Final Report
Site WA5A
Milk Production Facility

for the

NATIONAL AIR EMISSIONS MONITORING STUDY

to

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1 Overview

1.1 Introduction

The primary goals of the National Air Emissions Monitoring Study (NAEMS) were to: 1) quantify aerial pollutant emissions from dairy, pork, egg, and broiler production facilities, 2) provide reliable data for developing and validating emissions models for livestock and poultry production and for comparison with government regulatory thresholds, and 3) promote a national consensus on methods and procedures for measuring emissions from livestock operations. NAEMS consists of two components: a barn component and an open source component. Open source emissions measurements were conducted at a total of 10 different farms in the continental US. Farms chosen for monitoring were selected based on the location (relative to climate and typical practice), method of manure collection, manure storage and physical configuration of the buildings and lagoons/ basins relative to the surrounding terrain.

The NAEMS was managed by Purdue University, in its role as Independent Research Contractor (IRC) to the Agricultural Air Research Council (AARC). The Purdue Applied Meteorology Laboratory (PAML) maintained and calibrated equipment, collected samples, conducted all other on-site activities, and analyzed the data for all open sources.

The objective of this report is to present the quality-assured measurements of ammonia (NH_3), hydrogen sulfide (H_2S) emissions from a basin open source at the western dairy facility. Within that objective, this report will:

- Describe the farm and the basin monitored for the NAEMS
- Describe the monitoring methods and quality assurance
- Present tabulated daily averages of emissions

1.2 Procedures

To meet these objectives, gaseous emissions of NH_3 and H_2S from open sources were measured at a number of farm operations with a range of characteristics. Emissions were measured at a total of 10 farms over the course of two and one-half years.

The emissions from the basin were measured to determine the variation in emissions with time of year, stability of the atmosphere, and facility operation. Emissions were measured using models that rely on concentration and wind flow measurements. Basin emissions were measured for up to 21 d each season over two years. The duration of measurement periods designated ‘up to 21 d’ depends on the weather conditions during the 21-d interval for measurement. The DQO for completeness stipulates a 75% completeness of 10 d per quarter. Setting aside 21 d per quarter to acquire at least 7.5 d of valid data (75% of 10 d) minimized the risk of not meeting this completeness DQO due to instrumentation problems associated with unfavorable weather conditions.

Atmospheric concentrations of NH_3 around the basin were measured using narrow-bandwidth open path tunable-diode laser absorption spectroscopy (TDLAS). Atmospheric measurements of H_2S concentrations were made using pulsed fluorescence (PF) technology from air collected from 50 m synthetic open path systems (S-OPS) and sampled from a gas sampling system (GSS) that drew the air through the S-OPS. Emissions of NH_3 were determined from the difference in upwind and downwind concentration measurements from the TDLAS open path systems using two emissions models: a Gaussian plume fit model (Radial Plume Mapping: *RPM*; Arcadis Inc, Denver, CO) and a backward Lagrangian Stochastic (bLS) model (*WindTrax*; Thunder Beach Scientific, http://www.thunderbeachscientific.com). Emissions of H_2S were determined using the concentration measurements from the PF analyzer from air sampled by the air inlets of the S-OPS using two emissions models: a Ratiometric model using the ratio of these concentrations to NH_3 concentrations along the same path with the corresponding *RPM* NH_3 emissions measurement, and the bLS model. The critical measurements needed to make the emissions measurements are described in Table 1-1.

Measurements of the atmospheric temperature, relative humidity, barometric pressure, solar radiation and wetness were measured and recorded at an automated weather station established on the basin berm (Table 1-2).

Table 1-1: Critical measurements

Measurement	Method/ Instrument	Required operating range	MDL	Minimum sample frequency	Final data-aggregation
NH_3	TDLAS/ Boreal Laser, Inc. GasFinder 2.0 ™	1-800 ppb	5 ppm-m	1.2 s dwell	30 min & 24 h
H_2S	PF/Thermo Environmental 450i analyzer	1-800 ppb	2 ppb	60 s averaging	30 min & 24 h
Wind speed	3D Sonic anemometer/ RM Young 81000	0-60 $m\ s^{-1}$	0.01 $m\ s^{-1}$	160 Hz sampling/ 16 Hz averaging	30 min & 24 h
Wind direction	3D Sonic anemometer/ RM Young 81000	0^{o} -360^{o}	0.1^{o}	160 Hz sampling/ 16 Hz averaging	30 min & 24 h
3D turbulence wind components	3D Sonic anemometer/ RM Young 81000	0-40 $m\ s^{-1}$	0.01 $m\ s^{-1}$	160 Hz sampling/ 16 Hz averaging	30 min
Temperature variability	3D Sonic anemometer/ RM Young 81000	-50 to +50°C	0.01°C	160 Hz sampling/ 16 Hz averaging	30 min
GSS sample flow rate	GSS/SOP-S	10 **L** min^{-1}	0.1 **L** min^{-1}	30 s	30 min
GSS sampling manifold pressure	GSS/SOP-S	±60,000 Pa	±500 Pa	30 s	30 min
NH_3 emissions	Radial Plume Mapping Model	N/A	N/A	30 min	30 min, 24 h
H_2S emissions	Backward Lagrangian Stochastic Model	N/A	N/A	30 min	30 min, 24 h
NH_3 emissions	Backward Lagrangian Stochastic Model	N/A	N/A	30 min	30 min, 24 h
H_2S emissions	Ratiometric to RPM Model	N/A	N/A	30 min	30 min, 24 h

All measurements from around the basin (TDLAS, barometric pressure, air temperature and relative humidity, wetness, solar radiation and wind) were telemetered to an instrumentation trailer on site via radio communications. The instrumentation trailer also housed the GSS (with associated pressure, flow, temperature and humidity measurements) and PF analyzer for the measurement of H_2S in the S-OPS collected air and two computers that controlled the two TDLAS scanners and collected measurements made by the two TDLAS units. All measurements were then stored on a computer in the trailer that was downloaded daily by file transfer protocol (FTP) via the internet to a computer located at the PAML.

Additional information concerning farm operations was routinely collected from the producer.

Table 1-2: Non-critical measurements.

Measurement	Method/ Instrument	Required operating range	MDL	Minimum sample frequency	Final data-aggregation
Ambient temperature	Thermistor/ Campbell Scientific Inc HMP45C (Vaisala)	-40 to 50 ^{o} C	0.1 ^{o} C	5 min	30 min, 24 h
Relative humidity	Hygrometer/ Campbell Scientific Inc HMP45C (Vaisala)	0-100%	5%	5 min	30 min, 24 h
Barometric pressure	Aneroid barometer/ Setra 278	600 to 1100 hPa	600 hPa	5 min	30 min, 24 h
Surface wetness	VAC resistance grid/ Campbell Scientific Inc.	(binary)	(binary)	5 min	30 min & 24 h
Solar radiation	Silicon pyranometer/ LiCOR 190SB	0- 1200 W m^{-2}	10 W m^{-2}	5 min	30 min & 24 h

1.3 Farm description and operation

The western freestall dairy facility was located in Washington. The elevation at the farm was approximately 244 m. The farm consisted of six barns, a milking parlor, and an office (Fig. 1). The facility had a capacity of 4400 milking cows and 1200 dry cows in three units. Construction of the dairy was completed in 2002.

The farm had freestall style barns, with automated flushing that occurred four times daily. Manure was transferred to the upper basins from a sand separation pit. The two earthen-lined settling basins were located to the south of the barns, and were used in alternate years. Liquids were skimmed, separated, and returned as flush to the barns. While one basin was actively filled while the other was drying or sludge being entirely removed. The settled solids (sludge) were completely removed within a year by front end loader. These removed solids were then strained through Agpro screens and centrifugal/screw presses with the liquid transferred to large serpentine concrete basins for secondary settling. These settled solids were then dried for bedding. Removed water from the settled solids was stored in a large clarified water storage basin for dilution of barn flush water from the basins. Sludge from the settling basins prior to complete removal was periodically applied on surrounding land utilizing underground pressurized pipes and a no-till soil injector. Wastewater entered the measured basin from the northwest corner.

Gaseous emissions occur both during basin filling and during sludge removal. The east basin was rectangular with dimensions of 183 m by 72 m. The west basin was five-sided with dimensions of approximately 183 m long and 83 m wide with the southwest corner of the basin cut off. The berm on the west side dropped from 2 m high to 4 m high from south to north, flat along the south side, and dropping 15 m or more to the north toward the serpentine basins. The berm on the east side dropped about 1 to 2 m, then rises approximately 2 m to fields to the east. The east basin was measured for gaseous emissions. This basin had a surface area of 13,099 m^2 and a volume of 56,796 m^3.

Figure 1-1: Configuration of the WA5A farm.

1.4 Changes in farm operation

Calf hutches were added to the south of the basins between measurements periods 4 and 5.

1.5 Measurement layout

The NH_3 emissions from the two upper lagoons/settling basins were monitored for 8 to 20 d each quarter of the year for two years, using scanning TDLAS open-path instruments and 3-dimensional (3D) sonic anemometers, in conjunction with meteorological measurements and the radial plume mapping (*RPM*). H_2S emissions from the same lagoons/settling basins over the same periods of time were monitored using pulsed-florescence (PF) of air sampled through a Synthetic Open Path System (S-OPS) and 3-dimensional (3D) sonic anemometers, in conjunction with meteorological measurements and both the bLS emissions model and the *RPM* emissions model in combination with the ratiometric relationships of measured NH_3 and H_2S concentrations.

The path-integrated concentrations (PICs) of NH_3 were measured by TDLAS along optical paths defined by TDLAS/scanner systems and retro-reflectors. The scanning TDLAS instruments (TDLAS/scanner) were mounted at 1-m height above the basin berm (abl) at the northwest and southeast corners of the east basin (Figure 1-2). Towers for mounting retro-reflectors were located off the northeast and southwest corners of the east basin (Figure 1-2). A description of the position and path length of the optical paths along each side of the basin follows:

- West side: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 70 m and 140 m from the northwest TDLAS/scanner. Three retro-reflectors were mounted on the southwest tower 221 m from northwest TDLAS scanner at heights of 1.2 m, 6.9 m and 14.9 m abl.
- North side: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 26 m and 50 m along berm from northwest TDLAS/scanner. Three retro-reflectors were mounted on the northeast tower 84 m from the TDLAS/scanner at heights of 1.2 m, 7 m and 15 m abl.
- East side: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 71 m and 135 m from southeast TDLAS/scanner. Three retro-reflectors were mounted on the northeast tower 215 m from the southeast TDLAS/scanner at heights of 1.2 m, 7 m and 15 m abl.
- South side: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 32.5 and 63.5 m from southeast TDLAS/scanner. Three retro-reflectors were mounted on the southwest tower 94.5 m from the TDLAS scanner at heights of 1.2 m, 6.9 m and 14.9 m abl.

Two synthetic PICs of H_2S were measured by PF from air sampled from linear S-OPS positioned at 1-m abl. A 50 m long S-OPS path ran east parallel to the north berm and 10 m north of the north berm beginning at the northwest berm corner (Figure 1-2). The second 50-m long S-OPS path ran west parallel to and 2 m south of south berm beginning at the southeast berm corner (Figure 1-2). The flow through the S-OPS was maintained and sampled by a gas sampling system (GSS) located in the on-site instrumentation trailer. The temperature and humidity of the air flowing through the GSS, as well as the flow rate through and the suction in the negative-pressure portion of the GSS were measured and recorded on a data logger (Model CR800, Campbell Scientific, Logan, Utah).

Figure 1-2: Locations of instrumentation around the basin under measurement. Retro-reflectors are indicated according to side (north, south, east, and west) with 345 indicating the location of a tower. TDLAS/scanner locations are indicated by TS. The locations of the two S-OPS are indicated by the solid yellow lines. The instrumentation trailer was located in the northeast corner of the basin.

Meteorological measurements (barometric pressure, air temperature, relative humidity, solar radiation, and surface wetness) were located on the meteorological tower located on the dividing berm between the east and west basins 23 m north of the southwest corner of the east basin. The 3D sonic anemometers were located on the meteorological tower at 2.5 m abl and on the southwest tower (Figure 1-2) at 4 m and 17 m abl.

2 Monitoring activities

2.1 Measurement periods

This location was measured as part of an approximate 20-d rotation between three other farms. The equipment was on site a total of 112 d over six measurement periods (Table 2.1-1). Setup calibrations and site takedowns reduced the number of measurement days from the total number of days on site. NH_3 emissions were measured 101.9 d and H_2S emissions were measured 80.7 d.

Table 2.1-1: Measurement Periods

Period	Start date	End date	# days
3	2/25/2008	3/12/2008	13
4	3/12/2008	3/26/2008	14
5	8/8/2008	9/3/2008	26
6	9/3/2008	9/26/2008	23
8	5/18/2009	6/4/2009	16
9	6/4/2009	6/20/2009	15

2.2 Site visits

The field operation team involved in the set-up, take-down, and on-site calibration checks visited this farm 21 d (Table 2.2-1). Visits to set up the site instrumentation and conduct calibration verification checks of instruments typically lasted 3 d while visits for calibration verifications and take-down of the equipment on site typically needed 2 d.

Table 2.2-1 Dates of site visits

Year	Spring	Summer	Fall	Winter
2007				Feb 25,26,27,28,29
2008	Mar 12,13,26	Aug 8,9,10,11,12,13	Sep 4,26	
2009	May 19,20,21,	Jun 4,19		

2.3 Instrumentation QA/QC

Calibration verification checks of the instruments making the critical measurements and some of the non-critical measurements most susceptible to deterioration were generally conducted within 21-d intervals on site. Instruments checked during these visits (with indication of Section documenting the instrument performance and calibration verification check results) included:

- GasFinder 2.0™ NH_3 TDLAS serial number (s/n) 1026, 1027, 1028, 1029 and 1032 (Section 6.1)
- TEC 450i H_2S Analyzer s/n 0733825128 (Section 6.2)
- RM Young 81000 3D sonic anemometers s/n 1920, 1921, 1927, 1928, 1932 and 1936 (Section 6.3)
- GSS/ S-OPS s/n 4-0017 (Section 6.6)

In addition, the instruments making the critical measurements were calibrated at least semi-annually. During the semi-annual calibrations, multipoint calibrations were conducted on the TDLAS (Section 6.1) and TEC 450i (Section 6.2) instruments and an inter-comparison conducted on the sonic anemometers

(Section 6.3) with three unused 'reference' anemometers. A further QA check was made by inter-comparing TDLAS units: on May 21, 2009 two TDLAS units were inter-compared on site (s/n 1028 and 1029).

2.4 Audits

Two internal audits were conducted at this location: 1) on 12 March 2008 with particular attention to the TDLAS calibration verification, and 2) on 21 May 2009 with particular attention to the operation documentation. The TDLAS units on location (s/n 1027 and 1029) were inter-compared on 21 May 2008.

2.5 Remote site checks

Over the course of measurements, there were 50 remote checks made through the computer for instruments operating at this location.

2.6 Measurement data acquisition

Data from the TDLAS units (Model GasFinder 2.0™ NH3-OP, Boreal Laser Inc., Spruce Grove, Alberta, Canada) were acquired using the Boreal Laser *GasView MP* software (Boreal Laser Inc., Spruce Grove, Alberta, Canada) program running on laptops dedicated to this purpose (one laptop per TDLAS unit). The TDLAS units sent back data through 2.4 GHz wireless modems about every 1.2 s. This software also controlled the movements of the scanner (Model PTU-D300, Directed Perception Inc., Burlingame, CA) that aimed the TDLAS units.

Weather data were saved to the internal memory of the data logger (Model CR1000, Campbell Scientific Inc, Logan, UT) at 5-min intervals. Optimally, these data were transferred to the trailer through 2.4 GHz wireless modem at intervals of 10 min using *LoggerNet* software (Campbell Scientific Inc, Logan, UT). However, communications interference at a number of sites significantly impeded this regular data transfer. Thus, it was sometimes necessary to download data directly to a laptop during site visits. The data were then transferred from the laptop to the trailer computer using a USB thumb-drive. As a backup, all data were also stored on a compact flash memory card that was brought back to Purdue and downloaded after each period.

Data from the gas sampling system (GSS) were saved to a data logger (Model CR800, Campbell Scientific Inc, Logan, UT) located in the trailer at intervals of 30 s. These data included the line currently being sampled and the mass flow rate. The data were transferred through a serial cable to the trailer computer every 10 min using *LoggerNet*.

Data from the H_2S analyzer (Model 450i, Thermo Fisher Scientific, Franklin, MA)were downloaded in real-time through a serial cable to the trailer computer using the *iPort*® (Thermo Fisher Scientific, Franklin, MA) software program. The *iPort* software frequently disconnected from the analyzer, so that during our daily status checks from PAML it was frequently necessary to reconnect *iPort* to the analyzer, download data back to the time when *iPort* had crashed and stopped collecting data, and restart real-time data collection

Data from the 3D sonic anemometers (Model 81000, RM Young Inc., Traverse City, MI) were downloaded to the data acquisition computer in the trailer using custom built Visual Basic software. Binary data from up to four anemometers were transferred at 16 Hz through 900 MHz wireless modems to a single polling modem connected to the data acquisition computer in the trailer. The software time stamped and stored each 16 Hz data point and calculated 100-s and 300-s averages, variances, and covariances for each component of the wind and the sonic anemometer temperature.

Files were transferred from the instrument trailers to the PAML FTP server using the program *rsync* in the *cygwin* environment (open source programs). This transfer took place every six h, as long as the internet connection was available. The program was set up so that only new or modified files were transferred each time, so that only the updated data were transferred. A log of each file transferred was produced by the *rsync* program. The *rsync* program was used to transfer data daily from the PAML FTP server to the PAML data computer. This transfer was performed early each morning before the automated quality control software runs. Two copies of the data were stored on the Data computer. One copy was placed in the directory “FTP” and was never modified. This copy represents the original data as transferred from the trailers. The other copy of the data was placed in the directory “Data”. The data processing and quality control programs used this copy of the data, and modifications and corrections were made to this copy of the data as needed to allow the data to be processed. These modifications will be described below. It is important to note that no actual data numbers were changed during these modifications.

In addition to the copies of the data transferred over the internet, a copy of the data for each period was produced on a CD and DVD. To ensure complete and accurate data transfer, a data comparison program was used to compare the data on the CD/DVDs with the data in the “FTP” directory.

3 Data processing and analysis

Before final data processing, the data files were examined to ensure that they were ready to be processed. Modifications to the files were required due to human error, issues related to changing from one site or period to another, and bugs in the data collection software. None of the actual data were modified in this file preparation, only filenames and/or the file in which the data appeared were changed. A detailed log was kept of each modification.

Deleting empty files: Data files created but not filled with data occurred as a byproduct of the data collection systems. The sonic anemometer data collection program was set up to start automatically when the trailer LAN server computer (hereafter termed LAN) was started. As a result, when the LAN was started at a new location empty files were often created because the sonic anemometers were not yet in place. If the location and/or period were not adjusted in the sonic anemometer parameter input file before the computer was shut down at the previous site, these empty files would be present in the directory from this previous location or period. These empty files contain no data and were deleted. Empty files also sometimes occurred for the TDLAS units if the TDLAS laptop was still logging but no data were being transferred from the TDL. These empty files were generally deleted, although they were sometimes retained since empty files can be handled by the data analysis and QC software. Even if deleted from the "data" directory, these empty files will still be present in the "FTP" directory, and in some cases these empty files will be useful in determining whether missing TDLAS data are due to problems with the TDLAS unit itself or with the TDLAS data collection laptop computer. Empty files in other data sets were also deleted.

Moving/deleting data from surrounding periods: When moving from one site to another or switching periods during a "back-to-back" site visit, several changes need to be made for the data to be saved in the directories for the new site or period. If these changes were not made when the LAN was first started or before the computer was shut down at the preceding site, data for the new site was often saved in the directory for the preceding site. Data were moved from the file for one site to the file for the correct site. Data to be moved were identified by breaks in the data timestamps corresponding to the period when the equipment was shut down and in transit from one site to the next. Data were most often moved in the files for the CR1000 data logger and GSS (CR800 data logger), as these data files started adding new data immediately when the LAN was turned on, and it was easy to forget to immediately make the directory and file name change in *Loggernet*.

Combining data files: The *iPort* software used to collect data from the H_2S analyzer occasionally lost its connection with the analyzer causing the data collection to stop. These events were noticed during the daily site checks from PAML at which time the missing data were filled from the internal memory on the analyzer and a new data file was started to collect the data in real-time. To allow the quality control software to run most efficiently, these multiple data files were combined into a single file at the conclusion of the period. The files that were included in this single file were placed in a subdirectory of the H_2S data folder named "Pieces". On isolated occasions, the CR1000-logged or CR800-logged data for a period were split into more than one file, and these data files were generally combined into a single file for the period, unless a change was made to the data stream in between the files (e.g. adding temperature and relative humidity probe to the gas sampling system output).

Renaming files: On some occasions, files had to be renamed due to human error in naming the files or, in the early days of the project, because of the lack of a finalized file structure in which the field operations staff had been trained. These changes were primarily to the TDLAS data files, when the files on the TDLAS laptops were not named appropriately or else TDLAS1 and TDLAS2 were reversed. Various files for other instruments also had to be renamed for a variety of reasons.

Data Processing and Quality Control Input Files: The data processing and quality control software programs require inputs that describe the data to be analyzed. The input parameters for a given site and period are in a single *Excel* workbook consisting of a separate worksheet for each component of the data processing software. These parameter files were produced and then independently double-checked for errors.

3.1 QA/QC software procedures

The valid data times were produced by examining the data in a preliminary run through the data and finding in the records the times when the instrument was calibrated and times when the instrument was known to be malfunctioning. The data excluded as being from a calibration or period of instrument malfunction were placed in separate columns in the output files and plotted in a different color on the output graphs.

Because measurements were acquired on various data acquisition systems, time synchronization of the various systems was critical. The time synchronization data were obtained from the remote site visits conducted as part of the daily status checks. Time corrections were only included if the instrument time was more than one min off from the LAN. In the end, corrections were made only to the TEC 450i H_2S analyzer as this instrument would infrequently be out of sync by several minutes due to issues with its automatic time updates. The time synchronization is especially important for the TEC 450i because it samples from lines located on both sides of the basin and the time difference could lead to H_2S concentrations being recorded for the wrong S-OPS line (side of source).

One worksheet in the *Excel* parameter workbook for each site contains a list of the times of valid data for each data stream and one worksheet indicates when an instrument was out of time synchronization with the LAN as well as the time correction required to bring the data stream into time synchronization with the LAN.

Once the data files were prepared for final processing and the input parameter files were produced for each site and period, the data were processed through the custom designed software for this purpose. Through the duration of the project, each data stream was processed through a separate program, but in preparation for the final data processing these individual programs were combined into a single program to allow for more efficient data processing and easier debugging, as processes that were previously done multiple times in the earlier software versions are now done only once.

The order in which the various data streams were processed was determined by the dependencies in the data processing and quality control between the various instruments: a given data stream may depend on one or more of the preceding streams, but not on following data streams. For each data stream, the data were first loaded into arrays and any corrections for time synchronization applied. The flags were then assigned based on the QAPP. After this, the data exclusion times were applied and the data appropriately broken up into columns. Finally, the data were loaded into *Excel*, plots were produced, and the final data files were saved.

3.2 Data exclusions

Data were excluded from processing due to equipment failures, calibration failures, and because calibration checks were in progress. Periods of invalidated measurements associated with the calibration check failures are documented in the calibration reports in Section 8. Significant data exclusions of greater than one-day duration are indicated below by instrument. All time references are in Universal Coordinate Time (UTC):

TDLAS measurement exclusions: Examples of events resulting in measurement exclusions include the following issues. Specific events are described in Table 3.2-1.

Table 3.2-1: TDLAS exclusion events

Exclusion		Exclusion		Reason
3/2/2008	09:47:00	3/12/2008	20:58:50	northwest scanner and TDL 1; power issues
8/23/2008	19:24:08	8/27/2008	20:21:25	TDLAS 1 power failure
5/27/2009	03:50:22	5/31/2009	00:14:37	TDLAS 2 unknown failure; no data
5/21/2009	23:40:48	6/4/2009	21:48:07	TDLAS 1 (1027) failed

Air temperature and relative humidity measurement exclusions: The air temperature and relative humidity sensor experienced four exclusion events that are described in Table 3.2-2.

Table 3.2-2: Air temperature and relative humidity sensor measurement exclusion events

Begin		End		Reason
Air temperature				
2/3/2008	03:20:00	3/5/2008	16:05:00	Power lost on northwest side of basin
3/9/2008	21:55:00	3/11/2008	17:05:00	Power lost on northwest side of basin
8/14/2008	00:15:00	8/15/2008	00:05:00	Power lost on northwest side of basin
6/4/2009	21:20:00	6/9/2009	16:30:00	No power at met station
Relative humidity				
3/2/2008	03:20:00	3/5/2008	16:05:00	Power lost on northwest side of basin
3/9/2008	21:55:00	3/11/2008	17:05:00	Power lost on northwest side of basin
8/14/2008	00:15:00	8/15/2008	00:05:00	Power lost on northwest side of basin
6/4/2009	21:20:00	6/9/2009	16:30:00	No power at met station

Wetness measurement exclusions: There were four instances of wetness measurement exclusions, which are described in Table 3.2-3.

Table 3.2-3: Wetness sensor exclusion events

Begin		End		Reason
3/2/2008	03:20:00	3/5/2008	16:05:00	Power lost on northwest side of basin
3/9/2008	21:55:00	3/11/2008	17:05:00	Power lost on northwest side of basin
8/14/2008	00:15:00	8/15/2008	00:05:00	Power lost on northwest side of basin
6/4/2009	21:20:00	6/9/2009	16:30:00	No power at met station

Pressure measurement exclusions: The barometer used at this location experienced 4 exclusion events as described in Table 3.2-4.

Table 3.2-4: Barometric pressure measurement exclusion events

Begin		End		Reason
3/2/2008	03:20:00	3/5/2008	16:05:00	Power lost on northwest side of basin
3/9/2008	21:55:00	3/11/2008	17:05:00	Power lost on northwest side of basin
8/14/2008	00:15:00	8/15/2008	00:05:00	Power lost on northwest side of basin
6/4/2009	21:20:00	6/9/2009	16:30:00	No power at meteorological station

Sonic anemometer measurement exclusions: Sonic anemometers experienced communications interference throughout the study. Excluded measurements are summarized in Table 3.2-4.

Table 3.2-1: Sonic anemometer measurement exclusions

Begin		End		Reason
3/2/2008	03:20:00	3/5/2008	16:05:00	Sonic anemometer 1 due to power loss on northwest side of basin
3/4/2008	20:30:00	3/6/2008	13:55:00	All 3 sonic anemometers; sonic anemometer program failure
3/15/2008	20:05:00	3/17/2008	12:50:00	All 3 sonic anemometers; sonic anemometer program failure
8/15/2008	21:35:00	8/18/2008	12:05:00	All 3 sonic anemometers; sonic anemometer program failure
8/30/2008	14:10:00	9/3/2008	16:30:00	Sonic anemometer 2 no data collected
6/4/2009	21:20:00	6/9/2009	16:30:00	All 3 sonic anemometers power failure

GSS/S-OPS measurement exclusions: Excluded measurements are summarized in Table 3.2-3.

Table 3.2-3: GSS/S-OPS measurement exclusions

Begin		End		Reason
GSS				
3/12/2008	00:15:00	4/3/2008	19:45:00	Pump turned off; H_2S Analyzer sent to manufacturer for repair
9/6/2008	19:15:00	9/9/2008	07:15:00	GSS solenoids not switching
9/14/2008	16:45:00	9/17/2008	15:45:00	GSS solenoids not switching
9/23/2008	16:15:00	9/26/2008	23:15:00	GSS solenoids not switching
S-OPS				
3/12/2008	00:15	4/3/2008	19:45	Opening in line, repaired

3.3 Data correction procedures

Calibration adjustments based on the multipoint calibrations and calibration verifications were made to the NH_3 and H_2S gas concentration measurements. All concentration measurements were normalized to 101.325 kPa and 20 ^{o}C (STP) within the instruments. The measured system response corrections used the entire record of calibration verifications and adjusted for a bias associated with the sampling system defined by the EPA Method 301 S-OPS validation by using a correction factor of 0.98. No corrections were required for the sonic anemometer measurements.

3.4 Data validation procedures

3.4.1 NH_3 concentration measurements

Because of the nature of the TDLAS data, the TDLAS routine is the most complicated portion of the data processing and quality control software. It is broken into several subroutines. The first subroutine flags pan/tilt locations that are likely to be in supersaturated "holes" in the retro-reflector array. The TDLAS instrument contains a sensor that detects the intensity of the energy returned from the retro-reflector in arbitrary units. Light levels of between 500 and 12000 are required for data to be considered valid. The light level sensor in the TDLAS instrument has a maximum value of 16368 (arbitrary units). Additional returned energy causes the light level to decrease. This creates a supersaturated condition in which the light levels appear valid, but in reality the returned energy is much greater than the allowable threshold for a valid reading. This leads to erroneous instrument readings, frequently indicated by low r^2 values that are associated with large path integrated concentrations (PICs). The term "hole" refers to a region of light levels that appear valid surrounded by maxed-out light levels. A hole is a region where the instrument will give faulty data, even though the light levels appear valid. The hole-finding algorithm goes through all the data points defined in "optimize" strings output by the instrument each time the scanner moves to a new location and determines data points that either have maximized light levels (16368) on the current day or else are surrounded above and below or to the left and to the right by points that have maximized light levels on the current day. The routine produces a list of locations (pan and tilt) and days that are probably supersaturated.

The next subroutine inputs all the concentration data and calculates averages over each dwell on a retro-reflector array. A scanner moved the TDLAS from one retro-reflector to another, dwelling for about 15 s on each retro-reflector array. The *GasView MP* program produced a flag that indicated when the scanner was moving. Once this flag indicated that the scanner had stopped its movement, one additional 1-s value was ignored, and then the remaining points were averaged to produce the dwell averages. The additional ignored value helped reduce the occurrence of data from the preceding path leaking into the current path because of communications delays.

On the next pass, concentration data from pan/tilt locations and days that were determined to be super-saturated were flagged as supersaturated. However, it was found that simply using the light levels as the super-saturation criteria resulted in the removal of much data that was clearly not super-saturated. To determine which points truly were super-saturated and which were not, a threshold curve of PIC as a function of r^2 was produced (for valid data, r^2 generally increases as PIC increases). As part of the determination of this PIC vs. r^2 threshold, a record was kept for each retro-reflector array of the ten largest path integrated concentrations corresponding to each r^2 value from pan/tilt locations that were not determined from the initial hole-finding routine to be super-saturated. Based on this top-ten record, the PIC vs. r^2 threshold was determined by searching for outlying values that might indicate a PIC value that should have been indicated as super-saturated but were not.

Once the PIC vs. r^2 threshold curve was determined, a final pass was made through the data, this time comparing the PIC value for each data point with the threshold value at the current r^2. This resulted in four categories of points depending on whether or not super-saturation was indicated by the hole-finding algorithm and whether or not super-saturation was indicated by the hole-finding routine.

In a final pass through the data, data from the individual dwells was averaged up to the 30-min time intervals required by the *WindTrax* and *RPM* emissions models.

3.4.2 H_2S concentration measurements

The H_2S data processing routine first loaded all the H_2S data into an array. Based on the GSS data array, the data were then sorted by source side and a determination was made whether the

GSS had been sampling that side long enough and whether enough time remained until the end of sampling that side for the H_2S data to be considered valid. The data were then sorted and averaged into 30-min intervals for placement into the *WindTrax* input file.

3.4.3 S-OPS sampling

The GSS software routine imported the CR800 data and produced two separate arrays of the data. The time grid for one array was based on when the SOPs changed from one line to the other line. This array was later used when separating the H_2S data according to which SOPs line was being measured and determining whether enough time had elapsed since the previous line-switch and enough time remained before the next line switch to consider the data valid. The other array was based on a regular 30-min grid. This array was used to produce output over the intervals required as input to *WindTrax*. Output from the GSS were also used to ensure that adequate flow was present for the instruments, that condensation was not a problem inside the GSS, and that there were no major issues with the S-OPS lines (leaks, etc.).

3.4.4 Wind component measurements

The sonic anemometer software imported the 300-s sonic anemometer data files and produced the final sonic anemometer QC output file and also arrays of data at 30-min intervals for use by the *WindTrax* and *RPM* emissions models. The *WindTrax* arrays contain the turbulence statistics required as inputs to *WindTrax* and also flags used for characterizing the output from the *WindTrax* or else the reason that sonic anemometer data were not suitable for use by *WindTrax* during a particular data interval. The *RPM* arrays contained the wind direction and wind speed averaged over a 30-min interval and interpolated to 10 levels from the surface to 20 m above the surface.

At some sites and during some periods one or more sonic anemometers experienced intermittent communications interference. This interference reduced the number of 16-Hz data points recorded in the trailer and also led to some spurious data points that resulted in some outlying, unphysical data points. These spurious data had little impact on the mean wind speeds, but did impact the variances, sometimes significantly. It was found that the spurious variances were nearly always associated with sonic anemometer temperature variance of greater than 2.5 K^2, while realistic variances never exceeded this same value. To be considered a valid 300-s period, at least 90% (4320) of the possible 4800 16-Hz values had to be present and the sonic anemometer temperature variance had to be less than 2.5 K^2 to be considered a valid 30-min interval, at least 3 of the 6 possible 300-s intervals were required to be valid. This acceptance scheme caught most of the unacceptable variances.

3.5 Emission calculations

3.5.1 NH_3 emissions by RPM

The *RPM* model was used to estimate the NH_3 emission rates based on the TDLAS and sonic anemometer data. Running the supplied version of *RPM* was very time consuming and inefficient and produced data at short intervals on the order of several minutes (time for a scan through all the paths). To make *RPM* processing much quicker and efficient, the sonic anemometer and TDLAS data processing programs were used to skip the first two stages of *RPM* data processing by producing data in the proper format and with the proper filenames for level 3 processing by the *RPM*. These files were produced at an interval of 30 min with all the data for a site and period contained in a single *RPM* input file. This allowed an entire period of data to be

RPM processed with just a few clicks of the mouse, instead of with many clicks just for each individual day. The 30-min time interval was appropriate because the focus of the NAEMS study is on the long-term emissions over the course of the day rather than on the minute-by-minute emissions. In addition, the 30-min interval also allowed for a higher percentage of data capture since not all paths were necessarily required to be present for the entire 30-min interval.

3.5.2 NH_3 emissions by bLS

Data input into the *WindTrax* model were produced by combining output from the sonic anemometer and TDLAS portions of the data processing software. The *WindTrax* program was run by a portion of the data processing software that assigns values to the concentrations and wind statistics required by the model and told the model to run depending on whether or not the u_* and L values were acceptable.

GoogleEarth® was used extensively in producing the site maps required by *WindTrax*. By the end of the project, each site had a high-resolution image on *GoogleEarth*® sufficient to see the outline of the source area. A GPS was used to obtain precise latitudes and longitudes for the TDLAS units and each of the retro-reflectors. Labeled location markers were then placed at these coordinate locations. When the locations were obviously wrong (the accuracy indicated by the GPS was generally on the order of 4 m or so), either because the path crossed the basin or because it was not correctly placed relative to the corner, the markers were moved slightly to the approximate proper location. The image was then saved and loaded into *WindTrax*, where it was used to define the source areas and measurement paths.

All data required for post-processing the *WindTrax* output were placed into the *WindTrax* output file.

3.5.3 Validation of bLS emissions model

All ½ hourly emissions calculated using the *Windtrax* bLS emissions model in which there was a corresponding *RPM* emissions measurement were compared by pairs using EPA Method 301. The precision of the bLS method for each pair of bLS and *RPM* measurements of emissions was assessed assuming the *RPM* method was the reference. The F-test was used to determine if the precision of the bLS method was significantly different from that of the *RPM* method under a range of meteorological conditions. The experimental *F*-value was calculated according to

$$F = \frac{S^2_{bLS}}{S^2_{RPM}}$$

where S^2_{bLS} is the variance of the bLS measurement method determined from all PICs, and S^2_{RPM} is the variance of the *RPM* measurement method determined from five to ten PICs (depending on the incidence angle) on a given downwind side (and possibly an upwind side) for the paired 30-min measurement periods. The experimental *F*-value was compared to the critical range of *F* at a 95% confidence level for the appropriate degrees of freedom associated with the number of measurements used in the variance calculations in both the numerator and denominator. If the experimental *F* was above the critical range, the precision of the bLS method was significantly greater than the *RPM* method. If the experimental *F* was below the critical range, the precision of the bLS method was accepted as equivalent to the *RPM* method.

The bias of the bLS method was determined from the measurement periods and beam lines used in the precision determination. Bias was determined by t-test of the mean differences in emissions calculations for each meteorological condition evaluated for precision. An 80% confidence interval was used (t=1.397). The correction factor was calculated if the difference was significant.. If the correction factor was more than 1.10 or less than 0.90, then the bLS method was considered biased accordingly relative to the *RPM* emissions measurements for the location but not invalidated.

3.5.4 H_2S emissions by Ratiometric

Ratiometric H_2S emissions were determined by first finding 30-min intervals for which all the following conditions were satisfied: the *RPM* calculated a valid emission, one of the S-OPS lines was downwind (angle < 60 degrees) and both S-OPS lines had valid H_2S readings, and the TDLAS path corresponding to the downwind H_2S path had a valid concentration. An upwind TDLAS concentration was not used in the calculations. If the preceding conditions were met, then the H_2S emission was estimated as:

$$Flux_{H2S} = Flux_{RPM-NH3} \frac{34.0818\left([H_2S]_{downwind} - [H_2S]_{upwind}\right)}{17030.4[NH_3]_{downwind}}$$

The yield for the Ratiometric method for determining H_2S emissions was limited significantly by the generally poor yield for the *RPM* emissions method for NH_3.

3.5.5 H_2S emissions by bLS

Data input into the *WindTrax* model were produced by combining output from the sonic anemometer, GSS, and H_2S portions of the data processing software. The *WindTrax* program was run by a portion of the data processing software that assigns values to the concentrations and wind statistics required by the model and tells the model to run depending on whether or not the u_* and L values are acceptable.

GoogleEarth® was used extensively in producing the site maps required by *WindTrax*. By the end of the project, each site had a high-resolution image on *GoogleEarth*® sufficient to see the outline of the source area. A GPS was used to obtain precise latitudes and longitudes for the ends of the S-OPS lines. Labeled location markers were then placed at these coordinate locations. When the locations were obviously wrong (the accuracy indicated by the GPS was generally on the order of 4 m or so), either because the path crossed the basin or because it was not correctly placed relative to the corner, the markers were moved slightly to the approximate proper location. The image was then saved and loaded into *WindTrax*, where it was used to define the source areas and measurement paths. All data required for post-processing the *WindTrax* output were placed into the *WindTrax* output file.

4 Results

4.1 Farm activity

Pertinent activities affecting the basin emissions include transfer of waste from barns into the basin, irrigation with wastewater (Table 4.1-1) and sludge removal from the basin. Animal inventories for the calculation of basin loading rates are indicated in Table 4.1-1.

Table 4.1-1 Producer activities

Period	Activity	Animal inventory
3: 2/25-3/12/2008	No events, West basin full and drying, East basin filling	4430
4: 3/12-3/26/2008	No events, West basin full and drying, East basin filling	4430
5: 8/8 - 9/3/2008	West basin sludge being removed, East basin filling 8/10 Spread manure East of dairy 8/16 Spread manure East of dairy 9/2 Spread manure East of Dairy.	4398
6: 9/3 - 9/26/2008	West basin filling, East basin filling 9/8-9/18 started liquid manure soil injection 9/23 Spread manure East of dairy.	4398
8: 5/18 - 6/4/2009	West basin filling, East basin filling and drying	4328
9: 6/4 - 6/20/2009	West basin filling, East basin filling and drying	4328

4.2 Weather conditions

4.2.1 Synoptic weather events

Weather conditions during the measurement periods varied widely as expected for dry Steppe climates (Table 4.2-1). Sixteen percent of the days had extra-tropical frontal systems overhead while 84% of the days were under the general influence of extra-tropical high pressure. The Daily Weather Maps for the measurement days are found in Section 6.9.

