Metadata for Atmospheric Measurements at the Commerce City Mobile (CCM) Monitoring Station

8 November 2023 Revision

Site location

The Commerce City Mobile station (CCM) facility is a climate-controlled, insulated trailer approximately 12 ft long x 8 ft wide x 8 ft tall. Affixed to the roof of the trailer is an aluminum tower reaching 4.6 m height above the ground, which supports the meteorological equipment and air sampling inlet lines.

The Commerce City Mobile station changed monitoring locations (21 sites total) in the Commerce City, Globeville, and Elyria-Swansea areas near Denver, CO, every few weeks according to Table 1 below. It remained several months at its final location.

Table 1: CCM monitoring locations

Site ID	Address	Start (Date, Time-UTC)	End (Date, Time-UTC)	Latitude (°N)	Longitude (°W)	Elevation (ft)
S01	6650 Clermont St., Commerce City, CO 80022	02/02/22 00:35	02/25/22 18:54	39.81750	104.93481	5144
S02	4800 Washington St., Denver, CO 80216	02/25/22 21:38	04/05/22 16:01	39.78315	104.97658	5151
S03	6690 E 72nd Ave., Commerce City, CO 80022	04/05/22 20:13	05/02/22 16:40	39.82652	104.91005	5167
S04	7530 Niagara St., Commerce City, CO 80022	05/02/22 19:40	05/16/22 19:47	39.83330	104.91066	5161
S05	7191 Pontiac St., Commerce City, CO 80022	05/17/22 03:11	06/03/22 20:24	39.82662	104.90651	5171
S06	6587E 80th Ave., Commerce City CO 80022	06/03/22 23:32	06/15/22 12:12	39.84212	104.91175	5138
S07	6693 Oneida St., Commerce City CO 80022	06/15/22 19:30	06/29/22 17:07	39.81830	104.90840	5190
S08	7970 Kimberly St., Commerce City, CO 80022	06/29/22 19:21	07/11/22 17:20	39.84139	104.91640	5125
S09	7631 Monaco St., Commerce City, CO 80022	07/11/22 20:04	07/29/22 17:03	39.83583	104.91308	5153
S10	6060 Parkway Dr., Commerce City, CO 80022	07/29/22 21:01	08/16/22 18:45	39.80645	104.92707	5171
S11	2501 E 48th Ave., Denver, CO 80216	08/16/22 21:32	09/07/22 20:00	39.78413	104.95616	5187
S12	4717 Claude Ct., Denver, CO 80216	09/12/22 21:30	09/26/22 20:03	39.78239	104.96050	5187
S13	7161 Olive St., Commerce City, CO 80022	09/26/22 22:24	10/11/22 15:14	39.82615	104.90752	5171
S14	7180 Pontiac St., Commerce City, CO 80022	10/11/22 17:17	10/25/22 11:00	39.82655	104.90600	5171
S15	6191 E61 Ave., Commerce City, CO 80022	10/25/22 23:00	11/08/22 22:27	39.80724	104.91531	5194

S16	4790 Thompson Ct., Denver, CO 80216	11/08/22 23:58	11/18/22 18:09	39.78368	104.95477	5187
S17	615 E Elk Pl., Denver, CO 80216	11/18/22 21:10	12/08/22 16:53	39.78316	104.97954	5151
S18	4755 Gaylord St., Denver, CO 80216	12/08/22 20:04	12/28/22 20:10	39.78295	104.96161	5187
S19	6210 E 66th Pl., Commerce City, CO 80022	12/28/22 23:35	01/26/23 16:42	39.81663	104.91620	5174
S20	3200 E52nd Ave., Denver, CO 80216	01/26/23 22:00	02/14/23 16:41	39.79068	104.94883	5177
S21	5160 York St., Denver, CO 80216	02/14/23 19:37	07/24/23 18:00	39.79004	104.95895	5167

Wind Speed / Wind Direction

Wind conditions are recorded with a Campbell Scientific MetSENS500 mounted on a meteorological tower at 4.8 m height. The stated resolution for the MetSENS500 wind speed is 0.01 m/s and for wind direction is 1 degree with ±3 degree accuracy.

Temperature, Relative Humidity, Barometric Pressure

Temperature, relative humidity, and barometric pressure are measured with a Campbell Scientific MetSENS500 mounted on a meteorological tower at 4.8 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.

Carbon Dioxide (CO_2)

Carbon dioxide was monitored with a Picarro G2301 cavity ring down spectrometer from 2/1/2022 until 9/30/2022 23:59 UTC. Ambient air is sampled from an inlet at 4.5 m height at ~200 scc/min. 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 6 weeks. The manufacturer's calibration settings are applied.

