ACT-America: L2 In Situ Atmospheric Gas Concentrations from Flasks, Eastern USA

Get Data

Documentation Revision Date: 2021-02-02

Dataset Version: 1.2

Summary

This dataset provides atmospheric carbon dioxide (CO2), methane (CH4), carbon monoxide (CO), molecular hydrogen (H2), nitrous oxide (N2O), sulfur hexafluoride (SF6), and other trace gas mole fractions (i.e., concentrations) from airborne campaigns over North America for the NASA Atmospheric Carbon and Transport - America (ACT-America) project. ACT-America's mission spanned five years and included five six-week field campaigns covering all four seasons and three regions of the central and eastern United States. Two instrumented 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. The data were derived from laboratory measurements of whole air samples collected by Programmable Flask Packages (PFP) onboard the two ACT-America aircraft. Approximately 10 - 12 discrete flask samples were captured during each of the 195 flights. This dataset provides results from all five campaigns, including Summer 2016, Winter 2017, Fall 2017, Spring 2018, and Summer 2019.

ACT-America's overall mission spanned five years and included field campaigns covering all four seasons over central and eastern regions of the United States. ACT-America's objectives were to study the transport and fluxes of atmospheric CO_2 and CH_4. Two instrumented aircraft platforms, the NASA Langley Beechcraft B-200 King Air and the NASA Wallops Flight Facility's C-130 Hercules, were used to collect high-quality in-situ measurements across a variety of continental surfaces and atmospheric conditions. At times they flew directly under Orbiting Carbon Observatory-2 (OCO-2) overpasses to evaluate the ability of OCO-2 to observe high-resolution atmospheric CO_2 variations. The C-130 aircraft was also equipped with active remote sensing instruments for planetary boundary layer height detection and column greenhouse gas measurements.

This dataset contains 390 data files total; 195 files in netCDF (*.nc) format and 195 data files in ICARTT (*.ict) format. Each netCDF file has a corresponding file in ICARTT format that has identical trace gas data but the ICARTT file contains no aircraft navigation or meteorological data.

