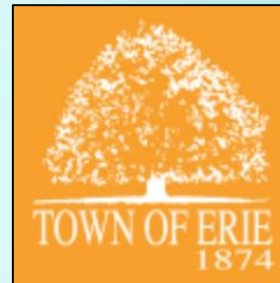


Front Range Local Government Air Quality Studies

Boulder County, City of Longmont,
Town of Erie, City & County of Broomfield

AQCC July 21, 2022



Presenters and Researchers

- **Boulder County**

- Cindy Copeland, Air & Climate Policy Advisor, Boulder County Commissioners' Office
- Bill Hayes, Air Program Manager, Boulder County Public Health

- **Longmont**

- Jane Turner, Oil & Gas & Air Quality Program Manager

- **Erie**

- David Frank, Energy & Environmental Program Specialist

- **City and County of Broomfield**

- Mindy Olkjer, Oil & Gas Program Manager
- Andrew Valdez, Deputy Director, Department of Strategic Initiatives

Researchers Available for Questions Today:

Meagan Weisner, Senior Environmental Epidemiologist,
City & County of Broomfield

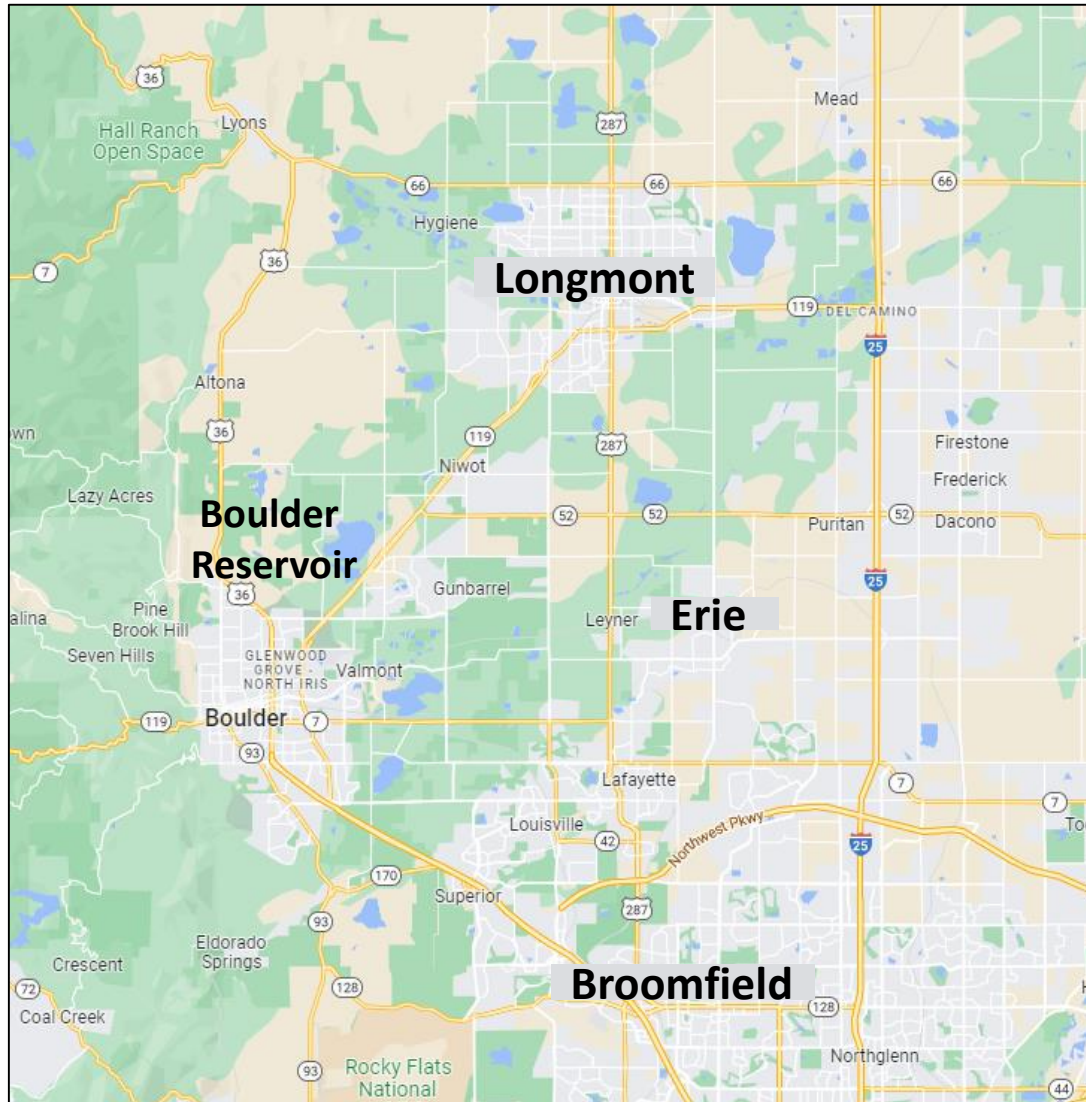
Brent Buck, AJAX Analytics

Dr. Detlev Helmig, Boulder A.I.R.

Key Messages

- Local sources continue to be a heavy influence on ozone concentrations in the Denver Metro/North Front Range (DMNFR) nonattainment area
- Ground level methane monitoring shows no decline in levels
 - 2017-2021 Boulder Reservoir data record
 - Methane levels increasing faster than the global average
- Emissions inventory underrepresents emissions
 - Broomfield and Erie have provided concrete examples of un-inventoried sources
 - CDPHE's aerial monitoring and increased funding through 2022 legislation will help
- Individuals living close to multi-well, horizontal oil and gas sources (within 1 mile) report greater upper respiratory and acute health symptoms (e.g. nosebleeds) more often than residents living at distances further away

Front Range Local Government Air Quality Study Locations



- **Boulder County**
 - 1 Boulder AIR Station
 - 2017 to present
- **City of Longmont**
 - 2 Boulder AIR Stations
 - Late 2019 to present
- **City & County of Broomfield**
 - 2 Boulder AIR Stations
 - 12 Ajax Sensors
 - Nov. 2021 to Present
- **Town of Erie**
 - 1 Boulder AIR Station
 - 10 Ajax Sensors
 - Fall 2021 to present

Why are local governments funding their own studies?

- Sampling near sources better reflects local emissions
- Desire to improve understanding of local air quality
 - Limited State monitors measure few pollutants
- Climate concerns
- Residents have health concerns
 - Ozone, Air Toxics
 - VOCs (e.g. benzene)
- Equity and Disproportionately Impacted Communities
- Leak detection – these emissions are not included in the inventory

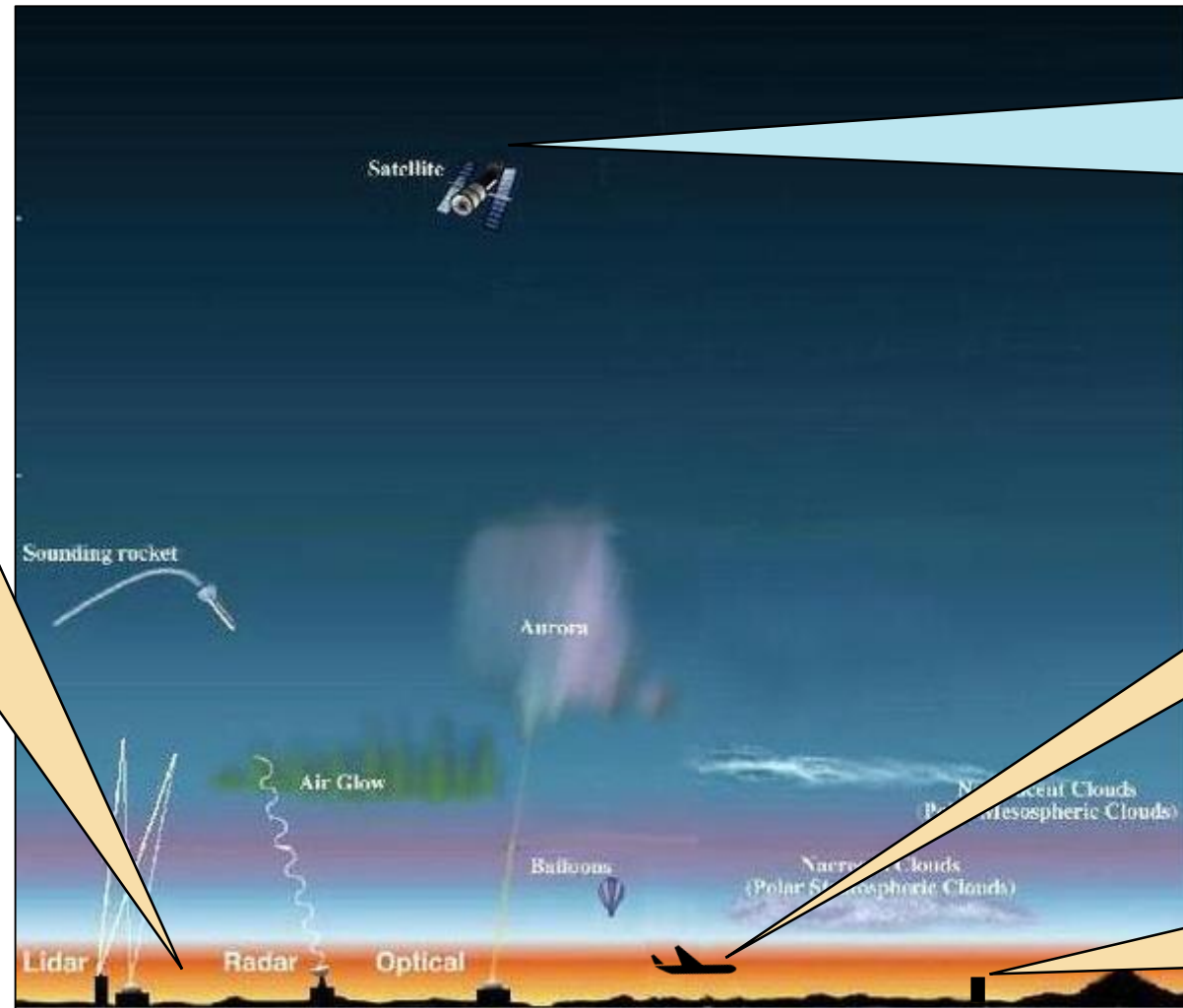


Oil and gas infrastructure in Erie

The importance of the boundary layer

The **boundary layer** is the layer of air close to the surface (the first few thousand feet above the ground).

This is where air mixes and pollutants are dispersed. Surface-level ozone forms in the boundary layer.



Satellites detect gases through the entire atmosphere and the boundary layer is most important for informing policy.

Aerial air quality studies are flown in the boundary layer

Ground-based instruments are in the boundary layer

Limitations of AIRS satellite data

- NASA's AIRS satellite estimates a daily average concentration of methane over a large area (grid cell)
- Gases are measured through the whole atmosphere with lower sensitivity for pollutants in the boundary layer
- Location specific ground-truthing is required
- NASA's AIRS has uncertain accuracy for methane compared to ground-based instruments, especially at our latitude (Zhang et al., 2021)

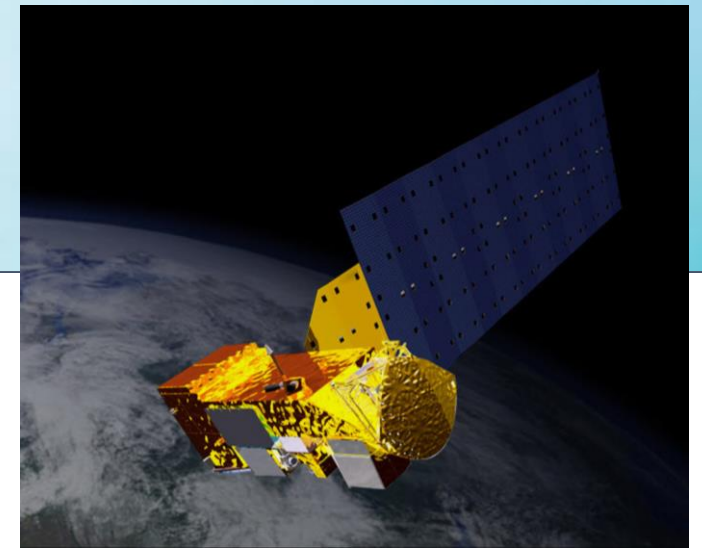


Image credit: airs.jpl.nasa.gov

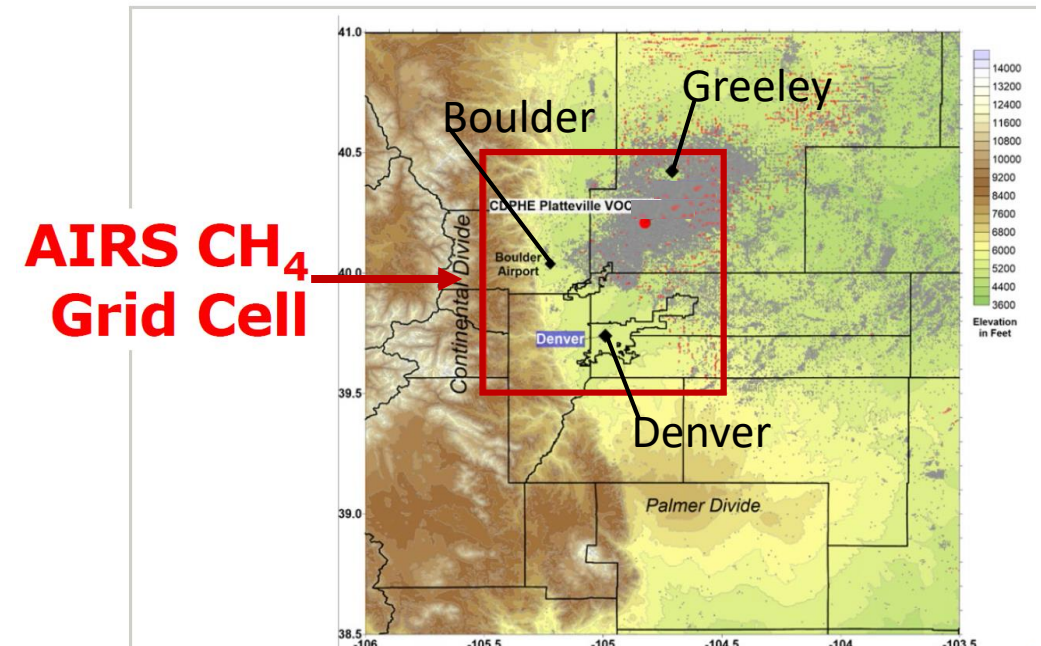


Image adapted from Weld County/Ramboll

Boulder County Air Quality Study

Bill Hayes, PE
Air Quality Coordinator
Boulder County Public Health



Boulder County Air Studies



- Monitoring nitrogen oxides (NO_x), volatile organic compounds (VOCs), and methane began in 2017
- Quantify and understand impacts of oil and gas emissions on air quality
- Monitoring station located at Boulder Reservoir
 - Co-located with CDPHE's ozone monitor
- Modeling analyses of 13 non-methane VOCs (NMVOCs)
- Four peer-reviewed publications with data
- Boulder County oil & gas inspection program



