Boulder A.I.R. L.L.C; 2820 Lafayette Dr., Boulder, CO 80305, U.S.A.; dh.bouldair@gmail.com

March 12, 2025

To:

City of Longmont
350 Kimbark Street
Longmont, CO 80501

Attn: Dr. Jane Turner

Re: Longmont Regional Air Quality Study – Year 2024 Quarters 3 and 4 Report

Dear Dr. Turner,

Please find included with this letter the report for quarters 3 and 4 of 2024 for our work on the Longmont Air Quality Study, covering data from July 1st – December 31st. This report includes graphs with the full monitoring data that were acquired during this period, as well as selected data analyses and interpretations. Please note that all data and analyses presented are preliminary unless otherwise noted.

Thank you for providing this opportunity for air quality monitoring to Longmont citizens and the City of Longmont. We would be happy to discuss any questions that you, other City staff or Longmont citizens may have.

Sincerely,

Detlev Helmig

***Boulder AIR LLC***

# Longmont Air Quality Study Q3 and Q4 2024 Report

**Prepared by Detlev Helmig, Dani Caputi, Jacques Hueber, Susan Simoncic, and Michel Stahli**

*Longmont Lykins Gulch (top) and Longmont Union Reservoir (bottom) monitoring stations.*

# Executive Summary

This report summarizes the data and preliminary findings from the Longmont Air Quality Study. The report includes graphical analyses of all data acquired at the Lykins Gulch (LLG) and Longmont Union Reservoir (LUR) stations during July - December, i.e., Quarters 3 and 4 (Q3 and Q4), 2024. All variables were reported in near-real time on the public Longmont Air Quality Now web portal. Preliminary data comparisons and analyses of selected events that resulted in enhanced concentrations are presented in this report. LLG and LUR data are compared with each other and with concurrent observations from the Boulder Reservoir (BRZ), the Erie Community Center (ECC), Broomfield Soaring Eagle Park (BSE), and Broomfield North Pecos (BNP), collectively referred to as the Front Range Coalition Monitoring Network.

Findings from this period indicate that the 2024 ozone season was exceptionally severe, behind only the 2021 ozone season in terms of number of 70 ppb exceedance days at LUR (34 in 2021 versus 23 in 2024). Additionally, particulate matter pollution exceeded 35 µg/m$^3$ during August 1$^{st}$ – 2$^{nd}$ at LUR, when peak and 1-minute and 24-hour PM 2.5 values of 218 and 55 µg/m$^3$ were recorded. There were several additional periods with elevated PM2.5 levels, likely influenced by wildfire smoke, during summer and autumn months. The report also underscores the persistence of chemical plumes with highly elevated petroleum hydrocarbon pollution, including elevated levels of benzene, further emphasizing the continuing occurrences of oil and natural gas emissions.

## Table of Contents

## 1. Project Scope and Goals

No changes from the 2024 Q1-2 report.

## 2. Overview of the Monitoring Program

No changes from the 2024 Q1-2 report.

## 3. Air Quality Monitoring Study Updates

Observations from this air monitoring program is now being utilized by the Regional Air Quality Council (RAQC) in their chemical modelling. See section 6 for further details.

A manuscript titled "Late Winter Ozone and PM 2.5 NAAQS Exceedance in the Northern Colorado Front Range in Relation to Oil and Natural Gas Emissions" is currently under peer-review with the Journal of Geophysical Research. The study analyzes an anomalous off-season high ozone event in March 2021. The Longmont data were integral to this study, as the spatial extent and severity of the episode was only recognized thanks to the data that were recorded with the monitoring stations in place. During this event, the second highest 24-hour average levels of fine particulate matter (PM 2.5) pollution in the entire history of the LUR station was observed. Upon publication, we expect this article to improve the understanding of how oil and gas activities are impacting air quality in the NCFR, as it demonstrates that oil and gas emissions and meteorological conditions can amplify ozone levels not only in the summer but year-round.

A number of grant proposals have been developed by Boulder AIR and partnering researchers building on the Broomfield data for in-depth studies of specific aspects of NCFR air quality. These following projects have been awarded:

*"Air Quality Trends in Texas and Colorado as associated with Unconventional Oil and Gas Development (UOG)"; submitted by Texas A&M University and Boulder AIR, with funding received from the Health Effects Institute (HEI), 2024.*

*"Comprehensive Ozone Source Location Analysis"; submitted by the Local Air Monitoring Coalition with funding received by the Colorado Air Quality Enterprise, 2024.*

*"How much of the Denver Metro Northern Front Range Ozone is produced from Isoprene?"; submitted by Boulder AIR with funding received by the Colorado Air Quality Enterprise, 2024.*

## 4. Data Quality Assurance/Quality Control Process

### *4.1. Longmont Union Reservoir (LUR)*

#### *4.1.1 Picarro ($CO_2$ and methane)*

The 6-month linearity check was performed on December 9, 2024. No other service was required on the instrument.

#### *4.1.2. GRIMM (Particulate Matter, PM)*

The new GRIMM had the 6-month maintenance and testing on December 8, 2024, and passed all system flow tests, and 2.5 µm and 1.0 µm standard tests.

*4.1.3. Wind vane*

The 6-month testing of the RM Young wind vane occurred on September 6, 2024. The wind vane passed all wind direction and speed tests, using the same procedures and equipment as for a CDPHE audit.

*4.1.4. Ozone*

Quarterly calibration checks through the tower inlet were performed on September 5, 2024, and December 9, 2024. All checks passed. A yearly calibration check of the ozone monitor against an EPA-certified standard was performed on September 3, 2024. The calibration check passed (slope between 0.98 – 1.02 and intercept <1 ppb), and no recalibration was necessary. The site calibrator was replaced on December 31, 2024, with another calibrator that was previously serviced and recalibrated against an EPA-certified standard.

*4.1.5. $NO_x$*

$NO_x$ quarterly calibrations were done on September 29, 2024, and December 06, 2024. Small adjustments were made to the zero and span settings.

*4.1.6. Volatile Organic Compounds (VOCs)*

The adsorbent trap thermo-electric coolers were replaced on October 30, 2024, to maintain proper adsorbent trap cooling performance. The adsorbent trap was replaced on December 13, 2024, to correct for a slight drop in the response for heavier VOCs (>= $C_6$) that was observed on the previously used trap.

### *4.2. Lykins Gulch (LLG)*

*4.2.1. Picarro ($CO_2$ and methane)*

The 6-month linearity check was performed on December 20, 2024. No other service was required on the instrument.

*4.2.2. Wind vane*

The 6-month testing of the RM Young wind vane occurred on September 4, 2024. The wind vane passed all wind direction and speed tests, using the same procedures and equipment as a CDPHE audit.

*4.2.3. Ozone*

Quarterly calibration checks through the tower inlet were performed on September 7, 2024, and December 6, 2024. All checks passed. A yearly calibration check of the ozone monitor against an EPA-certified standard was performed on December 6, 2024. The calibration check passed (slope between 0.98 –

1.02 and intercept <1 ppb), and no recalibration was necessary. A yearly calibration check of the site calibrator against an EPA-certified standard was performed on December 6, 2024, and the calibration check passed. A small adjustment in the calibration factors were made. The temperature inside both the LLG and LUR monitoring stations has remained stable throughout Q3 and Q4. No air conditioning issue was detected.

## 5. Website Development

A core component of Boulder AIR's mission is to provide high quality atmospheric pollutant monitoring data with full transparency and open access. As such, the Boulder AIR website is a cornerstone of data dissemination and public outreach.

As of February 20th 2025, the *Longmont Air Quality Now* webpage (https://www.bouldair.com/longmont.htm) has received a total of 45,058 views. Data from the Longmont air monitoring sites are also included for data comparisons with up to five other monitoring programs on the *AirLive* Combined Data Graphs website (https://www.bouldair.com/NoCoFrontRange.htm), which has received 18,354 visits as of February 20th, 2025.

## 6. Data Archiving and Sharing

LUR VOC data and meteorology data through 2022 (newly included 2021 and 2022) were accepted into the EPA's Ambient Monitoring Archive (AMA) for the Hazardous Air Pollutants (HAPs) in November 2023 and are now publicly posted and available at this link: https://www.epa.gov/amtic/amtic-ambient-monitoring-archive-haps.

LUR 2021 – 2023 VOC data were submitted to the EBAS archive on Nov 25, 2024. They have been accepted into the EBAS archive and are available at this link: https://ebas-data.nilu.no/. Note that the EBAS archive only stores hourly averages of the data.

LUR 2020 – 2023 $NO_x$ data were submitted to the EBAS archive on Sep 13, 2024. They have been accepted into the EBAS archive and are available at this link: https://ebas-data.nilu.no/. Note that the EBAS archive only stores hourly averages of the data.

LUR 2020 – 2023 meteorological data were submitted to the EBAS archive on Aug 28, 2024. They have been accepted into the EBAS archive and are available at this link: https://ebas-data.nilu.no/. Note that the EBAS archive only stores hourly averages of the data.

In October 2024, data from the Longmont air monitoring program were provided to the Regional Air Quality Council (RAQC) to be used in their State Implementation Plan (SIP) chemical modelling. As of December 2024, ozone, $NO_x$, and VOC data are being used to create the 2022 modelling base year, for predicting future emissions based on population and policy changes. This will result in much higher spatial and temporal resolution chemical ozone modeling and more accurate prediction of ozone production to inform future policies for bringing the NCFR in compliance with the ozone NAAQS.

2023 summer data were shared with the National Center for Atmospheric Research (NCAR) for use in MELODIES-MONET (https://www2.acom.ucar.edu/modeling/melodies), a tool for SIP evaluation.

## 7. Data for Quarters 3 and 4, 2024

The data that were recorded in Q3 and Q4, 2024, are included in this report in graphical time series format in Supplement A (LUR) and Supplement B (LLG). In Supplement C, the variables that are measured at both sites are shown together in a set of time series graphs. These graphs provide the records of the completeness of the data coverage and general features in the dynamic, diurnal, and seasonal changes. Data coverage for all variables were >95% for the full quarter.

## 8. Boulder A.I.R. Presentations

During Q3 and Q4, 2024, there were eight Boulder A.I.R. presentations in which Longmont monitoring results were included, discussed below.

