-based Planetary Boundary Layer Heights, Eastern USA

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Documentation Revision Date: 2020-09-14

Dataset Version: 1.1

Summary

This dataset provides profile-based estimates of the height to the top of the planetary boundary layer (PBL), also known as the atmospheric boundary layer (ABL), in meters above mean sea level estimated from meteorological measurements acquired during ascending or descending vertical profile flight segments during NASA's Atmospheric Carbon and Transport - America (ACT-America) airborne campaign. ACT-America flights sampled the atmosphere over the central and eastern United States seasonally from 2016 - 2019. Two aircraft platforms, the NASA Langley Beechcraft B-200 King Air and the NASA Goddard Space Flight Center's C-130 Hercules, were used to collect high-quality in situ measurements across a variety of continental surfaces and atmospheric conditions.

With meteorological data from identified profile flight segments, the height of the first maximum in the potential temperature gradient was used to mark the PBL top height. When the potential temperature gradient did not provide a clear height, gradients in water vapor mixing ratio were used. This method was previously explored within numerous past work (e.g., Seibert et al., 2000; Groenemeijer et al., 2009; Pal et al., 2010). The geographic coordinates for the top height are the center location of the profile flight segment.

There is one data file in this dataset in comma-separated value (*.csv) format. The file provides data from the Summer 2016, Winter 2017, Fall 2017, Spring 2018, and Summer 2019 campaigns.



Figure 1. The ACT-America team on the tarmac with the B-200 King Air and C-130 Hercules NASA aircraft in Shreveport, Louisiana.

Citation

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1. Dataset Overview

This dataset provides profile-based estimates of the height to the top of the planetary boundary layer (PBL), also known as the atmospheric boundary layer (ABL), in meters above mean sea level estimated from meteorological measurements acquired during ascending or descending vertical profile flight segments during NASA's Atmospheric Carbon and Transport - America (ACT-America) airborne campaign. ACT-America flights sampled the atmosphere over the central and eastern United States seasonally from 2016 - 2019. Two aircraft platforms, the NASA Langley Beechcraft B-200 King Air and the NASA Goddard Space Flight Center's C-130 Hercules, were used to collect high-quality in situ measurements across a variety of continental surfaces and atmospheric conditions.

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Project: [Atmospheric Carbon and Transport - America \(ACT-America\)](#)

The ACT-America, or Atmospheric Carbon and Transport - America, project was a NASA Earth Venture Suborbital-2 mission to study the transport and fluxes of atmospheric carbon dioxide and methane across three regions in the eastern United States. Each flight campaign measured how weather systems transport these greenhouse gases. Ground-based measurements of greenhouse gases were also collected. Better estimates of greenhouse gas sources and sinks are needed for climate management and for prediction of future climate.

Related Dataset:

Yang, M.M., J.D. Barrick, C. Sweeney, J.P. Digangi, and J.R. Bennett. 2018. ACT-America: L1 Meteorological and Aircraft Navigational Data. ORNL DAAC, Oak Ridge, Tennessee, USA. <https://doi.org/10.3334/ORNLDAAC/1574>

2. Data Characteristics

Spatial Coverage: Flights over eastern and central United States

Spatial Resolution: Point measurements

Temporal Coverage: Periodic flights took place during each intensive campaign.

Campaign	Data Beginning and Ending Dates
Summer 2016	2016-07-11 to 2016-08-28
Winter 2017	2017-01-21 to 2017-03-10
Fall 2017	2017-10-03 to 2017-11-13
Spring 2018	2018-04-12 to 2018-05-20
Summer 2019	2019-06-20 to 2019-07-26

Temporal Resolution: Ranging from minutes to hours

Study Area: Latitude and longitude are given in decimal degrees.

Site	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
Eastern and Central United States	-106.36	-73.126	49.493	28.65

Data File Information

There is a single data file in this dataset in comma-separated value (*.csv) format: **Profile_Based_PBL_Heights.csv**.

User Note: This new revision, V1.1, has added data from the 2019 summer campaign. No change has been made to the data of the first 4 campaigns that have previously been published (V1) at the ORNL DAAC. 2019 is the final data addition.

Missing values are reported as -9999. For the Summer 2016 Campaign, there are 22 missing points for the B200 and 55 missing for the C130 flights. No other data are missing.

User Note: PBL is also known as the atmospheric boundary layer (ABL). The PBL top height is reported in meters above mean sea level (MSL). To obtain the depth/thickness of the PBL in meters above ground level (AGL), the underlying topography must be used. Ground elevation in m above MSL is available in the related dataset (Yang et al., 2018: <https://doi.org/10.3334/ORNLDAAC/1574>).

Table 1. Variable names and descriptions.

