Boulder Atmosphere Innovation Research

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May 21, 2021

To:

City of Longmont
350 Kimbark Street
Longmont, CO 80501

Attn: Dr. Jane Turner

Re: Longmont Regional Air Quality Study – Year 2021 Quarter 1 Report

Dear Dr. Turner,

Please find included with this letter the January – March (Quarter 1) 2021 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

Detlev Helmig

Boulder AIR LLC

2021 Quarter 1 (January – March) Report

Longmont Air Quality Study

Executive Summary

This report summarizes the data and preliminary findings from the Longmont Air Quality Study during January through March of 2021. 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 Longmont Municipal Airport (LMA) and Longmont Union Reservoir (LUR) during January-March, i.e. Quarter 1 (Q1), 2021. In addition, data comparisons and analyses of selected events that resulted in enhanced concentrations are presented. LMA and LUR data are compared with each other and also with concurrent observations from the Boulder Reservoir and the Broomfield Soaring Eagle Park and Livingston sites.

The ozone National Ambient Air Quality Standard (NAAQS) was exceeded twice during Q1, on March 19th and 20th, at several stations along the Front Range, including LMA and LUR. The NAAQS for fine particulate matter, PM_2.5, was exceeded on three consecutive days from March 19-21, including at LUR, with a maximum value of 58 $\mu g\ m^{-3}$ for the 24-hour averaged readings. To the best of our knowledge, such a poor air quality event has not occurred along the Front Range during winter – spring since the year 2001. We present chemistry and supporting meteorological data for this event in the main report and in Supplements D and E.

Occurrences of elevated oil and gas tracer concentrations at LUR, as observed in Q1 of 2020, were less frequent in general. There were two notable exceptions, though, with short (15 – 20 minutes) highly elevated concentration spikes that were observed at LUR. These plumes had elevated concentrations of methane and light petroleum hydrocarbon compounds, with a typical natural gas signature. Concentrations for light hydrocarbons exceeded the measurement range of the volatile organic compounds (VOCs) analyzer. Peak concentrations within the plume for light alkane VOCs were estimated at 1000-3500 times, and benzene 20-160 times above the background. Both plumes were transported to LUR from the east across the Union Reservoir.

Table of Contents

1. Project Scope and Goals

No changes from Q4, 2020 report.

2. Overview of the Monitoring Program

No major changes from Q4, 2020 report. The Picarro methane/CO2 analyzers were upgraded to a Windows 10 operating system. The gas chromatograph at LUR was upgraded from an Agilent 5890 to a newer Agilent 6890 instrument. We have been cloning all computer drives and are keeping the cloned copies at a safe location as a backup of the full instrument data system configuration.

3. Air Quality Monitoring Study Updates

No changes from Q4, 2020 report.

4. Data Quality Assurance/Quality Control Process

No changes from Q4, 2020 report.

5. Website Development

As of May 11, 2021, there have been 14390 page visits to the Longmont Air Quality Now website since the visitor counter was added to the website on May 24, 2020. Based on this number, the website receives approximately 1200 visits per month.

A new tab was added to the website, labeled 'More VOCs at Union Reservoir.' This page presents time series graphs of a number of new VOC species, i.e. ethene, propene, cyclopentane, i-pentane, n-pentane, isoprene, n-hexane, n-heptane, n-octane, ethyl-benzene, m&p-xylene, and o-xylene.

We moved all of our automated data processing, the website hosting, and a data backup to an Amazon Web Server (AWS) client as this is a more powerful and easily expandable service. We upgraded storage and processor power for faster processing and web posting of the real-time data.

6. Data Archiving

The new AWS system mentioned above will become the primary data repository for use by our team and from which we draw data to be shared externally. We will continue to keep several external drives updated as a redundancy measure.

7. Data for Quarter 1, 2021

The data that were recorded in Q1, 2021, are included in this report in graphical time series format in Supplement A (LMA) 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 >95% for the full quarter.

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

Details of the March air pollution event are presented in Supplements D and E, with an emphasis on LMA and LUR data. Supplement E also includes details of additional notable chemical measurements, such as spikes in the VOC measurements.

8. Selected Data Examples and Preliminary Interpretations

Ozone

The full Q1 ozone records for LMA and LUR are presented in Figures SA8 and SA9 for LMA and SB8 and SB9 for LUR.

The 8-hour ozone National Air Quality Standard (NAAQS) was exceeded at LMA and LUR on March 19th and March 20th, with a maximum 8-hour averaged ozone value of 75 ppb on March 19th at LMA and LUR, and 81 ppb and 83 ppb at LMA and LUR, respectively, on March 20th (Figure SD1). This was an unusual occurrence because the 'ozone season' is typically regarded as May – August. When looking at the highest maximum hourly ozone values for every day in March over the last twenty years in Boulder, (Figure 21), we see that the maximum hourly ozone values for this 2021 event were much greater than any March hourly ozone maxima measured in the last 20 years. These ozone exceedances occurred under very stable and stagnant weather conditions, with a shallow temperature inversion observed during these days. We discuss this event in more detail in a later section, as well as in Supplements D and E.

Figure 1 presents a statistical analysis of the full Q1 ozone data, comparing the Longmont data with observations from Boulder Reservoir (BRZ) and Broomfield Soaring Eagle Park (BSE). As the amount of daylight hours increased from January through March, so did ozone levels since there were progressively longer periods of sunlight for photochemical production. Median values of ozone were lower at LMA and LUR than at the BSE and BRZ stations. The Longmont sites have less ozone than the other sites because there is more NO_x in the Longmont area, due to nearby traffic (Figure 14). During the winter season, nitric oxide emissions primarily act as a sink of ozone, rather than promoting photochemical ozone production, as observed during the summer.

CO_2

The full Q1 CO_2 records are available in Figures SA6 and SB6 for LMA and LUR, respectively. The statistical comparison of the monitoring data is presented in Figure 2. The wind speed/wind direction analyses are shown in Figure 3. In January, median values of CO_2 at LUR exceeded the median values at the other sites, whereas the LUR median values were similar to those of the other sites during February and March. The greatest values and the greatest variability of CO_2 measurements occurred in January at LUR. The results from the wind direction/speed analyses comparing Q1 2021 to the previous three quarters (Figure 4) show that there was possibly a somewhat stronger contribution from the east and northwest. Again, LMA shows a relatively strong CO_2 source to the west of the site. During the past month we became aware that natural gas heaters are operated in the light aircraft hangers to the west of the monitoring sites, which might be a potential source of the observed CO_2 emissions.

Figure 5 and Table 1 provide comparisons of CO_2 data between Q1 2020 and Q1 2021. The increase in CO_2 mean values between Q1 2020 and Q1 2021 was 2.8 ppm, just under the global increase in CO_2 between February 2020 and February 2021 of approximately 2.96 ppm. Over 25,000 individual 5-min annual data points were considered in the comparison. This is in contrast to the Q4 2019/2020 comparison, in which CO_2 values dropped from one year to the next. In 2021 we also saw higher median CO_2 values than in 2020, as well as greater 5th and 95th percentile values. The COVID lockdowns in March 2020 occurred in the middle and latter parts of the month and during Q1 2021, traffic, etc. was closer to normal, therefore, the COVID lockdown did not play much of a role when comparing these two quarters. The Q2 2020/2021 comparisons may show more interesting results as there was possibly a difference in traffic between these two quarters due to the COVID lockdowns. As always, there could have been differences in meteorology during these two years that drove the differences in observed concentrations of atmospheric trace gases.

Methane

The full Q1 methane records are available in Figures SA7 and SB7 for LMA and LUR, respectively. Median values of methane were greatest at LUR. For all months, LUR median values decreased for each subsequent month of the quarter (Figure 6). LUR had high percentile values for each month, but unlike last quarter, not necessarily the highest 95th percentile values. In March, BSE had greater 95th percentile values than LUR. LMA median methane values tended to be greater than those measured at BRZ, but similar to those at BSE. The wind dependency of elevated methane was about the same as during the preceding quarters (Figure 7). For both sites, transport from the north to east continued to be the predominant source sectors.

The Q1 2020 versus Q1 2021 comparison of methane at LMA is presented in Figure 8. Numerical results of this analysis are included in Table 1. The increase in mean methane values of 32.2 ppb between Q1 2020 and Q1 2021 at LMA, when interpreted against the approximately 20 ppb increase in the global methane background between January 2020 and January 2021, indicates a greater increase between quarters at LMA than seen globally in January. Mean, median, and percentile values of methane all increased from Q1 2020 to Q1 2021.

VOCs

The full Q1 LUR records for six selected VOCs are available in Figures SB10–SB16. Figure 9 presents a full year record of ethane, benzene, and acetylene from March 2020 – March 2021. These graphs show continued declines in the oil and gas tracers ethane and benzene relative to March 2020. Excluding some short-lived spikes in January and February 2021, the winter/early spring observations of ethane and benzene have stayed relatively low, especially in March 2021 vs March 2020.

The statistical comparison of the VOCs plotted in Figure 10 shows again how VOCs are overall higher at LUR in comparison to the other sites, as in the previous Quarter. Median values of ethane, propane, and benzene decreased from January to March at LUR. The most variability, as indicated by the higher 95th percentile values at LUR, occurred in February for ethane and propane and in January for benzene. Figure 11 and Table 1 show the comparison of Q1 2020 statistics for ethane and benzene compared to those of 2021. The mean values of ethane decreased, but more striking was the decrease in the standard deviation and upper-percentile values, indicating much less variability in the Q1 ethane measurements between 2020 and 2021 (Table 1). For benzene, there was a decrease in the mean values between the two quarters, and a small decrease in the upper percentile values.

Analysis of large, coincident spikes in methane, ethane, and propane in the January VOC records are presented in Supplement E, Boulder A.I.R's presentation to the Longmont City Council. These spikes contributed to the large percentile values at LUR. In particular, there were two ethane spikes, one on January 6th, the other on February 1st, that were so high in concentration that they saturated the sensor, requiring Boulder A.I.R. scientists to estimate maximum measured values through determining their concentration from ratios to other quantified VOCs species. While very short-lived (~ 7 minutes for the maximum ethane values on January 6th), the calculated maximum ethane values were 1000 – 3000 times higher than background values. In the January case, the winds during the VOC spike event were easterly, and in February they were east-northeasterly, in both cases indicating transport from areas with active oil and gas wells. In both cases, there was an early-morning temperature inversion that inhibited vertical mixing, trapping pollutants in a shallow layer near the ground, thus contributing to the high concentrations. This winter-time scenario of pollutants trapped in the vertical, combined with little horizontal transport due to weak winds, highlights how far high pollution plumes can travel over the landscape in the winter, and the challgenges of establishing appropriate setbacks for residential neighborhoods and schools in areas where oil and gas extraction is occurring.

Wind speed/wind direction dependence results of ethane, propane, acetylene, and benzene are shown in Figure 12. Compared to Q4 2020 analyses, there was a stronger signal to the northeast for potential sources of ethane, propane, and benzene, perhaps related to the spikes mentioned above. The acetylene analysis looks similar to that of Q4 2020.

The analysis of VOCs signatures, using VOC/VOC ratio values, are shown in Figure 13. The propane/ethane ratios and the i/n-pentane ratios were similar to those seen in Q4 2020. The benzene/toluene and i/n-butane ratios, however, look quite different in Q1 2021 than they did in Q4 2020. The maximum in the benzene/toluene ratio shifted from the northwest in 2020 to the southeast in 2021. For the i/n-butane ratios, the maximum ratios shifted from the southwest in Q4 2020 to the west-northwest in Q1 2021. These changes are likely attributable to a directional shift in emission sources that exert a strong influence on the pollution levels seen at the LUR station.

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. The time series data show a decline in NO and NO_x over the course of Q1. Mean values of NO and NO_x were greatest at LUR, relative to BSE and BRZ (Figure 14). Dependency of NO and NO_x on wind direction and wind speed is presented in Figure 15.

