MOBILE MONITORING ASSESSMENT OF METHANE AND OZONE PRECURSORS IN THE PINEDALE ANTICLINE PROJECT AREA DURING WINTER 2012/2013
(MAPA)

02/12/2013 to 03/08/2013

Data Summary Report

Prepared for

WYOMING DEPARTMENT OF ENVIRONMENTAL QUALITY
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List of Abbreviations and Acronyms

ATSC	Atmospheric Science Department
AQ	Collection error (data logger)
AV	Power Failure
BJ	Operator error
BTEX	Benzene, Toluene, Ethyl-benzene and Xylene isomers
CH_4	Methane
DA	Aberrant data (negative spiking below zero range)
DQO	Data Quality Objectives
GC	Gas Chromatography
GPS	Global Positioning System
H_2	Hydrogen
H_2S	Hydrogen Sulfide
MAPA	Mobile Monitoring Assessment of Methane and Ozone Precursors in the Pinedale Anticline Project Area During Winter 2012/2013
MS	Mass Spectrometry
NAAQS	National Ambient Air Quality Standard
NCAR	National Center for Atmospheric Research
NIST	National Institute of Standards and Technology
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NO_x	Oxides of Nitrogen
NS	Influenced by nearby source
O_3	Ozone
OPA	Ozone Precursor Analyzer
PAPA	Pinedale Anticline Project Area
PASQUA	Pinedale Anticline Spatial Air Quality Assessment
PC	Personal Computer
PPBV	Parts per Billion Volume
RL	Other (no measurement the data is reported with a data stream that has more values per unit of time)
QA	Quality Assurance
QAPP	Quality Assurance Project Plan

SOP	Standard Operating Procedure
UGRB	Upper Green River Basin
US	United States
UV	Ultra Violet
UW	University of Wyoming
US EPA	United States Environmental Protection Agency
V	Validated Value
VOC	Volatile Organic Compounds
WDEQ-AQD	Wyoming Department of Environmental Quality Air Quality Division

1.0 INTRODUCTION

The University of Wyoming's (UW) Atmospheric Science Department (ATSC) was contracted by the Wyoming Department of Environmental Quality, Air Quality Division (DEQ-AQD) to perform the MAPA project. This report describes the work performed for this project. A summary of the data collected is given through data capture statistics and illustrated with plots. Data analysis is not provided as this is outside of the scope of the contract.

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2.0 BACKGROUND

Natural gas development in Southwest Wyoming, particularly in the Jonah Field and Pinedale Anticline Project Area (PAPA), has received considerable attention due to observed winter ozone episodes in Sublette County. Ozone in ambient air is regulated through the Clean Air Act of 1970 and subsequent amendments. In March 2008, US EPA promulgated a new National Ambient Air Quality Standard (NAAQS) for ozone. The new standard was lowered from 0.08 ppm to 0.075 ppm based on the fourth highest 8-hour average value per year at a given monitoring site, averaged over three years. Based on monitoring results from 2006 through 2008, WDEQ-AQD's Boulder monitor, in Sublette County was out of compliance with this standard. Violation of this standard is based on data through the third quarter of 2008 showing a three-year average 8-hour ozone concentration of 0.080 ppm ozone. WDEQ-AQD evaluated whether a nonattainment area should be designated due to the monitored results at the Boulder monitor. Using EPA's guidance in the Robert J. Meyers December 4, 2008 memo, the WDEQ-AQD performed a nine-factor analysis that supports WDEQ-AQD's recommendation that the Upper Green River Basin (UGRB) be designated as a non-attainment area for the 2008 ozone NAAQS.

Worldwide air pollution data invariably demonstrate ozone pollution is most prevalent during summer months. This is because ozone production is driven by the photochemical reaction of precursor compounds. Ambient ozone monitoring conducted by WDEQ-AQD has indicated elevated ozone levels in the UGRB during winter months. Ozone episodes are related to particular environmental conditions such as low pollutant dispersion due to wintertime temperature inversions, and enhanced photochemical reactions due to high albedo of snow-covered terrain.

The project conducted mobile measurements to provide enhanced spatial ozone (O_3), methane (CH_4) and oxides of nitrogen (NO_x) data for the area impacted by ozone pollution episodes. We used an automobile-based mobile laboratory for measuring and mapping ground-level ambient data to yield a comprehensive assessment of the spatial variation of methane, ozone and NO_x levels throughout the study area.

The goal of this project is to provide data to assist efforts in understanding the spatial distribution of ozone precursor emissions in the project area. Sampling will be performed during the period February 10^{th} 2013 through 9^{th} March 2013. Specifically, the monitoring data from the MAPA project will help to better quantify the spatial variability of methane, NOx and ozone concentrations and to also provide grab measurements of volatile organic compounds (VOC) at select locations.

3.0 OBJECTIVES

The primary aim is to provide a spatial measurement survey of methane, oxides of nitrogen, ozone together with targeted canister sampling for and key VOC to provide a better understanding of the spatial distribution patterns of these precursors in the Pinedale Anticline Project Area (PAPA).

Wintertime ozone air pollution events are associated with emissions from oil and gas development and specific winter time meteorological conditions: snow cover, strong temperature inversions, low mixing heights, low wind speeds, and clear skies. The importance of high quality information that properly characterizes the spatial and temporal distribution of key precursor pollutants associated with the formation of high wintertime ozone cannot be underestimated. This monitoring study focused on obtaining ambient pollutant data throughout the PAPA.

Objective 1. Assess methane, NO_x and ozone accumulation in the study area by mobile monitoring during different wintertime meteorological conditions.

Objective 2. Perform VOC measurements at selected sites in the study area by canister sampling. Perform ad hoc and planned grab samples during mobile monitoring.

For objective 1 on-road mobile sampling in and around PAPA was conducted. Mobile sampling used a fast response CH_4 and H_2S analyzer manufactured by Picarro, Inc. The analyzer employs Cavity Ring-Down Spectrometry technology, which allows for a 5-second sampling rate and measurement of the species of interest. Additional instrumentation includes 2B Technologies ozone and Nitric Oxide/Nitrogen Dioxide (NO/NO_2) analyzers from 2B Technologies. This instrumentation allows for a 10-second sampling rate for NO_x. A GPS unit provided important ancillary data to determine the location for each measurement. For objective 2 stationary sampling consisted of grab samples with 6L Summa canisters. Samples were also collected during the course of on-road driving circuits. Canister samples were returned to the UW laboratory facility and analyzed using the Perkin Elmer Ozone Precursor Analysis (OPA) system. The OPA system employs gas chromatography to analyze thirty VOC species.

4.0 METHODOLOGICAL APPROACH

Sampling during on-road driving circuits will be undertaken in and around Pinedale Anticline Project Area (PAPA) with the route outlined in Figure 4.1.

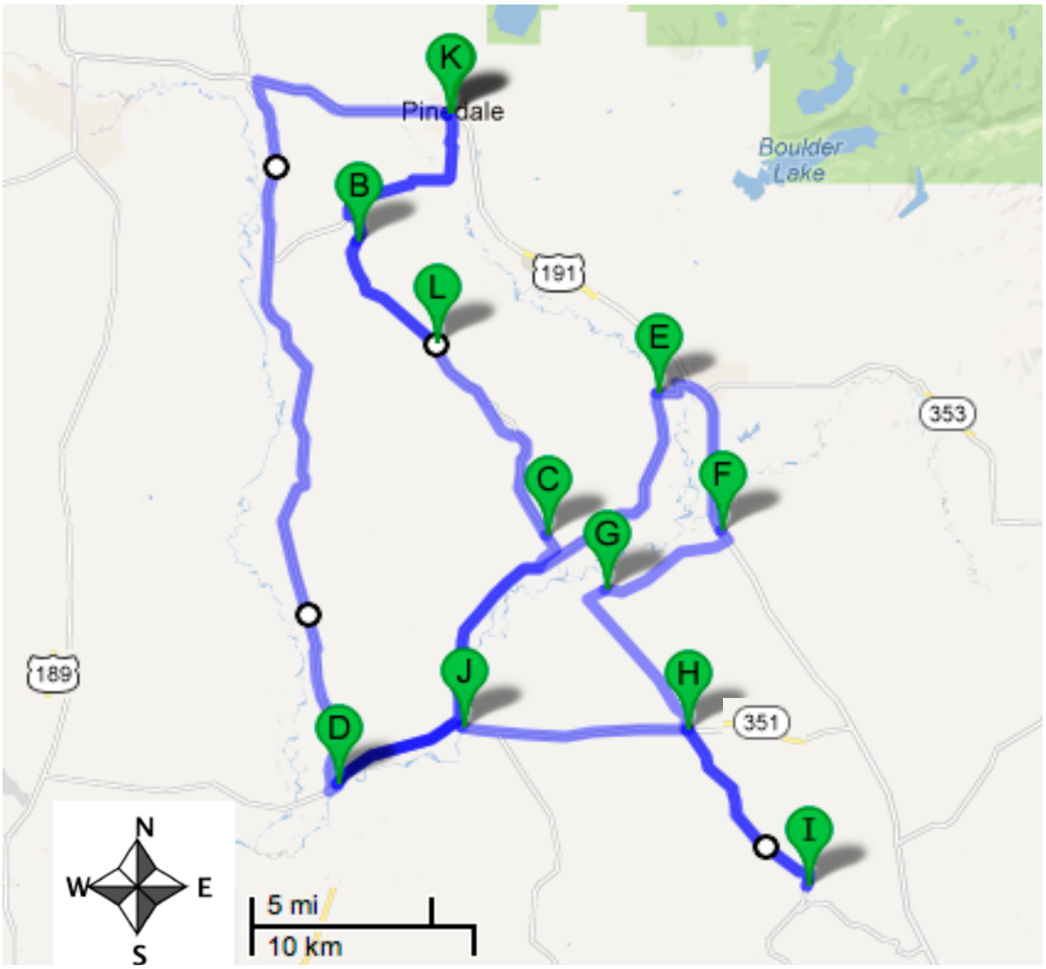


Figure 4.1: Proposed Circuit Within 40 km by 25 km Project Area

The route, given in Figure 4.1, covers a length of approximately 180 km (110 miles). The time duration is approximately 4 hours. The route starts at Point K in the town of Pinedale and follows Tyler Road into the northern end of the Pinedale Anticline past canister site “Mesa TOP”, point B. After passing the Hennick Road entrance the route proceeds along the spine of the Mesa between points L (Mesa North) and C (Pinedale Complex). The route then proceeds West on the Paradise Road to the junction with US 351, Point J, and then doubles back on Paradise Road to the WDEQ-AQD Boulder network site and then onto the Eastern end of Paradise Road, via DEQ Boulder, to the junction of US Highway 191, point E. The route then heads South on US 191 before turning onto Boulder South Road at point F until the junction of Boulder Crest Road at point G. The route then heads South on Boulder Crest Road, with a loop around the Anticline Disposal Facility and passes point H (Boulder 351) to take a loop on Middle

Crest Road to point I (Middle Fork) and back to point H. The route then heads West on US 351 past Olson Ranch before turning at point D onto Green River Road. The route then heads North until meeting the Junction of US 191. Returning to the point of origin in Pinedale completes the circuit.

Each measurement day usually consisted of two circuits. The daytime period is critical due to the potential for photochemical ozone production. The relative importance of the other circuits was dependent on atmospheric conditions, and potential for ozone production. Daytime measurements were undertaken on days when elevated 8-hour ozone concentrations are expected. Evening and mighttime circuits were conducted during stable atmospheric conditions to evaluate localized buildup of ozone precursors.

Routes time periods are outlined below in Table 4.1. The circuit was within areas known for ozone production, precursor accumulation and pollutant transport. Field monitoring was set for a minimum of four weeks during ozone season with a target of a total of 32 circuits for the project. The route incorporates the ten canister sampling locations used for VOC and NO_x surveys performed during the final year of the PASQUA project. This route enables ambient air sampling throughout the Pinedale Anticline Project Area, as well as upwind and downwind measurements from outside of the development area. There are four basic time periods categorized by the time of day. Each period has different emission, dispersion and atmospheric reactivity potential as indicated by Table 4.1.

Table 4.1. Circuit Time Periods

Period	**Code**	**Times**	**Atmospheric conditions**
Nighttime	NT	midnight – sunrise	Highest precursor concentrations; Lower traffic emissions; and Lowest ozone concentrations.
Morning	AM	sunrise – midday	Medium precursor concentrations; Higher traffic emissions; and Low ozone concentrations.
Daytime	PM	midday – sunset	Lower precursor concentrations; Lower traffic emissions; and Higher ozone concentrations due to photochemical production.
Evening	EV	sunset – midnight	Lower precursor concentrations; Higher traffic emissions; and Transported produced ozone may be encountered.

The vehicle-based mobile laboratory was equipped with instrumentation to as shown in Table 4.2, along with the VOC canister information. Due to the fact that measurements are made while the vehicle-based mobile laboratory is en route, fast-response, mobile analyzers were utilized. Fast measurement of NO, NO_2 and NO_x as separate parameters is difficult due to the time needed to switch between measuring each parameter. To ensure the best quality of NO_x measurement the 2B system will be operated with NO_2 continuously converted to NO with NO then being reported as NO_x. The instruments store the data on internal drives. Data is downloaded at the end of the monitoring day to dedicated data loggers.

Table 4.2. Data Measurement Methods

Compound	Method	Federal Equivalent or Reference Method	Averaging Time and range	Frequency
Methane	Ring down spectrometry (Picarro G2204 CH_4 Analyzer)	No **	5-sec. 0 to 500 ppm	Continuous
Ozone	UV Photometric (2B Technologies 202 or 211)	Yes/No **	10-sec. 0 to 2000 ppb	Continuous
Oxides of nitrogen	Chemiluminescence (2B technologies 401/410)	No***	10-sec. 0 to 2000 ppb	Continuous
Volatile Organic Compounds*	6L silonite canister (Entech) with thermal desorption / gas chromatography (Perkin Elmer OPA system)	Yes	20-sec.	Discontinuous

*The following list of VOC are anticipated to be reported: Ethane, ethene (ethylene), ethyne (acetylene), propane, propene (propylene), prop-1-yne (propyne), butane, 2-methylpropane (i-butane), trans-but-2-ene (trans-2-butene), cis-but-2-ene (cis-2-butene), 1,3-butadiene, pentane, 2-methylbutane (i-pentane), 1-pentene, trans-2-pentene (trans-2-pentene), cis-2-pentene (ci-2-pentene), 2-methyl-1,3-butadiene (isoprene), cyclopentane, hexane, 2-methylpentane (i-hexane), 3-methylpentane, heptane, octane, cyclohexane, benzene, toluene, ethyl-benzene, *m+p*-Xylene, *o*-Xylene, styrene.
** New methodology that is not yet approved as an FRM or FEM, but whose performance meets or exceeds currently approved FEM analyzers.
*** An experimental absolute method.

Ambient air analyzers are subject to internal performance checks at the beginning and end of the monitoring campaign. Performance calibration curves consist of a 5-point calibration curve. These calibration curves follow the procedure used by audit contractors for the WDEQ-AQD air quality network stations. At the start and end of day, a zero air check is performed. At the end of each week a span check is performed. Raw measurement data are downloaded and converted to provisional raw data with warm-up zero, ambient, zero and span data differentiated at a later date. Raw data are converted to final data based upon 5-point calibration curves with reference to weekly 1-point span checks.

Each analyzer used for measurement incorporates on-board storage. Measurement data are transferred from the analyzers to a lap top computer, converted to a standard format (.csv) and transferred to redundant storage locations at the Department of Atmospheric Science. Data are stored in a consistent structure for easy identification of date, time and all other recorded parameters. For VOC canister data, the sample time, location, and canister number are added to measurement data.

At the start and end of each monitoring circuit, the time stamp for each instrument is synchronized or noted. The Picarro mobile monitoring system serves as the master reference for all GPS location data and time stamp data points. The first step for data collation is accessing the raw data files for the given circuit. Collated data files are set for 5-second and longer averaging times. Data are then cleaned according to the applicable SOPs. Data validation incorporates calibration curve and span data to produce validated final data using applicable SOPs.

Data visualization is initially available during mobile monitoring as measured data are mapped in real-time. Upon completion of a mobile measurement circuit, the raw data file is completed and re-named according to date and time protocols.

As noted in Table 4.2. Canisters samples were analyzed for VOC at the University of Wyoming using the Perkin Elmer OPA system. The sampling time for a VOC canister is set as grab of approximately 20 seconds. The analysis time for the Perkin-Elmer TurboMatrix 300 thermal desorber is one forty-minute sample of the air from the canister. The sample is then transferred to the Clarus GC 500 which performs peak analysis on two columns. Data for each hourly sample are separated into two distinct channels by TotalChrom Workstation and stored on the GC PC. Spatial measurements of VOC are either at a set location as noted in Table 4.3 or through ad hoc mobile sampling at sites on the route that have elevated methane values on one or more days.

Table 4.3. Canister VOC Monitoring Sites

No.	Site Name	Position
1	DEQ BOULDER	42.7184, -109.7522
2	QEP 1. MESA NORTH (O3w10)	42.7530, -109.8577
3	BOULDER CREST UW1 4.5-06B	42.6593, -109.7845
4	BLM 3. Hennick Draw*	42.8032, -109.9623

*This site is on East Green River Road. The four selected sites are chosen to be as close as possible to those in the Statement of Work of the contract. These sites are selected, as they are the safest to park the motor vehicle for sufficient time to allow for a valid grab sample.

An upper target number of canister samples for the entire project is eighty. The following three PASQUA sampling sites will be used: Mesa North, Boulder Crest and WDEQ-AQD Boulder. An additional PASQUA BTEX (benzene, toluene, ethylbenzene and xylene isomers) site on East Green River Road at Hennick Draw will be used. The first two sites are relatively close to emissions, WDEQ-AQD Boulder has well mixed air and East Green River Road is upwind of PAPA. Together these sites show the widest variation of anticipated VOC concentration ranges. It should be noted that the on-line Perkin Elmer gas chromatographic system is a "one shot" set-up. The system performance is defined by response through precision and reproducibility assessments. Internal checks are performed for each monitoring project, with calibration curve performed using different trap times. This includes a trap time of zero minutes. This is a true blank for the system. Through the project periodic runs with ultra pure zero area are undertaken both directly and indirectly via a canister. These are not true blanks as even ultra pure zero air contains trace levels of VOC that can be quantified by the Perkin Elmer OPA.

Duplicates are performed for span checks of the system. Similar checks of the performance of the canisters were undertaken when filled with span gas. The same protocol is applied to the analysis of ambient canisters and ambient on-line sampling. Canister cleaning is accomplished by cycling between evacuations, refilling with nitrogen followed by evacuation to vacuum. A humidification chamber is used to add moisture to the flush gas for assistance in displacing volatile organic compounds off the interior surface of the canister and manifold tubing. Canisters are simultaneously heated with an oven to facilitate removal of surface bound contaminants. One canister is then filled with zero air. The analysis of this canister is compared to a direct measurement of zero air to determine if the cleaning process adds quantifiable levels. More detail of sampling set-up are given in the MAPA QAPP and associated SOP.

4.1 Quality Assurance

Quality assurance procedures are provided in the MAPA QAPP. Of particular importance is the initial set-up of the equipment, operating protocols and post processing procedures. Operation includes calibration, instrument maintenance, and troubleshooting. At the start and end of the monitoring period, UW conducted an internal audit of all instrumentation. Internal audit results are referenced for final data validation procedures. Routine operation and data collection activities are systematic and follow procedures as detailed in instrument-specific Standard Operating Procedures (SOP).

Internal checks of ozone, oxides of nitrogen and methane monitors were performed to assure that instruments are operating properly. Instruments are initially challenged with zero air to establish accuracy with regards to background, or zero measurement levels. Following zero air, instruments are challenged with varying dilutions of calibrant, either in the form of NIST traceable gas or, in the case of ozone, EPA certified transfer standard. Ozone is challenged with approximately 50, 90, and 190 ppb of O_3 from the ozone transfer standard. Oxides of nitrogen are challenged with approximately 30, 50, 100, and 200 ppb of NO from a NIST traceable calibrant gas. Oxides of nitrogen are also challenged with Nitrogen dioxide via gas phase titration of approximately 11, 18, and 20 percent ozone to test converter efficiency at the end of the study. Methane is challenged with approximately 2.0, 2.5, and 5.0 ppm of CH_4 from a NIST traceable calibrant gas.

After the internal calibration curve is performed, instrument response is recorded in a spreadsheet that calculates relative percent difference between calibration standard and instrument response, slope, intercept, and correlation. Instruments are calibrated according to instrument specific SOPs listed previously.

The MAPA QAPP outlines the criteria parameters for determining the quality of measurement data. This project relies upon EPA's Generic Guide to Statistical Aspects of Developing an Environmental Results Program for advice in making decisions related to data quality optimization. Particular attention is given to data accuracy, precision, comparability and representativeness. Data accuracy is assured through calibration and subsequent data validation. Table 4.4 shows the calibration approach.

Table 4.4. Calibration, Zero and Span Activities

Analyzer	% Tolerance	Calibration Standard	Calibration Frequency	Zero/Span Standard	Zero/Span Frequency	Span Certificate
2B 211	±10%	UW Primary UV Photometer	Start and end	Span with internal ozone generator and zero with scrubbed air	daily/weekly	Yes
2B 401/410	±10%	Certified NO mixture	Start and end	Span with certified NO and zero with scrubbed air	daily/weekly	Yes
Picarro G2204	±10%	Certified CH_4 and H_2S mixture	Start and end	Span with certified CH_4 and zero with zero cylinder	daily/weekly	Yes
Thermo 49ips	±10%	EPA Primary UV Photometer	Annually or when out of spec	N/A	daily/weekly	Yes
PE OPA	±10%	Apel-Riemer	Post processing	Cylinder with certified levels	weekly	NCAR

Raw data precision is determined from daily zero span and zero checks. Comparability of data collected by different sites is set by adoption of the similar protocols, QAPP and calibration procedures. Our approach is comparable to that used in fixed monitoring situations. However mobile monitoring does not operate to the same standards as fixed sites that operate continuously. Completeness will be evaluated based on one-minute and hourly averages to be consistent with EPA standard protocol and other WDEQ-AQD sites, using the following formula:

$$Completeness = 100 \times \frac{D_X - D_C}{D_C}$$

With regard to discrete measurements, *Dx* is the number of samples for each species in which valid results are obtained and *Dc* is the number of samples scheduled to be collected and analyzed during the year. Completeness for continuous methods is the percentage of valid data obtained from the total amount possible, over a given time period. Documentation of success or failure to meet required Data Quality Objectives (DQO) will be provided at the completion of the project. Target measurement quality objectives are given in Table 4.5. Data recovery is calculated from the maximum possible data capture. Completeness is set from the start and end of end circuit. This calculation excludes data from routine span, zero and calibration. Circuit objective data quality is set to the base of 32 circuits.

Table 4.5. Data Quality Objectives – Project Goals

Measurement	Circuits	Completeness
O_3	90%	75%
NO_x	90%	75%
CH_4	90%	75%
VOC	n/a	75%*

O_3 = ozone; NO_x = oxides of nitrogen; CH_4 = methane; VOC = volatile organic compounds

*The aim was to produce eighty VOC measurements.

5.0 DATA COLLECTION AND VALIDATION

5.1. Data Collection

Raw data were uploaded daily via direct connection from the instrument to a laptop acting as a data logger. The purpose of daily uploads is to perform preliminary data quality checks and to concatenate current data to previously collected data.

5.2 Data Validation

This project employs a three-level data validation process. These levels, and the validation codes that designate them, are defined in Tables 2-1 and 2-2, respectively.

Table 5.1. Gaseous Validation Process Summary.

Level 0 Validation
Level 0 data are obtained directly from the data loggers that acquire the data in the field. Averaging times represent the minimum intervals recorded by the data logger, which do not necessarily correspond to the averaging periods specified for the database files. Level 0 data have not been edited for instrument downtime, nor have procedural adjustments for baseline and span changes been applied. Level 0 data are consulted on a regular basis to ascertain instrument functionality and to identify potential episodes prior to receipt of Level 1 data.
Level 1 Validation
Level 1 data have passed several validation tests applied by the measurement investigator prior to data submission. The general features of Level 1 are: 1) removal of values when monitoring instruments fail specified validation criteria; 2) flagging measurements when significant deviations from measurement assumptions have occurred; 3) verifying computer file entries against data sheets, where appropriate; 4) replacement of data from a backup data acquisition system in the event of failure of the primary system; and 5) adjustment of measurement values for quantifiable baseline and span or interference biases.
Level 2 Validation
Level 2 These data have been assembled into a collated data file. Level 2 validation is the first step in data analysis. Level 2 validation involves the testing of measurement assumptions, comparison of collocated instruments, and internal consistency tests.

Table 5.2. Gaseous data validation flags.

Code	Meaning
V	Validated value
NS	Influenced by nearby source
AV	Power Failure
RL	Other (no measurement the data is reported with a data stream that has more values per unit of time)
AQ	Collection error (data logger)
DA	Aberrant data (negative spiking below zero range)
BJ	Operator error

All instrumentation operated according to expectations with the exception of the oxides of nitrogen analyzer. Static zero calibration revealed variation from -10 ppbv to +10 ppbv. As such the zero for this instrument has a wide range. This fluctuating behavior was not evident for span gas and so calibration curves were not impacted. In mobile monitoring the instrument did exhibiting spiking below the zero range. This data was removed and coded as aberrant data. The spiking behavior was not evident above the zero range.

6.0 OPERATIONAL SUMMARY

Table 6.1. Mobile Sampling Run #1, 12 February 2013, 07:58–13:00

Time MST	Activities and Time Checks	Operational Notes
07:58	Log Cabin Motel	Start of run
08:02	Route adjustment	Tyler Road access was closed due to Sublette County Sheriff activities. Route was accessed via US Highway 191.
08:18	Hennick Gate No. 1	
09:01	Hennick Gate No. 2	Routine Canister Sample 01
09:15	Mesa North	
10:26	Paradise Road & US Highway 351	
10:44	Boulder DEQ	Routine Canister Sample 02
11:11	Boulder Crest	Routine Canister Sample 03
11:43	Middle Fork	
12:35	Hennick Draw Road	Routine Canister Sample 04
13:00	Log Cabin Motel	End of run
A. There was a failure of the power supply for the Picarro vacuum pump during the period from 8:25 to 8:45. The access route for the Mesa South Loop was tested during this period.		

Table 6.2. Mobile Sampling Run #2, 12 February 2013, 13:22–17:10

Time MST	Activities and Time Checks	Operational Notes
13:22	Log Cabin Motel	Start of run
13:30	Hennick Gate No. 1	
13:48	Hennick Gate No. 2	
13:55	Mesa North	
14:57	Paradise Road & US Highway 351	
15:16	Boulder DEQ	
15:37	Boulder Crest	
16:06	Middle Fork	
16:54	Hennick Draw Road	
17:10	Log Cabin Motel	End of run
A. The access route for the Mesa Loop was determined during this period.		

Table 6.3. Mobile Sampling Run #3, 13 February 2013, 07:49–11:32

Time MST	Activities and Time Checks	Operational Notes
07:49	Log Cabin Motel	Start of run
07:57	Hennick Gate No. 1	
08:15	Hennick Gate No. 2	
08:22	Mesa North	Routine Canister Sample 05
09:09	Paradise Road & US Highway 351	
09:26	Boulder DEQ	Routine Canister Sample 06
09:53	Boulder Crest	Routine Canister Sample 07
10:22	Middle Fork	
11:08	Hennick Draw Road	Routine Canister Sample 08
11:32	Log Cabin Motel	End of run

Table 6.4. Mobile Sampling Run #4, 13 February 2013, 13:06–16:42

Time MST	Activities and Time Checks	Operational Notes
13:06	Log Cabin Motel	Start of run
13:14	Hennick Gate No. 1	
13:31	Hennick Gate No. 2	
13:37	Mesa North	
14:19	Paradise Road & US Highway 351	
14:34	Boulder DEQ	
14:48	Boulder South Road Lizard Head	
15:04	Boulder Crest	
15:30	Middle Fork	
16:20	Hennick Draw Road	
16:42	Log Cabin Motel	End of run
A. There was a failure of the power supply for the Picarro vacuum pump during the period from 13:26 to 14:54.		

Table 6.5. Mobile Sampling Run #5, 14 February 2013, 07:58–11:57

Time MST	Activities and Time Checks	Operational Notes
07:58	Log Cabin Motel	Start of run
08:06	Hennick Gate No. 1	
08:23	Hennick Gate No. 2	
08:32	Mesa North	Routine Canister Sample 09
09:11	Pinedale Complex	
09:23	Paradise Road & US Highway 351	
09:42	Boulder DEQ	Routine Canister Sample 10
10:10	Boulder Crest	Routine Canister Sample 11
10:44	Middle Fork	
11:33	Hennick Draw Road	Routine Canister Sample 12
11:57	Log Cabin Motel	End of run
A. There was a failure of the power supply for the 2B NO_x instrument during the period from 09:48 to 10:11.		

Table 6.6. Mobile Sampling Run #6, 14 February 2013, 12:52–16:29

Time MST	Activities and Time Checks	Operational Notes
12:52	Log Cabin Motel	Start of run
13:00	Hennick Gate No. 1	
13:18	Hennick Gate No. 2	
13:28	Mesa North	
14:10	Paradise Road & US Highway 351	
15:00	Boulder Crest	
15:27	Middle Fork	
16:12	Hennick Draw Road	
16:29	Log Cabin Motel	End of run
A. There was a failure of the power supply for the Picarro vacuum pump during the period from 13:11 to 13:23. 2B power supply failure from 14:10 to 14:36.		

Table 6.7. Mobile Sampling Run #7, 15 February 2013, 08:28–11:51

Time MST	Activities and Time Checks	Operational Notes
08:28	Log Cabin Motel	Start of run
08:36	Hennick Gate No. 1	
08:54	Hennick Gate No. 2	
09:01	Mesa North	
09:41	Paradise Road & US Highway 351	
09:58	Boulder DEQ	
10:19	Boulder Crest	
10:27	Anticline Disposal	
10:48	Middle Fork	
11:33	Hennick Draw Road	
11:51	Log Cabin Motel	End of run

Table 6.8. Mobile Sampling Run #8, 15 February 2013, 13:06–16:21

Time MST	Activities and Time Checks	Operational Notes
13:06	Log Cabin Motel	Start of run
13:13	Hennick Gate No. 1	
13:32	Hennick Gate No. 2	
13:41	Mesa North	
14:21	Paradise Road & US Highway 351	
14:37	Boulder DEQ	
14:56	Boulder Crest	
15:20	Middle Fork	
16:04	Hennick Draw Road	
16:21	Log Cabin Motel	End of run

Table 6.9. Mobile Sampling Run #9, 16 February 2013, 13:00–17:09

Time MST	Activities and Time Checks	Operational Notes
13:00	Log Cabin Motel	Start of run
13:08	Hennick Gate No. 1	
13:34	Hennick Gate No. 2	
13:47	Mesa North	
14:34	Paradise Road & US Highway 351	
14:53	Boulder DEQ	
15:16	Boulder Crest	
15:44	Middle Fork	
16:40	Hennick Draw Road	
17:09	Log Cabin Motel	End of run

Table 6.10. Mobile Sampling Run #10, 17 February 2013, 13:02–19:18

Time MST	Activities and Time Checks	Operational Notes
13:02	Log Cabin Motel	Start of run
13:10	Hennick Gate No. 1	
16:12	Hennick Gate No. 2	
16:20	Mesa North	
17:16	Boulder DEQ	
17:38	Boulder Crest	
18:07	Middle Fork	
18:59	Hennick Draw Road	
19:18	Log Cabin Motel	End of run
A. There was a shutdown of the power supply for the Picarro during re-sets of the mobile kit server during the periods from 13:35 to 13:49; 14:16 to 14:35 and 15:39 to 16:01.		

Table 6.11. Mobile Sampling Run #11, 18 February 2013, 07:59–11:54

Time MST	Activities and Time Checks	Operational Notes
07:59	Log Cabin Motel	Start of run
08:07	Hennick Gate No. 1	
08:33	Hennick Gate No. 2	
08:43	Mesa North	Routine Canister Sample 13
09:47	Boulder DEQ	Routine Canister Sample 14
10:12	Boulder Crest	Routine Canister Sample 15
10:42	Middle Fork	
11:31	Hennick Draw Road	Routine Canister Sample 16
11:54	Log Cabin Motel	End of run
A. The NO_x data logger was started at 8:09.		

Table 6.12. Mobile Sampling Run #12, 18 February 2013, 12:59–17:22

Time MST	Activities and Time Checks	Operational Notes
12:59	Log Cabin Motel	Start of run
13:06	Hennick Gate No. 1	
13:21	Hennick Gate No. 2	
13:30	Mesa North	
14:11	Paradise Road & US Highway 351	
14:30	Boulder DEQ	
14:48	UW BSR	
15:19	Boulder Crest	
15:35	Anticline Disposal	Grab Sample 01
15:50	Middle Crest and US Highway 351	
16:14	Middle Fork	
17:01	Hennick Draw Road	
17:22	Log Cabin Motel	End of run

Table 6.13. Mobile Sampling Run #13, 19 February 2013, 19:30–23:42

Time MST	Activities and Time Checks	Operational Notes
19:30	Log Cabin Motel	Start of run
19:36	Hennick Gate No. 1	
19:53	Hennick Gate No. 2	
20:04	Mesa North	Routine Canister Sample 17
20:32	Mesa South Loop	
20:42	Mesa South	
20:50	Pinedale Complex	
21:05	Paradise Road & US Highway 351	
21:21	Boulder DEQ	Routine Canister Sample 18
21:50	Boulder Crest	Routine Canister Sample 19
22:22	Middle Fork	
23:18	Hennick Draw Road	Routine Canister Sample 20
23:42	Log Cabin Motel	End of run
A. Following a truck from 20:11 to 20:24. There was a failure of the power supply for the NO_2 convertor during the period 20:33 to 20:45.		

Table 6.14. Mobile Sampling Run #14, 20 February 2013, 00:24–04:19

Time MST	Activities and Time Checks	Operational Notes
00:24	Log Cabin Motel	Start of run
00:32	Hennick Gate No. 1	
00:50	Hennick Gate No. 2	
00:58	Mesa North	
01:29	Mesa South Loop	
02:03	Boulder DEQ	
02:29	Boulder Crest	
03:02	Middle Fork	
03:56	Hennick Draw Road	
04:19	Log Cabin Motel	End of run
A. Following a truck from 1:45 to 2:00.		

Table 6.15. Mobile Sampling Run #15, 20 February 2013, 13:14–16:55

Time MST	Activities and Time Checks	Operational Notes
13:14	Log Cabin Motel	Start of run
13:21	Hennick Gate No. 1	
13:41	Hennick Gate No. 2	
13:47	Mesa North	
14:57	Boulder DEQ	
15:20	Boulder Crest	
15:47	Middle Fork	
16:34	Hennick Draw Road	
16:55	Log Cabin Motel	End of run
A. Following a sedan from 15:58 to 16:03.		

Table 6.16. Mobile Sampling Run #16, 20 February 2013, 19:12–23:22

Time MST	Activities and Time Checks	Operational Notes
19:12	Log Cabin Motel	Start of run
19:18	Hennick Gate No. 1	
19:51	Hennick Gate No. 2	
19:59	Mesa North	
20:15	Boulder South Loop	Grab Sample 02
21:03	Boulder DEQ	
21:29	Boulder Crest	
21:46	Middle Crest	Grab Sample 03
22:05	Middle Fork	
22:58	Hennick Draw Road	
23:22	Log Cabin Motel	End of run

Table 6.17. Mobile Sampling Run #17, 24 February 2013, 19:29–23:49

Time MST	Activities and Time Checks	Operational Notes
19:29	Log Cabin Motel	Start of run
19:36	Hennick Gate No. 1	
19:50	Hennick Gate No. 2	
20:07	Mesa North	Routine Canister Sample 21
20:35	Mesa So. Loop	Grab Sample 04
20:49	Pinedale Complex	Grab Sample 05
21:06	Paradise Road & US Highway 351	
21:25	Boulder DEQ	Routine Canister Sample 22
21:51	Boulder Crest	Routine Canister Sample 23
21:59	Anticline Disposal	Grab Sample 06
22:15	Middle Crest by rig	Grab Sample 07
22:22	Middle Crest by liquids gathering	Grab Sample 08
22:33	Middle Fork	
23:26	Hennick Draw Road	Routine Canister Sample 24
23:49	Log Cabin Motel	End of run
A. There was a failure of the N_2O supply for the 2B ozone instrument at the start of this run. No ozone data was collected.		

Table 6.18. Mobile Sampling Run #18, 25 February 2013, 08:10–11:48

Time MST	Activities and Time Checks	Operational Notes
08:10	Log Cabin Motel	Start of run
08:17	Hennick Gate No. 1	
08:33	Hennick Gate No. 2	
08:41	Mesa North	Routine Canister Sample 25
09:15	Pinedale Complex	Grab Sample 09
09:34	Paradise Road & US Highway 351	
09:52	Boulder DEQ	Routine Canister Sample 26
10:18	Boulder Crest	Routine Canister Sample 27
10:29	Anticline Disposal	Grab Sample 10
10:46	Middle Fork	
11:28	Hennick Draw Road	Routine Canister Sample 28
11:48	Log Cabin Motel	End of run
A. No ozone data was collected. Following an SUV from 9:41 to 9:47.		

Table 6.19. Mobile Sampling Run #19, 25 February 2013, 13:04–16:50

Time MST	Activities and Time Checks	Operational Notes
13:04	Log Cabin Motel	Start of run
13:12	Hennick Gate No. 1	
13:27	Hennick Gate No. 2	
13:33	Mesa North	Routine Canister Sample 29
14:05	Pinedale Complex	Grab Sample 11
14:19	Paradise Road & US Highway 351	
14:35	Boulder DEQ	Routine Canister Sample 30
15:02	Boulder Crest	Routine Canister Sample 31
15:11	Anticline Disposal	Grab Sample 12
15:17	Anticline Disposal	Grab Sample 13
15:37	Middle Fork	
16:26	Hennick Draw Road	Routine Canister Sample 32
16:46	Pine Street	Grab Sample 14 (heavy traffic)
16:50	Log Cabin Motel	End of run
A. No ozone data was collected.		

Table 6.20. Mobile Sampling Run #20, 02 March 2013, 08:10–11:40

Time MST	Activities and Time Checks	Operational Notes
08:10	Log Cabin Motel	Start of run
08:17	Hennick Gate No. 1	
08:35	Hennick Gate No. 2	
08:45	Mesa North	Routine Canister Sample 33
09:27	Paradise Road & US Highway 351	
09:44	Boulder DEQ	Routine Canister Sample 34
10:07	Boulder Crest	Routine Canister Sample 35
10:34	Middle Fork	
11:18	Hennick Draw Road	Routine Canister Sample 36
11:40	Log Cabin Motel	End of run

Table 6.21. Mobile Sampling Run #21, 02 March 2013, 12:55–16:40

Time MST	Activities and Time Checks	Operational Notes
12:55	Log Cabin Motel	Start of run
13:03	Hennick Gate No. 1	
13:22	Hennick Gate No. 2	
13:44	Mesa North	Routine Canister Sample 37
14:25	Paradise Road & US Highway 351	
14:41	Boulder DEQ	Routine Canister Sample 38
15:04	Boulder Crest	Routine Canister Sample 39
15:31	Middle Fork	
16:19	Hennick Draw Road	Routine Canister Sample 40
16:40	Log Cabin Motel	End of run
A. Following a truck from 13:54 to 13:56. Following a sedan from 15:47 to 15:54.		

Table 6.22. Mobile Sampling Run #22, 02 March 2013, 18:50–23:33

Time MST	Activities and Time Checks	Operational Notes
18:50	Log Cabin Motel	Start of run
18:58	Hennick Gate No. 1	
19:22	Hennick Gate No. 2	
19:38	Mesa North	Routine Canister Sample 41
20:47	Paradise Road & US Highway 351	
21:07	Boulder DEQ	Routine Canister Sample 42
21:42	Boulder Crest	Routine Canister Sample 43
22:03	Middle Crest	Grab Sample 15
22:20	Middle Fork	
23:14	Hennick Draw Road	
23:33	Log Cabin Motel	End of run
A. There was a failure of the N_2O supply for the 2B ozone instrument from 19:05 to 19:30		

Table 6.23. Mobile Sampling Run #23, 03 March 2013, 08:27–12:45

Time MST	Activities and Time Checks	Operational Notes
08:27	Log Cabin Motel	Start of run
08:33	Hennick Gate No. 1	
08:49	Hennick Gate No. 2	
08:54	Mesa North	
09:38	Paradise Road & US Highway 351	
09:54	Boulder DEQ	Routine Canister Sample 44
10:20	Boulder Crest	
10:31	Anticline Disposal	Grab Sample 16
10:52	Middle Fork	
11:41	Hennick Draw Road	
11:53	Log Cabin Motel	End of run
A. Inlet for Picarro disconnected from 8:27 to 10:20.		

Table 6.24. Mobile Sampling Run #24, 03 March 2013, 13:23–16:49

Time MST	Activities and Time Checks	Operational Notes
13:23	Log Cabin Motel	Start of run
13:30	Hennick Gate No. 1	
13:45	Hennick Gate No. 2	
13:51	Mesa North	Routine Canister Sample 45
14:34	Paradise Road & US Highway 351	
14:50	Boulder DEQ	
15:14	Boulder Crest	
15:41	Middle Fork	
16:27	Hennick Draw Road	
16:49	Log Cabin Motel	End of run

Table 6.25. Mobile Sampling Run #25, 05 March 2013, 07:54–11:32

Time MST	Activities and Time Checks	Operational Notes
07:54	Log Cabin Motel	Start of run
08:04	Hennick Gate No. 1	
08:22	Hennick Gate No. 2	
08:30	Mesa North	Routine Canister Sample 46
08:41	Mesa South Loop Entry	
08:51	Mesa South Loop Turnaround	
09:00	Mesa South Loop Exit	
09:05	Pinedale Complex	
09:10	Paradise Road Entrance	
09:20	Paradise Road & US Highway 351	
09:35	Boulder DEQ	Routine Canister Sample 47
09:46	New Fork Boat Launch	
09:52	UW Boulder South Road	
09:58	Boulder Crest	Routine Canister Sample 48
10:07	Anticline Disposal Turnaround	
10:18	Middle Crest & US Highway 351	
10:27	Middle Fork	
11:11	Hennick Draw Road	Routine Canister Sample 49
11:32	Log Cabin Motel	End of run
* 2B instrument logs were not started until 08:04.		

Table 6.26. Mobile Sampling Run #26, 05 March 2013, 13:01–16:19

Time MST	Activities and Time Checks	Operational Notes
13:01	Log Cabin Motel	Start of run
13:10	Hennick Gate No. 1	
13:27	Hennick Gate No. 2	
13:34	Mesa North	
13:43	Mesa South Loop Entry	
13:53	Mesa South Loop Turnaround	
14:03	Mesa South Loop Exit	
14:09	Paradise Road Entry Parking Lot	
14:18	Paradise Road & US Highway 351	
14:34	Boulder DEQ	
14:53	Boulder Crest	
15:17	Middle Fork	
16:19	Log Cabin Motel	End of run

Table 6.27. Mobile Sampling Run #27, 06 March 2013, 07:53–11:14

Time MST	Activities and Time Checks	Operational Notes
07:53	Log Cabin Motel	Start of run
08:01	Hennick Gate No. 1	
08:20	Hennick Gate No. 2	
08:27	Mesa North	Routine Canister Sample 50
09:10	Paradise Road & US Highway 351	
09:25	Boulder DEQ	Routine Canister Sample 51
09:48	Boulder Crest	
10:13	Middle Fork	
10:58	Hennick Draw Road	
11:14	Log Cabin Motel	End of run

Table 6.28. Mobile Sampling Run #28, 06 March 2013, 12:56–16:08

Time MST	Activities and Time Checks	Operational Notes
12:57	Log Cabin Motel	Start of run
13:05	Hennick Gate No. 1	
13:21	Hennick Gate No. 2	
13:28	Mesa North	Routine Canister Sample 52
13:38	Mesa South Loop Entry	
13:49	Mesa South Loop Turnaround	Grab Sample 17
14:01	Mesa South Loop Exit	
14:13	Paradise Road & US Highway 351	
14:28	Boulder DEQ	
14:47	Boulder Crest	
15:09	Middle Fork	
15:50	Hennick Draw Road	
16:08	Log Cabin Motel	End of run

Table 6.29. Mobile Sampling Run #29, 07 March 2013, 07:47–10:56

Time MST	Activities and Time Checks	Operational Notes
07:47	Log Cabin Motel	Start of run
07:55	Hennick Gate No. 1	
08:12	Hennick Gate No. 2	
08:19	Mesa North	
08:55	Paradise Road & US Highway 351	
09:11	Boulder DEQ	
09:29	Boulder Crest	
09:53	Middle Fork	
10:38	Hennick Draw Road	
10:56	Log Cabin Motel	End of run
A. There was a failure of the N_2O supply for the 2B ozone instrument from 9:53 to 10:47. Following a truck from 09:55 to 10:05.		

Table 6.20. Mobile Sampling Run #30, 07 March 2013, 12:58–16:04

Time MST	Activities and Time Checks	Operational Notes
12:58	Log Cabin Motel	Start of run
13:05	Hennick Gate No. 1	
13:20	Hennick Gate No. 2	
13:27	Mesa North	
14:05	Paradise Road & US Highway 351	
14:20	Boulder DEQ	
14:40	Boulder Crest	
15:03	Middle Fork	
15:46	Hennick Draw Road	
16:04	Log Cabin Motel	End of run

Table 6.31. Mobile Sampling Run #31, 08 March 2013, 08:10–11:53

Time MST	Activities and Time Checks	Operational Notes
08:10	Log Cabin Motel	Start of run
08:18	Hennick Gate No. 1	
08:31	Hennick Gate No. 2	
08:39	Mesa North	Routine Canister Sample 53
08:55	Mesa South Loop	Grab Sample 18
09:44	Boulder DEQ	Routine Canister Sample 54
10:09	Boulder Crest	Routine Canister Sample 55
10:16	Anticline Disposal	Grab Sample 19
10:20	Anticline Disposal	Grab Sample 20
10:32	Anticline Disposal	Grab Sample 21
10:49	Middle Fork	
11:31	Hennick Draw Road	Routine Canister Sample 56
11:53	Log Cabin Motel	End of run
A. Following a pickup from 10:02 to 10:04. Heavy traffic on US Highway 191 to Pinedale from 11:45.		

Table 6.32. Mobile Sampling Run #32, 08 March 2013, 12:58–16:42

Time MST	Activities and Time Checks	Operational Notes
12:58	Log Cabin Motel	Start of run
13:05	Hennick Gate No. 1	
13:21	Hennick Gate No. 2	
13:29	Mesa North	Routine Canister Sample 57
14:15	Paradise Road & US Highway 351	
14:35	Boulder DEQ	Routine Canister Sample 58
15:00	Boulder Crest	Routine Canister Sample 59
15:31	Middle Fork	
16:20	Hennick Draw Road	Routine Canister Sample 60
16:42	Log Cabin Motel	End of run
A. Following a pickup from 15:33 to 15:38 and from 15:43 to 15:45.		

7.0 DATA SUMMARY

7.1 Data Capture

Tables 7.1 through 7.32 show the quality assurance codes for each pollutant and monitoring circuit. These tables show data recovery for each of the pollutants considered in MAPA.

Table 7.1. Data Recovery Mobile Sampling Run #1, 12 February 2013, 07:58–13:00

Data Code	CH_4	NO_x	O_3
V	3386	1652	1808
NS			
AV	243		
RL		1815	1814
AQ		7	7
DA		155	
BJ			
% Valid	93	91	100

Table 7.2. Data Recovery Mobile Sampling Run #2, 12 February 2013, 13:22–17:10

Data Code	CH_4	NO_x	O_3
V	2742	1150	1371
NS			
AV			
RL		1371	1371
AQ		7	
DA		214	
BJ			
% Valid	100	84	100

Table 7.3. Data Recovery Mobile Sampling Run #3, 13 February 2013, 07:49–11:32

Data Code	CH_4	NO_x	O_3
V	2674	1287	1334
NS			
AV			
RL		1337	1337
AQ		7	3
DA		43	
BJ			
% Valid	100	96	100

Table 7.4. Data Recovery Mobile Sampling Run #4, 13 February 2013, 13:06–16:42

Data Code	CH_4	NO_x	O_3
V	1534	1039	1290
NS			
AV	1055		
RL		1294	1294
AQ		136	5
DA		120	
BJ			
% Valid	59	80	100

Table 7.5. Data Recovery Mobile Sampling Run #5, 14 February 2013, 07:58–11:57

Data Code	CH_4	NO_x	O_3
V	2870	1219	1433
NS			
AV			
RL		1436	1435
AQ		6	2
DA		209	
BJ			
% Valid	100	85	100

Table 7.6. Data Recovery Mobile Sampling Run #6, 14 February 2013, 12:52–16:29

Data Code	CH_4	NO_x	O_3
V	2458	1041	1297
NS			
AV	142	156	
RL		1300	1300
AQ		6	3
DA		97	
BJ			
% Valid	95	80	100

Table 7.7. Data Recovery Mobile Sampling Run #7, 15 February 2013, 08:28–11:51

Data Code	CH_4	NO_x	O_3
V	2439	1128	1220
NS			
AV			
RL		1221	1219
AQ		6	
DA		84	
BJ			
% Valid	100	93	100

Table 7.8. Data Recovery Mobile Sampling Run #8, 15 February 2013, 13:06–16:21

Data Code	CH_4	NO_x	O_3
V	2340	1051	1160
NS			
AV			
RL		1171	1180
AQ		6	
DA		112	
BJ			
% Valid	100	90	100

Table 7.9. Data Recovery Mobile Sampling Run #9, 16 February 2013, 13:00–17:09

Data Code	CH_4	NO_x	O_3
V	2989	1477	1495
NS			
AV			
RL		1496	1494
AQ		6	
DA		10	
BJ			
% Valid	100	99	100

Table 7.10. Data Recovery Mobile Sampling Run #10, 17 February 2013, 13:02–19:18

Data Code	CH_4	NO_x	O_3
V	3826	2186	2251
NS			
AV	676		
RL		2252	2251
AQ		6	
DA		58	
BJ			
% Valid	85	97	100

Table 7.11. Data Recovery Mobile Sampling Run #11, 18 February 2013, 07:59–11:54

Data Code	CH_4	NO_x	O_3
V	2831	1306	1413
NS			
AV			
RL		1416	1416
AQ		6	2
DA		39	
BJ		64	
% Valid	100	92	100

Table 7.12. Data Recovery Mobile Sampling Run #12, 18 February 2013, 12:59–17:22

Data Code	CH_4	NO_x	O_3
V	3163	1453	1582
NS			
AV			
RL		1582	1581
AQ		6	
DA		122	
BJ			
% Valid	100	92	100

Table 7.13. Data Recovery Mobile Sampling Run #13, 19 February 2013, 19:30–23:42

Data Code	CH_4	NO_x	O_3
V	3031	1341	1502
NS		78	
AV		78	
RL		1516	1516
AQ		6	13
DA		12	
BJ			
% Valid	100	94	99

Table 7.14. Data Recovery Mobile Sampling Run #14, 20 February 2013, 00:24–04:19

Data Code	CH_4	NO_x	O_3
V	2818	1302	1409
NS		96	
AV			
RL		1410	1409
AQ		6	
DA		4	
BJ			
% Valid	100	99	100

Table 7.15. Data Recovery Mobile Sampling Run #15, 20 February 2013, 13:14–16:55

Data Code	CH_4	NO_x	O_3
V	2648	1255	1321
NS		36	
AV			
RL		1325	1324
AQ		6	3
DA		26	
BJ			
% Valid	100	98	100

Table 7.16. Data Recovery Mobile Sampling Run #16, 20 February 2013, 19:12–23:22

Data Code	**CH_4**	**NO_x**	**O_3**
V	3009	1484	1504
NS			
AV			
RL		1506	1505
AQ		6	
DA		13	
BJ			
% Valid	100	99	100

Table 7.17. Data Recovery Mobile Sampling Run #17, 24 February 2013, 19:29–23:49

Data Code	**CH_4**	**NO_x**	**O_3**
V	3130	1550	0
NS			
AV			
RL		1566	1565
AQ		6	
DA		8	
BJ			1565
% Valid	100	99	0

Table 7.18. Data Recovery Mobile Sampling Run #18, 25 February 2013, 08:10–11:48

Data Code	**CH_4**	**NO_x**	**O_3**
V	2617	1216	0
NS		42	
AV			
RL		1310	1308
AQ		6	
DA		43	
BJ			1309
% Valid	100	96	0

Table 7.19. Data Recovery Mobile Sampling Run #19, 25 February 2013, 13:04–16:50

Data Code	CH_4	NO_x	O_3
V	2712	1332	0
NS			
AV			
RL		1357	1356
AQ		6	
DA		17	
BJ			1356
% Valid	100	98	0

Table 7.20. Data Recovery Mobile Sampling Run #20, 02 March 2013, 08:10–11:40

Data Code	CH_4	NO_x	O_3
V	2520	1213	1260
NS			
AV			
RL		1261	1260
AQ		6	
DA		40	
BJ			
% Valid	100	96	100

Table 7.21. Data Recovery Mobile Sampling Run #21, 02 March 2013, 12:55–16:40

Data Code	CH_4	NO_x	O_3
V	2704	1207	1012
NS		63	
AV			
RL		1355	1352
AQ		6	340
DA		73	
BJ			
% Valid	100	94	75

Table 7.22. Data Recovery Mobile Sampling Run #22, 02 March 2013, 18:50–23:33

Data Code	CH_4	NO_x	O_3
V	3399	1642	1546
NS			
AV			
RL		1702	1700
AQ		10	1
DA		45	
BJ			152
% Valid	100	97	91

Table 7.23. Data Recovery Mobile Sampling Run #23, 03 March 2013, 08:27–12:

Data Code	CH_4	NO_x	O_3
V	1111	1154	1182
NS			
AV			
RL		1242	1237
AQ		6	54
DA		71	
BJ	1362		
% Valid	45	94	96

Table 7.24. Data Recovery Mobile Sampling Run #24, 03 March 2013, 13:23–16:49

Data Code	CH_4	NO_x	O_3
V	2473	1193	924
NS			
AV			
RL		1238	1237
AQ		6	312
DA		36	
BJ			
% Valid	100	97	75

Table 7.25. Data Recovery Mobile Sampling Run #25, 05 March 2013, 07:54–11:32

Data Code	CH_4	NO_x	O_3
V	2606	1195	1221
NS			
AV			
RL		1304	1302
AQ			
DA		29	
BJ		78	83
% Valid	100	92	94

Table 7.26. Data Recovery Mobile Sampling Run #26, 05 March 2013, 13:01–16:19

Data Code	CH_4	NO_x	O_3
V	2377	1114	871
NS			
AV			
RL		1189	1189
AQ		6	317
DA		68	
BJ			
% Valid	100	94	73

Table 7.27. Data Recovery Mobile Sampling Run #27, 06 March 2013, 07:53–11:14

Data Code	CH_4	NO_x	O_3
V	2411	1148	1205
NS			
AV			
RL		1206	1206
AQ		13	
DA		44	
BJ			
% Valid	100	95	100

Table 7.28. Data Recovery Mobile Sampling Run #28, 06 March 2013, 12:56–16:08

Data Code	CH_4	NO_x	O_3
V	2288	977	1140
NS			
AV			
RL		1145	1144
AQ		6	0
DA		160	
BJ			4
% Valid	100	85	100

Table 7.29. Data Recovery Mobile Sampling Run #29, 07 March 2013, 07:47–10:56

Data Code	CH_4	NO_x	O_3
V	2272	1038	811
NS		62	
AV			
RL		1137	1136
AQ		6	
DA		29	
BJ			325
% Valid	100	97	71

Table 7.30. Data Recovery Mobile Sampling Run #30, 07 March 2013, 12:58–16:04

Data Code	CH_4	NO_x	O_3
V	2236	1010	1118
NS			
AV			
RL		1119	1118
AQ		6	
DA		101	
BJ			
% Valid	100	90	100

Table 7.31. Data Recovery Mobile Sampling Run #31, 08 March 2013, 08:10–11:53

Data Code	CH_4	NO_x	O_3
V	2670	1271	1325
NS		10	
AV			
RL		1337	1336
AQ		6	9
DA		46	
BJ			
% Valid	100	96	99

Table 7.32. Data Recovery Mobile Sampling Run #32, 08 March 2013, 12:58–16:42

Data Code	CH_4	NO_x	O_3
V	2685	1246	1088
NS		40	
AV			
RL		1342	1342
AQ		6	255
DA		51	
BJ			
% Valid	100	96	81

Data recovery information presented in Table 5-1 is calculated from all measurement data points. Thus RL codes are excluded from calculations. For Tables 7.1 to 7.32 the total number of possible data points, in relation to the total number of valid ambient data points, are shown. The number possible is the period from when data is produced from the instrument, i.e. from switch on until switch off. Collected data exclude equipment warm-up. The percent valid value is equal to number collected divided by the number possible. Valid data are ambient data that is either valid or valid influenced by a nearby source. Table 7.33 show the data recovery for each run to enable determination of whether data targets were met for the MAPA project. The target value of 75% data coverage was exceeded for all three-pollutant parameters for the number of circuits completed. As noted in section 6 of this data summary report the gas supply for the O3 systems was not operated properly for three circuits. The data completeness is also calculated against the base of the total of 32 circuits. Again the data quality target objective was exceeded for all three pollutants.

For VOC a total of 81 grab samples were collected and 80 valid measurements were reported leading to a completeness of 99%, again exceeding the target value of 75%.

The thirty two circuits had the following distribution according to the time period as defined by Table 4.1:

- Morning 12 circuits
- Afternoon 15 circuits
- Evening 4 circuits
- Nighttime 1 circuit

Table 7.33. Valid Data Recovery for Mobile Sampling Runs

Run	CH_4	NO_x	O_3
1	93	91	100
2	100	84	100
3	100	96	100
4	59	80	100
5	100	85	100
6	95	80	100
7	100	93	100
8	100	90	100
9	100	99	100
10	85	97	100
11	100	92	100
12	100	92	100
13	100	94	99
14	100	99	100
15	100	98	100
16	100	99	100
17	100	99	0
18	100	96	0
19	100	98	0
20	100	96	100
21	100	94	75
22	100	97	91
23	45	94	96
24	100	97	75
25	100	92	94
26	100	94	73
27	100	95	100
28	100	85	100
29	100	97	71
30	100	90	100
31	100	96	99
32	100	96	81
Total runs	32	32	32
Circuits	100%	100%	91%
Completeness	94%	100%	84%

7.2 Data Illustration

The time series plots, Figure 7.1 through 7.32 illustrate the pollution behavior for each mobile monitoring circuit. The scales are consistent for O_3 and NO_x, however due the wide variations for CH_4 three ranges are used, namely 0 to 14 ppm, 0 to 40 ppm and 0 to 75 ppm.

These plots, influenced by changing dispersion conditions throughout the day, are useful for gaining an insight into the contributions of various emission sources upon meteorologically driven variation. These plots constructed from 5 and 10 second averaged values, and provide a first insight into source influenced behavior that is set upon the general meteorological conditions for the given time of day. These figures are complemented by spatial maps for each pollutant for each monitoring circuit. Appendix I illustrates CH_4, Appendix II illustrates O_3 and Appendix III illustrates NO_x.