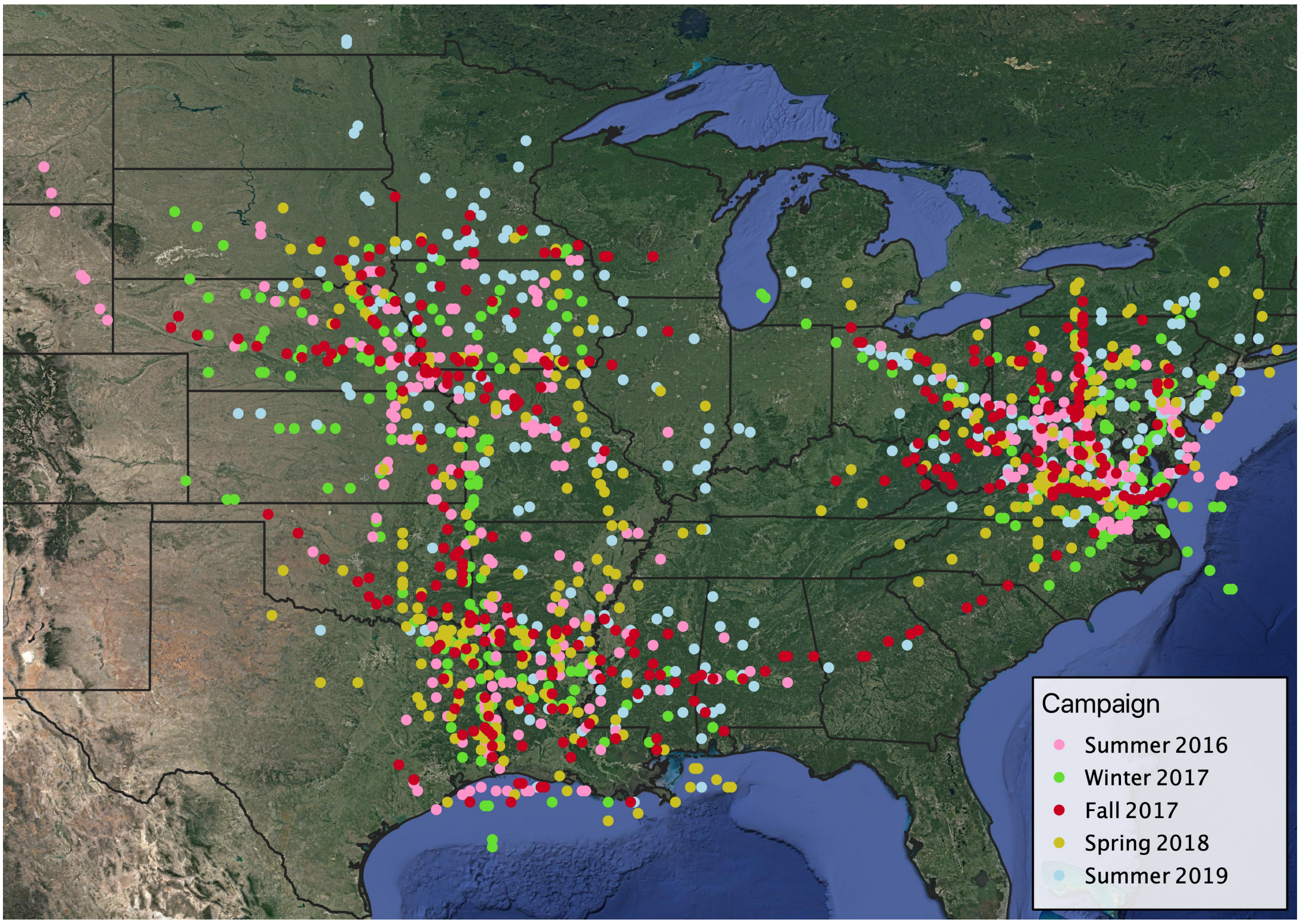

Figure 1. Locations of ACT-America flask air samples collected during all five airborne campaigns from 2016 to 2019.

Citation

Sweeney, C., B.C. Baier, J.B. Miller, P. Lang, B.R. Miller, S. Lehman, S.E. Michel, and M.M. Yang. 2018. ACT-America: L2 In Situ Atmospheric Gas Concentrations from Flasks, Eastern USA. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1575

Table of Contents

1. Dataset Overview

This dataset provides atmospheric carbon dioxide (CO_2), methane (CH_4), carbon monoxide (CO), molecular hydrogen (H_2), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), and other trace gas mole fractions (i.e., concentrations) from airborne campaigns over North America for the NASA Atmospheric Carbon and Transport - America (ACT-America) project. ACT-America's mission spanned five years and includes five six-week field campaigns covering all four seasons and three regions of the central and eastern United States. Two instrumented 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. The data were derived from laboratory measurements of whole air samples collected by Programmable Flask Packages (PFP) onboard the two ACT-America aircraft. Approximately 10 - 12 discrete flask samples were captured during each of the 195 flights. This dataset provides results from all five campaigns, including Summer 2016, Winter 2017, Fall 2017, Spring 2018, and Summer 2019.

ACT-America's overall mission spanned five years and included field campaigns covering all four seasons over central and eastern regions of the United States. ACT-America's objectives were to study the transport and fluxes of atmospheric CO_2 and CH_4. Two instrumented aircraft platforms, the NASA Langley Beechcraft B-200 King Air and the NASA Wallops Flight Facility's C-130 Hercules, were used to collect high-quality in-situ measurements across a variety of continental surfaces and atmospheric conditions. At times they flew directly under Orbiting Carbon Observatory-2 (OCO-2) overpasses to evaluate the ability of OCO-2 to observe high-resolution atmospheric CO_2 variations. The C-130 aircraft was also equipped with active remote sensing instruments for planetary boundary layer height detection and column greenhouse gas measurements.

Project: Atmospheric Carbon and Transport - 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. ACT-America conducted five flight campaigns spanning all four seasons throughout 2016—2019 and measured how weather systems transported greenhouse gases. Ground-based measurements were also collected. The objective of the study was to enable more accurate and precise estimates of the sources and sinks of greenhouse gases, as better estimates are needed for climate management and for prediction of future climate. Three primary sources of uncertainty (i.e., transport error, prior flux uncertainty, and limited data density) were addressed to improve the inference of carbon dioxide and methane sources and sinks.

