Metadata for Atmospheric Measurements at the Broomfield North Pecos (BNP) Monitoring station

Boulder A.I.R.
Prepared by K. Potter

Site location

39.9814°N, 105.00655°W, 1611 m asl (5285 ft)

The station facility is a climate-controlled, insulated trailer approximately 12 ft long x 8 ft wide x 8 ft tall. Attached to the trailer is a 20 ft triangular meteorological aluminum tower which supports the meteorological equipment and air sampling inlet lines.

Wind Speed / Wind Direction

Wind conditions are recorded with an RM Young Wind Monitor AQ, 05305-PT, wind vane mounted on the meteorological tower at 5.4 m height. Beginning 8/25/2022, a Campbell Scientific MetSENS500 sonic anemometer was collocated with the wind vane. Every 6 months, wind speed and wind direction calibration checks are performed by an operator on the RM Young Wind Monitor, using a vane angle stand (RM Young, 18112) and an anemometer drive (RM Young, 200-15,000 RPM, 18802) standard. For the wind direction, South (180 degrees), West (270 degrees), East (90 degrees) and North (0 degrees) positions are checked, rotating the sensor clockwise and then counterclockwise, for a total of 8 points. For the wind speed, 4 speeds are used: 600 rpm (3.07 m/s), 1700 rpm (8.70 m/s), 3300 rpm (16.90 m/s) and 5400 rpm (27.65 m/s) in both directions (clockwise and counterclockwise) along with a zero check for a total of 9 points. An audit has been performed by the Colorado Department of Public Health and Environment (CDPHE) on the RM Young Wind Monitor on 7 February 2022. The wind speed sensor had 0.0% to -0.3% error for both clockwise and counterclockwise directions across all audited wind speeds. The wind direction sensor and vane alignment had <5 degrees composite error for all wind directions, thus meeting quality control requirements. The lower detection limit (LDL) for the RM Young wind speed is 0.4 m/s. Undetected wind is reported as half of the LDL, or 0.2 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

Temperature and relative humidity are measured with a Campbell Scientific CS215-L50-PT probe housed inside a RM Young 6-Plate Solar Radiation Shield mounted on the meteorological tower at 5.4 m height above the surface using the factory calibration. An audit was performed by the Colorado Department of Public Health and Environment (CDPHE) of the accuracy of the temperature and relative humidity readings on 7 February 2022. The instrument passed in all audit criteria with temperature reading accuracy having an error of -0.1 degrees C (passing is <2 degrees C), and relative humidity having a 2.9% error (passing is <5%). The manufacturer stated resolution of the CS215-L temperature measurement is 0.01 degree Celsius. The stated relative humidity resolution is 0.03%.

Methane (CH_4)

Methane is monitored with a Picarro G-2301 cavity ring down spectrometer. Ambient air is sampled at 400 scc/min from an inlet at 4.75 m height. The sampling line consists of 7 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 (2413 ppb CH_4). 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. After ~3 months of use the test atmosphere is again cross-referenced to the NOAA GML scale to account for potential drift. Every 6 months, a calibration check is performed with an 1852.18 ppb CH_4 primary standard from NOAA (certification date 04/2015). Additionally, a calibration check and 5-level linearity check are performed by dynamic dilution of a 497 ppm CH_4 primary EPA-grade standard (EPA protocol grade gas, Praxair, production date 06/09/2022) with zero air using a Thermo Fisher Scientific 146i Multi-gas Calibrator. Zero air is supplied from a compressed UHP grade zero-air cylinder (General Air). Uncertainty is calculated as the greater of 4.68 ppb or 0.19% for 1-minute data and was assessed within the range of 1827.3 ppb to 3072.8 ppb. For values outside this range, the uncertainty may be higher.

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 4.75 m above the surface on the meteorological tower at a purge rate of 1.5 L/min. The sampling line consists of 12 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. 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 4.89). 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 20 - 30 VOCs are traced and quantified routinely. A subset of selected VOC tracers are plotted on the web portal (https://www.bouldair.com/broomfield.htm).

Beginning in May 2024 the list of quantified VOCs was expanded from 20 to 33 compounds:

ethane
ethene

propane
cyclopropane
propene
i-butane
n-butane
acetylene
trans-2-butene
1-butene
i-butene
cis-2-butene
cyclopentane
i-pentane
n-pentane
1,3-butadiene
trans-2-pentene
1-pentene
cyclohexane
2-methylpentane
3-methylpentane
n-hexane
isoprene
C7H16_alkane_isomers*
n-heptane
benzene
2,2,4-trimethylpentane
C8H18_alkane_isomers*
n-octane
toluene
ethyl-benzene
m&p-xylene
o-xylene

*C7H16_alkane_isomers includes:
2,2-dimethylpentane
2,4-dimethylpentane
methylcyclohexane
2,2,3-trimethylbutane
3,3-dimethylpentane
ethylcyclopentane
2,3-dimethylpentane
3-ethylpentane
3-methylhexane
2-methylhexane

*C8H18_alkane_isomers includes:
4-methylheptane
n-propylcyclopentane
2-methylheptane
3-methylheptane

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.

The calibration scale is tied to the World Meteorological Organization (WMO) Global Atmospheric Watch (GAW) VOCs scale, using a certified multicomponent 10-ppb primary standard (Table 1) acquired from the U.K. National Physics Laboratory (NPL, calibration date 3/9/2020) – the central calibration laboratory for VOCs recommended by WMO-GAW program. The calibration standard is run weekly by an operator. 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. Compounds not in the NPL standard use the average CRF value of the respective carbon number alkanes or alkenes (e.g. i-butene's CRF is the average CRF of trans-2-butene, 1-butene, and cis-2-butene).

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). A zero air (blank) sample and a lab-calibrated multi-component working standard are run every 65 runs (~every three days). Zero air is generated from a Parker zero-air generator followed by 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	9.87	0.30	
ethene	9.68	0.20	
propane	9.75	0.20	
propene	9.69	0.20	
i-butane	9.93	0.25	2-methylpropane
acetylene	10.20	0.60	ethyne
n-butane	9.84	0.20	
trans-2-butene	9.88	0.20	trans-but-2-ene
1-butene	9.82	0.20	but-1-ene
cis-2-butene	9.85	0.20	cis-but-2-ene
i-pentane	9.71	0.20	2-methylbutane
n-pentane	9.76	0.20	
1_3-butadiene	9.96	0.20	1,3-butadiene

trans-pent-2-ene	9.81	0.20	
pent-1-ene	9.97	0.20	
2-methylpentane	10.24	0.21	
n-hexane	10.24	0.21	
isoprene	10.20	0.21	
n-heptane	10.25	0.21	
benzene	9.69	0.20	
2_2_4_trimethylpentane	9.62	0.20	2,2,4-trimethylpentane
n-octane	9.65	0.20	
toluene	9.42	0.24	
ethyl-benzene	10.19	0.26	
m&p-xylene	19.80	0.50	m-xylene+p-xylene
o-xylene	9.75	0.25	
1_3_5_trimethylbenzene	9.54	0.24	1,3,5-trimethylbenzene
1_2_4_trimethylbenzene	9.69	0.25	1,2,4-trimethylbenzene
1_2_3_trimethylbenzene	10.01	0.26	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 March 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**.**