Boulder Atmosphere Innovation Research

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Sept. 30, 2020

To:

City of Longmont
350 Kimbark Street
Longmont, CO 80501

Attn: Dr. Jane Turner

Re: Longmont Regional Air Quality Study – Year 2019 Summary Report

Dear Dr. Turner,

Please find included with this letter the revised annual report for our work on the Longmont Air Quality Study. This report describes the initial phase of the monitoring shelter and equipment installation. Analyses of the monitoring data analyses will be presented in subsequent quarterly and annual reports as the data from the operation of the stations become available.

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

2019 Summary Report

Longmont Air Quality Study

Executive Summary

This report summarizes the implementation of the Longmont Air Quality Study during 2019. Two monitoring stations were configured and installed – one at the Longmont Municipal Airport and another at Union Reservoir. The buildings/shelters, instrumentation and equipment, and monitoring configuration are described. Obtaining required permits, selection of the monitoring shelters, their fabrication and installation, and providing power and internet service to the sites took significantly longer than anticipated at the onset of the program, which delayed the onset of the monitoring between fall 2019 to early 2020. The Longmont Municipal Airport site began recording data in late September 2019. The first instruments were installed at Union Reservoir during mid-December 2019. A website for reporting the observations became live shortly after the onset of the monitoring in September 2019. This provides citizens and city staff an online portal to observe the project progress and real-time continuous measurements. The website has become increasingly popular since its launch, having received well in excess of 2000 visits in its first 6 months. The report constitutes a progress update mostly focusing on the siting and installation of the monitoring stations. It also includes graphical displays of the data that were recorded prior to the end of reporting period (December 31, 2019).

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1. Project Scope/Overview and Goals

a. Monitoring of greenhouse gases upwind and downwind of Longmont

The scope of this contract is to provide ambient monitoring at two locations within the boundaries of the City of Longmont (hereafter referred to as City). In order to assess the City's path towards a sustainable (carbon neutral) community, the monitoring of primary greenhouse gases was initiated. The monitoring sites were placed up and downwind of the City, along a transect of the primary wind direction. Taking the measurements from both sites will then allow determination the footprint of observed enhancements in greenhouse gas concentrations, and of the increase in greenhouse gas concentrations from City emissions as air masses travel over the City footprint. Building on these data and utilizing modeling tools will allow for estimation of emissions from the City footprint.

b. Monitoring of primary oil and gas emissions

These measurements target primary air pollutants that are of concern for human health, in particular those released from oil and gas operations, as well as oil and gas emission that contribute to greenhouse warming. This requires continuous monitoring of primary pollutants and tracers emitted from oil and gas activities during all stages of well development to routine production. Besides capturing primary emissions, the monitoring is also meant to assess secondary pollutants such as ozone and particulate matter, which result from atmospheric processing of primary emissions.

c. Provide monitoring and interpretation of results to the public

Graphical data from the observations are shared with the public through a public web portal in near real time. Data analyses and interpretations will be provided to the City of Longmont in quarterly and annual reports and in public presentations.

d. Provide data to public, research community, and industry partners

Numerical data will be shared with the public, research community, and industry partners on request and after quality control and signing of a data sharing agreement.

2. Overview of the Monitoring Program

a. Selection of locations

i. East

During the first phase, several meetings were arranged with City staff for planning for the project progression. Important topics were the monitoring sites selection, required site support, website content and design, and communication contacts. The Union Reservoir was identified early on as a favorable location for a site in east Longmont because of its public exposure, location within a gated area, and its siting and distance from assumed large direct emission sources. However, a walk-through of Union Reservoir park facilities showed that none of the existing buildings at the Union Reservoir appeared suitable for accommodating a monitoring station. A major constraint was the proximity of existing building to large trees, which can interfere with the sampling of atmospheric constituents. Regulatory protocols prohibit trees within a certain distance to sampling inlets and meteorological measurements, and none of the existing buildings met these requirements. Therefore, a portable building was installed in an open, tree-free location on the west shore of the reservoir – approximately 15 meters (m) northwest of the end of the western access road. The site required new power and internet installation. The organization, building acquisition, required permits, power, and internet were all responsibilities of the City. Boulder A.I.R. assisted in this process by proving help and advice in design and configuration questions. Establishing this infrastructure took significantly longer than originally anticipated. The building became available for occupation during the first week of December, 2019. Figure 1 shows the final location of the Union Reservoir monitoring site, and Figure 2 shows images of the building and the adjacent meteorological tower.

ii. West

Finding a suitable site in the western part of the City was more challenging. Several options were considered, but a building that met requirements was not available. Therefore, a trailer was placed within the Longmont Municipal Airport gated area, approximately 100 m south of the southwest corner of the airstrip. An instrument trailer was rented from CU Boulder as a temporary instrument shelter and placed at the airport in September 2019 while the City was researching options and pricing for a City-owned building. During January 2020, the City purchased a trailer, which replaced the temporary CU trailer. Power and internet were installed during late August. Installation of the communication system caused delays, as it required a wireless connection to the outside, with cabled connections to various instruments inside the trailer. With help of City IT staff, a workable solution was developed. A wiring and setup diagram of the communication setup is included in the report as Supplement A. Figure 3 presents the final location of the Longmont Municipal Airport monitoring site, and Figure 4 shows the instrument trailer with the adjacent meteorological tower.

Figure 5 depicts the locations and variables being measured at of both Longmont monitoring operations within the regional network of adjacent Northern Colorado Front Range air monitoring locations.

iii. Site Codes/Abbreviations

It is customary to use 3-letter codes for atmospheric monitoring sites. These 3-letter codes are recognized nationally and internationally and used in all kinds of communications and for data repositories. For the two Longmont sites, we chose:

LUR - for **L**ongmont **U**nion **R**eservoir

LMA - for **L**ongmont **M**unicipal **A**irport

The National Oceanic and Atmospheric Administration (NOAA) and global data portals ensured that these abbreviations were available and unique to Longmont's monitoring sites. These abbreviations will be used in the remainder of this document for the two sites' names.

b. Analytes and Variables Monitored

1. Carbon dioxide

Carbon dioxide (CO_2) is the oxidation product of the combustion of carbon-based fuels. CO_2 is the most significant greenhouse gas, causing approximately 60% of the human-caused climate warming. CO_2 has increased from approximately 280 parts per million (ppm) before the Industrial Revolution, to approximately 410 ppm in 2020. The background CO_2 growth rate has accelerated from ~0.6 ppm year^{-1} 40 years ago, to ~2.3 ppm year^{-1} during the last decade. Background

CO_2 shows a seasonal cycle of approximately 5 ppm at Longmont's latitude, with the summer minimum caused by the increased CO_2 uptake by vegetation. Daily cycles at ground level can vary much more than this due to ecosystem respiration, atmospheric boundary level heights and industrial activity. For more information on atmospheric CO_2, see [*EPA*, 2020a].

2. Methane

Methane is a potent greenhouse gas. Its atmospheric background concentration has more than doubled since the pre-industrial era. Methane has an atmospheric lifetime of about a decade, and because of its relatively long lifetime, its background concentration is relatively evenly around the globe. Emissions arise from a multitude of sources, with oil and natural gas operations, livestock, landfills, and wastewater treatment plants being the primary emission categories in northeastern Colorado. Nearby emission sources can cause spikes in which methane is elevated over the approximately 1900 parts per billion (ppb) northern hemispheric background. For more information on methane see, see [*EPA*, 2020a]

3. Volatile Organic Compounds

Volatile Organic Compounds (VOCs) comprise a large group of many individual chemicals containing mostly carbon, hydrogen, oxygen, and to a lesser extent, nitrogen, and halogens (chlorine, fluorine). VOCs are emitted from both natural vegetation and anthropogenic sources, such as solvents, fuels, paints, consumer products, and incomplete combustion. VOCs have highly variable atmospheric lifetimes spanning from minutes to several months. During their chemical oxidation in the atmosphere, VOCs contribute to formation of ground-level ozone (a criteria pollutant) at regional and continental scales. Larger molecule VOC species, and the oxidation of all VOCs, can also contribute to aerosol (i.e. particulate matter) formation. Consequently, VOCs are an important constituent of air pollution and smog. Globally, ethane and propane are the most abundant anthropogenic VOCs. They have atmospheric lifetimes of about 2 months and 2 weeks, respectively. Oil and gas production and processing activities are the main source of ethane and propane [*Pétron et al.*, 2012; *Helmig et al.*, 2014]. Propane can also be released to the atmosphere from storage and distribution of liquefied petroleum gas. Aromatic VOCs (i.e. benzene, toluene) have been recognized because of their harmful health effects, with benzene being a known human carcinogen [*ATSDR*, 2020]. For more information on VOCs see [*EPA*, 2020e]

4. Nitrogen oxides

Nitric oxide (NO) and nitrogen dioxide (NO_2) are the dominant nitrogen oxidation products formed from fuel combustion. The sum of the two are commonly referred to as NO_x ($NO_x = NO + NO_2$). NO_x production generally increases with burning temperature, which makes engines and fossil-fuel fired power plants major sources of NO_x. Depending on environmental conditions, in particular the presence of sunlight and VOCs, these two gases quickly inter-convert in the atmosphere. With the addition of VOCs, these reactions lead to the formation of ground-level ozone, nitric acid, and particulate nitrate – all components of photo-chemical smog. For more information on NO_x see [*EPA*, 2020c].

5. Ozone

Ozone (O_3) is not directly emitted by any pollution source. Instead, it is formed in the atmosphere through a chain of photochemical reactions. In the stratosphere, intense UV-C radiation photolyzes oxygen molecules, which then re-combine with molecular oxygen to form ozone. At ground level, a series of chemical reactions involving NO_x, VOCs, and lower-intensity sunlight lead to elevated levels. Ozone in the stratosphere, at ppm levels, is essential for protecting life from intense UV radiation, but at ground level, without pollution from anthropogenic influence, relatively low levels less than ~ 30 ppb occur. Breathing air with unnaturally high levels of ozone is harmful to most forms of life on Earth. Therefore, for the protection of human health, ozone is a regulated pollutant. The current U.S. National Ambient Air Quality Standard (NAAQS) for ozone is 70 ppb for recordings averaged over an 8-hour interval. The Denver Metropolitan Area and Northern Colorado Northern Front Range (which includes the City of Longmont), have been designated as an ozone non-attainment area (NAA) because of repeated exceedances of this standard. The additional ozone in the lower atmosphere that results from human influences is also contributing to climate change. The ozone that is contributed through pollution is considered a greenhouse gas and ranked third overall in total climate forcing, after CO_2 and methane. For more information on surface ozone, see: EPA website about surface ozone [*EPA*, 2020b]; ozone history in Colorado [*CDPHE*, 2019]; review article on Colorado surface ozone [*Bien and Helmig*, 2018].

6. Particulate Matter

Particulate matter, often referred to as atmospheric aerosol, is the total of solid and liquid particles that are suspended in the atmosphere. Particulate matter sources are diverse and can include dust, pollen, soot, smoke, sea spray, and other liquid droplets. Organic and inorganic chemicals can adhere to particulate matter and influence the particle properties and health effects. Particulate matter is often abbreviated PM, with a number following that indicates the size of the particles that are considered. PM10 includes all particles smaller than 10 micrometers. PM2.5 classifies particles smaller than 2.5 micrometers. These fine particles can penetrate deep into people's lungs when inhaled, which bears the potential for higher health risks. The current EPA health standard for PM2.5 is 35 micrograms/m^3 for averaged 24-hour exposure, and 12 microgram/m^3 for the annual average. For more information on particulate matter see: EPA website about particulate matter [*EPA*, 2020d].

7. Meteorological Variables

Monitored meteorological variables at each site include ambient temperature, ambient relative humidity, wind direction, wind speed, incoming solar radiation. All sensors are research/ regulatory grade (i.e. either Federal Reference Method (FRM) of Federal Equivalent Method (FEM; [*EPA*, 2016]).

8. Webcam

Each site also has an Amcrest web camera mounted on the tower. The camera provides images of the surrounding area. Images are updated every 30 minutes.

3. Air Quality Monitoring Study Updates

While the measurement sites were prepared, monitoring instrumentation, computing equipment, and communication hardware were acquired. The timeline summarizing year 2019 progress is provided in Table 1.

The following major equipment items were installed at LUR:

- One Picarro-G2401 methane/CO_2 analyzer
- One GRIMM EDM-180 particle analyzer for $PM_{2.5}$ and PM_{10} mass
- One Thermo Scientific Model 49C UV absorption ozone monitor
- One Thermo Scientific Model 49C PS ozone calibrator
- One Teledyne API-T200P ultratrace nitrogen oxide monitor with photolytic NO_2 converter
- Meteorological sensors (wind speed/direction vane/propeller anemometer (RM Young Wind Monitor AQ), temperature/humidity sensor (CSL Temperature/RG Probe) in radiation shield, visible spectrum radiation sensor (Apogee SP-110-SS))
- Webcam (Amcrest Ultra HD 4K)
- Campbell CRX data logger (CR1000X)
- Data system computer
- One Thermo Scientific Model 146i calibrator for nitrogen oxides calibration
- Two Synaccess Netbooters for remote systems startup/shut down
- One custom-built pre-concentration system for Volatile Organic Compounds (VOCs), interfaced to an Agilent 5890 gas chromatograph with flame ionization detector
- SRI gas chromatography data system (Single Channel Model 333)
- One nitric oxide (NO) primary calibration standard (~ 1 ppm in nitrogen, Praxair)
- Two multicomponent VOCs primary calibration standards in ultra-high purity nitrogen (used for quantification of ethane, ethene, acetylene, propane, propene, i- and n-butane, i- and n-pentane, benzene, toluene, heptane, isoprene, ethyl-benzene, m-, o-, and p-xylene (~ 10 ppb and ~ 200 ppb, National Physics Laboratory (NPL), U.K.)
- Two primary methane and CO_2 calibration standards (see table below for mole fractions, NOAA Global Monitoring Laboratory, Boulder)

A picture showing the LUR instrument racks and the gas chromatograph analyzer is provided in Figure 6.

The following major equipment items were installed at LMA:

- One Picarro-G2401 methane/CO_2 analyzer
- One Thermo Scientific Model 49C UV absorption ozone monitor
- One Thermo Scientific Model 49C PS ozone calibrator
- Meteorological sensors (wind speed/direction vane/propeller anemometer, temperature/humidity sensor in radiation shield, visible spectrum radiation sensor; same brands/models as for LUR)
- Webcam (same brand/model as for LUR)
- Campbell CRX data logger (CR1000X)
- Data system computer
- One Synaccess Netbooter for remote systems startup/shut down
- Two primary methane and CO_2 calibration standards from the NOAA Global Monitoring Laboratory, Boulder

A picture showing the LMA instrumentation is provided in Figure 7.

