Boulder Atmosphere Innovation Research

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May 31, 2022

To:

City of Longmont
350 Kimbark Street
Longmont, CO 80501

Attn: Dr. Jane Turner

Re: Longmont Regional Air Quality Study – Year 2022 Quarter 1 Report

Dear Dr. Turner,

Please find included with this letter the January – March (Quarter 1) 2022 report for our work on the Longmont Air Quality Study. The monitoring data and data interpretations are presented.

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,

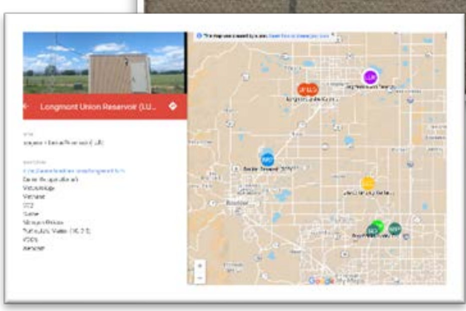
Detlev Helmig

Boulder AIR LLC

2022 Quarter 1 (January – March) Report

Longmont Air Quality Study

LLG after completion of the installation
(Photo by Jacques Hueber)



New interactive Boulder A.I.R. station map ([Boulder A.I.R. Network Stations - Google My Maps]). Click on a station to find out what measurements occur there.

Executive Summary

This report summarizes the data and preliminary findings from the Longmont Air Quality Study during January through March of 2022. All variables were reported in near-real time on the public *Longmont Air Quality Now* web portal.

This report includes graphical analyses of all data acquired at the Lykins Gulch (LLG) and Longmont Union Reservoir (LUR) stations during January - March, i.e. Quarter 1 (Q1), 2022. In addition, data comparisons and analyses of selected events that resulted in enhanced concentrations are presented. LLG and LUR data are compared with each other and also with concurrent observations from the Boulder Reservoir (BRZ), Broomfield Soaring Eagle Park (BSE), Broomfield North Pecos (BNP), and the Erie Community Center (ECC). We also include some comparisons from the new Commerce City Fixed (CCF) site, which is located just north of the Suncor refinery.

There were no exceedances of the particulate matter National Ambient Air Quality Standard (NAAQS) or the ozone NAAQS during Q1 2022.

There were two days with large methane peaks > 5000 ppb (February 5th and February 13th). The details of these methane peaks, along with VOC measurements at the same times, are shown in Supplements D and E. A new analysis was added to this quarterly report that presents the monthly count of the number of times one-minute methane measurements at LUR exceeded 5000 ppb. After a reduction in counts from Q1 2020, occurrences of high methane peaks increased again in February and March of 2022.

Another new analysis is presented in this quarterly report aims to investigate relative year-to-year concentration changes in in CO_2 and CH_4 and how these compare to the global trends (changes in CO_2 and CH_4 measurements at LUR were compared to the global changes over the course of 5 quarter-to-quarter comparisons (e.g., Q1 2021 mean measurements minus Q1 2020 mean measurements, Q2 2021 mean measurements minus Q2 2020 mean measurements, and so on). Higher than global trends would indicate an increase of emissions in the footprint area of the monitoring, and changes that are smaller than the global background would indicate that emissions have come down. For CO_2, in 4 out of 5 comparisons, the increase in mean quarterly measurements at LUR exceeded the global increase. Q4 2021 – Q4 2020 mean measurements indicated the only decrease in the CO_2 measured at LUR relative to the global increase. The results for CH_4 were similar in that there was a drop in the Q4 2021 – Q4 2020 measurements, and a slight negative difference in the Q1 2021 – Q1 2020 relative to the global change in methane. A comparison of the differences in mean wind speed was also included in this analysis, and indicates that greater wind speeds in Q4 2021 (especially at the 75th and 95th percentiles (not shown)) indicate there was likely greater mixing and dilution of pollutants during that quarter, leading to smaller quarterly means in the pollutants. This analysis is not yet conclusive, future quarter-to-quarter comparisons will add to the understanding of these data.

Table of Contents

1. Project Scope and Goals

No changes from the Q4, 2021 report.

2. Overview of the Monitoring Program

No changes from the Q4, 2021 report.

Early in January of Q1 2022, during very cold weather, there was a problem with the thermostat at the LUR shelter. There was not much insulation in the wall where the thermostat was mounted and on very cold nights, the thermostat registered air too cold, i.e. below the actual room temperature, while the temperature inside the shelter became quite warm from the instrumentation. The air conditioner was not turning on and eventually the instrumentation began shutting down due to high temperatures in the shelter. Two layers of insulation board were place behind the thermostat to insulate it from outside temperature extremes, and the air conditioner is now running properly.

The LLG Picarro methane and CO_2 analyzer had an instrument failure in early March due to fan failure. Data are missing from March 5th to March 14th. The instrument has been working properly again after a fan was replaced to repair the instrument.

A data acquisition computer power supply failed in March, and the computer was replaced. About 12 hours of data are missing on March 31st due to this outage.

3. Air Quality Monitoring Study Updates

No changes from the Q4, 2021 report.

4. Data Quality Assurance/Quality Control Process

The meteorological instrumentation at LUR was audited by the Colorado Department of Public Health & Environment (CDPHE) on Feb. 7th, 2022. Both the temperature and wind sensors passed the audit and fell within the state regulatory guidelines.

The audit report is included as Supplement F.

The newly installed webcam is working well.

5. Website Development

During Q1, 2022, there were 1060 visits to the Longmont Air Quality Now website. LUR and LLG data can now also be compared to data from the new Commerce City Fixed (CCF) site in the Interactive Data Analysis Tool (IDAT, [Boulder A.I.R. Interactive (bouldairtools.com)](bouldairtools.com). There is also a new interactive site map (Boulder A.I.R. Network Stations - Google My Maps) that allows the user to click on a station location marker and see what measurements are taken at that station. There is an example screen shot on the report cover page.

6. Data Archiving

No changes from the Q4, 2021, report.

The U.S. Environmental Protection Agency (EPA) requested VOC and meteorological data from Boulder A.I.R. for stations that had the desired data before 12/31/2020. This included data from LUR. Data that were requested and provided include:

1,3-butadiene
n-hexane
benzene
toluene
ethylbenzene
xylenes (o-, m-, and p-)
wind speed
wind direction
temperature
pressure

Metadata needed for the archive, such as units, sensor information, etc. were also provided.

7. Data for Quarter 1, 2022

The data that were recorded in Q1, 2022, are included in this report in graphical time series format in Supplement A (LLG) and Supplement B (LUR). These graphs provide the records of the completeness of the data coverage and general features in the dynamic, diurnal, and seasonal changes. Some of the data (e.g. wind direction) are difficult to interpret when 3 months of data are included in the same plot. In these instances, the primary objective is to show general trends and that the data are nearly continuous – not to point out individual features. Data coverage for all variables is more than 95% for the full quarter, except for the methane and CO_2 instrument outage mentioned above.

In Supplement C, the variables that are measured at all sites are shown together in a set of time series graphs. These graphs are presented to highlight similarities and differences between the two monitoring locations.

8. Selected Data Examples and Preliminary Interpretations

Ozone

The full Q1 ozone records for LLG are presented in Figures SA8 and SA9, and in figures SB8 and SB9 for LUR. The general trend in ozone measurements for Q1 was for slightly more ozone to be measured at each station from one month to the next as the number of hours of daylight increased throughout the quarter and promoted more photochemical ozone production. Westerly winds transport background ozone into the Front Range, which occasionally can appear as enhancing ozone values measured along the Front Range as it replaces air that has been stagnant and may have a signature of depleted ozone from the deposition and chemical destruction that can occur in surface air during the winter. There were no exceedances of the NAAQS 8-hour ozone limit at any of the stations during Q1.

Figure 1 presents a statistical analysis of the full Q1 ozone data, comparing the Longmont data with observations from Boulder Reservoir (BRZ), Broomfield Soaring Eagle Park (BSE), Erie Community Center (ECC), and for the first time, the Commerce City Fixed (CCF) site. (See the map of active Boulder AIR stations on the front cover for the CCF location, indicated by the dark blue dot.) More ozone was measured at LLG than at LUR. The continued higher NO_x levels measured at LUR (Figure 14) cause more ozone depletion at night, resulting in overall lower ozone at night and in the early morning. This lower ozone morning starting value can, under calm air circulation conditions, result in an overall delayed ozone production at LUR and slightly lower ozone afternoon maximum values. During Q1, the least amount of ozone was measured at CCF while the most amount of ozone was measured at the BSE and BRZ stations.

CO_2

The full Q1 CO_2 records are available in Figures SA6 and SB6 for LLG and LUR, respectively. The statistical comparison of the monitoring data is presented in Figure 2. LUR ranked second highest in CO_2, with higher values only observed at the CCF station. Less CO_2 was measured in March than in January, at all stations, likely because there will be more vertical mixing and dilution in March when the surface temperatures are warmer than in January and February. The wind speed/wind direction analyses are shown in Figure 3. The main source of CO_2 at LLG appeared to be just to the west of LLG under light winds, with sources also to the northeast, east, and south associated with stronger winds and therefore more dilution. There was a stronger signature of CO_2 transport from the northeast in Q1 compared to Q4 2021. There was a CO_2 and CH_4 data outage at LLG from March 5th to March 14th.