Table 4.2-1: Synoptic weather events during measurements

Measurement period	# days	# warm front passages	# cold front passages	# days stationary front	# days tropical storm
3	13	0	3	1	0
4	14	0	1	0	0
5	26	0	4	0	0
6	23	0	2	0	0
8	16	0	2	0	0
9	15	0	0	4	0

4.2.2 Variation in barometric pressure, solar radiation, air temperature and wetness

Over the course of the measurement periods, the mean daily air temperature varied from 4.1^{o}C to 31.7^{o}C while the barometric pressure varied from 97.26 kPa to 100.19 kPa (Section 6.10). Sky conditions ranged from clear skies with maximum ½ h solar irradiance of 1159 W m^{-2} to overcast conditions with maximum ½ h solar irradiance of 86 W m^{-2} (Section 6.10).

4.2.3 Variation in air temperature and relative humidity

The relationship between the daily mean air temperature and humidity compared with the monthly climatology is indicated in Figure 4-1. Temperatures were generally within the climatological normal conditions throughout the study measurement periods at this location.

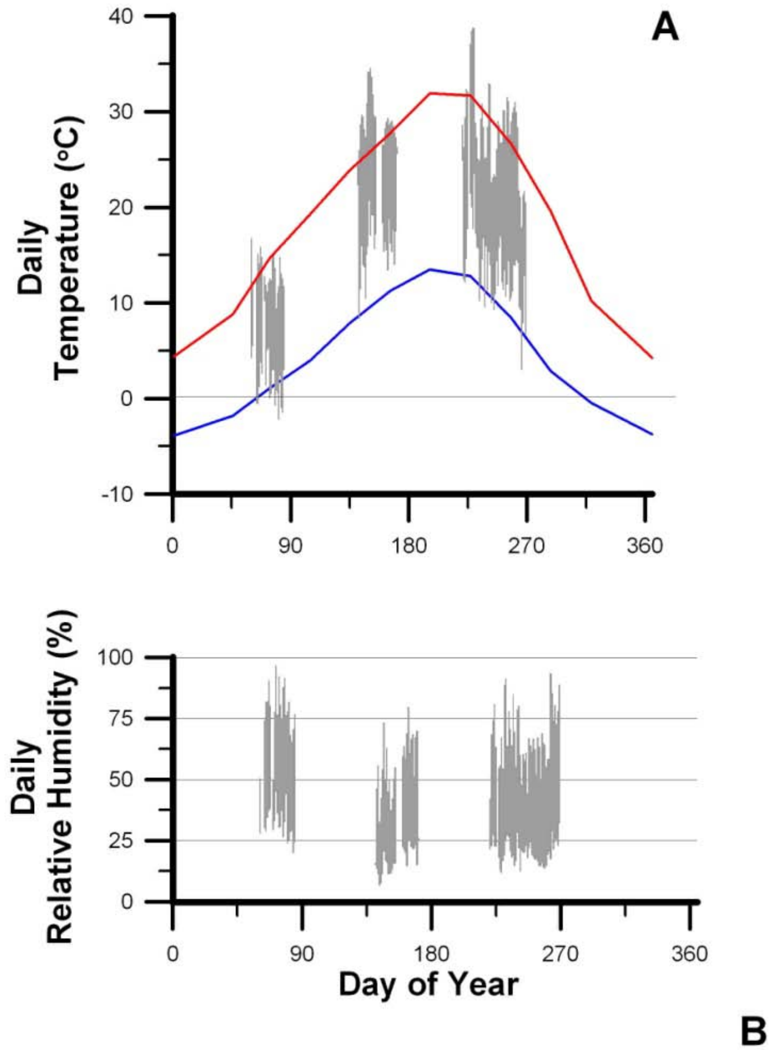

Figure 4-1: Variation in daily temperatures and relative humidity during measurements. The mean monthly climatological maximum (red solid line) and minimum (blue solid line) temperature are compared against the daily maximum and minimum temperatures for measurement days (grey bars) in panel A. The maximum and minimum relative humidity for measurement days is indicated by the grey bars in panel B.

4.2.4 Wind conditions

Wind conditions for each measurement period are illustrated in Figures 4.2-1 through 4.2-3. The bLS emission calculation exclusion regions due to surrounding sources (wind directions of 225^{o}

through 360°) are indicated as a grayed region in the figures. No wind direction exclusions were needed for the *RPM* emissions calculations.

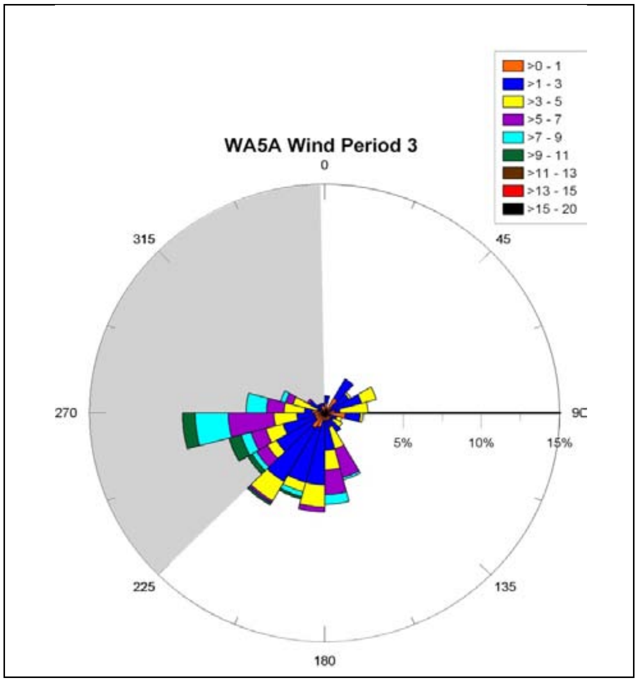

Figure 4.2-1: Wind rose for ½ hourly wind measurements during the winter measurement period. The period in which measurements were made is indicated. The relative portion of time in which the wind is from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of m s^{-1}) is indicated by colors within each triangle. The shaded region defines the excluded wind directions.

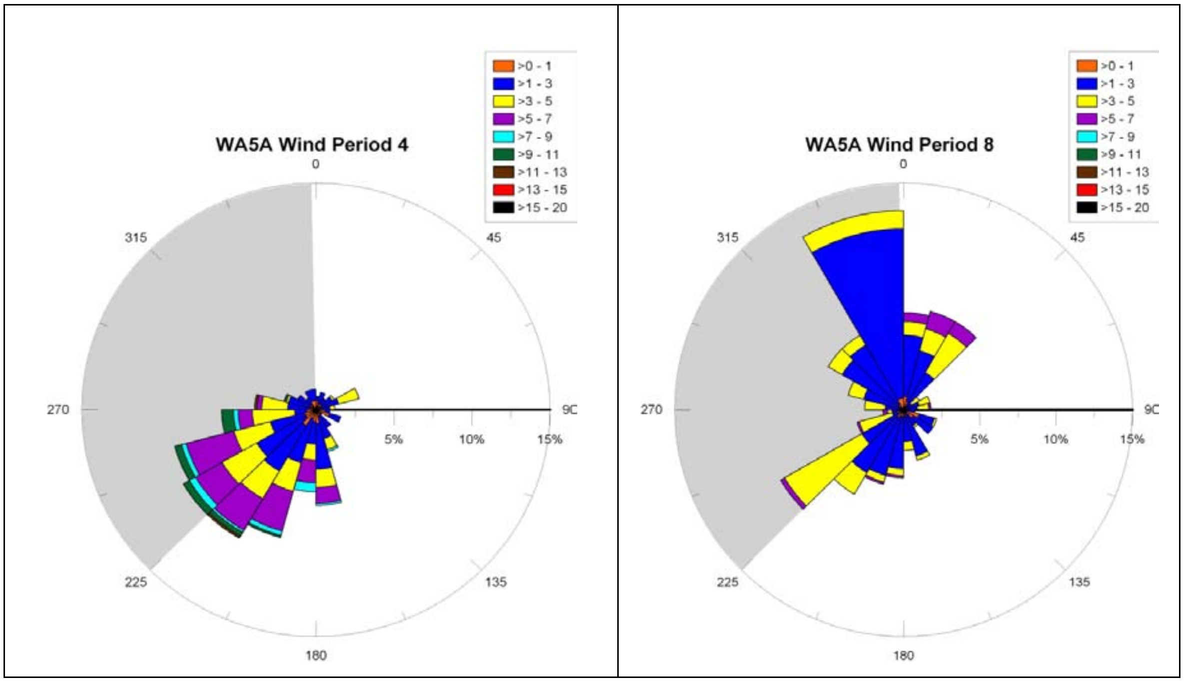

Figure 4.2-2: Wind roses for ½ hourly wind measurements during the spring measurement periods. The periods in which measurements were made are indicated. The relative portion of time in which the wind is from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of m s^{-1}) is indicated by colors within each triangle. The shaded regions define the excluded wind directions.

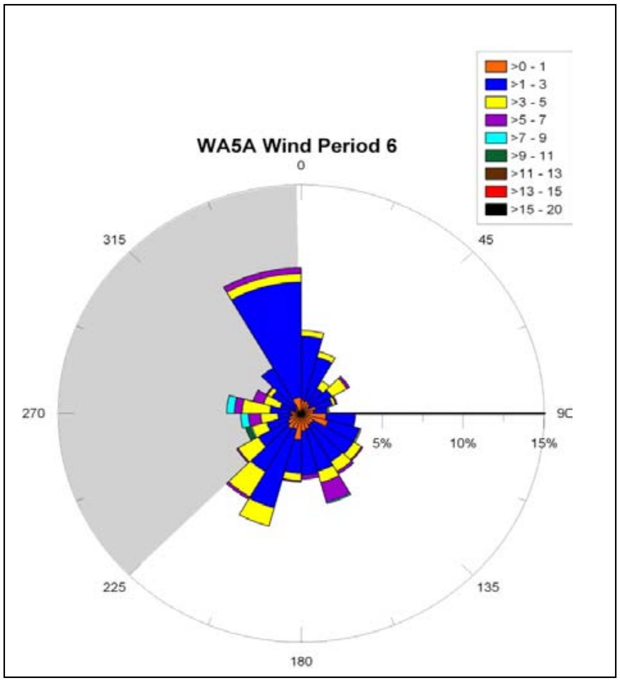

Figure 4.2-3: Wind rose for ½ hourly wind measurements during the fall measurement period. The period in which measurements were made is indicated. The relative portion of time in which the wind is from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of m s^{-1}) is indicated by colors within each triangle. The shaded region defines the excluded wind directions.

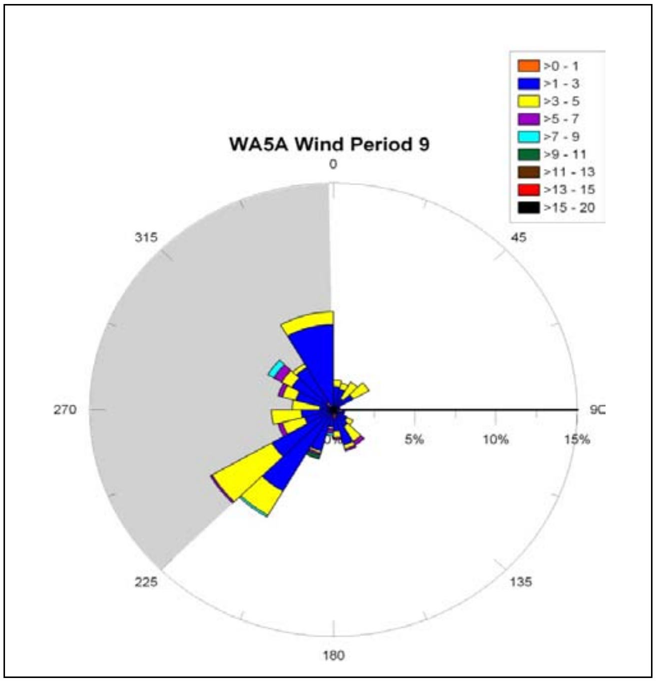

Figure 4.2-4: Wind rose for ½ hourly wind measurements during the summer measurement period. The period in which measurements were made is indicated. The relative portion of time in which the wind is from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of m s^{-1}) is indicated by colors within each triangle. The shaded region defines the excluded wind directions.

4.3 Basin conditions

4.3.1 Basin appearance, liquid depth and sludge depth

The appearance of the basin was recorded on almost every site visit (Table 4.3-1). The basin generally appeared brown and entirely crusted.

Table 4.3-1: Basin physical characteristics

Period	Date, appearance (color/crust)
3:2/25-3/12/2008	2/25/08 - brown/ no crust 2/26/08 - brown/ no crust 2/27/08 - brown/ no crust 2/28/08 - brown/ no crust 2/29/08 - brown/ no crust
4: 3/12-3/26/2008	3/12/08 - brown/1% crust 3/13/08 - brown w/yellow film/1% crust 3/26/08 - brown/5% crust
5: 8/8 - 9/3/2008	8/8/08 - brown/100% crust 8/9/08 - brown/100% crust 8/10/08 - brown/100% crust 8/11/08 - brown/100% crust 8/12/08 - brown/100% crust 8/13/08 - brown/100% crust

Period	Date, appearance (color/crust)
6: 9/3 - 9/26/2008	9/4/08 - brown/100% crust 9/26/08 - brown/100% crust
8: 5/18 - 6/4/2009	5/19/09 - brown/100% crust 5/20/09 - brown/100% crust 5/21/09 - brown/100% crust
9: 6/4 - 6/20/2009	6/4/09 - brown/100% crust 6/19/09 - brown/100% crust

4.4 Emissions

Emissions data were calculated on a ½ h basis since this was the interval over which the S-OPS system sampled both sides of the basin and since this interval is in the range over which turbulence statistics are often calculated. Emissions reported on a head basis were scaled by the design animal population and not the animal population at the time of measurements to account for the longer term manure storage of the basin. Emissions reported on an animal unit (AU) basis assumed an animal weight of 500 lb equals 1 AU and the typical animal weight values reported by the producer. Piglets and calves were not included in the populations or AU determinations. Emissions reported on an area basis are based on the surface area of the basin.

Due to the rotation in use of the basins described in Section 1.3, the time axis is in sequential days. The NAEMS day refers to the days after measurements began for the entire project (not this location).

Comparison of RPM and bLS emissions models

The comparison between the RPM and bLS emissions models was conducted according to the USEPA Method 301 'Field Validation of Pollutant Measurement Method' using NH_3 emissions measurements. The comparison based on 233 ½ h measurement periods over the entire measurement time at this location. Results showed that the bLS emissions had a significantly different precision (F=1.16, critical F 1.0) and a significant bias over the *RPM* emissions (t=-1.47, $t_{0.2}$=1.29) with a corresponding correction factor for the bLS of 0.93 (Table 4.4.1-1). Consequently the ½ h bLS emissions measurements were biased low by 7% compared with the *RPM* measurements.

Table 4.4.1-1: Comparison of the bLS and RPM NH_3 emissions

	RPM	bLS	bLS-RPM
Mean emission (g s^{-1})	0.524	0.491	-0.033
Standard Deviation (g s^{-1})	0.311	0.335	
Variance of the mean (g s^{-1})	0.098	0.112	

4.4.1 NH_3 emissions

4.4.1.1 Mean daily NH_3 emissions

There was no distinct temporal pattern evident in the emissions based on the *RPM* model (Figure 4.4.1-1). Emissions were generally between 5 g to 15g $NH_3 d^{-1} hd^{-1}$. The daily emissions during the beginning of measurements was generally less than measurements later however these emissions measurements may be underestimated by up to 40% due to the interference of atmospheric moisture. The only daily emissions measurements estimated with more than 75% of the day's emissions are around September 2008. The daily NH_3 emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the *RPM* model are listed in Section 6.12.1.

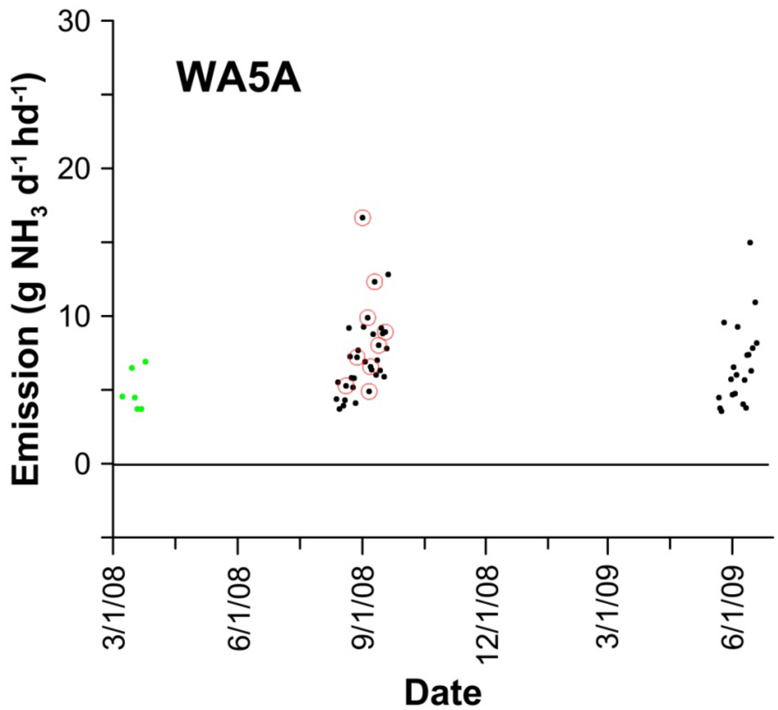

Figure 4.4.1-1: Annual variation in RPM-determined daily NH_3 emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day. The green solid circles indicate moisture interference with the NH_3 concentration measurement.

There was a distinct temporal pattern evident in the emissions based on the bLS model (Figure 4.4.1-2). Emissions were initially between 0 and 18g $NH_3d^{-1}hd^{-1}$ diminishing gradually to approximately 5 g $NH_3d^{-1}hd^{-1}$. The daily emissions during the beginning of measurements may be underestimated by 40% due to the interference of atmospheric moisture however the dryness of the environment probably resulted in less of an underestimate than 40%. Only one day's estimated daily emissions was based on more than 75% of the day's emissions. This consequently limits the confidence in the calculated emissions. The daily NH_3 emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the bLS model are listed in Section 6.12.2.

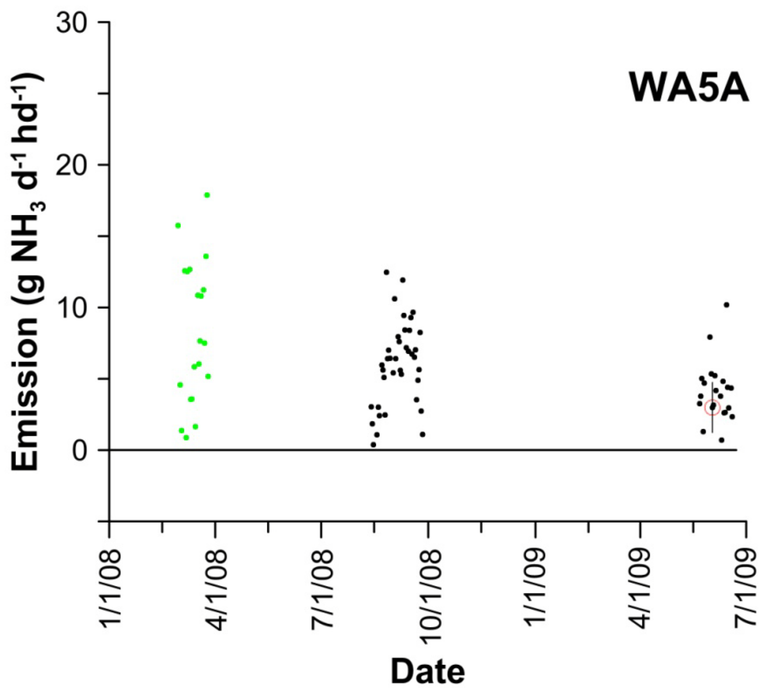

Figure 4.4.1-2: Annual variation in bLS-determined daily NH_3 emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day. The green solid circles indicate moisture interference with the NH_3 concentration measurement. The bars represent the standard deviation of emissions based on individual ½ h values when at least 75% of the day had valid measurements.

The bLS model was influenced by the calculated background concentrations. Results indicated that the background concentration of NH_3 was generally less than 0.1 ppm (Figure 4.4.1-3). Given that the typical path length around the basin was 200 m and the typical background concentration is less than 0.3 ppm, this corresponds to a background concentration for a given PIC of approximately 60 ppm-m. This is approximately 30 times the MDL for the TDLAS instruments of 2 ppm-m (Section 6.1) and therefore represents a real background for this location. Negative background concentrations occur when the winds are variable resulting in no distinct upwind or downwind S-OPS.

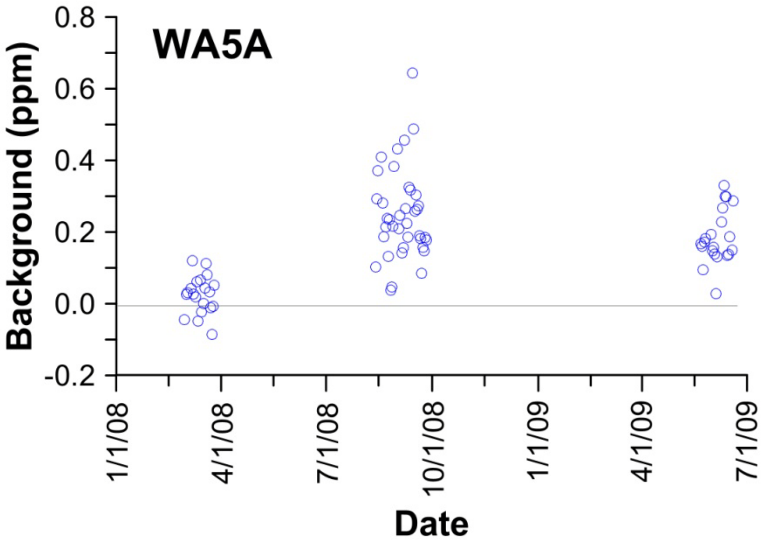

Figure 4.4.1-3: Annual variation in bLS-determined mean daily background concentration of NH_3.

4.4.1.2 Diurnal variation in NH_3 emissions

In general, there was a weak diurnal pattern to the NH_3 emissions with the likelihood for high emissions greater during the day than at night (Figure 4.4.1-4).

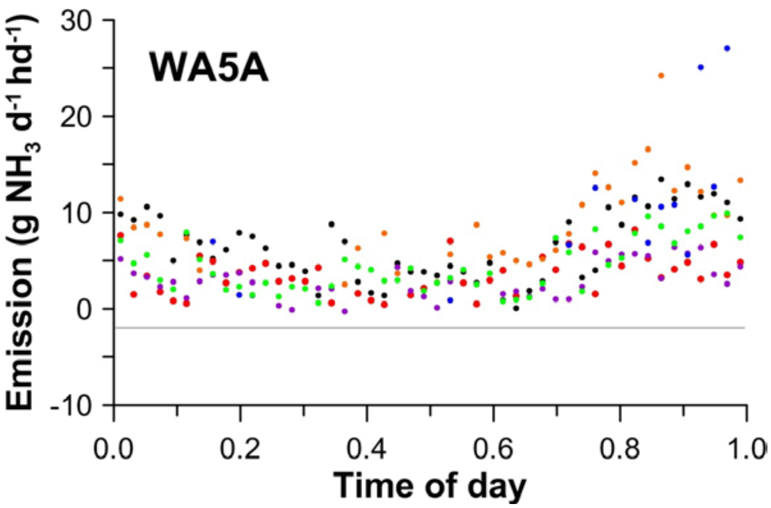

Figure 4.4.1-4: Diurnal variation in bLS-computed NH_3 emissions. Time based on Universal Time Coordinates. The mean emission for each half-hour of the day within a given measurement period (Period 2-Fall (pink), Period3-Winter (brown), Period 4-Spring (orange), Period 5-Summer (green), Period 6-Fall (black), Period 7-Winter (blue), Period 8-Spring (red), and Period 9-Summer (purple)) are indicated.

4.4.1.3 NH_3 emissions data completeness

Unless otherwise indicated, emissions completeness and failure totals are given in number of days corresponding to the total number of ½ h intervals for which the indicated condition was true. This number of days does not indicate the data completeness for any individual day. Therefore, an additional value giving the total number of days with at least 36 valid ½ h periods (corresponding to 75% completeness on a daily basis) is given. Because of the requirement of 5 to 10 valid TDLAS measurements before an *RPM* emission measurement is possible, the number of valid ½ h periods with *RPM* emissions was greatly limited. The wind conditions and wind direction exclusion region did not greatly reduce the yield of valid bLS emission measurements. The completeness statistics are summarized in Table 4.4.1-2.

Table 4.4.1-2: Completeness statistics for NH_3 emissions measurements

	Measurement period						
	3	**4**	**5**	**6**	**8**	**9**	**Total**
NH_3 RPM model							
Valid 1/2 h measurements (d)	0.0	0.2	11.2	10.6	2.0	4.6	**28.8**
Measurements excluded due to wind direction (d)	1.9	2.0	0.5	1.3	0.3	1.0	**7.0**
Measurements excluded because at least one downwind path is missing or invalid (d)	7.1	7.7	6.8	5.7	11.0	2.6	**40.9**
Number of days (d) with ≥36 valid 1/2 h periods	0.0	0.0	5.0	6.0	0.0	1.0	**12.0**
NH_3 bLS model							
Valid 1/2 h measurements (d)	0.5	1.5	3.7	5.3	2.4	2.3	**15.6**
Measurements excluded due to wind direction (d)	4.1	5.6	9.6	8.6	3.0	5.6	**36.5**
Measurements excluded because touchdown fraction < 0.1 (d)	1.0	0.0	1.8	0.2	3.0	0.0	**5.9**
Measurements excluded because $u_* < 0.15$ m s^{-1} or $\|L\| < 2$ m (d)	3.8	3.6	3.4	5.4	2.8	2.0	**21.1**
Number of days (d) with ≥36 valid 1/2 h periods	0.0	0.0	0.0	0.0	1.0	0.0	**1.0**

In total 28.8 d of valid NH_3 emissions were determined using the *RPM* model from the 101.9 d of measurements. Of these days, only 12 d had at least 36 valid ½ h NH_3 emissions. The absence or invalidation of at least one downwind path led to 40.9 d for which emissions could not be calculated.

In total 15 d of valid NH_3 emissions were determined from the 101.9 d of measurement using the bLS model, with only one day having at least 36 valid ½ h NH_3 emissions. The exclusion wind directions due to the location of the adjacent manure storage basin relative to the basin studied resulted in the loss of 36 d of measurements. Invalid turbulence statistics ($u_* < 0.15$ m s^{-1} or $|L| < 2$ m) led to 21 d for which emissions could not be calculated. A touchdown fraction of less than 0.1 led to the exclusion of 6 d of data. Low touchdown fractions indicated that little, if any, downwind data was available. This corresponded to either when the downwind TDL was not present or else the downwind paths were lost because of invalid light levels.

The *RPM* model requires all 5 or 10 (depending on the wind direction) downwind paths to have valid concentration readings for at least a portion of the ½ h interval. This contrasts with the bLS model which requires only 1 downwind surface path to have valid concentration readings. This difference is largely responsible for the much greater completeness for the bLS model than the *RPM* model. The *RPM* model uses ½ h mean wind speed and direction, in contrast to the bLS model that requires extensive turbulence statistics over this same period. As a result, there are times when the *RPM* model produces a valid emission while the bLS model does not. However there are times when the wind direction invalidated the bLS emissions measurement due to lack of upwind TDL measurement but the *RPM* emissions measurement was valid.

4.4.2 H_2S emissions

4.4.2.1 Mean daily H_2S emissions

There was an apparent decline in emissions evident in the emissions based on the Ratiometric model (Figure 4.4.2-1). Emissions were generally 2 g H_2S $d^{-1}hd^{-1}$ or less. Only one day of emissions measurements during the beginning of the study was possible due to instrument problems. There were no days in which more than 75% of the day's emissions were available for calculating the daily emission rate. The daily H_2S emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the Ratiometric model are listed in Section 6.12.3.

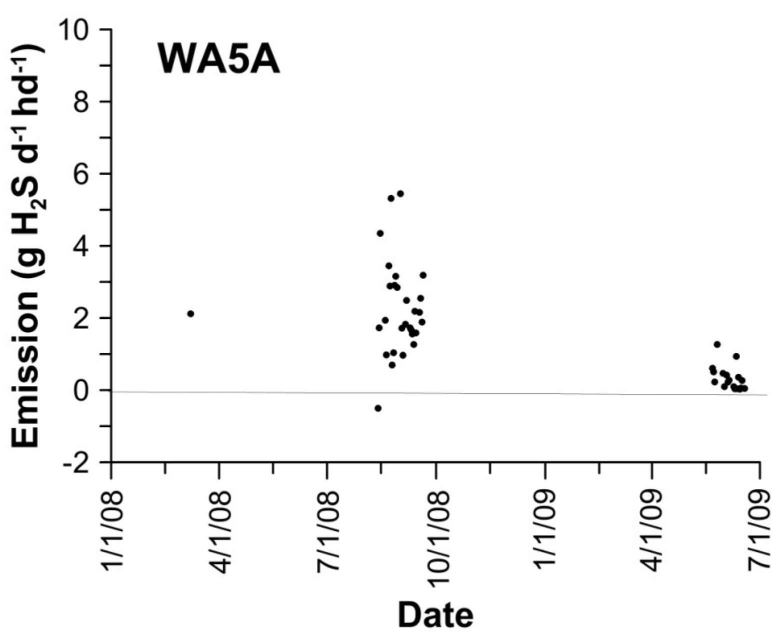

Figure 4.4.2-1: Annual variation in Ratiometric-determined daily H_2S emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day.

There was an apparent decline in emissions evident in the emissions based on the bLS model (Figure 4.4.2-1). Emissions were generally 4 g H_2S $d^{-1}hd^{-1}$ or less. There were no days in which more than 75% of the day's emissions were available for calculating the daily emission rate. The daily H_2S emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the bLS model are listed in Section 6.12.4.

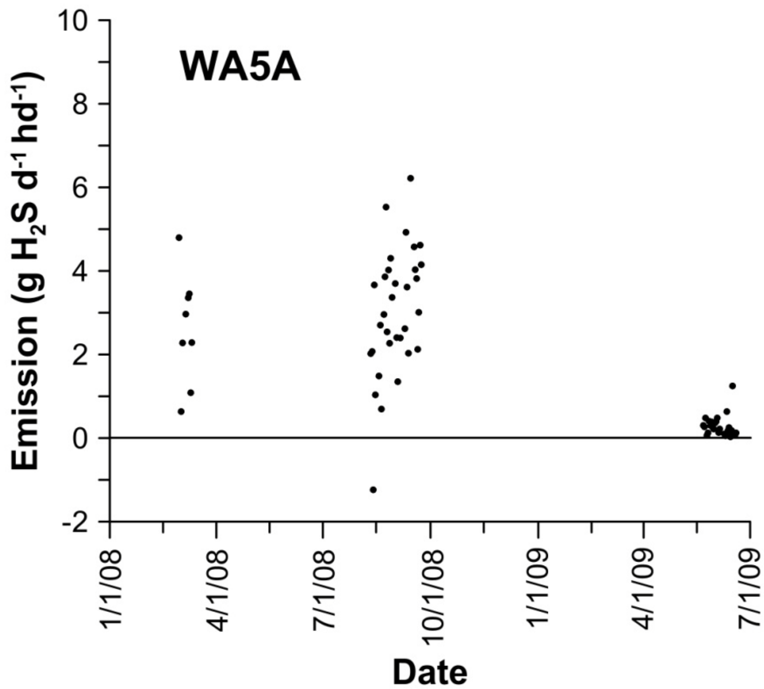

Figure 4.4.2-2: Annual variation in bLS-determined daily H_2S emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day. The bars represent the standard deviation of emissions based on individual ½ h values when at least 75% of the day had valid measurements. The green solid circles indicate moisture interference with the NH_3 concentration measurement.

The bLS emission model depends on a good estimate of the background H_2S concentration. Results indicate that the background concentration was generally less than ± 5 ppb but had a significant number of higher concentrations (Figure 4.4.3-3). Two values are above the top of the y-axis at 180 g H_2S $d^{-1}hd^{-1}$ (8/18/2008) and 305 g H_2S $d^{-1}hd^{-1}$ (8/20/2008). The high background concentrations indicate nearby sources of H_2S.

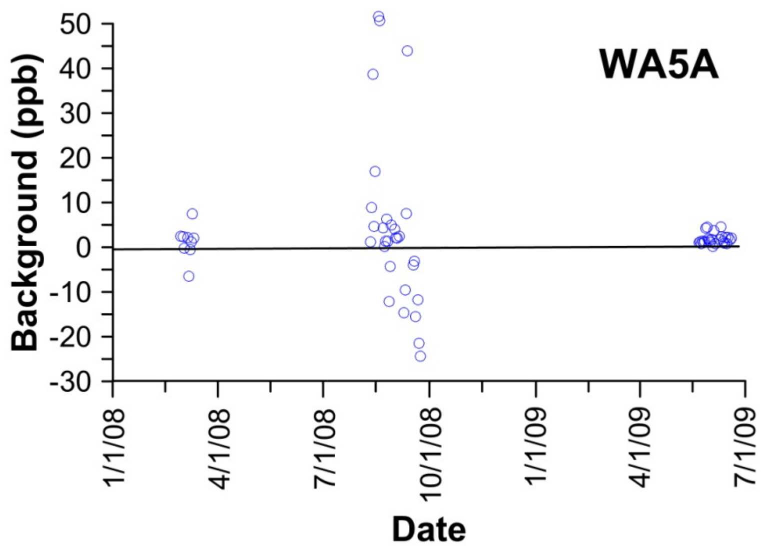

Figure 4.4.3-3: Annual variation in bLS-determined mean daily background concentration of H_2S.

4.4.2.2 Diurnal variation in H_2S emissions

There was no distinct diurnal periodicity in the H_2S emissions measurements (Figure 4.4.2-4).

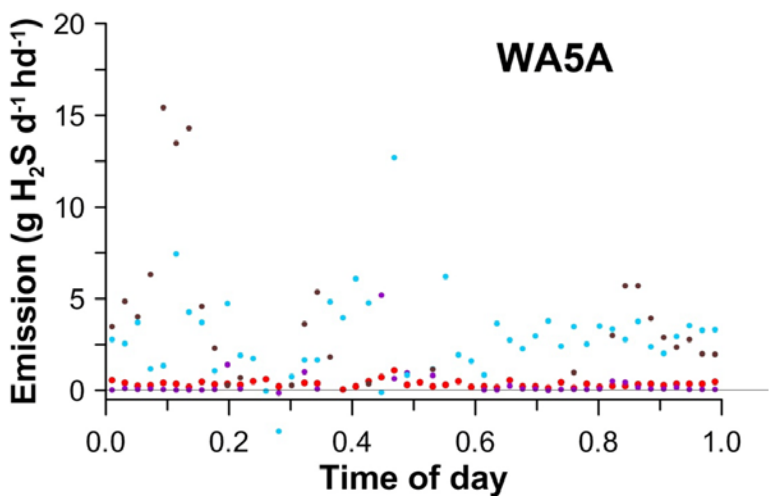

Figure 4.4.2-4: Diurnal variation in bLS-computed H_2S emissions. Time based on Universal Time Coordinates. The mean emission for each half-hour of the day within a given measurement period (Period 3-Winter (brown), Period 4-Spring (green), Period 5-Summer (light blue), Period 6-Fall (black), Period 7-Winter (blue), Period 8-Spring (red), and Period 9-Summer (purple)) are indicated.

4.4.2.3 H_2S emissions data completeness

H_2S Measurements were begun in Period 3. Consequently there were no measurements possible for autumn 2007. As described for the NH_3 emissions, emissions completeness and failure totals are given in number of days corresponding to the total number of ½ h intervals for which the indicated condition was true. This number of days does not indicate the data completeness for any individual day. The completeness statistics are summarized in Table 4.4.2-1.

The H_2S emissions were measured a total of 80.7 d at this location. The majority of measurements were invalidated as a result wind direction (Figure 1-2). Because there were few valid ½ measurements of the NH_3 emissions based on the *RPM* model (Table 4.4.1-2), the number of valid ½ periods of valid Ratiometric emissions measurements of H_2S is small. The majority of bLS emissions measurements were invalidated due to wind conditions. In total, 6 d of valid H_2S emissions were determined using the Ratiometric emission method, with no days having at least 36 valid ½ h H_2S emissions. Valid H_2S emissions for 12 d were determined using the bLS model, with no days having at least 36 valid ½ h H_2S emissions. Invalid turbulence statistics ($u_* < 0.15$ m s^{-1} or $|L| < 2$ m) excluded 15 d, largely due to low wind speeds. Wind direction exclusions invalidated 33 d of measurements.

Table 4.4.2-1: Completeness statistics for H_2S emissions measurements

	Measurement period						Total
	3	4	5	6	8	9	**Total**
H_2S Ratiometric model							
Valid 1/2 h measurements (d)	0.0	0.0	2.3	2.4	0.6	0.8	**6.1**
Number of days (d) with ≥ 36 valid 1/2 h periods	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
H_2S bLS model							
Valid 1/2 h measurements (d)	1.2	0.0	3.5	2.2	3.3	2.1	**12.2**
Measurements excluded due to wind direction (d)	3.5	0.0	11.6	6.3	6.2	5.5	**33.0**
Measurements excluded because angle of attack > 60 degrees (d)	0.5	0.0	1.0	0.5	0.6	0.1	**2.7**
Measurements excluded because $u_* < 0.15$ m s^{-1} or |L| < 2 m (d)	3.6	0.0	3.2	3.2	2.9	2.1	**15.0**
Number of days (d) with ≥ 36 valid 1/2 h periods	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**

4.4.3 Estimation of emission measurement errors

Errors in the response of the TDLAS due to atmospheric moisture limited the accuracy of the TDLAS serial numbers 1026, 1027, and 1028 prior to July 21, 2008. TDLAS 1026 was used at WA5A from 2/28/2008 to 3/26/2008 (Measurement periods 3 and 4). Under the calibration verification checks, the TDLAS error of all units was 10% accuracy. However due to the short path length of the calibration verification, these checks did not assess water vapor interferences experienced in the long path lengths around the area sources. Inter-comparisons between various TDLAS units experiencing atmospheric moisture interference and units without apparent interference revealed reduced responses with the moisture-affected units of 28%, 68%, 36% and 31% for atmospheric moisture varying from dewpoint temperatures of -2^{o}C to 20^{o}C. A conservative estimate of the bias of all of the above TDLAS units with evident moisture interference was estimated at -40%.

4.4.3.1 Error in RPM-measured NH_3 emissions

Tracer releases studies indicated that the RPM emissions measurement has an error in accuracy of approximately ±15% (Hashmonay et al., 2001; Verma et al., 2005; USEPA, 2007). The TDLAS measurement error was 10% (Section 6.1). Combining errors results in an expected error in the RPM-measurement of NH_3 emissions of ± 18%. In addition, the NH_3 measurements made using the TDLAS units with moisture interference had a bias of -40%.

4.4.3.2 Error in bLS-measured NH_3 and H_2S emission

Tracer studies using TDLAS concentration measurements in combination with the bLS emissions model averaged over roughly two hour periods indicated the bLS method error for a given 15-min period varied with stability: overestimated by 12% under near neutral conditions, underestimated by 13% under unstable conditions, and overestimated by 38% under stable conditions (Flesch et al., 2004). Under conditions when Monin Obukhov similarity theory was valid, the bLS-calculated emission rate was biased 6% high with a standard deviation of 16%.