Study Findings Overview

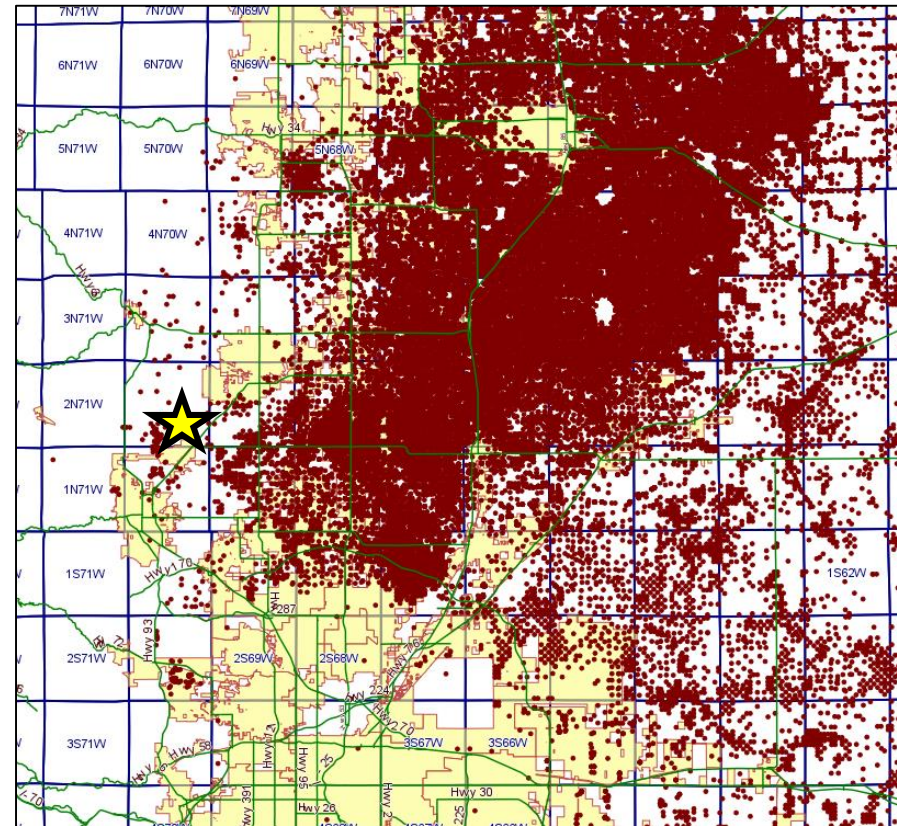
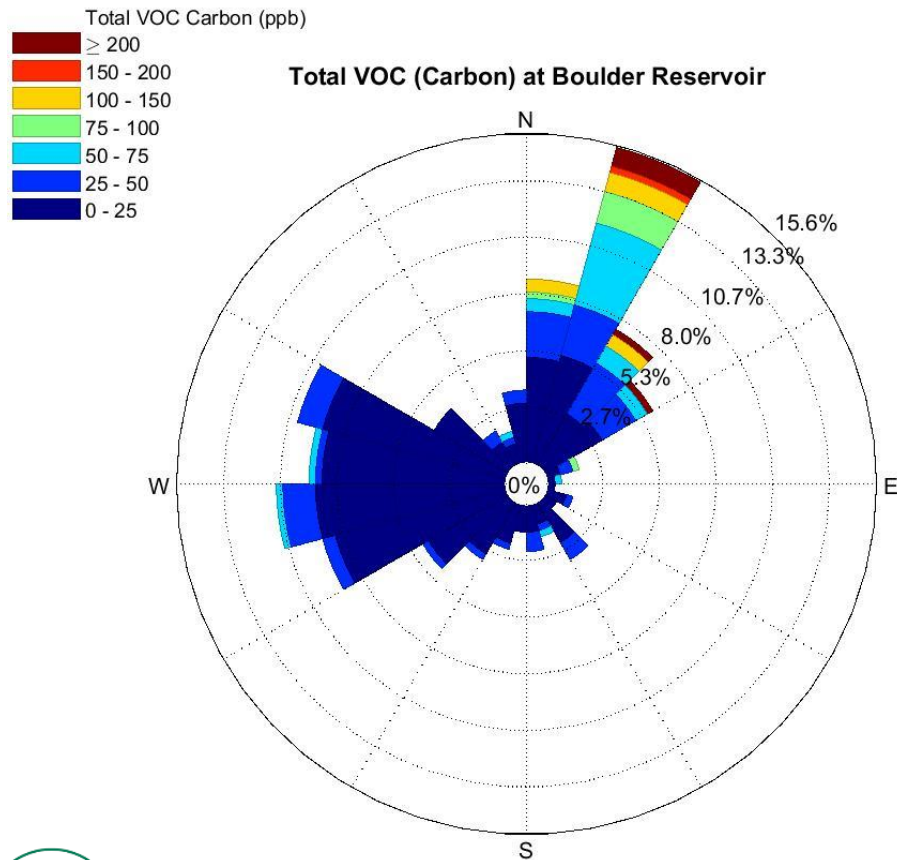


- High correlation between concentrations and air transport
- Impacts from Northeast of site
- Link between ozone exceedances and emissions
- Ground level methane monitoring shows no decline in emissions, 2017-2021
- Oil & gas inspection program found that 64% of sites with leaks had them in multiple calendar years



Oil and gas infrastructure in Boulder County

Dependence of Concentrations on Wind Direction



- ★ Boulder Reservoir Monitoring Station
- COGCC well locations



Oil and Gas Fingerprint: i/n Pentane Ratio



Pentanes are emitted from gasoline vapors and oil and gas production. Pentanes also contribute to ozone formation.



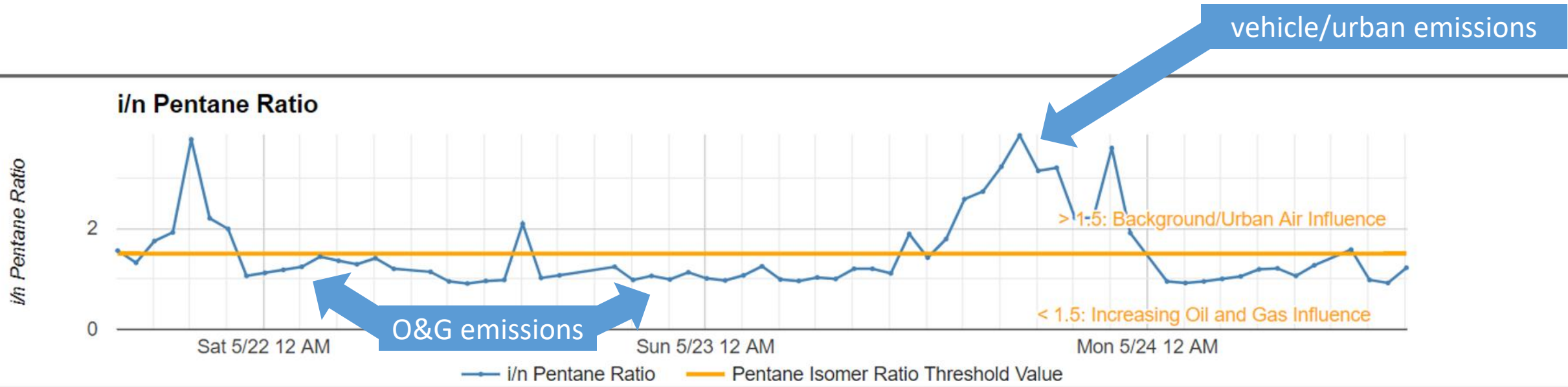
Oil and gas emissions typically have a ratio of less than 1 (0.8-0.9)

i/n Pentane Ratio



Emissions from vehicles and urban areas have a ratio of greater than 2

i/n Pentane Ratio at Boulder Reservoir



In recent years, the average i/n pentane ratio at Boulder Reservoir has been 1.1, indicating that pentane emissions from oil and gas production are more prevalent than pentane emissions from vehicles and urban areas.

Colorado State University Modeling Analyses

- Partnered with CSU to analyze Boulder County air monitoring data (data record goes back to 2017)
 - Multiyear dataset of 13 nonmethane VOCs
 - Estimates oil and gas and other source contributions to NMVOCs
- 2 separate modeling analyses show that:
 - Elevated VOCs and non-methane VOCs are associated with oil and gas producing regions¹
- The majority of high ozone days analyzed were not impacted by wildfire smoke²

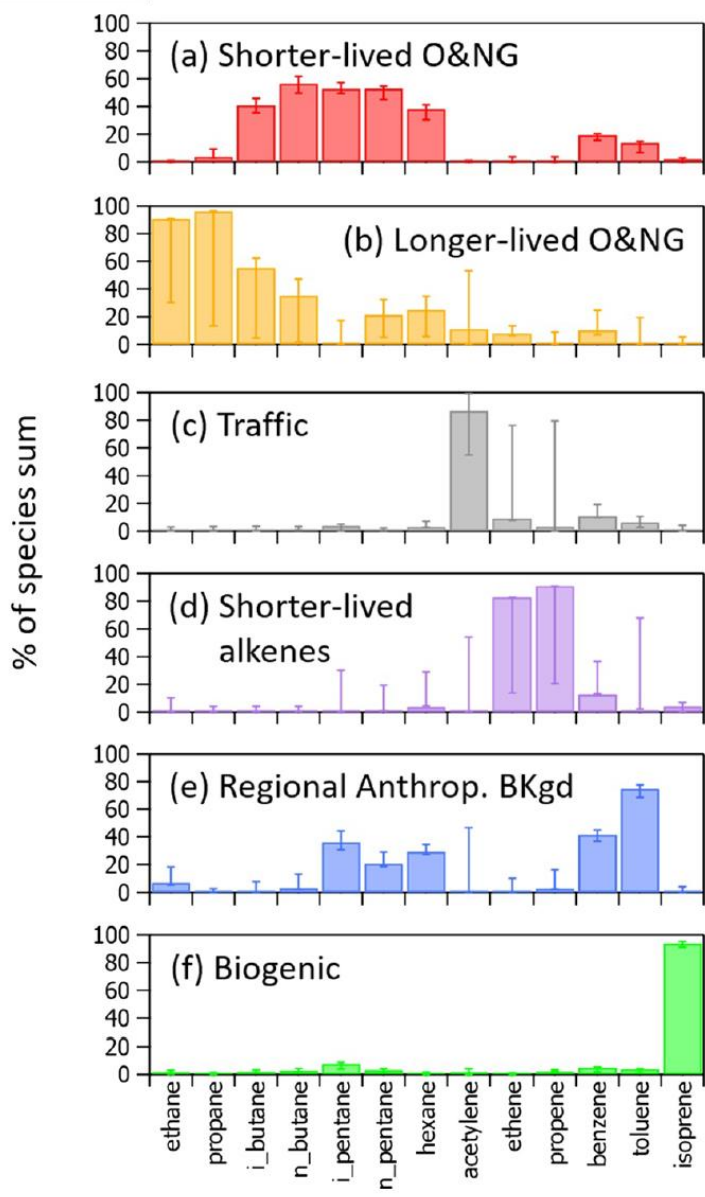
1. Seasonality and Source Apportionment of Nonmethane Volatile Organic Compounds at Boulder Reservoir, Colorado, Between 2017 and 2019
– Pollack et al., 2021

2. Weekend-Weekday Implications and the Impact of Wildfire Smoke on Ozone and Its Precursors at Boulder Reservoir, Colorado Between 2017 and 2019 – Pollack et al., 2021

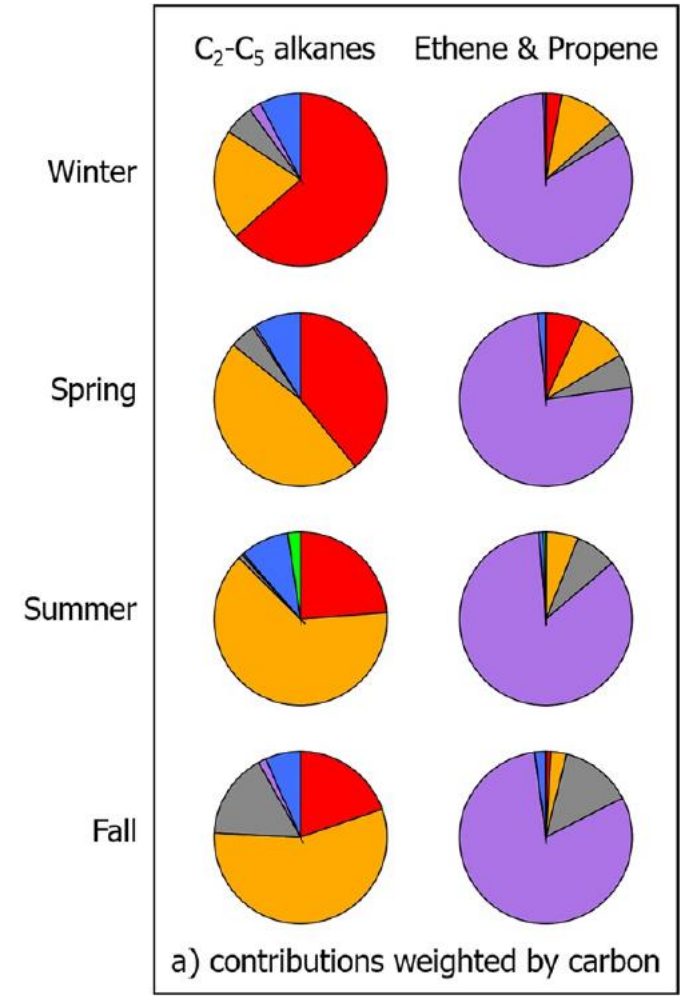
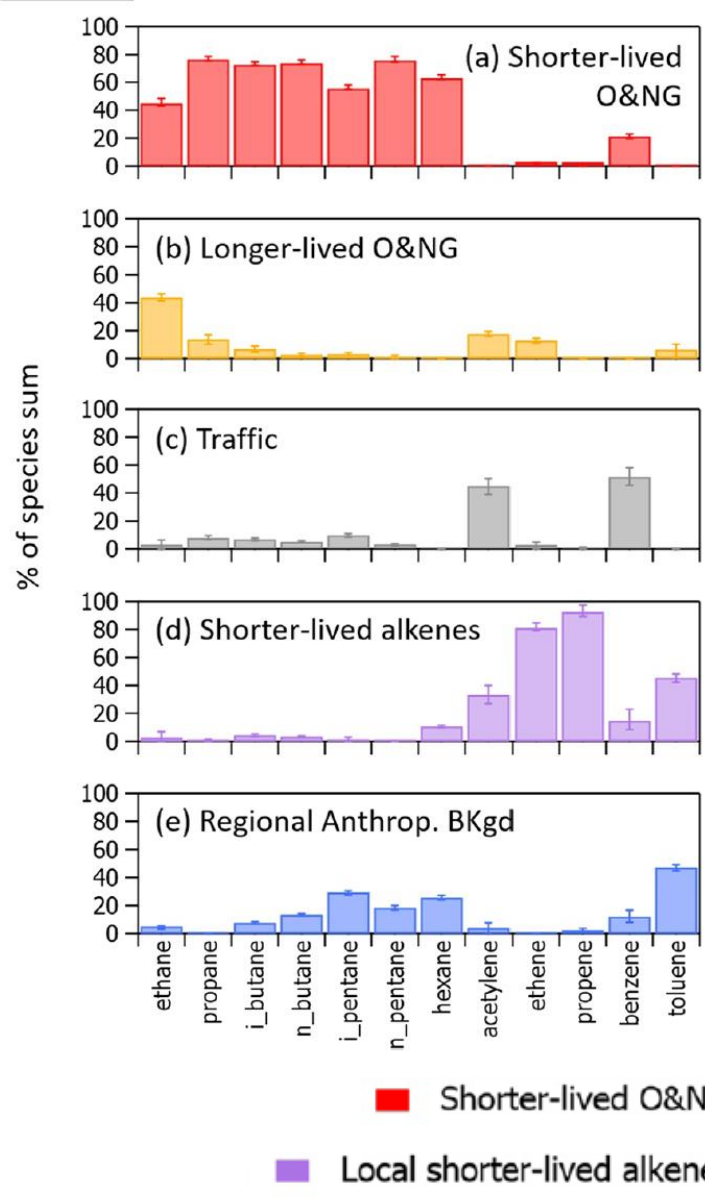


Summer

Factor Profiles

**Winter**

Factor Profiles



Left: Positive Matrix Factorization factor profiles (source signatures) derived from 2017 – 2019 Boulder Reservoir NMVOC data. **Right:** Corresponding PMF-derived source contributions. (Pollack et al., JGR Atmospheres, 10.1029/2020JDO34234.