Figure 4 compares the CO_2 heat maps for four quarters: Q4 2020 and Q1 2021 data from the former Longmont Municipal Airport (LMA) station, and Q4 2021 and Q1 2022 data from the LLG station. The objective of these analyses is to further investigate the previously reported source of CO_2 to the west of LMA and if the relocation of the monitoring station is reflected in a change of the CO_2 source signature. The LMA station was moved LLG during October 2021, so the LLG Q4 2021 plot includes data from November and December of that year – this is enough data to assess the potential CO_2 sources near LLG for this comparison. The heat map patterns produced from the LLG data have similarities to the key features seen in the LMA data, such as a source of higher CO_2 values from the west of the station at low wind speeds and a more diffuse looking source region to the east of the station, indicating CO_2 was transported from the city of Longmont to the west at higher wind speeds. There does not seem to be a difference that is outside of the noise and uncertainty of the analysis in the CO_2 wind sector/speed attributions. It therefore does not seem that the CO_2 enhancements that were noted in the LMA data previously were an artifact/pollution signal from nearby the monitoring site location.

Table 1 provides comparisons of CO_2 data at LUR between Q1 2021 and Q1 2022. The increase in CO_2 mean values between Q1 2021 and Q1 2022 was 8.2 ppm, while the average global change in CO_2 between February 2021 and February 2022 was a 2.6 ppm increase. Over 120,000 individual 5-min annual data points were considered in the comparison. The fact that CO_2 increased at LUR at a higher rate (2.3/3.2 times higher for the median/mean values, respectively) than the global average could be interpreted that CO_2 emissions from the station surrounding (including Longmont) have increased during this one-year time span. In Q1 2022, CO_2 mean values and all percentile values were larger than in Q1 2021. As always, there could have been differences in meteorology during these two years that drove the differences in observed concentrations of atmospheric trace gases. For atmospheric trace gases with high variability in their mole fractions, as observed here, longer time records and application of sophisticated trend analysis tools are required for an accurate trend analysis.

The same analysis was done for five consecutive quarters to gain more statistical significance in this analysis. Figure 5 compares the quarter-to-quarter change in the CO_2 measured at LUR with the global change in CO_2 measured in 1 month of the same quarter (obtained from NOAA [Global Monitoring Laboratory - Carbon Cycle Greenhouse Gases (noaa.gov)]), represented by the green bar graphs. The black line plot indicates the ratio of the local (LUR) change in CO_2 to that of the global change of CO_2. The blue line plot represents the differences in the quarterly averages of the surface wind speed, measured at LUR. In four of the five quarter-to-quarter comparisons presented, the measured change at LUR exceeded the global change measured by NOAA. The comparison of CO_2 Q4 data between 2021 and 2020 is opposite in sign of the other comparisons, however. The comparison of the mean wind speed for these two quarters indicates that there were higher wind speeds in 2020, contributing to greater mixing and dilution of pollutants throughout the quarter. This is consistent with a similar analysis of the LUR CH_4 data (shown later). It therefore appears likely that the deviating behavior in the Q4 comparison was caused by the unusually higher winds in 2020, which caused lower CO2 values. Overall, there four out of five of these comparisons show higher CO_2 increases for LUR than in the global data, which makes it appear more likely that CO_2 emissions have been increasing rather than decreasing over this time window. This analysis is not yet conclusive, and additional quarter-to-quarter comparisons incorporating future data will be needed to add to the understanding of these data and confidence in their interpretation.

Methane

The full Q1 methane records are available in Figures SA7 and SB7 for LLG and LUR, respectively. In the statistical comparisons among the stations (Figure 6A), which includes CCF data for the first time, higher values of methane were measured at CCF, with exceptionally high 95th percentile values in January, outpacing the methane measurements at all other Boulder A.I.R. stations. The comparison between LLG and LUR methane measurements time series across the quarter (Figures SA7 and SB7, respectively) were striking, with LUR measuring 98 peaks > 5000 ppb in the one-minute methane data during 14 different days, while no one-minute peak > 5000 ppb was measured at LLG. For comparison, in Q1 2020 there were 120 times when the one-minute methane data at LUR exceeded 5000 ppb, over 12 days. Q1 2021 was different, with only 32 times that the one-minute data exceeded 5000 ppb, and those measurements occurred over 2 days. A plot showing the monthly count of one-minute methane measurements > 5000 ppb at LUR between Jan 1st , 2020 and March 31st, 2022 is shown in Figure 6B. (Measurements started in August 2019, however, there were no measured one-minute values > 5000 ppb in 2019.) Supplements D and E provide additional analysis of methane peaks that were measured at LUR on February 5th 2022 and February 13th 2022, respectively. The data in Figure 6B show that after 18 months of more moderate methane peak occurrences February and March 2022 saw a notable increase in the frequency of elevated methane spikes at the LUR monitoring station, possibly indicating an increase in upwind methane emissions.

Table 1 shows the numerical values of the comparison between Q1 2021 and Q1 2022 methane. The mean values between the datasets showed a 43 ppb increase in Q1 2022, while the global mean values for January 2021 compared to January 2022 had an 18 ppb increase. Similar to the conclusion about the CO_2 sources, this behavior suggests that methane emission in the upwind footprint area have increased at a higher rate than the global average.

Wind rose and heat map analyses for LLG and LUR data are shown in Figure 7. The data indicate that there were relatively strong methane sources to the east of LLG. Similar to the CO_2 wind dependency analysis, in Q1 there was a stronger transport signature from the NE to go along with the high incidence of northeasterly winds. At LUR, there were methane sources to the northwest, northeast, and southeast of the station.

Figure 8 shows quarter-to-quarter comparisons for CH_4 measured at LUR, similar to the analysis shown in Figure 5 for CO_2. The main difference between the two analyses is that for the Q1 2021-2020 comparison, the change in data measured at LUR was negative, showing a slight reduction in CH_4 between the two quarters. The negative change in Q4 2022 – 2021 data was consistent with the CO_2 analysis. As already discussed above, both quarters where there were methane decreases coincide with relatively high with speed conditions. It is therefore likely that this behavior is largely driven by the difference in winds and dilution. More comparisons will need to be added to this analysis to eventually eliminate the wind influence through averaging over more data and longer time intervals.

VOCs

The full Q1 LUR records for six selected VOCs are available in Figures SB10–SB16. Figure 9 presents a 25-month record of ethane, benzene, and acetylene from March 2020 – March 2022.

The statistical comparison of the VOCs is plotted in Figure 10. The statistical analysis of ethane and propane (Figure 10) indicates more ethane and propane were measured at LUR than at the other stations, and month-to-month decreases. The 95th percentiles for propane measured at LUR were higher than what was measured at the other stations. Overall, looking at the mean values, more benzene was measured at ECC, while the second highest amount of benzene was measured at LUR (Figure 10, bottom).

Figure 11 shows the comparison of Q1 2022 statistics for ethane and benzene compared to those of Q1 2021 and Q1 2020 (the first time a 3-year comparison is presented). For ethane and benzene, the mean, median, and the 95th percentile measured values were greater in Q1 2022 than in Q1 2021 (Table 1, Figure 11), except for the median benzene values, which did not change.

Wind speed/wind direction dependence results of ethane, propane, acetylene, and benzene are shown in Figure 12. Compared to the Q4 2021 analyses, the heat map transport pattern was similar for acetylene. For the other species, there was a more prominent source to the north that was not seen in Q4 2021.

The analysis of VOCs signatures, using VOC/VOC ratio values, are shown in Figure 13. The i-pentane/n-pentane ratio plot clearly shows that air associated with oil and gas production to the northeast of LUR was advected to LUR (ratio values < 1.5), and background/urban air was advected to LUR from the west (ratio values > 1.5, darkest red/orange). The propane/ethane analysis, in particular, suggests the presence of a relatively strong natural gas source with a characteristic chemical tracer signature straight north to LUR.

Nitrogen Oxides (NO, NO_x)

The Q1 LUR record for nitric oxide (NO) is available in Figure SB17, and the record for total nitrogen oxides (NO_x) in Figure SB18. Figure 14 shows the statistical analyses for NO (top) and NO_x (bottom). LUR had the highest mean and 95th percentile values for NO. There was a decline in NO and NO_x measurements from one month to the next. Dependency of NO and NO_x on wind direction and wind speed is presented in Figure 15. As In Q4, there was a well-defined source of NO to the southeast of LUR, and a NO_x source to the west. A change from last quarter was the indication of a strong source of NO to the northeast of LUR see during high winds.

Particulate Matter (PM)

PM10 and PM2.5 LUR Q1 monitoring results are presented in Figures SB19 and SB20. The 24-hour averaged PM2.5 data are available in Figure SB21. There were no exceedances of the PM 2.5 NAAQS this quarter.

The statistical comparison of LUR data with BSE and ECC data is presented in Figure 16. For Q1 comparisons, we also have data from the CCF station during February and March. Higher PM 10 and PM 2.5 were measured at CCF than at any other station.

9. Summary

There were no exceedances of the particulate matter National Ambient Air Quality Standard (NAAQS) or the ozone NAAQS.

There were two days with large methane peaks > 5000 ppb (February 5th and February 13th) at LUR. The details of these methane peaks, along with VOC measurements at the same times, are shown in Supplements D and E. Most of the methane plumes transport events were associated with air transport from the north to southeast. A new analysis was added to this quarterly report that presents the monthly count of the number of times one-minute methane measurements at LUR exceeded 5000 ppb. After a reduction in counts from Q1 2020, the counts increased in February and March of 2022.

Another new analysis was presented in this quarterly report that shows the changes in CO_2 and CH_4 measurements at LUR compared to the global changes over the course of 5 quarter-to-quarter comparisons (e.g., Q1 2021 mean measurements minus Q1 2020 mean measurements, Q2 2021 mean measurements minus Q2 2020 mean measurements, and so on). For CO_2, in 4 out of 5 comparisons, the increase in mean quarterly measurements at LUR exceeded the global increase. Q4 2021 – Q4 2020 mean measurements indicated the only decrease in the CO_2 measured at LUR relative to the global increase. The results for CH_4 were similar in that there was the large reduction in the Q4 2021 – Q4 2020 measurements, and a difference in the Q1 2021 – Q1 2020 slowed a slight decrease in methane relative to the global change. A comparison of the differences in mean wind speed indicates that greater wind speeds in Q4 2021 (especially at the 75th and 95th percentiles (not shown)) likely led to smaller quarterly means in the pollutants. This analysis is not yet conclusive, additional (future) quarter-to-quarter comparisons will add to the further understanding of these data.