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, in comparison to the NAAQS threshold value, are available in Figure SB21. The statistical comparison of LUR data with BSE data is presented in Figure 16. LUR had slightly larger median values of PM2.5 than BSE. Median values of PM10 were similar between LUR and BSE. The variability of PM2.5 and PM10 were greatest in March because of the smog event that occurred (details in the next section). The 24-hour PM2.5 air NAAQS was exceeded on three days, March 19th, 20th, and 21st (Figure SB21). The highest maximum value, at ~ 58 $\mu g\ m^{-3}$, was recorded on March 19. This value was not as high as the October 19th value seen in the Q4 2020 report of 64.8 $\mu g\ m^{-3}$, which was associated with wildfire plumes.

9. March Air Pollution Event

On March 19th and 20th, ozone, particulate matter, and other chemical species rose to high levels in the Northern Colorado Front Range, mostly north of the Denver metro area as measured by Boulder A.I.R. and CDPHE. We present details of these measurements at LMA and LUR, with comparisons with other measurements from the Boulder A.I.R. network, as well as the meteorological conditions that supported this event. Supplement D has meteorological analysis for this event and Supplement E contains Boulder A.I.R.'s presentation to the Longmont City Council.

Figure 17 shows 8-hour averaged ozone at LMA and LUR and 24-hour averaged PM2.5 at LUR from March 2020 through March 2021. This 13-month time series shows that the high-ozone event in March 2021 at LUR was unusual for this time of year, with the rest of the ozone exceedances occurring in the late spring or summer months. The coincident large spike in PM2.5 in March was not the highest recorded throughout the 13 months, yet it was similar in magnitude to PM2.5 spikes associated with the wildfires that occurred in the summer and fall of 2020. Hourly-averaged ozone and 8-hour averaged ozone for March 18-22 are shown in Figure 18 from the BSE, BRZ, and the LMA and LUR stations. The 8-hour ozone NAAQS was exceeded on March 19th at the Longmont stations and at all Boulder A.I.R. stations on March 20th. The 24-hour averaged PM2.5 time series, also seen Figure 18, show that the PM2.5 NAAQS was exceeded at LUR and BSE on the 19th, 20th, and the 21st. The build-up of surface ozone and particulate matter leading to these exceedances occurred over three days (March 18-20) at all of the stations, and concentrations of other species also increased during these days.

This build-up of ozone, PM2.5, and other species happened, in part, because of cold temperatures at the surface, leading to a very strong temperature inversion that did not allow pollutants to be mixed upward, away from the surface (see the vertical temperature data in the series of Denver NWS radiosondes in Supplement D). This means there was no vertical dilution of pollutants. Also, the winds were weak during this time (Figure 19, top).

There was a very shallow layer of upslope winds (winds with an easterly component) during the afternoons of this event that was capped by the temperature inversion, so what little transport of pollution there was, was toward the foothills, where pollutants can accumulate due to the terrain. The sustained northeasterly to easterly flow (0° to 90°, Figure 19, bottom) continuously transported air that was enriched with oil and gas emissions from the Weld County area from east to west, as evidenced by the VOCs measurements.

These weather features occurred because high pressure dominated the Front Range, leading to quiet weather conditions that did not support the formation of stronger winds or precipitation (Supplement D). Approximately 20 inches of snow had fallen in the area the week before this event. The remaining snow cover contributed to the formation of the shallow temperature inversion as well as the formation of ozone because of additional light reflected off the surface of the snow, enhancing the photochemical production of ozone. Thus, several meteorological factors joined together to bring about this pollution event.

As seen in Figure 20, this area of high ozone was very localized, affecting the Front Range from Denver to Fort Collins, bringing us the worst air quality in the nation on this day. The event was ended by the passage of a cold front that occurred between midnight and 3 am on March 21st. This cold front brought in cleaner air from the northwest as well as stronger winds that could transport the pollution out of the region. A cold front passage also causes vertical mixing along the front, which can dilute pollution near the surface. Lastly, in Figure 21, a plot of the daily hourly ozone maxima for every March since 2001 shows that daily ozone maxima for March 19-21, 2021, far exceeded any other March hourly ozone maxima for the last 20 years. Similarly, 2001-2020 January and February data did not show any prior pollution events of this magnitude.

Tables

Table 1:
Comparison of the statistics of CO_2 and methane data (5-min averages) at LMA and ethane and benzene at LUR during Q1 of 2020 and Q1 of 2021. "Abs Diff" is the 2021 value minus the 2020 value.

Year		2020	2021	Abs Diff	% Diff
CH_4	count	26106	25793	-313	1.0
(ppb)	mean	2036.7	2068.9	32.2	1.6
	std	101.8	106.6	4.8	4.7
	min	1890	1911.8	21.8	1.2
	5%	1930	1950.1	20.1	1.0
	25%	1966	1996.1	30.1	1.5
	50%	2020	2043.7	23.7	1.2
	75%	2076	2113	37.0	1.8
	95%	2220	2262.7	42.7	1.9
	max	3048	2751	-297	9.7
CO_2	count	26106	25793	-313	1.0
(ppm)	mean	427.7	430.4	2.8	0.6
	std	12.6	11.9	-0.7	6.0
	min	410.0	412.6	2.6	0.6
	5%	412.6	416.0	3.4	0.8
	25%	418.0	422.5	4.5	1.1
	50%	425.2	427.8	2.6	0.6
	75%	434.6	435.5	0.9	0.2
	95%	451.8	454.8	3.0	0.7
	max	507.6	536.3	28.7	5.6
Ethane	count	853	2008	1155	135
(ppb)	mean	31.5	15.9	-15.6	49.5
	std	67.1	23.3	-43.8	65.3
	min	1.17	1.06	-0.108	9.23
	5%	1.996	2.09	0.103	5.19
	25%	5.81	5.63	-0.194	3.34
	50%	12.7	11.2	-1.54	12.1
	75%	26.9	20.5	-6.44	23.9
	95%	125	42.3	-83.1	66.2
	max	564	604.9	40.9	7.25
Benzene	count	853	2008	1155	135
(ppb)	mean	0.323	0.172	-0.152	46.9
	std	0.697	0.222	-0.475	68.1
	min	0.030	0.017	-0.013	42.4
	5%	0.045	0.050	0.005	11.1
	25%	0.085	0.086	0.002	2.1
	50%	0.139	0.126	-0.013	9.5
	75%	0.289	0.204	-0.085	29.3
	95%	1.10	0.418	-0.682	62.0
	max	8.04	6.30	-1.739	21.6

Figures

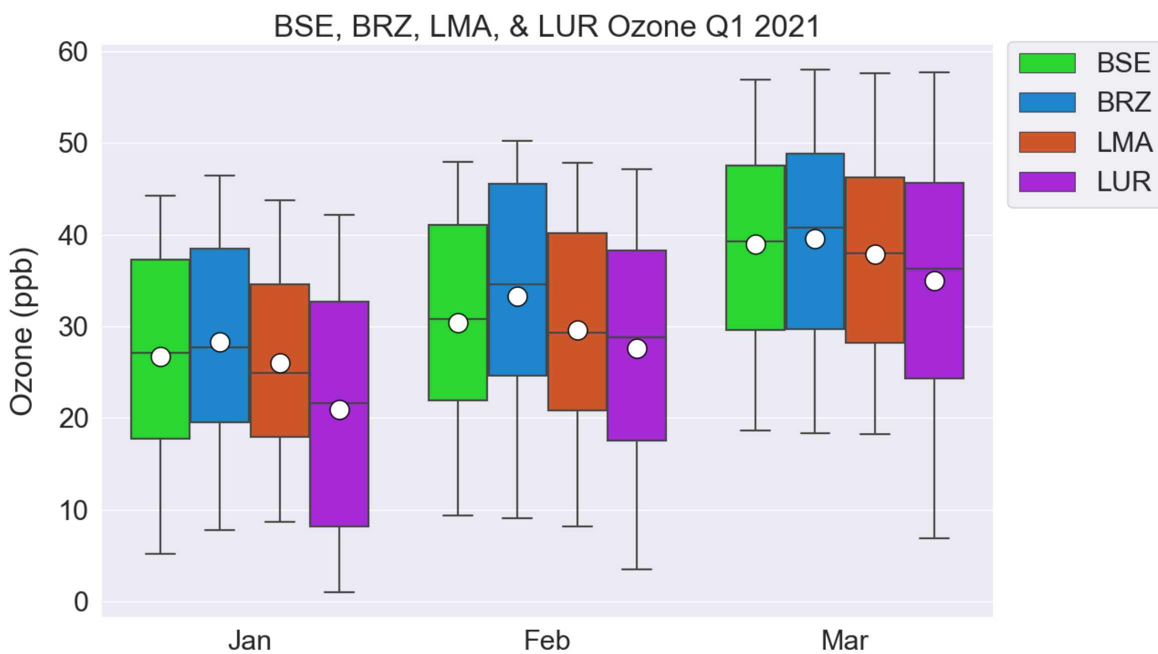


Figure 1:
Comparison of the ozone distribution at BSE, BRZ, LMA, and LUR during Jan – Mar 2021. These box whisker plots show the median value as the center line, the 25-75 percentile distribution as the colored boxes, and the 5-percentile and 95-percentile values as the whiskers. The white dot on each box illustrates the mean value at each site. Ozone at LUR showed the overall lowest percentile values, followed by LMA. These differences are mostly driven by higher levels of nitrogen oxides at the Longmont sites. Nitric oxide, particularly in the winter, is a sink of ozone at low light conditions (nighttime hours).

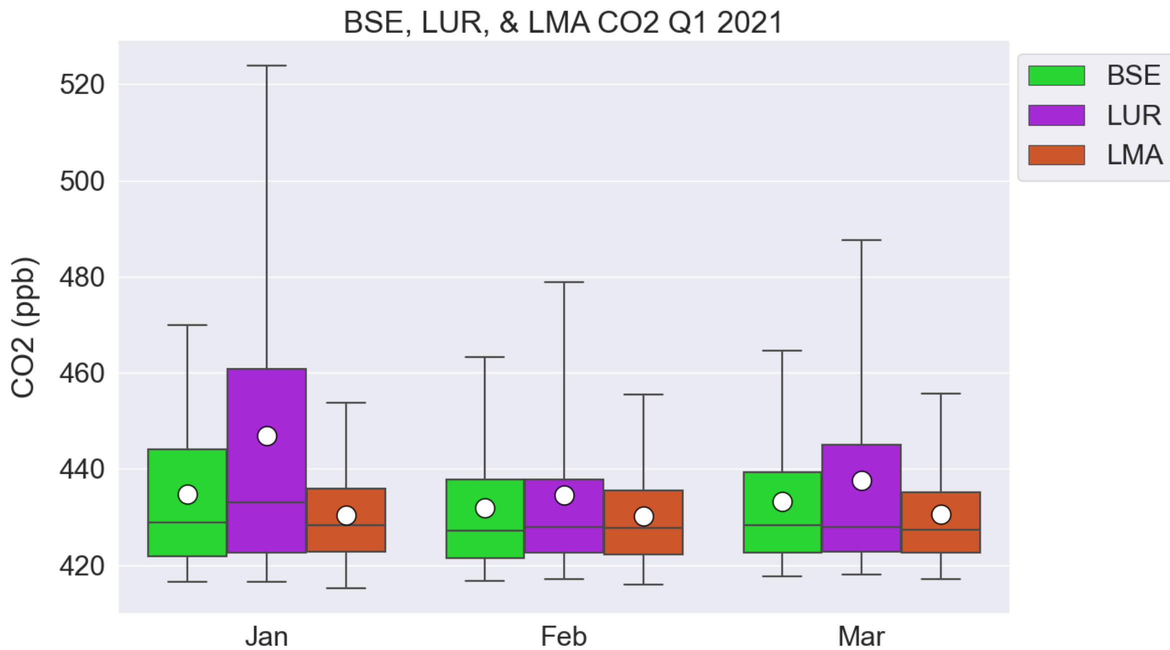


Figure 2:
Comparison of the CO_2 distribution at LMA, LUR, and BSE during Jan – Mar 2021. See Figure 1 for explanation of the box whisker plot format. LUR had the overall highest variability and highest CO_2 percentile values among these three sites, likely indicating the strongest CO_2 sources in the vicinity of the LUR station.

