U.S. DEPARTMENT OF ENERGY | Office of Science

DOE/SC-ARM-17-008

Balloon-Borne Full-Column Greenhouse Gas Profiling Field Campaign Report

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March 2017

ARM CLIMATE RESEARCH FACILITY

DISCLAIMER

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Executive Summary

The vertical distributions of CO2, CH_4, and other gases provide important constraints for the determination of terrestrial and ocean sources and sinks of carbon and other biogeochemical processes in the Earth system. The DOE Biological and Environmental Research Program (DOE-BER) and the NOAA Earth System Research Laboratory (NOAA-ESRL) collaborate to quantify the vertically resolved distribution of atmospheric carbon-cycle gases (CO_2, and CH_4) within approximately 99% of the atmospheric column at the DOE ARM Southern Great Plains Facility in Oklahoma. In 2015, flights were delayed while research at NOAA focused on evaluating sources of systematic errors in the gas collection and analysis system and modifying the sampling system to provide duplicate air samples in a single flight package. In 2017, we look forward to proposing additional sampling and analysis at ARM-SGP (and other sites) that characterize the vertical distribution of CO_2 and CH_4 over time and space.

Acronyms and Abbreviations

ARM	Atmospheric Radiation Measurement Climate Research Facility
BER	Biological and Environmental Research, a DOE program
CESM	Community Earth System Model
DOE	U.S. Department of Energy
IOP	intensive operational period
NOAA-ESRL	National Oceanic and Atmospheric Administration Earth System Research Laboratory
SGP	Southern Great Plains
TCCON	Total Column Carbon Observing Network

Contents

Figures

Tables

1.0 Background

The vertical distributions of CO_2, CH_4, and other gases provide important constraints for the determination of terrestrial and ocean sources and sinks of carbon and other biogeochemical processes in the Earth system. Remote sensing from ground-based and satellite-borne platforms require in-situ validation. To address these measurement needs, we conducted a collaborative measurement campaign at the U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Climate Research Facility Southern Great Plains (SGP) observatory in Oklahoma that joined the DOE Biological and Environmental Research Program (DOE-BER) and the NOAA Earth System Research Laboratory (NOAA-ESRL) to quantify the vertically resolved distribution of atmospheric carbon-cycle gases (CO_2 and CH_4) throughout approximately 99% of the atmospheric column using AirCore sampling technology (Karion et al., 2012). Team members include Principal Investigators Marc L. Fischer (Lawrence Berkeley National Laboratory; LBNL) and Colm Sweeney (NOAA-ESRL). Co-investigators from NOAA-ESRL include Sonya Wolter, Jack Higgs, Tim Newberger, Pieter Tans, and Russell Chadwick. We thank John Schatz, Craig Webb, and Pat Dowell for assistance with work at ARM-SGP, and flight controllers at Kansas City Center and Vance Air Force Base.

2.0 Notable Events or Highlights

Poor luck in finding flight opportunities with good weather at SGP and the loss of flight equipment during a trip New Zealand limited us to a single campaign in the 2015-2016 period. In October, 2016, we conducted four balloon launches at the DOE ARM Southern Great Plains Facility in Oklahoma. On two of the flights two lightweight Aircores were flow together, producing a total of six successful sample collections, without the loss of any packages or significant safety or logistical issues. In addition, the flights at SGP provided essential instrument development, enabling significant advances instrument design, logistics for flight and recovery, and data analysis procedures. The resulting instrument system and operations are now near a state where reliable high-quality sample collection can be achieved throughout the atmospheric column.

3.0 Lessons Learned

From the flights and laboratory testing, we learned that slowing the initial descent of the package following cut-down from the balloon allows a better measure of the high-altitude portion of the flight. Specific lessons learned include:

- A new lightweight package Aircore allows two Aircores to be flown together while remaining under the 6-lb package weight that is exempt from Federal Aviation Administration regulations.
- Guided decent following cut-down will be useful to ease ground recovery and a system for automated guidance is now being developed with National Aeronautics and Space Administration (NASA) support.

4.0 Results

Over the course of the 2015-2016 campaign, we developed the sampling, recovery, and analysis systems, and performed six successful Aircore sample collections. Figure 1 shows the schematic of the AirCore flight train used at ARM-SGP. We note the newest configuration mentioned in Lessons Learned now employs two smaller balloons rather than a single larger balloon, enabling gradual descent from the stratosphere.

