Metadata for Atmospheric Measurements at the Loving New Mexico (LNM) Monitoring Station

July 2024 Revision

Site location

32.29740°N, 104.10948°W, 930 m asl (3051 ft)

The station facility is a climate-controlled, insulated trailer approximately 18 ft long x 8 ft wide x 8 ft tall. Approximately 5 m southeast of the trailer is a 10 m triangular meteorological aluminum tower which supports the meteorological equipment and air sampling inlet lines.

Wind Speed / Wind Direction

Wind conditions are recorded with a Campbell Scientific MetSENS500 sonic anemometer mounted on the meteorological tower at 8.7 m height. The stated resolution for wind speed is 0.01 m/s. The manufacturer stated resolution for wind direction is 1 degree with ±3 degree accuracy. The lower detection limit (LDL) for the MetSENS500 wind speed is 0.01 m/s. Undetected wind is reported as half of the LDL, or 0.005 m/s, and in these instances the wind direction is reported as NaN. The ½LDL correction is applied to the original 1-minute data, not to any further averaged data (e.g. 5-minute or hourly).

Temperature, Relative Humidity, Barometric Pressure

Temperature, relative humidity, and barometric pressure are measured with a Campbell Scientific MetSENS500 mounted on the meteorological tower at 8.7 m height above the surface using the factory calibration. The manufacturer stated resolution of the temperature measurement is 0.1 degree Celsius with ±3 degree C accuracy. The stated relative humidity resolution is 0.1% with ±2% accuracy. The stated resolution of the pressure measurement is 0.1 hPa with ±0.5 hPa accuracy.

Solar radiation

Incoming solar radiation is monitored with an Apogee SP-110-SS pyranometer on the meteorological tower at 8.5 m height above the surface. The sensor dome is cleaned every 2 months.

Sound

Sound is monitored with a Brüel & Kjær (B&K) 2250-L sound level meter (SML) comprised of a microphone, a preamplifier, and a main processor. The microphone converts the sound signal into an equivalent electric signal. Sound processing includes applying frequency and time weightings to the signal according to international standards, such as IEC 61672-1. Frequency weighting adjusts how the sound level meter responds to different sound frequencies and are necessary because the human ear's sensitivity to sound varies according to the sound's frequency. A-weighting adjusts the signal in a way that best resembles the human ear's response to sound at medium-range levels. A-

weighted sound measurements are commonly used for regulatory purposes regarding worker health and hearing conservation. C-weighting takes into account the energy present at low frequencies as well as high frequencies. Comparison of A- and C-weighted sound measurements can be used to determine if the source of noise is predominantly low- or high-frequency noise. The amount of energy present in sound pressure level is reported as an averaged sound pressure level, called the equivalent continuous sound level (Leq). A- and C-weighting are reflected as equivalent continuous sound levels by LAeq or LCeq if processed by A-weighting or C-weighting filters, respectively. LAeq and LCeq are reported as 5-minute moving-averages in decibels (dB) referenced to 20mPa.

The B&K 2250-L sound meter is mounted to the meteorological tower at a height of 3 meters above ground level, inside a Nanuk 909 waterproof enclosure. The sound meter is oriented vertically with the instrument's microphone extending outside the enclosures side wall. A UA-0237 windscreen is placed over the instrument's microphone.

Ozone (O_3)

Ozone is recorded with a Thermo Fisher Scientific model 49C UV absorption monitor. Ambient air is sampled from an inlet mounted at 6.1 m height above the surface. The sampling line consists of 11 m length, ¼ inch o.d., 5/32 inch i.d. PFA tubing, equipped with an inlet PFA filter holder that houses a 5 micron Teflon membrane filter. Inlet filters are replaced every two months. The time resolution of the ozone monitoring is one minute. The monitoring and calibration protocol follow the federal regulatory monitoring requirements according to the specifications of '40 Code of Federal Regulations (CFR) Part 58'.

