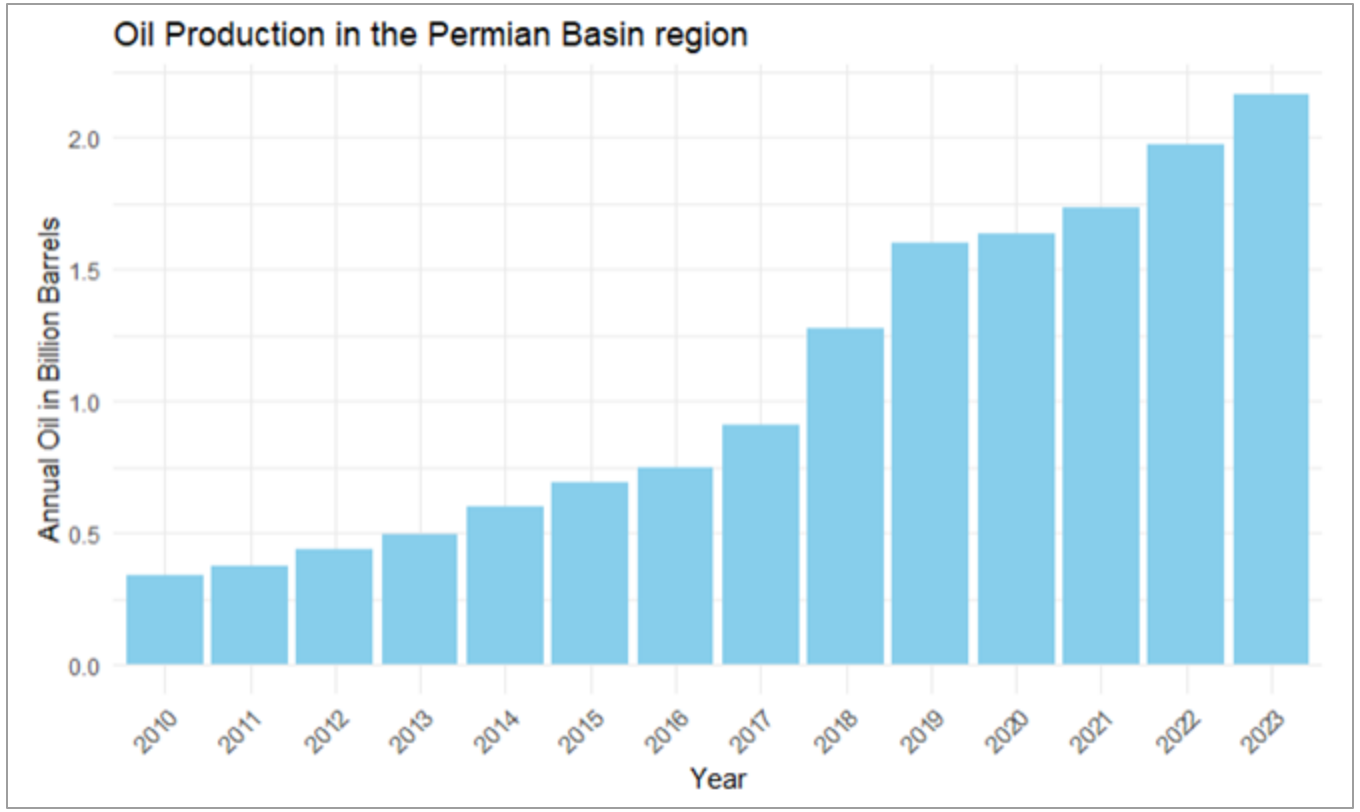
Assessing source contributions to air quality and noise in unconventional oil shale plays

HEI TRACER Webinar 1
January 29, 2025

UNIVERSITY OF TORONTO
TEXAS A&M UNIVERSITY
BOULDER AIR
UCLA Fielding School of Public Health
USC University of Southern California
HEI energy

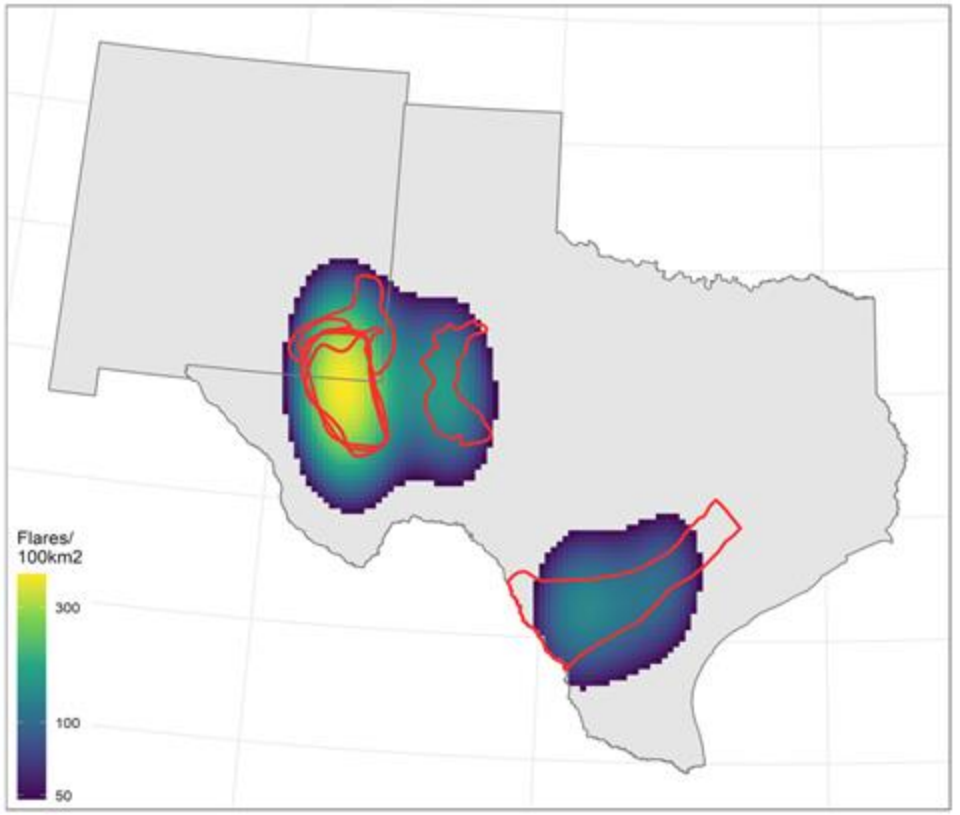
Study Motivation

Annual oil production has increased over 8-fold since 2010 at wells located in the Permian Basin.



Data from Enverus (based on monthly production values)

Density of gas flaring in the Permian Basin and the Eagle Ford Shale reflects oil exploration.



Cushing *et al* (2021) *Environ. Res. Lett.* **16** 034032

Project Description
Measurements 1

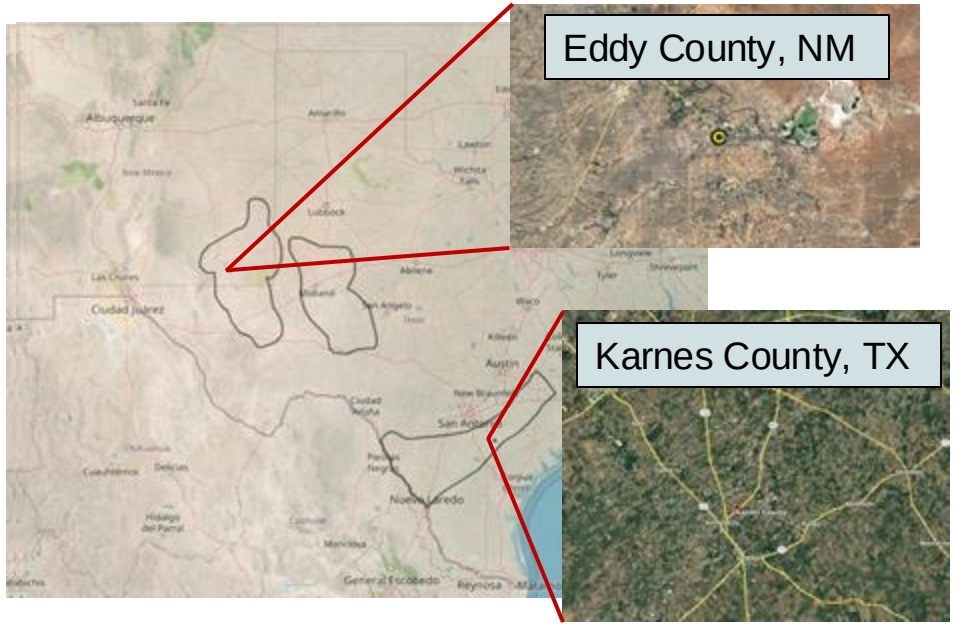
To characterize the impact of UOGD activities on ambient air pollution and noise by collecting high temporal resolution data from a stationary monitoring platform in the Permian Basin. *We hypothesize that chemical and noise signatures near UOGD will show high temporal variability, and will differ from Denver Julesburg Basin.*

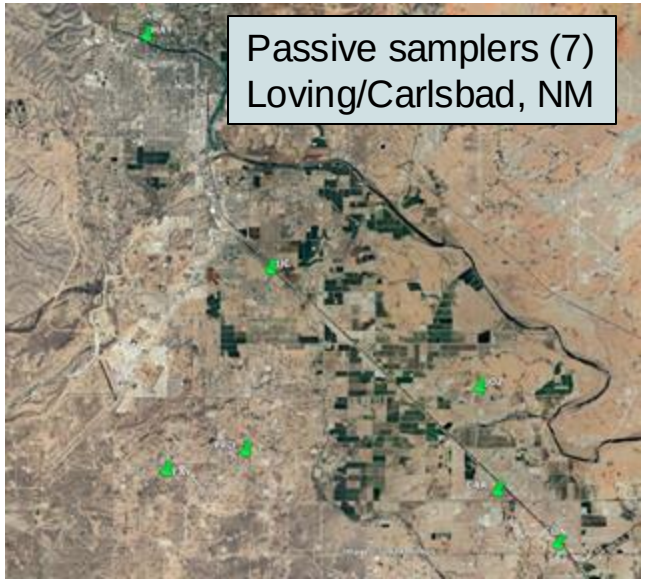
Approach: Through a combination of automated, continuous stationary atmospheric monitoring and source apportionment modeling, we will identify UOGD processes that result in ambient air pollutants, radioactivity, and noise. Using source apportionment techniques, we will distinguish UOGD-related pollution from other local sources such as vehicle traffic.

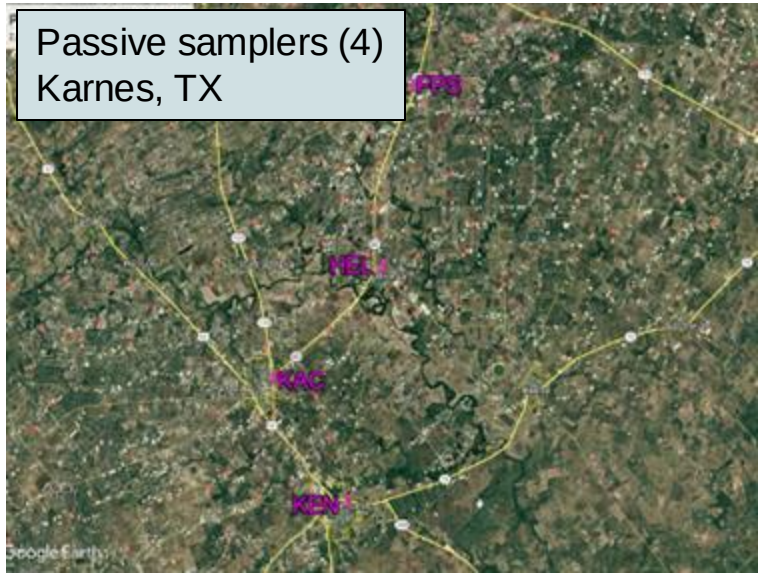
Project Description
Measurements 2

To understand the spatial distributions of targeted petroleum hydrocarbons in ambient air leveraging a dense network of time-integrated passive samplers. *We hypothesize that spatial distributions of concentrations of petroleum hydrocarbons will be different between shale areas and will have distinct seasonal patterns.*

<u>Approach:</u> Deploy a spatially dense set of passive samplers to characterize exposures over basins and seasons such as to enable a better understanding of the factors influencing the UOGD exposures and inform subsequent health studies.







