Assessing source contributions to air quality in southeast New Mexico

Research Team

Meredith Franklin (Assoc. Professor, Univ. of Toronto) Exposure assessment, statistics, data science

Gunnar Schade (Associate Professor, Texas A&M University), Unconventional oil and gas development studies, distributed sampling

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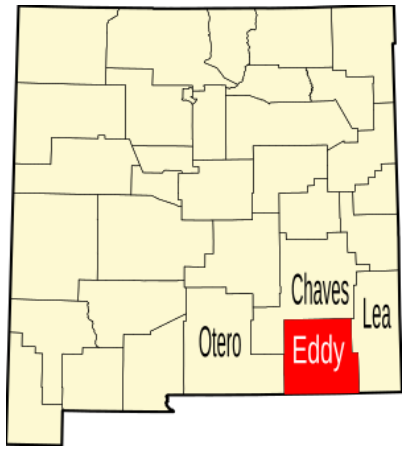
Jill Johnston (Associate Professor, University of Southern California) Environmental health and justice, community engagement

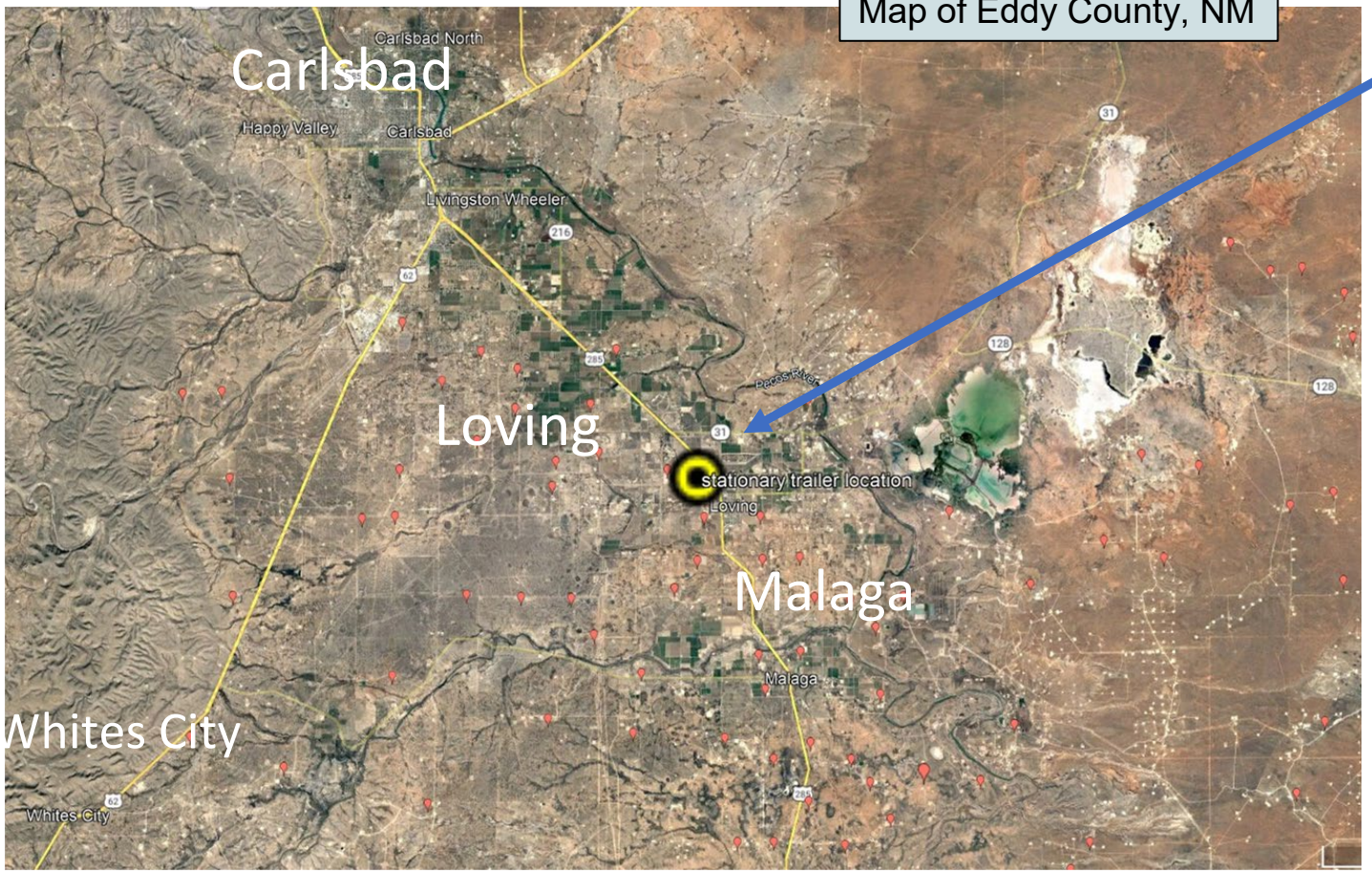
Lara Cushing (Assistant Professor, University of California LA), Environmental health and epidemiology, community engagement

Overview of study site in Loving, NM



Stationary monitoring trailer location

Map of Eddy County, NM



Overview of stationary monitoring

- One year duration, April 2023 – May 2024
- Highly sensitive, regulatory rated instruments and protocols
- Fully automated, 24/7 operation, less than 2% downtime
- Most extensive (# of monitored pollutants, # of measurements) air monitoring in New Mexico

- Data reported in real time to the public within minutes after measurement (https://bouldair.com/loving.htm)

Study Findings

NEW MEXICO POLITICAL REPORT ☰ MENU SEARCH GOT A TIP? SUBSCRIBE DONATE

NEWS ENVIRONMENT ABORTION LOCAL QUICK READS

August 26, 2024

In this tiny New Mexico town, the air quality is worse than in downtown L.A.

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By Capital & Main

- **Ozone pollution – Highest levels ever recorded in NM**
- **Causes of high ozone – Mostly oil and natural gas emissions**

Why are we so concerned about ozone?

Ozone (O_3) is a strong oxidant. It has been regulated through the Clean Air Act since 1970.

<u>Elevated levels of surface ozone can cause:</u>

- Shortness of breath
- Chest pain when inhaling deeply
- Wheezing and coughing
- Increased susceptibility to respiratory infections
- Inflammation of the lungs and airways
- Increased risk of asthma attacks

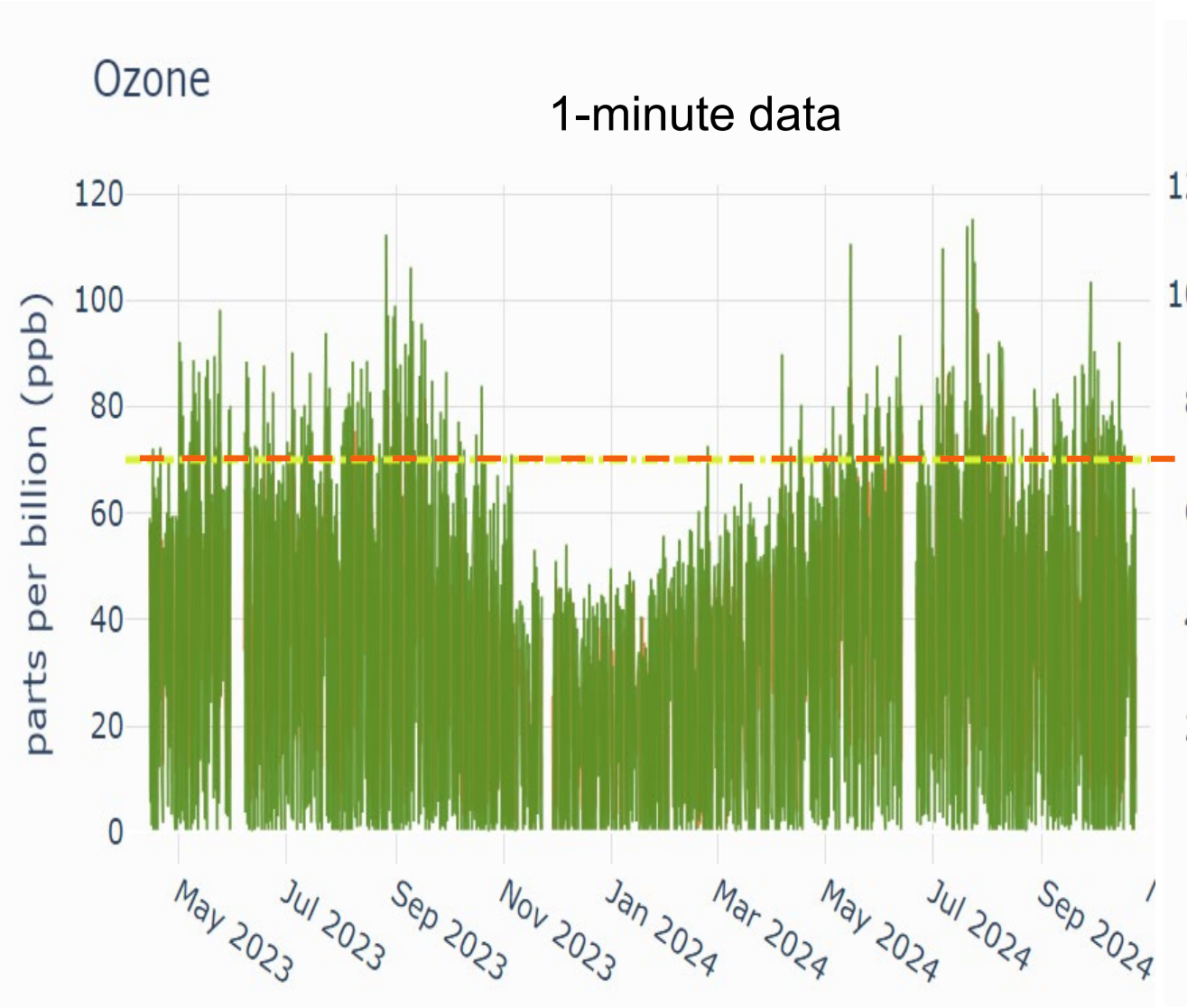
….. (American Lung Association)

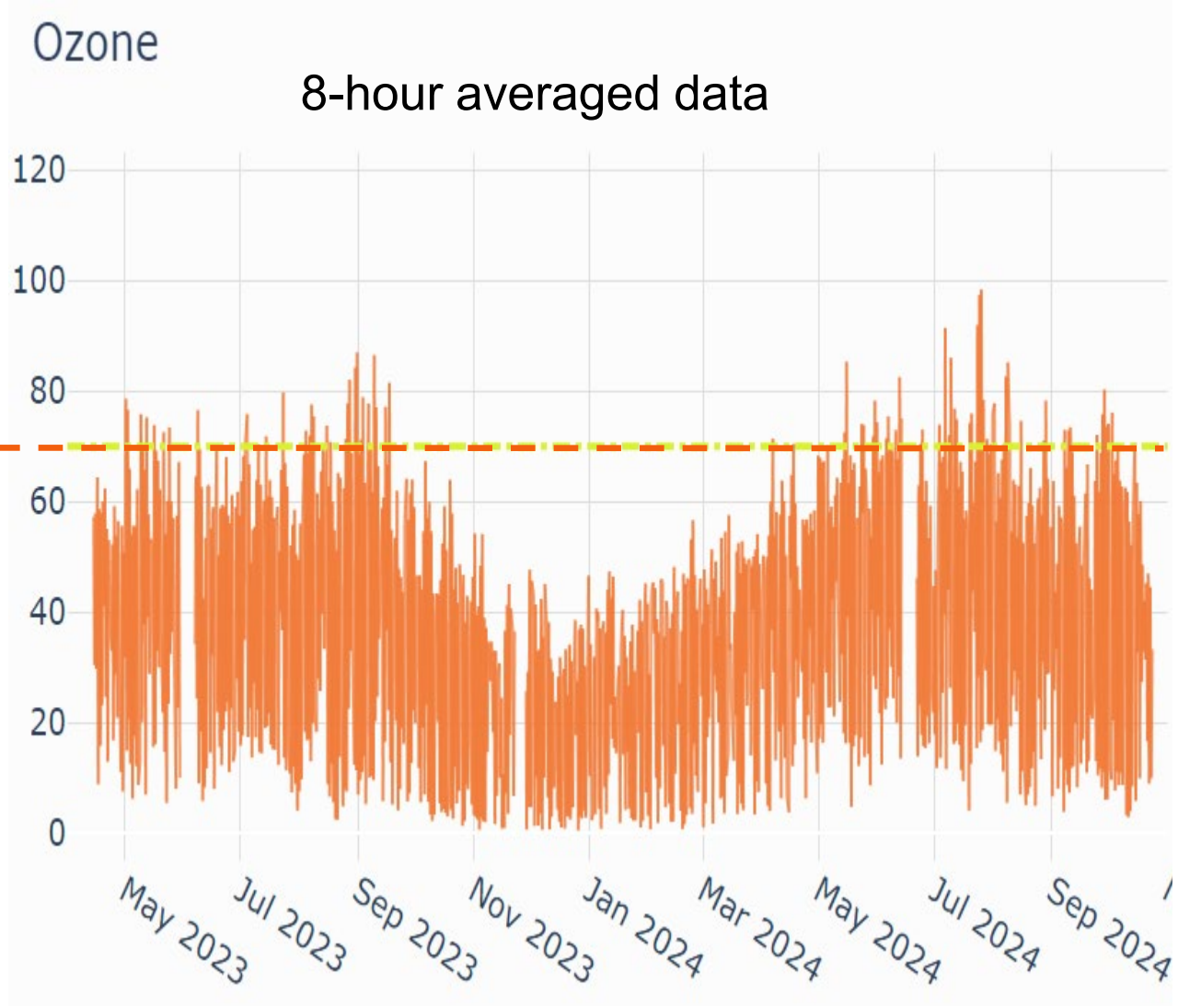
→ Increased risk of death;
~ 5000-6000 premature deaths in US per year

