NACP MCI: Tower Atmospheric CO2 Concentrations, Upper Midwest Region, USA, 2007-2009

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Revision date: February 11, 2014

Summary:

This data set provides high precision and high accuracy atmospheric CO_2 data from seven well instrumented towers located in the U.S. Upper Midwest. The overall sampling period was from January 2007 through December 2009 although actual sampling dates vary within this time period for individual towers and sampling heights above ground level. The measurements were obtained in support of the North American Carbon Program (NACP) Mid-Continent Intensive (MCI) campaign and were used in inverse modeling of regional CO_2 fluxes by NACP MCI contributors at Pennsylvania State University (PSU) and Colorado State University (CSU).

The sampling network included: the five "Ring 2" towers [Centerville (Iowa), Galesville (Wisconsin), Kewanee (Illinois), Mead (Nebraska), and Round Lake (Minnesota)] deployed and operated by PSU; the Missouri Ozarks (Missouri) co-located AmeriFlux site [PSU/Oak Ridge National Laboratory (ORNL)]; and the Rosemount (Minnesota) tower trace gas observatory [University of Minnesota, Rosemount Research and Outreach Center (RROC)]. The study region has a mostly agricultural landscape and is one of the strongest and most localized regions of CO_2 drawdown in the world.

Hourly CO_2 dry mole fractions (in ppm) were averaged from measurements made at different above-ground levels on the towers and are reported in Coordinated Universal Time (UTC). For the five Ring 2 sites, daily daytime average CO_2 dry mole fractions were also calculated, from hourly values between 12:00-17:00 local standard time and reported in UTC.

There are seven compressed (.zip) data files and one comma-separated (.csv) file with this data set. Data quality flags are provided in each file.

Revision Note: The title of this data set was changed on February 11, 2013 at the request of the contributors to provide a more accurate description of its contents.

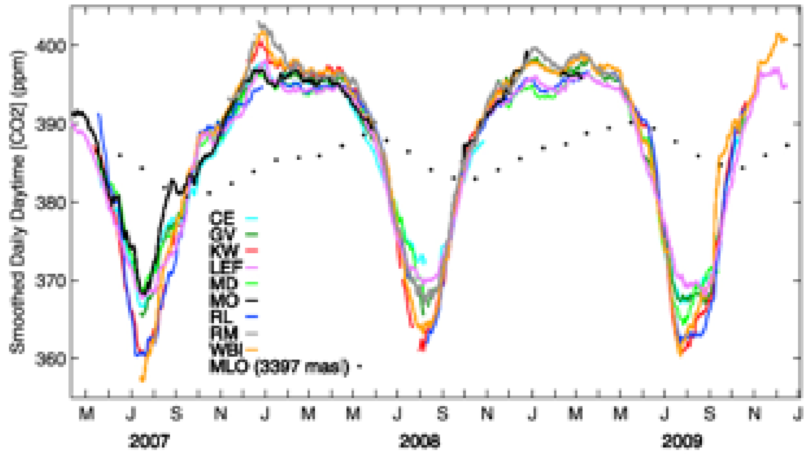

Figure 1. Smoothed CO_2 mole fraction for tower sites in the MCI region. See Table 1 for site name abbreviations. Data for Mauna Loa (MLO), representing the tropospheric "background," are shown for reference (data courtesy of NOAA-ESRL; see http://esrl.noaa.gov/gmd/). Rosemount data are courtesy of T. Griffis (University of Minnesota). Source: Miles et al. (2012).

Data and Documentation Access:

Get Data: http://daac.ornl.gov/cgi-bin/dsviewer.pl?ds_id=1202

Supplemental Information:

- MCI Region boundary is included as an ESRI Shapefile (NACP_MCI_Boundary_Shapefile.zip).
- MCI Region county boundaries are included as an ESRI Shapefile (NACP_MCI_US_County_Boundaries_Shapefile.zip).
- MCI Region state names, county names, and county Federal Information Processing Standard (FIPS) codes are included as a comma separated value (CSV) file (NACP_MCI_US_County_Names.csv).

Related Data Products:

- NACP MCI: CO2 Flux from Inversion Modeling, Upper Midwest Region, USA, 2007
- NACP MCI: CO2 Emissions Inventory, Upper Midwest Region, USA, 2007

Data Citation:

Cite this data set as follows:

Miles, N.L., S.J. Richardson, K.J. Davis, A.E. Andrews, T.J. Griffis, V. Bandaru, and K.P. Hosman. 2014. NACP MCI: Tower Atmospheric CO2 Concentrations, Upper Midwest Region, USA, 2007-2009. Data set. Available on-line [http://daac.ornl.gov] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, USA. http://dx.doi.org/10.3334/ORNLDAAC/1202