What We Measured in Loving, NM

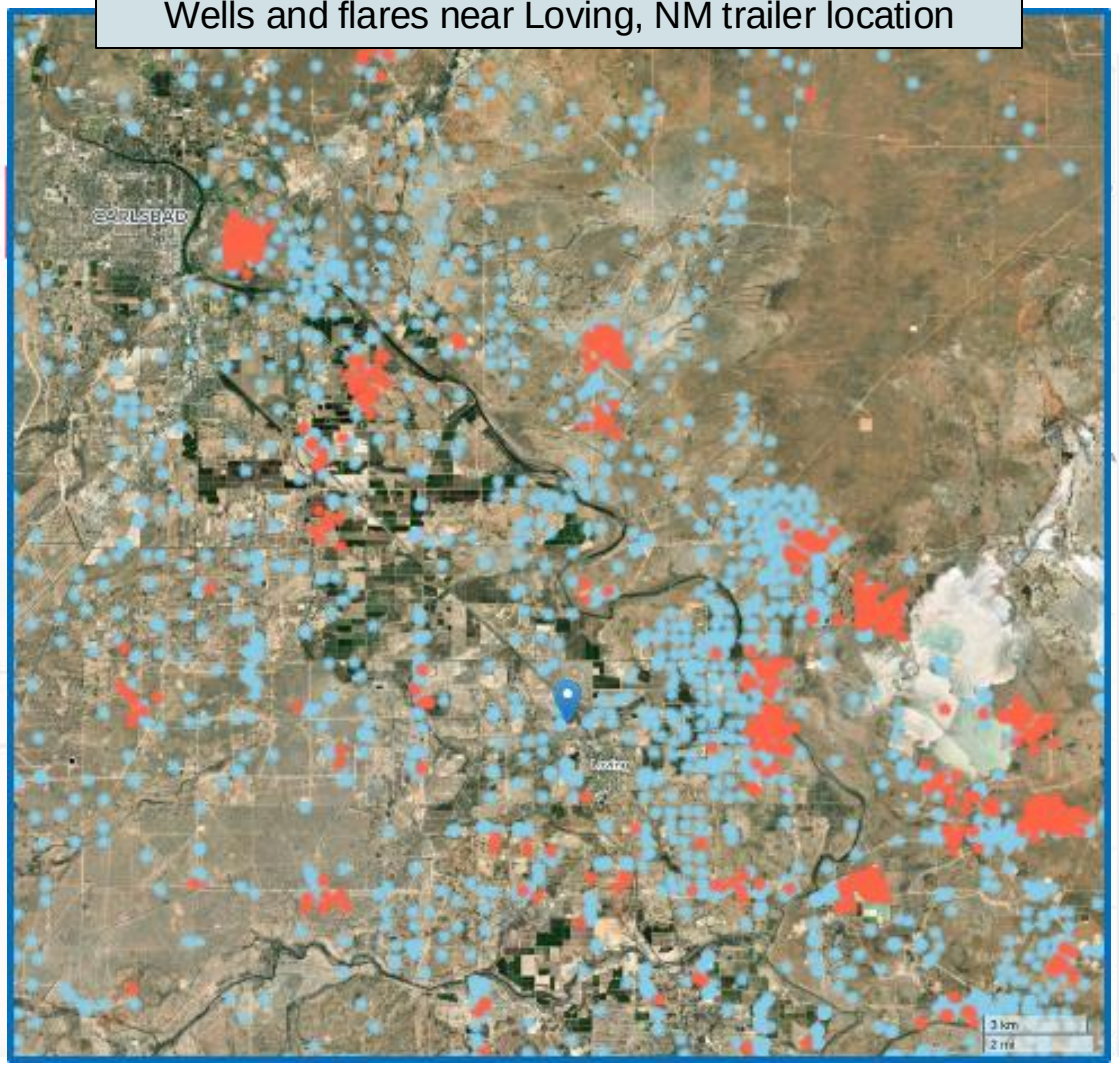
Sampling period May 1, 2023 through May 31, 2024

Air Pollutants, Greenhouse Gases, Radioactivity

- Methane (CH_4)
- Volatile organic compounds (VOCs)
  - Including ethane, benzene
- Nitrogen Oxides (NO_x)
- Ozone (O_3)
- Sulfur Dioxide (SO_2)
- Hydrogen Sulfide (H_2S)
- Carbon Monoxide (CO)
- Carbon Dioxide (CO_2)
- Black Carbon (BC)
- Radioactivity

Double Flare near Carlsbad, NM

Wells and flares near Loving, NM trailer location



Noise

- Decibel levels at different frequencies

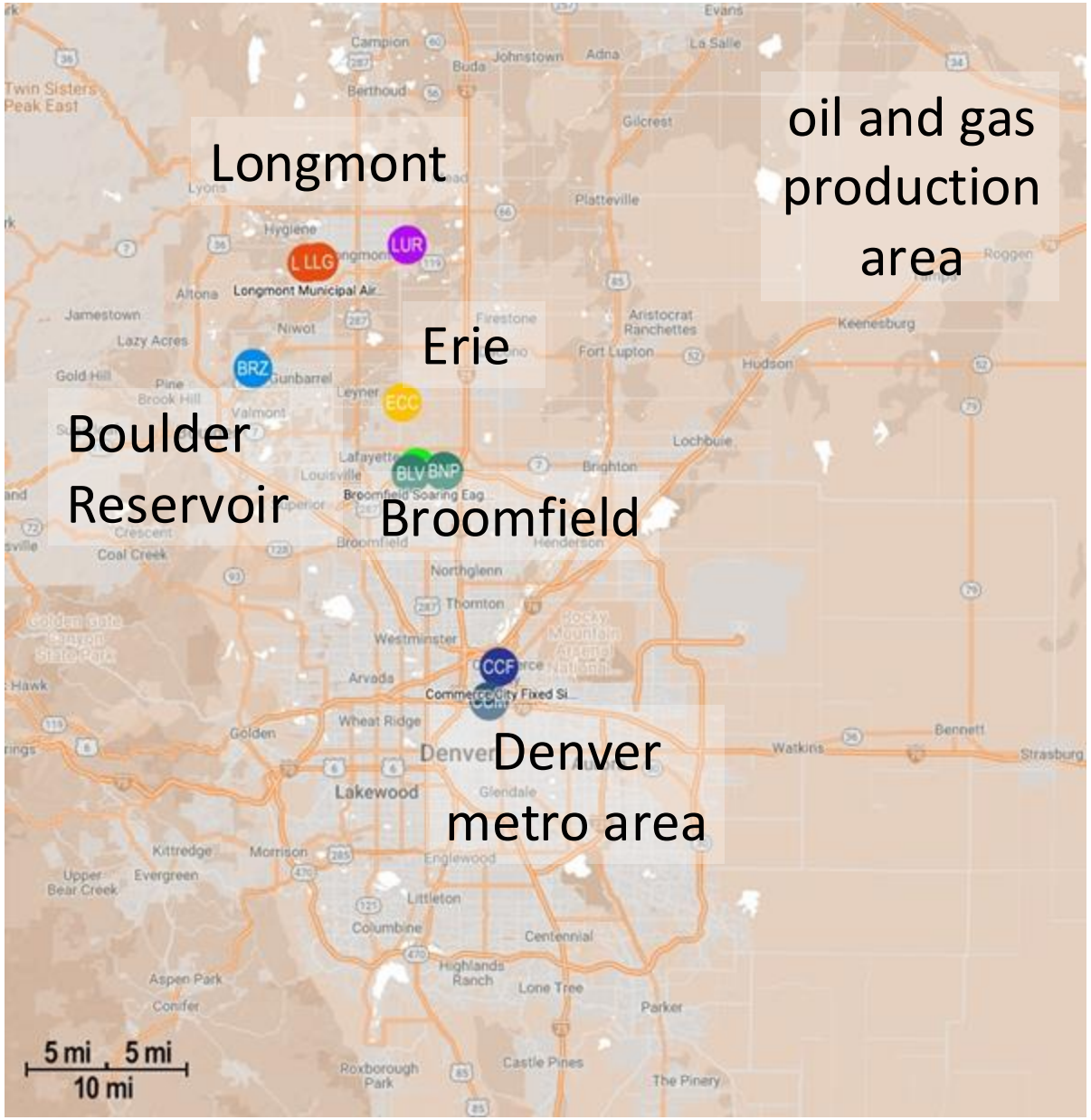
Passive Sampling

- C_6-C_{10} Hydrocarbons

Colorado Front Range Comparison Sites

Legend

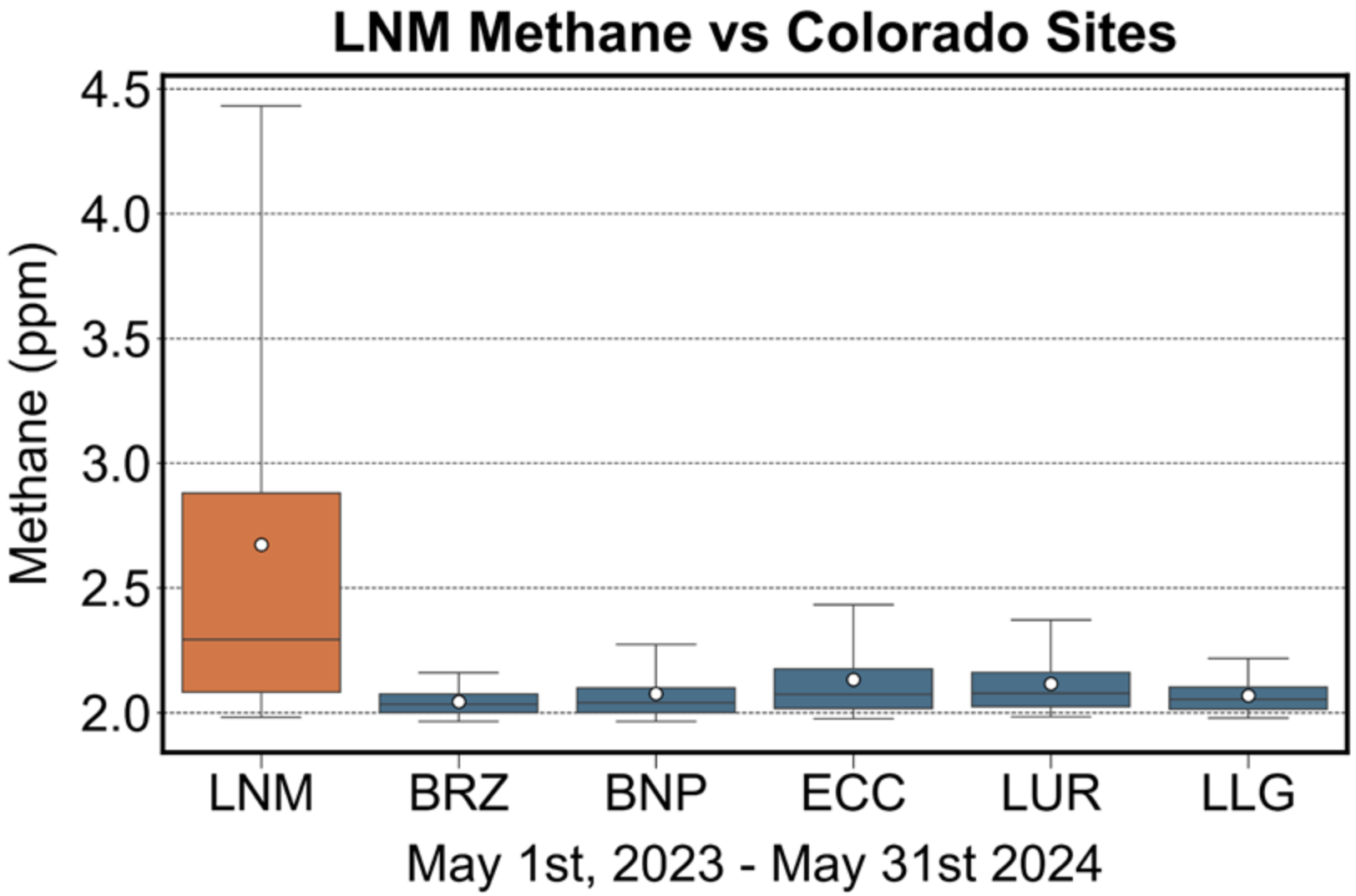
LUR: Longmont Union Reservoir
LLG: Longmont Lykins Gulch
BRZ: Boulder Reservoir
ECC: Erie Community Center
BNP: Broomfield North Pecos

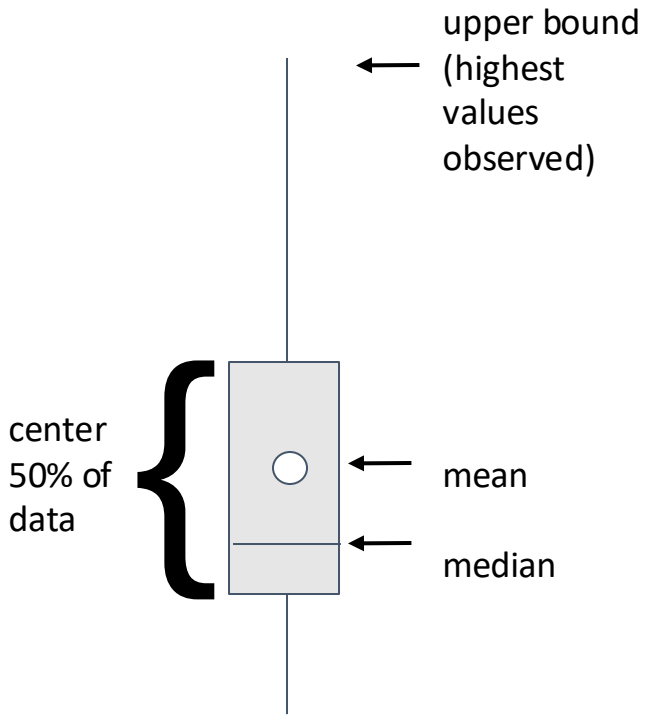


These sites are operated by Boulder AIR and use the same measurement techniques as the Loving, NM site.