Tables

Table 1:
Comparison of the statistics of CO_2 and CH_4 data (5-min averages) and ethane and benzene at LUR during Q1 of 2021 and Q1 of 2022. "Abs Diff" is the 2022 value minus the 2021 value. % Diff shows the relative change between the two years. The Local/ Global column shows the relative ratio of the increase seen in the Longmont data in comparison to the global background.

Species	Stat	2021	2022	Abs Diff	% Diff	Local/Global
CO_2	count	128692	127432	-1260	-1.0	
ppm	mean	439.7	447.9	8.2	1.9	3.2
	std	27.4	31.1	3.8	13.7	
	min	413.1	416.0	2.9	0.7	
	5%	417.1	420.0	2.9	0.7	
	25%	422.6	425.0	2.4	0.6	
	50%	429.0	435.0	6.0	1.4	2.3
	75%	446.4	463.0	16.6	3.7	
	95%	501.0	512.0	11.0	2.2	
	max	612.8	737.0	124.2	20.3	
	Global mean	415.2	417.8	2.6	1.0	
CH_4	count	128692	127432	-1260	-1.0	
ppb	mean	2140	2183	43	2.0	2.3
	std	274	290	16	5.9	
	min	1912	1930	18	0.9	
	5%	1956	1980	24	1.2	
	25%	2014	2040	26	1.3	
	50%	2096	2130	34	1.6	1.9
	75%	2217	2260	44	2.0	
	95%	2448	2540	92	3.7	
	max	32985	28900	-4085	-12	
	Global mean	1891	1909	18	1.0	
Ethane	count	2020	2034	14	0.7	
ppb	mean	15.85	20.55	4.70	29.7	
	std	23.23	36.09	12.87	55.4	
	min	1.06	0.85	-0.21	-20.0	
	5%	2.09	2.27	0.18	8.7	
	25%	5.62	6.16	0.54	9.6	
	50%	11.12	12.82	1.70	15.2	
	75%	20.39	24.26	3.87	19.0	
	95%	42.31	53.59	11.28	26.6	
	max	604.90	622.10	17.20	2.8	
Benzene	count	2020	2034	14	0.7	
ppb	mean	0.17	0.19	0.02	10.4	
	std	0.22	0.23	0.01	4.4	
	min	0.00	0.01	0.01	-	
	5%	0.05	0.03	-0.02	-35.9	
	25%	0.09	0.07	-0.01	-14.4	
	50%	0.13	0.13	0.00	1.2	
	75%	0.20	0.24	0.04	17.5	
	95%	0.42	0.48	0.07	15.6	
	max	6.30	4.85	-1.45	-23.1	

Figures

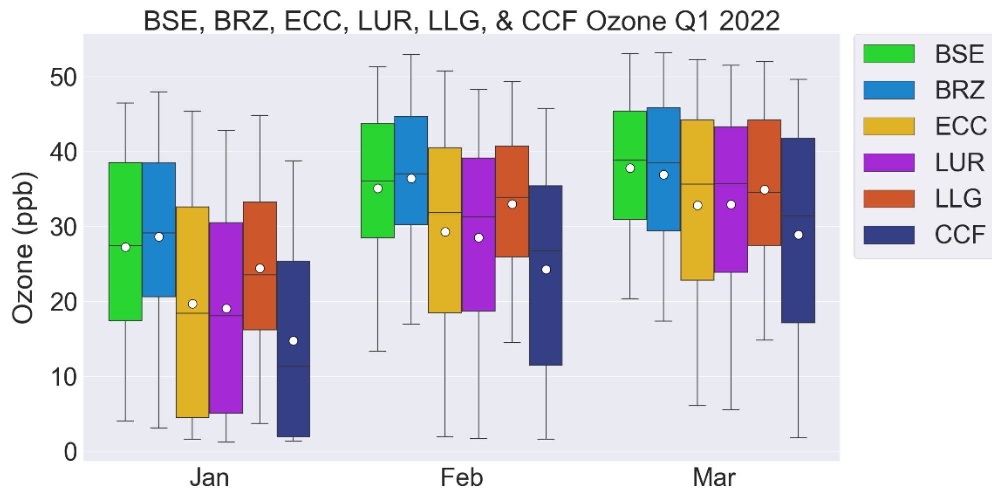


Figure 1:
Comparison of the ozone distribution at BSE, BRZ, ECC, LUR, LLG, and, for the first time, CCF, during January – March 2022. These box whisker plots show the median value as the center line, the 25-75 percentile distribution as the colored boxes, and the 5-percentile and 95-percentile values as the whiskers. The white dot on each box illustrates the mean value at each site.

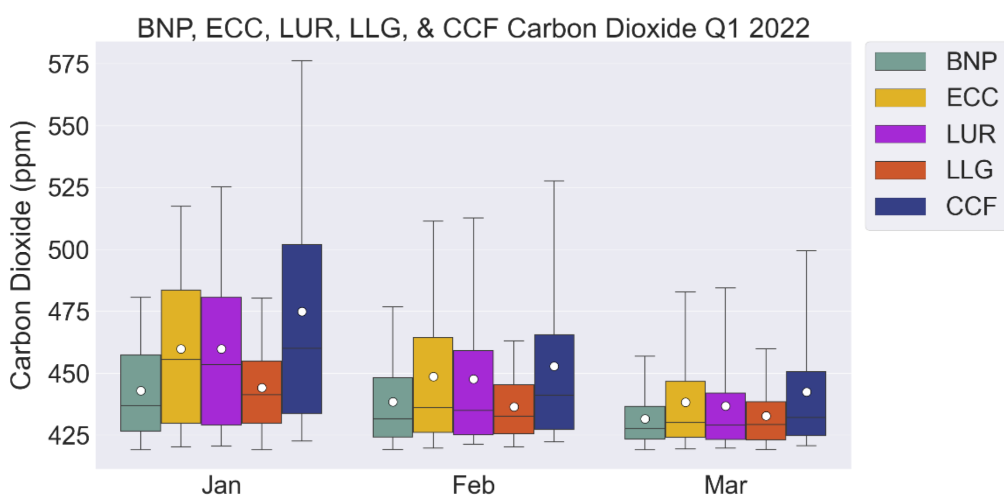


Figure 2:
Comparison of the CO_2 distribution at BNP, ECC, LUR, LLG, and for the first time CCF, during January – March 2022. See Figure 1 for explanation of the box whisker plot format.

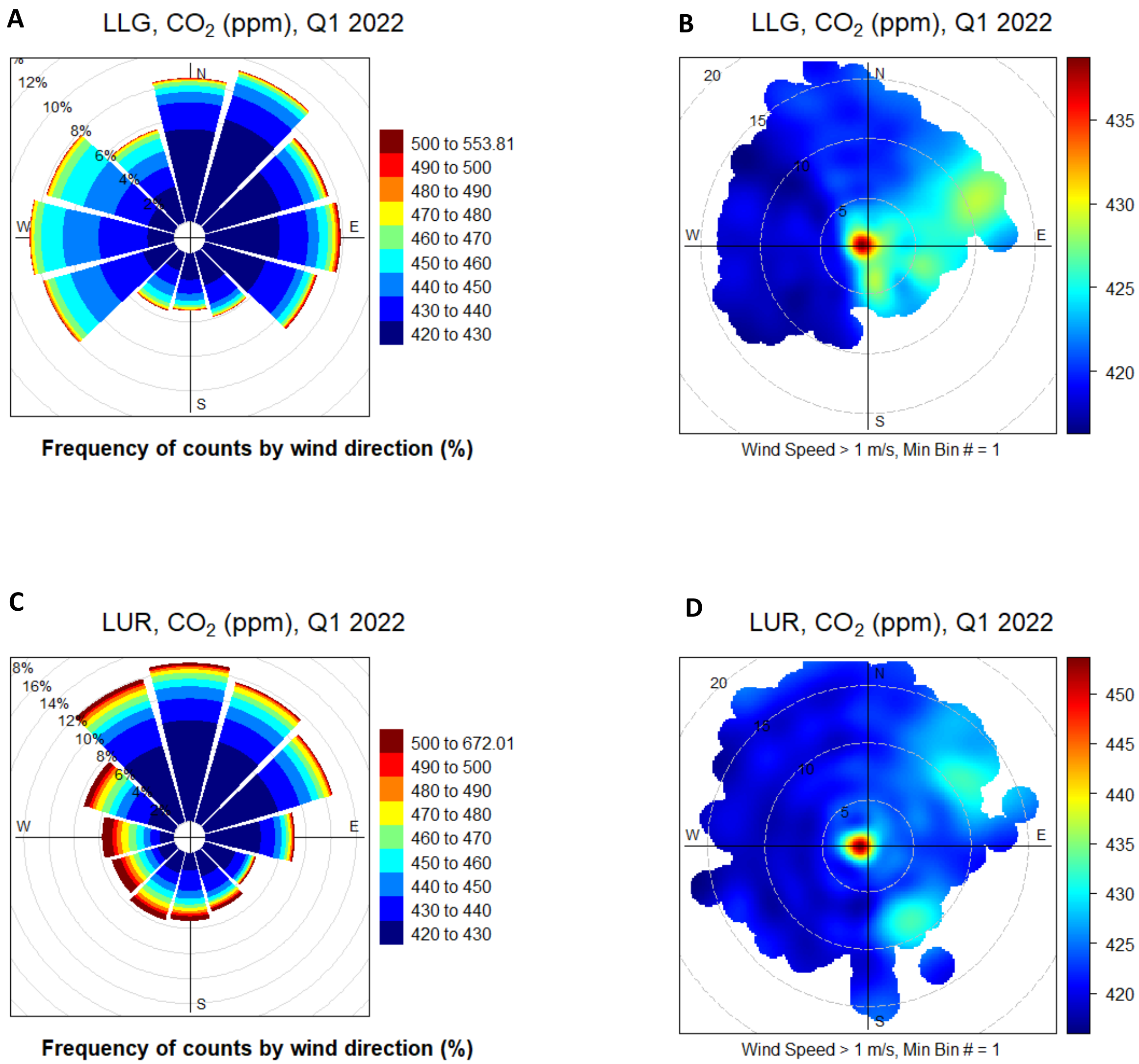


Figure 3:
Wind rose (left) and wind heat map analysis showing the dependency of CO_2 mole fractions at LLG (top, A, B) and LUR (bottom, C, D) during January – March 2022. The LUR site is east of the City of Longmont. These analyses suggests that the city is the primary source for enhanced CO_2 observed at LUR.