Laubach and Kelliher (2005) evaluated the theoretical errors of the bLS model. The breakdown of their 22% model error included a 12% error for the estimate of the Monin-Obukov Length (L) derived from measurements, a 5% error in turbulence statistics (10% error for the normalized variability statistics in the x and y directions and 5% in the z direction), a 15% error associated with the roughness length (z_o) estimate, and a 10% error due to the stochastic methodology. This was consistent with tracer-estimated errors of the bLS emission calculation method, when constrained by the data quality indicators of the bLS method, of between 5% and 36%.

For this study, we assumed the above theoretical random error of 22% for the bLS emissions measurements. The TDLAS measurement error was 10% (Section 6.1). At this location the daily mean bLS emissions bias from the RPM emissions measurement was -6% (from the RPM/bLS method comparison in Section 4.4). As previously stated, the TDLAS units with moisture interference had a bias of -40%. Combining errors resulted in an expected error in the RPM-measurement of NH_3 emissions of ± 24% with a bias of -46% for TDLAS NH_3 measurements made by units with moisture interference and a bias of -6% for TDLAS NH_3 measurements made by units without moisture interference.

The H_2S PF instrument measurement error was 10% (Section 6.2). Given the expected error in the bLS measurement of emissions of 22%, the H_2S emissions error was estimated as ± 24%

4.4.3.3 Error in Ratiometric-measured H_2S emission

The Ratiometric method of H_2S emissions measurement depends on the RPM measurement of NH_3 emissions. The RPM emissions measurement had an error of approximately ±15%. Since the Ratiometric method ratios the emissions and concentrations of NH_3, there was no affect of the moisture interference in the TDLAS measurement on the H_2S emissions calculation. Given the H_2S PF instrument measurement error of 10% (Section 6.2), the combined error for the ratiometric measurement of H_2S emissions was ± 18%.

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6 Appendices

6.1 TDLAS NH_3 calibrations

Five TDLAS units (Model GasFinder2™ NH3OP, Boreal Laser Inc., Spruce Grove, Alberta, Canada) were used at this location: serial numbers 1026, 1027, 1028, 1029, and 1032.

TDLAS 1026, was multipoint calibrated seven times (Figure 6.1-1). The response was non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multipoint calibration on 1/17/07 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$$\text{ppm-m} = -0.97 + 1.0197 * X - 4.410E\text{-}5 * X^2 + 1.591E\text{-}8 * X^3$$

where X was the instrument response. The response of the sensor was influenced by humidity until July, 21 2008 due to an error in the factory settings for the spectral waveband analysis window. At that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference cell resulting in unusually low r^2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments) but did change the maximum r^2 reached by the instrument when in the field for long path lengths and high humidity.

A zero concentration was not reportable by this instrument because the concentration was based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 σ) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.04 ppm-m prior to the July 2008 modification and 1.77 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-2) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-3). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 8.27 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-2) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on 4/28/2009 and 11/10/2009 while negative biases exceeding the DQI occurred over the period 4/2/2008 through 7/1/2008 (Figure 6.1-2). The 4/28/2009 and 11/10/2009 bias exceedances were followed the same or next day with a passing verification and were deemed to be a result of operator error. The negative bias over the period 4/2/2008 through

7/1/2008 was not a result of calibration cylinder certification error (three different cylinders were used). During operations the bias was only intermittently evident because to different multipoint calibration was applied to the calibration verification measurements during the progress of the study than finally applied during the analysis. Repeated calibrations within 24 h often showed biases differing by more than 10 ppm-m suggesting operator errors. Although this instrument had a bias associated with water vapor interference, the instrument was in use in dry climates during this time. The measurements made during this period are considered valid and the error assumed to be due to the calibration verification operator.

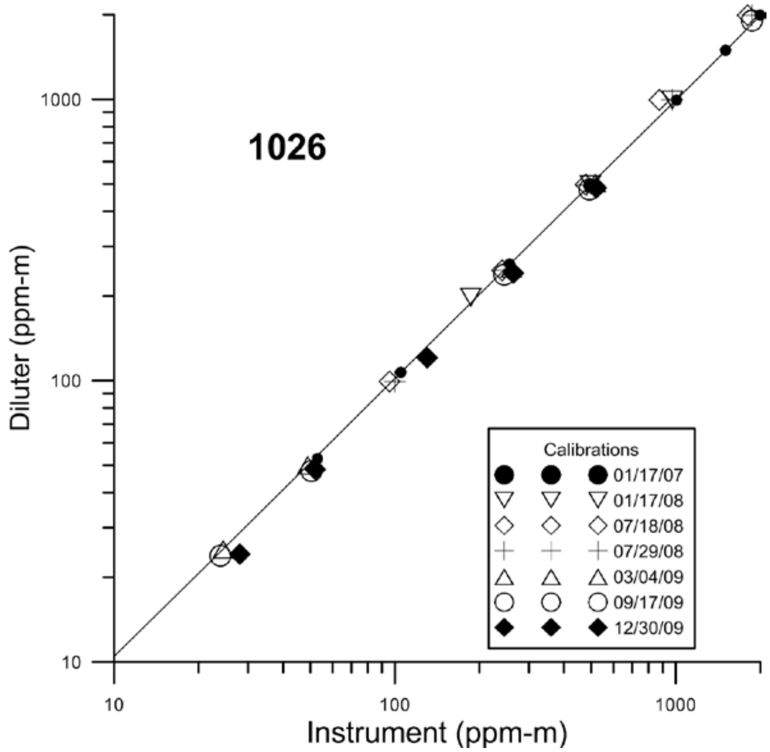


Figure 6.1-1: Multipoint calibrations of TDLAS 1026. The solid line is the 3rd order polynomial regressions for the chosen multipoint calibrations.

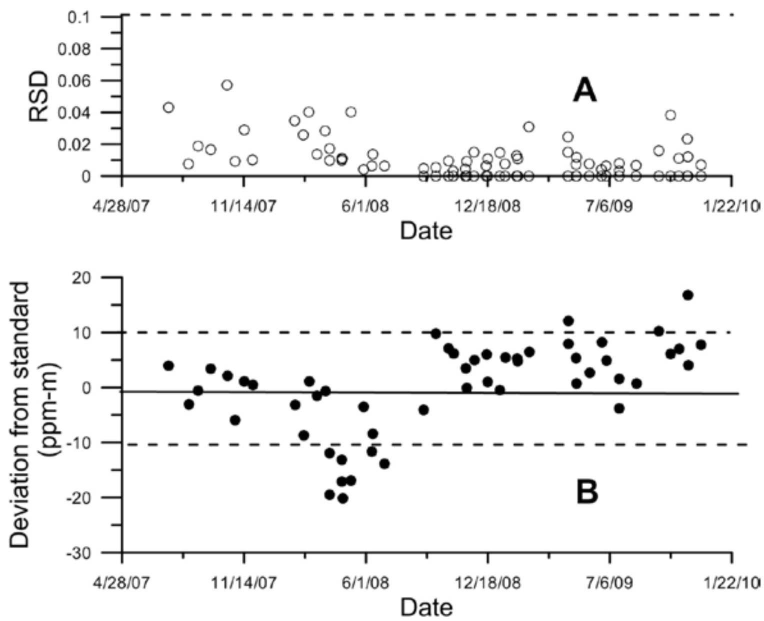


Figure 6.1-2: Control charts of TDLAS 1026

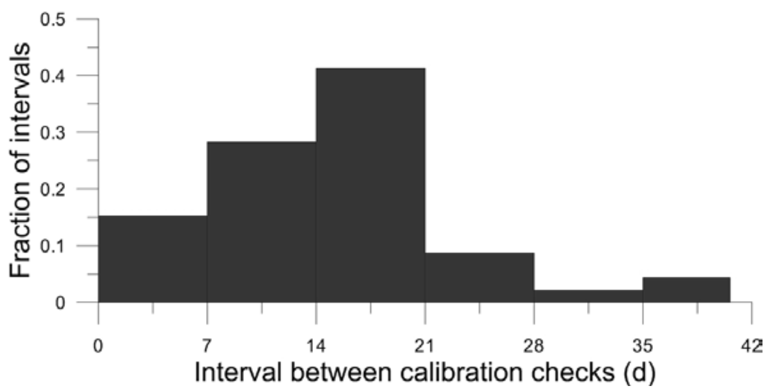


Figure 6.1-3: Calibration check intervals of TDLAS 1026

TDLAS 1027 was multipoint calibrated eight times during the study (Figure 6.1-4). The response was non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multipoint calibration on 6/18/2008 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$$\text{ppm-m} = 2.24 + 0.9936 * X - 3.59E\text{-}5 * X^2 + 6.230E\text{-}8 * X^3$$

where X was the instrument response. The response of the sensor was influenced by humidity until 7/21/2008 due to an error in the factory settings for the spectral waveband analysis window. At that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference cell resulting in unusually low r^2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments) but did change the maximum r^2 reached by the instrument when in the field for long path lengths and high humidity.

A zero concentration was not reportable by this instrument because the concentration was based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 σ) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.13 ppm-m prior to the July 2008 modification and 1.83 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-5) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-6). The large fraction of checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 5.36 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-5) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on 9/26/2008 and 9/24/2009 (Figure 6.1-4). No negative biases exceeding the DQI occurred. Since both positive bias exceedances were followed by a DQI compliant verification on the subsequent calibration verification without intervention, it is assumed that operator error was the cause for the non-compliance.

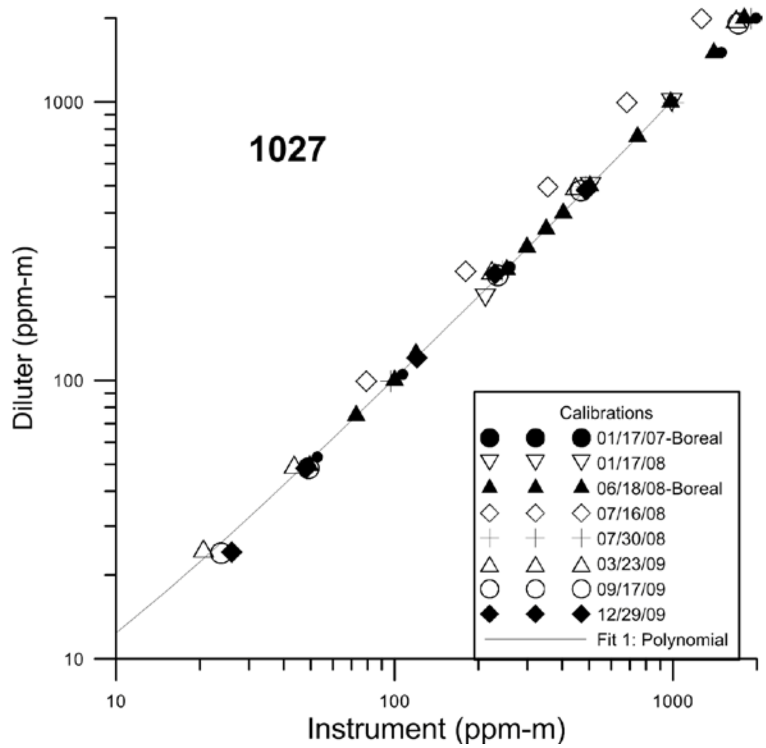


Figure 6.1-4: Multipoint calibrations of TDLAS 1027. The solid line is the 3rd order polynomial regressions for the chosen multipoint calibrations.

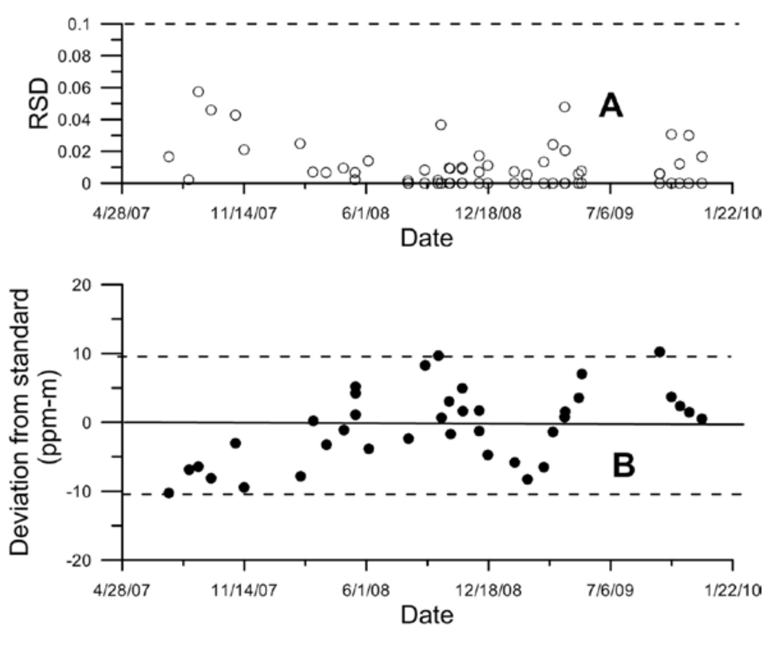


Figure 6.1-5: Control charts of TDLAS 1027

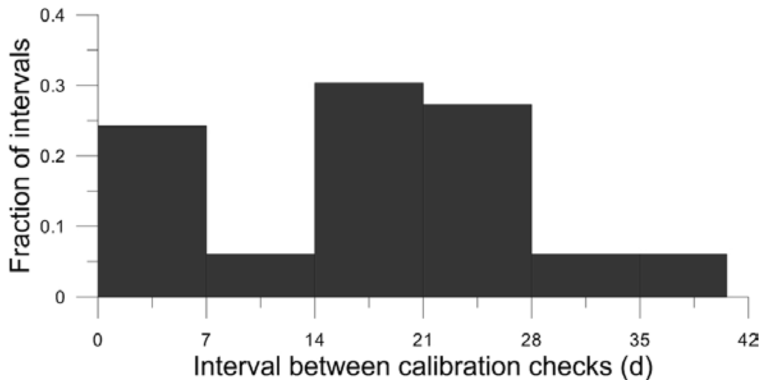


Figure 6.1-6: Calibration check intervals of TDLAS 1027

TDLAS 1028 was multipoint calibrated six times during the study (Figure 6.1-7). The response was non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multipoint calibration on 5/23/2007 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$$\text{ppm-m} = 1.46 + 0.985 * X + 8.465\text{E-}6 * X^2 + 3.879\text{E-}8 * X^3$$

where X was the instrument response. The response of the sensor was influenced by humidity until 7/21/2008 due to an error in the factory settings for the spectral waveband analysis window. At that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference cell resulting in unusually low r^2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments) but did change the maximum r^2 reached by the instrument when in the field for long path lengths and high humidity.

A zero concentration was not reportable by this instrument because the concentration was based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 σ) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.48 ppm-m prior to the July 2008 modification and 1.91 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-8) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-9). The large fraction of checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 6.46 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-8) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on three dates (9/26/2008, 10/1/20008 and 9/24/2009) while negative biases exceeding the DQI occurred on 12/16/2008 (Figure 6.1-8). In all cases except the short 9/24/2008 through 10/1/2008 period, subsequent calibration verifications did not indicate the same exceedance bias and it is concluded that operator error resulted in the exceedances rather than instrument failure.

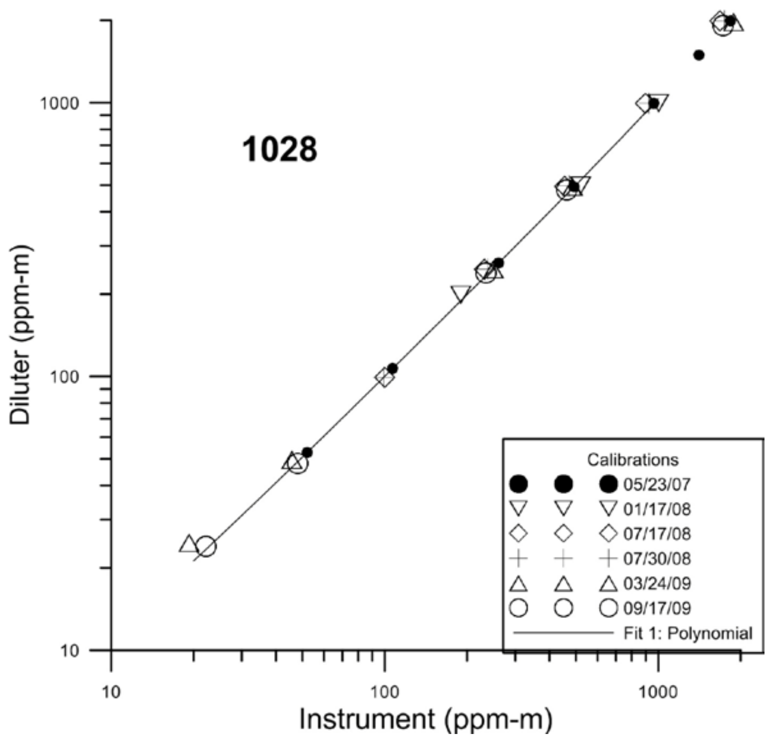


Figure 6.1-7: Multipoint calibrations of TDLAS 1028. The solid line is the 3rd order polynomial regressions for the chosen multipoint calibrations.

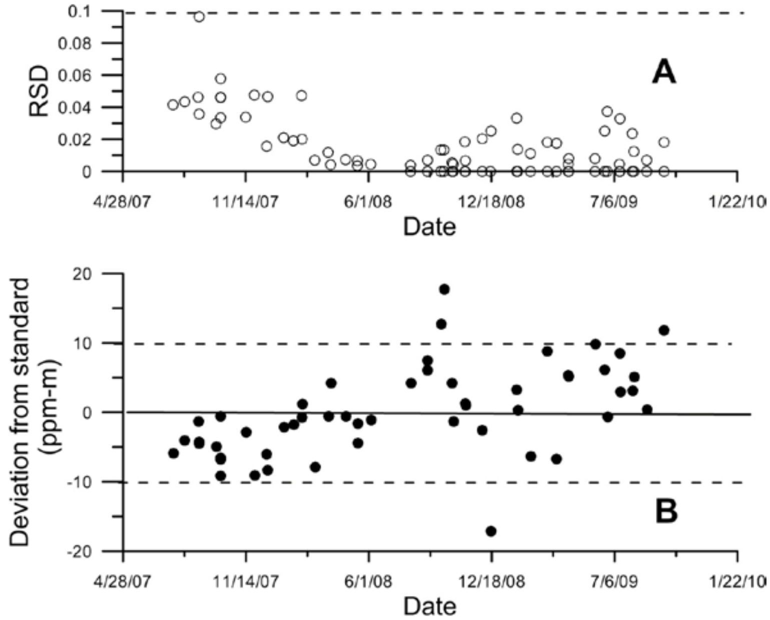


Figure 6.1-8: Control charts of TDLAS 1028

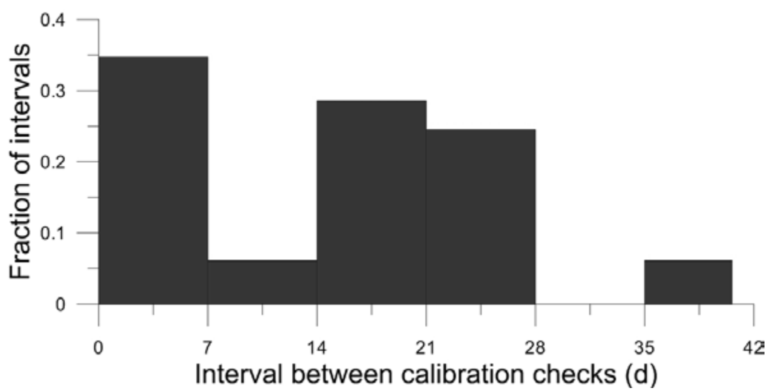


Figure 6.1-9: Calibration check intervals of TDLAS 1028

TDLAS 1029 was multipoint calibrated seven times during the study (Figure 6.1-10). The response was non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. Table 6.1-1 indicated the multipoint calibrations used during different periods in the study.

Table 6.1-1: Multipoint calibration application

Period of applicability (mm/dd/yyyy)		
Begin	**End**	**Multipoint calibration**
6/24/2007	03/01/2008	05/24/2007
3/24/2008	07/15/2008	03/24/2008
7/31/2008	08/03/2009	03/04/2009
8/4/2009	12/2/2009	12/29/2009

The offsets of the calibration equations were determined from a least squares fit of the appropriate period (Table 6.1-1) of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibrations. The regression equations were:

05/24/07: ppm-m = -1.48 + 0.967 * X + 4.842E-005 * X^2 - 7.312-009 * X

03/24/08: ppm-m = -2.58 + 0.998 * X - 1.611E-004 * X^2 + 7.449E-008 * X^3

03/04/09: ppm-m = 4.36 + 1.069 * X + 1.128-004 * X^2 - 1.206E-007 * X^3

12/29/09: ppm-m = 5.48+ 1.268 * X - 6.072E-005 * X^2

where X was the instrument response. In July 2008 factory representatives adjusted the response of this unit. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments).

A zero concentration was not reportable by this instrument because the concentration was based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 σ) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.74 ppm-m prior to the July 2008 modification and 1.66 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The MDL prior to the July 2008 modification was greater than the offset in the calibration regression equations but less than the offset in the calibration equations after the modification. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-11) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-12). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equations was 4.65, 4.15, 5.23, and 4.27 ppm-m respectively. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-11) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A negative bias exceeding the DQI threshold occurred on two dates (Figure 6.1-11). No positive bias exceeding the DQI threshold occurred. In all cases subsequent calibration verifications did not indicate the same exceedance bias and it is concluded that operator error resulted in the exceedances rather than instrument failure.

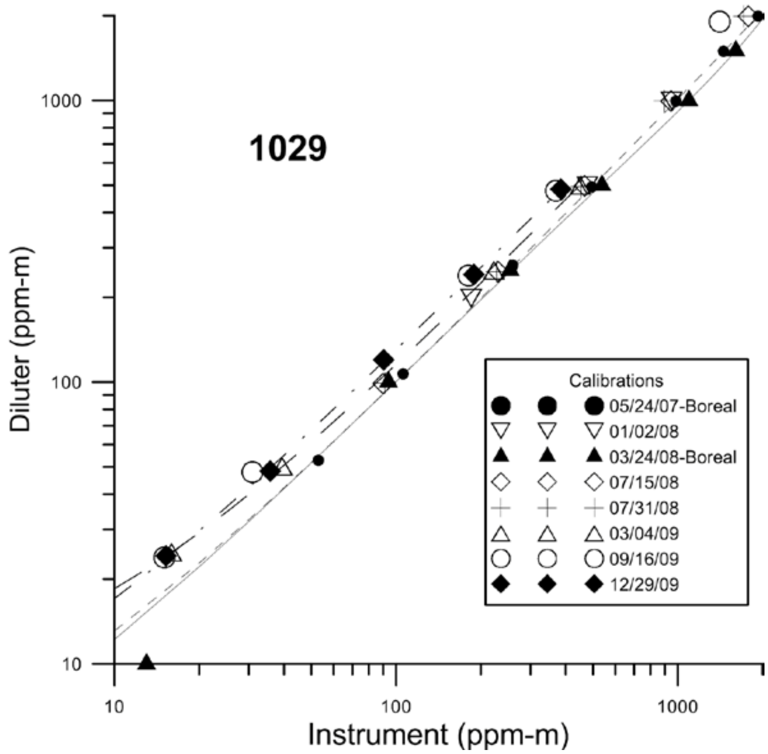


Figure 6.1-10: Multipoint calibrations of TDLAS 1029. The solid (5/24/07), dotted (3/24/08), dashed (3/4/09) and dash-dot (12/29/09) lines are the 3rd order polynomial regressions for the chosen multipoint calibrations.

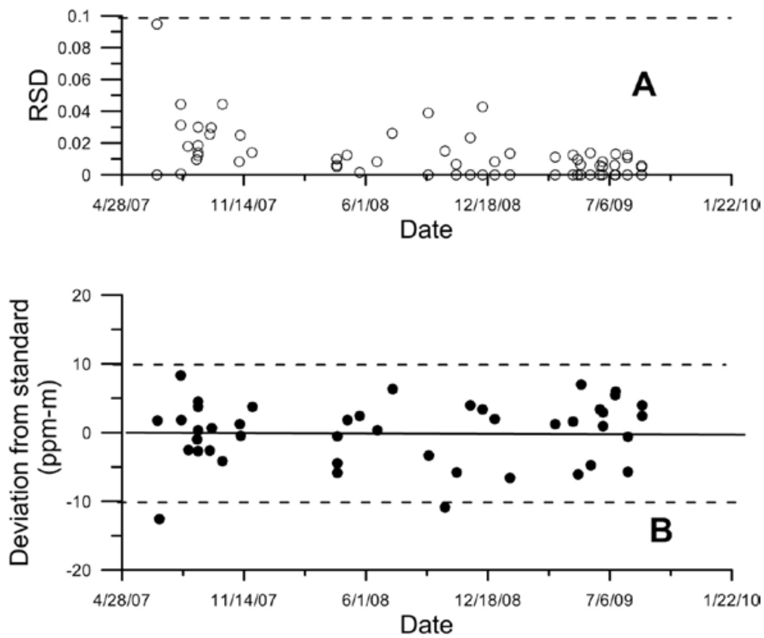


Figure 6.1-11: Control charts of TDLAS 1029

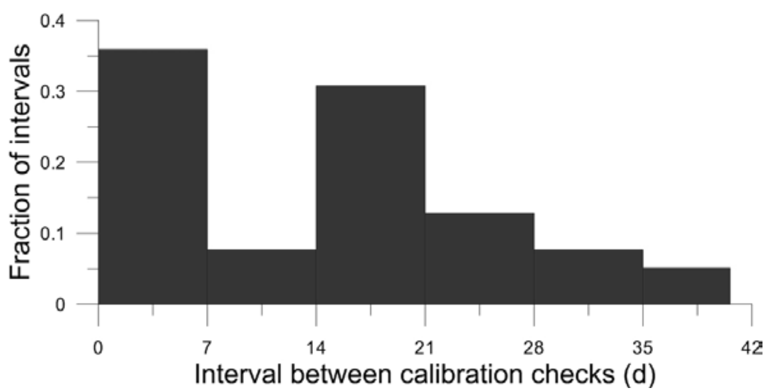


Figure 6.1-12: Calibration check intervals of TDLAS 1029

TDLAS 1032, was multipoint calibrated six times (Figure 6.1-13). The response is non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. Table 6.1-2 indicated the multipoint calibrations used during different periods in the study.

Table 1- Multipoint calibration application

Period of applicability (mm/dd/yyyy)		
Begin	**End**	**Multipoint calibration**
9/21/2007	8/1/2008	9/12/2007
8/27/2008	8/18/2009	3/4/2009

The offset of the calibration equation was determined from a least squares fit of the appropriate period (Table 6.1-2) of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibrations. The regression equations were:

9/12/07: ppm-m = $-4.35 + 1.005 * X + 3.563\text{ E-005} * X^2 - 2.618\text{ E-008} * X^3$

3/4/09: ppm-m = $-0.69 + 0.995 * X - 2.3298\text{ E-004} * X^2 + 2.891\text{ E-007} * X^3$

where X was the instrument response. In July 2008 factory representatives adjusted the response of this unit. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments). The laser was found on 7/21/2008 to not be internally grounded properly, resulting is the inclusion of responses at very low light levels. The no-return light levels were above the minimum light level threshold considered for a valid instrument measurement.

A zero concentration was not reportable by this instrument because the concentration was based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 σ) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.60 ppm-m prior to the July 2008 modification and 1.36 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The MDL was greater than the offset in the calibration equation for measurements prior to July 2008 and less than that after July 2008. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-14) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-15). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 6.13 and 5.61 ppm-m respectively. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-14) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias exceeding the DQI occurred on 3/26/2008 and 9/10/2008 (Figure 6.1-14). These exceedances were preceeded and followed by valid calibration verifications and it is assumed that since no modifications of the instrument were made that the exceedances are due to operator error. A negative bias exceeding the DQI was indicated in the calibration verifications on 5/6/2008

(Figure 6.1-14). The grounding problem found on 7/21/2008 (described above) may have been the cause for the period of consistently negative verifications after 4/21/08 when the background light levels exceeded the minimum acceptable light level. However since the 5/6/2008 exceedance was followed by compliant verifications (although low) without correction of the grounding problem it is assumed that the measurements are valid throughout the period of the grounding problem.

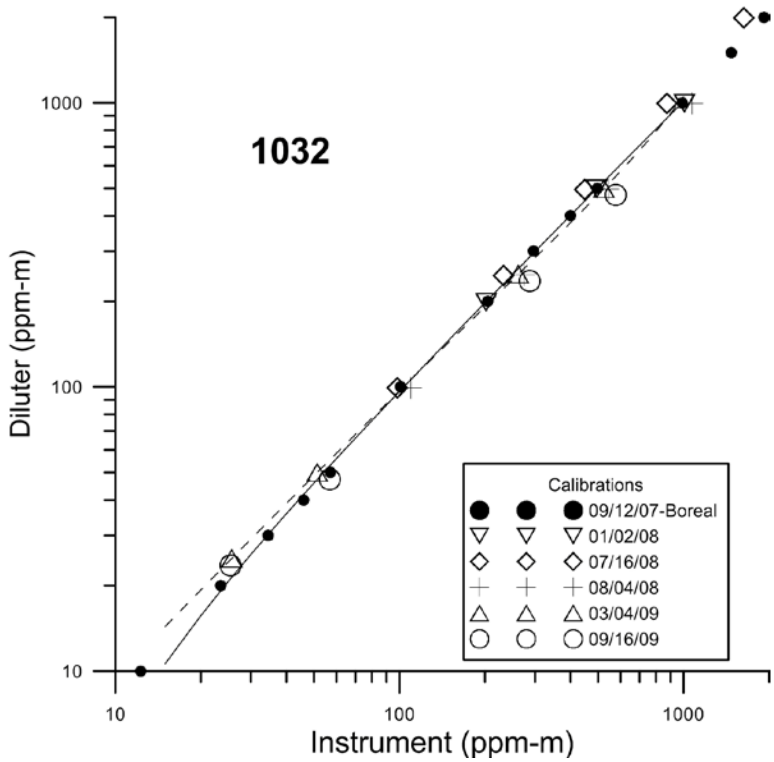


Figure 6.1-13: Multipoint calibrations of TDLAS 1032. The solid (9/12/07) and dashed (3/4/09) lines are the 3rd order polynomial regressions for the chosen multipoint calibrations.

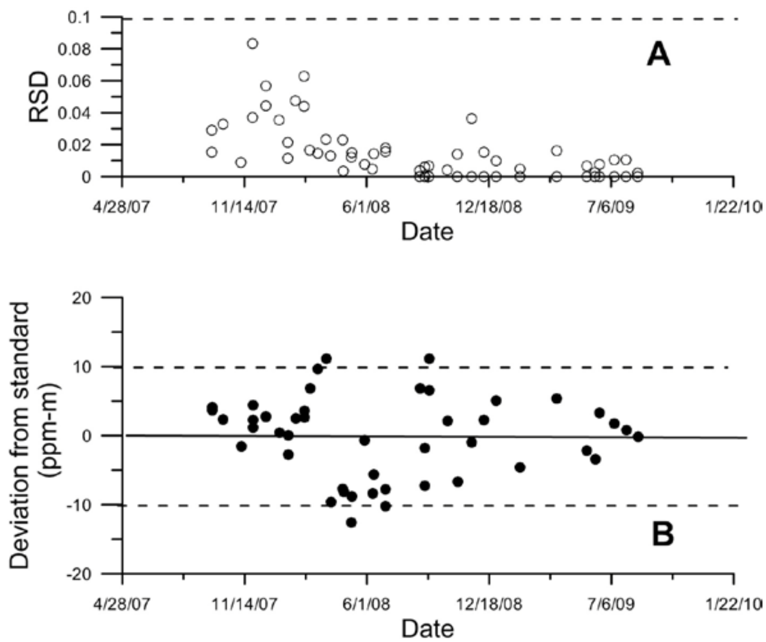


Figure 6.1-14: Control charts of TDLAS 1032

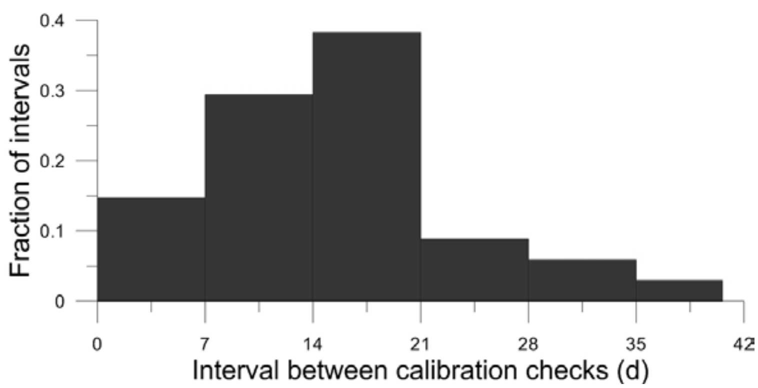


Figure 6.1-15: Calibration check intervals of TDLAS 1032

6.2 TEC 450i analyzer H_2S calibrations

The H_2S Analyzer (Model TEC 450i, Thermo Fisher Scientific, Franklin, MA), serial number 0733825128, was multipoint calibrated eight times (Figure 6.2-1). The coefficient of determination (r^2) for linear fits to the calibration values were never less than 0.999 although the slope of the linear regression equation varied from 0.73 to 1.38 (Table 6.2-1). Part of the variation in slope was a result of the H_2S calibration cylinders used. The initial multipoint calibration was conducted prior to the complete burn-in of the converter and consequently differs greatly from the other calibrations.

Table 6.2-1: Multipoint H_2S calibrations

Date	Slope (ppb/response)	Intercept (ppb)	r^2
12/12/2007	1.38	-0.0220	0.999
7/11/2008	0.99	0.0034	0.999
8/13/2008	1.18	-0.0045	0.999
9/4/2008	1.22	0.0065	0.999
3/25/2009	0.73	0.0068	0.999
6/19/2009	1.14	-0.0037	0.999
6/24/2009	0.75	0.0075	0.999
09/09/2009	1.14	-0.0052	0.999

The standard deviation of instrument response with CEM zero air measured over a one hour period was 0.83 ppb (10/19/2009). The instrument MDL, defined as 3σ was 2.5 ppb and is indicated in Figure 6.2-2A with dashed lines. This is much less than the mean absolute multipoint calibration intercept concentration of 7.5 ppb.

Instrument performance calibration checks (Figures 6.2-2 and 6.2-3) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.2-4). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. Instrument response was converted into measured concentrations by multiplying the instrument response by the long-term mean ratio of diluted calibration gas by instrument reading. The long-term mean ratio for this instrument was 0.788. The mean zero concentration was +1.7 ppb, less than the MDL.

The instrument measurement accuracy DQI was 10% of full scale (FS; 1 ppm). Three major periods of instrument bias that exceeded the ± 10% of FS are evident (Figure 6.2-2). The first period extended from the beginning of the measurements until 9/5/2008. Based on the correlation of instrument performance and the calibration cylinder used, it was determined that the concentration of H_2S in the SGAL053 cylinder, which could not be independently verified, was significantly below indicated specification. This resulted in unusually high ratios of diluter concentration versus instrument response (1.01 to 1.18) up until when the cylinder was replaced. The second period was from 11/4/2008 to 12/16/2008 when the calibration checks were inconsistent. Checks conducted on 11/4 and 12/16 at the end of measurement periods failed while checks made two days later at the set up of the next site passed. Since no modifications/repairs of the instruments were done in the interim between these calibrations, we assume that the FOS must have erred in their procedures.

The third period of calibration check failures occurred after April 2009. High zero checks (Figure 6.2-2A) and low reference checks (Figure 6.2-2B) occurred throughout this time. The instrument response time was observed to be unusually long (11 min versus typical 5 min) when specifically checked in July 2009. After the prescribed 10 min interval, which is specified in the SOP, the response was only 59% of the span value when the long time constant was discovered. Given the SOP reference value of 0.5 ppm, the 59% response after 10 min corresponds to approximately 0.2 ppm less than the stabilized reference value. The control chart of the calibration checks (Figure 6.2-2) showed a shift in response of approximately -0.2 ppm that occurred in May 2009 and continued through July 2009 but then appeared to return to normal operation in August 2009. This change in time response occurred during dusty conditions when the equipment was at WA5A. The change in response resulted in two multipoint calibrations in the field (Table 6.2-1).

The instrument measurement precision DQI was 10% of FS. Precision DQI exceedances (Figure 6.2-3) occurred on 9/5/2008, 6/4/2009 and 8/4/2009. The failure on 9/5/2008 was associated with a change in calibration cylinder (from SGAL053 to FF27944). As previously discussed, it is believed that the certified concentration in SGAL053 was low, resulting a significant shift in the measured diluter concentration when the new cylinder began use. The failure on 6/4/2009 and 8/4/2009 were probably associated with variable response the instrument during the period of the shift in response time of the instrument.

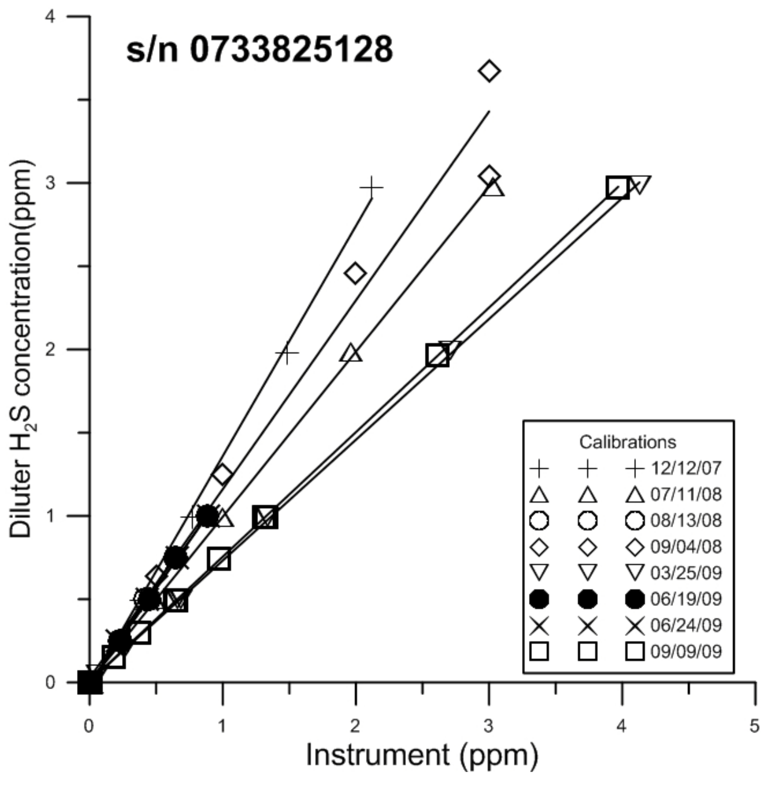


Figure 6.2-1: Multipoint calibrations of the 450i SO2/ H_2S Analyzer

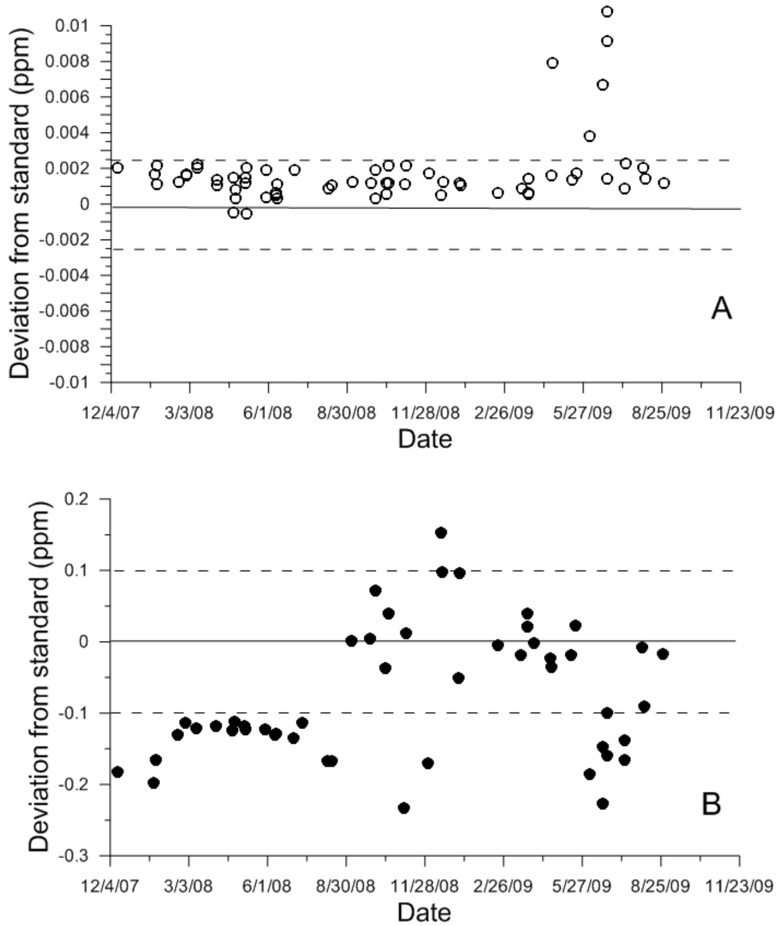


Figure 6.2-2: Instrument Control Charts.