Also – Ozone in Greenhouse Gas:

1. CO_2 (55%)
2. Methane (30%)
3. <u>Ozone (8%)</u>

2023 – 2024 Ozone results for Loving, NM

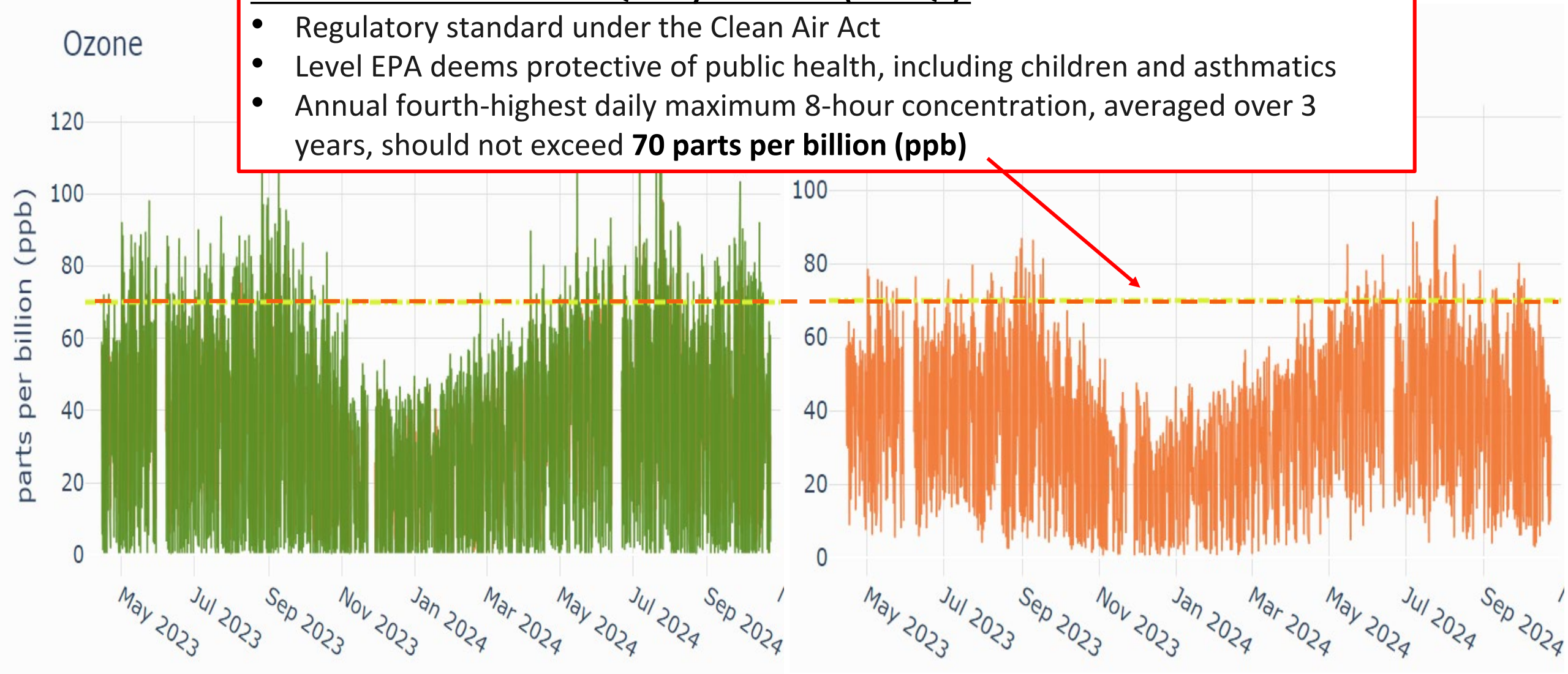




2023 – 2024 Ozone results for Loving, NM

EPA National Ambient Air Quality Standard (NAAQS):

- Regulatory standard under the Clean Air Act
- Level EPA deems protective of public health, including children and asthmatics
- Annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years, should not exceed **70 parts per billion (ppb)**



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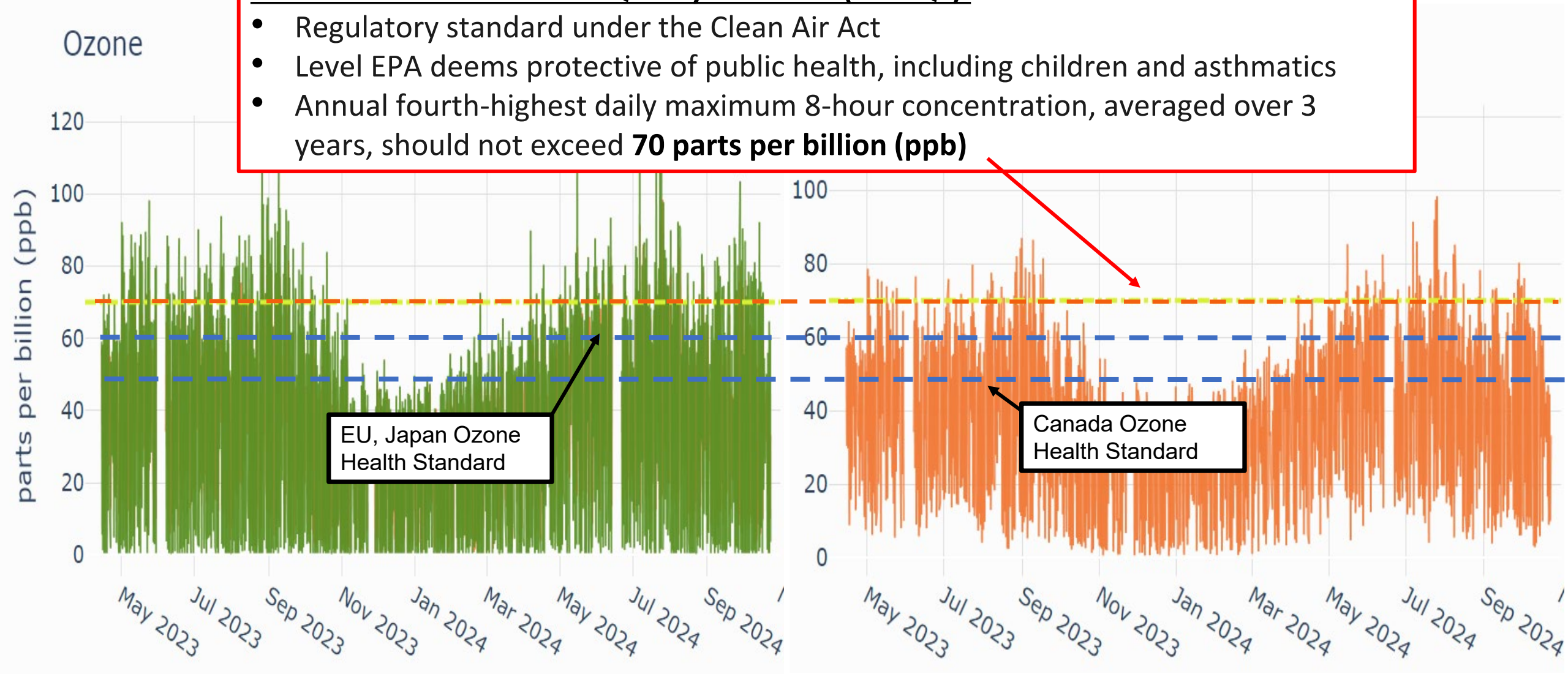


2023 and 2024 occurrences of 8-hour ozone > 70 ppb at Loving, NM

2023 (full year)			
O3_8hr (ppb)	day-month	year	# days > 75/70 ppb NAAQS
87.1	31-Aug	2023	
86.7	9-Sep	2023	
84.3	30-Aug	2023	
82.1	27-Aug	2023	
81.6	17-Sep	2023	
79.7	23-Jul	2023	
78.9	3-Sep	2023	
78.6	1-May	2023	
77.9	26-Aug	2023	
77.8	6-Sep	2023	
77.7	7-Aug	2023	
77.7	6-Jun	2023	
77.3	15-Sep	2023	
77.2	10-Sep	2023	
76.6	2-May	2023	
76.6	8-Jun	2023	
76.0	4-Jul	2023	17
75.8	9-May	2023	
75.7	12-May	2023	
75.7	15-Aug	2023	
75.6	8-Aug	2023	
74.0	16-May	2023	
73.5	24-May	2023	
72.9	4-Aug	2023	
72.6	21-May	2023	
72.0	6-Aug	2023	
71.8	14-Jul	2023	
71.7	10-Jul	2023	
71.3	25-Aug	2023	
71.2	2-Sep	2023	
71.0	3-Jul	2023	
70.9	17-Aug	2023	
70.4	10-May	2023	
70.3	18-Jun	2023	