This data set was originally published as: Miles, N.L., S.J. Richardson, K.J. Davis, A.E. Andrews, T.J. Griffis, V. Bandaru, and K.P. Hosman. 2014. NACP MCI: CO2 Flux Tower Measurements, Upper Midwest Region, USA, 2007-2009. Data set. Available on-line [http://daac.ornl.gov] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, USA. http://dx.doi.org/10.3334/ORNLDAAC/1202

Table of Contents:

1. Data Set Overview:

Project: North American Carbon Programt (NACP)

The NACP (Denning et al., 2005; Wofsy and Harriss, 2002) is a multidisciplinary research program to obtain scientific understanding of North America's carbon sources and sinks and of changes in carbon stocks needed to meet societal concerns and to provide tools for decision makers. Successful execution of the NACP has required an unprecedented level of coordination among observational, experimental, and modeling efforts regarding terrestrial, oceanic, atmospheric, and human components. The project has relied upon a rich and diverse array of existing observational networks, monitoring sites, and experimental field studies in North America and its adjacent oceans. It is supported by a number of different federal agencies through a variety of intramural and extramural funding mechanisms and award instruments. The Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC) is the archive for the NACP synthesis data products.

This data set is part of the NACP MCI experimental campaign which was designed to evaluate innovative methods for CO_2 flux inversion and data assimilation by performing quantitative comparison of "top-down" and "bottom-up" inventory estimates of a regional carbon budget. The region selected for this study is one of the strongest and most localized regions of CO_2 drawdown in the world. The agricultural landscape is relatively flat and hosts a regional network of instrumented tall towers for atmospheric CO_2 measurements (Figure 2), making the area advantageous for inverse modeling experiments.

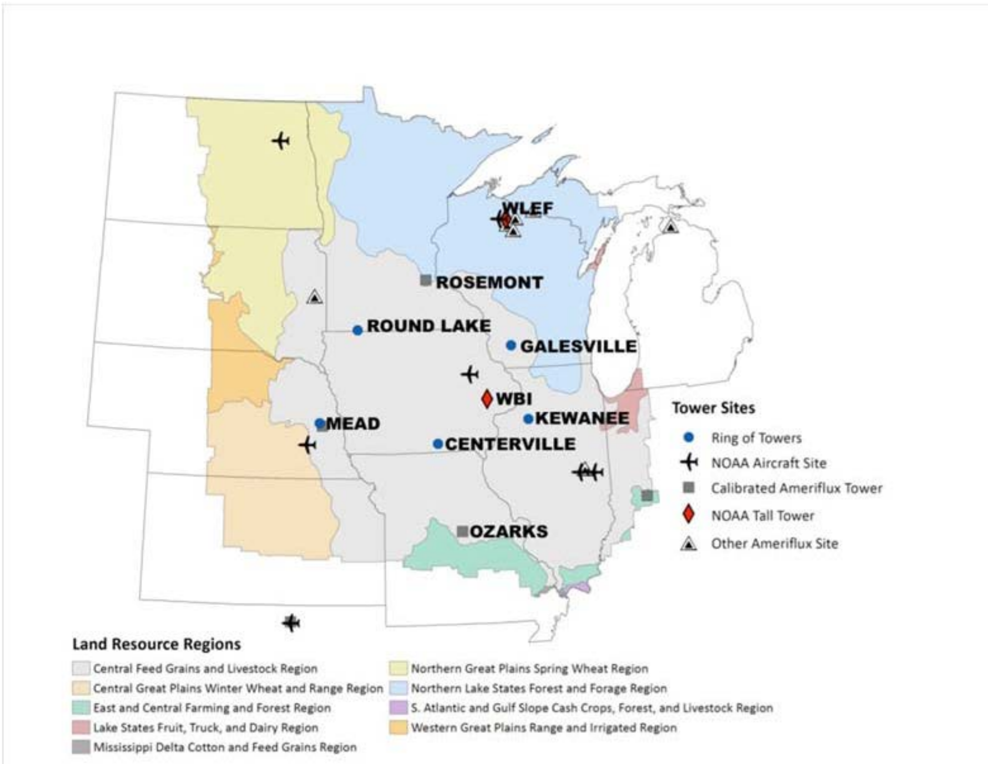

Figure 2. Map of MCI domain located in U.S. Upper Midwest. Source: Schuh et al. (2013).

Table 1. Authors

Note: For questions regarding the Rosemount, Minnesota site, please contact Tim Griffis. For all other sites, contact Natasha Miles and Scott Richardson.