The zero check (panel A) and span check (panel B) are indicated. The dashed lines in panel A represent the MDL. The dashed lines in panel B represent 10% of the Full Scale value (1 ppm).

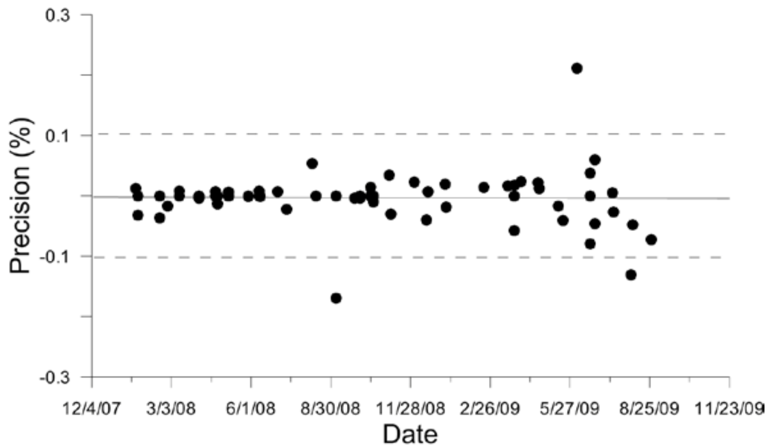


Figure 6.2-3: Instrument Precision

The precision of span checks are indicated. The dashed lines in panel A represent the MDL. The dashed lines represent 10% of the Full Scale value (1 ppm).

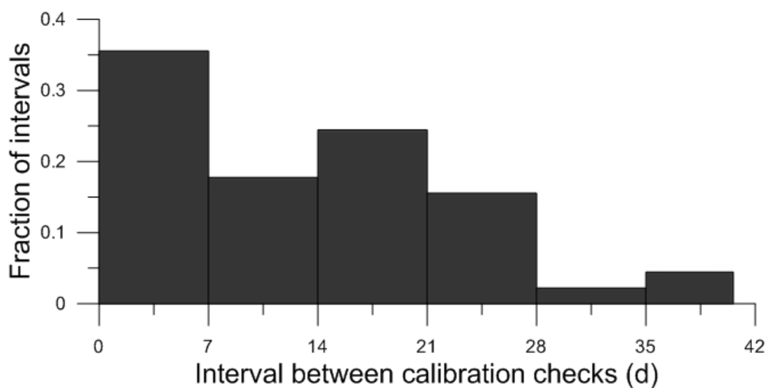


Figure 6.2-4: Calibration check intervals

6.3 Sonic anemometer calibrations

Five sonic anemometers (Model 81000, RM Young Inc, Traverse City, MI) were used at this location: serial numbers 1927, 1920, 1921, 1932, and 1936.

The sonic anemometer 1927 was inter-compared with three reference anemometers of identical design five times during the study (Table 6.3-1). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 35 times (Figure 6.3-1). The majority of calibration checks were made within 21 d (Figure 6.3-2). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 m s^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-1B). This instrument passed this check on all checks except 9/23-25/2008 and was taken out of service. Laboratory testing indicated wetness in the sensor. The sensor was dried, tested, and put back to use.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 m s^{-1} of zero (Figure 6.3-1A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-1: Standards inter-comparisons

Calibration date		**Mean difference from reference anemometers (m s^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/8-12/2007	6/12-14/2007	-0.025	-0.043
1/21/2008	1/23/2008	-0.051	-0.033
7/16-17/2008	7/17-18/2008	+0.042	+0.029
3/23-25/2009	3/25-27/2009	-0.050	-0.028
9/1-2/2009	9/2-3/2009	-0.035	-0.023

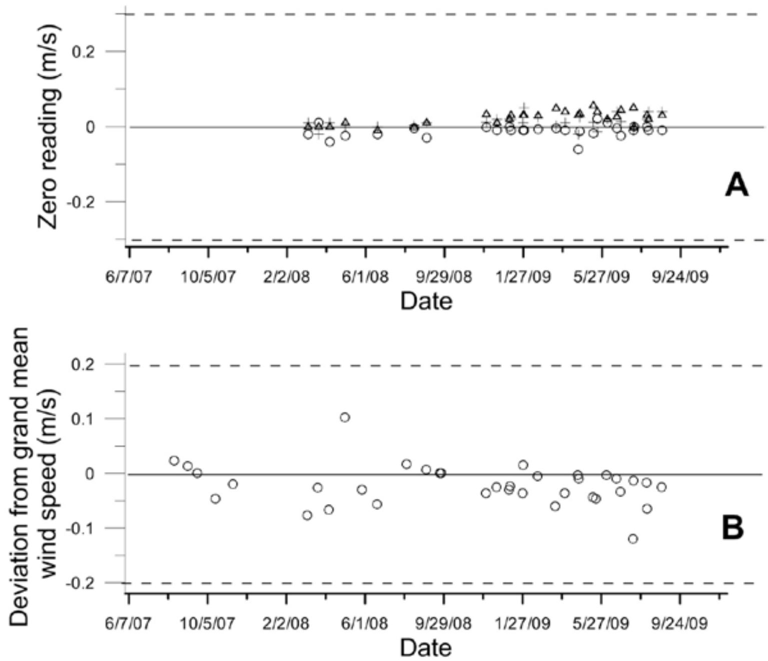


Figure 6.3-1: On-site quality assurance of sonic anemometer 1927. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

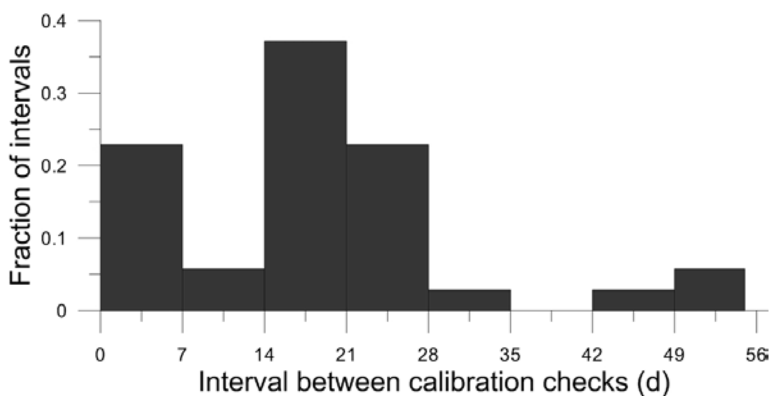


Figure 6.3-2: Inter-comparison check intervals for sonic anemometer 1927

The sonic anemometer 1920 was inter-compared with three reference anemometers of identical design five times during the study (Table 6.2-2). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 51 times (Figure 6.3-3). The majority of calibration checks were made within 21 d (Figure 6.3-4). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 m s^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-3B). This instrument passed this check at all times. However this instrument developed intermittent problems during operation and was sent to the factory for repair 10/10/2008.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 m s^{-1} of zero (Figure 6.3-3A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-2: Standards inter-comparisons

Calibration date		Mean difference from reference anemometers (m s^{-1})	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/19-22/2007	6/29-7/2/2007	+0.001	+0.002
1/17-19/2008	1/20-21/2008	+0.045	+0.003
7/18-21/2008	7/21-22/2008	+0.017	-0.006
3/23-25/2009	3/25-27/2009	-0.036	-0.033
9/1-2/2009	9/2-3/2009	-0.046	-0.025

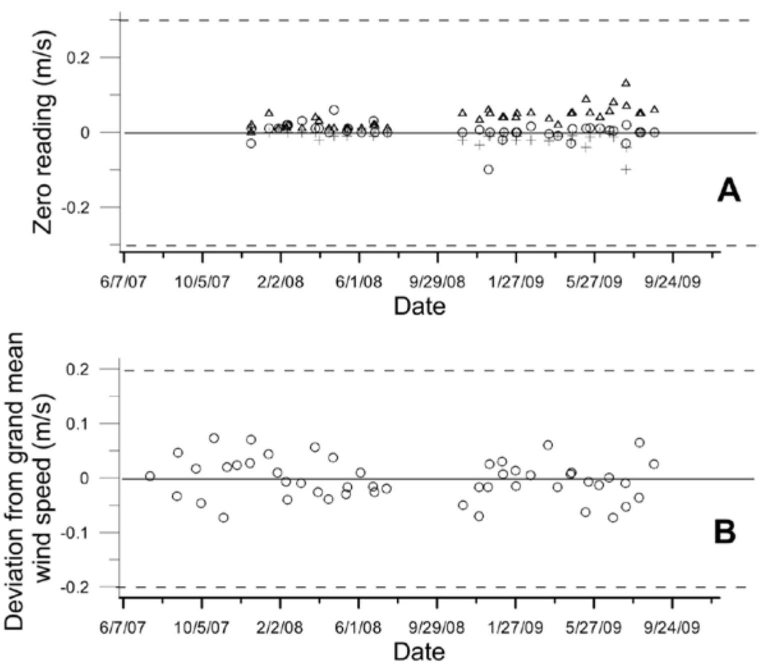


Figure 6.3-3: On-site quality assurance of sonic anemometer 1920. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

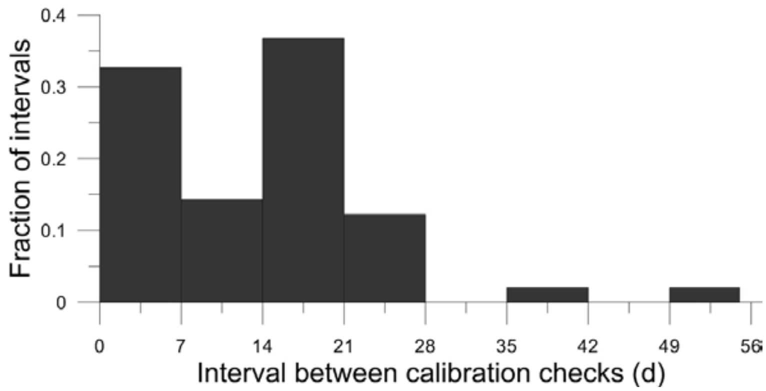


Figure 6.3-2: Inter-comparison check intervals for sonic anemometer 1920.

The sonic anemometer 1921 was inter-compared with three reference anemometers of identical design six times during the study (Table 6.3-3). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 43 times (Figure 6.3-5). The majority of calibration checks were made within 21 d (Figure 6.3-6). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 m s^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-5B). This instrument passed this check at all times. However this instrument developed intermittent problems during operation and was sent to the factory for repair 12/9/2008.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 m s^{-1} of zero (Figure 6.3-5A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-3: Standards inter-comparisons

Calibration date		Mean difference from reference anemometers (m s^{-1})	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/15-18/2007	6/18-19/2007	+0.008	-0.003
12/27-28/2007	12/29-31/2007	-0.034	+0.001
7/10-11/2008	7/11-14/2008	+0.029	-0.022
3/23-25/2009	3/25-27/2009	-0.021	-0.040
9/8-14/2009	9/15-16/2009	+0.028	+0.038
12/18-19/2009	12/21-23/2009	+0.078	+0.002

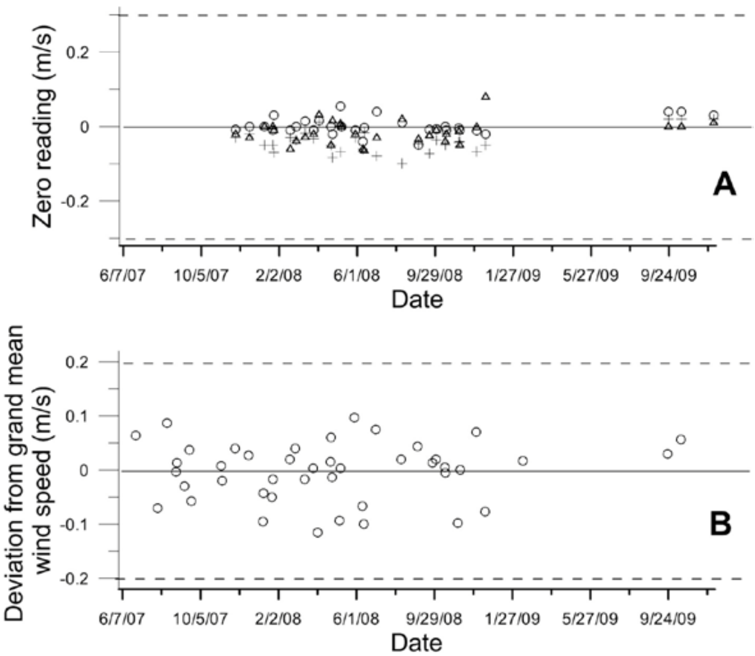


Figure 6.3-5: On-site quality assurance of sonic anemometer 1921. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

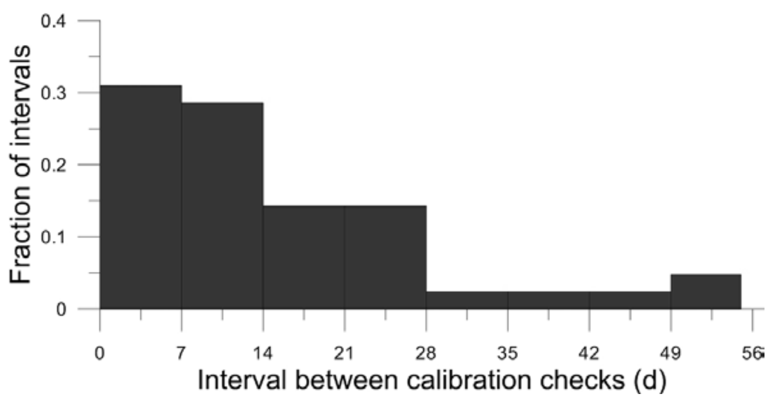


Figure 6.3-6: Inter-comparison check intervals for sonic anemometer 1921.

The sonic anemometer 1932 was inter-compared with three reference anemometers of identical design six times during the study (Table 6.3-4). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 55 times (Figure 6.3-7). The majority of calibration checks were made within 21 d (Figure 6.3-8). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 m s^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-7B). This instrument passed this check on all checks except 10/15-16/2008 and was taken out of service. Laboratory testing indicated wetness in the sensor. The sensor was dried, tested, and put back in use.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 m s^{-1} of zero (Figure 6.3-7B). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-4: Standards inter-comparisons

Calibration date		Mean difference from reference anemometers (m s^{-1})	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/15-17/2007	6/18-19/2007	+0.004	+0.160
12/27-28/2007	12/29-31/2007	+0.014	-0.009
7/10-11/2008	7/11-14/2008	+0.008	+0.031
3/3-5/2009	3/5-6/2009	-0.024	-0.005
9/8-14/2009	9/15-16/2009	-0.025	-0.044
1/7-9/2010	1/23-24/2010	+0.020	-0.016

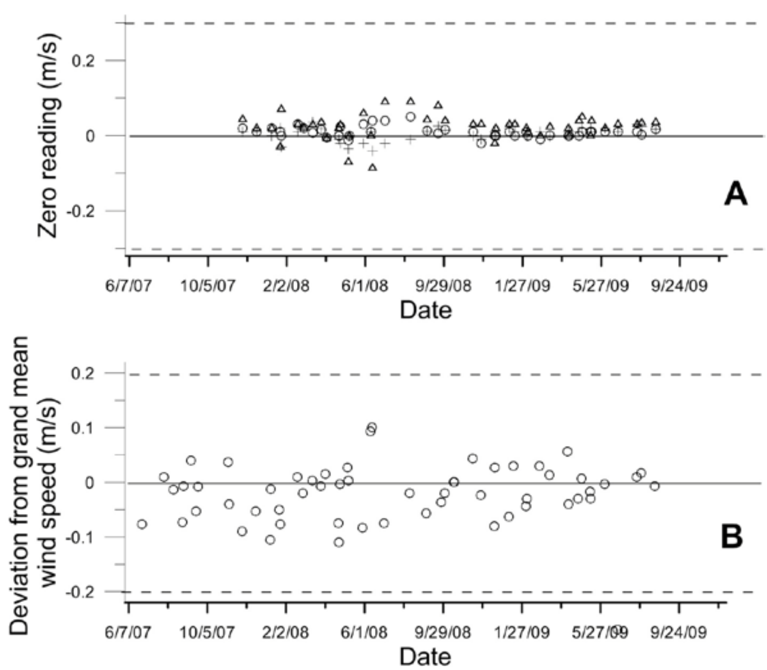


Figure 6.3-7: On-site quality assurance of sonic anemometer 1932. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

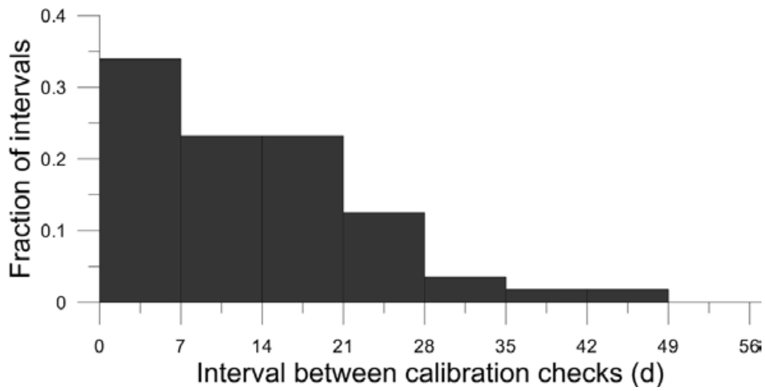


Figure 6.3-8: Inter-comparison check intervals for sonic anemometer 1932.

The sonic anemometer 1936 was inter-compared with three reference anemometers of identical design five times during the study (Table 6.3-5). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 41 times (Figure 6.3-9). The majority of calibration checks were made within 21 d (Figure 6.3-10). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 m s^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-9B). This instrument passed this check at all times.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 m s^{-1} of zero (Figure 6.3-9A). Records of the zero checks made before 12/2007 were recorded as pass/fail- not indicating the actual measurements. The instrument always passed this DQI.

Table 6.3-5: Standards inter-comparisons

Calibration date		Mean difference from reference anemometers (m s[-1])	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/15-18/2007	6/18-19/2007	+0.011	-0.036
12/27-28/2007	12/29-31/2007	-0.022	-0.009
7/10-11/2008	7/11-14/2008	+0.021	-0.019
3/23-25/2009	3/25-27/2009	+0.018	+0.047
9/1-2/2009	9/2-3/2009	-0.029	-0.016

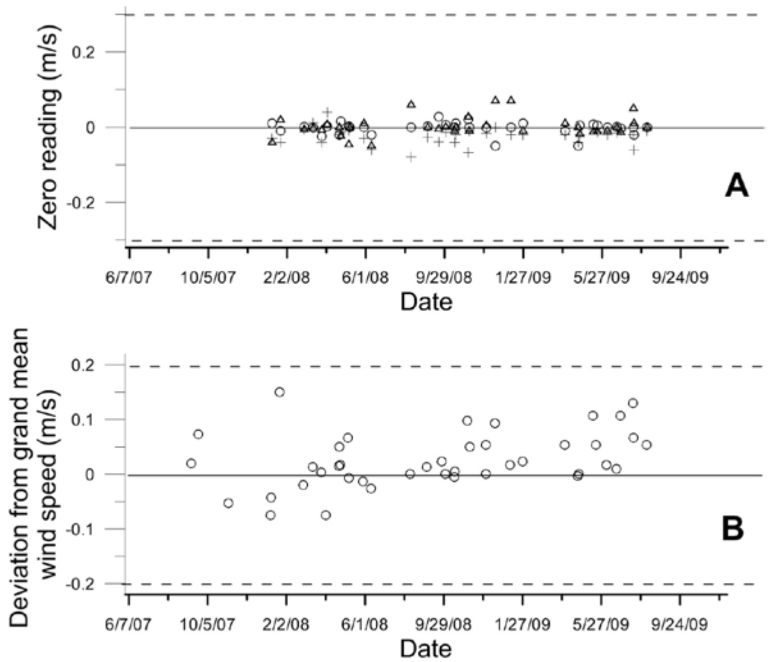


Figure 6.3-9: On-site quality assurance of sonic anemometer 1936. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

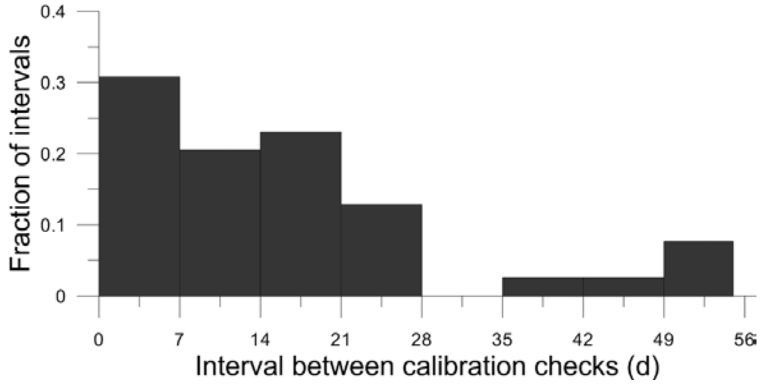


Figure 6.3-10: Inter-comparison check intervals for sonic anemometer 1936.

6.4 S-OPS operational checks

The Synthetic Open Path Systems (S-OPS; s/n B and E) and the Gas Sampling System (GSS s/n 4-0017) were checked at the beginning and end of every measurement period. A leak check and maximum flow check were made for both the S-OPS in combination with the GSS and for the GSS alone. In addition, the balance of flow into each inlet in the S-OPS was checked before and after each measurement period.

Results of the leak tests for both the GSS and the Combined GSS/S-OPS are indicated in sequence in Table 1. Consequently records of the checks at a given measurement site are interspersed according to the sequence of measurements for this trailer. Leaks in the GSS rarely occurred, however leaks in the S-OPS occurred several times in the study. These leaks were apparently a result of vibration within the GSS. The permissible leak in the S-OPS/GSS or GSS alone was 10% of the maximum flow. Details of the leak check failure follow:

- S-OPS leak check failure of single lines on 9/3/2008, 10/2/2008, 12/6/2008, 5/14/2009, 8/4/2009, 10/29/2009 were not resolved during the site visit due to time constraints. Repairs to the S-OPS were made on the subsequent visit.
- GSS leak check failure on 1/6/2009 was a result of pump diaphragm failure.

The impact of leak check failures in the S-OPS lines (with the exception of those at the GSS inlet filters) was minimal as the leaks were at junctions of tubing and tubing/inlet filters and would allow air into the lines that differ only from height above the berm from the air sampled along the inlets themselves. The impact of GSS leak check failures associated with pump diaphragm failures would only influence the volume of flow available to the H_2S analyzer. In all cases flow available to the analyzer greatly exceeded that used by the analyzer (1.5 L min^{-1}) (Table 1).

Table 6.6-1: Record of leak checks for GSS and GSS/S-OPS

Date	Site	GSS solenoid	GSS mass flow (L min^{-1})	GSS pressure (kPa)	GSS check result	S-OPS max flow (L min^{-1})	S-OPS mass flow (L min^{-1})	S-OPS pressure (kPa)	S-OPS check result
3/13/2008	WA5A	2	0.08	-41.29	Pass	8	0.56	-41.19	Pass
		3	0.01	-41.46	Pass	10.1	0.43	-39.25	Pass
4/3/2008	TX5A	2	0.00	-37.94	Pass	9.3	0.46	-40.07	Pass
		3	-0.01	-40.41	Pass	9.7	0.34	-40.19	Pass
4/22/2008	TX5A	2	0.09	-31.84	Pass	9.2	0.50	-32.48	Pass
		3	0.04	-40.85	Pass	9.6	0.36	-39.59	Pass
4/24/2008	OK4A	2	0.07	-30.69	Pass	8.4	0.44	-31.03	Pass
		3	0.01	-28.52	Pass	9.7	0.63	-28.7	Pass
5/6/2008	OK4A	2	0.14	-24.42	Pass	8.5	0.65	-26.2	Pass
		3	0.17	-24.74	Fail	9.8	0.66	-23.07	Pass
5/8/2008	OK3A	2	-0.14	-32.28	Pass	9.7	0.11	-30.99	Pass
		3	-0.14	-31.16	Pass	9.2	0.51	-30.83	Pass
5/29/2008	OK3A	2	0.15	-30.98	Fail	9.8	0.31	-32.07	Pass
		3	0.27	-30.89	Fail	9.2	0.58	-32.37	Pass
6/10/2008	OK3A	2	0.07	-39.64	Pass	9.7	0.37	-38.89	Pass
		3	0.06	-40.66	Pass	N/A	N/A	N/A	N/A
6/11/2008	TX5A	2	0.19	-39.52	Fail	9.4	0.19	-38.31	Pass
		3	0.00	-38.5	Pass	9.5	0.77	-38.43	Pass
7/1/2008	TX5A	2	0.15	-31.62	Fail	9.3	0.28	-31.17	Pass
		3	0.15	-31.69	Fail	9.3	1.00	-32.02	Pass
8/10/2008	WA5A	2	0.09	-40.9	Pass	7.5	0.44	-40.5	Pass

Date	Site	GSS solenoid	GSS mass flow (L min^{-1})	GSS pressure (kPa)	GSS check result	S-OPS max flow (L min^{-1})	S-OPS mass flow (L min^{-1})	S-OPS pressure (kPa)	S-OPS check result
		3	0.07	-40.35	Pass	10.5	0.75	-38.31	Pass
9/3/2008	WA5A	2	0.27	-32.88	Fail	8	6.86	-23.56	Fail
		3	0.30	-32.92	Fail	10.5	0.53	-34.62	Pass
9/3/2008	WA5A	2	0.20	-32.22	Fail	8	0.43	-32.51	Pass
		3	0.30	-32.36	Fail	10.5	0.52	-32.73	Pass
9/26/2008	WA5A	2	0.53	-38.99	Fail	8.1	0.33	-40.01	Pass
		3	0.19	-37.03	Fail	10.5	0.41	-39.44	Pass
10/2/2008	OK4A	2	0.23	-40.69	Fail	9.6	0.95	-0.43	Pass
		3	0.23	-39.56	Fail	8.6	0.87	-0.04	Fail
10/15/2008	OK4A	2	0.17	-41.03	Fail	9.8	0.32	-38.14	Pass
		3	0.18	-38.71	Fail	8.5	0.32	-38.9	Pass
10/16/2008	TX5A	2	0.20	-39.65	Fail	9.7	0.28	-39.72	Pass
		3	0.23	-40.98	Fail	9.5	0.59	-39.55	Pass
11/4/2008	TX5A	2	0.33	-41.59	Fail	9.4	0.31	-39.62	Pass
		3	0.32	-41.56	Fail	9.3	0.50	-40.62	Pass
11/6/2008	OK3A	2	0.33	-39.79	Fail	8.7	0.73	-42.34	Pass
		3	0.32	-38.77	Fail	9.3	0.47	-39.46	Pass
12/3/2008	OK3A	2	0.79	-40.32	Fail	8.4	0.65	-39.24	Pass
		3	0.83	-39.05	Fail	9.2	0.43	-40.53	Pass
12/16/2008	OK3A	2	0.72	-37.7	Fail	8.6	1.05	-40.13	Fail
		3	0.79	-36.81	Fail	9.5	0.91	-40.65	Pass
12/18/2008	TX5A	2	1.98	-38.41	Fail	9.4	0.92	-37.74	Pass
		3	2.09	-38.03	Fail	9.4	0.90	-37.46	Pass
1/6/2009	TX5A	2	0.12	-40.6	Pass	9.1	2.09	-37.63	Fail
		3	0.13	-40.35	Pass	8.9	2.12	-37.72	Fail
1/8/2009	OK4A	2	0.11	-38.95	Pass	9.8	0.41	-39.67	Pass
		3	0.11	-37.59	Pass	7.2	0.30	-41.91	Pass
1/27/2009	OK4A	2	0.09	-38.64	Pass	9.4	0.36	-40.34	Pass
		3	0.09	-38.15	Pass	8.3	0.20	-41.46	Pass
1/29/2009	TX5A	2	0.05	-37.73	Pass	9.8	0.37	-38.37	Pass
		3	0.17	-38.46	Fail	9.6	0.24	-37.24	Pass
2/19/2009	TX5A	2	0.19	-36.64	Fail	9.9	0.92	-39.35	Pass
		3	0.04	-36.77	Pass	9.7	0.64	-38.72	Pass
3/18/2009	TX5A	2	0.15	-38.19	Fail	9.3	0.65	-37.14	Pass
		3	0.07	-39.28	Pass	9.8	0.45	-37.54	Pass
4/21/2009	OK4A	2	0.15	0.06	Fail	10.2	0.55	-40.07	Pass
		3	0.01	-39.72	Pass	9	0.24	-37.98	Pass
4/22/2009	OK3A	2	0.14	-40.11	Pass	9.7	0.30	-38.44	Pass
		3	0.05	-38.69	Pass	8.8	0.77	-27.92	Pass
5/14/2009	OK3A	2	0.20	-39.22	Fail	9.7	0.26	-38.46	Pass
		3	0.09	-39.13	Pass	8.6	0.88	-38.07	Fail
5/21/2009	WA5A	2	0.17	-37.7	Fail	7.9	0.18	-39.69	Pass
		3	0.02	-39.6	Pass	10.5	0.96	-39.37	Pass
6/4/2009	WA5A	2	0.18	-40.86	Fail	8.6	0.24	-40.49	Pass
		3	0.04	-38.48	Pass	10.5	0.97	-38.07	Pass
6/19/2009	WA5A	2	0.33	-39.5	Fail	8.7	0.25	-38.74	Pass
		3	0.14	-39.6	Pass	10.5	0.95	-37.89	Pass
6/23/2009	OK4A	2	0.07	-39.89	Pass	9.7	0.37	-39.37	Pass
		3	0.04	-38.56	Pass	8.8	0.60	-40.96	Pass
7/14/2009	OK4A	2	0.25	-39.85	Fail	8.5	0.14	-40.79	Pass
		3	0.08	-38.49	Pass	9.7	0.13	-39.51	Pass
7/15/2009	OK3A	2	0.02	-38.14	Pass	8.7	0.63	-38.59	Pass
		3	0.04	-36.71	Pass	9.9	0.08	-39.75	Pass
8/4/2009	OK3A	2	0.06	-38.09	Pass	8.5	2.25	-37.22	Fail

Date	Site	GSS solenoid	GSS mass flow (L min^{-1})	GSS pressure (kPa)	GSS check result	S-OPS max flow (L min^{-1})	S-OPS mass flow (L min^{-1})	S-OPS pressure (kPa)	S-OPS check result
		3	0.11	-34.41	Pass	9.7	0.09	-39.78	Pass
8/6/2009	TX5A	2	0.05	-38.3	Pass	9.8	0.75	-39.4	Pass
		3	0.00	-40.36	Pass	9.9	0.14	-38.93	Pass
8/27/2009	TX5A	2	0.02	-39.89	Pass	9.7	0.65	-37.52	Pass
		3	0.05	-40.26	Pass	9.5	0.11	-38.95	Pass
9/23/2009	NC3A	2	0.06	-40.15	Pass	10.1	0.34	-39.61	Pass
		3	0.07	-38.33	Pass	0	-0.60	-0.05	Pass
10/13/2009	NC3A	2	0.17	-39.38	Fail	9.6	0.41	-39.03	Pass
		3	0.04	-37.77	Pass	10	0.20	-41.33	Pass
10/27/2009	NC3A	2	0.08	-41.29	Pass	10	0.26	-39.3	Pass
		3	0.01	-41.46	Pass	9.3	1.45	0.11	Fail
10/27/2009	NC3A	2	0.00	-37.94	Pass	10	0.26	-39.3	Pass
		3	-0.01	-40.41	Pass	9.3	0.51	-40.26	Pass
11/11/2009	NC3A	2	0.04	-39.92	Pass	10	0.79	-40.71	Pass
		3	0.04	-39.74	Pass	9.6	0.27	-40.26	Pass

The inlet flow balance checks are summarized in sequence in Tables 2A and 2B. Consequently records of the checks at a given measurement site are interspersed according to the sequence of measurements for this trailer. While the inlet flow balance was measured at the beginning and end of each measurement period, results showed that the balance throughout the period was not assured if the balance test indicated an adequate balance. Balance across the inlets at any time during a period or at the beginning or end of a period was limited due to wetness of the inlet filters associated with fog, ice, snow, or rain. In addition dust on the inlet filters contributed to an undetermined rate of flow degradation of individual inlets over a period. Spider webs would also restrict flow across the inlet filters. The allowable tolerance in the inlet balance was that the flow through any inlet was within 10% of the expected flow for the inlet.

Condensation or liquid water intrusion into the Teflon tubing of the S-OPS occurred often in the tubing around the area sources. Analysis of the problem revealed that condensation occurred as the air cooled in transit from the inlet to the trailer through tubing under a negative net radiation balance (particularly at night). In addition, water intrusion occurred during the leak testing if any water had accumulated along the junction between the filter/inlet and the S-OPS tubing. The impact of the liquid water in the S-OPS tubing on the measured concentration of H_2S was minimal due to the low solubility of H_2S.

Table 6.6-2A: Record of flow balancing- Side 1 (s/n B)

			Delta inlet flow (Beginning-End) (L min-1)										
Start date	**End date**	**Site**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Check results**
3/13/2008	4/3/2008	WA5A	-0.20	-0.21	-0.06	-0.14	-0.20	-0.24	-0.21	-0.04	-0.20	-0.23	**Fail**
4/3/2008	4/22/2008	TX5A	-0.08	-0.07	-0.08	-0.09	-0.07	-0.09	-0.13	-0.09	-0.12	-0.14	**Pass**
4/24/2008	5/6/2008	OK4A	-0.02	-0.04	-0.01	-0.14	-0.02	-0.03	-0.09	-0.10	-0.07	-0.12	**Fail**
5/8/2008	5/29/2008	OK3A	0.01	0.02	0.02	0.02	0.02	0.03	0.01	0.03	0.01	0.04	**Pass**
5/29/2008	6/10/2008	OK3A	M	M	M	M	M	M	M	M	M	M	**M**
6/11/2008	7/1/2008	TX5A	-0.01	-0.01	-0.02	-0.01	-0.02	-0.02	-0.01	-0.01	-0.02	-0.02	**Pass**
7/1/2008	8/10/2008	TX5A	0.35	0.38	0.11	0.39	0.27	0.31	0.30	0.18	0.34	0.31	**Pass**
8/10/2008	9/3/2008	WA5A	0.00	-0.10	0.11	-0.20	0.00	0.00	-0.10	0.00	-0.10	0.00	**Fail**
9/3/2008	9/26/2008	WA5A	0.00	-0.10	-0.10	0.10	0.00	-0.20	-0.10	0.10	0.00	0.00	**Fail**
10/2/2008	10/15/2008	OK4A	0.02	-0.02	0.01	0.01	-0.03	0.06	0.06	0.05	0.04	0.02	**Fail**
10/16/2008	11/4/2008	TX5A	0.02	0.00	0.00	-0.01	-0.02	-0.05	-0.05	0.00	0.01	0.03	**Pass**
11/6/2008	12/3/2008	OK3A	0.03	0.00	0.00	0.01	-0.02	0.03	0.04	0.05	0.05	0.05	**Pass**
12/3/2008	12/16/2008	OK3A	-0.02	-0.01	-0.01	0.00	0.04	-0.06	0.04	-0.04	-0.03	-0.03	**Pass**
12/18/2008	1/6/2009	TX5A	-0.02	-0.06	-0.03	0.00	-0.04	-0.02	-0.02	0.00	0.01	-0.01	**Fail**
1/8/2009	1/27/2009	OK4A	-0.02	-0.04	-0.04	0.00	-0.05	-0.01	0.00	0.00	0.00	0.01	**Pass**
1/29/2009	02/19/2009	TX5A	-0.04	-0.02	0.00	0.06	0.00	-0.06	0.00	-0.02	-0.02	0.00	**Pass**
2/19/2009	3/18/2009	TX5A	0.01	-0.02	0.01	0.01	0.01	-0.02	0.00	0.00	0.00	-0.01	**Fail**
3/18/2009	4/2/2009	TX5A	0.06	0.06	0.05	0.06	0.04	0.08	0.06	0.10	0.05	0.11	**Pass**
4/02/2009	4/21/2009	OK4A	0.02	0.05	0.04	0.04	-0.03	0.01	0.02	0.01	-0.01	-0.01	**Pass**
4/22/2009	5/14/2009	OK4A	-0.03	-0.04	-0.02	-0.03	-0.02	-0.14	-0.02	-0.01	-0.02	-0.03	**Pass**
5/14/2009	5/21/2009	OK4A	0.23	0.24	0.27	0.28	0.17	0.28	0.23	0.26	0.17	0.29	**Pass**
5/21/2009	6/4/2009	WA5A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**Pass**
6/4/2009	6/19/2009	WA5A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**Pass**
6/23/2009	7/14/2009	OK4A	0.00	-0.02	-0.03	-0.01	-0.04	0.01	0.01	0.00	-0.01	-0.04	**Pass**
7/15/2009	8/4/2009	OK3A	0.05	0.04	0.13	0.09	0.13	0.20	0.16	0.14	0.14	0.18	**Pass**
8/6/2009	8/27/2009	TX5A	0.05	0.05	0.01	0.00	0.01	0.03	0.02	0.03	0.06	0.04	**Pass**
8/27/2009	9/24/2009	TX5A	-0.10	-0.06	-0.05	-0.06	-0.08	-0.01	-0.04	-0.05	-0.14	-0.01	**Pass**
9/24/2009	10/13/2009	NC3A	0.00	-0.03	0.00	-0.05	-0.03	-0.08	87.39	-0.11	-0.12	0.06	**Pass**
10/13/2009	10/27/2009	NC3A	-0.02	-0.05	-0.04	-0.03	-0.04	-0.04	-0.03	-0.03	-0.05	0.00	**Pass**
10/27/2009	11/11/2009	NC3A	0.00	-0.02	-0.01	-0.01	-0.01	0.00	-0.02	0.00	-0.04	0.02	**Pass**
11/11/2009	12/2/2009	NC3A	0.02	0.04	-0.11	-0.01	0.01	0.00	-0.03	-0.08	0.37	0.03	**Fail**

M: missing measurements.