31

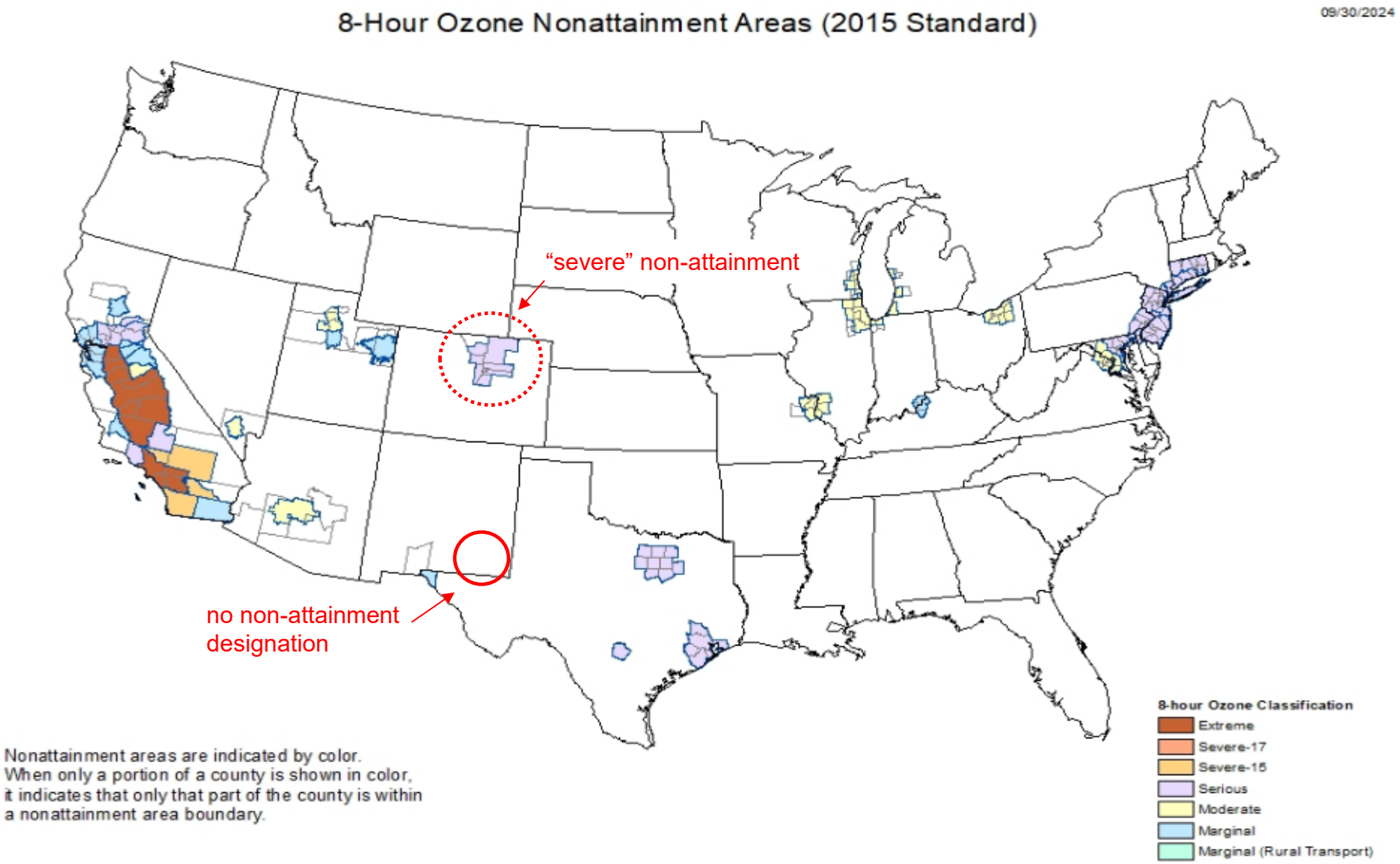
2024 (until Oct 25th)			
O3_8hr (ppb)	day-month	year	# days > 75/70 ppb NAAQS
99.8	25-Jul	2024	
97.7	24-Jul	2024	
92.4	23-Jul	2024	
91.5	6-Jul	2024	
86.8	26-Jul	2024	
86.3	9-Jul	2024	
85.4	8-Aug	2024	
85.4	15-May	2024	
82.7	7-Aug	2024	
82.5	12-Jun	2024	
80.4	28-Sep	2024	
79.6	30-Sep	2024	
78.3	28-Aug	2024	
78.3	30-May	2024	
78.1	1-Aug	2024	
77.7	10-Jul	2024	
77.5	11-Jul	2024	
77.2	20-Jul	2024	
76.3	27-Jul	2024	
76.1	2-Oct	2024	
76.0	31-Jul	2024	21
75.8	27-Sep	2024	
75.6	6-Jun	2024	
75.2	12-Jul	2024	
75.1	23-May	2024	
75.1	13-Jun	2024	
74.7	3-Jul	2024	
74.7	9-Aug	2024	
74.6	15-Aug	2024	
74.6	31-May	2024	
74.3	19-Jul	2024	
74.2	24-May	2024	
73.6	29-Sep	2024	
73.5	10-Sep	2024	
73.2	7-Sep	2024	
73.0	24-Jun	2024	
73.0	10-Jun	2024	
73.0	9-Sep	2024	
72.6	14-May	2024	
72.1	24-Sep	2024	
72.0	8-Jul	2024	
71.9	29-May	2024	
71.6	5-Jun	2024	
71.4	6-Apr	2024	
71.3	28-Jul	2024	
71.0	27-Aug	2024	
70.7	7-Apr	2024	
70.7	14-Oct	2024	
70.6	6-Aug	2024	
70.5	17-Apr	2024	
70.4	23-Jun	2024	
70.4	30-Jul	2024	
70.2	3-Jun	2024	
70.1	5-May	2024	

46

Loving 2023-2024 mean 4th:
86.8 ppb

Number of ozone NAAQS exceedance days

US ozone non-attainment areas



Loving 2023-2024 4th highest mean ozone compared to EPA ozone non-attainment area design values

Table 1a. Design Values in Areas Previously Designated Nonattainment for the 2015 8-Hour Ozone NAAQS

AQS Data Retrieval: 5/7/2024 | Last Updated: 6/4/2024

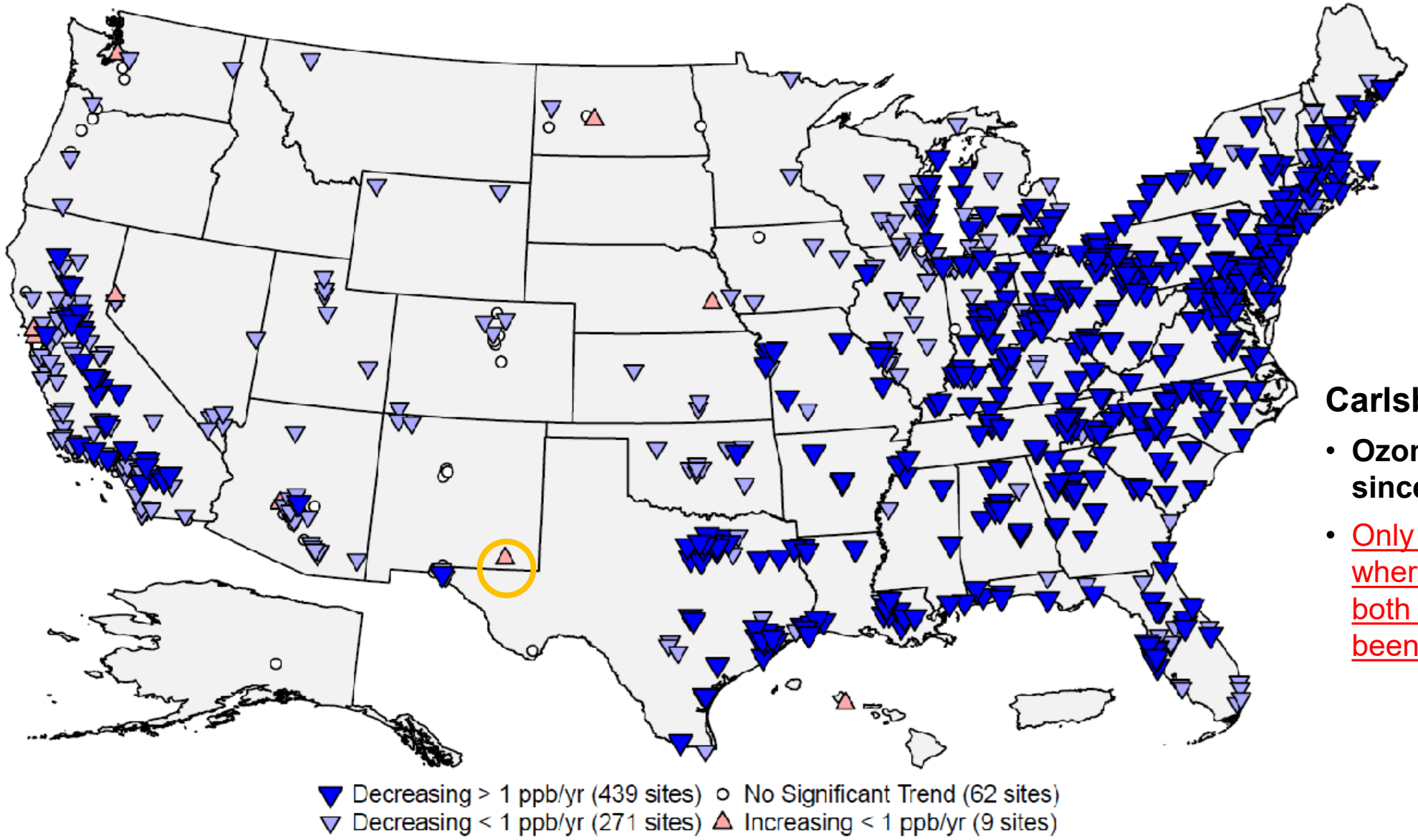
Designated Area	EPA Region(s)	Designation Status [1]	Classification [1]	2021-2023 Design Value (ppm) [2,3]	Met NAAQS?
Los Angeles-South Coast Air Basin, CA	9	Nonattainment	Extreme	0.106	No
Morongo Band of Mission Indians, CA	9	Nonattainment	Serious	0.094	No
Los Angeles-San Bernardino Counties (West Mojave Desert), CA	9	Nonattainment	Severe 15	0.090	No
San Joaquin Valley, CA	9	Nonattainment	Extreme	0.090	No
Loving, NM	**6**	**n/a**	**n/a**	**0.087**	**n/a**
Riverside County (Coachella Valley), CA	9	Nonattainment	Severe 15	0.085	No
Houston-Galveston-Brazoria, TX	6	Nonattainment	Moderate	0.083	No
New York-Northern New Jersey-Long Island, NY-NJ-CT	1,2	Nonattainment	Moderate	0.082	No
Dallas-Fort Worth, TX	6	Nonattainment	Moderate	0.081	No
Denver Metro/North Front Range, CO	8	Nonattainment	Moderate	0.081	No
Phoenix-Mesa, AZ	9	Nonattainment	Moderate	0.080	No
El Paso-Las Cruces, TX-NM	6	Nonattainment	Marginal	0.079	No
San Diego County, CA	9	Nonattainment	Severe 15	0.079	No
Nevada County (Western part), CA	9	Nonattainment	Serious	0.078	No
Chicago, IL-IN-WI	5	Nonattainment	Moderate	0.077	No
Imperial County, CA	9	Nonattainment	Marginal	0.077	No
Muskegon County, MI	5	Nonattainment	Moderate	0.077	No
Northern Wasatch Front, UT	8	Nonattainment	Moderate	0.077	No
Sheboygan County, WI	5	Nonattainment	Moderate	0.077	No
Uinta Basin, UT	8	Nonattainment	Marginal	0.077	No
Sacramento Metro, CA	9	Nonattainment	Serious	0.076	No [5]
San Antonio, TX	6	Nonattainment	Moderate	0.076	No
Allegan County, MI	5	Nonattainment	Moderate	0.075	No
Kern County (Eastern Kern), CA	9	Nonattainment	Serious	0.075	No
Ventura County, CA	9	Nonattainment	Serious	0.075	No
Las Vegas, NV	9	Nonattainment	Moderate	0.074	No
Milwaukee, WI	5	Nonattainment	Moderate	0.074	No
St. Louis, MO-IL	5,7	Nonattainment	Moderate	0.074	No
Baltimore, MD	3	Nonattainment	Moderate	0.073	No
Berrien County, MI	5	Nonattainment	Moderate	0.073	No
Cleveland, OH	5	Nonattainment	Moderate	0.073	No
Greater Connecticut, CT	1	Nonattainment	Moderate	0.073	No
Manitowoc County, WI	5	Maintenance	Marginal	0.073	No
Mariposa County, CA	9	Nonattainment	Moderate	0.073	No
Philadelphia-Wilmington-Atlantic City, PA-NJ-MD-DE	2,3	Nonattainment	Moderate	0.073	No
Door County, WI	5	Maintenance	Marginal	0.072	No
Louisville, KY-IN	4,5	Nonattainment	Moderate	0.072	No
Southern Wasatch Front, UT	8	Nonattainment	Marginal	0.072	No
Tuscan Buttes, CA	9	Nonattainment	Marginal	0.072	No
Detroit, MI	5	Maintenance	Moderate	0.071	No
San Luis Obispo (Eastern part), CA	9	Nonattainment	Marginal	0.071	No
Sutter Buttes, CA	9	Nonattainment	Marginal	0.071	No
Washington, DC-MD-VA	3	Nonattainment	Moderate	0.071	No
Atlanta, GA	4	Maintenance	Marginal	0.070	Yes
Cincinnati, OH-KY	4,5	Maintenance	Moderate	0.070	Yes
San Francisco Bay Area, CA	9	Nonattainment	Marginal	0.070	Yes [5]
Yuma, AZ	9	Nonattainment	Marginal	0.070	Yes
Butte County, CA	9	Nonattainment	Marginal	0.067	Yes
Columbus, OH	5	Maintenance	Marginal	0.067	Yes
Calaveras County, CA	9	Nonattainment	Marginal	0.066	Yes
Amador County, CA	9	Nonattainment	Marginal	0.065	Yes
Tuolumne County, CA	9	Nonattainment	Marginal		Incomplete

51 ozone non-attainment areas

With its 2023-2024 value of 86.9 Loving would be 5th worst ozone polluted area in the US.

https://www.epa.gov/air-trends/air-quality-design-values

Ozone design value trends across the United States (EPA 2023)



Carlsbad-Artesia:

- **Ozone above NAAQS since 2018**
- Only location in the US where ozone has been both increasing and been above the NAAQS.

source: www.epa.gov/air-quality-analysis/ozone-naaqs-review-analyses-and-data-sets