The following three presentations were given at the American Geophysical Union 2024 Fall Meeting in Washington D.C., December 9th – 13th, 2024:

*Highly Elevated Atmospheric Methane from Oil and Natural Gas Emissions in Loving, NM*

*Atmospheric Radioactivity in Loving, NM, and its Relationship to Oil and Natural Gas Development in the Permian Basin*

*Southeast New Mexico has Become the Second Most Polluted Ozone Region in the U.S. due to Oil and Gas Emissions.*

On October 28th, 2024, Dr. Detlev Helmig presented to the New Mexico Water and Natural Resources Committee: *Assessing source contributions to air quality in southeast New Mexico.*

Dr. Helmig also presented at the 18th International Global Atmospheric Chemistry conference, September 9th – 13th, 2024 in Kuala Lumpur, Malaysia. The presentation was titled: *The Dirtiest Zip Code in the U.S.?*

Dr. Gunnar Schade presented to the New Mexico Radioactive and Hazardous Materials Committee on September 13th, 2024. The presentation was titled: *Selected Results from Air Quality Research in the Carlsbad, NM area.*

Dr. Schade also presented at the American Chemical Society Fall Symposium on August 18th, 2024. The presentation was titled: *Seasonal Methane Measurements in the Western Permian Basin, Loving, NM*.

On November 16th, 2024, Dr. Schade, Dr. Lara Cushing, and Dr. Dani Caputi presented at a local community workshop in Carlsbad, NM: *Air Quality Research in the Loving, NM Area*.

## 9. Selected Data Examples and Preliminary Interpretations

### *9.1. Ozone*

Ozone is not a directly emitted pollutant. It is formed in the atmosphere by a chain of photo-chemical reactions that involve sunlight, nitrogen oxides, and VOCs, which therefore are considered crucial precursor emissions that impact ozone production and maxima, and degradation of air quality. The NAAQS for the maximum daily 8-hour average ozone mixing ratio (MDA8 $O_3$) was lowered to 70 parts per billion (ppb) in 2015 in recognition of the insufficient protection of human health with the previous standard that was set to 75 ppb in 2008. In 2022, the Northern Colorado Front Range (NCFR) was further downgraded to a *severe* nonattainment area for the 2008 NAAQS standard (after previously having been designated a *serious* nonattainment area for ten years) because of the continuing high summertime ozone conditions and lack of air quality improvements. Ozone monitoring data over 8 hours are averaged and truncated, therefore, 8-hour average mixing ratios must be >70.9 ppb and >75.9 ppb to be considered above the 2015 and 2008 standards, respectively. Attainment to the standard is determined by the 3-year mean of the $4^{th}$-highest 8-hour average, which is referred to as the ozone Design Value. Both standards are observed by the EPA when designating non-attainment status to urban areas or air basins.

The full Q3 and Q4, 2024 ozone records for LUR are presented in Figures SA13 – 16, and in Figures SB13 – 16 for LLG. Table 1 shows the $1^{st}$ through $5^{th}$ highest MDA8 $O_3$ values in years 2022-2024 in Longmont, along with other sites where ozone is monitored within the Front Range Coalition network. The 2024 ozone season has been particularly problematic. Behind 2021, it has been the second worst season in the 6 years of air monitoring conducted by Boulder AIR. In 2024, there were 23 days when the 70 ppb MDA8 $O_3$ standard was exceeded at LUR, and 18 days at LLG. The highest MDA8 $O_3$ during 2024 measured at LUR was 91.7 ppb, i.e. 21.7 ppb above the NAAQS. The 2022-2024 ozone design value at LUR and LLG are 78.7 and 77.3 ppb, respectively, which exceeds both the 2008 (75 ppb) and 2015 (70 ppb) ozone NAAQS, and therefore places Longmont in non-compliance with the Clean Air Act (Table 2). The 2022-2024 design value at LUR is higher than the values at all other stations within the Front Range Coalition network, and the $4^{th}$ highest of all sites where ozone is monitored in Colorado within the Public Health and Environment (CDPHE) and Environmental Protection Agency (EPA) networks.

Figure 1 presents a statistical analysis of the full Q3-Q4 one-minute resolution ozone data from the Longmont stations, compared to data from ECC and BSE. The highest ozone at each station was observed in July, with mean values of 50 – 60 ppb and upper quartile values of nearly 70 ppb, i.e. the 2015 ozone standard. The decrease in the number of daylight hours resulted in a decrease in ozone measured at each station during subsequent months through November. One interesting feature of the winter ozone data is the $5^{th}$ percentile values in November and December at LUR approaching 0 ppb, which is not seen at LLG or BSE. This is likely due to the low elevation of Longmont Union Reservoir enabling nitric oxide emissions from surrounding residential areas to pool into the area at night, resulting in ozone depletion events.

### *9.2. Carbon Dioxide*

The full Q1 and Q2, 2024 $CO_2$ records are available in Figures SA9-10 for LUR and SB9-10 for LLG. The statistical comparison of the one-minute resolution monitoring data is presented in Figure 2.

From July to October, $CO_2$ levels at LLG and LUR were similar. However, in November and December, LUR recorded mean $CO_2$ levels about 10 ppm higher and $95^{th}$ percentile values about 30 ppm higher than at LLG. This difference is likely due to the lower elevation of Union Reservoir, where nocturnal drainage flows from the west bring in $CO_2$-rich air. At night, a lower boundary layer traps emissions from the city in that direction, leading to higher concentrations.

Wind analysis (Figure 5) supports this explanation. At LUR, light westerly winds (<3 m/s) correspond with median $CO_2$ levels about 20 ppm higher than those from other wind directions. Meanwhile, LLG, which is located in the eastern part relative to the city, shows $CO_2$ increases from all wind directions, especially in Q4 when atmospheric mixing was weaker.

Updates to the $CO_2$ trend analysis will be provided on a yearly basis, continuing with the next (Q1-Q2 2025) report.

### *9.3. Methane*

Methane and light alkanes (ethane, propane, butane, and pentane) are natural gas constituents that are frequently observed in ambient air within the NCFR in O&NG plumes [1-4]. The global background methane is ≈1.9 parts per million (ppm), and levels exceeding 5 ppm can sometimes be suggestive of plumes that originated from venting, or leaking wells or pipelines. However, it should be noted that methane has additional non-O&NG sources, including landfills, dairy farms, and agriculture [5-8]. Additionally, methane is a potent greenhouse gas that is the second-largest contributor to climate change (after carbon dioxide), and thus its trends are important to track carefully.

The full Q3-Q4 2024 methane records are available in Figures SA11-12 for LUR and SB11-12 for LLG. Methane exceeded 5 ppm three times at LUR (6193 ppb on July 2$^{nd}$ at 2:50 MST, 5936 ppb on August 16$^{th}$ at 18:41 MST, and 6183 ppb on December 8$^{th}$ at 12:53 MST) and twice at LLG (6060 ppb on July 15$^{th}$ at 13:54 MST, and 5325 ppb on October 25$^{th}$ at 18:22 MST). All of these were transient occurrences, with enhancements above background lasting for one hour or less.

The statistical analysis of the full Q3 and Q4 methane data is shown in Figure 4. Higher mean, median, and 95$^{th}$ percentile values of methane were observed at LUR compared to all other sites in the Front Range coalition network for July – September by 40 – 120 ppb. From October – December, methane observed at ECC exceeded that of LUR, but LUR methane still exceeded the values recorded at all other sites by similar amounts as in Q3. As seen with most other pollutants, the onset of the colder temperatures in winter months resulted in less atmospheric mixing and thus higher methane concentrations. Heat map analyses for LLG and LUR methane data are shown in Figure 5. Methane exceeding the global background was transported to LLG mainly from the east sector, and to LUR mainly from the northeast sector.

Updates to the methane trend analysis will be provided on a yearly basis, continuing with the next (Q1-Q2 2025) report.

### *9.4. Volatile Organic Compounds*

The monitoring of VOCs is important for several reasons. Along with nitric oxides, they are an important precursor to ozone formation. Additionally, it allows an easier differentiation between O&NG and non-O&NG sources of pollution.  Some VOCs, e.g. benzene, are also harmful to human health.

Unlike methane, which has many source categories, ethane is a more selective tracer of emissions from O&NG operations [9-12]. In addition to ethane, the influence of O&NG operations on chemical composition in atmospheric plumes can be inferred from an analysis of the ratio of two VOCs, specifically that of isomeric *i*/*n*-pentane, as ratio values characteristic of O&NG emission sources typically fall between approximately 0.75 and 1.2 [9-12].

Another important VOC is benzene. While not an O&NG tracer, benzene is one of the most widely studied hydrocarbons, and the EPA designates it as a pollutant that from inhalation can cause chronic health effects and cancer [13-15]. For benzene, Boulder AIR uses a 0.9 ppb threshold for sending automated air quality alerts. It corresponds to the California Office of Environmental Health Hazard Assessments maximum threshold at which there are no known non-cancerous chronic health impacts if an individual breathes this amount of benzene for up to a lifetime.

The full Q3 and Q4, 2024 LUR records for nine selected VOCs are available in Figures SA17-34. There was one event when ethane exceeded 60 ppb, which occurred on December 1$^{st}$ and spanned three hourly observation samples (03:00 – 05:10). Ethane during these three VOC observations ranged from 69.7 –

77.3 ppb, and propane ranged from 53.6 – 62.1 ppb. Butanes and pentanes show smaller enhancements of approximately twice background levels during this period, and enhancements of heavier alkanes did not occur. The isomeric pentane ratio during these observations fell in a very narrow range of 0.99 – 1.03, which suggests a raw oil source of this anomalous VOC plume. Winds were variable but averaged westerly, between 0 – 2 m/s.

There were three events when benzene exceeded 0.9 ppb during the report period. The first event was on August 1st between 03:00 – 06 :10, when benzene ranged from 1.15 – 2.51 ppb. Ethane reached up to 18.8 ppb which was 4.5 times the August median. A small methane increase was observed during this period, reaching up to 2760 ppb. Winds were due west at 1-3 m/s. The isomeric pentane ratio during these observations ranged from 0.69 – 1.20. Together with the coinciding ethane enhancement, this suggests a possible origin from O&NG emissions.