Related Publication

Sweeney, C., A. Karion, S. Wolter, T. Newberger, D. Guenther, J. A. Higgs, A. E. Andrews, P. M. Lang, D. Neff, E. Dlugokencky, J. B. Miller, S. A. Montzka, B. R. Miller, K. A. Masarie, S. C. Biraud, P. C. Novelli, M. Crotwell, A. M. Crotwell, K. Thoning, and P. P. Tans. 2015. Seasonal climatology of CO2 across North America from aircraft measurements in the NOAA/ESRL Global Greenhouse Gas Reference Network. Journal of Geophysical Research: Atmospheres 120:5155–5190. https://doi.org/10.1002/2014JD022591

Related Datasets

Davis, K.J., M.D. Obland, B. Lin, T. Lauvaux, C. O'Dell, B. Meadows, E.V. Browell, J.P. DiGangi, C. Sweeney, M.J. McGill, J.D. Barrick, A.R. Nehrir, M.M. Yang, J.R. Bennett, B.C. Baier, A. Roiger, S. Pal, T. Gerken, A. Fried, S. Feng, R. Shrestha, M.A. Shook, G. Chen, L.J. Campbell, Z.R. Barkley, and R.M. Pauly. 2018. ACT-America: L3 Merged In Situ Atmospheric Trace Gases and Flask Data, Eastern USA. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1593

Pal, S. 2019. ACT-America: Profile-based Planetary Boundary Layer Heights, Eastern USA. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1706

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

Acknowledgments

This work was supported by NASA EVS-2 grant number NNX15AG76G.

2. Data Characteristics

Spatial Coverage: Flights over eastern and central United States

Spatial Resolution: Point measurements

Temporal Coverage: Periodic flights occurred during each intensive campaign

Campaign	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	2019-06-17 to 2019-07-27

Temporal Resolution: Approximately 10–12 flask samples were captured during each flight

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

Site	Northernmost Latitude	Southernmost Latitude	Westernmost Longitude	Easternmost Longitude
Eastern and Central United States	49.403	27.802	-104.237	-72.942

Data File Information

This dataset contains 390 data files total; 195 files in netCDF (*.nc) format and 195 data files in ICARTT (*.ict) format. Each netCDF file has a corresponding file in ICARTT format that has identical trace gas data but the ICARTT file contains no aircraft navigation or meteorological data.

NetCDF files follow the standards of the NetCDF Climate and Forecast (CF) Metadata Conventions V1.6. Variables are structured as GeoTrajectory, where the observations for a flight segment are connected along a one-dimensional track in space and with time increasing monotonically along the track. These files contain gas concentrations and data from the respective aircraft's flight navigation system and meteorological instruments for approximately 10–12 discrete flask samples collected during each of the 195 flights.

ICARTT files follow ICARTT File Format Standards V1.1. The ICARTT files contain the same gas concentration data as the netCDF files (i.e., Start_UTC, Stop_UTC, Mid_UTC, gas concentrations) but no navigational or meteorological information.

Companion File Information

Additional information on the aircraft platforms deployed by ACT-America is provided in **Platform_B200.pdf** and **Platform_C130.pdf**.

Data File Details

File Naming Convention

Files are organized by instrument and aircraft for the flights on a given date. The naming convention is the same for netCDF and ICARTT files. Files are named according to the format **ACTAMERICA-PFP-<aircraft>_<YYYYMMDD>_<R#>_<L#>.<ext>** (e.g., ACTAMERICA-PFP_C130_20190727_R0.nc), where

<aircraft> is either 'B200' or 'C130',
<YYYYMMDD> is the flight date in UTC time,
<R#> is the revision number of the data, where a higher number indicates a more recent revision (e.g., R1 = first revision),
<L#> is the launch number as some flights had more than one launch (e.g., L1 = first launch),
<ext> is the file extension, either '.nc' (netCDF) or '.ict' (ICARTT).