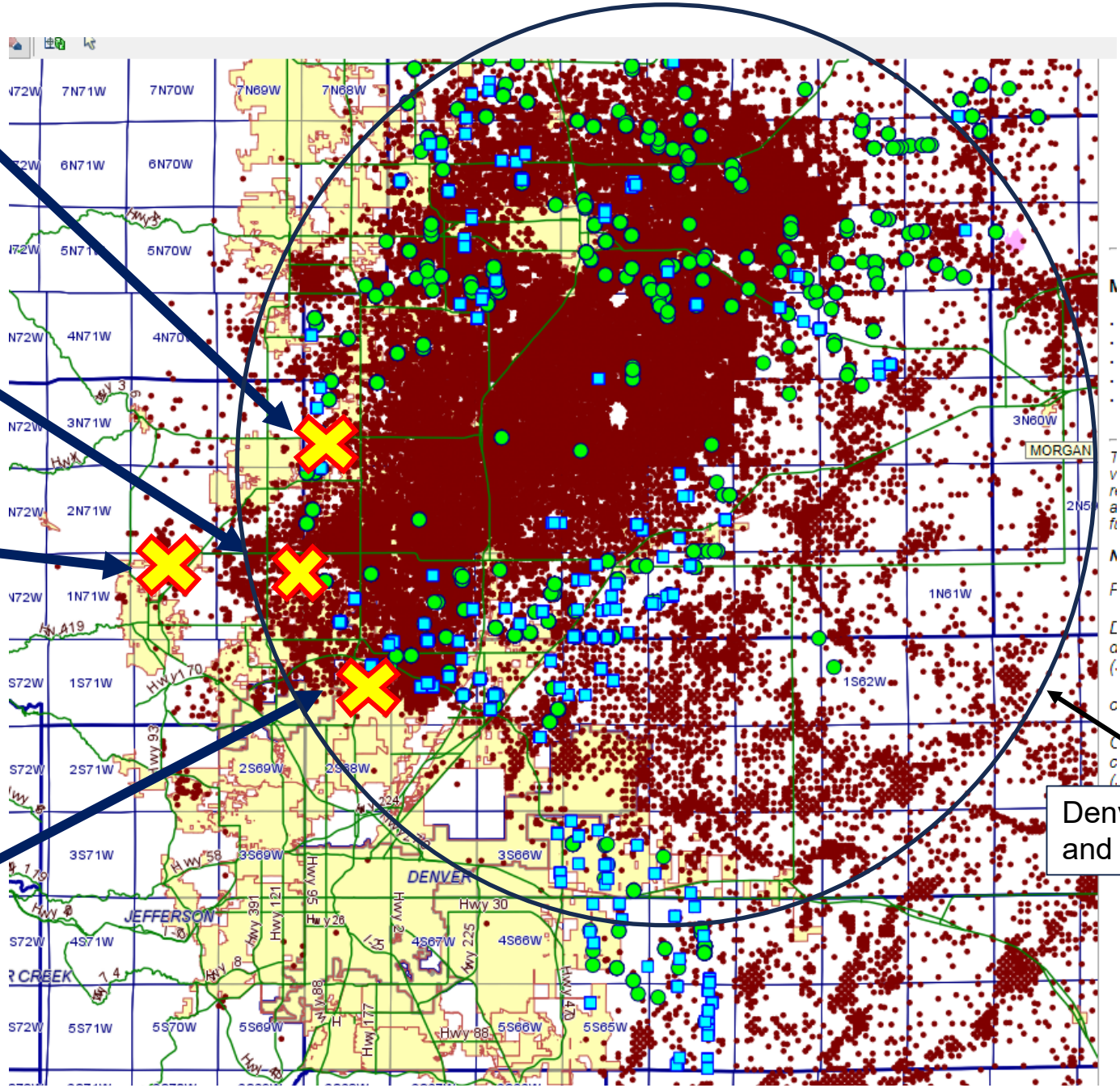
Comparison data from Colorado Front Range monitoring stations

Longmont Union Reservoir (LUR)

Erie Community Center (ECC)

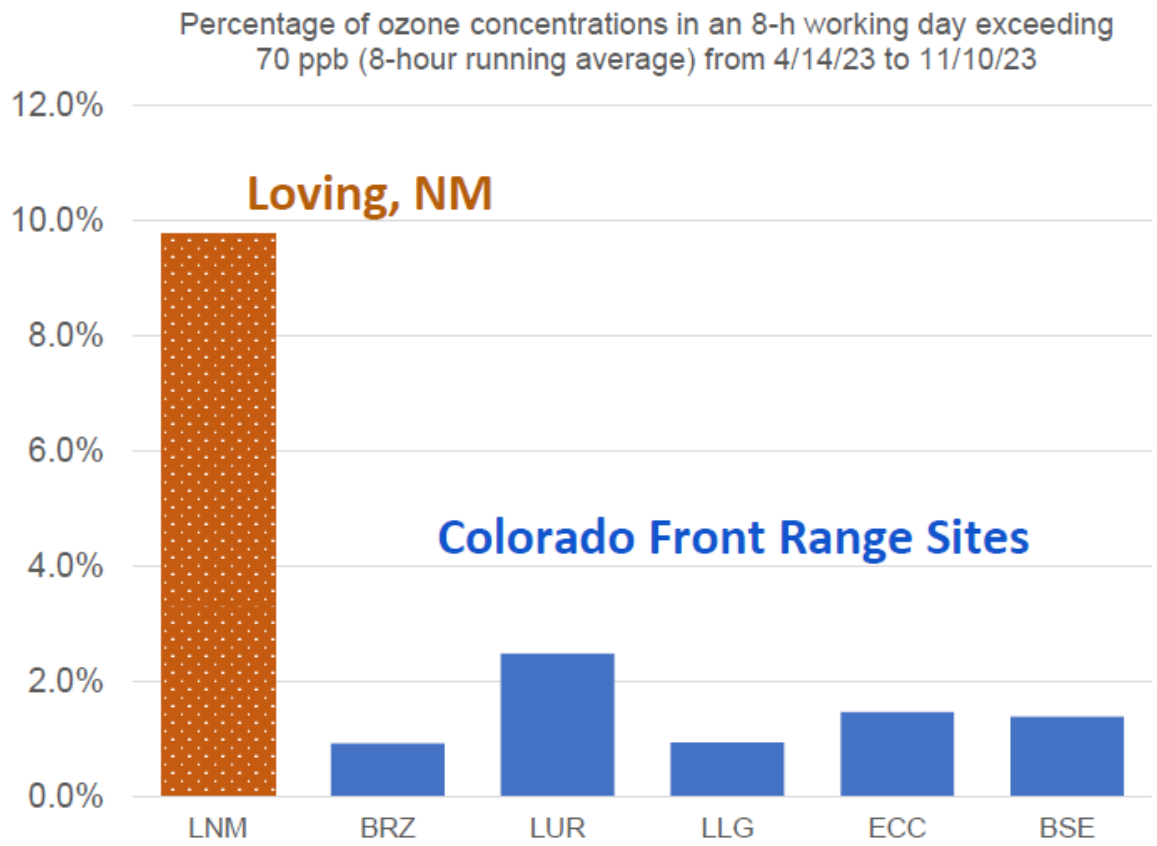
Boulder Reservoir (BRZ)

Broomfield Soaring Eagle (BSE)



Denver Julesburg Oil and Gas Basin

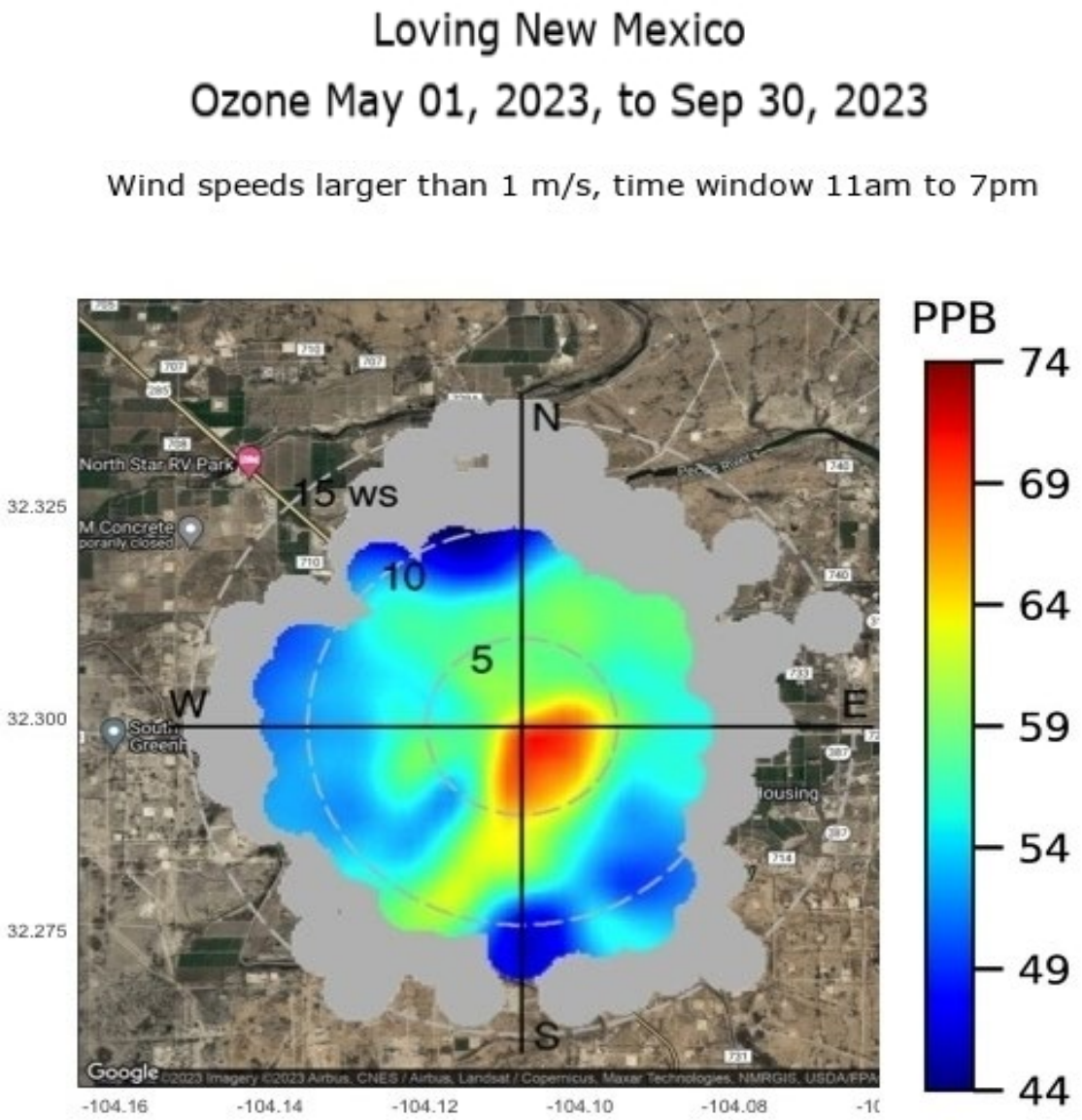
Comparison of 2023 Loving ozone with Colorado Front Range



In summer 2023, when compared to five Colorado Front Range sites that are in an ozone *non-attainment* area, we found:

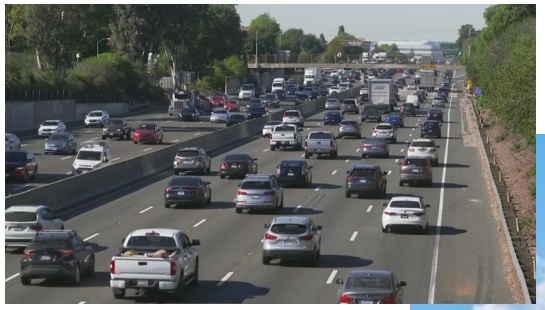
→ **Number of minutes with ozone >70 ppb was 5-7 times higher in Loving, NM, than at CO sites.**