Figure 7.1. Circuit 1: 2/12/2013 AM

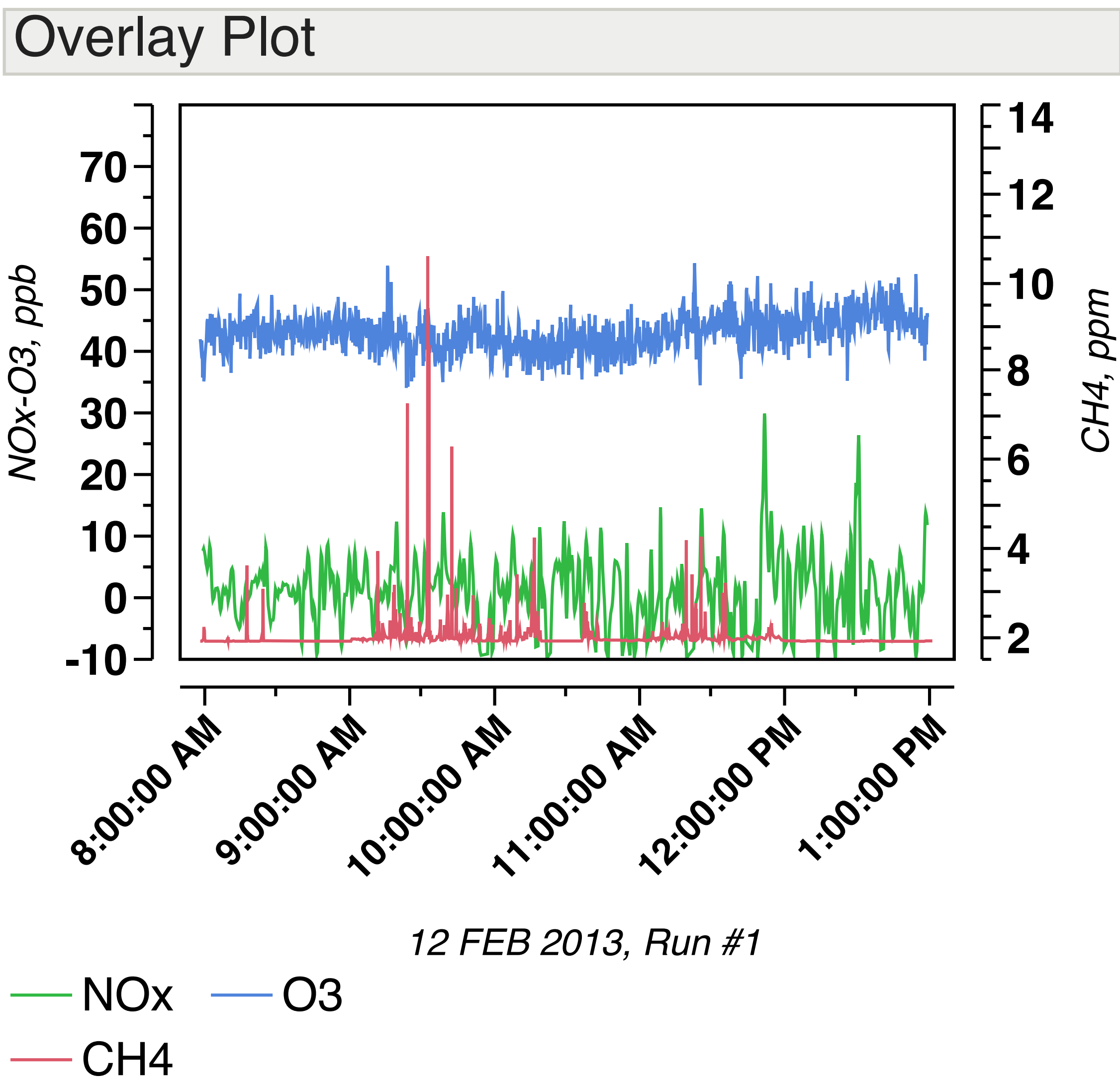


Figure 7.2. Circuit 2: 2/12/2013 PM

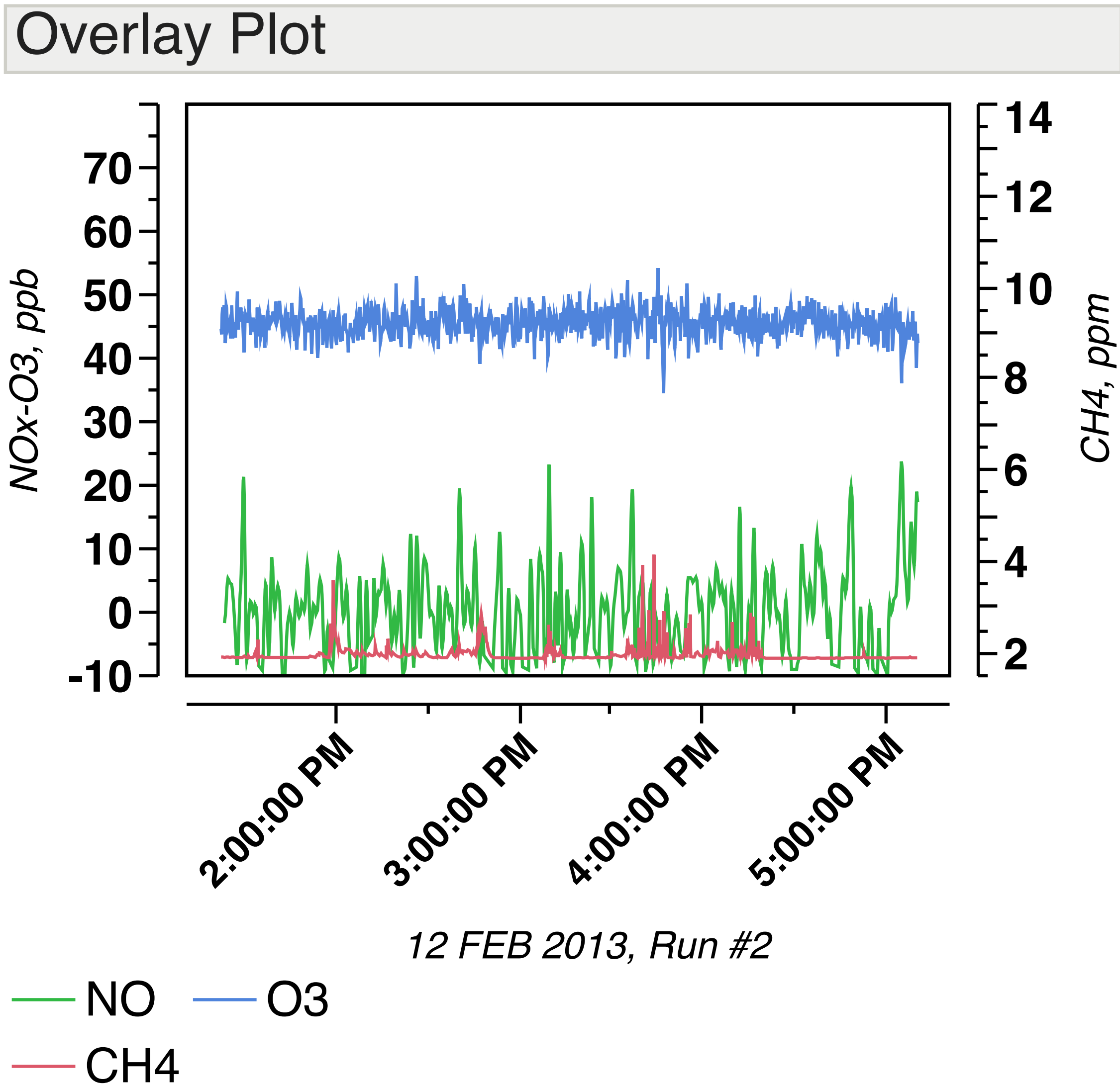


Figure 7.3. Circuit 3: 2/13/2013 AM

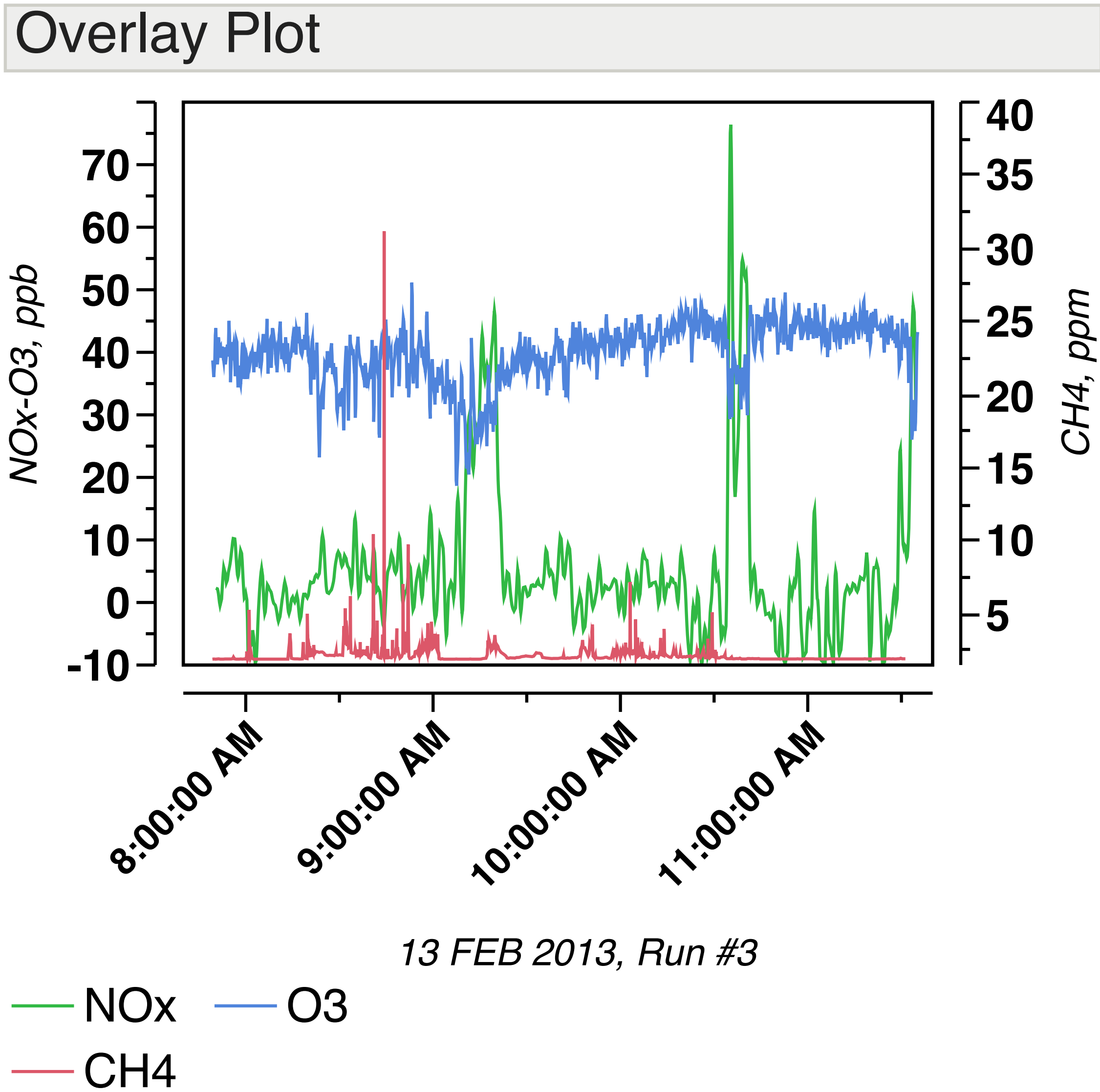


Figure 7.4. Circuit 4: 2/13/2013 AM

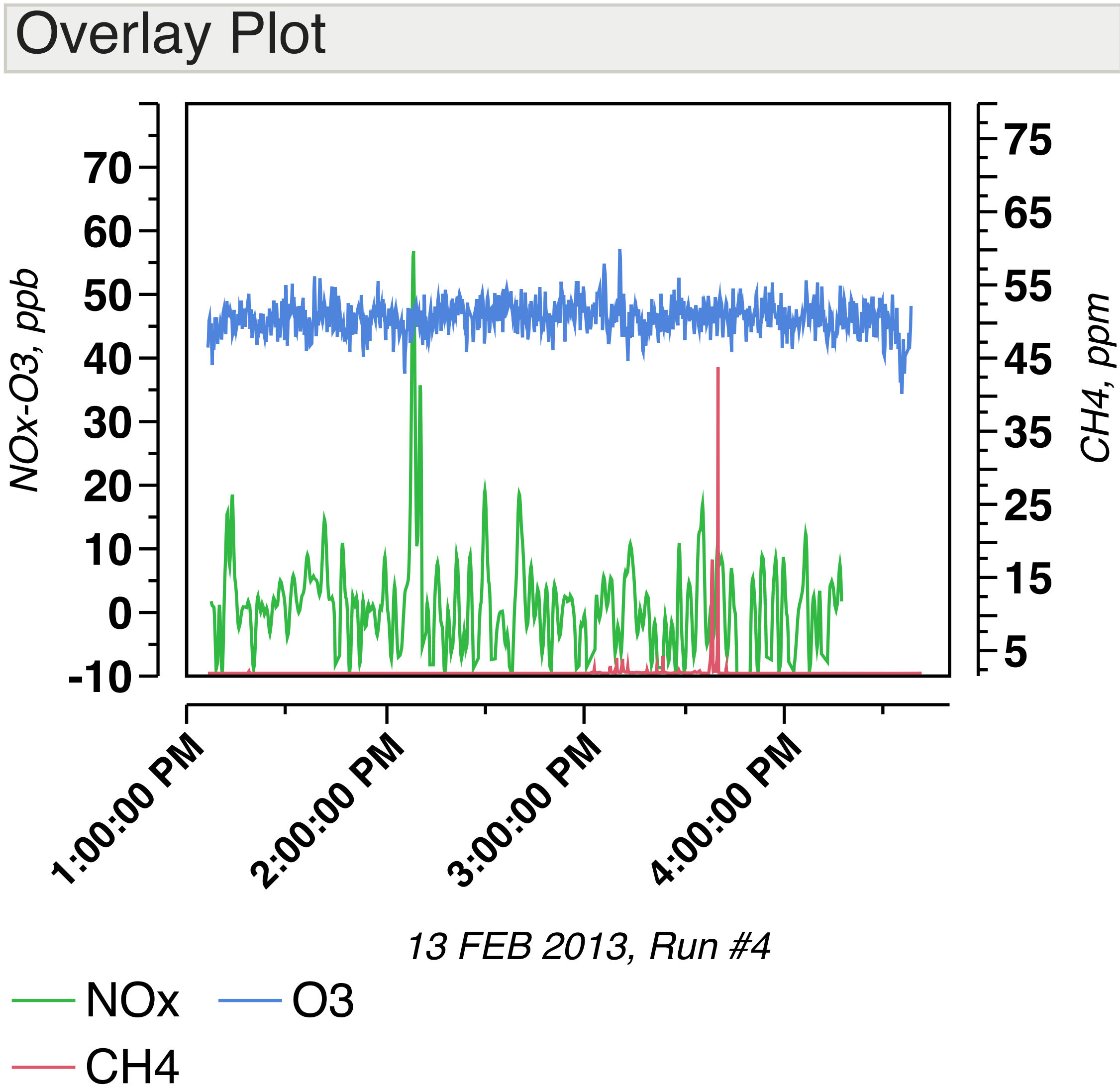


Figure 7.5. Circuit 5: 2/14/2013 AM

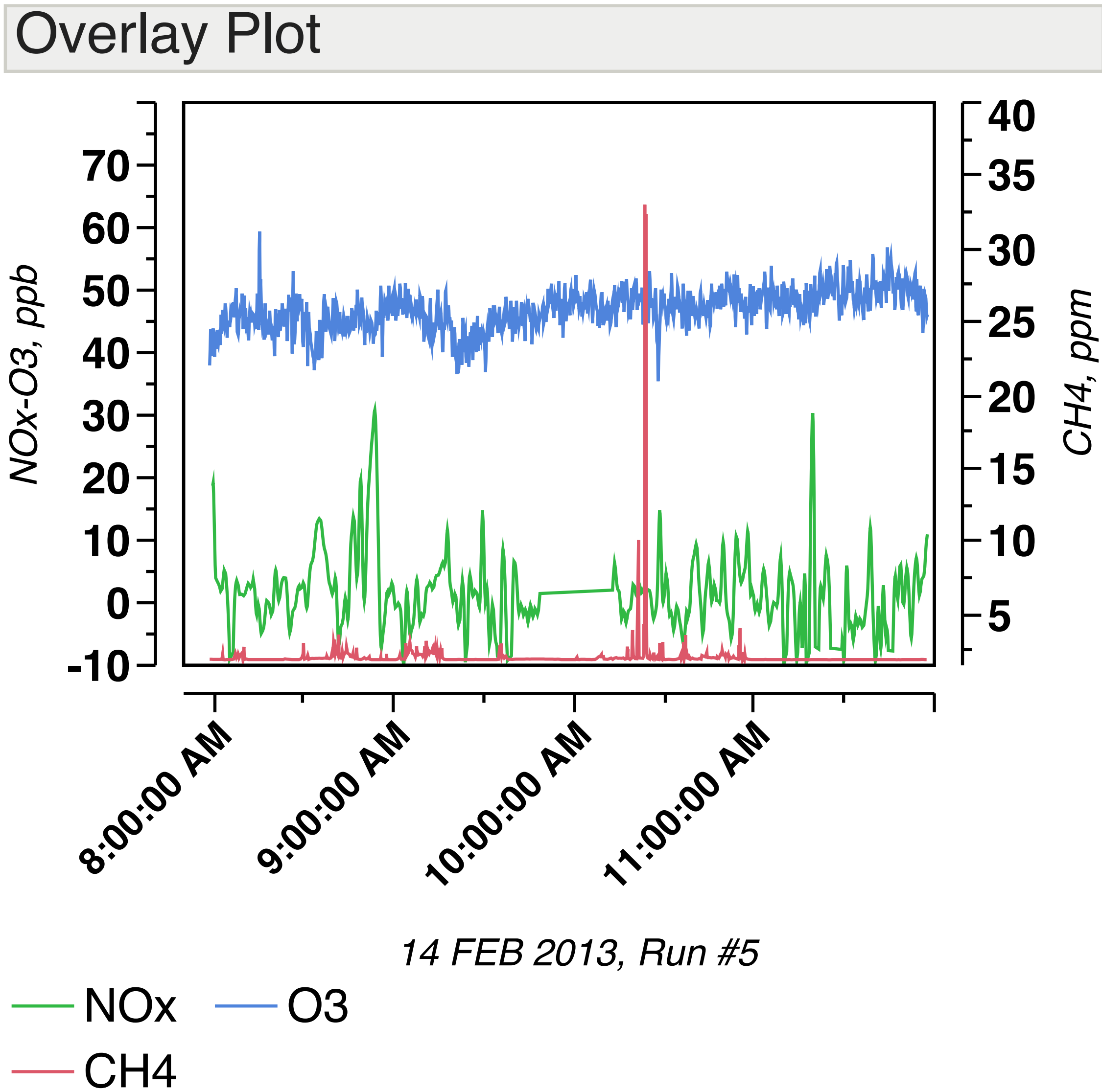


Figure 7.6. Circuit 6: 2/14/2013 AM

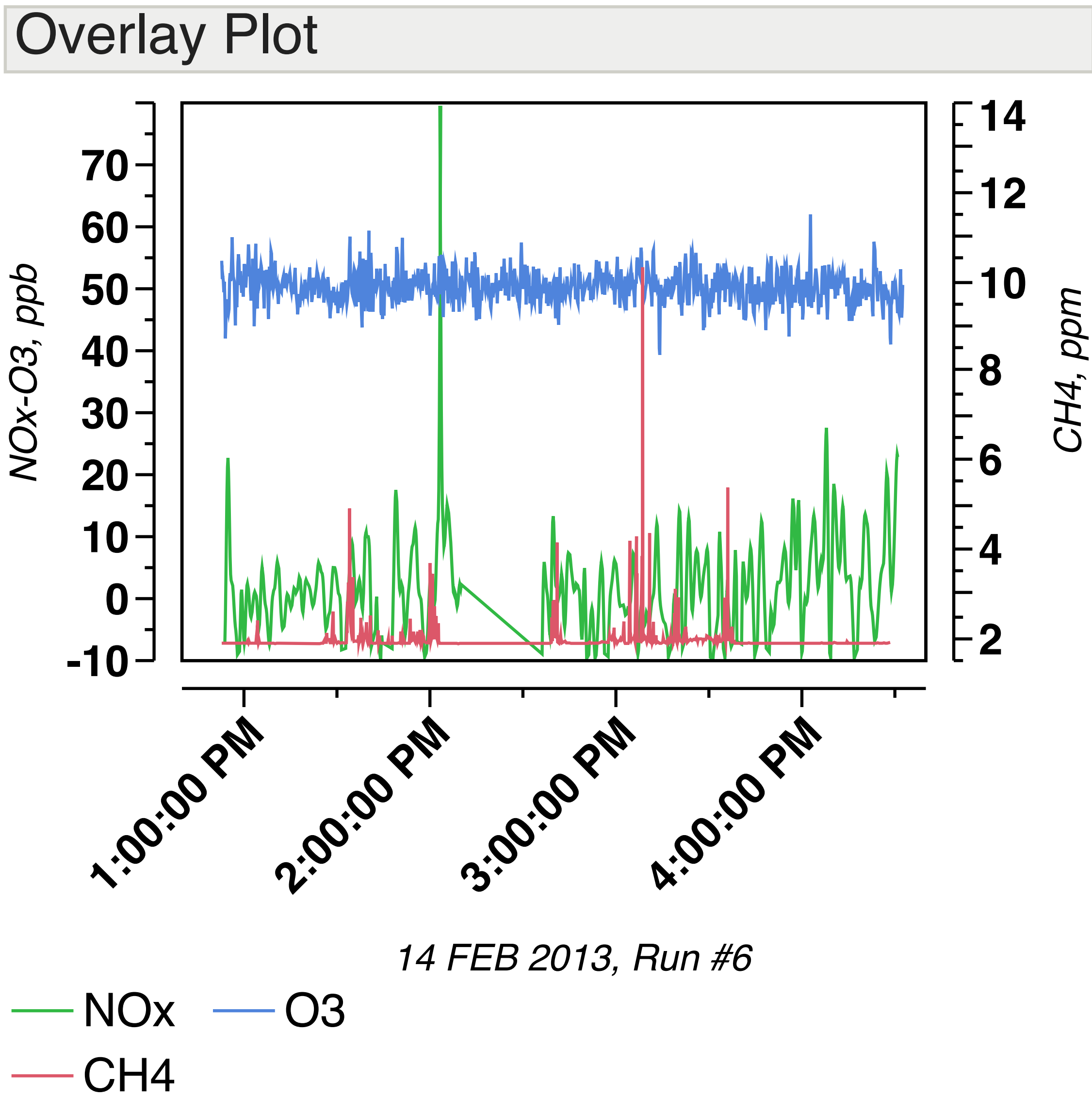


Figure 7.7. Circuit 7: 2/15/2013 AM

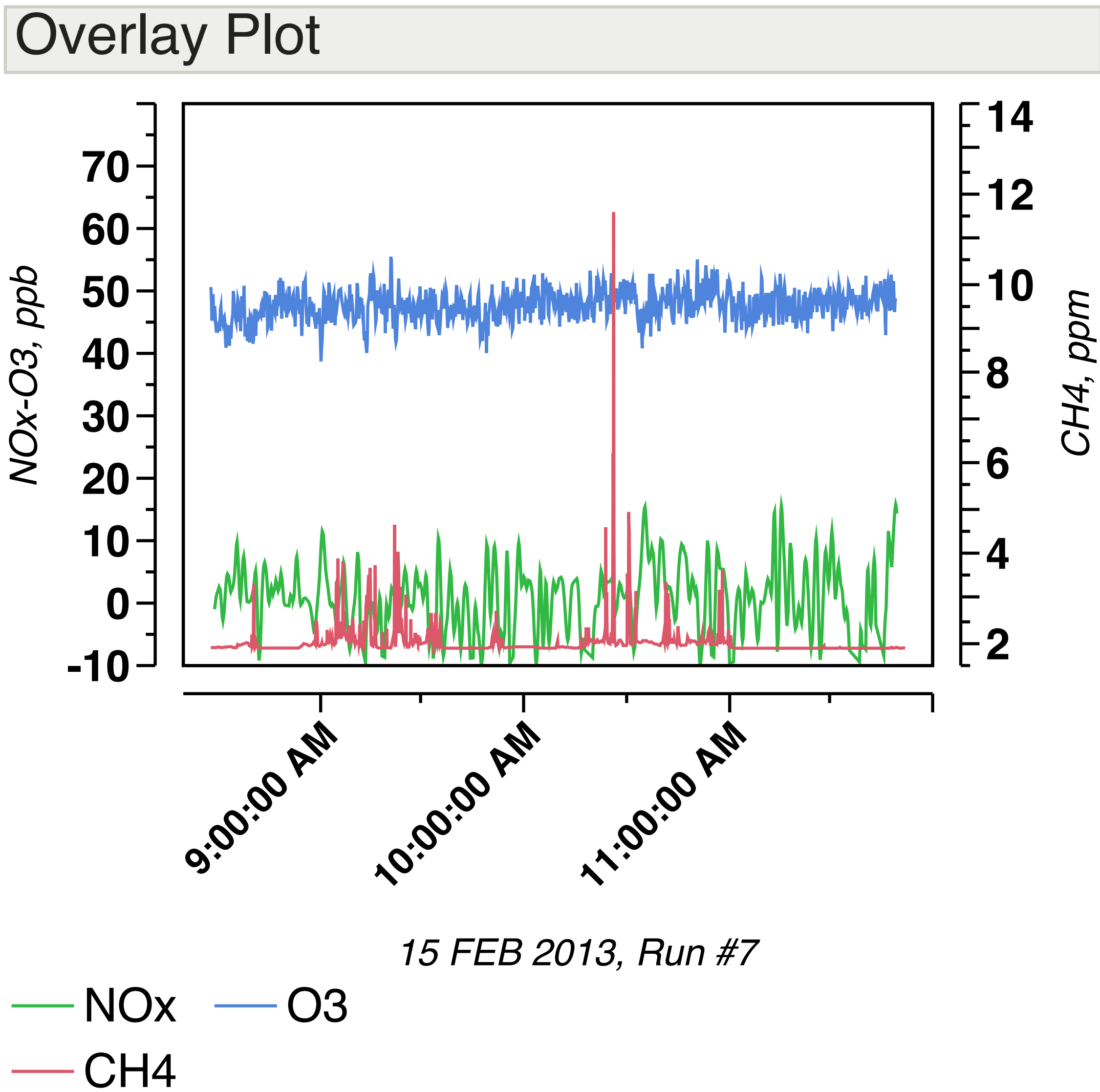


Figure 7.8. Circuit 8: 2/15/2013 AM

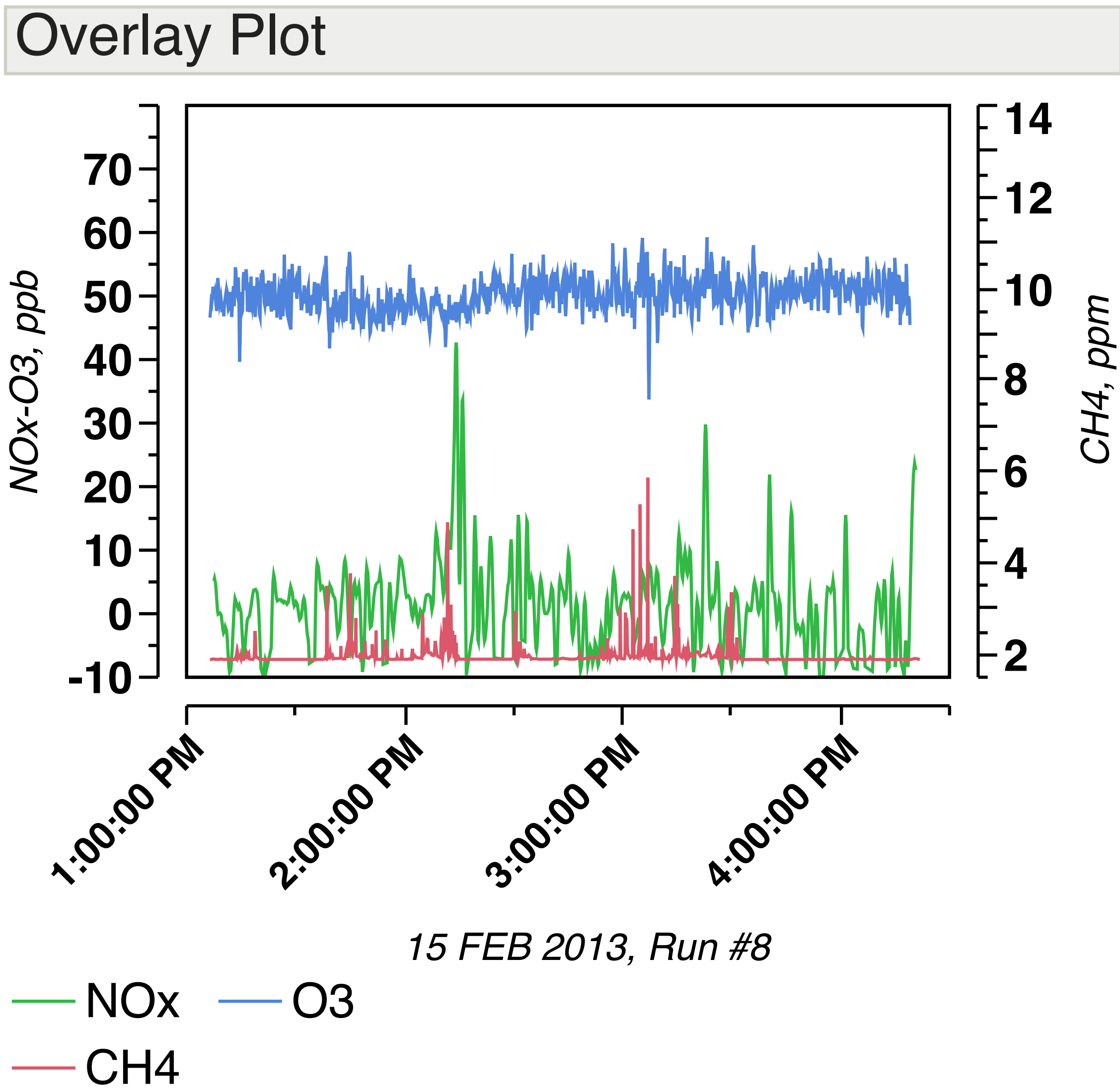


Figure 7.9. Circuit 9: 2/16/2013 AM

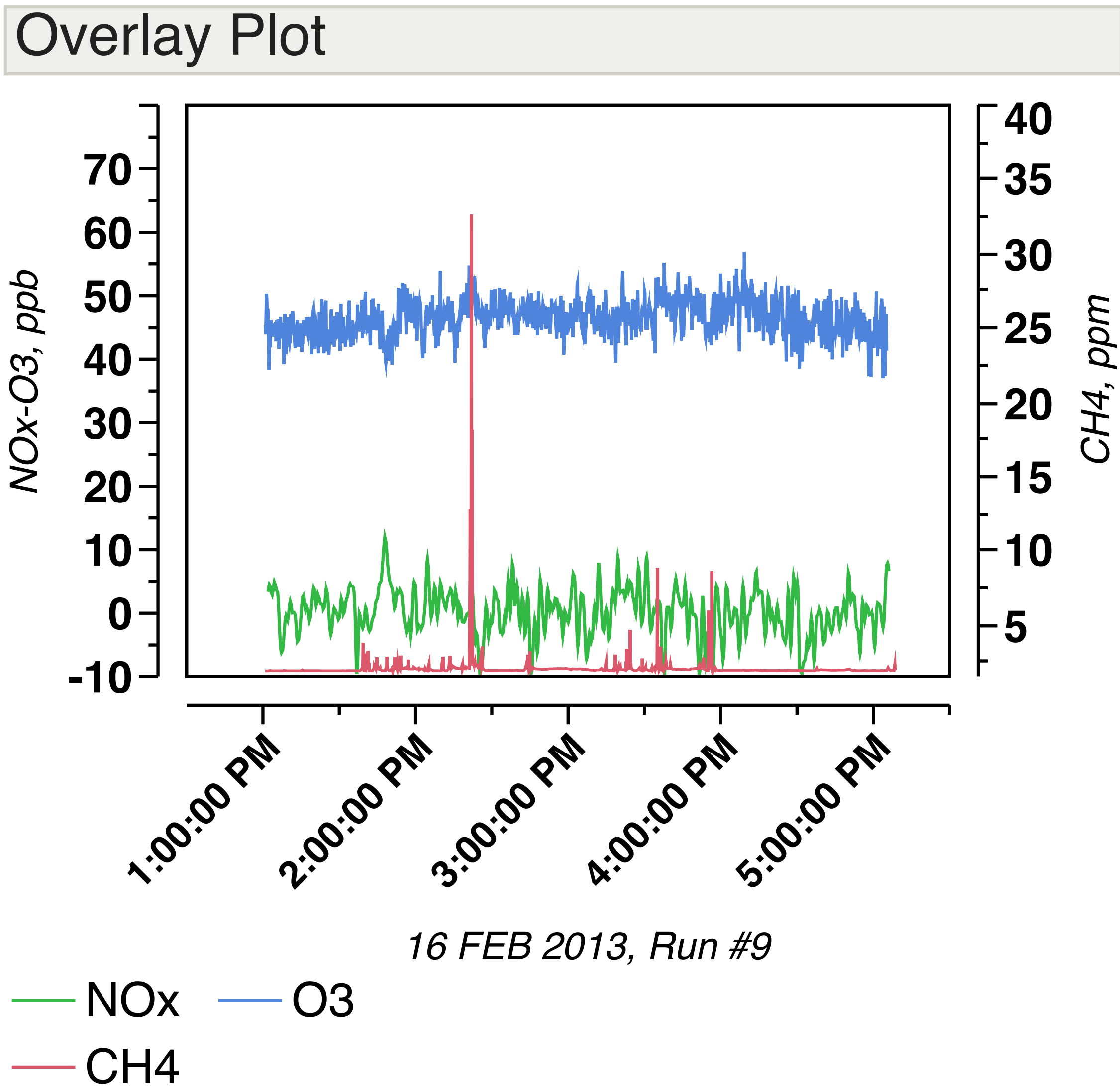


Figure 7.10. Circuit 10: 2/17/2013 AM

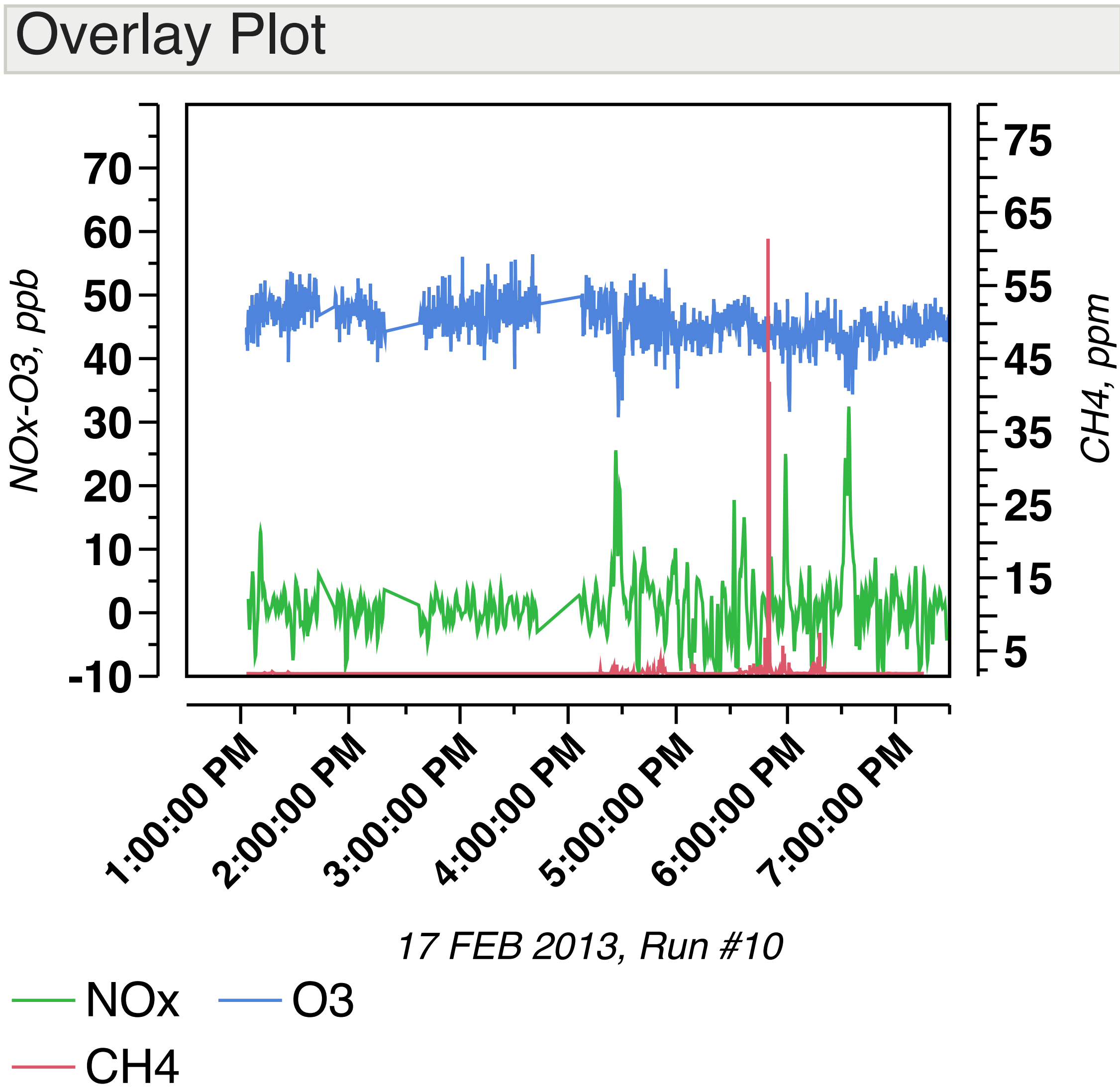


Figure 7.11. Circuit 11: 2/18/2013 AM

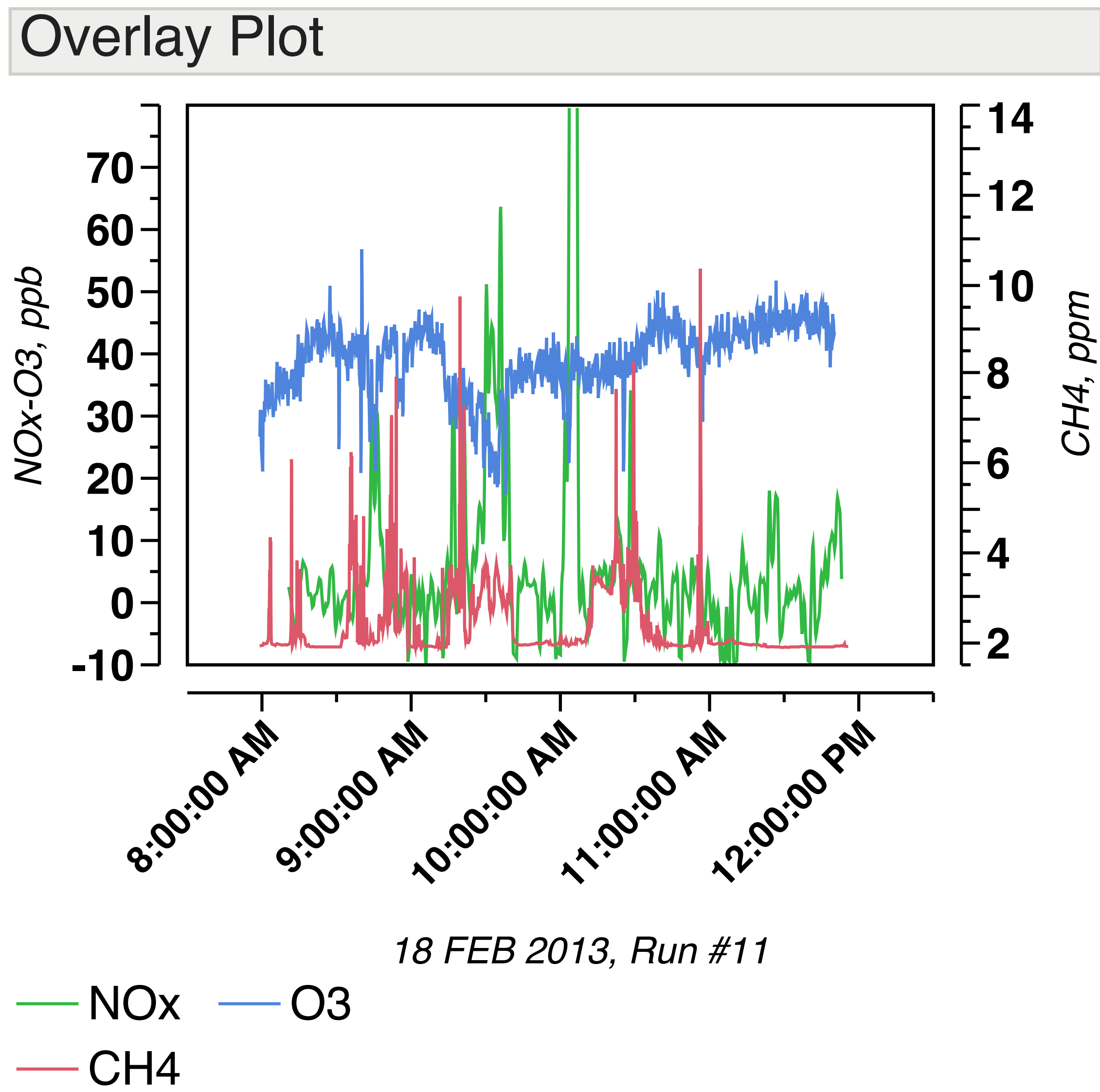


Figure 7.12. Circuit 12: 2/18/2013 AM

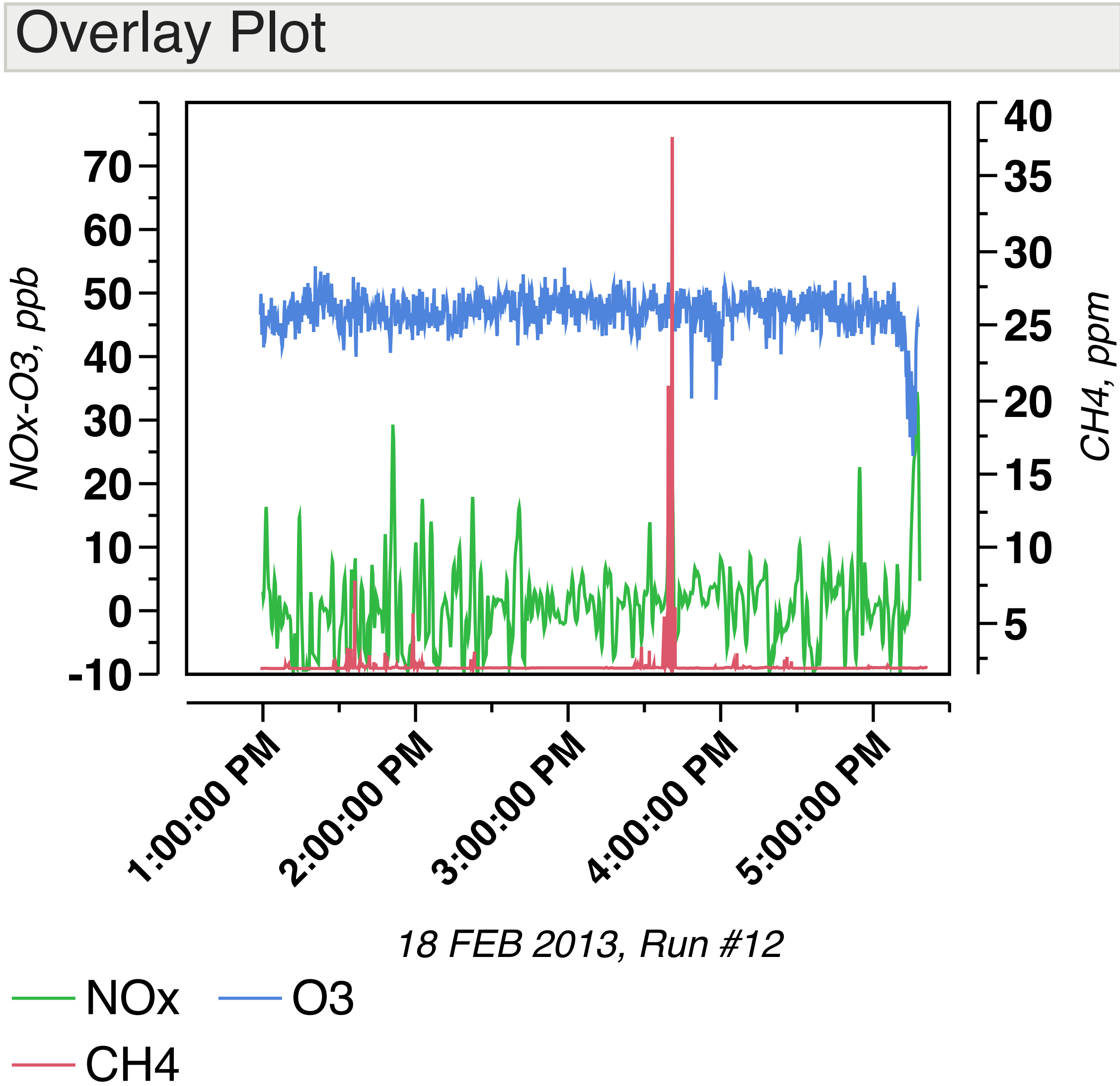


Figure 7.13. Circuit 13: 2/19/2013 AM

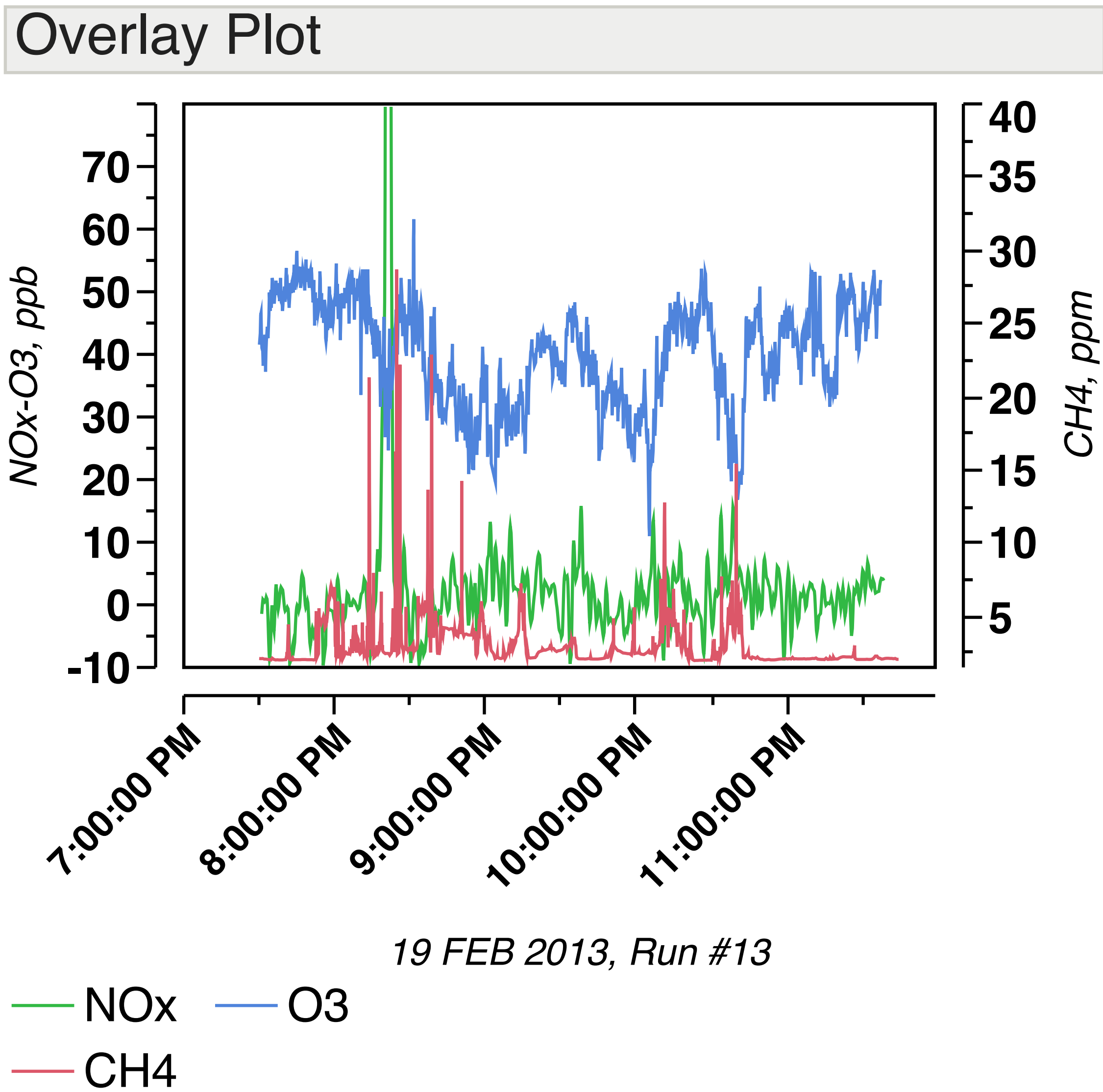


Figure 7.14. Circuit 14: 2/20/2013 AM

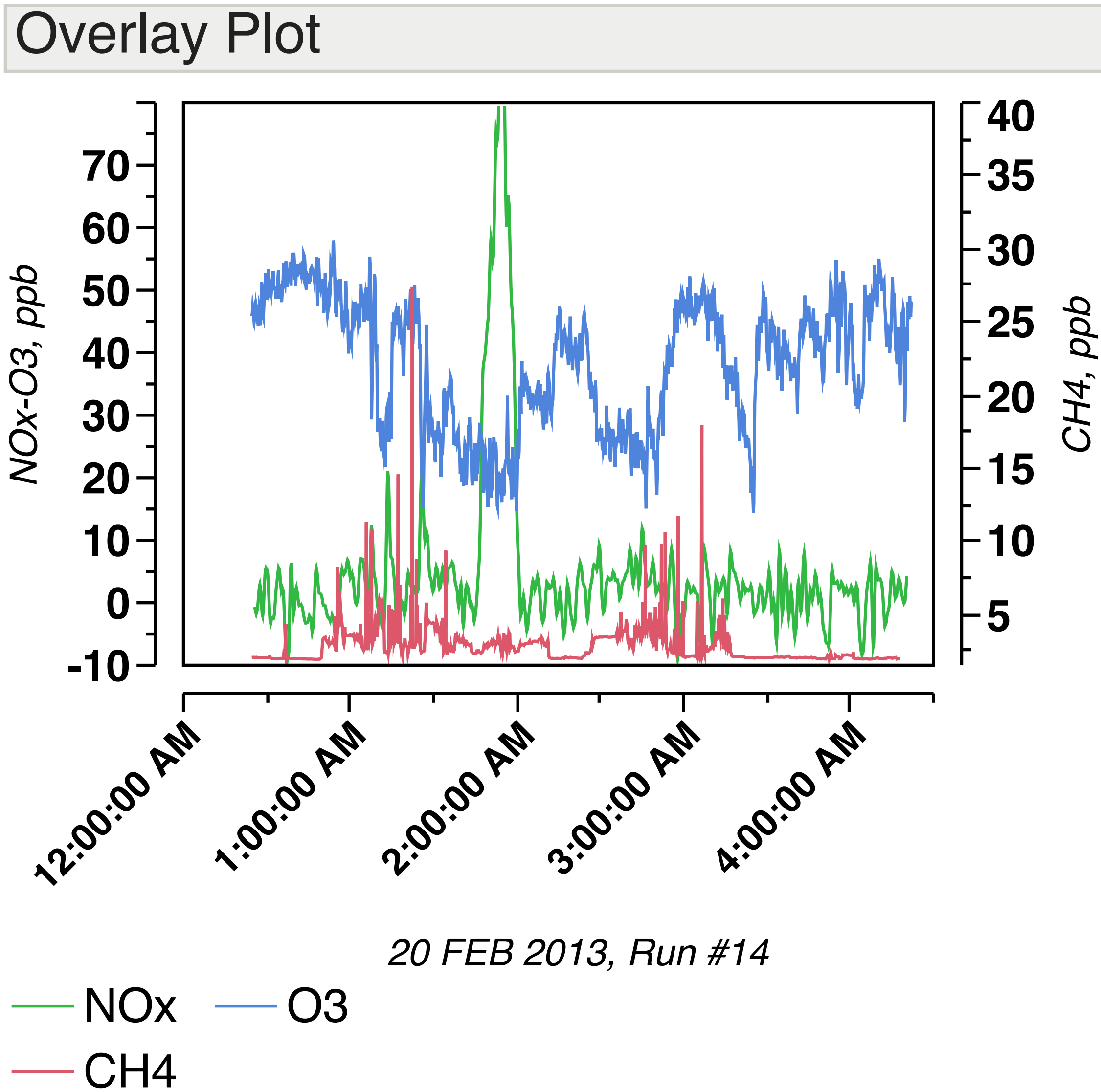


Figure 7.15. Circuit 15: 2/20/2013 AM

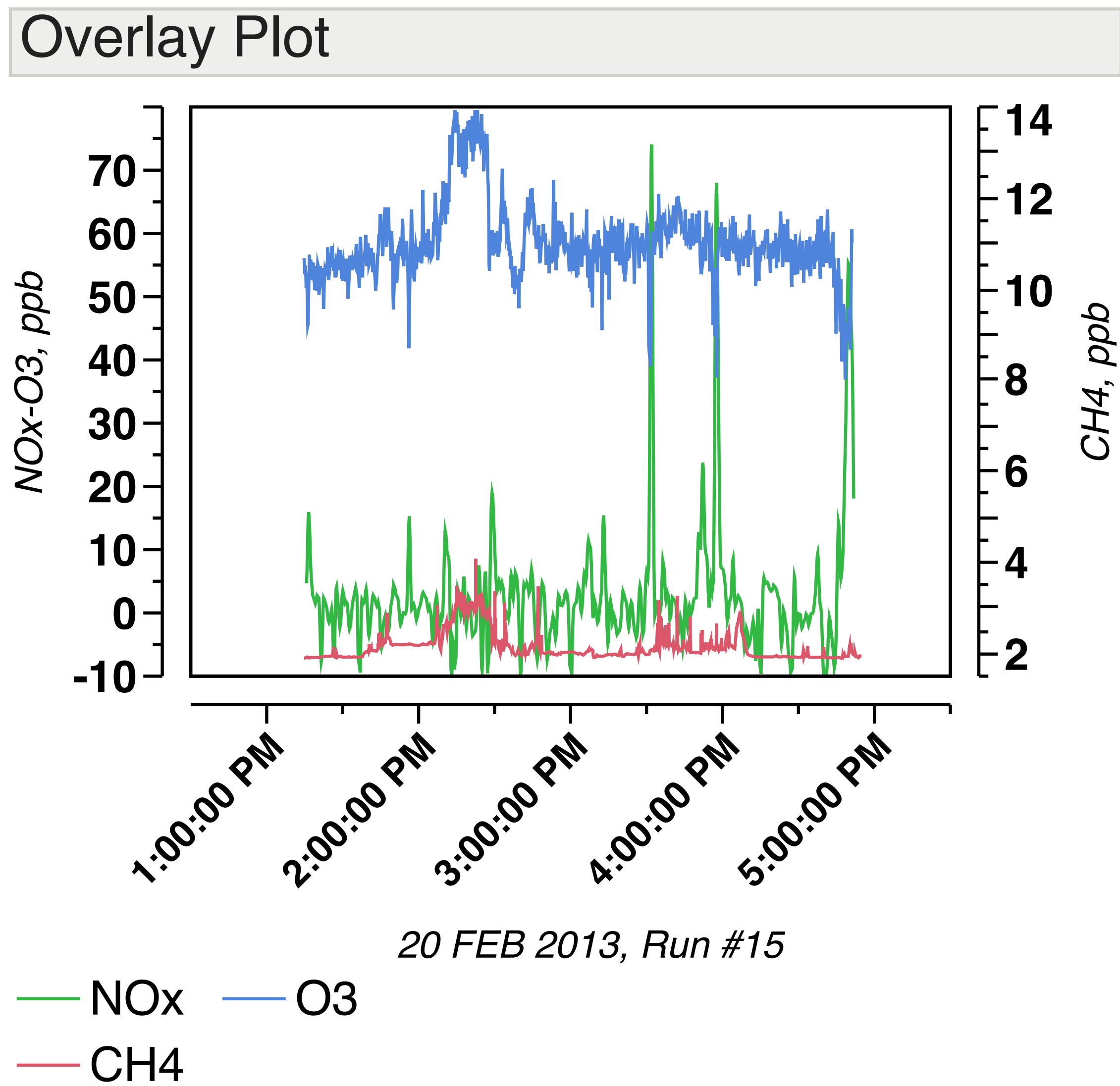


Figure 7.16. Circuit 16: 2/20/2013 AM

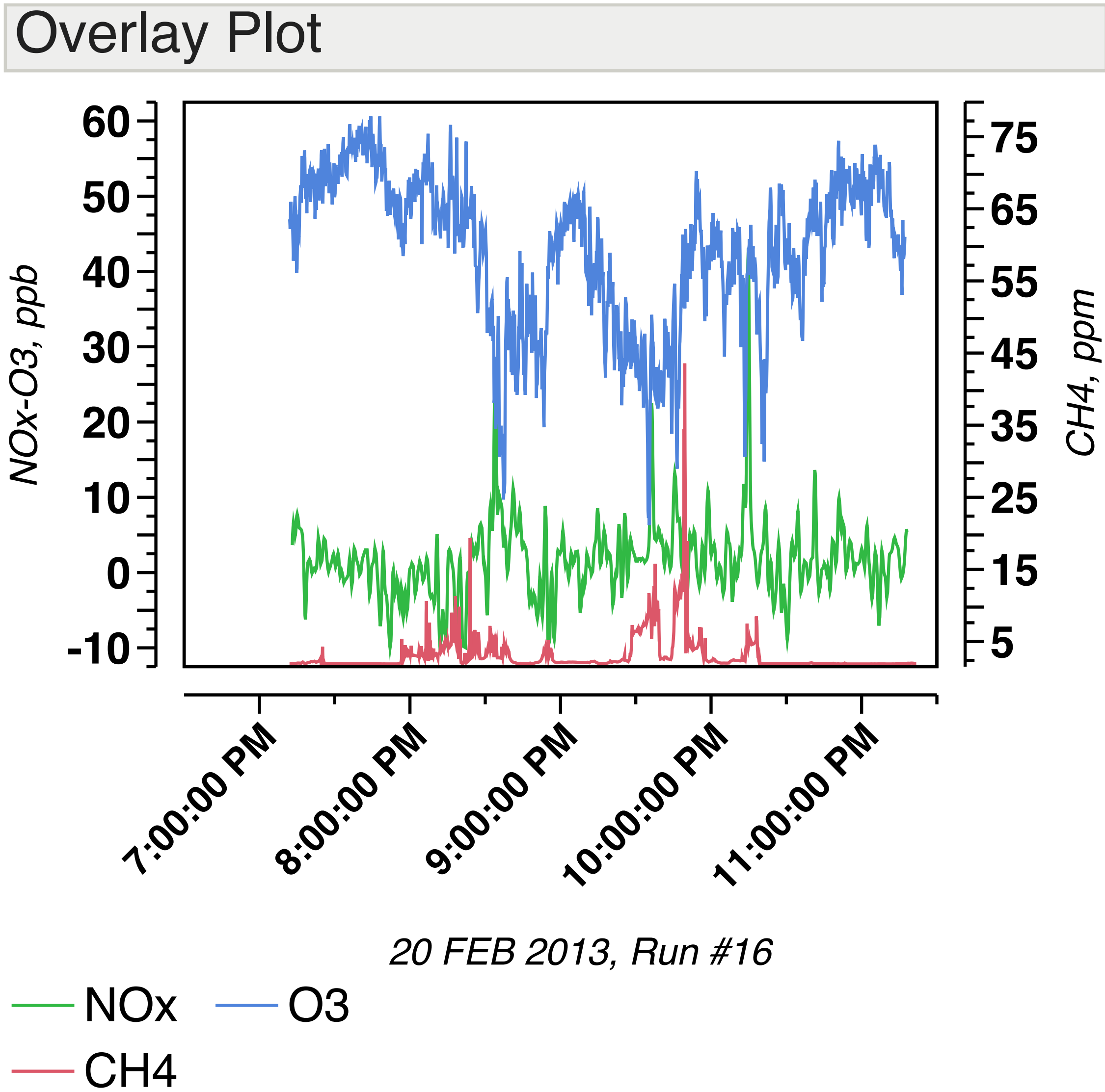


Figure 7.17. Circuit 17: 2/24/2013 AM

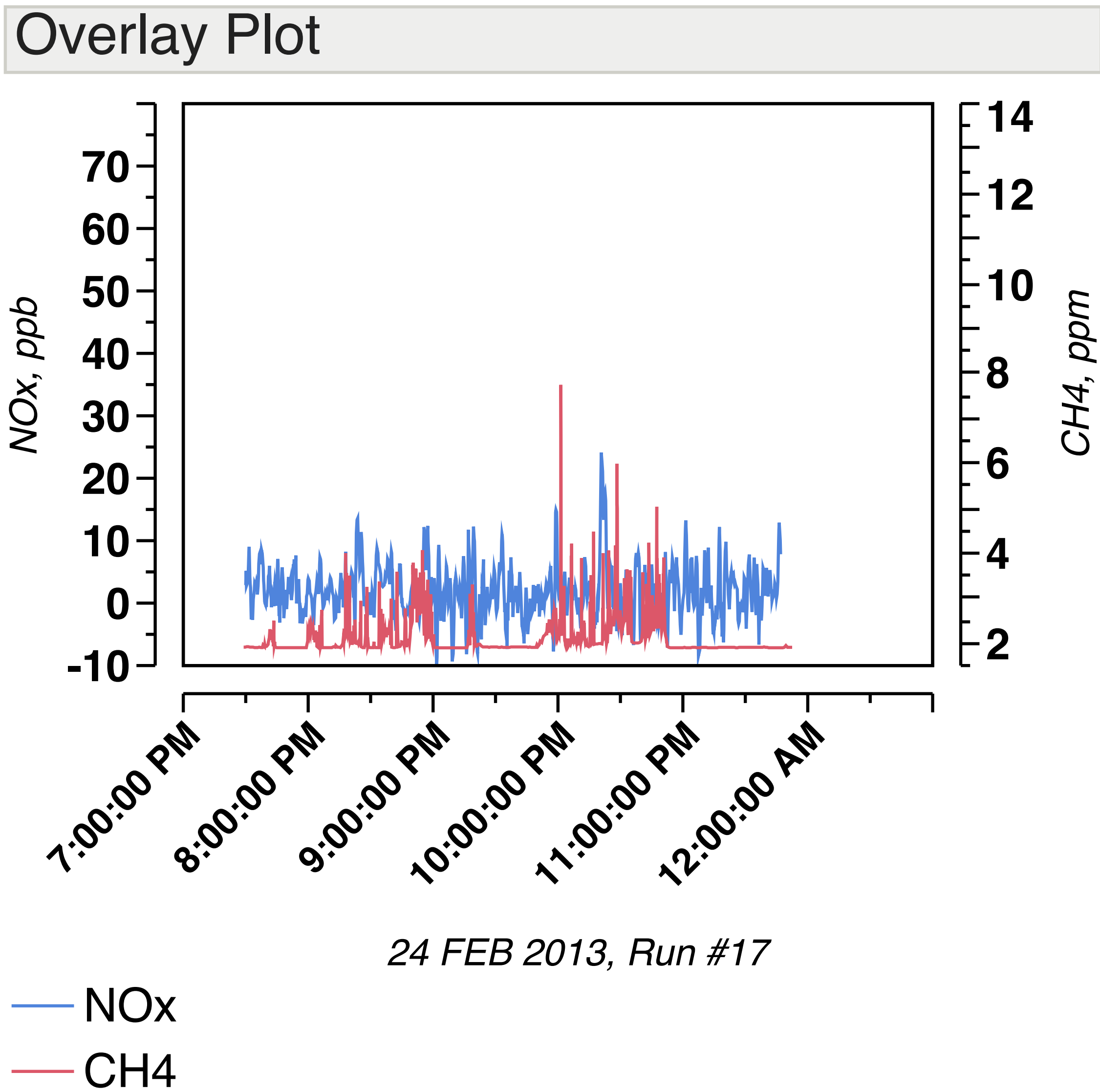


Figure 7.18. Circuit 18: 2/25/2013 AM

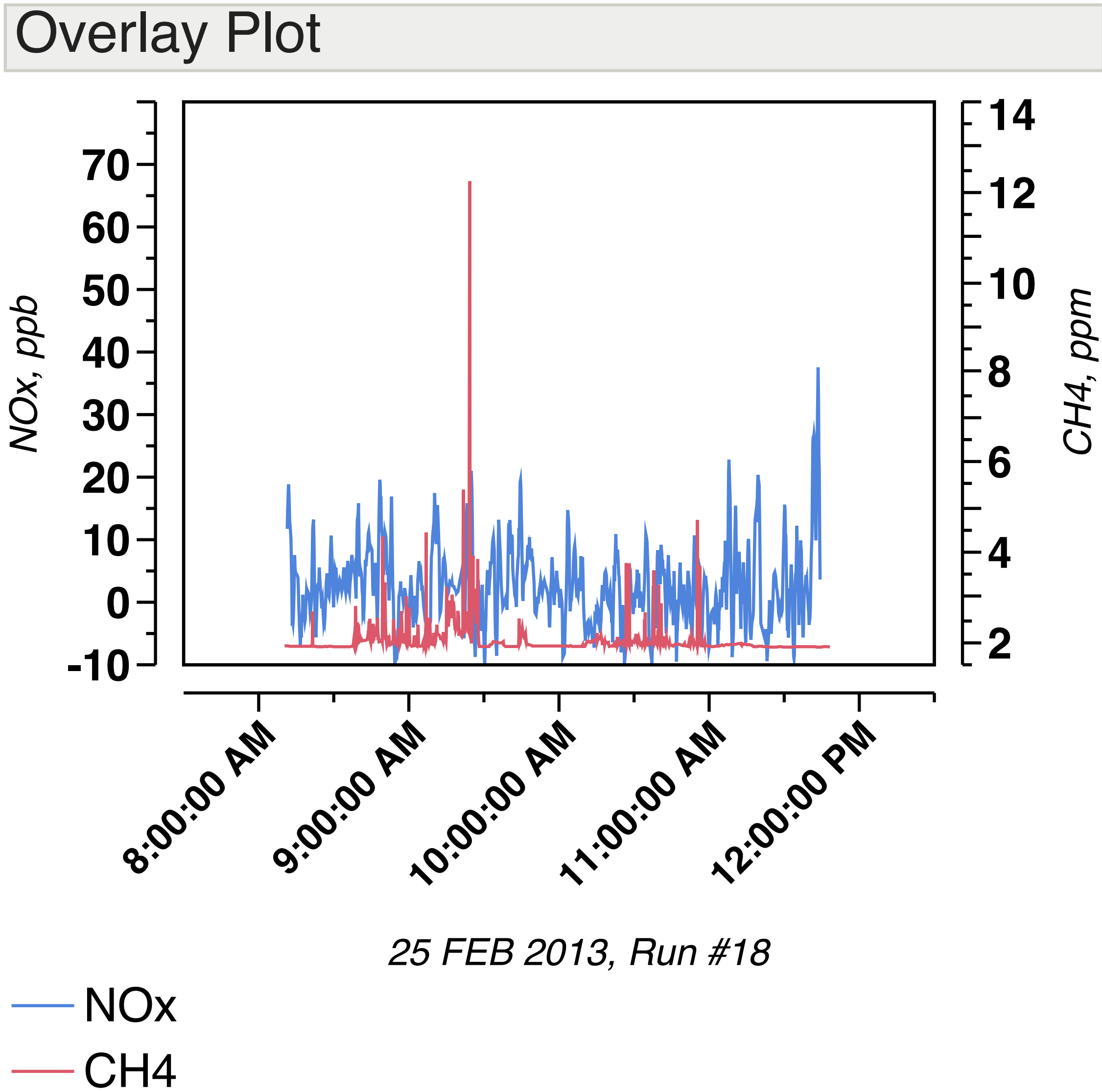


Figure 7.19. Circuit 19: 2/25/2013 AM

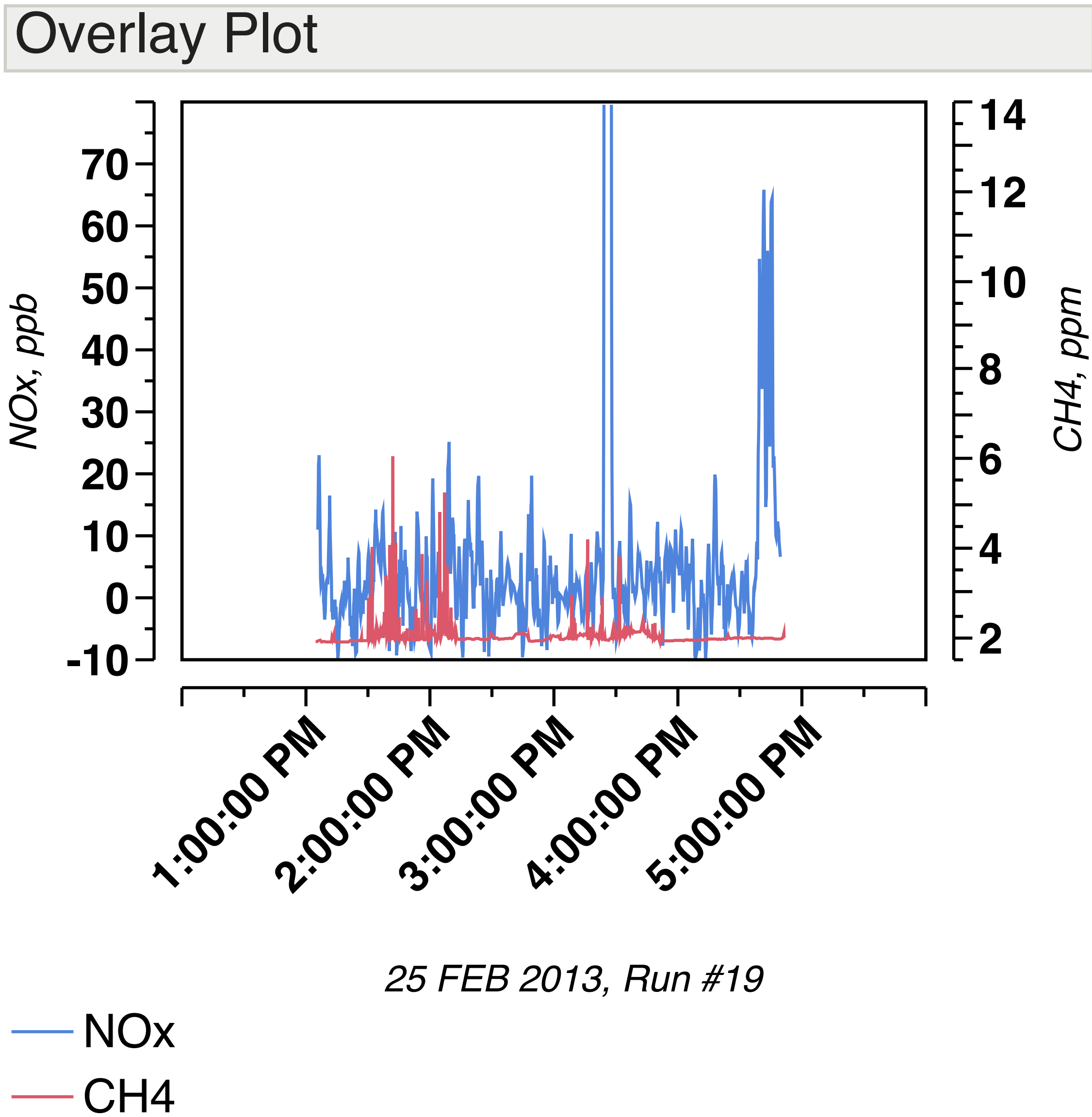


Figure 7.20. Circuit 20: 3/2/2013 AM

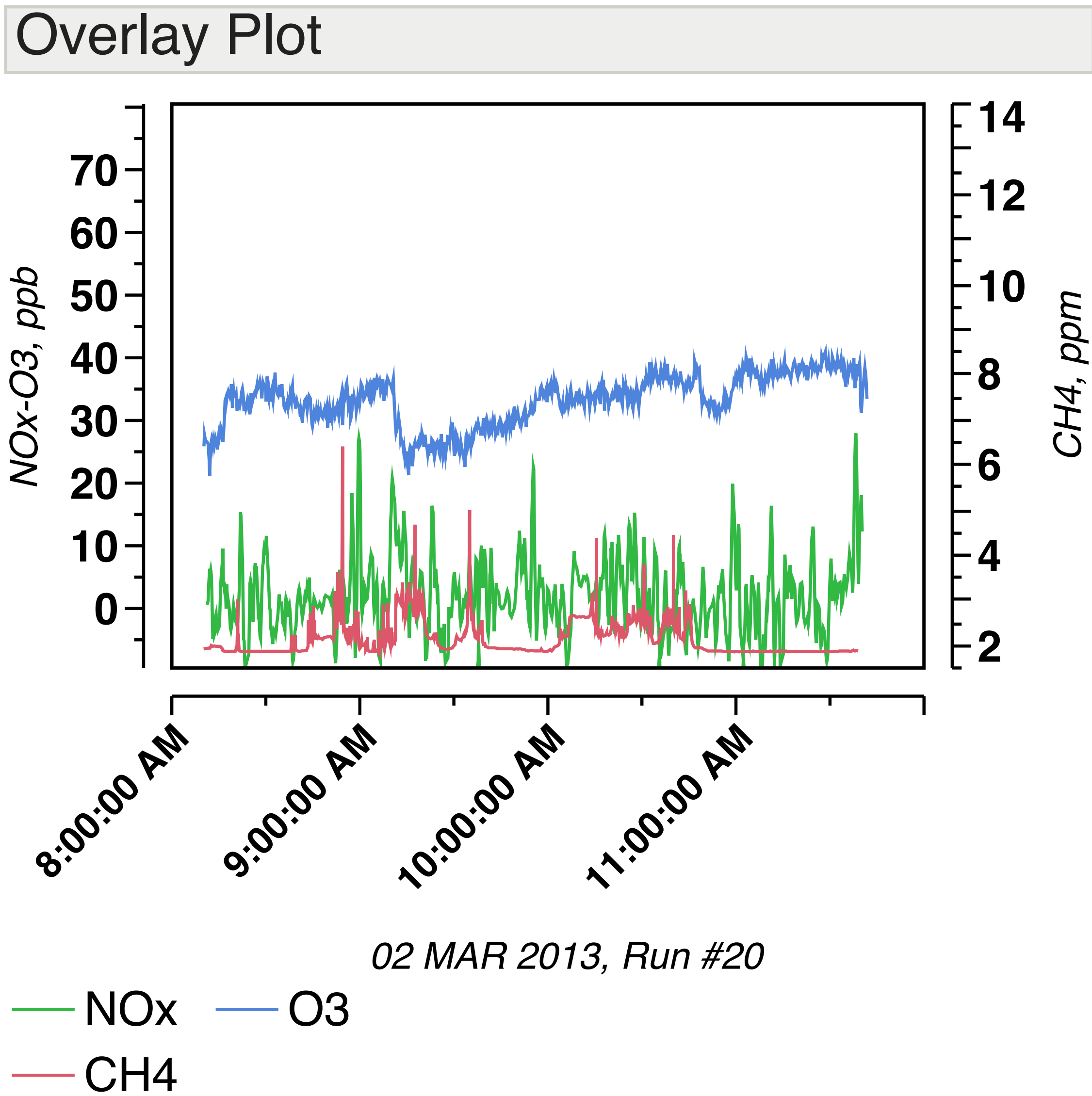


Figure 7.21. Circuit 21: 3/2/2013 AM

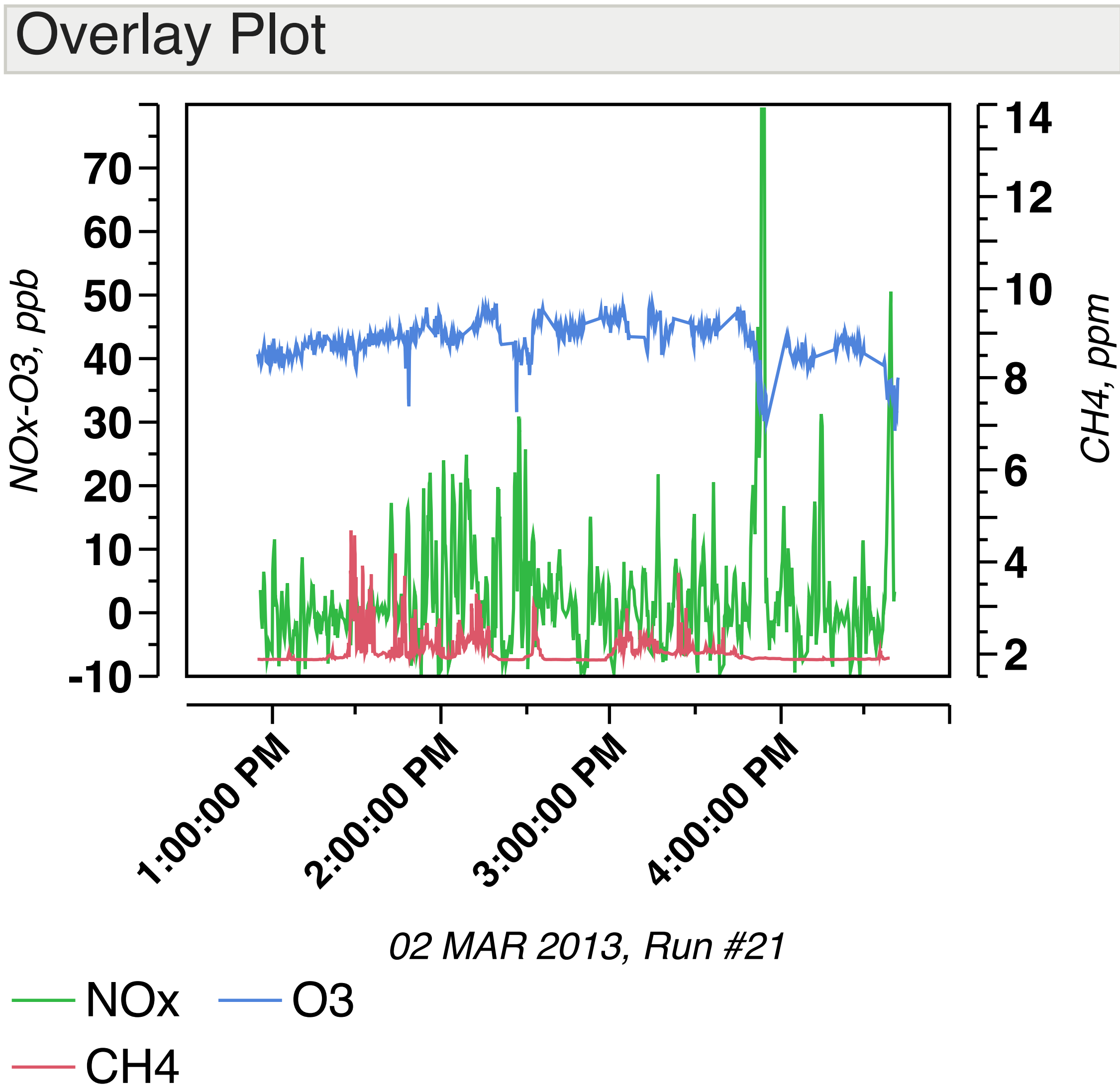


Figure 7.22. Circuit 22: 3/2/2013 AM

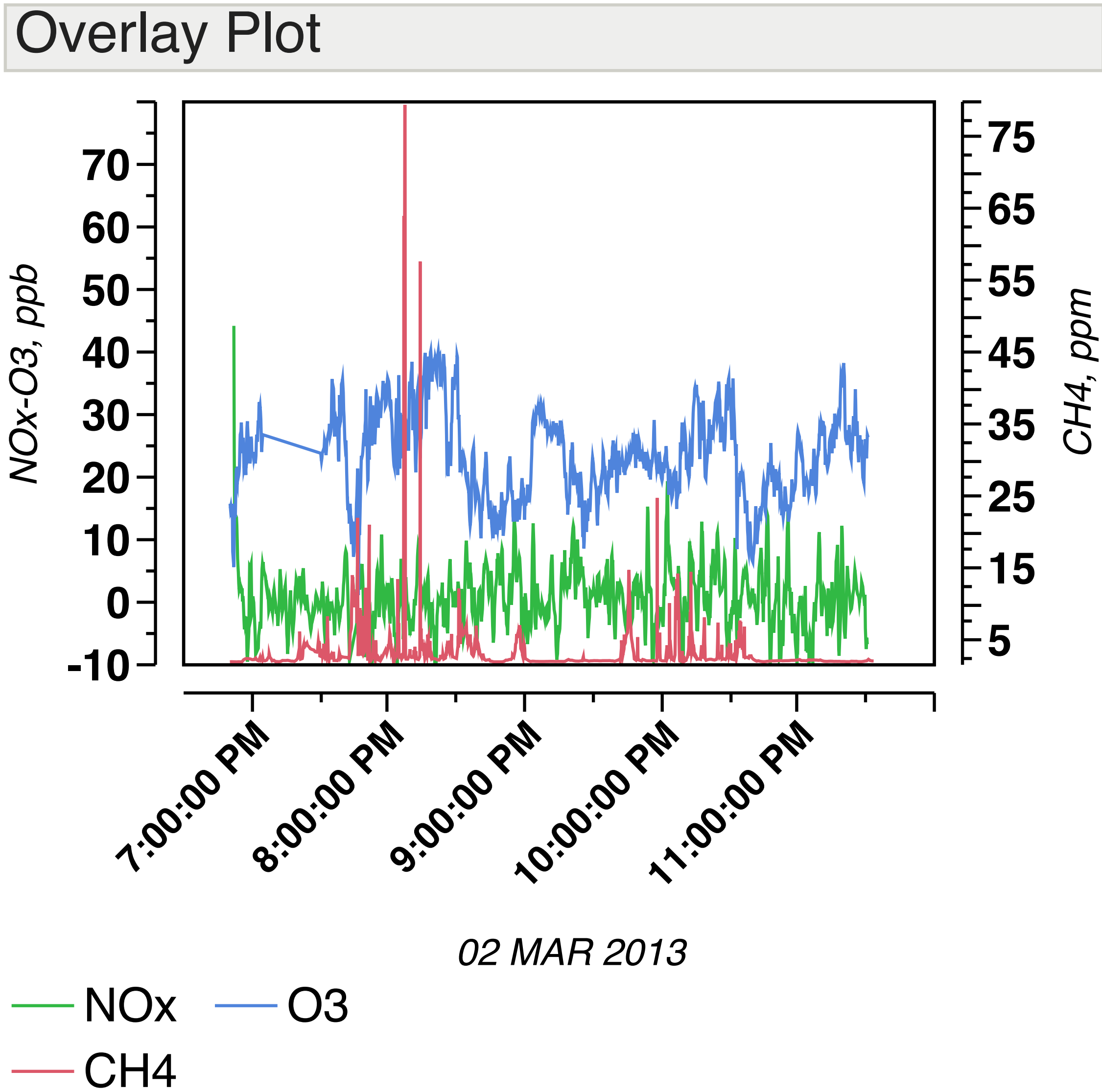


Figure 7.23. Circuit 23: 3/3/2013 AM

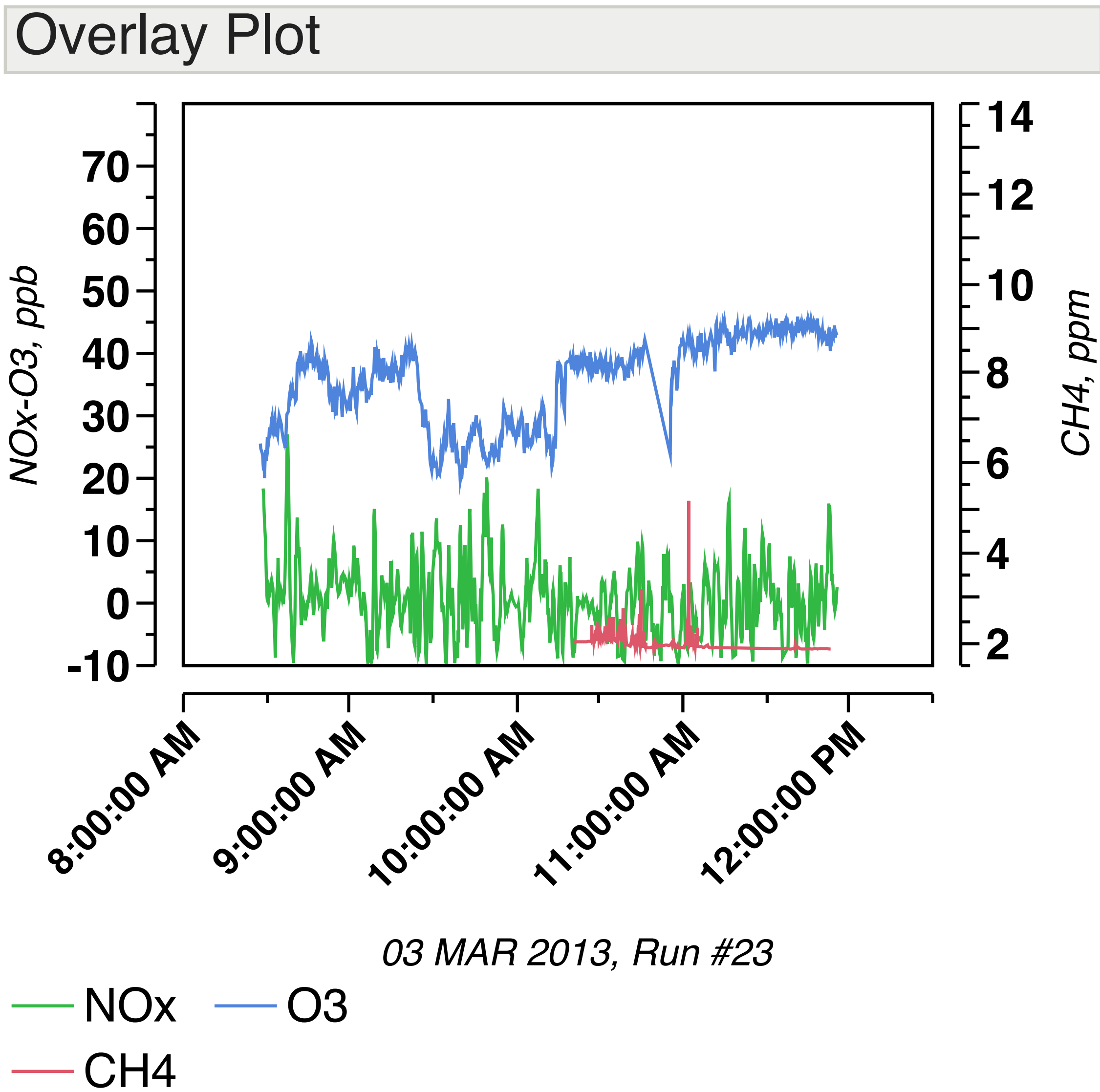


Figure 7.24. Circuit 24: 3/3/2013 AM

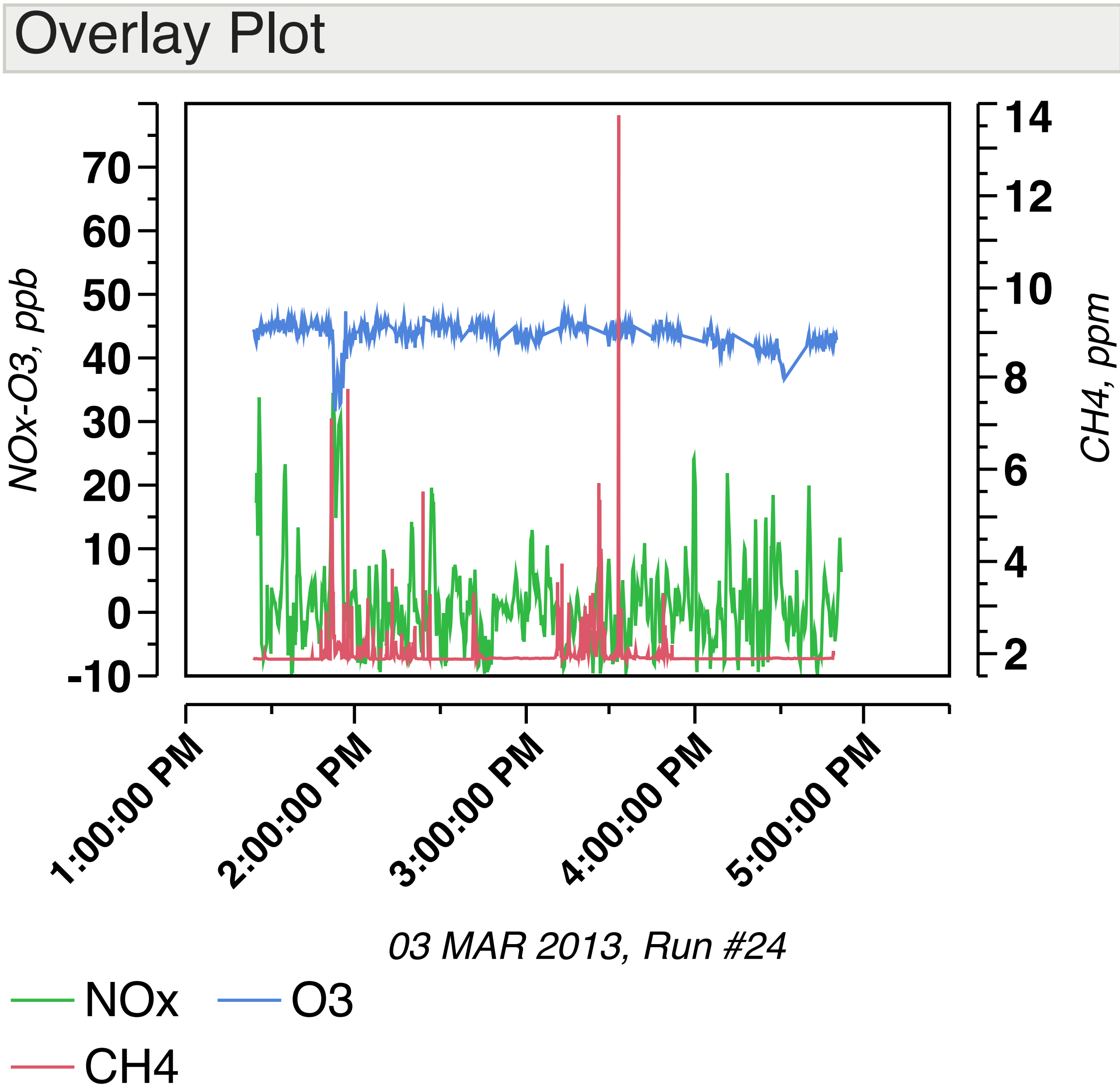


Figure 7.25. Circuit 25: 3/5/2013 AM

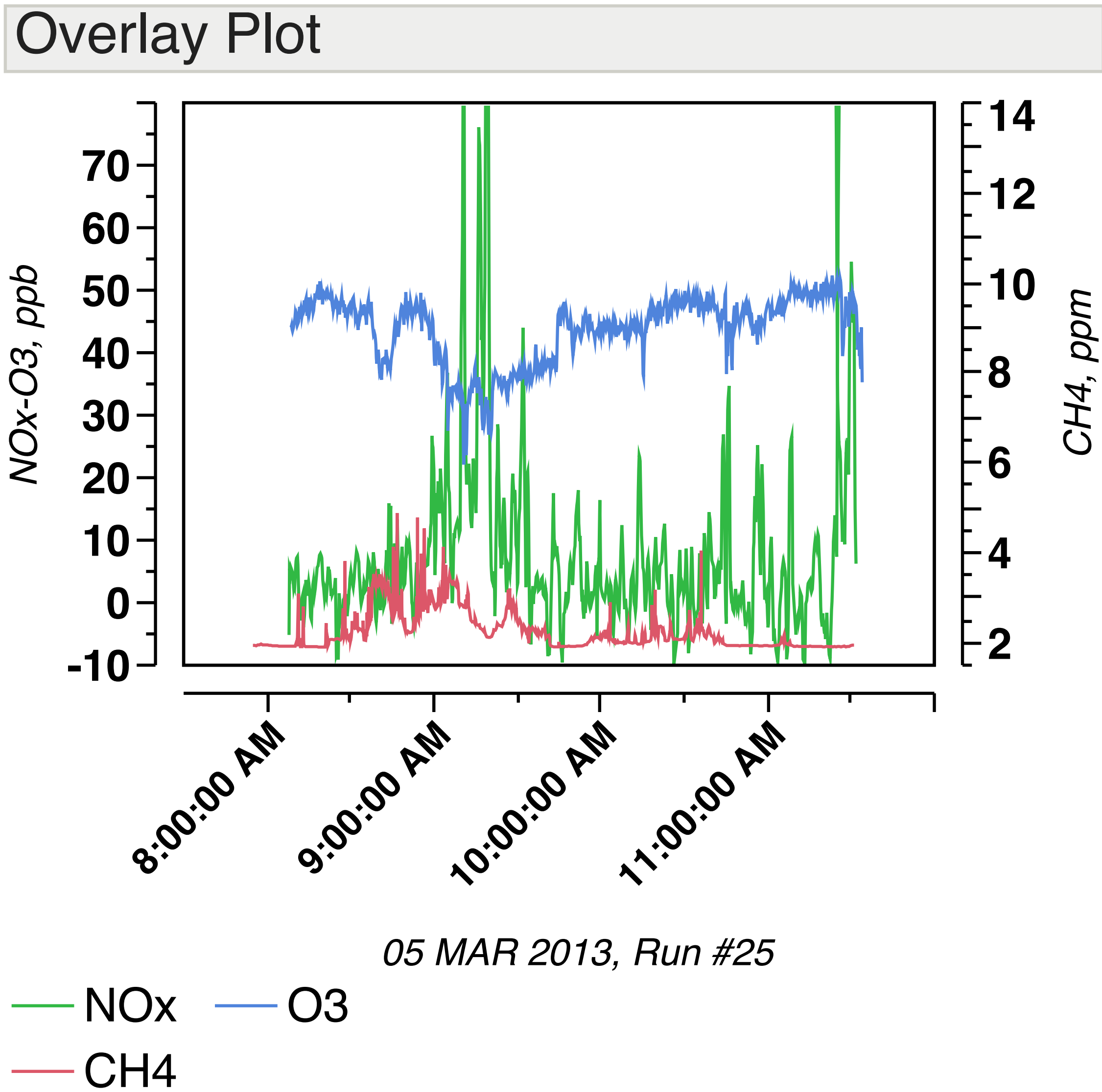


Figure 7.26. Circuit 26: 3/5/2013 AM

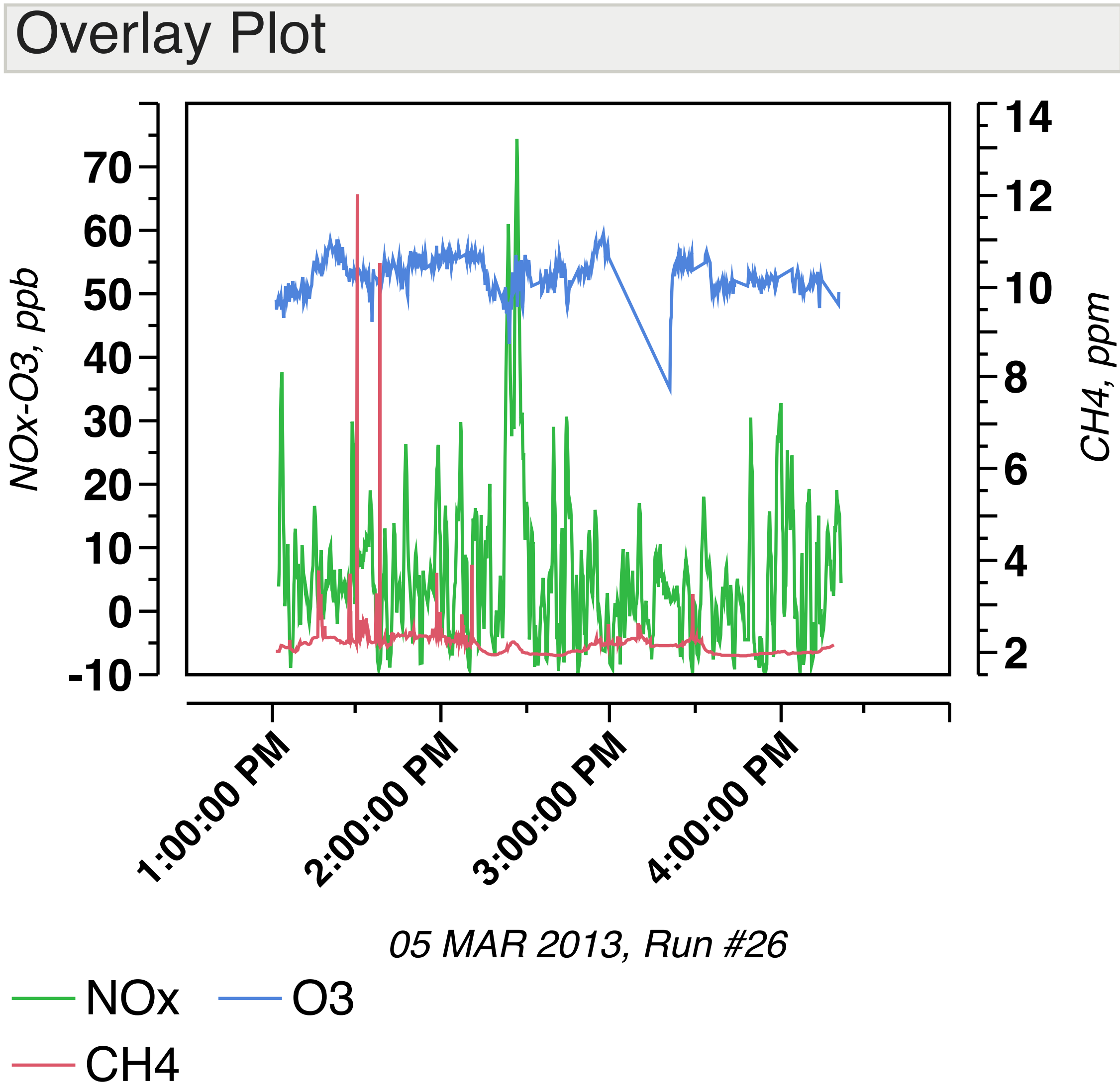


Figure 7.27. Circuit 27: 3/6/2013 AM

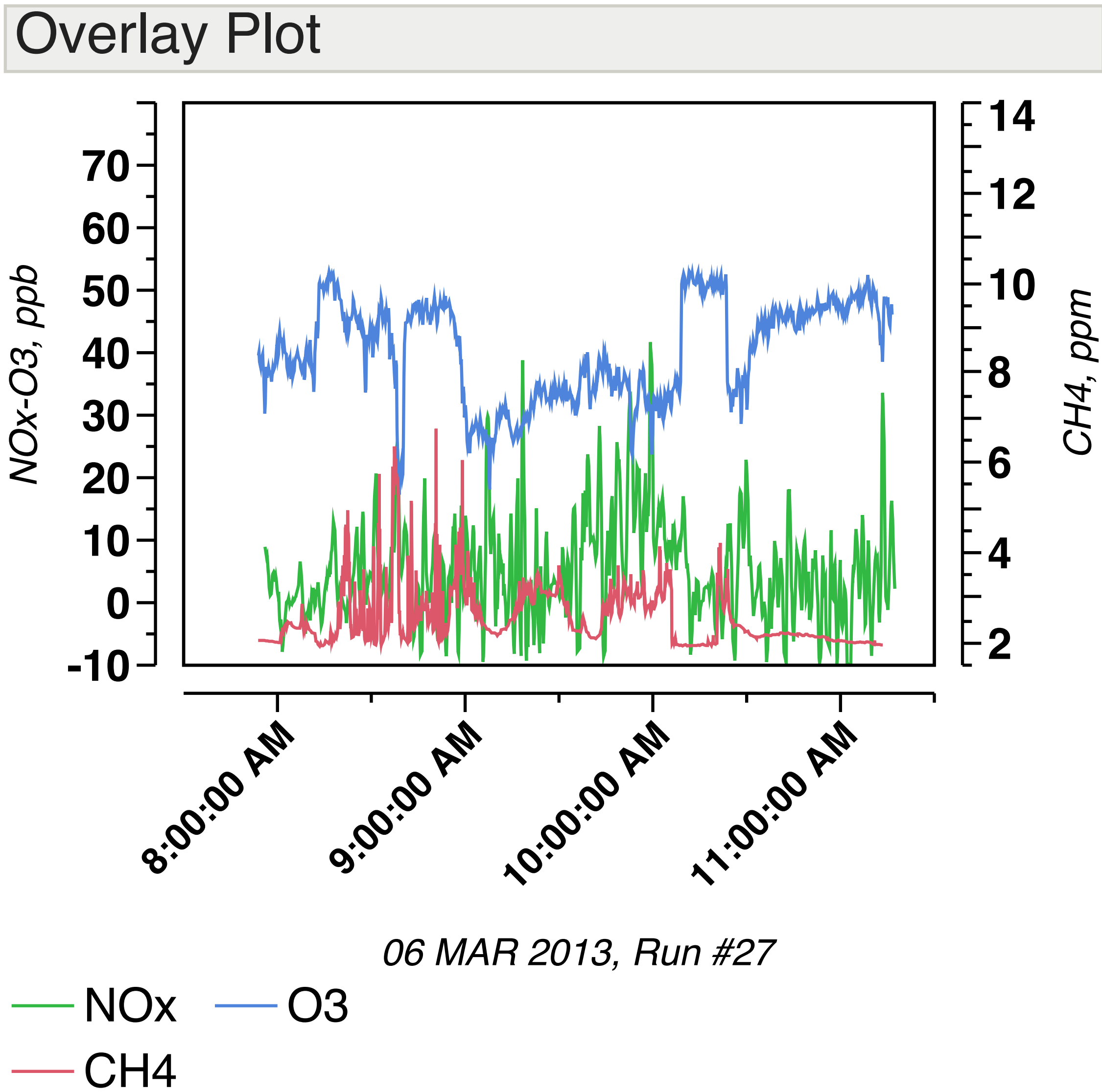


Figure 7.28. Circuit 28: 3/6/2013 AM

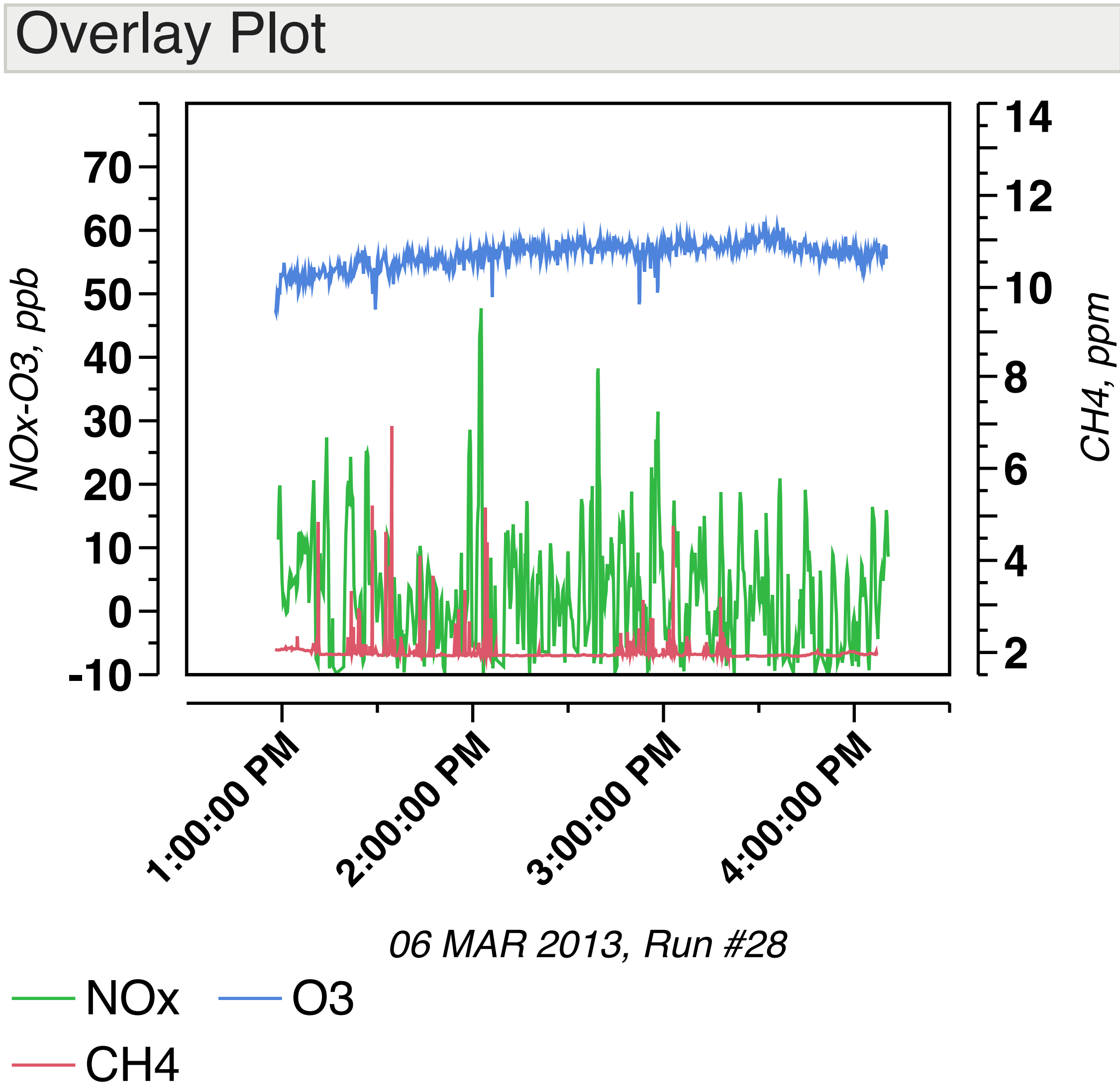


Figure 7.29. Circuit 29: 3/7/2013 AM

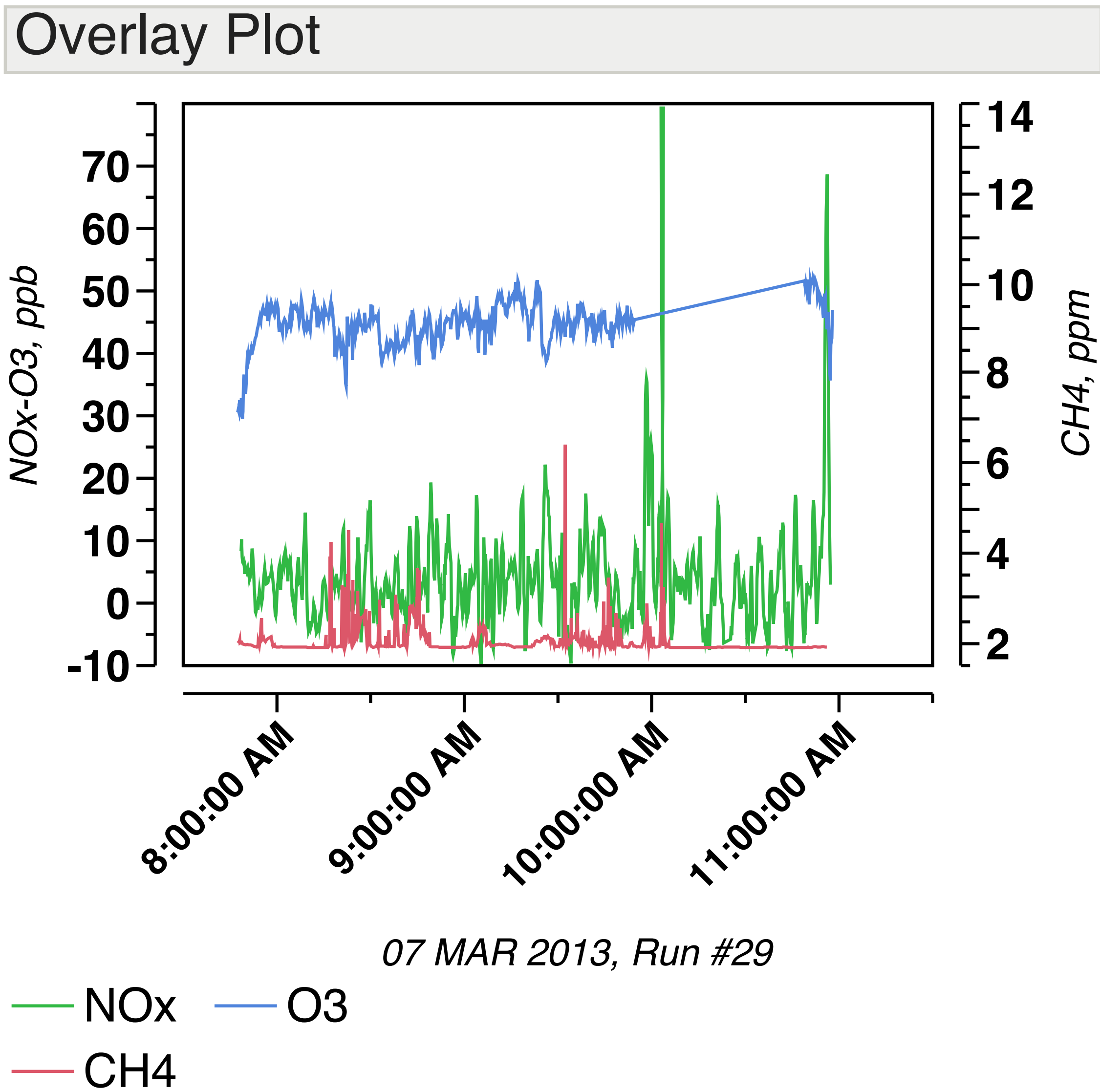


Figure 7.30. Circuit 30: 3/7/2013 AM

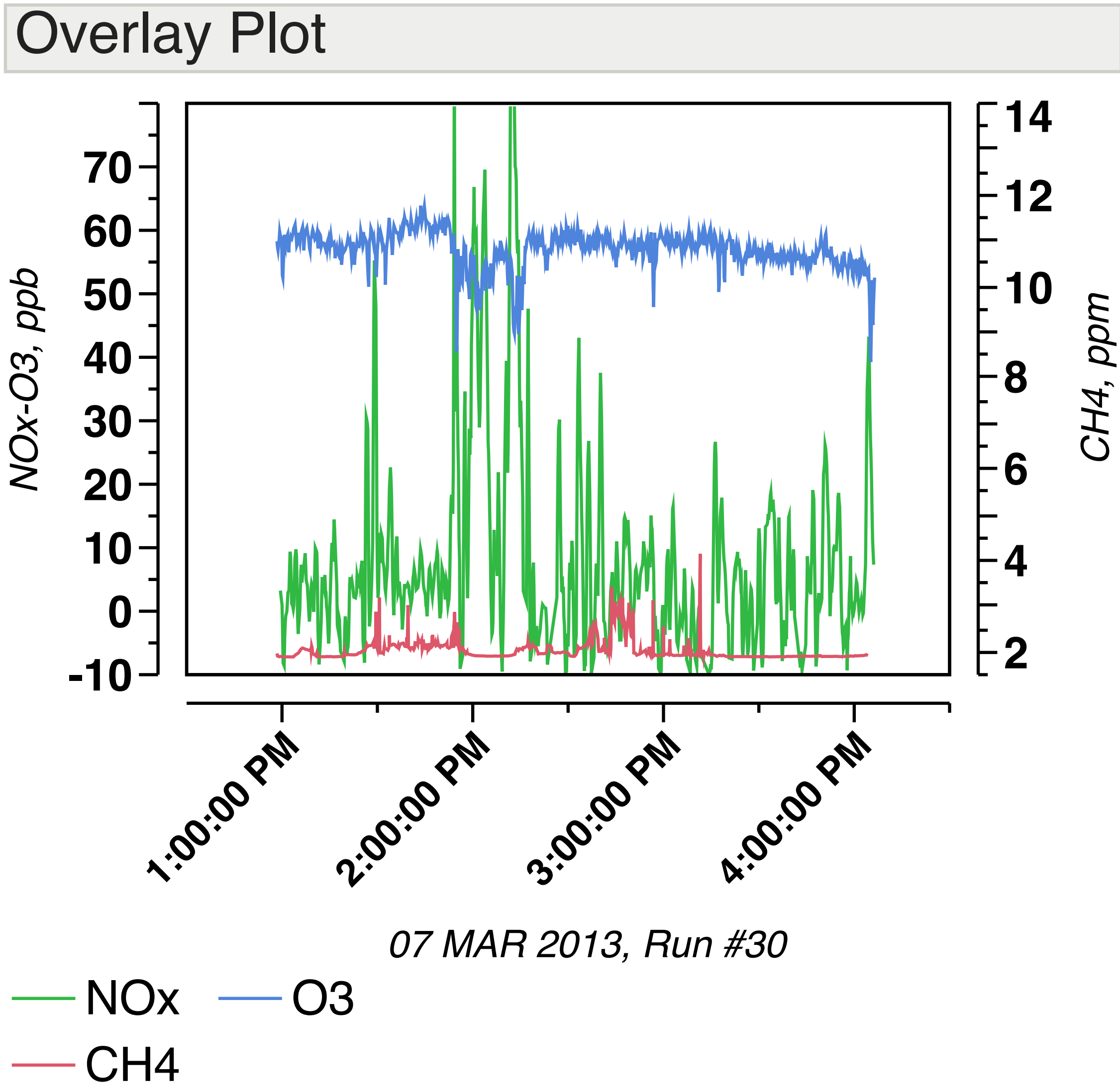


Figure 7.31. Circuit 31: 3/8/2013 AM

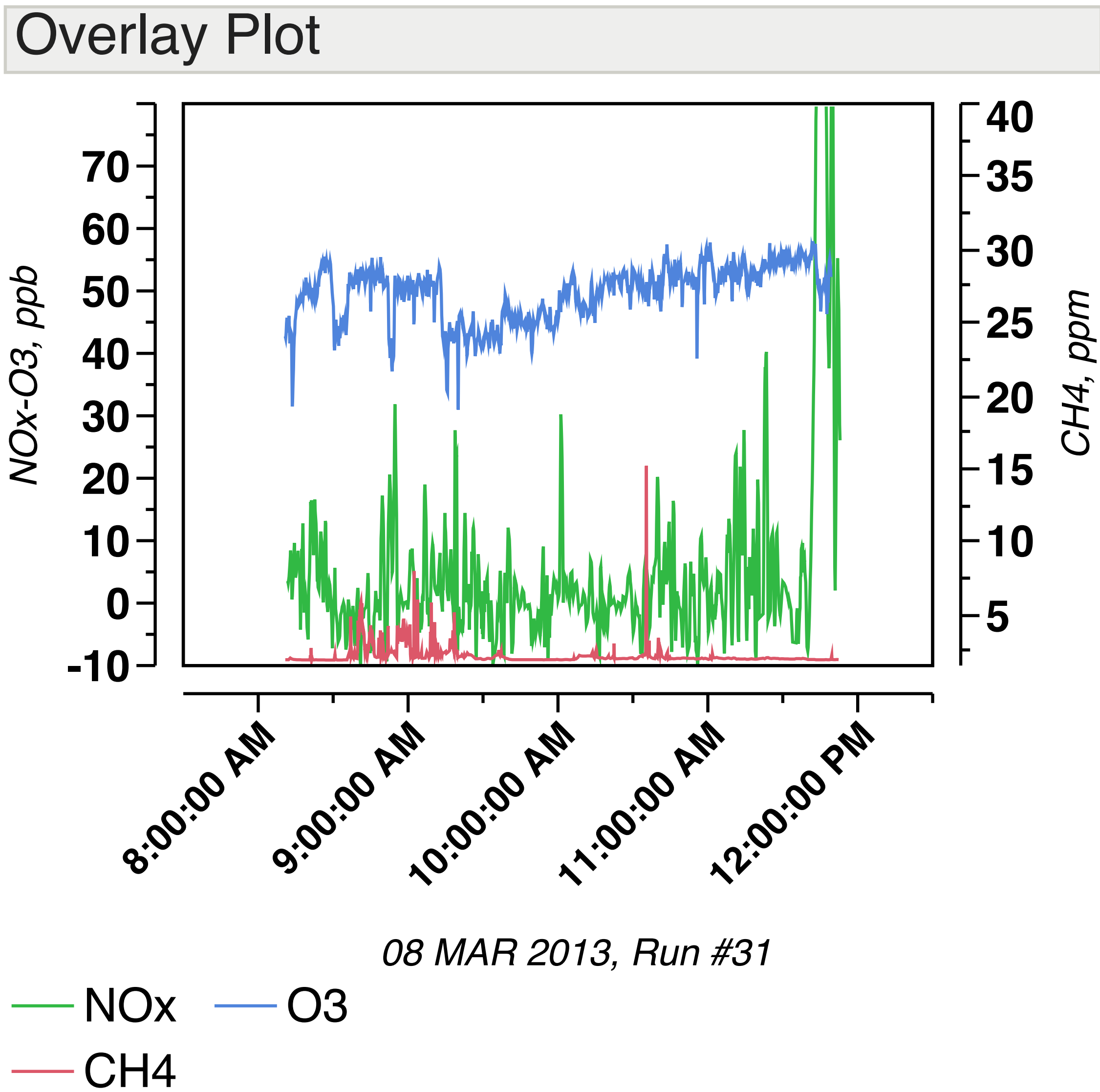


Figure 7.32. Circuit 32: 3/8/2013 AM

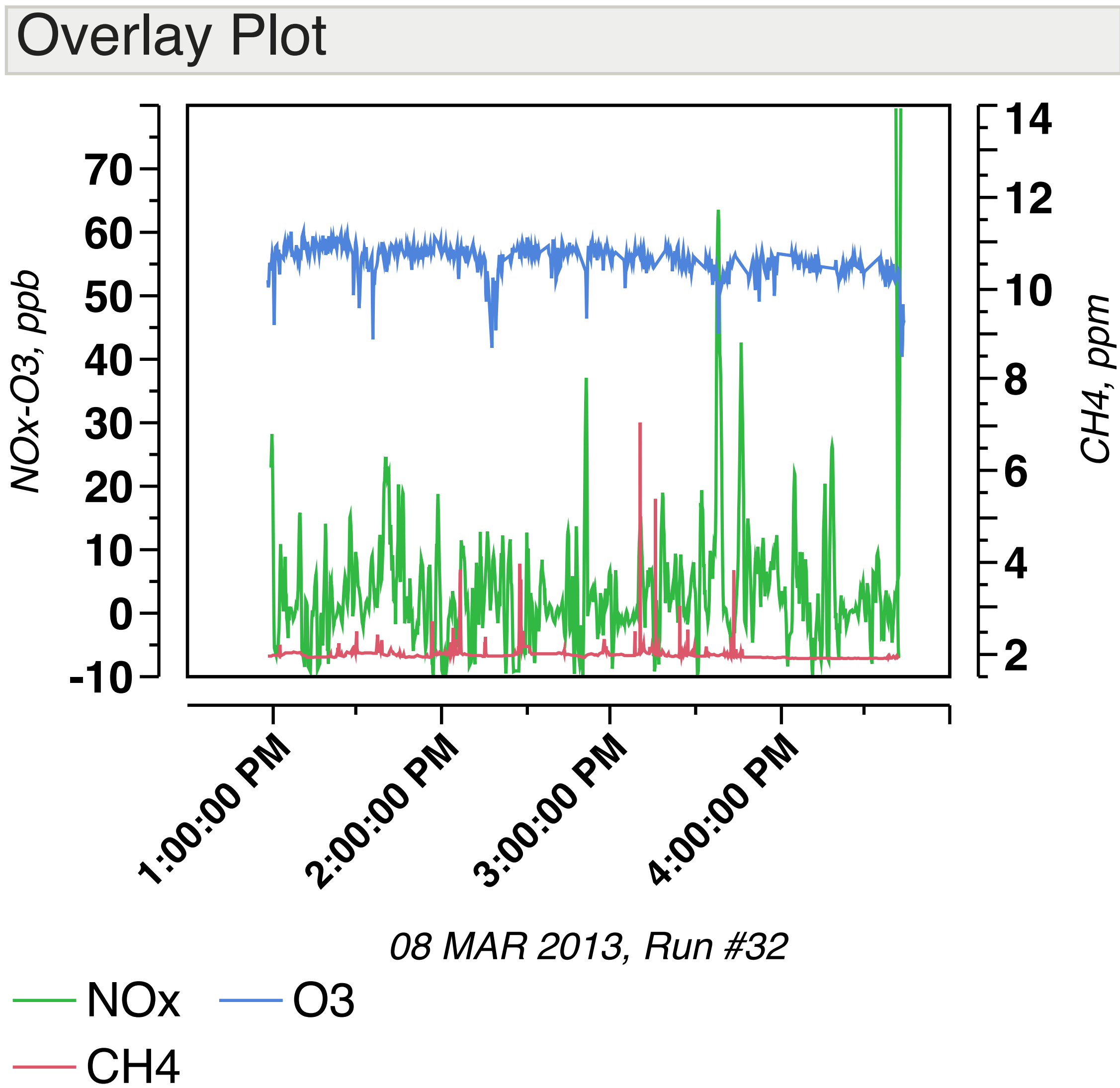


Table 7.34 provides a summary of the VOC reported for the eighty valid samples. Alaknes and aromatic compounds are the most significant in terms of mixing ratios. Table 7.34 presents basic statistics for all of the thirty-one VOC species monitored. Ethane and propane account for over 50% of the measured VOC as ppbv.

Table 7-34. VOC grab samples.

Group	Compound	Min ppbv	Max ppbv	Mean ppbv	Mean %
Alkane	ethane	1.0	485.1	37.6	38
Alkene	ethene	0.0	8.3	0.6	1
Alkane	propane	0.2	161.5	13.2	13
Alkene	propene	0.0	1.3	0.1	0
Alkane	i-butane	0.0	35.8	3.3	3
Alkane	n-butane	0.0	39.8	3.6	4
Alkyne	ethyne	0.0	84.1	1.7	2
Alkene	t-2-butene	0.0	0.1	0.0	0
Alkene	1-butene	0.0	0.3	0.0	0
Alkene	c-2-butene	0.0	0.0	0.0	0
Alkane	cyclopentane	0.0	5.9	0.3	0
Alkane	i-pentane	0.0	40.9	2.5	3
Alkane	n-pentane	0.0	35.4	2.1	2
Alkene	1,3-butadiene	0.0	0.2	0.0	0
Alkyne	propyne	0.0	0.0	0.0	0
Alkene	t-2-pentene	0.0	0.0	0.0	0
Alkene	1-pentene	0.0	0.0	0.0	0
Alkene	c-2-pentene	0.0	0.0	0.0	0
Alkane	2-methylpentane	0.0	36.3	1.5	2
Alkane	3-methylpentane	0.0	20.7	0.9	1
Alkane	n-hexane	0.0	53.3	2.3	2
Alkene	isoprene	0.0	0.0	0.0	0
Aromatic	benzene	0.1	112.3	4.6	5
Alkane	cyclohexane	0.0	59.9	2.9	3
Alkane	n-heptane	0.0	61.9	2.4	2
Aromatic	toluene	0.1	201.6	9.7	10
Alkane	n-octane	0.0	54.9	1.9	2
Aromatic	ethylbenzene	0.0	12.3	0.5	1
Aromatic	*m*+*p*-xylene	0.0	118.3	5.2	5
Aromatic	styrene	0.0	3.5	0.2	0
Aromatic	*o*-xylene	0.0	18.3	0.8	1

Table 7.35 provides a summary of the VOC reported at different measurement locations where sampling was performed three or more times.

Table 7-35. Selected VOC at different selected locations.

Location	Compound	n	Mean ppbv	Max ppbv
Hennick	ethane	9	2.7	7.1
Hennick	toluene	9	0.2	0.7
Mesa North	ethane	16	38.3	148.4