Methane Trends at Boulder Reservoir

- Soon to be published study of 2017-2021 data
- Difference between methane from **West** is consistently lower than levels from the **Northeast** (DJB)
- Levels have not decreased from 2017-2021
- No indications of reductions in local methane

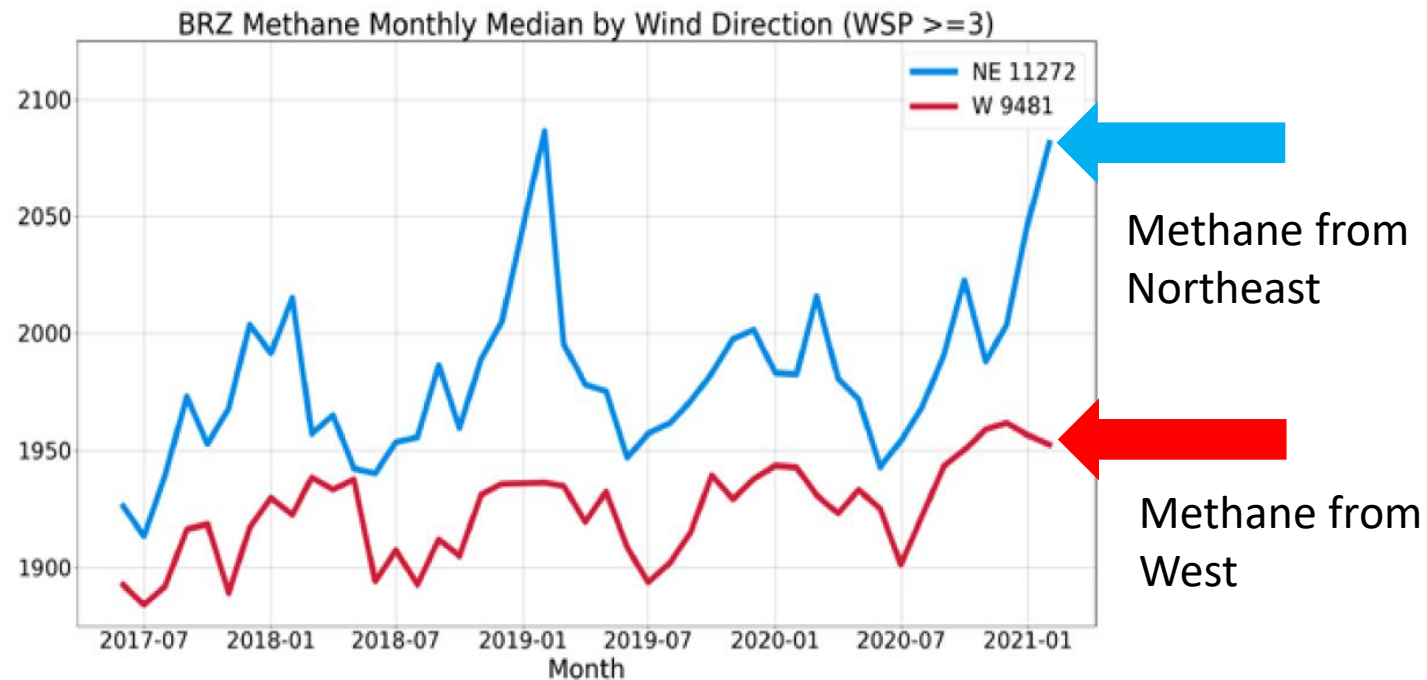


Figure adapted from Boulder A.I.R.
Graph shows methane when winds are greater than 3 m/s.

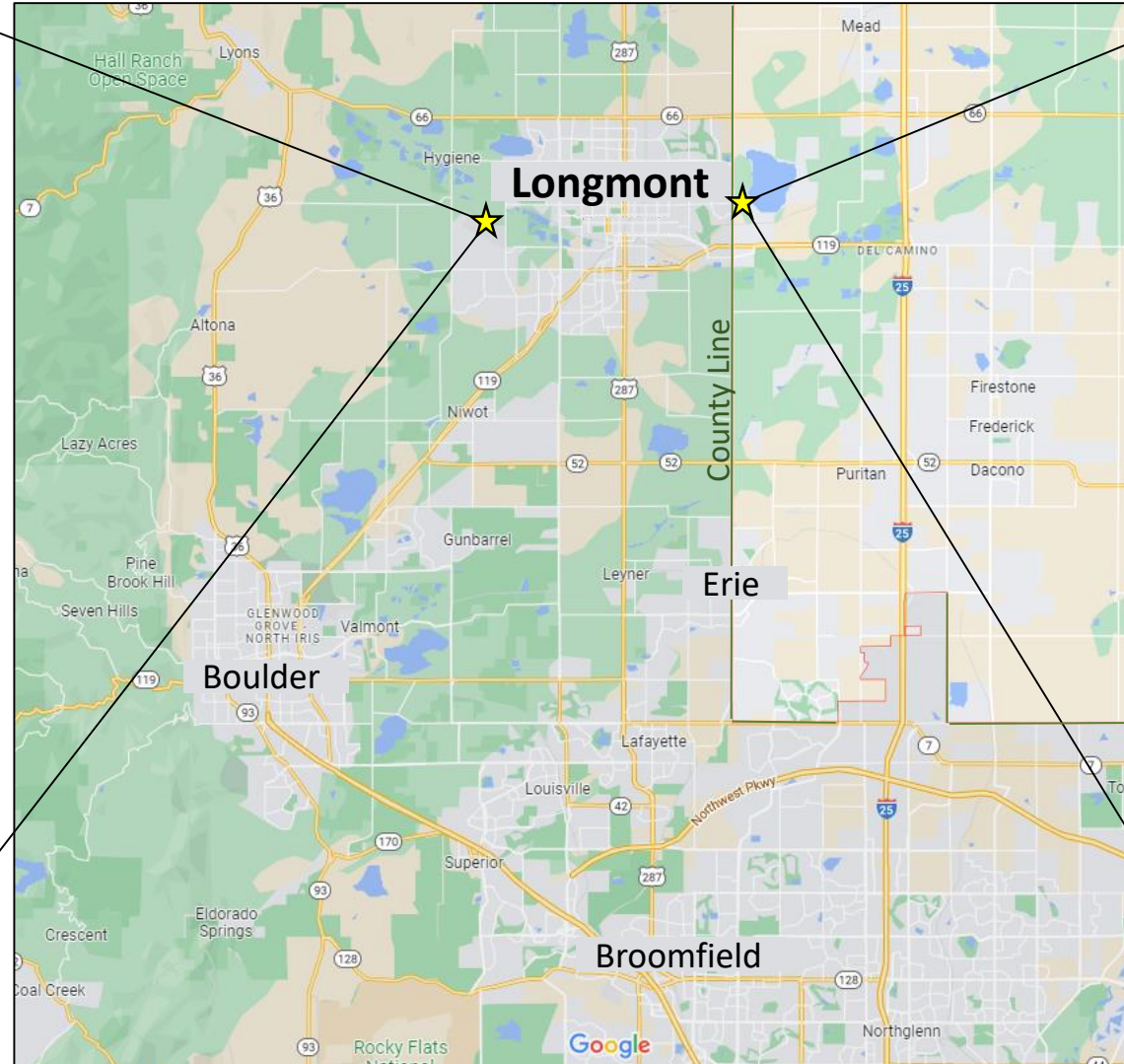
City of Longmont Air Quality Study

Jane Turner, PE, PhD

Oil & Gas and Air Quality Program Manager
Local Governmental Designee, COGCC



City of Longmont

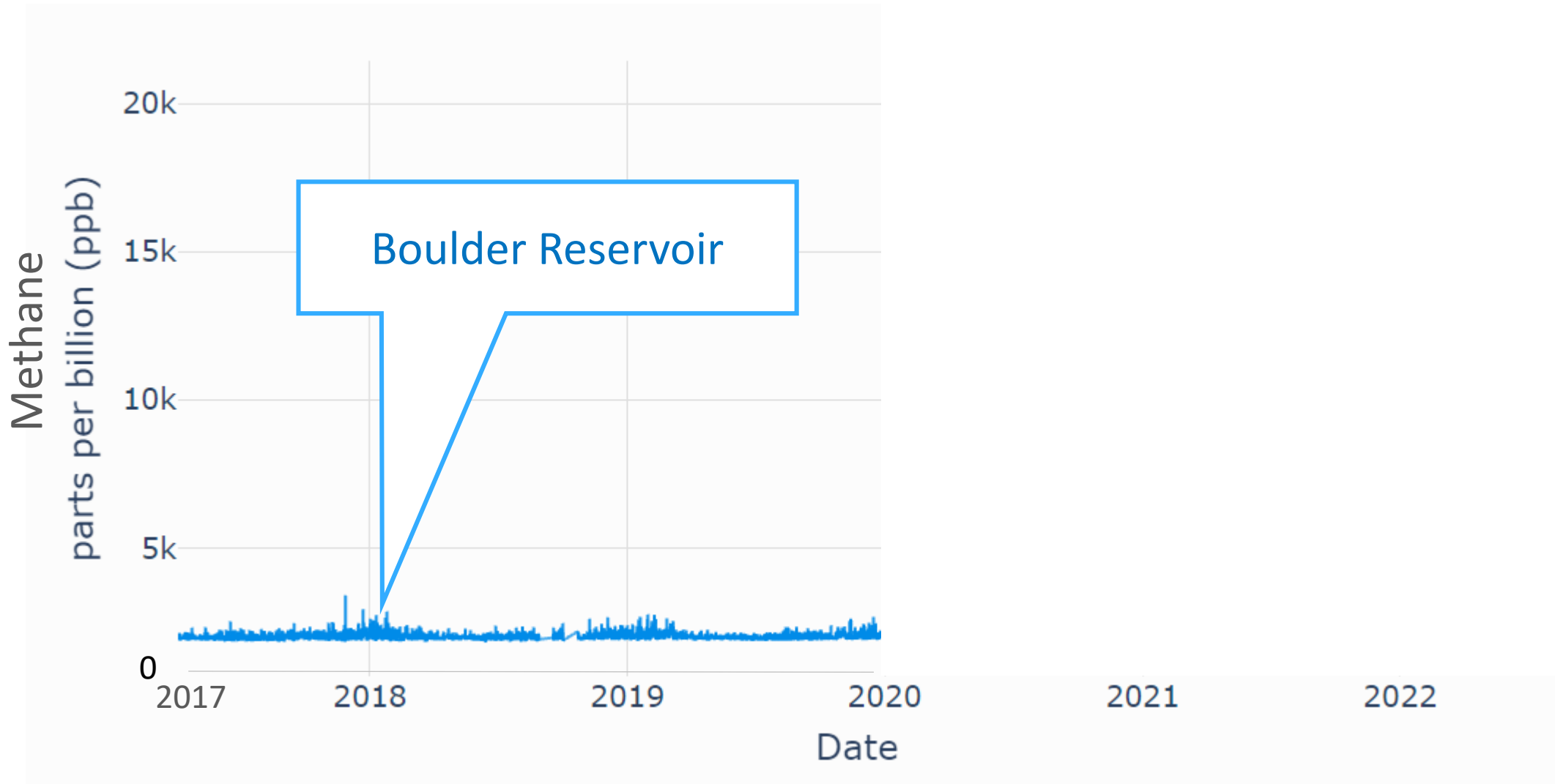


Lykins Gulch Station
(formerly located at municipal airport)