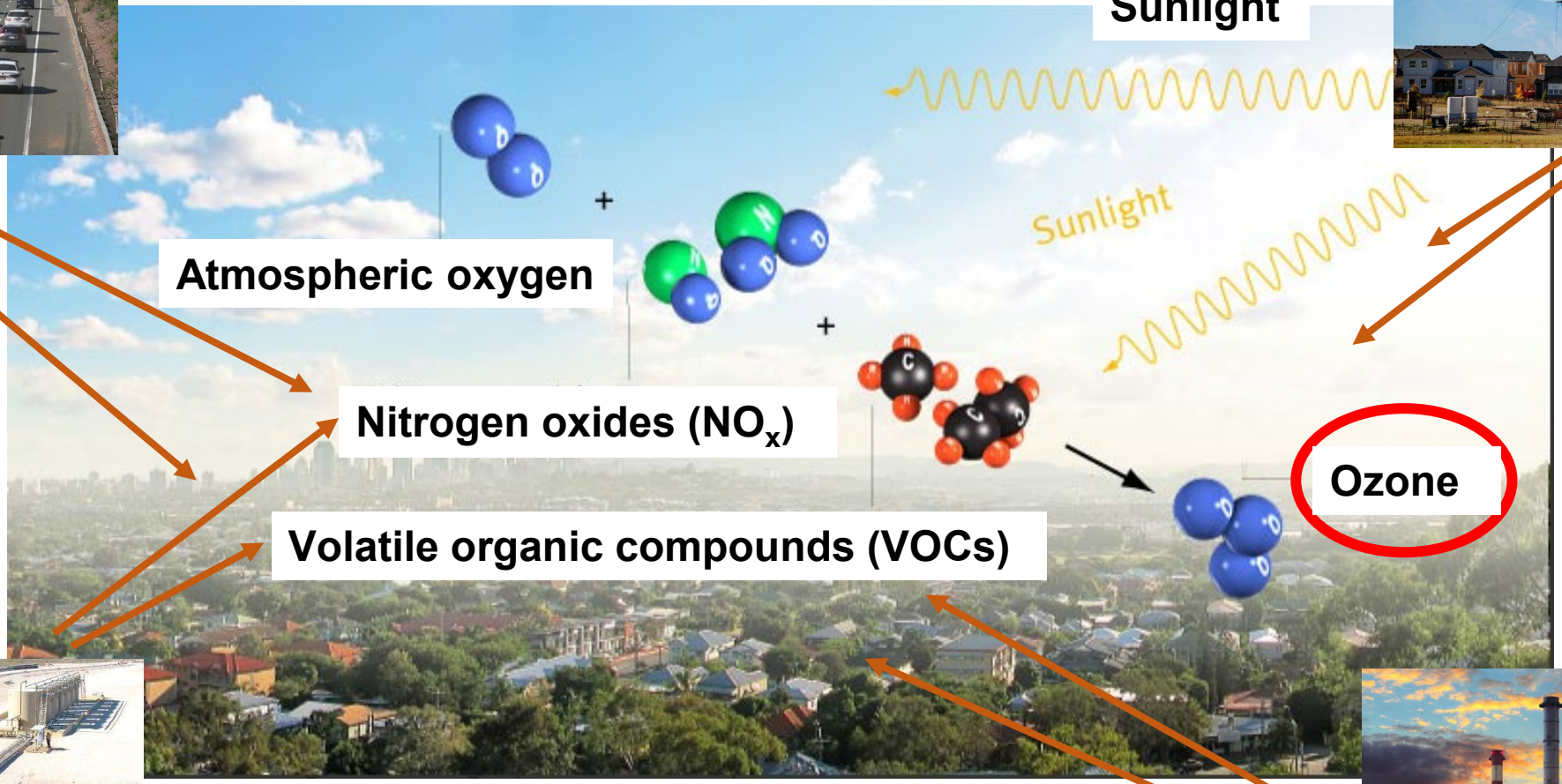
Where is the high ozone coming from?



- Weak southeast winds associated with highest daytime ozone.
- On average, air transported from the Permian Basin had 10–15 ppb higher ozone than air from most other directions.

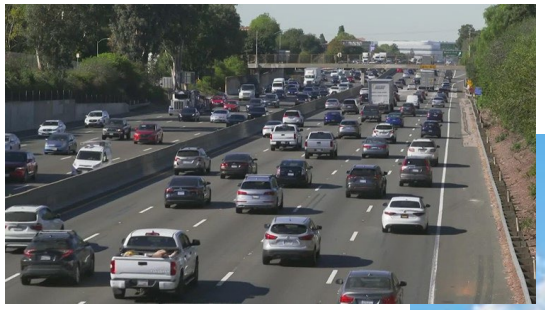
What is causing ozone pollution?





https://www.qld.gov.au/environment/management/monitoring/air/air-pollution/pollutants/ozone

What is causing ozone pollution?



Sunlight

Atmospheric oxygen

Nitrogen oxides (NO_x)

Volatile organic compounds (VOCs)

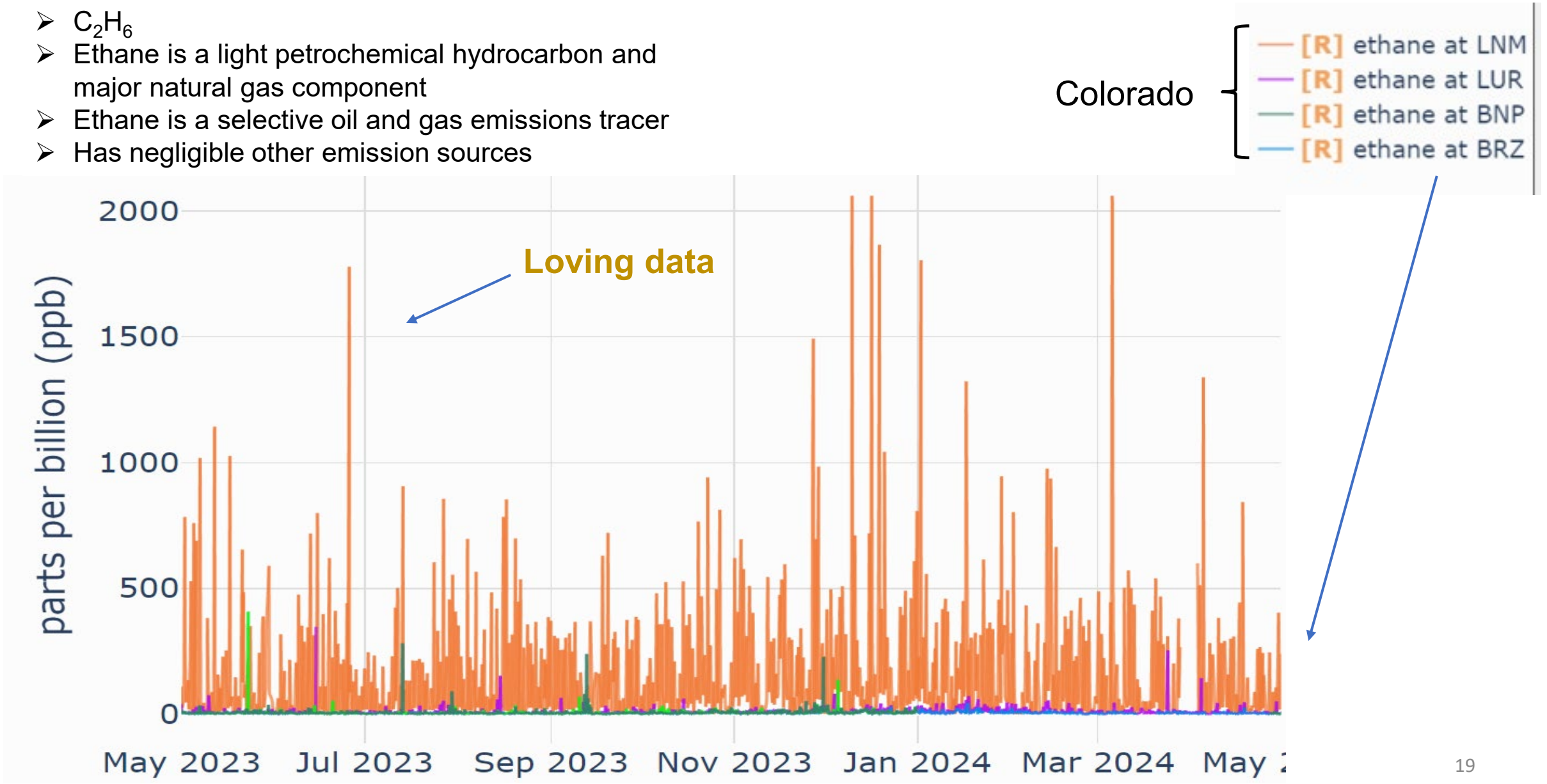
Sunlight

Ozone

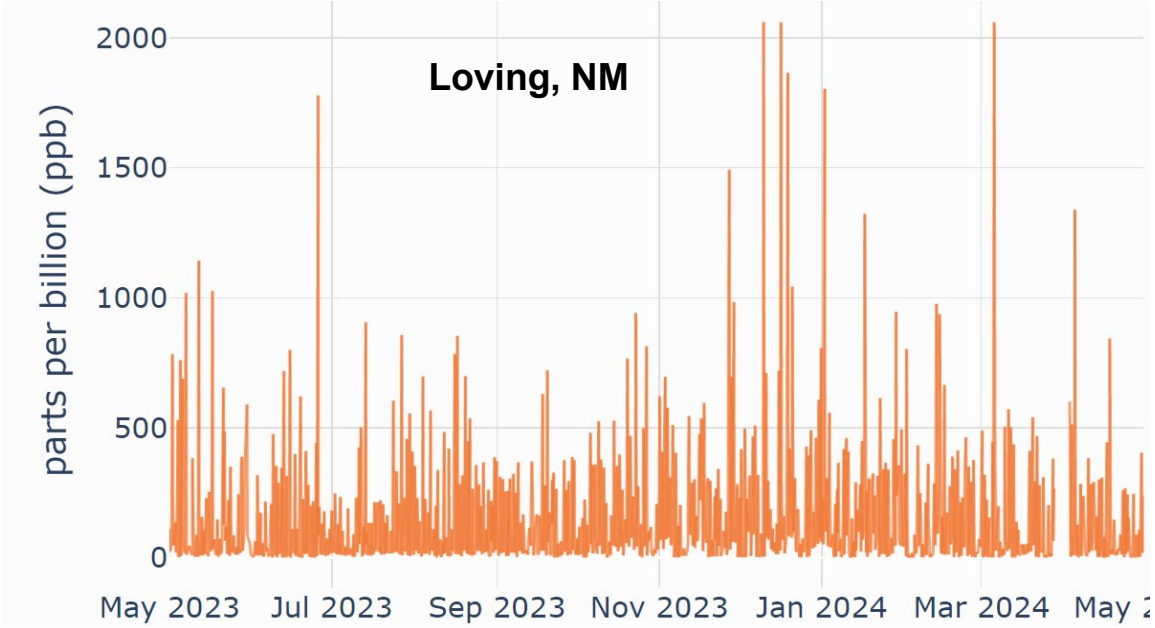
https://www.qld.gov.au/environment/management/monitoring/air/air-pollution/pollutants/ozone

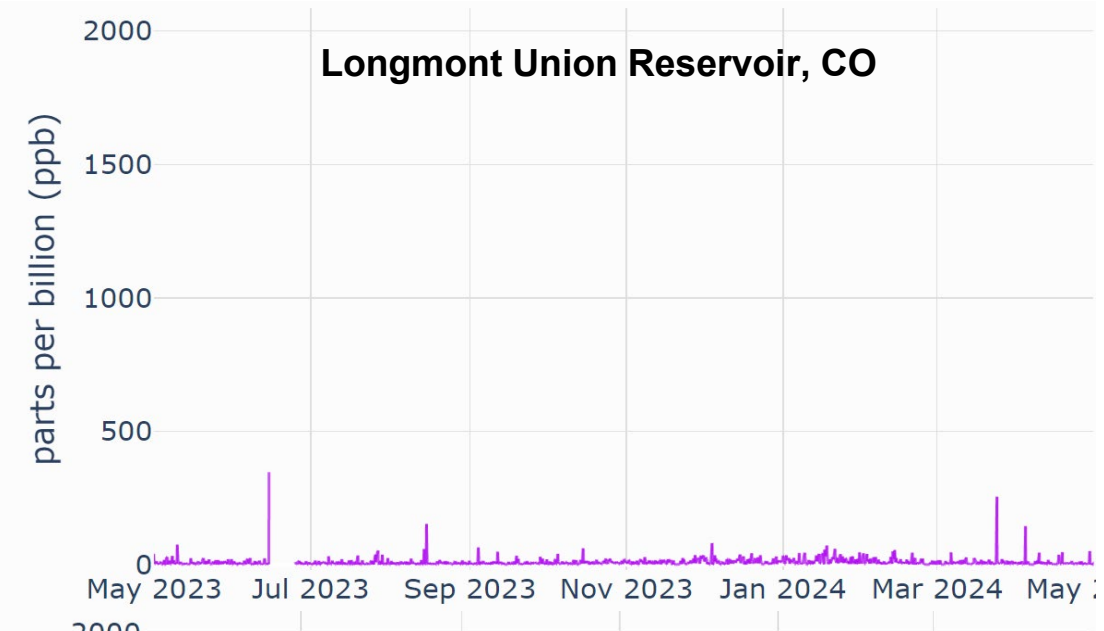
Ethane at Loving, NM, compared to Colorado sites