Table 6.6-2B: Record of flow balancing- Side 2 (s/n E)

			Delta inlet flow (Beginning-End) (L min⁻¹)										
Start date	**End date**	**Site**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Check results**
3/13/2008	4/3/2008	WA5A	0.19	0.18	0.11	0.19	0.14	0.14	0.15	0.17	0.15	0.21	**Fail**
4/3/2008	4/22/2008	TX5A	-0.03	-0.03	0.01	-0.04	-0.09	-0.06	0.00	0.01	0.00	0.00	**Pass**
4/24/2008	5/6/2008	OK4A	0.00	0.00	0.00	-0.03	-0.02	-0.05	0.06	-0.01	-0.03	0.06	**Fail**
5/08/2008	5/29/2008	OK3A	0.02	0.01	0.04	0.00	0.05	0.02	0.01	0.04	0.02	0.02	**Pass**
5/29/2008	6/10/2008	OK3A	-0.01	-0.01	-0.02	0.00	0.00	-0.02	0.01	-0.04	-0.02	0.00	**Pass**
6/11/2008	7/1/2008	TX5A	0.01	0.00	0.00	0.01	-0.01	-0.02	-0.02	-0.02	-0.01	-0.03	**Pass**
7/1/2008	7/29/2008	TX5A	-0.03	-0.09	0.00	-0.05	-0.03	-0.06	0.02	-0.03	-0.02	0.00	**Pass**
8/10/2008	9/3/2008	WA5A	0.05	0.14	0.09	0.10	0.16	0.14	0.12	0.15	0.18	0.15	**Pass**
9/3/2008	9/26/2008	WA5A	-0.04	-0.06	-0.02	-0.01	0.00	0.00	0.02	-0.04	0.02	0.00	**Pass**
10/2/2008	10/15/2008	OK4A	0.00	0.01	-0.02	0.00	-0.01	0.01	0.03	0.03	0.11	0.00	**Pass**
10/16/2008	11/4/2008	TX5A	-0.02	-0.05	-0.03	-0.04	0.00	0.00	-0.04	-0.04	-0.01	-0.02	**Pass**
11/6/2008	12/3/2008	OK3A	-0.01	0.01	0.00	-0.02	0.14	-0.07	0.01	0.02	0.02	0.02	**Fail**
12/3/2008	12/16/2008	OK3A	0.01	-0.02	-0.01	-0.02	-0.01	0.02	0.00	0.00	-0.02	-0.01	**Pass**
12/18/2008	1/6/2009	TX5A	-0.03	-0.08	-0.05	-0.05	-0.06	-0.05	-0.06	-0.04	-0.07	-0.02	**Pass**
1/8/2009	1/27/2009	OK4A	-0.04	-0.03	-0.03	-0.04	-0.04	-0.02	-0.03	-0.02	-0.02	-0.01	**Pass**
1/29/2009	2/19/2009	TX5A	0.00	-0.05	0.00	0.01	-0.02	-0.05	0.02	0.02	0.12	-0.01	**Pass**
2/19/2009	3/18/2009	TX5A	0.03	0.03	0.04	0.03	0.02	0.04	0.01	0.02	0.03	0.01	**Fail**
3/18/2009	4/2/2009	TX5A	-0.14	-0.12	-0.13	-0.12	-0.14	-0.16	-0.14	-0.12	-0.15	-0.14	**Pass**
4/02/2009	4/21/2009	OK4A	0.00	0.05	0.05	0.04	0.04	0.07	0.05	0.03	0.01	0.02	**Pass**
4/22/2009	5/14/2009	OK3A	-0.06	0.00	0.00	-0.01	0.01	0.02	0.01	0.03	0.03	0.00	**Pass**
5/14/2009	5/21/2009	OK3A	-0.07	-0.11	-0.13	-0.11	-0.21	-0.10	-0.19	-0.16	-0.17	-0.18	**Pass**
5/21/2009	6/4/2009	WA5A	0.01	0.00	0.00	0.01	0.07	-0.03	0.05	0.02	0.00	0.00	**Pass**
6/4/2009	6/19/2009	WA5A	0.01	0.01	-0.04	-0.03	-0.03	-0.03	-0.02	-0.01	-0.02	0.00	**Pass**
6/23/2009	7/14/2009	OK3A	-0.02	-0.02	0.00	-0.02	-0.02	0.03	-0.03	-0.02	-0.02	0.01	**Pass**
7/15/2009	8/4/2009	OK3A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**Pass**
8/4/2009	8/6/2009	OK3A	0.00	-0.01	0.01	0.01	-0.01	0.01	-0.01	0.02	0.01	0.00	**Pass**
8/6/2009	8/27/2009	TX5A	0.00	-0.03	-0.05	-0.04	-0.02	-0.02	-0.01	0.01	0.01	0.03	**Pass**
8/27/2009	9/23/2009	TX5A	0.05	0.05	0.08	0.11	0.22	0.22	0.21	0.25	0.22	0.21	**Fail**
9/24/2009	10/13/2009	NC3A	0.02	0.03	0.00	0.02	0.00	0.00	0.00	-0.03	0.00	0.16	**Fail**
10/13/2009	10/27/2009	NC3A	0.00	-0.01	0.12	-0.05	-0.02	-0.12	-0.04	-0.05	-0.06	0.00	**Pass**
10/27/2009	11/11/2009	NC3A	0.15	0.06	0.18	0.10	-0.05	0.25	0.25	0.05	0.21	-0.60	**Fail**

The nominal planned interval between S-OPS checks was 20 d (three weeks). S-OPS checks were conducted at this long-term measurement location a relatively few times with the period of time between checks varying from one to three weeks (Figure 1). Shorter intervals between checks occurred due to work on the systems.

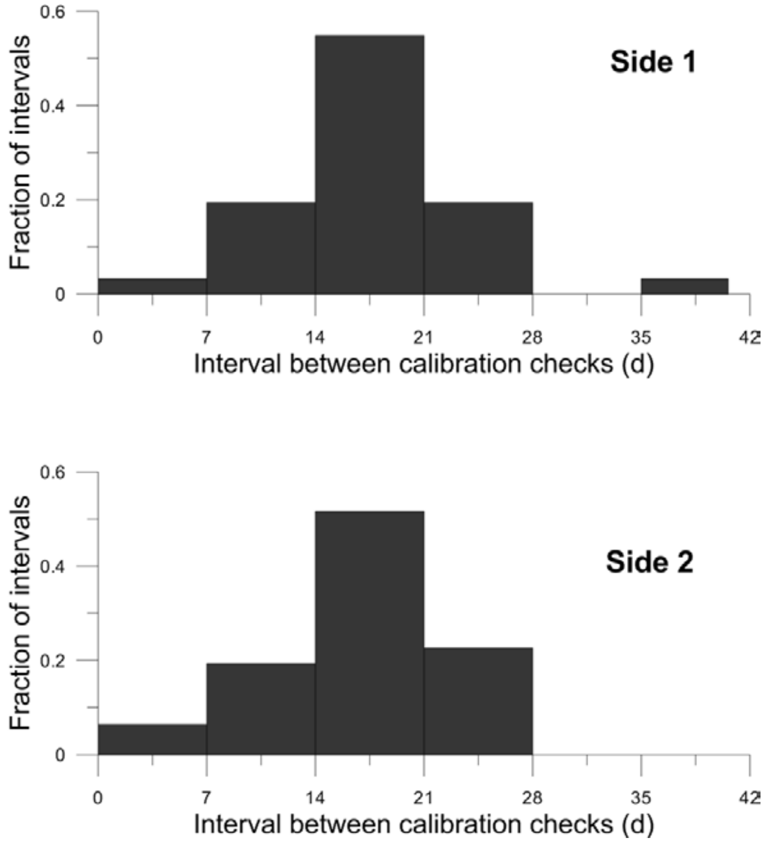


Figure 6.6-1: Intervals between checks

6.5 Miscellaneous meteorological and basin calibrations

6.5.1 Air temperature/humidity

A hygrothermometer (Model HMP45C, Vaisala Inc., Helsinki, Finland) measured both air temperature and relative humidity. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The calibration checks are documented in Table 6.7-1.

Table 6.7-1: Calibration record of Vaisala HMP45C, s/n 4410015

Relative humidity (RH)					
Calibration date	**Expected RH (%)**	**Measured RH (%)**	**Deviation from expected RH (%)**	**Average deviation RH (%)**	**Action**
2/17/2010	21	18.8	2.2		
	50	48.2	1.9		
	98	94.3	3.7		
				2.6	Accept
9/18/2009	11	19.9	-8.9		
	50	50.4	-0.4		
	98	85.4	12.6		
				7.3	Adjust
	11	10.7	0.2		
	98	95.2	2.8		
	50	36.7	13.3		
	11	11.2	-0.2		
	50	42.1	7.9		
				4.9	Accept
3/26/2009	23	20.3	2.7	2.7	Accept
Temperature (T)					
Calibration date	**Expected T (°C)**	**Measured T (°C)**	**Deviation from expected T (°C)**		**Action**
2/17/2010	24.3	24.5	-0.2		Accept
9/18/2009	26.5	26.9	-0.4		Accept
3/26/2009	24.9	24.9	0.0		Accept

6.5.2 Barometric Pressure

An aneroid barometer (Model 278, Setra Inc, Boxborough, MA.) with serial number 3033740 was used to measure barometric pressure. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-2.

Table 6.7-2: Calibration record of Setra 278 s/n 3033740

Calibration Date	Expected value range (hPa)	Number of comparisons	Mean difference from reference (hPa)	Action
2/11-12/2010	998.6-992.5	5	1.5	Pass
9/16-17/2009	997.5-1000.1	6	0.9	Pass
3/24-25/2009	986.0-992.0	6	1.4	Pass
7/9-11/2008	993.1-996.8	6	1.5	Pass
1/3-4/2008	1018.4-1001.7	6	2.5	Pass

6.5.3 Solar radiation

The LiCOR was used to measure solar radiation. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-3.

Table 6.7-3: Calibration record of LiCOR 200SB Pyranometer, s/n PY554449

Calibration Date	Mean difference from reference	Mean deviation from standard (%)	Action
3/5/2010	4.84	0.91	Retry
3/6/2010	1.40	0.37	Pass
8/30/2006	—	—	Pass, Factory Calibration

6.5.4 CR1000 data logger

The CR1000 data logger was used to log all air temperature, relative humidity, barometric pressure, and wetness. Calibration checks of this unit were conducted at the beginning and end of the study. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-4.

Table 6.7-4: Calibration record of Campbell Scientific CR1000 data logger, s/n 7888 (7677)

SE channel	Input (mV)	Tolerance SE|DE (mV)	Measured mV	Error (mV)	Measured mV	Error (mV)
FACTORY CALIBRATION						
Calibration date: 1/18/2007			**Single-ended**		**Differential**	
13	5000	± 3	5000.48	0.096	5001.02	0.02
13	-5000	± 3	-5001.56	0.31	-5001.02	0.02
13	2500	± 1.5	—	—	2500.34	0.34
13	250	± 0.15	—	—	250.042	0.042
13	25	± 0.015	—	—	25.004	0.004
13	7.5	± 0.0045	—	—	7.49724	0.00037
13	2.5	± 0.0015	—	—	2.49923	0.00062
13	-2.5	± 0.0015	—	—	-2.49906	0.00024
13	5000	± 6	4999.31	0.31	4998.64	1.6
13	5000	± 6	5000.58	0.58	5001.02	0.02
13	5000	± 6	—	—	—	—
13	5000	± 6	—	—	—	—
PAML CALIBRATIONS						
Calibration date: 2/5/2007			**Single-ended**		**Differential**	
1	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
2	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
3	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
4	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
5	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
6	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
7	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
8	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
9	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
10	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
12	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
13	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
14	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
15	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
16	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
Calibration date: 3/10/2010			**Single-ended**		**Differential**	
1	100	± 0.19 | 0.06	99.37	0.006	—	—

SE channel	Input (mV)	Tolerance SE|DE (mV)	Measured mV	Error (mV)	Measured mV	Error (mV)
2	100	± 0.19 | 0.06	99.37	0.006	99.71	0.003
3	100	± 0.19 | 0.06	99.37	0.006	—	—
4	100	± 0.19 | 0.06	99.37	0.006	—	—
5	100	± 0.19 | 0.06	99.37	0.006	99.71	0.003
6	100	± 0.19 | 0.06	99.37	0.006	99.71	0.003
7	100	± 0.19 | 0.06	99.37	0.006	99.71	0.003
8	100	± 0.19 | 0.06	99.37	0.006	99.71	0.003
9	100	± 0.19 | 0.06	99.37	0.006	—	—
10	100	± 0.19 | 0.06	99.37	0.006	—	—
11	100	± 0.19 | 0.06	99.37	0.006	—	—
12	100	± 0.19 | 0.06	99.37	0.006	—	—
13	100	± 0.19 | 0.06	99.37	0.006	—	—
14	100	± 0.19 | 0.06	99.37	0.006	—	—
15	100	± 0.19 | 0.06	99.37	0.006	—	—
16	100	± 0.19 | 0.06	99.37	0.006	—	—
Calibration date: 3/10/2010			**Single-ended**		**Differential**	
1	0	± 0.19 | 0.06	0	0	—	—
2	0	± 0.19 | 0.06	0	0	0	0
3	0	± 0.19 | 0.06	0	0	—	—
4	0	± 0.19 | 0.06	0	0	—	—
5	0	± 0.19 | 0.06	0	0	0	0
6	0	± 0.19 | 0.06	0	0	0	0
7	0	± 0.19 | 0.06	0	0	0	0
8	0	± 0.19 | 0.06	0	0	0	0
9	0	± 0.19 | 0.06	0	0	—	—
10	0	± 0.19 | 0.06	0	0	—	—
11	0	± 0.19 | 0.06	0	0	—	—
12	0	± 0.19 | 0.06	0	0	—	—
13	0	± 0.19 | 0.06	0	0	—	—
14	0	± 0.19 | 0.06	0	0	—	—
15	0	± 0.19 | 0.06	0	0	—	—
16	0	± 0.19 | 0.06	0	0	—	—

6.5.5 CR800 data logger

The CR800 data logger was used to log all GSS measurements (air temperature and relative humidity, flow rate, and pressure). Calibration checks of this unit were conducted only at end of the study. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-5.

Table 6.7-5: Calibration record of Campbell Scientific CR800 data logger, s/n 3698

Calibration date: 3/10/2010			**Single-ended**	
Channel	**Input (mV)**	**Tolerance SE | DE (mV)**	**Measured mV**	**Error (%)**
1	0	± 0.19 | 0.06	99.2	0.01
2	0	± 0.19 | 0.06	99.2	0.01
3	0	± 0.19 | 0.06	99.2	0.01
4	0	± 0.19 | 0.06	99.2	0.01
5	0	± 0.19 | 0.06	99.2	0.01
6	0	± 0.19 | 0.06	99.2	0.01
Calibration date: 3/10/2010			**Single-ended**	
Channel	**Input (mV)**	**Tolerance SE | DE (mV)**	**Measured mV**	**Error (%)**
1	0	± 0.19 | 0.06	0	0
2	0	± 0.19 | 0.06	0	0
3	0	± 0.19 | 0.06	0	0
4	0	± 0.19 | 0.06	0	0
5	0	± 0.19 | 0.06	0	0
6	0	± 0.19 | 0.06	0	0

6.6 Site activity

Time HH:MM (UTC)	Date (mm/dd/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
	2/25/2008	Setup	Leveled ground for trailer. Tied down trailer. Mounted antennas.
	2/25/2008	Setup	Mounted retro-reflectors on towers. Shopped for bolt for met tower, ground rods.
	2/26/2008	Setup	Stu started trenches (~0.25 east basin); Scott finished trenching, excluding across roads.
	2/26/2008	Setup	Wired towers and trailers. Pounded ground rod at trailer. Started pounding ground rod at southwest corner of west basin but sledgehammer broke.
	2/26/2008	Setup	Electrician showed up in afternoon and started laying wire.
	2/27/2008	Setup	Set up ground retro-reflectors and sonic anemometers on met tower for inter-comparison. Scanner tripod (southeast) with tripods.
	2/27/2008	Setup	Finished trenching. Electrician continued to lay wire and wire boxes; ran out of wire. It will be delivered tomorrow morning to finish electrical work.
	2/27/2008	Setup	Installed underground tubing for S-OPS lines to run under roads.
	2/27/2008	Setup	All ground rods pounded except for southeast tower; will use generator from electrician.
	2/27/2008	Setup	All towers finished wiring (to bottom outlet and plugs).
	2/27/2008	Setup	Pounded S-OPS posts and installed inlets with tubing. Used 1000 ft along west side. Connected with plastic union.
	2/27/2008	Setup	Taped underground tubing pipe around tubing to minimize dirt entering pipes.
	2/28/2008	Setup	Power hooked up to trailer in the afternoon.
	2/28/2008	Setup	Motherboard for H_2S analyzer switched out with new motherboard. Display light comes on, but no characters are shown on display. Put back old motherboard (old motherboard currently in use). Noticed prong on new motherboard for display was bent.
	2/28/2008	Setup	Changed plastic union on west side tubing with metal union.
	2/28/2008	Setup	Cut tubing near trailer so tubing can permanently stay in underground pipe under road (near trailer (two tubes are hard to pass through tubing)). Metal connectors on both ends.
	2/28/2008	Setup	UPS at northwest corner dead; plugged scanner directly into alignment and will charge UPS overnight.
	2/28/2008	Setup	Aligned TDLAS at southeast corner using power from generator.
	2/28/2008	Setup	Scanner at northwest corner did not originally start up; unplugged scanner from power supply; jiggled cords, plugged back in; scanner initiated and TDLAS turned on.
	2/28/2008	Setup	Forgot to check pressures from gas cylinders.
	2/28/2008	Setup	H_2S calibration was closer to 0.5 ppm than baseline done in lab.
	2/28/2008	Setup	GSS acceptance
	2/28/2008	Setup	S-OPS acceptance
20:05-21:05	2/28/2008	Setup	Sonic anemometer inter-comparison: Sensor 1: 1.68 Sensor 2: 1.74 Sensor 3: 1.74
20:44-20:49	2/28/2008	Setup	Calibrated TDLAS 1026: Mean: 24.1 SD: 0.97 RSD: 4.0% Bias: -3.5%

Time HH:MM (UTC)	Date (mm/dd/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
21:16-21:21	2/28/2008	Setup	Calibrated TDLAS 1032: Mean: 24.8 SD: 0.41 RSD: 1.77% Bias: -0.6%
21:48	2/28/2008	Setup	Zero sonic anemometer calibration. All pass.
23:25	2/28/2008	Setup	450i Calibration Verification Check
23:40	2/28/2008	Setup	450i Reference Precision Check
23:50	2/28/2008	Setup	450i Calibration Verification Check
	2/29/2008	Setup	Aligned both TDLAS units. Scanner 1 is TDL 1032, 1-5 on west side, 6-10 on north side. Scanner 2 is 1026, 1-5 on south side, 6-10 on east side.
	2/29/2008	Setup	Checked power, logging of CR800, CR1000, H_2S, and TDLAS 1 and 2.
	2/29/2008	Setup	Started met, sonic anemometers, TDLAS/scanners, and H_2S.
	2/29/2008	Setup	Measured coordinated of S-OPS.
	3/4/2008	Remote	Met tower, sonic anemometer 1 (on met tower), and TDL/scanner 1032 do not have power.
	3/6/2008	Remote	Check if power has been corrected.
21:42	3/12/2008	Calibration	450i Reference Precision Check
	3/13/2008	Calibration	S-OPS Inlet Flow Verification (south): Fail
	3/13/2008	Calibration	S-OPS Inlet Flow Verification (north): Fail
	3/13/2008	Calibration	GSS Max Flow Test conducted (solenoids 2 and 3)
	3/13/2008	Calibration	GSS No Flow Test conducted (solenoids 2 and 3)
	3/13/2008	Calibration	S-OPS Max Flow Test conducted (solenoids 2 and 3)
	3/13/2008	Calibration	S-OPS/GSS Leak Test: Pass (solenoids 2 and 3)
15:05-16:05	3/13/2008	Calibration	Sonic anemometer inter-comparison. All pass
16:23	3/13/2008	Calibration	Zero sonic calibration. All pass.
	3/17/2008	Remote	Check status.
14:55	3/20/2008	Remote	Daily Status Check from PAML Notes: No H_2S analyzer in west trailer. No communications with CR1000
13:55	3/21/2008	Remote	Daily Status Checks from PAML Notes: CR1000 not communicating with trailer. No H_2s analyzer present. No Innova present.
13:15	3/24/2008	Remote	Daily Status Check from PAML Notes: No H_2S analyzer; no Innova. Keep eye on TDL 1 calibration worksheet "Centerline Duty Cycle"; seems to increase (not drastically). Limited communication with CR 1000; no data available for viewing. "Append Filename to Logged Lived" was checked in Log File Operations (TDL 1). Unchecked box and renamed new log file to "TDL1_WA5A_YYY_MM_HHMMSS.gvl" Will go back and change filenames currently named "TDL1_WA5A_ ____.gvl" to correct format. Need to change strings in filename to correct format.
15:30	3/25/2008	Remote	Daily Status Check from PAML - Notes: H_2S analyzer out for repair. Filenames for TDLAS 2 were corrected yesterday. Backup monitor not enough space to perform backup.
	3/26/2008	Takedown	Strong odor at basin
	3/26/2008	Takedown	Inlet pumping.
	3/26/2008	Takedown	TDLASs aligned upon arrival.
	3/26/2008	Takedown	No H_2S analyzer to calibrate. GSS has not been running; no acceptance performed.
	3/26/2008	Takedown	Evidence of power failure on 3/24/2008 (at 14:52:26, UPS

Time HH:MM (UTC)	**Date** (mm/dd/yyyy)	**Activity** (setup, takedown, calibration, repair, remote)	**Event**
			switched to battery power). At 17:52:30, AC restored message sent to registered clients to Load Segment 2.
17:25-17:30	3/26/2008	Takedown	Calibrated TDLAS 1032: Mean: 46.3 SD: 1.07 RSD: 2.3% Bias: -7.4%
17:35-18:35	3/26/2008	Takedown	Sonic inter-comparison: Sensor 1: 5.03 Sensor 2: 5.04 Sensor 3: 5.03 Action: pass
17:59-18:04	3/26/2008	Takedown	Calibrated TDLAS 1026: Mean: 47.7 SD: 1.36 RSD: 2.8% Bias: -4.3%
19:15	3/26/2008	Takedown	Barometer audit: pass.
19:36	3/26/2008	Takedown	Zero sonic calibration. All pass.
00:17	3/27/2008	Takedown	Wetness sensor calibration: accepted.
	8/8/2008	Setup	Setup and level trailer; hooked up power to trailers.
	8/8/2008	Setup	Setup ground retro-reflectors and TDLAS/scanner units.
20:43	8/8/2008	Setup	Calibrated TDLAS 1028 Mean: 48.94 SD: 0.18 RSD: 0.4% Bias: -9.8%
21:39	8/8/2008	Setup	Calibrated TDLAS 1027 Mean: 51.50 SD: 0.08 RSD: 0.2% Bias: -5.7%
	8/9/2008	Setup	Center power circuit between basins will not work. Tried many different fixes but could not get it to work. Also, southeast circuit was not working since an outlet was run over and crushed. Replaced outlet and it is now working.
	8/9/2008	Setup	Tried to aim southeast scanner. Had to re-aim it three times to get it to hold paths. When running *GasView MP* program, scanner worked only for a short time before losing paths again.
	8/9/2008	Setup	Found broken connected on scanner in northwest corner (s/n: 1205). Must have broken during shipping back from Directed Perception.
19:40-20:40	8/9/2008	Setup	Sonic inter-comparison. All pass
21:31	8/9/2008	Setup	Zero sonic calibration. All pass.
21:29	8/9/2008	Setup	Barometer audit: pass.
21:31	8/9/2008	Setup	Wetness sensor calibration: accepted.
	8/10/2008	Setup	Used extension cord run from northwest tower to power the northwest scanner. Moved met station to beside the south tower and plugged into the tower power. Found a cut in the wire on center circuit. Will try to splice together tomorrow.
	8/10/2008	Setup	When northwest scanner was powered up, it made a really bad grinding noise while moving on the pan axis. Tried to aim it many times, but it would not hold paths. Tried to send new command string to scanners, but they would not accept it. Scanners would read "initializing pan/tilt unit, but then they would just freeze up that way. When we tried to move the scanner it would just shake and not go anywhere.
	8/10/2008	Setup	Everything is now working on the site except for the TDLAS/scanners.
	8/10/2008	Setup	S-OPS balance: North
	8/10/2008	Setup	S-OPS balance: South
	8/11/2008	Setup	Worked on scanners to try and get them working properly, but had not success. Communicated with Boreal Laser, and they will talk to Directed Perception to try to solve the problem. Old scanners to be shipped overnight to get here Wed morning.

Time HH:MM (UTC)	**Date** (mm/dd/yyyy)	**Activity** (setup, takedown, calibration, repair, remote)	**Event**
	8/11/2008	Setup	Performed SO_2 calibration on TEC 450i.
	8/13/2008	Setup	Maintenance list completed
	8/14/2008	Setup	Innova single point calibration.
	8/15/2008	Remote	Fixed minor issues in computer setup. In *rsync* program, the GSS files were not being shipped…corrected. In data logger, the Table 1 data were set to collect "Most Recently Logged Records." Should be "Data Logged Since Last Collection." Major issues collecting data from CR1000. Added "WA5A" to beginning of all 450i filenames.
14:00	8/15/2008	Remote	Daily Status Check from PAML Notes: Every other data point is missing in CR1000 data due to incorrect setting in *Loggernet*. Gap in data from 592.1 to 593.03. Innova flag 16. Reference cell quatily stuck at 10,000; reference r^2 often below 99.
13:38	8/18/2008	Remote	Daily Status Check from PAML Notes: Sonic error happened on 8/15/2008 at 21:37. Very irregular time stamp in data led to problem. See 100 and 300 s data for this time. Restarted program at 12:00. Sonic program stopped again at 14:26 (runtime error 9); restarted program at 14:40 today. Flag 16 in Innova data. Cannot connect to CR 1000.
12:43	8/19/2008	Remote	Daily Status Check from PAML Notes: Lost connection to both TDLAS 1 and 2 laptops (must have performed an automatic windows update). Computers restarted themselves, and all paths were still on. Checked time on TDL 1 just before shutdown, and the clocks were within 10 s; after restart time was off by almost 4 min. About 2 min later the clocks on the TDLAS laptops updated, and both clocks were very close to LAN time. Later, the laptops kept losing time compared to the LAN. Not sure if it is because of a slow internet connection. When the TDLAS screen is minimized and reopened, the time is up to date. Must be due to slow connection. The sonic program stopped again at 19:39 UTC. I restarted the program right away. Innova flag 16. Cannot connect to CR 1000.
13:09	8/20/2008	Remote	Daily Status Check from PAML Notes: H_2S file is updating fine, but does not show connection on *iPort*. Innova flag 16. Cannot connect to CR 1000.
13:50	8/21/2008	Remote	Daily Status Check from PAML Notes: Stopped sonic and Innova program. Still unable to see H_2S screen although data still updating. Found second *iPort* window in the process and shut down. Restarted *iPort* and data file. Restarted sonic and Innova programs. Innova flag 16 (pump test failure). No CR 1000 data since day 593.
12:20	8/22/2008	Remote	Daily Status Check from PAML Notes: No communication with CR1000. Sonic 1 flagging from about 8/21 11:00 to 8/21 15:00.
12:42	8/25/2008	Remote	Daily Status Check from PAML Notes: TDLAS 1 has lost power. Will call the farm manager to reset the GFCI on the southeast circuit. Cannot connect to the CR 1000. Innova flag 16.
12:50	8/26/2008	Remote	Daily Status Check from PAML Notes: TDLAS 1 still has no power. Re-aimed path 6 on TDLAS 2. Had to move TDLAS down 5 steps; later, moved TDLAS down 5 steps because the light level was maximized. Innova flag 16. Cannot connect to CR 1000.

Time HH:MM (UTC)	**Date** (mm/dd/yyyy)	**Activity** (setup, takedown, calibration, repair, remote)	**Event**
14:21	8/27/2008	Remote	Daily Status Check from PAML Notes: No power to TDLAS 1. Were communicating with Hung Soo from the Engineering Group today to try to get the power working on TDLAS 1. An obstruction is blocking path 1 on TDLAS 2. Innova flag 16. Cannot connect to CR 1000.
12:11	8/28/2008	Remote	Daily Status Check from PAML Notes: On 8/27/2008, was able to get power working on TDLAS 1 with help from Hung Soo from the engineering NAEMS team. The H_2S file is missing data points sporadically. It works well for awhile and then misses points. Cannot connect to CR 1000.
12:48	8/29/2008	Remote	Daily Status Check from PAML Notes: i*Port* had stopped working at about 00:30 UTC on 8/29/2008. Had to stop the sonic and Innova programs in order to start the *iPort* back up again. Restarted the sonic and Innova programs. Made a fill data file for the H_2S for the time that the *iPort* was shut down. Very slow connection on TDLAS 1, and it is difficult to tell time synchronization. Innova flag 16. Cannot connect to CR 1000.
	9/2/2008	Calibration	Electronic data chain of custody form completed.
	9/3/2008	Calibration	S-OPS balance: North
	9/3/2008	Calibration	S-OPS balance: South
	9/3/2008	Calibration	Basin site layout made.
17:20-18:20	9/3/2008	Calibration	Sonic inter-comparison. All pass
19:13	9/3/2008	Calibration	Zero sonic calibration. All pass.
20:55 and 22:25	9/3-4/2008	Calibration	Calibrated TDLAS 1027 Mean: 41.32 SD: 0.35 RSD: 0.8% Bias: -8.6% Notes: During calibration, could not reach value greater than 43 ppm-m. Stopped TDLAS calibration--continued next day after diluter MFC calibration. Accidentally stepped in front of beam during calibration gas run; removed this part during calculations (~22:13).
	9/4/2008	Calibration	Performed TEC 450i, Zero MFC, and Gas MFC calibrations according to directions given from PAAQL--see scanned documents
	9/4/2008	Calibration	Restarted LAN and both Panasonics; updated software on all computers.
	9/4/2008	Calibration	Burned CD's/DVD's
	9/4/2008	Calibration	Current measuring basin (East side) is 100% crusted. Yesterday inlets in both basins were pumping but more pumping into west basin than west one. Today, no pumping into east basin. Switching to west basin, but continuing measurements on east basin.
	9/4/2008	Calibration	Strong H_2S odor upon arrival.
	9/4/2008	Calibration	Yesterday, TDLAS 1 was not running upon FOS arrival.
	9/4/2008	Calibration	CR 1000 still not connecting to LAN long enough to download data. Used laptop yesterday to download and transfer to LAN.
	9/4/2008	Calibration	Check GSS inlet filter solenoid 2 (north side) at takedown. Could be plugged due to open tubing at inlet 4 T. Still have sufficient flow but less it was at start of period. S-OPS max flow test (< 1 LPM).
	9/4/2008	Calibration	Orange light given when switching out CR 1000 memory card.
	9/4/2008	Calibration	Tied old and new NH_3 cylinders with TDLAS 1028--both

Time HH:MM (UTC)	**Date** (mm/dd/yyyy)	**Activity** (setup, takedown, calibration, repair, remote)	**Event**
			cylinders seemed low. 3% error on 400 ppm tank--120 ppm. 3% error on 500 ppm tank--15 ppm.
	9/4/2008	Calibration	Performed Innova multipoint calibration (800 ppm, 200, 100, and 10 with 800 ppm tank). Single point calibration with 10 ppm tank.
	9/4/2008	Calibration	H_2S reading high using new (29.6 ppm) tank (~0.635 ppm). Performed multipoint on H_2S.
	9/4/2008	Calibration	Innova calibration verification: CH_4 and NH_3; CH_4 15% high. Multipoint CH_4 800 ppm tank.
	9/4/2008	Calibration	H_2S calibration verification: high for 0.5 ppm. Multipoint calibration done.
	9/4/2008	Calibration	Retro heights and plastics determined and mapped.
	9/4/2008	Calibration	Maintenance list completed
16:34	9/4/2008	Calibration	Barometer audit: pass.
16:55	9/4/2008	Calibration	Wetness sensor calibration: accepted.
20:04-21:41	9/4/2008	Calibration	Calibrated TDLAS 1028 See calibration sheet for details. Notes: Tied in old/new tanks. 3% of 500 ppm (errors of tanks) ~15 ppm. 3% of 4000 ppm (used during multipoint for cal curves) ~120 ppm. Need to account for tank accuracies/errors.
22:30-00:34	9/4/2008	Calibration	Innova multipoint calibration.
14:00	9/5/2008	Remote	Daily Status Check from PAML Notes: Path 10 on TDLAS 2 has had low light levels on the past 2 scans. After a few min path 10 is back on. Perhaps an obstruction of some type? Flags in H_2S data from 614.09-614.17 (calibration). Innova flag 25; too early in period to tell. GSS Mass Flow 1 (blue) follows 2 from 613.42-613.80 (not switching during this time). Found that TDL 1 data were being saved to period 5. Logged onto TDL 1 PC and corrected. No communication with CR 1000.
13:00	9/8/2008	Remote	Daily Status Check from PAML Notes: H_2S analyzer lost communication with computer so values as of 615.4 were zero--will restart remotely. Had to stop sonic and Innova programs to restart H_2S program in *iPort*. Filled data starting at 9:15 UTC 9/6/2008. Restarted sonic and Innova programs. Sonic 3 had missing data due to flagging and spike counts over 160 overnight. Majority of spike counts was under 160. GSS solenoids not switching as of 615.8 (9/6/2008). No communication with CR 1000.
16:30	9/9/2008	Remote	Daily Status Check from PAML Notes: Sonic 3 had afternoon flagging. Sonic 2 had spike counts over 160 points, but the majority was under 160. H_2S analyzer data had flag 1 because the program stopped due to communications. Innova flag 16 (pump failure). GSS mass flow was normal again at day 618.3. Limited communications with CR 1000.
12:05	9/10/2008	Remote	Daily Status Check from PAML Notes: Sonic 2 had some flagging but not much. Sonic 3 had flagging during the afternoon. Innova flag failure (pump failure). Limited communication with CR 1000.
13:00	9/11/2008	Remote	Daily Status Check from PAML Notes: Sonic 3 had flagging and spike counts over 160 yesterday. Innova flag 16 (pump failure). Communication problems with CR 1000.
12:45	9/12/2008	Remote	Sonic 3 had flagging during the afternoon. No Innova

Time HH:MM (UTC)	**Date** (mm/dd/yyyy)	**Activity** (setup, takedown, calibration, repair, remote)	**Event**
			concentrations since day 620.9; program may have failed--will check when logged in remotely. Innova flag 16 (pump failure). Limited communication with CR 1000.
12:30	9/15/2008	Remote	Daily Status Check from PAML Notes: TDL 2 path 6 was not aligned--realigned. Originally (P6906, T283); after alignment (P6904, T284). GSS not switching sides as of yesterday at day 623.7, 12pm PDT; will continue to monitor throughout the day to see if will correct itself (corrected itself yesterday). If no correction, will contact Hung Soo to check GSS connections when he arrives at the site. Sonic anemometers 2 and 3 were flagging. Sonic anemometer 2 had random flagging while sonic 3 had flagging during daytime hours. Limited communications with CR 1000.
12:15	9/16/2008	Remote	Daily Status Check from PAML Notes: H_2S data updating but cannot locate iPort on taskbar; will restart sonic anemometers, Innova, and *iPort* to view *iPort* status. GSS switching back and forth between two paths/solenoids (corrected itself). Sonic 1 had flagging throughout the day yesterday; only 8 values as max. Sonic 3 is flagging everyday during daytime hours. Average w values minorly shift differently from zero for all sonic anemometers, but could be from terrain. Innova flag 16 (pump failure). GSS pressure and mass flow indicate solenoids are not switching. Limited communicated with CR 1000.
12:30	9/17/2008	Remote	Daily Status Check from PAML Notes: Sonic 3 flagging during daytime hours. Innova flag 16 (pump failure). Solenoids no longer getting stuck on solenoid 2; now switching between both solenoids and getting stuck on both. Limited communication with CR 1000.
12:15	9/18/2008	Remote	Daily Status Check from PAML Notes: Sonic 3 flagging during daytime hours. Innova flag 16 (pump failure). As of day 626.7, GSS pressure and flow collecting from correct path; still may switch sides/sounds; have history of doing so throughout measurement period. Limited communication with CR 1000.
12:10	9/19/2008	Remote	Daily Status Check from PAML Notes: Sonic 3 has flagging during daytime hours. As of yesterday's QC check, pressures and flow have been normal on GSS. Innova flag 16 (pump failure). CR 1000 has limited communication with LAN.
12:15	9/24/2008	Remote	Daily Status Check from PAML Notes: Internet very slow, and it keeps kicking me off. Were back on site in two days to check status. Poor CR 1000 communications. Sonic 3 is flagging during daytime hours. As of 632.8, "0" solenoid stuck on "1" on GSS. H_2S values are 0 as of 629.5. *iPort* probably closed; will start.
	9/26/2008	Takedown	Upon arrival, TDL 1 path 10 was not aligned.
	9/26/2008	Takedown	TEC 450i not running so created a "fill" file
	9/26/2008	Takedown	Tower retro-reflectors contained a lot of bird droppings on case and windows.
	9/26/2008	Takedown	northwest (TDL 2) TDLAS window was very dirty (have pictures).
	9/26/2008	Takedown	When performing S-OPS/GSS tests, noticed GSS stuck on solenoid 2 (north path). Moved wires around and working now (but connections are not loose).