4. Data Quality Assurance/Quality Control Process

i. Data recording

Data from the monitors are recorded by computers in the monitoring shelters with either custom-written software (ozone, NO_x, PM, VOCs) or manufacturer-provided software (meteorological variables, CH_4 and CO_2). Methane and carbon dioxide concentrations are recorded at 1-second time resolution; other variables (apart from VOCs) are averaged to 1-minute intervals. VOCs are sampled by pre-concentrating ambient air samples over a 10-min period, using gas chromatography to separate the individual VOCs where they are detected and converted to ambient concentrations. This process requires approximately 1 hour. Calibrations and other instrument operations require additional time, which results in an average VOC reporting period of approximately 75 minutes. Webcam images are recorded every 30 minutes.

ii. Data backup

Data are transferred from the field computers every ten minutes to a central server. In addition, all data are backed up by automated scripts to three standalone data backup drives. One of the data loggers is in the LUR building. The other two dataloggers are located in separate offices of Boulder AIR personnel.

iii. Data quality control

1. Ozone: The LUR and LMA primary ozone monitors were calibrated before field deployment against a laboratory monitor that is referenced against the NOAA Global Monitoring Laboratory (Boulder, CO) reference standard. At LUR, second ozone monitor is configured as a calibrator and is co-located with the primary analyzers. Each night, the primary analyzer collects both a zero and an 80-ppb span check sample for tracing the analyzer instrument response. Two hours later, a 50-ppb span check is also performed. The 50 and 80 ppb standards are generated using the ozone calibrator (Figure 7). Those measurements are flagged and do not show up in the data records displayed on the web portal. Sampling line inlet filters are used to remove dust and other particles and keep the instruments and tubing clean. These are replaced every 2 months.

2. CO_2 and Methane: The Picarro factory-provided calibration variables are used for both gases. Side-by-side comparison of the LMA and LUR analyzers have shown <0.1% deviation between the two analyzes (see more discussion below). A similarly low deviation has been found in the comparison with the Boulder Reservoir gas chromatography methane data, and the Broomfield Soaring Eagle Picarro analyzers during high wind episodes, when concentrations of these gases throughout the region become very uniform and close to global background levels. Every 49 hours, the instruments sequentially sample two NOAA Global Monitoring Laboratory reference gases for five minutes. The mixing ratio ranges were chosen to span the anticipated concentration range for ambient samples. Details are shown in Tables 1 and 2.

Data from these standard runs are flagged and do not show up in the graphs on the website. The readings are plotted in a separate analysis over time to trace the long-term instrument response.

3. Nitrogen Oxides: A 1-ppm EPA-grade (NO calibration standard purchased from Praxair) is used for NO and NO_2 calibration. The standard is diluted with NO_x-free air using the Thermo Scientific 146i dynamic dilution calibrator. A zero and two span checks at levels of 40 ppb, and 160 ppb are run every two

Table 1:
CO_2 and CH_4 gas calibration standards used at LUR.

Standard name	[CO_2] (ppm)	[CH_4] (ppb)
Low	390.33	1827.3
High	600.51	3072.8

Table 2:
CO_2 and CH_4 gas calibration standards used at LMA.

Standard name	[CO_2] (ppm)	[CH_4] (ppb)
Low	389.73	1823.2
High	598.46	3049.8

weeks. The NO-NO_2 conversion efficiency is tested with the 146i as well, by using ozone to convert a fraction of the NO to NO_2, and then tracing the total NO_x result.

4. VOCs (data coming in 2020). VOCs are calibrated against a multicomponent 10-ppb standard that was acquired from the U.K. National Physics Laboratory. This standard is run approximately every week during site visits. In addition, a 200-ppb NPL standard is run quarterly to check for the linearity of the instrument response. A zero air (blank) sample and a lab-calibrated multi-component working standard are run every 65 runs (~every three days).

5. Particulate Matter (data coming in 2020). The factory-provided calibration variables are used. Bi-weekly instrument checks include flow and temperature checks. The analyzer will be sent to the manufacturer after 1.5 years use for recalibration.

6. Meteorological Measurements. Factory-calibration functions are used for all meteorological measurements. Wind direction was calibrated by orienting the wind vane to the estimated north direction. The accuracy of the wind direction orientation is estimated to be +/- 15 degrees. We intend to do a calibration check with a GPS compass in the near future.

5. Website Development

A web portal, named 'Longmont Air Quality Now', was developed that reports the monitoring data from both sites in near real time to the public. Data are averaged to 5-minute means, and those values are then tabulated, graphed, and uploaded to the website every 15 minutes. The website has seven tabs, with each of those reporting distinctly different variables or information. The tabs are: Current Conditions, 3-Day Graphs, 30-Day Graphs, Web Cams, Info, Methods, and Contacts. Webcams at each site record images every 30 minutes, with the previous four of those being displayed under the Web Cams tab. Screenshots of the website tabs are displayed in this report as Figure 8a-g. A site visit counter at the bottom of the page keeps track of the number of site visits. We are also working on an online interactive data analysis tool that will allow users to select any of the monitoring data for graphical display from the Longmont monitoring sites, as well as comparisons with data from other Northern Colorado Front Range sites, including the observations from the Boulder Reservoir and Broomfield sites. This tool will be linked from the 'Longmont Air Quality Now' website. Public release is anticipated during October 2020.

6. Data Archiving

An automated data backup was implemented for secure and redundant archiving. There are three independent data backup devices that are located in three different physical locations. All data that are recorded by the suite of instruments are saved to each of these devices by automated protocols every hour.

7. Data for 2019

Data that were recorded in 2019 are included in this report in graphical format as Supplement B (LMA) and Supplement C (LUR). These figures are primarily intended to demonstrate the data coverage and dynamical behavior in the data. A few data gaps at LMA resulted from technical issues with the Picarro computer, which have since been resolved by a hard drive exchange. Please note that these data should be considered preliminary data until data quality assurance protocols are finalized and have been applied.

8. Selected Data Examples and Preliminary Interpretations

More in-depth analyses and interpretation of the data will be presented in following reports. Some interesting features are highlighted below. During the time that the LUR building was not yet available, both Picarro instruments for methane and CO_2 measurements were co-located for 2.5 months at LMA. This process enabled a direct comparison of the accuracy and precision of the analyzers. Figure 9 shows six weeks of methane data from these measurements that started on September 28, including ~ four weeks of a co-located comparison that took place until December 12. The data traces to that point actually do not clearly indicate that these are measurements from two analyzers, as the recordings fall so closely on top of each other. Deviations between both measurements are well below 0.1% (< 20 ppb) as can be seen in the enlargement figure (Figure 10). A more accurate evaluation of these data will be presented in a subsequent report. On December 13, one of the analyzers was moved to LUR, with the monitoring at that site then starting the next day. From then on, the two measurements clearly diverge, as can be easily seen by the two different colors of the data traces and in Figure 11, which shows an enlargement of that monitoring window. And very clearly, methane data from LUR show higher variability, and an overall larger number of spikes with elevated readings, as well as a higher frequency of elevated concentration events. During a period when it became very windy (December 28, Figure 9), emissions from local sources were dispersed quickly, so both measurements agree and match the expected background methane concentrations (1900 ppb). Similar features were seen in the CO_2 recordings that are displayed in Figure 12. These preliminary analyses demonstrate the high accuracy of the methane and CO_2 measurements. In addition, the data show that the east side of Longmont, which is closer to emission sources, clearly experiences higher average methane concentrations than the western side.

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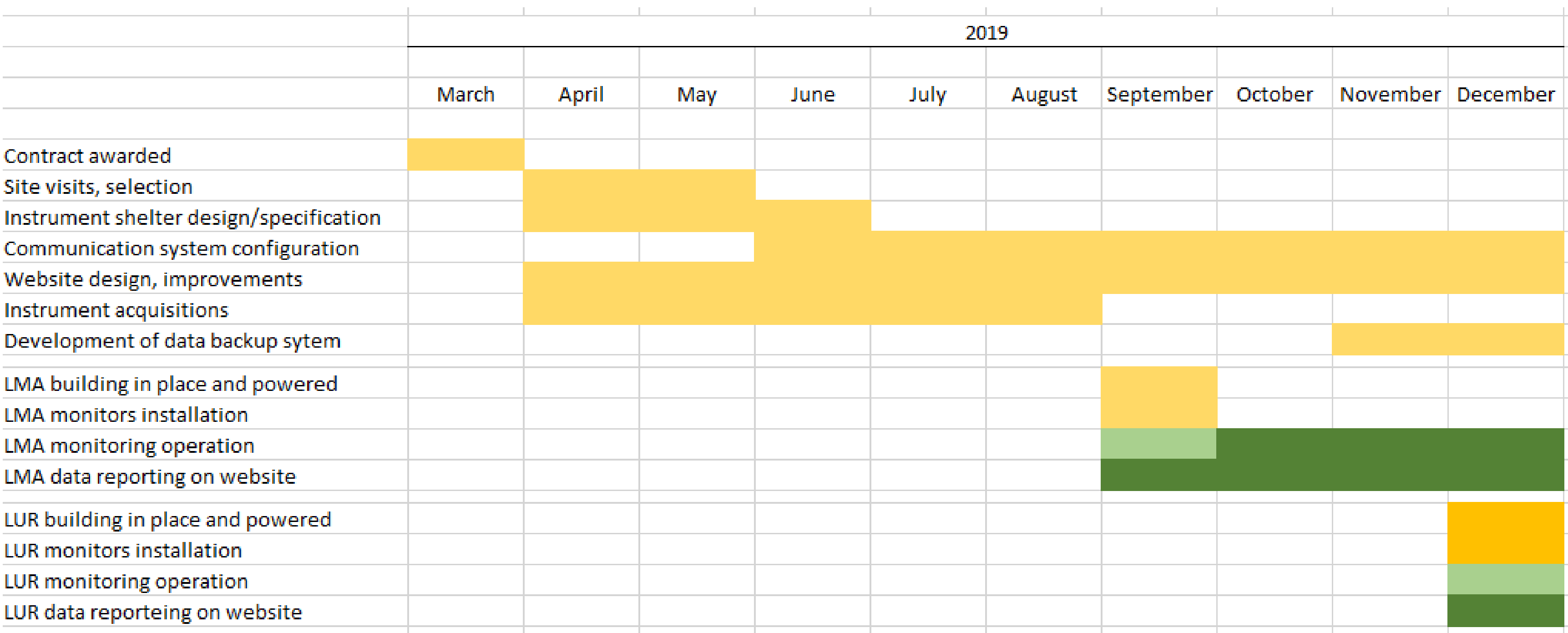
Tables and Figures

Table 1
Year 2019 Longmont air monitoring sites installation and operation log. The orange color indicates work progress, light green indicates monitoring operations being ramped up, and dark green color indicates ongoing monitoring, i.e. the completed task meeting the monitoring project goal.



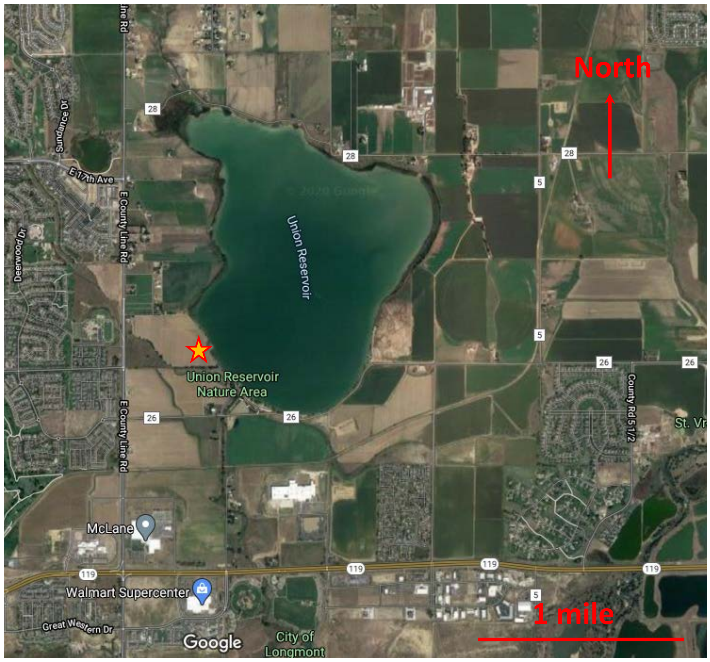


Figure 1:
Google Earth image showing the location of the LUR monitoring site on the southwest shore of Union Reservoir indicated by the star. Latitude 40.1761° N, Longitude 105.0479° W. County Line Road and CO State Highway 119 can be seen in the right and bottom portions of the figure.

Figure 2:
LUR Instrument shelter with adjacent meteorological tower looking towards the west (A) and east (B). The water surface of the Union Reservoir can be seen in the background of the latter figure.

Figure 3:
Google Earth image with the location of the LMA monitoring site within the fenced airport area indicated by the star. Latitude 40.1606° N, 105.1597° E. Airport Road and Rogers Road can be seen to the south and east of the site.

Figure 4:
LMA instrument trailer with the adjacent meteorological tower.

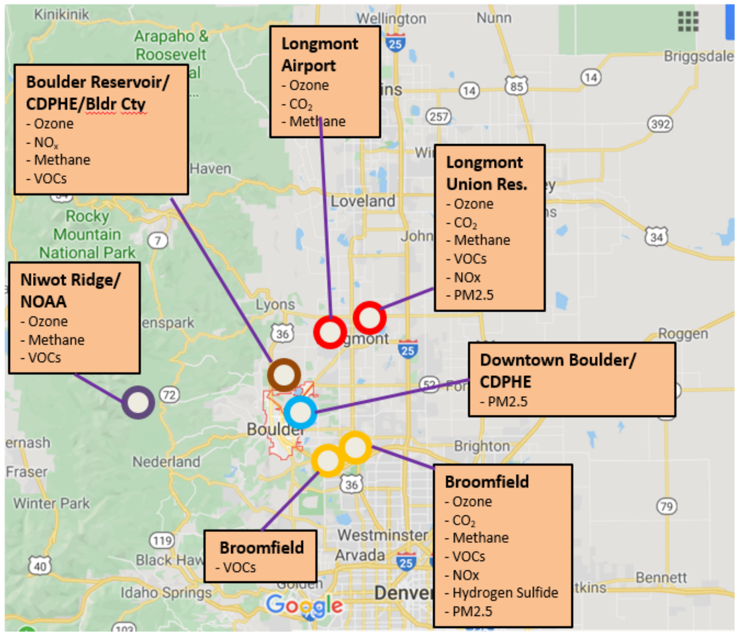


Figure 5:
Map showing the Front Range monitoring stations operated by Boulder A.I.R. in Broomfield, Boulder, and Longmont. Also included are two sites managed by the Colorado Department of Public Health and environment (CDPHE) in Boulder, and the Niwot Ridge site (~10,000 ft. elevation) near the Continental Divide operated by NOAA. It should be noted that the NIWOT ridge site is used for long-term observations of relatively clean continental background air, and the Boulder City CDPHE site only includes PM2.5 measurements.