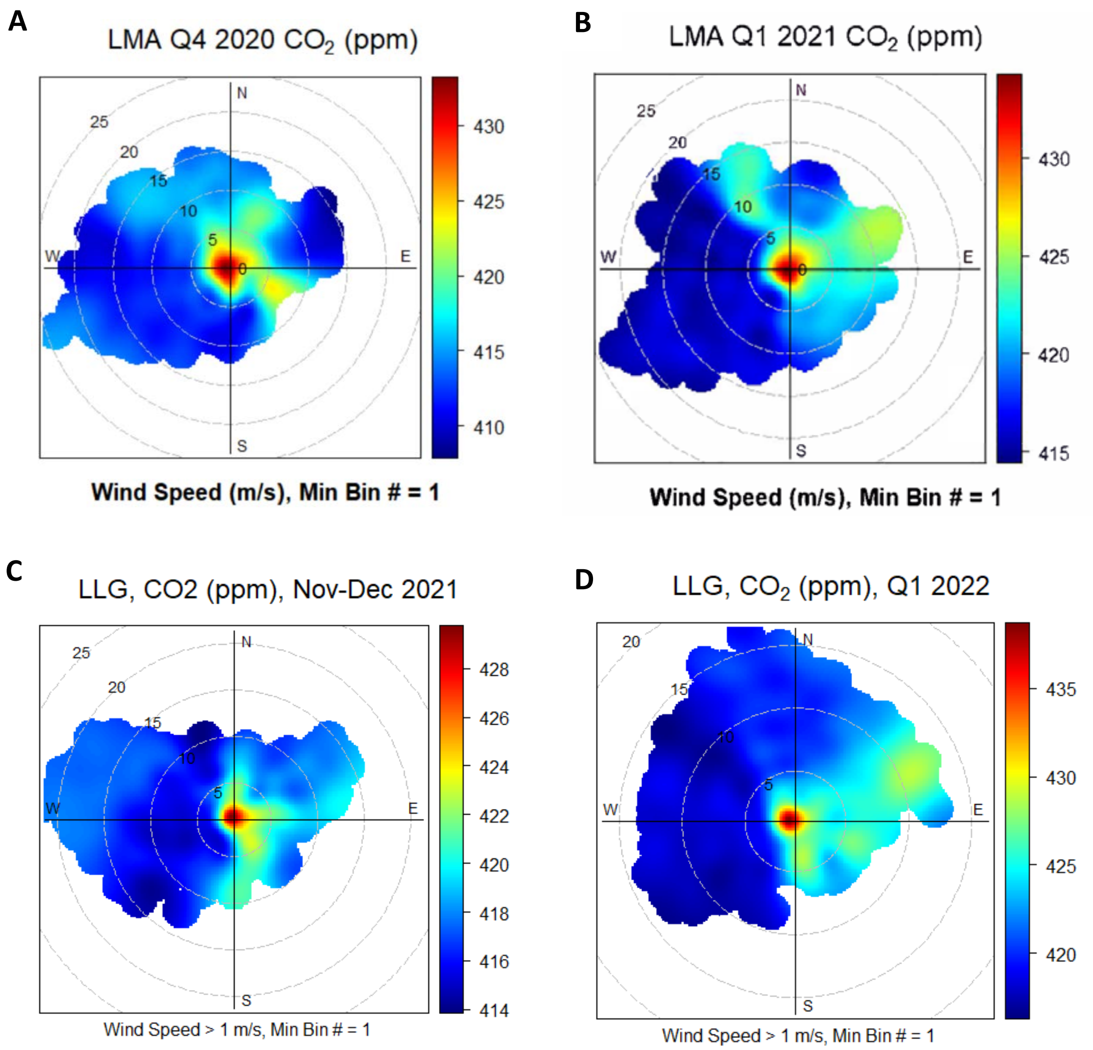


Figure 4:
Heat map analysis showing the dependency of CO_2 mole fractions at LMA (top, A, B) and LLG (bottom, C, D) during Q4 2020 (A) , Q1 2021 (B) , two months of Q4 2021 (C, due to the station move from LMA to LLG during the month of October), and Q1 2022 (D). This analysis investigates possible differences in the observations between these two westerly Longmont monitoring sites.

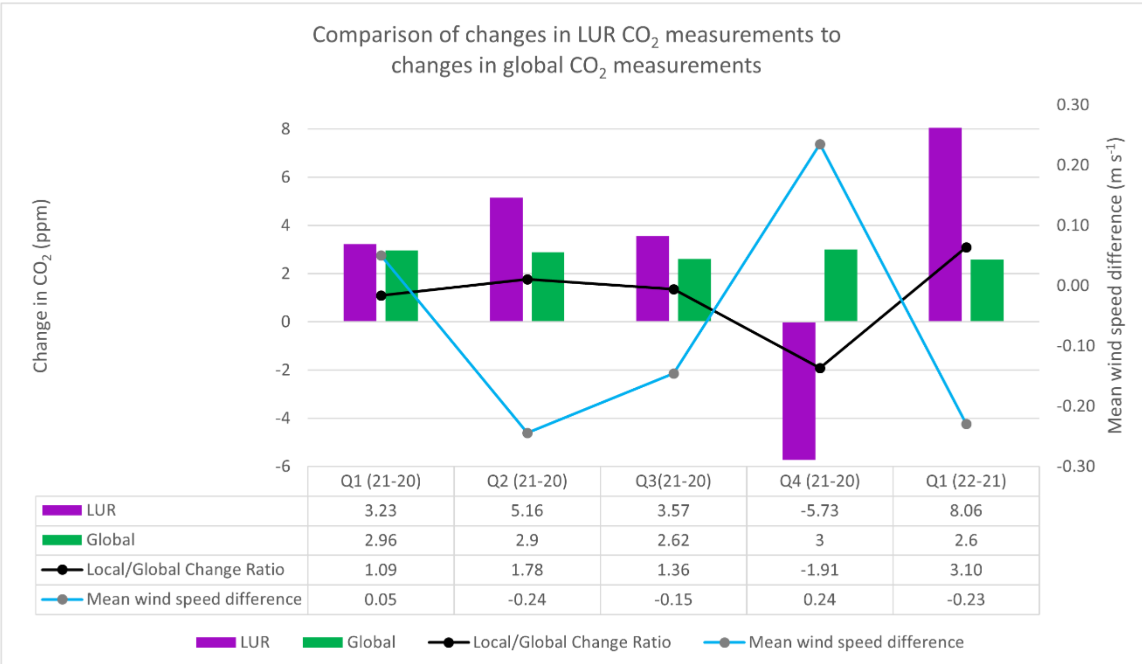
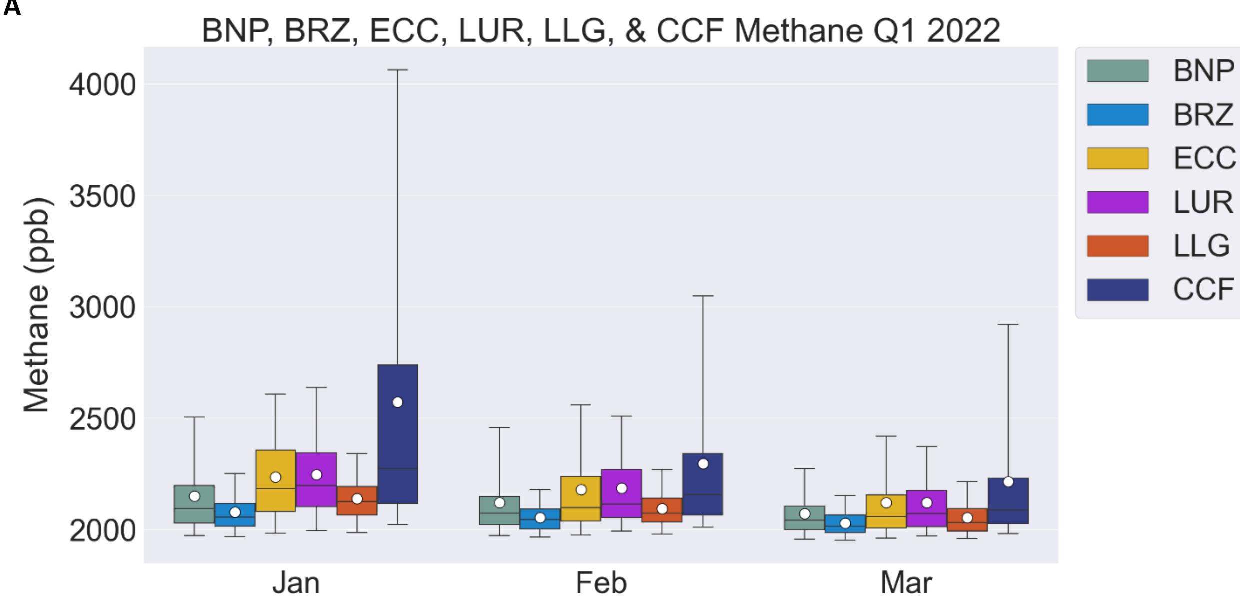


Figure 5:
Comparisons of the quarter-to-quarter change in the CO_2 measured at LUR with the global change in CO_2 measured in 1 month of the same quarter (obtained from Global Monitoring Laboratory - Carbon Cycle Greenhouse Gases (noaa.gov)). The quarter and years being compared are noted in the top row of the table. Purple bars represent LUR data, green bars represent global data. The black line plot indicates the ratio of the local (LUR) change in CO_2 to that of the global change of CO_2. The blue line plot represents the differences in the quarterly averages of the surface wind speed, measured at LUR.