See: https://bouldairtools.com/interactive/

Comparative statistics: LNM vs. Colorado

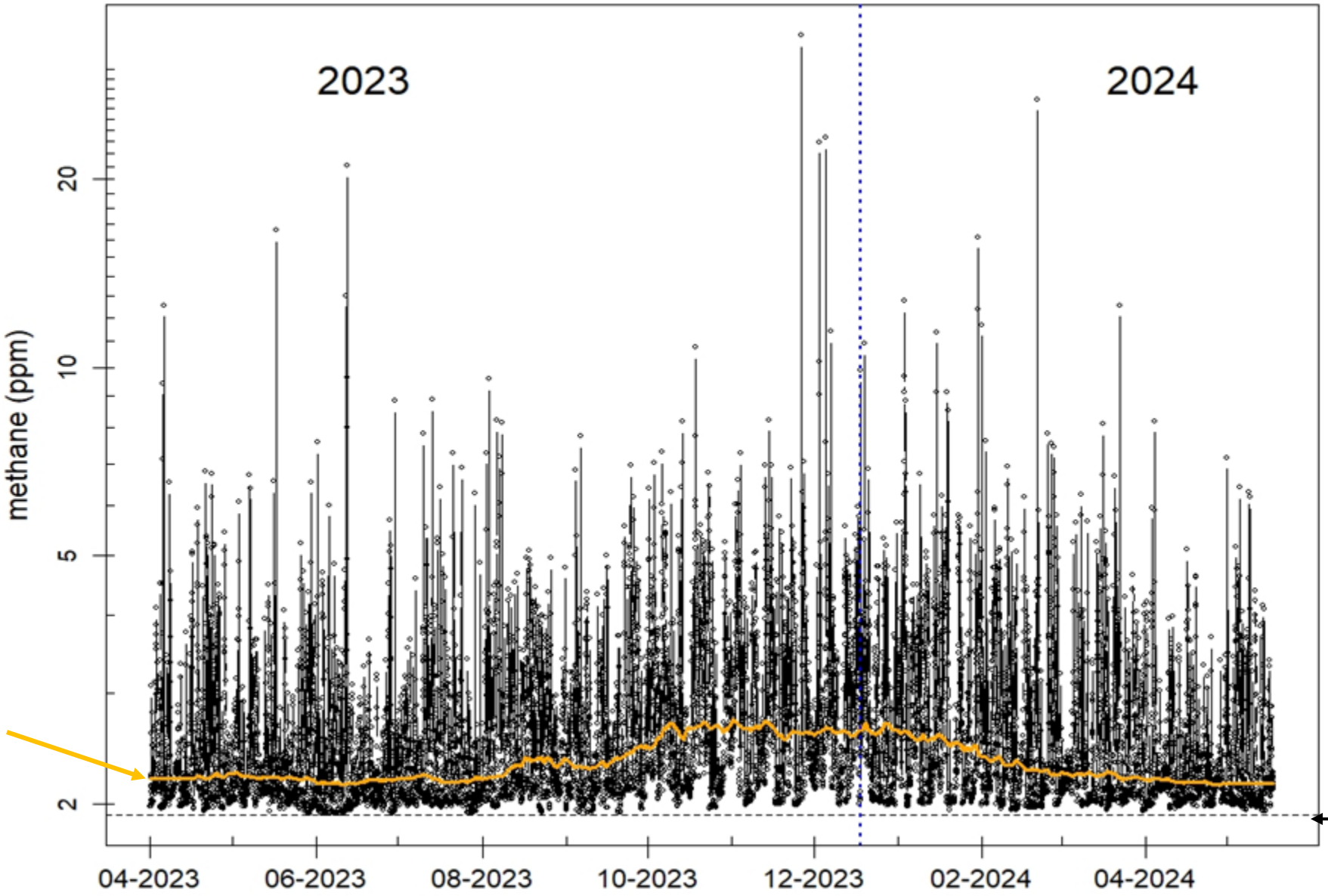




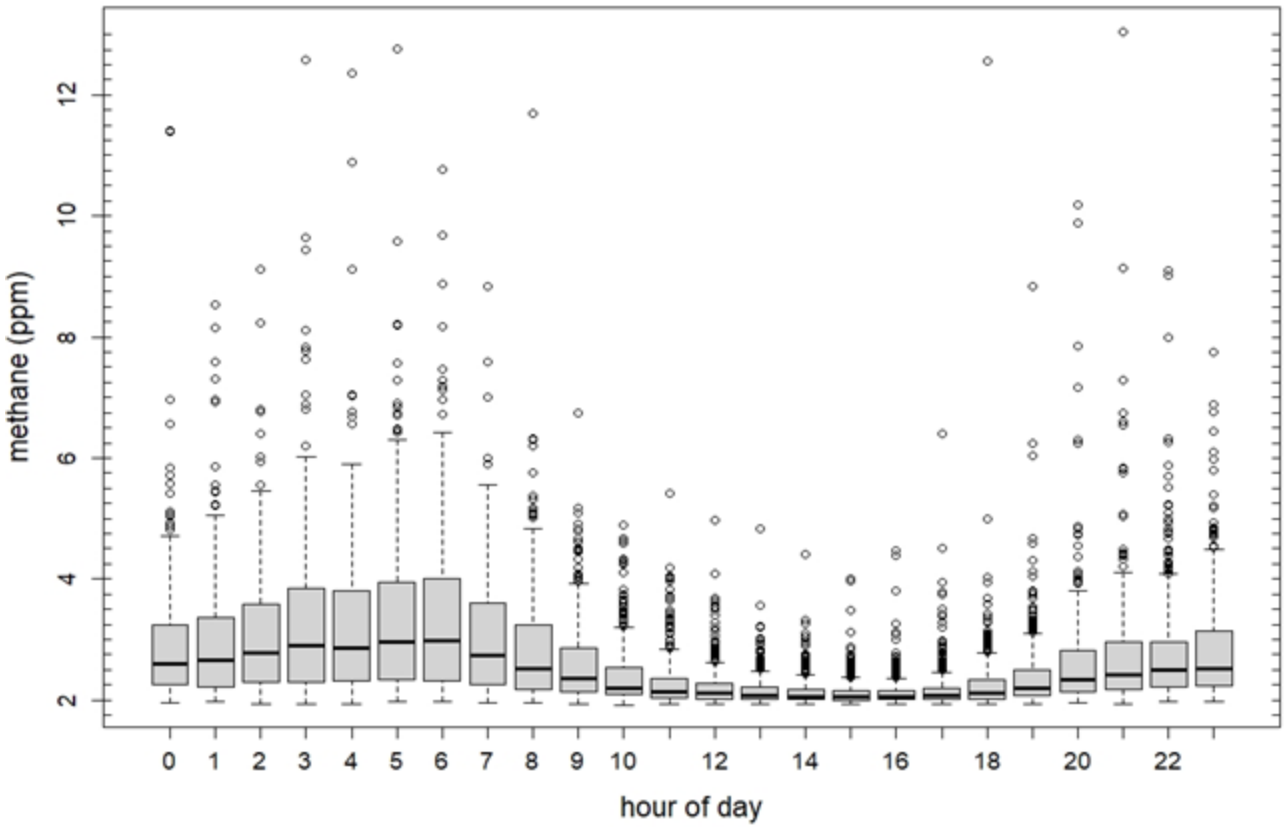
Methane at LNM

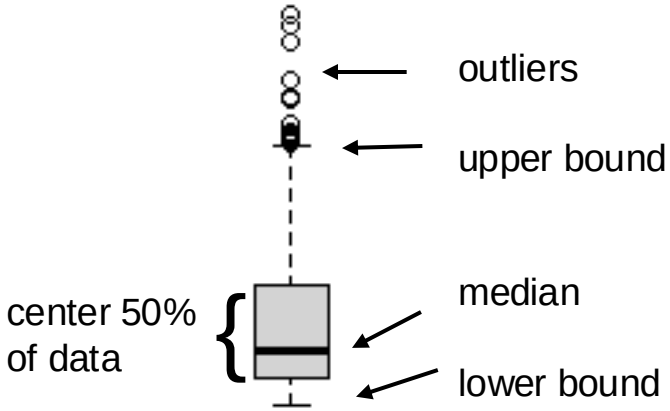
Methane time series shows:

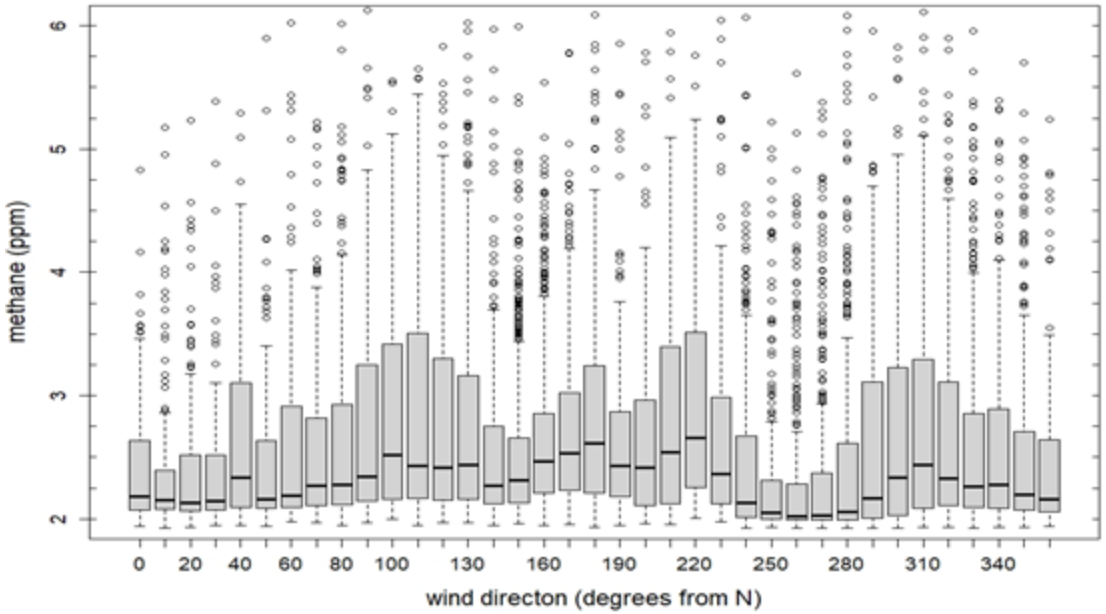
- Frequent high concentration plumes.
- Seasonal changes, higher concentrations in winter due to reduced atmospheric mixing and less sunlight.