The calibration scale is referenced against an EPA Region 8 primary ozone reference standard. Daily zero and span checks are performed automatically using a Thermo Fisher Scientific 49C calibrator unit. These checks are performed at night by introducing the calibration gases through the calibration valve of the instrument. First, zero air is introduced for 6 minutes, followed by 80 ppb of ozone for 6 more minutes. Two hours later, a mid-range check at 50 ppb is performed for 6 minutes. Quarterly, a full range linearity check is performed using the same calibrator unit. Six different levels of ozone are introduced: 0 ppb, 25 ppb, 50 ppb, 100 ppb, 200 pbb, 400 ppb. Also quarterly an inlet check is performed by feeding the calibrator output through the inlet filter on the tower and the entire inlet line to the instrument, and then running a standard calibration check. Yearly, a calibration check is performed using a level 2 standard (a Thermo Fisher Scientific 49C calibrator unit) following the same protocol as for the quarterly checks. The level 2 standard was last referenced against an EPA Region 8 primary ozone reference standard on May 4th 2022. From calibration check performance, the following corrections have been applied to the data:

Start	*End*	*Correction applied*
11/23/2023 03:17 UTC	11/28/2023 05:49 UTC	Data omission, instrument operating out of spec

The lower detection limit (LDL) for ozone is 1 ppb as reported by the instrument manufacturer. Measurements below this value are reported as ½ of the LDL, 0.5 ppb. The ½LDL correction is applied to the original 1-minute data, not to any further averaged data (e.g. 5-minute or hourly).

Carbon Dioxide (CO_2)

Carbon dioxide is monitored with a Picarro G2301 cavity ring down spectrometer. Ambient air is sampled at 215 scc/min from an inlet at 6.1 m height. The sampling line consists of 11 m length, ¼ inch o.d., 5/32 inch i.d. PFA tubing, equipped with an inlet PFA filter holder that houses a 5 micron Teflon membrane filter. Membrane filters are replaced every month. The manufacturer's calibration settings are applied. Calibration checks are conducted every 49 hours by introducing a breathing air grade ambient air gas mixture from a compressed tank (549.95 ppm CO_2 (last analysis 04/03/2023), EY0002069). The CO_2 mole fraction of this test atmosphere has been cross-referenced against the NOAA Global Atmospheric Monitoring Laboratory (GML) CO_2 scale and is estimated to have an accuracy error of <3 ppm.

Methane (CH_4)

Methane is monitored with a Picarro G2301 cavity ring down spectrometer. Ambient air is sampled at 215 scc/min from an inlet at 6.1 m height. The sampling line consists of 11 m length, ¼ inch o.d., 5/32 inch i.d. PFA tubing, equipped with an inlet PFA filter holder that houses a 5 micron Teflon membrane filter. Membrane filters are replaced every two months. The manufacturer's calibration settings are applied. Calibration checks are conducted every 49 hours by introducing a breathing air grade ambient air gas mixture from a compressed tank (2842.0 ppb CH_4 (last analysis 04/03/2023), EY0002069). The CH_4 mole fraction of this test atmosphere has been cross-referenced against the NOAA Global Atmospheric Monitoring Laboratory (GML) CH_4 scale and is estimated to have an accuracy error of <2 ppb.

Nitrogen Oxides (NO_x)

NO and NO_2 are monitored with a Teledyne Model API T200UP chemiluminescence analyzer. This analyzer uses a photolytic converter for the NO_2 determination. The sampling line consists of 11 m length, ¼ inch o.d., 5/32 inch i.d. PFA tubing equipped with a PFA filter holder that houses a 5 micron Teflon membrane filter. Membrane filters are replaced every two months. The sampling inlet is mounted on the meteorological tower at 6.1 m height. The monitoring and calibration protocol follow the federal regulatory monitoring requirements according to the specifications of '40 Code of Federal Regulations (CFR) Part 58'. Calibrations are performed using dynamic dilution and titration of a 9.81 parts per million (ppm) NO primary EPA-grade standard (EPA protocol grade gas, Linde Gas & Equipment, certification date 09/26/2022) with a Teledyne T700 Dilution Calibrator. The output of the calibrator is introduced through the span port of the instrument. Zero air is generated by running compressed air through a catalyst (platinum on alumina pellets) at 380 degrees C and then through Sofnofil and Charcoal scrubbers. Quarterly, full calibrations of the NO_x analyzer are performed using the output of the calibrator to introduce span gas to the span port of the instrument and zero air through the zero air port of the analyzer. For these calibrations, a zero adjustment is made first, followed by NO and NO_x span adjustments using 180 ppb NO. Then, a 6-level linearity check is performed (0 ppb NO, 20 ppb NO, 40 ppb NO, 80 ppb NO, 120 ppb NO, 180 ppb NO). The conversion efficiency adjustment is done next, at 2 different levels using the GPT: 150 ppb NO_2 (for 180 NOx) and 20 ppb NO_2 (for 40 ppb NOx). Every 3 days, calibration checks are performed for zero, a single span value of 180 ppb NO, and a single NO_2 mid-point value using the same calibrator connected to the span port of the analyzer, with the zero air sourced via the calibrator into the span port of the