Contact	Email
Miles, Natasha L.	nmiles@met.psu.edu
Richardson, Scott J.	richardson@psu.edu
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Griffis, Tim	timgriffis@umn.edu
Hosman, Kevin P.	hosmank@missouri.edu

2. Data Description:

This data set contains CO_2 dry mole fraction data (in ppm) from a seven towers located in the U.S. upper Midwest. The overall sampling period was from January 2007 through December 2009 although actual sampling dates vary within this time period for individual towers and sampling heights above ground level. Measurements were averaged to hourly and/or daily daytime time scales. There are seven data files (.zip format) which correspond to the seven towers. When expanded, the .zip data files contain files in comma-separated-value format (.csv).

2.1. Spatial Coverage

Site: U.S. Upper Midwest

Site Boundaries:(All latitude and longitude given in decimal degrees)

Site (Region)	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
U.S. Upper Midwest	-96.4559	-89.9724	44.6886	38.7441

2.2. Spatial Resolution

Point (lat/lon) centered around flux tower.

2.3. Temporal Coverage

Overall: January 2007 through December 2009. Measurement dates vary per tower location and height above ground level. See Table 2.

2.4. Temporal Resolution

Hourly CO_2 dry mole fraction data are reported in Coordinated Universal Time (UTC) for all seven locations. See Data Acquisition Materials and Methods section for information on sampling interval and hourly averaging scheme for each site. Daily daytime average CO_2 dry mole fraction data for the five Ring 2 sites cover the time period 12:00–17:00 (LST) and are reported in UTC. Time is given as fractional day of year, decimal time (UTC).

Table 2. Site Names, Latitudes, Longitudes, Elevation, Sampling Heights, and Sampling Dates.

Site Code	Full Name	Latitude (degrees N)	Longitude (degrees W)	Elevation (m AMSL)	Sampling Heights (m AGL)	Overall Sampling Dates
CE	Centerville, Iowa	40.7919	-92.8775	286	30	04/30/2007-10/31/2008
					110	04/28/2007-11/04/2009
GV	Galesville, Wisconsin	44.0910	-91.3382	251	30	06/30/2007-04/21//2009
					140	06/30/2007-11/04/2009
KW	Kewanee, Illinois	41.2762	-89.9724	247	30	04/27/2007-12/11/2008
					140	04/27/2007-11/04/2009
MM	Mead, Nebraska	41.1386	-96.4559	358	30	05/01/2007-03/30/2009
					120	05/01/2007-11/04/2009
RL	Round Lake, Minnesota	43.5263	-95.4137	469	30	05/03/2007-04/21/2009
					110	05/03/2007-11/04/2009
MO	Missouri Ozarks, Missouri	38.7441	-92.2000	219	30	01/01/2007-03/06/2009
RM	Rosemount, Minnesota	44.6886	-93.0728	290	100	05/21/2007-12/31/2009
					200	01/01/2007-12/31/2009

Notes: CE, GV, KW, MD, and RL are Ring 2 sites.

AMSL = elevation above mean sea level.

AGL = height above ground level. In Ring 2 data files, Level 1 = higher sampling height; Level 2 = lower sampling height. In the Rosemount data file, the first column = measurements at 200 m AGL; the second column = measurements at 100 m AGL.

Measurements from four NOAA Towers were also used as input data for the MCI Inversion Study (e.g., WLEF and WBI shown in Figure 2, among others) but are not included in this data set.

2.5. Data File Information

Table 3. Data Files

FILE NAMES	DATA FILES	DESCRIPTION
Centerville.zip	ce_level1_hourly.csv	Hourly mean CO_2 dry mole fraction at 110-m AGL, 2007-2009
	ce_level1_dda.csv	Daily daytime average CO_2 dry mole fraction at 110-m AGL, 2007-2009
	ce_level2_hourly.csv	Hourly mean CO_2 dry mole fraction at 30-m AGL, 2007-2009
	ce_level2_dda.csv	Daily daytime average CO_2 dry mole fraction at 30-m AGL, 2007-2009
Galesville.zip	gv_level1_hourly.csv	Hourly mean CO_2 dry mole fraction at 140-m AGL, 2007-2009
	gv_level1_dda.csv	Daily daytime average CO_2 dry mole fraction at 140-m AGL, 2007-2009
	gv_level2_hourly.csv	Hourly mean CO_2 dry mole fraction at 30-m AGL, 2007-2009
	gv_level2_dda.csv	Daily daytime average CO_2 dry mole fraction at 30-m AGL, 2007-2009
Kwanee.zip	kw_level1_hourly.csv	Hourly mean CO_2 dry mole fraction at 140-m AGL, 2007-2009
	kw_level1_dda.csv	Daily daytime average CO_2 dry mole fraction at 140-m AGL, 2007-2009
	kw_level2_hourly.csv	Hourly mean CO_2 dry mole fraction at 30-m AGL, 2007-2009
	kw_level2_dda.csv	Daily daytime average CO_2 dry mole fraction at 30-m AGL, 2007-2009
Mead.zip	mm_level1_hourly.csv	Hourly mean CO_2 dry mole fraction at 120-m AGL, 2007-2009
	mm_level1_dda.csv	Daily daytime average CO_2 dry mole fraction at 120-m AGL, 2007-2009
	mm_level2_hourly.csv	Hourly mean CO_2 dry mole fraction at 30-m AGL, 2007-2009
	mm_level2_dda.csv	Daily daytime average CO_2 dry mole fraction at 30-m AGL, 2007-2009
Round_Lake.zip	rl_level1_hourly.csv	Hourly mean CO_2 dry mole fraction at 110-m AGL, 2007-2009
	rl_level1_dda.csv	Daily daytime average CO_2 dry mole fraction at 110-m AGL, 2007-2009
	rl_level2_hourly.csv	Hourly mean CO_2 dry mole fraction at 30-m AGL, 2007-2009
	rl_level2_dda.csv	Daily daytime average CO_2 dry mole fraction at 30-m AGL, 2007-2009
Missouri_Ozarks.zip	mo_2007_hourly.csv	Hourly mean CO_2 dry mole fraction at 30-m AGL, 2007
	mo_2008_hourly.csv	Hourly mean CO_2 dry mole fraction at 30-m AGL, 2008
	mo_2009_hourly.csv	Hourly mean CO_2 dry mole fraction at 30-m AGL, 2009
	rm_2007_hourly.csv	Hourly mean CO_2 dry mole fraction at 100-m and 200-m AGL, 2007