Mesa North	toluene	16	15.9	162.2
Boulder Crest	ethane	14	41.3	312.7
Boulder Crest	toluene	14	7.2	51.8
DEQ Boulder	ethane	16	14.5	67.7
DEQ Boulder	toluene	16	0.9	3.1
Anticline Disposal	ethane	9	17.1	62.7
Anticline Disposal	toluene	9	18.5	87.9
Mesa South Loop	ethane	4	69.4	179.4
Mesa South Loop	toluene	4	53.1	201.6
Middle Crest	ethane	3	312.2	485.1
Middle Crest	toluene	3	8.0	11.3
Pinedale Complex	ethane	3	39.6	55.5
Pinedale Complex	toluene	3	0.8	1.1

Table 7.35 reveals important differences between sites for ethane and toluene behavior. These differences may reflect the relative influence of different emission sources at these sites. Hennick is the upwind site relatively uninfluenced by emissions and this is shown by the low reported concentrations for both ethane and toluene. Mesa North is in an area influenced by both production and drilling activities, with elevated ethane and toluene. The nearby Mesa South Loop sampling was undertaken downwind of flow back operations and the pollutant behavior at site is similar to Mesa North. By contrast the Middle Crest sampling was downwind of drilling operations and shows elevated ethane, not toluene. The Pinedale complex sampling was close to large compression operations and shows elevated ethane, but not toluene. The Anticline Disposal sampling was downwind of water treatment ponds and toluene is elevated. The Boulder Crest site was downwind of drilling rigs and the Anticline Disposal and showed elevation of ethane and toluene. By contrast the lower mixing ratios at DEQ Boulder are reflective of being downwind of well-mixed emissions.

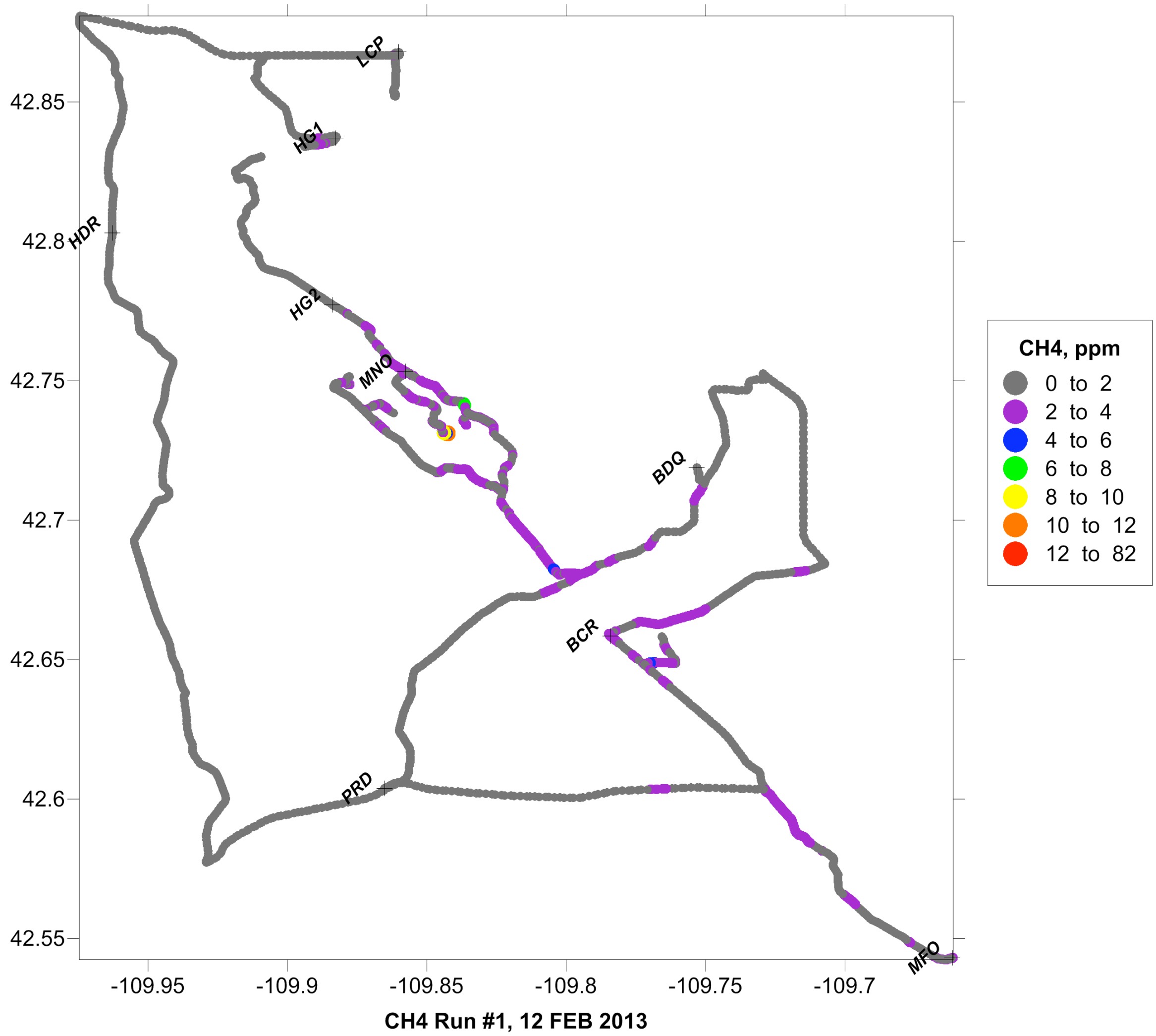
8.0 CONCLUSIONS

For the two-month duration of the study, the following conclusions may be drawn from the basic summary data:

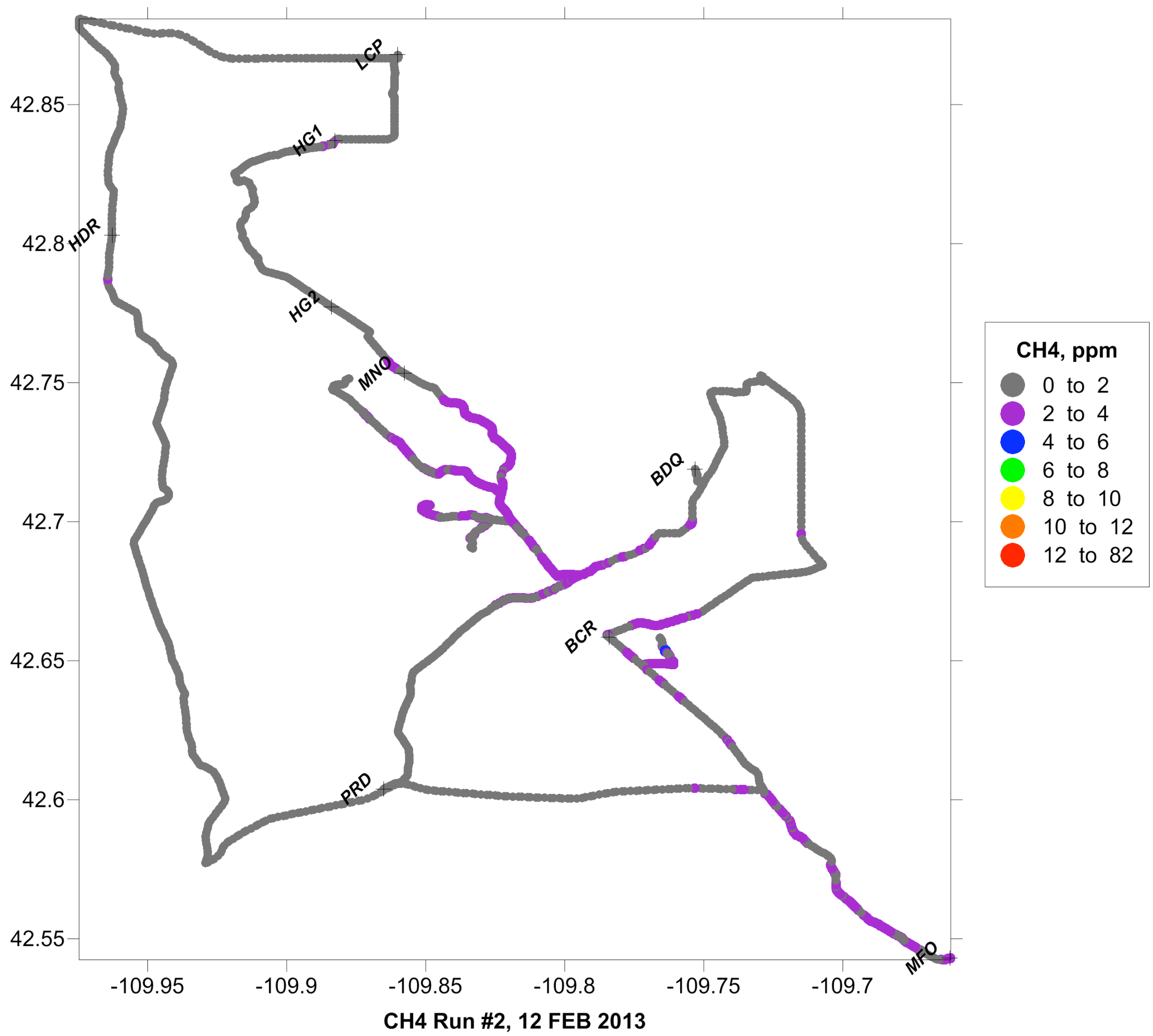
- The mobile monitoring circuits completed data objective for methane was exceeded; 100% actual vs. 90% target.
- The mobile monitoring circuit completeness data objective for methane was exceeded; 94% actual vs. 75% target.
- The mobile monitoring circuits completed data objective for oxides of nitrogen was exceeded; 100% actual vs. 90% target.
- The mobile monitoring circuit completeness data objective for oxides of nitrogen was exceeded; 100% actual vs. 75% target.
- The mobile monitoring circuits completed data objective for ozone was exceeded; 91% actual vs. 90% target.
- The mobile monitoring circuit completeness data objective for ozone was exceeded; 84% actual vs. 75% target.
- The VOC grab sampling data objective was exceeded; 99% actual vs. 75% target.
- Instrumentation performed according to expectations with the exception of the oxides of nitrogen instrument. During static operation the zero value shifted from -10 ppb to +10 ppb. During mobile operation aberrant negative spiking was evident and removed during data validation.
- Overlay plots show the value of simultaneous measurements with different behavior clearly visible for the three measured pollutants.
- Overlay plots reveal significant day-to-day and intra day variation that indicates the influence of meteorological conditions for pollutant accumulation and dispersion.
- For methane a large number of emission plumes were encountered in the study area, in particular with the spine of the Pinedale Anticline Development Area.
- For oxides of nitrogen concentrations were generally low and the most significant elevations above background were associated with nearby traffic sources.
- For ozone concentrations were low and no significant ozone episodes were encountered.
- Spatial pollution maps for the three pollutants show that the methodology has utility for understanding pollutant behavior and pollutant distributions for modeling.
- VOC sampling revealed considerable variation in VOC concentration and distributions between selected sites.
- Alkenes were often below the method detection limit.
- Alkanes were the dominant class, lower molecular species were highly correlated with methane, indicating the importance of natural gas emission sources.
- Aromatics were significant and showed variation linked to different emission sources with BTEX elevation associated with specific locations.
- VOC samples indicated the influence of drilling, completion (flow back), production and water treatment activities.