A calibration check and 5-level linearity check was performed on 7/18/2022 by dynamic dilution of a 4.90% CO_2 primary EPA-grade standard (EPA protocol grade gas, Praxair, production date 06/09/2022, LL19210) with zero air using a Thermo Scientific 146i Multi-gas Calibrator. Zero air is supplied from a compressed UHP grade zero-air cylinder (General Air).

Methane (CH_4)

Methane was monitored with two different instruments, a Picarro G2301 cavity ring down spectrometer from 2/1/2022 until 9/30/2022 23:59 UTC and a Picarro G4302 from 10/1/2022 00:00 UTC until end-of-sampling 7/24/2023. Ambient air is sampled from an inlet at 4.5 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 6 weeks. The manufacturer's calibration settings are applied.

G2301: Ambient air is sampled at ~200 scc/min. Every 12 months (7/18/2022 and 7/07/2023), a calibration check and 5-level linearity check was performed by dynamic dilution of a 497 ppm CH_4 primary EPA-grade standard (EPA protocol grade gas, Praxair, production date 06/09/2022, LL19210) with zero air using a Thermo Scientific 146i Multi-gas Calibrator. Zero air is supplied from a compressed UHP grade zero-air cylinder (General Air).

G4302: Ambient air is sampled at ~3.0 sL/min. Every 6 months 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, LL19210) with zero air using a Thermo Scientific 146i Multi-gas Calibrator. Zero air is supplied from a compressed UHP grade zero-air cylinder (General Air). Weekly, the analyzer is tested against breathing air grade compressed gas (2,319.7 ppb CH_4 (last analysis 7/18/2022), CC738525). The methane mole fraction of this test atmosphere has been cross referenced to the NOAA Global Atmospheric Monitoring (GML) methane 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. Data are available from the study start until 4/10/2023, when the instrument developed a hardware issue and replacement parts were not available until the study had finished. This analyzer uses a photolytic converter for the NO_2 determination. 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. The sampling inlet is mounted on a meteorological tower at 4.5 m height. Membrane filters are replaced every 6 weeks. 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 10.29 parts per million (ppm) NO primary EPA-grade standard (EPA protocol grade gas, Praxair, production date 01/12/2022, EY0002392) with a Thermo Scientific 146C Multi-gas Calibrator equipped with a Gas Phase Titration system (GPT). The output of the calibrator is introduced through the span port of the instrument. Zero air is generated by a Thermo Scientific T111 Zero Air Supply and supplemental Sofnofil and Charcoal scrubbers. Quarterly (performed 4/12/22, 6/10/22, 7/21/22, 9/13/22, 11/14/22, 2/06/23), full calibrations of the NO_x analyzer are performed using a transfer standard gas calibrator, a Thermo Scientific 146i Multi-gas Calibrator equipped with GPT (SN 146i-AT3BEAA). The output of the transfer standard gas calibrator supplies 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. The conversion efficiency adjustment is done next, at 2 different levels using the GPT: 150 ppb NO_2 (for 180 NO_x, 17.5% O_3) and 20 ppb NO_2 (for 40 ppb NO_x, 10% O_3). A linearity check for NO_2 is then performed using 9 levels of NO_2 (0, 20, 40, 80, 120, 160, 180, 320, 500 ppb). Weekly, calibration checks are performed for zero and a single span value of 160 ppb NO using the 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 replaced with ½ of the lower detection limit, 0.025 ppb.

Particulate Matter

A GRIMM EDM180 monitor is used for the particulates monitoring. 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, 3.4 m above ground level, 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 (volumetric flow meter) and zero tests using a 0.05 micron particle filter are performed by an operator at the sample inlet. Every 6 months (performed 3/14/2023 and 8/2/2023), a field test is performed by an operator to check the instrument performance. For these tests, a GRIMM Field Test Kit 185 creates an aerosol by atomizing a diluted polystyrene latex standard suspension (1 micron and 2.5 micron, Durag, Inc) which is introduced directly into the instrument inlet. The 6-month maintenance also includes: leak check, cleaning of sample inlet pipe, cleaning of sample air duct inside the optical chamber, flow rate audit with mass flow meter, ambient pressure verification with independent manometer, and internal filters replaced as needed. The lower detection limit for PM10 and PM2.5 is 0.1 µg/m³ as reported by the manufacturer.