Rosemount.zip	rm_2008_hourly.csv	Hourly mean CO_2 dry mole fraction at 100-m and 200-m AGL, 2008
	rm_2009_hourly.csv	Hourly mean CO_2 dry mole fraction at 100-m and 200-m AGL, 2009
ring2_mci_sites.csv		Provides descriptions for each site including latitude, longitude, sampling height, and instrumentation data

2.6. Data File Descriptions

The data files provide mean CO_2 dry mole fraction observations from seven towers located in the U.S. Midwest. Measurements were made at different levels above ground. Hourly CO_2 averages are provided for all seven sites. Daily daytime CO_2 averages are also provided for the five Ring 2 sites. Missing values are denoted by the value -999. The value -888 is used in the Rosemount data files where CO_2 values out of biophysical limits (< 335 and > 435 ppm) were removed by ORNL DAAC and replaced with a missing value code.

Table 4. Ring 2 Hourly Data Files

COLUMN	COLUMN HEADING	DEFINITION	UNITS
1	Inst	Serial number of instrument used to collect data	Alphanumeric
2	Site	2 letter code indicating site of data collection	Text
3	Level	Level of air sample. Level 1 is the higher level (> 100-m AGL) and level 2 is the lower level (30-m AGL).	Numeric
4	Year	Year of data collection	YYYY
5	DOY	Day of year	DD
6	Hour	Hour of collection (UTC)	HH_UTC
7	Time	Fractional day of year (UTC)	Decimal_time_UTC
8	CO2	Hourly mean CO_2 dry mole fraction	ppm
9	QualityFlag	1: error estimated to be < 0.1 ppm 2: error estimated to be > 0.1 ppm but < 0.2 ppm 3: error estimated to be > 0.2 ppm but < 0.3 ppm 4: error estimated to be > 0.3 ppm but < 0.5 ppm 5: error estimated to be > 0.5 ppm (not recommended to be used; CO_2 listed as -999) 0: missing data (CO_2 listed as -999.00)	Numeric

Table 5. Ring 2 Daily Daytime Average Data Files

COLUMN	COLUMN HEADING	DEFINITION	UNITS
1	Inst	Serial number of instrument used to collect data	Alphanumeric
2	Site	2 letter code indicating site of data collection	Text
3	Level	Level of air sample. Level 1 is the higher level (> 100 m AGL) and level 2 is the lower level (30 m AGL).	Numeric
4	Year	Year of data collection	YYYY
5	DOY	Day of year	DD

6	CO2 (ppm)	Daily daytime average CO_2 dry mole fraction between 12:00 and 17:00 local reported in UTC	ppm
7	QualityFlag	1: error estimated to be < 0.1 ppm 2: error estimated to be > 0.1 ppm but < 0.2 ppm 3: error estimated to be > 0.2 ppm but < 0.3 ppm 4: error estimated to be > 0.3 ppm but < 0.5 ppm 5: error estimated to be > 0.5 ppm (not recommended to be used; CO_2 listed as -999) 0: missing data (CO_2 listed as -999.00)	Numeric

Table 6. Missouri Ozarks Data Files

COLUMN	COLUMN HEADING	DEFINITION	UNITS
1	Year	Year of data collection	YYYY
2	DOY	Day of year	DD
3	Hour	Hour of collection (UTC)	HH_UTC
4	CO2 (ppm)	Hourly mean CO_2 dry mole fraction	ppm
5	QualityFlag	1: error estimated to be < <0.3 ppm 2: error estimated to be > 0.3 ppm but < 0.5 ppm 3: error estimated to be > 0.5 ppm (DO Not Use)	Numeric