Methane Plumes at all Directions and Daytimes (10-min averages)

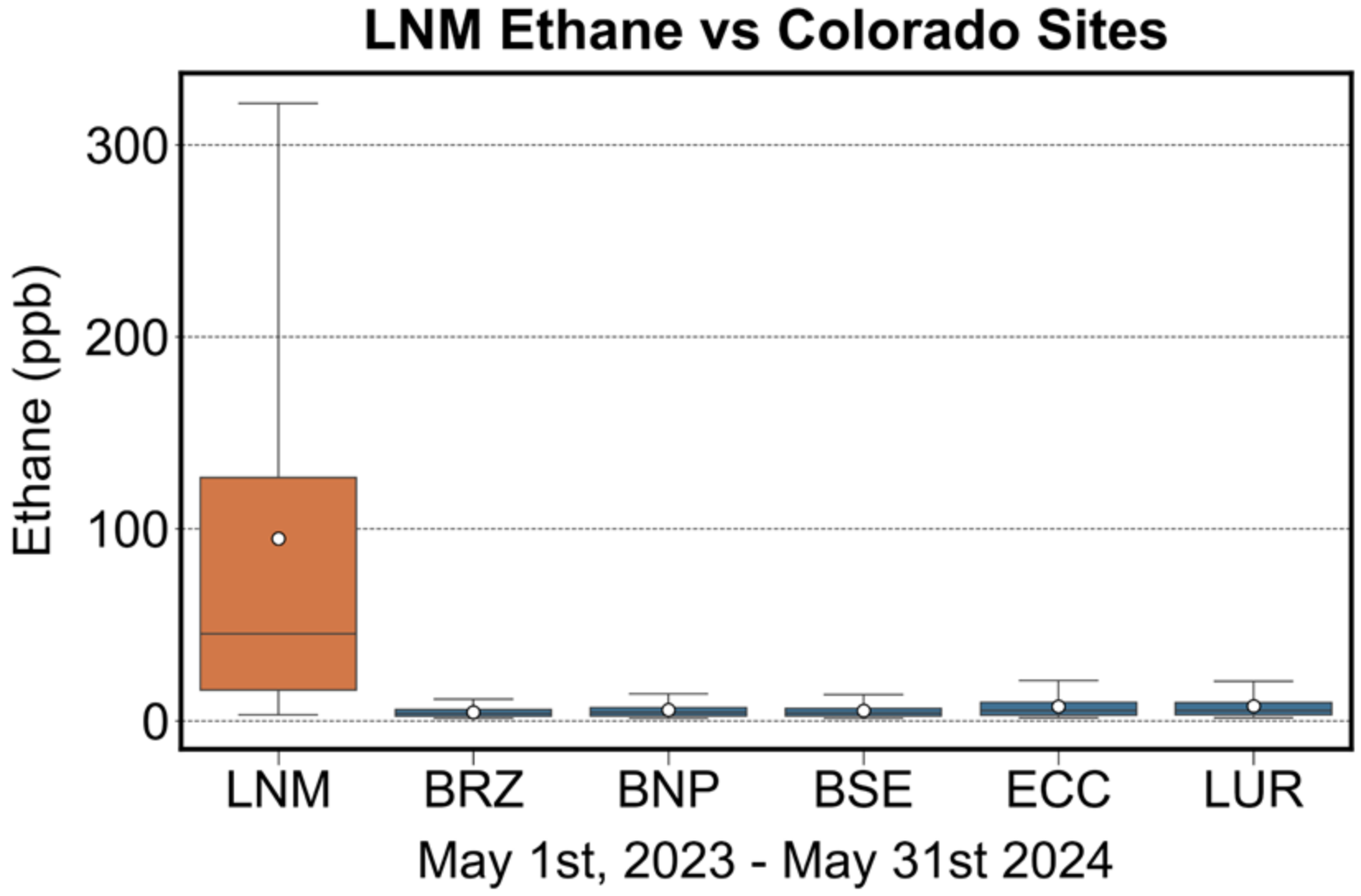






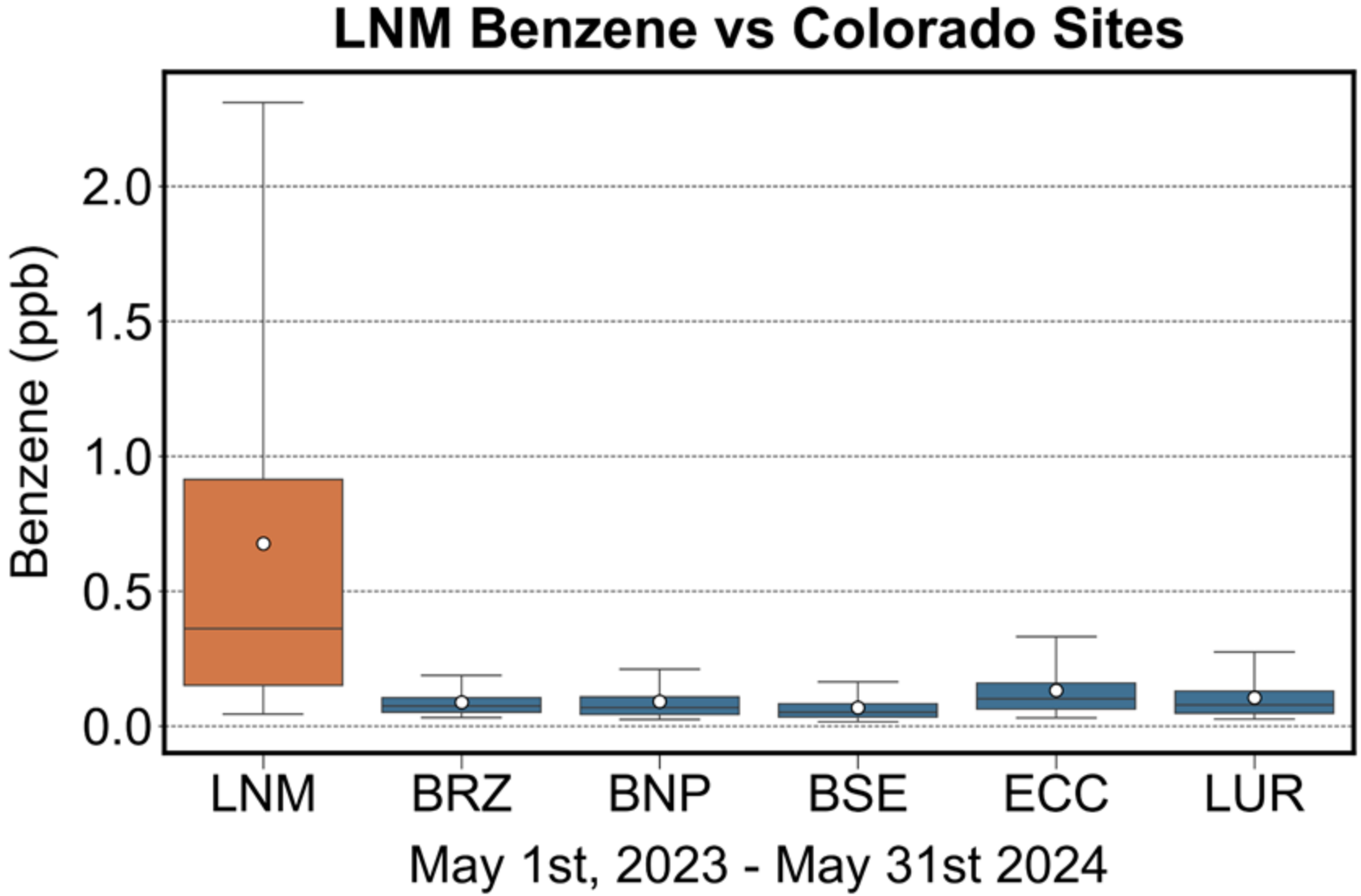
- Methane plumes, depicted at levels above 95%, are seen at all times of day.
- Median levels at night are 3 ppm, 50% above background.
- Levels from southeast to southwest are 25% higher, this is highlighting the fetch over the Permian-Delaware basin.

Ethane at Loving, NM, compared to Colorado sites



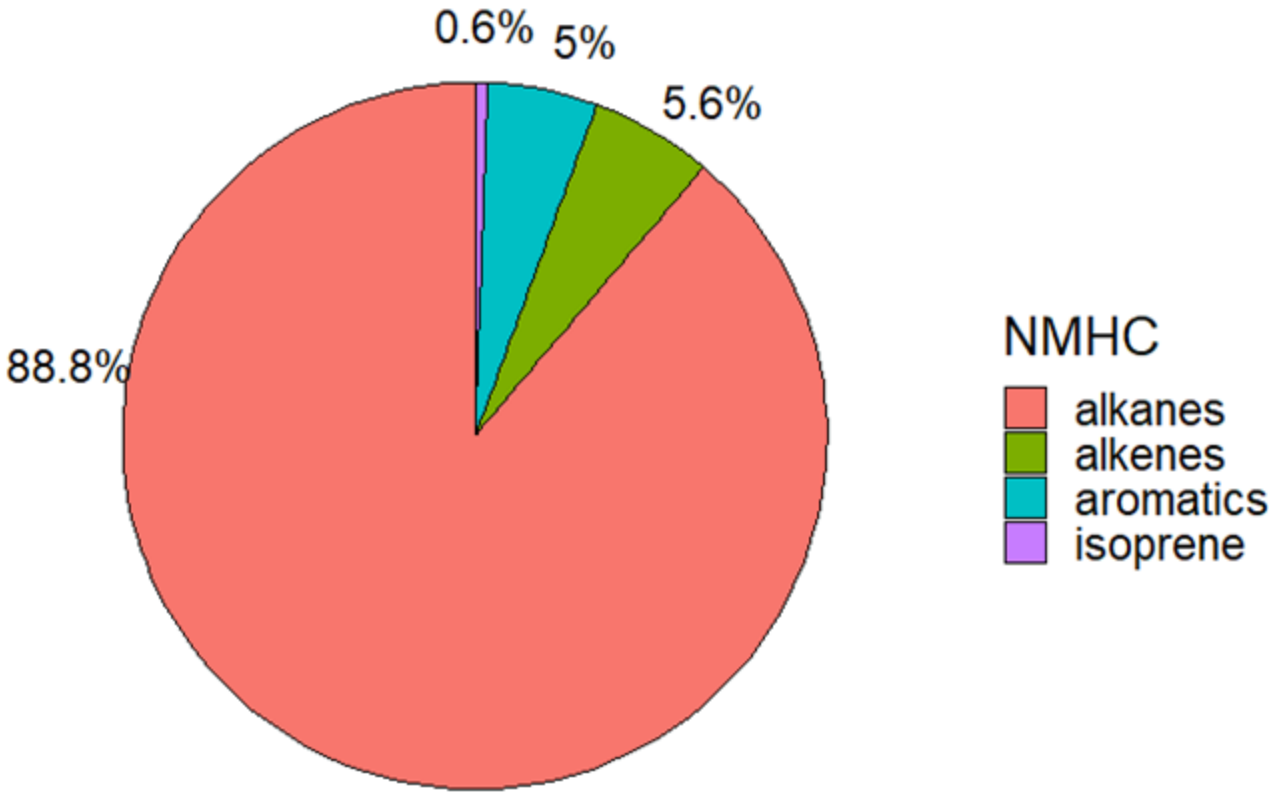
Benzene at Loving, NM, compared to Colorado sites

Benzene average concentration was 9–11 times higher in Loving than at Colorado comparison sites.