Quality Flags

Missing values: All missing data are flagged with a value of -9999.

LOD flags: If a reported result is a Limit of Detection (LOD) value for a given measurement, the value is marked with a LOD flag.

- Measurements above the upper LOD are flagged with -7777.
- Measurements below the lower LOD are flagged with -8888.

The measurement upper and lower LOD values (or N/A) are provided in the netCDF global attributes and ICARTT header as applicable.

Table 1. Names and descriptions for flask variables. These variables are present in both netCDF and ICARTT files.

Variable Name	Units	Description
CHLF_MoleFraction_PFP	part per trillion	Chloroform mole fraction
BRFM_MoleFraction_PFP	part per trillion	BRFM mole fraction
C2H6_CAMS2	part per trillion	Ethane mole fraction
CCl4_MoleFraction_PFP	part per trillion	CCl4 mole fraction
CS2_MoleFraction_PFP	part per trillion	CS2 mole fraction
F112_MoleFraction_PFP	part per trillion	F112 mole fraction
F124_MoleFraction_PFP	part per trillion	F124 mole fraction
F141B_MoleFraction_PFP	part per trillion	Dichlorofluoroethane mole fraction
HF21_MoleFraction_PFP	part per trillion	HF21 mole fraction
NF3_MoleFraction_PFP	part per trillion	NF3 mole fraction
SF6_MoleFraction_PFP	part per trillion	Sulfur Hexafloride mole fraction
HF22_MoleFraction_PFP	part per trillion	HF22 mole fraction
nC6H14_MoleFraction_PFP	part per trillion	n-Hexane mole fraction
PCE_MoleFraction_PFP	part per trillion	Perchloroethylene mole fraction
SF6_CCGG_MoleFraction_PFP	part per trillion	Sulfur Hexafloride mole fraction
BENZ_MoleFraction_PFP	part per trillion	Benzene mole fraction
C2F6_MoleFraction_PFP	part per trillion	Hexafluorethane mole fraction
C2H2_MoleFraction_PFP	part per trillion	Acetylene mole fraction
C2H6_MoleFraction_PFP	part per trillion	Ethane mole fraction
C3H8_MoleFraction_PFP	part per trillion	Propane mole fraction
CF4_MoleFraction_PFP	part per trillion	Carbon Tetrafloride mole fraction
CH2BrCl_MoleFraction_PFP	part per trillion	Bromochloromethane mole fraction

CH3I_MoleFraction_PFP	part per trillion	Methyl Iodide mole fraction
CH4_MoleFraction_PFP	part per billion	Methane mole fraction
CH4C13_PFP	part per million	C-13 of CH4
CO_MoleFraction_PFP	part per billion	Carbon Monoxide mole fraction
CO2_MoleFraction_PFP	part per million	Carbon Dioxide mole fraction
DIBR_MoleFraction_PFP	part per trillion	Dibromomethane mole fraction
DICL_MoleFraction_PFP	part per trillion	Dimethyl Chloride mole fraction
F113_MoleFraction_PFP	part per trillion	F113 mole fraction
F115_MoleFraction_PFP	part per trillion	F115 mole fraction
F11B_MoleFraction_PFP	part per trillion	F11 mole fraction
F125_MoleFraction_PFP	part per trillion	Pentafluoroethane mole fraction
F13_MoleFraction_PFP	part per trillion	F13 mole fraction
F134A_MoleFraction_PFP	part per trillion	Tetrafluoroethane mole fraction
F143a_MoleFraction_PFP	part per trillion	1-1-1-Trifluoroethane mole fraction
F152A_MoleFraction_PFP	part per trillion	1-1-Difluoroethane mole fraction
F227e_MoleFraction_PFP	part per trillion	F227 mole fraction
F23_MoleFraction_PFP	part per trillion	Fluoroform mole fraction
F236fa_MoleFraction_PFP	part per trillion	F236fa mole fraction
F32_MoleFraction_PFP	part per trillion	F32 mole fraction
F365m_MoleFraction_PFP	part per trillion	Pentafluorobutane mole fraction
FC12_MoleFraction_PFP	part per trillion	FC12 mole fraction
H1211_MoleFraction_PFP	part per trillion	Halon 1211 mole fraction
H1301_MoleFraction_PFP	part per trillion	Halon 1301 mole fraction
H2_MoleFraction_PFP	part per billion	Hydrogen mole fraction
H2402_MoleFraction_PFP	part per trillion	Halon 2402 mole fraction
HF133a_MoleFraction_PFP	part per trillion	HF133a mole fraction
iC4H10_MoleFraction_PFP	part per trillion	isoButane mole fraction
iC5H12_MoleFraction_PFP	part per trillion	isoPentane mole fraction
MCFA_MoleFraction_PFP	part per trillion	MCFA mole fraction
MEBR_MoleFraction_PFP	part per trillion	Methyl Bromide mole fraction
MECL_MoleFraction_PFP	part per trillion	Methyl Chloride mole fraction
N2O_MoleFraction_PFP	part per billion	Nitrous Oxide mole fraction
nC4H10_MoleFraction_PFP	part per trillion	neoButane mole fraction
nC5H12_MoleFraction_PFP	part per trillion	neoPentane mole fraction
OCS_MoleFraction_PFP	part per trillion	Carbonyl Sulfide mole fraction
P218_MoleFraction_PFP	part per trillion	P218 mole fraction
SO2F2_MoleFraction_PFP	part per trillion	Sulfuryl Fluoride mole fraction
TCE_MoleFraction_PFP	part per trillion	Trichloroethylene mole fraction
TOL_MoleFraction_PFP	part per trillion	Toluene mole fraction