analyzer. The lower detection limit reported by the manufacturer for NO, NO_2, and NO_x is 0.05 ppb. Measurements below this value are reported as ½ of the LDL, 0.025 ppb. The ½LDL correction is applied to the original 1-minute data, not to any further averaged data (e.g. 5-minute or hourly).

Hydrogen Sulfide (H_2S)

H_2S is analyzed by gas-phase ultraviolet fluorescence with a Teledyne T101 analyzer in air that is pulled at 615 scc/min from an inlet mounted at 6.1 m height above the surface. The sampling line consists of 11 m length, ¼ inch o.d., 5/32 inch i.d. PFA tubing equipped with an inlet PFA filter holder that houses a 5 micron Teflon membrane filter. Membrane filters are replaced every two months. Calibrations are performed by dynamic dilution of a 5.36 parts per million (ppm) H_2S primary EPA-grade standard (EPA protocol grade gas, Linde Gas & Equipment, certification date 09/26/2022), using a Teledyne T700 Dilution Calibrator. Zero air is generated by running compressed air through a catalyst (platinum on alumina pellets) at 380 degrees C and then through Sofnofil and Charcoal scrubbers. Every 3 days, calibration checks are performed for zero and a single span value of 200 ppb H_2S using the same calibrator connected to the span port of the analyzer, with the zero air sourced via the calibrator into the span port of the analyzer. Quarterly, full calibrations of the H_2S analyzer are performed using the output of the calibrator to introduce span gas to the span port of the instrument and zero air through the zero air port of the analyzer. For these calibrations, a zero adjustment is made first, followed by H_2S span adjustments using 200 ppb H_2S. Every 6 months, a 5-level linearity check is performed (0 ppb, 25 ppb, 50 ppb, 75 ppb, 100 ppb, 200 ppb). The lower detection limit reported by the manufacturer is 0.4 ppb. Measurements below this value are reported as ½ of the LDL, 0.2 ppb. The ½LDL correction is applied to the original 1-minute data, not to any further averaged data (e.g. 5-minute or hourly).

Sulfur Dioxide (SO_2)

SO_2 is analyzed by gas-phase ultraviolet fluorescence with a Teledyne T101 analyzer. Ambient air is pulled at 615 scc/min from an inlet mounted at 6.1 m height above the surface. The sampling line consists of 11 m length, ¼ inch o.d., 5/32 inch i.d. PFA tubing equipped with an inlet PFA filter holder that houses a 5 micron Teflon membrane filter. Membrane filters are replaced every two months. The monitoring and calibration protocol follow the federal regulatory monitoring requirements according to the specifications of '40 Code of Federal Regulations (CFR) Part 58'. Calibrations are performed by dynamic dilution of a 5.08 parts per million (ppm) SO_2 primary EPA-grade standard (EPA protocol grade gas, Linde Gas & Equipment, certification date 08/31/2022), using a Thermo Fisher Scientific 146i Multi-gas Calibrator. Zero air is generated by running compressed air through a catalyst (platinum on alumina pellets) at 380 degrees C and then through Sofnofil and Charcoal scrubbers. Every 3 days, calibration checks are performed for zero and a single span value of 200 ppb SO_2 using the same calibrator connected to the span port of the analyzer, with the zero air sourced via the calibrator into the span port of the analyzer. Quarterly, full calibrations of the SO_2 analyzer are performed using the output of the calibrator to introduce span gas to the span port of the instrument and zero air through the zero air port of the analyzer. For these calibrations, a zero adjustment is made first, followed by span adjustments using 200 ppb SO_2. Every 6 months, a 5-level linearity check is performed (0 ppb, 25 ppb, 50 ppb, 75 ppb, 100 ppb, 200 ppb). The lower detection limit reported by the manufacturer is 0.4 ppb. Measurements below this value are reported as ½ of the

LDL, 0.2 ppb. The ½LDL correction is applied to the original 1-minute data, not to any further averaged data (e.g. 5-minute or hourly).