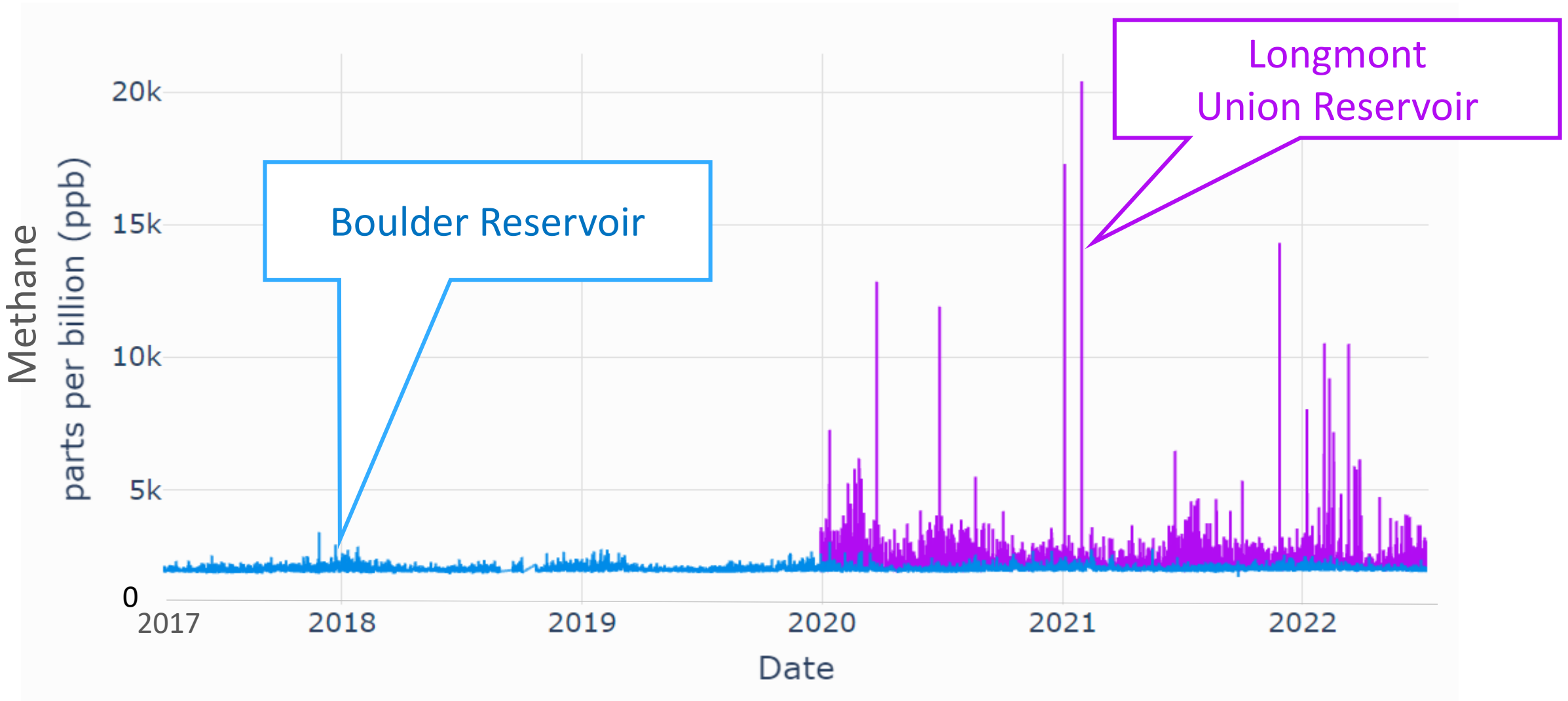


Union Reservoir Station

Methane: Boulder Reservoir vs. Union Reservoir



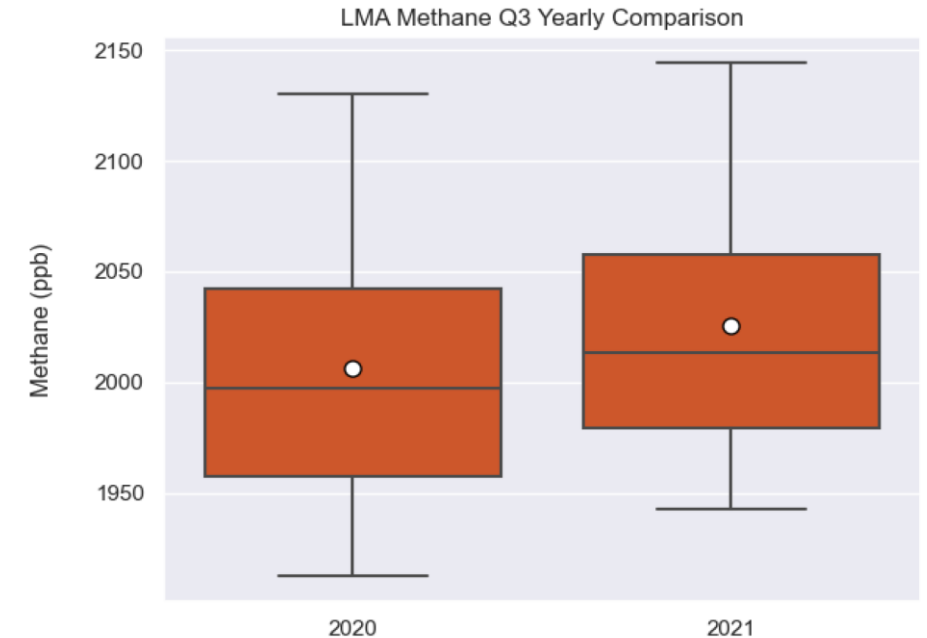
Methane: Boulder Reservoir vs. Union Reservoir



General Methane Trend for Longmont: Increasing faster than the global average



- NOAA - 2020 global mean methane increased
 - 15 ppb
- Mean methane increase in West Longmont
 - Q3 2020 to 20201
 - 19 ppb
- Mean methane increase in East Longmont
 - Q3 2020 to 20201
 - 30 ppb
- Data supports that local emissions are increasing
- Data collection and analysis continues



Source: Boulder AIR Longmont Q3 2021 Report
Longmontcolorado.gov

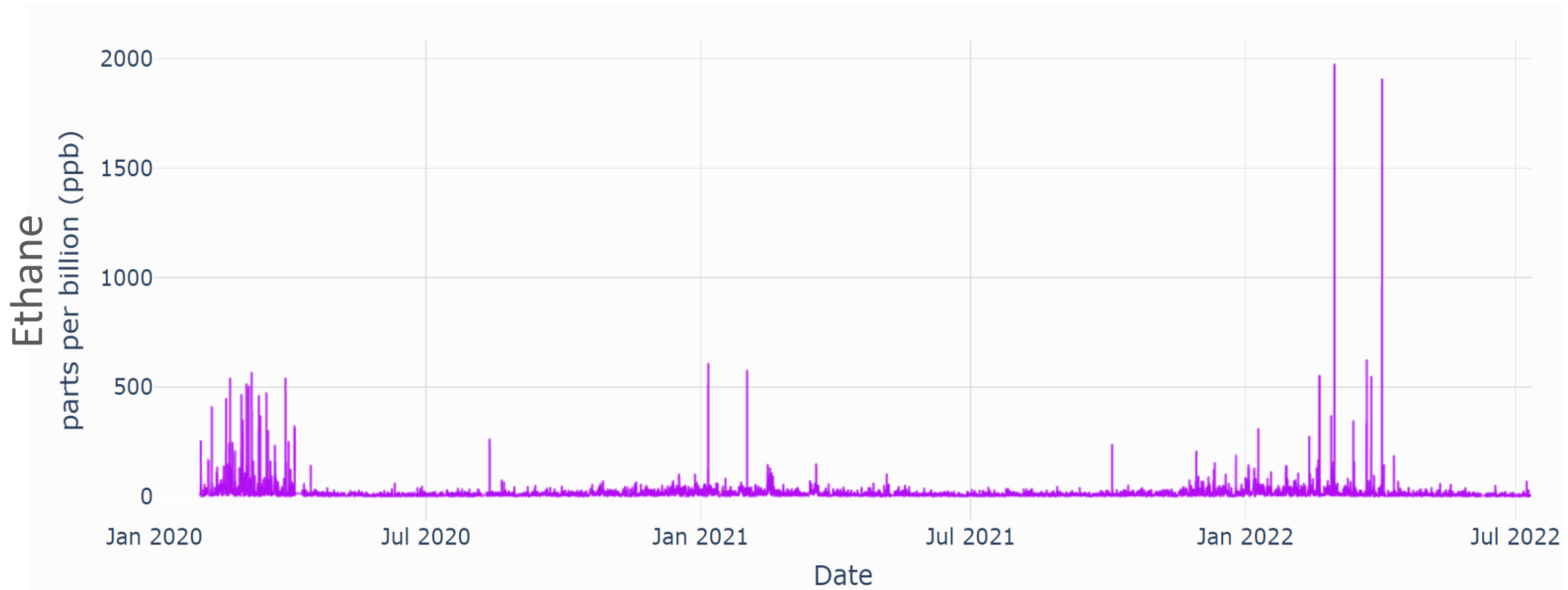
Source: Ed Dlugokencky, NOAA/GML gml.noaa.gov/ccgg/trends_ch4

Ethane plumes: Longmont Union Reservoir



Ethane is a selective tracer for oil and gas activity because there are few other sources.

Over 350 major ethane plumes recorded measured since monitoring began.

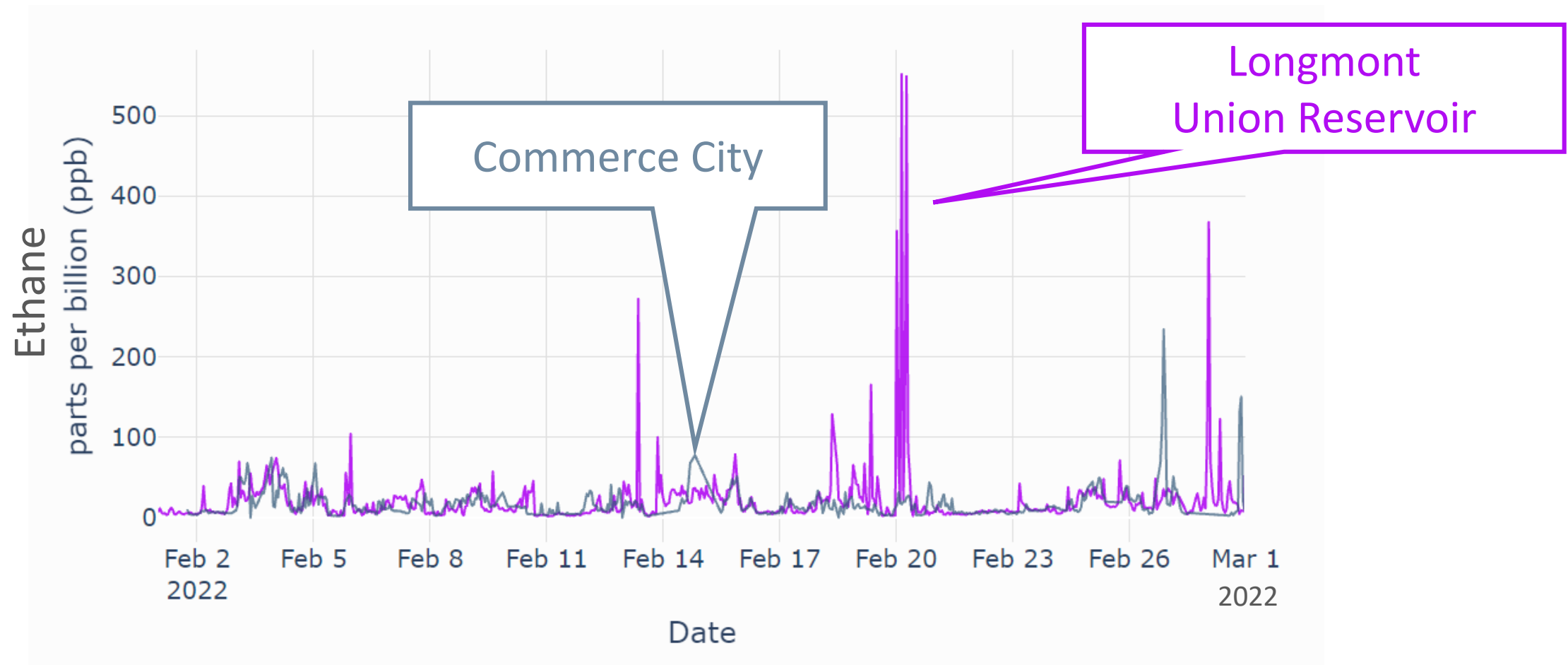


Ethane >25 times higher than background levels considered to be a plume.

Ethane: Longmont vs. Commerce City Feb. 2022



Ethane is a selective tracer for oil and gas activity because there are few other sources.