Table 2. Names and descriptions of navigation and meteorological variables. These variables are present in only netCDF files.

Variable Name	Units	Description
time	seconds	seconds since 2016-01-01 00:00:00.0 UTC
time_bnds		boundary (start and end time) of each time step
Start_UTC	seconds	start UTC time of day for measurement
Stop_UTC	seconds	stop UTC time of day for measurement interval
Mid_UTC	seconds	mean UTC time of day of measurement interval
Flight_ID		Flight identification (aircraft and flight date)
Aircraft_Sun_Azimuth	degree	Platform azimuth angle
Aircraft_Sun_Elevation	degree	Solar elevation angle

Cabin_Pressure	millibars	Air pressure of cabin
Day_of_Year	day	Day of year starting Jan 1 UTC
Dew_Point	Celsius	Dew point temperature
Drift_Angle	degree	Drift angle
GPS_Altitude	meters	Global Positioning System altitude
GPS_Time	hours since 2016-01-01 00:00:00.0 UTC	Time
Ground_Speed	meters per second	Platform speed with respect to ground
Indicated_Air_Speed	knots	Indicated airspeed
Latitude	degrees north	Latitude, EPSG: 4326
Longitude	degrees east	Longitude, EPSG: 4326
Mach_Number		Mach number
Mixing_Ratio	grams per kilogram	H2O mixing ratio
Part_Press_Water_Vapor	millibars	Water vapor partial pressure in air
Pitch_Angle	degree	Platform pitch angle
Potential_Temp	Celsius	Potential temperature
Pressure_Altitude	feet	Barometric altitude
Relative_Humidity	percent	Relative humidity
Roll_Angle	degree	Platform roll angle
Sat_Vapor_Press_H2O	millibars	H_2O saturation vapor pressure of water
Sat_Vapor_Press_Ice	millibars	H_2O saturation vapor pressure of ice
Solar_Zenith_Angle	degree	Solar zenith angle
Static_Air_Temp	Celsius	Static air temperature
Static_Pressure	millibars	Air pressure
Sun_Azimuth	degree	Solar azimuth angle
Total_Air_Temp	Celsius	Total air temperature
Track_Angle	degree	Track angle
True_Air_Speed	knots	Platform speed with respect to air
True_Heading	degree	Platform yaw angle
Vertical_Speed	feet per minute	Vertical speed
Wind_Direction	degree	Wind direction
Wind_Speed	meters per second	Wind speed
Altitude_AGL_m	meters	Aircraft altitude above ground level
Ground_Elevation_m	meters	Ground elevation above mean sea level

Data Center Processing

The ORNL DAAC created netCDF files for each of the provided ICARTT files. Aircraft navigation and meteorological information were added to the netCDF files from Pal (2019) for B-200 flights and Yang et al. (2018) for C-130 flights.