Table 7. Rosemount Data Files

COLUMN	COLUMN HEADING	DEFINITION	UNITS
1	Year	Year of data collection	YYYY
2	DOY	Day of year	DD
3	Time	Time of data collection (UTC)	HHMM_UTC
4	Day_Time	Fractional day of year, decimal time (UTC)	Decimal_day_UTC
5	CO2_200_m_AGL	Hourly mean CO_2 dry mole fraction at approximately 200 m above ground level (AGL)	ppm
6	CO2_100_m_AGL	Hourly mean CO_2 dry mole fraction at approximately 100 m above ground level (AGL)	ppm
7	QualityFlag1	If > 0 mass flow controller is less than set point; then isotope ratio data are lower quality	Numeric
8	QualityFlag2	If > 0 TDL calibration values are not within expected range; then isotope ratio data are lower quality	Numeric
9	QualityFlag3	If > 0 values appear to be out of biophysical limits	Numeric

2.7. Companion File Information

Table 8. Companion Files

There are eight companion files with this data set. This includes a PDF of this guide document, and a document for each of the seven sites which provides information specific to the site.

FILE NAMES
NACP_MCI_Measurements.pdf
Centerville_RING2_readme.pdf
Galesville_RING2_readme.pdf
Kewanee_RING2_readme.pdf
Mead_RING2_readme.pdf
Round_Lake_RING2_readme.pdf
Missouri_Ozarks_readme.pdf
Rosemount_readme.pdf

3. Data Application and Derivation:

This data product contributes to a multidisciplinary research program to obtain scientific understanding of North America's carbon sources and sinks and of changes in carbon stocks needed to meet societal concerns and to provide tools for decision makers.

A primary goal of this study was to produce dense coverage of high-resolution, well-calibrated regional atmospheric CO_2 data over one of the strongest and most localized regions of CO_2 drawdown in the world (Miles et al., 2012). The CO_2 observation data from this study were used as input data to two sets of mesoscale MCI inversions which derived regional CO_2 fluxes with independent transport models at different resolutions and boundary conditions(NACP MCI: CO_2 Flux from Inversion Modeling, Upper Midwest Region, USA., 2007). The inversion results were compared with estimates from the NOAA Carbon Tracker inversion system (Lauvaux et al., 2012, Schuh et al., 2013) and with agricultural and forest inventory estimates of regional CO_2 emissions (NACP MCI: CO_2 Emissions Inventory, Upper Midwest Region, USA., 2007)].

4. Quality Assessment:

Richardson et al. (2012) document the quality assessment of the WS-CRDS instruments during the MCI at Ring 2 sites, including predeployment calibrations and deployment details, results from laboratory precision tests, water vapor correction to CO_2, round-robin field tests, analyzer drift, and an 8-month comparison of WS-CRDS to NOAA/ESRL nondispersive infrared (NDIR) spectroscopic gas detector measurements. For the Ring 2 data, excluding one site (Kewanee), 2σ of quasi-daily magnitudes of the drifts, before applying field calibrations, are less than 0.38 ppm over the entire 30-month field deployment (May 2007 through November 2009). After applying field calibrations using known tanks sampled every 20 h, residuals from known values ranged from 0.02 ± 0.14 to 0.17 ± 0.07 ppm, depending on the site. Eight months of WS-CRDS measurements collocated with a NOAA/ESRL NDIR system at West Branch, Iowa, showed median daytime-only differences of ~0.13± 0.63 ppm on a daily time scale (Richardson et al., 2012).

Quality flags based on estimated error are provided for the Ring 2 data. The error was estimated based on the degree to which the daily field calibration tank measurement differed from their known values, or problems with flow rate or missing daily field calibration. The field calibration tank values for the Ring 2 sites are: Kewanee: 360.84 and 395.48 ppm; Centerville: 361.00 and 396.14 ppm; Mead: 361.82 and 417.40 ppm; Round Lake: 337.76 and 364.16 ppm; and Galesville: 360.54 and 422.89 ppm (after 11/3/08, 351.20 and 413.68 ppm).

Stephens et al. (2011) describe the NDIR spectroscopic gas detector instrument LI-820 CO_2 concentration measurement system and calibration scheme utilized at Missouri Ozarks. Calibrations using 4 field tanks were performed every 4 hours, a target tank was sampled every hour, and an archive tank was sampled every 23 hours. Two nafion driers were used, ensuring that the difference in water vapor concentration between the dried sample and the moistened calibration gases was less than 300 ppm (corresponding to an error in the CO_2 measurement of 0.1 ppm). Flow control, such that the flow rate changes by less than 4 cc/min between the sample air and calibration gases, was achieved using a mini-regulator. Leak tests were automated. For details, see Stephens et al. (2011).