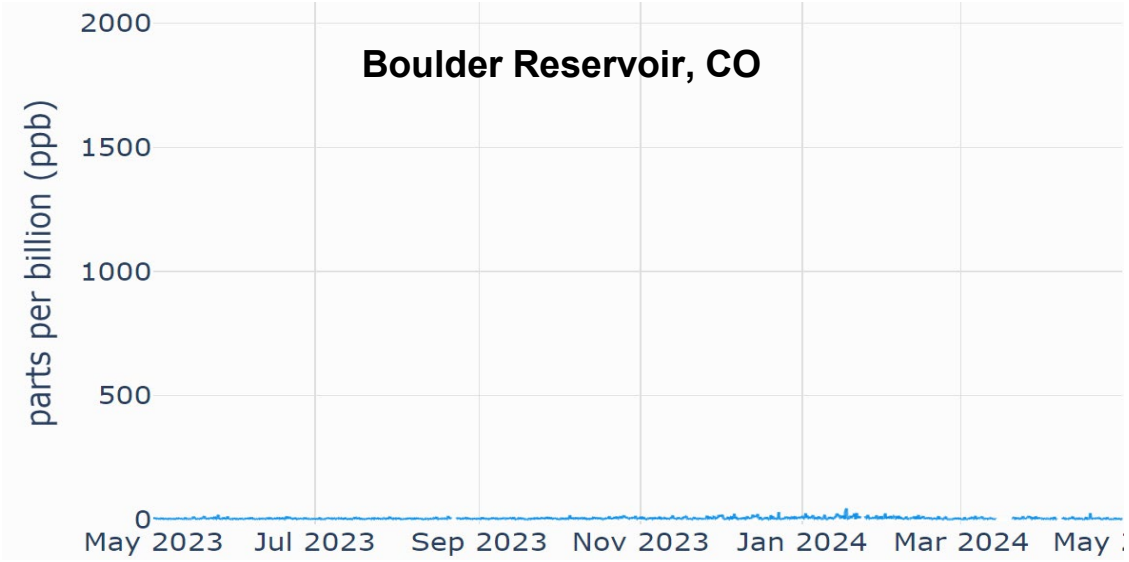
- C_2H_6
- Ethane is a light petrochemical hydrocarbon and major natural gas component
- Ethane is a selective oil and gas emissions tracer
- Has negligible other emission sources

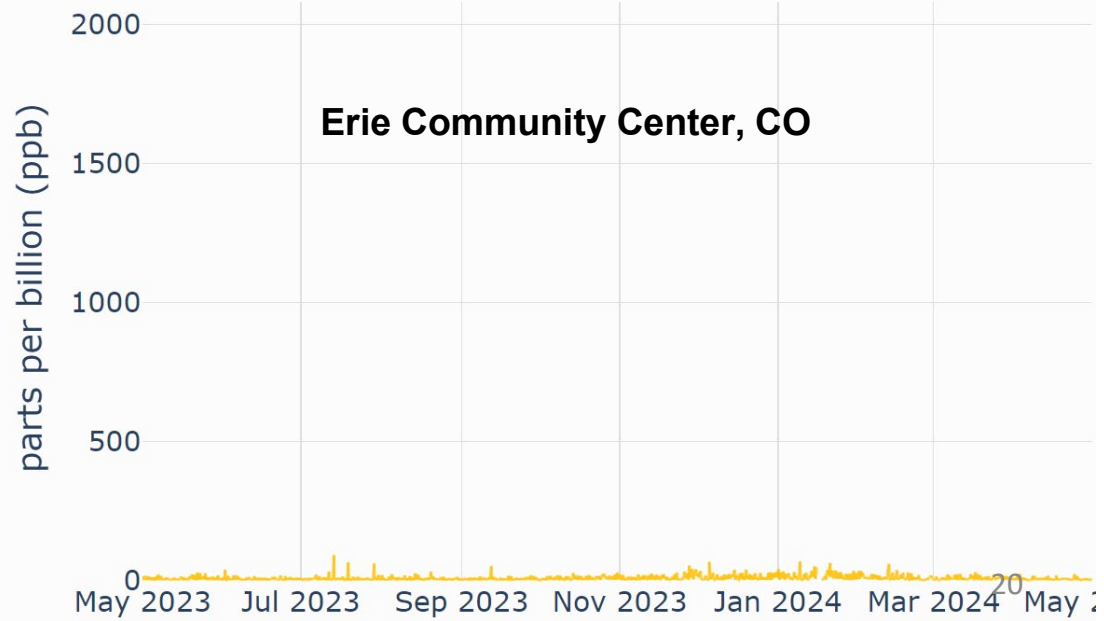


Ethane at Loving, NM, compared to Colorado sites

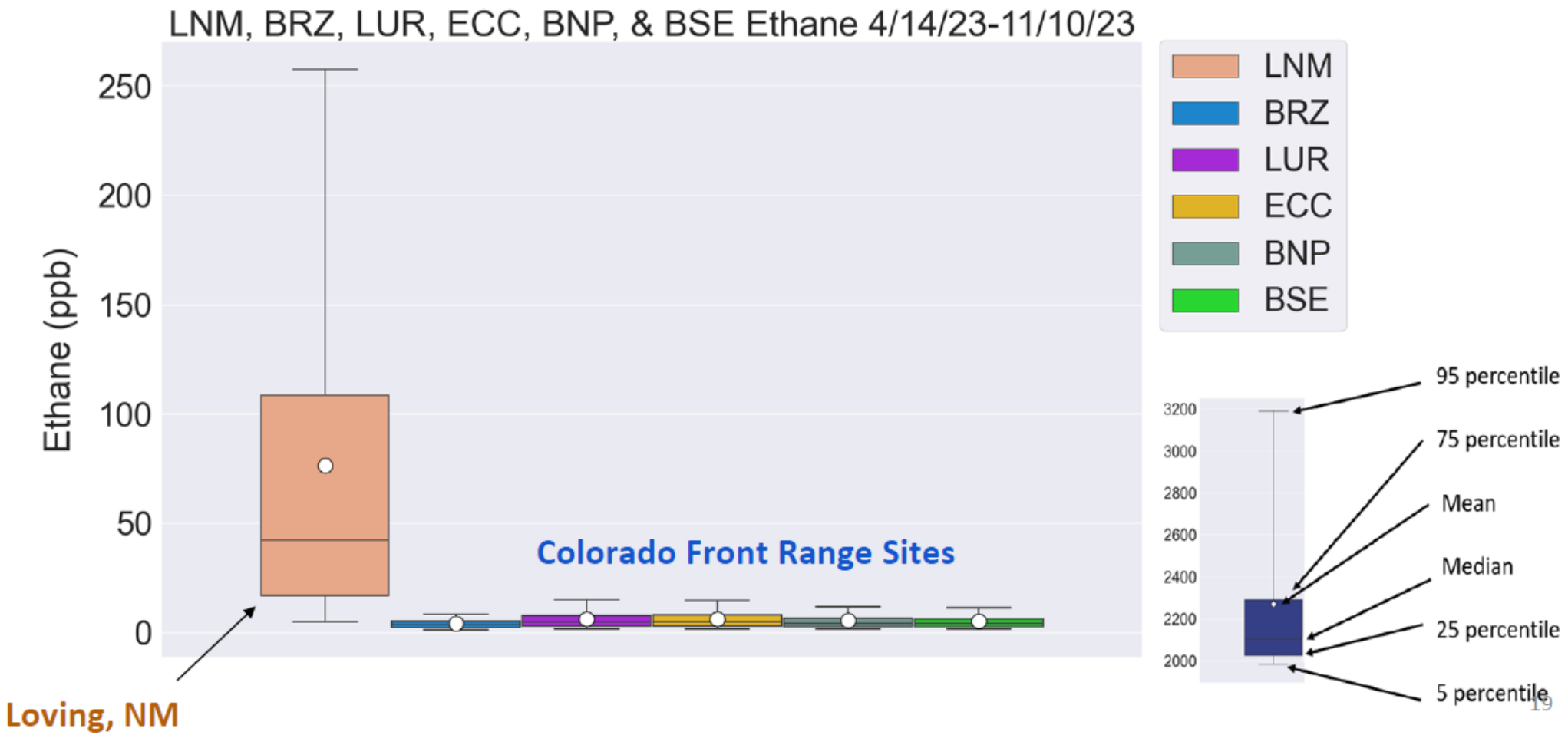








Ethane at Loving, NM, compared to Colorado sites



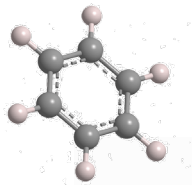
Benzene at Loving, NM, compared to Colorado sites

Web Search: "Health Risks" "Exposure" "Benzene" "No safe levels"

"There is no safe level of exposure to benzene, as it can cause health problems even at low levels. Benzene is a chemical that can cause acute leukemia and other hematological cancers. It can affect the blood-forming system at low levels of exposure, and there is no evidence of a threshold."

"Key sources including the CDC (Centers for Disease Control and Prevention), the EPA (Environmental Protection Agency), and the International Agency for Research on Cancer (IARC), classify benzene as a known human carcinogen and state that there is no safe level of exposure due to its potential to cause health issues even at low levels."