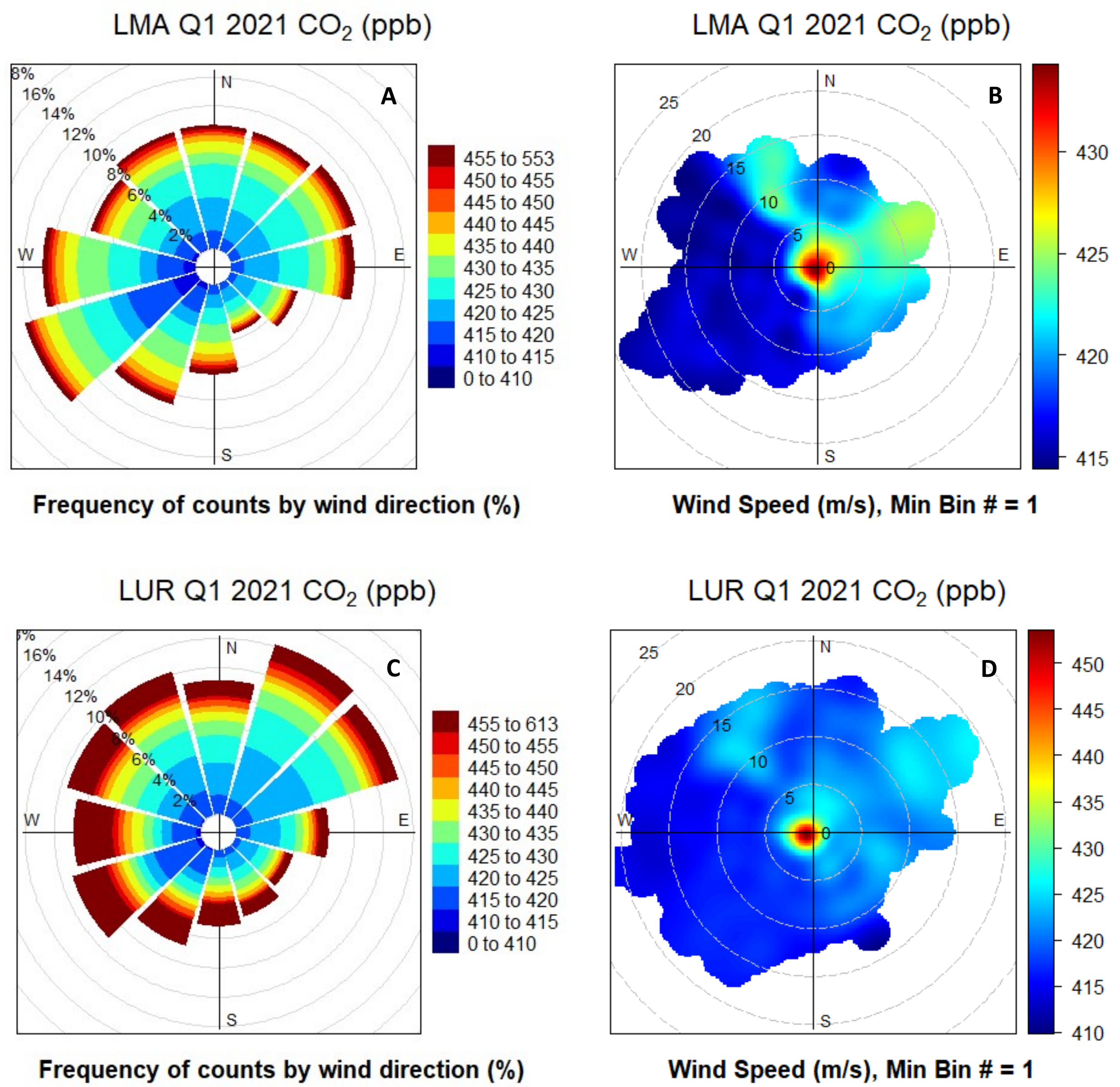


Figure 3:
Wind rose (left) and wind heat map analysis showing the dependency of CO_2 mole fractions at LMA (top, A, B) and LUR (bottom, C, D) during Jan – Mar 2021. The LUR site is east of the City of Longmont. These analyses suggests that the city is the primary source for enhanced CO_2 observed at LUR.

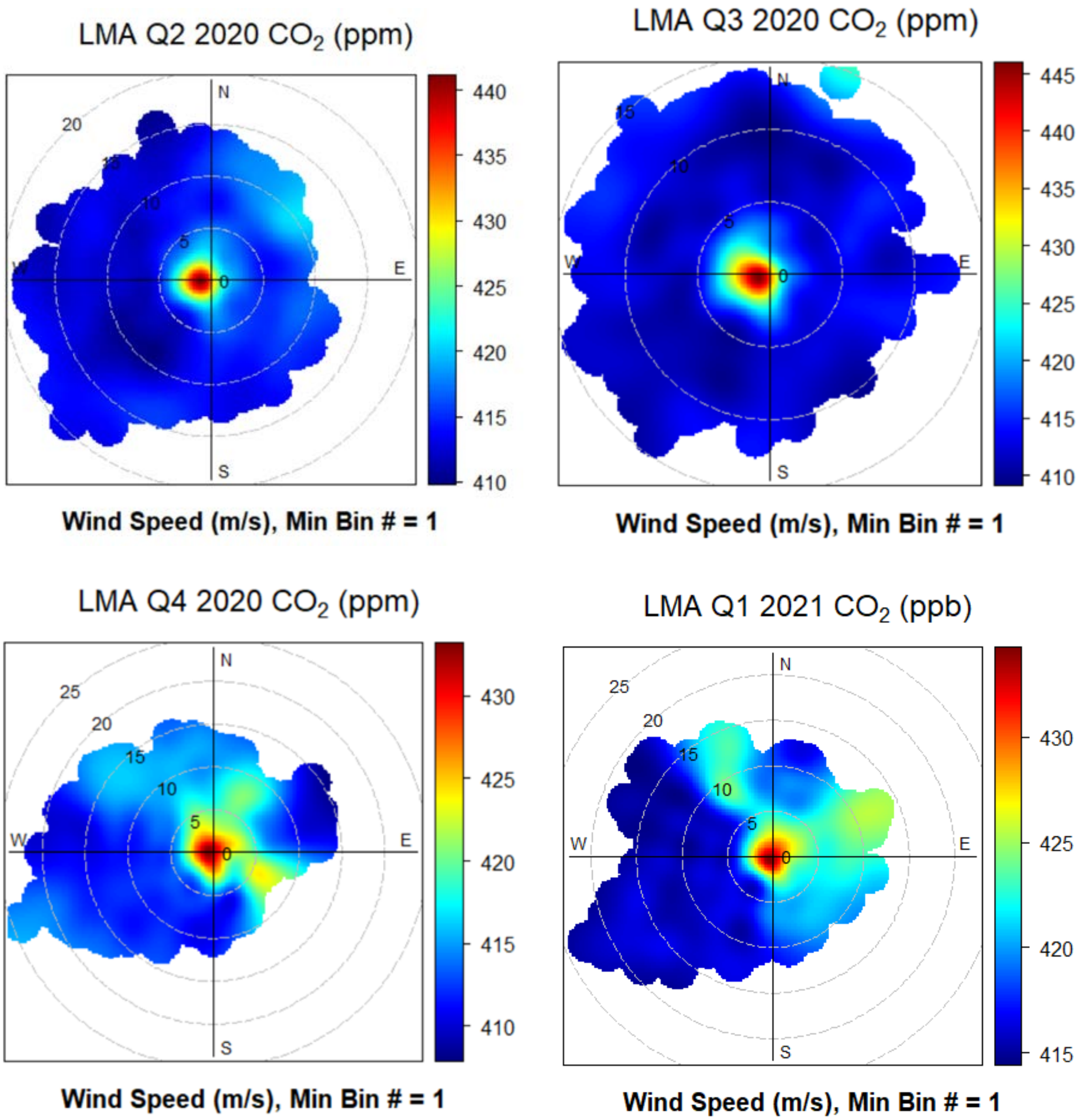


Figure 4:
Comparison of the wind speed/wind direction to observed CO_2 at LMA from Q2 2020 to Q1 of 2021. There is a consistent pattern with a relatively strong source to the west of the station throughout the year, with possibly additional sources emerging to the northwest and east of LMA.

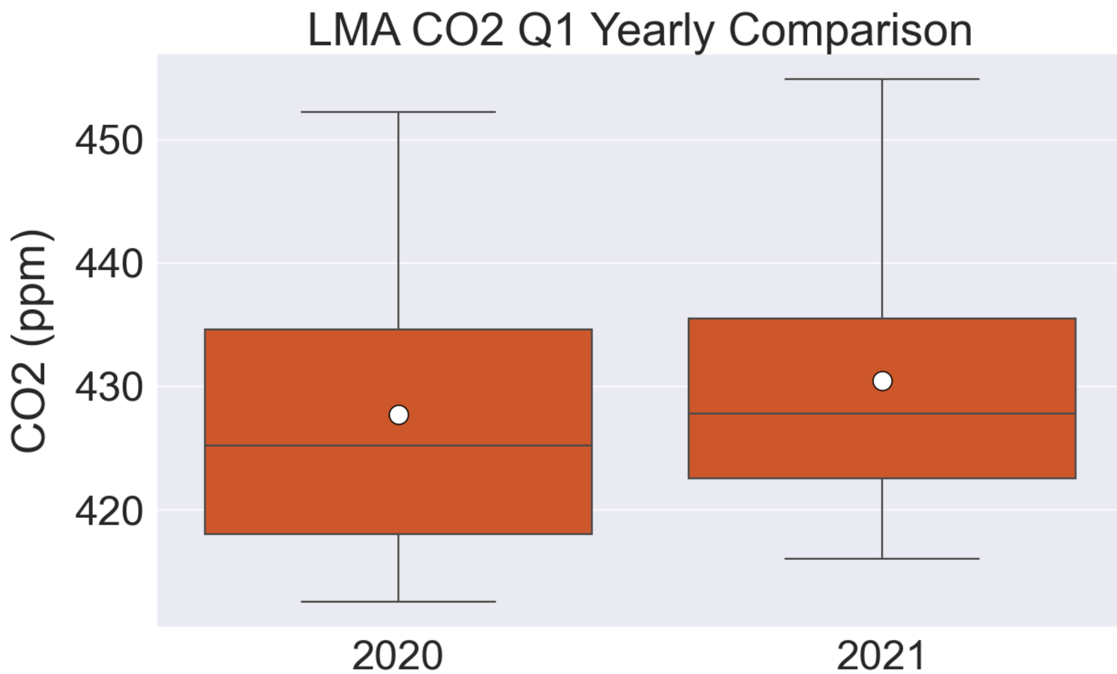


Figure 5:
Comparison of the CO_2 distribution at LMA during Q1 of 2020 and 2021. See Figure 1 for explanation of the box whisker plot format. The mean, median, and percentile values were all larger in 2021 than in 2020 (see Table 1 for the numerical values).