APPENDIX 1: Mobile methane maps

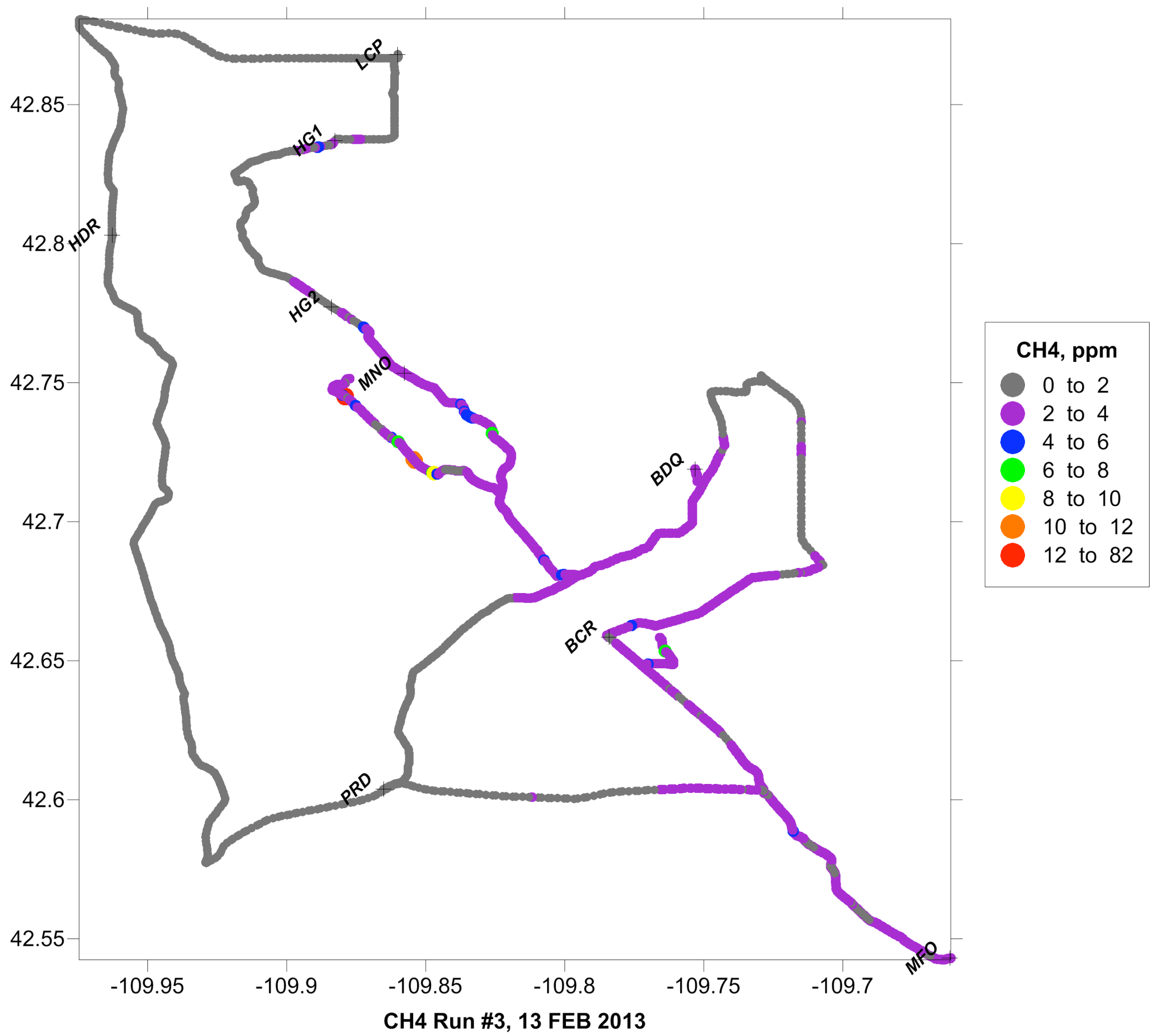
Circuit 1: 2/12/2013 AM



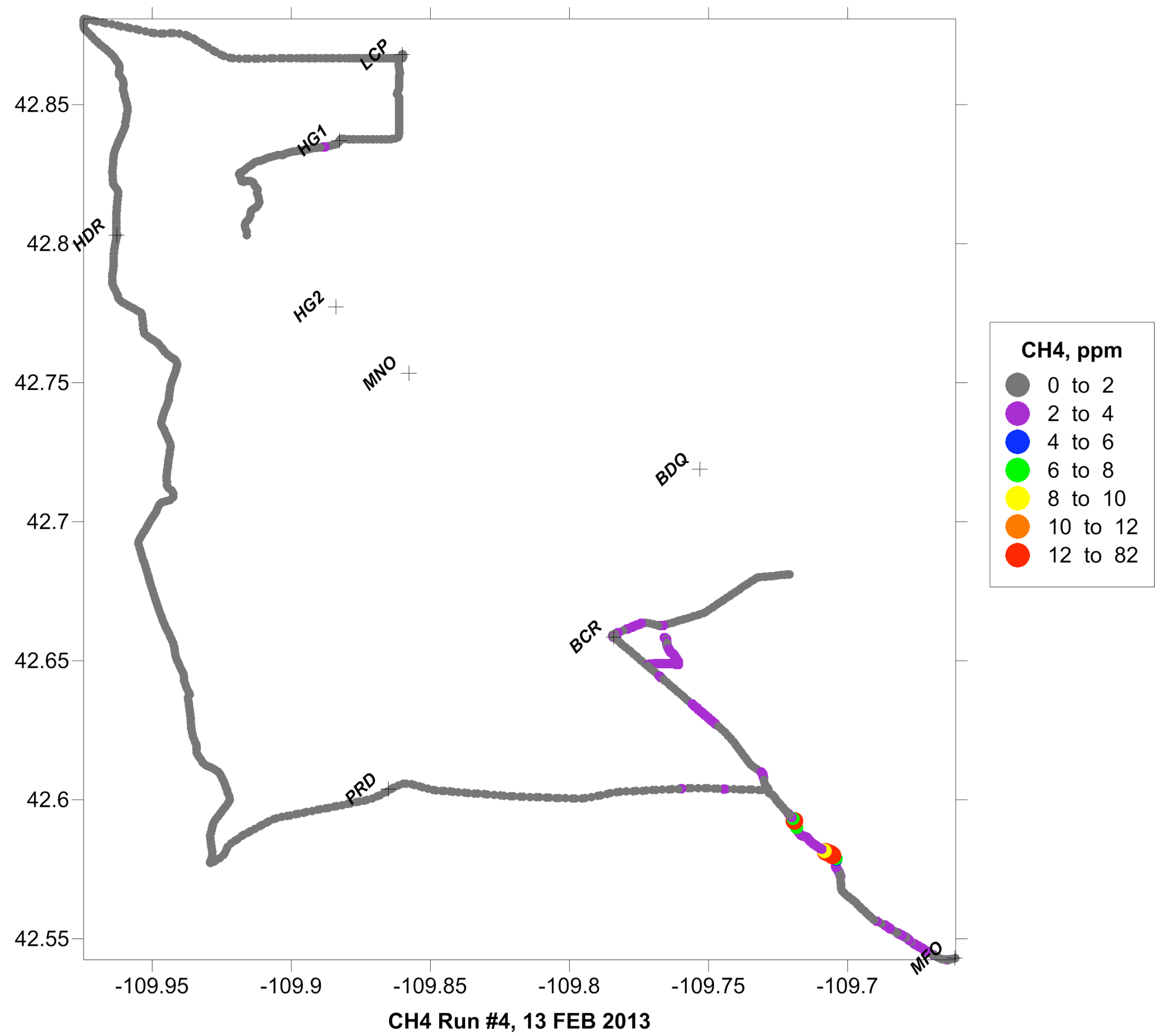
Circuit 2: 2/12/2013 PM



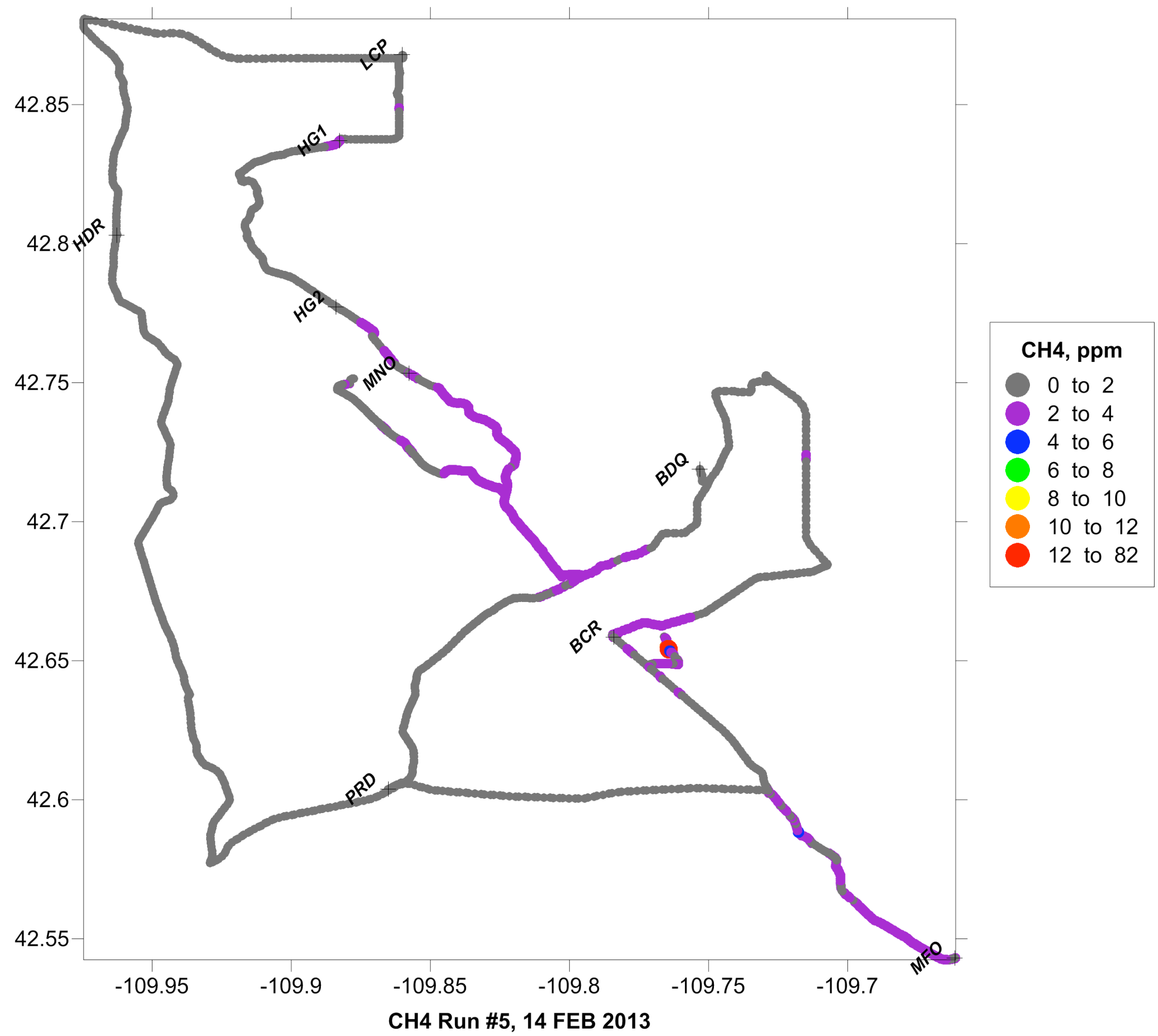
Circuit 3: 2/13/2013 AM



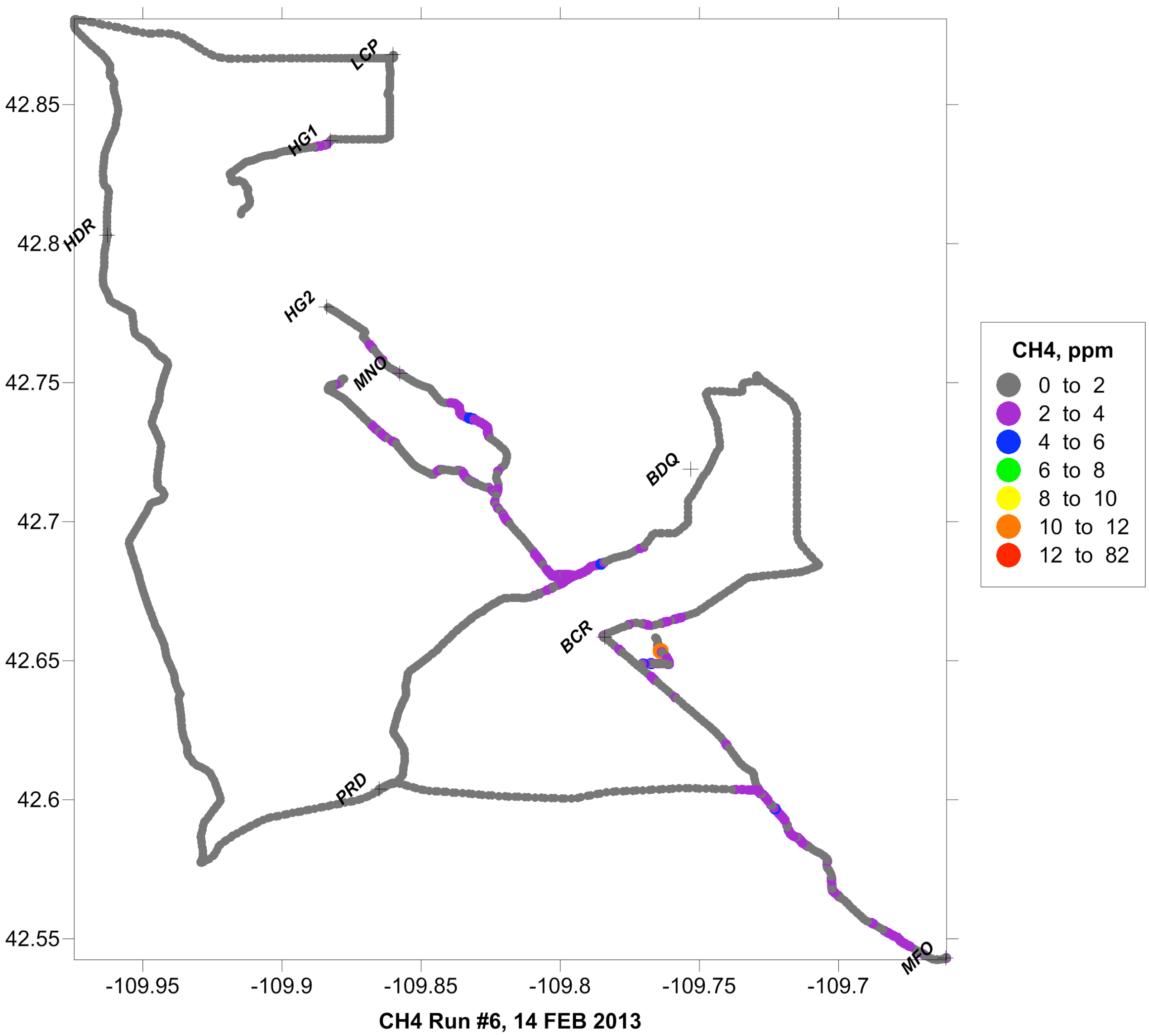
Circuit 4: 2/13/2013 PM



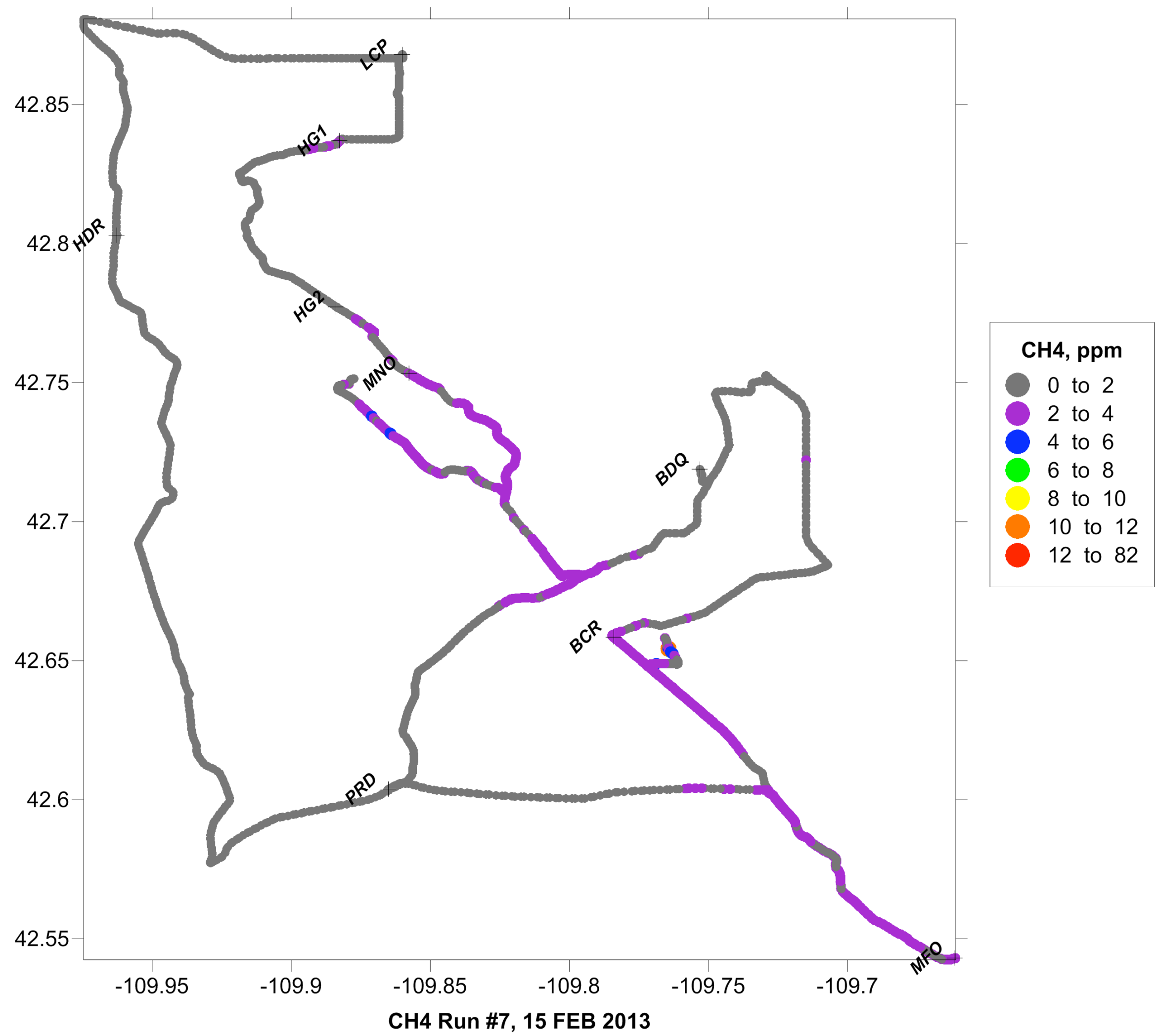
Circuit 5: 2/14/2013 AM



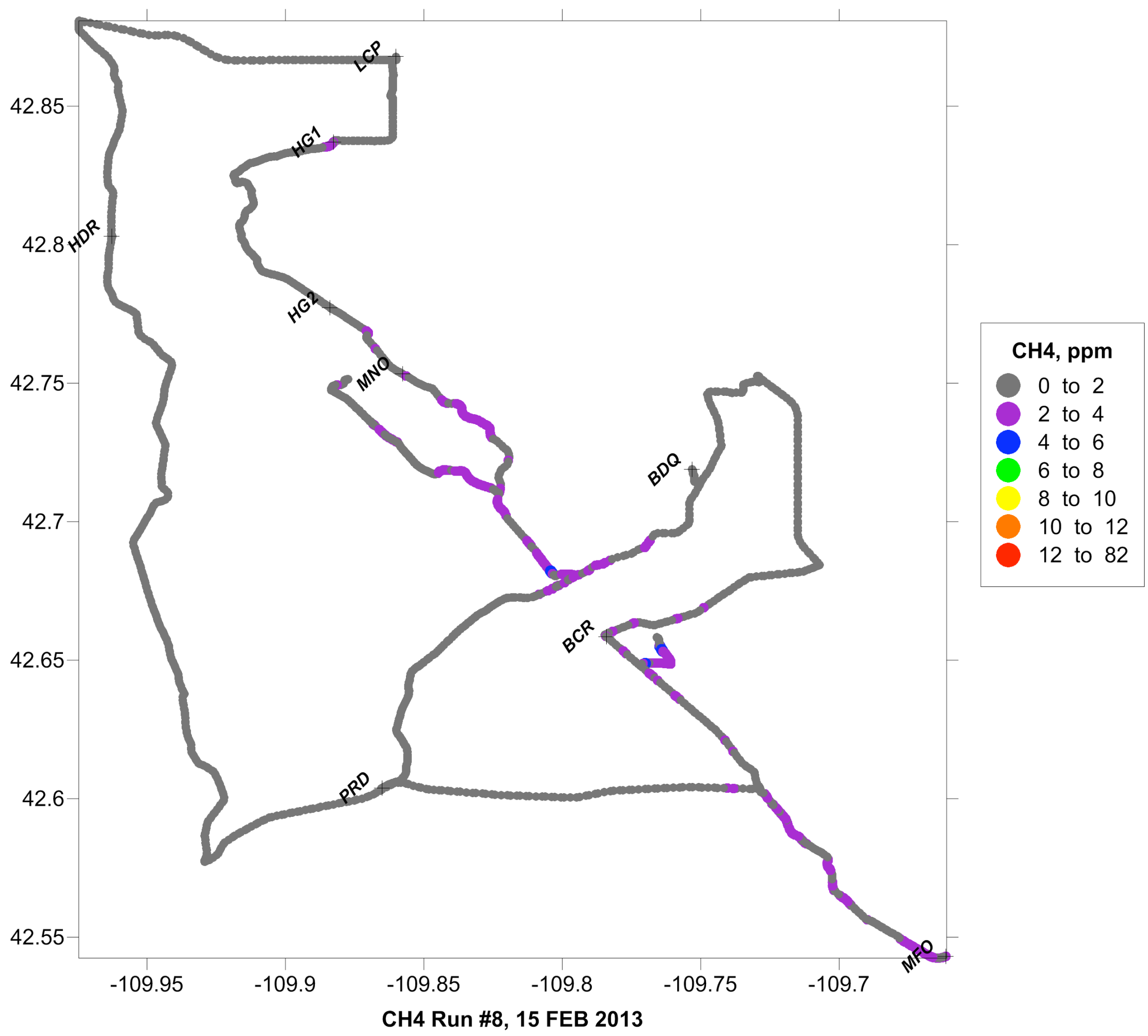
Circuit 6: 2/14/2013 PM



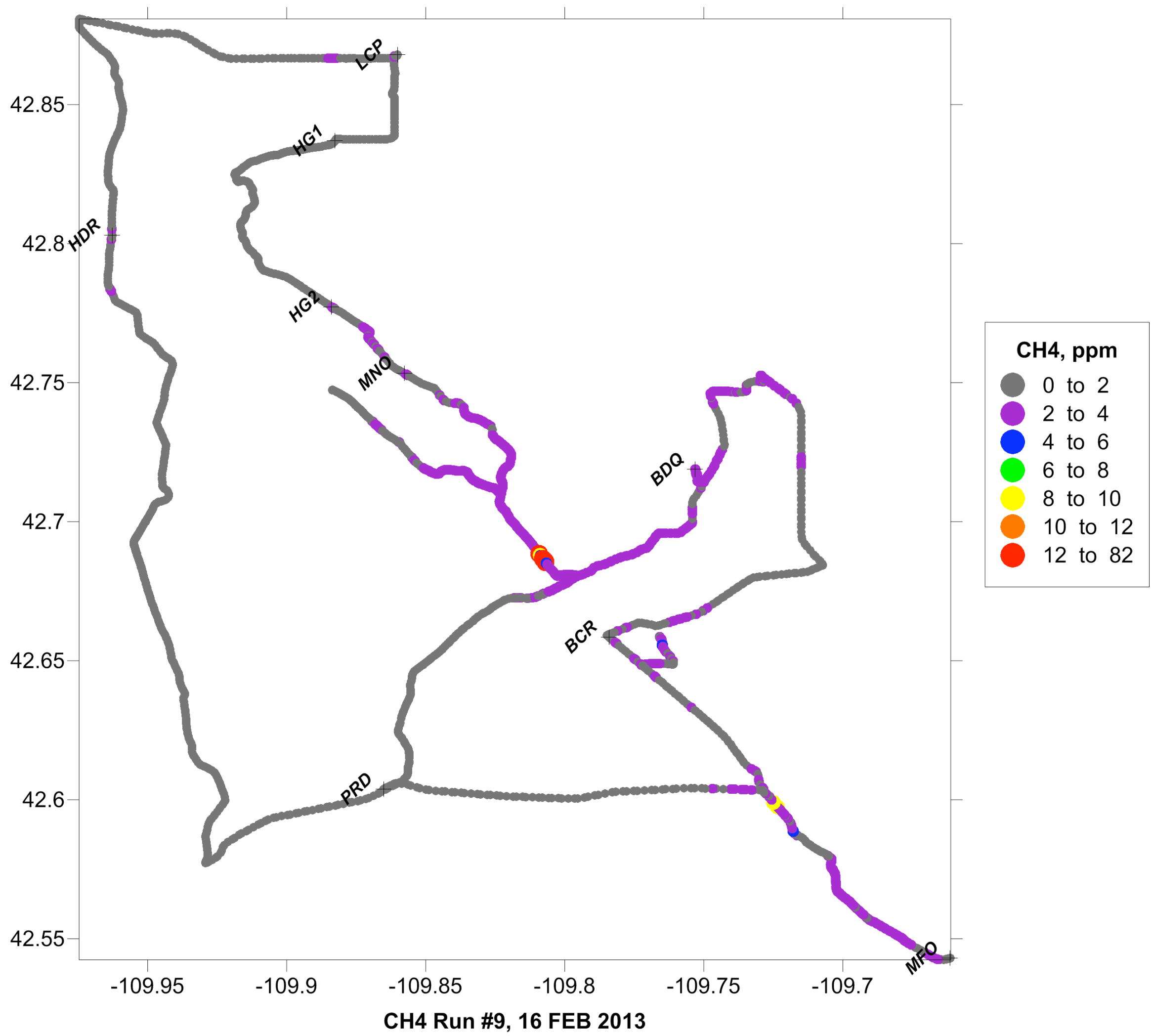
Circuit 7: 2/15/2013 AM



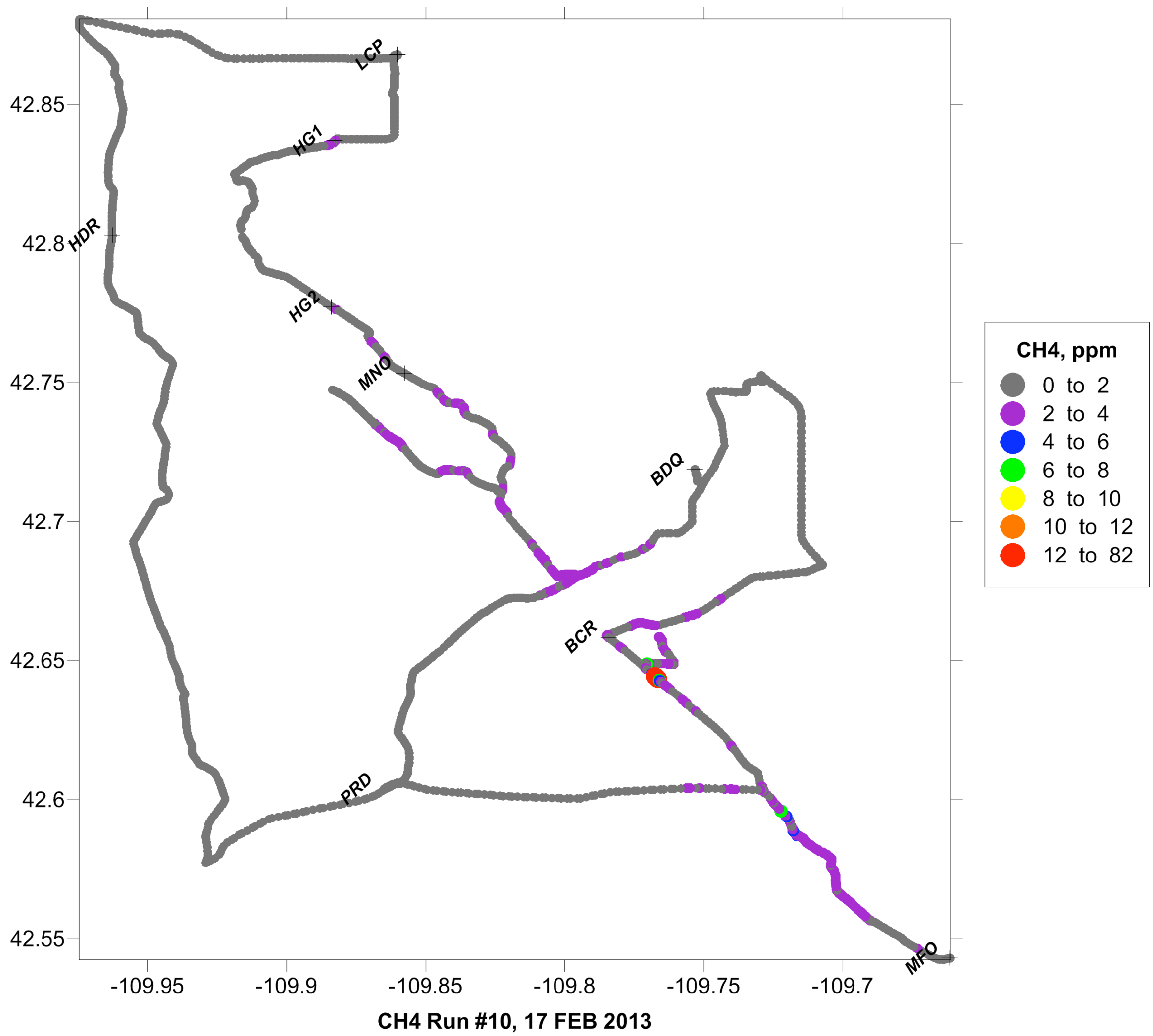
Circuit 8: 2/15/2013 PM



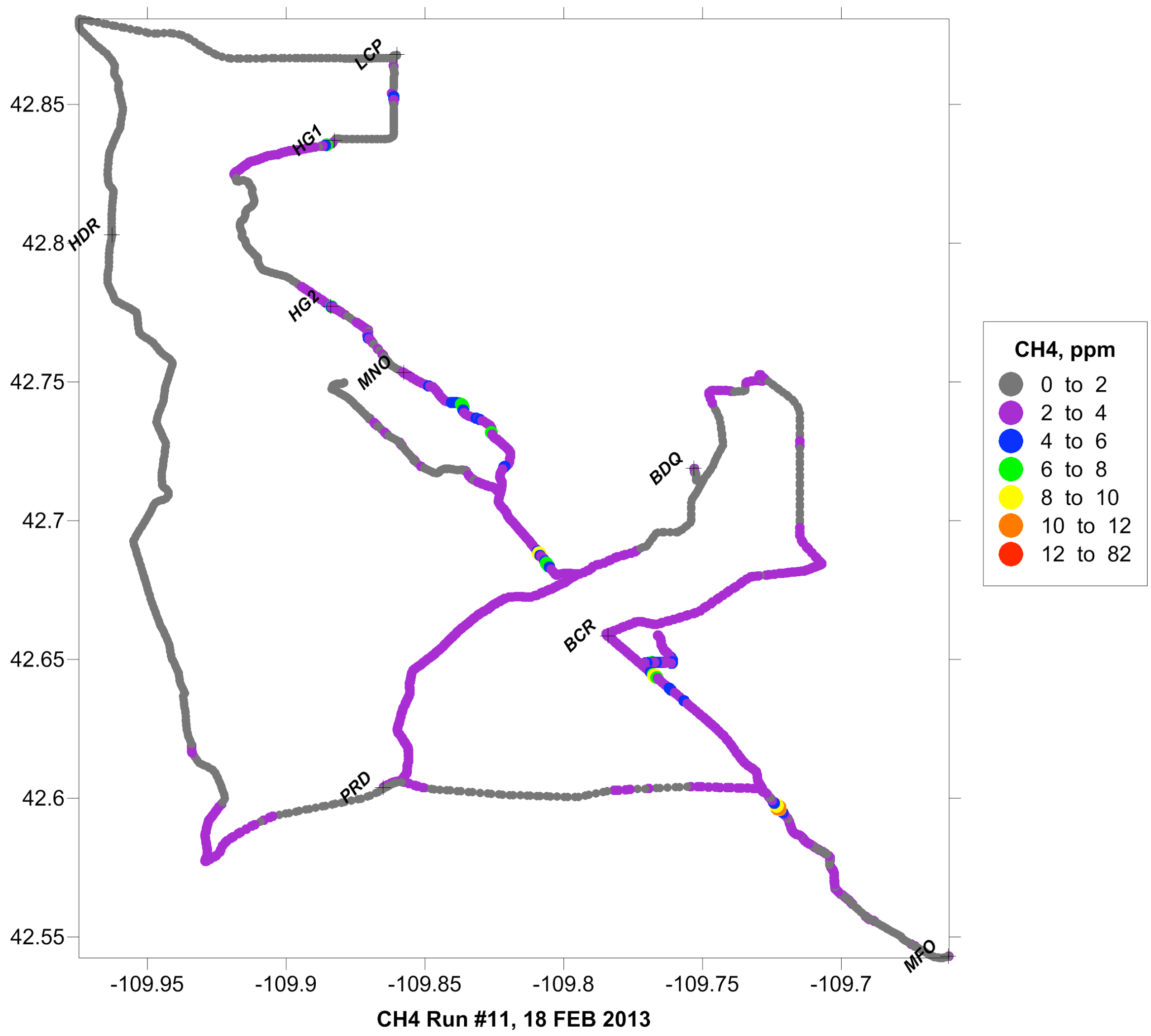
Circuit 9: 2/16/2013 PM



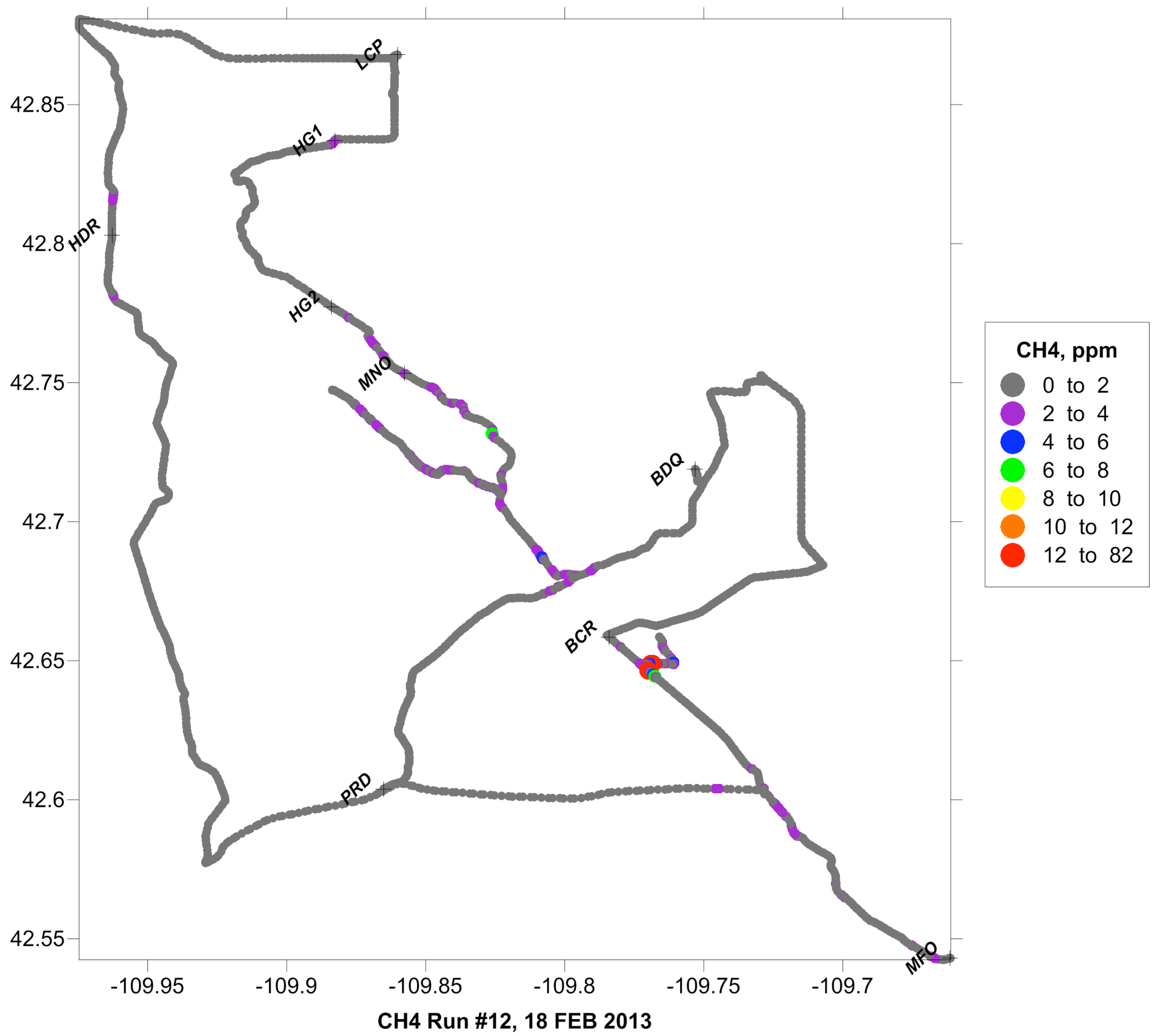
Circuit 10: 2/17/2013 PM



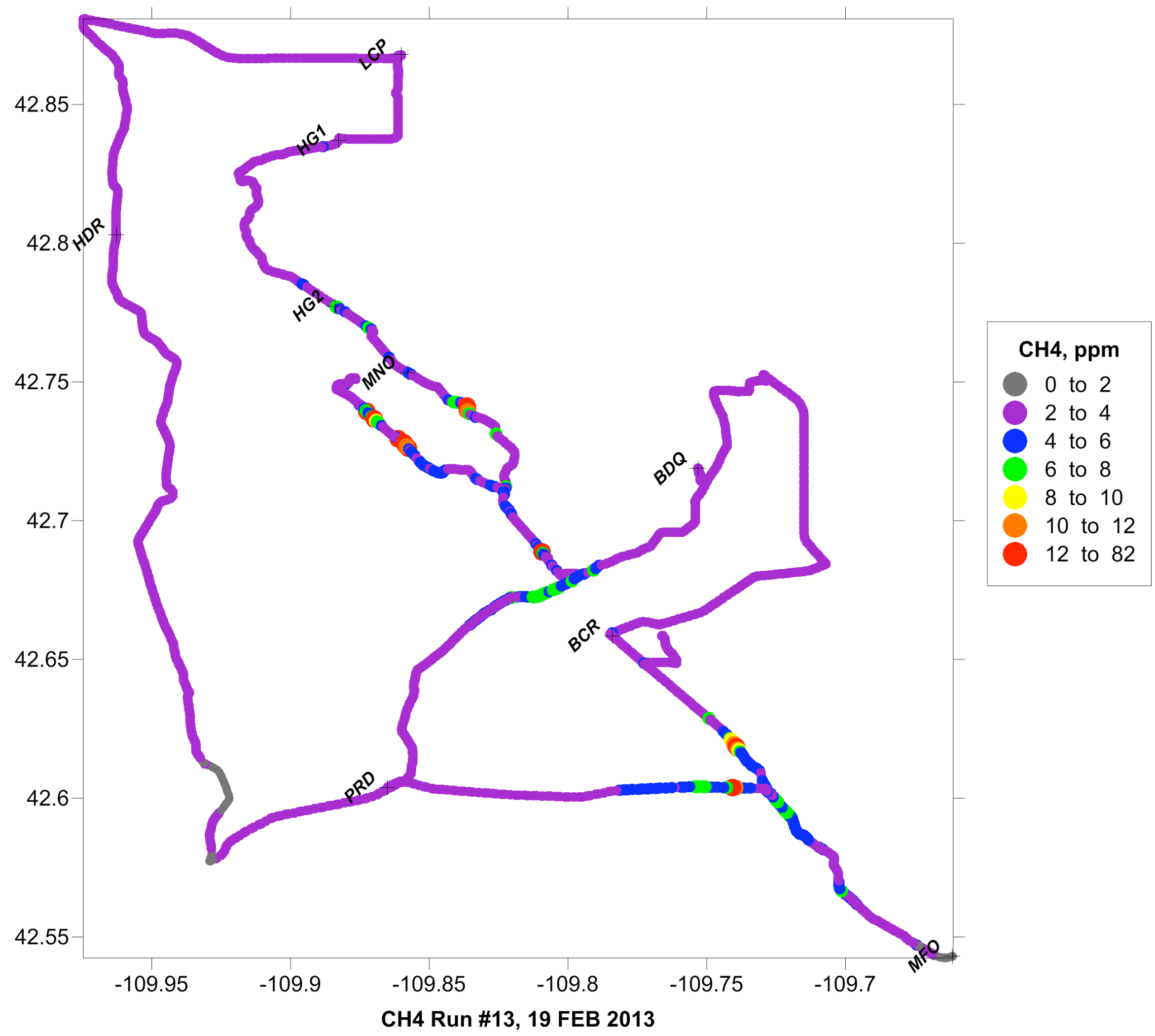
Circuit 11: 2/18/2013 AM



Circuit 12: 2/18/2013 PM



Circuit 13: 2/19/2013 EV



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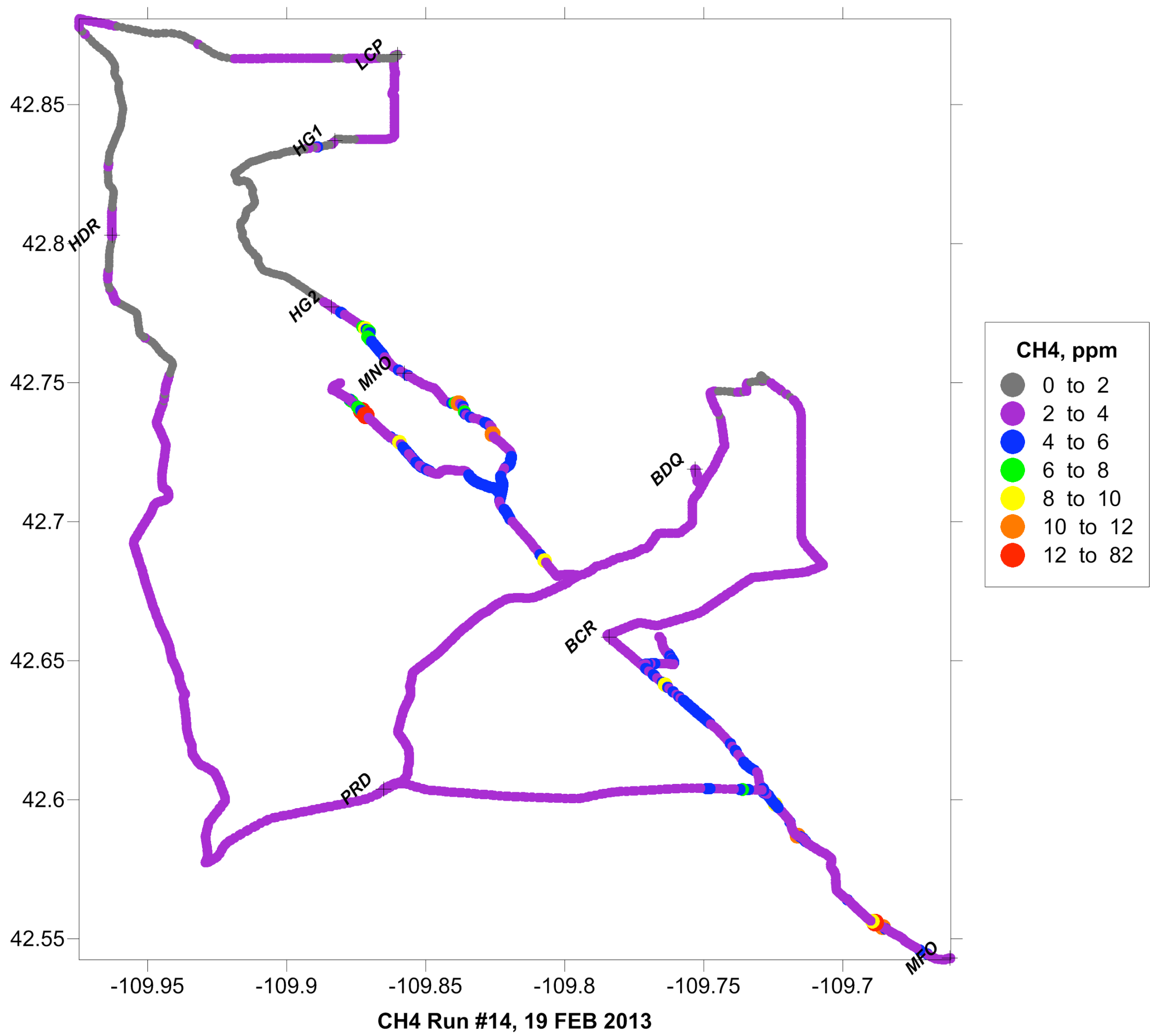

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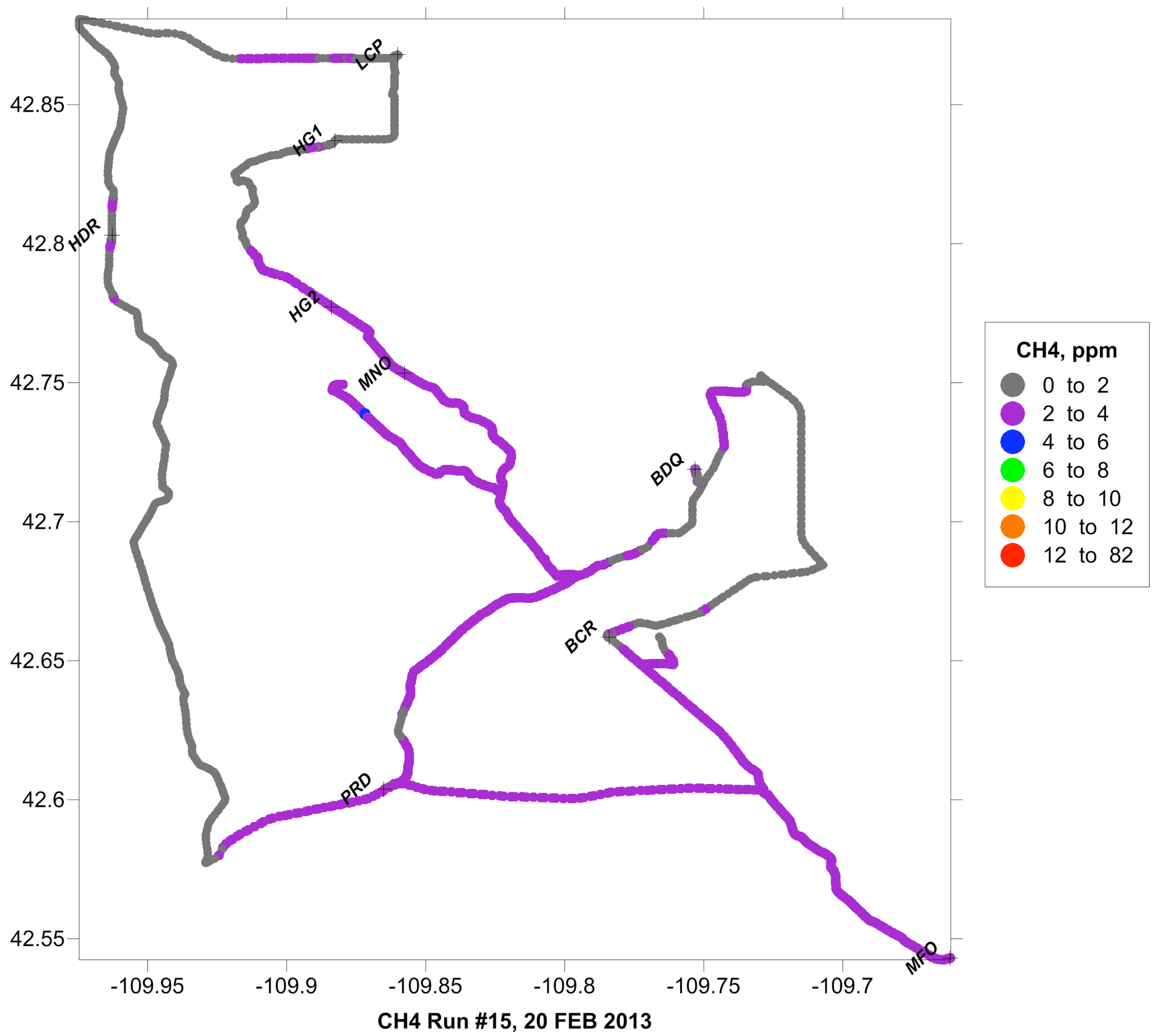

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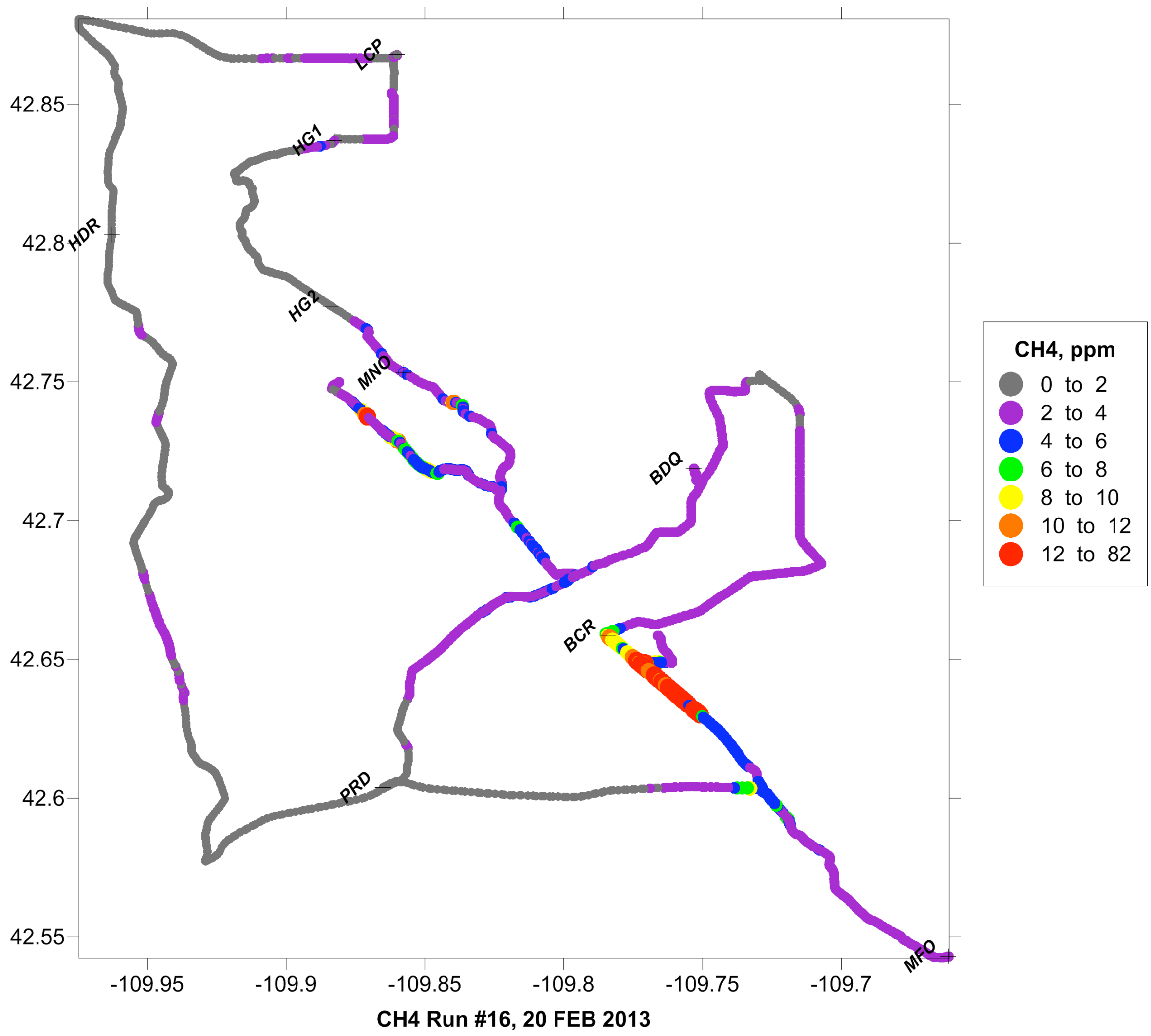

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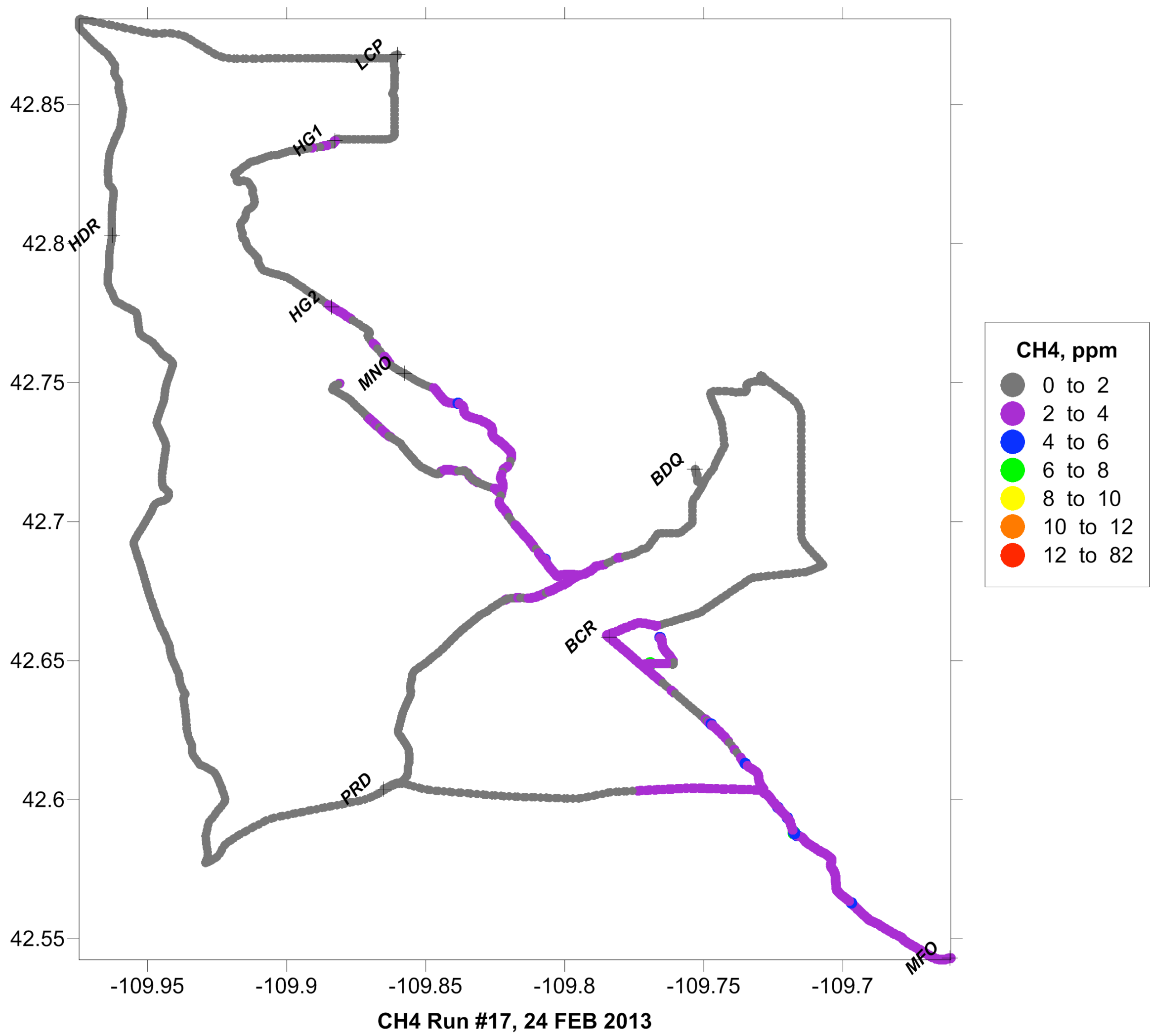
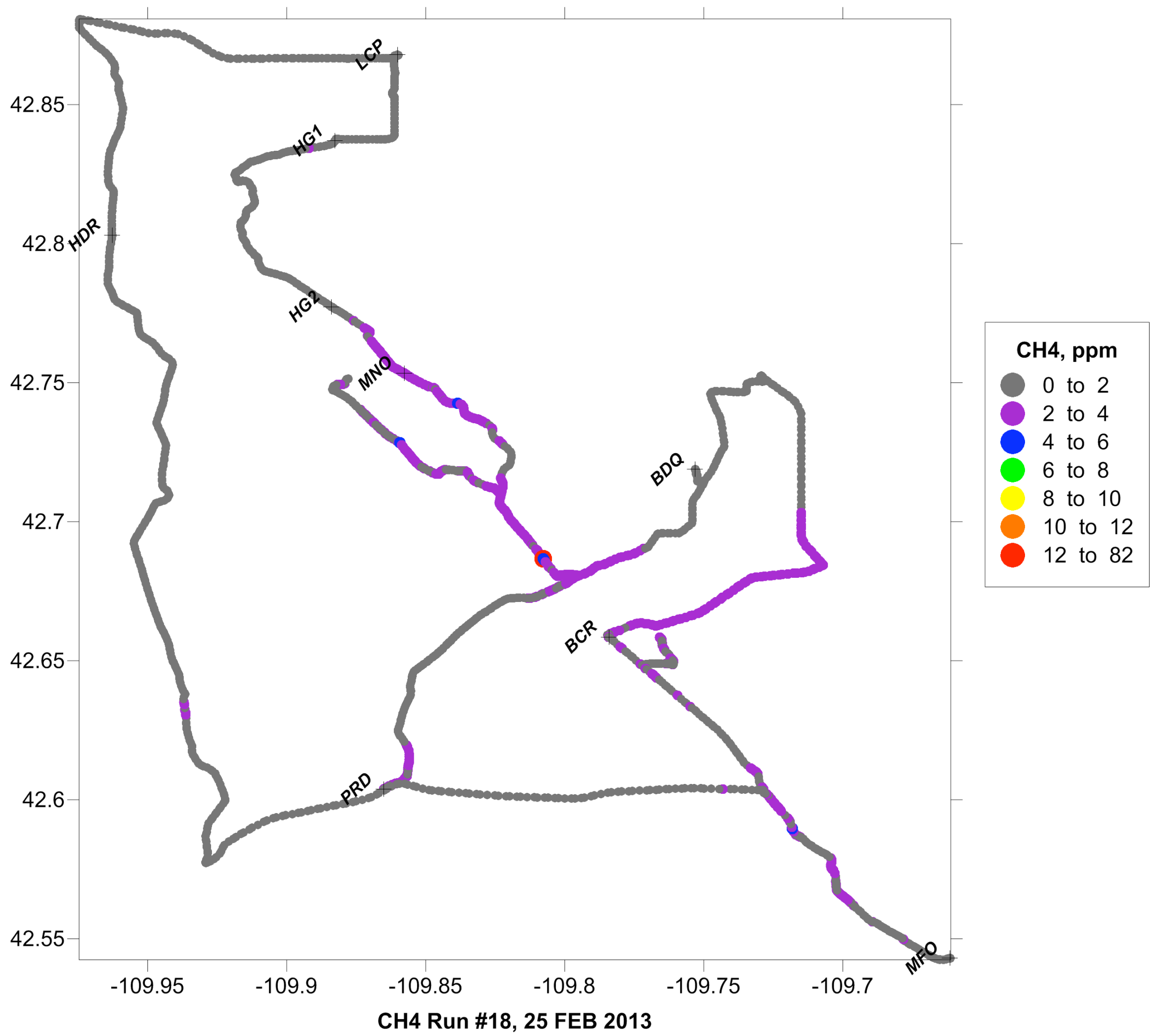
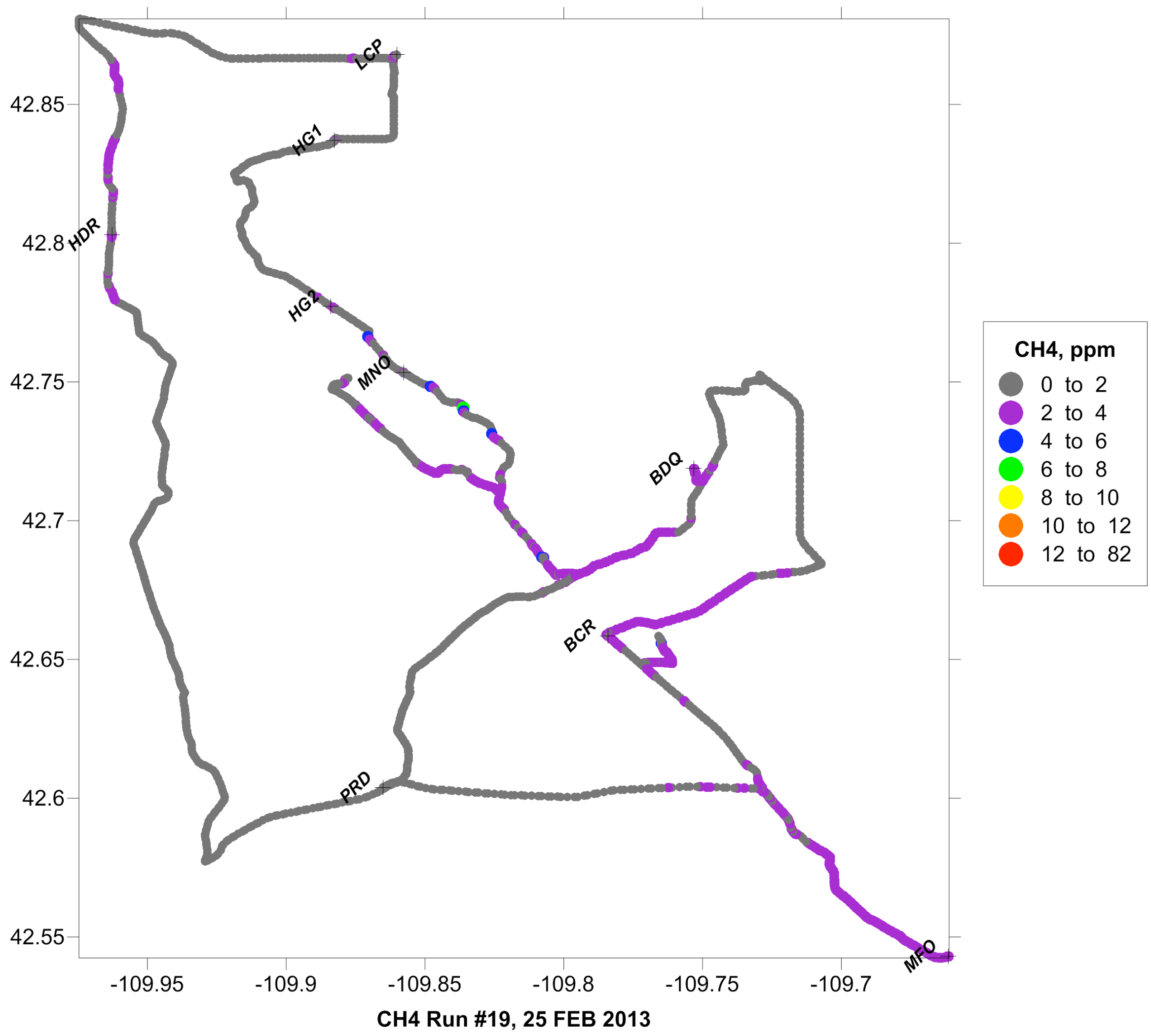


Circuit 18: 2/25/2013 AM



Circuit 19: 2/25/2013 PM



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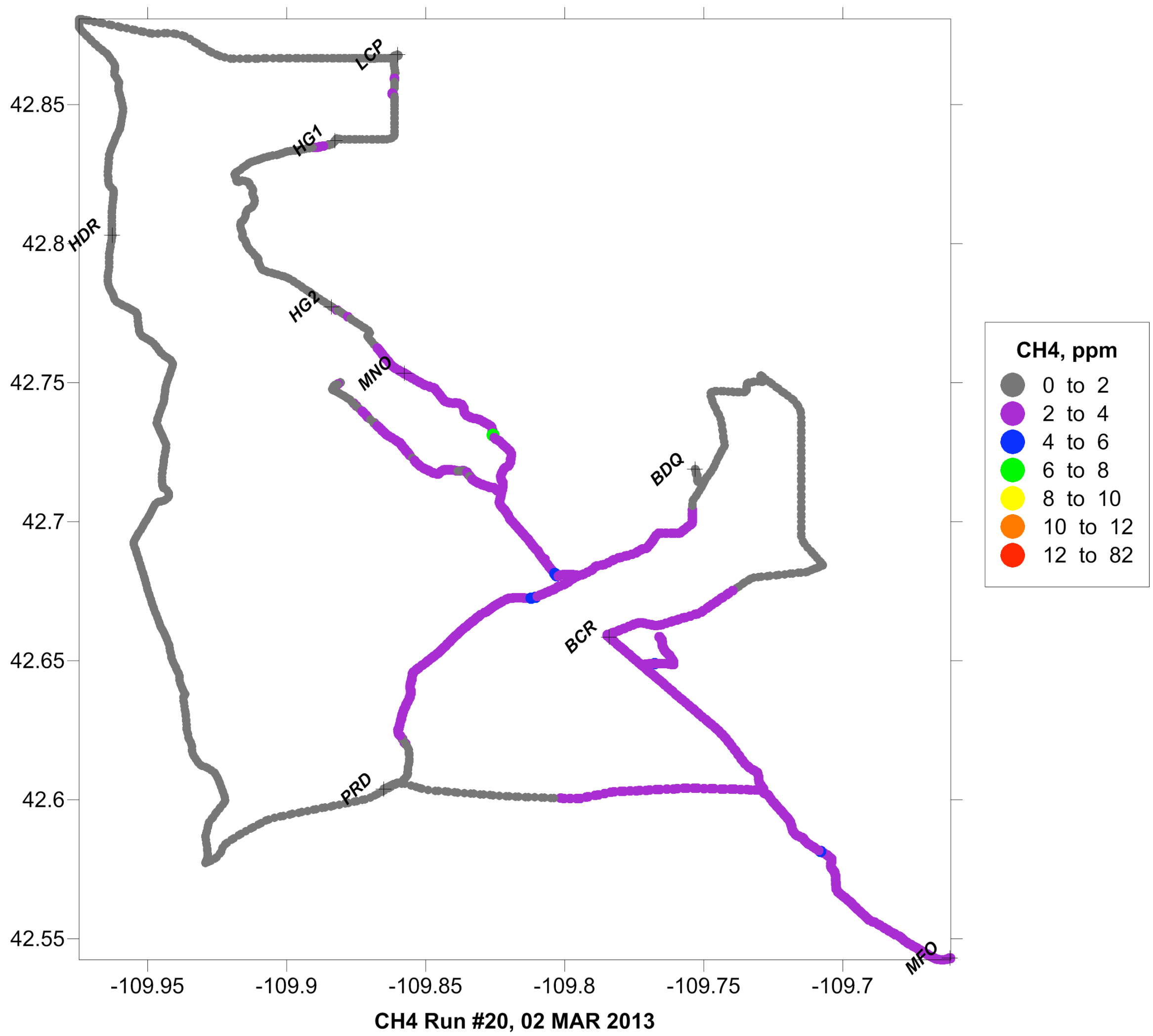

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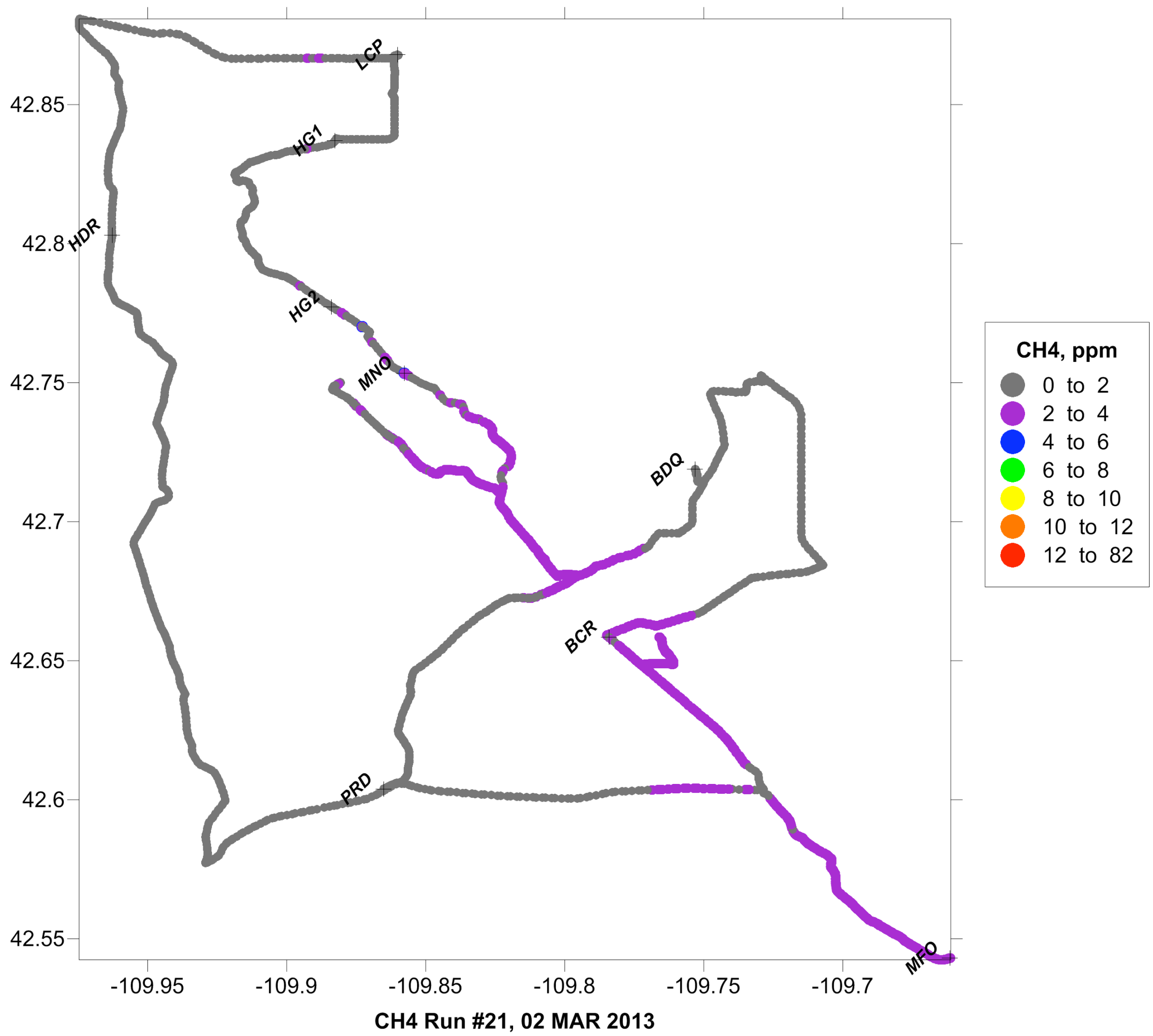