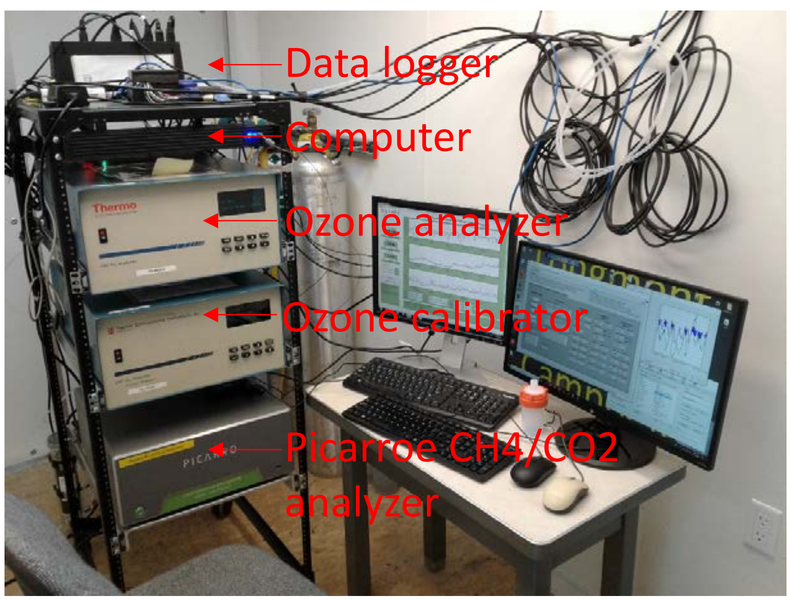


Figure 6:
Instrumentation and equipment inside the LMA trailer. The rack to the left contains the monitoring equipment as indicated by the red text. Gas cylinders containing methane and CO_2 calibration standards can be seen in the back.

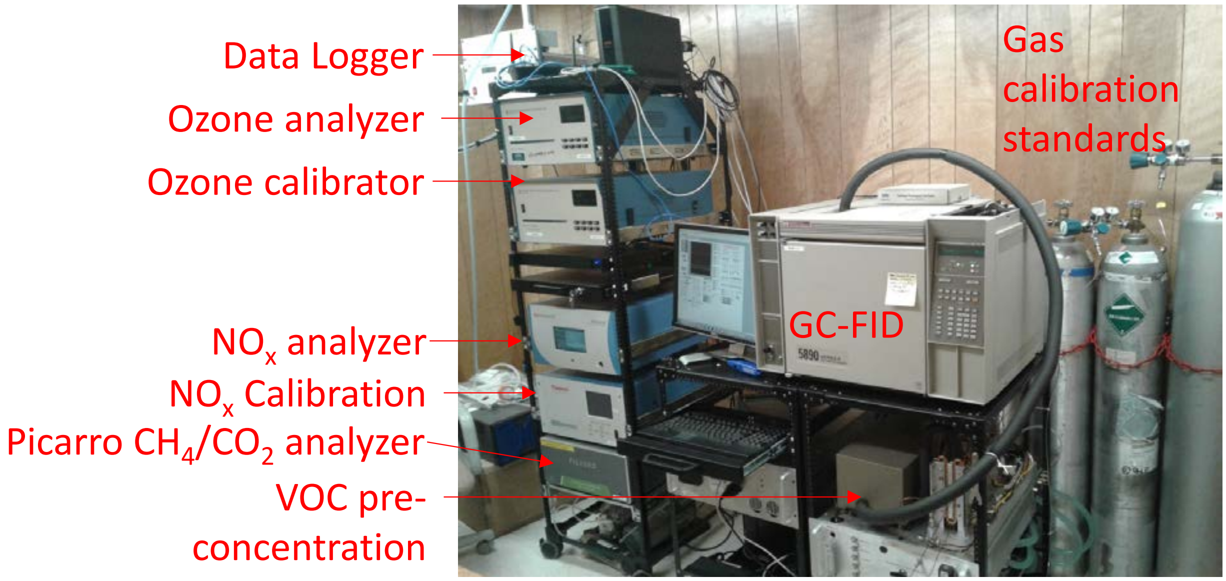
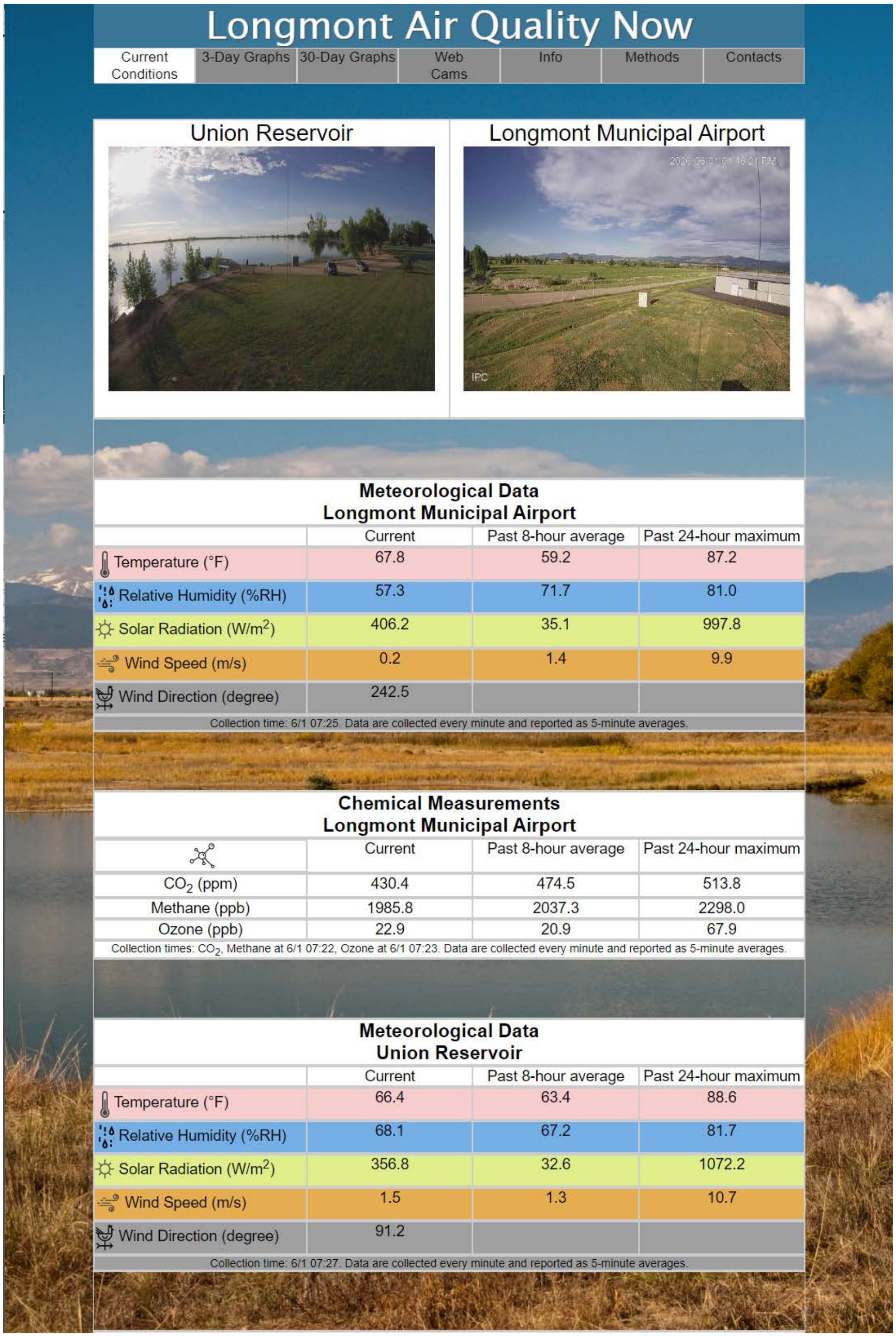


Figure 7:
Instrumentation and equipment inside the LUR instrument shelter. The instrument rack on the left contains the data logger and other instruments as labeled. VOCs are measured using the pre-concentration unit and GC-FID on the rack to the right. Gas cylinders containing calibrations standards are shown to the right.



Longmont Air Quality Now

Current Conditions | 3-Day Graphs | 30-Day Graphs | Web Cams | Info | Methods | Contacts

Union Reservoir

Longmont Municipal Airport

Meteorological Data
Longmont Municipal Airport

	Current	Past 8-hour average	Past 24-hour maximum
Temperature (°F)	67.8	59.2	87.2
Relative Humidity (%RH)	57.3	71.7	81.0
Solar Radiation (W/m^2)	406.2	35.1	997.8
Wind Speed (m/s)	0.2	1.4	9.9
Wind Direction (degree)	242.5		

Collection time: 6/1 07:25. Data are collected every minute and reported as 5-minute averages.

Chemical Measurements
Longmont Municipal Airport

	Current	Past 8-hour average	Past 24-hour maximum
CO_2 (ppm)	430.4	474.5	513.8
Methane (ppb)	1985.8	2037.3	2298.0
Ozone (ppb)	22.9	20.9	67.9

Collection times: CO_2, Methane at 6/1 07:22, Ozone at 6/1 07:23. Data are collected every minute and reported as 5-minute averages.

Meteorological Data
Union Reservoir

	Current	Past 8-hour average	Past 24-hour maximum
Temperature (°F)	66.4	63.4	88.6
Relative Humidity (%RH)	68.1	67.2	81.7
Solar Radiation (W/m^2)	356.8	32.6	1072.2
Wind Speed (m/s)	1.5	1.3	10.7
Wind Direction (degree)	91.2		

Collection time: 6/1 07:27. Data are collected every minute and reported as 5-minute averages.

Figure 8a:
Screenshot of the Longmont Air Quality Now website homepage with tabulated summary results of current conditions, past 8-hour average, and the maximum concentrations observed in the previous 24-hour period. (https://www.bouldair.com/longmont.htm).

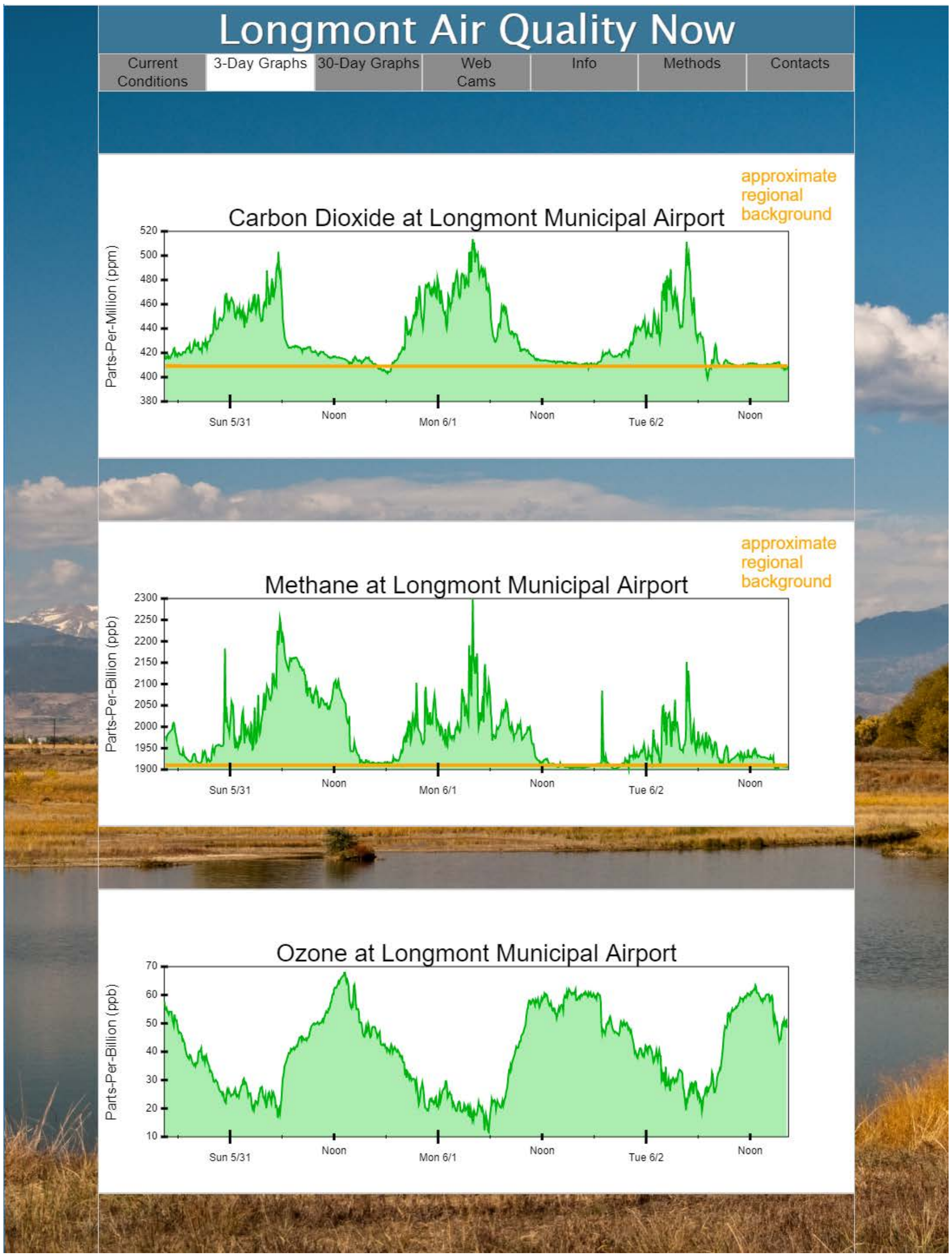


Figure 8b:
Screenshot of the Longmont Air Quality Now website homepage second tab with 3-day graphs of CO_2, methane and ozone. All variables are plotted, but only 3 are included here due to space limitations. (https://www.bouldair.com/longmont.htm).