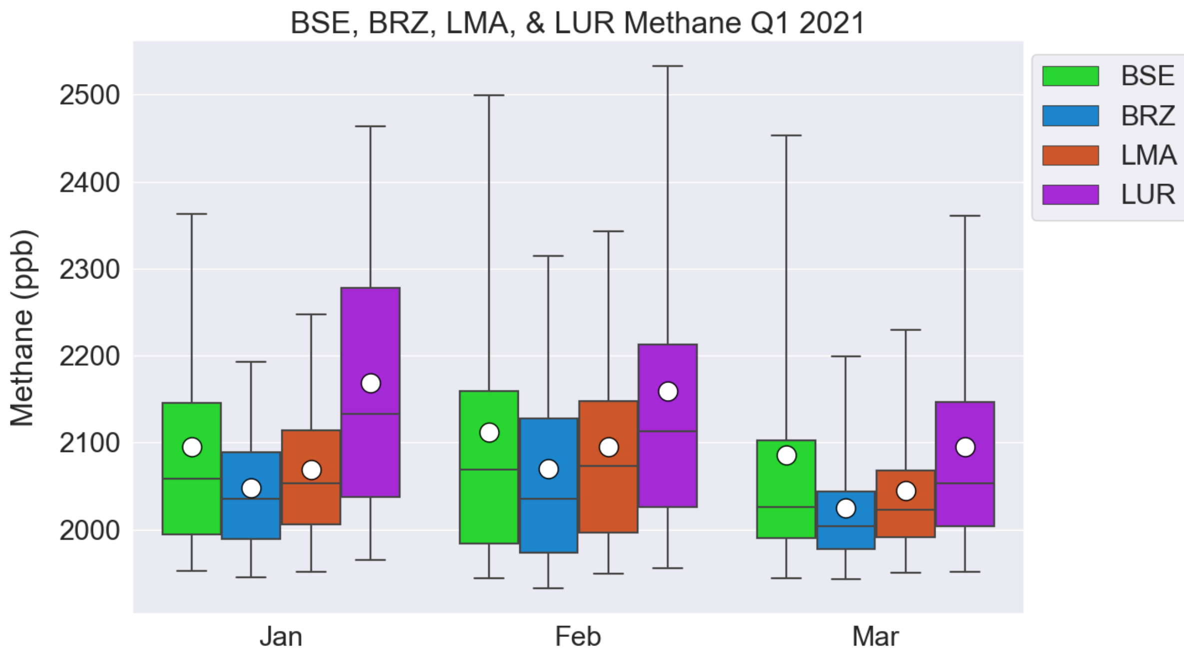


Figure 6:
Comparison of the methane distribution at BSE, BRZ, LMA, and LUR during Jan – Mar 2021. See Figure 1 for explanation of the box whisker plot format. Between the two Longmont sites, LUR has higher absolute values and variance.

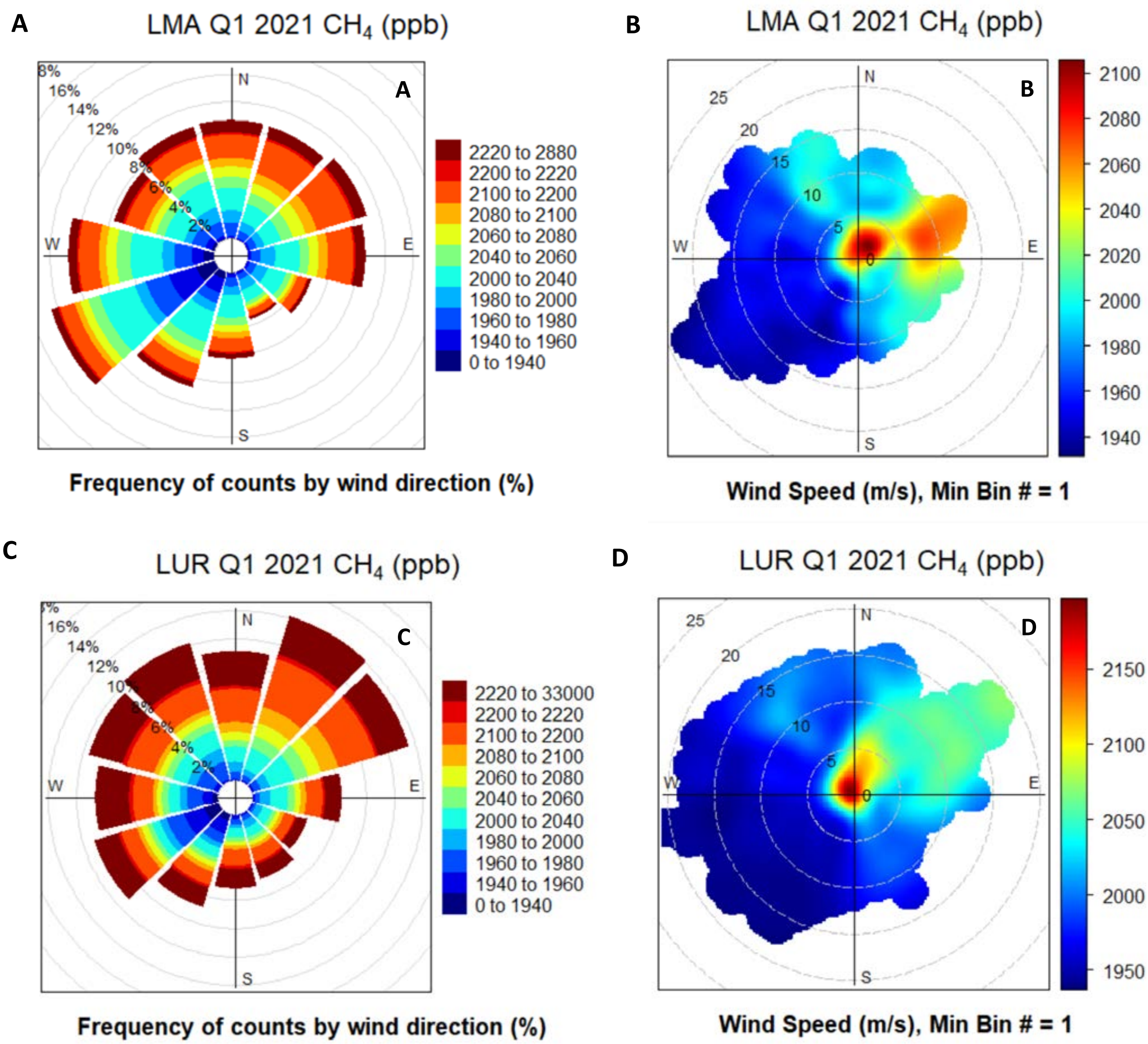


Figure 7:
Wind rose (left) and wind heat map analysis showing the dependency of CH_4 mole fractions at LMA (top, A, B) and LUR (bottom, C, D) during Jan – Mar 2021.

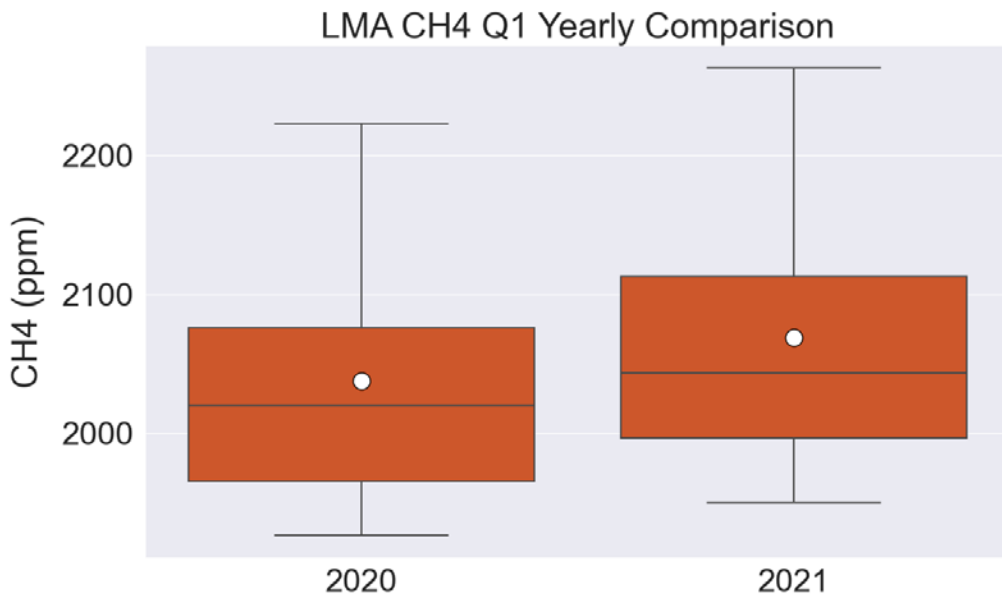


Figure 8:
Comparison of the methane distribution at LMA during Q1 of 2020 and 2021. See Figure 1 for explanation of the box whisker plot format. The numerical values for the statistical distributions are presented in Table 1. The mean, median, and percentile values were all larger in 2021 than in 2020.

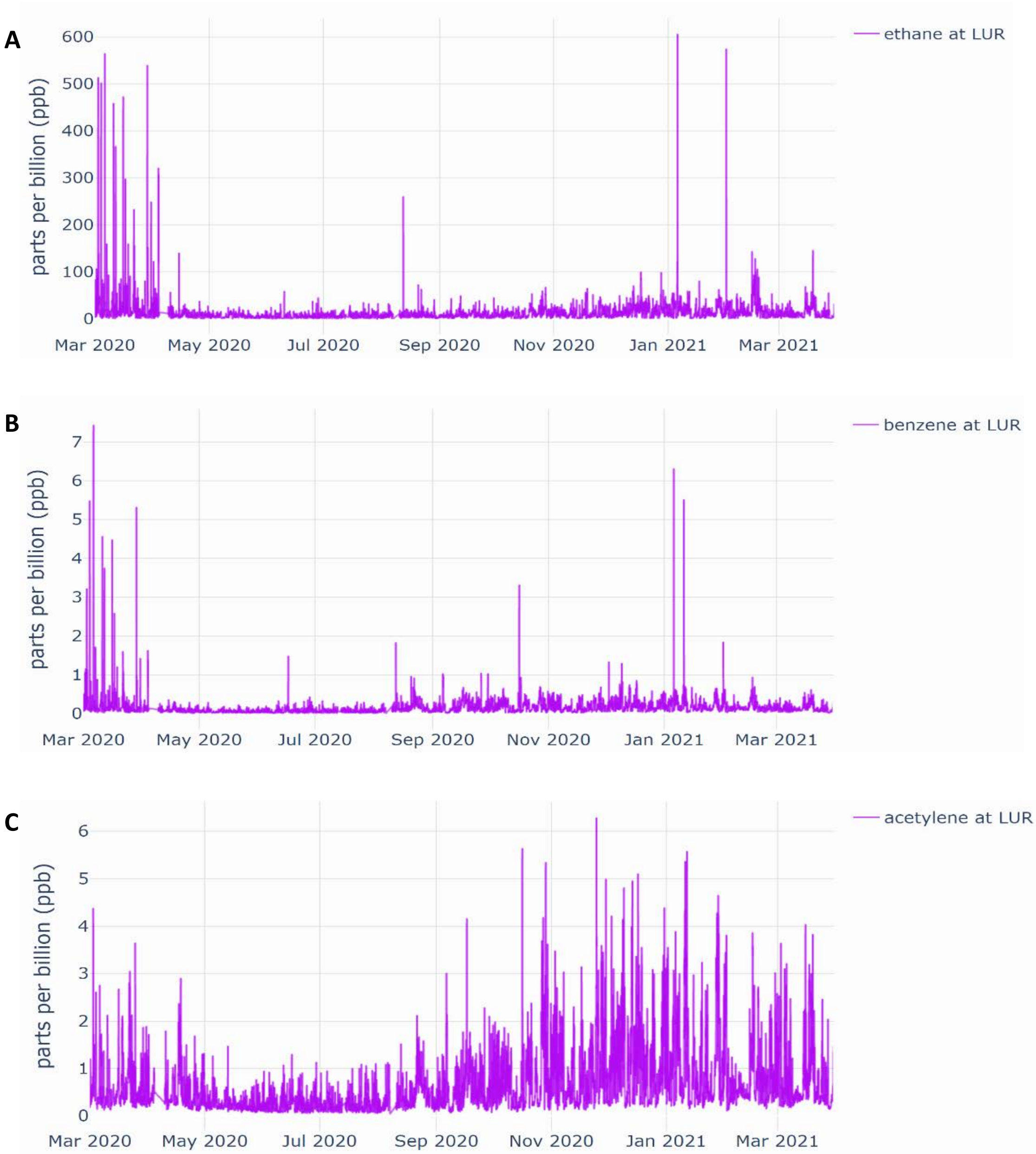


Figure 9:
Ethane (A, top), benzene (B, middle), and acetylene (C, bottom) at LUR between March 1, 2020 and March 31, 2021. Lower frequency and lower maximum values of concentration spikes during the summer are observed for all three compounds. These summer minima are mostly caused by the stronger mixing (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. The behavior of the oil and gas tracer ethane is quite different. Here, occurrences of spikes were overall lower in the fall-winter, excluding the large spikes that occurred in January 2021. A similar pattern was observed for benzene. The March 2021 levels of ethane and benzene were lower than those of March 2020. These features suggest that there has been a continuing shift (decline) in the source strength for these two compounds.