The second benzene event was observed on August 25th from 02:00 – 02:10 (spanning only one VOC sample), when benzene reached 2.28 ppb. There was no enhancement of methane, ethane, or propane. There was an enhancement of i-pentane to approximately three times background levels, and the isomeric pentane ratio was 5.2. Winds were 1-1.5 m/s from the southwest. The chemical data from this event suggest an origin from a liquid raw hydrocarbon mixture (oil) rather than volatile natural gas.

The third benzene event was observed on October 2nd from 09:00 – 09:10 (spanning only one VOC sample), when benzene reached 0.97 ppb. There was no enhancement of methane, however, all monitored $C_2$-$C_8$ alkanes exhibited significant enhancements. The highest mole fraction was observed for propane, which reached 56.4 ppb, and ethane reached 28.6 ppb. Butanes, pentanes, and n-hexane were all enhanced approximately 30 times above their background levels, and n-octane was enhanced approximately 3 times above its background level. Winds were northeast between 1 – 3 m/s.

The statistical comparison of selected VOCs is plotted in Figures 6 and 7. Throughout the report period, similar means and medians of monthly ethane values were observed at LUR and ECC, which were consistently higher than those of the remaining stations (BNP, BSE, BRZ). The relative difference in means between LUR and BRZ were lowest in July (5% higher at LUR) and highest in December (110% higher at LUR). This result is likely due to a combination of less atmospheric mixing in the winter and a closer proximity to O&NG wells at LUR compared to BRZ. The 95th percentile values of propane were consistently highest at LUR for each month, sometimes exceeding the values of other stations by more than a factor of 2. Mean and 95th percentile benzene values at LUR were similar to those at BSE, but lower than at ECC.

Wind speed/wind direction dependence results for ethane, propane, benzene, and the isomeric pentane ratio at LUR are shown in Figures 8 and 9. Higher ethane and propane values are observed when winds were from the north and east, particularly in Q4. The higher values of benzene are transported to LUR under light (<3 m/s) westerly wind directions. However, there appears to be some transport from the northeast as well, with levels of approximately 2-4 times those observed with southwesterly winds over 5 m/s. The isomeric pentane ratio is clearly distinct when comparing values associated with transport from the northeast (median ratios ranging from 0.9 – 1.1) with transport from the southwest (values > 1.4). The former is associated with O&NG production activity, while the latter is associated with urban emissions.

### *9.5 Nitrogen Oxides*

Nitrogen Oxides include both nitrogen oxide (NO) and nitrogen dioxide ($NO_2$), and these species are grouped together as $NO_x$. These compounds are closely related to ozone pollution in that their atmospheric processing creates ozone during the day. Conversely, NO can destroy ozone at night [16, 17].

The Q3 and Q4 LUR records for NO and $NO_x$ are shown in Figures SA35-38. Figures 10 and 11 show the statistical analyses for NO and $NO_x$. The mean and 95$^{th}$ percentile values of NO were higher at LUR compared to BSE for all months, and this difference became more pronounced with the onset of winter. The data are highly skewed, with 95$^{th}$ percentile values each month exceeding the medians by a factor of 20-30. Higher $NO_x$ was also observed at LUR compared to BSE and BRZ, with this difference also becoming more striking as winter approached. In November and December, the mean $NO_x$ at LUR was about 50% higher than at BSE and 100% higher than at BRZ.

Dependency of NO and $NO_x$ on wind direction and wind speed is presented in Figure 12. For both quarters, the highest median values of $NO_x$ are associated with light westerly winds < 3 m/s. This enhancement is most likely due to the proximity of the city of Longmont to the immediate west of the station, with vehicular emissions contributing to the high values observed. However, particularly in Q4, an enhancement of NO is observed from the east, possibly resulting from fresh emissions in that direction from highways, and/or farming or other industrial equipment.

### *9.6. Particulate Matter (PM)*

Particulate matter consists of tiny solid-phase aerosols suspended in the air. It is classified by particle size, as smaller aerosols can penetrate deeper into the lungs and cause more tissue damage and adverse health effects [18]. In 2006, the US EPA adopted a NAAQS for particulate matter of 10 micrometers or smaller in diameter (PM 10) of 150 micrograms per cubic meter ($\mu g/m^3$), and 35 $\mu g/m^3$ for PM 2.5, both for PM data averaged over 24 hours. In February 2024, the annual standard for PM 2.5 was lowered from 12 $\mu g/m^3$ (previously set in 2012) to 9 $\mu g/m^3$ as a compromise between previous standards and the World Health Organization recommendation of 5 $\mu g/m^3$.

Figures SA39-44 give the full July - December record of the particulate measurements PM 10 and PM 2.5 at LUR. During this time, there was one period when the 24-hour average PM 2.5 exceeded 35 $\mu g/m^3$, occurring on August 1$^{st}$ – 2$^{nd}$. During these days, peak 1-minute and 24-hour values of 218 and 55 $\mu g/m^3$ were recorded, and PM 10 reached a peak 1-minute value of 481 $\mu g/m^3$. This event was likely driven by smoke and haze originating from a small wildfire approximately 30 km west of Fort Collins. It is important to highlight that Longmont recorded the highest PM 2.5 levels during this event and was the only station with observations that exceeded the NAAQS. No other Front Range Coalition sites that monitor PM (ECC, BSE) recorded exceedances during this period, nor were there any other instances in Q3-Q4 2024 when the NAAQS was exceeded elsewhere but not at LUR.

Two other periods with elevated, but not NAAQS-exceeding PM 2.5 were noted. From July 22$^{nd}$ – 26$^{th}$, daily-averaged PM 2.5 ranged between approximately 20 – 30 $\mu g/m^3$, with short occurrences of PM 2.5 and PM 10 up to 82 $\mu g/m^3$ and 316 $\mu g/m^3$, respectively. Then, from October 1$^{st}$ – 10$^{th}$, 24-hour PM 2.5 values ranged from 10 – 30 $\mu g/m^3$, with 1-minute peaks up to 60 $\mu g/m^3$. Visible satellite imagery shows regional haze and light wildfire smoke descending from Canada during the July enhancement period. The combustion tracers benzene and acetylene were elevated approximately 2 times above background levels. The October enhancement period did not appear to be associated with wildfire smoke, as no smoke was visible on satellite imagery nor were the combustion tracers enhanced above background levels.

Figure 13 shows the comparison of PM 2.5 at BSE with observations at ECC and LUR, binned by month. Typically, summer months have deeper atmospheric boundary (mixing) layers, resulting in lower pollution concentrations than in winter. The PM data seen here defy this trend, with a maximum in July during the fire season. Another interesting observation is that Longmont consistently experienced higher mean PM 2.5 levels compared to Erie and Broomfield, by up to 30%. This may partially be explained by the higher latitude of Longmont, which results in comparatively shorter transport times and dilution from any wildfire smoke that is transported into the region from sources to the north of the Front Range.

## 10. Summary

The Longmont air monitoring program has helped shed light on many air quality concerns in the NCFR, including the severity of the 2024 ozone season. On an average year, only 3 days can exceed an 8-hour running mean of 70 ppb in order to be in attainment with the NAAQS. However, this year, there were 23 and 18 exceedance days observed at LUR and LLG. Several nighttime ozone depletion events were observed at LUR, corresponding with significantly higher levels of $NO_x$ compared to other sites. Elevated ozone can have serious health, environmental, and regulatory consequences. Elevated ozone levels worsen respiratory illnesses like asthma and bronchitis, particularly for vulnerable groups such as children and the elderly [19, 20]. Environmentally, high ozone damages ecosystems by harming forests [21] and decreasing crop yield [22]. If the NCFR fails to lower ozone levels in future seasons, it risks being reclassified to a more severe non-attainment status under the 2015 NAAQS, leading to even stricter emission controls and more regulatory pressure to reduce emissions of ozone-forming pollutants.

One exceedance of the PM 2.5 24-hour NAAQS occurred at LUR, which was likely associated with wildfire smoke. More generally, higher values of PM were observed in summer months this year compared to what has been previously found. Mean PM 2.5 values in July, August, and October exceeded the new 9 $\mu g/m^3$ NAAQS threshold for annual averaged recordings. This is an important finding and raises concerns for citizens as these are months when people spend a significant amount of time outdoors.

This report demonstrates the persistence of chemical plumes commonly associated with O&NG production. The isomeric pentane ratio at LUR shows a clear delineation between the O&NG sector to the east and the urban sector to the southwest. Additionally, three events occurred when benzene exceeded the alert threshold of 0.9 ppb, one of which was likely attributable to an O&NG VOC plume.

# Tables

**Table 1.** 1st through 5th highest MDA8 ozone value for BSE, ECC, LLG, and LUR from January 1st – December 31st, 2024.

| Site Code | Site Name | 1st Max 8-Hour (ppb) | Date 1st Max 8-Hour (ppb) | 2nd Max 8-Hour (ppb) | Date 2nd Max 8-Hour (ppb) | 3rd Max 8-Hour (ppb) | Date 3rd Max 8-Hour (ppb) | 4th Max 8-Hour (ppb) | Date 4th Max 8-Hour (ppb) | 5th Max 8-Hour (ppb) | Date 5th Max 8-Hour (ppb) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LLG | Longmont Lykins Gulch | 90.5 | 08/01 | 90.1 | 07/23 | 87.3 | 07/24 | 86.6 | 07/25 | 85.4 | 07/22 |
| LUR | Longmont Union Reservoir | 91.7 | 07/23 | 91.1 | 07/24 | 88.9 | 08/01 | 85.1 | 07/25 | 85.0 | 07/22 |
| BSE | Broomfield Soaring Eagle | 92.8 | 07/24 | 90.2 | 07/23 | 88.2 | 08/02 | 86.3 | 07/22 | 86.1 | 08/01 |
| ECC | Erie Community Center | 91.2 | 07/24 | 89.3 | 07/23 | 88.0 | 08/01 | 87.1 | 08/02 | 86.5 | 07/22 |

**Table 2.** 4th highest MDA8 ozone value for all stations in Table 1 from 2022-2024, along with the 3-year average of these values (ozone Design Value).