Stephens et al. (2011) acknowledge potential sources of noise or systematic bias in atmospheric CO_2 measurements using the NDIR LI-820 and describe how problems were solved. For example, the investigators overcame short-term noise with signal averaging and instrument drift with frequent calibrations. Additional potential sources of CO_2 measurement bias that they have addressed using automated diagnostics include: incomplete flushing of the sample cell and dead volumes, incomplete drying of the sample air, sensitivity to pressure broadening, sensitivity to temperature, leaks to ambient air, leaks of calibration gas through solenoid valves, and modification of CO_2 concentration by the drying system or plastic components (see Sect. 2.4 of Stephens et al., 2011). Stephens et al. (2011) also describe multiple side-by-side laboratory tests of up to six of systems with results showing median differences between systems varied about zero by 0.1 ppm (1-σ). Field measurements of known reference-gases at seven sites resulted in median errors of 0.01 to 0.17 ppm with 1-σ variance of ± 0.1 to 0.2 ppm.

The tunable diode laser (TDL) system used at Rosemount was evaluated for making continuous carbon isotope eddy covariance flux measurements over a short homogeneous soybean canopy by Griffis et al. (2008). TDL calibrations were performed every measurement cycle using a 3-point linear best fit with standards ranging from ~ 320 to 450 µmol/mol. This range was selected to bracket the strong daytime draw-down and nocturnal buildup of CO_2 during the growing season. A detailed discussion of the isotope calibration procedure, data processing, mixing ratio calculations, data quality control, EC-TDL precision, and flux footprint analyses are provided in Griffis et al. (2008) and in the auxiliary material to Griffis et al (2010).

The quality of the Rosemount tower data for 2009 may not be as good as that of data from previous years because of some calibration issues with the TDL and vacuum pump failure during the growing season of 2009." Extended pump failures occurred from DOY 145-195 and DOY 254-260.

Additional descriptions of quality assurance testing and instrument calibration are included in the Data Acquisition Materials and Methods section below.

5. Data Acquisition Materials and Methods:

Mid-Continent Intensive Region. The U.S. upper Midwest (Figure 2) was the region selected for the MCI because of its uncomplicated terrain and because the dominant crop ecosystems are extensively documented. The region is primarily agricultural, with cropland and grassland being the dominant vegetation types, but has forest cover in the southern and especially northern portions of the region (U.S. Geological Survey Land Cover Institute, 2010; see http://landcover.usgs.gov). Corn and soybeans are the dominant crops; in Iowa, the area planted with these crops is 52% and 41% of the total agricultural area, respectively [U.S. Department of Agriculture, National Agricultural Statistics Service (USDA, NASS), 2010].

Tower CO_2 Measurements. This data set contains CO_2 sensor data from seven instrumented towers located within the MCI study region. Data were collected from May 2007 through December 2009.

- Ring 2 Sites. The five towers [Centerville (Iowa), Galesville (Wisconsin), Kewanee (Illinois), Mead (Nebraska), and Round Lake (Minnesota)] were instrumented with wavelength-scanned cavity ring-down spectroscopy (WS-CRDS) systems (Picarro, Inc., Santa Clara, California, model CADS) (Crosson, 2008). Table 2 above provides the site locations, elevations above sea level, sampling heights, and sampling start/end dates for the five Ring 2 sites. The analyzers were calibrated before the field installation. The WS-CRDS instruments scan a $^{12}C^{16}O_2$ line of carbon dioxide which is then used to infer the total carbon dioxide content of the sample gas. The flow rate of the PSU WS-CRDS systems is approximately 200 ml/min. Except during hours in which the field standards were sampled, the upper level (110–140 m AGL) at each site was sampled for 45 min and the lower level (30 m AGL) was sampled for 15 min of each hour. These values were then used to compute averages at hourly resolution. Daily daytime averages were calculated from hourly values between 12:00–17:00 local standard time.

- Missouri Ozarks, Missouri. The Missouri Ozarks CO_2 measurement site is co-located with an ongoing AmeriFlux site (Gu et al., 2006; 2008; 2012) in the University of Missouri's Baskett Wildlife Research and Education Area within the Ozark border region of central Missouri. The site is uniquely located in the ecologically important transitional zone between the central hardwood region and the central grassland region of the United States. It is dominated by second-growth upland oak-hickory forests. The tower is equipped with a suite of meteorological and ecological instrumentation, including a well-calibrated nondispersive infrared (NDIR) spectroscopic gas detector instrument (Licor, Inc., Lincoln, Nebraska, model LI-820) based upon a single path, dual wavelength infrared detection system. For this study, CO_2 measurements were made at 30 m AGL. Air was drawn from a single inlet with an adjusted flow rate of 150 ml/min. The gas being analyzed was switched every 150 seconds (2.5 min.), and 1 min of data was ignored while the system flushed. Data were averaged to hourly concentrations. The system was calibrated every 4 hours using four real air standards (with hourly target and daily archive tests as well), temperature and pressure controlled, and automatically leak tested. Residuals from known tank values tested daily at the site were approximately 0.11 ± 0.21 ppm (Stephens et al., 2011).