A



B

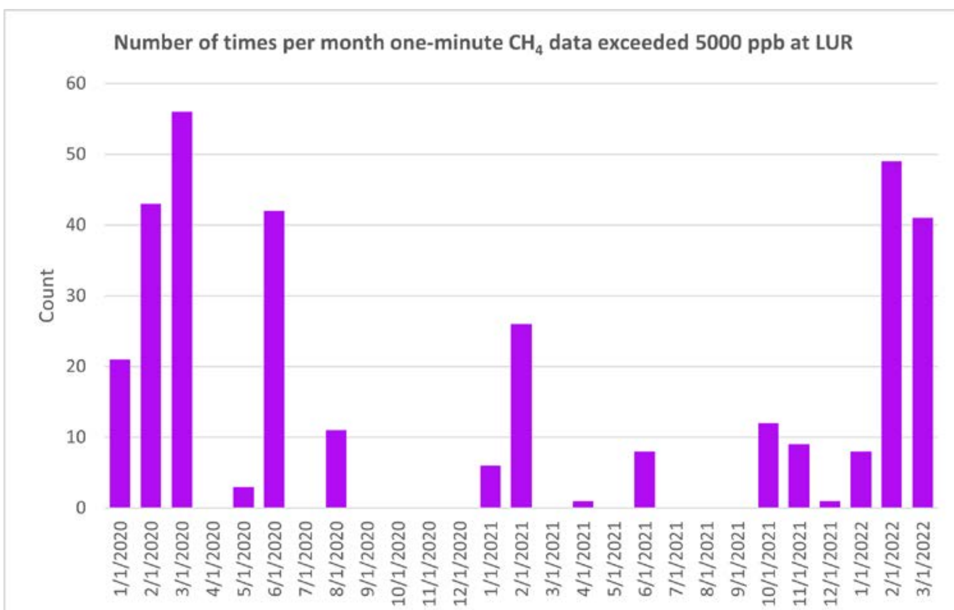


Figure 6:
(A) Comparison of the methane distribution at BNP, BRZ, ECC, LUR, LLG, and for the first time, CCF, during January – March 2022. See Figure 1 for explanation of the box whisker plot format. Between the two Longmont sites, LUR has higher absolute values and variance.
(B) Number of times each month a one-minute methane value > 5000 ppb was measured at LUR. From Jan 1, 2020 – Mar 31, 2022.

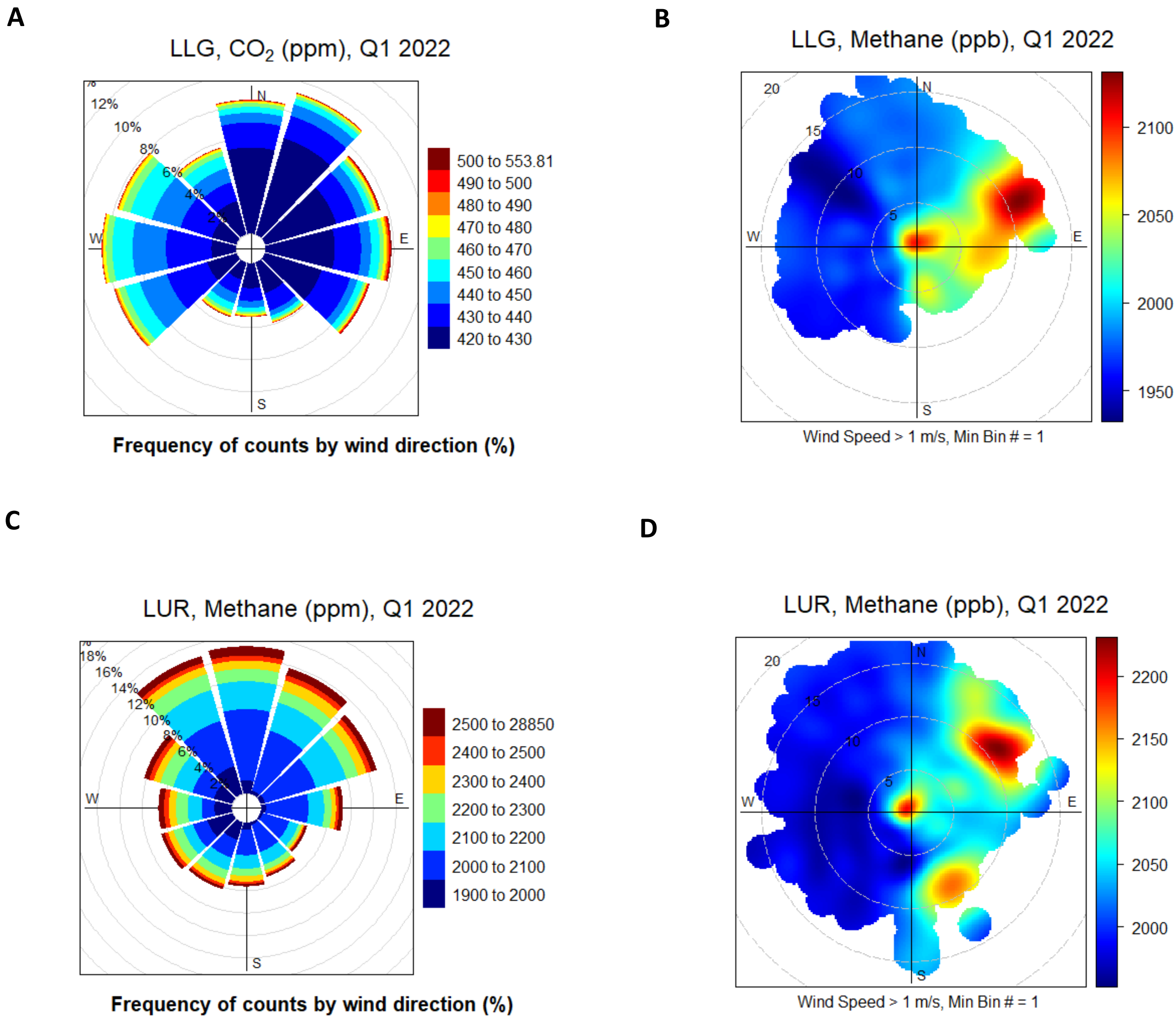
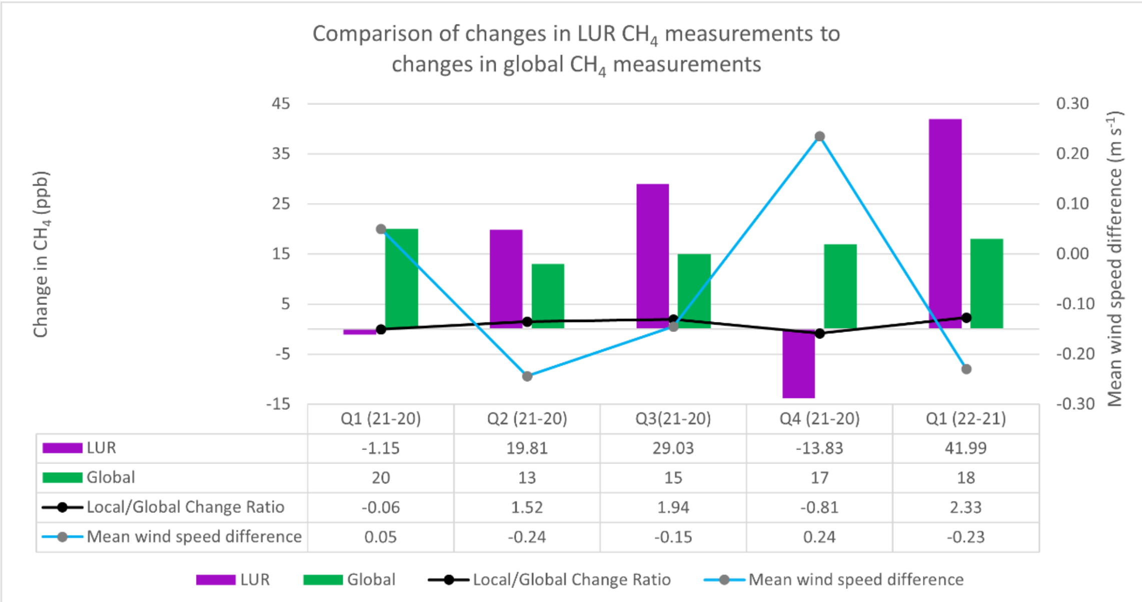


Figure 7:
Wind rose (left) and wind heat map analysis showing the dependency of CH_4 mole fractions at LLG (top, A, B) and LUR (bottom, C, D) during January – March 2022.



	Q1 (21-20)	Q2 (21-20)	Q3(21-20)	Q4 (21-20)	Q1 (22-21)
LUR	-1.15	19.81	29.03	-13.83	41.99
Global	20	13	15	17	18
Local/Global Change Ratio	-0.06	1.52	1.94	-0.81	2.33
Mean wind speed difference	0.05	-0.24	-0.15	0.24	-0.23

Figure 8:
Same as in Figure 4, except for methane.