| Site Code | Site Name | 2022 4th Maximum 8-Hour Average Value (ppb) | 2023 4th Maximum 8-Hour Average Value (ppb) | 2024 4th Maximum 8-Hour Average Value (ppb) | 2022-2024 3-Year Average 4th Maximum Value (ppb) |
|---|---|---|---|---|---|
| LLG | Longmont Lykins Gulch | 74.2 | 71.2 | 86.6 | **77.3** |
| LUR | Longmont Union Reservoir | 77.0 | 73.9 | 85.1 | **78.7** |
| BSE | Broomfield Soaring Eagle | 76.1 | 71.5 | 86.3 | **77.9** |
| ECC | Erie Community Center | 77.2 | 70.7 | 87.1 | **78.3** |

# Figures

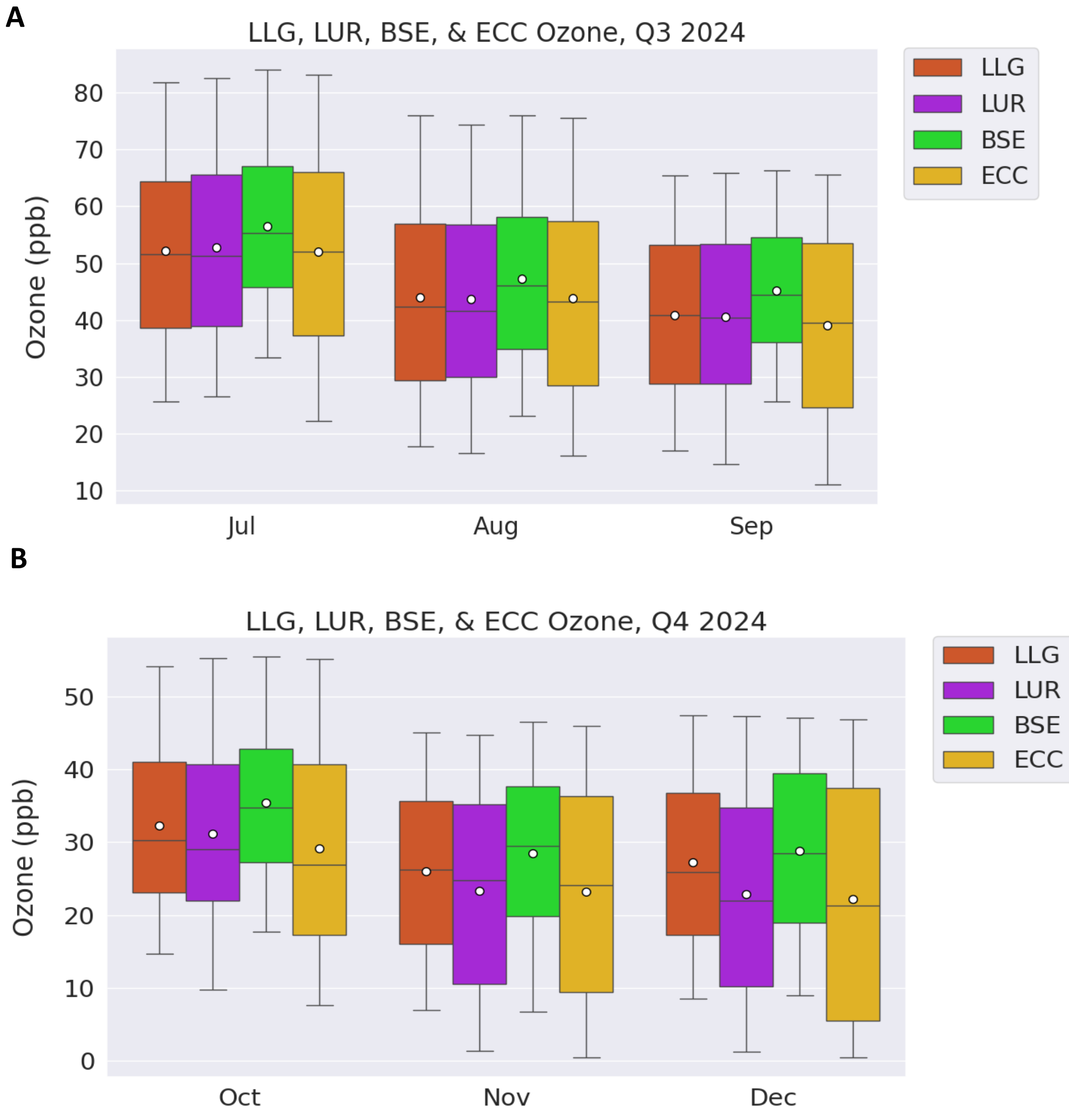



**Figure 1:**
Comparison of the ozone distribution at ECC, LUR, and LLG, during (A) January - March 2024 and (B) April – June 2024. These box whisker plots show the median value as the center line, the 25-75 percentile distribution as the colored boxes, and the 5-percentile and 95-percentile values as the whiskers. The white dot on each box illustrates the mean value at each site.

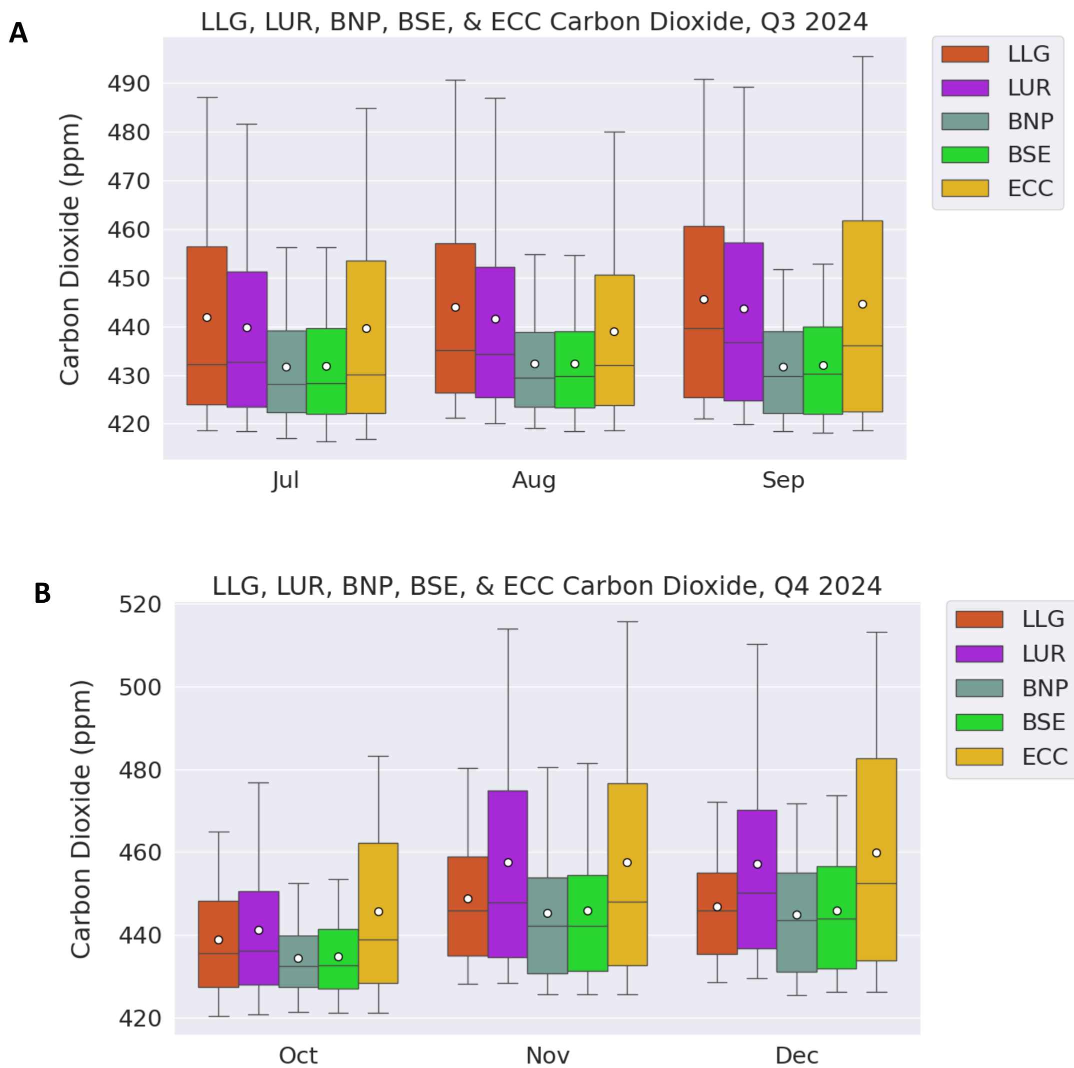



**Figure 2:**
Comparison of the $CO_2$ distribution at LUR, LLG, BNP, BSE, and ECC during (A) Q3 2024, (B) Q4 2024. See Figure 1 for an explanation of box-whisker plot format. Higher levels of CO2 were observed at the Longmont sites (LLG, LUR) compared to Broomfield sites (BNP, BSE) each month.