Column name	Units	Description
	vvvv-	

date	mm-dd	Sampling date (UTC)
hour	hh.hhh	Sampling time as decimal hour (UTC)
aircraft		B200 or C130 aircraft
latitude	decimal degrees	Latitude of the center location of the profile
longitude	decimal degrees	Longitude of the center location of the profile
PBL_height	m MSL	Height to the top of the planetary boundary layer (PBL) in meters above mean sea level (MSL) as derived from meteorological measurements acquired during a profile flight at this time and location

Data Center Processing

The *.csv file with data from prior campaigns was updated to include the 2019 Summer campaign data. The data were originally provided in .txt format:

- 2016_Summer_B200_C130_Profile_Based_PBL_Heights_v1.0.txt
- 2017_Winter_B200_C130_Profile_Based_PBL_Heights_v1.0.txt
- 2017_Fall_B200_C130_Profile_Based_PBL_Heights_v1.0.txt
- 2018_Spring_B200_C130_Profile_Based_PBL_Heights_v1.0.txt
- 2019_Summer_B200_C130_Profile_Based_PBL_Heights_v1.0.txt

2019 data are the final data addition.

3. Application and Derivation

ACT-America, or Atmospheric Carbon and Transport - America, conducted five airborne campaigns across three regions in the eastern United States to study the transport of atmospheric carbon. The eastern half of the United States is a region that includes a highly productive biosphere, vigorous agricultural activity, extensive gas and oil extraction and consumption, dynamic, seasonally varying weather patterns and the most extensive carbon cycle and meteorological observing networks on Earth, serves as an ideal setting for the mission.

Each 6-week campaign accurately and precisely quantified anomalies in atmospheric carbon, also known as Carbon Flux. Accurate carbon flux data is necessary to address all terrestrial carbon cycle science questions. ACT-America addressed the three primary sources of uncertainty in atmospheric inversions — transport error, prior flux uncertainty and limited data density.

ACT-America advances society’s ability to predict and manage future climate change by enabling policy-relevant quantification of the carbon cycle. Sources and sinks of atmospheric carbon dioxide (CO₂) and methane (CH₄) are poorly known at regional to continental scales. ACT-America enables and demonstrates a new generation of atmospheric inversion systems for quantifying CO₂ and CH₄ sources and sinks.

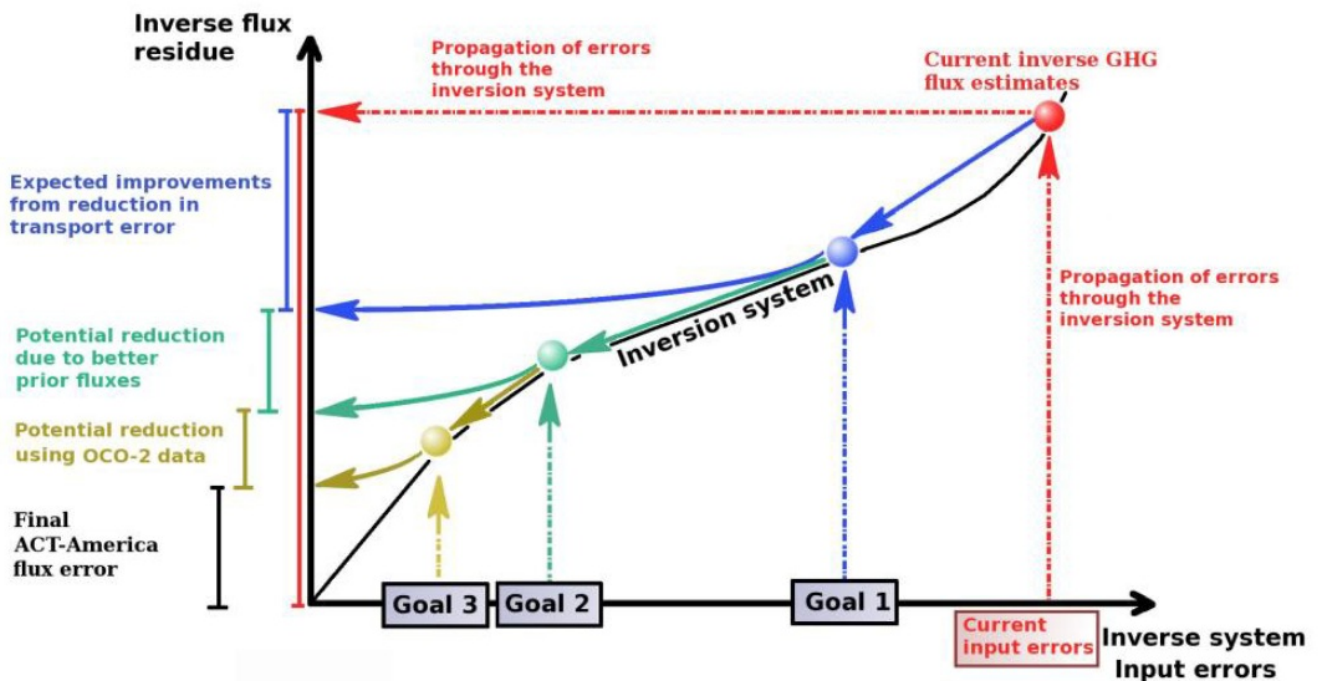


Figure 2. A schematic showing ACT-America project goals.