Time HH:MM (UTC)	**Date** (mm/dd/yyyy)	**Activity** (setup, takedown, calibration, repair, remote)	**Event**
	9/26/2008	Takedown	Barometer getting high voltages but seems to be reading correctly in *Loggernet*.
	9/26/2008	Takedown	TDL did not "pass" during calibrations, but suspect diluter is not functioning properly, causing TDL's to be reading low.
	9/26/2008	Takedown	Ran NH_3 through diluter as well; concentrations from Innova reading low for NH_3 but passing for CH$ (straight from tank).
	9/26/2008	Takedown	Maintenance list completed
17:55-18:55	9/26/2008	Takedown	Sonic inter-comparison; all pass.
19:41	9/26/2008	Takedown	Zero sonic calibration. All pass.
20:02	9/26/2008	Takedown	Barometer audit: pass.
20:05	9/26/2008	Takedown	Wetness sensor calibration: accepted.
21:22	9/26/2008	Takedown	Calibrated TDLAS 1028
22:12	9/26/2008	Takedown	Calibrated TDLAS 1027
	9/26/2008	Setup	Started sonic anemometers and will let them run overnight for inter-comparison.
	5/19/2009	Setup	Checked outlets on east basin. All outlets have power except for tripped GFCI on northeast corner (will replace).
20:10-20:27	5/19/2009	Setup	Calibrated TDLAS 1029
20:37-20:53	5/19/2009	Setup	Calibrated TDLAS 1027
21:27-21:58	5/19/2009	Setup	TEC 450i single point calibration
21:45-22:45	5/19/2009	Setup	Sonic inter-comparison; all pass.
	5/20/2009	Setup	Replaced GFCI outlet on northwest corner tower.
	5/20/2009	Setup	Performed TDLAS inter-comparison on TDLs 1027 and 1029. Started at 22:20 UTC and ended on 18:30 UTC 5/21/2009.
17:43	5/20/2009	Setup	Zero sonic calibration. All pass.
17:48	5/20/2009	Setup	Barometer audit: pass.
17:50	5/20/2009	Setup	Wetness sensor calibration: accepted.
	5/21/2009	Setup	Called electricians because the outlets between the basins have low power including the TDL outlet.
	5/21/2009	Setup	TDLAS 1027 ran well overnight, but it froze up after power cycling before alignment. Called Boreal and did a system reset: Put business card under clip on internal battery; switched memory save jumper from "save" to "not save" position; let TDL sit for 30 min. Will take TDL 1027 back to PAML .
	5/21/2009	Setup	Met station location diagramed on Open Site Notes.
	5/21/2009	Setup	Basin site layout made.
	5/21/2009	Setup	S-OPS sensor installation report completed.
	5/21/2009	Setup	Maintenance list completed
20:40	5/21/2009	Setup	S-OPS/GSS calibrations performed.
	5/22/2009	Remote	Daily Status Check from PAML Notes: TDL 1 (1027) is not present. No connection to CR 1000. Last update was on 5/22 at 00:07 UTC; cannot download data. QC parameter files not completed, so no QC check available.
14:15	5/26/2009	Remote	Daily Status Check from PAML Notes: TDLAS QC program not running properly. TDL 2 had a missing path. Tried moving TDL every direction but could not align path. May be blocked by pump or vehicle.
13:15	5/27/2009	Remote	Daily Status Check from PAML Notes: Could not remotely connect in the morning but was successful in afternoon. Power

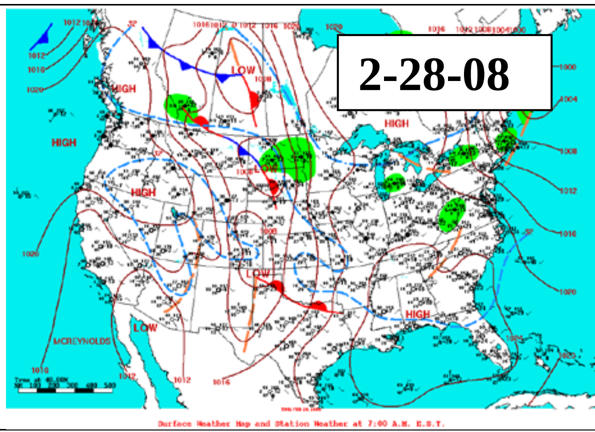
Time HH:MM (UTC)	**Date** (mm/dd/yyyy)	**Activity** (setup, takedown, calibration, repair, remote)	**Event**
			failures at site from 1:25:32-6:04:42 UTC on 5/27/2009. Filled missing H_2S data. TDL laptops were without power for too long and shut down. Will contact technician to restart computer. Restarted sonic anemometers after connecting to *iPort*.
19:15	5/28/2009	Remote	Daily Status Check from PAML Notes: No QC files available today as the modeling computer was turned off. Cannot connect to TDL laptops.
13:00	5/29/2009	Remote	Daily Status Check from PAML Notes: Not enough space to perform backup. Deleted previous backups to make room for a new backup. TDL laptops lost power and need to be restarted.
12:30	6/1/2009	Remote	Daily Status Check from PAML Notes: TDL laptops lost power and need to be restarted. FOS were on site by 6/4/2009. Not enough space to perform backup. Deleted previous backups to make room for a new backup. *iPort* closed at 12:28 UTC on 6/1/2009; stopped sonic anemometers, filled missing data, and restarted sonic anemometers.
13:00	6/2/2009	Remote	Daily Status Check from PAML Notes: Not enough space to perform backup. Deleted previous backups to make room for a new backup. TDL laptops lost power and need to be restarted. FOS were on site by 6/4/2009. TDL 1 not present at site.
13:00	6/3/2009	Remote	Daily Status Check from PAML Notes: TDL laptops lost power and need to be restarted. TDL 1 not present at site.
	6/4/2009	Calibration	TDL laptop for TDLAS 2 was turned on (both TDL laptops were on) upon arrival. However, FOS were unable to connect to TDL 2 computer (M:) from LAN. Restarted all computers and now LAN can connect to both TDL laptops.
	6/4/2009	Calibration	Found basin levels were low (see pictures); looks like farm operators pumped out all the liquid.
	6/4/2009	Calibration	Pumping into "freshwater" basin east of measurement basin.
	6/4/2009	Calibration	New outlet on northwest corner of east basin (TDL 2 corner). Voltage with nothing plugged in was about 120 VAC. When scanner/TDLAS unit is plugged in, outlet voltage is about 44 VAC (scanner/TDLAS does not turn on). Plugged scanner/TDLAS unit back into extension cord for outlet on the north side of the west basin. Scanner/TDLAS system now has power and will turn on.
	6/4/2009	Calibration	Error message: "Not enough space to perform backups." Deleted previous backups to make room for new backups.
	6/4/2009	Calibration	Maintenance list completed
	6/4/2009	Calibration	Basin site layout made. Located with Open Site Notes for 6/4/2009.
19:10-20:09	6/4/2009	Calibration	Sonic inter-comparison; all pass.
19:18-19:43	6/4/2009	Calibration	Calibrated TDLAS 1029
19:30-22:35	6/4/2009	Calibration	S-OPS/GSS calibrations performed. Inlet balance sheet is attached to calibration form.
19:52-20:10	6/4/2009	Calibration	Calibrated TDLAS 1028
19:56	6/4/2009	Calibration	Barometer audit: pass.
19:59	6/4/2009	Calibration	Wetness sensor calibration: accepted.
20:20	6/4/2009	Calibration	Sonic zero/bias check; all pass.
22:04	6/4/2009	Calibration	TEC 450i calibration. Notes: Calibration gas test failed. Will wait

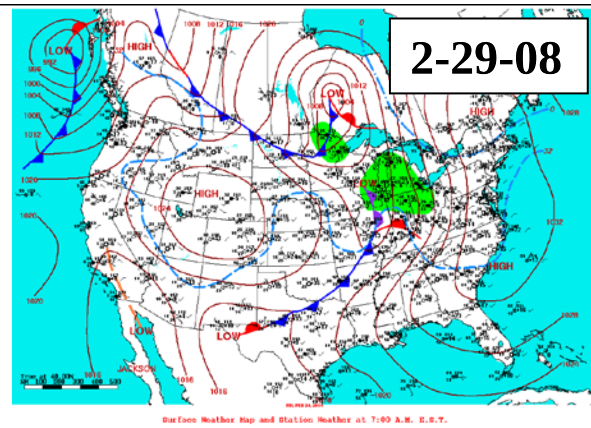
Time HH:MM (UTC)	**Date** (mm/dd/yyyy)	**Activity** (setup, takedown, calibration, repair, remote)	**Event**
			until next visit, and if it fails again, a multipoint calibration were performed.
14:40	6/5/2009	Remote	Daily Status Check from PAML Notes: TDL 1 paths 1, 2, 3, 4, and 6 were off this morning. Unable to find paths 1-4; may be wet from storms last night. They face south and wind was from south. All 3 sonic anemometers have zeros in data starting at 6/5/2009 5:35 UTC. Will check out further remotely.
12:30	6/8/2009	Remote	Daily Status Check from PAML Notes: No power at tower or at weather station; currently there is no sonic data or CR 1000 data. Power was lost on Friday (6/5/2009) night. TDL 2 path 3 not aligned; could not manually align the path. Will let path optimize and check later. Not enough space to perform backup. Deleted previous backups to make room for a new backup.
12:45	6/9/2009	Remote	Daily Status Check from PAML Notes: *Loggernet* no connected to CR 800; restarted *Loggernet* and connected immediately to CR 800. Early in the day, experienced power trouble with sonic anemometers; no sonic anemometers were working. At 17:00 UTC sonic anemometers started working again. Found *iPort* error when started working too. Stopped sonic anemometers to fill missing data. Filled data starting at 15:42 UTC on 6/9/2009. Restarted real-time H_2S data and sonic anemometers. CR 1000 still not working.
12:15	6/10/2009	Remote	Daily Status Check from PAML Notes: Yesterday's GSS/H_2S/Innova QC run showed normal TEC 450i values--now graphs are before yesterday. Today's values are normal. TDL 2 CDC is currently ok, but it had temporarily dropped to 133. Not enough space to perform backup; deleted previous backups to make room for new ones. Technicians were on site today to see what is wrong with TDL 2 retro 3. TDL 2's paths were not aligned; moved about 10 steps left and about 40-50 steps down. Saved new setup.
14:45	6/11/2009	Remote	Daily Status Check from PAML Notes: H_2S chamber pressure increasing at the end of the data returned. CDC in TDL 1 experienced a brief drop a couple of days ago. Yesterday, the water removed from TDL 1 retro 3; this should increase the amount of time all ten paths are aligned. Re-aimed TDL 1 paths 3, 6, and 9; all paths are now aligned.
13:00	6/12/2009	Remote	Daily Status Check from PAML Notes: No basin probes present at site.
12:15	6/15/2009	Remote	Daily Status Check from PAML Notes: TDL 2 path 2 was not aimed; TDLAS QC check shows path 2 was not aligned today and was aligned 1.5% of the time yesterday.
13:15	6/16/2009	Remote	Daily Status Check from PAML Notes: Upon remote login found McShield.exe Application error.
12:00	6/17/2009	Remote	Daily Status Check from PAML
13:40	6/18/2009	Remote	Daily Status Check from PAML
13:07	6/19/2009	Remote	Daily Status Check from PAML
	6/19/2009	Takedown	Upon arrival, TDL 1 path 8 was not aligned.
	6/19/2009	Takedown	UPS activity: 5/27/2009 06:04:42: UPS output power has been restored to Load Segment 2. 6/14/2009 00:51:41: UPS switched to battery power. 00:51:45: AC Restored Message sent

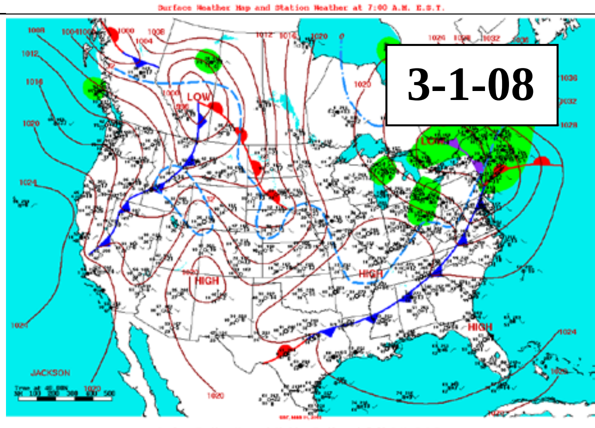
Time HH:MM (UTC)	Date (mm/dd/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
			to registered clients connected to Load Segment 2.
	6/19/2009	Takedown	LAN computer message: "Not enough space to perform backup." Deleted previous backups to make room for new backups
	6/19/2009	Takedown	TEC 450i did not pass calibration; performed a new multipoint calibration for a new multipoint curve.
	6/19/2009	Takedown	Maintenance list completed
	6/19/2009	Takedown	S-OPS/GSS calibrations
17:43	6/19/2009	Takedown	Stopped H_2S data collection.
18:20-19:20	6/19/2009	Takedown	Sonic inter-comparison; all pass.
20:03	6/19/2009	Takedown	Zero sonic calibration. All pass.
20:05	6/19/2009	Takedown	Barometer audit: pass.
20:07	6/19/2009	Takedown	Wetness sensor calibration: accepted.
21:29	6/19/2009	Takedown	Performed TEC 450i Single point calibration Notes: Instrument failed calibration; will perform multipoint calibration.
21:43	6/19/2009	Takedown	TEC 450i multipoint calibration
23:16-23:31	6/19/2009	Takedown	Calibrated TDLAS 1029
23:42-23:58	6/19/2009	Takedown	Calibrated TDLAS 1028

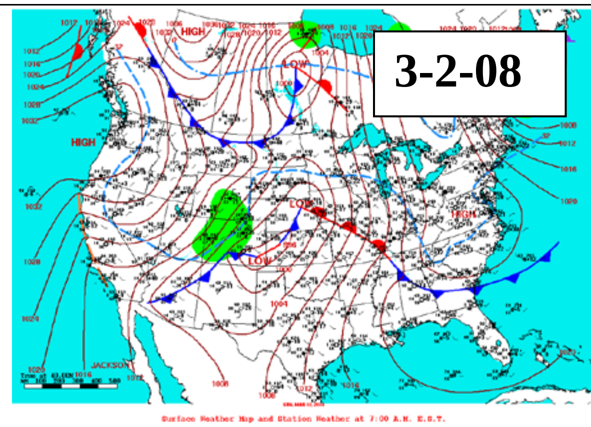
6.7 Site weather

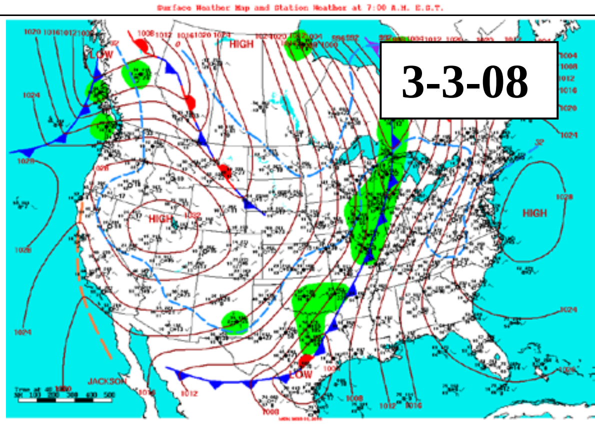
Period 3

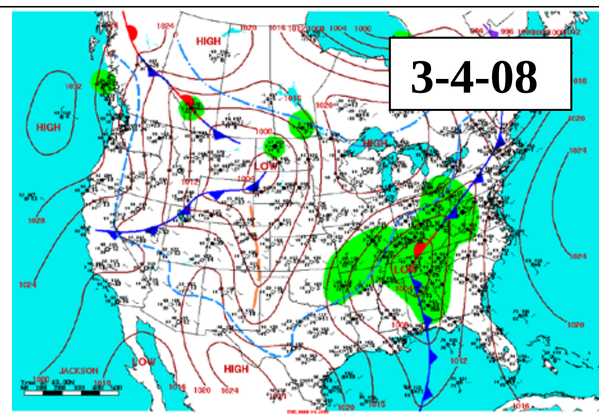


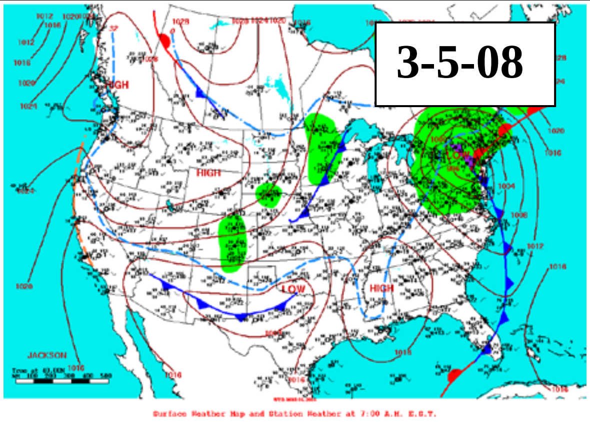


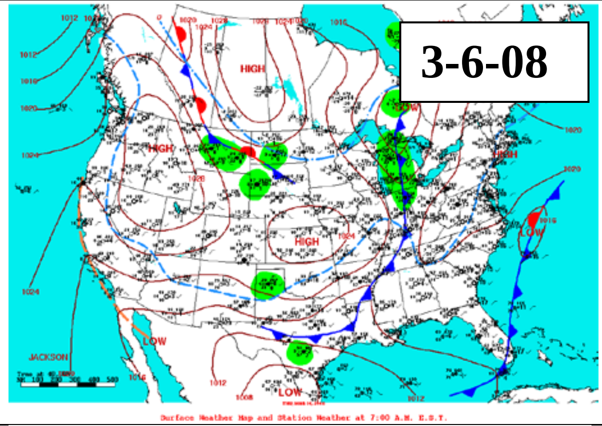


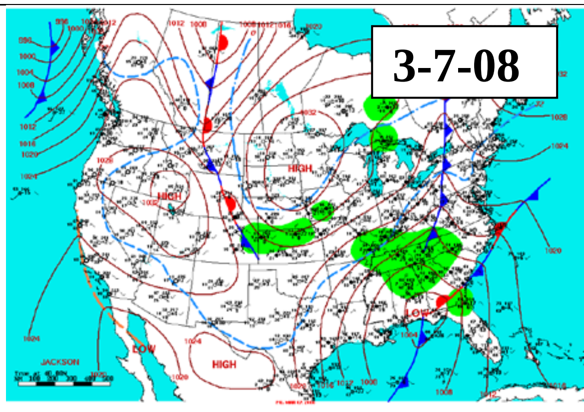


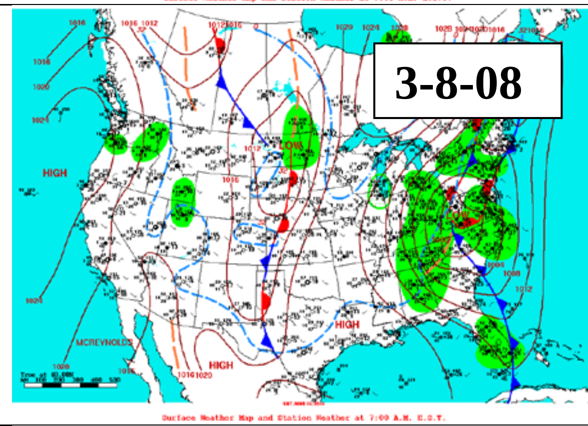


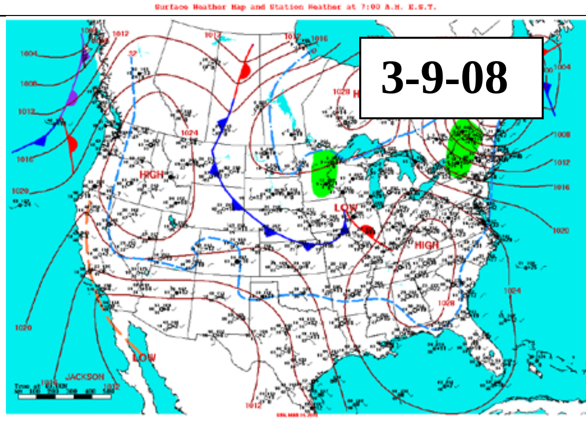


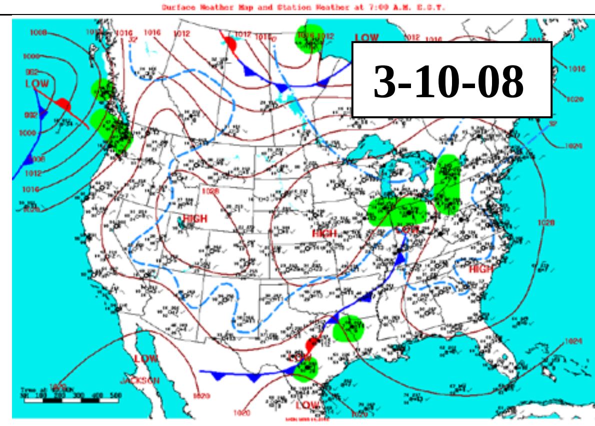


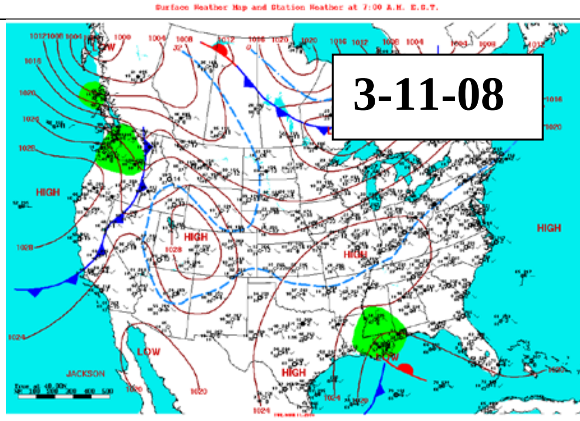












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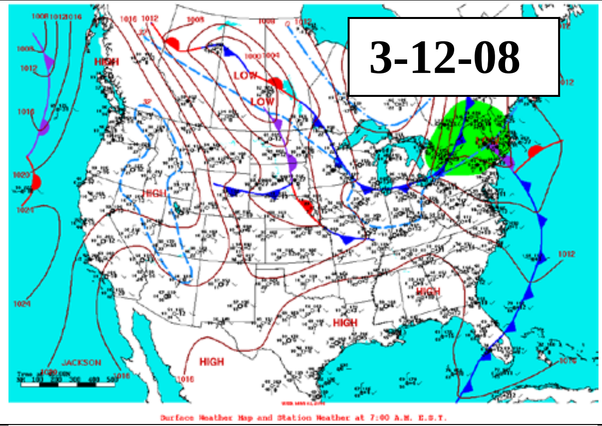
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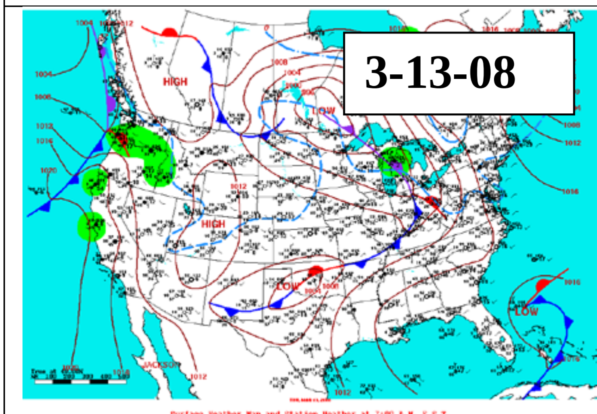
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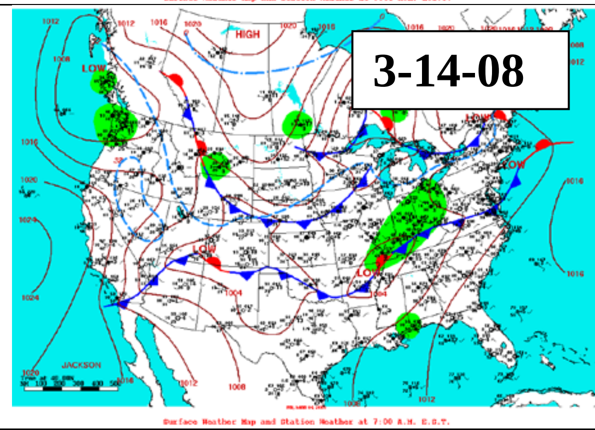
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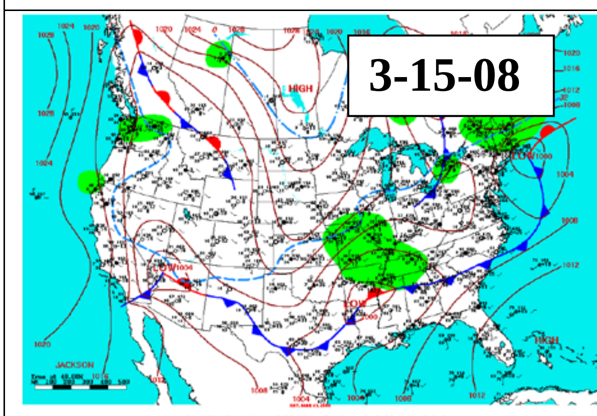
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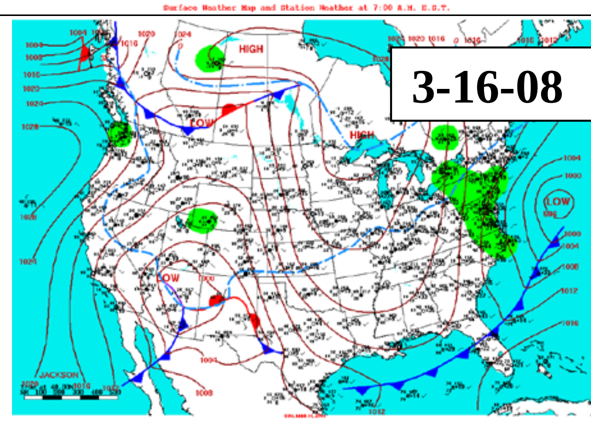
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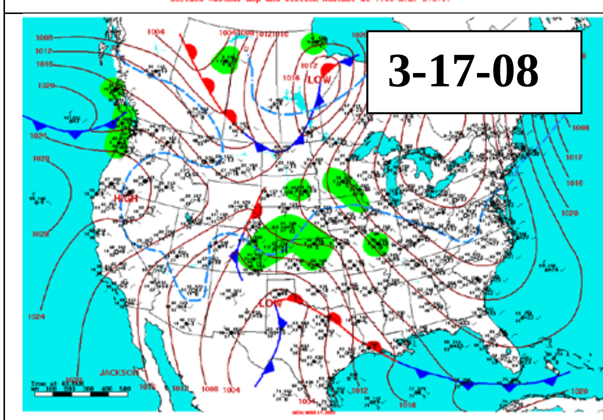
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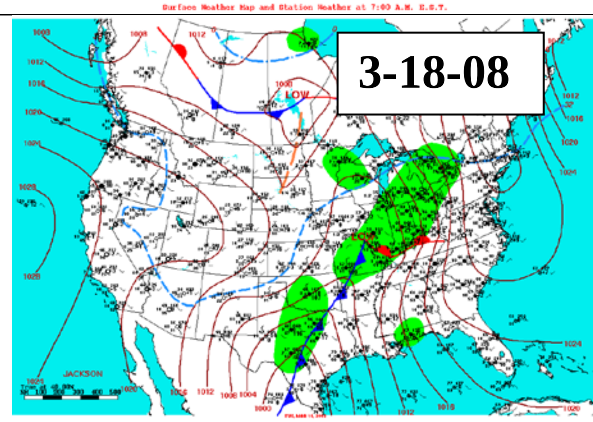
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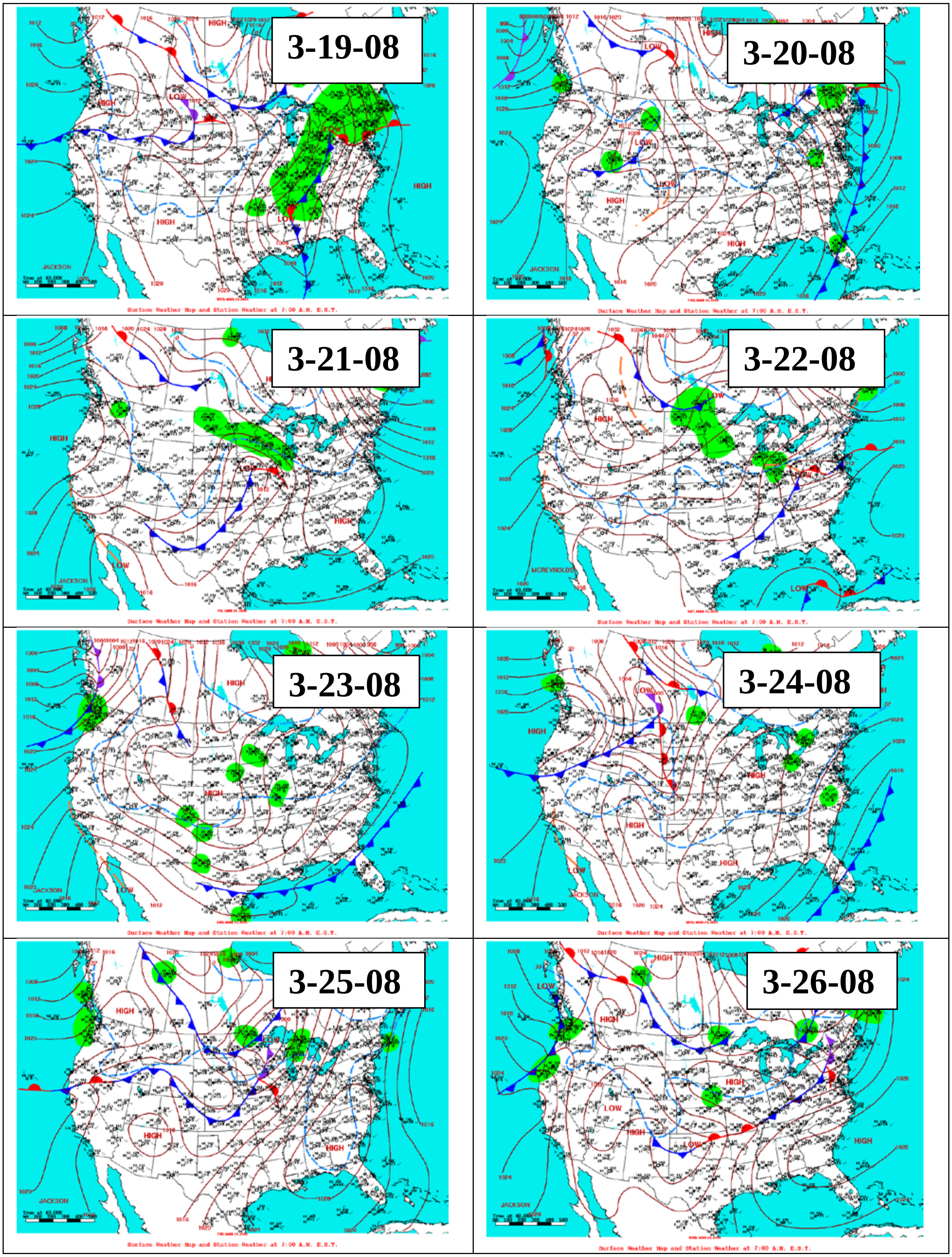
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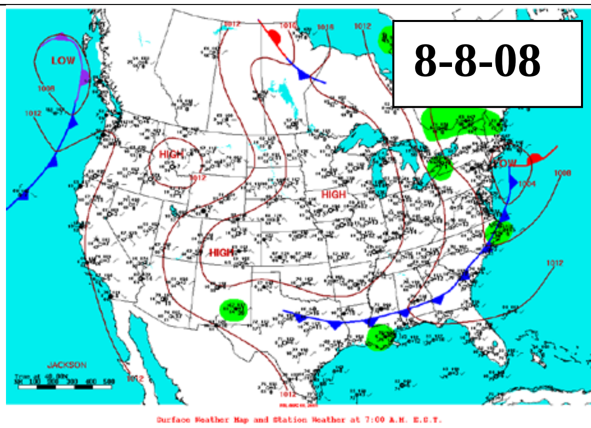
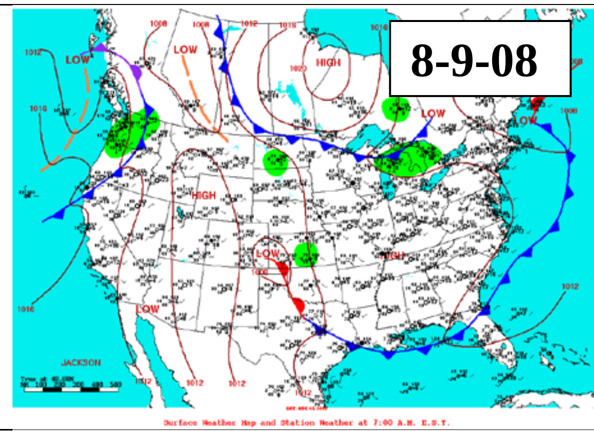
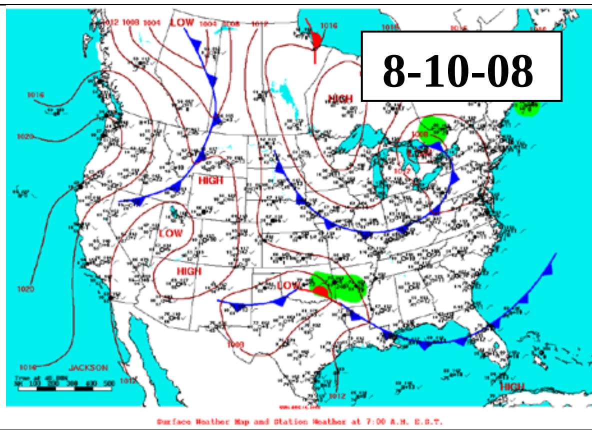
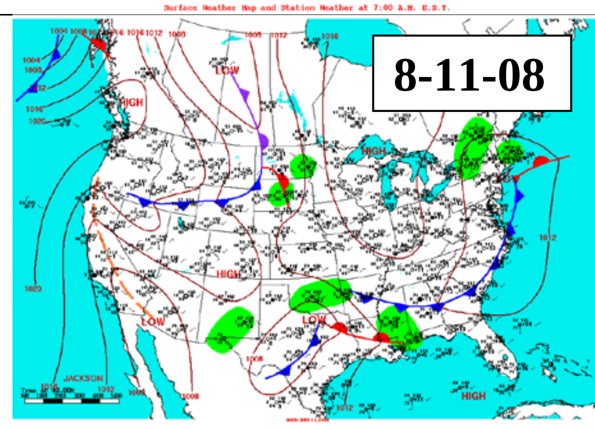
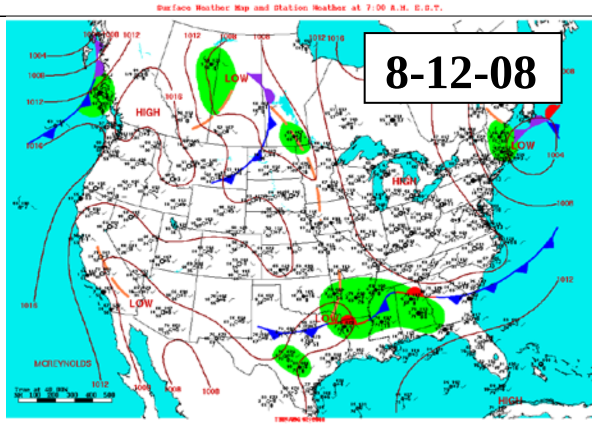
Period 5

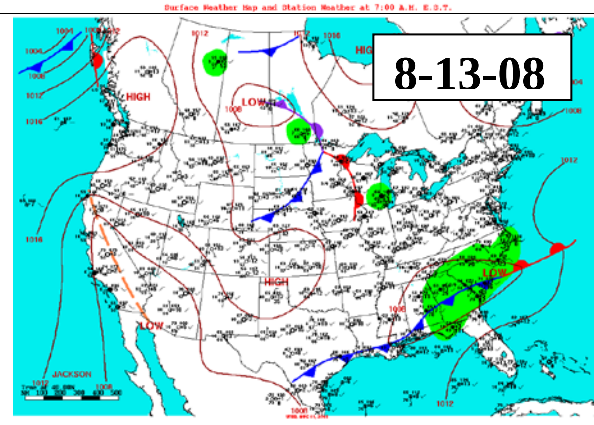


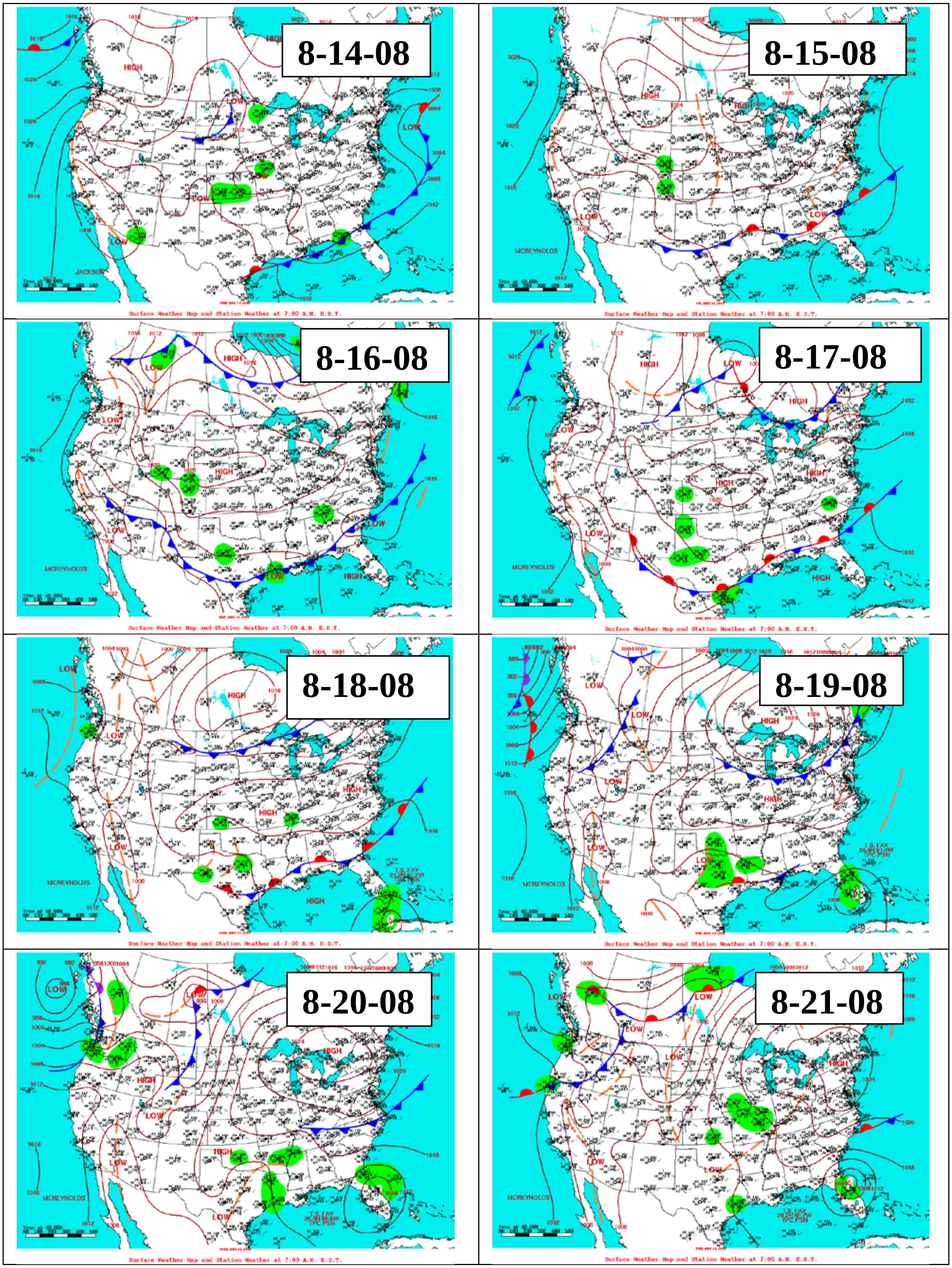








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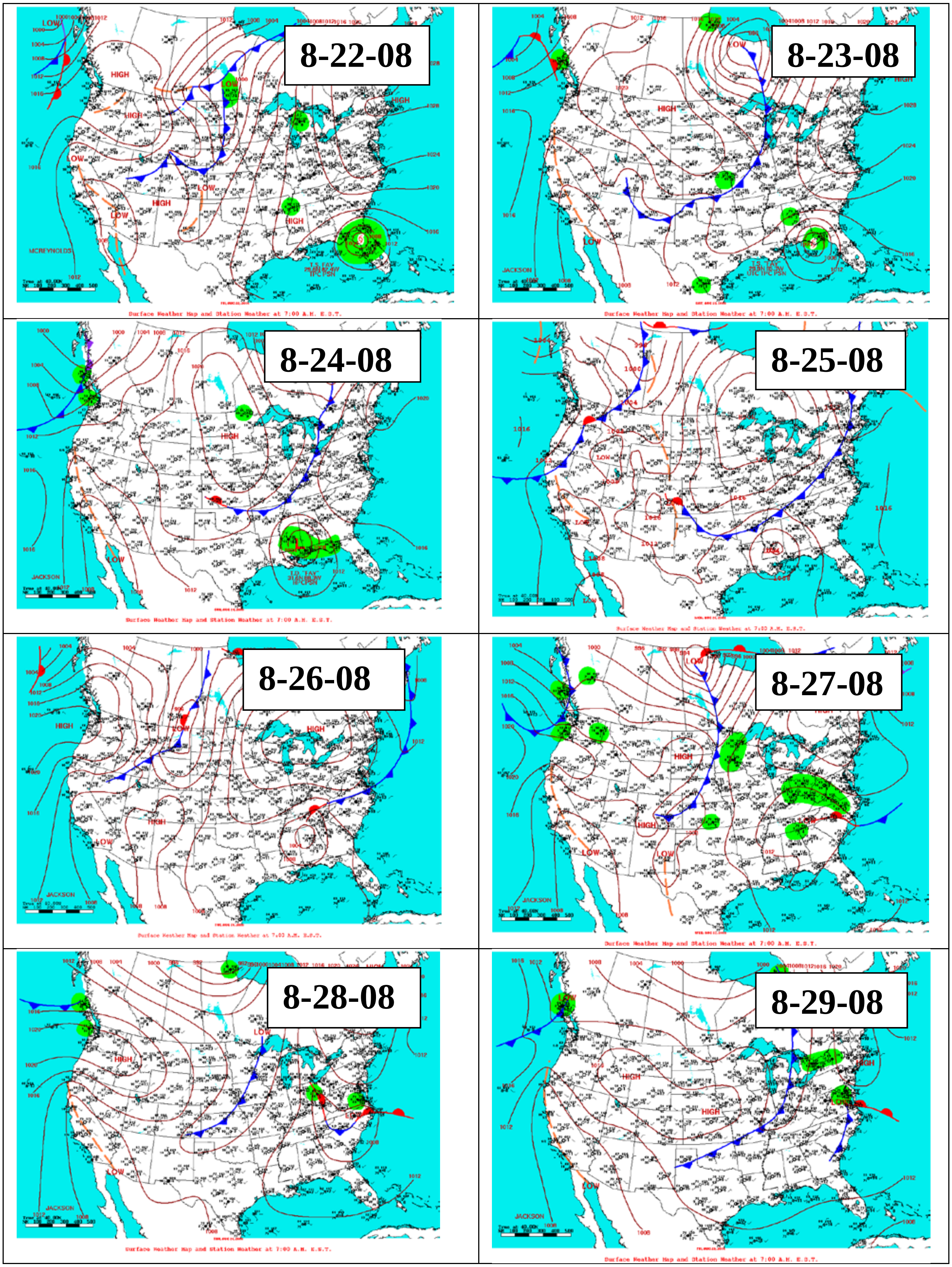
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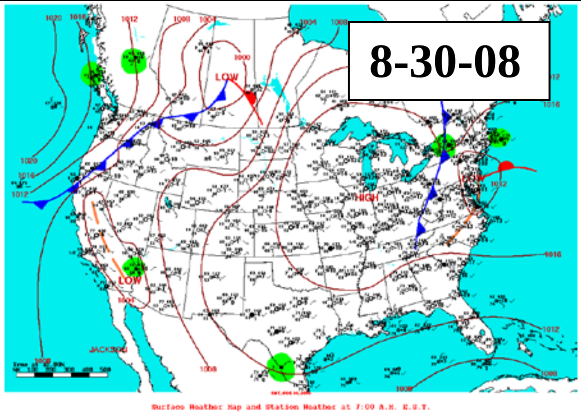