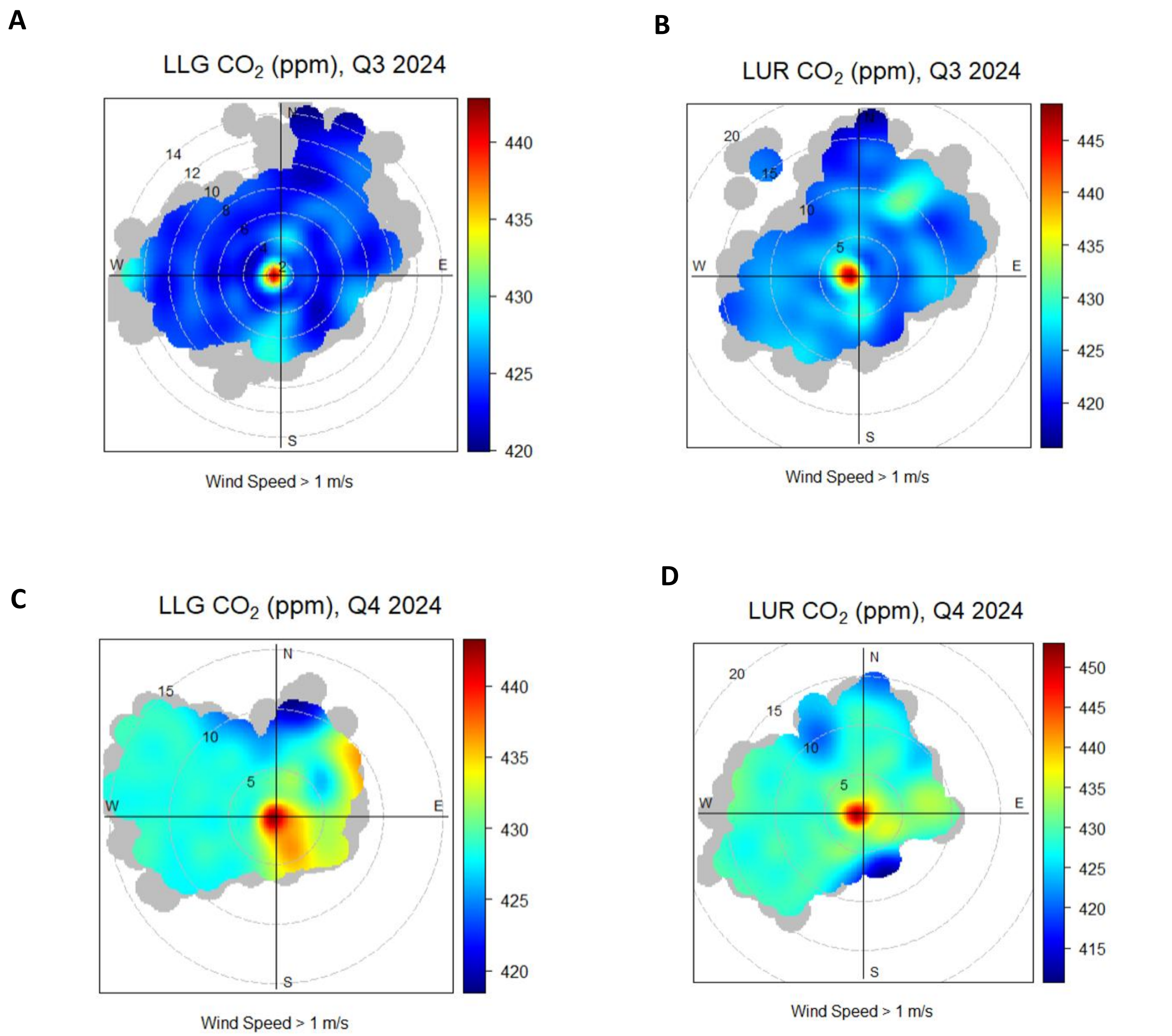



**Figure 3:**
Wind heat map analysis showing the dependency of $CO_2$ mole fractions at (A, C) LLG and (B, D) LUR during Q3-Q4 2024. The dependency of $CO_2$ is shown as a function of wind speed (m/s) and wind direction, with the color scales indicating median $CO_2$ value for a given wind speed and direction. The orientation of the data reflects the wind direction on a 360-degree circular compass, and the concentric rings from the center the wind speed. The color indicates the median observed $CO_2$ in ppm according to the color bar scale in the legend. The LUR site is east of the City of Longmont. These analyses suggest that the city is the primary source for enhanced $CO_2$ observed at LUR.

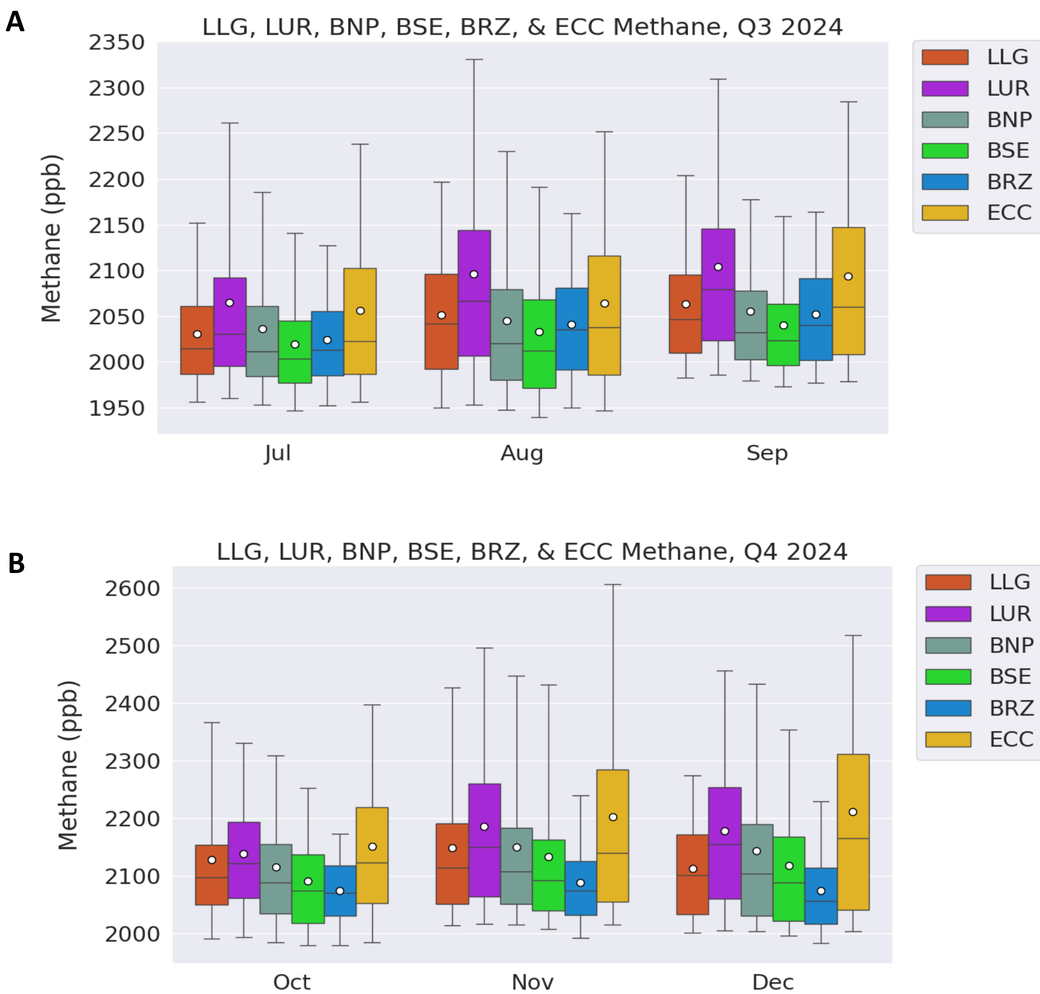



**Figure 4:**
Comparison of the methane distribution at BRZ, ECC, LUR, and LLG, during (A) Q3 2024 and (B) Q4 2024. See Figure 1 for an explanation of box-whisker plot format. Between the two Longmont sites, LUR has higher absolute values and variance.

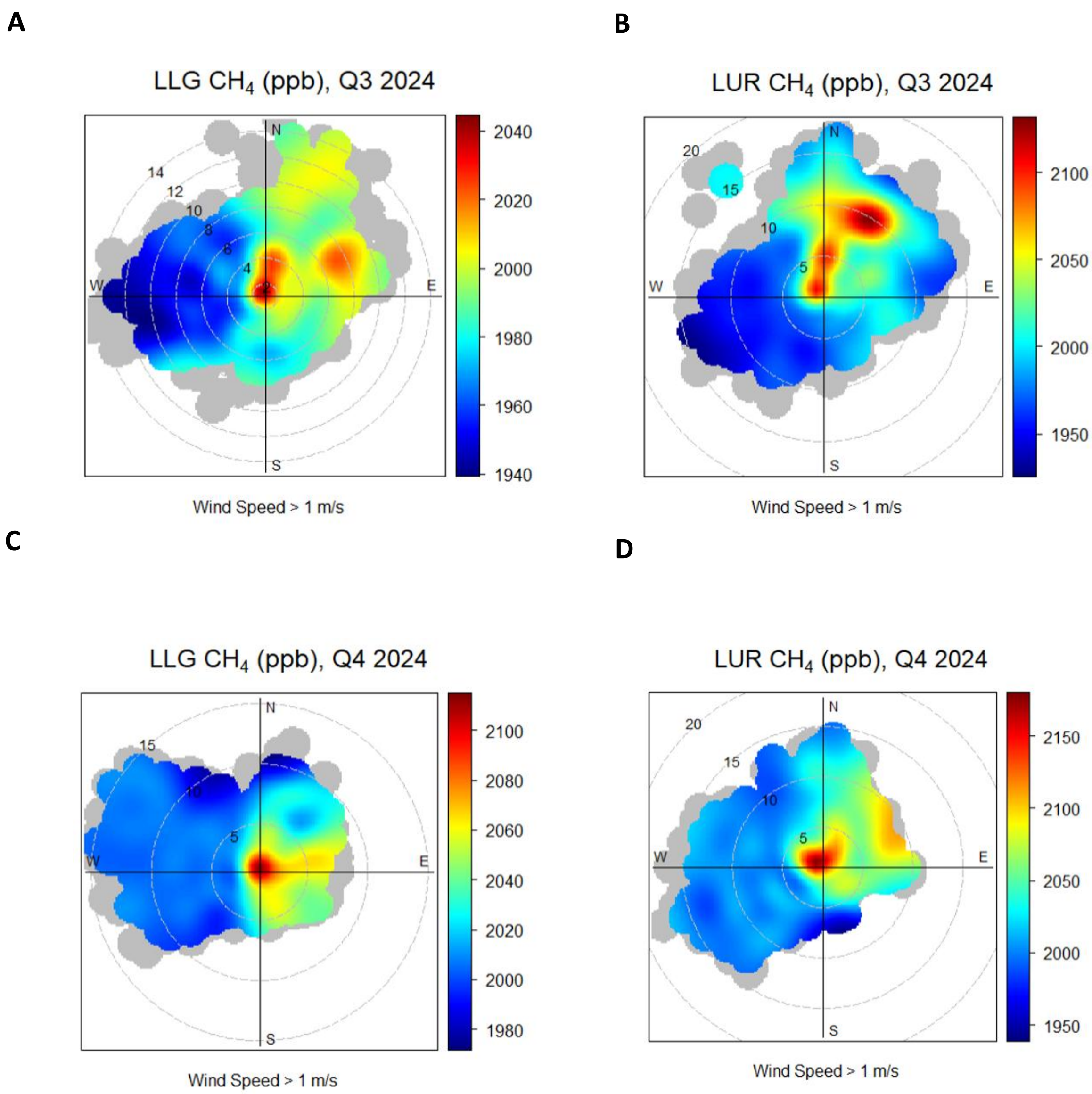



**Figure 5:**
Wind heat map analysis (see Figure 3 for explanation) showing the dependency of methane ($CH_4$) mole fractions at (A, C) LLG and (B, D) LUR during Q3-Q4 2024. Higher values of methane are generally observed when winds are blowing from the east.