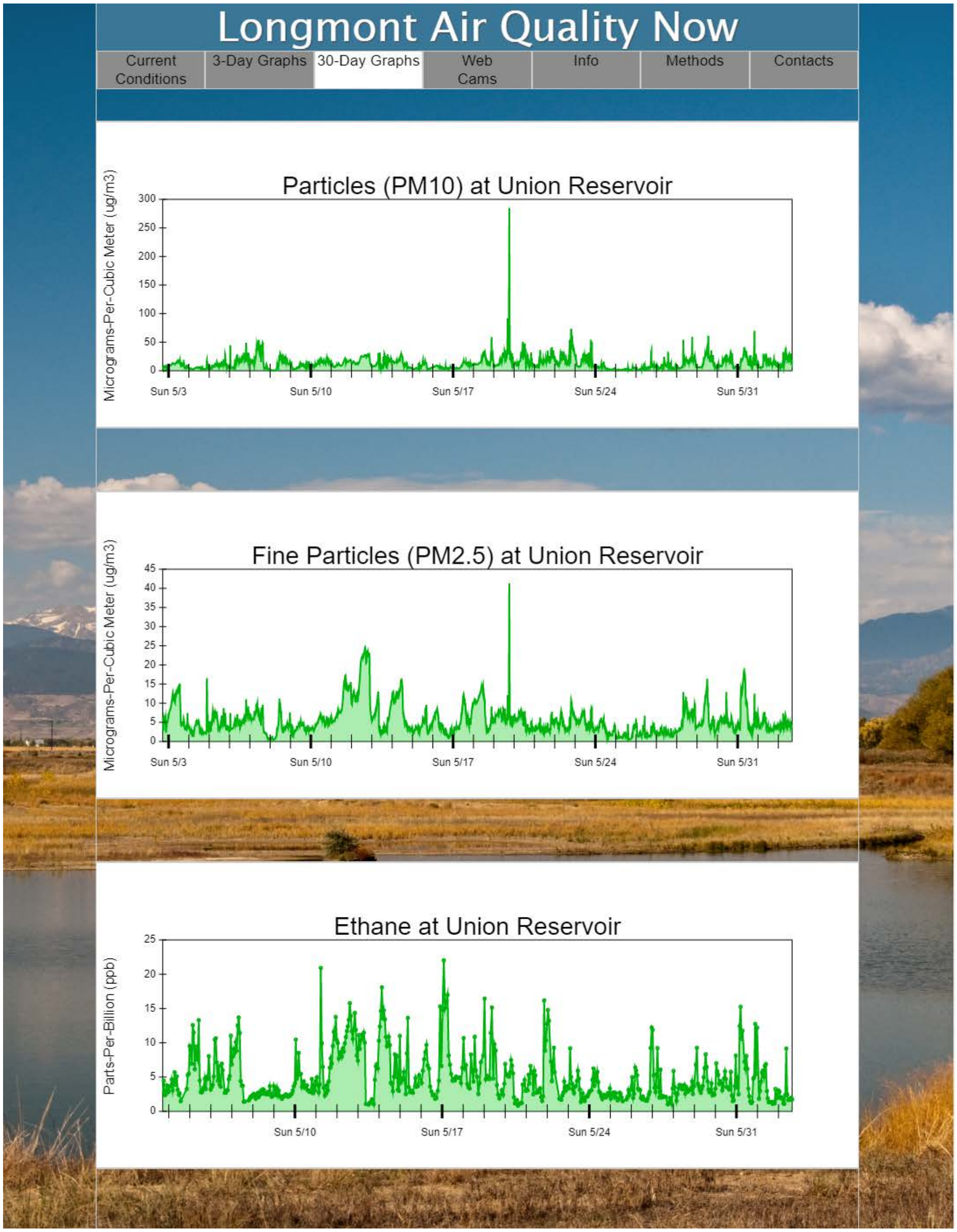
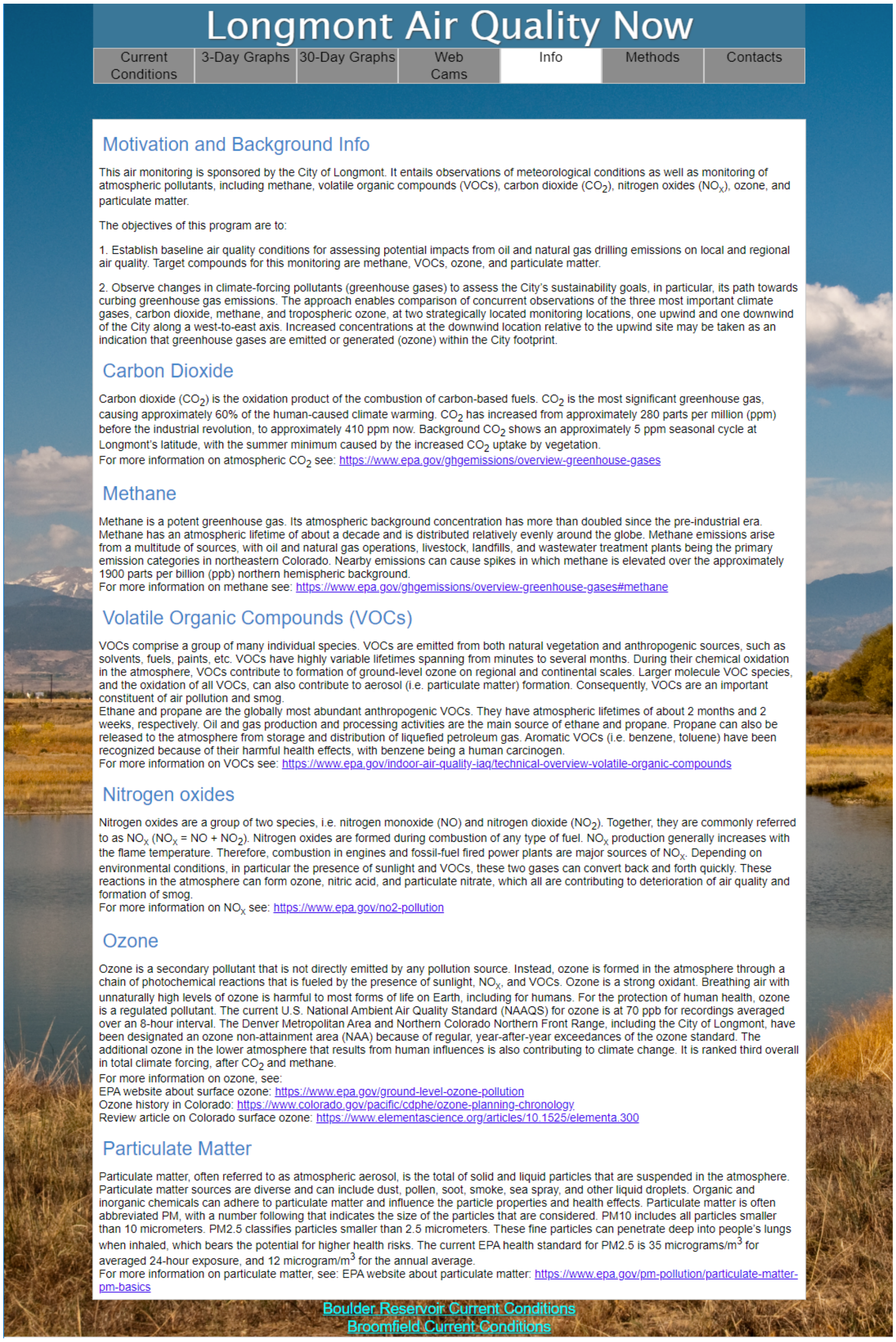


Figure 8c:
Screenshot of the Longmont Air Quality Now website homepage third tab with 30-day graphs of $PM_{2.5}$, PM_{10} and ethane observations. All variables are plotted, but only 3 are included here due to space limitations. (https://www.bouldair.com/longmont.htm).

Figure 8d:
Screenshot of the Longmont Air Quality Now website tab with past 2-hour webpage images (https://www.bouldair.com/longmont.htm).



Longmont Air Quality Now

Current Conditions | 3-Day Graphs | 30-Day Graphs | Web Cams | Info | Methods | Contacts

Motivation and Background Info

This air monitoring is sponsored by the City of Longmont. It entails observations of meteorological conditions as well as monitoring of atmospheric pollutants, including methane, volatile organic compounds (VOCs), carbon dioxide (CO_2), nitrogen oxides (NO_x), ozone, and particulate matter.

The objectives of this program are to:

1. Establish baseline air quality conditions for assessing potential impacts from oil and natural gas drilling emissions on local and regional air quality. Target compounds for this monitoring are methane, VOCs, ozone, and particulate matter.

2. Observe changes in climate-forcing pollutants (greenhouse gases) to assess the City's sustainability goals, in particular, its path towards curbing greenhouse gas emissions. The approach enables comparison of concurrent observations of the three most important climate gases, carbon dioxide, methane, and tropospheric ozone, at two strategically located monitoring locations, one upwind and one downwind of the City along a west-to-east axis. Increased concentrations at the downwind location relative to the upwind site may be taken as an indication that greenhouse gases are emitted or generated (ozone) within the City footprint.

Carbon Dioxide

Carbon dioxide (CO_2) is the oxidation product of the combustion of carbon-based fuels. CO_2 is the most significant greenhouse gas, causing approximately 60% of the human-caused climate warming. CO_2 has increased from approximately 280 parts per million (ppm) before the industrial revolution, to approximately 410 ppm now. Background CO_2 shows an approximately 5 ppm seasonal cycle at Longmont's latitude, with the summer minimum caused by the increased CO_2 uptake by vegetation.
For more information on atmospheric CO_2 see: https://www.epa.gov/ghgemissions/overview-greenhouse-gases

Methane

Methane is a potent greenhouse gas. Its atmospheric background concentration has more than doubled since the pre-industrial era. Methane has an atmospheric lifetime of about a decade and is distributed relatively evenly around the globe. Methane emissions arise from a multitude of sources, with oil and natural gas operations, livestock, landfills, and wastewater treatment plants being the primary emission categories in northeastern Colorado. Nearby emissions can cause spikes in which methane is elevated over the approximately 1900 parts per billion (ppb) northern hemispheric background.
For more information on methane see: https://www.epa.gov/ghgemissions/overview-greenhouse-gases#methane

Volatile Organic Compounds (VOCs)

VOCs comprise a group of many individual species. VOCs are emitted from both natural vegetation and anthropogenic sources, such as solvents, fuels, paints, etc. VOCs have highly variable lifetimes spanning from minutes to several months. During their chemical oxidation in the atmosphere, VOCs contribute to formation of ground-level ozone on regional and continental scales. Larger molecule VOC species, and the oxidation of all VOCs, can also contribute to aerosol (i.e. particulate matter) formation. Consequently, VOCs are an important constituent of air pollution and smog.
Ethane and propane are the globally most abundant anthropogenic VOCs. They have atmospheric lifetimes of about 2 months and 2 weeks, respectively. Oil and gas production and processing activities are the main source of ethane and propane. Propane can also be released to the atmosphere from storage and distribution of liquefied petroleum gas. Aromatic VOCs (i.e. benzene, toluene) have been recognized because of their harmful health effects, with benzene being a human carcinogen.
For more information on VOCs see: https://www.epa.gov/indoor-air-quality-iaq/technical-overview-volatile-organic-compounds

Nitrogen oxides

Nitrogen oxides are a group of two species, i.e. nitrogen monoxide (NO) and nitrogen dioxide (NO_2). Together, they are commonly referred to as NO_x (NO_x = NO + NO_2). Nitrogen oxides are formed during combustion of any type of fuel. NO_x production generally increases with the flame temperature. Therefore, combustion in engines and fossil-fuel fired power plants are major sources of NO_x. Depending on environmental conditions, in particular the presence of sunlight and VOCs, these two gases can convert back and forth quickly. These reactions in the atmosphere can form ozone, nitric acid, and particulate nitrate, which all are contributing to deterioration of air quality and formation of smog.
For more information on NO_x see: https://www.epa.gov/no2-pollution

Ozone

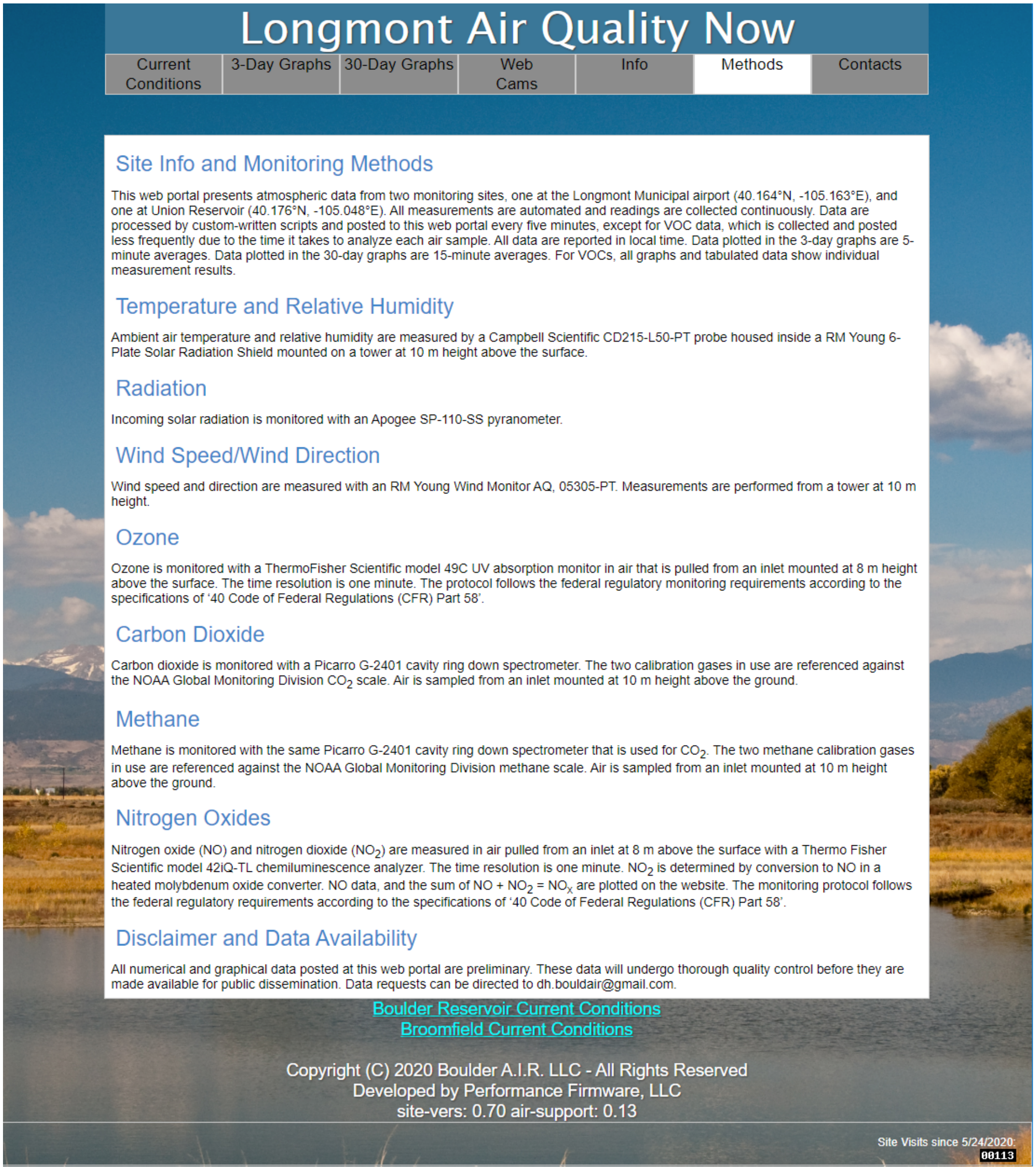
Ozone is a secondary pollutant that is not directly emitted by any pollution source. Instead, ozone is formed in the atmosphere through a chain of photochemical reactions that is fueled by the presence of sunlight, NO_x, and VOCs. Ozone is a strong oxidant. Breathing air with unnaturally high levels of ozone is harmful to most forms of life on Earth, including for humans. For the protection of human health, ozone is a regulated pollutant. The current U.S. National Ambient Air Quality Standard (NAAQS) for ozone is at 70 ppb for recordings averaged over an 8-hour interval. The Denver Metropolitan Area and Northern Colorado Northern Front Range, including the City of Longmont, have been designated an ozone non-attainment area (NAA) because of regular, year-after-year exceedances of the ozone standard. The additional ozone in the lower atmosphere that results from human influences is also contributing to climate change. It is ranked third overall in total climate forcing, after CO_2 and methane.
For more information on ozone, see:
EPA website about surface ozone: https://www.epa.gov/ground-level-ozone-pollution
Ozone history in Colorado: https://www.colorado.gov/pacific/cdphe/ozone-planning-chronology
Review article on Colorado surface ozone: https://www.elementascience.org/articles/10.1525/elementa.300