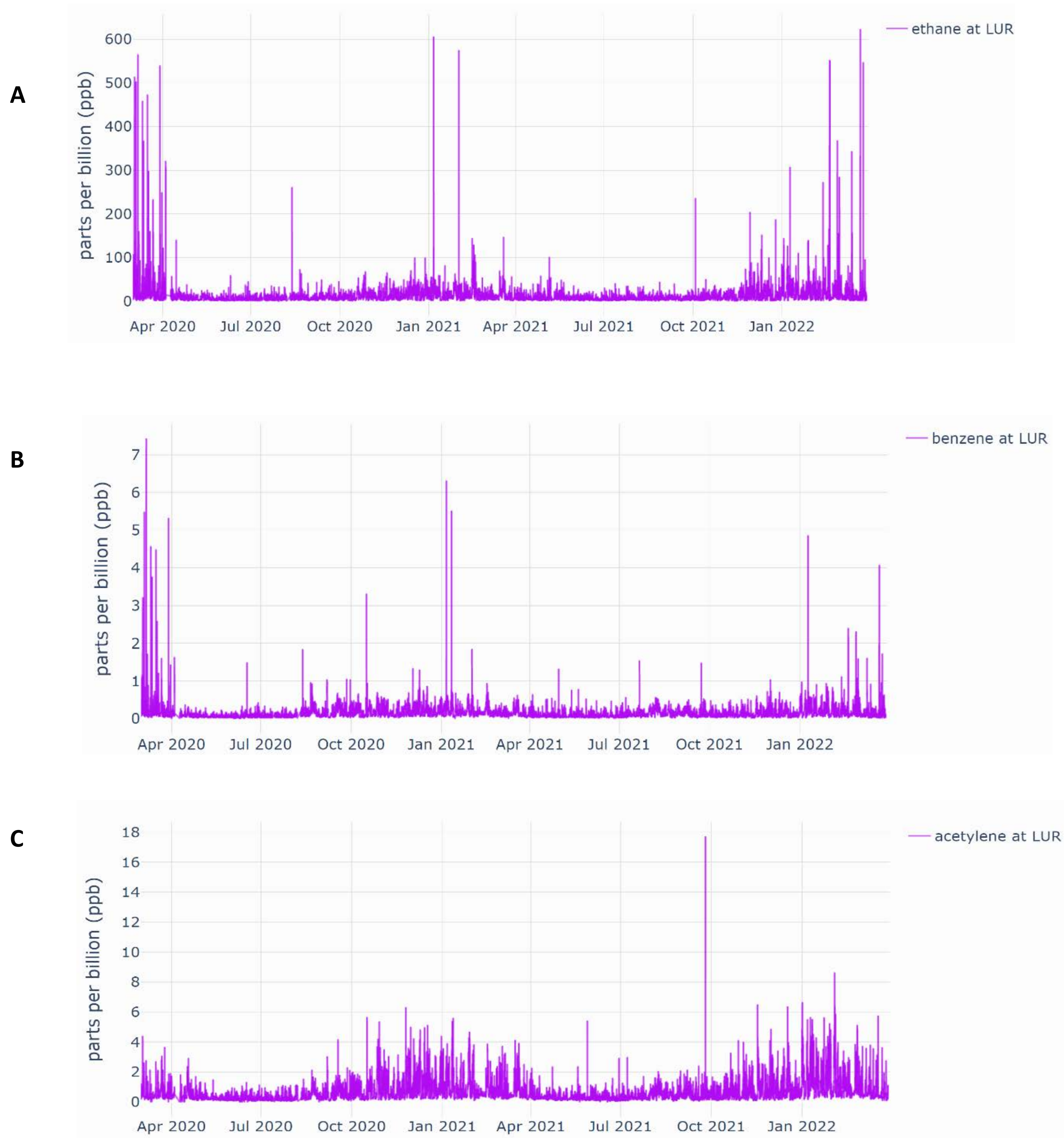
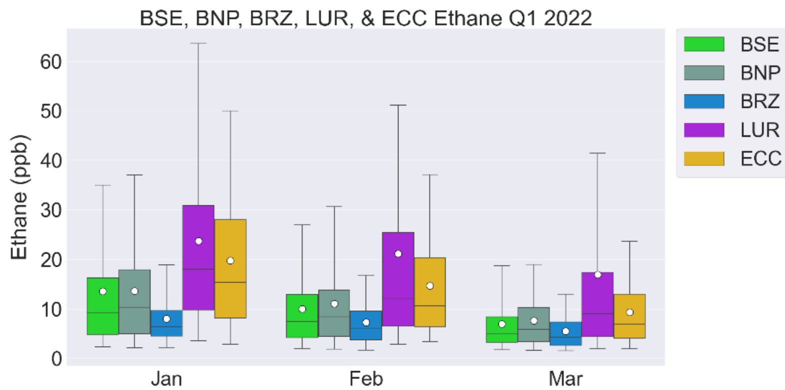
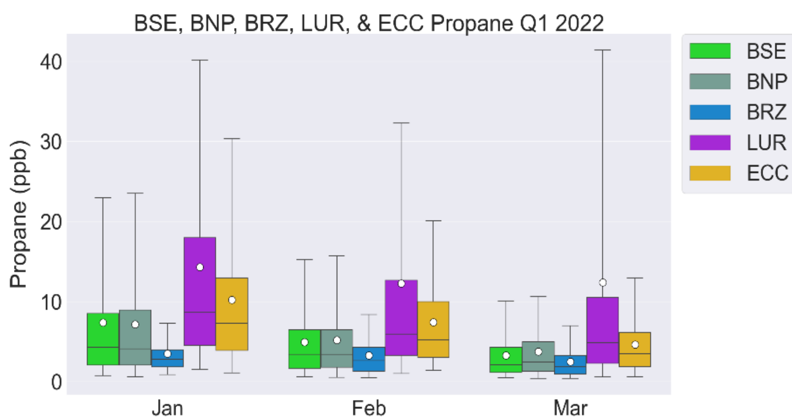


Figure 9:
Ethane (A, top), benzene (B, middle), and acetylene (C, bottom) at LUR between March 1, 2020 and March 31, 2022. Lower frequency and lower maximum values of concentration spikes during the summer are observed for all three compounds. These summer minima are mostly caused by the stronger mixing (dilution) of surface air from thermal convection. For acetylene, a compound that is mostly the result of combustion, similar peak patterns are observed for the spring, fall, and winter months. These time series suggest that there was a decline in the source strength for ethane and benzene from the earliest measurements, however, in late November 2021, measurements of ethane at LUR started to increase compared to previous months.

A



B



C

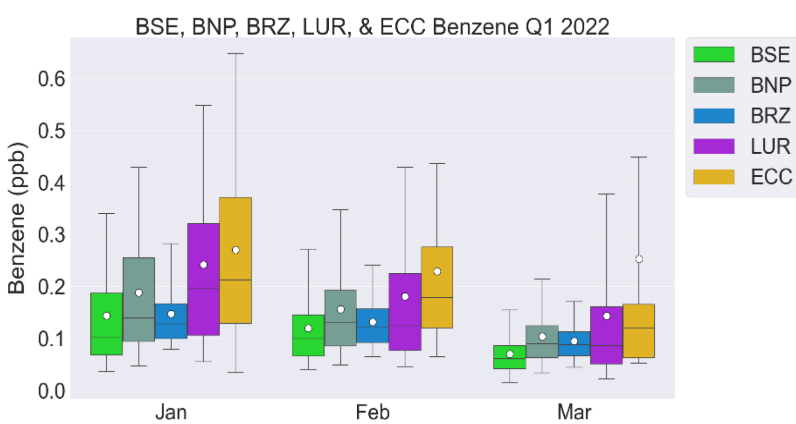
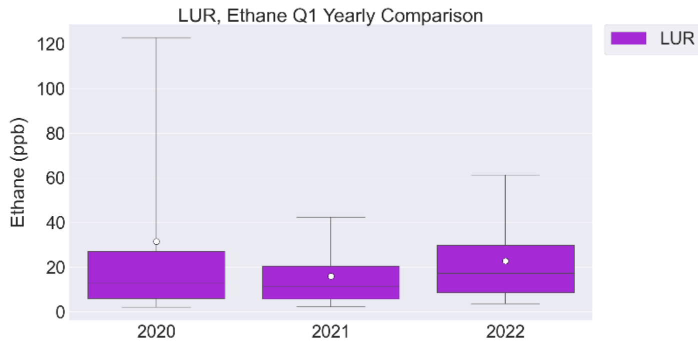


Figure 10:
Comparison of the distribution of ethane (A), propane (B), and benzene (C) at BSE, BNP, BRZ, LUR, and ECC during Q1. See Figure 1 for explanation of the box whisker plot format.

A



B

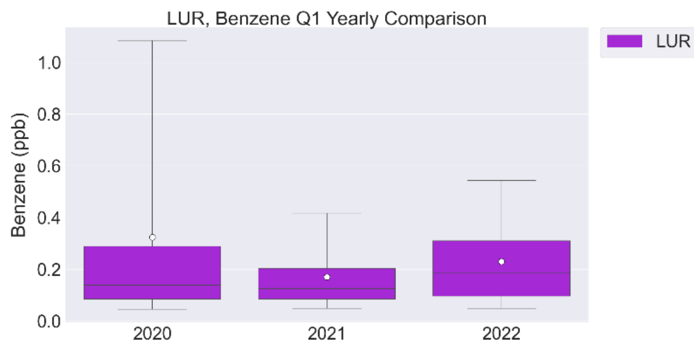


Figure 11:
Comparison of the ethane distribution (top, A) and the benzene distribution (bottom, B) at LUR during Q1 of 2020, 2021, and 2022. See Figure 1 for explanation of the box whisker plot format. The numerical values for the statistical distributions for Q1 2021 and 2022 are presented in Table 1. The mean, median, and values 95th percentile values were higher for Q1 in 2022.