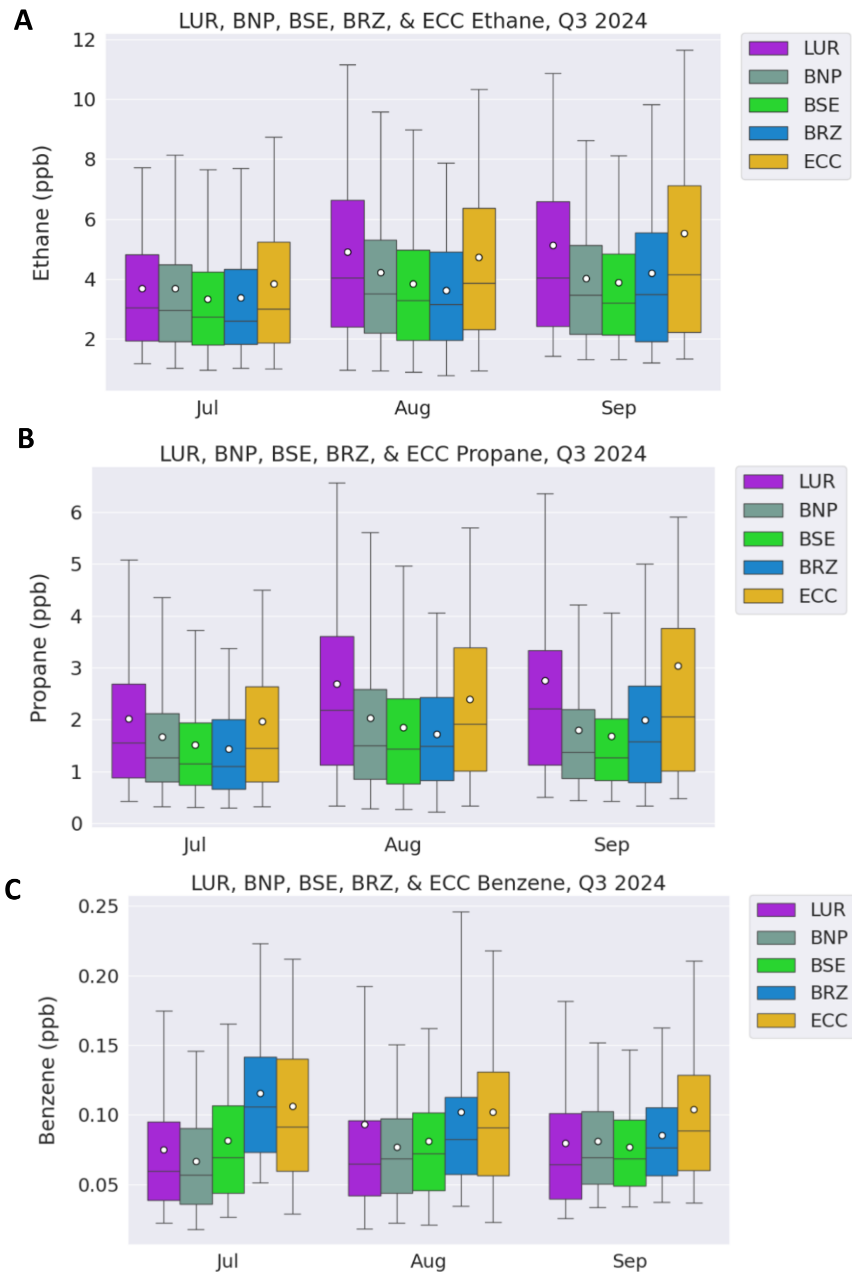



**Figure 6:**
Comparison of the distribution of (A) ethane, (B) propane, and (C) benzene at BRZ, ECC, and LUR during Q1, 2024. See Figure 1 for an explanation of box-whisker plot format. Longmont receives higher levels of O&NG tracers ethane and propane than all Broomfield and Boulder Reservoir.