Town of Erie Air Quality Monitoring Program

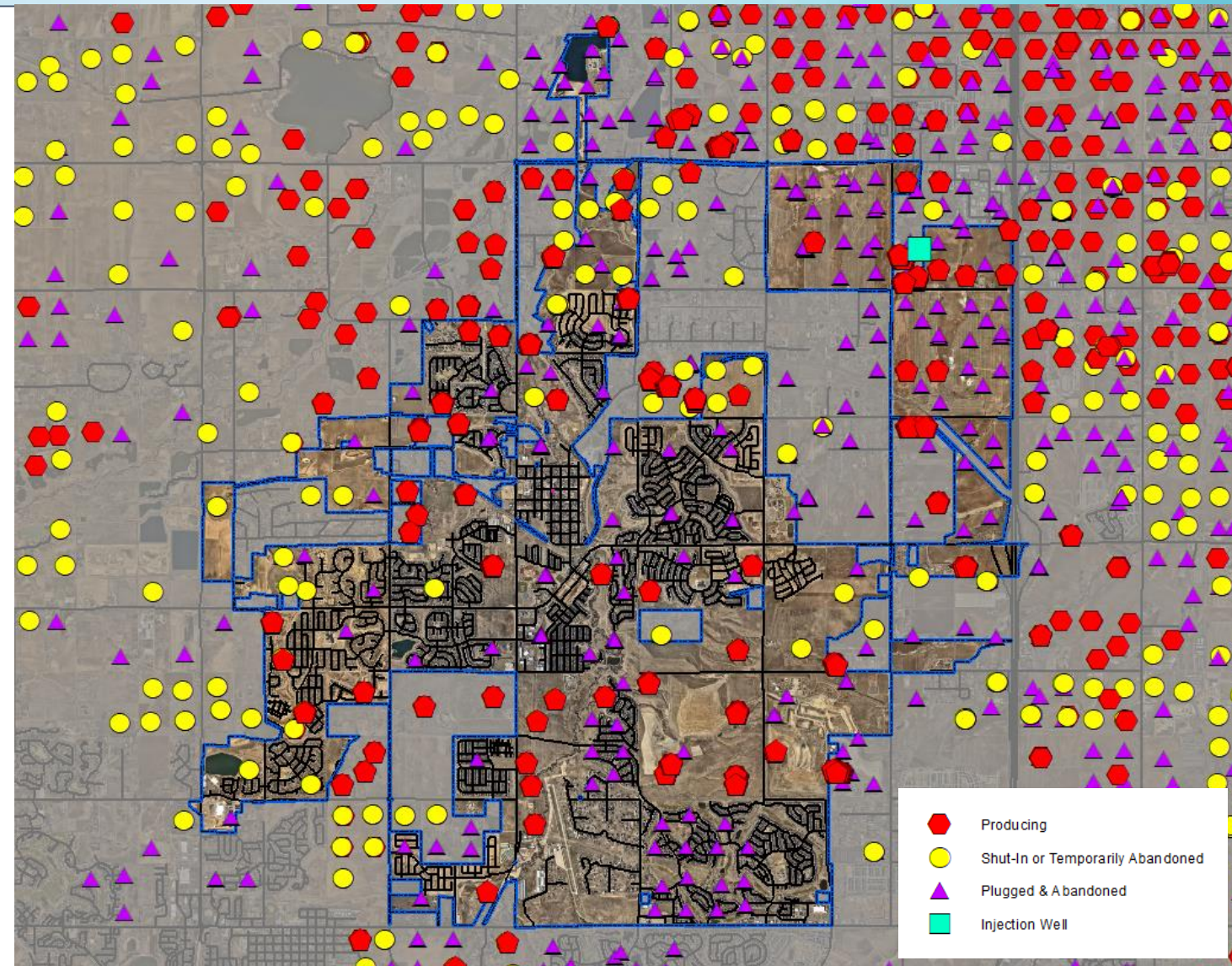
David Frank

Energy and Environmental Program Specialist
Local Governmental Designee, COGCC



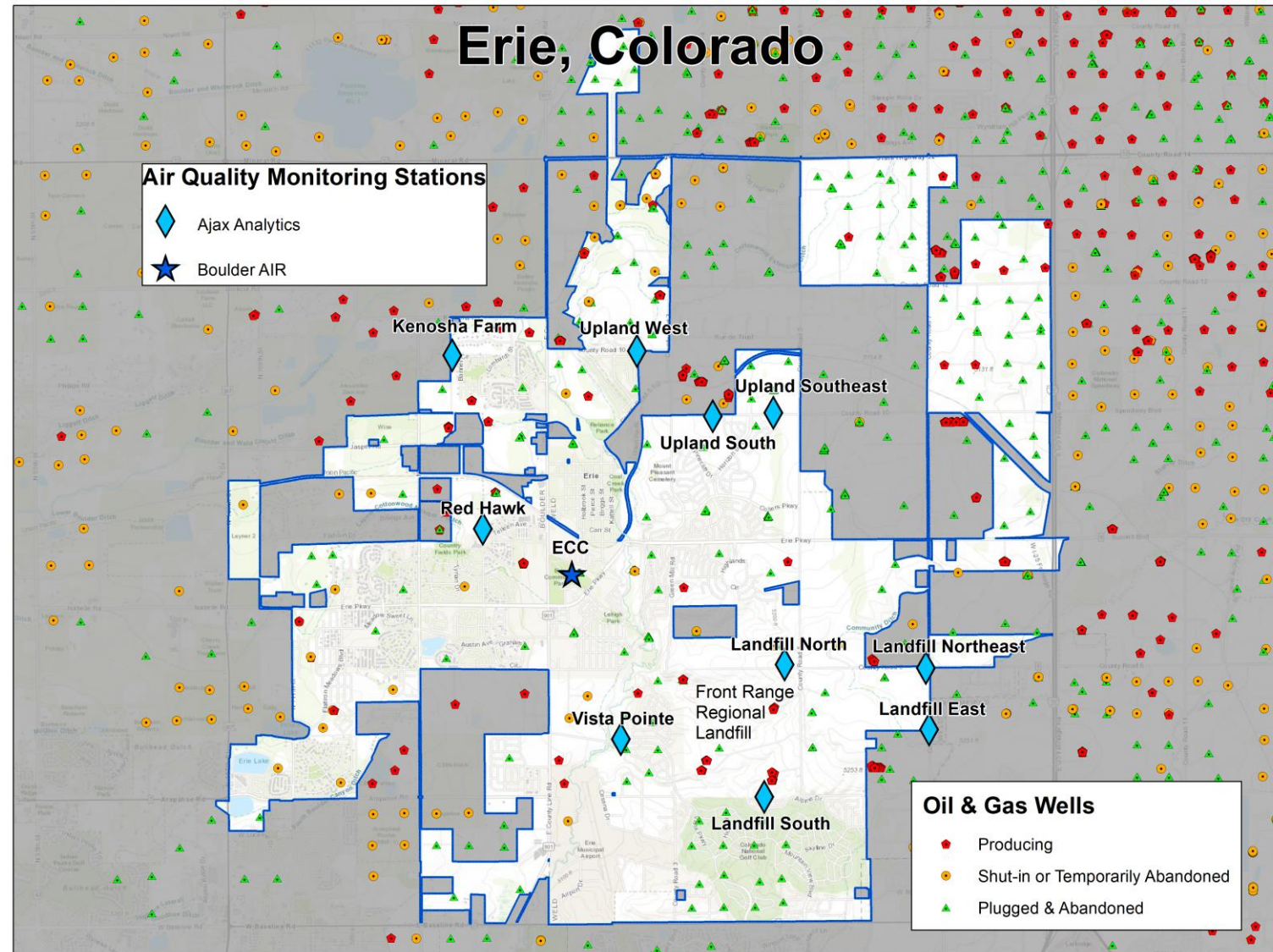
Oil and Gas Facilities near Erie

- 138 O&G wells within Erie limits (101 producing, 36 shut-in, 1 TA)
- 296 O&G wells within 2,000ft of Erie (223 producing, 60 shut-in, 13 TA)
- 209 Plugged and abandoned wells within Erie limits (13 pre-2013)
- 172 Plugged and abandoned wells within 2,000ft of Erie (29 pre-2013)
- 1 Deep Injection Well



Erie Air Quality Monitoring Program

- Boulder AIR Monitoring Station located at the Erie Community Center
- 10 Ajax Analytics/CSU Monitoring Stations located across town
- Operating since Fall 2021



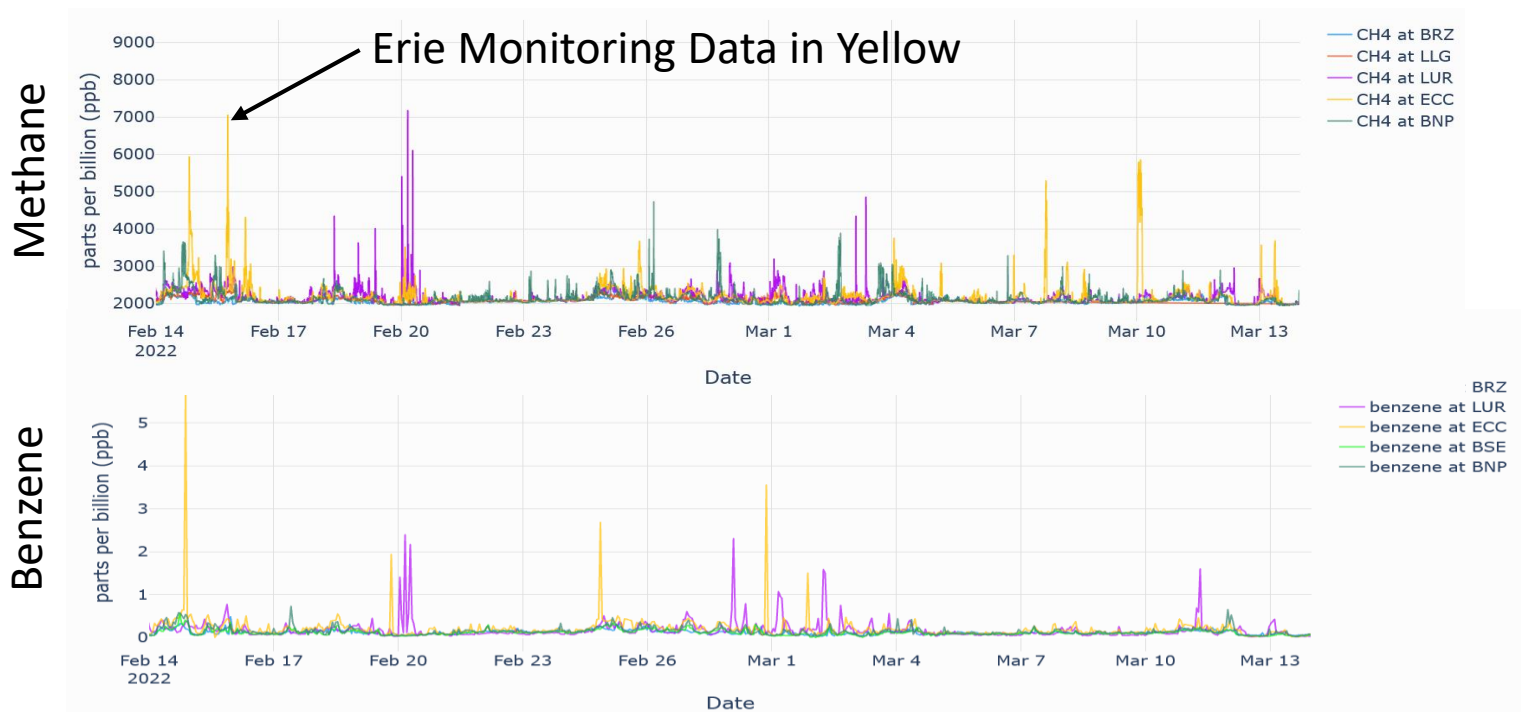
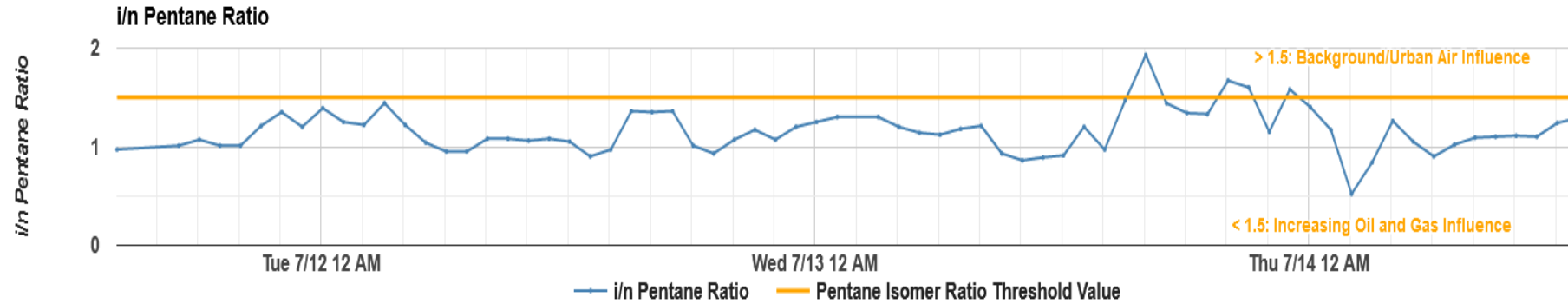
Erie Boulder AIR Monitoring Station

Boulder AIR Station located at the Erie Community Center

- Real-time monitoring of meteorological conditions as well as monitoring of atmospheric pollutants, including methane (CH₄), volatile organic compounds (VOCs), ozone (O₃), and particulate matter (fine and coarse aerosol).



Erie Boulder AIR Monitoring Station



Erie Ajax/CSU Monitoring Stations

Ajax/CSU Stations located
in Erie and Broomfield

- Weekly whole air SUMA Canister Samples at select sites
- PID sensor triggered SUMA Canister sampling to capture plume events
- 49 VOCs analyzed at the CSU Atmospheric Sciences Lab



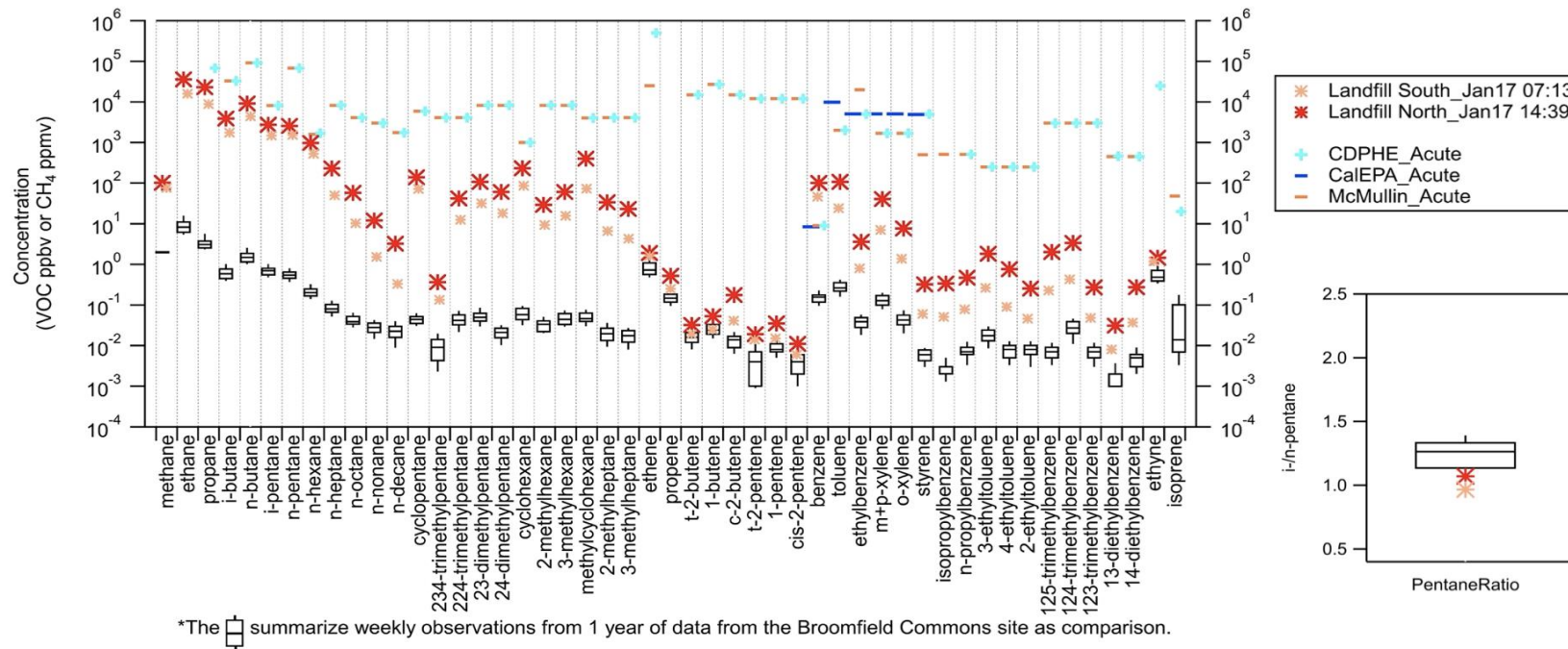
Erie Ajax/CSU Monitoring Stations

Average 1-week canister catches
TVOC CSU49 from October 2018 through June 2022



Erie Ajax/CSU Monitoring Stations

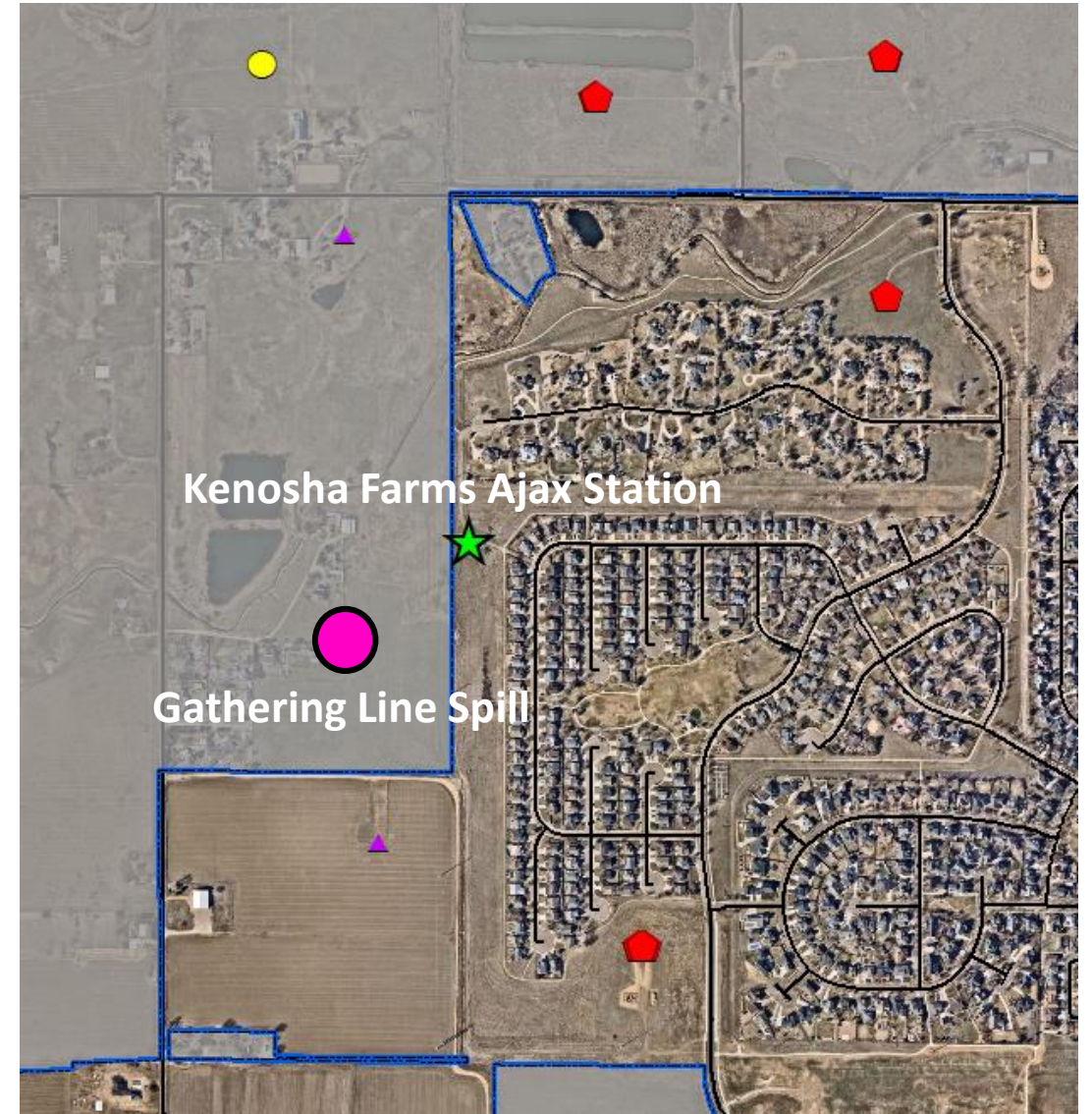
Landfill South & North_01/17



VOC concentrations in the triggered canisters collected at Landfill South and Landfill North on 01/17/22 are compared with the distributions of weekly values measured at Commons and with health guideline values. The i-/n- pentane ratios are shown in the right. The box and whisker plots show the 25th and 75th percentiles as the box, the 50th percentile as the line in the box, and the 10th and 90th percentiles as whiskers. Please note the use of a logarithmic scale indicating orders of magnitude of species concentrations. For exact values and comparisons to HGVs, please check the attached excel sheet.