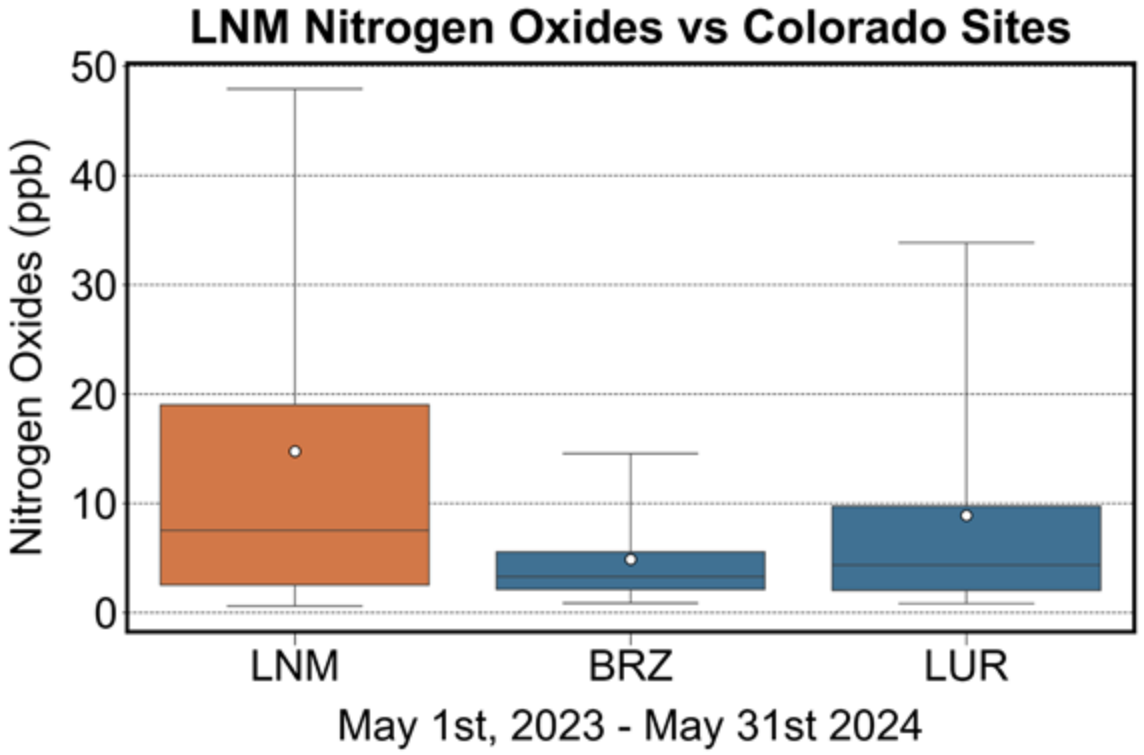
Non-Methane Hydrocarbons Drive Ozone Formation

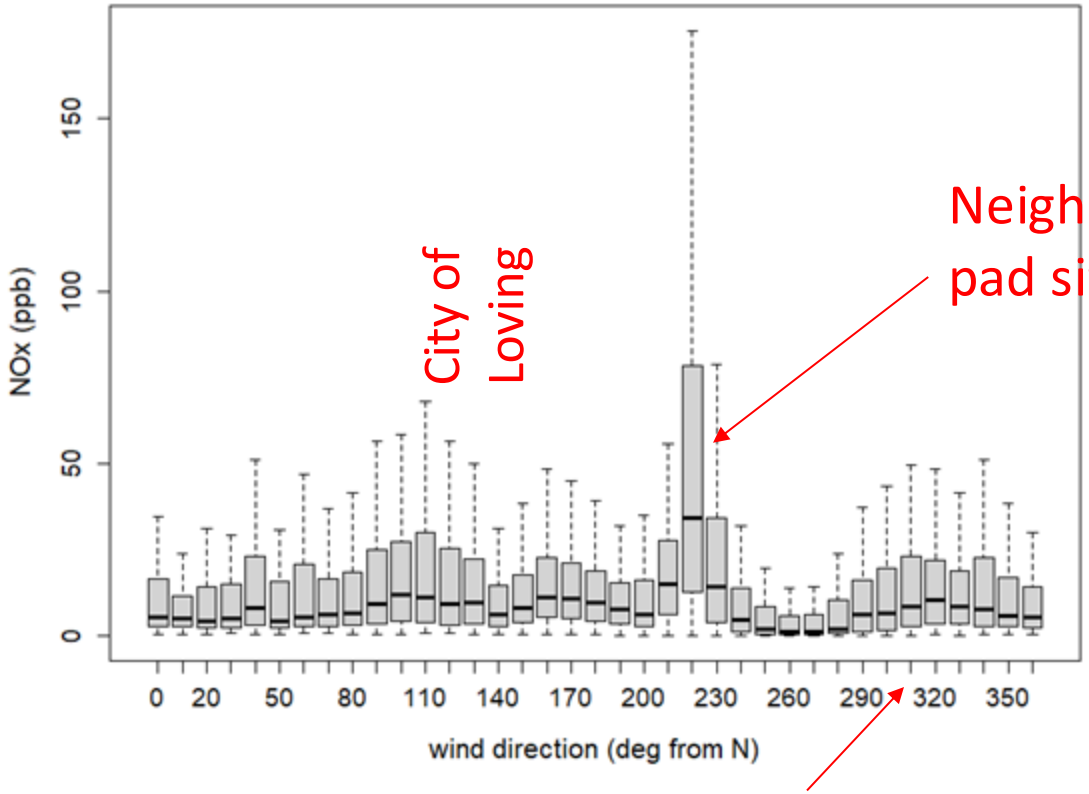
Measured hydrocarbon reactivity → ozone formation potential



- The largest contributor to regional photochemical ozone formation is petroleum hydrocarbons.
- Combined, hydrocarbons associated with oil and gas production contribute more than 90% to the measured ozone formation potential.

Nitrogen Oxides Also Drive Ozone Formation





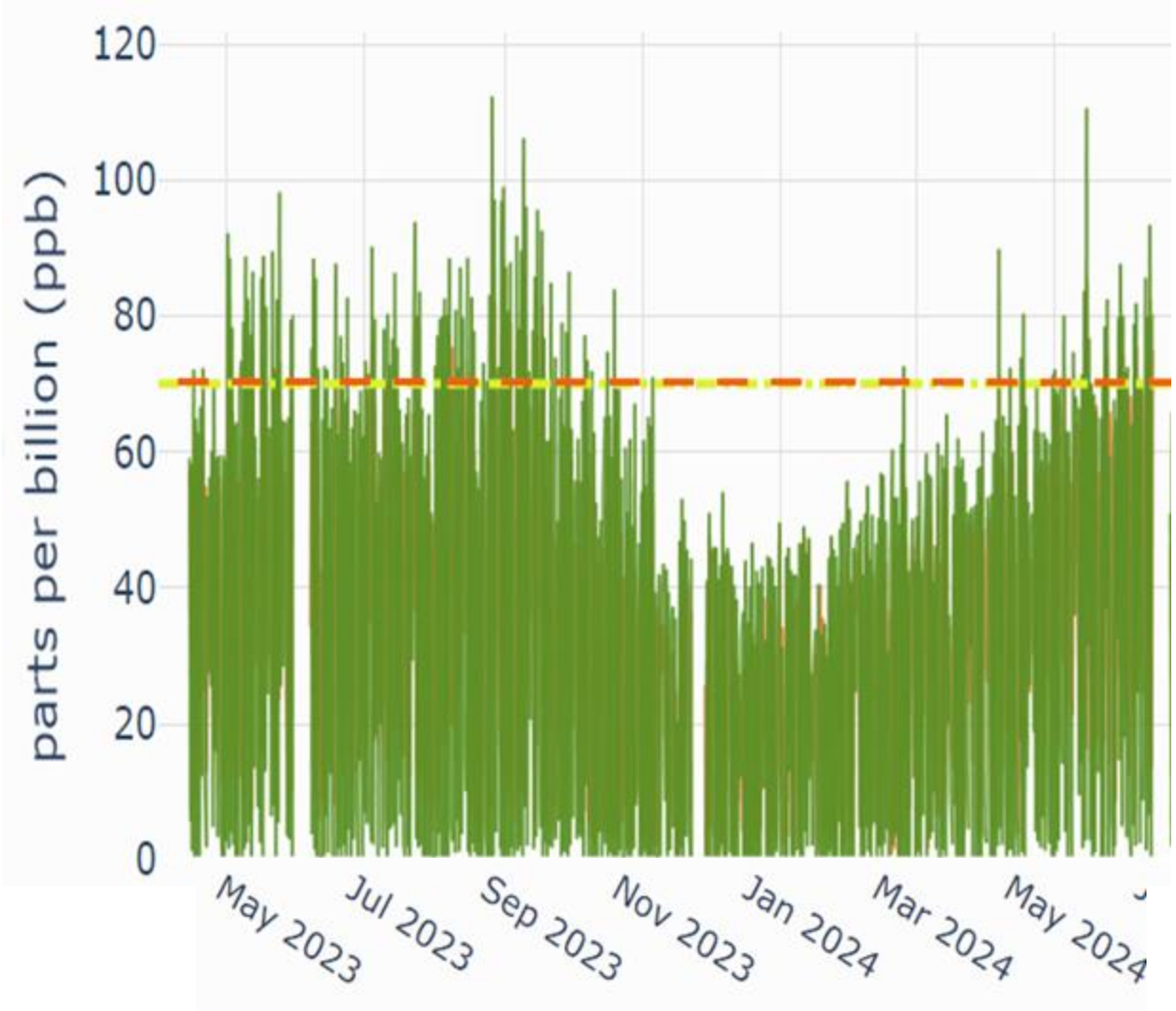
Ozone is high …

- … during daytime, especially noon to 6 pm, and for clear-skies
- … on spring and summer days, from April into October
  - … when it is dry, i.e. humidity is low
  - … when temperatures exceed 90 deg F.
  - … when winds are weak
  - … and air moves slowly out of southerly to easterly directions

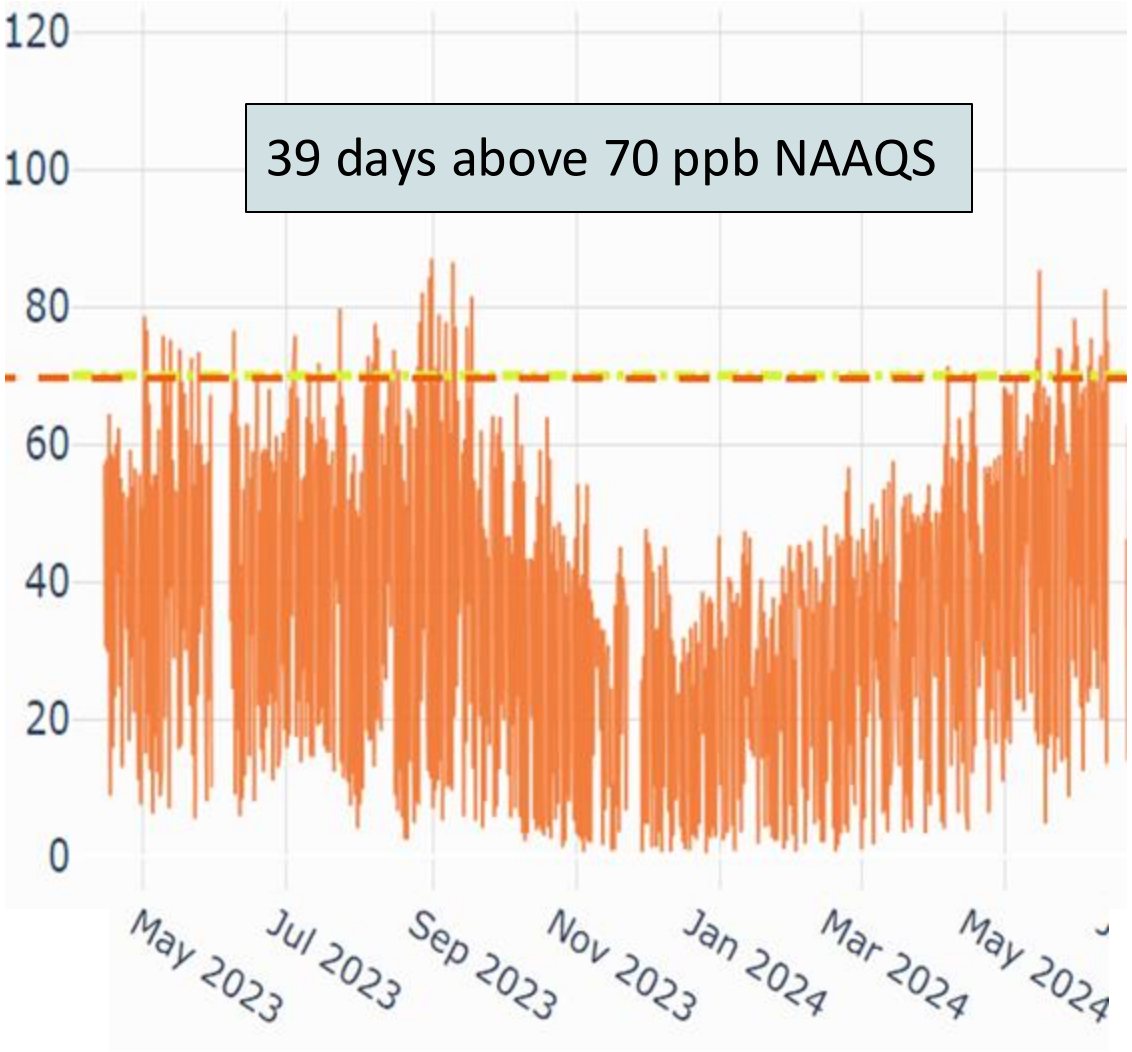
- Typically, since 2018, southeast NM has exceeded the 70-ppb threshold for ozone levels about 20-30 days each year
  - the 4th-highest daily 8-h maximum enters the legal limit calculations