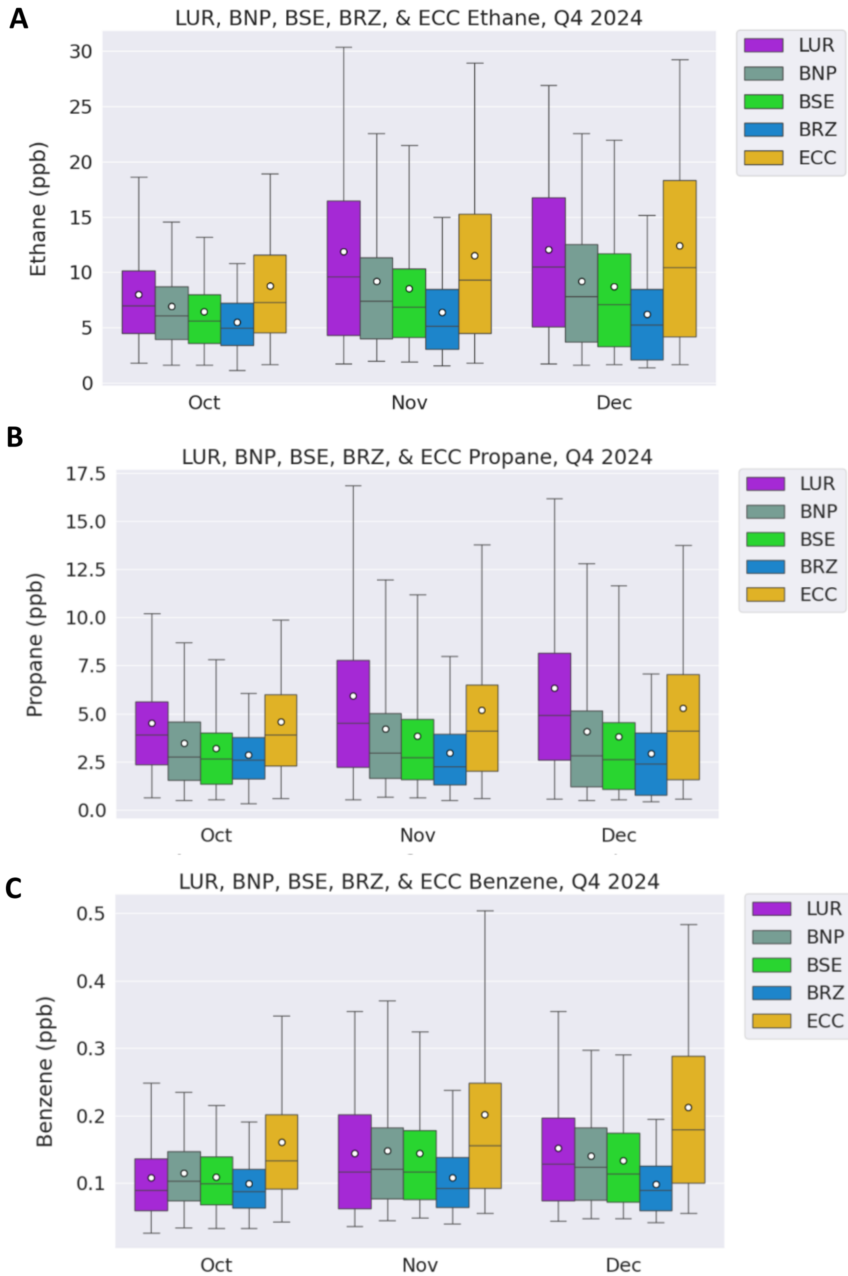



**Figure 7:**
As in Figure 6, except for Q4, 2024.

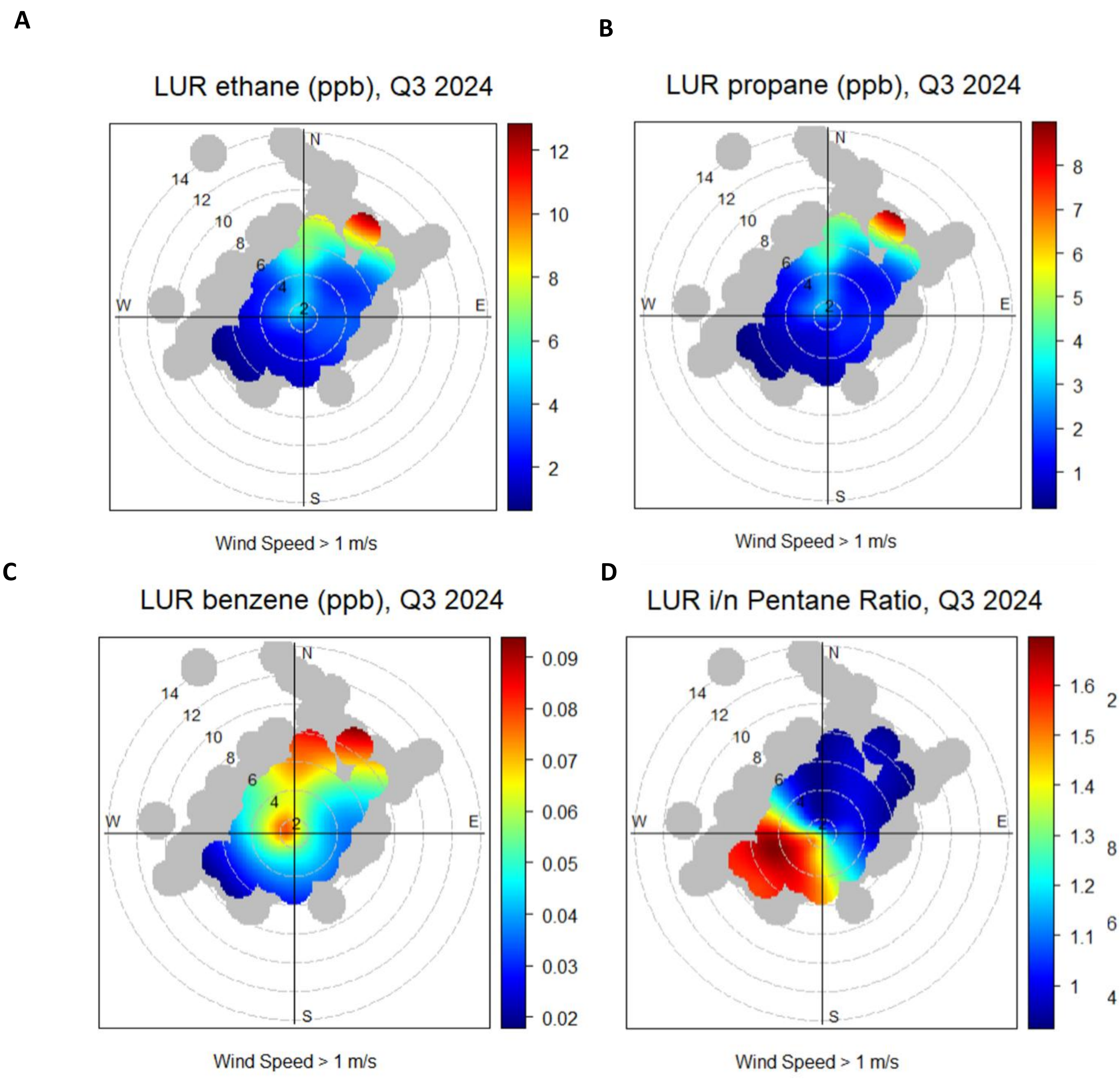



**Figure 8:**
Comparison of (A) ethane, (B) propane, (C) benzene, and (D) isomeric pentane ratio occurrences as a function of wind speed and direction at LUR during Q3 2024 (see Figure 3 for explanation). Particularly in plot (D), a clear delineation is observed between the O&NG sector to the northeast associated with lower values, and the urban sector to the southeast associated with higher values.

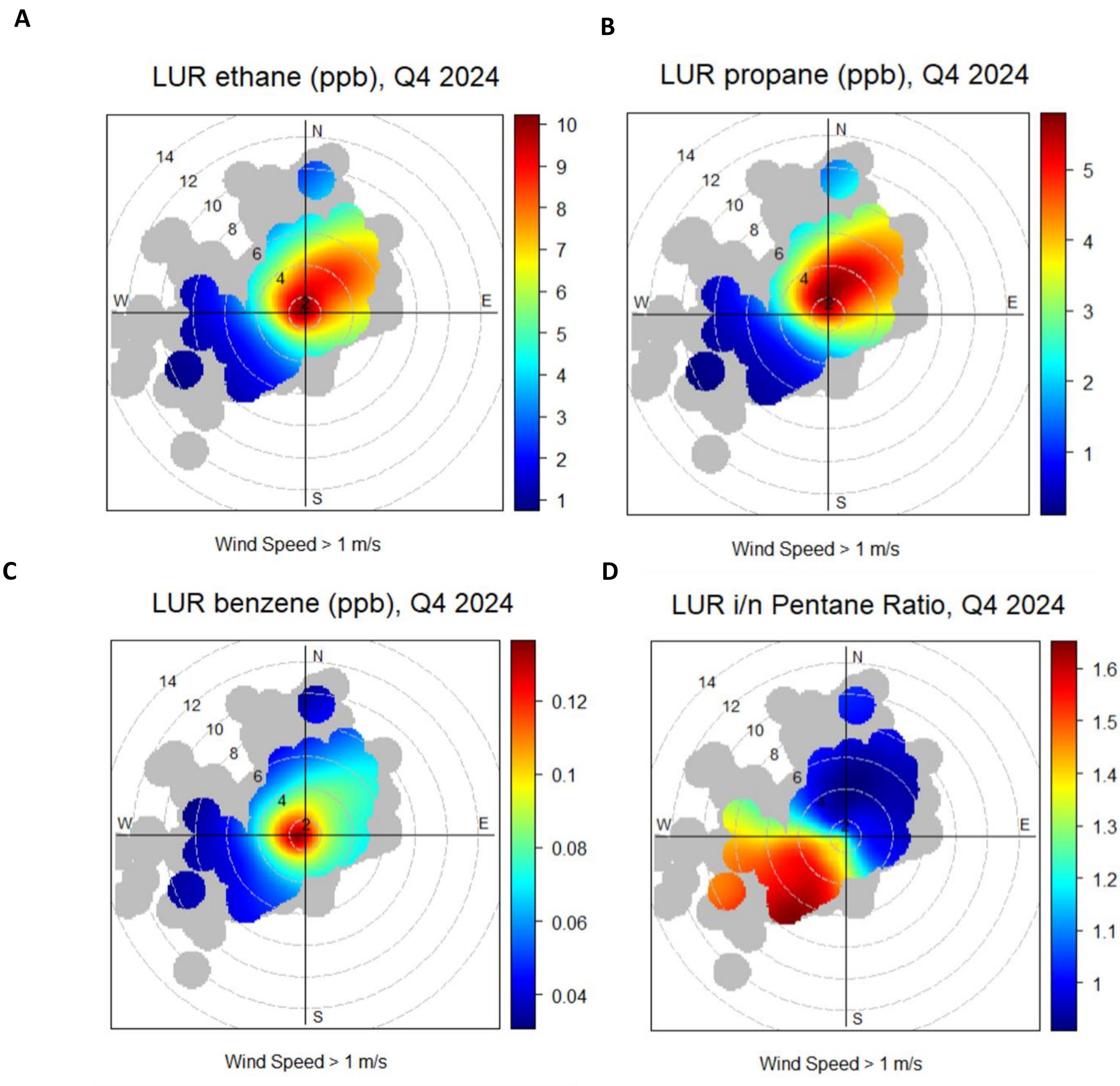
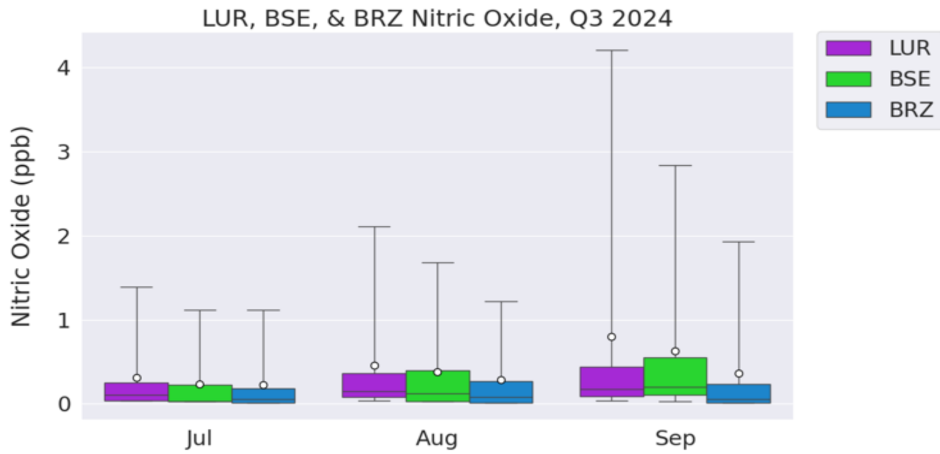



**Figure 9:**
As in Figure 8, except for Q4, 2024.

**A**




**B**

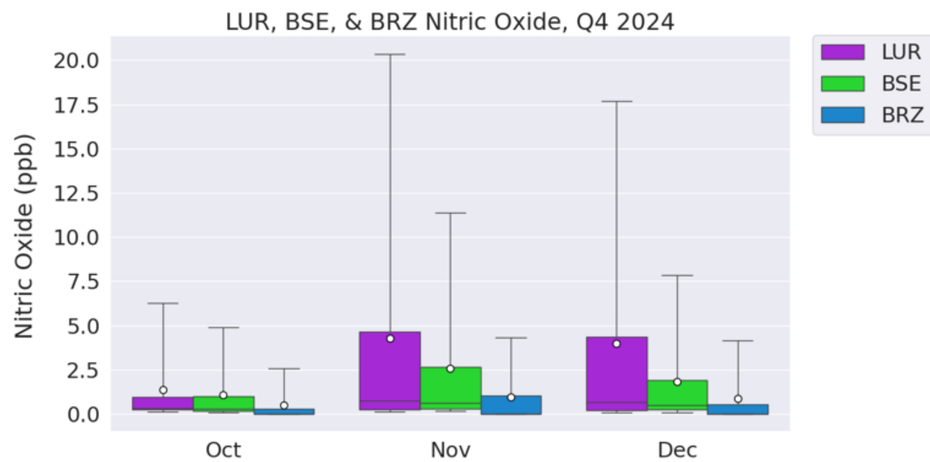



**Figure 10:**
Comparison of nitric oxide at LUR with BRZ and BSE during Q3-Q4 2024. See Figure 1 for an explanation of box-whisker plot format. Higher levels of NO are observed at LUR compared to the other sites.