Erie Ajax/CSU Kenosha Farms Station

- Installed to establish background air quality
- Average 1-week TVOC_CSU49
 - prior to 12/2 was 12.5 ppb
 - 12/2 - 5/19 was 61.9 ppb
 - After 5/19 was 8.7 ppb
- Anomalous plumes detected beginning early February 2022
- Winds from the S-WSW
- Gathering line leak discovered ~700 ft SW in May 2022
- No plumes detected after pipeline was removed from service and contaminated soils excavated



City and County of Broomfield Air Quality Monitoring

Mindy Olkjer

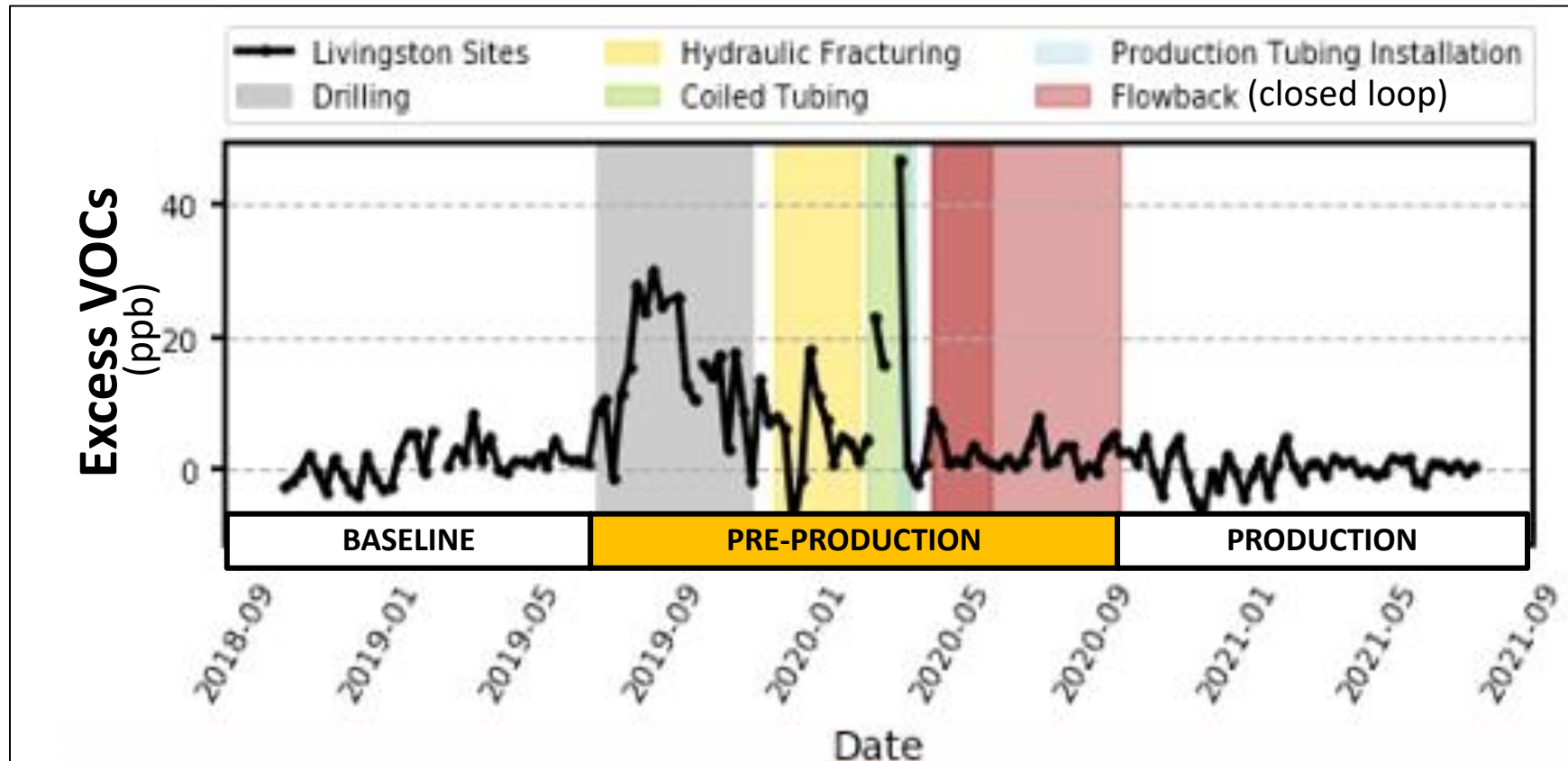
Oil and Gas Program Manager
Local Government Designee, COGCC



City & County of Broomfield



Pre-production activity is a clear contributor of excess volatile organic compounds (VOCs)



- Data from Broomfield's weekly air canister sample program shows pre-production activity is associated with excess VOCs and air toxics over baseline
- Pre-production activities include: drilling, hydraulic fracturing, and coiled tubing/plug mill out
- Known carcinogens have been observed, including benzene

City & County of Broomfield



During the fourth quarter of 2021, Broomfield's AQM program captured 49, 1-minute canister events

Start_Date_Time	Site	Oil and Gas Phase	Oil and Gas Pad	benzene ppbv
12/4/2021 4:37	United 1	Drilling, Hydraulic Fracturing, Coiled Tubing	United, NW B, NW A	25.664
12/4/2021 4:06	NWPKWY 2	Drilling, Hydraulic Fracturing, Coiled Tubing	United, NW B, NW A	25.103
11/30/2021 10:10	NWPKWY 2	Drilling, Hydraulic Fracturing	United, NW B	18.903
12/3/2021 6:25	United 2	Drilling, Hydraulic Fracturing, Coiled Tubing	United, NW B, NW A	16.571
12/4/2021 4:45	United 2	Drilling, Hydraulic Fracturing, Coiled Tubing	United, NW B, NW A	15.603
10/1/2021 22:42	NWPKWY 2	Drilling	NW B	14.970
10/9/2021 4:51	United 1	Drilling	NW B	14.453
12/4/2021 4:16	NWPKWY 3	Drilling, Hydraulic Fracturing, Coiled Tubing	United, NW B, NW A	12.566
10/7/2021 18:13	NWPKWY 2	Drilling	NW B	12.200
10/8/2021 13:51	NWPKWY 2	Drilling	NW B	10.537
10/8/2021 13:15	NWPKWY 2	Drilling	NW B	10.474
10/6/2021 22:34	NWPKWY 2	Drilling	NW B	10.183

Repeated Acute Events:

- Pre-production activities were occurring at 3 separate oil and gas sites during Q4 2021
- 12 events surpassed the acute HGV for benzene (9 ppb). Values ranged from 10.1 - 25.6 ppb (60 second samples)*
- The most significant events occurred on Dec 4 during drilling at United, coiled tubing at NWA and hydraulic fracturing at NWB. One hour benzene estimates reached 223 ppb

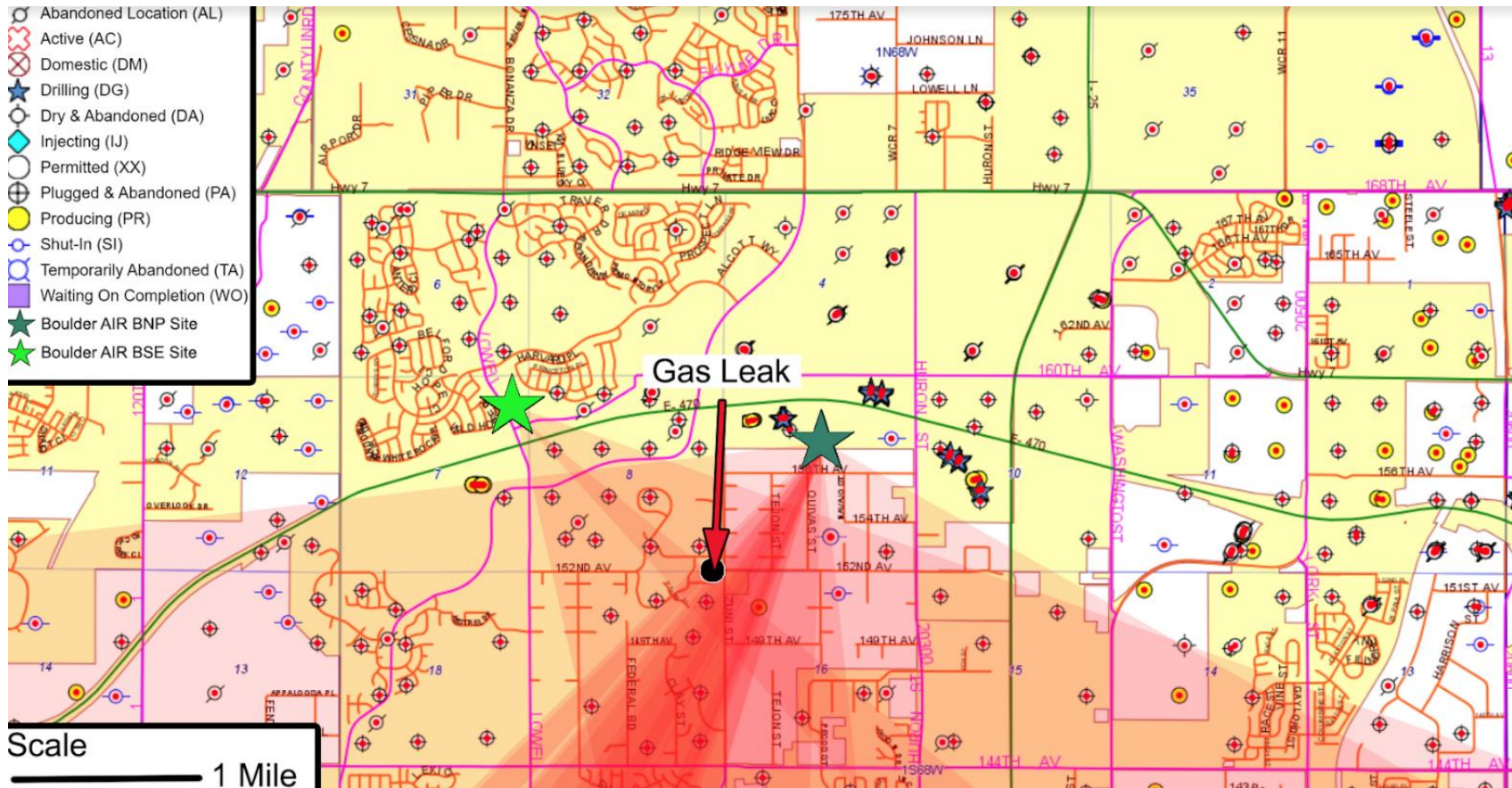
*Acute HGVs are set for a duration of a minimum, 1-hour exposure. 1-minute canisters are compared to acute HGVs as a way to benchmark potential exposure to nearby residents. Ajax Analytics has developed a method to extrapolate 1-minute readings to 1-hour averages; although this method has not been peer-reviewed, it serves as a way to better compare benzene values to acute HGVs.

AQM events that exceeded the HGV for benzene
Dec 4 canisters tied to coiled tubing event

City & County of Broomfield



Local monitoring helps us identify un-inventoried GHG emissions



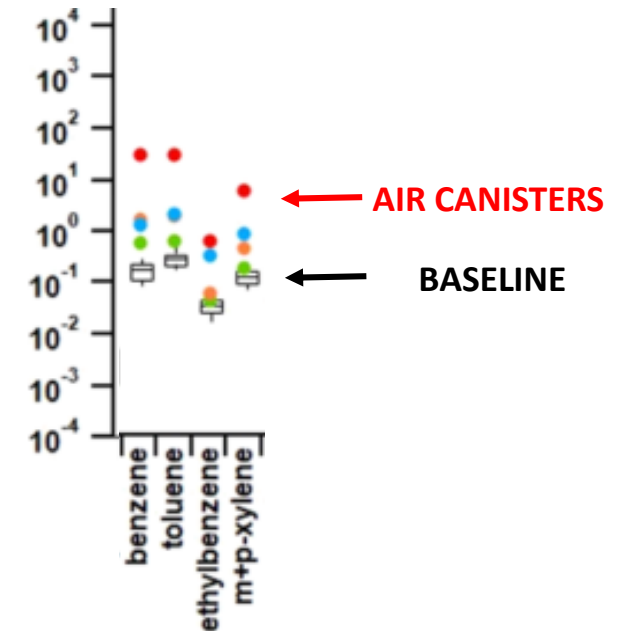
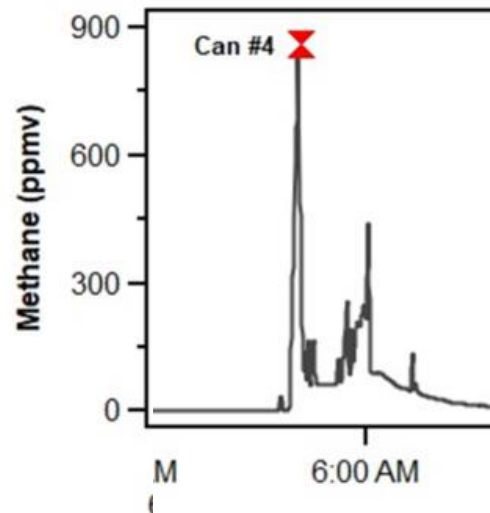
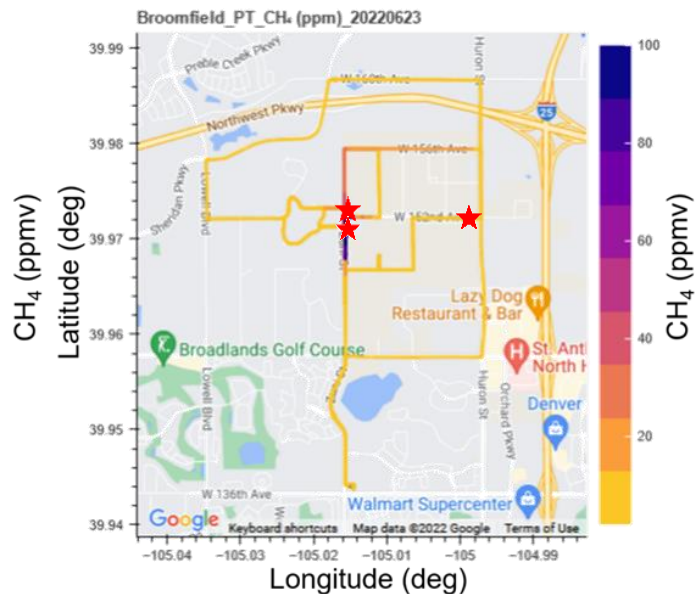
Combined peak wind direction figure. The darker red areas indicate where the wind was blowing from during ethane peak events. The two highest ethane peak events from BSE during this time interval (May 29th – June 12th, 2022) were also included.