ACT-America Goals:

1. To quantify and reduce atmospheric transport uncertainties.
2. To improve regional-scale, seasonal prior estimate of CO₂ and CH₄ fluxes.
3. To evaluate the sensitivity of Orbiting Carbon Observatory (OCO-2) column measurements to regional variability in tropospheric CO₂.

ACT-America achieved these goals by deploying airborne and ground-based platforms to obtain data that were combined with data from existing measurement networks and integrated with an ensemble of atmospheric inversion systems. Aircraft instrumented with remote and in situ sensors observed how mid-latitude weather systems interact with CO₂ and CH₄ sources and sinks to create atmospheric CO₂/CH₄ distributions. A model ensemble consisting of a mesoscale atmospheric transport model with multiple physics and resolutions options nested within global inversion models and surface CO₂/CH₄ flux ensembles was used to predict atmospheric CO₂ and CH₄ distributions.

Beyond the conclusion of the mission, application of the knowledge gained from this mission will improve diagnoses of the carbon cycle across the globe for decades.

4. Quality Assessment

Within the data, missing and out-of-range values are provided in the dataset as described. The table below lists the uncertainties associated with the corresponding instruments.

Variable name	C-130 System	B-200 System
Latitude/Longitude/GPS_Altitude	5 meters spherical error probability *	5 meters spherical error probability *
Ground Speed	0.01 m/s *	0.05 m/s *
True_Heading	0.015 deg *	0.07 deg *
Pitch_Angle, Roll_Angle	0.01 deg *	0.01 deg *
Dew_Point	0.2 deg C *	0.5 - 1.0 C (Dynamic Cond.)
Total_Air_Temp	1.5 deg C *	+/- 0.6 C (Dynamic Cond.)
Cabin_Pressure	0.25% FS *	N/A

* Uncertainties quoted on instrument specifications sheet.

5. Data Acquisition, Materials, and Methods

ACT-America Overview

The eastern half of the United States, a region that includes a highly productive biosphere, vigorous agricultural activity, extensive gas and oil extraction, dynamic, seasonally varying weather patterns and the most extensive carbon cycle and meteorological observing networks on Earth, serves as an ideal setting for the mission. Flights concentrated observations on three study domains: Northeast, South-central, and Midwest.

ACT-America deployed the NASA C-130 and B-200 aircraft to measure atmospheric CO₂ and CH₄ in the atmospheric boundary layer (ABL) and free troposphere (FT). In all five seasonal campaigns, a total of 121 days of research flights, more than 1,140 hours of observations, 570 level legs, and 1,363 vertical profiles were conducted. These flights were dedicated in a roughly 3:3:1 ratio among fair weather, stormy weather, and OCO-2 underpass flight patterns.

For fair and stormy weather flights, the C-130 flew at 3-8 km above ground, collecting in situ measurements in the lower FT, remotely sensed, column-averaged CO₂ measurements focused on the ABL, and occasional in situ vertical profiles. The B-200 primarily sampled the ABL. For OCO-2 underflights, the C-130 flew at 8 km above ground with the B-200 flying in the ABL, both along the OCO-2 flight track. The existing in situ tower CO₂/CH₄ observing network was enhanced with five additional tower sites.

Flight Plans

Data from the fair-weather flights are intended to quantify regional CO₂ and CH₄ fluxes, and to evaluate fair weather atmospheric C transport processes. The flight pattern was designed to provide extensive sampling of the ABL and lower FT in source/sink regions, meeting the requirements for the fair weather investigation. The C-130 aircraft flew a U-shape pattern with flight legs perpendicular to the wind, sampling FT and ABL properties downwind of the sources and sinks of C. The C-130 flew at roughly two times the midday ABL depth, (~3-4 km AGL) with periodic descents and ascents (5 to 10 times in a 6-8-hr flight) to sample the ABL. Although clear sky conditions were targeted, the C-130 would conduct more profiling if low-altitude clouds interfered with the remote sensors. The B-200 aircraft partook in two flights per day and sampled a subset of the C-130 flight path focusing on long transects in the ABL with periodic ascents to the FT. The two aircraft operated over the same time period, but precise coordination was not required.

Profile-based Planetary Boundary Layer Height

In addition to horizontal flight patterns, profile (vertical) flight segments were flown during ACT-America field campaigns over the three regions. Profiles were collected at six different times: take off, landing, spiral up and down, and en route ascent and descents. These occurred over a variety of flights owing to aircraft speed and mission planning purposes.

Within each identified profile, the location of first maximum in potential temperature gradient was used to mark the PBL top height. When the potential temperature gradient did not provide a clear height, gradients in water vapor mixing ratio were used. The coordinates for the top height are the center location of the profile flight segment.

The PBL top height is reported in m above MSL. To obtain the depth/thickness of the PBL in m AGL, the underlying topography must be used. Ground elevation in m about MSL is available in the related dataset (Yang et al., 2018).

For future PBL height measurements, PBL will be reported in m above ground level (AGL) instead of PBL top height in m above MSL.

6. Data Access

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

[ACT-America: Profile-based Planetary Boundary Layer Heights, Eastern USA](#)

Contact for Data Center Access Information:

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

7. References

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