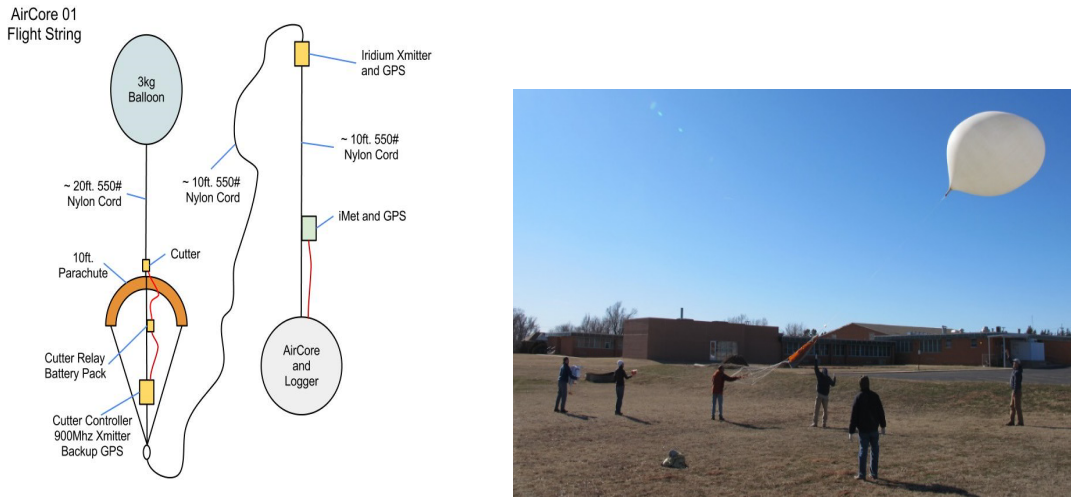

Figure 1. Schematic AirCore Flight String and balloon launch. The AirCore Balloon string is made up of several modules including the AirCore/Data logger, MET, Iridium, cutter, and parachute modules. For example, a balloon launch in January, 2012.

Data was collected on flight dates shown in Table 1. Three balloon-borne packages were launched on each date, providing a useful measure of reproducibility in CO_2 and CH_4 profiles obtained for the three AirCore samples on each day. For example, Figure 2 shows example profiles of CO_2 and CH_4 obtained on a subset of flights. In general, the agreement of column mean CO_2 (and CH_4) obtained for the dual profiles are sufficient to provide valuable measurement constraints for use in evaluating remote-sensed retrievals of the atmospheric columns from the TCCON instrument located at ARM-SGP and the TES, GOSAT, OCO2 satellite observations of CO_2 and CH_4 (for GOSAT). In addition to the comparison with TCCON and remote sensing (which is in progress), AirCore data from ARM-SGP played a useful part in recently published work of observations of troposphere-stratospheric exchange rates (Ray et al., 2014).

As noted above, the results of this intensive operational period (IOP) demonstrate that the instrument system and operations are now near a state at which reliable high-quality sample collection can be achieved throughout the atmospheric column on a routine basis. With the launch of OCO2 satellite, we consider ARM-SGP a key site for continued evaluation of the OCO2 column CO_2 retrievals because of the large seasonal variations in surface reflectance. We hence plan to propose a new IOP to gather data that will be used to provide critical tests of the OCO2 and GOSAT data products. Directly relevant to DOE-BER goals, both the AirCore profiles and column remote sensing provide data to parameterize and evaluate the Community Earth System Model (CESM) being developed by DOE-BER.

Table 1. AirCore flight dates and comments on whether ground-based tower (ARM-PGS) and aircraft (ARM-ACME) data are available for those dates.

AirCore SGP flight dates		
Date	PGS data	ACME data
20161021	yes	No
20161024	yes	No

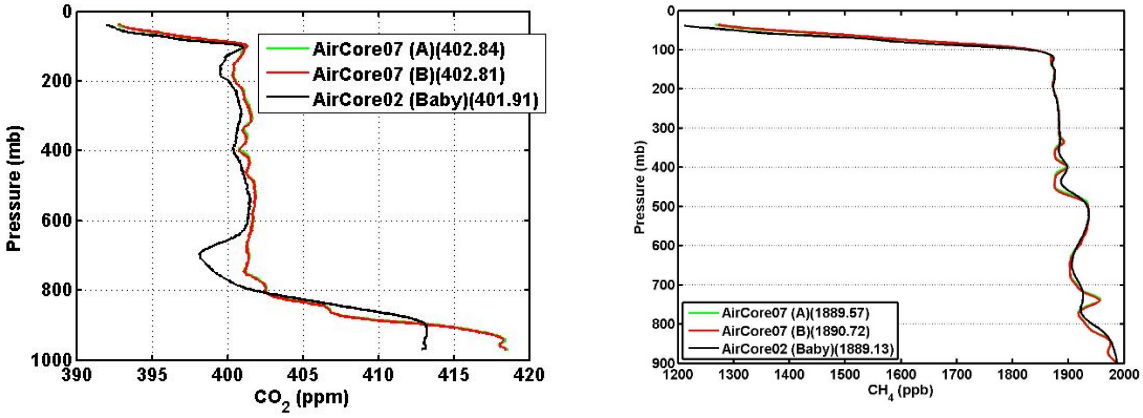

Figure 2. Measured profiles of CO_2 (left) and CH_4 (right) for three Aircore samples collected on October, 10, 2016. The CO_2 and CH_4 profiles and resulting pressure-weighted column mean (see inset legends) were essentially indistinguishable to within instrument noise for the paired Aircores (07 A & B). However, measurable differences were observed between the paired Aircores and the single Aircore (02), suggesting the presence of spatial variation in trace gas mixing ratios for both CO_2 and CH_4.

5.0 Public Outreach

No public outreach was included as part of this campaign.

6.0 Publications

6.1 Journal Articles/Manuscripts

N/A

6.2 Meeting Abstracts/Presentations/Posters

Fischer, M.L., et al., 2015. Full-column Greenhouse Gas Profiles Measured at ARM SGP. DOE Terrestrial Ecology Annual Meeting, May, 2015, Potomac MD.

7.0 References

Karion, A, C Sweeney, P Tans, and T Newberger. 2010. "AirCore: An innovative atmospheric sampling system." *Journal of Atmospheric and Oceanic Technology* 27(11): 1839-1853, doi:10.1175/2010JTECHA1448.1.


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