- Data from Broomfield's stationary AQM trailers led to the discovery of a natural gas leak in a gathering line
- The location on map was triangulated by tracing the source of a series of methane, ethane, and propane-rich plumes
- This event is notable because the Boulder A.I.R. North Pecos station is located nearly one mile from the midstream pipeline leak and recorded ethane readings were 100x over baseline

City & County of Broomfield



Local monitoring helps us identify un-inventoried GHG emissions



In late June 2022, CSU's Plumetracker mobile lab confirmed the source of the leak and captured additional data (continuous methane and 60-second **air canisters**)

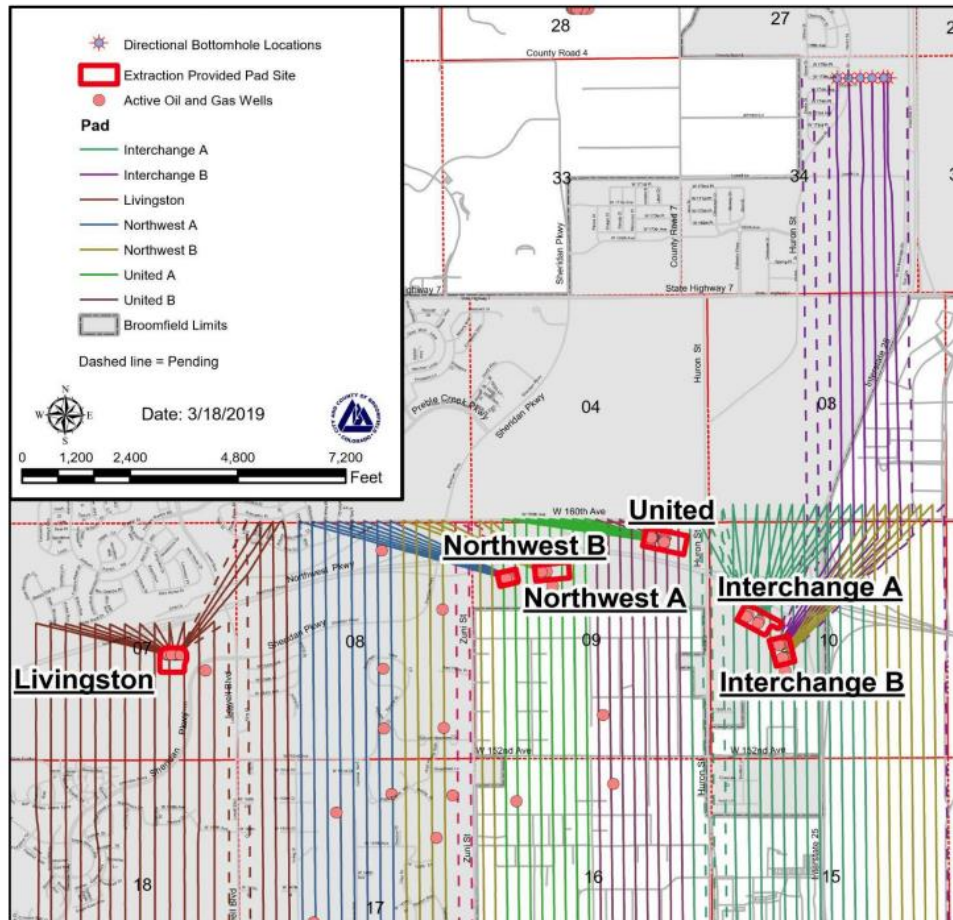
Methane levels measured in the vicinity of the leak reached as high as 828 ppm in a 60-second canister (atmospheric baseline is 2 ppm)

Canister #4 measured 24,729 ppb TVOC, with 828 ppm of methane, 2,294 ppb of ethane, and 29.7 ppb of benzene.

City & County of Broomfield



Oil and Gas Health Study



UOGD locations within the City and County of Broomfield

Overall Goal:

- The City and County of Broomfield's Department of Public Health and Environment, along with researchers from the University of Colorado School of Public Health, collected health data from 427 randomly identified Broomfield residents (living in separate households) to better understand self-reported health symptoms associated with living in proximity to unconventional oil and gas Development (UOGD) (i.e. horizontal, multi-well pads).

Methods:

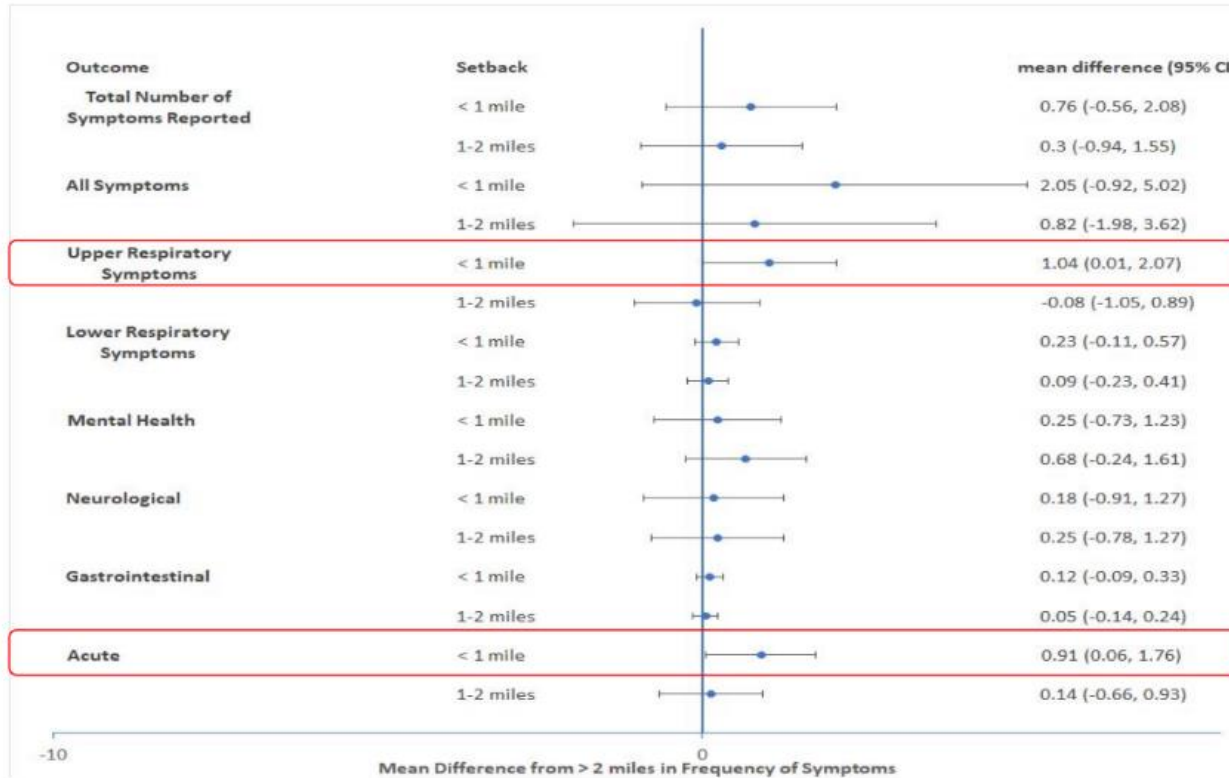
- Researchers applied least squares linear regression to test the association between distance to UOGD and summed Likert score for total, upper respiratory, lower respiratory, mental health, gastrointestinal, neurological, and acute health symptom categories and adjusted for covariates.

During the time health data was collected (October-December 2021), 3 UOGD sites were in pre-production phases in Broomfield and the AQM network captured dozens of plumes associated with air toxic releases during drilling, hydraulic fracturing, and coiled tubing.

City & County of Broomfield



Oil and Gas Health Study



The above graph shows that adult respondents living within 1 mile of a multi-well site reported significantly greater upper respiratory and acute symptoms.

*This study has been submitted to a peer-reviewed journal for potential publication. Read more here: <https://www.broomfieldvoice.com/oil-and-gas-health-survey>

Results:

1. Adult respondents living within 1 mile of a UOGD site in Broomfield reported significantly greater frequencies of upper respiratory and acute symptoms (nausea, vomiting, nosebleeds, lung irritation, shortness of breath, cough, throat irritation) than respondents living more than 2 miles from UOGD sites.
2. Children living within 2 miles of a UOGD site were reported by their parents to have experienced significantly greater frequencies of lower respiratory, gastrointestinal, and acute response symptoms than children living greater than 2 miles from UOGD sites.
3. Level of concern about air pollution, noise, and odors modified the results.

A possible explanation for these results is that the UOGD sites located within CCOB are large multi-well oil and gas sites, producing primarily oil as opposed to other studies which have focused on evaluating health symptoms near natural gas sites in Pennsylvania's Marcellus Shale.

Comparison with Recent Presentations to AQCC: Methane Trends

- AQCC has recently seen presentations indicating that methane emissions in the DMNFR are decreasing
- Local Government studies contradict these findings
- **Possible reasons for the difference in conclusions:**
 - Ramboll's analysis was identified as preliminary analysis
 - AIRS satellite data used in analyses was an estimated methane concentration for air at ~10,000 ft. elevation over a large grid cell
 - AIRS satellite trend data has significant uncertainty in correlation with the surface trend
 - Zhang et al. (2021) indicates that for the NOAA Niwot Ridge site, column-integrated AIRS data has a low correlation to data from the Niwot Ridge ground-based instruments
 - Analysis combined satellite data and ground-based data
 - Method is not scientifically accepted, results are not peer-reviewed

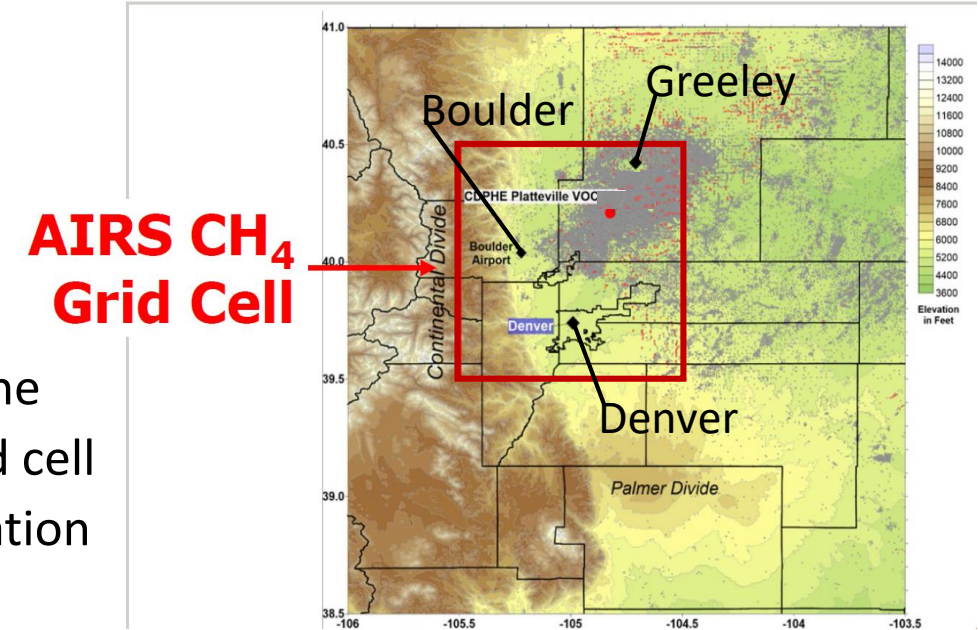


Image adapted from Weld County/Ramboll

Platteville Trend Considerations

Recent AQCC presentations have highlighted that methane concentrations are decreasing at CDPHE's Platteville Station

Platteville station is not a good representation of oil and gas development across the DJ Basin:

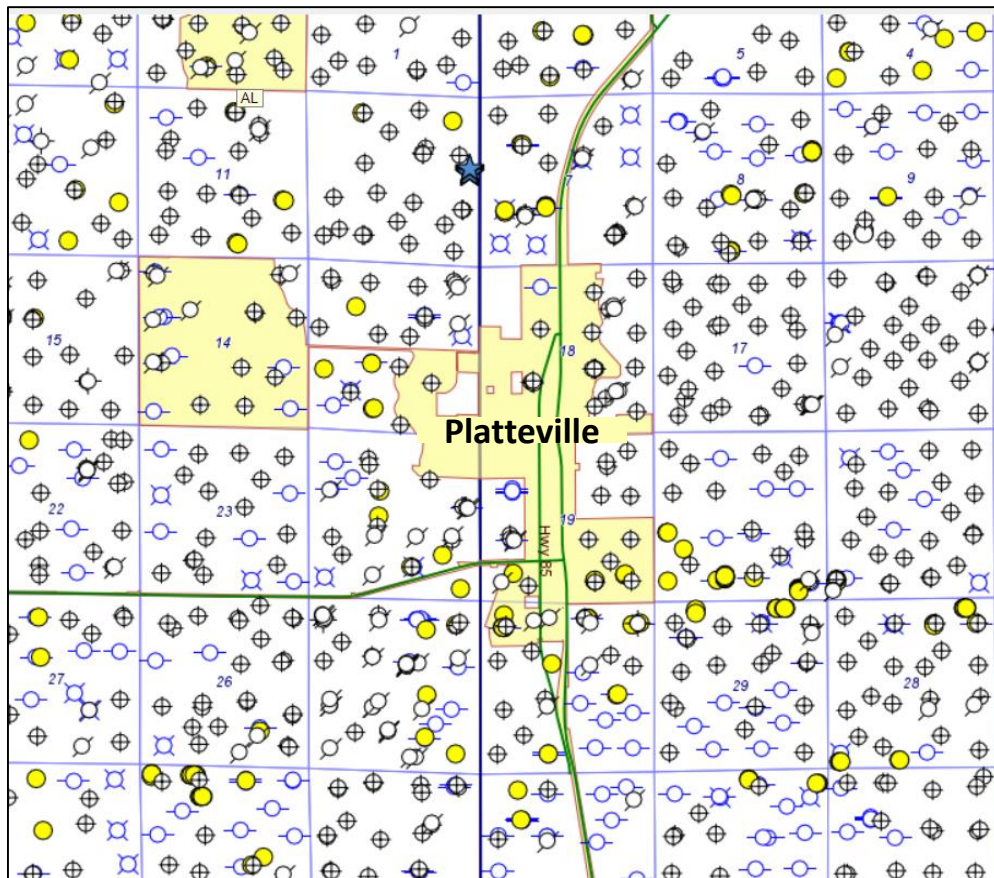
- Samples are taken once daily from 6-9am
- Early morning conditions are calm meaning samples may reflect only reflect nearby oil and gas operations