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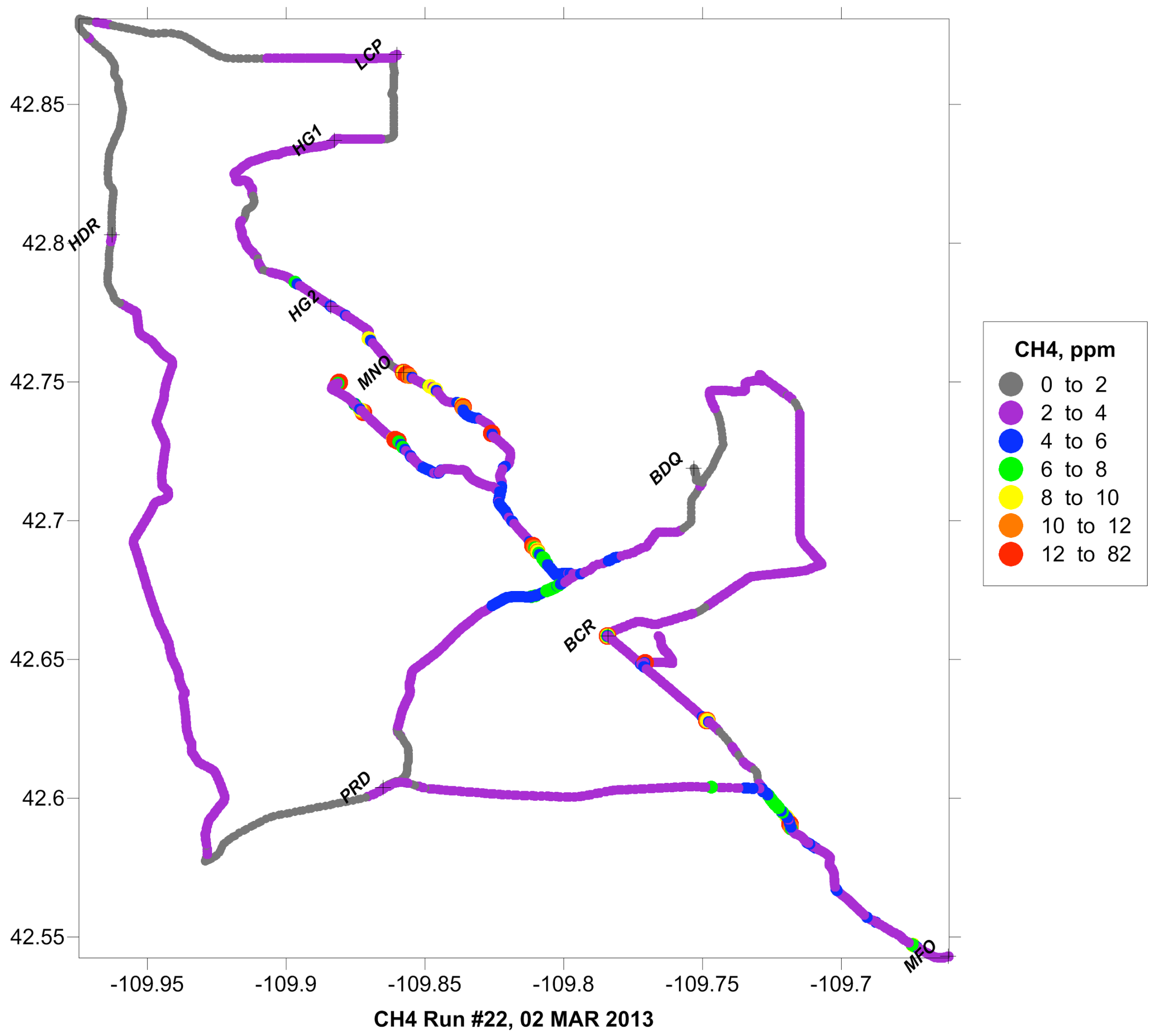
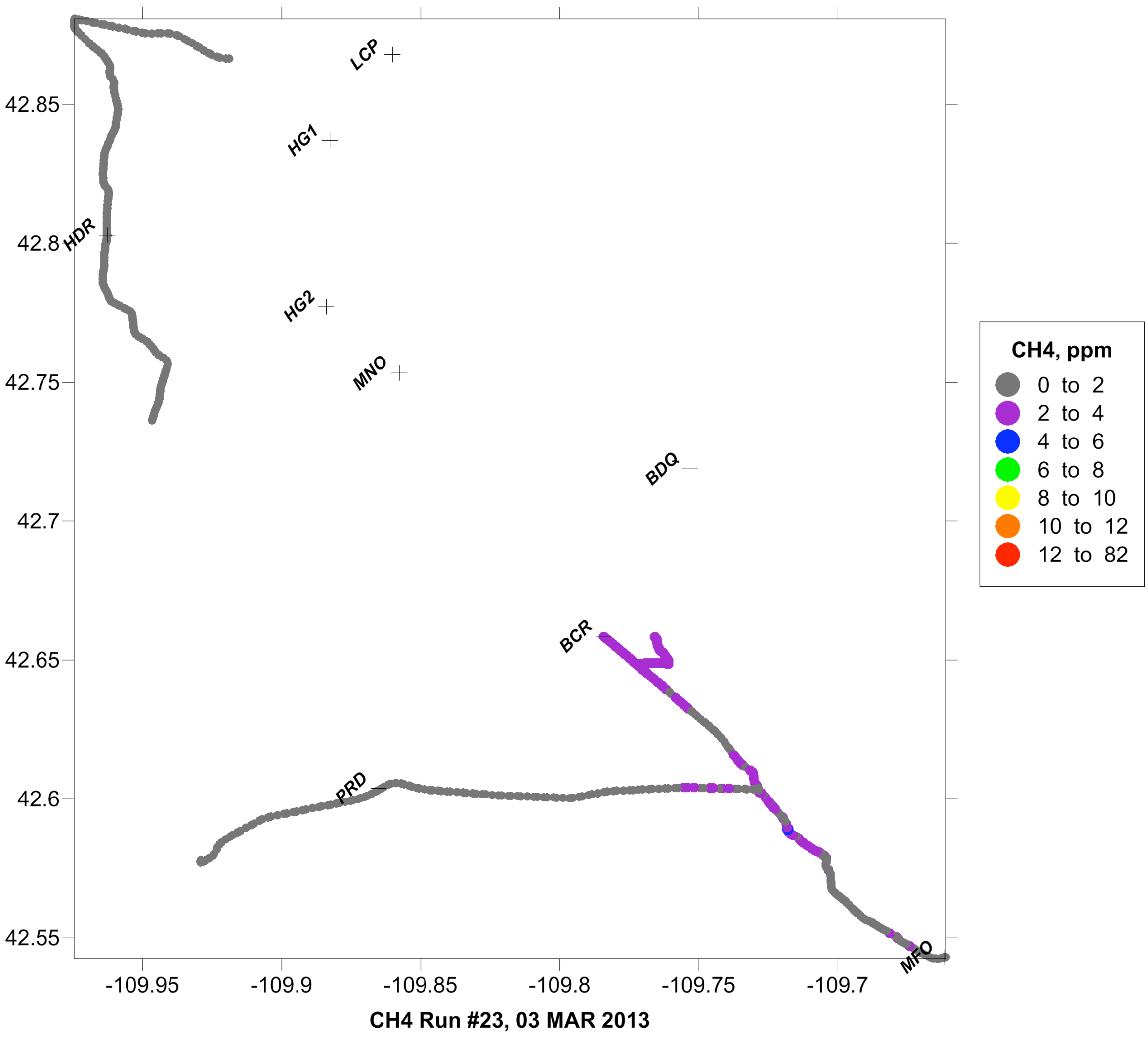


Circuit 23: 3/3/2013 AM



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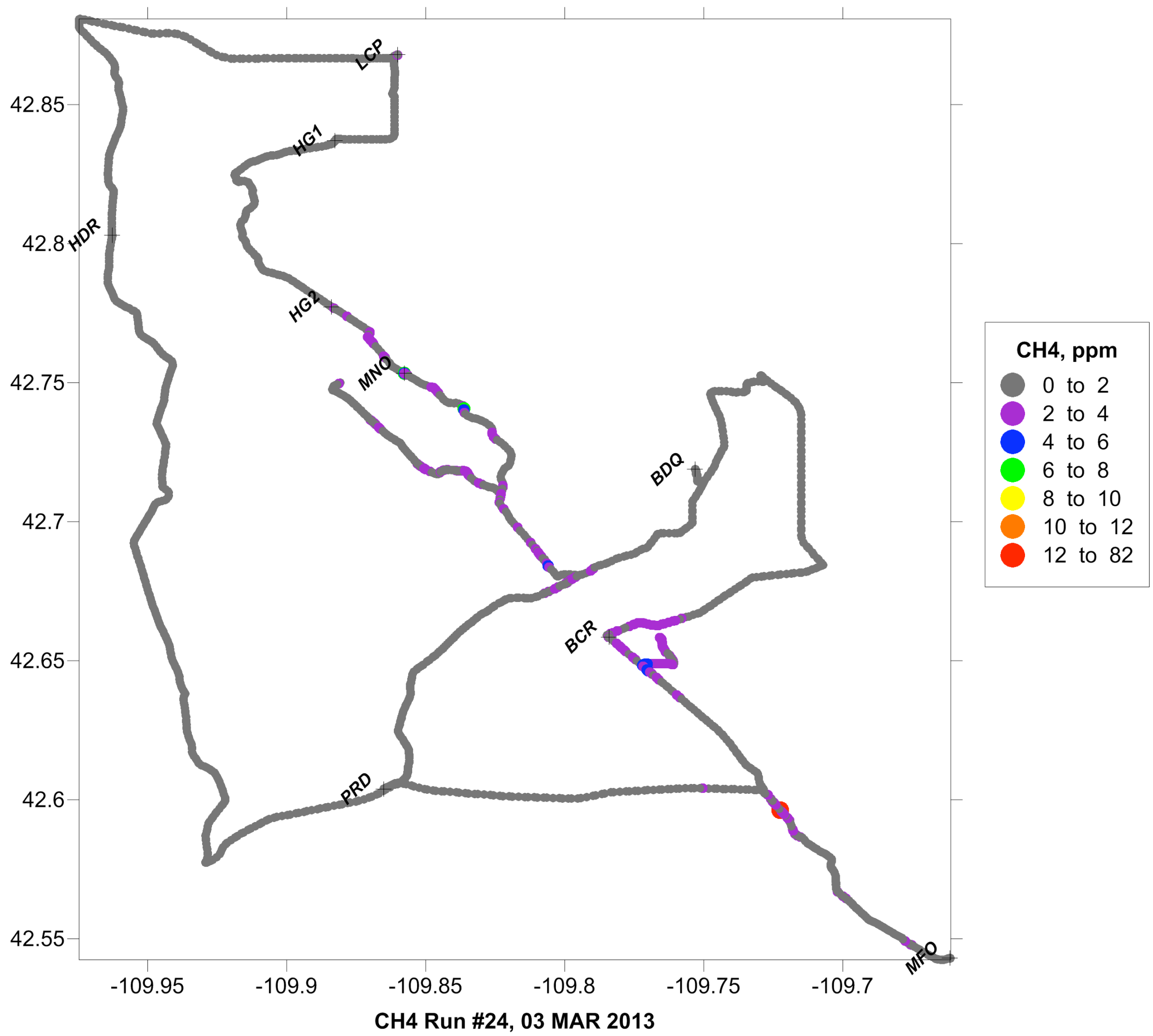

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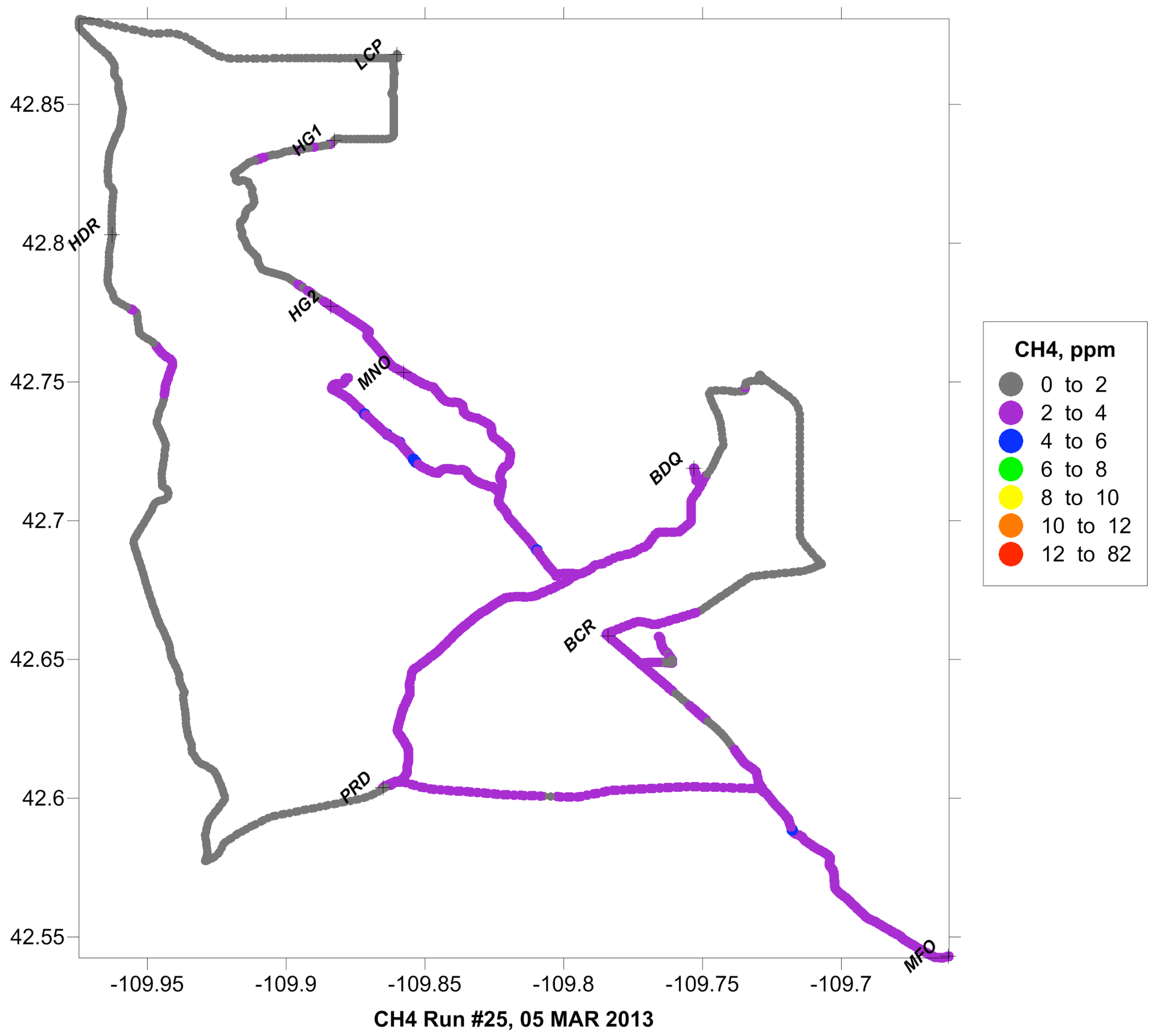

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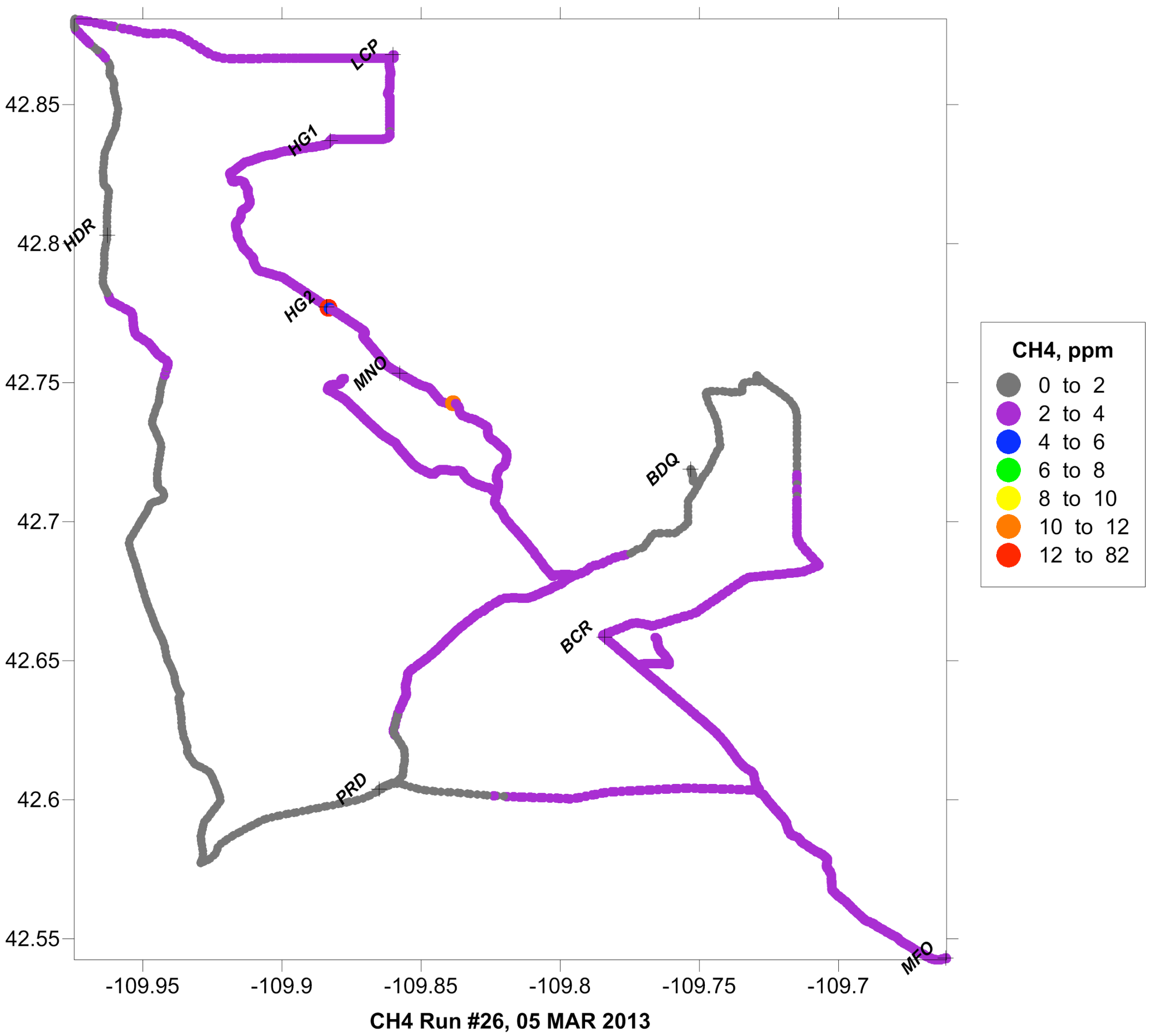
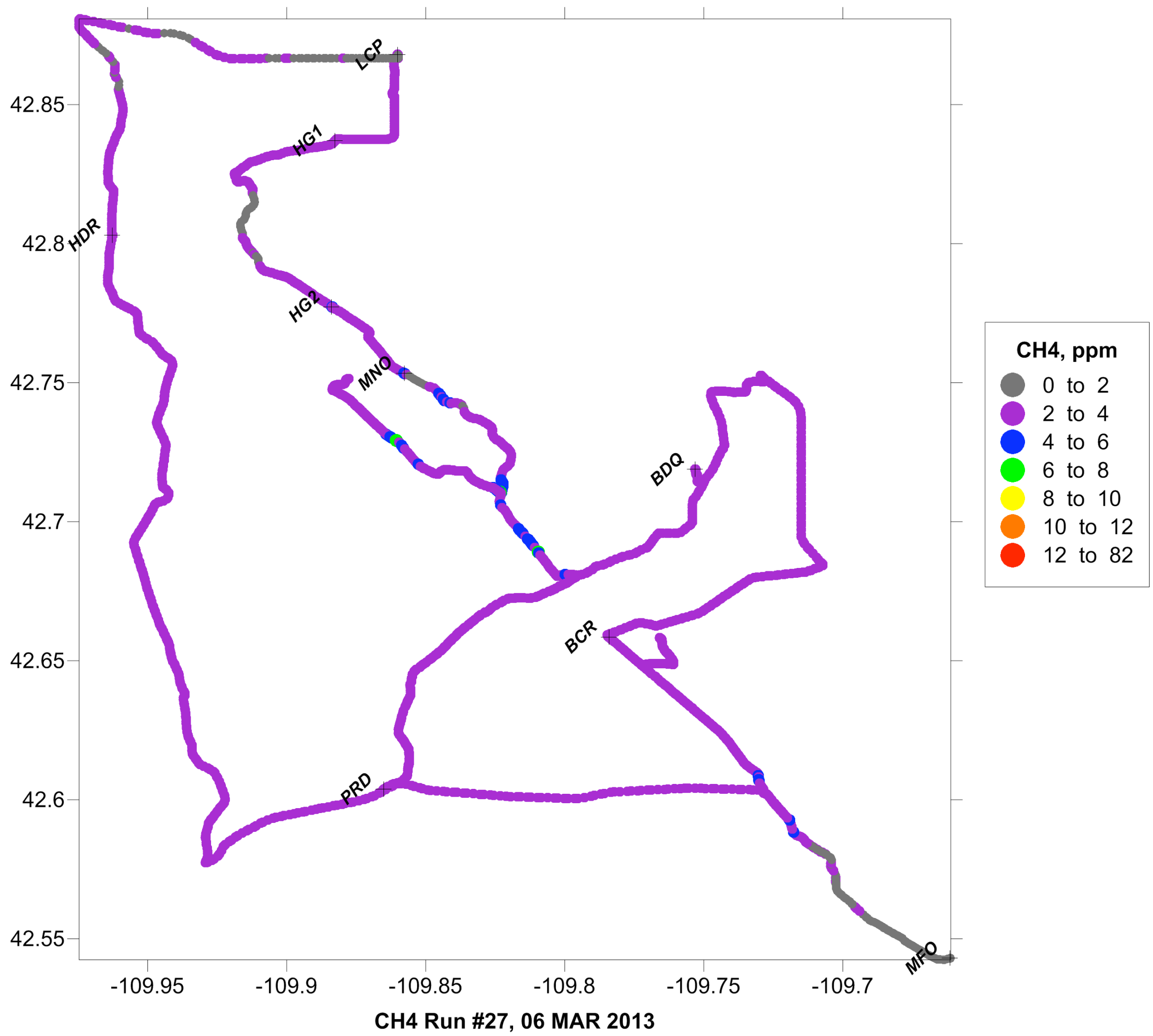


Circuit 27: 3/6/2013 AM



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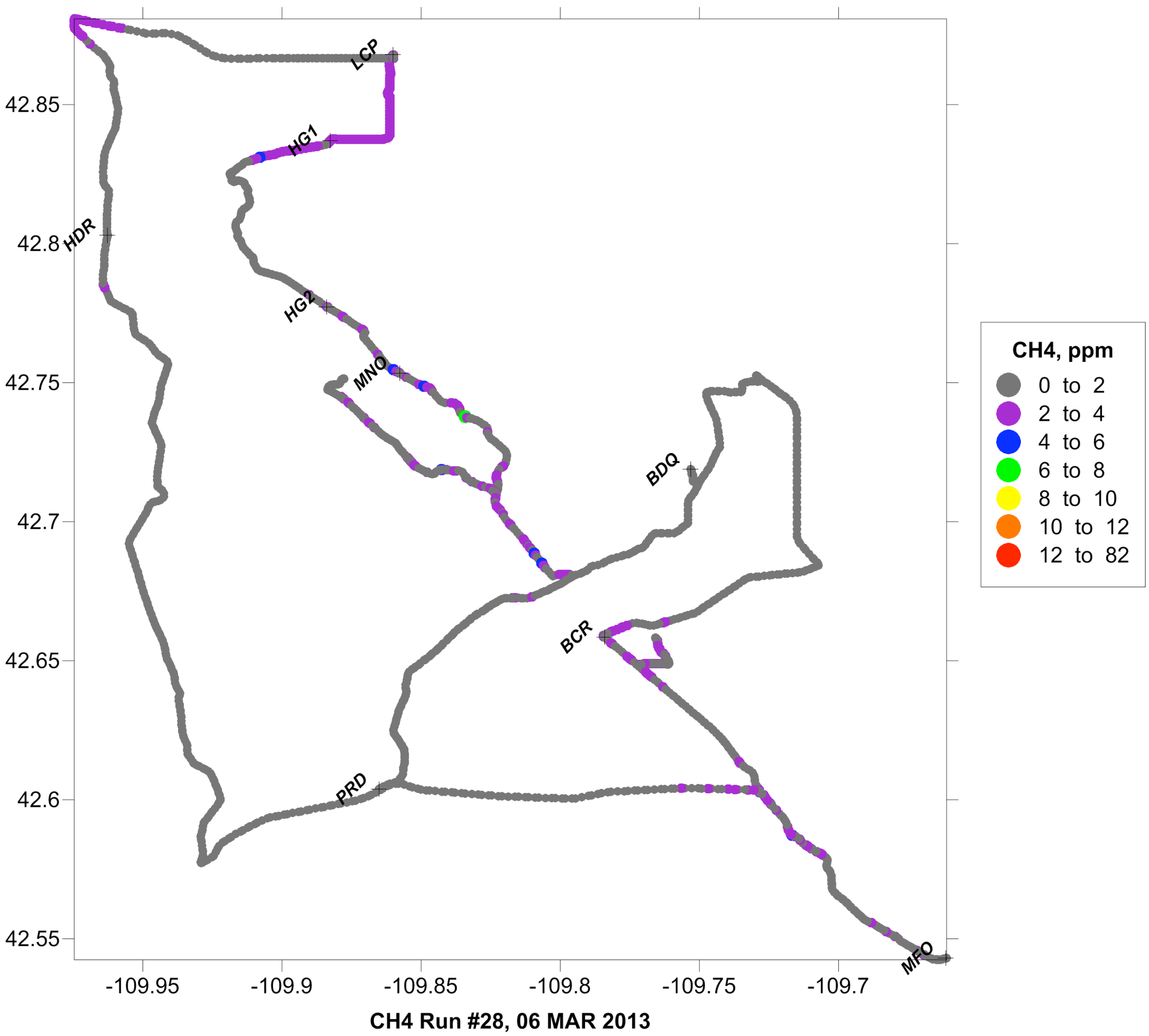

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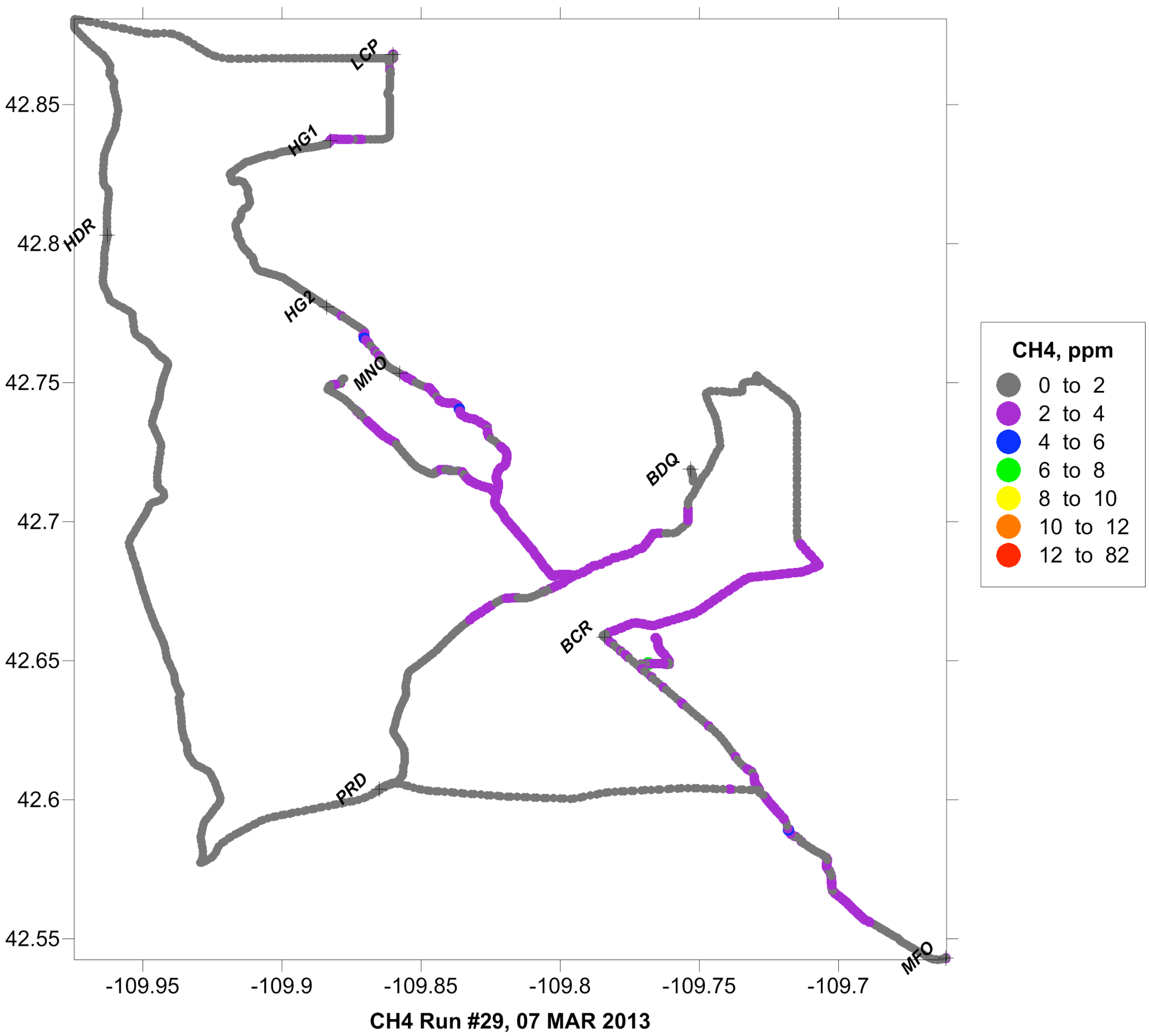

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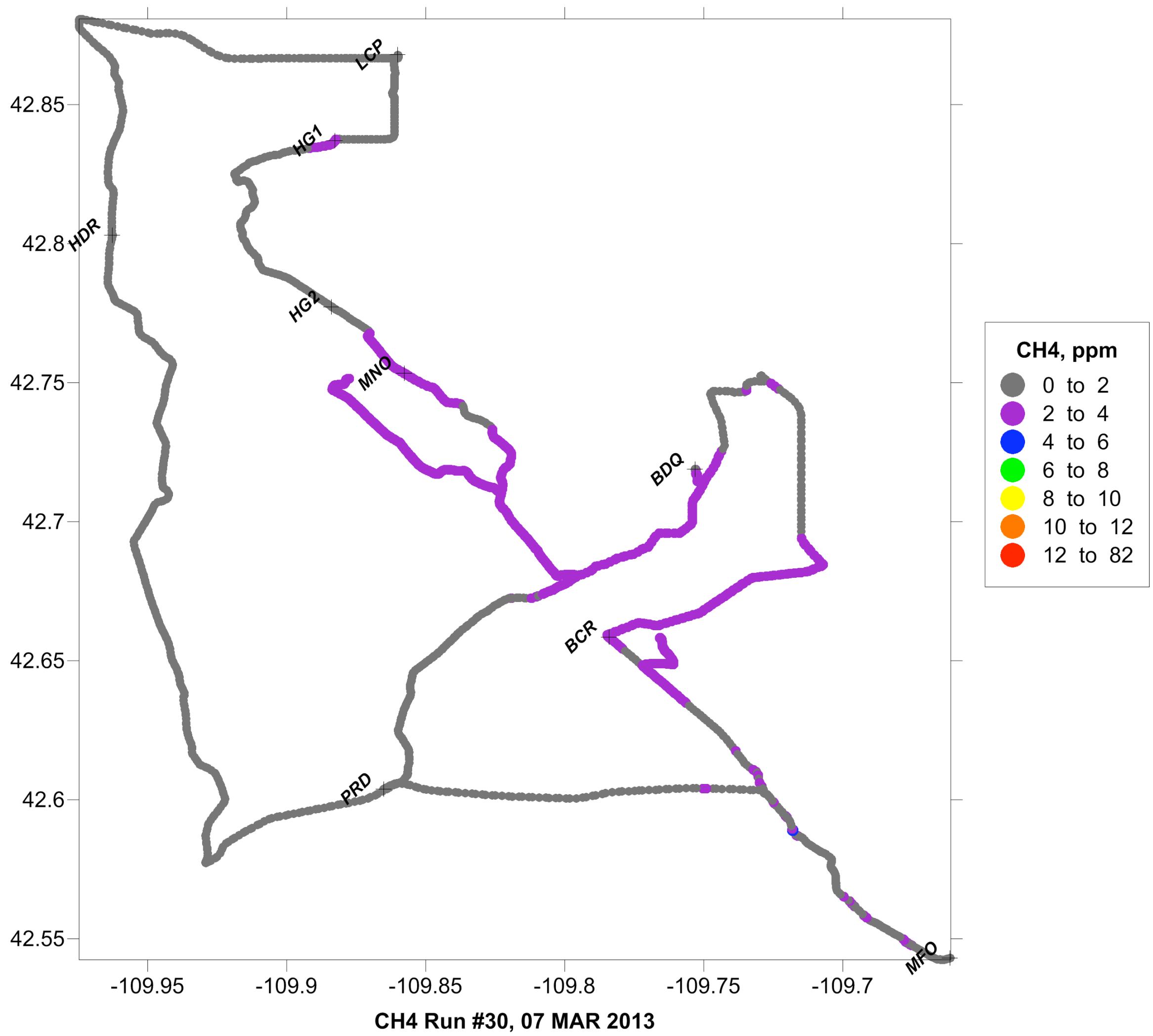

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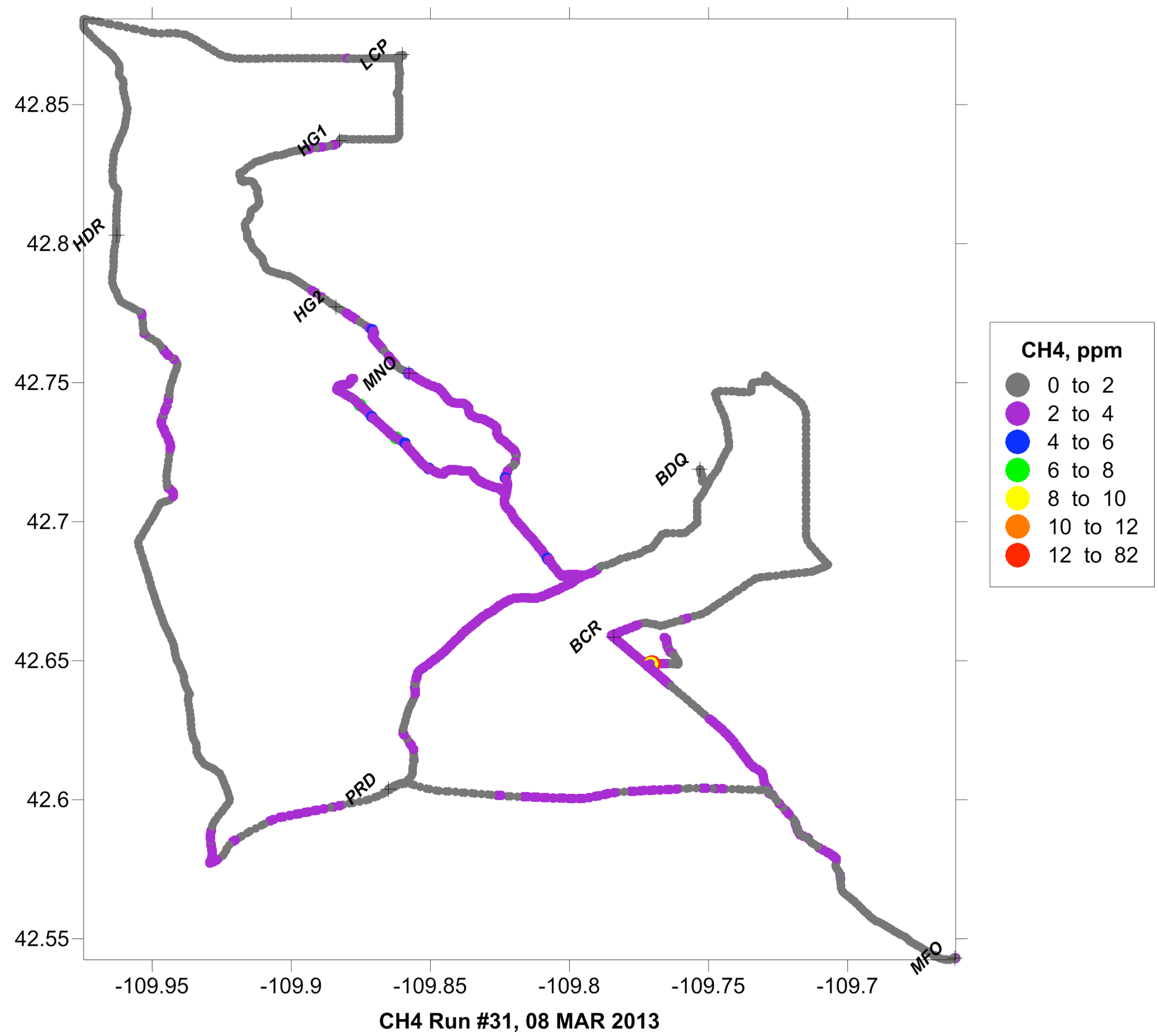
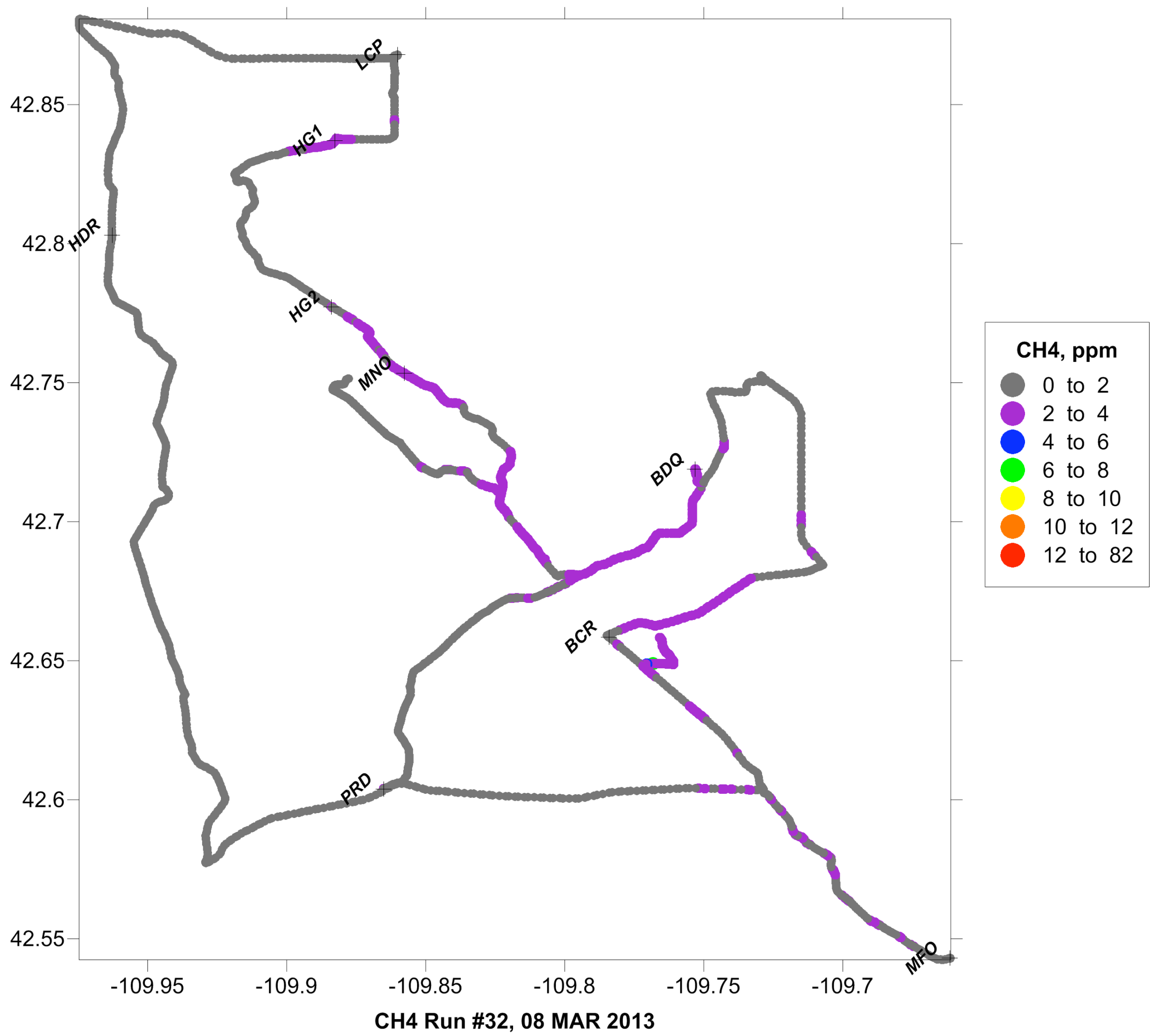
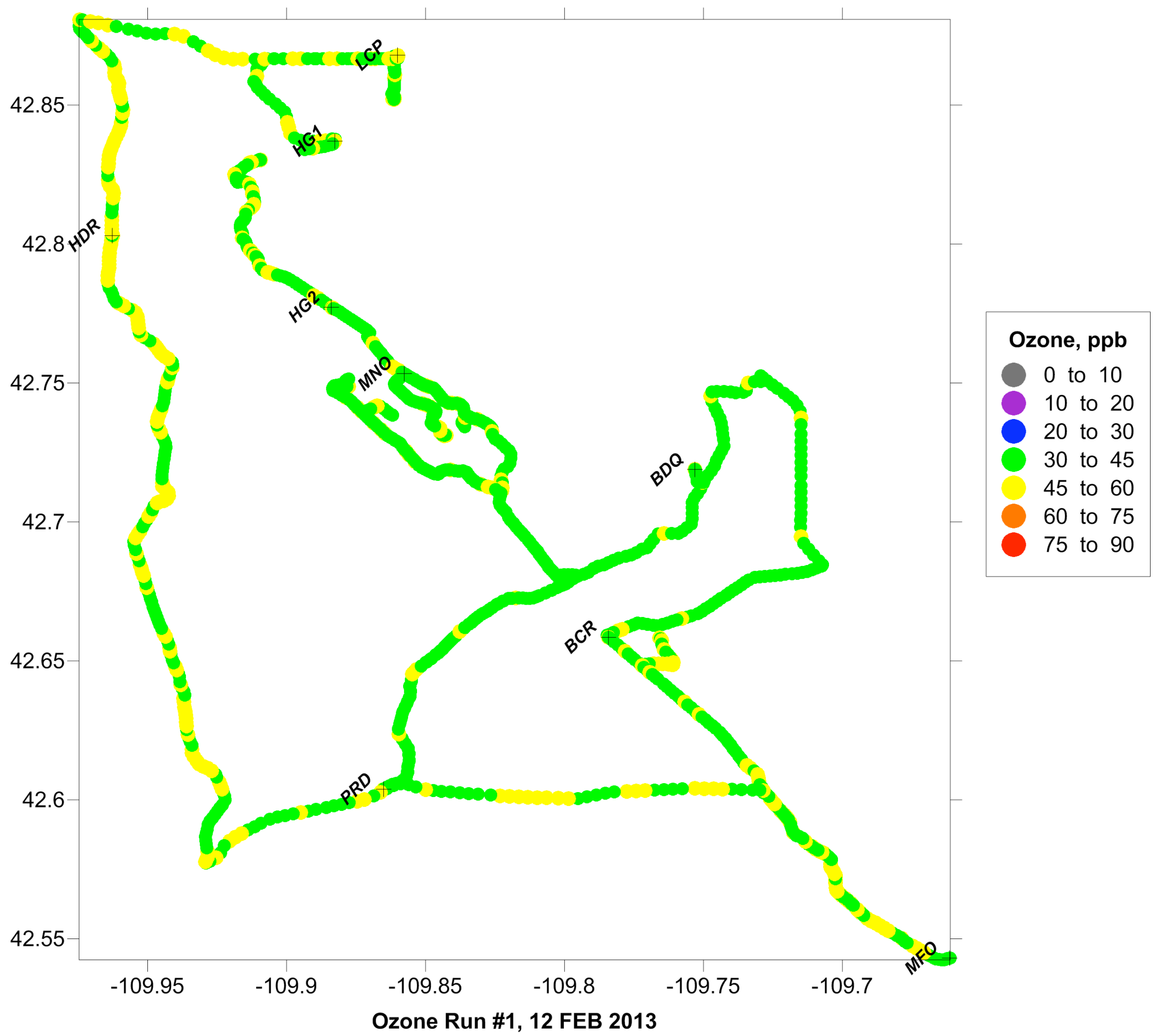


Circuit 32: 3/8/2013 PM



APPENDIX 2: Mobile ozone maps

Circuit 1: 2/12/2013 AM



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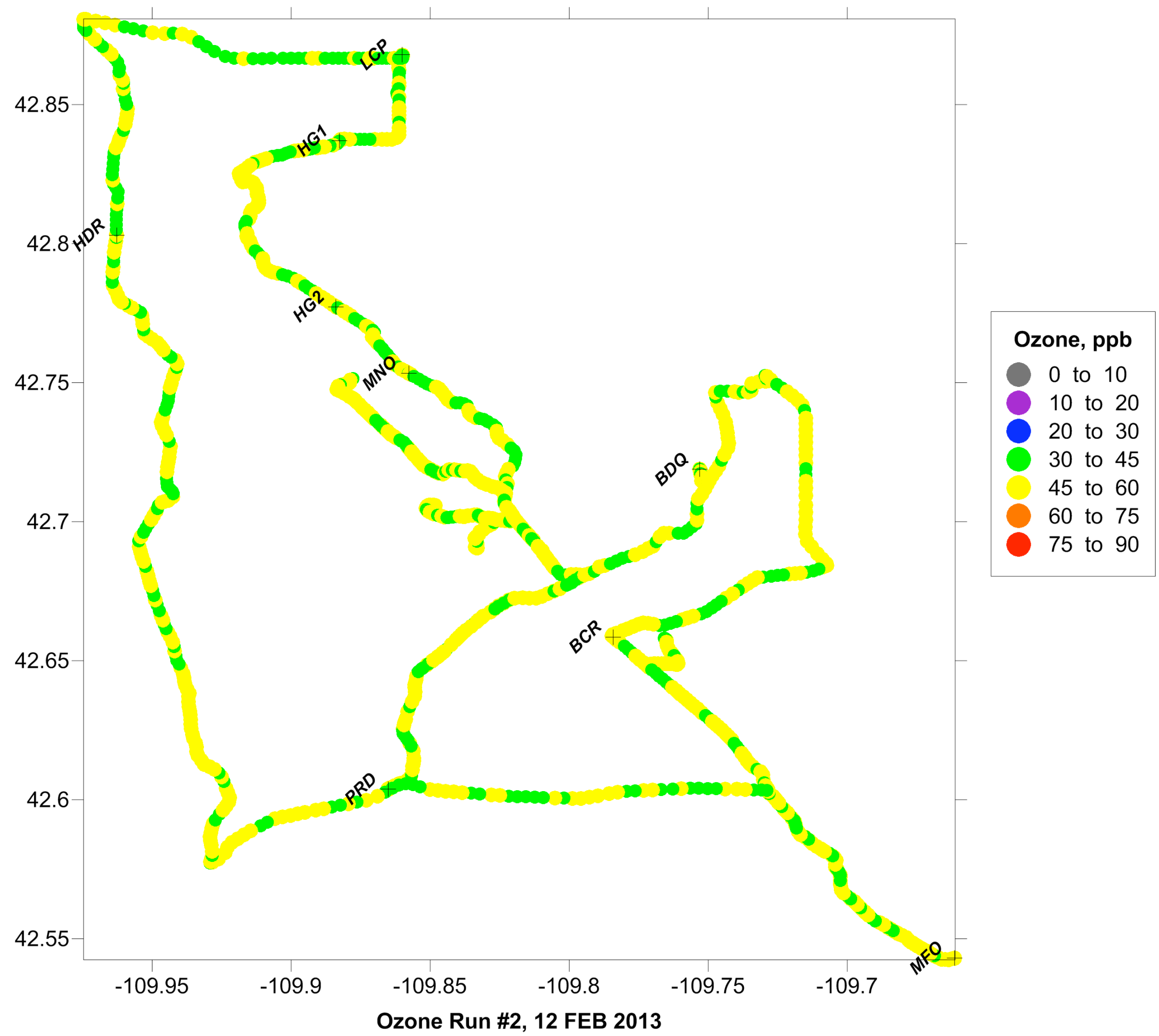

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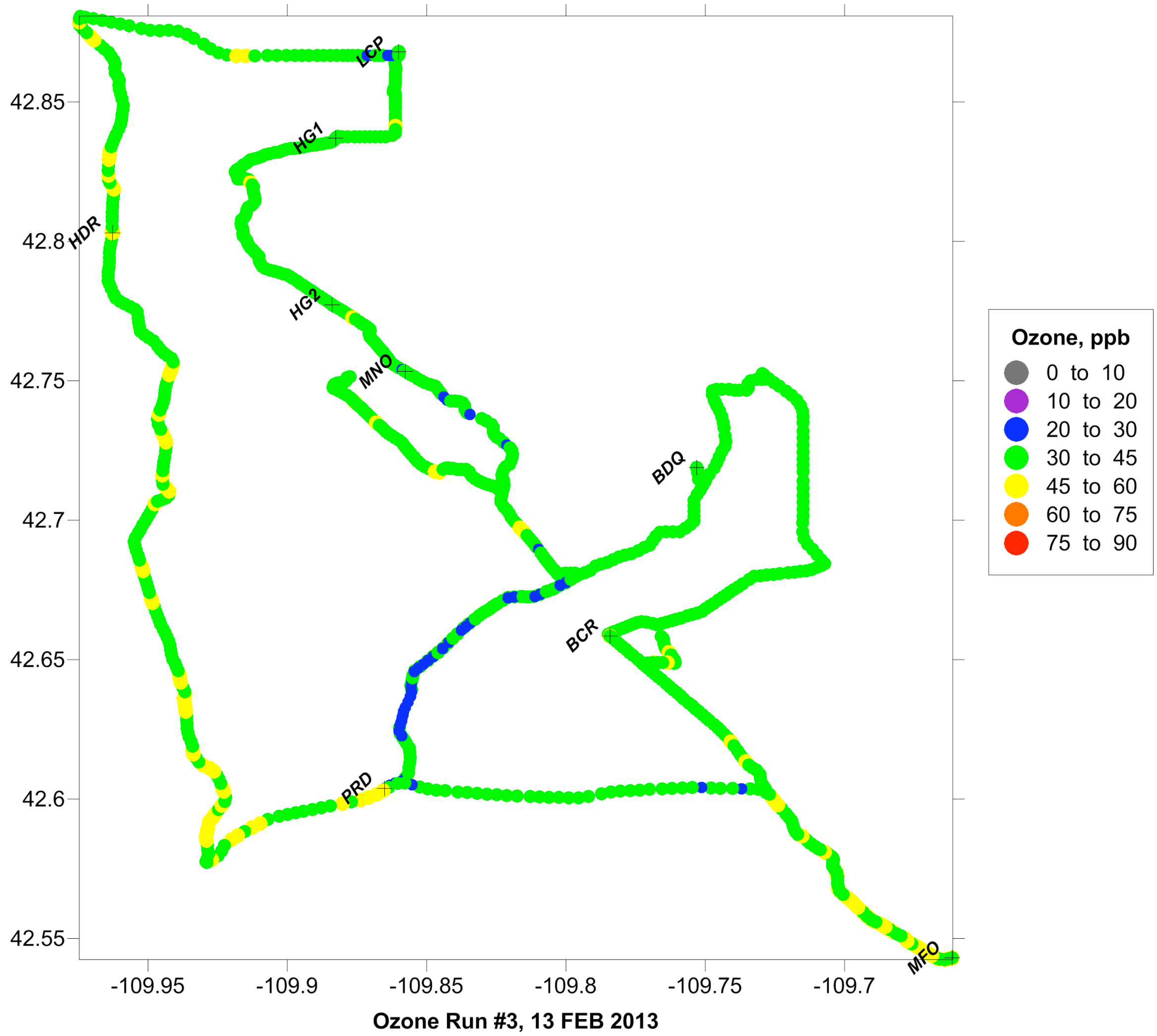

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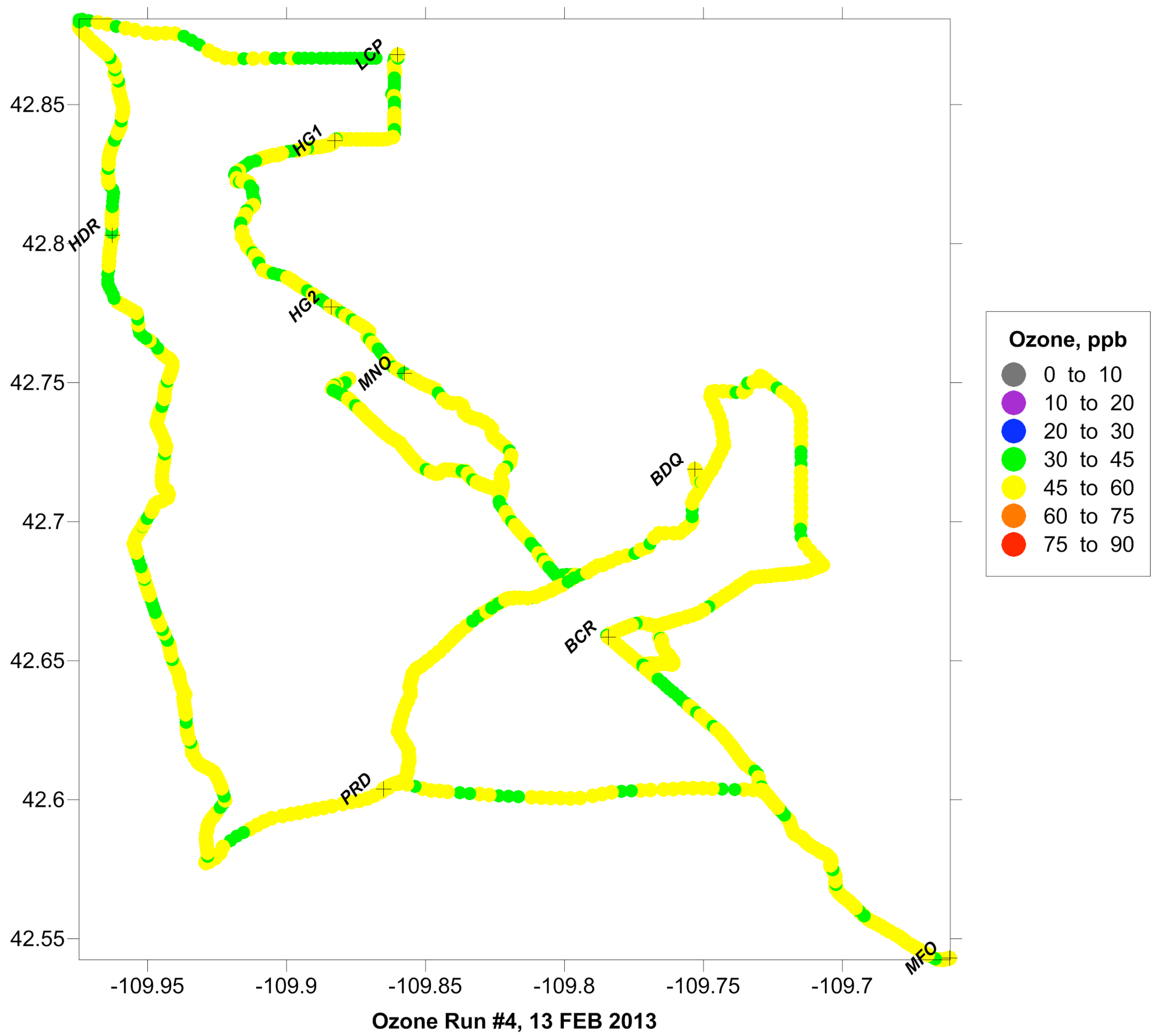

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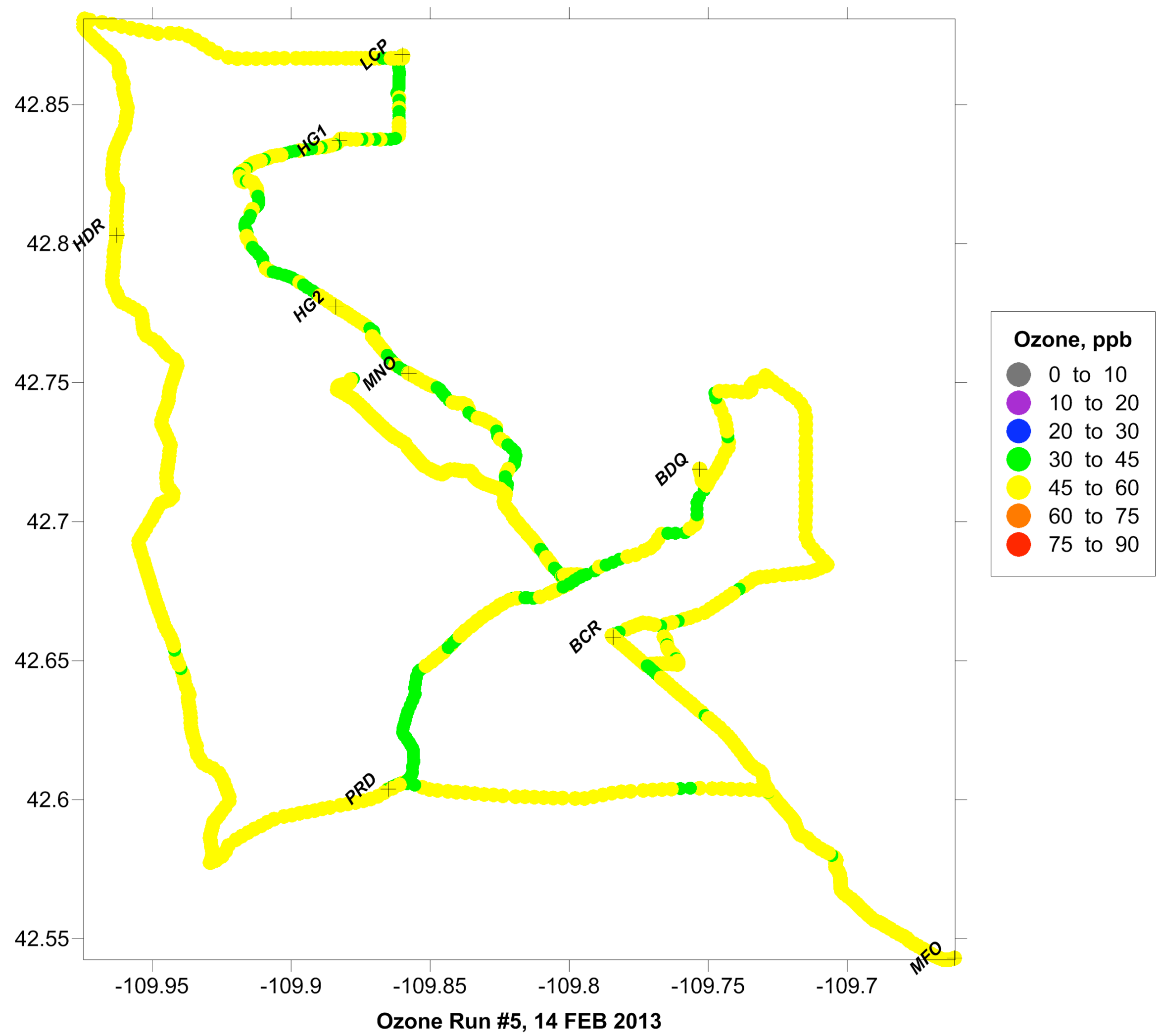
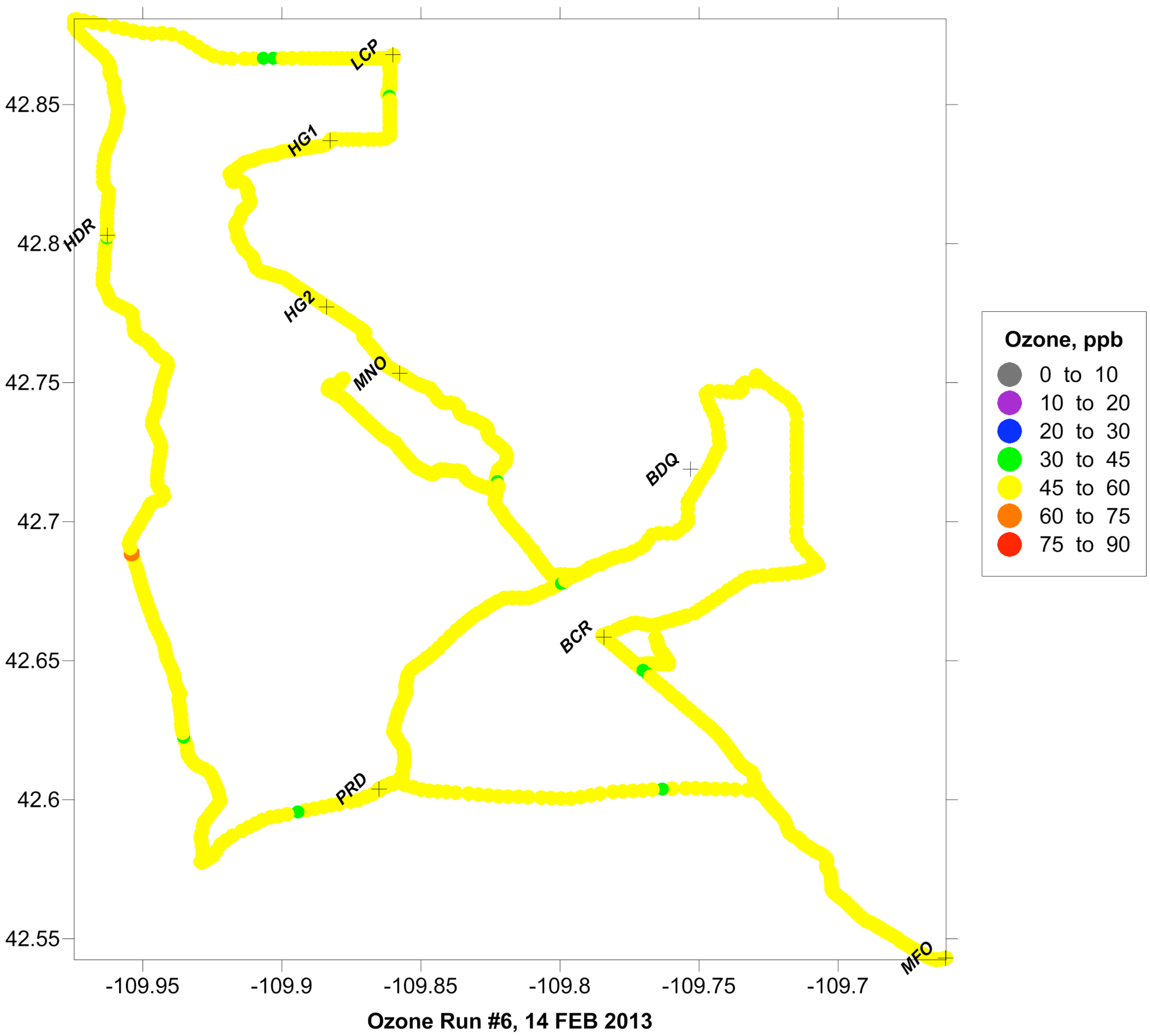
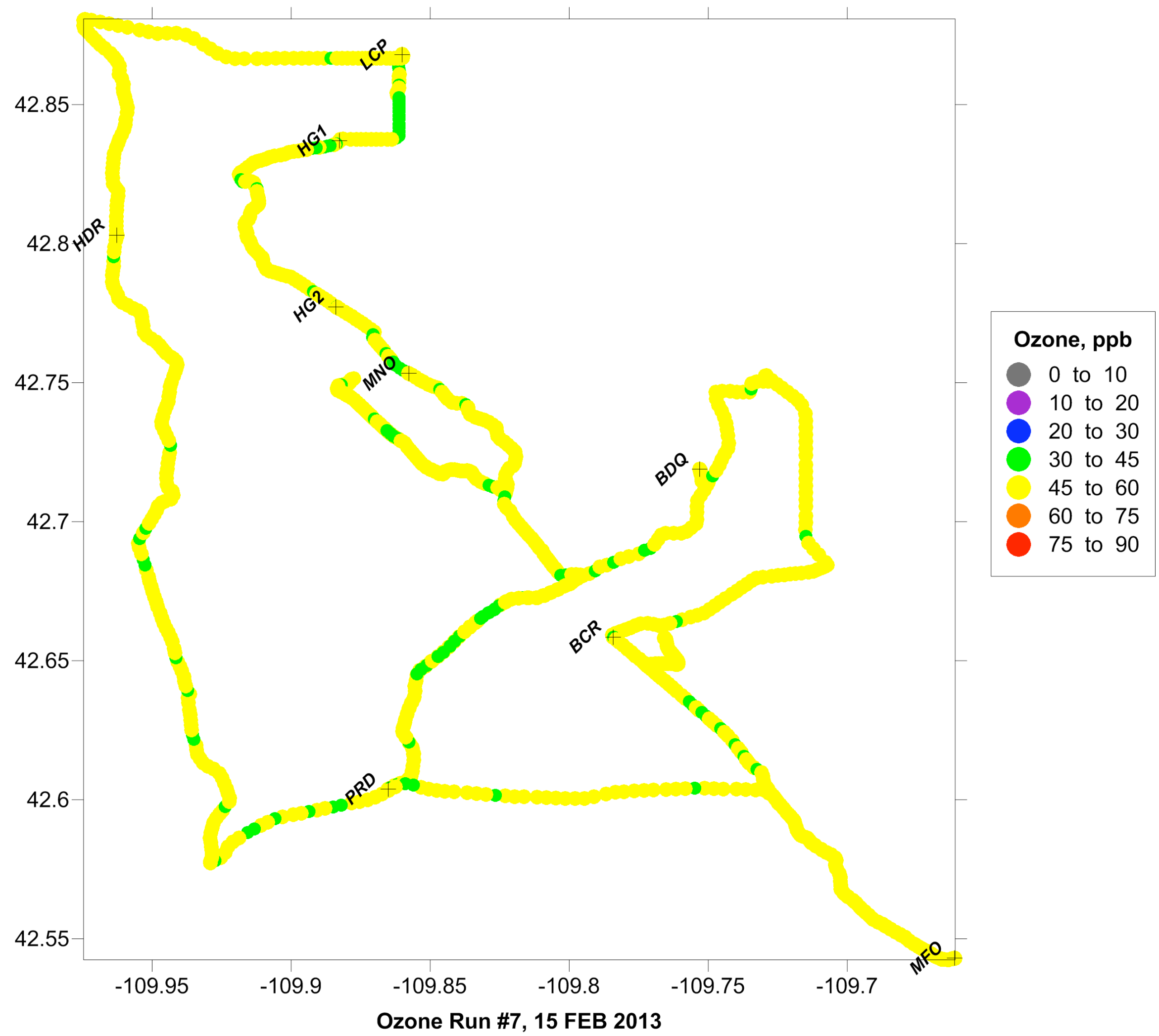