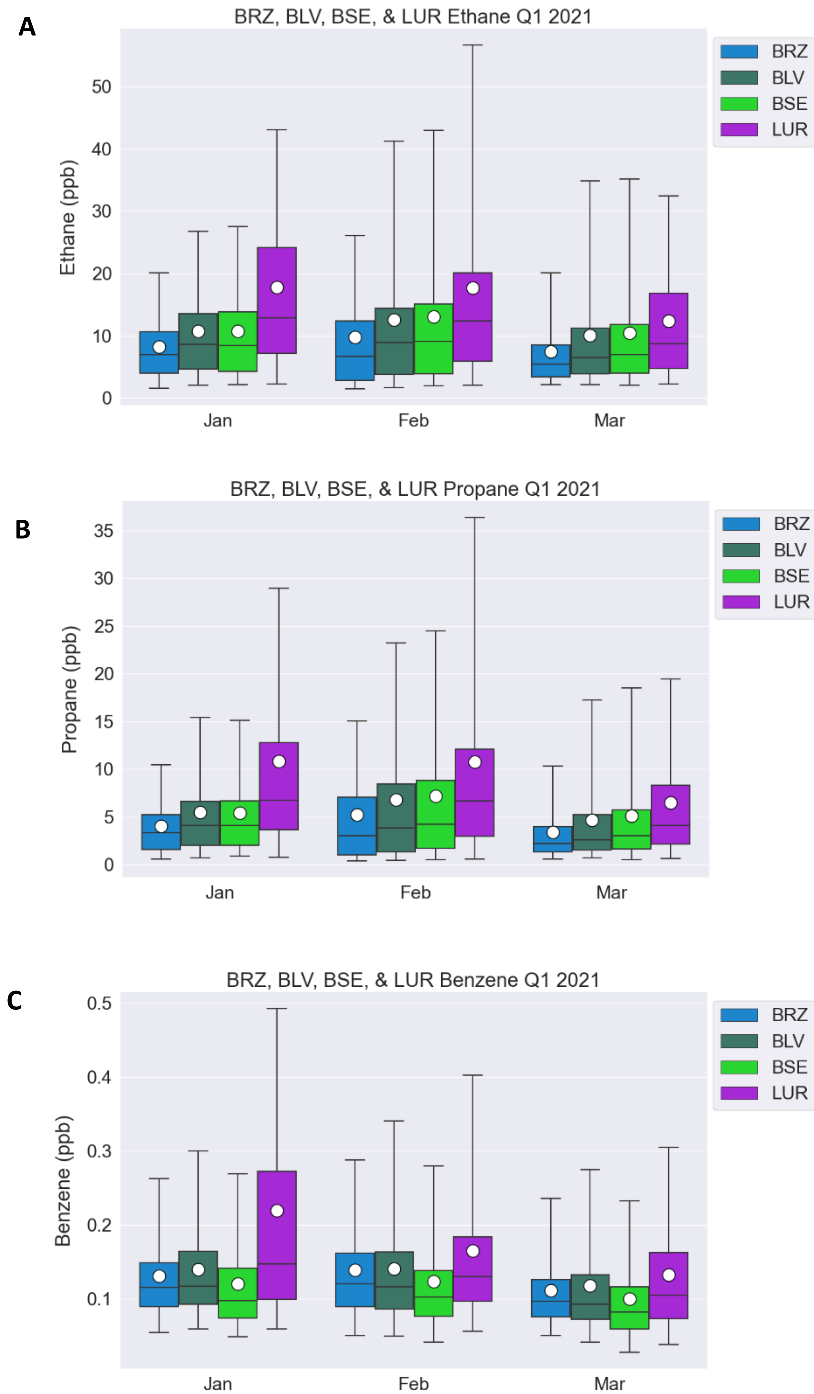


Figure 10:
Comparison of the distribution of ethane (A), propane (B), and benzene (C) at BRZ, BLV, BSE, and LUR during Q1. See Figure 1 for explanation of the box whisker plot formats. Ethane and propane 95th percentiles were very high at LUR in February. For benzene, LUR 95th percentile values were higher than at the other stations, but exceptionally high in January, with a decrease in the following months.

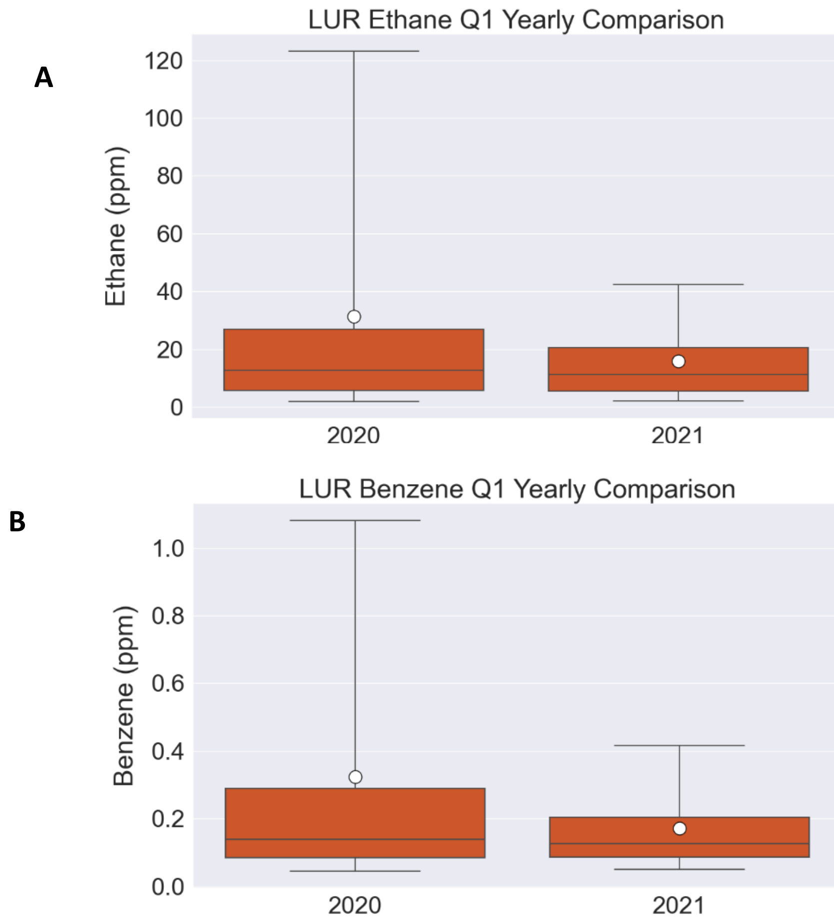


Figure 11:
Comparison of the ethane distribution (top, A) and the benzene distribution (bottom, B) at LUR during Q1 of 2020 and 2021. See Figure 1 for explanation of the box whisker plot format. The numerical values for the statistical distributions are presented in Table 1. The mean and 95th percentile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

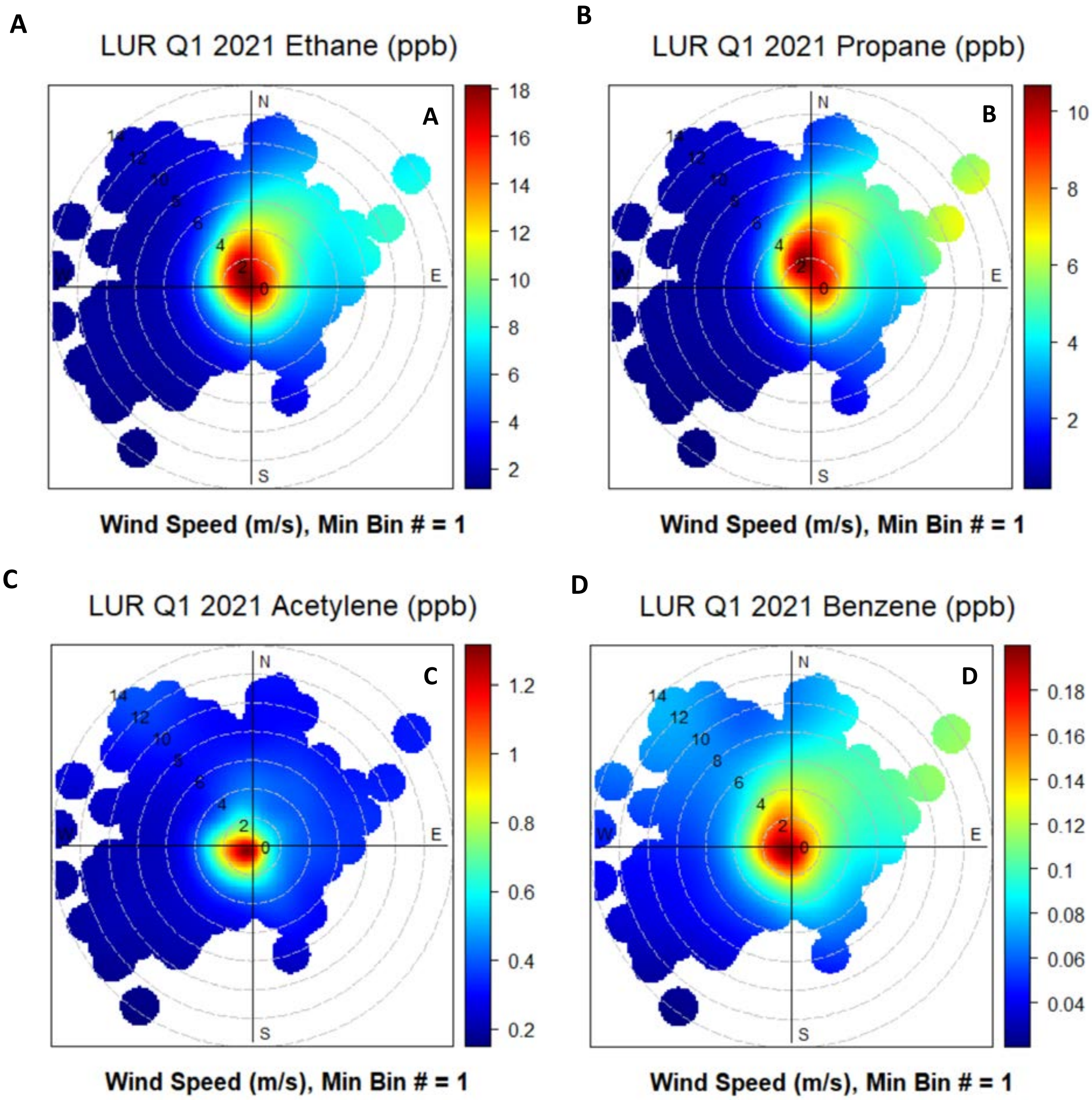


Figure 12:
Comparison of ethane (A), propane (B), acetylene (C), and benzene (D) occurrences as a function of wind speed and direction at LUR during Q1.