33

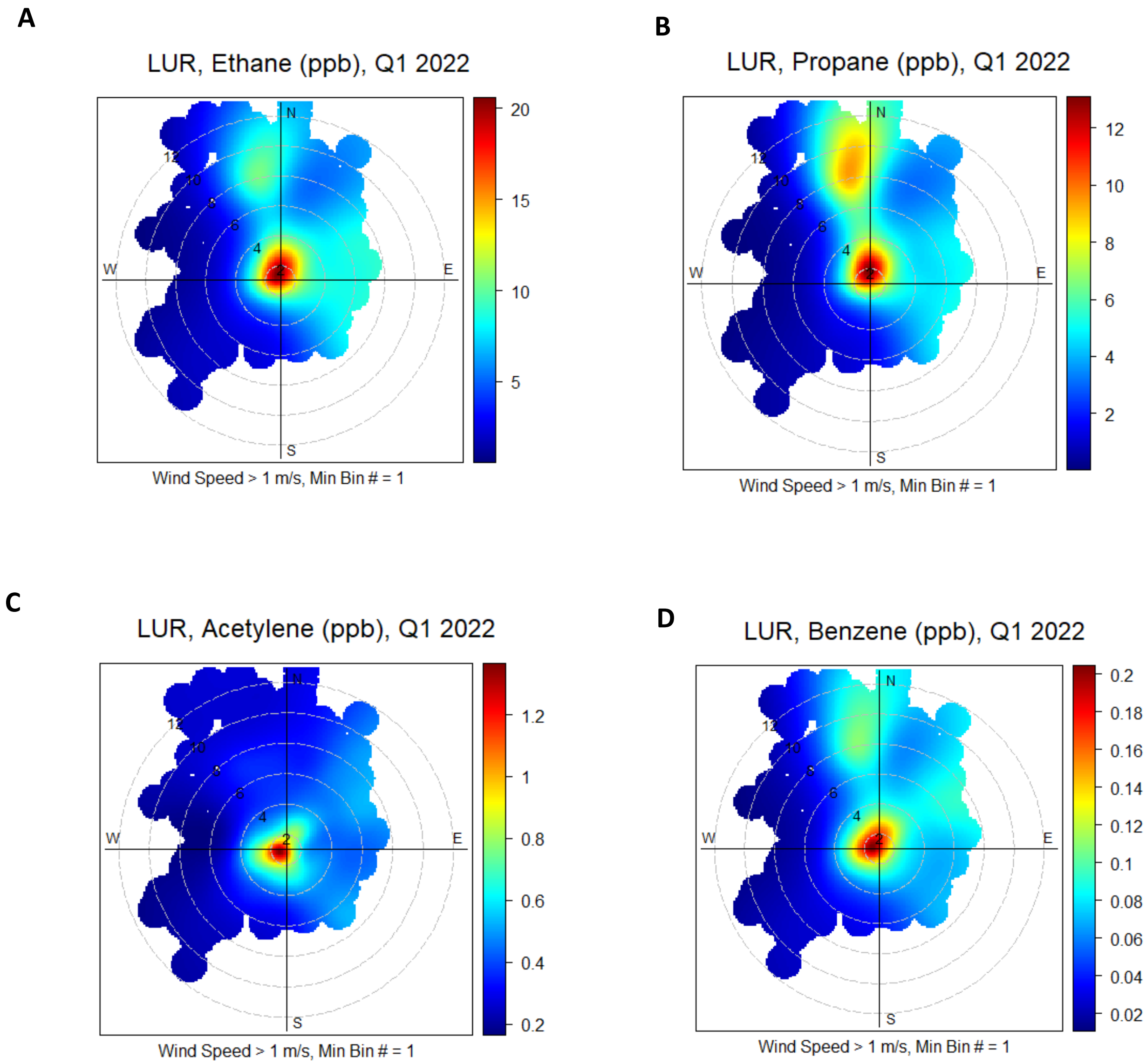


Figure 12:
Comparison of ethane (A), propane (B), acetylene (C), and benzene (D) occurrences as a function of wind speed and direction at LUR during Q1 2022.

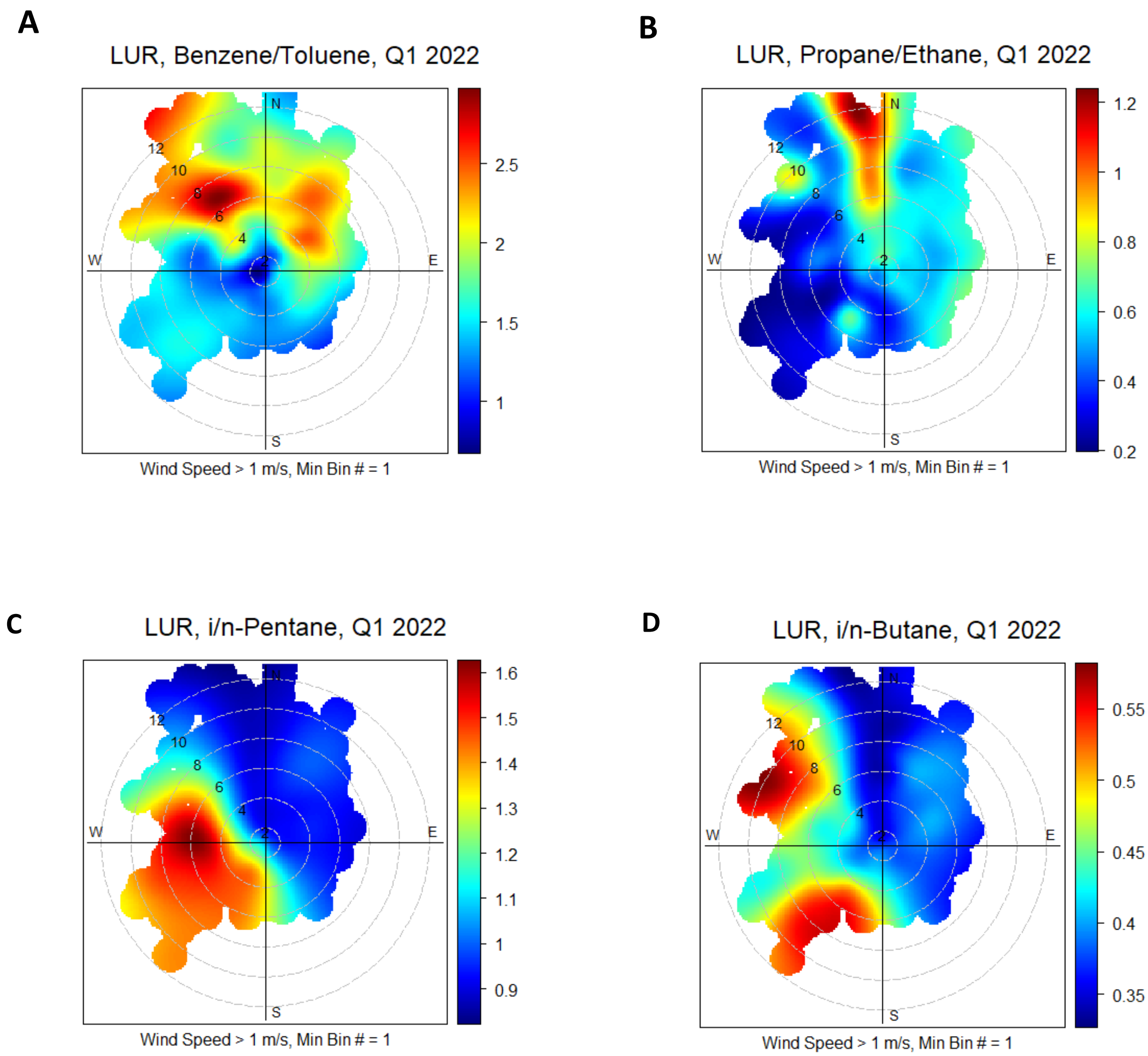
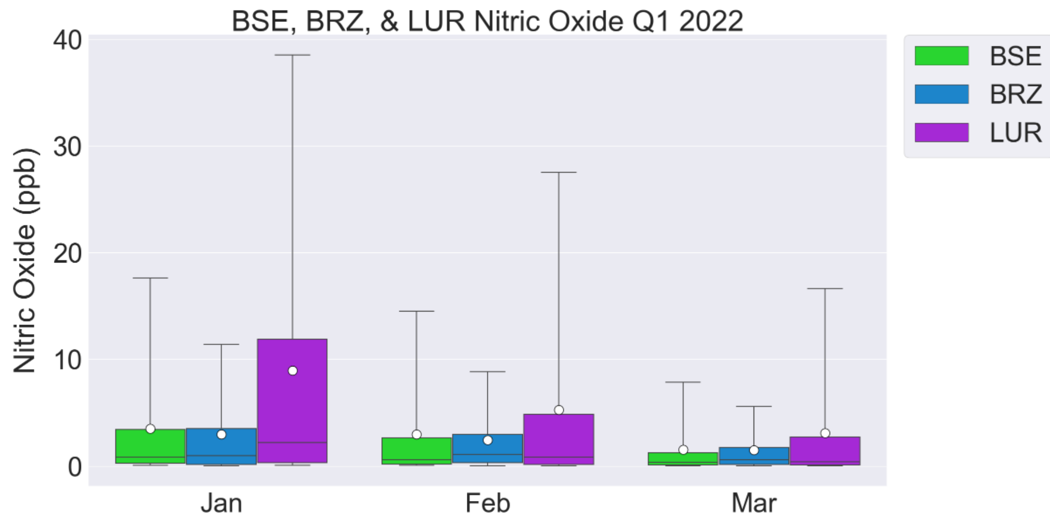


Figure 13:
Ratios of selected VOC pairs as a function of wind direction and wind speed during Q1 2022. These analyses show clear differences in the chemical signatures in air transported from different directions to the monitoring station.