Circuit 6: 2/14/2013 PM



Circuit 7: 2/15/2013 AM



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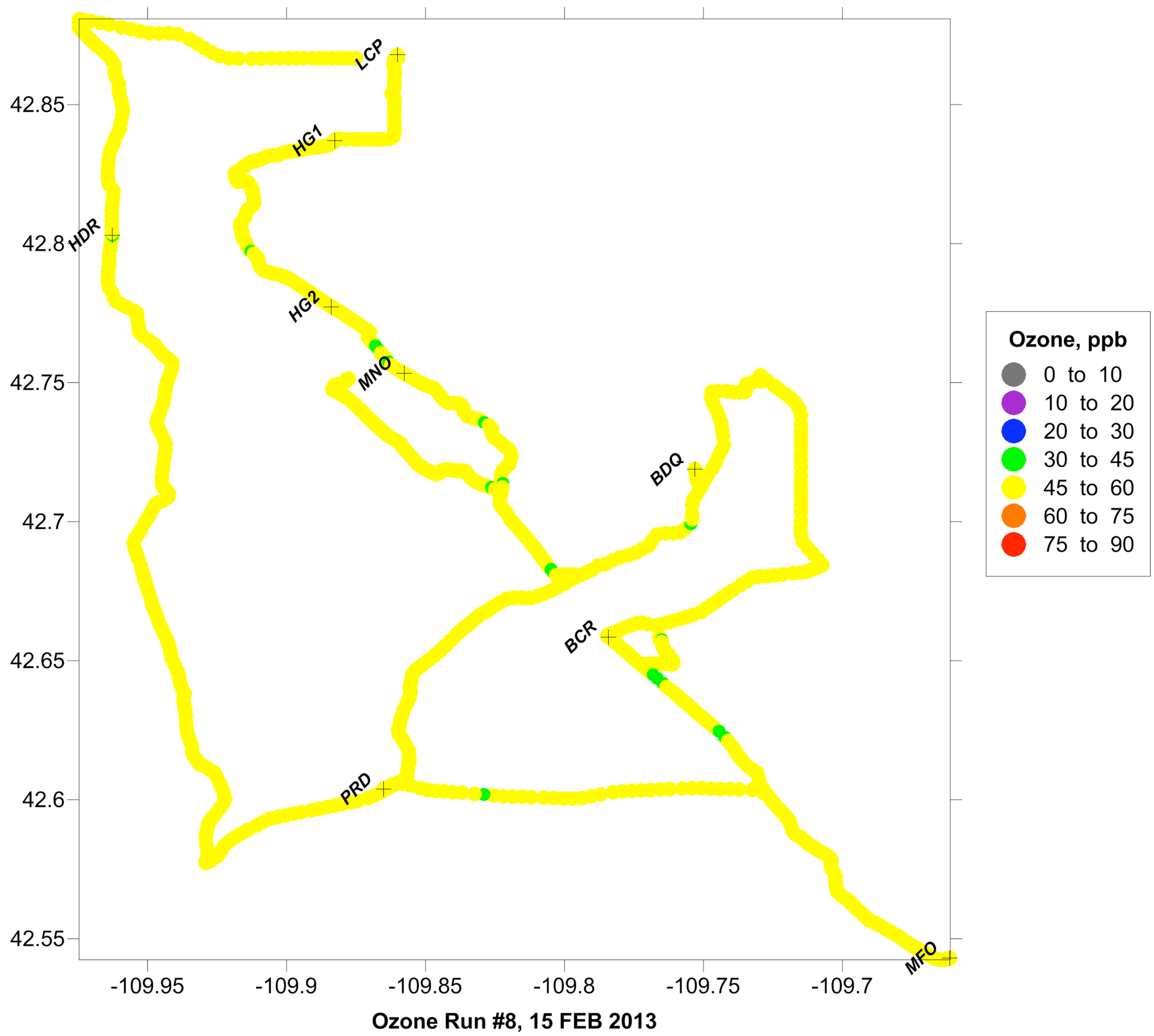
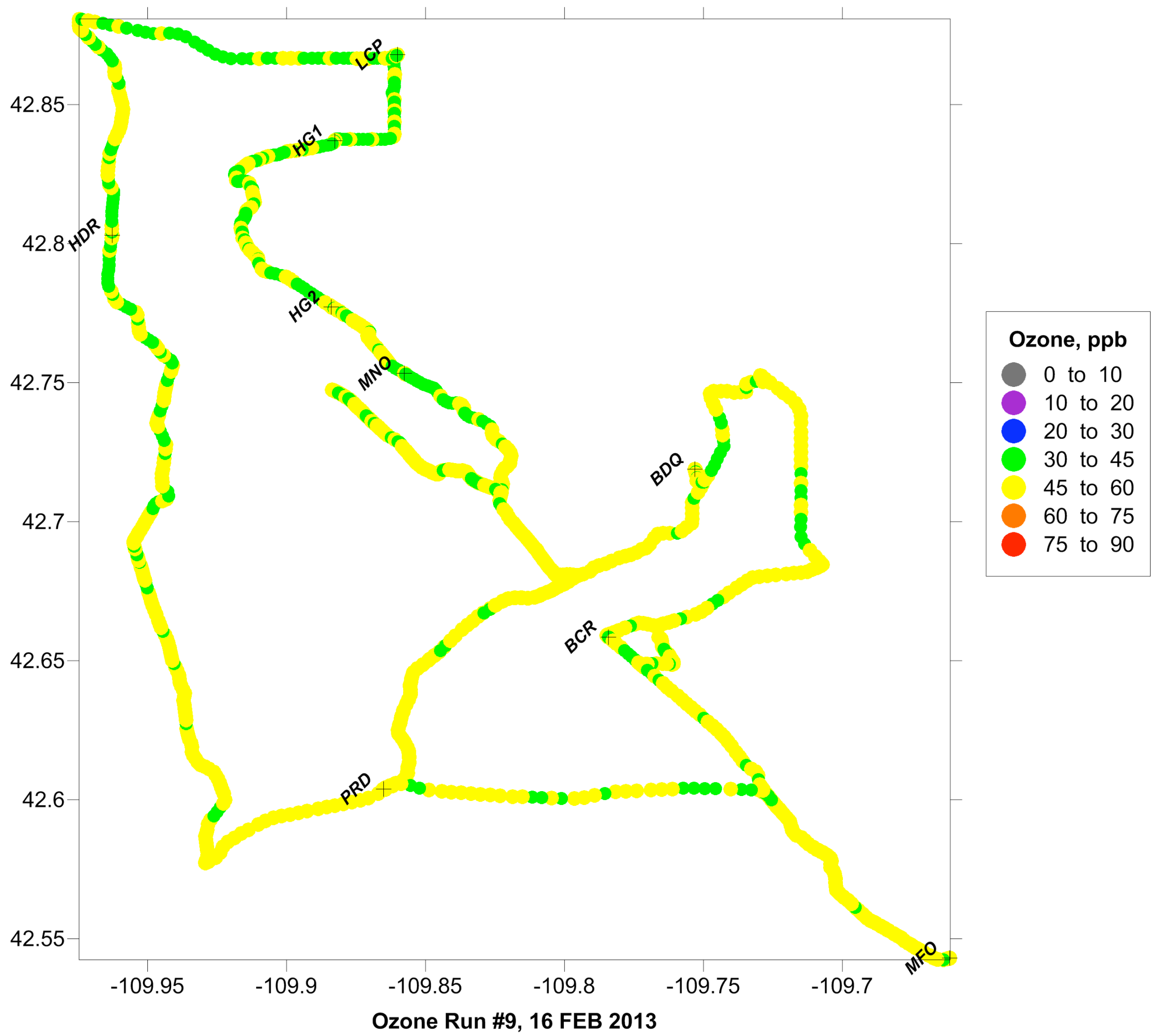
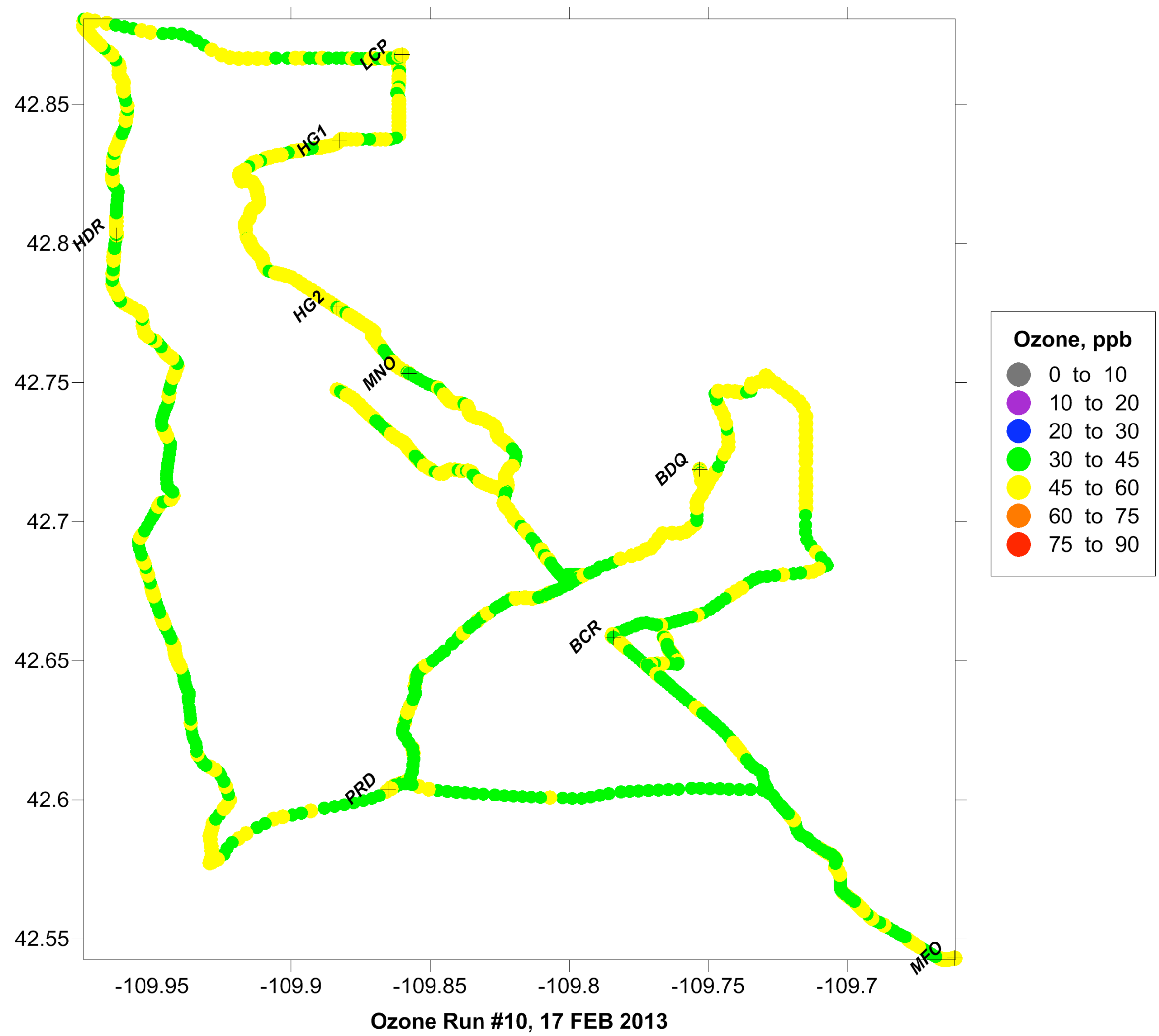


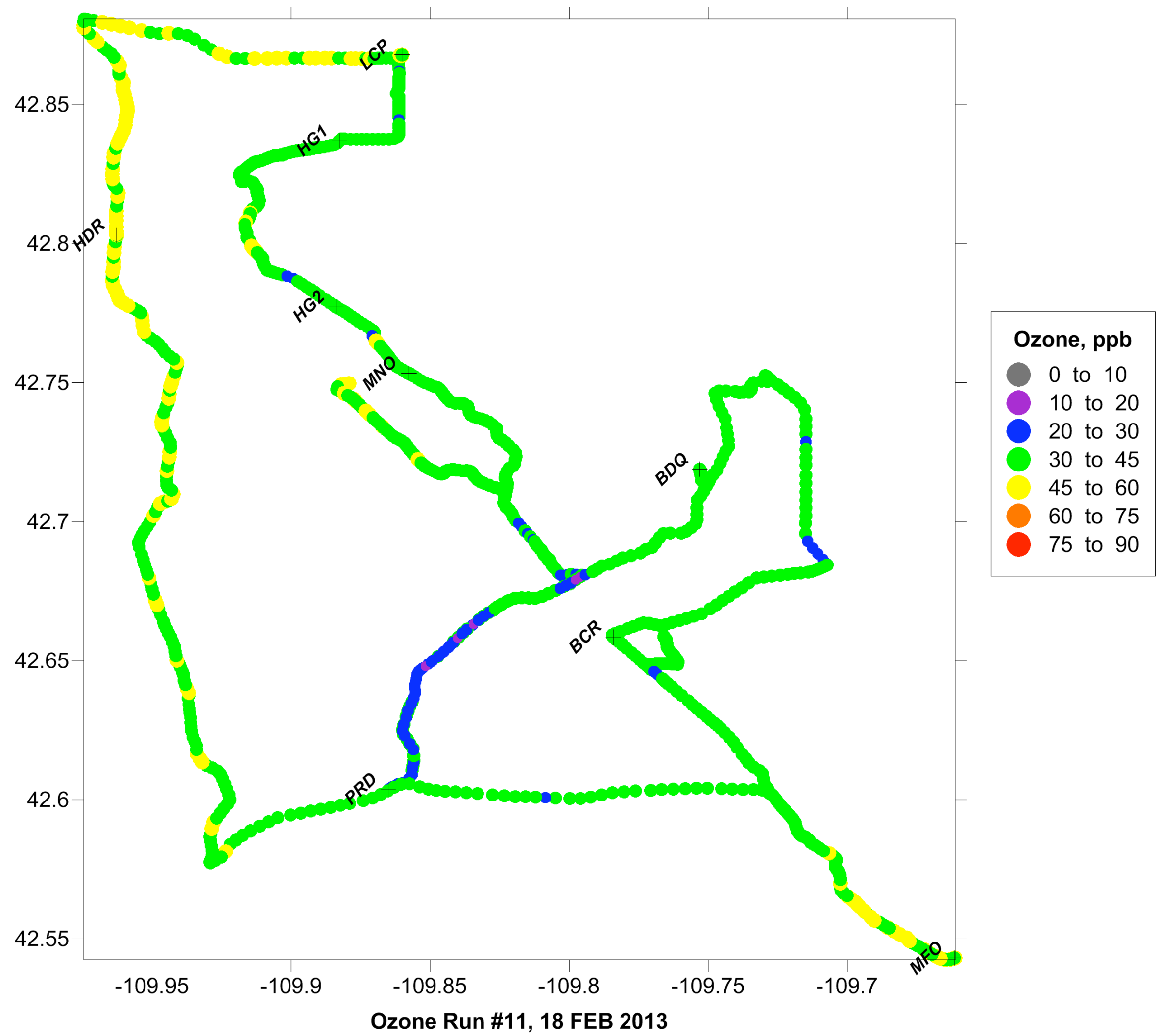
Circuit 9: 2/16/2013 PM



Circuit 10: 2/17/2013 PM



Circuit 11: 2/18/2013 AM



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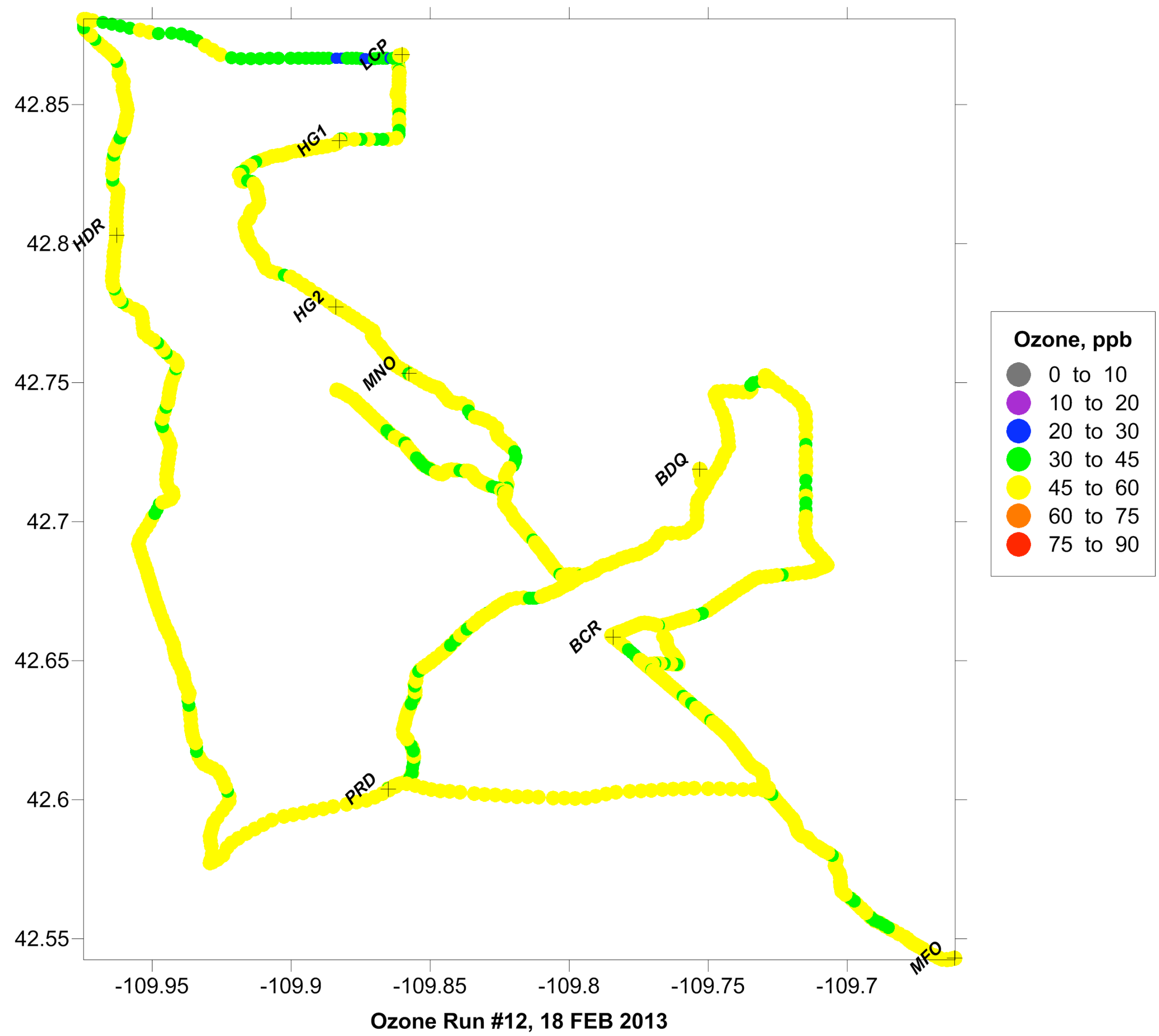
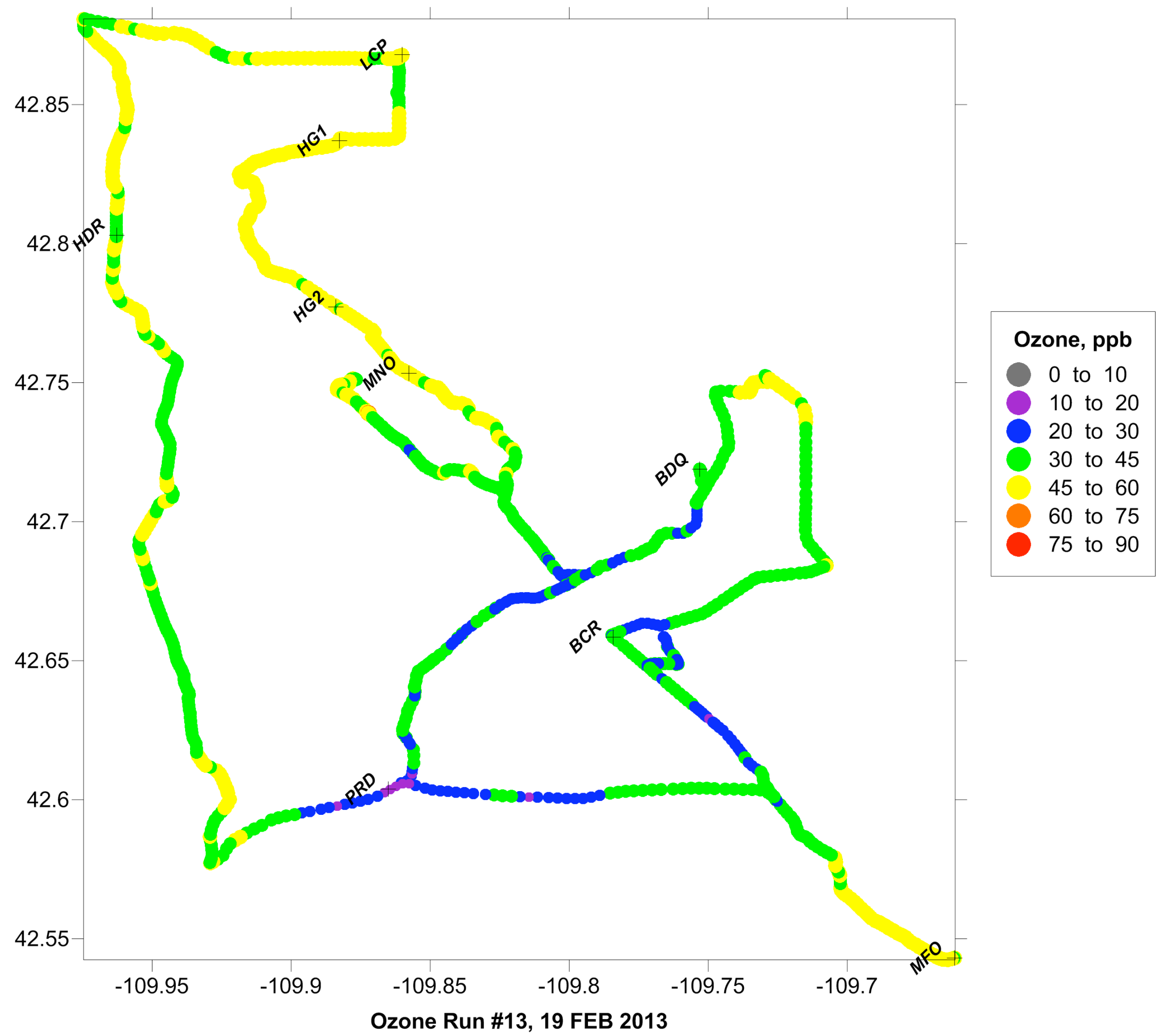


Circuit 13: 2/19/2013 EV



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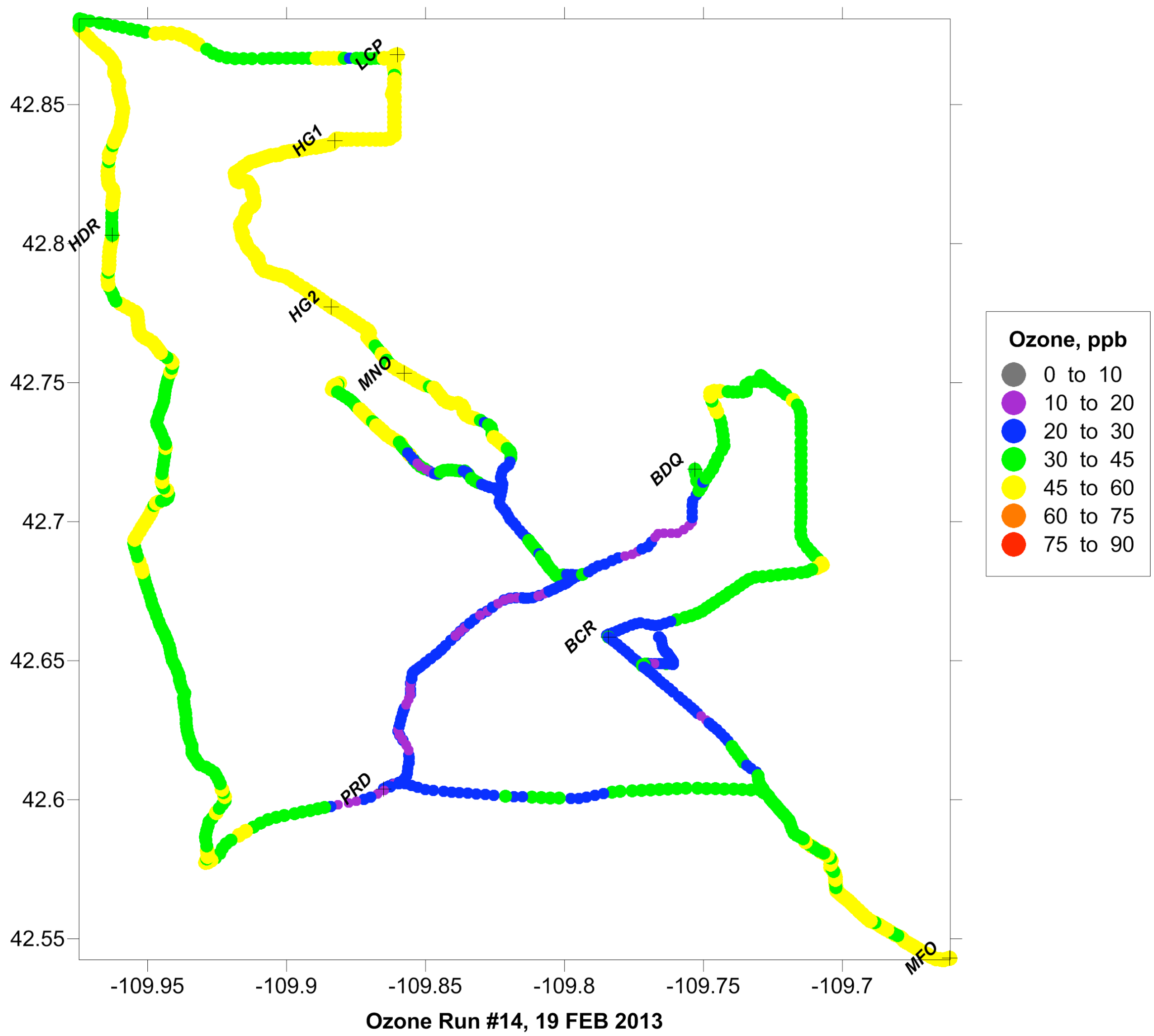

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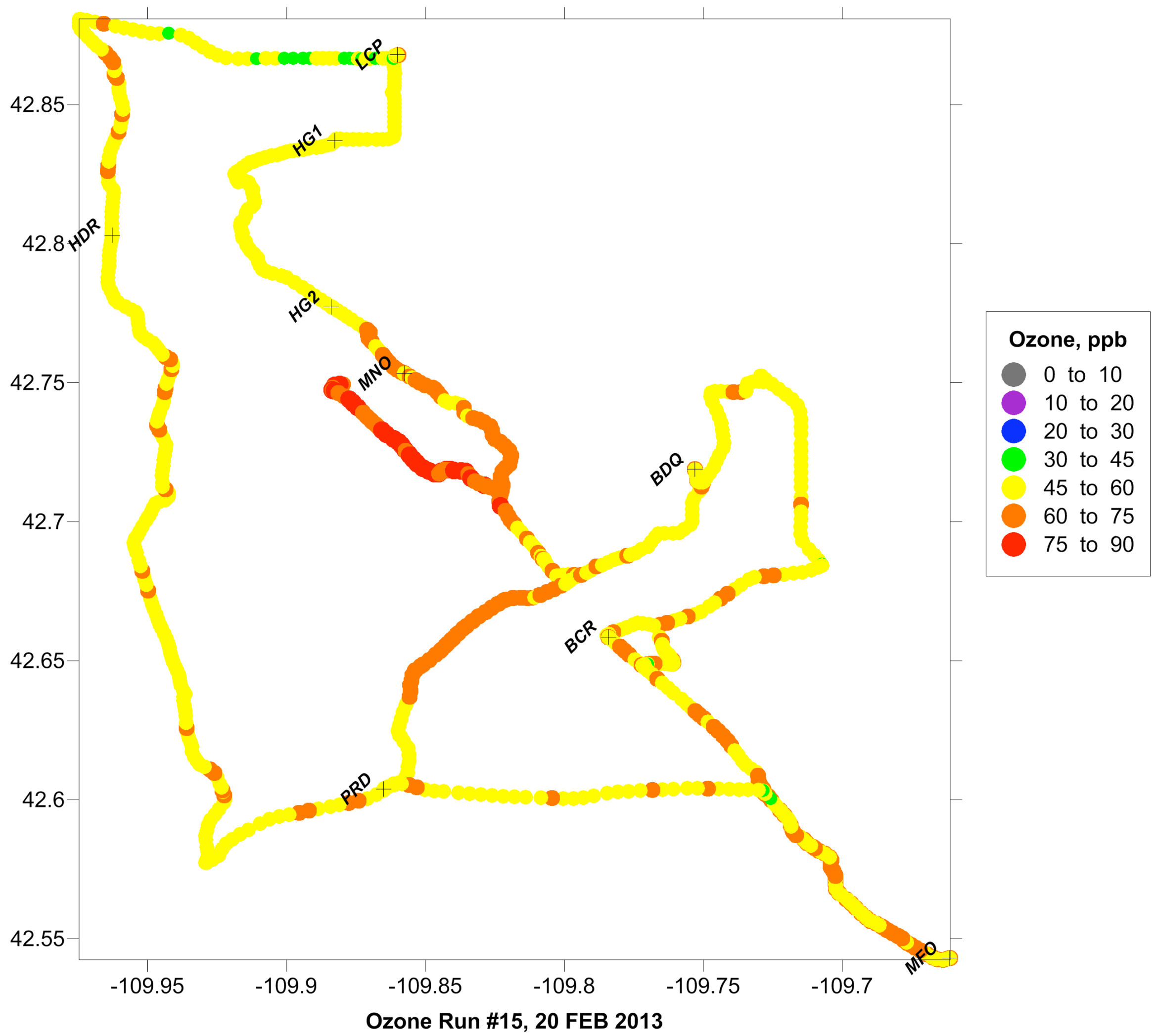

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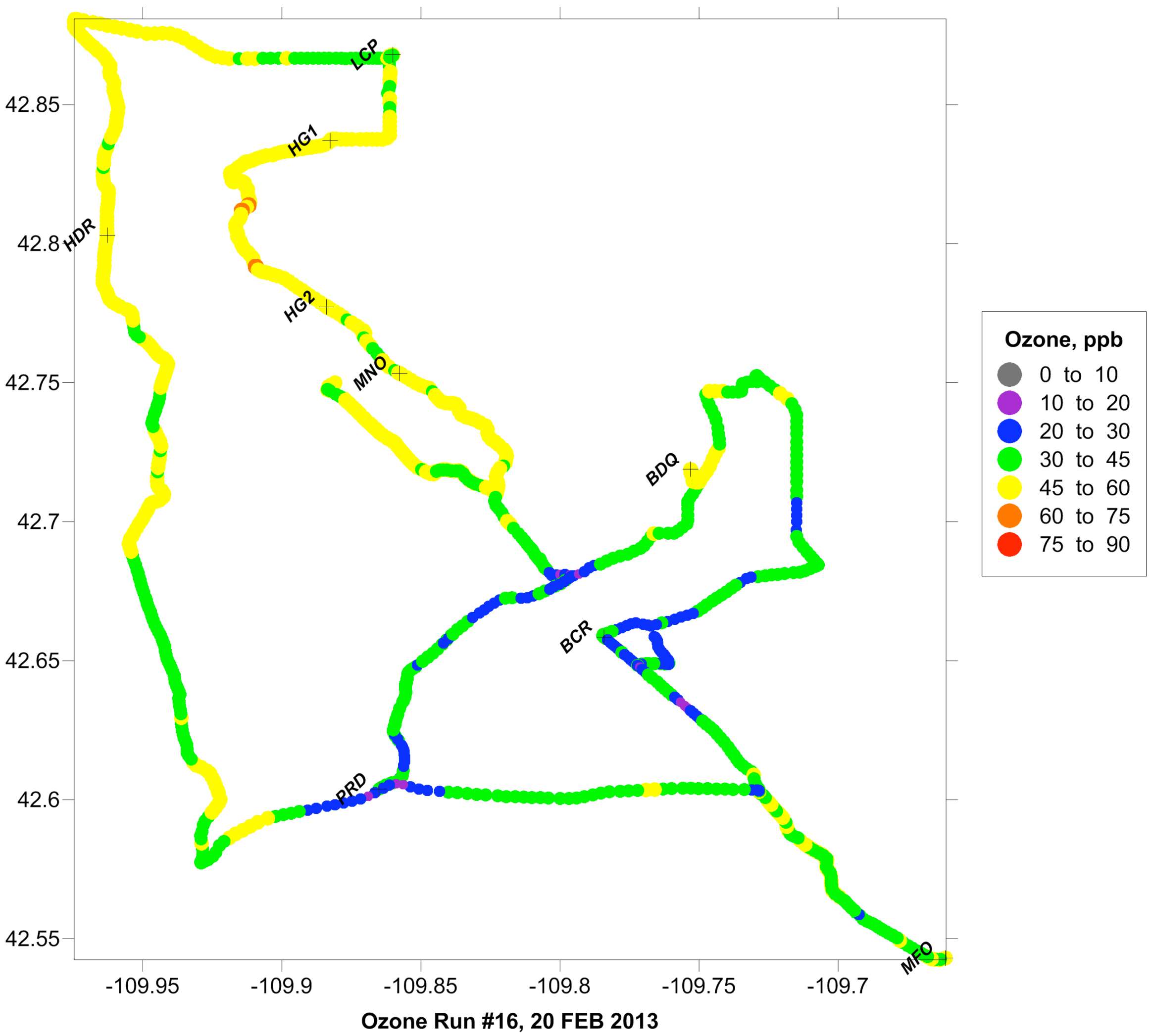
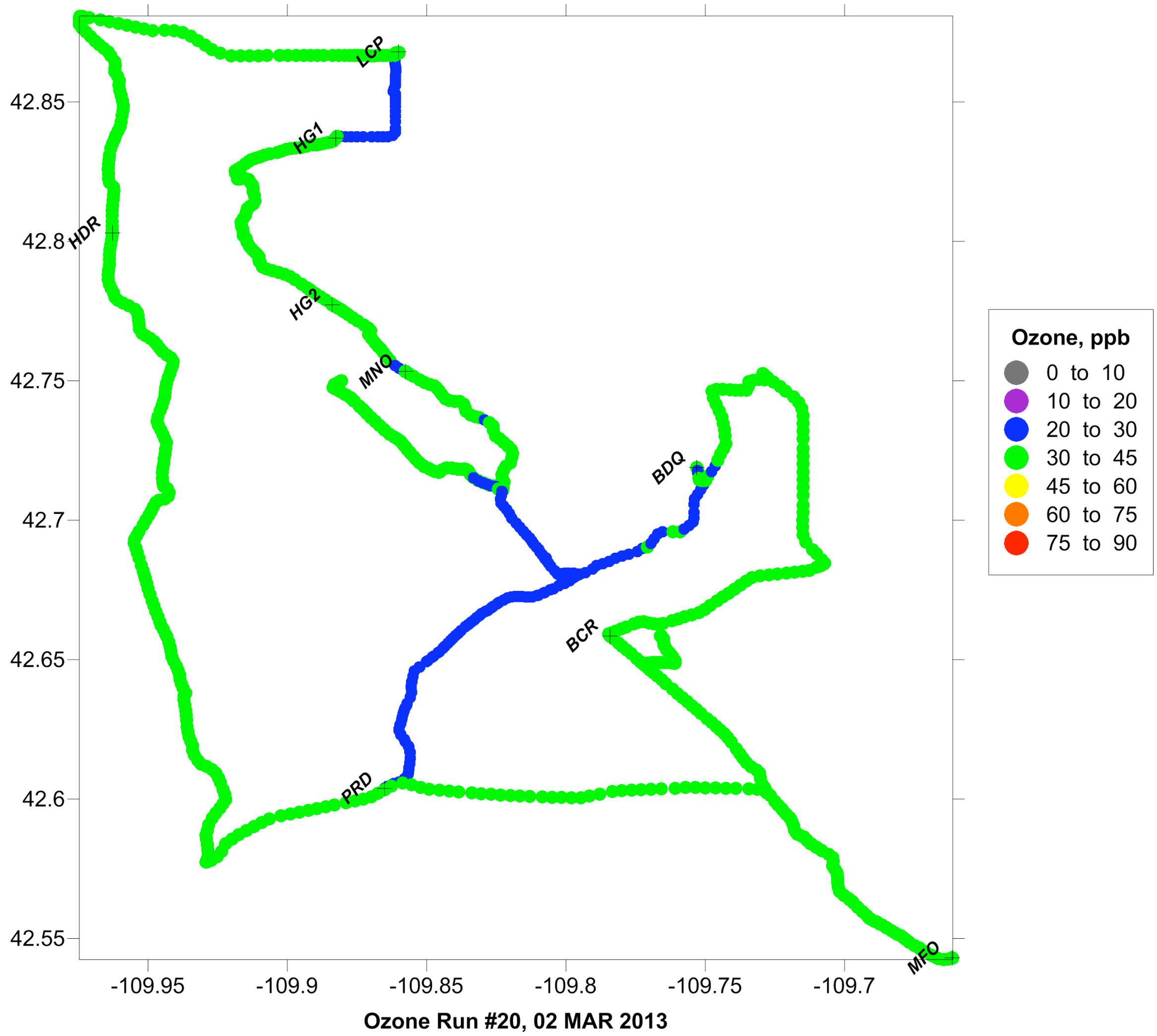
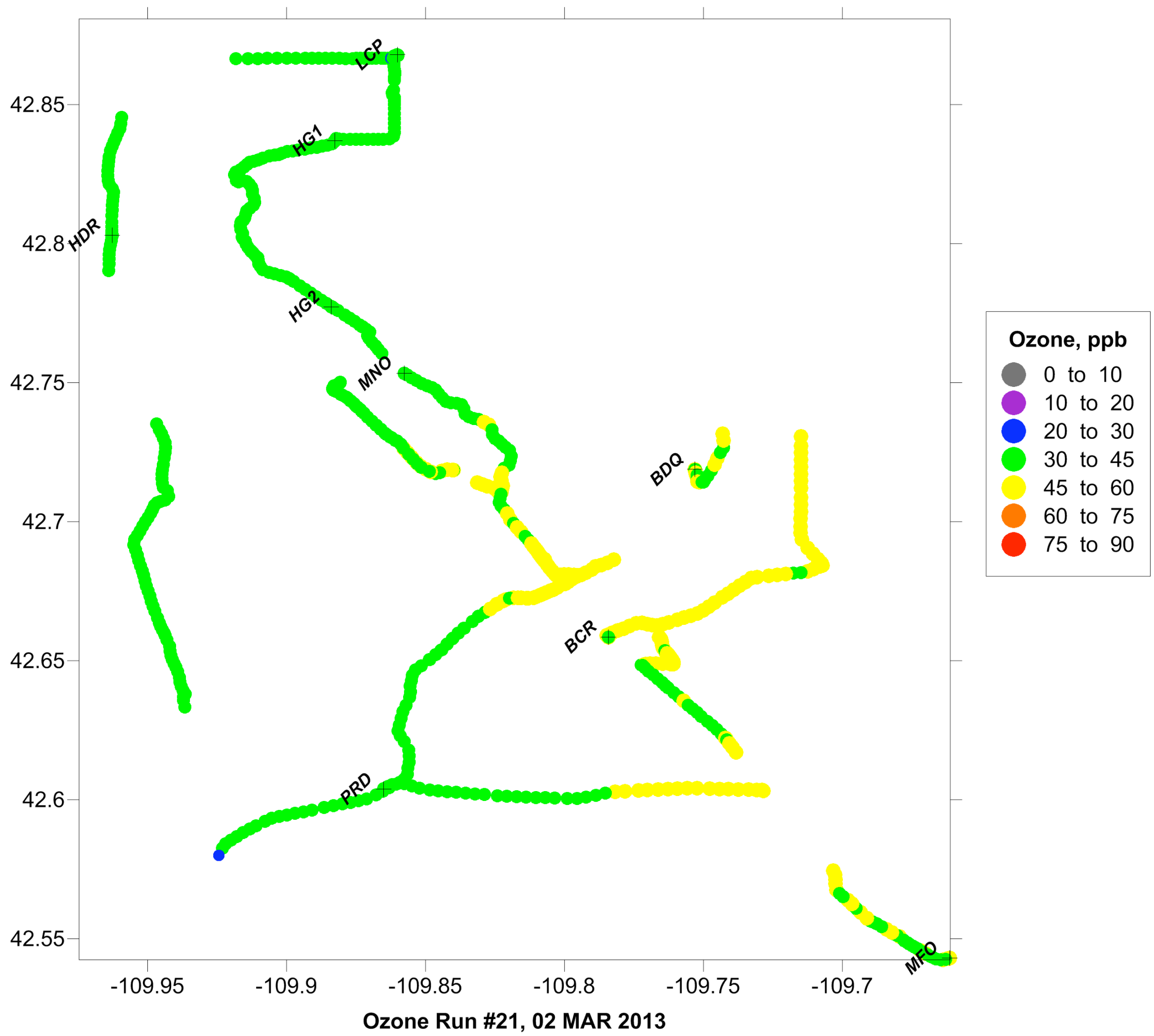


Circuit 20: 3/2/2013 AM



Circuit 21: 3/2/2013 PM



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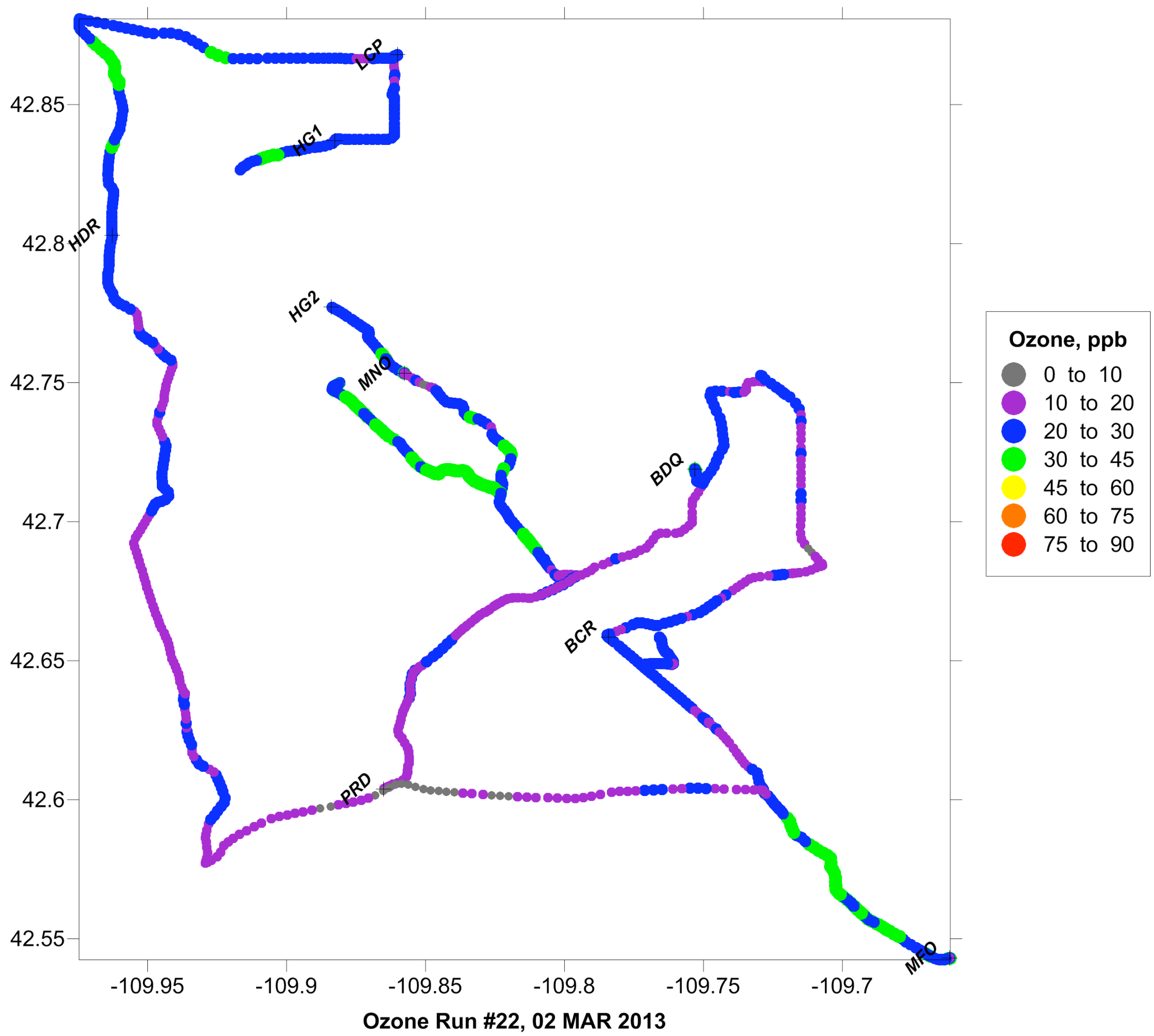
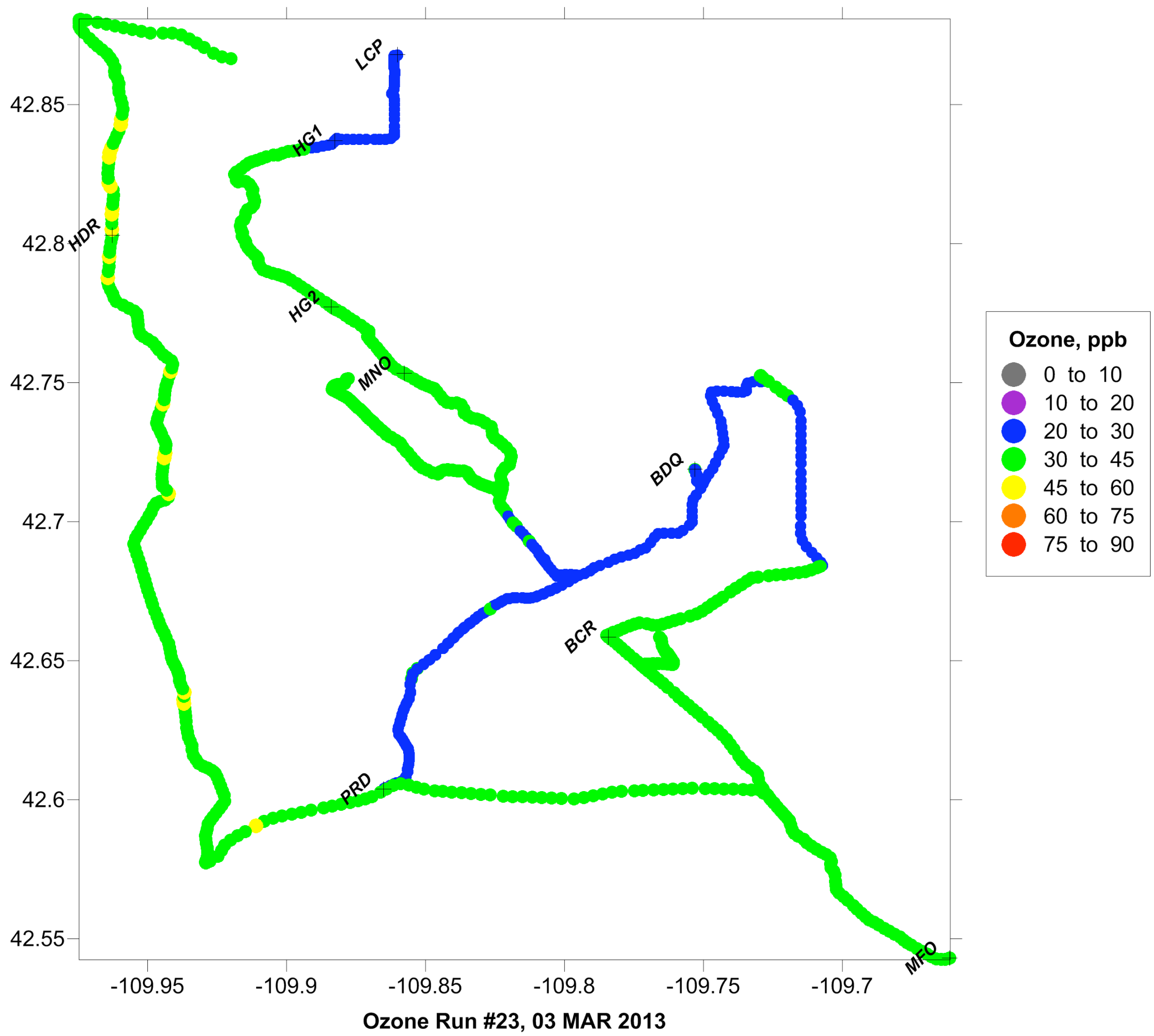


Circuit 23: 3/3/2013 AM



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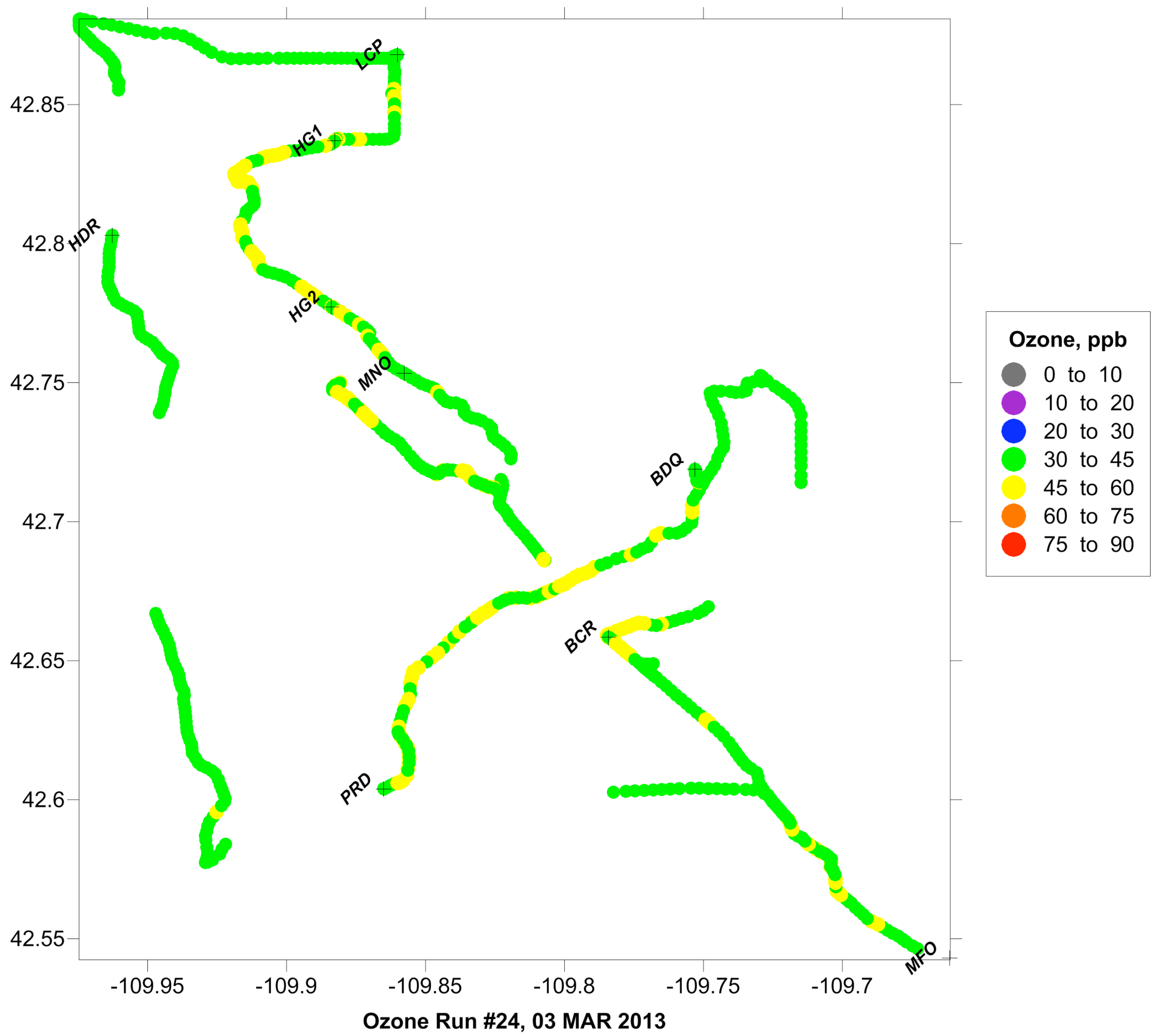

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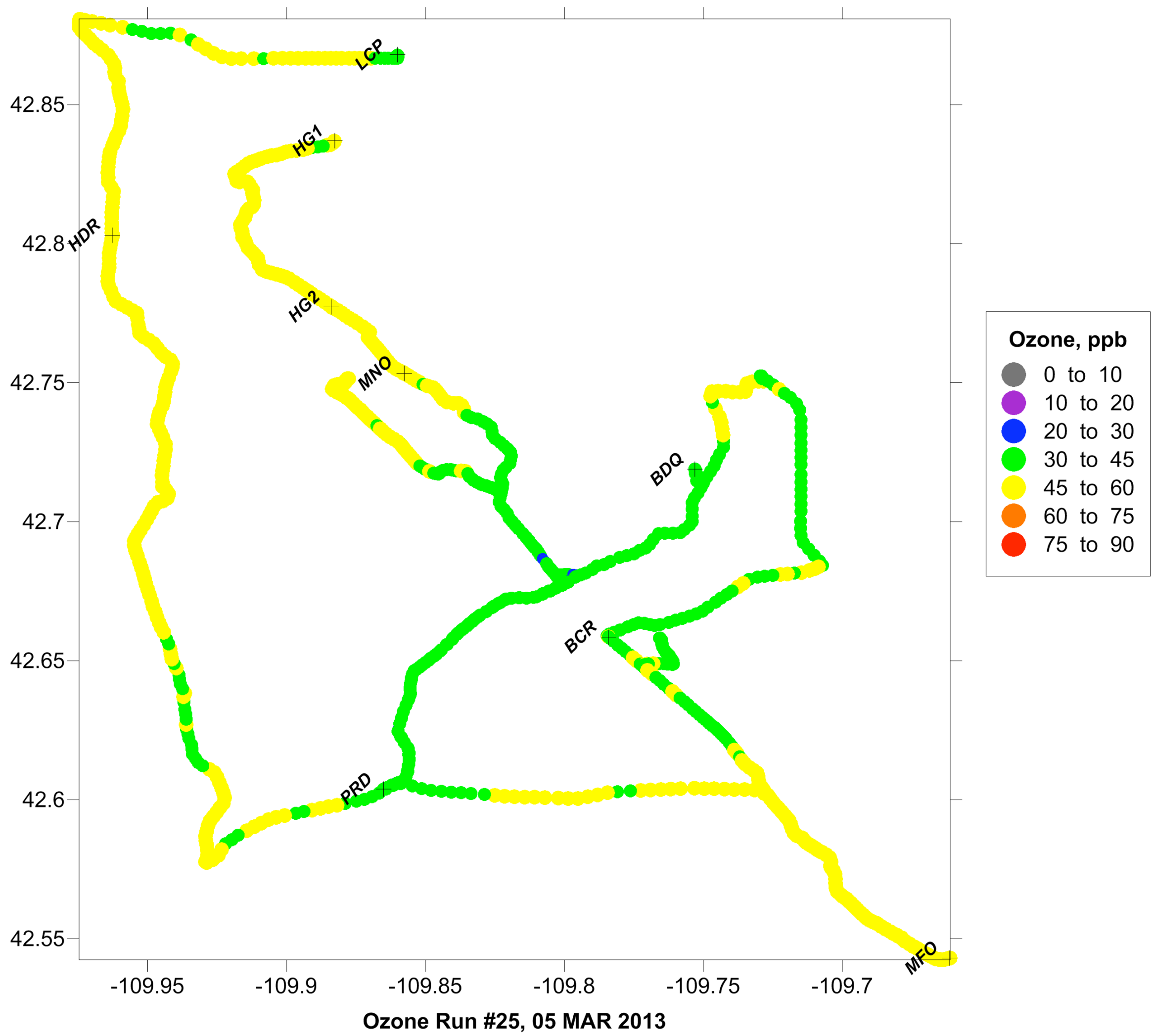
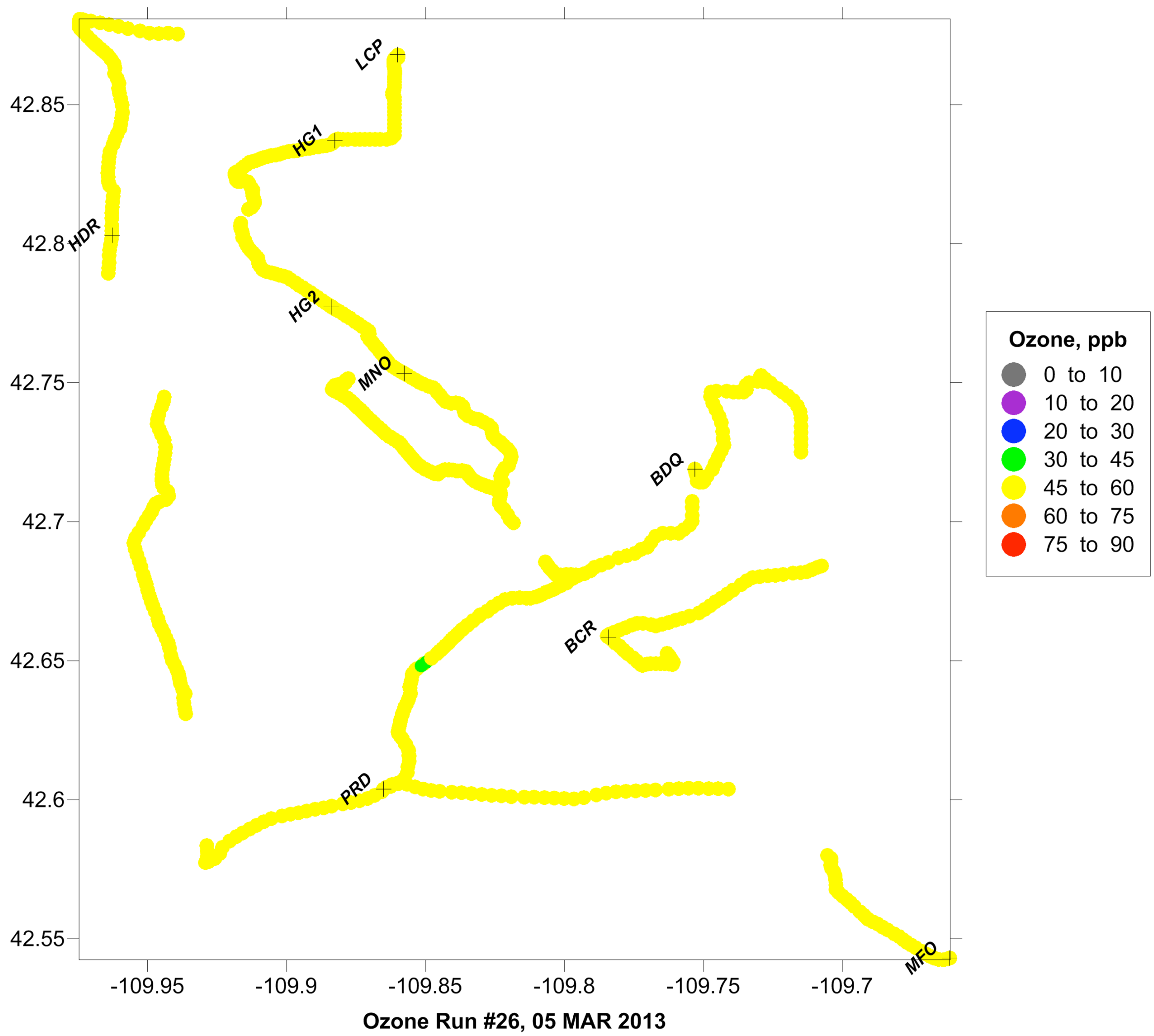


Circuit 26: 3/5/2013 PM



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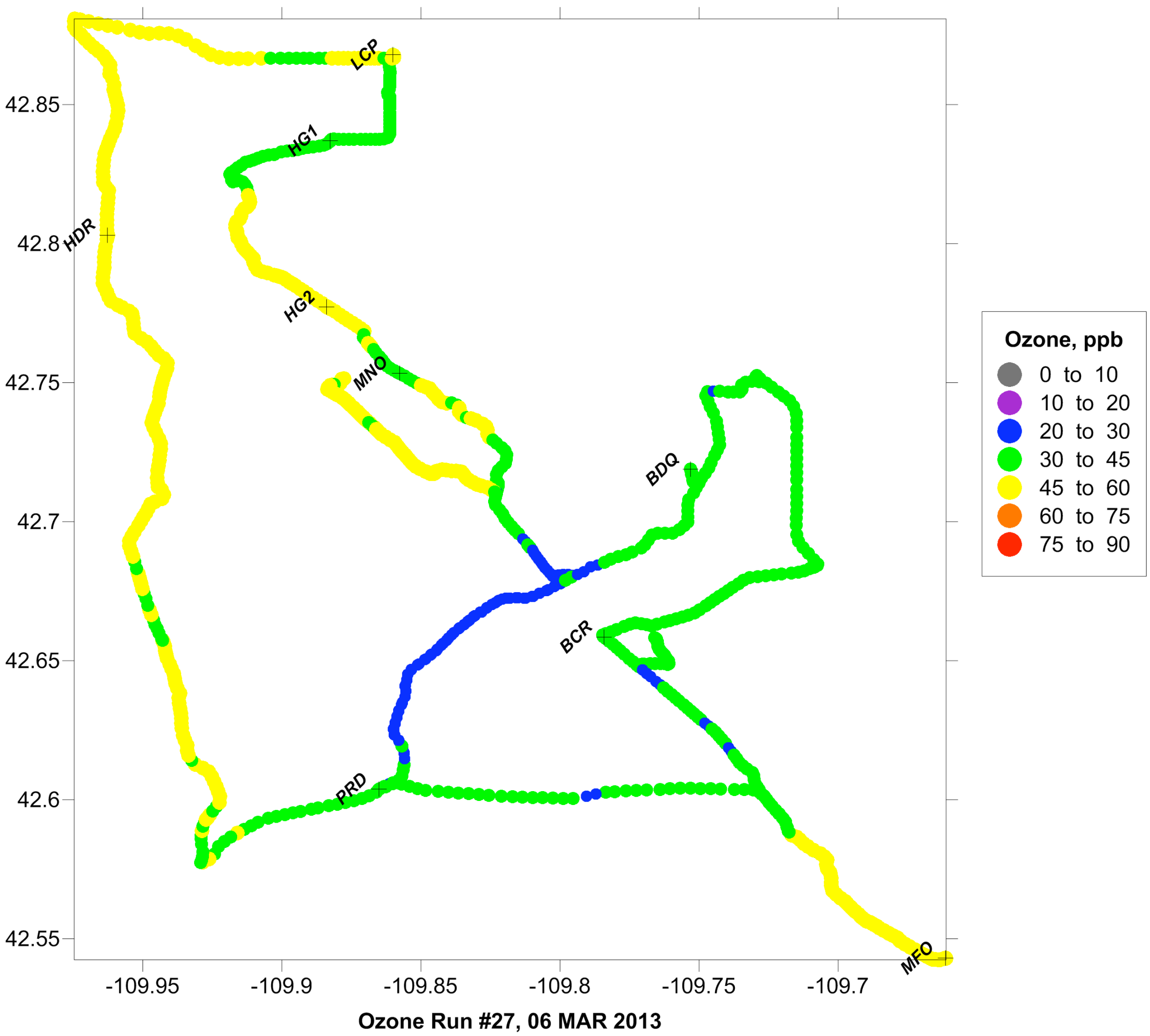

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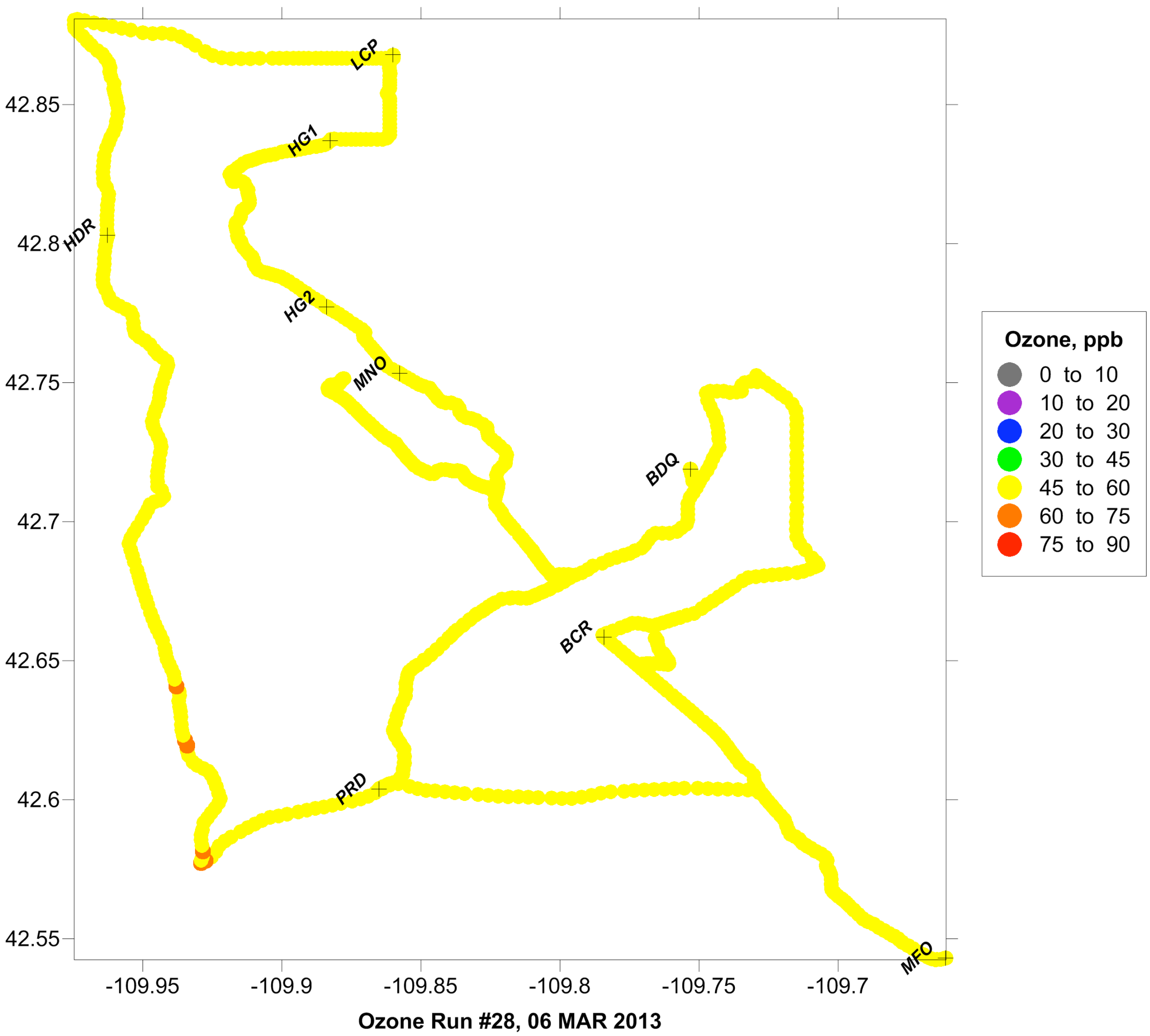