Particulate Matter

Particulate matter, often referred to as atmospheric aerosol, is the total of solid and liquid particles that are suspended in the atmosphere. Particulate matter sources are diverse and can include dust, pollen, soot, smoke, sea spray, and other liquid droplets. Organic and inorganic chemicals can adhere to particulate matter and influence the particle properties and health effects. Particulate matter is often abbreviated PM, with a number following that indicates the size of the particles that are considered. PM10 includes all particles smaller than 10 micrometers. PM2.5 classifies particles smaller than 2.5 micrometers. These fine particles can penetrate deep into people's lungs when inhaled, which bears the potential for higher health risks. The current EPA health standard for PM2.5 is 35 micrograms/m^3 for averaged 24-hour exposure, and 12 microgram/m^3 for the annual average.
For more information on particulate matter, see: EPA website about particulate matter: https://www.epa.gov/pm-pollution/particulate-matter-pm-basics

Boulder Reservoir Current Conditions
Broomfield Current Conditions

Figure 8e:
Screenshot of the Longmont Air Quality Now website tab with monitoring program background information (https://www.bouldair.com/longmont.htm).



Longmont Air Quality Now

Current Conditions | 3-Day Graphs | 30-Day Graphs | Web Cams | Info | Methods | Contacts

Site Info and Monitoring Methods

This web portal presents atmospheric data from two monitoring sites, one at the Longmont Municipal airport (40.164°N, -105.163°E), and one at Union Reservoir (40.176°N, -105.048°E). All measurements are automated and readings are collected continuously. Data are processed by custom-written scripts and posted to this web portal every five minutes, except for VOC data, which is collected and posted less frequently due to the time it takes to analyze each air sample. All data are reported in local time. Data plotted in the 3-day graphs are 5-minute averages. Data plotted in the 30-day graphs are 15-minute averages. For VOCs, all graphs and tabulated data show individual measurement results.

Temperature and Relative Humidity

Ambient air temperature and relative humidity are measured by a Campbell Scientific CD215-L50-PT probe housed inside a RM Young 6-Plate Solar Radiation Shield mounted on a tower at 10 m height above the surface.

Radiation

Incoming solar radiation is monitored with an Apogee SP-110-SS pyranometer.

Wind Speed/Wind Direction

Wind speed and direction are measured with an RM Young Wind Monitor AQ, 05305-PT. Measurements are performed from a tower at 10 m height.

Ozone

Ozone is monitored with a ThermoFisher Scientific model 49C UV absorption monitor in air that is pulled from an inlet mounted at 8 m height above the surface. The time resolution is one minute. The protocol follows the federal regulatory monitoring requirements according to the specifications of '40 Code of Federal Regulations (CFR) Part 58'.

Carbon Dioxide

Carbon dioxide is monitored with a Picarro G-2401 cavity ring down spectrometer. The two calibration gases in use are referenced against the NOAA Global Monitoring Division CO_2 scale. Air is sampled from an inlet mounted at 10 m height above the ground.

Methane

Methane is monitored with the same Picarro G-2401 cavity ring down spectrometer that is used for CO_2. The two methane calibration gases in use are referenced against the NOAA Global Monitoring Division methane scale. Air is sampled from an inlet mounted at 10 m height above the ground.

Nitrogen Oxides

Nitrogen oxide (NO) and nitrogen dioxide (NO_2) are measured in air pulled from an inlet at 8 m above the surface with a Thermo Fisher Scientific model 42iQ-TL chemiluminescence analyzer. The time resolution is one minute. NO_2 is determined by conversion to NO in a heated molybdenum oxide converter. NO data, and the sum of NO + NO_2 = NO_x are plotted on the website. The monitoring protocol follows the federal regulatory requirements according to the specifications of '40 Code of Federal Regulations (CFR) Part 58'.

Disclaimer and Data Availability

All numerical and graphical data posted at this web portal are preliminary. These data will undergo thorough quality control before they are made available for public dissemination. Data requests can be directed to dh.bouldair@gmail.com.

Boulder Reservoir Current Conditions
Broomfield Current Conditions

Copyright (C) 2020 Boulder A.I.R. LLC - All Rights Reserved
Developed by Performance Firmware, LLC
site-vers: 0.70 air-support: 0.13

Site Visits since 5/24/2020: 00113

Figure 8f:
Screenshot of the Longmont Air Quality Now website tab with monitoring methods information (https://www.bouldair.com/longmont.htm).

Figure 8g:
Screenshot of the Longmont Air Quality Now website tab with monitoring program contact information (https://www.bouldair.com/longmont.htm).

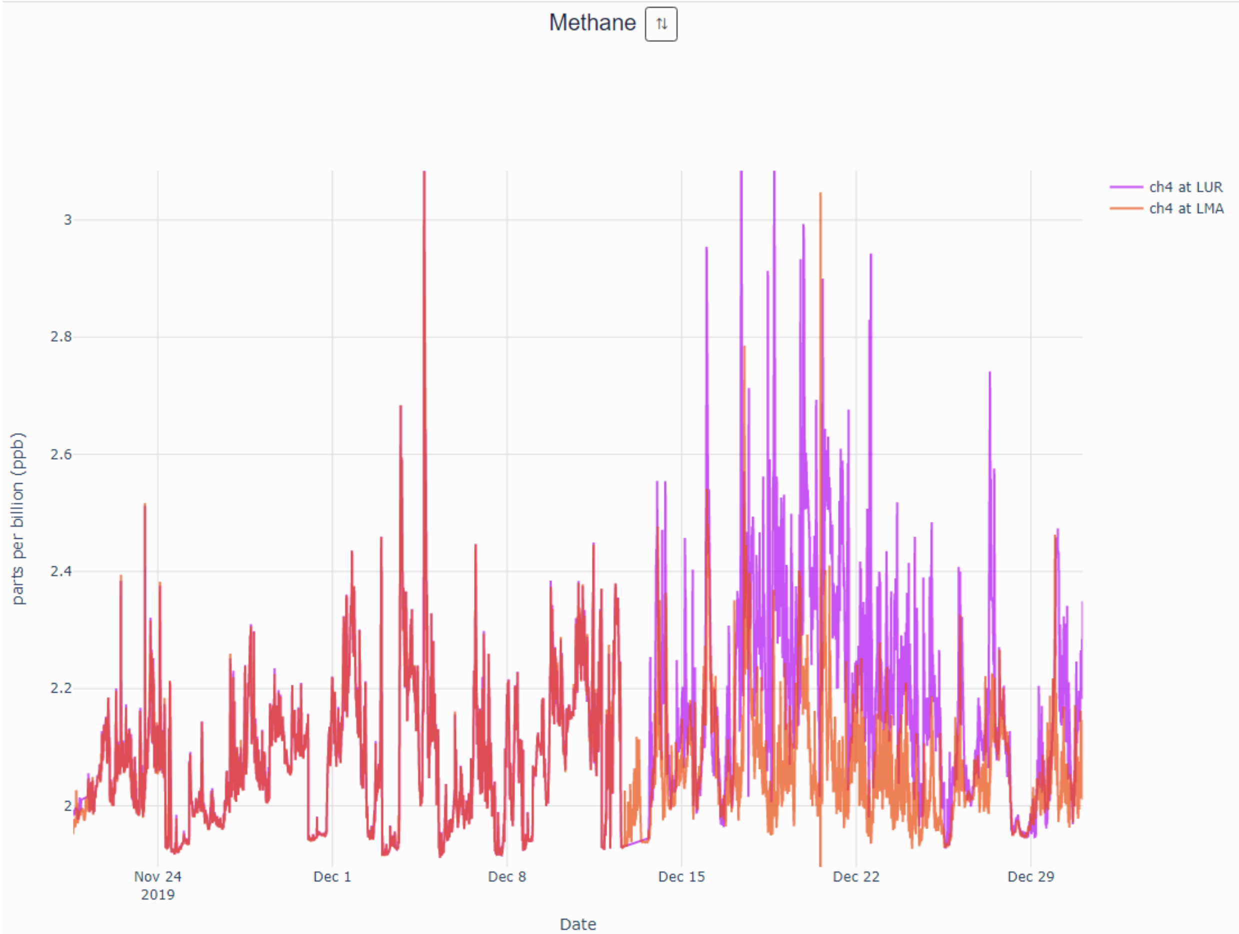


Figure 9:
Methane recorded with two Picarro analyzers during 2019. From November 23 until December 12, both instruments co-located at LMA. On December 13, 2019, the analyzer labeled LUR was moved to the new site. During the time of co-location, the data cannot be differentiated because one of the two data traces falls that closely on top of the other. Once moved to LUR, the analyzer then clearly deviates, recording overwhelmingly higher methane concentrations at LUR compared to LMA (see Figure 11 for an enlargement of that period).

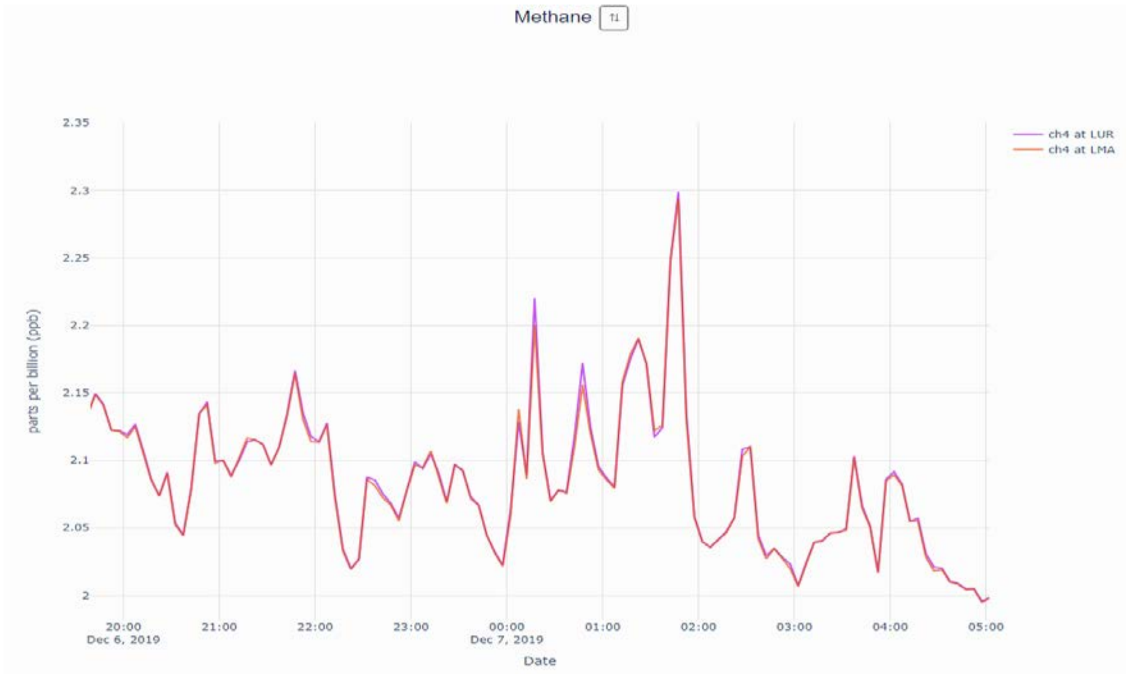


Figure 10:
Enlargement of Figure 9 showing the time window when the two analyzers were co-located at LMA. The analyzers' methane measurements are nearly indistinguishable.

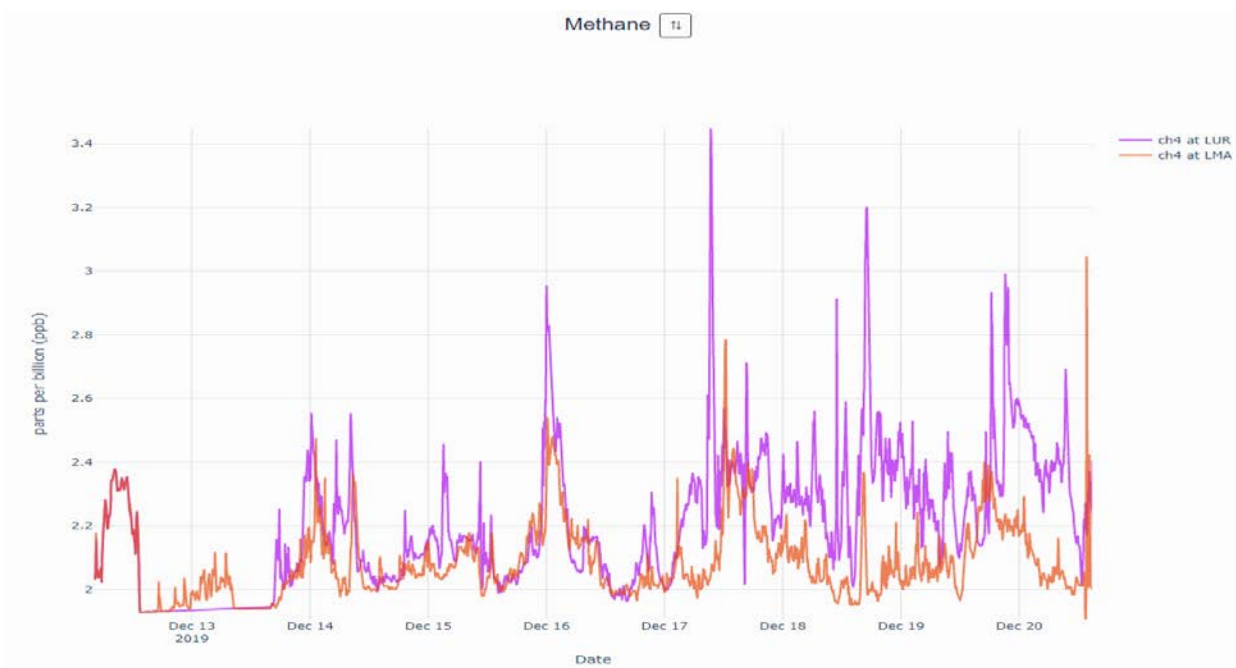


Figure 11:
Enlargement of Figure 9 showing the time window when the two analyzers were operated at the two different locations (LMA and LUR). Notice the generally higher methane concentrations at LUR, which is on the east side of the City and therefore closer to emission sources.