Volatile Organic Compounds

Volatile Organic Compounds (VOCs) are monitored with a preconcentration unit interfaced to a gas chromatograph (GC) using a flame ionization detector (FID). Sample air is pulled from an inlet at 4.5 m above the surface at a purge rate of 1.0 L/min. 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. The membrane inlet filters are replaced every 6 weeks. Hourly, VOCs are extracted over a 10-minute time window at 40 cc/min by pre-concentration with a Markes International UNITY-2 with Air Server series 2 thermal desorption instrument. Sample air is dried by flowing through a section of quartz tubing (Markes U-T1KORI) cooled to a temperature of -30 °C (Markes International Kori-xr) before collection on a sorbent media focusing trap (Markes U-T3ATX-2S). VOCs are then transferred by rapid heating to a GC system for analysis. The GC (Agilent 6890 GC) is equipped with 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 twenty VOCs are traced and quantified routinely. A subset of selected VOC tracers (ethane, propane, butane, pentane, hexane, octane, benzene, toluene, ethene, propene, isoprene, cyclopentane, ethyl-benzene, *m&p-*, *o*-xylene) are plotted on the web portal. Data represent the 10-minute mean VOC concentrations over the 10-minute sample collection period, with the timestamp at the middle of the sampling interval. The calibration scale is tied to the World Meteorological Organization (WMO) Global Atmospheric Watch (GAW) VOCs scale, using a certified multicomponent 4-ppb primary calibration standard (Table 2) acquired from the U.K. National Physics Laboratory (calibration date 2/13/2020, D723243) – the central calibration laboratory for VOCs recommended by WMO-GAW program. This 4-ppb primary NPL standard was used as the calibration tank from the

study start until 2/8/2023, after which it was replaced by a working NPL standard (EY0002087, a dilution of a high mole fraction NPL standard). The calibration standard is run weekly by an operator. Calibration carbon response factors (CRF) are updated monthly using the averaged result of the standard samples run the prior month, and are applied to the previous month's data 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) was 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 after each set of 24 ambient samples. Zero air is generated from a Thermo Scientific T111 Zero Air Supply followed by Sofnofil and Charcoal scrubbers.

Table 2: 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 two isomers are therefore reported at the sum of both.

All 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 3. 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 3: VOCs lower detection limits.

VOC	LDL Value (ppb)
ethane	0.023
ethene	0.022
propane	0.015
propene	0.016
i-butane	0.012
n-butane	0.011
acetylene	0.032
i-pentane	0.009
n-pentane	0.009
1,3-butadiene	0.012
n-hexane	0.008
isoprene	0.011
n-heptane	0.007
benzene	0.008
2,2,4-trimethylpentane	0.006
n-octane	0.006
toluene	0.007
ethyl-benzene	0.006
m&p-xylene	0.006
o-xylene	0.007
1,3,5-trimethylbenzene	0.006

VOC data corrections:

Zero-air blank subtractions

Blank peak area subtractions are determined using the mean peak area of zero air runs during a particular time window if 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 subtraction values and dates are provided in Table 4.

These peak area subtractions have been applied and are accounted for in the data set.

Table 4:

Compound	Start date (UTC)	End date (UTC)	Peak area subtraction	Approximate mixing ratio (ppb)
ethane	2/01/22 00:00	11/01/22 23:30	-1.0	0.147
ethane	11/02/22 00:00		-0.5	0.074
propane	2/01/22 00:00	7/31/22 23:30	-2.0	0.209
propane	8/01/22 00:00	9/07/22 23:30	-0.2	0.021
propane	9/08/22 00:00	11/01/22 23:30	-1.0	0.105
propane	11/02/22 00:00	12/01/22 23:30	-0.5	0.052
propane	12/02/22 00:00		-0.2	0.021
benzene	2/01/22 00:00	2/17/22 06:30	-2.0	0.113
benzene	2/17/22 07:00	3/05/22 13:30	-1.5	0.085
benzene	3/05/22 14:00	5/24/22 23:30	-1.0	0.057
benzene	5/25/22 00:00	8/01/22 23:30	-0.8	0.045
benzene	8/02/22 00:00	9/27/22 23:30	-0.3	0.017
benzene	9/28/22 00:00		-0.2	0.011
toluene	2/01/22 00:00	3/05/22 13:30	-1.00	0.048
toluene	3/05/22 14:00	7/14/22 23:30	-0.50	0.024
toluene	7/14/22 00:00	8/16/22 23:30	-0.35	0.017
toluene	8/17/22 00:00	9/07/22 23:00	-0.25	0.012
toluene	9/08/22 00:00		-0.15	0.007