Carbon Monoxide

CO is analyzed with a Thermo Fisher Scientific 48C analyzer. Ambient air is pulled at 480 scc/min from an inlet mounted at 6.1 m height above the surface. The sampling line consists of 11 m length, ¼ inch o.d., 5/32 inch i.d. PFA tubing equipped with an inlet PFA filter holder that houses a 5 micron Teflon membrane filter. Membrane filters are replaced every two months The instrument performs an automatic zero every 6 hours. Zero air is generated by running compressed air through a catalyst (platinum on alumina pellets) at 380 degrees C and then through Sofnofil and Charcoal scrubbers. Span calibrations use a 2.560 parts per million (ppm) CO primary EPA-grade standard (EPA protocol grade gas, Linde Gas & Equipment, certification date 03/27/2023). Every two weeks a span check is performed by an operator. Quarterly, a span calibration adjustment is made. The lower detection limit reported by the manufacturer is 0.013 ppb. Measurements below this value are reported as ½ of the LDL, 0.0065 ppb. The ½LDL correction is applied to the original 1-minute data, not to any further averaged data (e.g. 5-minute or hourly).

Radioactivity (alpha)

Radioactivity (alpha decay from radon gas and radon progeny on particulates) is monitored with two instruments at a height of 2 m above ground level. A Bertin Instruments AlphaGUARD DF2000 instrument is used for the measurement of the alpha radiation emitted from radon gas (Radon 222 and Radon 220) via a sample line of ¼ inch i.d. PFA tubing at a sample rate of ~2 L/min. A second instrument, the AlphaPM radon progeny monitor, measures alpha radiation emitted from radon progeny attached to particulate matter. The AlphaPM is in an airtight, temperature-controlled metal enclosure inside the instrument shelter and receives sample air through a 2-inch diameter (2 NPT) 12-inch long aluminum inlet pipe that protrudes through the shelter wall. The inlet pipe is heated to 30 degrees C to maintain above freezing air temperatures reaching the instrument. Air is circulated through the enclosure at approximately 5 to 6 L/min pulled with a small diaphragm pump, and the AlphaPM draws in sample air with its internal pump at a rate of 1.2 L/min. The AlphaPM filter is replaced approximately every 2 weeks. Both instruments have a synchronized 10-minute measurement cycle. Manufacturer calibration settings are used. The manufacturer recommends the instruments to be returned to the factory for a calibration check after five years of operation. The lower detection limit reported by the manufacturer for both instruments for alpha radiation from radon gas and radon progeny on particulates is 2 Bq/m^3 (0.054 pCi/L). Measurements below this value are reported as ½ of the LDL, 1 Bq/m^3 (0.027 pCi/L). The ½LDL correction is applied to the original 1-minute data, not to any further averaged data (e.g. 5-minute or hourly).

Volatile Organic Compounds

Volatile Organic Compounds (VOCs) are monitored with a custom-made preconcentration system interfaced to an Agilent 6890 gas chromatograph (GC) using a flame ionization detector (FID) detector. Sample air is pulled from an inlet at 6.1 m above the surface on the meteorological tower at a purge rate of 1.5 L/min. The sampling line consists of 13 m length, ¼ inch o.d., 5/32 inch i.d. PFA tubing, equipped with an inlet PFA filter holder that houses a 5 micron Teflon membrane filter which is