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 and fluxes 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 (CO_2) and methane (CH_4) are poorly known at regional to continental scales. ACT-America enables and demonstrates a new generation of atmospheric inversion systems for quantifying CO_2 and CH4 sources and sinks.

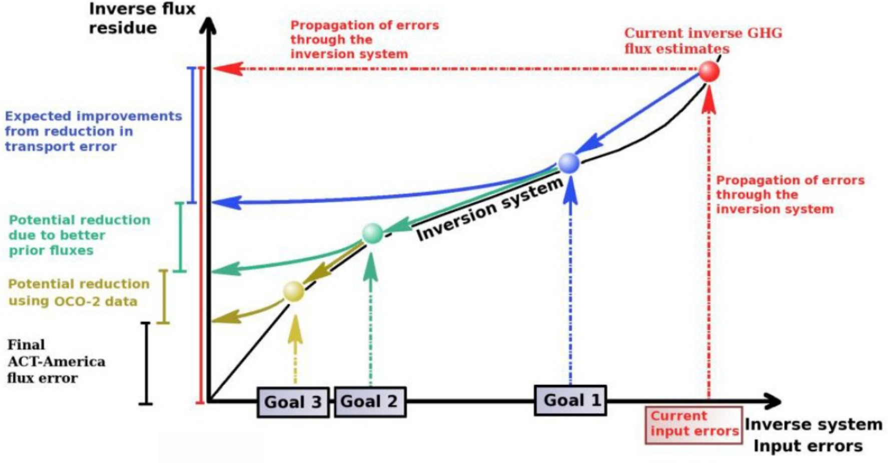

Figure 2. A schematic showing ACT-America mission goals.

ACT-America Goals:

1. To quantify and reduce atmospheric transport uncertainties.
2. To improve regional-scale, seasonal prior estimates of CO_2 and CH_4 fluxes.
3. To evaluate the sensitivity of Orbiting Carbon Observatory (OCO-2) column measurements to regional variability in tropospheric CO_2.

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 CO_2 and CH_4 sources and sinks to create atmospheric CO_2/CH_4 distributions. A model ensemble consisting of a mesoscale atmospheric transport model with multiple physics and resolutions options nested within global inversion models and surface CO_2/CH_4 flux ensembles was used to predict atmospheric CO_2 and CH_4 distributions.

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

4. Quality Assessment

There are multiple levels of quality control for 12-pack flask samples taken at each aircraft site, however, there are also multiple sources of errors that need to be assessed. Sources of error to the 12-pack flask measurement fall into three different categories: flask induced bias, sampling errors, and analysis errors. Details on instrument quality control information are available at https://www.esrl.noaa.gov/gmd/ccgg/aircraft/qc.html.

Table 3. Instrument precision as provided in the ACT-America proposal.

Instrument	Platform	Technique	Species/Parameter	Instrument Precision (Averaging Time)	STM Precision Requirement [over 20 km (~130 sec) unless otherwise noted]
Flasks	C-130H, B-200	GC/MS[3]	CO_2, CH_4, $^{14}CO_2$, COS	0.2 ppm CO_2 1 ppb CH_4 2 per mil $^{14}CO_2$ 2 ppt COS (all 10 sec)	1 ppm CO_2 4 ppb hourly CH_4 2 per mil $^{14}CO_2$ 10 ppt COS

5. Data Acquisition, Materials, and Methods

ACT-America Overview

ACT-America deployed the NASA C-130 and B-200 aircraft to measure atmospheric CO_2 and CH_4 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. Flights concentrated observations on three study domains: Northeast, South-central, and Midwest. These flights were dedicated in a roughly 3:3:1 ratio among fair weather, stormy weather, and OCO-2 underpass flight patterns (Crisp et al., 2004, Crisp et al., 2008).

