# Metadata for Atmospheric Measurements at the Erie Community Center (ECC) Monitoring station

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**Site location**

40.0402 N, 105.0519 W, 1538 m asl (5047 ft asl)

The station facility is a climate-controlled, insulated container building approximately 16 ft long x 8 ft wide x 8 ft tall. Two meters adjacent to the container is a 10 m triangular aluminum meteorological tower which supports the meteorological equipment and air sampling inlet lines.

**Wind Speed / Wind Direction**

Wind conditions are recorded with a Campbell Scientific MetSENS500, mounted on the meteorological tower at 9.2 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 9.2 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 19 November 2021. The instrument passed in all audit criteria with temperature reading accuracy having an error of -0.5 degrees C (passing is <2 degrees C), and relative humidity having a -0.2% error (passing is <5%). The manufacturer stated resolution of the temperature measurement is 0.1 degree Celsius with ±0.3 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 9.6 m height above the surface. The sensor dome is cleaned every 2 months.

**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 8.7 m height above the surface. The sampling line consists of 10 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. The level 2 standard has last been referenced against the EPA Region 8 primary ozone reference standard on 4 May 2022 and 21 Feb 2024. 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 the quarterly checks. From calibration check performance, the following corrections have been applied to the data:

| *Start* | *End* | *Correction applied* |
|---|---|---|
| 09/01/2021 00:00 UTC | 09/29/2021 18:47 UTC | Data omission, instrument operating out of spec |
| 09/09/2022 07:31 UTC | 10/21/2022 17:18 UTC | Slope Intercept<br>1.008 -0.3 |

An audit of the 49C was performed by the Colorado Department of Public Health and Environment (CDPHE) on 19 November 2021. The instrument passed all audit criteria with a calibration agreement slope 0.970 and an offset of 0.411 ppb, meeting EPA measurement quality requirements. The lower detection limit (LDL) for ozone is 1 ppb as reported by the instrument manufacturer. Measurements below this value are replaced with 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). Uncertainty is calculated as the greater of 1.6 ppb or 3.9% for 1-minute data and was assessed within the range of 0 ppb to 400 ppb.

**Methane ($CH_4$)**

Methane is monitored with a Picarro G2301 cavity ring down spectrometer. Ambient air is sampled at 400 scc/min from an inlet at 8.7 m height. The sampling line consists of 10 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 compressed gas from a tank (2631.9 ppb $CH_4$ (starting 9/29/2021), 2337.2 ppb $CH_4$ (starting 7/19/2022)). The methane mole fraction of this test atmosphere has been cross-referenced to the NOAA GML methane scale before use 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 $CH_4$ 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 5.44 ppb or 0.22% 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.

*Instrument Drift Corrections*

A monthly percent error correction to account for instrument drift (the analyzer's deviation from the standard) was applied to all historical methane data in October 2024. This correction is calculated and applied biannually thereafter to maintain accuracy and minimize deviations.

**Particulate Matter**

A GRIMM EDM180 monitor is used for measuring particulate matter (PM). This analyzer measures particles in the 0.25 – 32 µm (micrometer) size range by a laser scattering technique. Air is sampled from an inlet stack protruding approximately 1 m above the instrument shelter roof at ~1.2 L/min. The instrument has EPA certification, and the protocol follows requirements for regulatory PM monitoring. Two size ranges are reported: PM10 (coarse particles) for all particle mass smaller than 10 µm, and PM2.5 (fine particles) for all particle mass smaller than 2.5 µm. Weekly flow rate checks and zero tests using a 0.05 micron particle filter are performed by an operator at the sample inlet. Every 6 months, a field test is performed by an operator to check the instrument performance. For these tests, an aerosol test mixture is generated with a GRIMM Field Test Kit 185 by atomizing a diluted polystyrene latex standard suspension (1 micron and 2.5 micron, Durag Inc), which is then introduced directly into the instrument inlet. During this 6-month maintenance, the sample inlet pipe is also cleaned and internal filters are replaced as needed. The lower detection limit for PM10 and PM2.5 is 0.1 µg/m³ as reported by the manufacturer. Measurements below this value are replaced with ½ of the LDL, 0.05 µg/m³. The ½LDL correction is applied to the original 1-minute data, not to any further averaged data (e.g. 5-minute or hourly). Uncertainty is calculated as 17% for PM10 and 15.5% for 1-minute data.