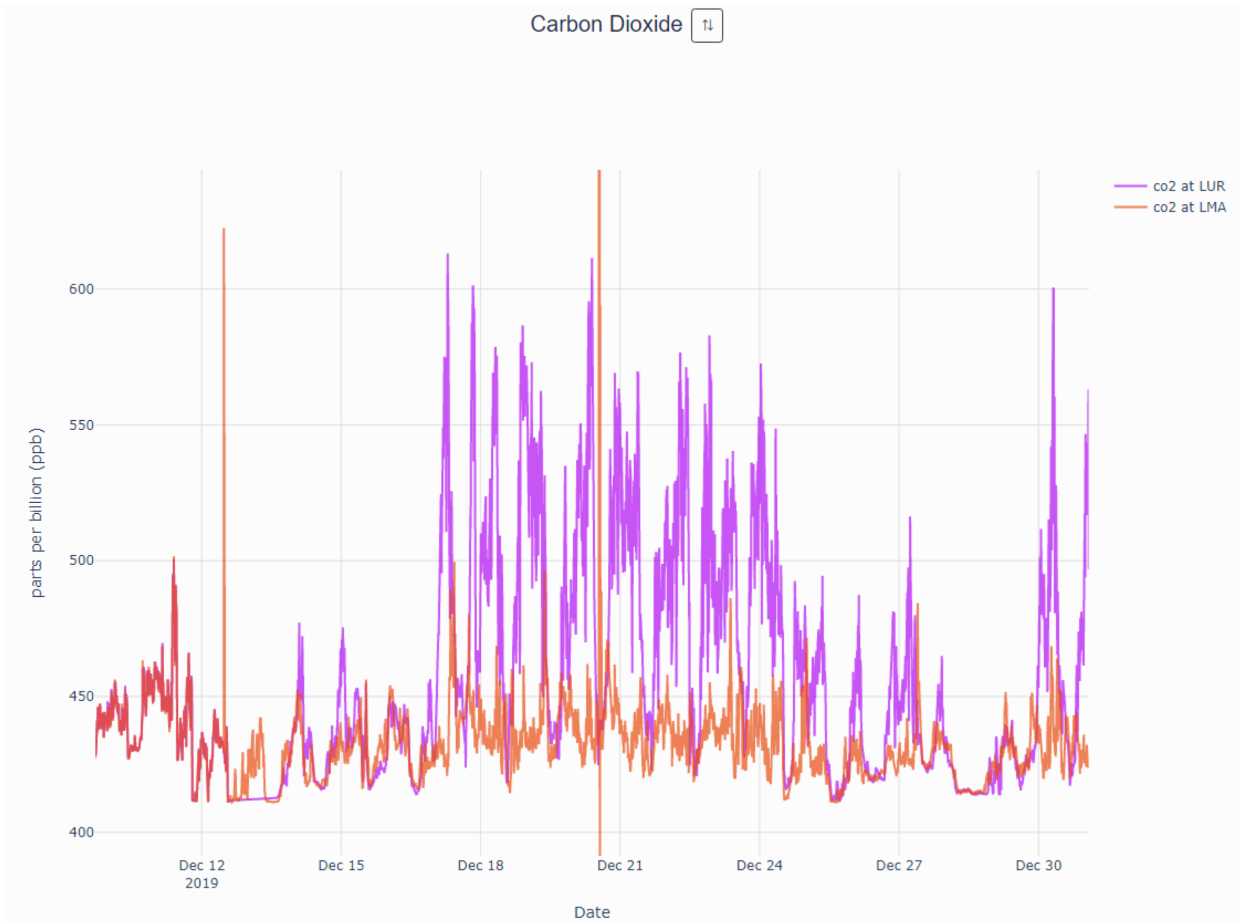
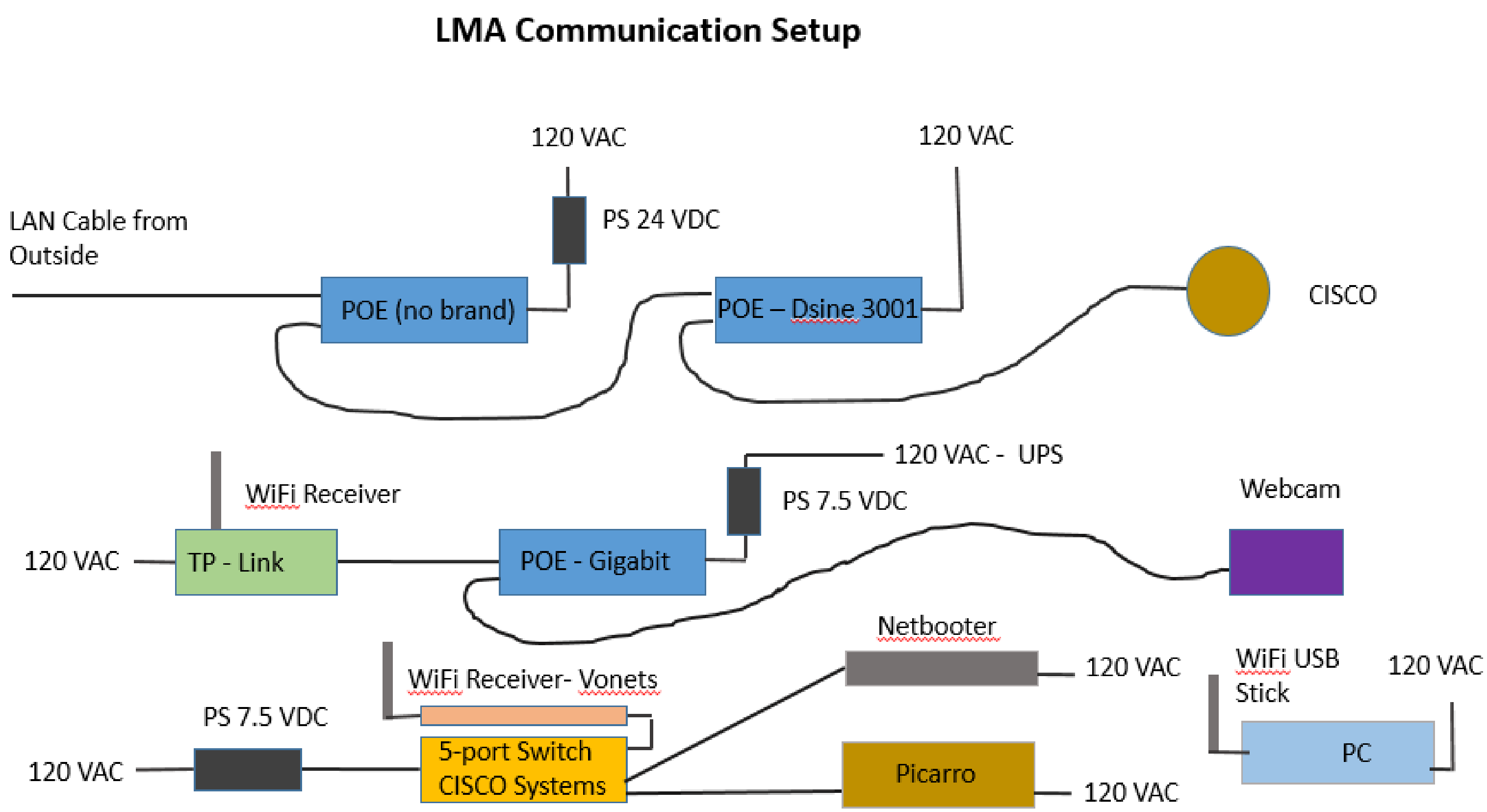


Figure 12:
Monitoring results for CO_2 while the two instruments were operated side-by-side (until December 12), and afterwards, with the second analyzer operated at LMA.

Supplement A

Communication System Setup at LMA



Supplement B

Preliminary Data LMA 2019

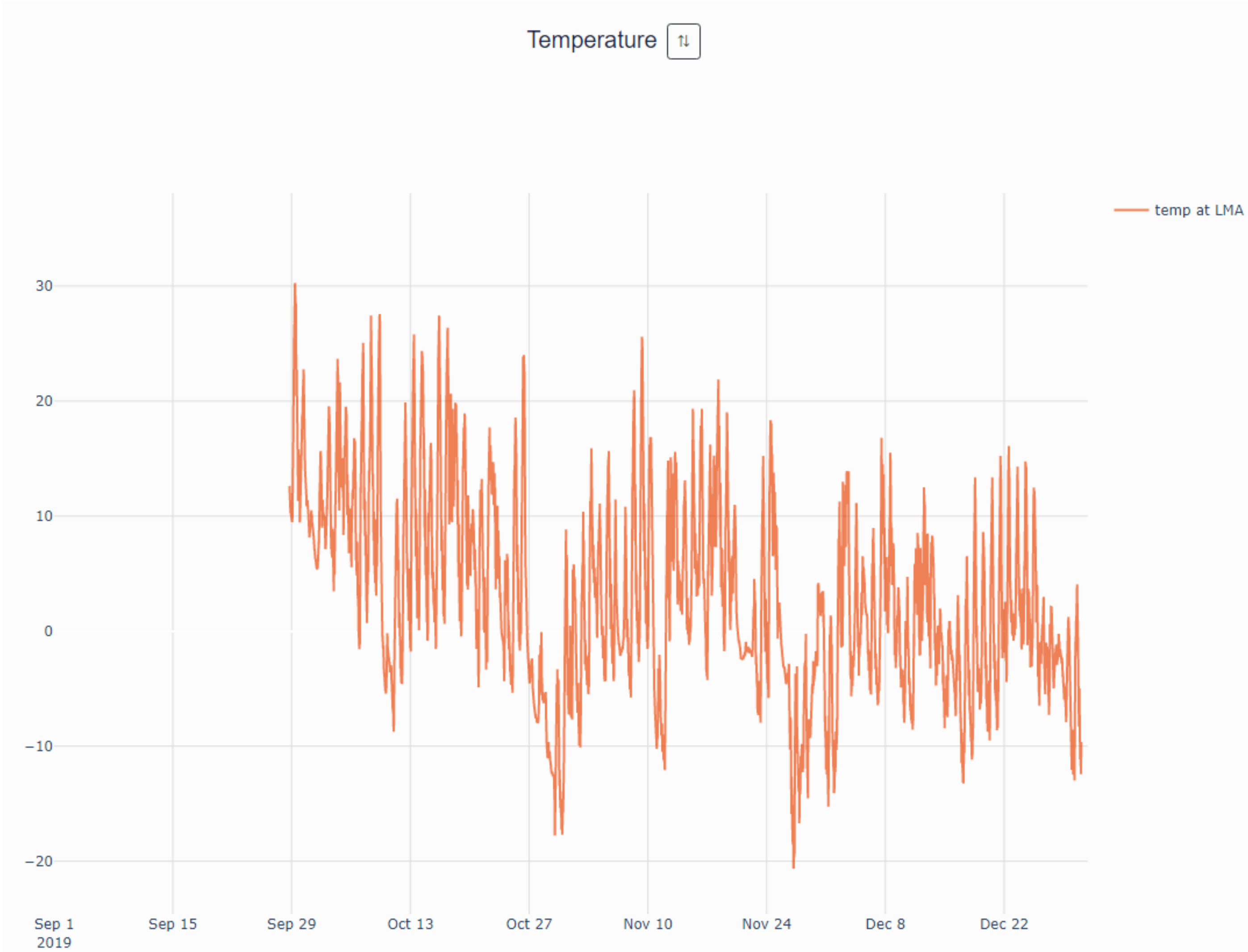


Figure SB-1:
LMA Temperature record September 29 – December 31, 2019.