Ozone measured during our study period

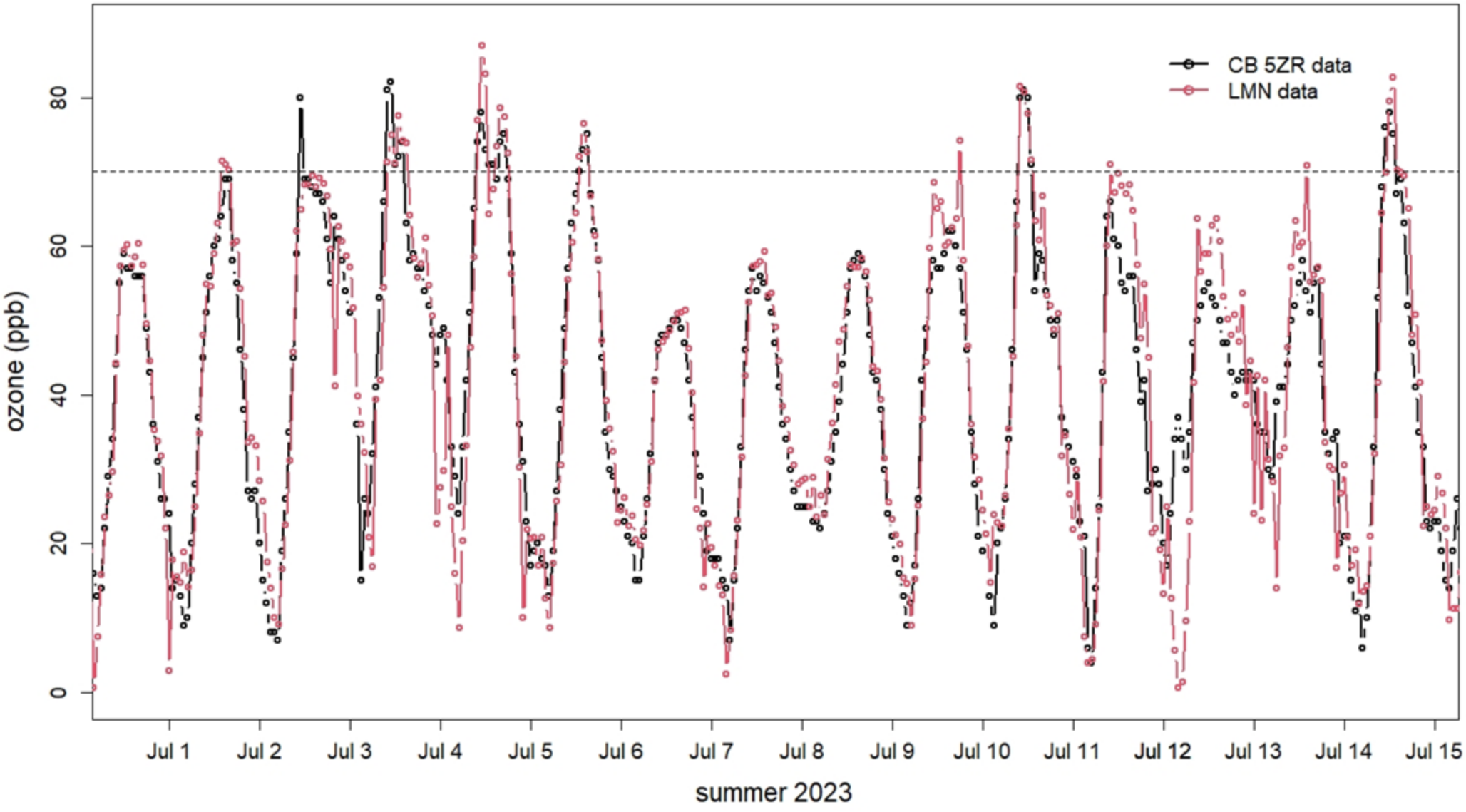
1-Minute Data



8-Hour Averaged Data

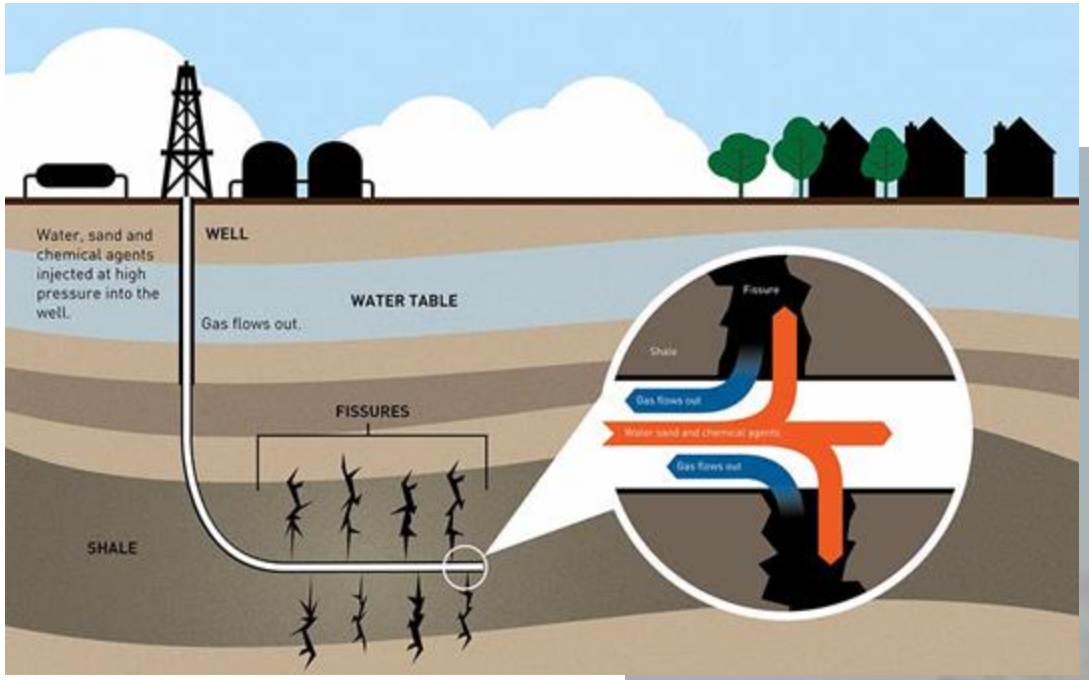


Comparing LNM Ozone to Carlsbad NMED site

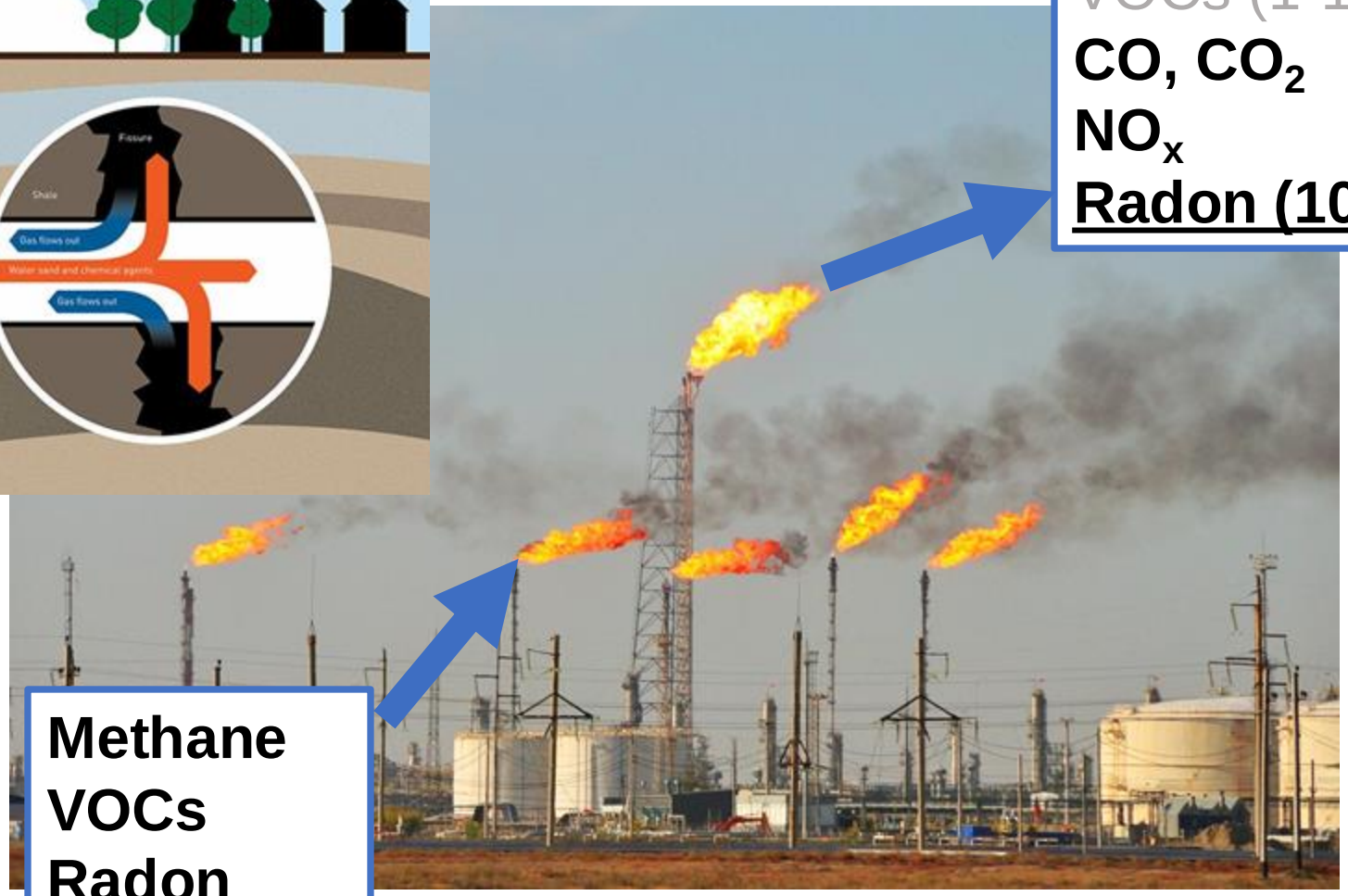


NOTE: NMED's 5ZR monitoring location is on the SW outskirts of Carlsbad about 11 miles NW from our LNM site.

Hydraulic Fracturing and Radioactivity Mobilization



Methane (1-10%)
VOCs (1-10%)
CO, CO_2
NO_x
Radon (100%)



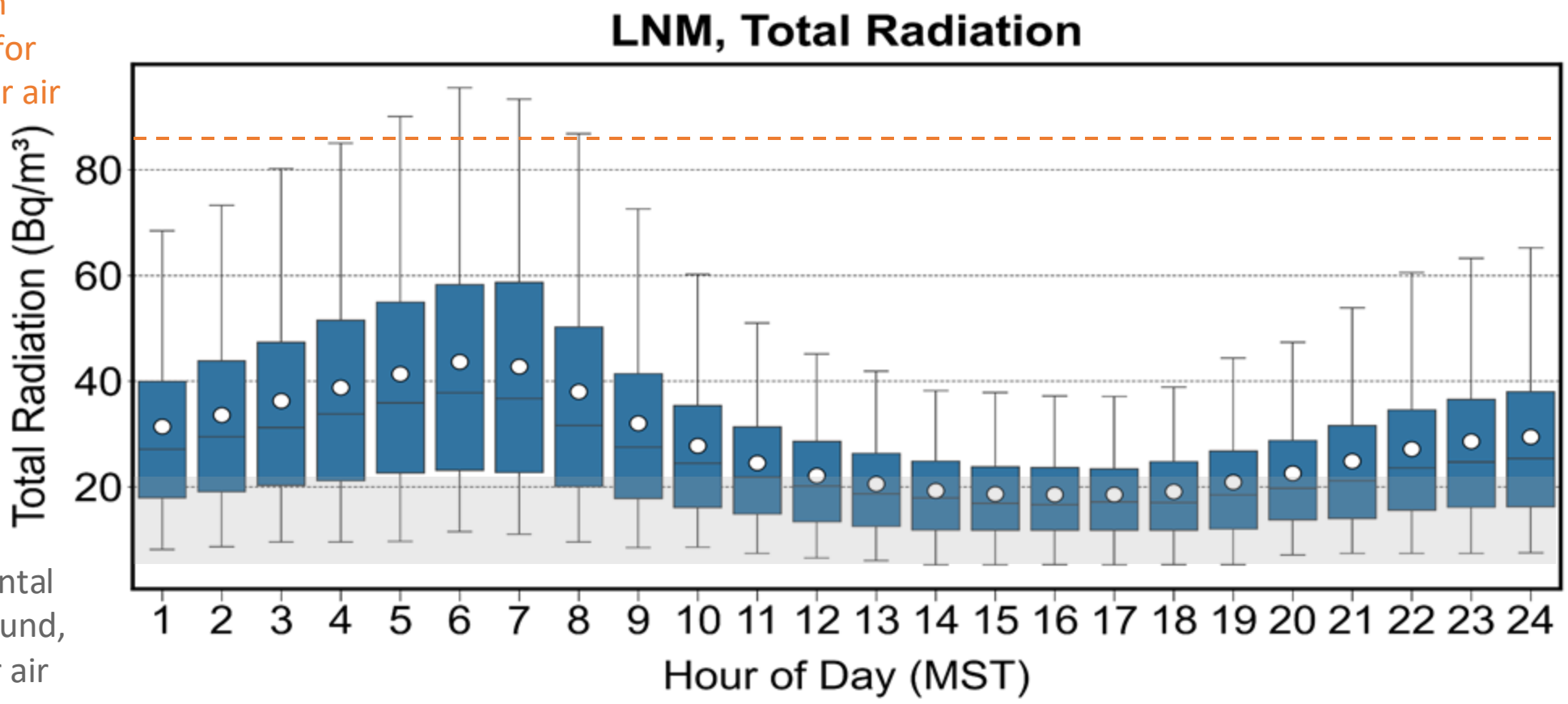
Methane
VOCs
Radon

https://arstechnica.com/science/2022/09/oil-industry-flaring-less-effective-than-thought-study/