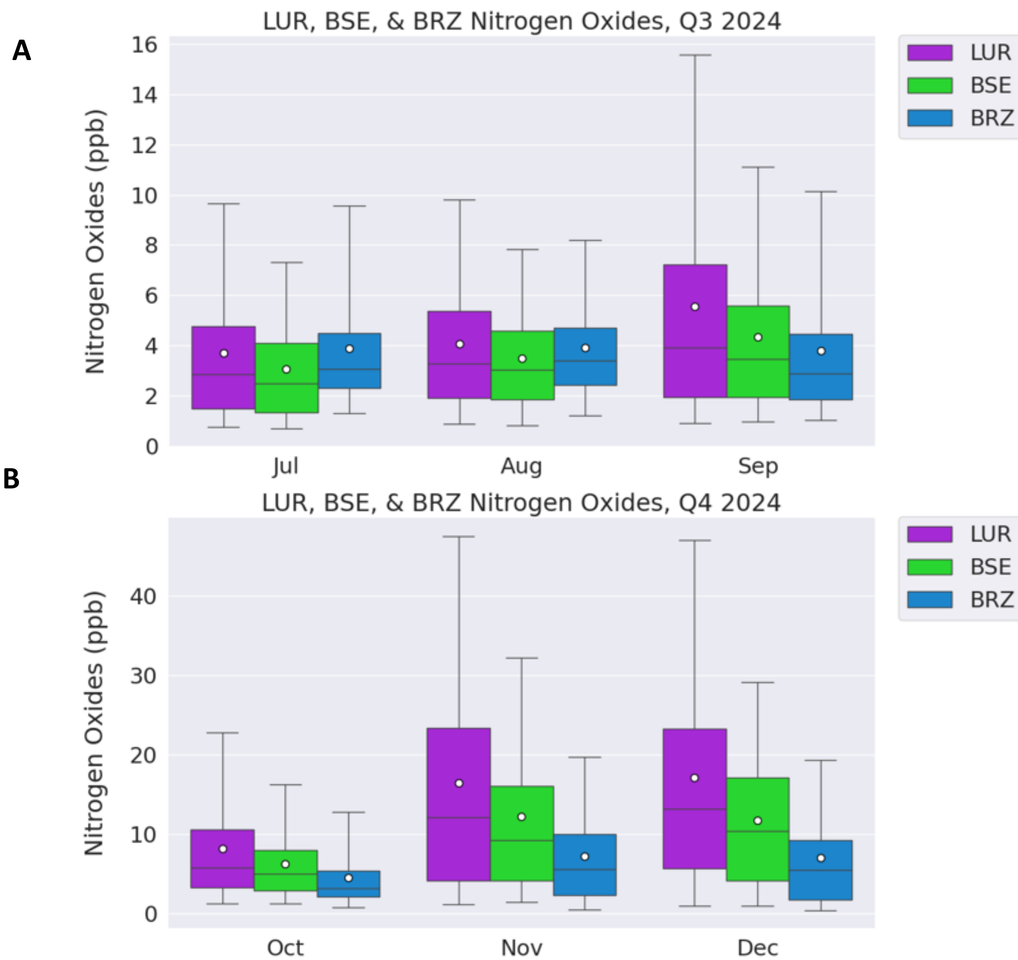



**Figure 11:**
Comparison of nitrogen oxides at LUR with BRZ and BSE during Q3-Q4 2024. See Figure 1 for an explanation of box-whisker plot format. Higher levels of $NO_x$ are observed at LUR compared to the other sites.

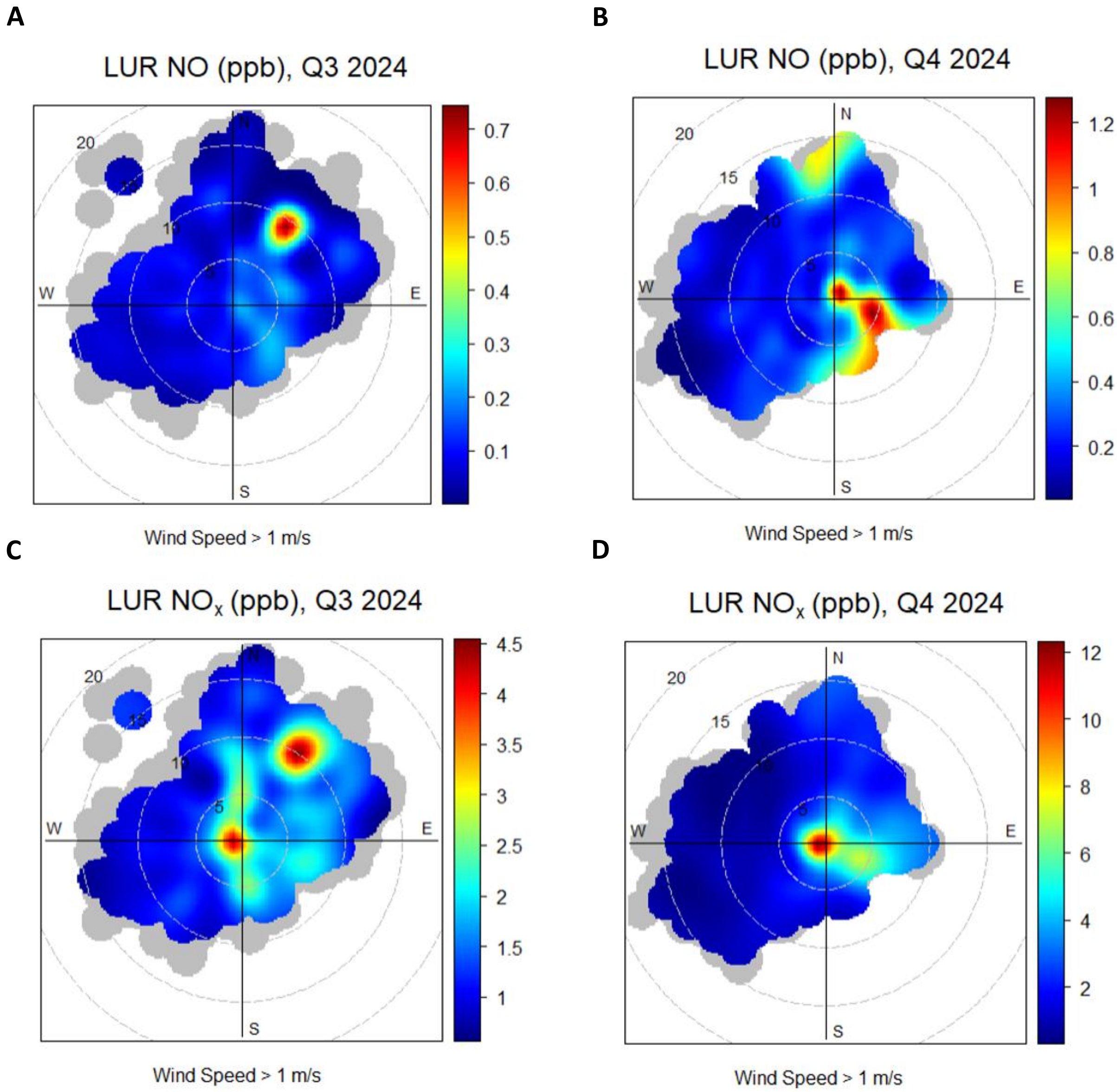



**Figure 12:**
Dependence of (A, B) nitric oxide and (C, D) nitrogen oxides as a function of wind speed and direction at LUR during Q3 – Q4 2024 (see Figure 3 for explanation). The City of Longmont, located to the west of LUR, appears to be the strongest upwind source for $NO_x$.

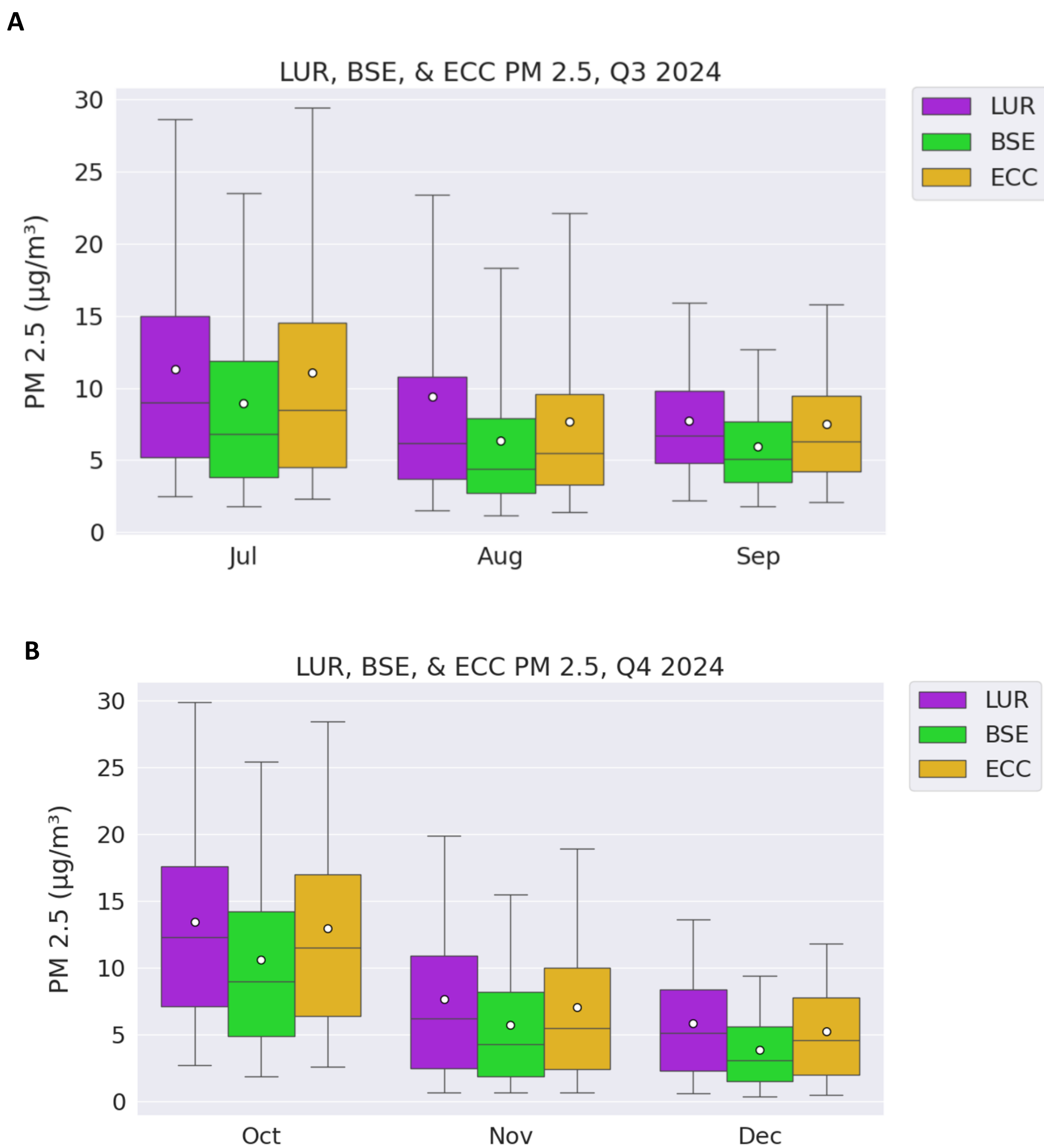



**Figure 13:**
Comparison of (A) PM 10 and (B) PM 2.5 at LUR and ECC, during Q3-Q4 2024. Comparison of nitric oxide at LUR with BRZ and BSE during Q3-Q4 2024. See Figure 1 for an explanation of box-whisker plot format. Longmont receives higher levels of PM pollution that Broomfield.

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