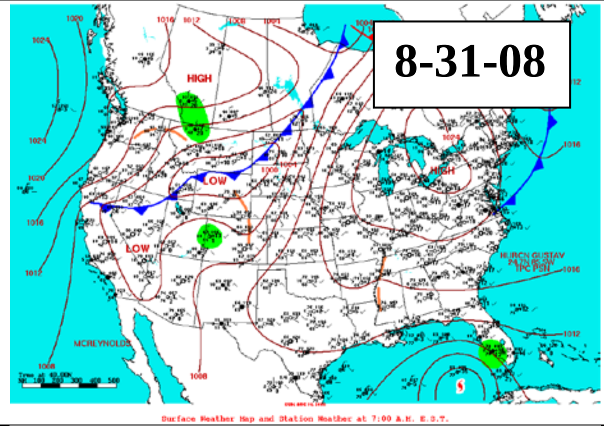

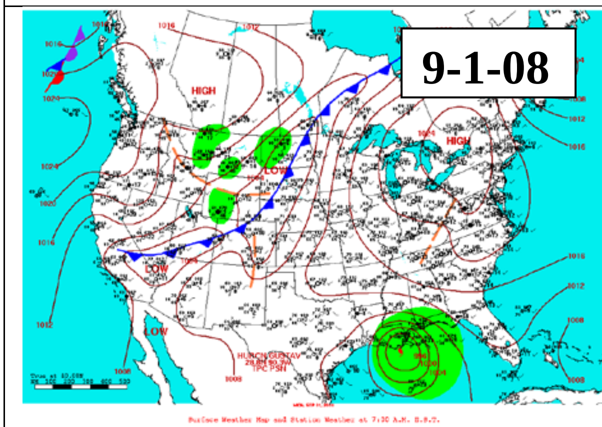

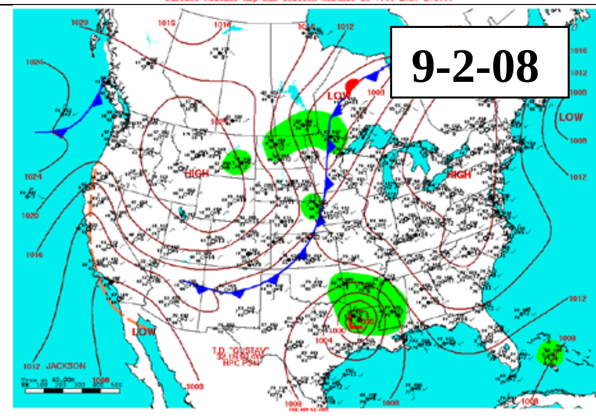

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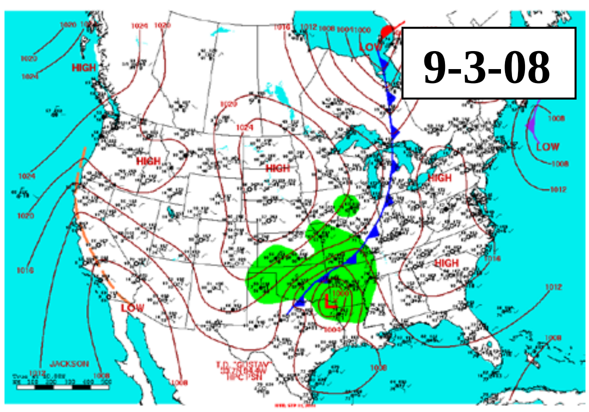

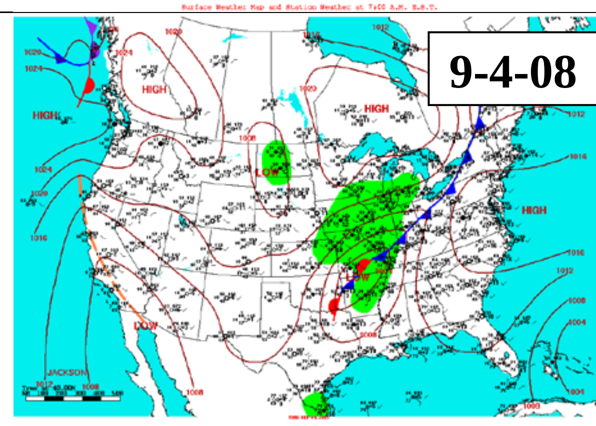

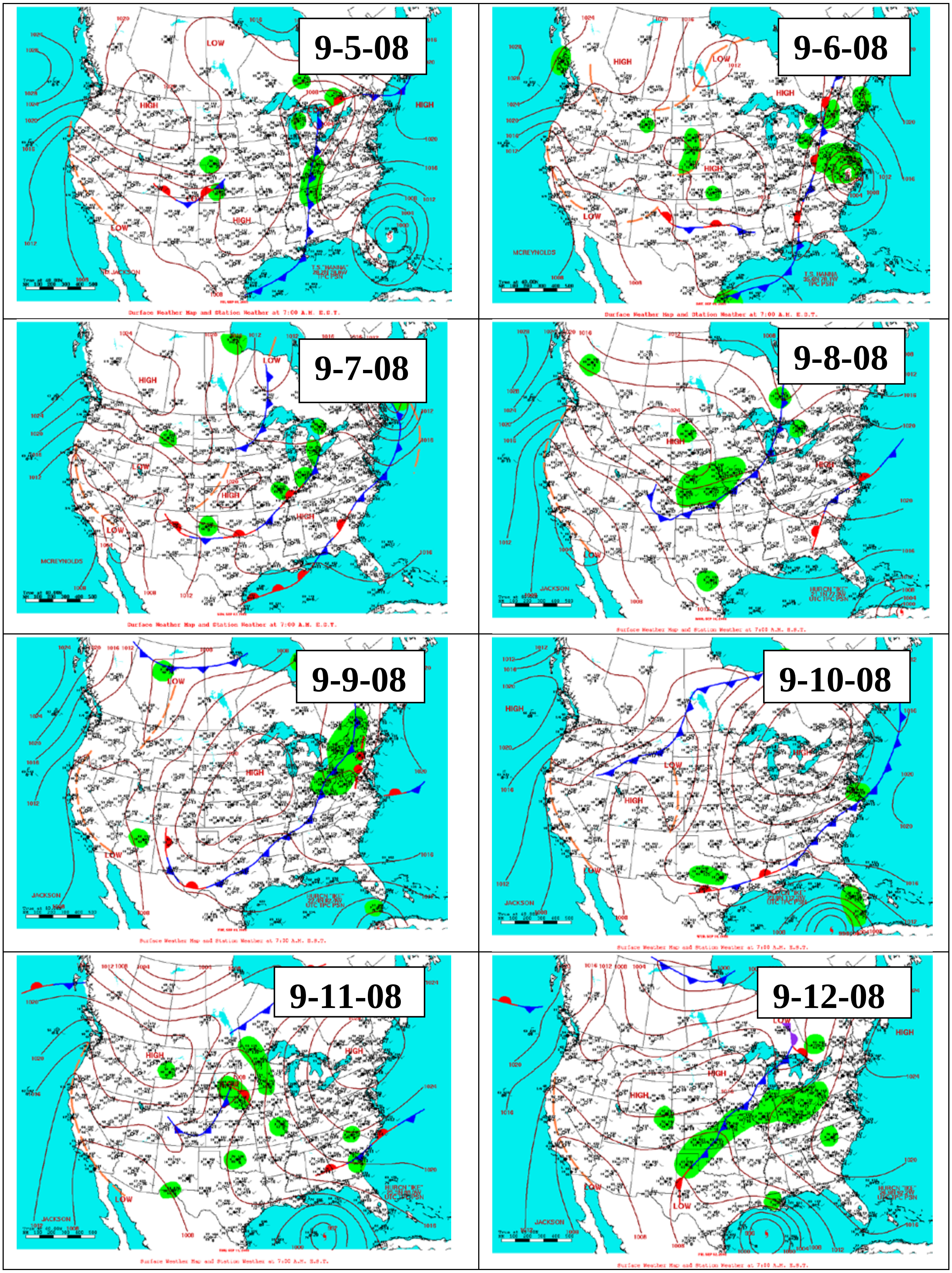
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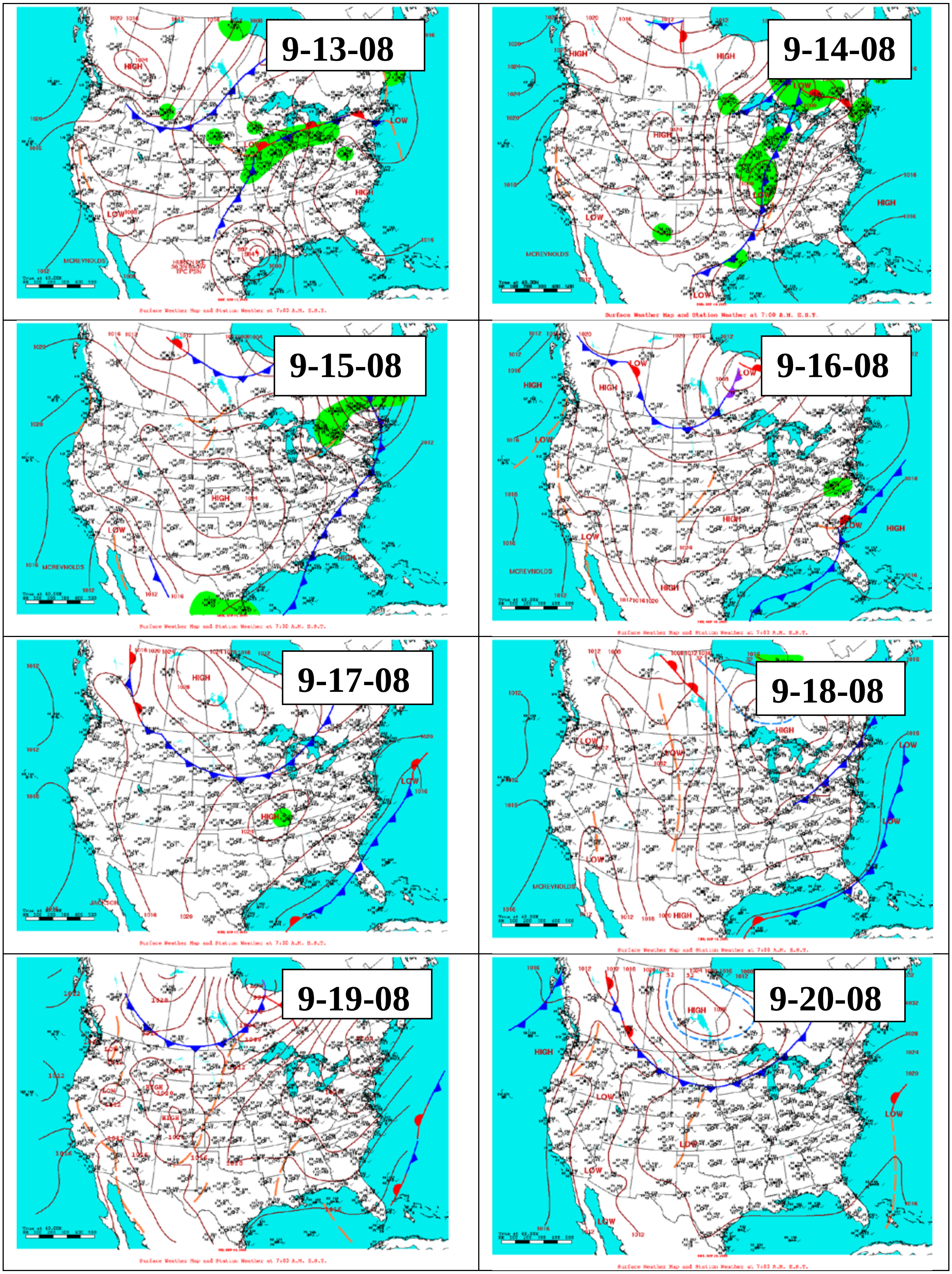
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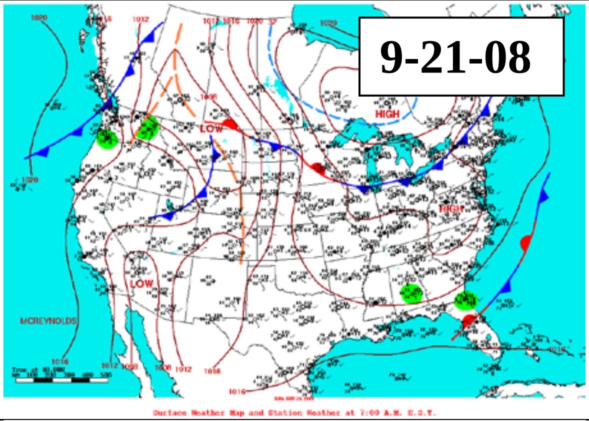

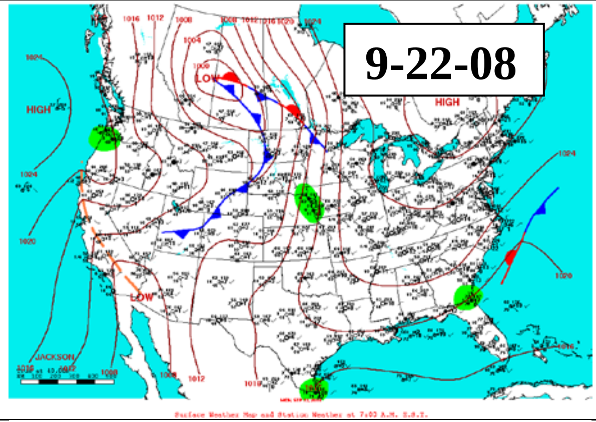

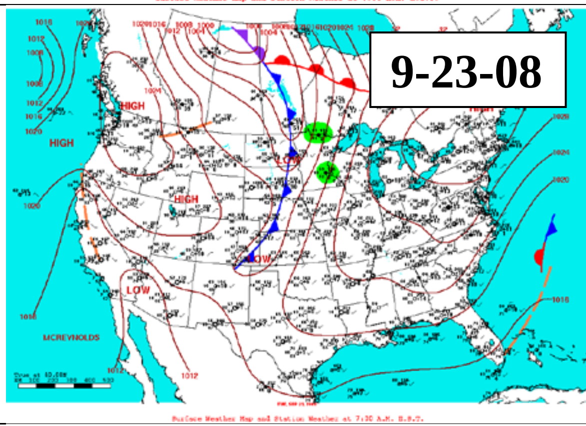

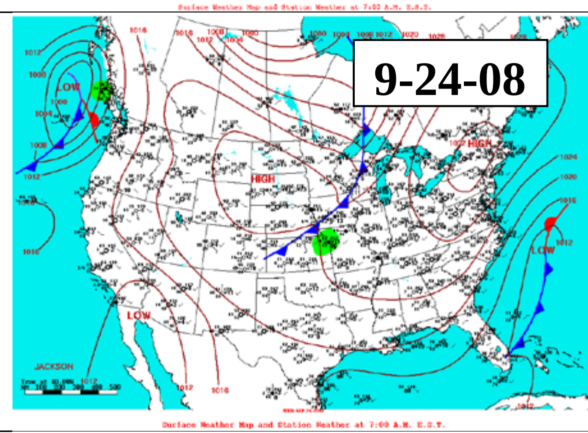

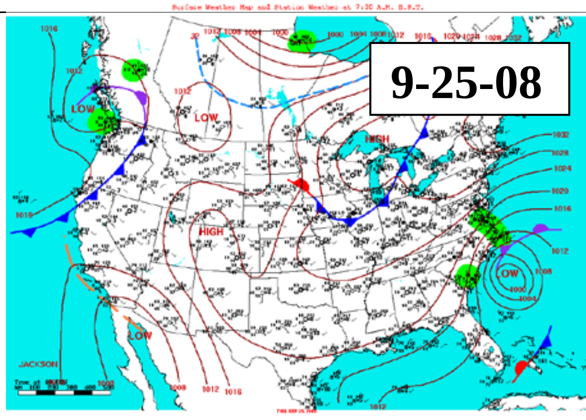

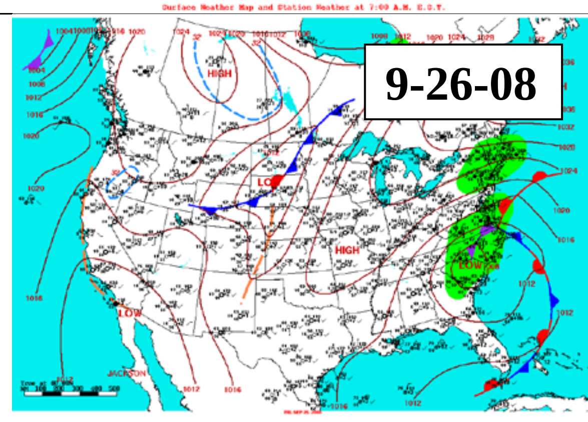

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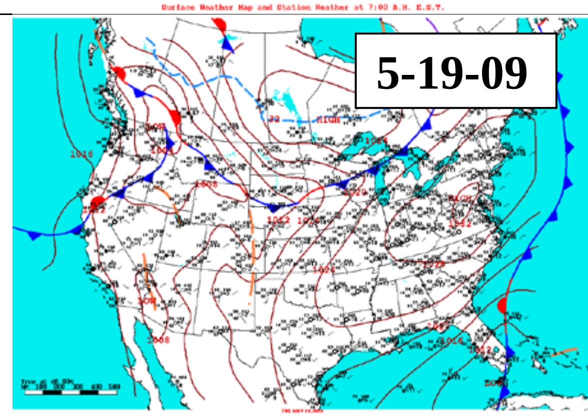

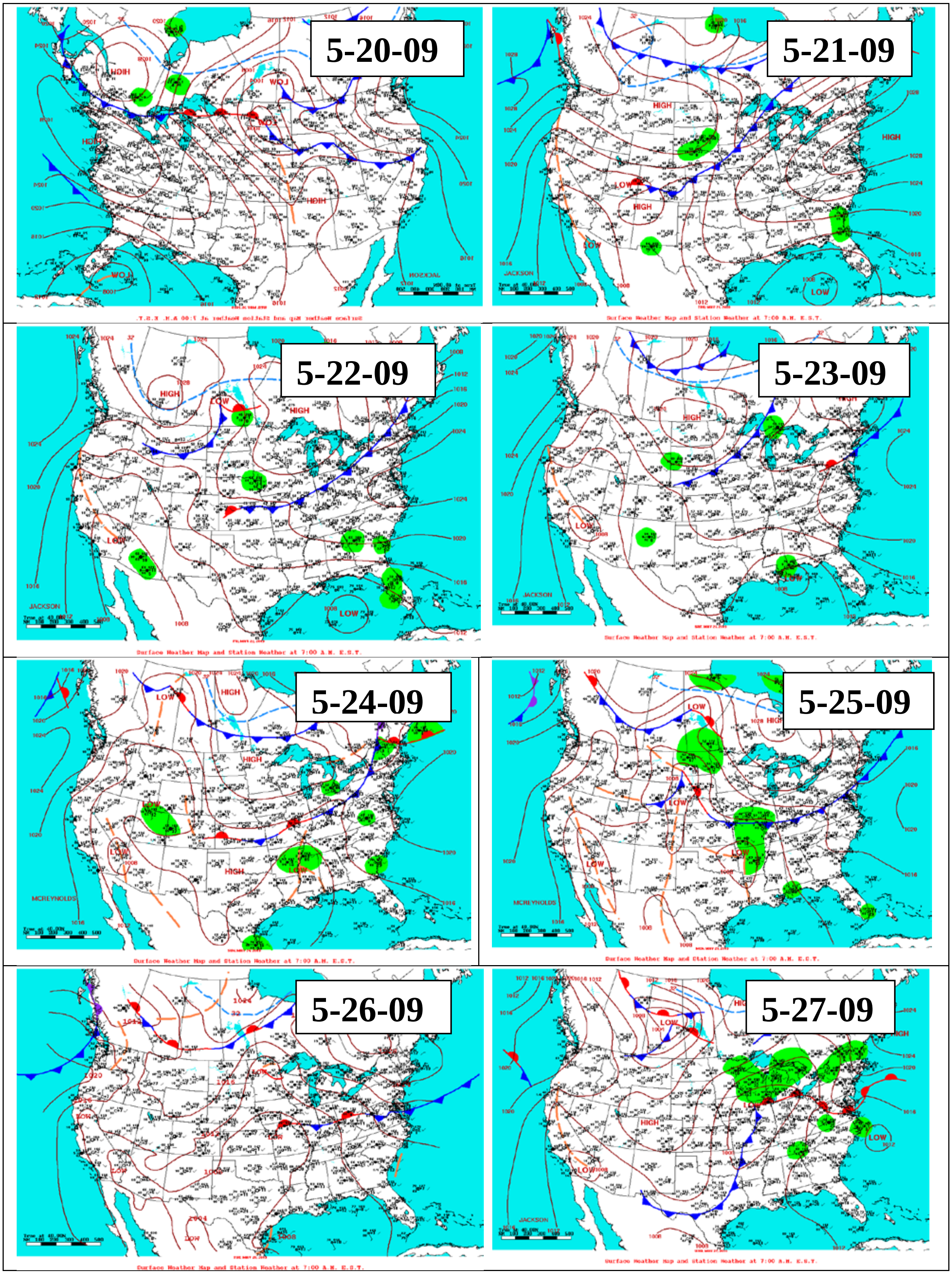
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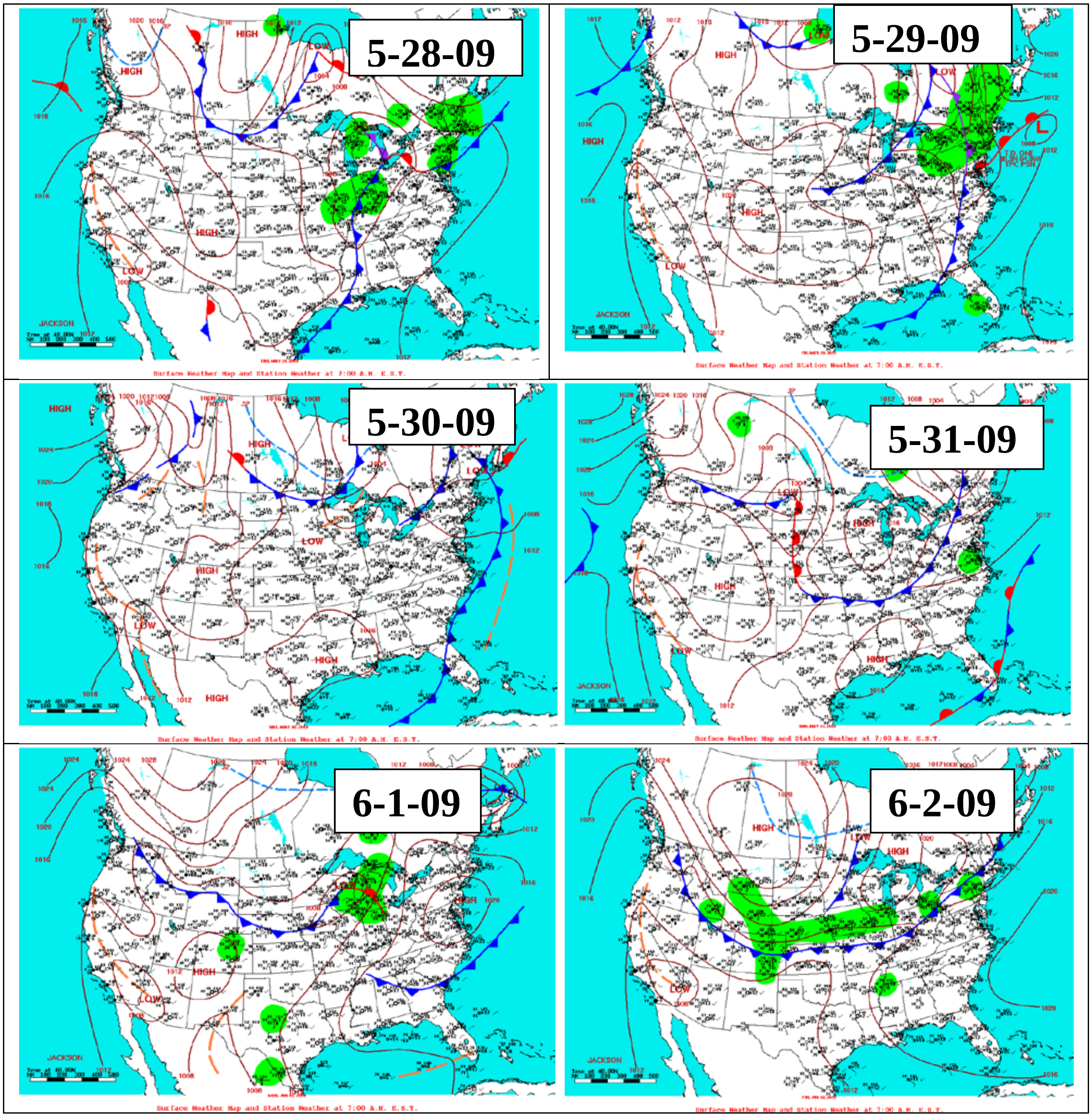
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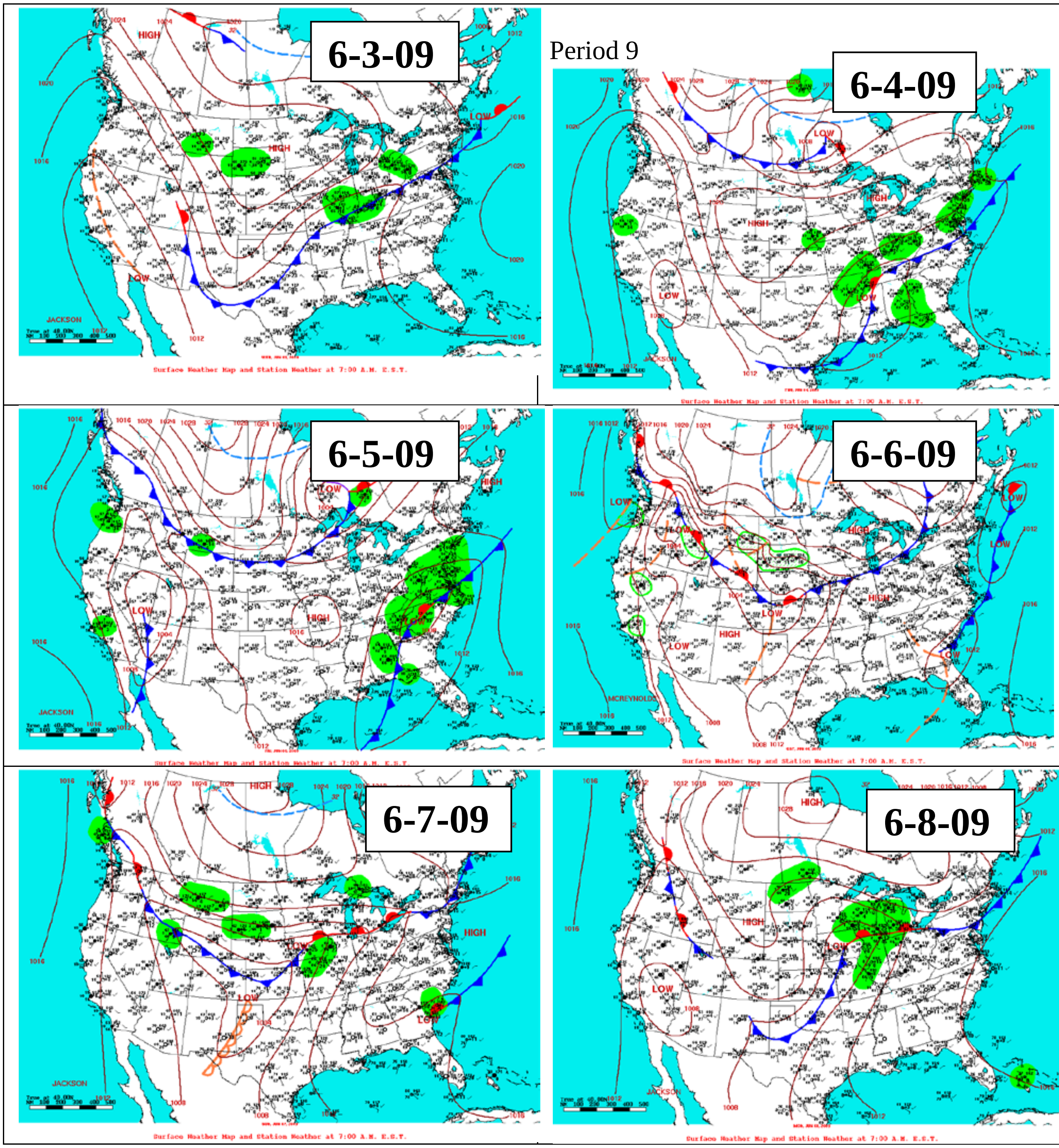
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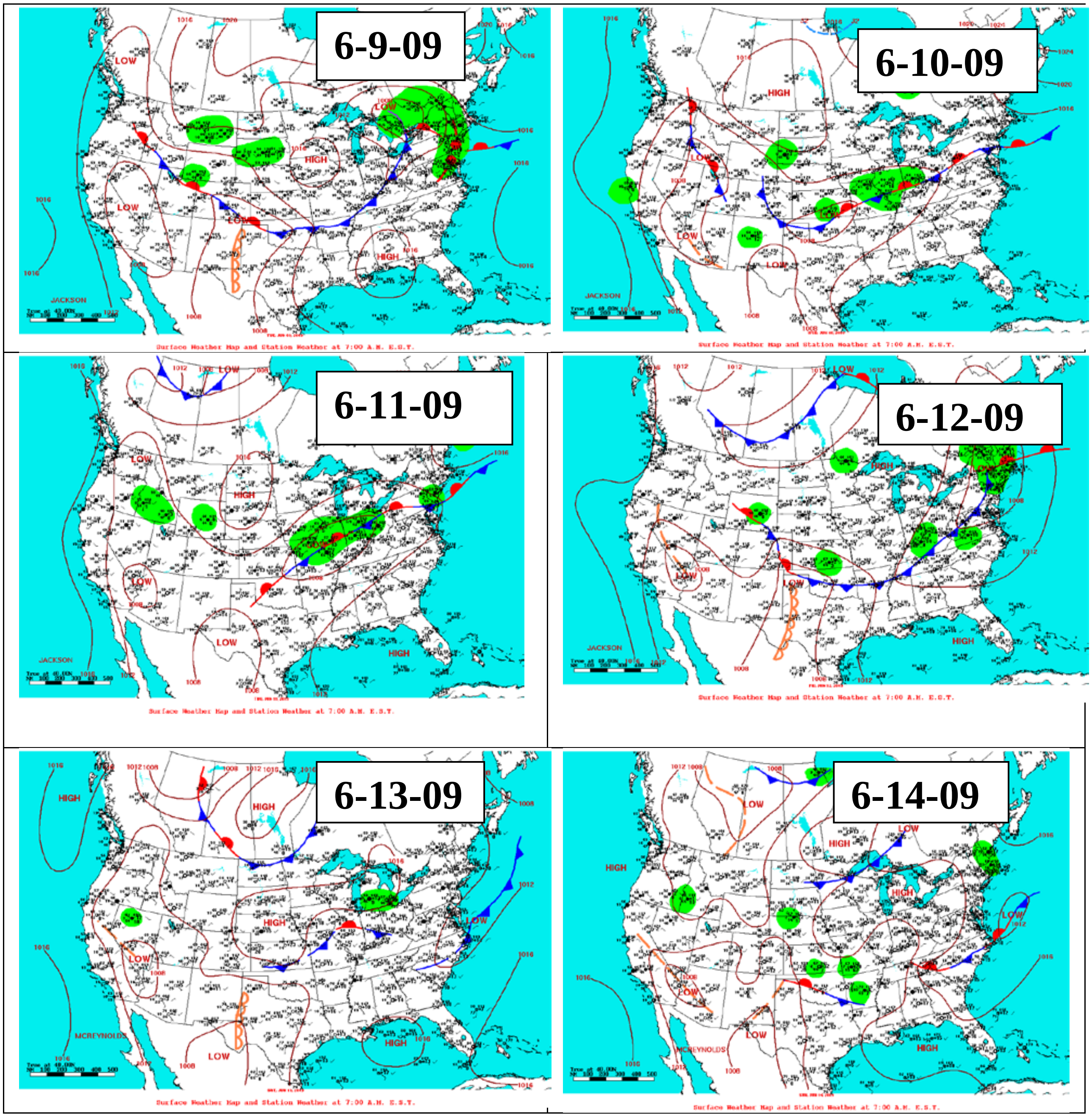
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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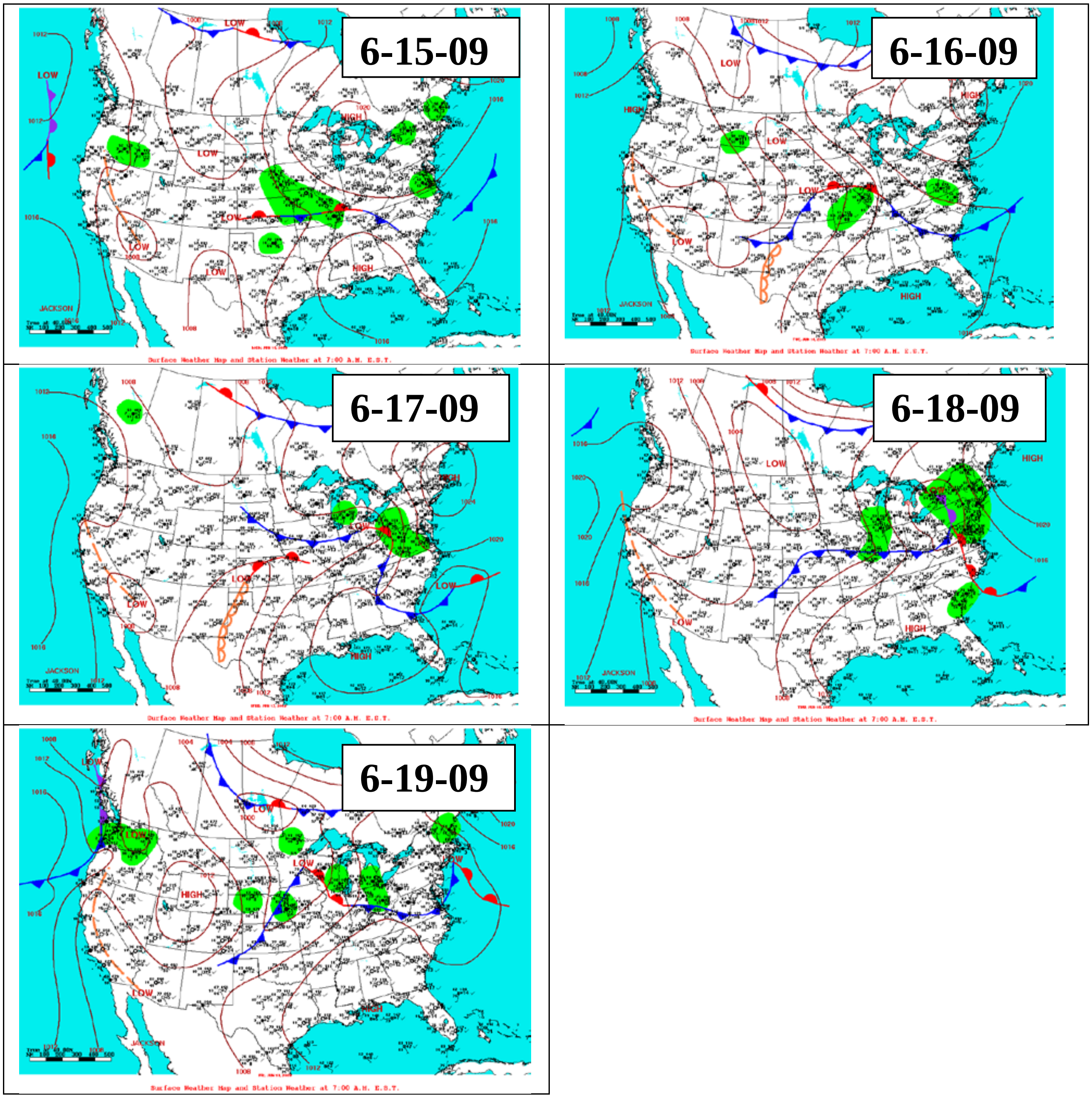
6-15-09
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6-18-09
6-19-09

6.8 Daily weather conditions

Date	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
Period 3				
2/29/2008	98.28	N/A	35%	9.1
3/1/2008	98.14	N/A	0%	9.6
3/2/2008	98.98	N/A	0%	8.8
3/3/2008	N/A	N/A	N/A	N/A
3/4/2008	N/A	N/A	N/A	N/A
3/5/2008	99.60	N/A	0%	8.6
3/6/2008	99.41	N/A	4%	6.4
3/7/2008	99.13	N/A	0%	8.4
3/8/2008	98.90	N/A	42%	9.0
3/9/2008	99.18	N/A	0%	7.1
3/10/2008	N/A	N/A	N/A	N/A
3/11/2008	99.29	N/A	0%	11.9
3/12/2008	99.05	N/A	1%	6.4
Period 4				
3/13/2008	97.95	501	55%	7.9
3/14/2008	97.71	599	0%	7.8
3/15/2008	97.87	821	12%	6.2
3/16/2008	98.66	735	4%	6.0
3/17/2008	98.85	861	0%	8.1
3/18/2008	98.49	846	4%	10.0
3/19/2008	98.74	737	5%	5.2
3/20/2008	98.63	597	0%	5.7
3/21/2008	99.37	914	0%	5.8
3/22/2008	100.19	733	10%	4.1
3/23/2008	98.95	372	0%	7.7
3/24/2008	98.86	747	0%	6.0
3/25/2008	98.82	778	0%	4.5
3/26/2008	98.32	642	0%	7.2
Period 5				
8/9/2008	98.10	927	0%	26.8
8/10/2008	98.58	815	0%	18.7
8/11/2008	98.66	857	0%	19.8
8/12/2008	98.21	942	3%	23.9
8/13/2008	98.25	839	0%	25.7
8/14/2008	98.20	528	0%	31.7
8/15/2008	98.30	853	0%	30.1