Total Radioactivity at Loving, NM

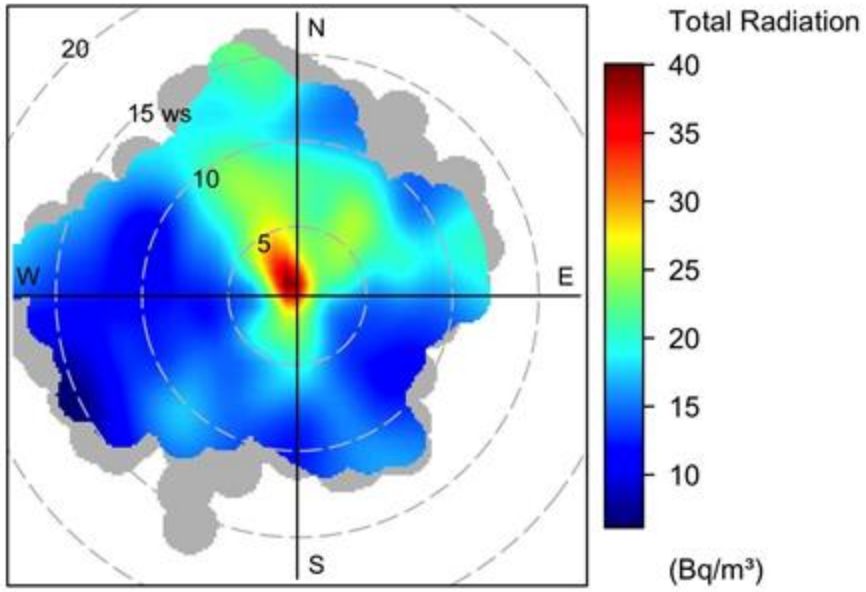
- Total radiation approx. two times above typical background levels.
- Radiation builds up at night, 2-3 times higher during early morning hours.

EPA lower action level for indoor air

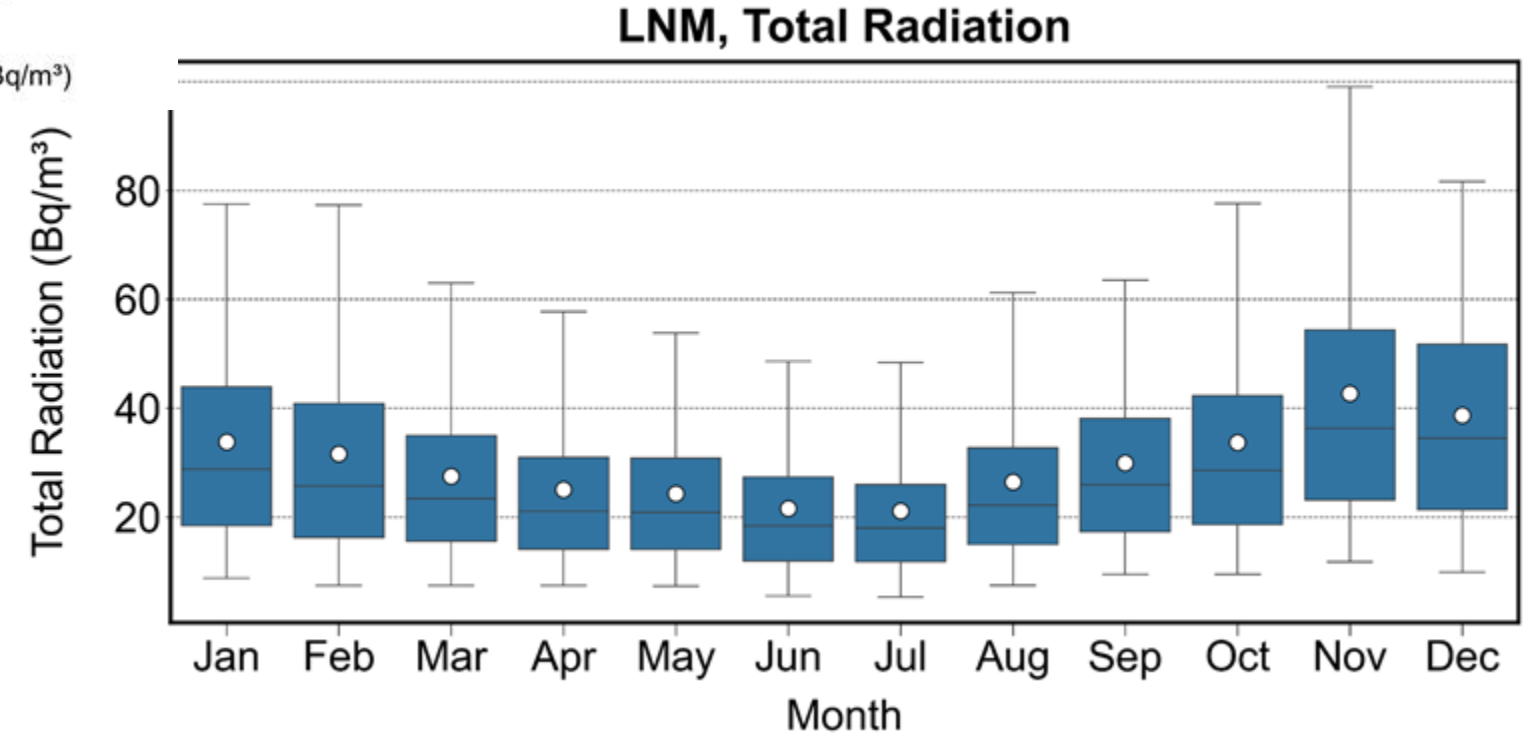


Continental background, outdoor air

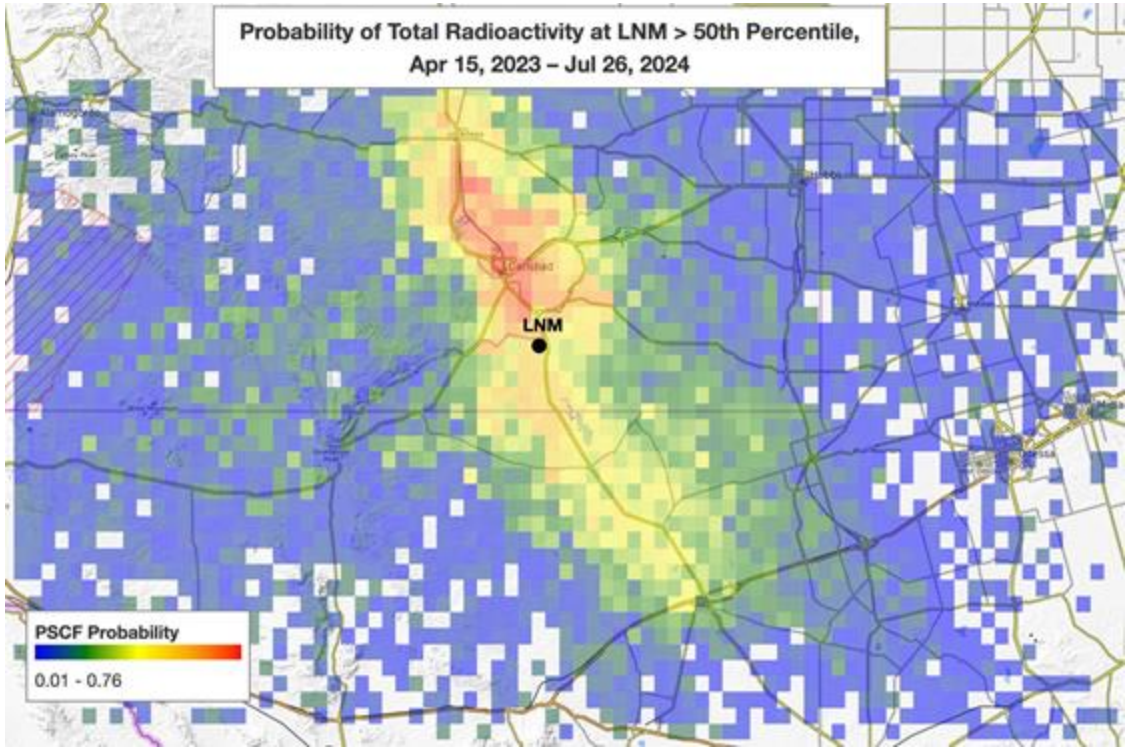
Total Radioactivity at Loving, NM



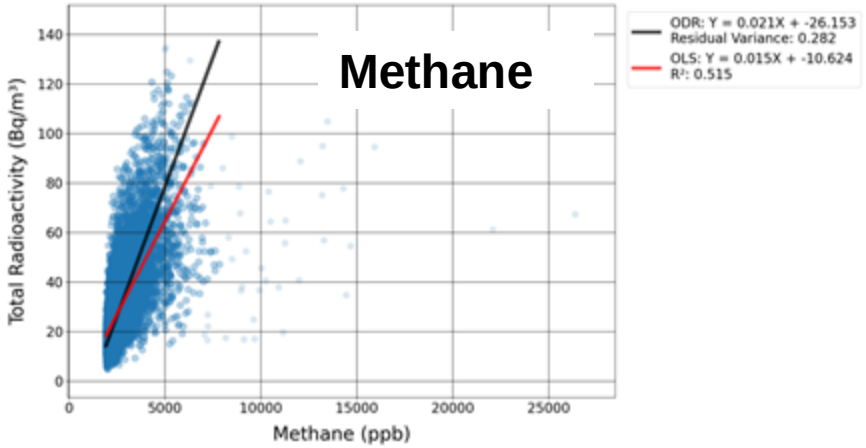
- Highest during low to moderate NW to NE winds.
- Winter values more variable and approximately 2 x higher than in summer.