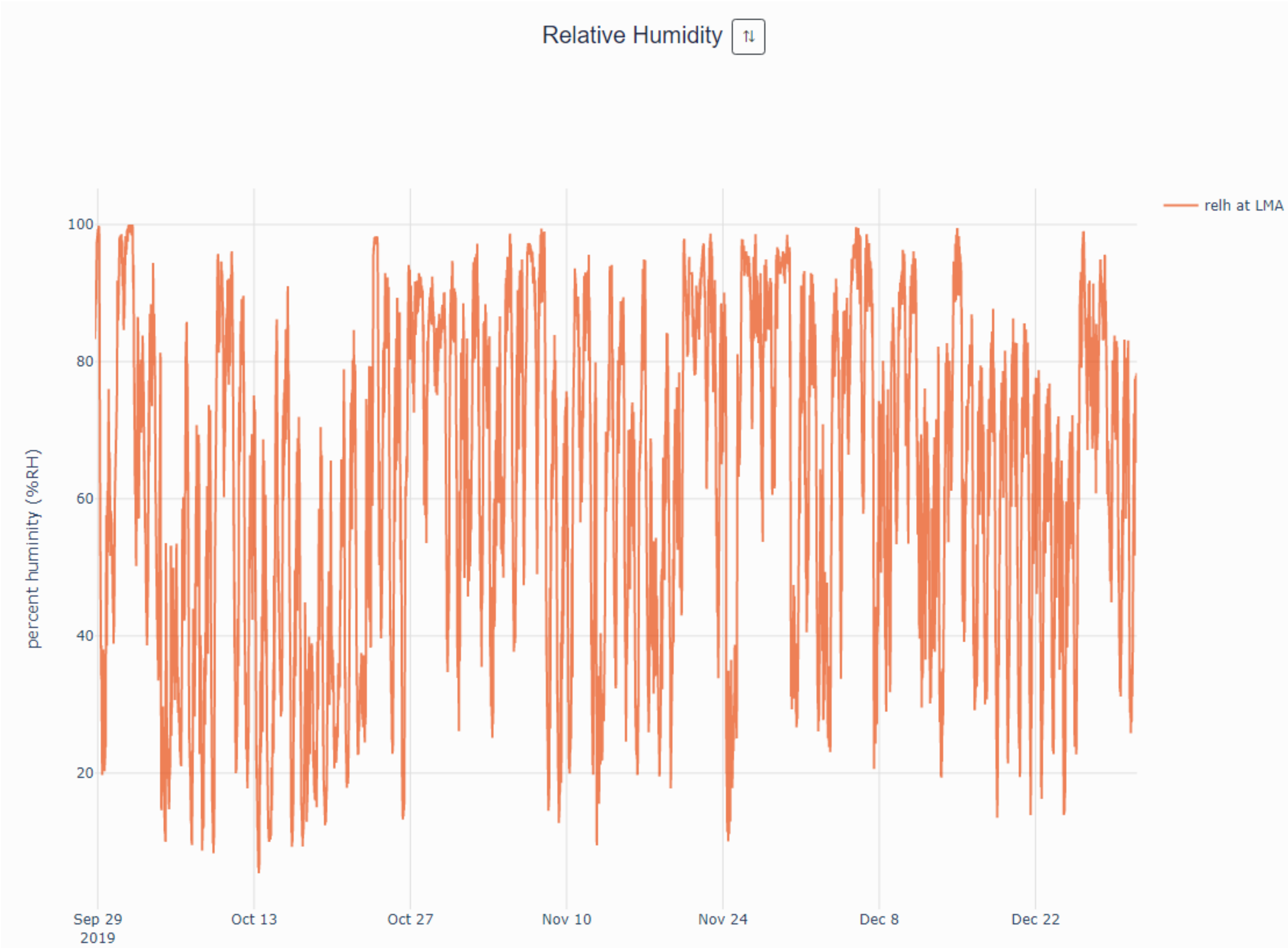


Figure SB-2:
LMA relative humidity record September 29 – December 31, 2019.

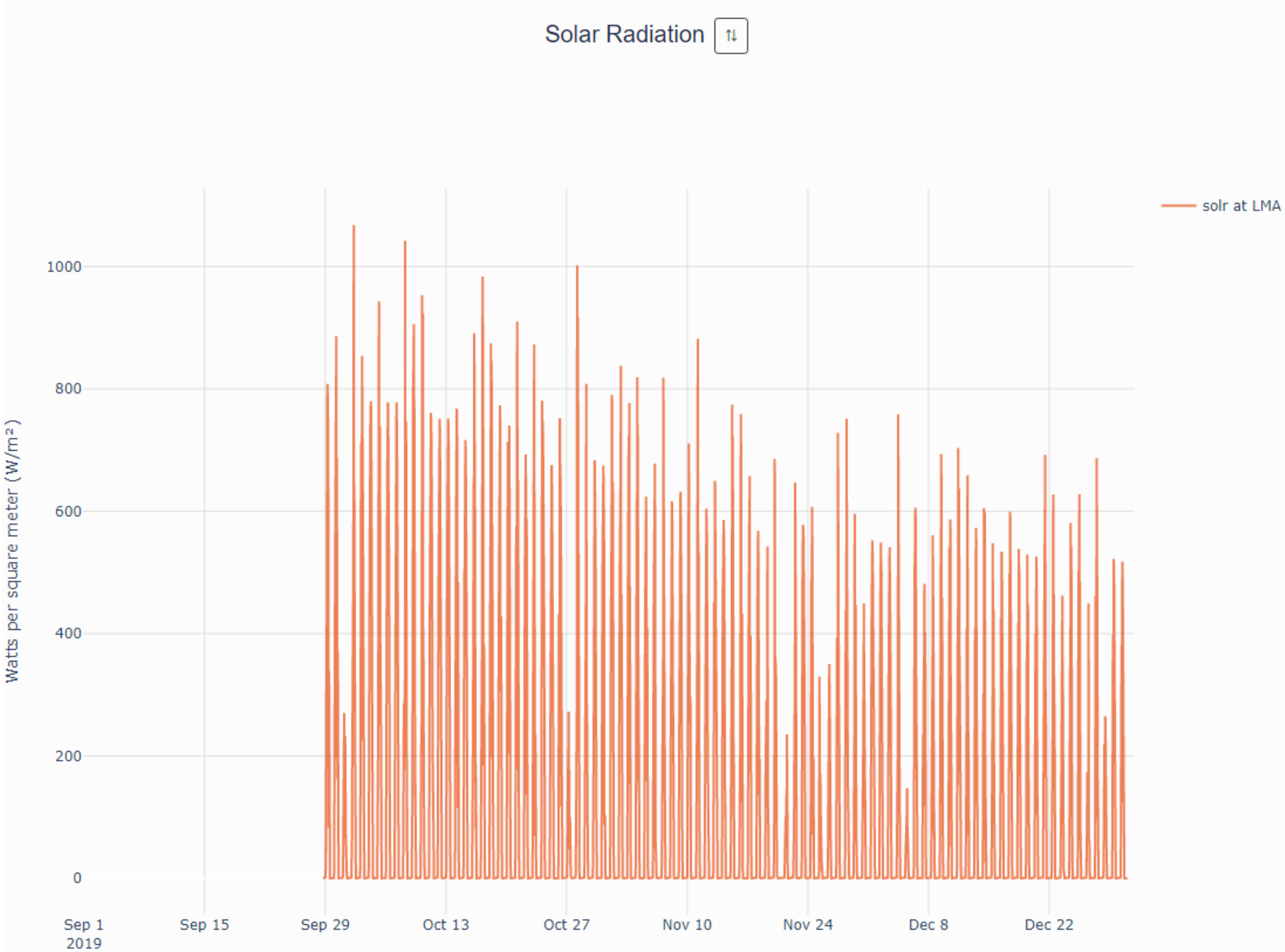


Figure SB-3:
LMA solar radiation record September 29 – December 31, 2019.

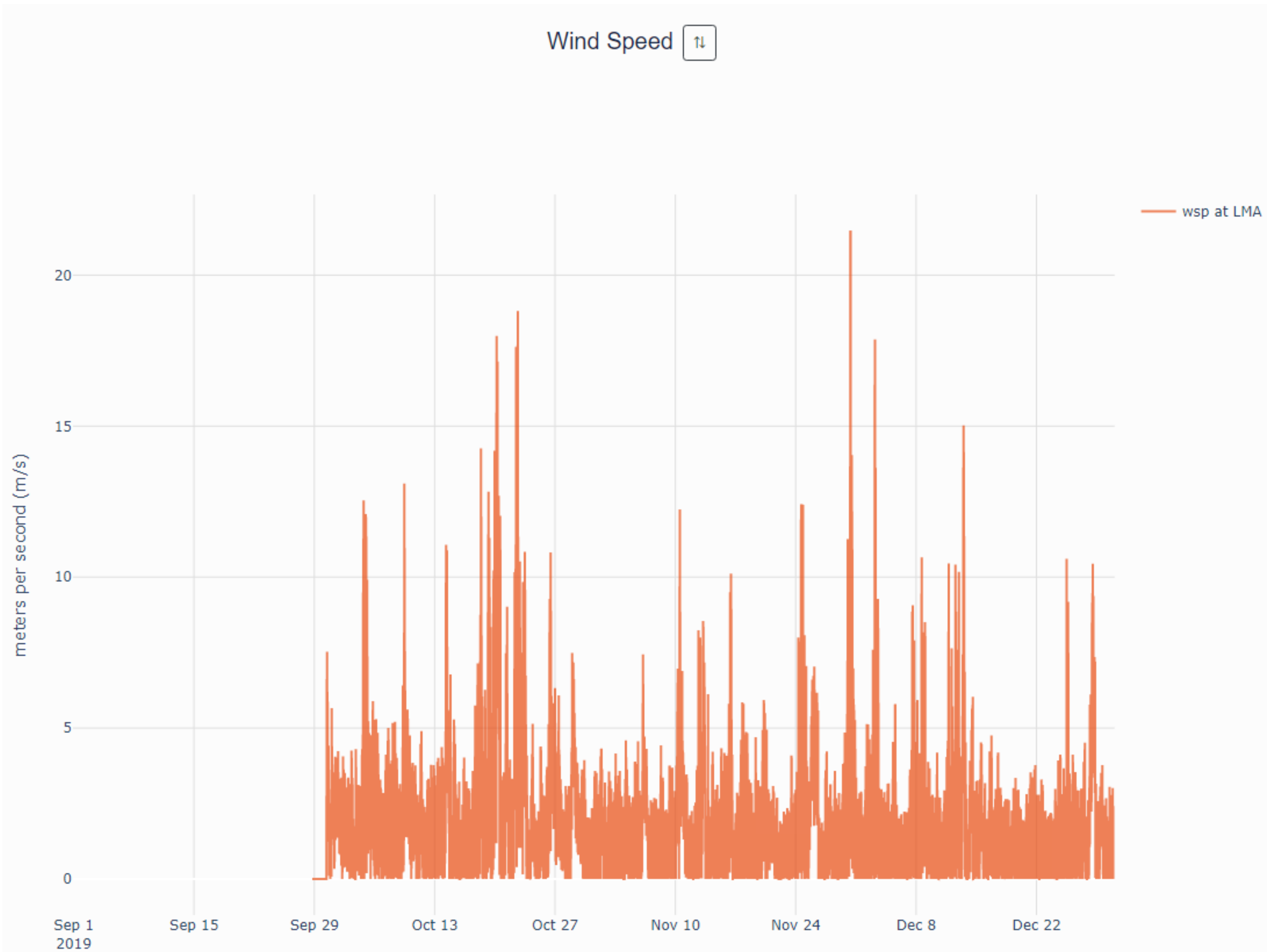


Figure SB-4:
LMA wind speed record September 30 – December 31, 2019.

Figure SB-5:
LMA wind direction record September 30 – December 31, 2019.

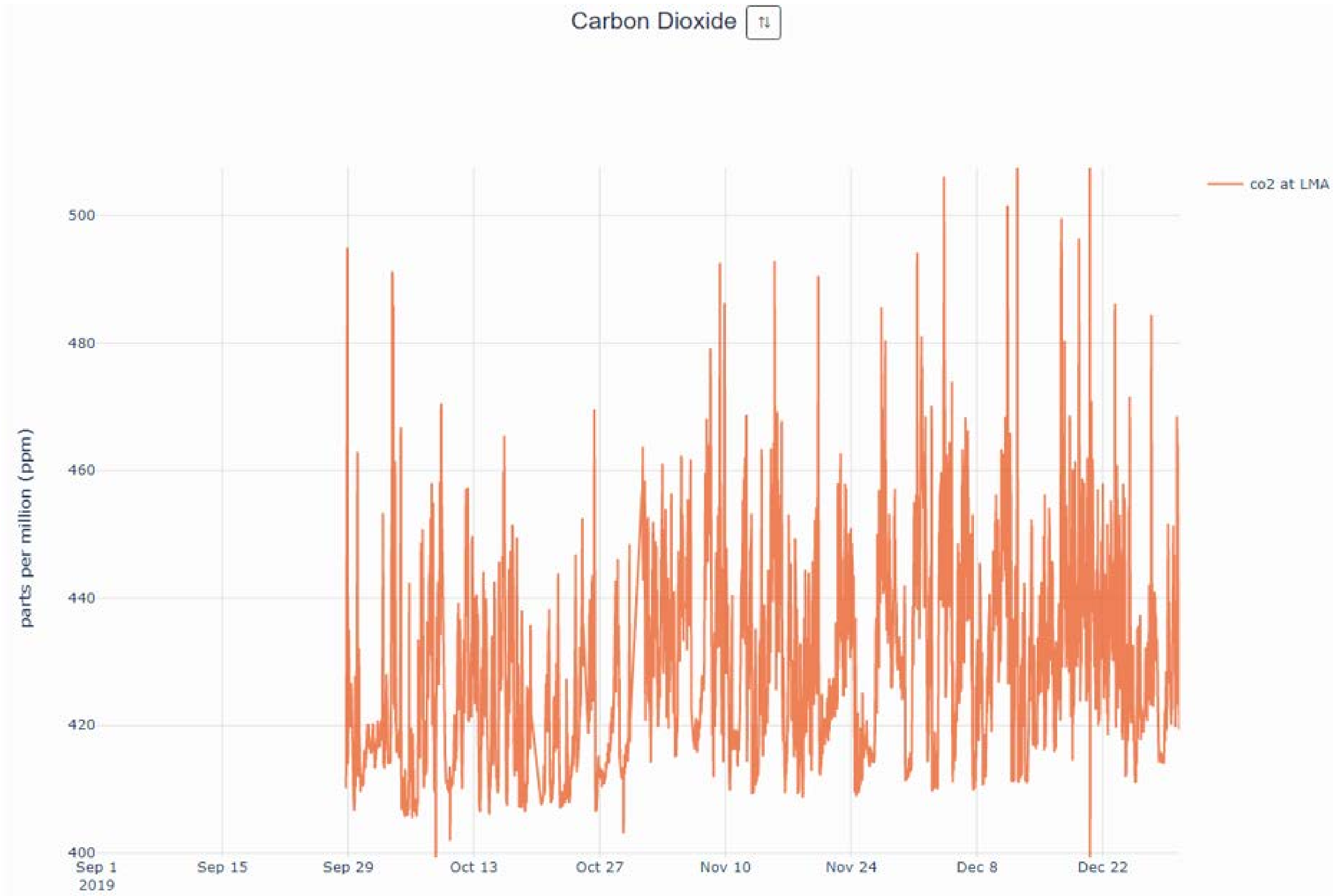


Figure SB-6:
LMA CO_2 record September 28 – December 31, 2019.