replaced every two months. The sampling line is inside a conduit heated to 40°C. Hourly, VOCs are extracted over a 10-minute time window at 40 cc/min. Carrier gas is H_2 from a Parker H2PEM-160 hydrogen generator or a tank of UHP H_2 (Airgas). To preconcentrate VOCs, sample air is directed through a Peltier-cooled water freezeout trap that is held at -45°C. The dried air then flows through an ozone scrubber that contains sodium-thiosulfate-impregnated glass wool, replaced annually. VOCs are then extracted from the downstream air flow on a micro-adsorbent trap (Carboxen 1000 and Carboxen 1016) held at -40°C. VOCs are transferred by rapid heating of the micro-adsorbent trap to 290°C and purged onto an alumina PLOT GC column (Al_2O_3/KCl PLOT, 50 m, 0.53 mm i.d., 15 um film thickness). After temperature-programmed separation, compound identification and quantification are accomplished with the FID using PeakSimple software (SRI Instruments, version 4.94). Within PeakSimple, specifically programmed peak integration is done automatically following each run. The tabulated peak area results are processed by automated scripts using monthly updated calibration carbon response factors (CRF) and effective carbon numbers (ECN) to calculate mixing ratios, which are reported in real time on the program website.

Approximately twenty VOCs are traced and quantified routinely. Data represent the 10-minute mean VOC mole fractions over the 10-minute sample collection period, with the recorded time stamp at the middle of that sampling period. A subset of selected VOC tracers (ethane, propane, butane, pentane, hexane, heptane, octane, benzene, toluene, acetylene, ethene, propene, isoprene, cyclopentane, ethyl-benzene, *m&p*-, *o*-xylene) are plotted on the web portal (https://www.bouldair.com/loving.htm).

The calibration scale is tied to the World Meteorological Organization (WMO) Global Atmospheric Watch (GAW) VOCs scale, using a certified multicomponent 4-ppb primary standard (Table 1) acquired from the U.K. National Physics Laboratory (NPL, calibration date 2/13/2020) – the central calibration laboratory for VOCs recommended by WMO-GAW program. The calibration standard is run approximately every three days. Calibration carbon response factors (CRF) are updated monthly using the averaged result of the NPL standard samples run the prior month, and are applied to the previous month's data record retroactively. Realtime data use the CRF values continuing from the prior month. In addition, a 200-ppb NPL standard and a high mole fraction VOC standard dilution curve are run annually to check for the linearity of the instrument response at high levels. The high mole fraction standard (635.4 ppb ethane, 640.6 ppb propane, 532.1 ppb i-butane, 532.1 n-butane, 320.8 ppb i-pentane, 320.8 ppb n-pentane) is diluted to various mixing ratios to create an instrument response curve (ratio of the measured/expected mole fraction vs. measured mole fraction). This same high mole fraction standard is run every 65 runs to monitor the continuity of the instrument response at high levels. A zero air (blank) sample is run every 65 runs (~every three days). Zero air is generated by running compressed air through a catalyst (platinum on alumina pellets) at 380 degrees C and then through Sofnofil and Charcoal scrubbers.

Table 1

National Physics Laboratory VOC calibration standard composition.

Database component name	mole fraction (ppbv)	Uncertainty (ppbv)	Name on certificate
ethane	4.00	0.08	
ethene	3.92	0.08	

propane	3.94	0.08	
propene	3.92	0.08	
i-butane	4.02	0.11	2-methylpropane
acetylene	4.13	0.21	ethyne
n-butane	3.98	0.08	
trans-2-butene	4.00	0.09	trans-but-2-ene
1-butene	3.97	0.08	but-1-ene
cis-2-butene	3.99	0.08	cis-but-2-ene
i-pentane	3.93	0.08	2-methylbutane
n-pentane	3.95	0.08	
1_3-butadiene	4.03	0.09	1,3-butadiene
trans-pent-2-ene	3.97	0.08	
pent-1-ene	4.03	0.09	
2-methylpentane	4.14	0.09	
n-hexane	4.14	0.11	
isoprene	4.13	0.09	
n-heptane	4.15	0.09	
benzene	3.92	0.08	
2_2_4_trimethylpentane	3.89	0.08	2,2,4-trimethylpentane
n-octane	3.91	0.08	
toluene	3.81	0.10	
ethyl-benzene	4.12	0.11	
m&p-xylene	8.02	0.21	m-xylene+p-xylene
o-xylene	3.95	0.10	
1_3_5_trimethylbenzene	3.86	0.10	1,3,5-trimethylbenzene
1_2_4_trimethylbenzene	3.92	0.10	1,2,4-trimethylbenzene
1_2_3_trimethylbenzene	4.05	0.11	1,2,3-trimethylbenzene

Two xylene isomers, meta-xylene and para-xylene, elute very closely together in the chromatogram and often cannot be separated as individual peaks. The results for these isomers are therefore reported at the sum of both.