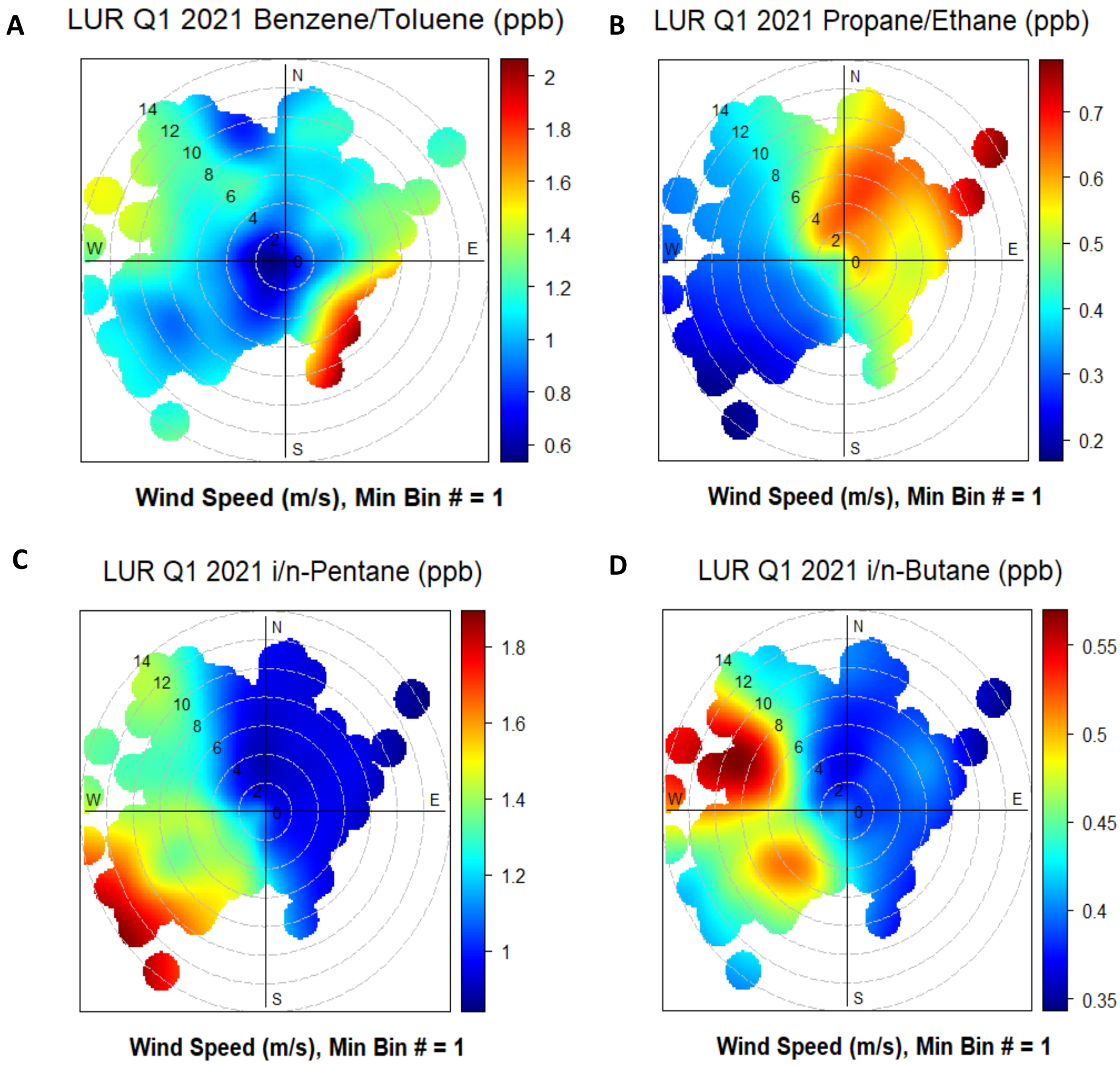
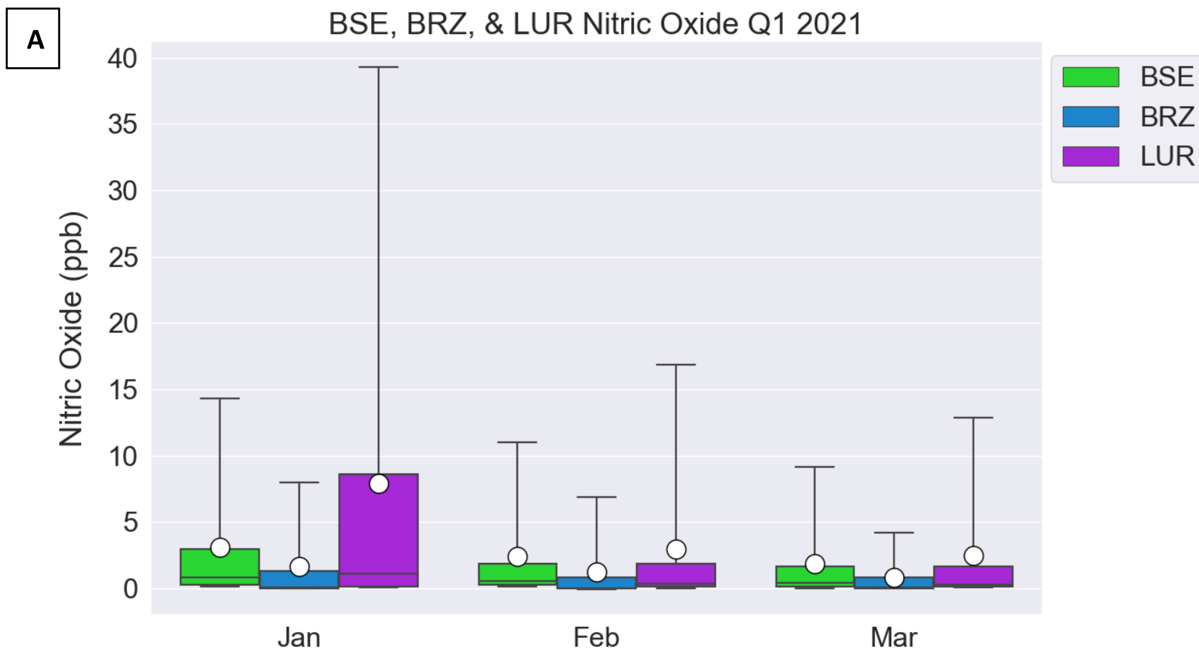


Figure 13:
Ratios of selected VOC pairs as a function of wind direction and wind speed during Q1. These analyses show clear differences in the chemical signatures in air transported from different directions to the monitoring station.



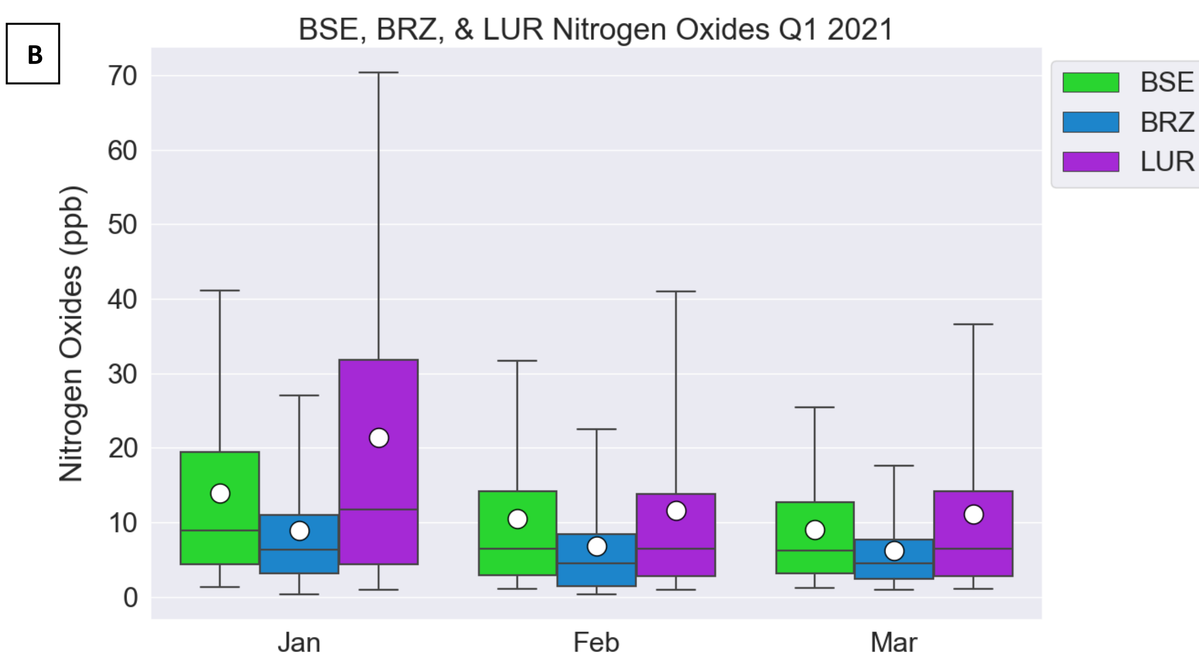


Figure 14:
Comparison of nitric oxide (A) and nitrogen oxides (B) at BSE, BRZ, and LUR during Jan – Mar 2021. See Figure 1 for explanation of the box whisker plot formats. These data continue a pattern seen previously at now even higher clarity: NO and NO_x mole fractions, and the variability in the data are higher at LUR than at sites in neighboring cities. At LUR, the 95th percentile values for both NO and NOx were high in January, and while they decreased in magnitude in February and March, they still exceeded the 95th percentile values at the other stations.