- Rosemount, Minnesota. The Rosemount tower trace gas observatory (deployed on Minnesota Public Radio communications tower, KCMP 89.3 FM) is located approximately 25-km to the south of Minneapolis/St. Paul at the University of Minnesota, Rosemount Research and Outreach Center (RROC). The tower was instrumented in April 2007 with two eddy covariance (EC) systems and one tunable diode laser (TDL). Two field-scale micrometeorological stations are located within about 3 km of the tall tower and have been part of the AmeriFlux network since 2004. For this study, carbon isotope molar mixing ratios $^{12}CO_2$ and $^{13}CO_2$ were measured in situ using TDL spectroscopy (TGA100A, Campbell Scientific, Incorporated, Logan, Utah, United States) (Bowling et al., 2003; Griffis et al., 2004; 2005; 2007; 2008; 2010). The TDL was maintained within an air conditioned communications building located at the base of the tower. While the air profile system consists of 4 sample inlets installed at ~32, 56, 100, and 200-m AGL which are used to compute F^i_S and concentration gradients, only data from 100 and 200-m AGL are presented in this data set. The top two levels are instrumented with sonic anemometer-thermometers (CSAT3, Campbell Scientific, Incorporated) for EC flux measurements. A 2-Hz EC digital filter passband option was applied using the TDL software.

A base flow rate (~ 20 L/min) of sample air was pulled continuously from each level to a custom designed manifold (Campbell Scientific Inc.) using a diaphragm pump (1023-101Q-SG608X, GAST Manufacturing Inc.). A vacuum pump (RB0021, Busch Inc. Virginia Beach, VA, USA) was used to sub-sample this flow for concentration and isotope analyses. Two naflon driers (PD625, Perma Pure Inc., NJ, USA) were used to ensure the sample air and calibration air were dried and brought to a common humidity (dew point temperature of ~ -21 degrees C). A third Nafion drier (PD1000) and vacuum pump provided the dry purge air for the sample air driers. The sampling system selected either a sub-sample of the air stream from one of the inlets or one of three calibration cylinders (traceable to the Earth System Research Laboratory - Global Monitoring Division, National Oceanic and Atmospheric Administration (ESRL-NOAA). The sub-sampled air was delivered to the TDL and an infrared gas analyzer (IRGA, LI7000, Licor Inc., Lincoln Nebraska, USA) via two mass flow controllers (16 M Series, Alicat Scientific, AZ, USA) at rates of 3 L/min and 0.85 L/min, respectively. The IRGA was maintained in a temperature-controlled housing (TCH, Model GA-TCH, Biometeorology and Soil Physics Group, University of British Columbia).

The raw concentration data were recorded at 10 Hz. Within each hour the concentration was measured 5 times. The sample duration was 11 minutes. The TDL analyzer was calibrated between each cycle.

6. Data Access:

This data set is available through the Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

Data Archive Center:

Contact for Data Center Access Information:
E-mail: uso@daac.ornl.gov
Telephone: +1 (865) 241-3952

7. References:

Bowling, D.R., S.D. Sargent, B.D. Tanner, and J.R. Ehleringer. 2003. Tunable diode laser absorption spectroscopy for ecosystem–atmosphere CO_2 isotopic exchange studies. Agric. For. Meteorol. 118: 1–19. doi:10.1016/S0168-1923(03)00074-1

Crosson, E.R. 2008. A cavity ring-down analyzer for measuring atmospheric levels of methane, carbon dioxide, and water vapor. Appl. Phys. B 92: 403–408. doi:10.1007/s00340-008-3135-y

Denning, A.S., et al. 2005. Science implementation strategy for the North American Carbon Program: A Report of the NACP Implementation Strategy Group of the U.S. Carbon Cycle Interagency Working Group. U.S. Carbon Cycle Science Program, Washington, DC. 68 pp.