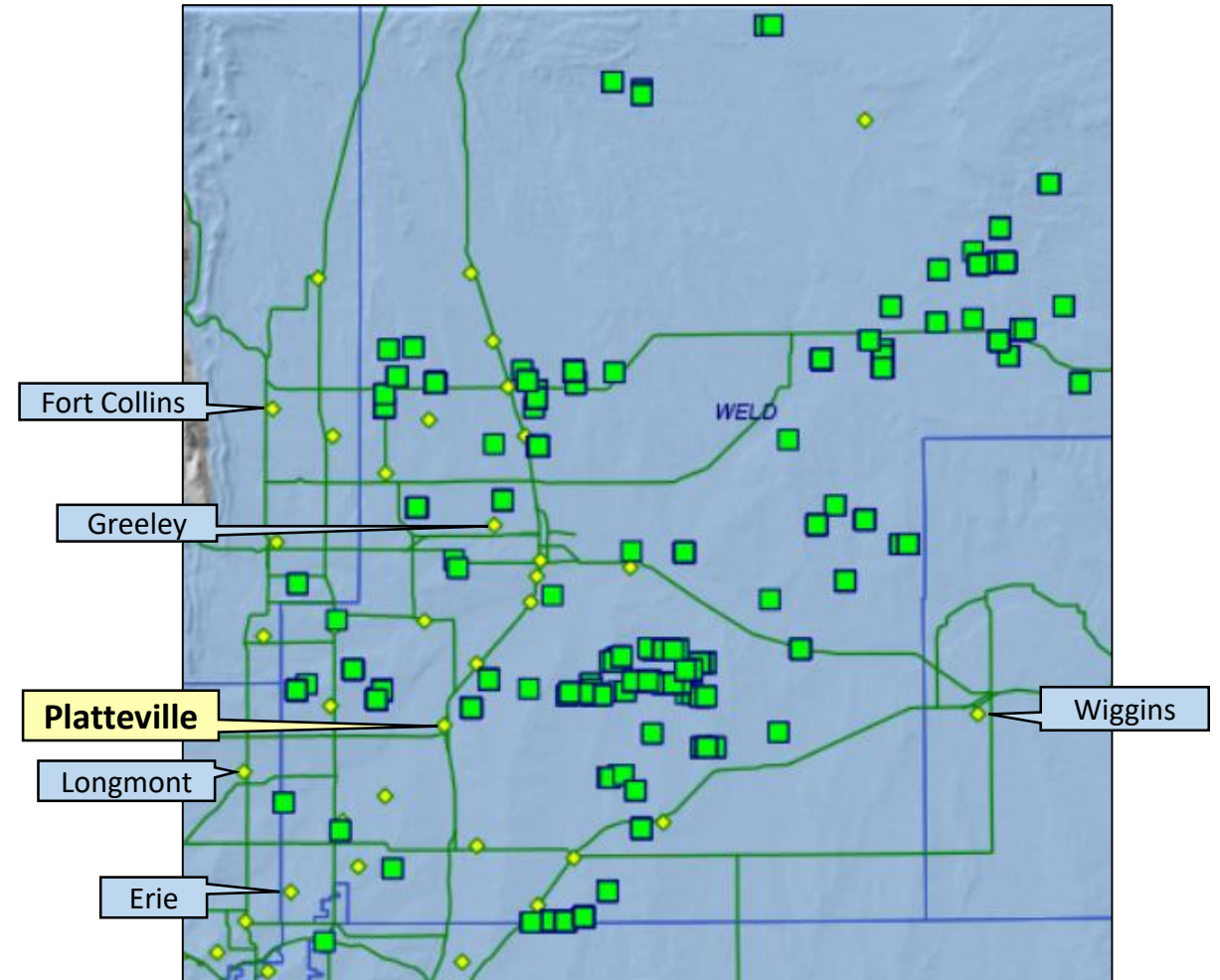
*CDPHE Platteville monitoring station
Photo credit: cpr.org*

Platteville Trend Considerations

Platteville is not where most new oil and gas development is occurring.



- ⊕ Plugged wells
- Producing wells
- Non-producing wells (shut in/temporarily abandoned)



■ Planned/approved well sites

Source: cogcc.state.co.us

Key Local Government Findings

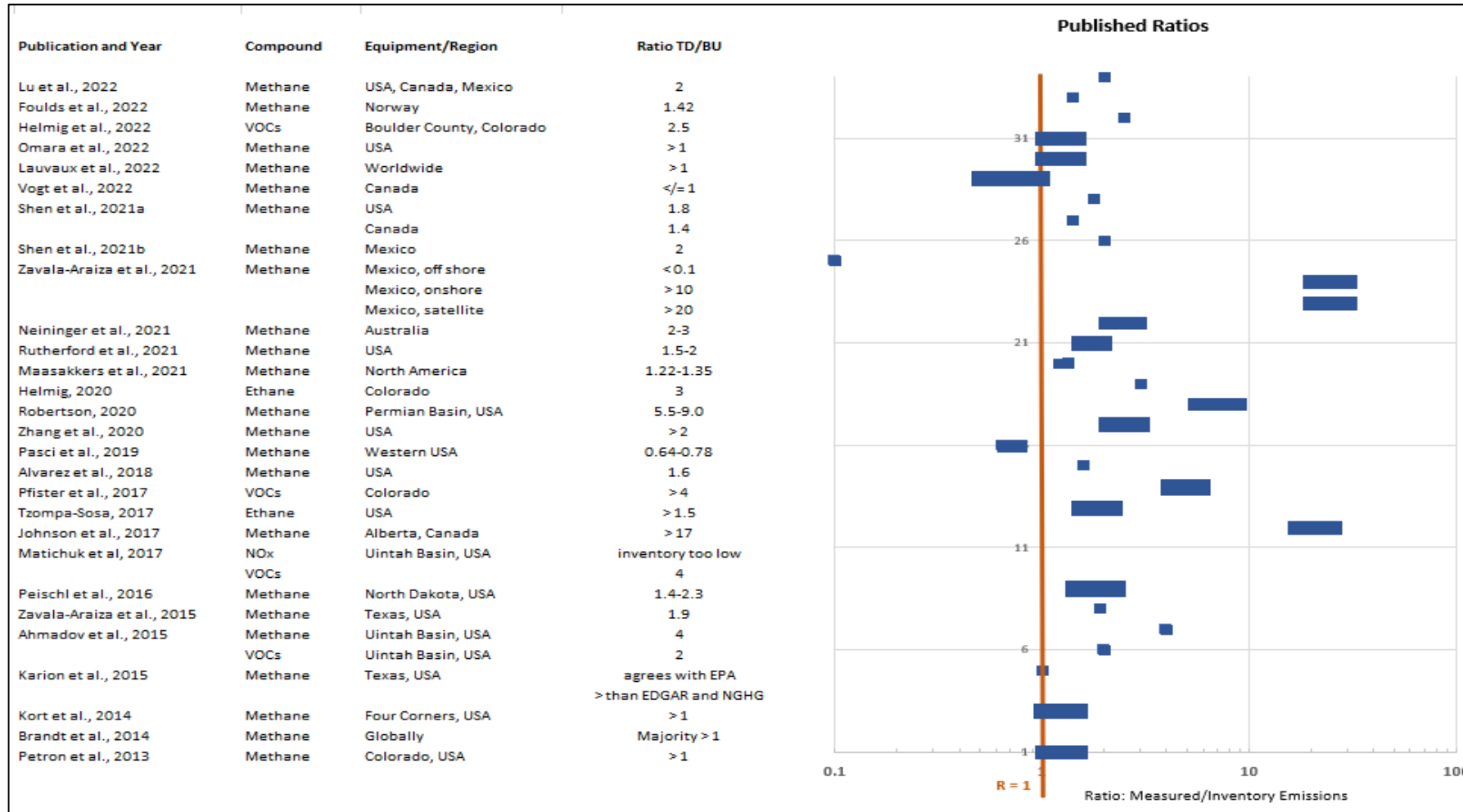
- Ozone concentrations in the DMNFR continue to be heavily influenced by local sources, including oil and gas
- Methane emitted by local sources has not decreased in recent years
 - Local sources of methane are fueling the climate crisis
- Despite newer regulations, oil and gas emissions have not decreased
 - Individual source emissions may have decreased but production has continued to increase
- Data shows that residents living within one mile of multi-well, horizontal oil and gas sites experience upper respiratory and acute health symptoms (e.g. nosebleeds) more often than residents living at distances further away

Recommendations

- Local governments have valuable data that needs to be considered alongside data from CDPHE and industry
 - Health impacts to our residents, including from ozone and air toxics, and the climate crisis are our primary concerns
 - Cumulative exposure impacts from living in proximity to multiple oil and gas sites may drive health risk
 - Our disproportionately impacted communities are more at risk
- Emissions inventory improvements are critical to improve understanding of source impacts
- All data needs to be scrutinized carefully to inform policy

Backup Slides

Published studies comparing top-down to bottom-up emissions



The ratio of top-down (TD) over bottom-up (BU) emissions is plotted on the x-axis. For the y-axis representation, here we list the papers in order of their publication year, with the most recently published work at the top of the scale. For papers where a numerical value for the ratio was given, it is listed in the fifth column. In several cases, results were given as “greater than a value of x”; those are indicated by the ‘>’ or ‘<’ sign. A graphical representation of the magnitude of the results is provided to the right of the table. The brown vertical line presents the ratio value of 1, where bottom-up and top-down values agree. For cases where results are reported as a range, the range from the maximum to minimum value is indicated by a blue horizontal bar. When results were given as ‘> x’, we chose an upper threshold value of 1.5 times ‘x’ for the graphical representation. Please note the logarithmic scale of the x-axis.

Cite: Fig 2, Ex. DH 1 to Earthjustice et al.’s comments, comment ID # EPA-HQ-OAR-2021-0668-0758.

Peer Reviewed Studies Associated with Boulder County Data

Helmig, D, et al. 2018. Contrasting behavior of slow and fast photoreactive gases during the August 21, 2017, solar eclipse. *Elem Sci Anth*, 6: 72. DOI: <https://doi.org/10.1525/elementa.322>

Asher, E, et al. 2021. Unpiloted Aircraft System Instrument for the Rapid Collection of Whole Air Samples and Measurements for Environmental Monitoring and Air Quality Studies, *Environ. Sci. Technol.* 2021, 55, 9, 5657–5667. <https://pubs.acs.org/doi/10.1021/acs.est.0c07213>

Pollack, I. B., D. Helmig, K. O'Dell, and E. V. Fischer (2021), Weekend-weekday implications and the impact of wildfire smoke on ozone and its precursors at Boulder Reservoir, Colorado between 2017 and 2019, *Journal of Geophysical Research: Atmospheres*, 126, e2021JD035221. <https://doi.org/10.1029/2021JD035221>.

Pollack, I. B., D. Helmig, K. O'Dell, and E. V. Fischer (2021), Seasonality and source apportionment of non-methane volatile organic compounds at Boulder Reservoir, Colorado, between 2017 and 2019, *Journal of Geophysical Research: Atmospheres*, 126, e2020JD034234. <https://doi.org/10.1029/2020JD034234>.

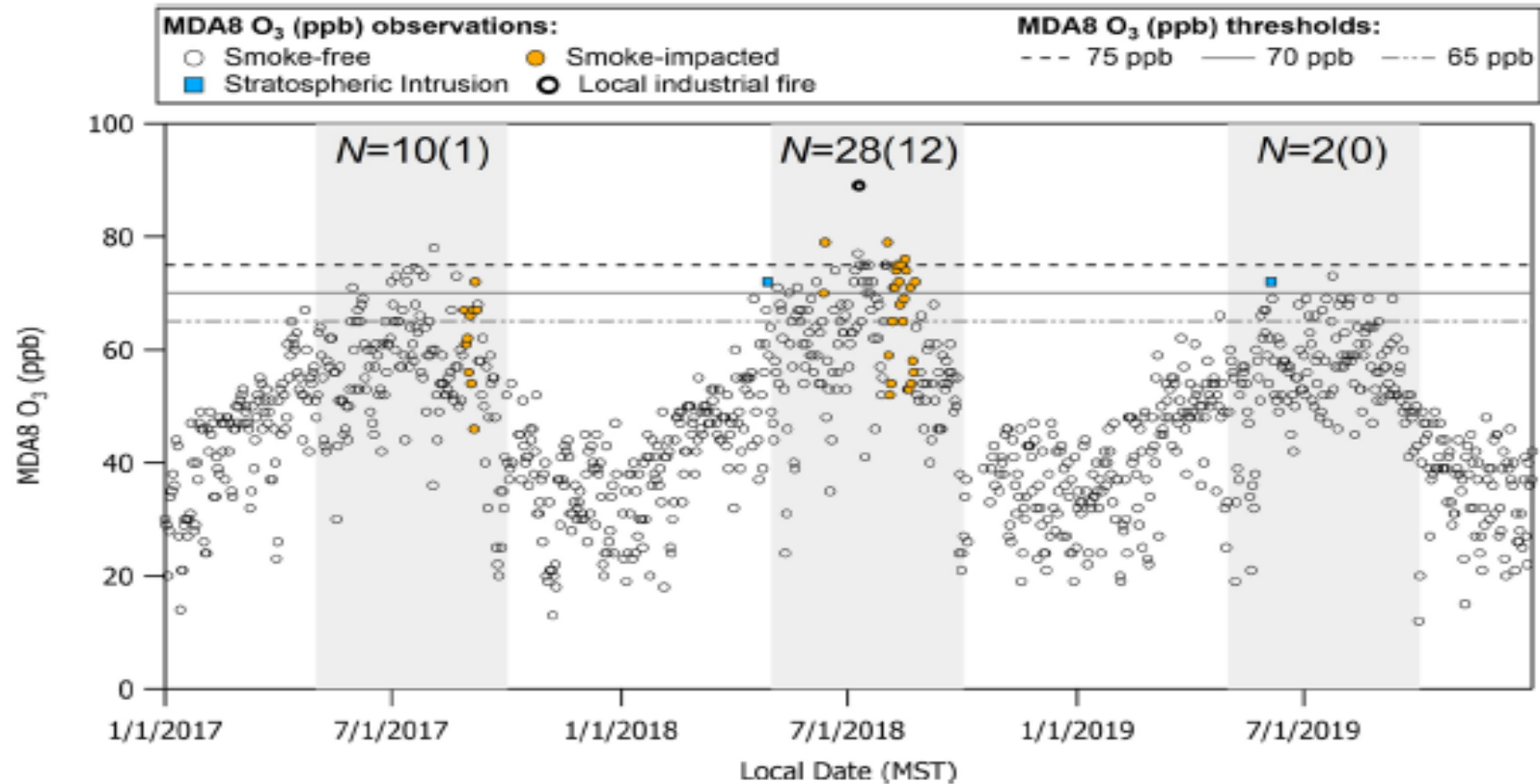


Figure 2. MDA8 O₃ at Boulder Reservoir between January 1, 2017 and December 31, 2019. The orange filled circles represent periods when the monitoring site is considered to be impacted by wildfire smoke, blue squares represent when the site is impacted by a stratospheric intrusion, and the heavy outlined black circle highlights a day that may have been impacted by a local industrial fire. Gray shaded areas represent the May-June-July-August-September (MJAS) O₃ season. Text within the gray shaded areas indicate the total number of days during the MJAS study period when MDA8 O₃ exceeds the 70 ppbv National Ambient Air Quality Standard (NAAQS); the number of days when MDA8 O₃ exceeds the 70 ppbv NAAQS that are also impacted by smoke associated with wildfires are shown in parentheses.

Pollack, I. B., D. Helmig, K. O'Dell, and E. V. Fischer (2021), Weekend-weekday implications and the impact of wildfire smoke on ozone and its precursors at Boulder Reservoir, Colorado between 2017 and 2019, *Journal of Geophysical Research: Atmospheres*, 126, e2021JD035221. <https://doi.org/10.1029/2021JD035221>.