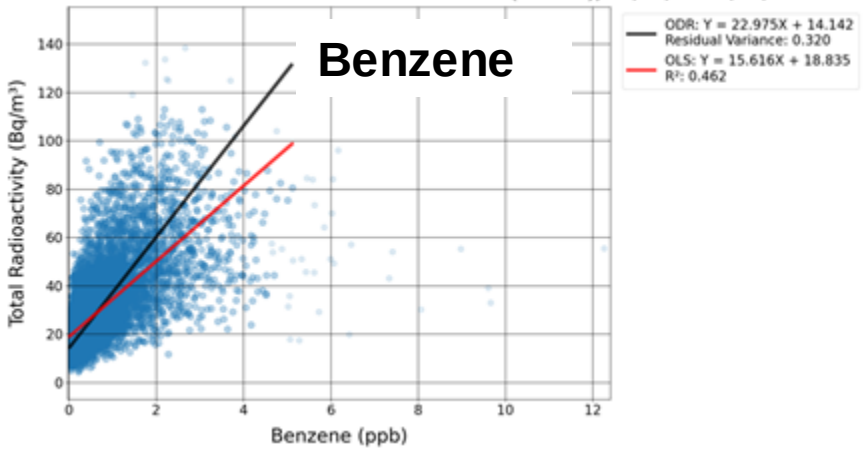


Total Radioactivity at Loving, NM

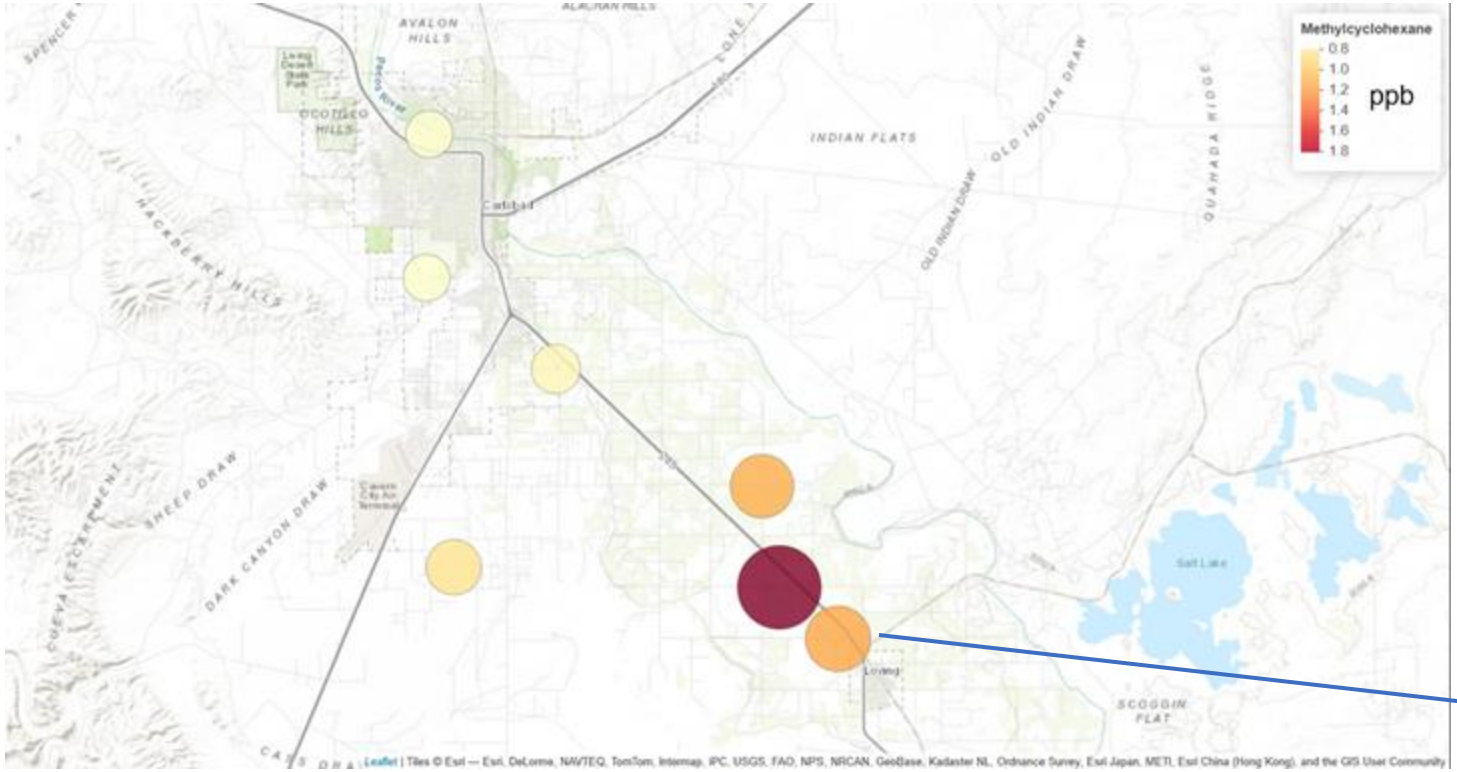


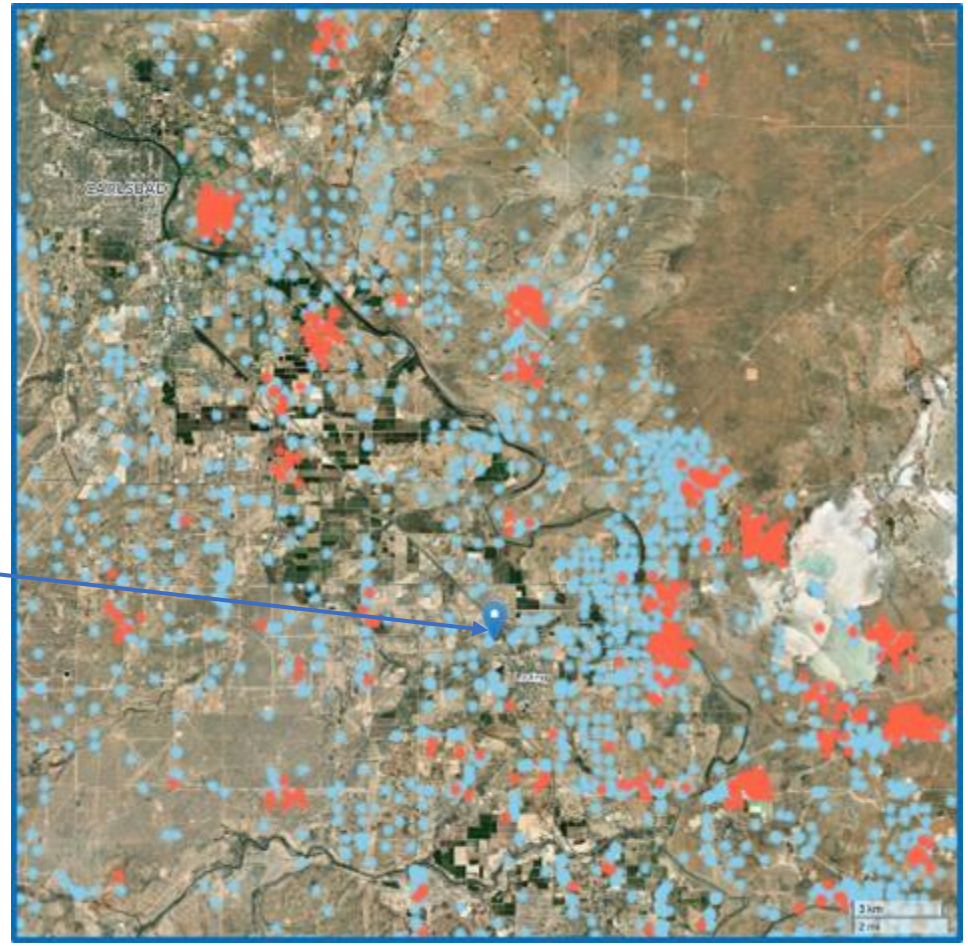
- Strongest surface source area overlays with the City of Carlsbad to NW and a sector to the SE.
- Correlation with chemical tracers





Passive Sampling Spatial Distributions



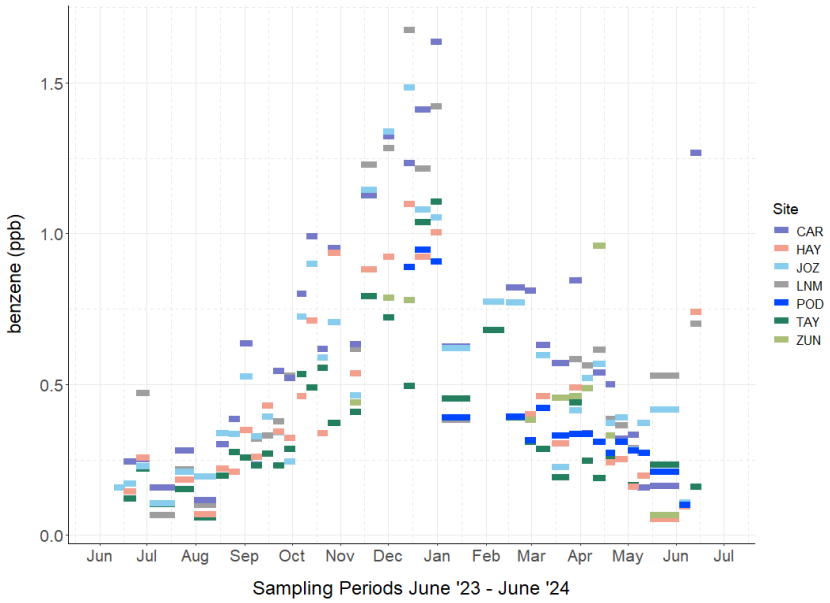


Average methylcyclohexane concentrations (above), a typical oil-production related hydrocarbon show gradients that correlate spatially with well density (right)

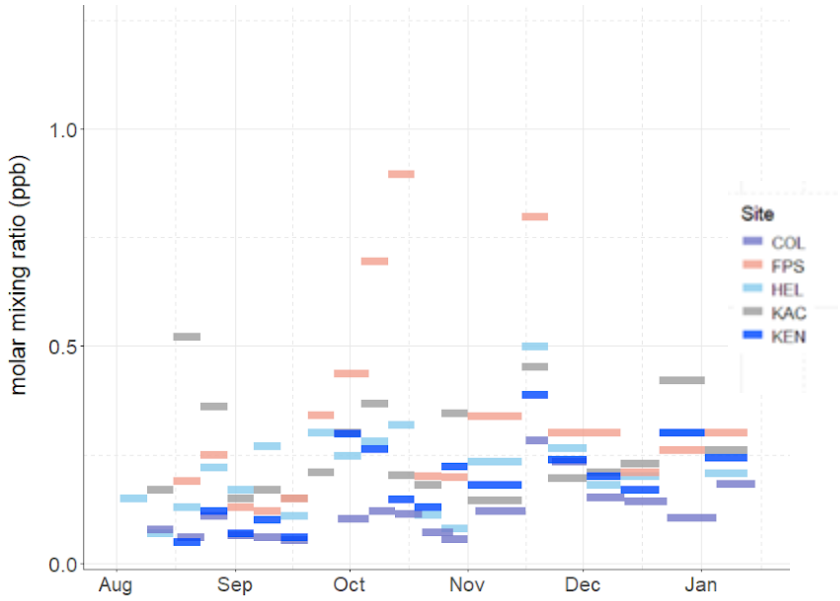
Passive Sampling

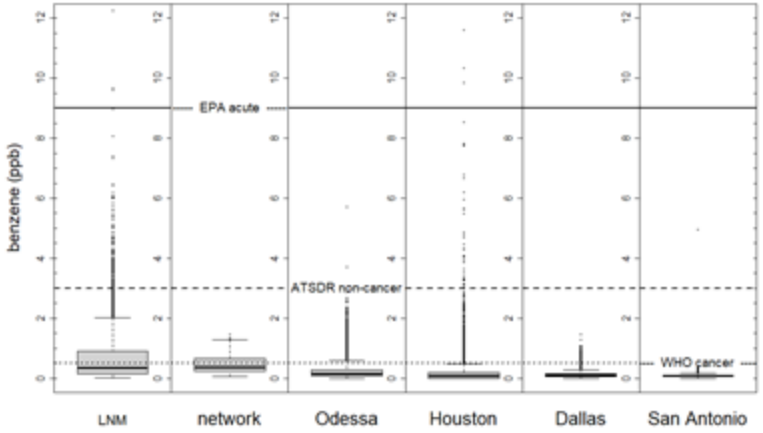
Benzene Temporal Trends and Comparisons

Seasonal changes of benzene abundances across the Permian Basin passive sampling sites.



Lower benzene abundances across the Eagle Ford passive sampling sites.





Site-level benzene distributions comparing LNM to passive monitoring to other sites in TX.

Summary 1

- Implemented continuous air monitoring in Loving, NM, in April 2023 and operated for one year – ended in June 2024.
- Compared to Colorado Front Range sites, the levels of methane, non-methane hydrocarbons (e.g. ethane and benzene), as well as ozone and nitrogen oxides are significantly higher.
- Oil and gas development completely dominates methane emissions in the area. Methane plumes are a good indicator for industry-related pollutant emissions.
- Eddy County, NM has been exceeding the ozone NAAQS.
- Comparing our data with other prior monitoring results suggests that ozone pollution levels are increasing, defying trends seen in most of the USA.
- Our data, and several prior peer-reviewed studies, suggest the regional ozone problem is largely due to very significant VOC emissions from oil & gas operations.

Summary 2

- Passive monitoring network of 7 sites in Permian basin (PB) and 4 sites in central Eagle Ford shale (EFS) captured spatial gradients in hydrocarbons.
- Clear gradients in oil-production hydrocarbon markers and benzene where well pad density is higher, particularly in the PB.
- Seasonal changes in all hydrocarbons, much more pronounced at PB than EFS sites.
- Concentrations on average higher in PB than EFS sites.
  - Concentrations in the PB higher than at urban monitoring sites in TX and CO
- Overall, to the best of our knowledge, this was the most extensive air monitoring program in the Permian Basin, and our measurements in the EFS complement prior work in this area.

Project Support

Thank you:

HEI Energy (funding)

*** Please note that all data presented are QA/Qced but our results have not yet undergone peer review**

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