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 CO_2 measurements focused on the ABL, and occasional in-situ vertical profiles. The B-200 primarily sampled the ABL. For OCO-2 under flights, 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 CO_2/CH_4 observing network was enhanced with five additional tower sites.

The mission delivered 2-3 times more high-quality lower tropospheric CO_2 and CH_4 observations than any previous airborne campaign.

Flight Plans

Data from the fair-weather flights are intended to quantify regional CO_2 and CH_4 fluxes, and to evaluate fair weather atmospheric C transport processes. The flight pattern is 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 will fly 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 will fly at roughly two times the midday ABL depth, (3–4 km above ground level) with periodic descents and ascents (5–10 times in a 6–8 hr flight) to sample the ABL. Although clear sky conditions will be targeted, the C-130 will conduct more profiling if low-altitude clouds interfere with the remote sensors. The B-200 aircraft will partake in two flights per day and will sample a subset of the C-130 flight path focusing on long transects in the ABL with periodic ascents to the FT. The two aircraft will operate over the same time period, but precise coordination is not required.

Data from stormy-weather flights will be used in combination with the data from fair-weather flights to evaluate the transport of C in the mid-latitudes. The flight plans include flight legs parallel to and crossing frontal boundaries at two or more altitudes, and crossing the frontal zone at two or more locations, meeting the requirements for the stormy weather investigation.

The pattern for the OCO-2 inter-comparison flights is designed to obtain data to evaluate the degree to which OCO-2 column CO_2 measurements capture true spatial variability in column CO_2 content over the continents. Two OCO-2 under flights will be conducted during each campaign and will be selected to cover varying surface reflectance, topography, and aerosol and cloud cover, all possible sources of bias in the OCO-2 measurements. The C-130 flights will be 1,000 km in length and flown at 8 km (28 ft) altitude to maximize the fraction of the atmospheric column sampled by the MFLL. The B-200 aircraft will sample a shorter (~360 km) leg in the ABL, often the largest source of variability in column CO_2. The B-200 flight will be centered with the C-130 and both aircraft will be vertically stacked during the OCO-2 overpass.

Airborne Instruments

ACT-America deployed high-quality, field-tested trace gas and meteorological instruments. This dataset includes measurements from discrete air samples captured by the flask sampling system onboard the aircraft. The two air-sampling devices, the Programmable Flask Package (PFP) and Programmable Compressor Package (PCP) systems are used routinely on aircraft as part of the NOAA/ESRL Greenhouse Gas Reference Network (Sweeney et al., 2015).

Figure 3. Flask sampling system for aircraft measurements. Left: Programmable Flash Package (PFP) containing 12 flasks. Right: Programmable Compressor Package (PCP) containing pumps for pressurizing the flasks. Source: NOAA Global Monitoring Laboratory

Programmable Flask Package

The 12-pack is composed of twelve, 0.7 L borosilicate glass flasks, a stainless-steel manifold system, glass valves sealed with Teflon O-rings, and a data logging and control system. The 7.5 cm diameter cylindrical flasks have glass valves at each end and are stacked in two rows of six. A flexible stainless-steel manifold connects all of the flasks in parallel on the inlet side of the flasks. The valves at both ends of the flasks can be opened and closed with motor-controlled valves. The valve mechanism is made of a glass rod and Teflon O-rings, which seals against a beveled glass valve seat when inserted into the valve body. The data logging and control system in the 12-pack provide the interface for controlling the sampling valves, as well as for storing a sampling plan and target flush volume and fill pressure for the samples. Actual sample flush volumes and fill pressures during sampling are recorded by the data logger, along with system status and a time stamp. When GPS position, ambient temperature, pressure, and relative humidity are available from external sensors, these values are also recorded by the data logger at 10-second intervals.

Programmable Compressor Package

The PCP includes two pumps that have been plumbed in series. The first-stage pump (KNF Model N828 with aluminum head and Viton diaphragm) is designed to ensure flow rates of at least 5 L/min at 8,000 masl and 15 L/min at sea level. The second-stage pump (KNF Model N814 with aluminum head and Viton diaphragm) is designed to ensure that samples can be reliably compressed to 40 psia at altitudes up to 8,000 masl. The PCP is powered by a nickel-metal hydride (NiMH) rechargeable battery, which enables the pumps to fill up to four 12-packs (48 flasks) before recharging.