Griffis, T.J., J.M. Baker, S D. Sargent, B D. Tanner, and J. Zhang. 2004. Measuring field scale isotopic CO_2 fluxes with tunable diode laser absorption spectroscopy and micrometeorological techniques. Agric. For. Meteorol. 124(1–2): 15-29, 38. doi:10.1016/j.agrformet.2004.01.009

Griffis, T.J., X. Lee, J.M. Baker, S.D. Sargent, and J Y. King. 2005. Feasibility of quantifying ecosystem atmosphere $C^{18}O^{16}O$ exchange using laser spectroscopy and the flux gradient method. Agric. For. Meteorol. 135(1–4): 44-60, 61. doi:10.1016/j.agrformet.2005.10.002

Griffis, T.J., J. Zhang, J.M. Baker, N. Kljun, and K. Billmark. 2007. Determining carbon isotope signatures from micrometeorological measurements: Implications for studying biosphere atmosphere exchange processes. Boundary Layer Meteorol. 123(2): 295-316. doi:10.1007/s10546-006-9143-8

Griffis, T.J., S.D. Sargent, J.M. Baker, X. Lee, B.D. Tanner, J. Greene, E. Swiatek, and K. Billmark. 2008. Direct measurement of biosphere atmosphere isotopic CO_2 exchange using the eddy covariance technique. J. Geophys. Res. 113, D08304. doi:10.1029/2007JD009297

Griffis, T.J., J.M. Baker, S.D. Sargent, M. Erickson, J. Corocoan, M. Chen, and K. Billmark. 2010. Influence of C_4 vegetation on $^{13}CO_2$ discrimination and isoforcing in the upper Midwest, United States. Global Biogeochem. Cycles 24: GB4006. doi:10.1029/2009GB003768

Gu, L., P.J. Hanson, W.M. Post, D.P. Kaiser, B. Yang, R. Nemani, S.G. Pallardy, and T. Meyers. 2008. The 2007 eastern U.S. spring freezes: Increased cold damage in a warming world? Biosciences 58: 253-262. doi:10.1641/B580311

Gu, L., T. Meyers, S.G. Pallardy, P.J. Hanson, B. Yang, M. Heuer, K.P. Hosman, J.S. Riggs, D. Sluss, and S.D. Wullschleger. 2006. Direct and indirect effects of atmospheric conditions and soil moisture on surface energy partitioning revealed by a prolonged drought at a temperate forest site. J. Geophys. Res. 111, D16102. doi:10.1029/2006JD007161

Gu, L., W.J. Massman, R. Leuning, S.G. Pallardy, T. Meyers, P.J. Hanson, J.S. Rigga, K.P. Hosman, and B. Yang. 2012. The fundamental equation of eddy covariance and its application in flux measurement. Agric. For. Meteorol. 152: 135-148. doi:10.1016/j.agrformet.2011.09.014

Lauvaux, T., A.E. Schuh, M. Uliasz, S. Richardson, N. Miles, A E. Andrews, C. Sweeney, L.I. Diaz, D. Martins, P.B. Shepson, and K.J. Davis. 2012. Constraining the CO_2 budget of the corn belt: exploring uncertainties from the assumptions in a mesoscale inverse system. Atmos. Chem. Phys. 12: 337-354. doi:10.5194/acp-12-337-2012

Miles, N.L., S.J. Richardson, K.J. Davis, T. Lauvaux, A.E. Andrews, T.O. West, V. Bandaru, and E. R. Crosson. 2012. Large amplitude spatial and temporal gradients in atmospheric boundary layer CO_2 mole fractions detected with a tower-based network in the U.S. upper Midwest. J. Geophys. Res. 117: G01019. doi:10.1029/2011JG001781

Richardson, S.J., N.L. Miles, K.J. Davis, E.R. Crosson, C. Rella, and A.E. Andrews. 2012. Field testing of cavity ring-down spectroscopy analyzers measuring carbon dioxide and water vapor. J. Atmos. Oceanic Technol. 29(3): 397-406. doi:10.1175/jtech-d-11-00063.1

Schuh, A.E., T. Lauvaux, T.O. West, A.S. Denning, K.J. Davis, N. Miles , S. Richardson, M. Uliasz , E. Lokupitiya, D. Cooley, A. Andrews, and S. Ogle. 2013. Evaluating atmospheric CO_2 inversions at multiple scales over a highly inventoried agricultural landscape. Global Change Biology 19: 1424-1439. doi: 10.1111/gcb.12141

Stephens, B.B., N.L. Miles, S.J. Richardson, A.S. Watt, and K J. Davis. 2011. Atmospheric CO_2 monitoring with single-cell NDIR-based analyzers. Atmos. Meas. Tech. 4: 2737-2748. doi:10.5194/amt-4-2737-2011

U.S. Department of Agriculture, National Agricultural Statistics Service (USDA, NASS). 2010. Quick Stats Database [http://www.nass.usda.gov/Quick_Stats/]. Washington, D.C.

Wofsy, S.C., and R.C. Harriss. 2002. The North American Carbon Program (NACP). Report of the NACP Committee of the U.S. Interagency Carbon Cycle Science Program. U.S. Global Change Research Program, Washington, DC. 56 pp.