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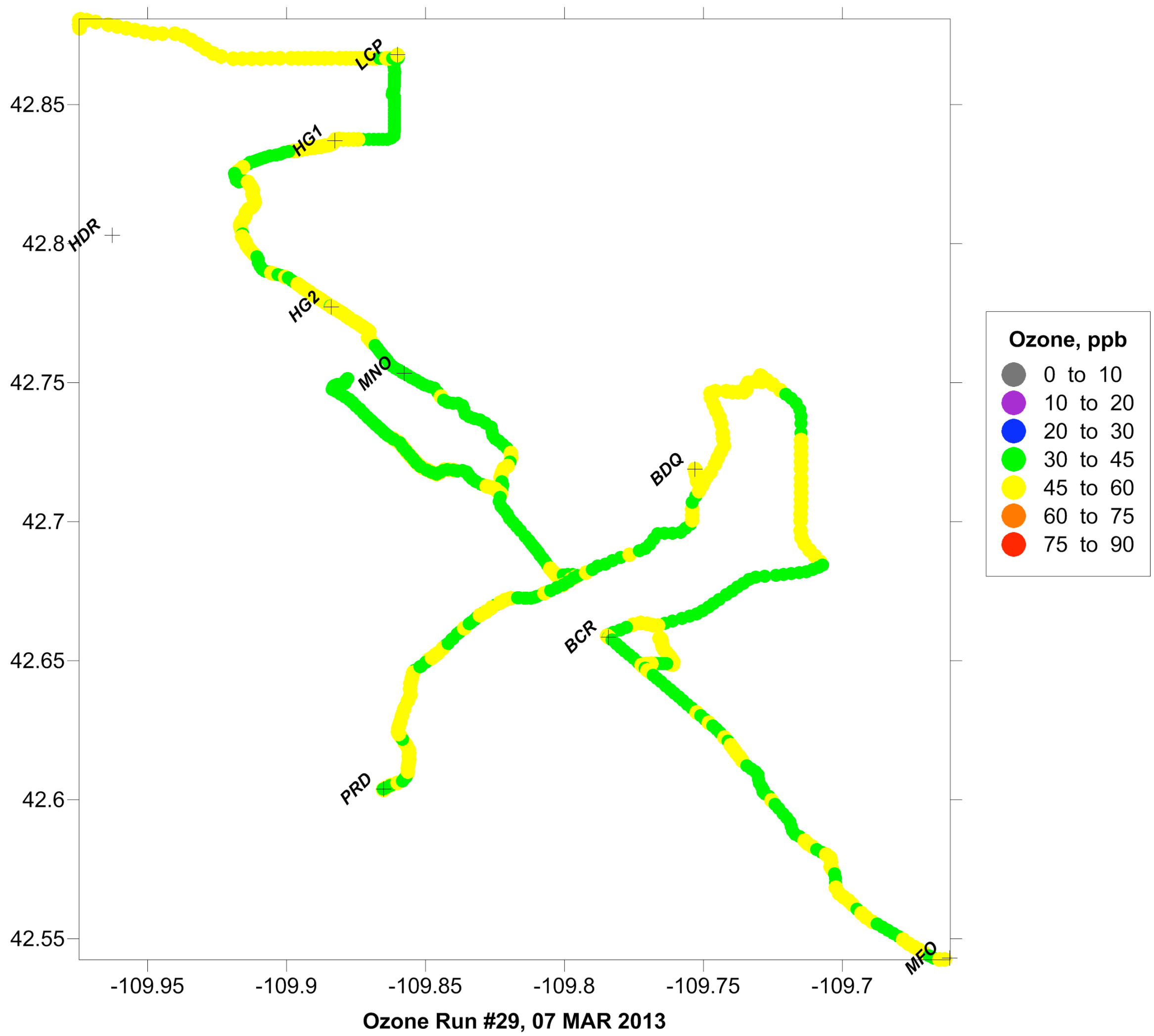

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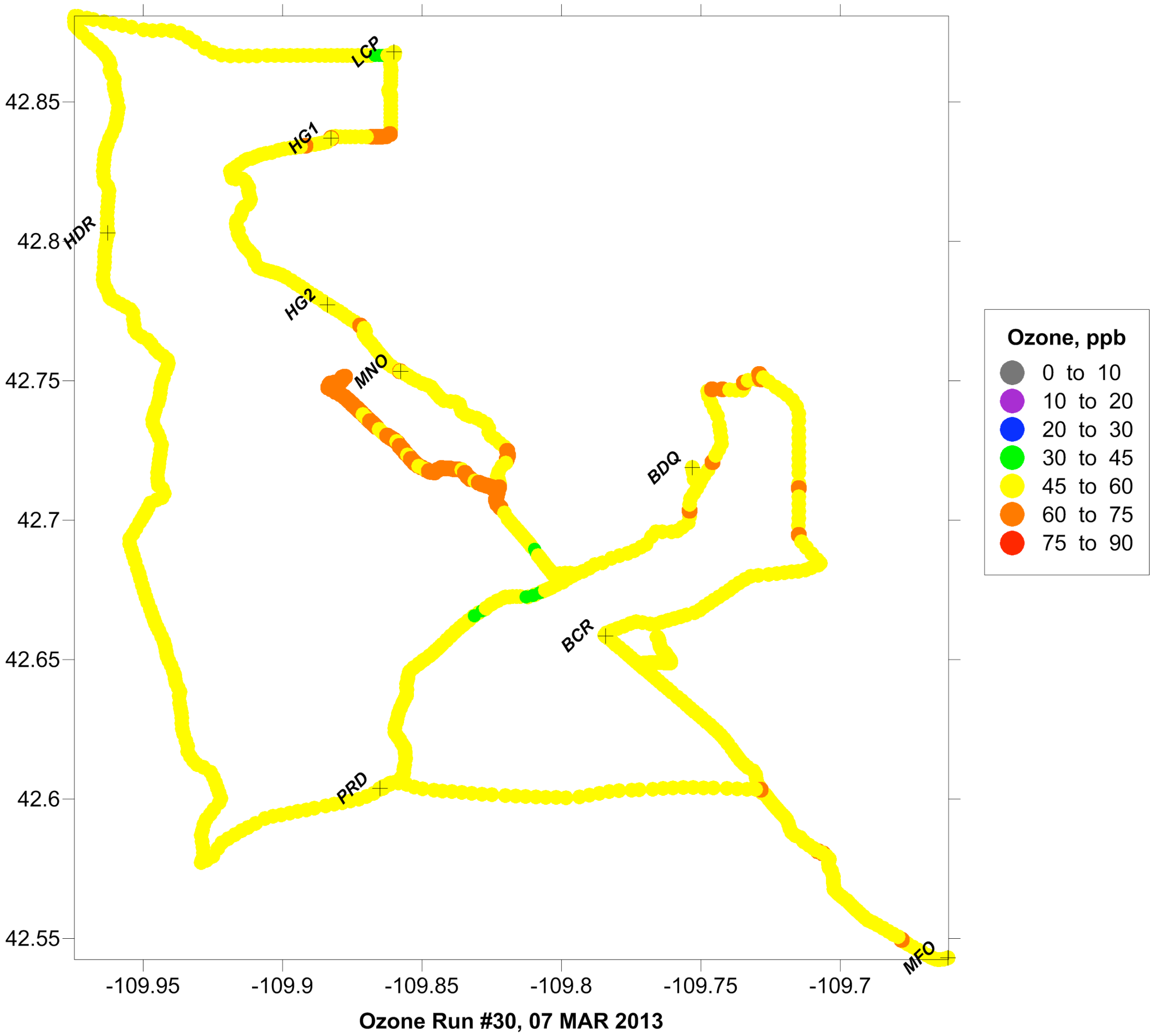

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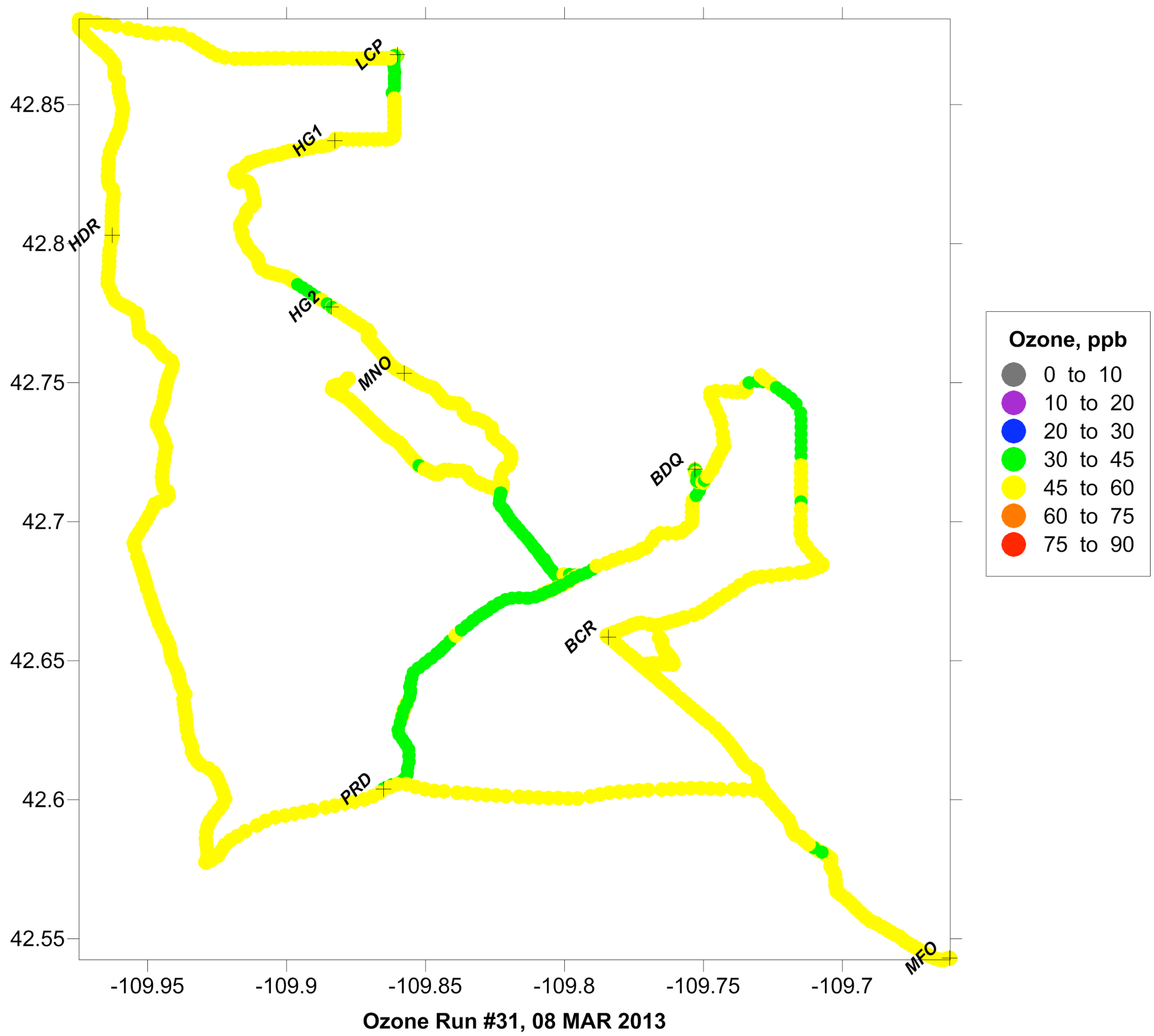

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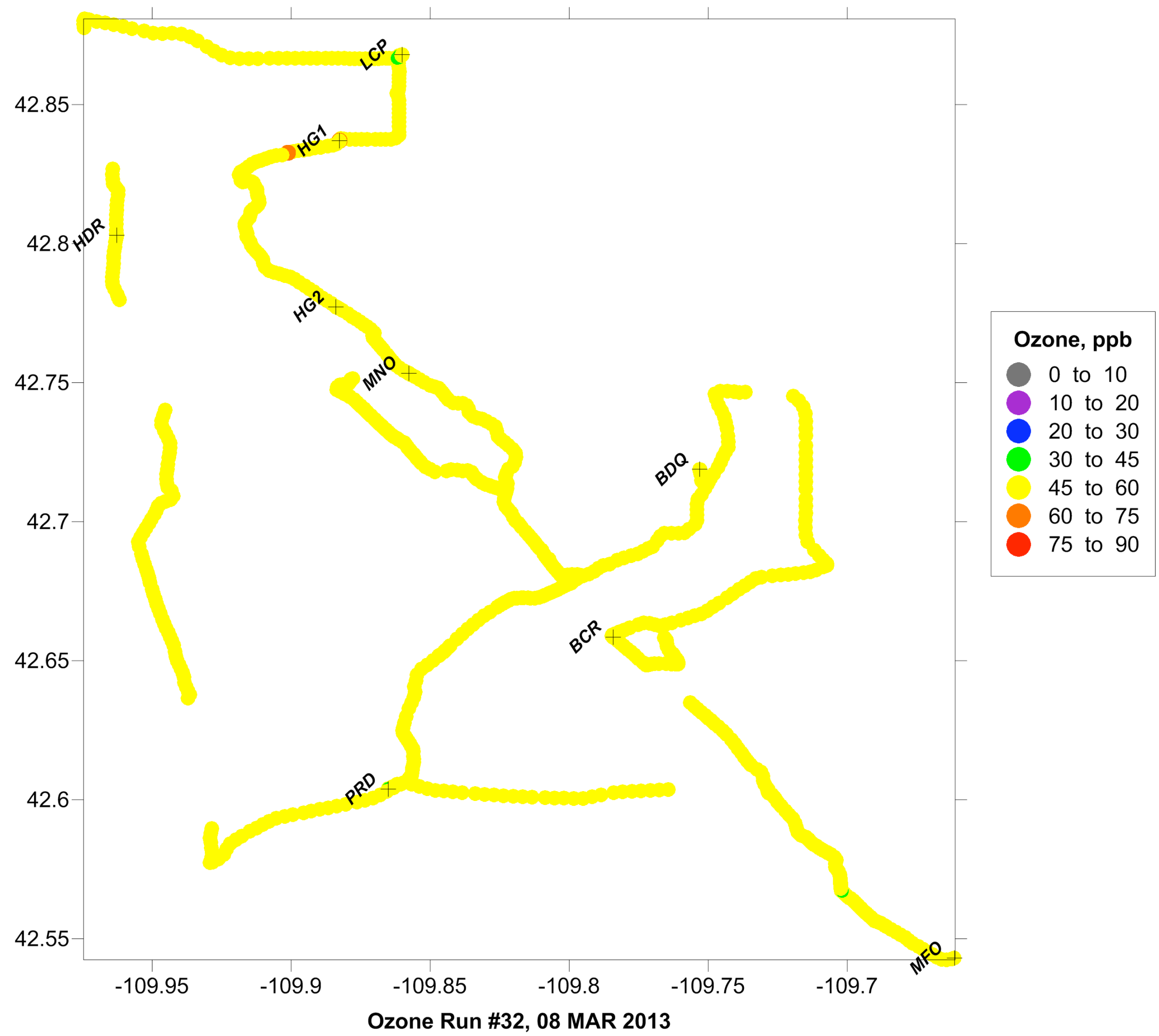
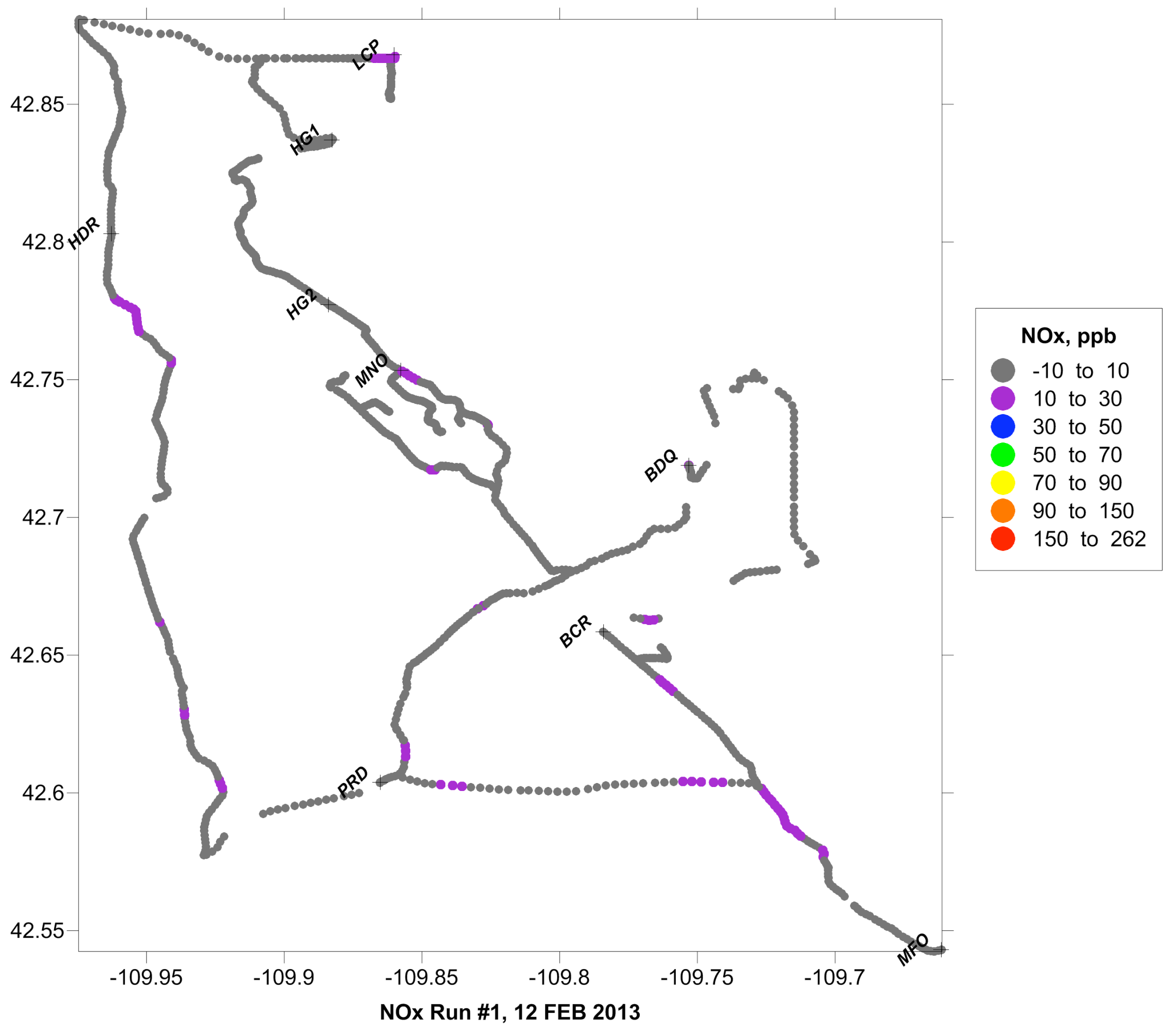


APPENDIX 3: Mobile oxides of nitrogen maps

Circuit 1: 2/12/2013 AM



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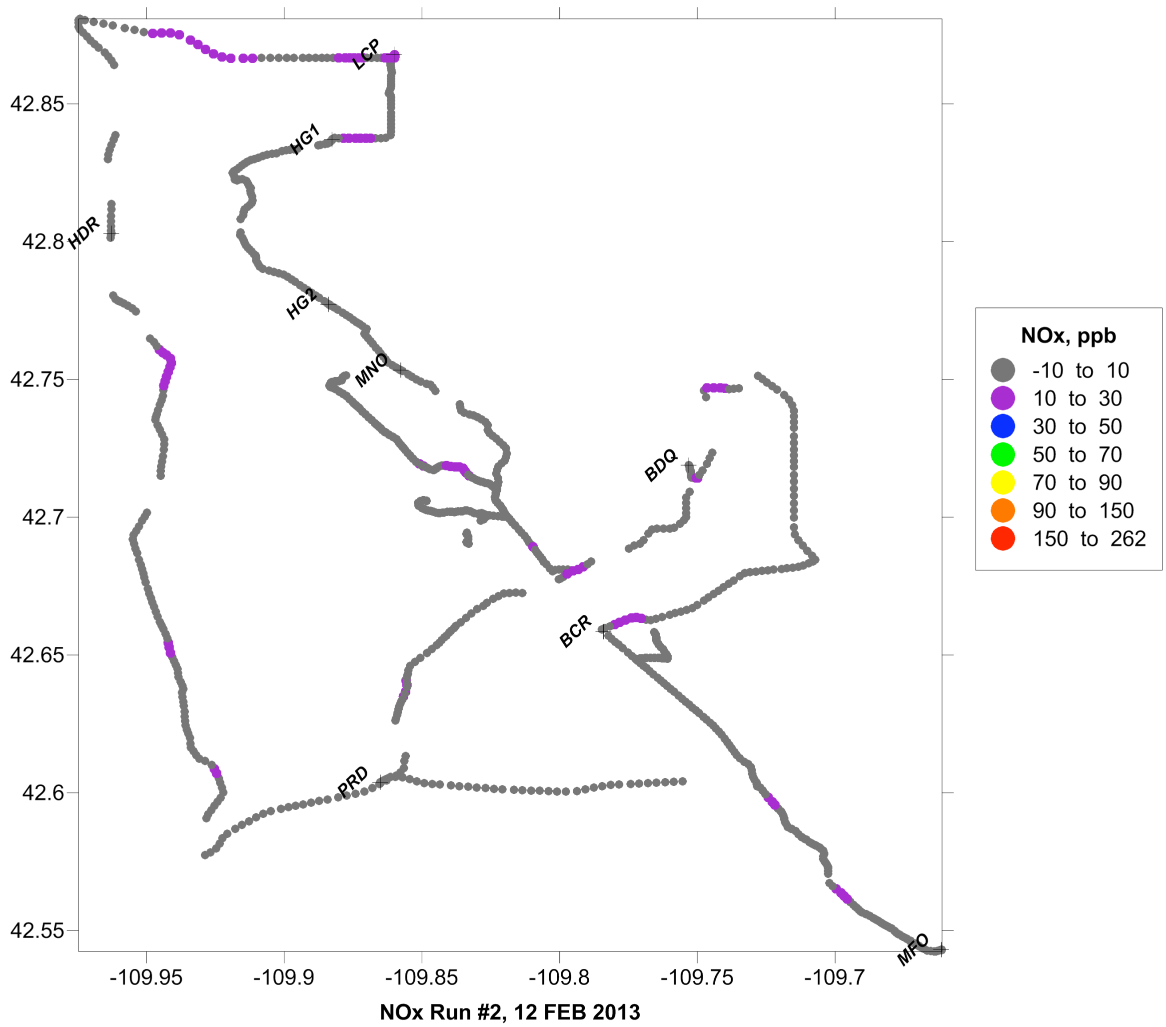

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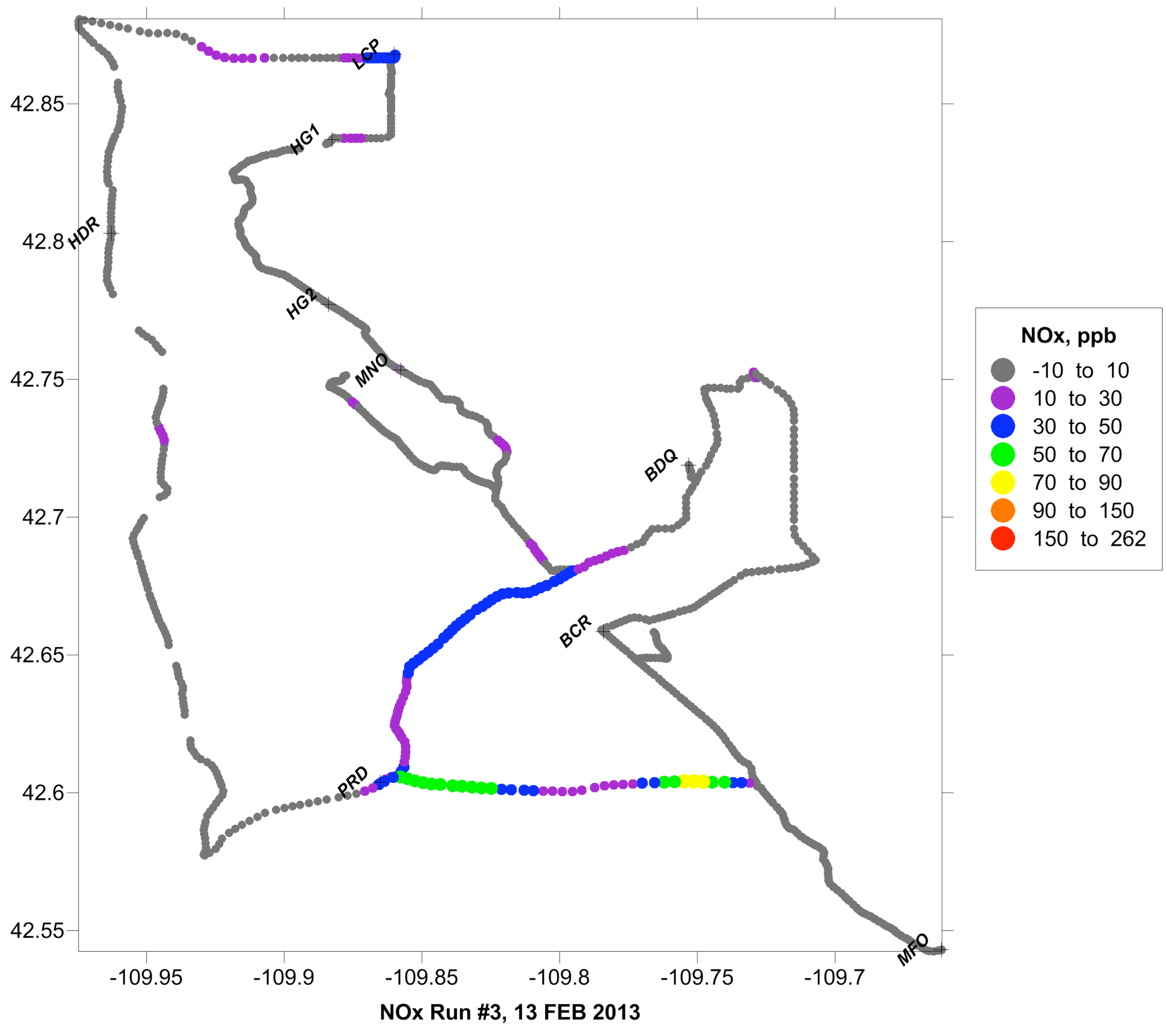
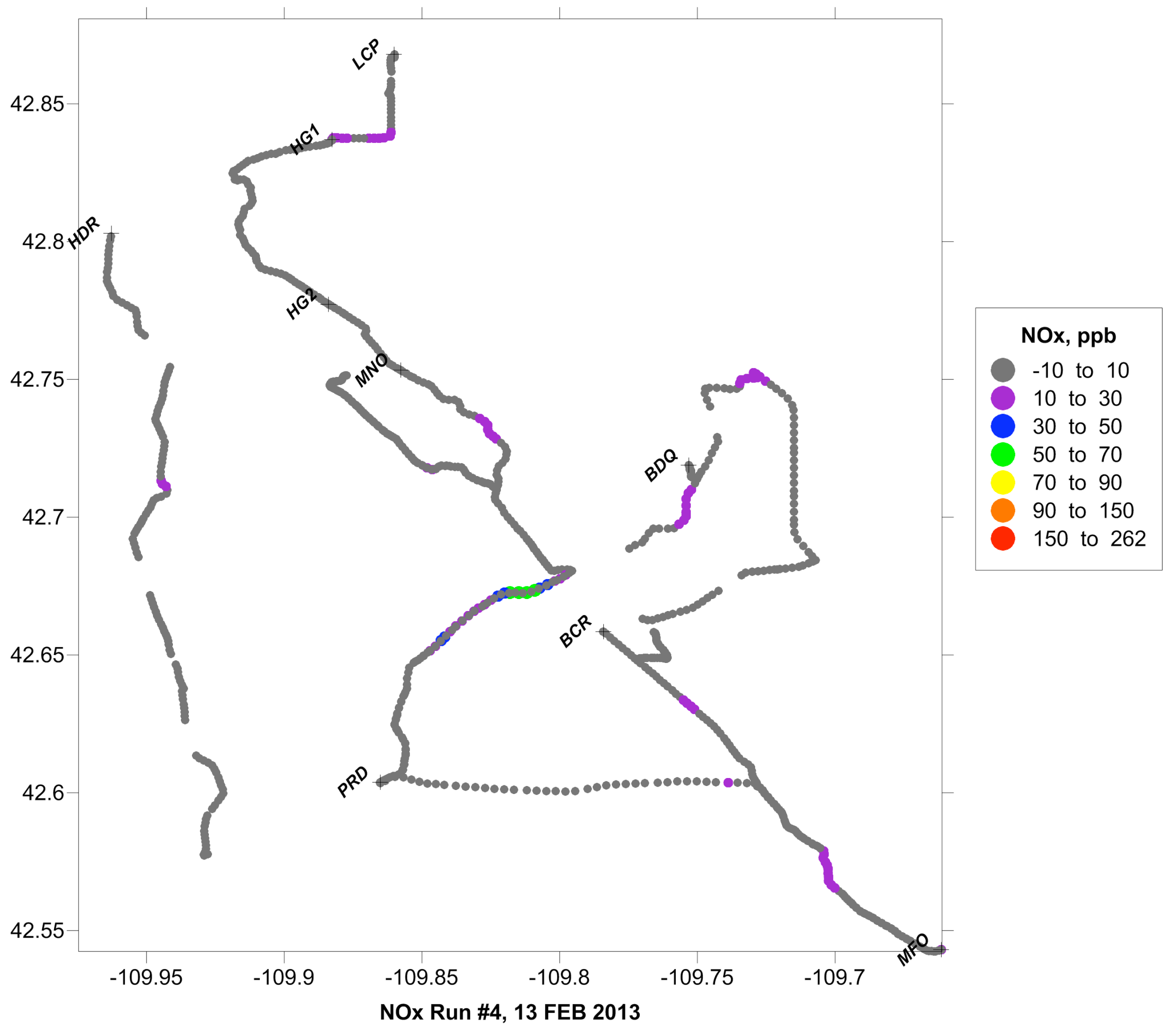


Circuit 4: 2/13/2013 PM



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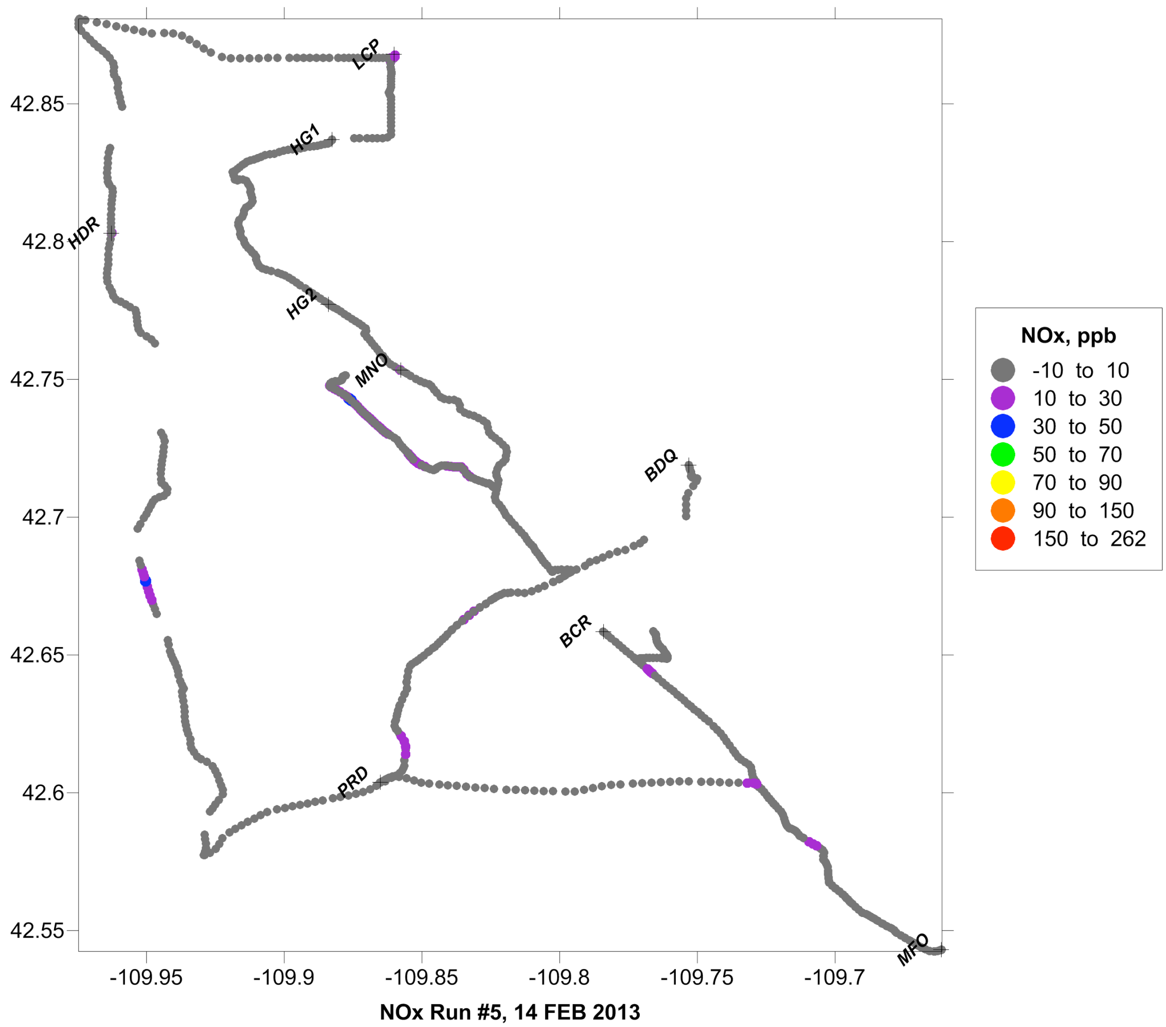

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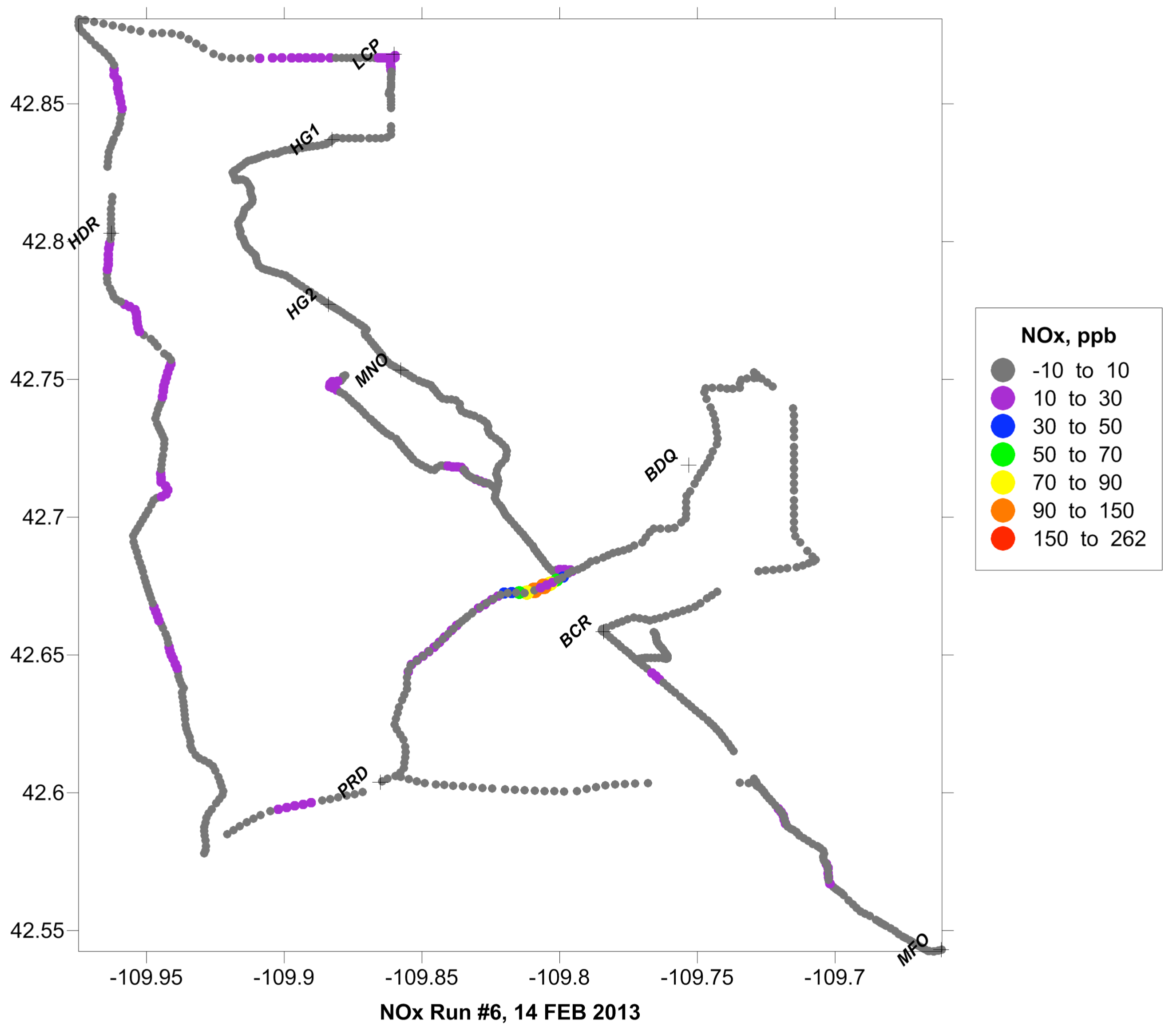

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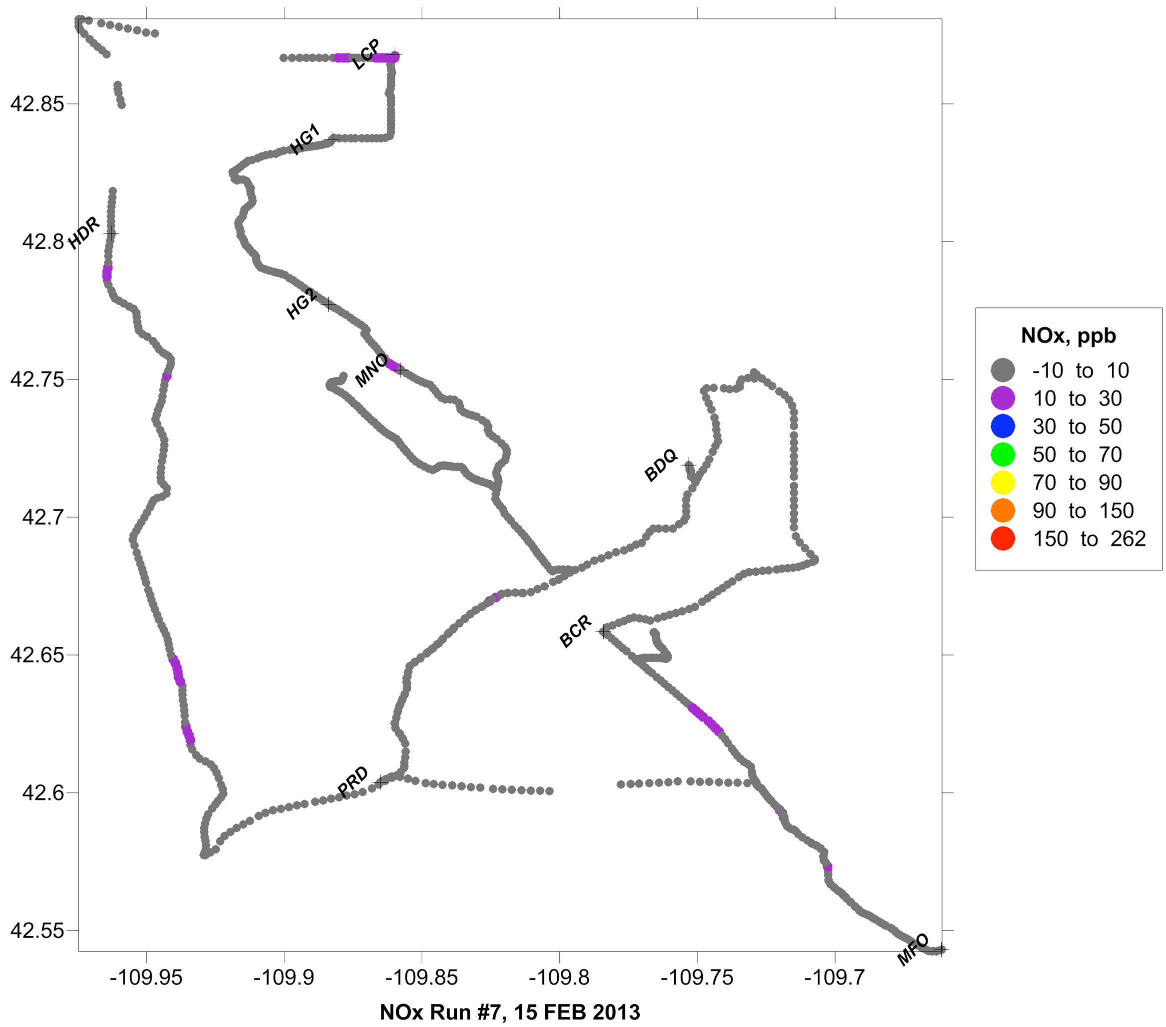
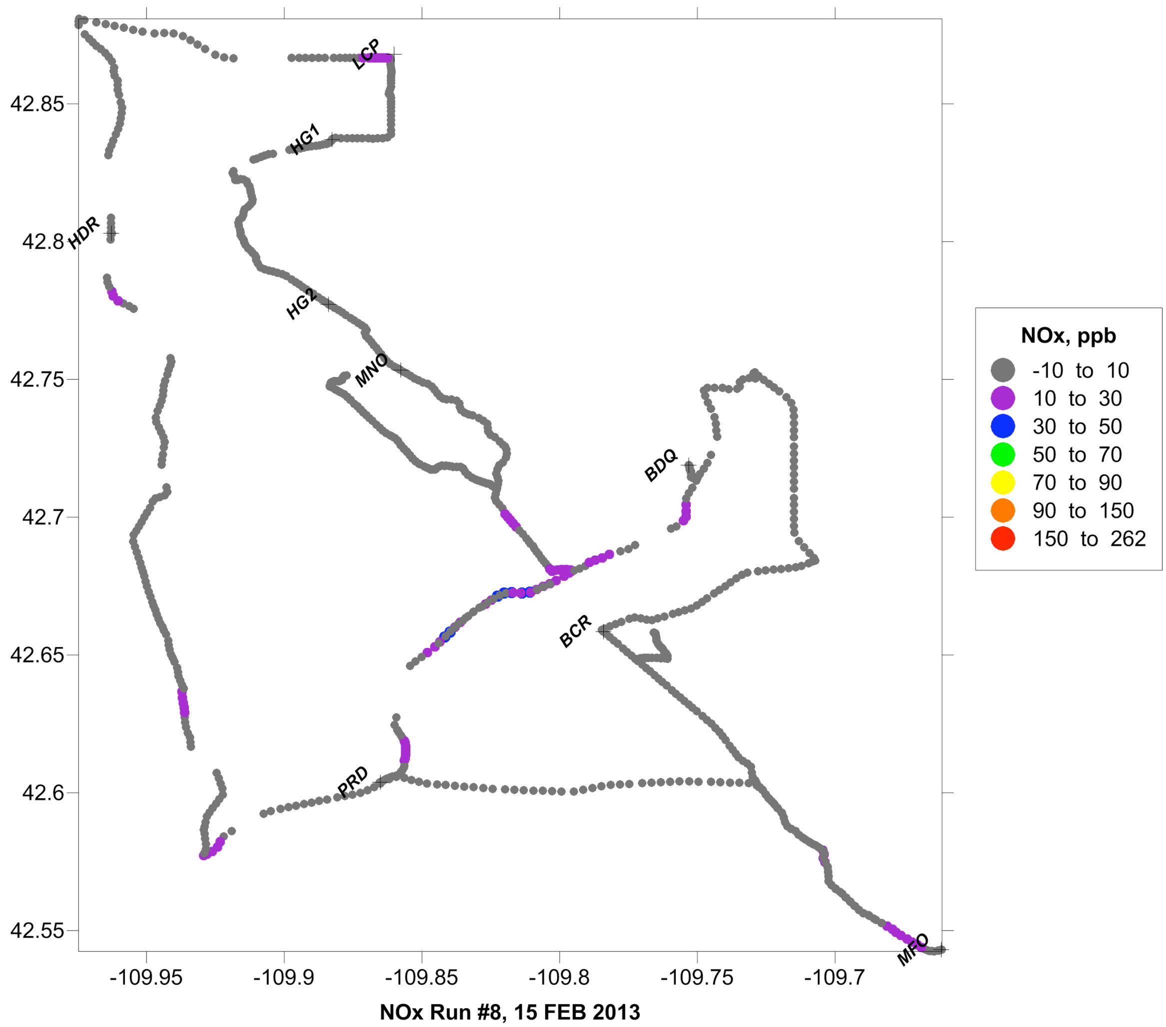
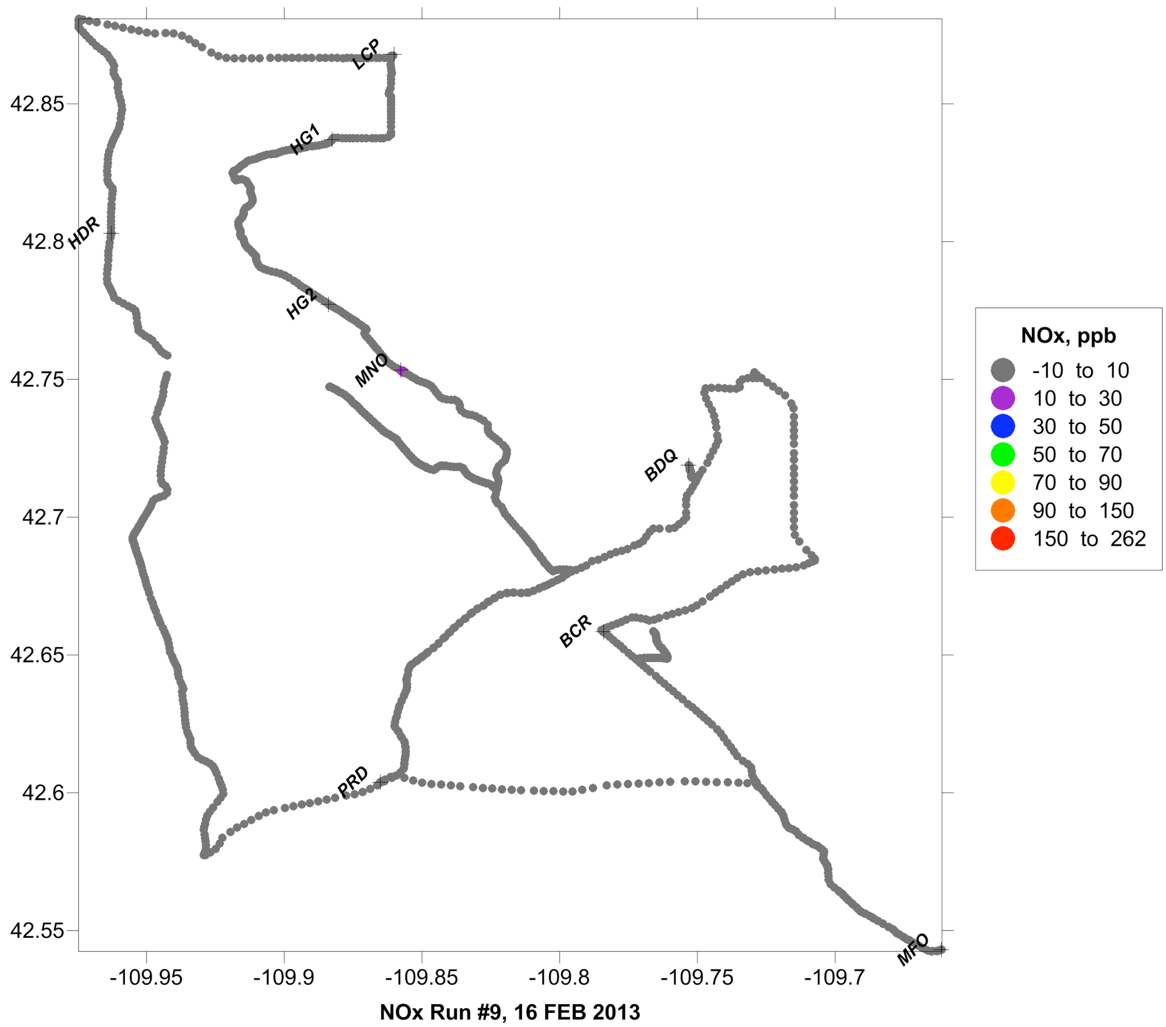


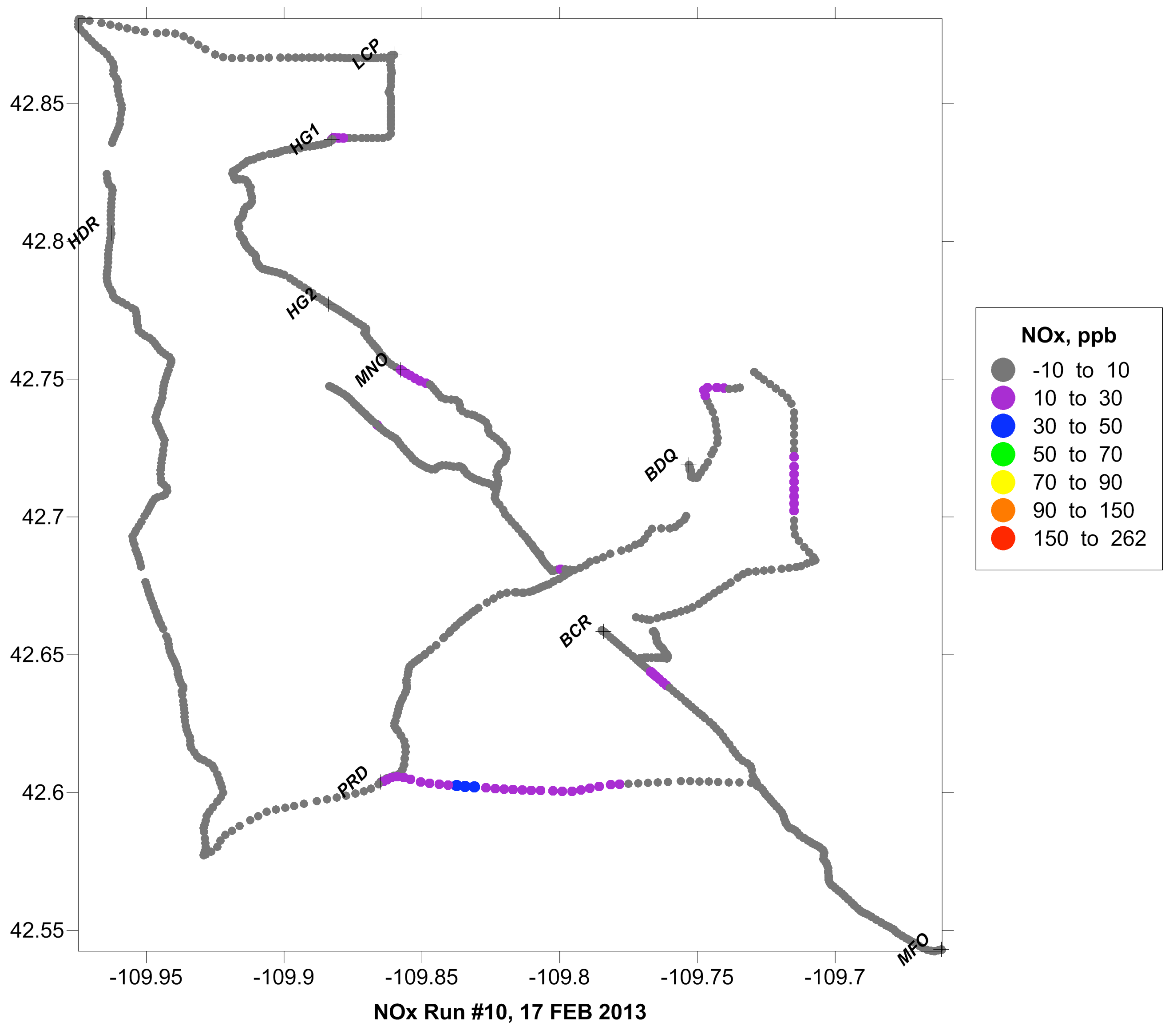
Circuit 8: 2/13/2013 PM



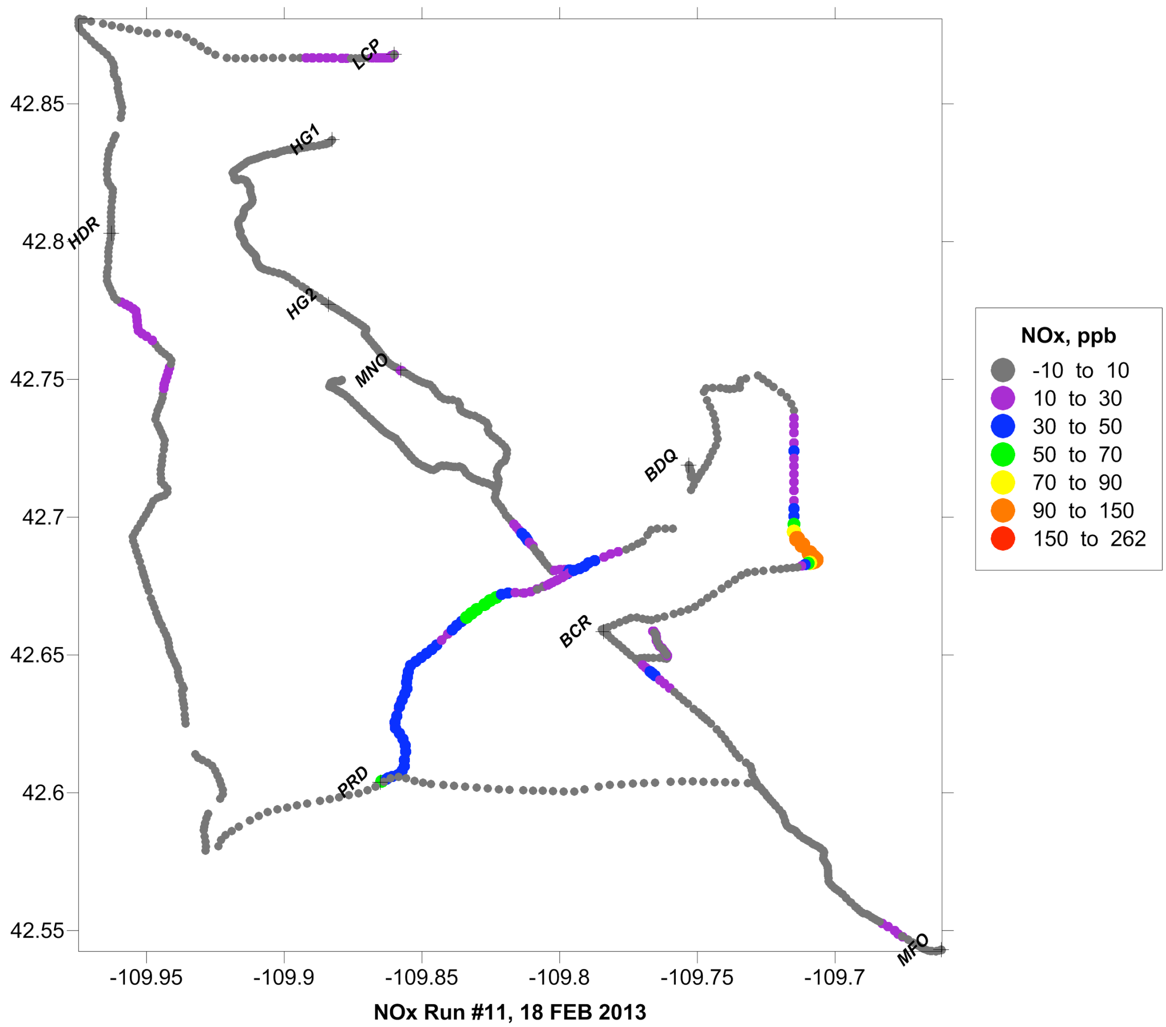
Circuit 9: 2/16/2013 PM



Circuit 10: 2/17/2013 PM



Circuit 11: 2/18/2013 AM



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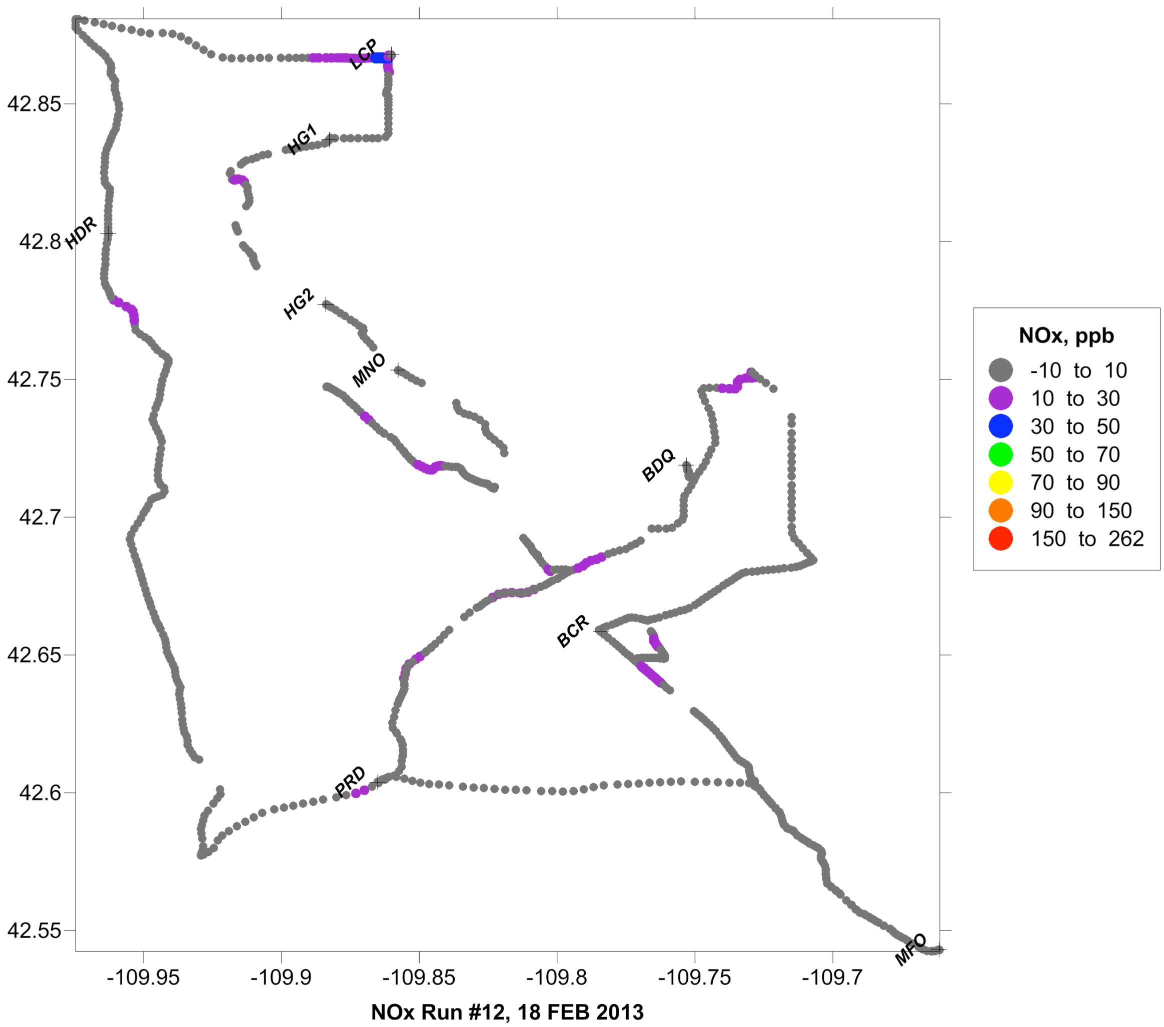

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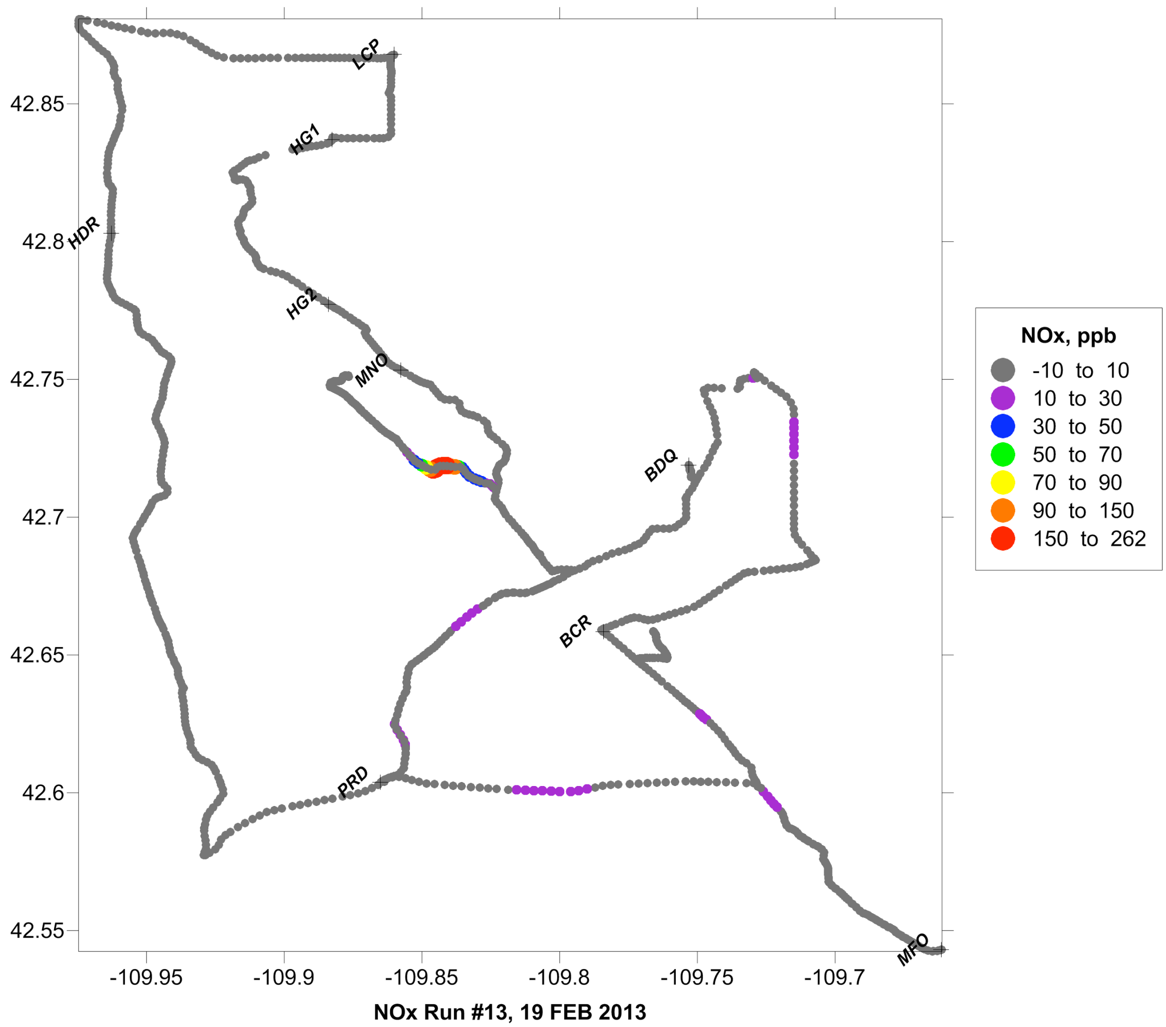