VOC data are reported in nanomoles per mole by volume (nmol mol^{-1}, i.e. 10^{-9}). The more commonly used unit ppb (parts-per-billion by volume) is used as a surrogate.

VOC lower detection limits (LDL) were calculated from the smallest, reliably identifiable FID peak area and the compound CRFs calculated monthly from the weekly standard runs. Since the calculation of LDL varies with the instrument response calibrated monthly, the lowest values seen in the data will also vary monthly. Representative lower detection limits from May 2023 are provided in Table 2. VOC species with no detected or quantifiable peak in the GC chromatograms are recorded as ½ of the lower detection limit (which similarly vary monthly).

Table 2

VOCs lower detection limits.

VOC	**LDL Value (ppb)**

ethane	0.023
ethene	0.024
propane	0.016
propene	0.016
i-butane	0.012
n-butane	0.011
acetylene	0.023
i-pentane	0.009
n-pentane	0.009
1,3-butadiene	0.012
n-hexane	0.008
isoprene	0.010
n-heptane	0.007
benzene	0.008
2,2,4-trimethylpentane	0.006
n-octane	0.008
Toluene	0.007
ethyl-benzene	0.009
m&p-xylene	0.009
o-xylene	0.009
1,3,5-trimethylbenzene	0.012

VOC data corrections:

Zero-air blank subtractions

Blanks are assessed from the periodic collection of the VOC-scrubbed zero air. Blank peak area subtractions are determined using the mean peak area of zero air runs during a particular time window that a detectable peak is present for a given compound. Most often this is delineated on a monthly basis, or following significant system work (e.g. installation of a new absorbent trap). Most VOCs show blank values below the limit of detection, or well below the response seen in ambient levels, and are therefore deemed negligible**.**

High mole fraction correction

A high mole fraction standard was run to test the VOC system for linearity at high levels. A high mole fraction standard (635.4 ppb ethane, 640.6 ppb propane, 532.1 ppb i-butane, 532.1 n-butane, 320.8 ppb i-pentane, 320.8 ppb n-pentane) was diluted to various mixing ratios to create an instrument response curve (ratio of the measured/expected mole fraction vs. measured mole fraction). Based on measured ambient measurements collected over the study period, a non-linear response correction

was applicable to high ethane, propane, i-butane, and n-butane measurements. A 2nd order polynomial was fit to the curve for these species.

Ethane:
Measurements were corrected to an upper bound of 700 ppb.
If the measured ethane value was above 250 ppb, we applied the following correction:

$$x \cdot \frac{1}{ax^2 + bx + c} = x_c$$

x : Measured mole fraction of ethane in parts per billion (ppb)

x_c: Corrected mole fraction of ethane in parts per billion (ppb)

a : - 1.35002824e-05

b : 5.94325536-03

c : 3.57090712e-01

Propane:
Measurements were corrected to an upper bound of 670 ppb.
If the measured propane value was above 189.2 ppb, we applied the following correction:

$$x \cdot \frac{1}{ax^2 + bx + c} = x_c$$

x : Measured mole fraction of propane in parts per billion (ppb)

x_c: Corrected mole fraction of propane in parts per billion (ppb)

a : 0

b : 2.84939e-03

c : 3.57090712e-01

i-butane:
Measurements were corrected to an upper bound of 545 ppb.
If the measured propane value was above 165.9 ppb, we applied the following correction:

$$x \cdot \frac{1}{ax^2 + bx + c} = x_c$$

x : Measured mole fraction of i-butane in parts per billion (ppb)

x_c: Corrected mole fraction of i-butane in parts per billion (ppb)

a : -3.34950807e-06

b : 7.13680256e-04

c : 9.32025239e-01

n-butane:
Measurements were corrected to an upper bound of 550 ppb.
If the measured propane value was above 166 ppb, we applied the following correction:

$$x \cdot \frac{1}{ax^2 + bx + c} = x_c$$

x : Measured mole fraction of n-butane in parts per billion (ppb)

x_c: Corrected mole fraction of n-butane in parts per billion (ppb)

a : -3.55554591e-06

b : 6.17320328e-04

c : 9.54935298e-01