A



B

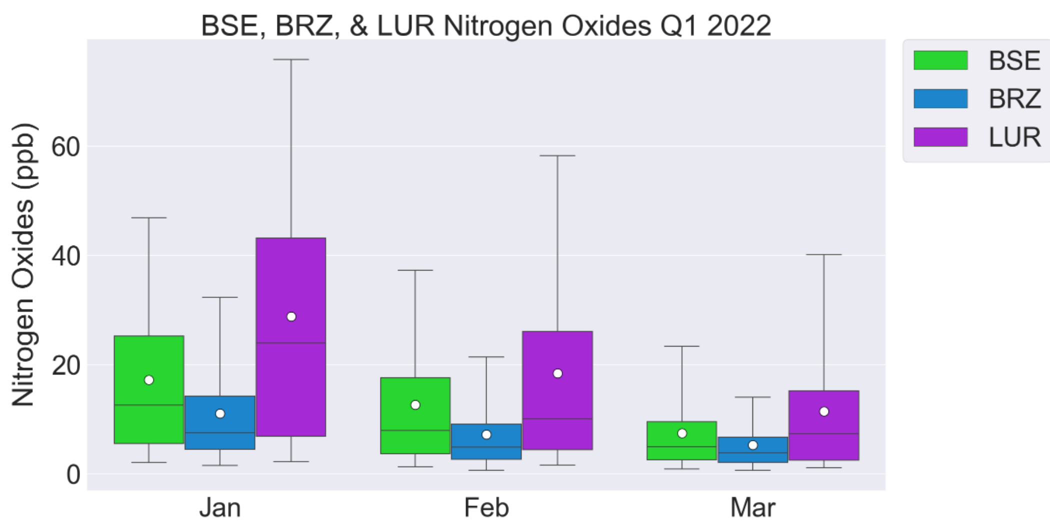


Figure 14:
Comparison of nitric oxide (A) and nitrogen oxides (B) at BSE, BRZ, and LUR during January – March 2022. See Figure 1 for explanation of the box whisker plot format.

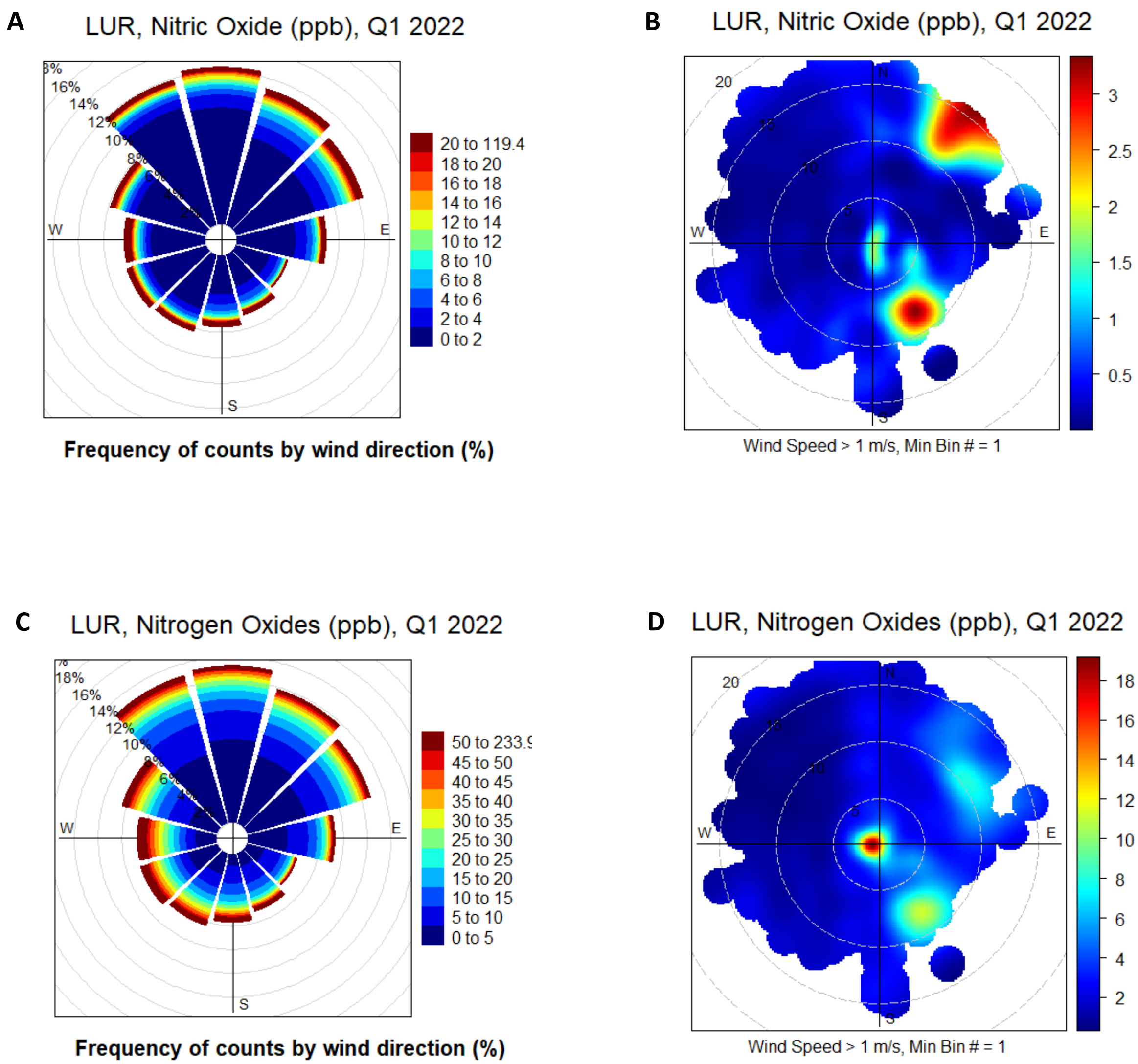
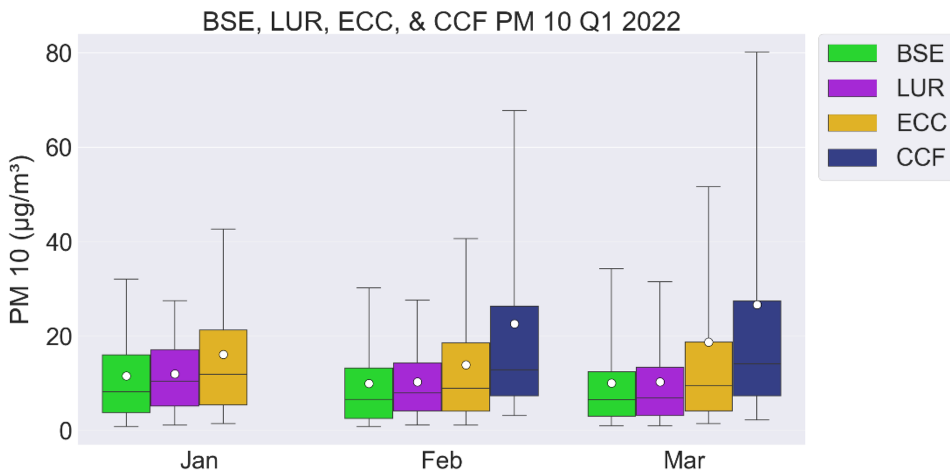


Figure 15:
Dependence of nitric oxide (A, B) and nitrogen oxides (C, D) as a function of wind speed and direction at LUR during January – March 2022. As seen in the prior data, the City of Longmont, located to the west, appears to be the strongest upwind source for NO_x.

A



B

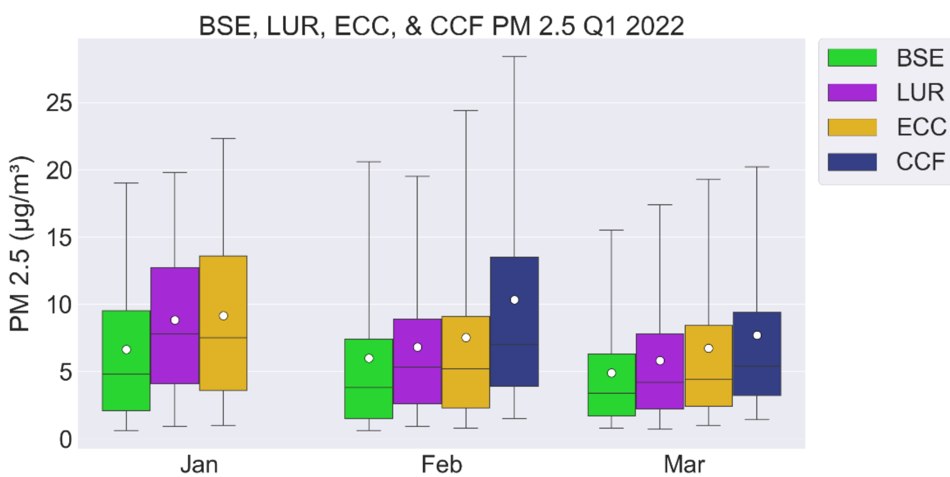


Figure 16:
Comparison of PM 10 (A, top) and PM 2.5 (B, bottom) at LUR, BSE, and ECC during January – March 2022. For the first time we also include CCF data, which was available during February - March 2022. See Figure 1 for explanation of the box whisker plot format.