Date	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
8/16/2008	97.94	908	0%	29.3
8/17/2008	97.53	884	0%	30.2
8/18/2008	97.26	951	0%	30.5
8/19/2008	97.64	913	39%	21.5
8/20/2008	97.43	933	26%	20.8
8/21/2008	97.53	1081	0%	20.0
8/22/2008	98.58	902	0%	17.1
8/23/2008	98.44	838	0%	19.5
8/24/2008	97.97	877	0%	23.2
8/25/2008	97.85	848	14%	20.8
8/26/2008	98.45	831	0%	16.5
8/27/2008	98.16	967	0%	20.6
8/28/2008	98.70	861	0%	19.1
8/29/2008	98.17	801	5%	23.4
8/30/2008	97.69	820	0%	20.6
8/31/2008	97.94	932	0%	15.0
9/1/2008	98.54	804	0%	16.1
9/2/2008	98.93	781	0%	16.1
9/3/2008	98.72	803	0%	16.9
Period 6				
9/4/2008	98.70	789	0%	19.9
9/5/2008	98.58	764	0%	20.3
9/6/2008	98.56	770	0%	21.5
9/7/2008	98.60	774	0%	21.3
9/8/2008	98.47	782	0%	19.3
9/9/2008	97.64	765	0%	20.0
9/10/2008	98.17	769	0%	20.0
9/11/2008	98.59	751	0%	18.8
9/12/2008	98.03	750	0%	20.5
9/13/2008	98.40	754	0%	20.9
9/14/2008	98.77	752	0%	18.5
9/15/2008	98.80	738	0%	19.1
9/16/2008	98.46	722	0%	20.7
9/17/2008	98.18	701	0%	21.7
9/18/2008	97.95	719	0%	22.2
9/19/2008	97.93	707	0%	22.4
9/20/2008	97.87	86	61%	19.2
9/21/2008	98.12	803	11%	15.2

Date	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
9/22/2008	98.48	717	0%	14.6
9/23/2008	99.11	715	0%	10.9
9/24/2008	98.50	879	0%	13.2
9/25/2008	98.19	685	2%	17.5
9/26/2008	98.83	681	19%	12.7
Period 8				
5/21/2009	98.57	492	0%	23.1
5/22/2009	98.56	929	0%	17.1
5/23/2009	98.25	950	0%	20.3
5/24/2009	98.10	941	0%	22.2
5/25/2009	98.21	934	0%	21.5
5/26/2009	98.32	938	0%	21.1
5/27/2009	98.54	941	8%	19.8
5/28/2009	98.39	932	0%	22.6
5/29/2009	98.21	907	0%	24.7
5/30/2009	98.03	940	0%	27.5
5/31/2009	97.92	983	0%	26.2
6/1/2009	97.89	1054	0%	26.4
6/2/2009	98.22	937	0%	24.3
6/3/2009	98.33	938	0%	22.7
6/4/2009	98.03	1040	0%	23.4
Period 9				
6/9/2009	97.81	960	0%	23.7
6/10/2009	97.89	1013	0%	21.2
6/11/2009	97.88	1048	0%	21.9
6/12/2009	97.90	1159	0%	22.4
6/13/2009	97.81	1059	18%	21.1
6/14/2009	97.77	979	1%	22.9
6/15/2009	97.79	950	1%	22.1
6/16/2009	97.95	1002	0%	22.7
6/17/2009	97.87	1040	0%	23.2
6/18/2009	98.12	1063	0%	21.4
6/19/2009	97.66	1027	5%	21.6
6/20/2009	97.50	588	0%	26.0

6.9 Daily site emissions and data completeness

6.9.1 Daily NH_3 emission using RPM emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid: Number of ½ h periods with valid emissions data
Direction limited: Number of ½ h periods invalidated because wind was from an excluded wind direction
Angle limited: Number of ½ h periods invalidated because angle of attack to the downwind side was greater than 60 degrees
Turbulence limited: Number of ½ h periods that the bLS model was not run because either u_* < 0.15 m s^{-1} or $|L| < 2$ m
Background (ppb): bLS model calculated daily average background concentration (ppb); average is over the ½ h periods included in the valid column
Emission average (μgm^{-2}s^{-1}): Daily average emission calculated from the valid ½ h periods
Emissions SD (μgm^{-2}s^{-1}): Daily emission standard deviation of the valid ½ h periods
Emission minimum (μgm^{-2}s^{-1}): Daily minimum emission of the valid ½ h periods
Emission maximum (μgm^{-2}s^{-1}): Daily maximum emission of the valid ½ h periods
Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area
Emission average (gd^{-1}hd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per head basis
Emission average (gd^{-1}AU^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per animal unit basis

Date	Valid	Direction limited	Missing downwind NH_3	Emission average (μgm^{-2}s^{-1})	Emission SD (μgm^{-2}s^{-1})	Emission minimum (μgm^{-2}s^{-1})	Emission maximum (μgm^{-2}s^{-1})	Emission average (kgd^{-1})	Emission average (gd^{-1}hd^{-1})	Emission average (gd^{-1}AU^{-1})
Period 3										
2/29/2008	0	0	8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/1/2008	0	13	21	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/2/2008	0	10	29	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/3/2008	0	14	33	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/4/2008	0	24	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/5/2008	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/6/2008	0	0	21	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/7/2008	0	0	42	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/8/2008	2	5	35	21.9	30.9	0.0	43.7	25.5	4.6	3.6
3/9/2008	0	2	43	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/10/2008	0	0	45	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/11/2008	0	18	21	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/12/2008	0	3	35	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 4										
3/13/2008	0	6	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/14/2008	0	5	34	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/15/2008	1	6	26	31.1	N/A	31.1	31.1	36.3	6.5	5.1
3/16/2008	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/17/2008	3	3	17	21.5	28.1	0.0	53.3	25.1	4.5	3.6

Date	Valid	Direction limited	Missing downwind NH_3	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
3/18/2008	0	10	32	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/19/2008	1	5	36	17.8	N/A	17.8	17.8	20.7	3.7	2.9
3/20/2008	0	7	39	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/21/2008	0	16	23	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/22/2008	1	5	33	17.8	N/A	17.8	17.8	20.7	3.7	2.9
3/23/2008	0	2	45	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/24/2008	0	19	23	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/25/2008	4	3	39	33.1	3.5	28.1	36.3	38.7	6.9	5.5
3/26/2008	0	8	23	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 5										
8/10/2008	0	0	45	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/11/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/12/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/13/2008	4	14	24	20.9	5.3	16.3	27.4	24.4	4.4	3.5
8/14/2008	15	17	0	26.5	23.2	5.2	74.8	30.9	5.5	4.4
8/15/2008	1	23	0	17.8	N/A	17.8	17.8	20.7	3.7	2.9
8/16/2008	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/17/2008	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/18/2008	2	17	0	18.9	1.6	17.8	20.0	22.0	3.9	3.1
8/19/2008	18	18	1	20.7	13.4	-3.7	43.7	24.1	4.3	3.4
8/20/2008	9	33	0	25.3	8.8	10.4	39.3	29.5	5.3	4.2
8/21/2008	0	43	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/22/2008	11	24	0	44.1	21.4	7.4	64.4	51.4	9.2	7.3
8/23/2008	22	1	5	34.8	20.1	-3.7	65.2	40.6	7.3	5.8
8/24/2008	22	3	14	27.9	14.1	0.0	54.8	32.6	5.8	4.6
8/25/2008	7	1	34	24.8	12.2	6.7	38.5	28.9	5.2	4.1
8/26/2008	6	2	38	27.8	15.9	15.6	58.5	32.4	5.8	4.6
8/27/2008	2	7	36	19.6	3.7	17.0	22.2	22.9	4.1	3.2
8/28/2008	22	20	0	34.5	27.3	0.0	111.1	40.3	7.2	5.7
8/29/2008	14	22	0	36.8	27.2	9.6	88.1	43.0	7.7	6.1
8/30/2008	0	42	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/31/2008	0	35	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/1/2008	1	41	0	80.0	N/A	80.0	80.0	93.3	16.7	13.2
9/2/2008	10	24	5	44.4	18.5	13.3	71.1	51.8	9.3	7.3
9/3/2008	7	2	21	33.1	22.9	-3.7	62.2	38.6	6.9	5.5
Period 6										
9/4/2008	0	2	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/5/2008	12	27	0	47.5	13.4	19.3	67.4	55.4	9.9	7.8
9/6/2008	6	39	0	23.5	3.9	17.8	29.6	27.4	4.9	3.9
9/7/2008	17	23	0	31.5	24.9	-24.4	80.0	36.7	6.6	5.2
9/8/2008	15	19	0	30.6	16.2	6.7	57.8	35.7	6.4	5.1
9/9/2008	24	11	0	42.1	29.2	1.5	91.9	49.1	8.8	7.0
9/10/2008	4	37	0	59.1	34.6	33.3	107.4	68.9	12.3	9.8
9/11/2008	22	11	1	28.9	22.1	-35.6	71.9	33.7	6.0	4.8
9/12/2008	20	7	0	33.7	15.4	9.6	66.7	39.3	7.0	5.6
9/13/2008	1	43	0	38.5	N/A	38.5	38.5	44.9	8.0	6.4

Date	Valid	Direction limited	Missing downwind NH_3	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
9/14/2008	12	11	7	30.3	22.2	-13.3	68.9	35.4	6.3	5.0
9/15/2008	17	8	2	44.1	28.5	11.1	95.6	51.5	9.2	7.3
9/16/2008	25	7	0	42.3	23.7	6.7	89.6	49.4	8.8	7.0
9/17/2008	26	7	0	28.3	19.7	0.0	63.0	33.0	5.9	4.7
9/18/2008	31	6	0	42.7	27.6	8.1	103.7	49.9	8.9	7.1
9/19/2008	12	21	0	37.5	36.2	-5.2	98.5	43.7	7.8	6.2
9/20/2008	5	11	31	61.5	19.2	36.3	87.4	71.7	12.8	10.2
9/21/2008	0	7	41	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/22/2008	0	8	40	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/23/2008	0	1	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/24/2008	0	0	46	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/25/2008	0	15	31	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/26/2008	0	4	27	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 8										
5/21/2009	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/22/2009	14	2	27	21.4	9.6	8.9	35.6	25.0	4.5	3.5
5/23/2009	12	2	32	18.0	7.8	8.1	31.9	21.0	3.8	3.0
5/24/2009	2	0	45	17.0	6.3	12.6	21.5	19.9	3.5	2.8
5/25/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/26/2009	1	6	41	45.9	N/A	45.9	45.9	53.6	9.6	7.6
5/27/2009	0	0	44	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/28/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/29/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/30/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/31/2009	7	10	29	27.4	13.5	0.0	40.7	32.0	5.7	4.5
6/1/2009	3	8	37	22.5	19.5	0.0	34.1	26.2	4.7	3.7
6/2/2009	19	0	29	31.3	12.3	0.0	47.4	36.6	6.5	5.2
6/3/2009	15	1	32	22.8	7.5	12.6	36.3	26.6	4.7	3.8
6/4/2009	3	7	21	28.9	9.8	17.8	36.3	33.7	6.0	4.8
Period 9										
6/5/2009	1	4	5	44.4	N/A	44.4	44.4	51.8	9.3	7.3
6/6/2009	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/7/2009	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/8/2009	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/9/2009	3	2	10	19.3	5.3	14.8	25.2	22.5	4.0	3.2
6/10/2009	4	2	31	27.2	4.2	23.7	33.3	31.8	5.7	4.5
6/11/2009	4	28	5	18.1	24.1	-7.4	42.2	21.2	3.8	3.0
6/12/2009	10	24	3	35.3	46.4	-13.3	128.9	41.1	7.3	5.8
6/13/2009	14	12	1	35.4	27.1	9.6	104.4	41.3	7.4	5.9
6/14/2009	1	19	28	71.9	N/A	71.9	71.9	83.8	15.0	11.9
6/15/2009	3	31	3	30.1	0.9	29.6	31.1	35.1	6.3	5.0
6/16/2009	3	31	7	37.5	22.5	13.3	57.8	43.8	7.8	6.2
6/17/2009	0	40	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/18/2009	4	12	23	52.4	23.1	22.2	78.5	61.1	10.9	8.7
6/19/2009	4	15	11	39.3	10.1	25.2	48.9	45.8	8.2	6.5

6.9.2 Daily NH_3 emission using bLS emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid: Number of ½ h periods with valid emissions data
Direction limited: Number of ½ h periods invalidated because wind was from an excluded wind direction
Angle limited: Number of ½ h periods invalidated because angle of attack to the downwind side was greater than 60 degrees
Turbulence limited: Number of ½ h periods that the bLS model was not run because either $u_* < 0.15$ m s^{-1} or $|L| < 2$ m
Background (ppb): bLS model calculated daily average background concentration (ppb); average is over the ½ h periods included in the valid column
Emission average (μg$m^{-2}s^{-1}$): Daily average emission calculated from the valid ½ h periods
Emissions SD (μg$m^{-2}s^{-1}$): Daily emission standard deviation of the valid ½ h periods
Emission minimum (μg$m^{-2}s^{-1}$): Daily minimum emission of the valid ½ h periods
Emission maximum (μg$m^{-2}s^{-1}$): Daily maximum emission of the valid ½ h periods
Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area
Emission average (gd^{-1}hd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per head basis
Emission average (gd^{-1}AU^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per animal unit basis

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average (μg$m^{-2}s^{-1}$)	Emission SD (μg$m^{-2}s^{-1}$)	Emission minimum (μg$m^{-2}s^{-1}$)	Emission maximum (μg$m^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average (gd^{-1}hd^{-1})	Emission average (gd^{-1}AU^{-1})
Period 3												
2/29/2008	7	1	0	0	-0.04	77.5	45.1	27.4	136.3	88.2	15.7	12.5
3/1/2008	0	46	0	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/2/2008	2	23	3	18	0.03	22.4	5.6	18.5	26.4	25.5	4.6	3.6
3/3/2008	1	28	5	3	0.03	6.8	N/A	6.8	6.8	7.7	1.4	1.1
3/4/2008	0	40	0	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/5/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/6/2008	1	0	7	9	0.04	61.8	N/A	61.8	61.8	70.4	12.6	10.0
3/7/2008	1	5	4	29	0.12	4.3	N/A	4.3	4.3	4.9	0.9	0.7
3/8/2008	4	2	4	37	0.03	61.6	40.1	14.8	110.5	70.1	12.5	9.9
3/9/2008	0	1	8	32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/10/2008	2	0	12	28	0.02	62.3	30.9	40.4	84.2	70.9	12.7	10.0
3/11/2008	2	38	3	2	0.06	17.4	24.0	0.4	34.4	19.8	3.5	2.8
3/12/2008	2	12	2	22	-0.05	17.7	21.4	2.6	32.8	20.1	3.6	2.8
Period 4												
3/13/2008	0	8	0	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/14/2008	2	39	0	4	0.07	28.7	13.9	18.9	38.5	32.7	5.8	4.6
3/15/2008	1	14	0	23	-0.02	8.1	N/A	8.1	8.1	9.2	1.6	1.3
3/16/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/17/2008	11	6	0	4	0.00	53.4	29.3	0.6	97.7	60.8	10.9	8.6
3/18/2008	3	42	0	2	0.04	29.7	20.2	6.8	44.6	33.8	6.0	4.8
3/19/2008	9	13	0	24	0.11	37.7	25.0	2.2	72.1	42.9	7.7	6.1
3/20/2008	8	22	0	18	0.08	53.2	10.8	38.1	69.8	60.5	10.8	8.6
3/21/2008	0	48	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/22/2008	9	8	0	27	0.03	55.3	16.9	17.3	80.3	62.9	11.2	8.9
3/23/2008	11	11	0	26	-0.01	36.9	17.4	24.2	85.2	42.0	7.5	6.0
3/24/2008	5	28	0	14	-0.09	66.8	15.8	48.1	84.7	76.0	13.6	10.8
3/25/2008	8	6	0	29	-0.01	88.0	54.3	11.0	198.7	100.1	17.9	14.2
3/26/2008	4	23	0	3	0.05	25.4	8.2	18.0	36.0	28.9	5.2	4.1
Period 5												
8/10/2008	0	0	9	13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu g m^{-2} s^{-1}$)	Emission SD ($\mu g m^{-2} s^{-1}$)	Emission minimum ($\mu g m^{-2} s^{-1}$)	Emission maximum ($\mu g m^{-2} s^{-1}$)	Emission average ($kg d^{-1}$)	Emission average ($g d^{-1} hd^{-1}$)	Emission average ($g d^{-1} AU^{-1}$)
8/11/2008	0	0	12	13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/12/2008	0	0	18	16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/13/2008	4	27	13	3	0.10	15.0	9.3	1.8	22.4	17.0	3.0	2.4
8/14/2008	13	20	0	11	0.29	9.1	11.4	-19.0	30.4	10.3	1.8	1.5
8/15/2008	7	20	0	9	0.37	1.8	2.7	-1.1	6.5	2.1	0.4	0.3
8/16/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/17/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/18/2008	2	19	0	0	0.41	5.3	17.5	-7.2	17.7	6.0	1.1	0.8
8/19/2008	18	19	0	4	0.28	14.8	11.3	2.5	38.2	16.8	3.0	2.4
8/20/2008	11	33	0	1	0.19	11.9	7.0	2.9	28.9	13.5	2.4	1.9
8/21/2008	0	47	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/22/2008	11	22	0	12	0.21	29.3	15.2	2.3	51.6	33.3	6.0	4.7
8/23/2008	17	4	1	17	0.24	27.6	16.4	0.1	60.0	31.4	5.6	4.4
8/24/2008	16	5	2	15	0.13	25.1	19.8	4.9	78.9	28.5	5.1	4.0
8/25/2008	14	10	6	2	0.23	12.1	10.2	-5.4	32.4	13.8	2.5	2.0
8/26/2008	11	12	12	1	0.04	61.4	35.3	3.9	97.4	69.8	12.5	9.9
8/27/2008	6	19	10	7	0.05	31.5	13.4	7.1	44.9	35.9	6.4	5.1
8/28/2008	20	16	0	9	0.22	34.4	25.5	5.3	104.9	39.2	7.0	5.6
8/29/2008	11	23	0	9	0.38	31.7	21.1	3.9	86.6	36.1	6.4	5.1
8/30/2008	0	47	0	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/31/2008	0	48	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/1/2008	2	45	0	1	0.43	26.6	29.0	6.1	47.1	30.3	5.4	4.3
9/2/2008	10	25	0	13	0.21	52.1	26.5	7.1	89.8	59.3	10.6	8.4
9/3/2008	3	1	2	6	0.25	31.6	16.5	16.4	49.1	35.9	6.4	5.1
Period 6												
9/4/2008	0	2	2	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/5/2008	11	20	0	14	0.14	39.2	14.4	7.5	56.4	44.6	8.0	6.3
9/6/2008	5	41	0	2	0.16	37.4	15.9	22.9	64.1	42.5	7.6	6.0
9/7/2008	12	22	0	10	0.46	27.5	24.9	0.4	83.1	31.3	5.6	4.4
9/8/2008	13	20	0	10	0.27	26.2	21.5	2.0	61.2	29.8	5.3	4.2
9/9/2008	13	12	0	15	0.22	58.6	36.7	6.9	97.7	66.7	11.9	9.5
9/10/2008	2	42	0	3	0.19	46.4	35.3	21.5	71.4	52.8	9.4	7.5
9/11/2008	24	8	0	10	0.33	41.4	23.2	3.6	83.9	47.1	8.4	6.7
9/12/2008	16	10	0	17	0.32	35.3	30.2	0.5	99.2	40.2	7.2	5.7
9/13/2008	0	44	0	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/14/2008	7	10	0	24	0.64	34.1	19.2	12.7	63.1	38.8	6.9	5.5
9/15/2008	16	7	0	17	0.49	41.4	34.8	0.3	98.3	47.1	8.4	6.7
9/16/2008	18	3	0	21	0.26	45.7	24.9	0.4	78.7	52.0	9.3	7.4
9/17/2008	18	9	0	9	0.30	33.1	22.0	3.9	70.7	37.7	6.7	5.3
9/18/2008	22	5	1	11	0.26	47.5	24.0	3.1	83.3	54.0	9.6	7.7
9/19/2008	12	21	0	9	0.27	32.0	27.2	-4.4	65.2	36.4	6.5	5.2
9/20/2008	18	18	0	7	0.19	34.6	25.4	0.4	78.2	39.3	7.0	5.6
9/21/2008	3	33	0	12	0.18	17.4	4.5	12.2	20.5	19.8	3.5	2.8
9/22/2008	4	32	0	12	0.08	24.1	8.1	15.5	35.1	27.4	4.9	3.9
9/23/2008	19	9	0	15	0.16	27.7	18.9	0.6	63.4	31.5	5.6	4.5
9/24/2008	12	7	1	21	0.15	40.6	33.7	-44.5	83.7	46.2	8.3	6.5
9/25/2008	7	29	1	4	0.19	13.4	18.2	-1.9	51.8	15.2	2.7	2.2
9/26/2008	4	9	3	14	0.18	5.4	2.7	2.6	8.0	6.2	1.1	0.9
Period 8												
5/21/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/22/2009	18	7	3	14	0.17	16.0	13.3	1.5	43.4	18.2	3.2	2.6
5/23/2009	12	15	5	11	0.16	18.6	16.8	3.8	55.6	21.2	3.8	3.0
5/24/2009	4	16	22	3	0.09	24.7	9.3	12.0	32.4	28.1	5.0	4.0
5/25/2009	2	16	25	3	0.17	6.3	6.5	1.8	10.9	7.2	1.3	1.0
5/26/2009	4	24	9	9	0.18	23.0	11.1	14.8	39.0	26.2	4.7	3.7
5/27/2009	0	0	16	11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/28/2009	0	0	19	9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/29/2009	0	0	18	12	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/30/2009	0	0	8	11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/31/2009	14	14	7	9	0.19	39.0	31.0	6.4	99.4	44.3	7.9	6.3
6/1/2009	7	23	2	10	0.15	26.3	13.9	9.2	49.1	29.9	5.3	4.2
6/2/2009	36	5	1	5	0.16	14.7	8.6	2.2	43.0	16.7	3.0	2.4
6/3/2009	12	17	2	11	0.14	15.5	14.5	2.6	48.1	17.7	3.2	2.5
6/4/2009	4	7	6	17	0.03	25.7	6.5	16.5	31.5	29.2	5.2	4.1
Period 9												
6/5/2009	1	10	0	0	0.13	20.5	N/A	20.5	20.5	23.4	4.2	3.3

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
6/6/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/7/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/8/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/9/2009	13	1	0	1	0.23	18.6	9.1	1.1	36.6	21.2	3.8	3.0
6/10/2009	19	14	0	14	0.27	3.4	7.7	-14.2	15.1	3.9	0.7	0.5
6/11/2009	4	25	1	15	0.33	23.7	19.5	0.7	48.2	26.9	4.8	3.8
6/12/2009	18	17	0	9	0.30	12.9	15.6	-9.0	45.9	14.7	2.6	2.1
6/13/2009	17	13	0	15	0.30	12.9	10.3	-1.3	35.9	14.7	2.6	2.1
6/14/2009	11	37	0	0	0.13	50.1	18.2	1.4	66.8	56.9	10.2	8.1
6/15/2009	4	37	0	7	0.14	21.6	9.1	9.0	28.5	24.6	4.4	3.5
6/16/2009	7	33	0	7	0.19	14.5	9.4	1.8	28.1	16.5	3.0	2.3
6/17/2009	0	41	0	7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/18/2009	6	32	0	6	0.15	21.4	21.7	-0.1	57.6	24.3	4.3	3.4
6/19/2009	9	8	0	16	0.29	11.5	9.3	1.2	31.9	13.1	2.3	1.9

6.9.3 Daily H_2S emission using Ratiometric emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid: Number of ½ h periods with valid emissions data
Emission average (μgm^{-2}s^{-1}): Daily average emission calculated from the valid ½ h periods
Emissions SD (μgm^{-2}s^{-1}): Daily emission standard deviation of the valid ½ h periods
Emission minimum (μgm^{-2}s^{-1}): Daily minimum emission of the valid ½ h periods
Emission maximum (μgm^{-2}s^{-1}): Daily maximum emission of the valid ½ h periods
Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area
Emission average (gd^{-1}hd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per head basis
Emission average (gd^{-1}AU^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per animal unit basis

Date	Valid	Emission average (μgm^{-2}s^{-1})	Emission SD (μgm^{-2}s^{-1})	Emission minimum (μgm^{-2}s^{-1})	Emission maximum (μgm^{-2}s^{-1})	Emission average (kgd^{-1})	Emission average (gd^{-1}h^{-1})	Emission average (gd^{-1}AU^{-1})
Period 3								
2/29/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/1/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/2/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/3/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/4/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/5/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/6/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/7/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/8/2008	2	10.2	41.4	0.0	20.3	11.8	2.1	1.7
3/9/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/10/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/11/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/12/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 4								
3/13/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/14/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/15/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/16/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/17/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/18/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/19/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/20/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/21/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/22/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/23/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/24/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/25/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/26/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 5								

Date	Valid	Emission average (μgm^{-2}s^{-1})	Emission SD (μgm^{-2}s^{-1})	Emission minimum (μgm^{-2}s^{-1})	Emission maximum (μgm^{-2}s^{-1})	Emission average (kgd^{-1})	Emission average (gd^{-1}h^{-1})	Emission average (gd^{-1}AU^{-1})
8/10/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/11/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/12/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/13/2008	1	-2.4	0.0	-2.4	-2.4	-2.9	-0.5	-0.4
8/14/2008	8	8.3	26.5	0.0	23.5	9.6	1.7	1.4
8/15/2008	1	20.8	0.0	20.8	20.8	24.3	4.3	3.4
8/16/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/17/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/18/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/19/2008	13	9.3	25.9	-0.8	19.5	10.8	1.9	1.5
8/20/2008	5	4.7	21.3	-14.2	18.2	5.4	1.0	0.8
8/21/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/22/2008	6	16.5	36.0	0.6	27.8	19.3	3.4	2.7
8/23/2008	14	13.8	30.3	-1.6	34.4	16.1	2.9	2.3
8/24/2008	8	25.5	37.7	8.0	64.7	29.7	5.3	4.2
8/25/2008	3	3.3	18.9	1.3	7.3	3.9	0.7	0.6
8/26/2008	6	5.0	20.6	1.4	7.2	5.8	1.0	0.8
8/27/2008	1	14.0	0.0	14.0	14.0	16.3	2.9	2.3
8/28/2008	17	15.1	31.3	1.9	28.9	17.7	3.2	2.5
8/29/2008	11	13.6	30.1	1.2	32.0	15.9	2.8	2.3
8/30/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/31/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/1/2008	1	26.2	0.0	26.2	26.2	30.5	5.4	4.3
9/2/2008	10	8.2	24.7	0.8	17.3	9.6	1.7	1.4
9/3/2008	5	4.7	20.7	1.0	10.2	5.4	1.0	0.8
Period 6								
9/4/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/5/2008	6	8.8	26.7	4.2	11.9	10.2	1.8	1.4
9/6/2008	2	12.0	40.9	10.3	13.6	13.9	2.5	2.0
9/7/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/8/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/9/2008	12	8.3	24.4	1.7	21.8	9.7	1.7	1.4
9/10/2008	3	8.0	29.4	5.7	12.3	9.3	1.7	1.3
9/11/2008	21	7.4	22.9	-0.8	14.9	8.7	1.6	1.2
9/12/2008	13	6.1	21.2	1.0	9.4	7.1	1.3	1.0
9/13/2008	1	10.5	0.0	10.5	10.5	12.2	2.2	1.7
9/14/2008	9	7.6	24.2	-1.5	13.0	8.9	1.6	1.3
9/15/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/16/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/17/2008	14	10.3	26.6	1.3	29.6	12.0	2.2	1.7
9/18/2008	23	12.2	28.2	3.4	21.8	14.3	2.5	2.0
9/19/2008	6	9.0	27.7	-0.3	18.0	10.5	1.9	1.5
9/20/2008	4	15.3	37.2	11.8	23.4	17.8	3.2	2.5
9/21/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/22/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/23/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Date	Valid	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}h^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
9/24/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/25/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/26/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 8								
5/21/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/22/2009	8	2.9	15.4	0.0	6.0	3.4	0.6	0.5
5/23/2009	7	2.4	14.3	0.0	3.7	2.8	0.5	0.4
5/24/2009	1	1.1	0.0	1.1	1.1	1.2	0.2	0.2
5/25/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/26/2009	1	6.1	0.0	6.1	6.1	7.1	1.3	1.0
5/27/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/28/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/29/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/30/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/31/2009	2	2.2	18.1	1.7	2.8	2.6	0.5	0.4
6/1/2009	2	0.5	8.4	0.4	0.6	0.6	0.1	0.1
6/2/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/3/2009	6	2.0	13.2	0.8	4.7	2.3	0.4	0.3
6/4/2009	2	1.1	12.5	0.7	1.5	1.2	0.2	0.2
Period 9								
6/5/2009	1	1.3	0.0	1.3	1.3	1.6	0.3	0.2
6/6/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/7/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/8/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/9/2009	3	0.4	7.0	-0.2	1.1	0.5	0.1	0.1
6/10/2009	1	0.2	0.0	0.2	0.2	0.2	0.0	0.0
6/11/2009	3	4.5	21.7	0.0	13.5	5.2	0.9	0.7
6/12/2009	9	0.1	3.5	-9.7	10.2	0.2	0.0	0.0
6/13/2009	12	1.7	11.6	-0.2	8.8	2.0	0.4	0.3
6/14/2009	1	0.1	0.0	0.1	0.1	0.1	0.0	0.0
6/15/2009	3	0.3	5.5	0.0	0.6	0.3	0.1	0.0
6/16/2009	3	1.3	11.8	0.9	1.6	1.5	0.3	0.2
6/17/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/18/2009	3	0.2	5.0	-0.1	0.5	0.3	0.0	0.0
6/19/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

6.9.4 Daily H_2S emission using bLS emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid: Number of ½ h periods with valid emissions data
Direction limited: Number of ½ h periods invalidated because wind was from an excluded wind direction
Angle limited: Number of ½ h periods invalidated because angle of attack to the downwind side was greater than 60 degrees
Turbulence limited: Number of ½ h periods that the bLS model was not run because either u_* < 0.15 m s^{-1} or |L| < 2 m
Background (ppb): bLS model calculated daily average background concentration (ppb); average is over the ½ h periods included in the valid column
Emission average (µgm^{-2}s^{-1}): Daily average emission calculated from the valid ½ h periods
Emissions SD (µgm^{-2}s^{-1}): Daily emission standard deviation of the valid ½ h periods
Emission minimum (µgm^{-2}s^{-1}): Daily minimum emission of the valid ½ h periods
Emission maximum (µgm^{-2}s^{-1}): Daily maximum emission of the valid ½ h periods
Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area
Emission average (gd^{-1}hd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per head basis
Emission average (gd^{-1}AU^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per animal unit basis

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average (µgm^{-1}s^{-1})	Emission SD (µgm^{-2}s^{-1})	Emission minimum (µgm^{-2}s^{-1})	Emission maximum (µgm^{-2}s^{-1})	Emission average (kgd^{-1})	Emission average (gd^{-1}hd^{-1})	Emission average (gd AU^{-1})
Period 3												
2/29/2008	6	1	0	0	2.4	22.2	8.9	15.0	39.0	26.8	4.8	3.8
3/1/2008	0	46	0	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/2/2008	5	23	0	18	2.3	3.0	1.7	1.8	6.0	3.6	0.6	0.5
3/3/2008	8	27	0	3	-0.2	10.5	8.3	1.3	24.8	12.7	2.3	1.8
3/4/2008	0	39	0	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/5/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/6/2008	10	0	0	10	2.1	13.8	7.9	4.5	26.4	16.6	3.0	2.4
3/7/2008	8	5	1	33	-6.5	57.4	46.4	5.3	122.7	69.3	12.4	9.8
3/8/2008	7	2	1	38	-0.5	15.6	13.0	2.6	34.1	18.8	3.4	2.7
3/9/2008	9	1	5	33	1.2	16.0	7.2	3.3	27.2	19.3	3.4	2.7
3/10/2008	1	0	13	33	7.5	5.0	N/A	5.0	5.0	6.1	1.1	0.9
3/11/2008	2	26	4	2	2.1	10.6	15.0	0.0	21.2	12.8	2.3	1.8
Period 5												
8/10/2008	0	1	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/11/2008	9	18	2	15	1.2	9.4	4.0	3.9	16.0	11.3	2.0	1.6
8/12/2008	22	4	4	16	8.9	9.6	12.9	-33.8	27.7	11.6	2.1	1.6
8/13/2008	1	37	4	3	38.7	-5.7	N/A	-5.7	-5.7	-6.9	-1.2	-1.0
8/14/2008	9	20	4	12	4.7	17.0	5.5	9.3	26.5	20.5	3.7	2.9
8/15/2008	6	19	1	9	16.9	4.8	6.2	0.1	16.9	5.8	1.0	0.8
8/16/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-1}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-}AU^{-1}$)
8/17/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/18/2008	1	19	1	0	51.6	6.9	N/A	6.9	6.9	8.3	1.5	1.2
8/19/2008	13	19	4	4	50.7	12.5	21.2	-40.8	54.0	15.1	2.7	2.1
8/20/2008	7	33	4	1	104.6	3.2	21.6	-37.7	25.9	3.9	0.7	0.5
8/21/2008	0	47	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/22/2008	8	22	2	12	4.3	13.7	6.7	2.8	23.0	16.5	3.0	2.3
8/23/2008	14	5	2	18	0.2	17.9	9.1	0.6	37.9	21.6	3.9	3.1
8/24/2008	11	7	6	16	1.3	25.6	16.2	6.4	53.8	31.0	5.5	4.4
8/25/2008	11	26	3	2	6.2	11.8	9.1	1.8	30.2	14.2	2.5	2.0
8/26/2008	10	33	1	1	1.4	18.6	9.5	4.2	36.8	22.5	4.0	3.2
8/27/2008	3	27	4	7	-12.2	10.5	4.9	6.2	15.9	12.7	2.3	1.8
8/28/2008	17	16	3	9	-4.3	19.9	13.8	5.4	58.8	24.1	4.3	3.4
8/29/2008	9	21	2	9	4.9	15.6	8.4	2.2	24.5	18.9	3.4	2.7
8/30/2008	0	47	0	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/31/2008	0	48	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/1/2008	2	45	0	1	4.0	17.2	14.8	6.7	27.6	20.7	3.7	2.9
9/2/2008	10	25	0	13	2.1	11.1	8.5	1.4	24.1	13.5	2.4	1.9
9/3/2008	3	16	0	6	2.1	6.2	2.6	4.2	9.1	7.5	1.3	1.1
Period 6												
9/4/2008	0	9	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/5/2008	4	19	0	14	2.4	11.1	4.0	5.5	15.0	13.4	2.4	1.9
9/6/2008	0	35	0	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/7/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/8/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/9/2008	9	8	1	10	-14.6	12.1	8.3	3.1	32.6	14.6	2.6	2.1
9/10/2008	1	42	1	3	-9.6	22.8	N/A	22.8	22.8	27.6	4.9	3.9
9/11/2008	22	8	1	11	7.5	16.7	10.7	-0.1	38.4	20.2	3.6	2.9
9/12/2008	12	10	2	18	43.9	9.4	8.5	-2.8	26.5	11.4	2.0	1.6
9/13/2008	0	43	0	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/14/2008	3	2	1	21	-84.2	28.8	21.5	15.2	53.7	34.8	6.2	4.9
9/15/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/16/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/17/2008	9	9	2	5	-4.0	21.2	22.1	2.9	66.0	25.6	4.6	3.6
9/18/2008	18	5	4	12	-3.1	18.7	18.8	3.7	57.9	22.6	4.0	3.2
9/19/2008	6	21	6	10	-15.6	17.7	15.9	0.5	41.7	21.4	3.8	3.0
9/20/2008	12	18	4	7	317.8	9.8	25.1	-52.6	42.8	11.9	2.1	1.7
9/21/2008	2	31	1	12	-11.8	13.9	10.5	6.5	21.4	16.8	3.0	2.4
9/22/2008	3	32	1	12	-21.5	21.4	15.2	4.1	32.8	25.8	4.6	3.7
9/23/2008	3	9	1	12	-24.4	19.2	7.0	14.5	27.3	23.2	4.1	3.3
Period 8												
5/22/2009	17	12	0	16	1.0	1.4	1.4	0.0	5.3	1.7	0.3	0.2
5/23/2009	11	22	0	11	1.2	1.2	1.0	0.2	2.7	1.5	0.3	0.2
5/24/2009	4	38	0	3	0.8	2.2	1.2	0.6	3.6	2.7	0.5	0.4
5/25/2009	2	42	0	3	1.4	0.3	0.4	0.0	0.6	0.4	0.1	0.1
5/26/2009	4	34	0	9	1.1	0.6	0.5	0.3	1.4	0.7	0.1	0.1
5/27/2009	14	14	3	11	1.2	1.9	1.2	0.1	4.7	2.3	0.4	0.3

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average (μgm^{-1}s^{-1})	Emission SD (μgm^{-2}s^{-1})	Emission minimum (μgm^{-2}s^{-1})	Emission maximum (μgm^{-2}s^{-1})	Emission average (kgd^{-1})	Emission average (gd^{-1}hd^{-1})	Emission average (gd^{-}AU^{-1})
5/28/2009	16	12	7	10	4.2	1.4	1.0	0.1	3.1	1.7	0.3	0.2
5/29/2009	18	8	9	12	4.5	1.8	2.0	-0.4	6.7	2.2	0.4	0.3
5/30/2009	12	24	0	11	1.8	1.2	0.7	0.0	2.3	1.5	0.3	0.2
5/31/2009	9	22	3	9	1.5	1.0	1.1	0.1	3.4	1.2	0.2	0.2
6/1/2009	7	30	0	10	1.1	1.7	1.4	0.3	4.0	2.0	0.4	0.3
6/2/2009	27	5	8	5	1.7	1.9	0.7	0.1	3.0	2.2	0.4	0.3
6/3/2009	11	24	1	11	0.2	2.2	2.0	0.7	7.7	2.7	0.5	0.4
6/4/2009	5	9	0	18	3.7	0.6	0.7	0.1	1.3	0.7	0.1	0.1
Period 9												
6/5/2009	1	10	0	0	0.8	1.0	N/A	1.0	1.0	1.2	0.2	0.2
6/6/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/7/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/8/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/9/2009	13	1	0	1	1.7	0.4	0.5	-0.3	2.0	0.5	0.1	0.1
6/10/2009	20	14	0	14	4.6	0.3	0.4	-0.7	0.8	0.3	0.1	0.0
6/11/2009	4	24	0	15	2.4	3.0	5.8	0.0	11.6	3.6	0.6	0.5
6/12/2009	17	17	1	9	1.4	0.8	2.9	-0.3	11.9	1.0	0.2	0.1
6/13/2009	13	13	2	15	0.9	1.2	2.1	-0.3	6.4	1.4	0.2	0.2
6/14/2009	11	33	0	0	2.2	0.1	0.2	-0.1	0.4	0.2	0.0	0.0
6/15/2009	4	37	0	7	0.8	0.8	1.1	0.0	2.5	1.0	0.2	0.1
6/16/2009	7	33	0	8	2.2	5.8	8.4	0.0	24.1	7.0	1.2	1.0
6/17/2009	0	41	0	7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/18/2009	6	32	0	7	1.7	0.3	0.3	-0.1	0.8	0.4	0.1	0.1
6/19/2009	7	8	1	16	2.0	0.6	0.6	0.1	1.9	0.7	0.1	0.1