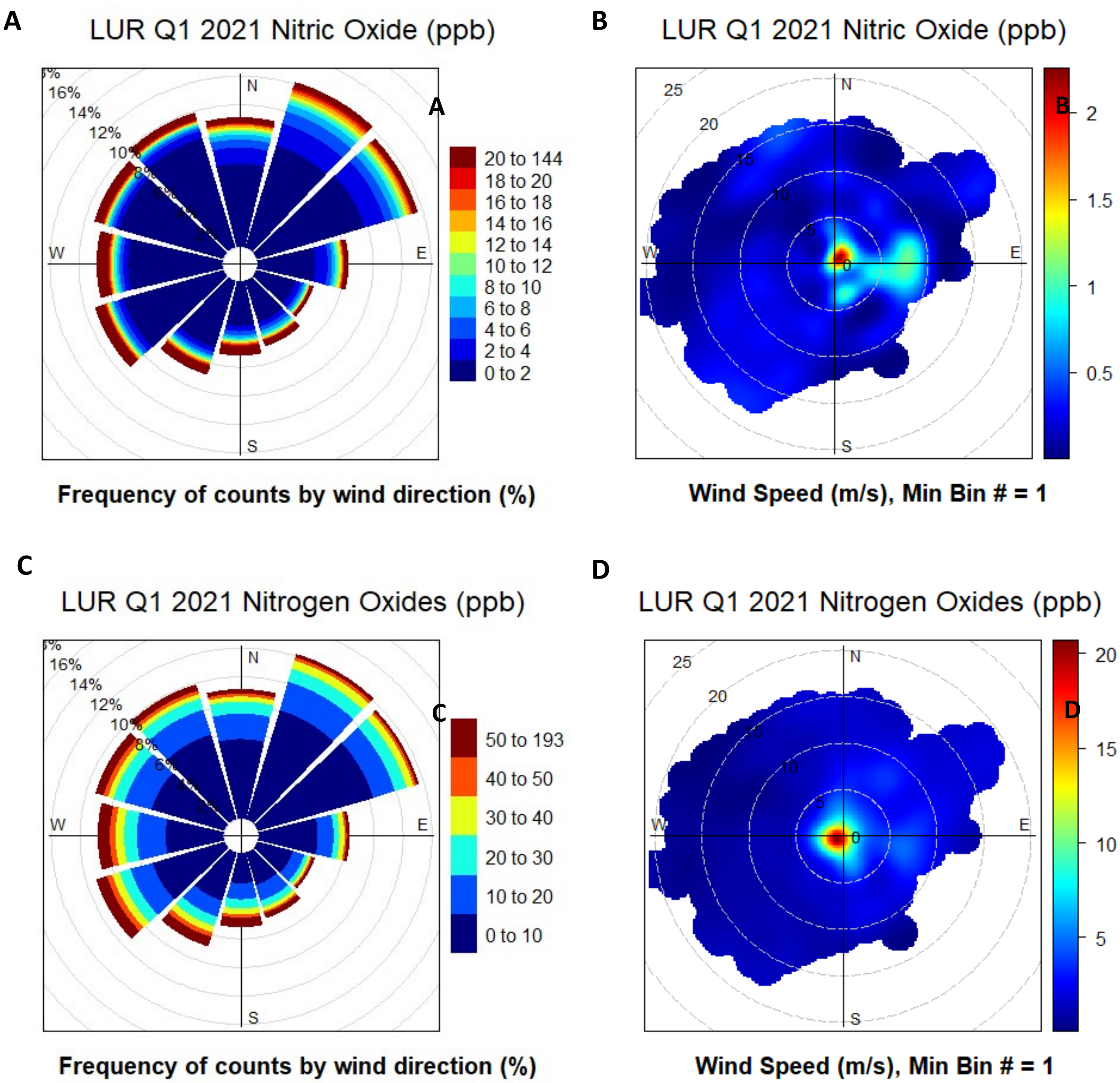
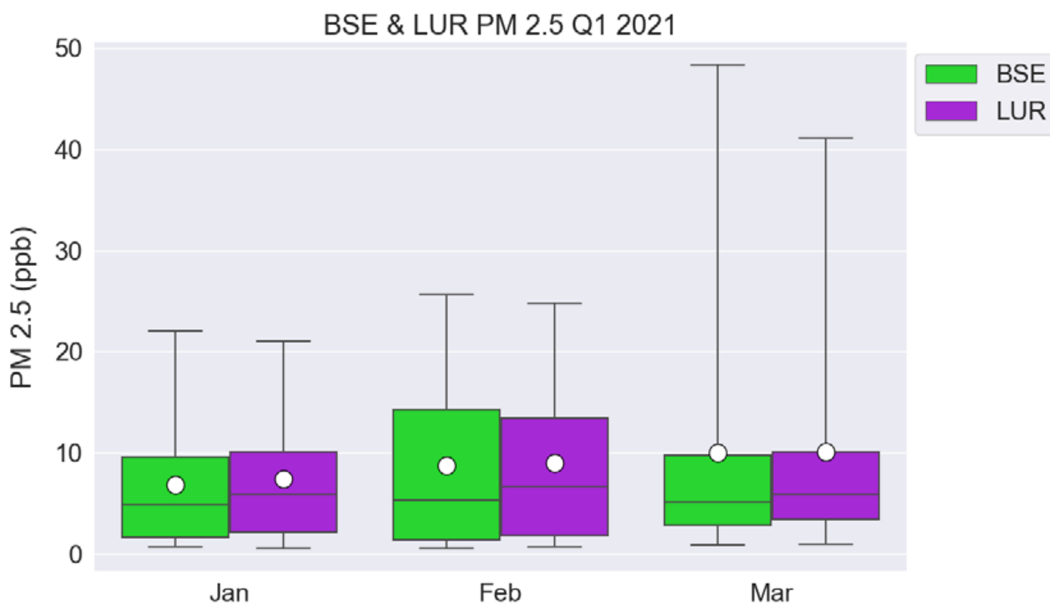


Figure 15:
Dependence of nitric oxide (A, B) and nitrogen oxides (C, D) as a function of wind speed and direction at LUR during Jan - Mar 2021. As seen in the prior data, the City of Longmont, located to the west, appears to be the strongest upwind source for NO_2. NO results are not quite as well defined.

A



B

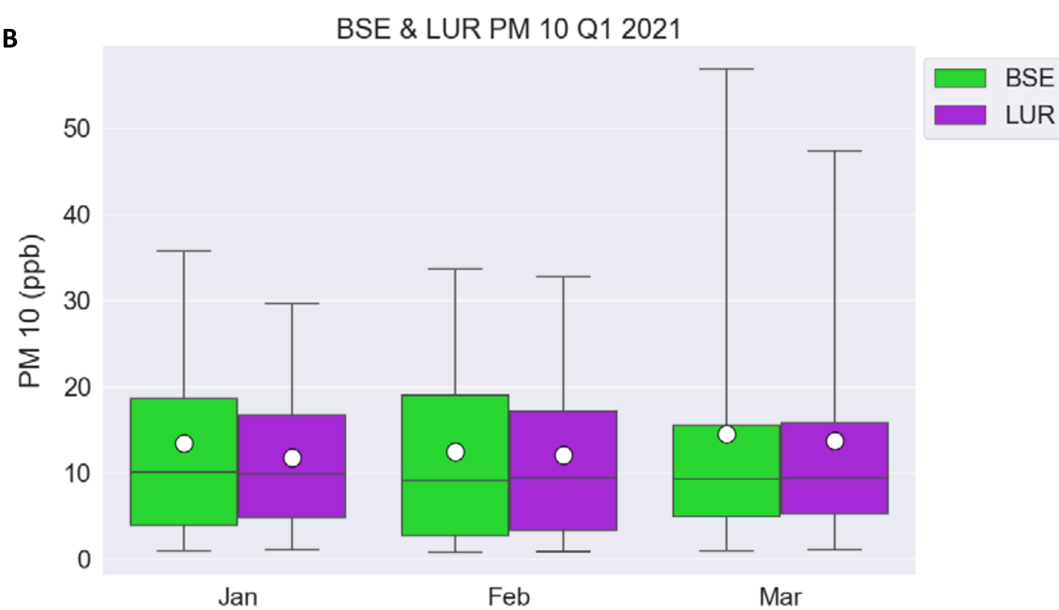
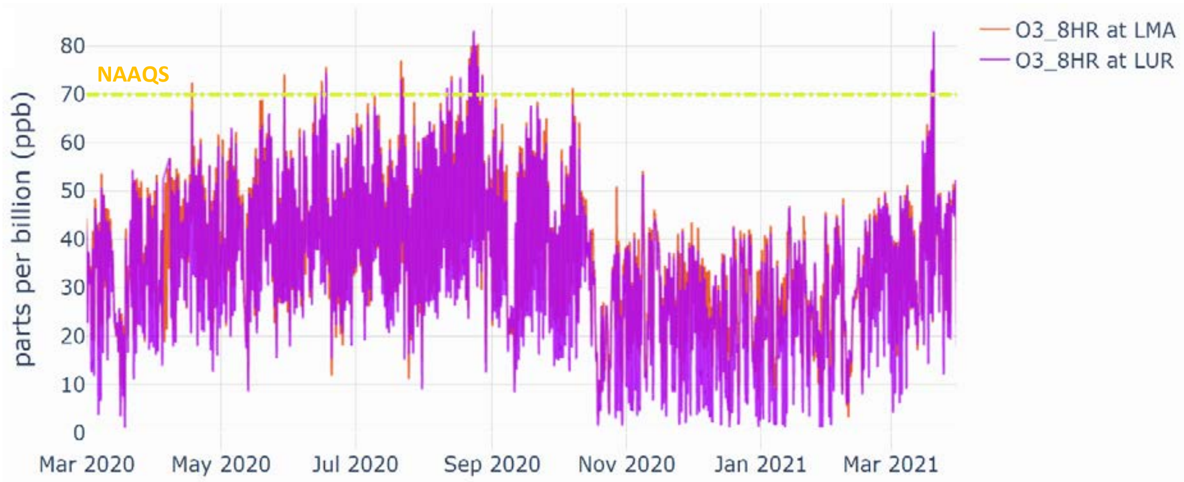


Figure 16:
Comparison of PM 2.5 (A) and PM 10 (B) at LUR and BSE during Jan - Mar 2021. See Figure 1 for explanation of the box whisker plot formats. Median values of particulate matter were similar between the two stations. The month of March had much more variability than January or February.

A



B

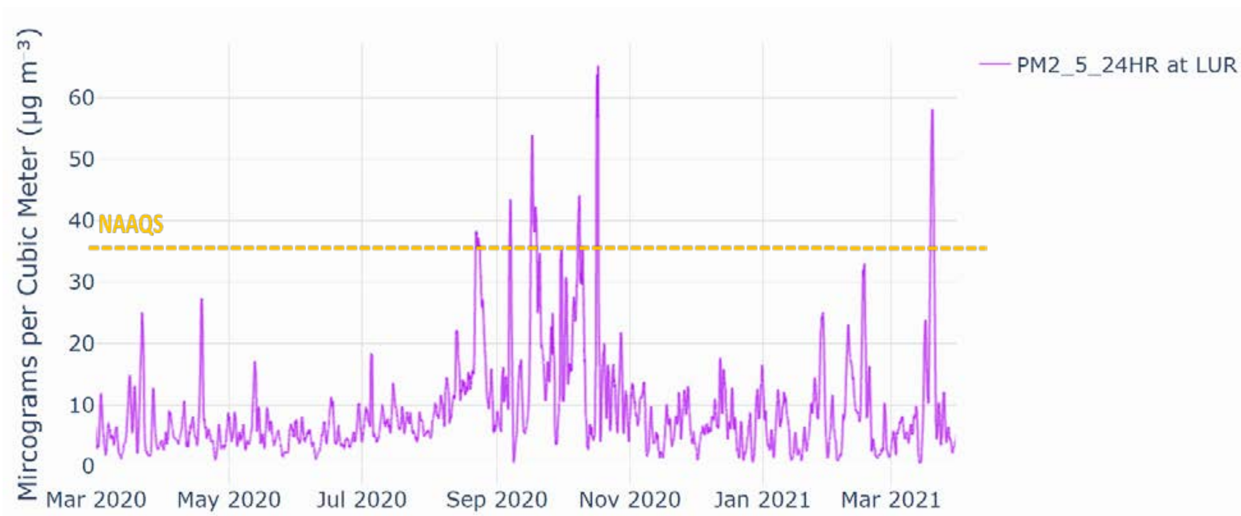


Figure 17:
8-hr averaged ozone (top) and 24-hr averaged PM2.5 (bottom) from March 2020 through March 2021. The dotted green line on the ozone plot indicates the NAAQS for 8-hour ozone (70 ppbv) and the yellow line on the PM 2.5 plot indicates the NAAQS for 24-hr PM2.5 (35 μg/m^3).