Benzene at Loving, NM, compared to Colorado sites

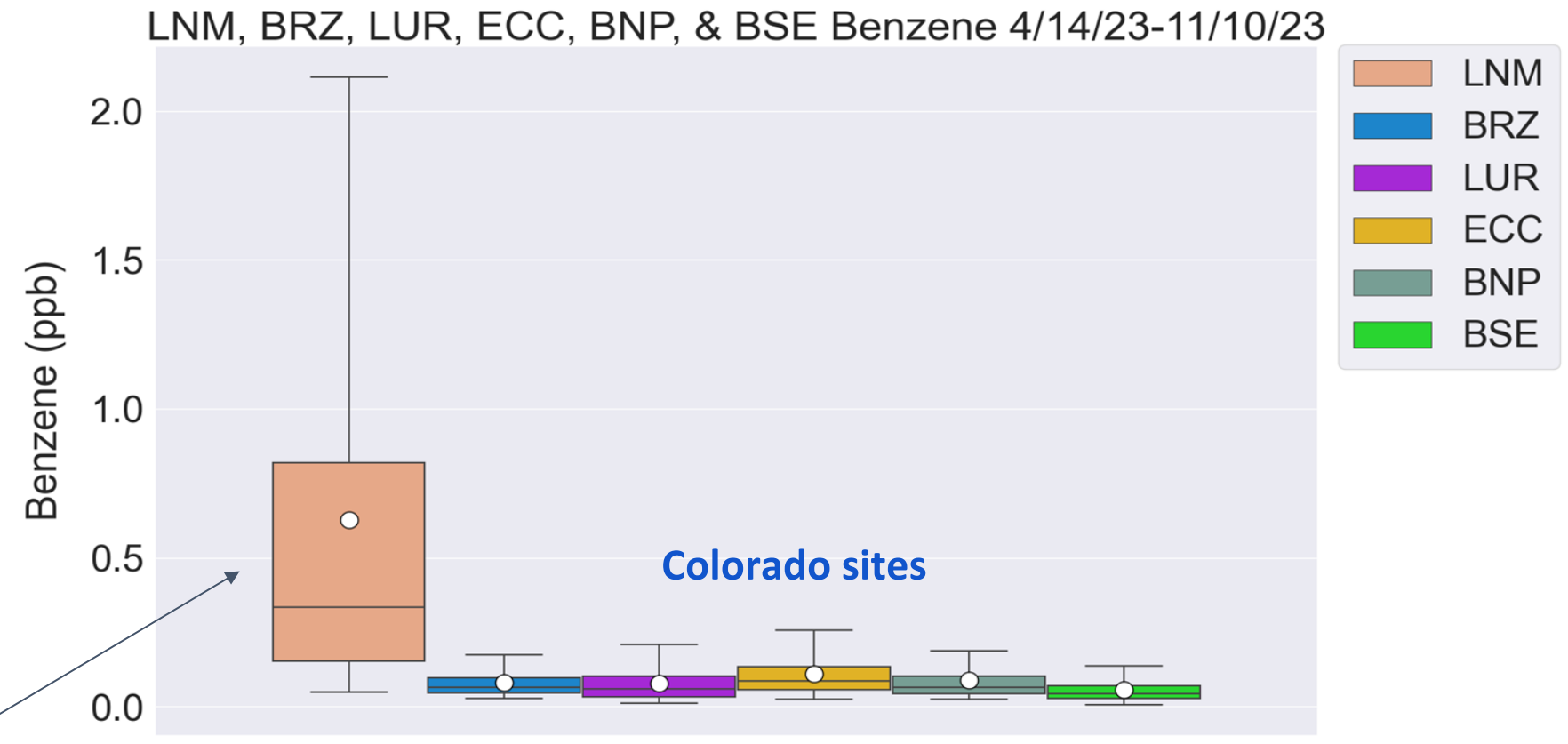


Loving

Colorado sites

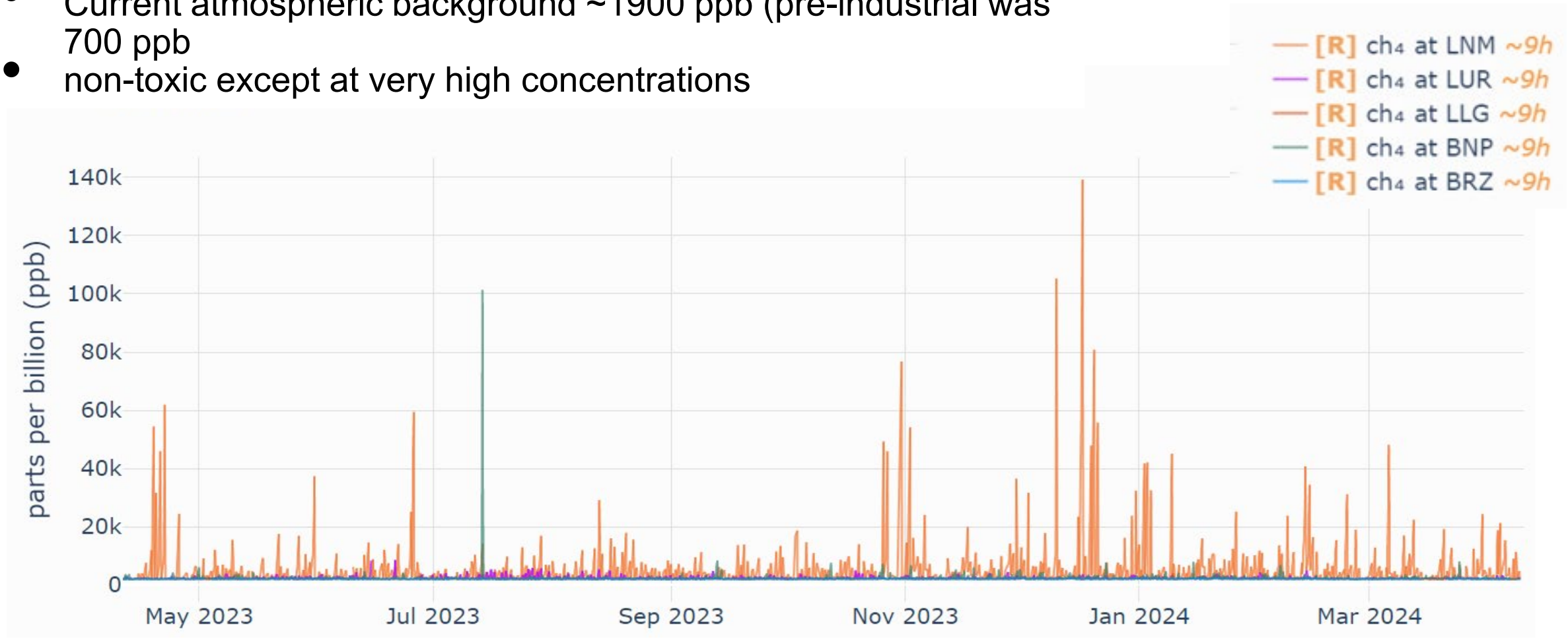
Benzene at Loving, NM, compared to Colorado sites

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

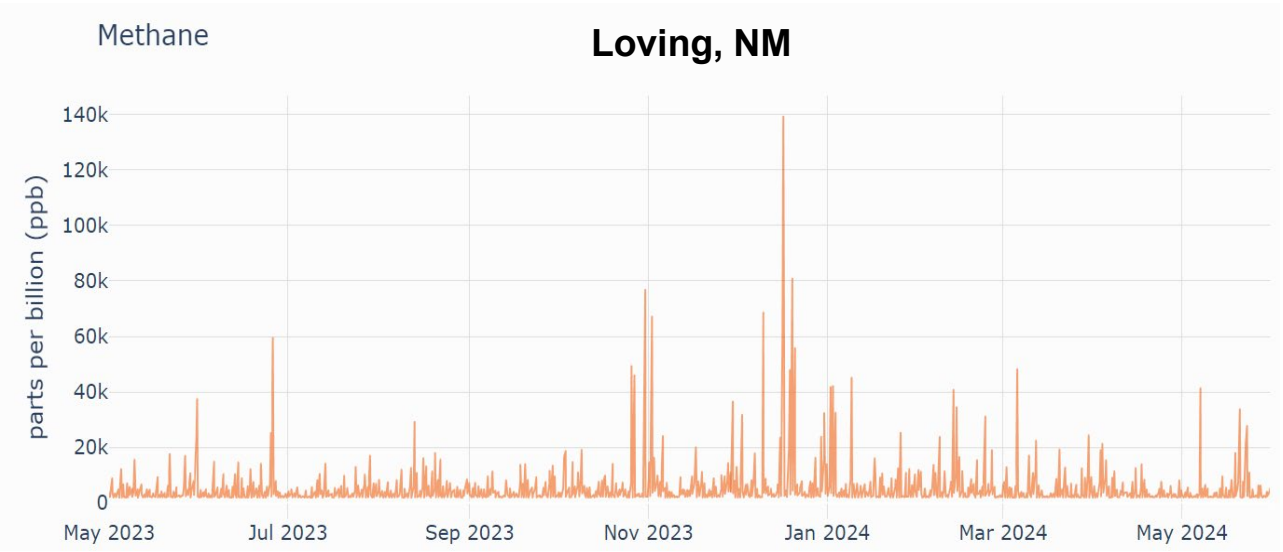


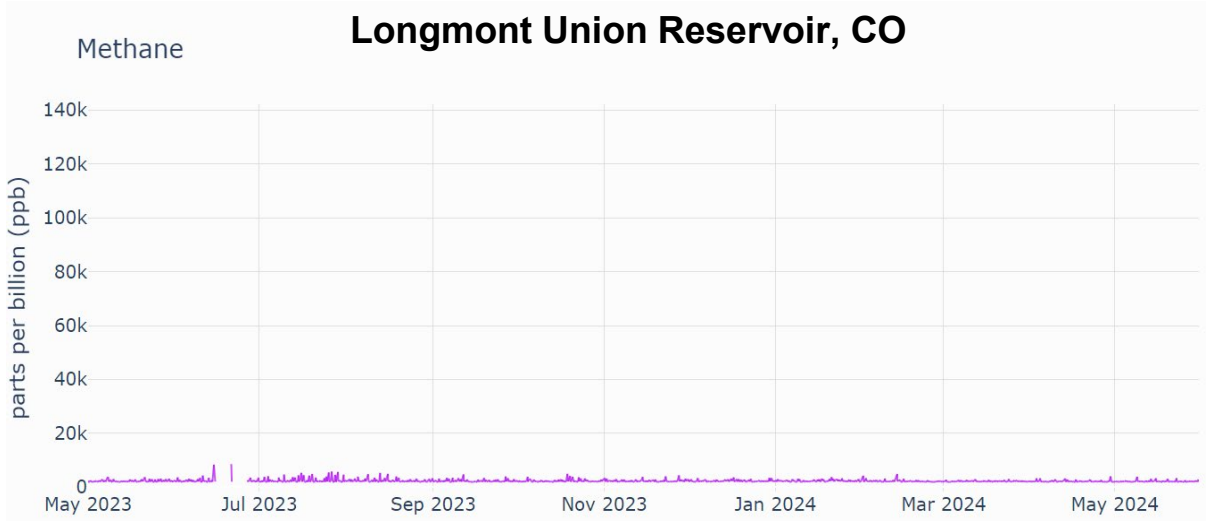
Methane at Loving, NM, compared to Colorado sites

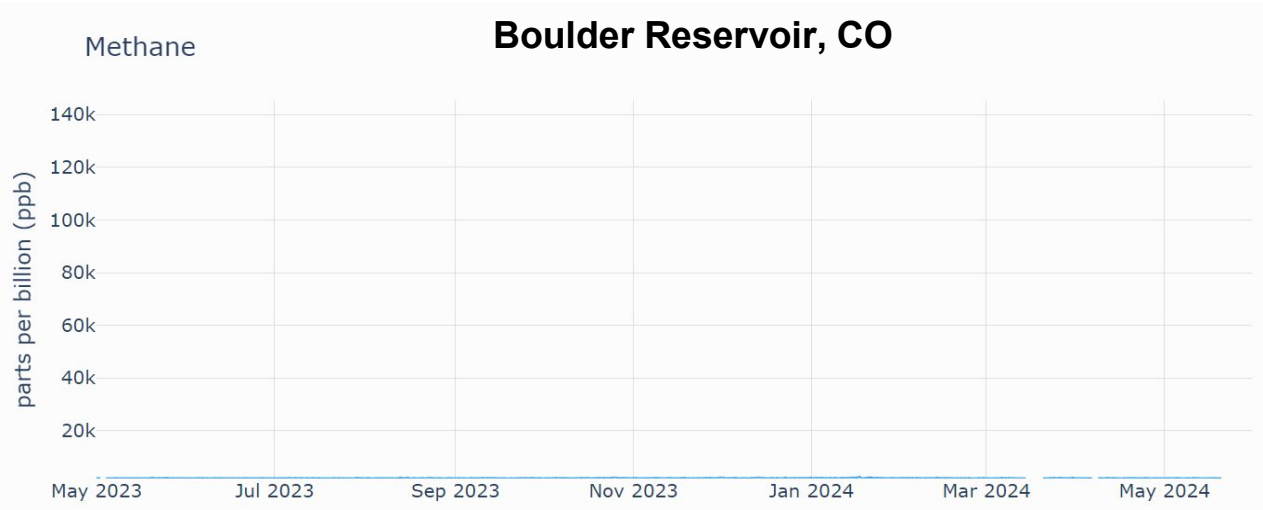
- potent Greenhouse Gas causing ~ 30% of Global Warming
- major constituent of natural gas
- Current atmospheric background ~1900 ppb (pre-industrial was 700 ppb
- non-toxic except at very high concentrations