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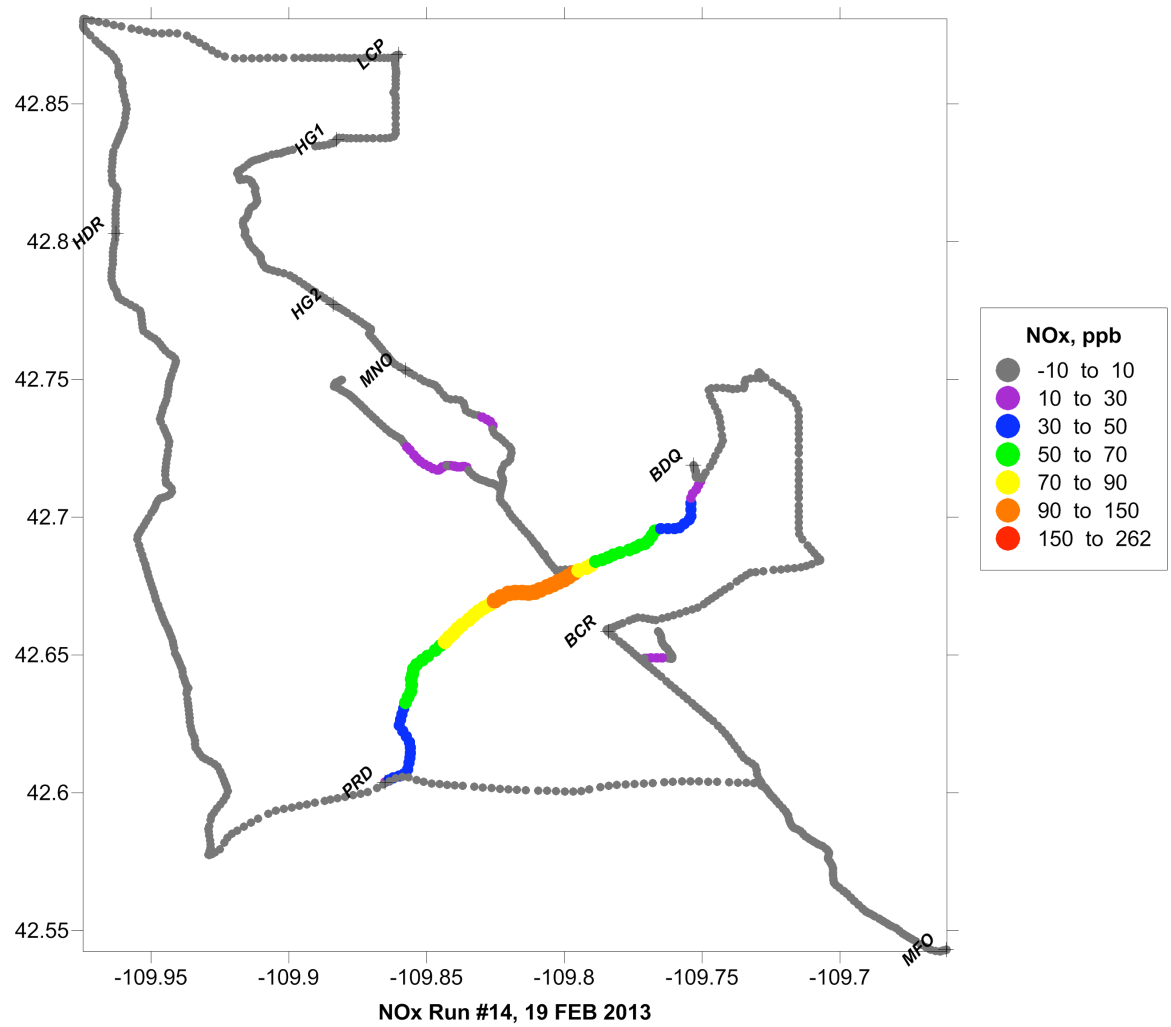

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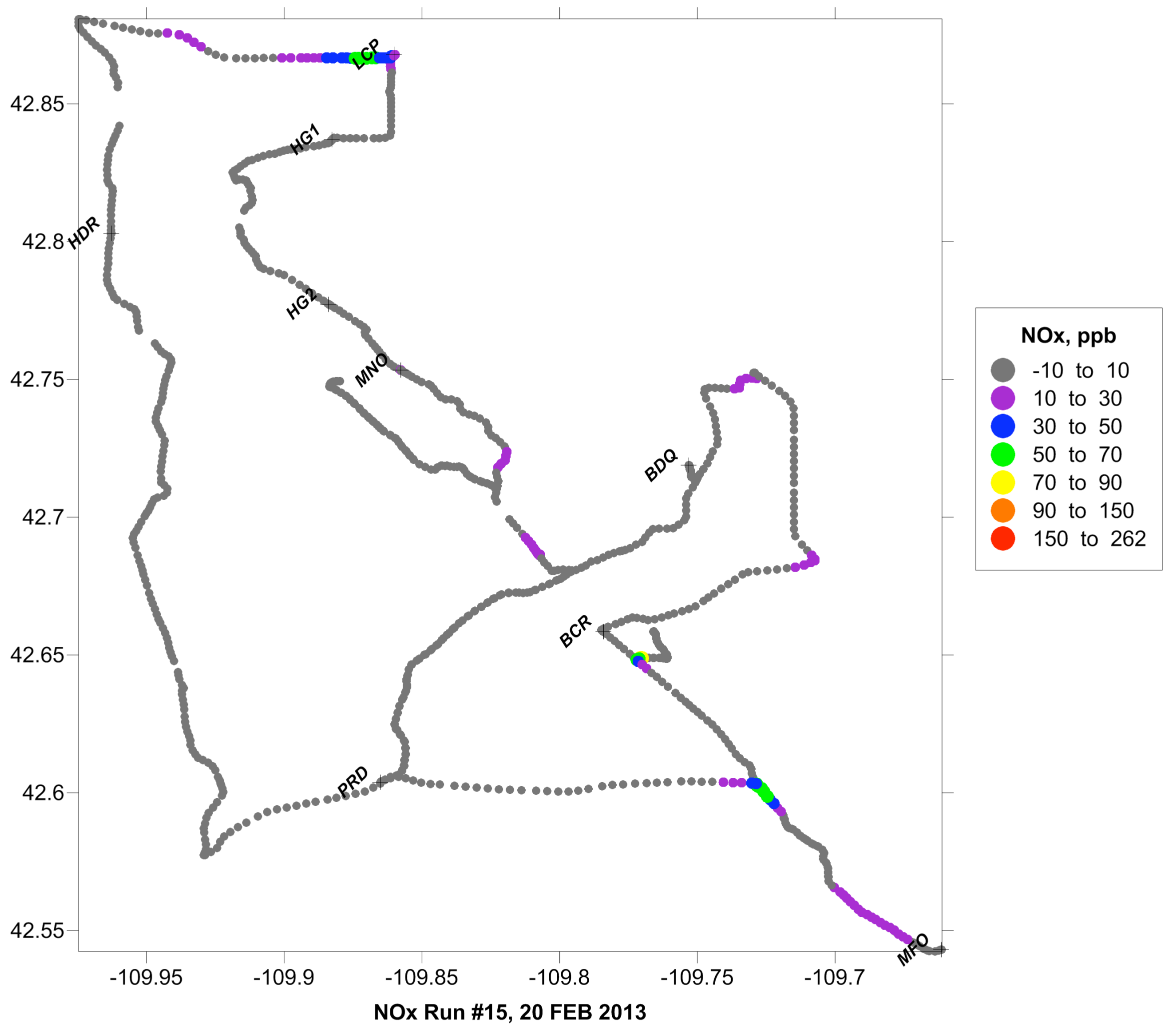

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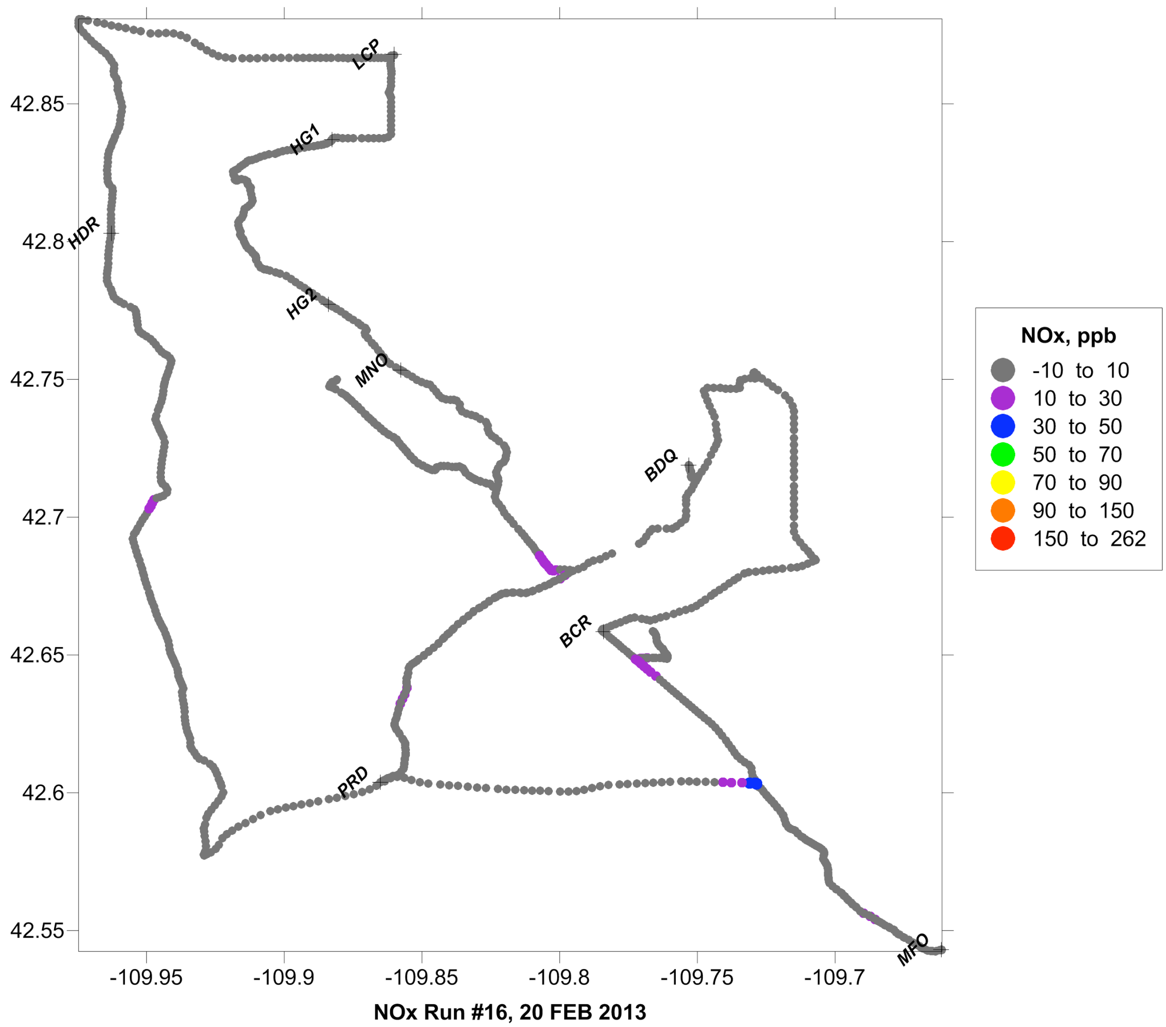
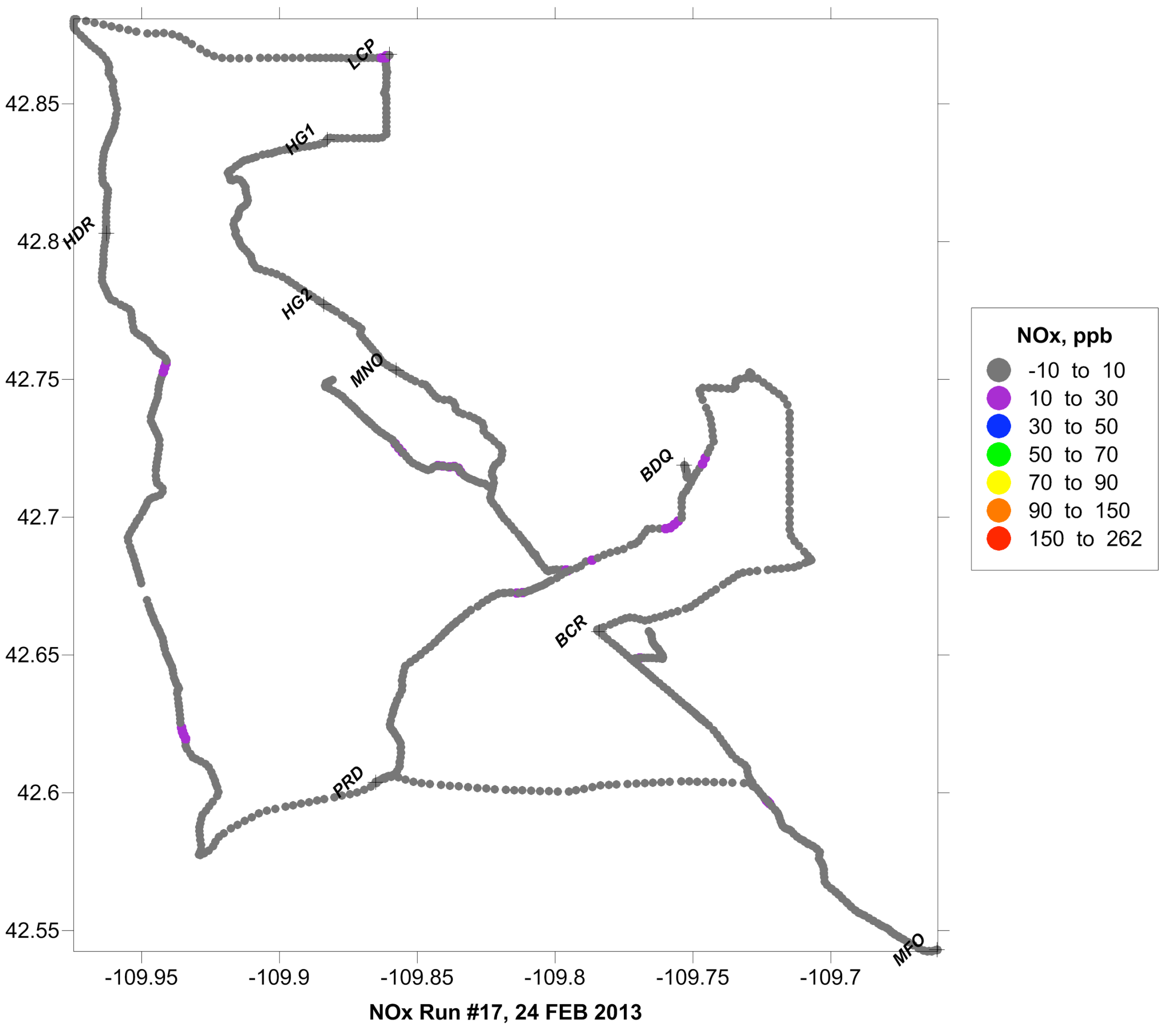
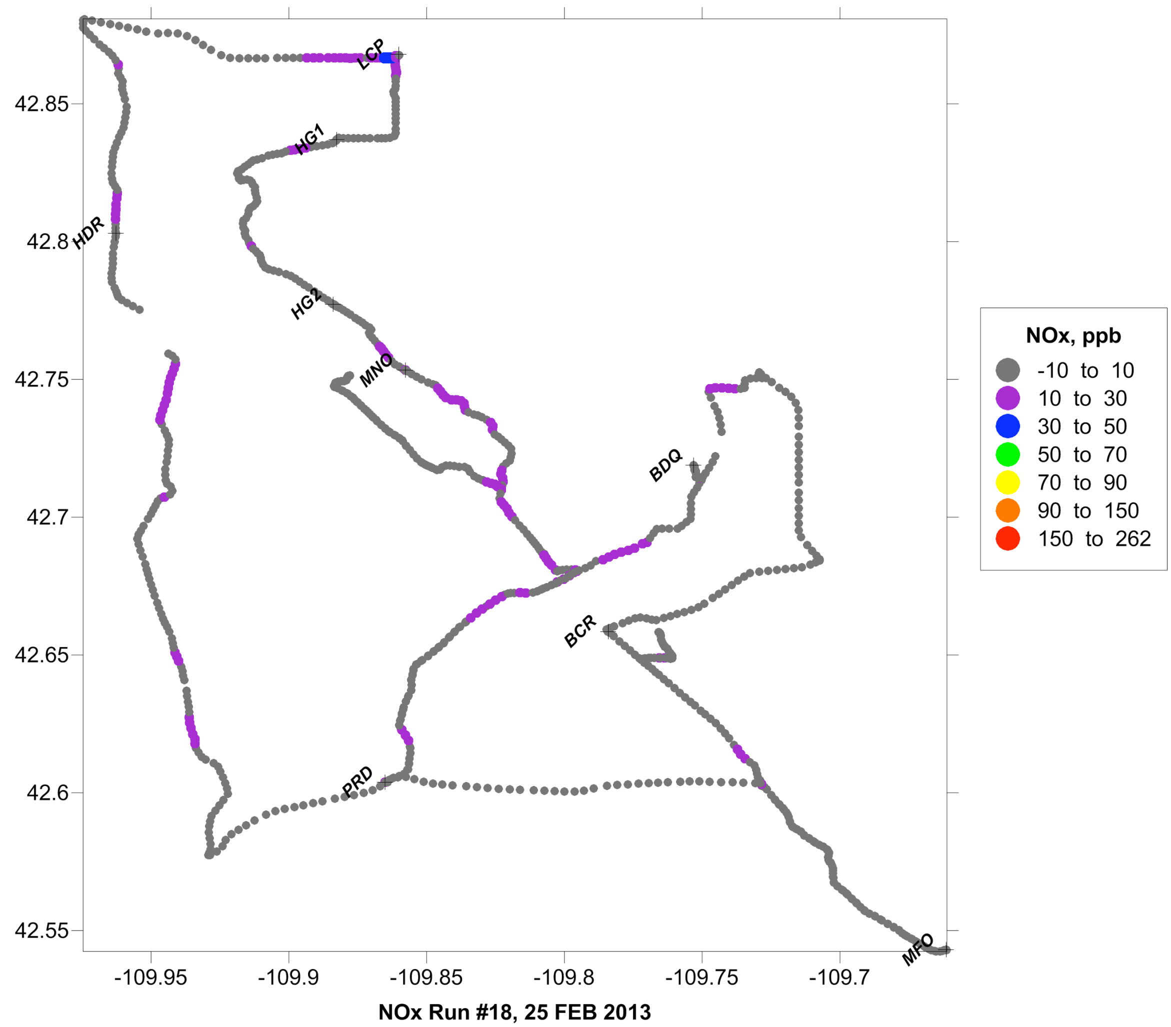


Circuit 17: 2/24/2013 EV



Circuit 18: 2/25/2013 AM



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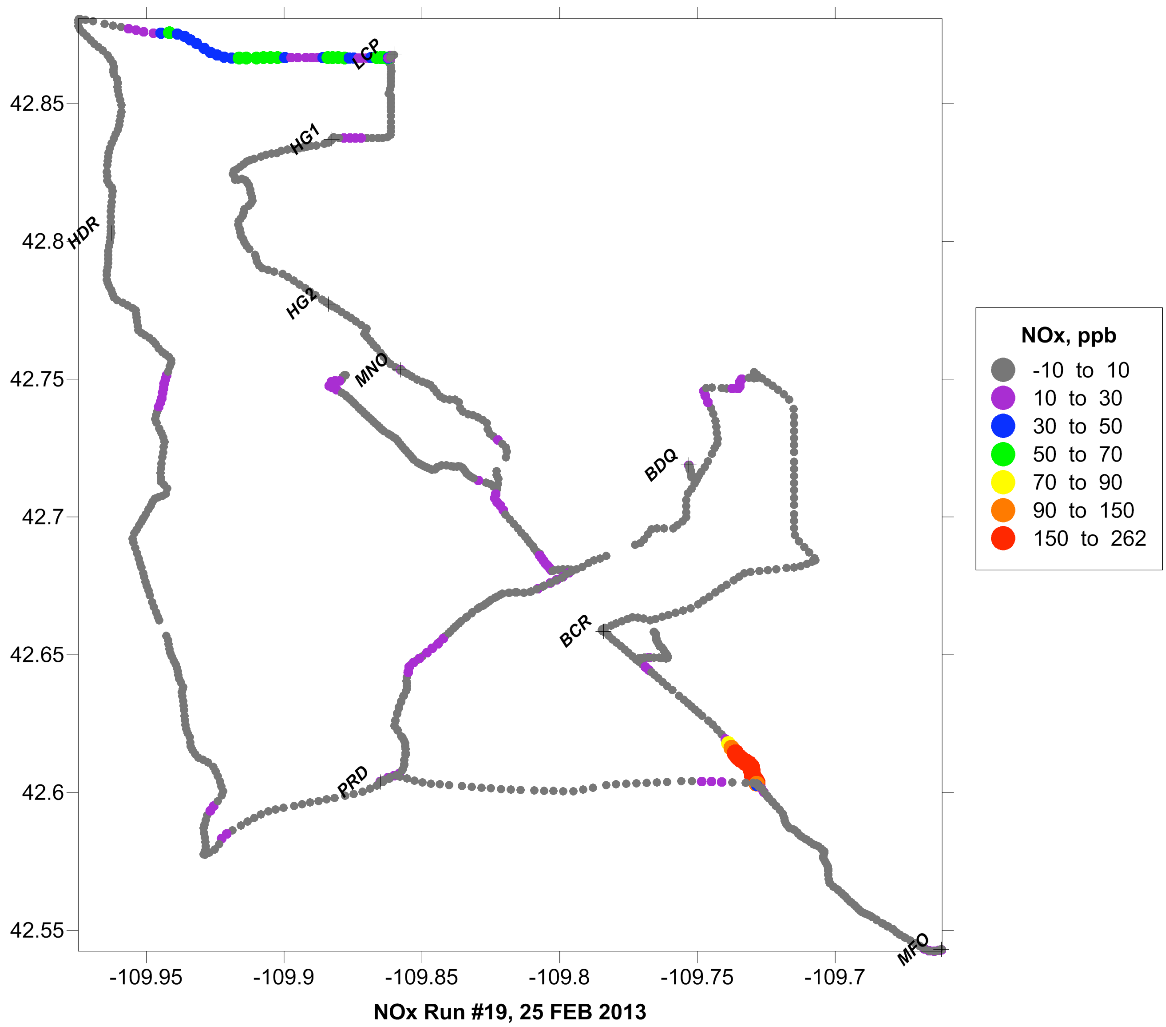
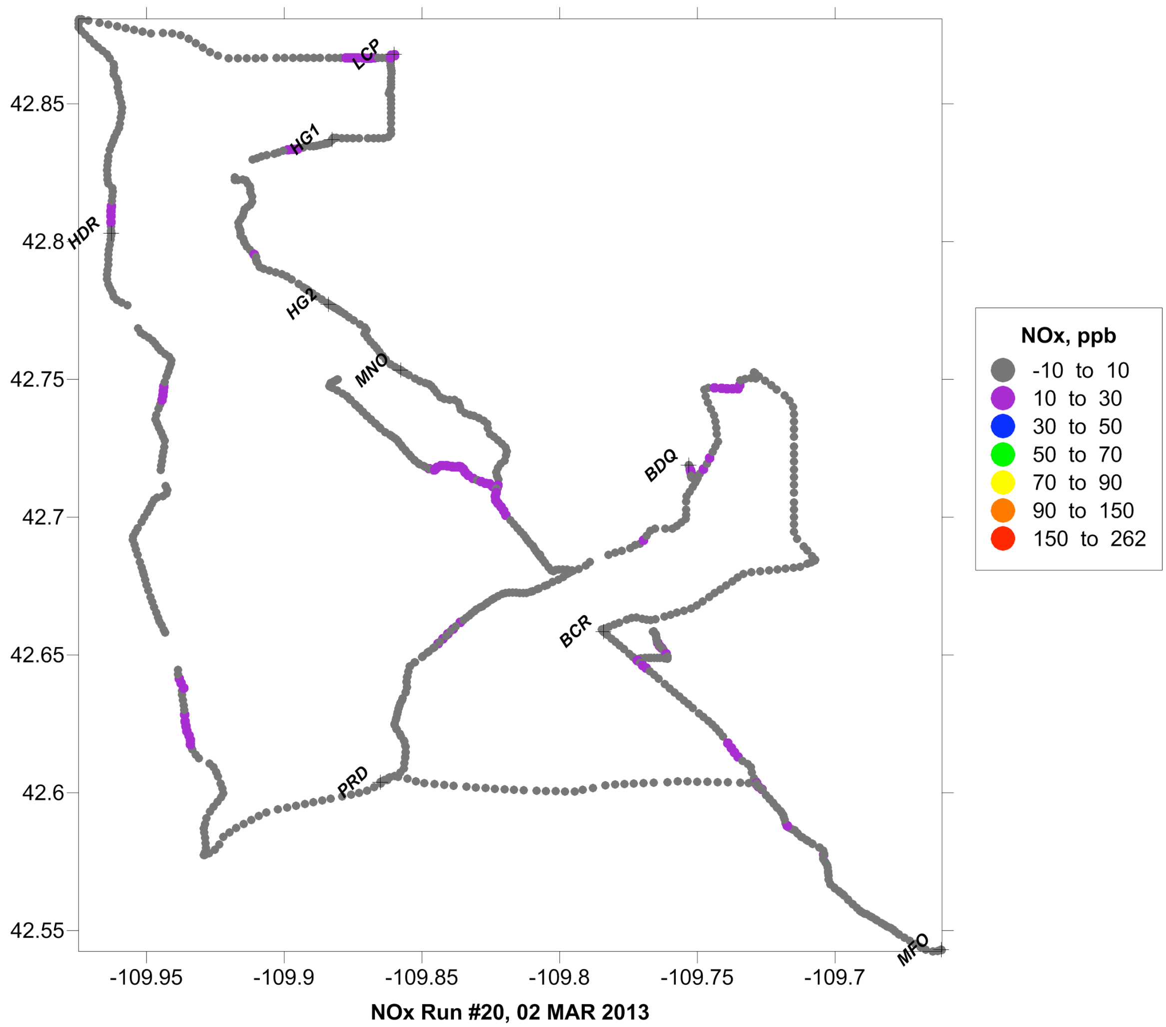
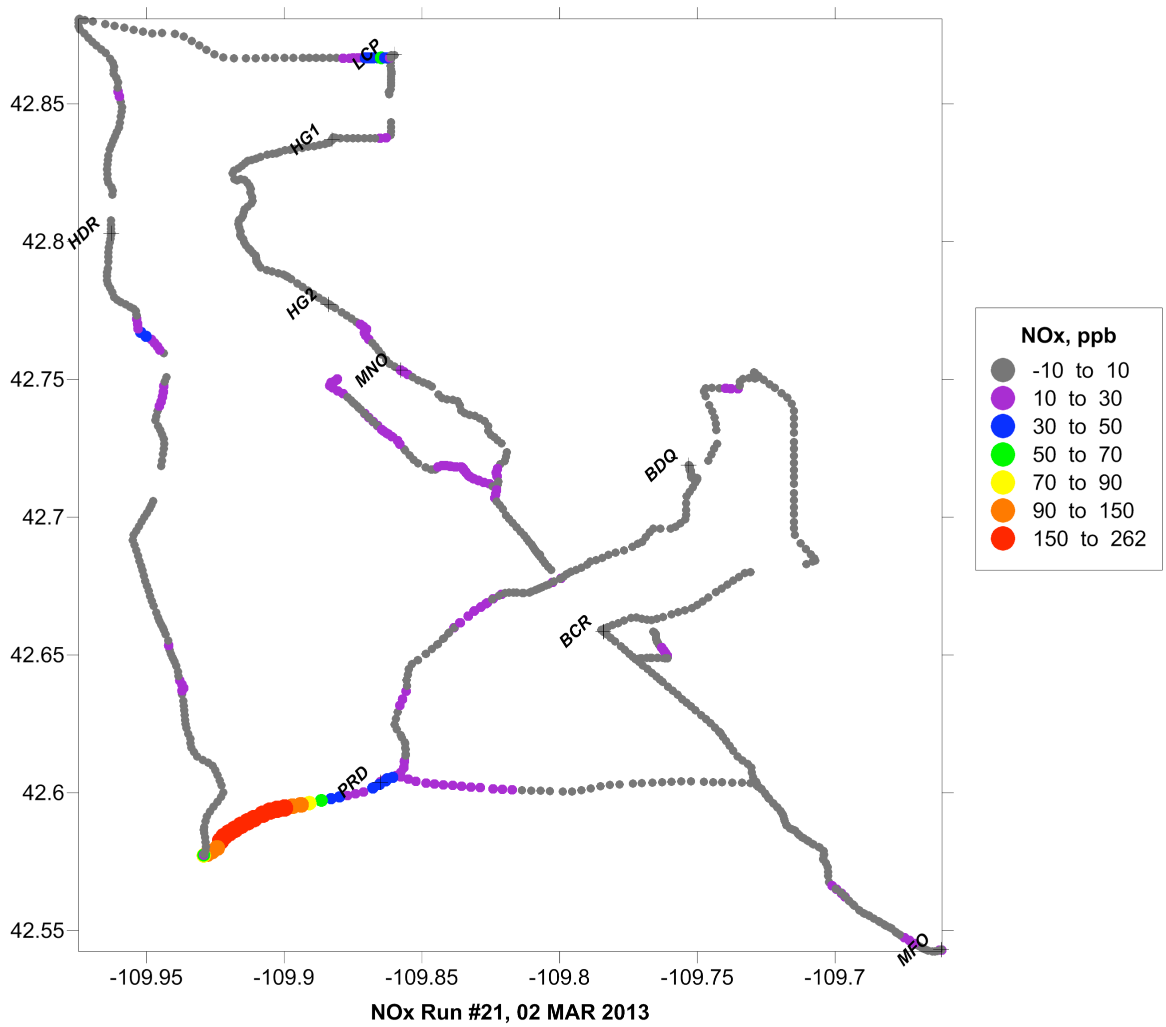


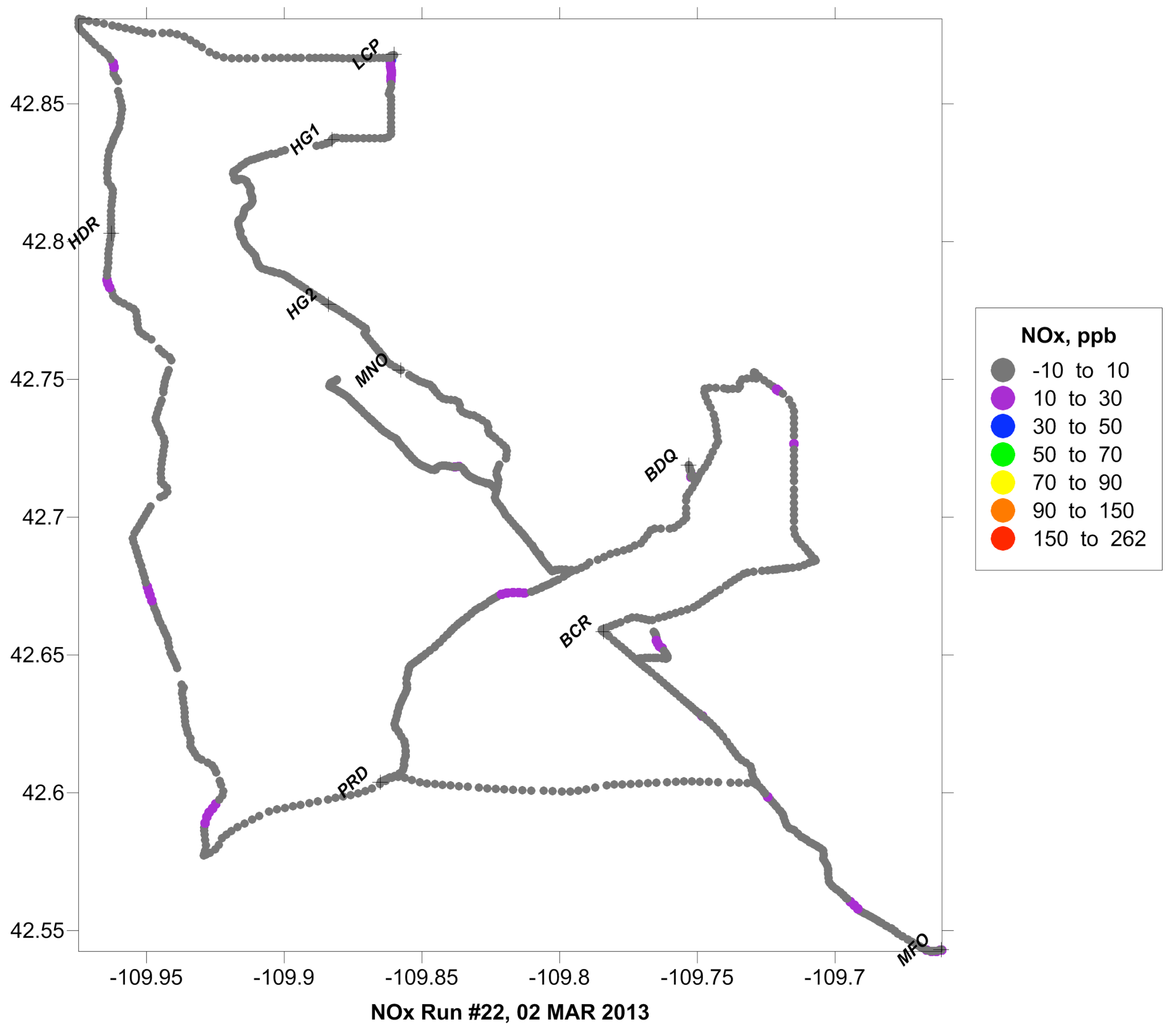
Circuit 20: 3/2/2013 AM



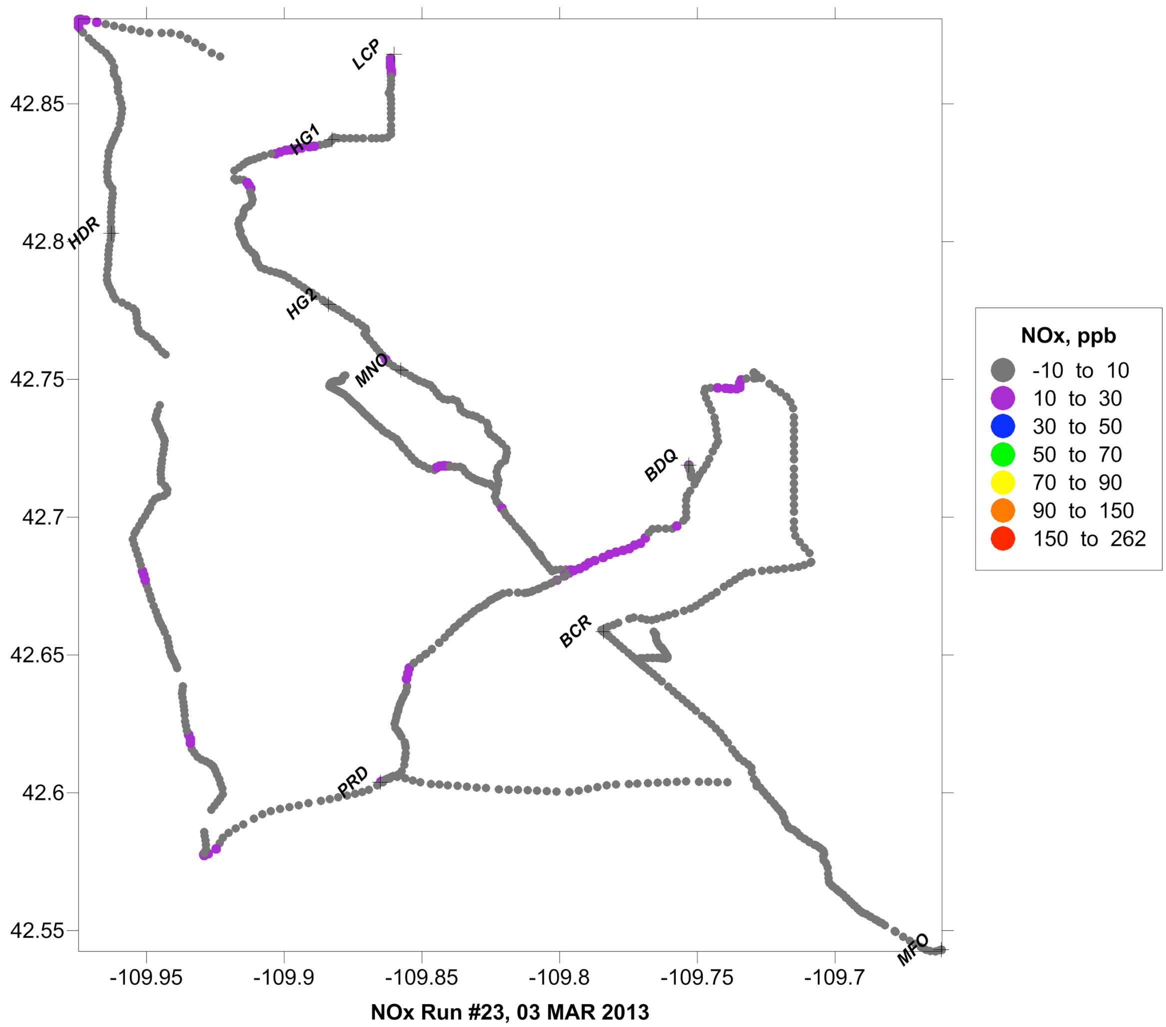
Circuit 21: 3/2/2013 PM



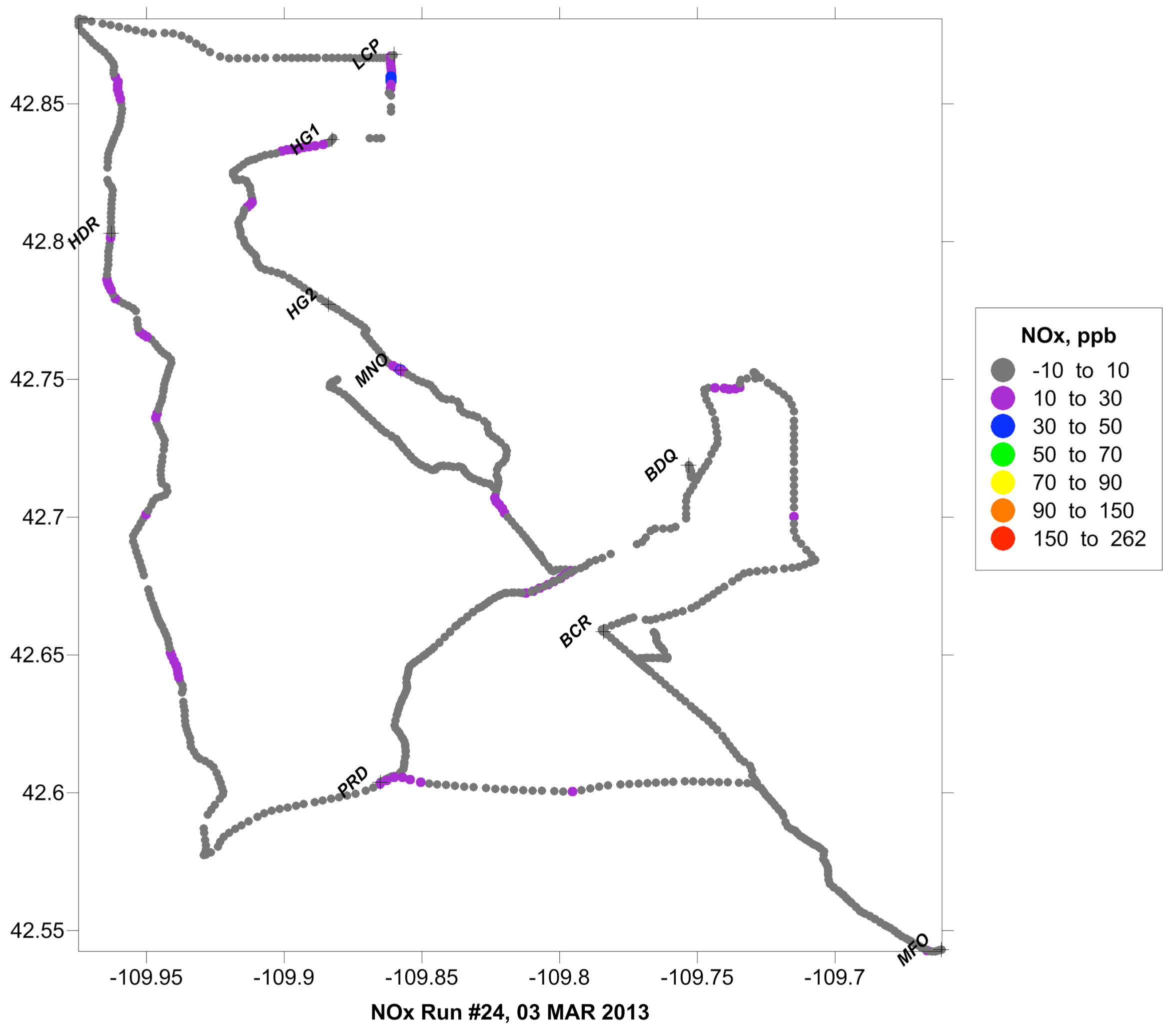
Circuit 22: 3/2/2013 EV



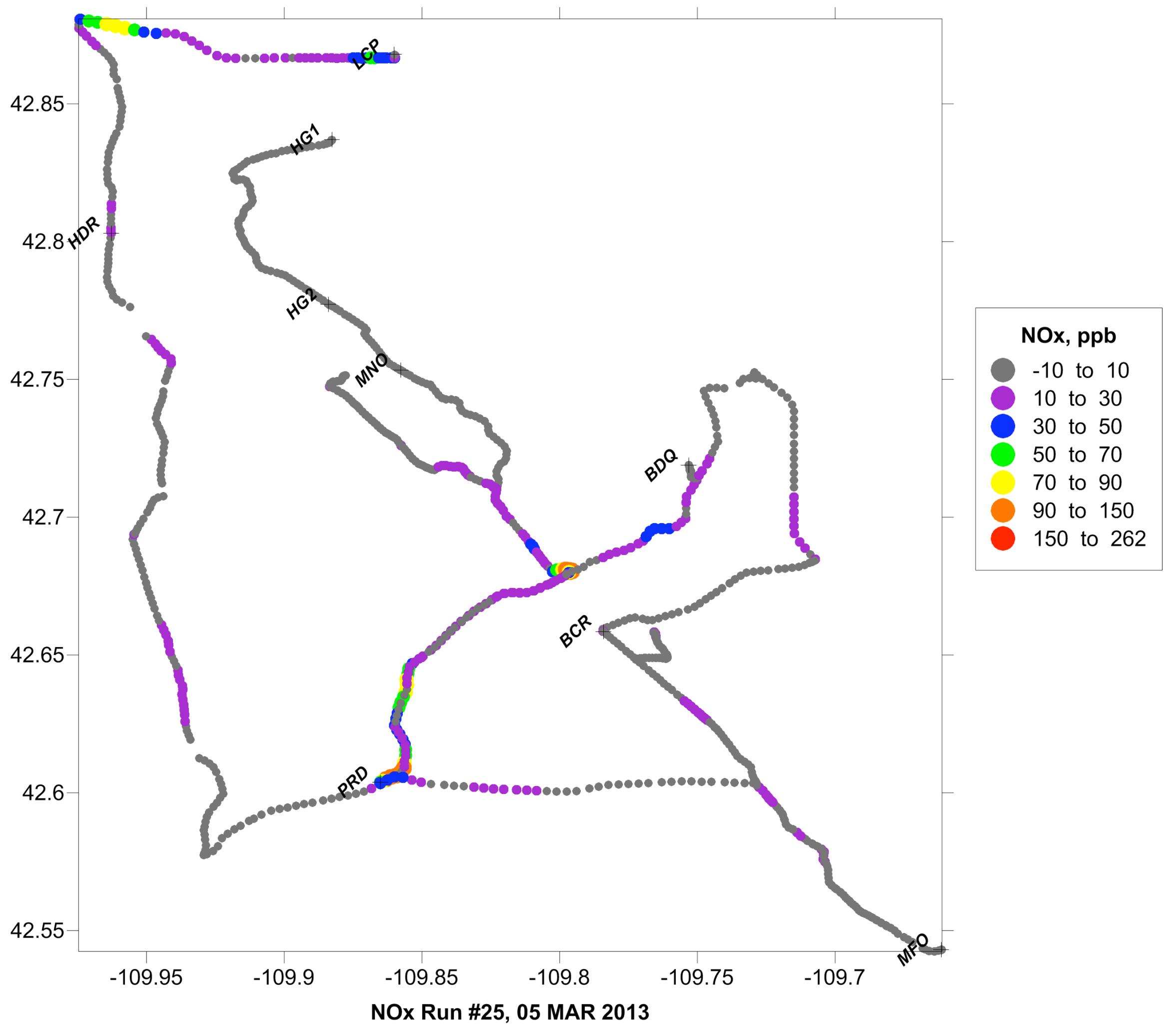
Circuit 23: 3/3/2013 AM



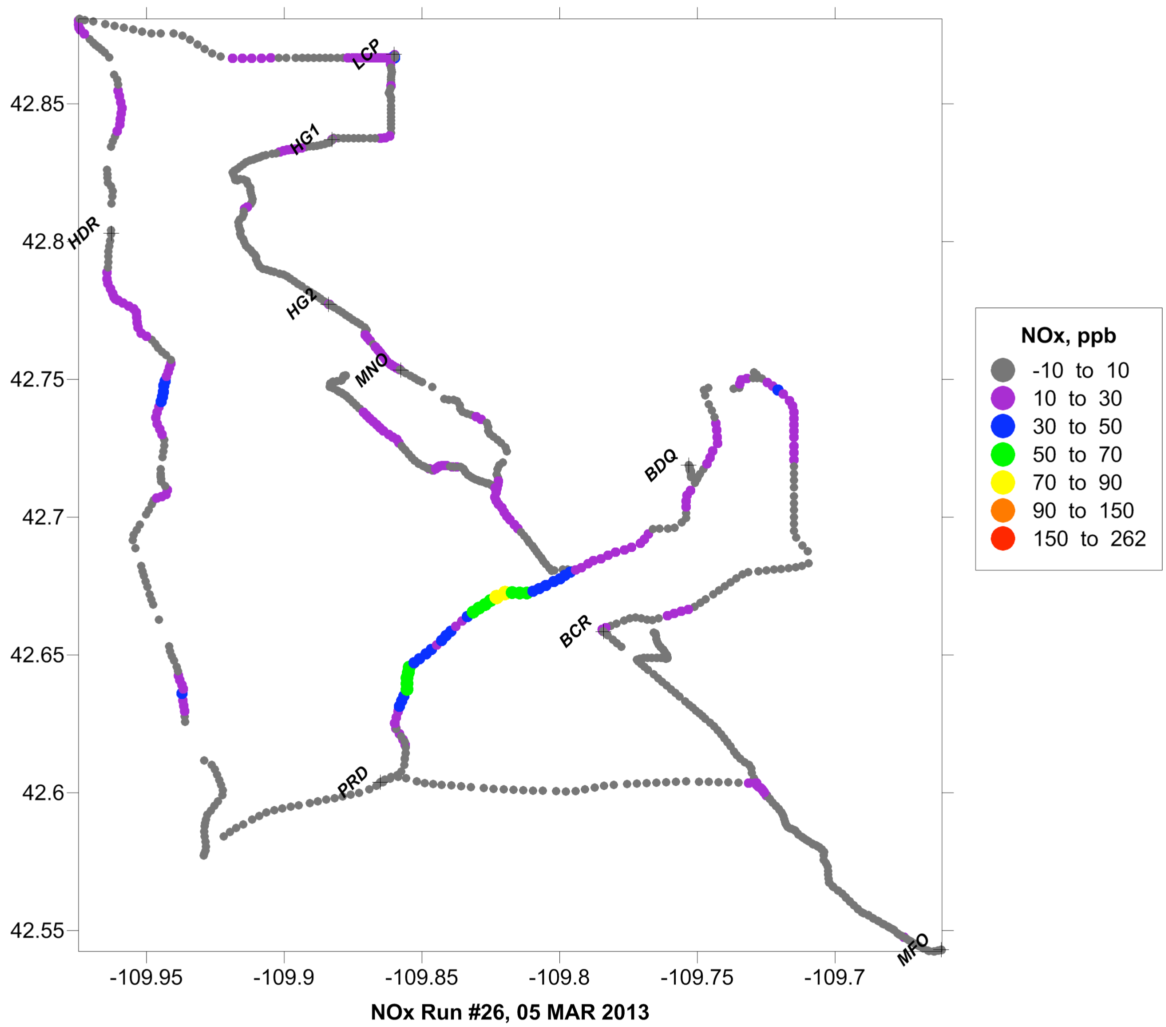
Circuit 24: 3/3/2013 PM



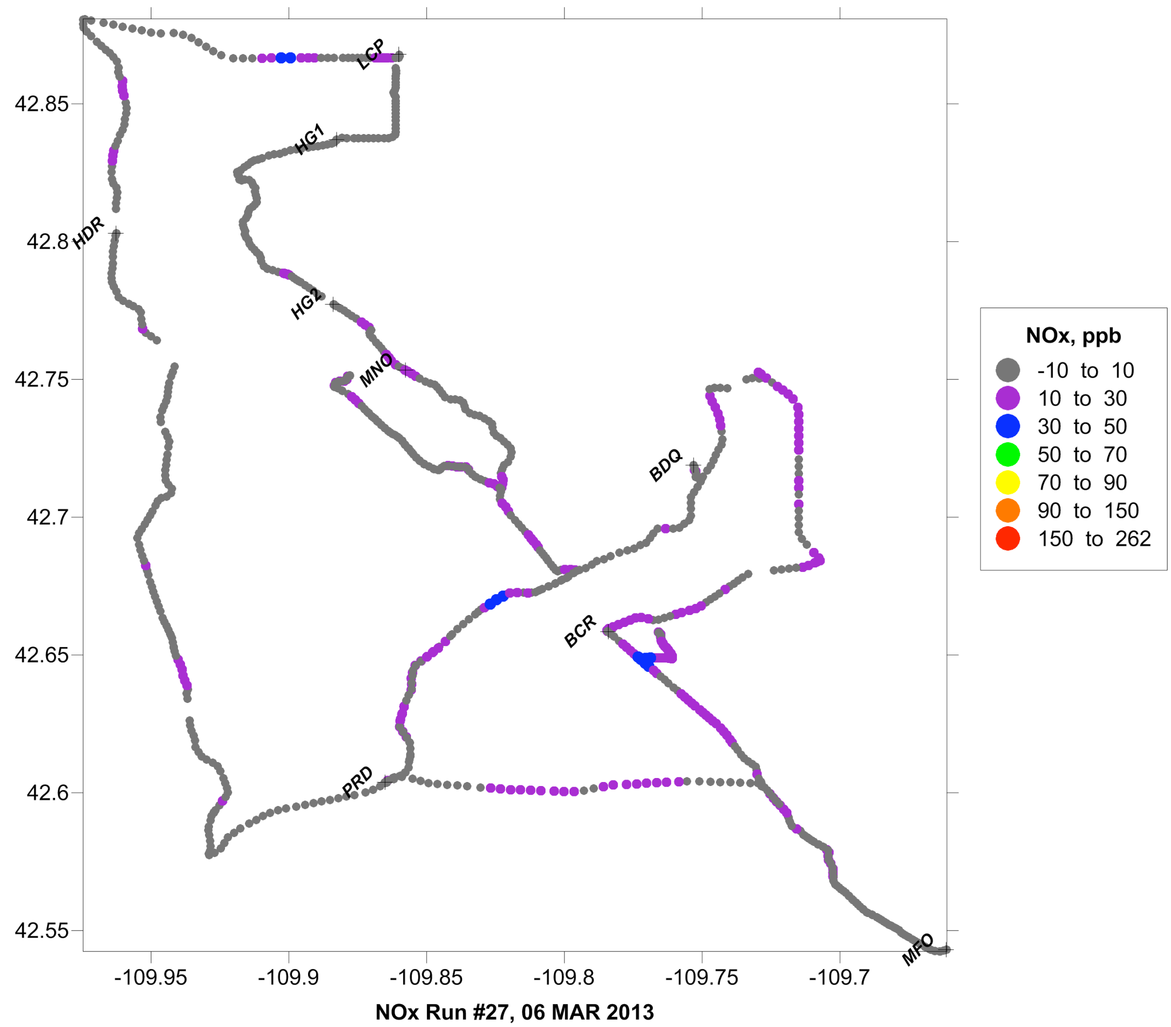
Circuit 25: 3/5/2013 AM



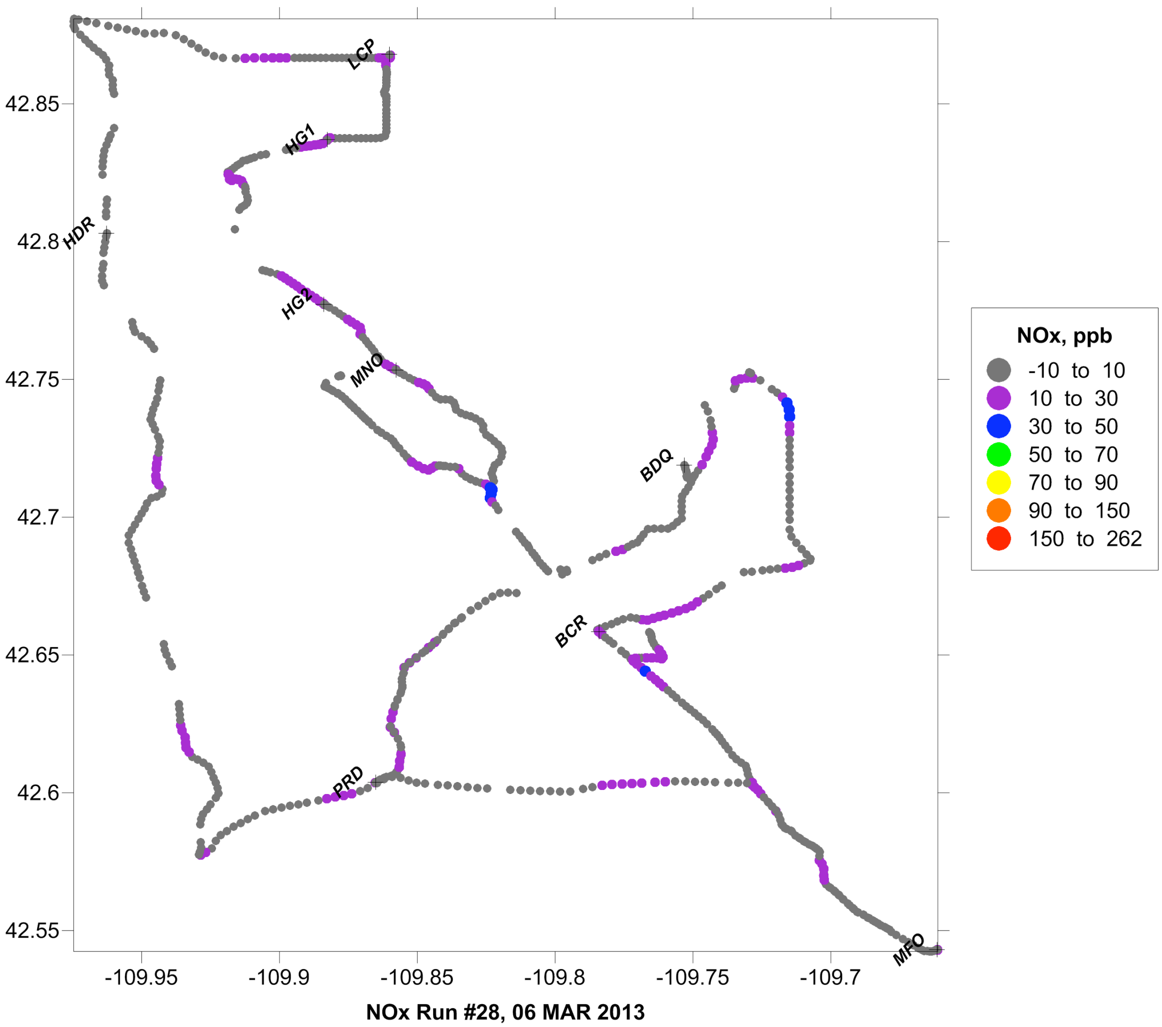
Circuit 26: 3/5/2013 PM



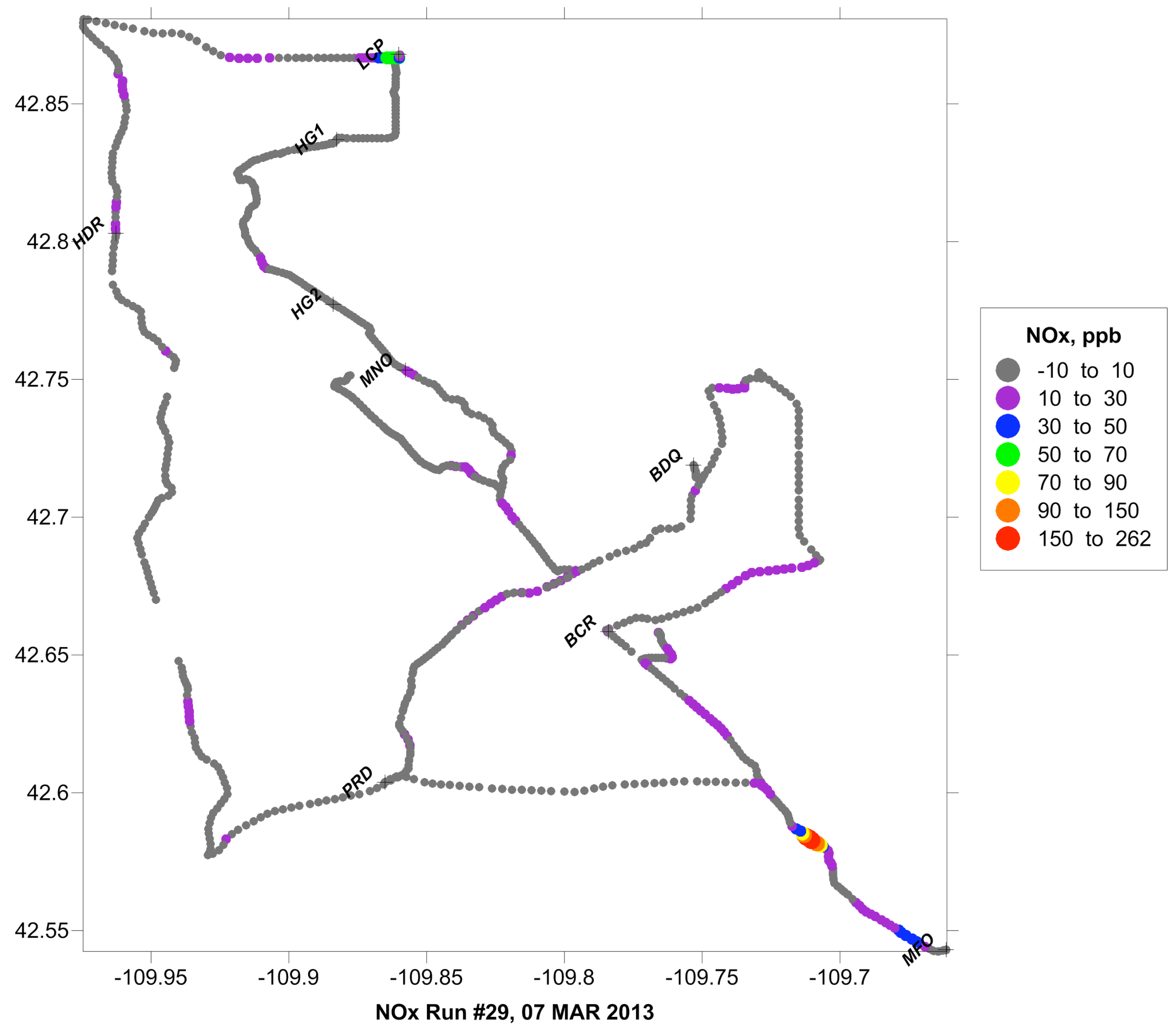
Circuit 27: 3/6/2013 AM



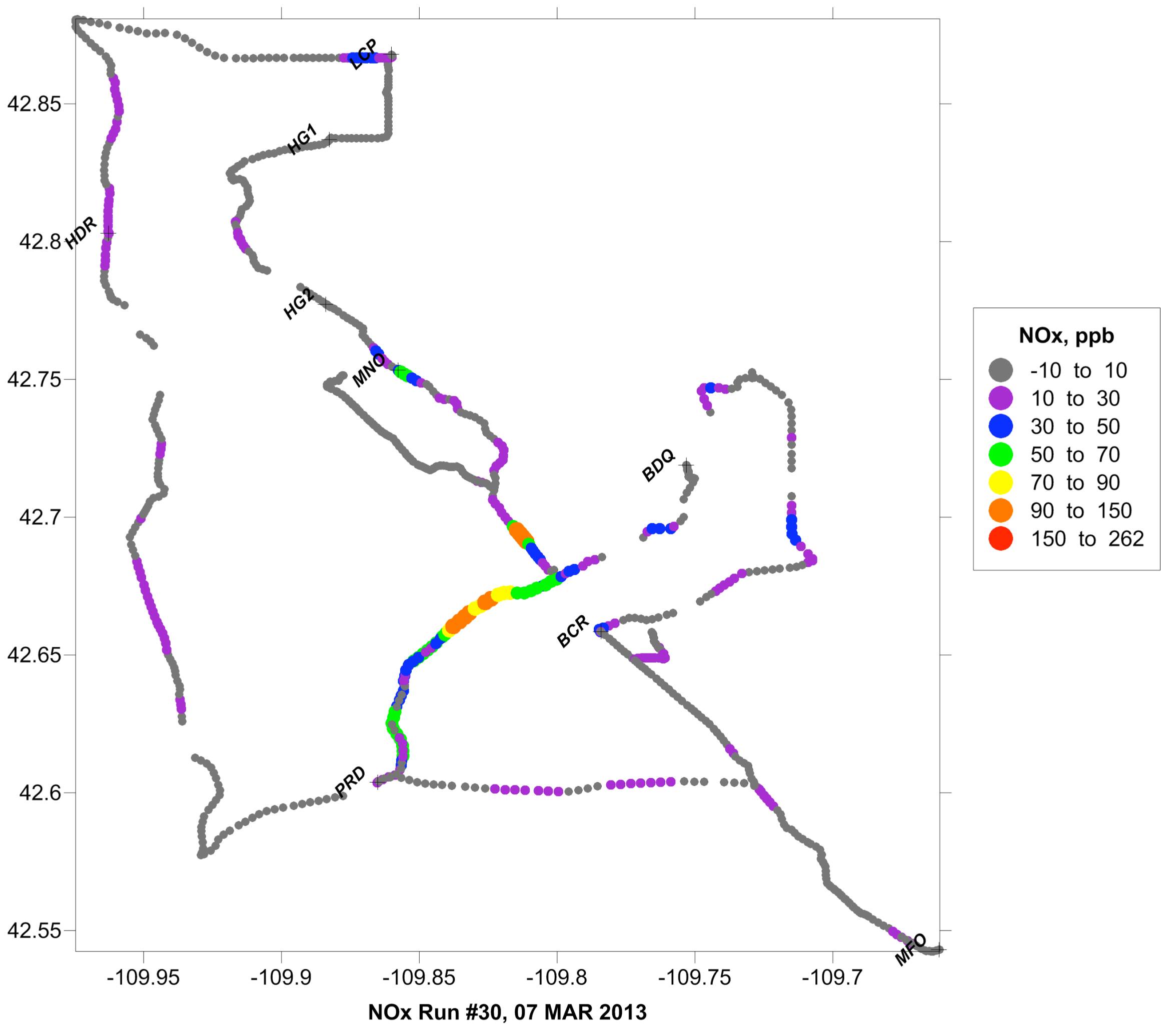
Circuit 28: 3/6/2013 PM



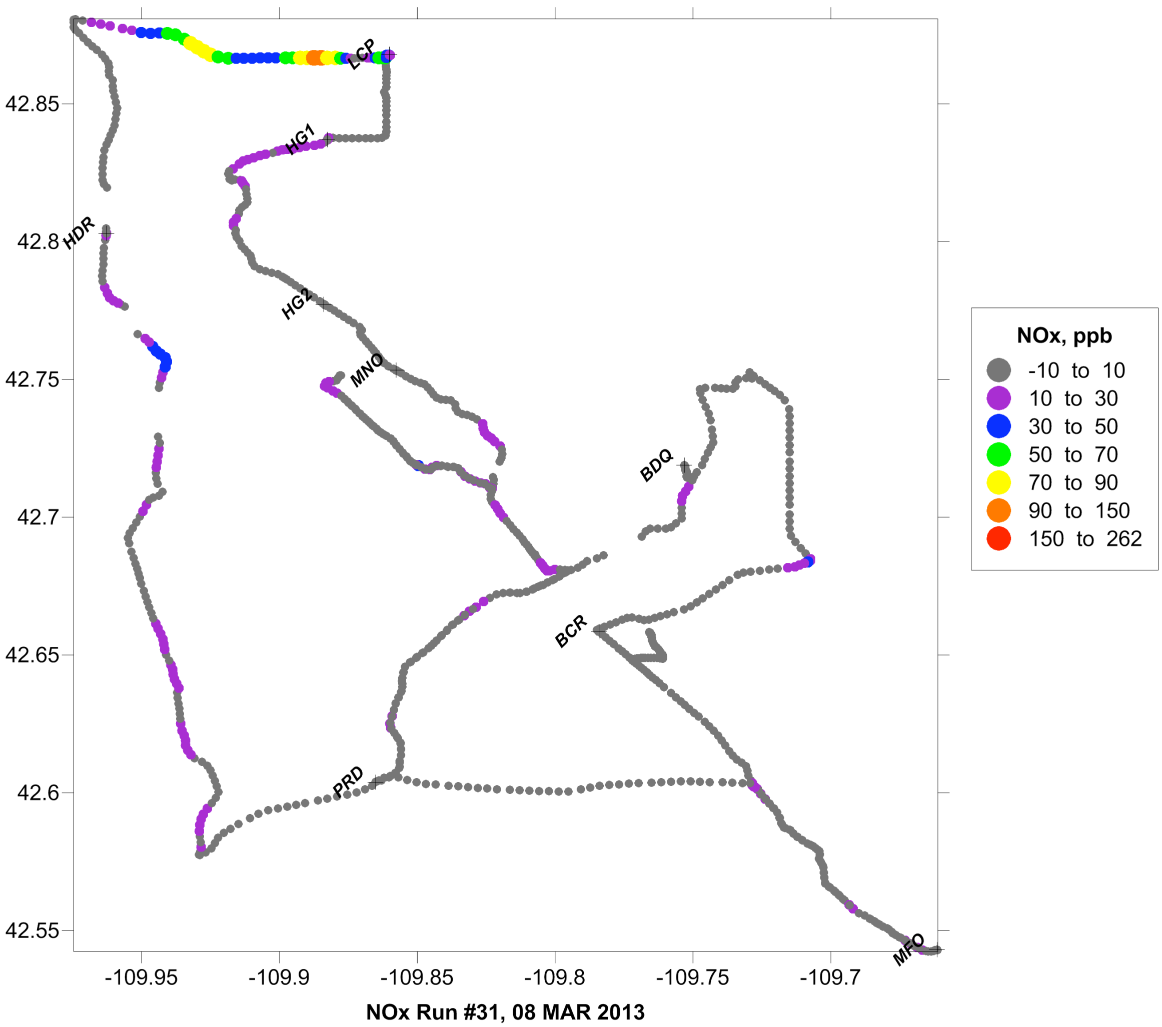
Circuit 29: 3/7/2013 AM



Circuit 30: 3/7/2013 PM



Circuit 31: 3/8/2013 AM



Circuit 32: 3/8/2013 PM