Sampling

A typical sampling routine uses one PCP and one or more PFP(s) that are pre-programmed with a flight-specific sampling plan of target altitudes for each sample. Sampling is timed to coincide with the overflight of a ground site of interest, or when interesting geophysical conditions are encountered. The PCP is connected to an LED display that communicates target sampling altitudes to the pilot. The pilot maintains the aircraft at a consistent altitude for the duration of each sample collection, typically under 40 seconds. For each sample, the inlet line and compression manifold are flushed with about 5 liters of ambient air. Valves on both ends of the current flask are then opened and the flask is flushed with about 10 more liters of ambient air to displace the dry, low CO_2 fill gas with which the flasks are shipped. The sample flush air is measured by a mass flow meter to ensure that a sufficient volume passes through the manifold and flask before the downstream valve is closed and pressurization begins. Sample flush volumes and fill pressures during sampling are recorded by the data logger, along with ambient temperature, pressure, and relative humidity. GPS position and time stamp are also recorded with each sample.

6. Data Access

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

ACT-America: L2 In Situ Atmospheric Gas Concentrations from Flasks, Eastern USA

Contact for Data Center Access Information:

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

7. References

Crisp, D., R.M. Atlas, F.-M. Breon, L.R. Brown, J.P. Burrows, P. Ciais, B.J. Connor, S.C. Doney, I.Y. Fung, D.J. Jacob, C.E. Miller, D. O'Brien, S. Pawson, J.T. Randerson, P. Rayner, R.J. Salawitch, S.P. Sander, B. Sen, G.L. Stephens, P.P. Tans, G.C. Toon, P.O. Wennberg, S.C. Wofsy, Y.L. Yung, Z. Kuang, B. Chudasama, G. Sprague, B. Weiss, R. Pollock, D. Kenyon, and S. Schroll. 2004. The Orbiting Carbon Observatory (OCO) mission. Advances in Space Research 34:700–709. https://doi.org/10.1016/j.asr.2003.08.062

Crisp, D. 2008. NASA Orbiting Carbon Observatory: measuring the column averaged carbon dioxide mole fraction from space. Journal of Applied Remote Sensing 2:023508. https://doi.org/10.1117/1.2898457

Davis, K.J., M.D. Obland, B. Lin, T. Lauvaux, C. O'Dell, B. Meadows, E.V. Browell, J.P. DiGangi, C. Sweeney, M.J. McGill, J.D. Barrick, A.R. Nehrir, M.M. Yang, J.R. Bennett, B.C. Baier, A. Roiger, S. Pal, T. Gerken, A. Fried, S. Feng, R. Shrestha, M.A. Shook, G. Chen, L.J. Campbell, Z.R. Barkley, and R.M. Pauly. 2018. ACT-America: L3 Merged In Situ Atmospheric Trace Gases and Flask Data, Eastern USA. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1593

Pal, S. 2019. ACT-America: Profile-based Planetary Boundary Layer Heights, Eastern USA. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1706

Sweeney, C., A. Karion, S. Wolter, T. Newberger, D. Guenther, J.A. Higgs, A.E. Andrews, P.M. Lang, D. Neff, E. Dlugokencky, J.B. Miller, S.A. Montzka, B.R. Miller, K.A. Masarie, S.C. Biraud, P.C. Novelli, M. Crotwell, A.M. Crotwell, K. Thoning, and P.P. Tans. 2015. Seasonal climatology of CO2 across North America from aircraft measurements in the NOAA/ESRL Global Greenhouse Gas Reference Network. Journal of Geophysical Research: Atmospheres 120:5155–5190. https://doi.org/10.1002/2014JD022591

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

8. Dataset Revisions

Version	Release Date	Description of Changes
1.2	2021-02-22	Updated earlier campaign data and added Summer 2019 campaign data.
1.1	2019-03-27	Updated earlier campaign data and added Fall 2017 and Spring 2018 campaign data.
1.0	2018-06-26	Initial data added for Summer 2016 and Winter 2017 campaigns.