

Metadata for Atmospheric Measurements at the Longmont Lykins Gulch (LLG)

Monitoring station

Boulder A.I.R.

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Site location

40.1615 N, 105.1443 W, 1526 m asl (5008 ft asl)

The station facility is a climate-controlled, insulated trailer approximately 12 ft long x 8 ft wide x 8 ft tall. Four meters adjacent to 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 an RM Young Wind Monitor AQ, 05305-PT, mounted on the meteorological tower at 9.1 m height. 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 19 November 2021. The wind speed sensor had <0.2% error for both clockwise and counterclockwise directions across all audited wind speeds. The wind direction sensor and vane alignment had <3.7 degrees error for all wind directions. 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, 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 9.1 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 1.1 degrees C (passing is <2 degrees C), and relative humidity having a 0.6% 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%.

Solar radiation

Incoming solar radiation is monitored with an Apogee SP-110-SS pyranometer on the meteorological tower at 9.0 m height above the surface. The sensor dome is cleaned every 2 months.

Ozone (O₃)

Ozone is recorded with a Thermo Fisher Scientific model 49C UV absorption monitor. Ambient air is sampled from an inlet mounted at 8.6 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 was last referenced against an 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 ppb, 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. From calibration check performance, the following correction has been applied to the data:

Start	End	Slope	Intercept
05/30/2022 20:45 UTC	10/13/2022 21:33 UTC	1.016	-0.4

An audit of the 49C monitor was performed by CDPHE on 19 November 2021. The instrument passed all audit criteria with a calibration agreement slope 0.972 and an offset of 0.555 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.

Carbon Dioxide (CO₂)

Carbon dioxide is monitored with a Picarro G2301 cavity ring down spectrometer. Ambient air is sampled at 400 scc/min from an inlet at 8.6 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. Sample air is dried immediately before the instrument sample port using Nafion tubing with counterpurge flow dried

with Drierite to between 0.08% and 0.09% H₂O, a dewpoint of around -27 °C. A Nafion dryer was added in the sampling line to remove water 05/2024.

The manufacturer's calibration settings are applied. Calibration checks are conducted every 49 hours by introducing in sequence two NOAA certified calibration gases that are referenced against the NOAA Global Monitoring Laboratory CO₂ scale (598.46 ppm CO₂, 389.73 ppm CO₂). Every 6 months, a calibration check and 5-level linearity check are performed by dynamic dilution of a 4.90% CO₂ primary EPA-grade standard (EPA protocol grade gas, Praxair, production date 06/09/2022) that is diluted 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 0.07% or 0.35 ppm for 1-minute data and was assessed within the range of 389.73 ppm to 598.46 ppm. 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 CO₂ data in October 2024. This correction is calculated and applied biannually thereafter to maintain accuracy and minimize deviations.

Methane (CH₄)

Methane is monitored with a Picarro G2301 cavity ring down spectrometer. Ambient air is sampled at 400 scc/min from an inlet at 8.6 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. Sample air is dried immediately before the instrument sample port using Nafion tubing with counterpurge flow dried with Drierite to between 0.08% and 0.09% H₂O, a dewpoint of around -27 °C.

The manufacturer's calibration settings are applied. Calibration checks are conducted every 49 hours by introducing in sequence two NOAA certified calibration gases that are referenced against the NOAA Global Monitoring Laboratory CH₄ scale (3049.8 ppb CH₄, 1823.2 ppb CH₄). Every 6 months, a calibration check is performed with an 1852.18 ppb CH₄ 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 CH₄ 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 4.83 ppb or 0.20% for 1-minute data and was assessed within the range of 1823.2 ppb to 3049.8 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.