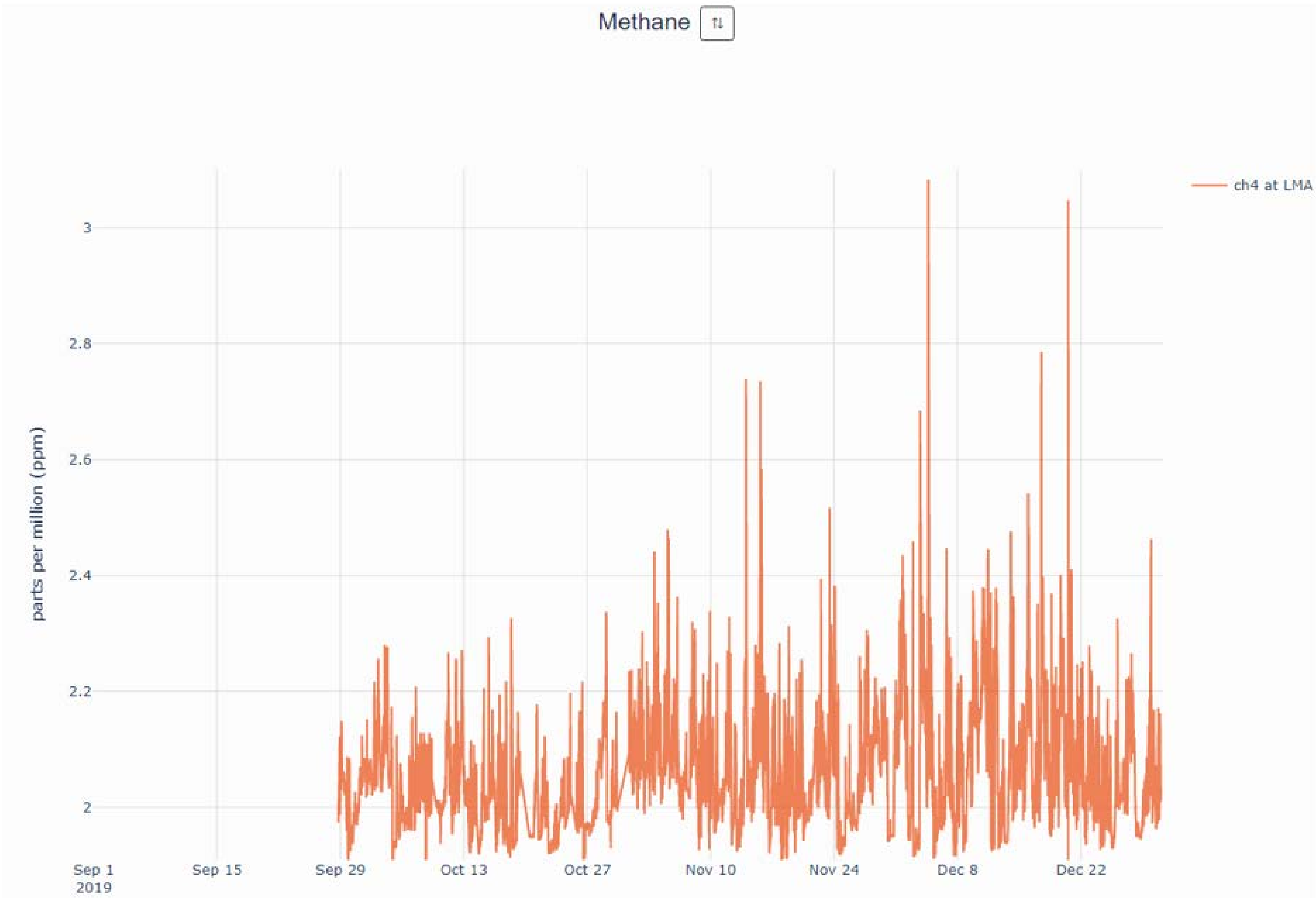


Figure SB-7:
LMA methane record September 28 – December 31, 2019.

Supplement C

Preliminary Data LUR 2019

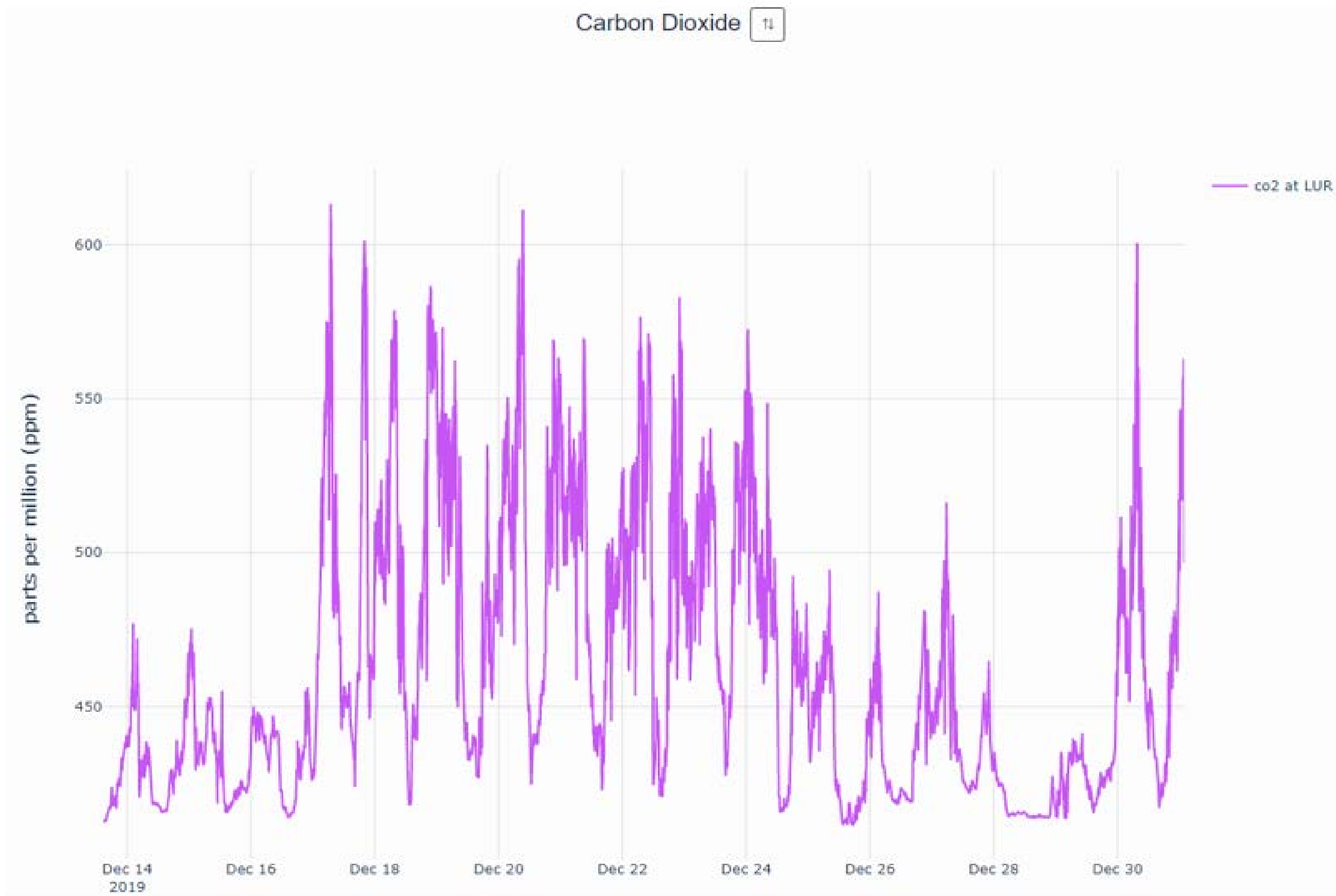


Figure SC-1:
LUR CO_2 record December 13 – December 31, 2019.

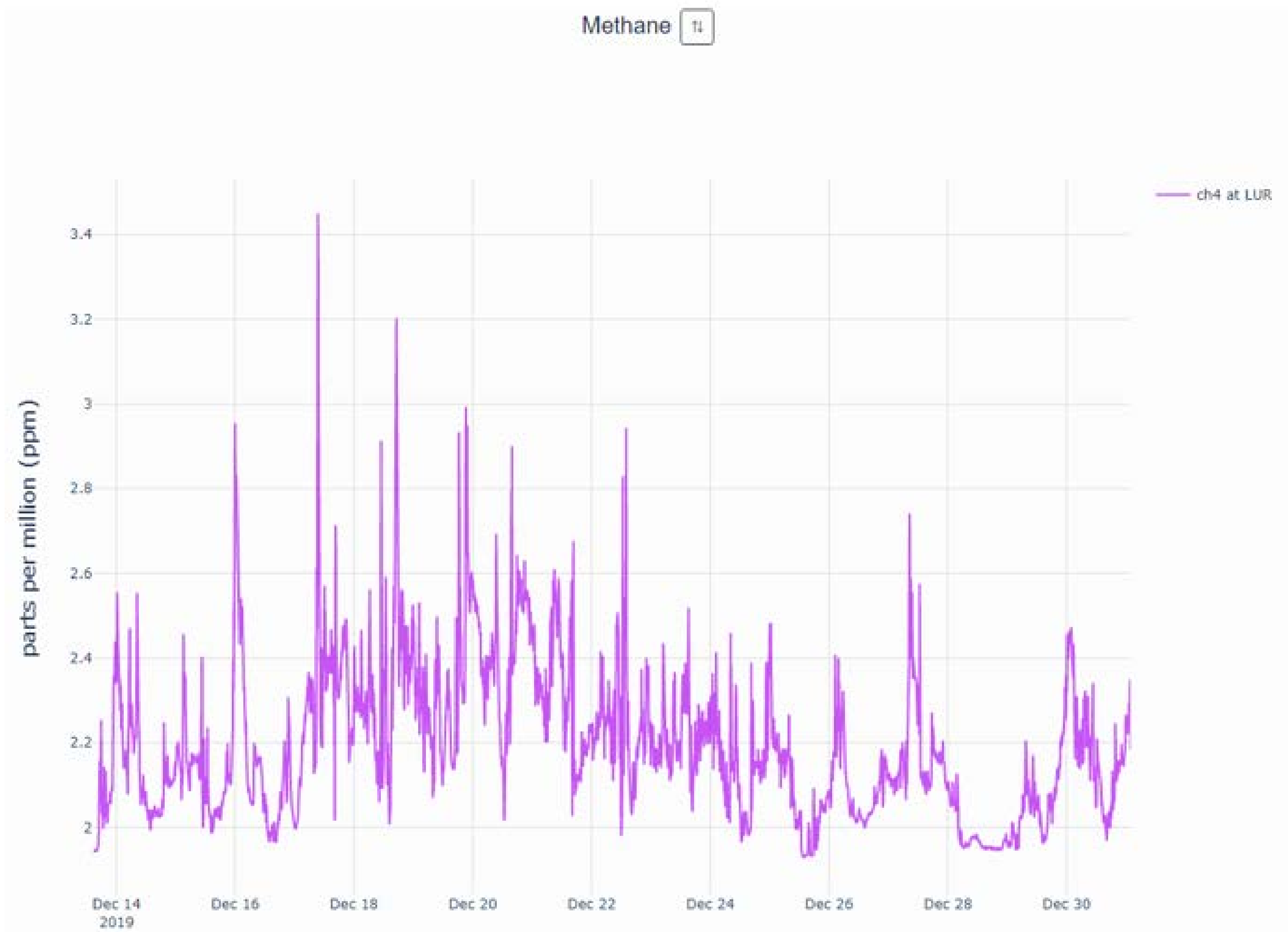


Figure SC-2:
LUR methane record December 13 – December 31, 2019.

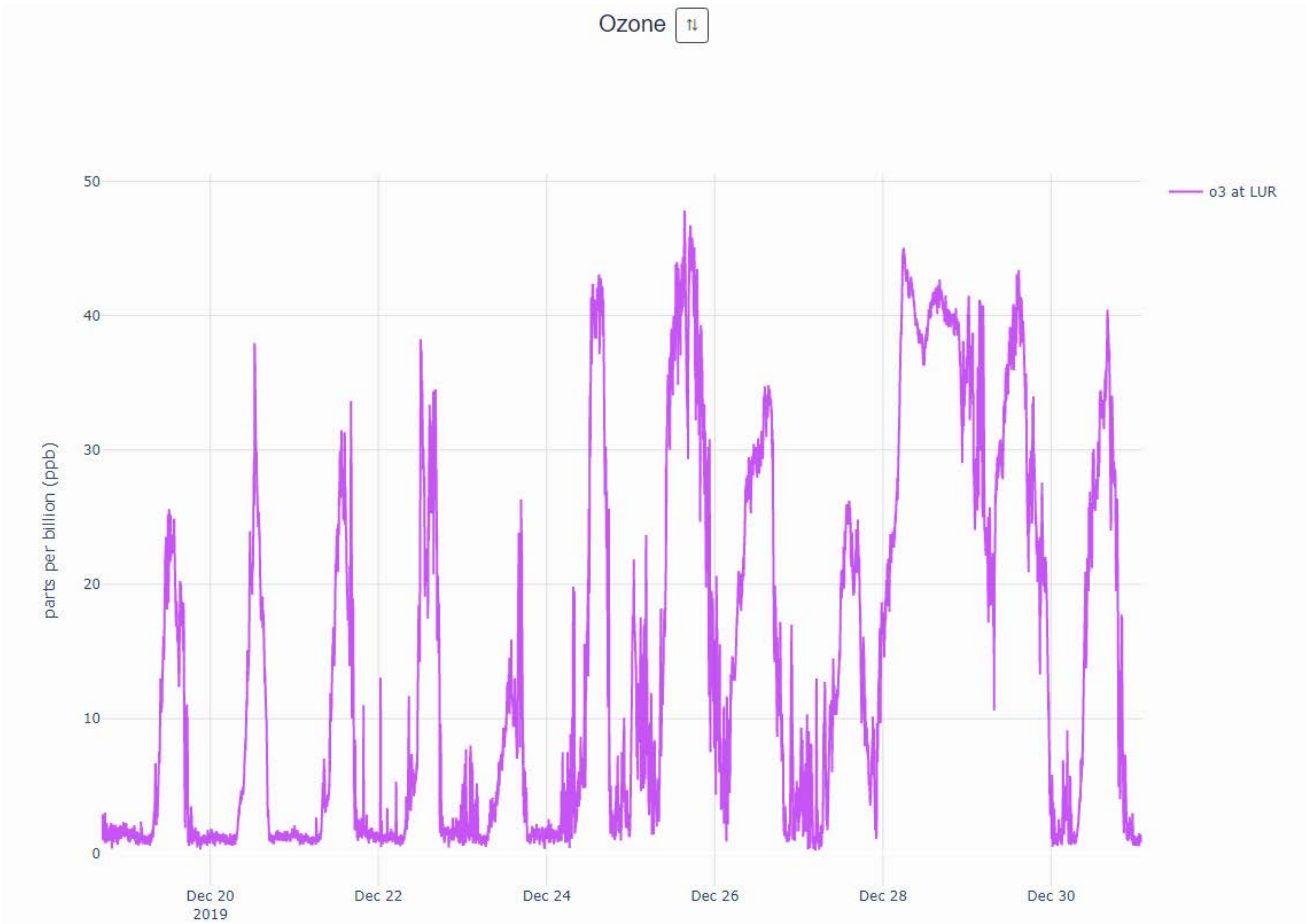


Figure SC-3:
LUR ozone record December 19 – December 31, 2019.