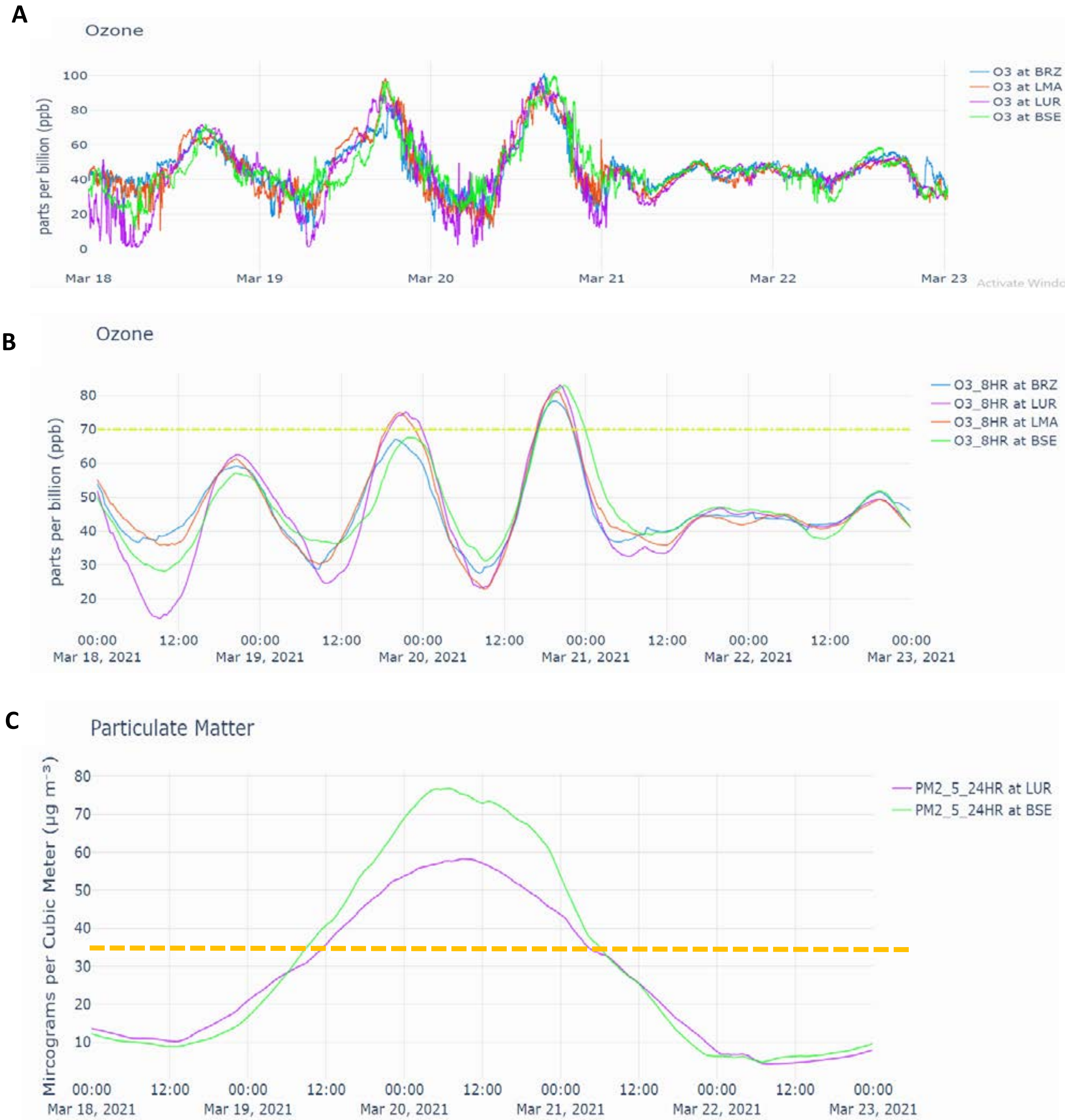


Figure 18:
5-min ozone (top, A) and 8-hr averaged ozone (middle, B) from all 4 network stations for the days surrounding and including the March high-ozone event. 24-hr PM2.5 measurements (bottom, C) from LUR and BSE for the same times.

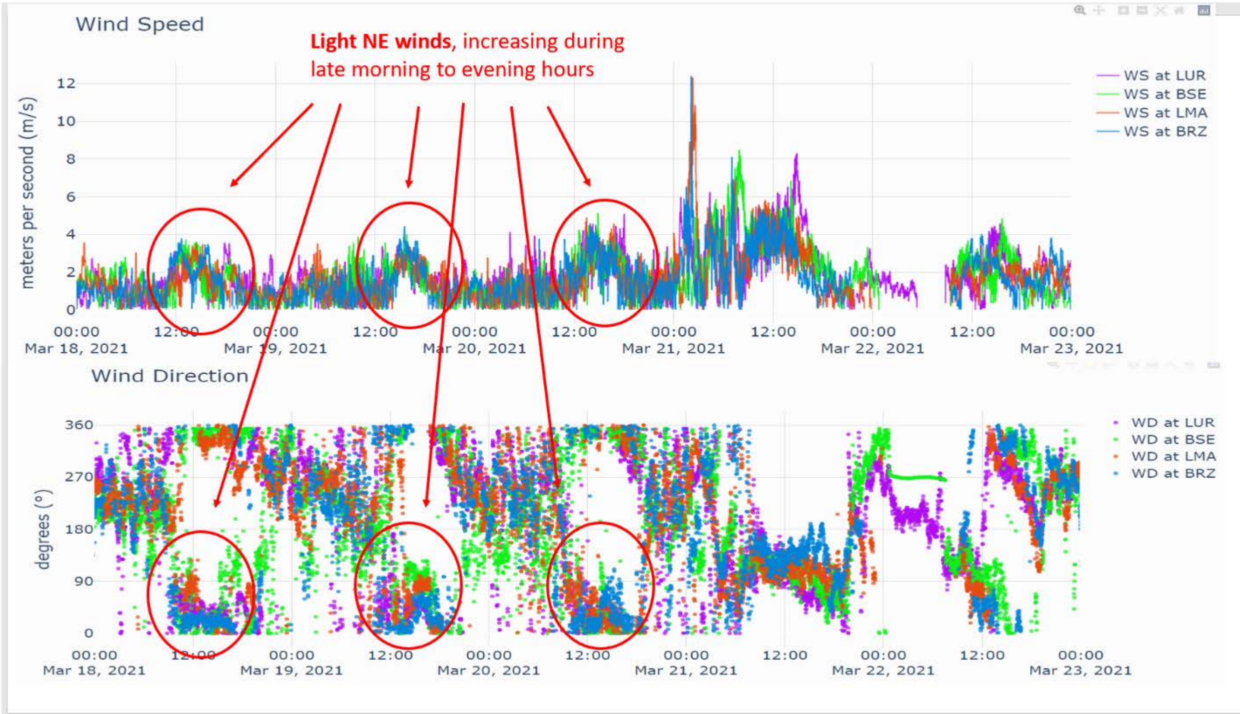


Figure 19:
Wind speed (top) and wind direction (bottom) from LUR, BSE, LMA, and BRZ during the March 2021 pollution event.

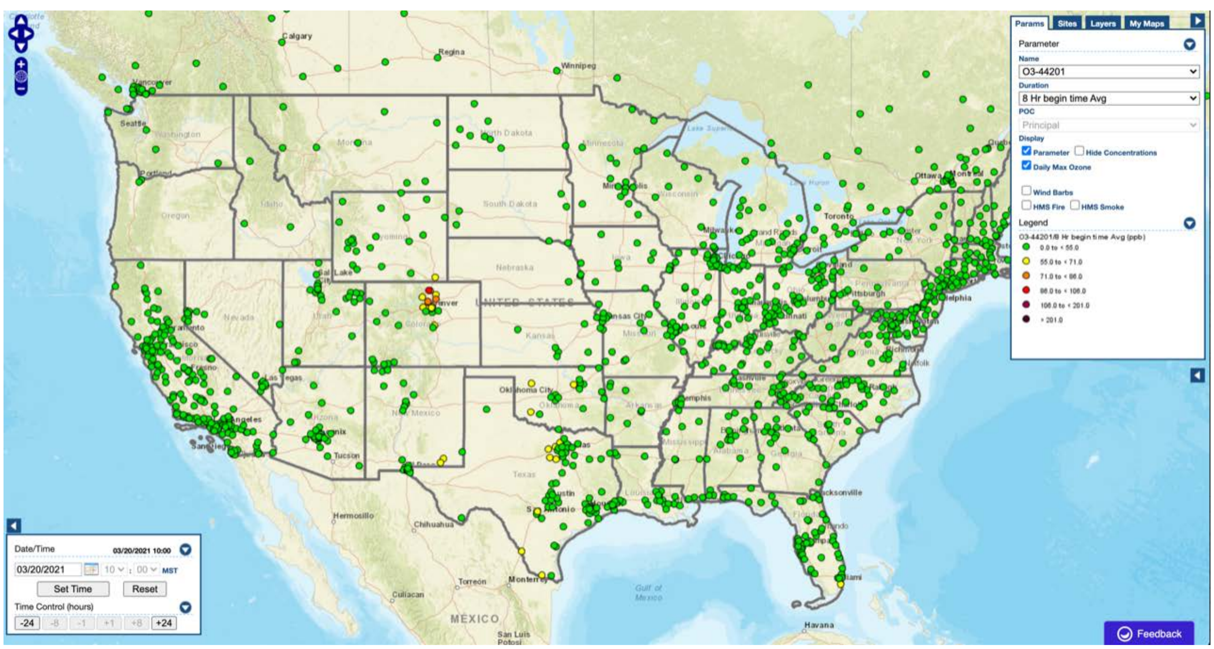


Figure 20:
8-hour ozone maxima across the U.S. on March 20, 2021. Source: http://airnowtech.org/

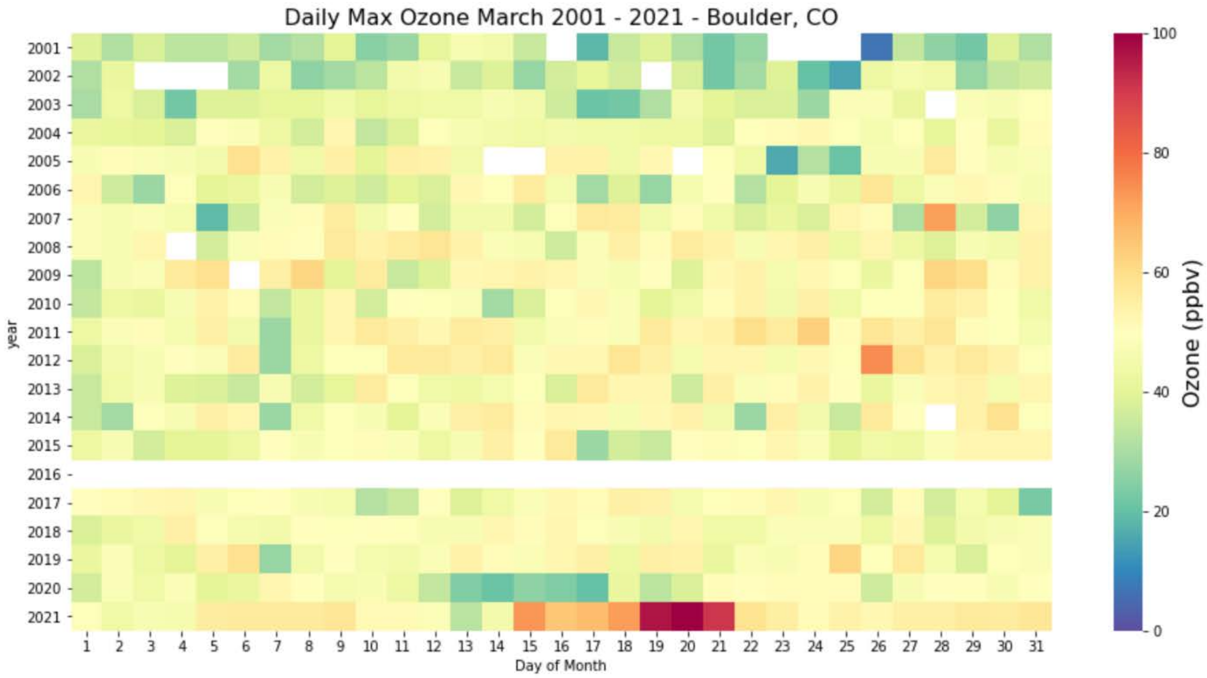


Figure 21:
21 years of hourly ozone maxima for each day in March from 2001 through 2021. Data from 2001 - 2015 are from the South Boulder Creek station and data from 2016 – present is from the Boulder Reservoir station. Data downloaded from https://www.epa.gov/outdoor-air-quality-data/download-daily-data.