**Volatile Organic Compounds**

Volatile Organic Compounds (VOCs) are monitored with a custom-made preconcentration system interfaced to an Agilent 6890 gas chromatograph (GC) using two flame ionization detector (FID) detectors. Sample air is pulled from an inlet at 8.7 m above the surface on a 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 to a 30 m DB-624 column, after which a column switch facilitates directing the lighter VOCs (ethane through isoprene) to a 30 m alumina PLOT column, while the heavier VOCs are directed to a second 30 m DB-624 column. After temperature-programmed GC separation, each GC column is directed to separate FIDs. Compound identification and quantification are accomplished 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 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.

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 acquired from the U.K. National Physics Laboratory (NPL, calibration date 2/5/2020), the central calibration laboratory recommended by the WMO-GAW program (Table 1). 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. 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 is run every 65 runs (~every three days). Zero-air is generated with a custom-built catalytic system using platinum on alumina pellets heated to 380C.

Table 1: National Physics Laboratory VOCs primary calibration standard composition.

| Database component name | mole fraction (ppbv) | Uncertainty (ppbv) | Name on certificate |
|---|---|---|---|
| ethane | 4.00 | 0.09 | |
| ethene | 3.92 | 0.08 | |
| propane | 3.95 | 0.08 | |
| propene | 3.93 | 0.08 | |
| i-butane | 4.02 | 0.11 | 2-methylpropane |
| acetylene | 4.14 | 0.21 | ethyne |
| n-butane | 3.99 | 0.08 | |
| trans-2-butene | 4.00 | 0.09 | trans-but-2-ene |
| 1-butene | 3.98 | 0.08 | but-1-ene |
| cis-2-butene | 3.99 | 0.08 | cis-but-2-ene |
| i-pentane | 3.94 | 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 | 4.04 | 0.09 | |
| 2-methylpentane | 4.15 | 0.09 | |
| n-hexane | 4.15 | 0.09 | |
| isoprene | 4.13 | 0.09 | |
| n-heptane | 4.16 | 0.09 | |
| benzene | 3.93 | 0.08 | |
| 2_2_4_trimethylpentane | 3.90 | 0.08 | 2,2,4-trimethylpentane |
| n-octane | 3.91 | 0.08 | |
| toluene | 3.82 | 0.10 | |
| ethyl-benzene | 4.13 | 0.11 | |
| m&p-xylene | 8.03 | 0.21 | m-xylene+p-xylene |
| o-xylene | 3.95 | 0.10 | |
| 1_3_5_trimethylbenzene | 3.87 | 0.10 | 1,3,5-trimethylbenzene |
| 1_2_4_trimethylbenzene | 3.93 | 0.10 | 1,2,4-trimethylbenzene |
| 1_2_3_trimethylbenzene | 4.06 | 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 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 | 0.025 |
| ethene | 0.023 |
| propane | 0.017 |
| propene | 0.017 |
| i-butane | 0.013 |
| n-butane | 0.013 |
| acetylene | 0.038 |
| i-pentane | 0.010 |

| | |
|---|---|
| n-pentane | 0.010 |
| 1,3-butadiene | 0.013 |
| n-hexane | 0.008 |
| isoprene | 0.010 |
| n-heptane | 0.007 |
| benzene | 0.010 |
| 2,2,4-trimethylpentane | 0.005 |
| n-octane | 0.007 |
| toluene | 0.010 |
| ethyl-benzene | 0.010 |
| m&p-xylene | 0.008 |
| o-xylene | 0.008 |
| 1,3,5-trimethylbenzene | 0.009 |

VOC data corrections:

*Zero-air blank subtractions*

Blanks are assessed from the periodic collection of the VOC-scrubbed zero air runs. 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**.** Blank peak area value subtraction for benzene and toluene occurs as follows. These peak area subtractions have been applied and are accounted for in the data set.

| Compound | Start date (UTC) | End date (UTC) | Peak area subtraction | Approximate mixing ratio of subtraction (ppb) |
|---|---|---|---|---|
| benzene | 10/01/2021 0:00 | 11/01/2021 0:00 | -0.62 | 0.033 |
| benzene | 11/01/2021 0:00 | 01/01/2022 0:00 | -0.43 | 0.023 |
| toluene | 10/01/2021 0:00 | 11/01/2021 0:00 | -0.78 | 0.039 |
| toluene | 11/01/2021 0:00 | 01/01/2022 0:00 | -0.74 | 0.037 |

*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, non-linear response correction was only applicable to n-butane measurements. A 2$^{nd}$ order polynomial was fit to the curve. Measurements were corrected to an upper bound of 535 ppb.

If the measured n-butane value was above 200 ppb, we applied the following correction:

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

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

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

$a$ : -3.14047088e-07

$b$ : -8.64129820e-05

$c$ : 9.79678869e-01