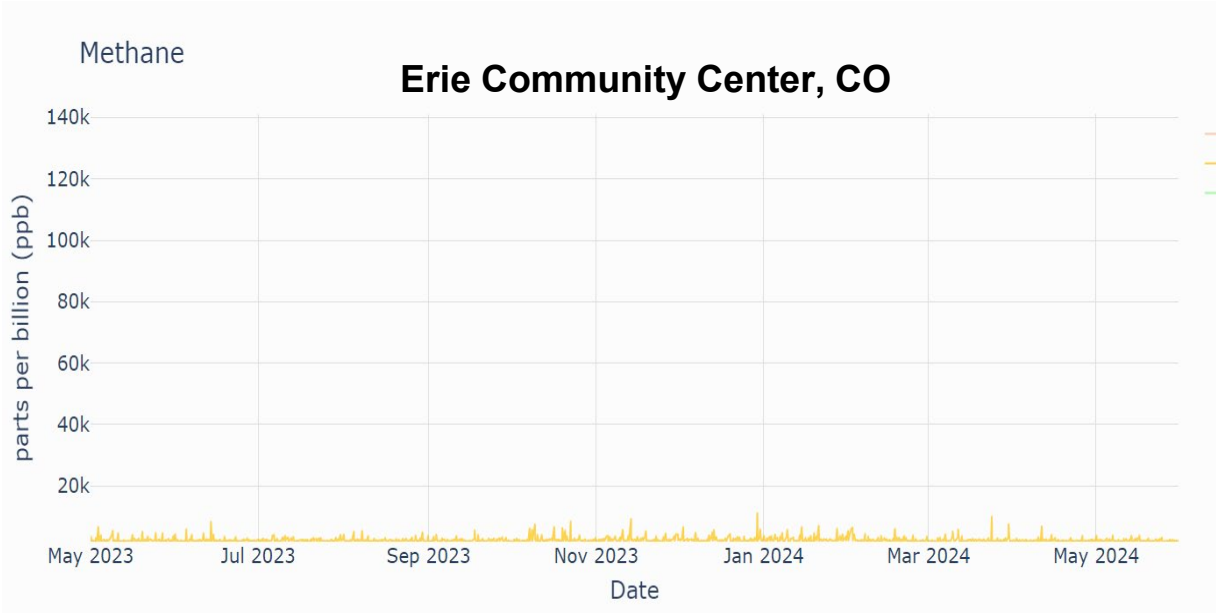


Methane at Loving, NM, compared to Colorado sites

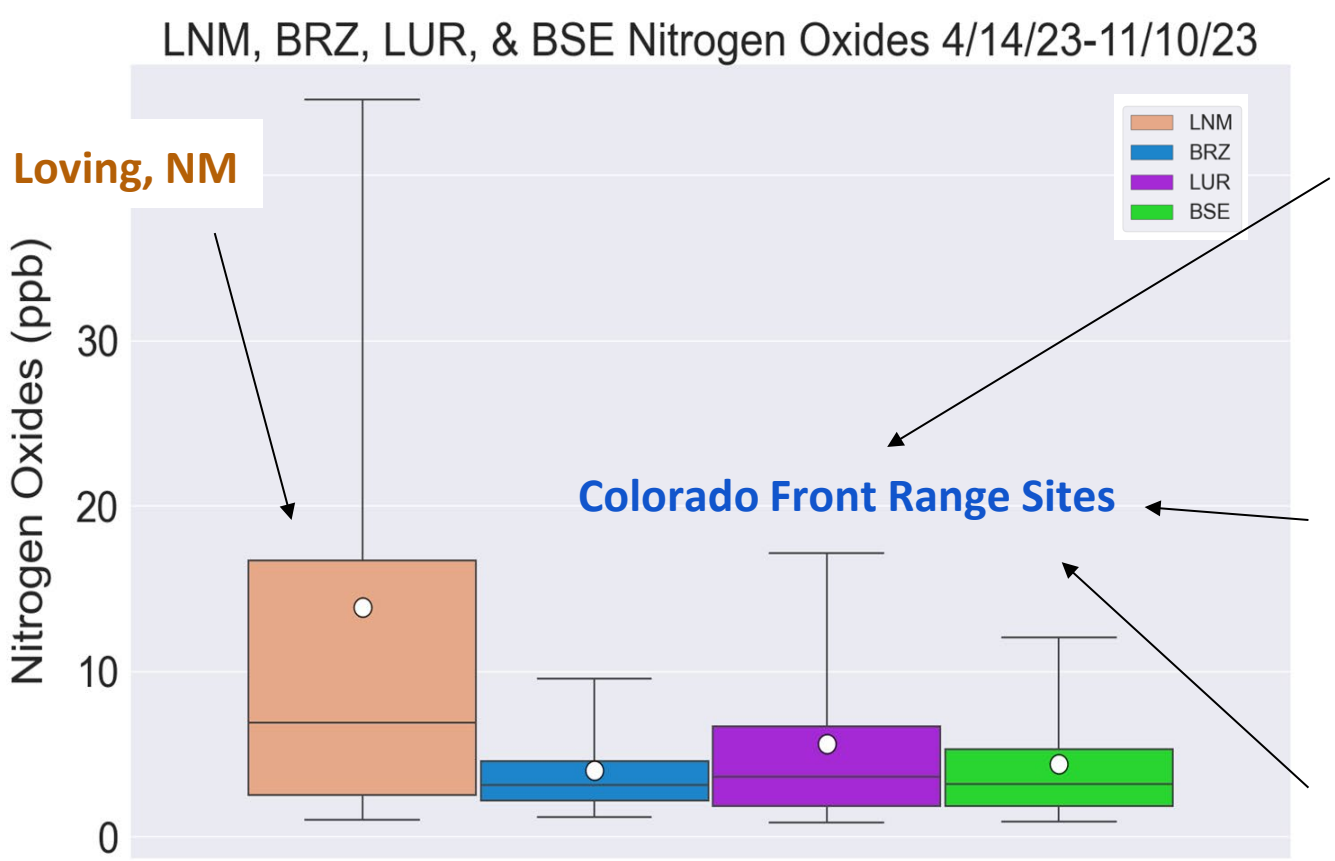


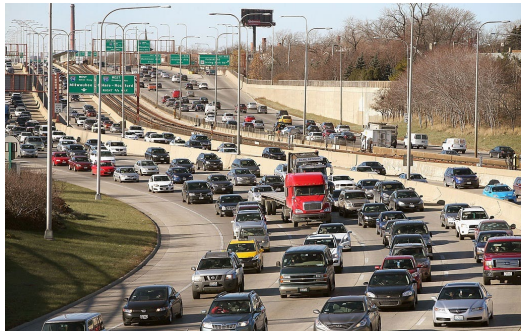






Nitrogen oxides (NOx) at Loving, NM, compared to Colorado sites





Eddy County population density 13 vs 4,674 people per square mile in Denver

Summary

- Implemented air monitoring in Loving, NM, in April 2023 and operated for one year – ended in June 2024.
- Operated continuously with less than 2% downtime.
- To the best of our knowledge, most extensive air monitoring program in NM.
- Eddy County has been exceeding the NAAQS threshold but is not yet been designated as out of compliance under the Clean Air Act.
  - more ozone exceedances and higher ozone than comparison sites in CO and nationwide that have been designated as serious non-attainment status for 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 emissions of NOx and VOC emissions from oil & gas operations.

Acknowledgements

HEI energy

ConocoPhillips for letting us carry out this research on their property in Loving, NM

Disclaimer

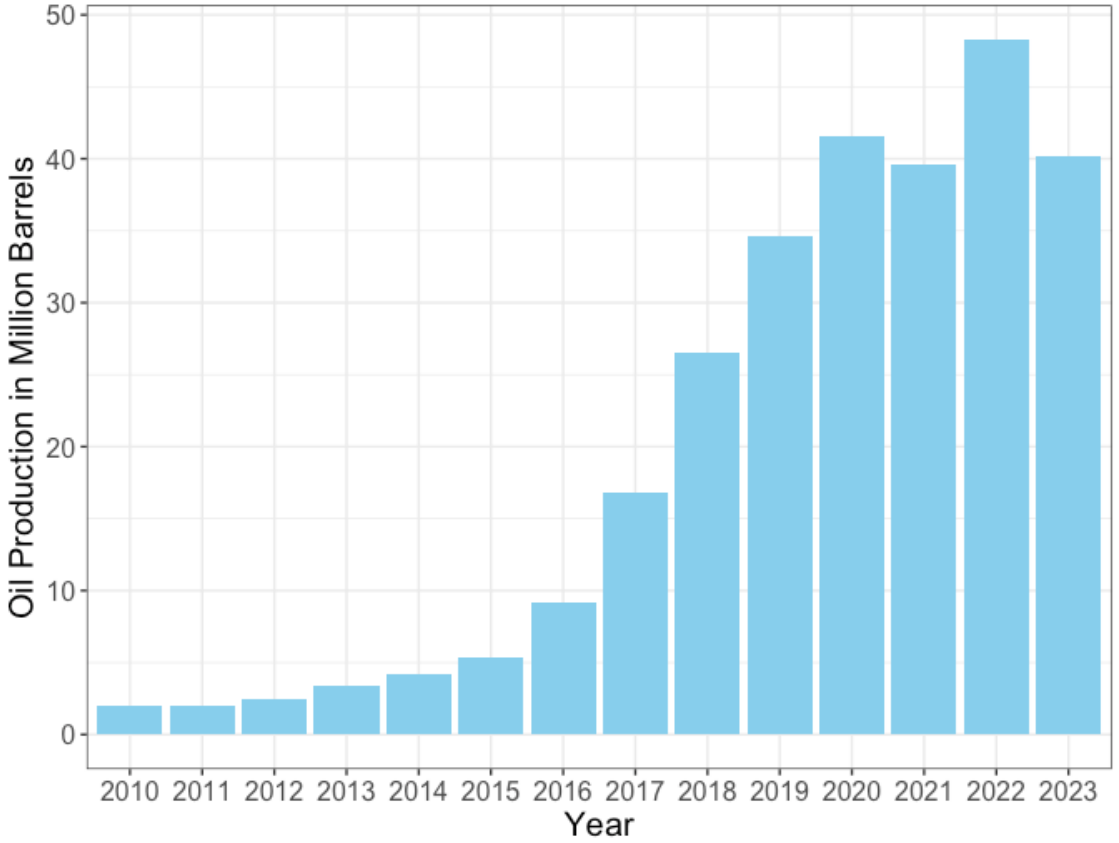
None of the research results presented herein have yet undergone HEI's rigorous peer review process.

Q&A Slides

General

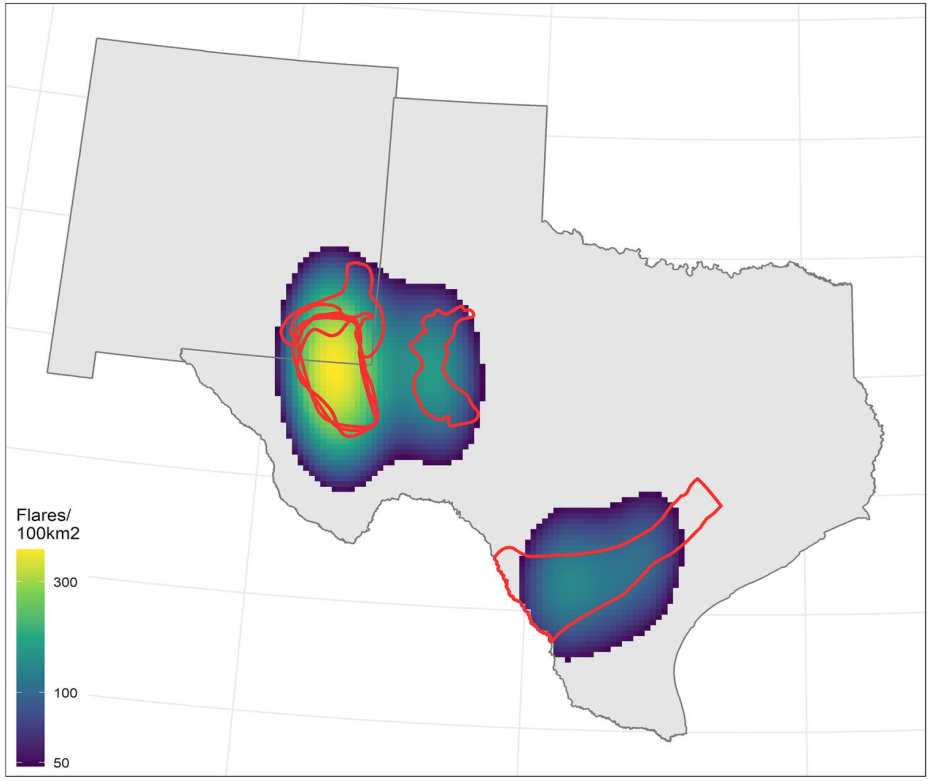
Study Motivation

Annual oil production has increased over 5 times since 2016 at wells located within 15 miles of Carlsbad, NM.



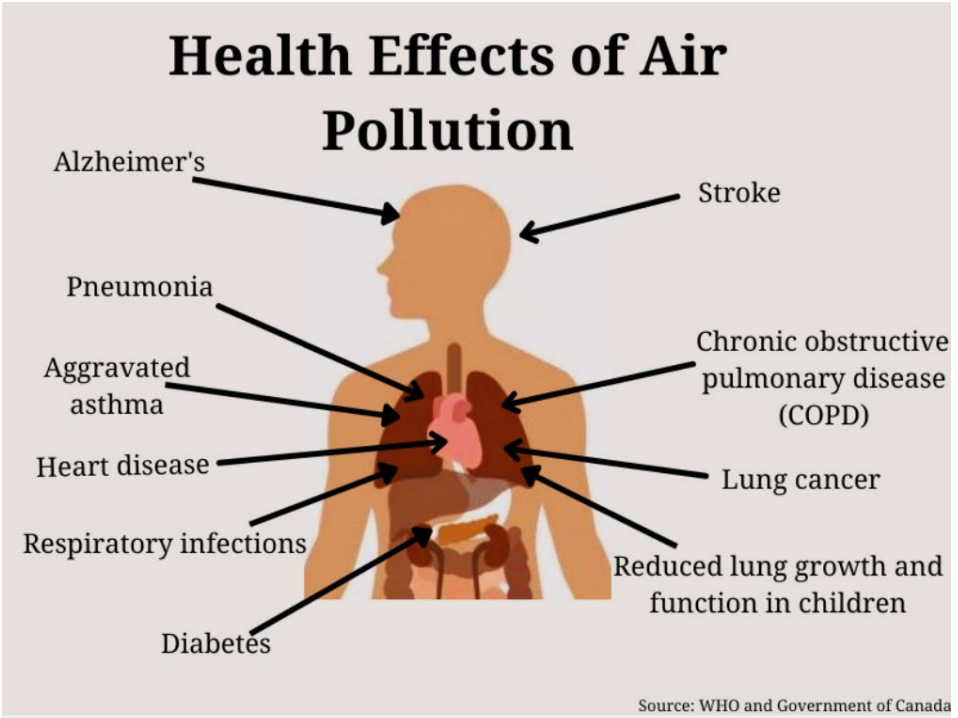
Data from EnverusTM (pulled 12/6/2023)

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



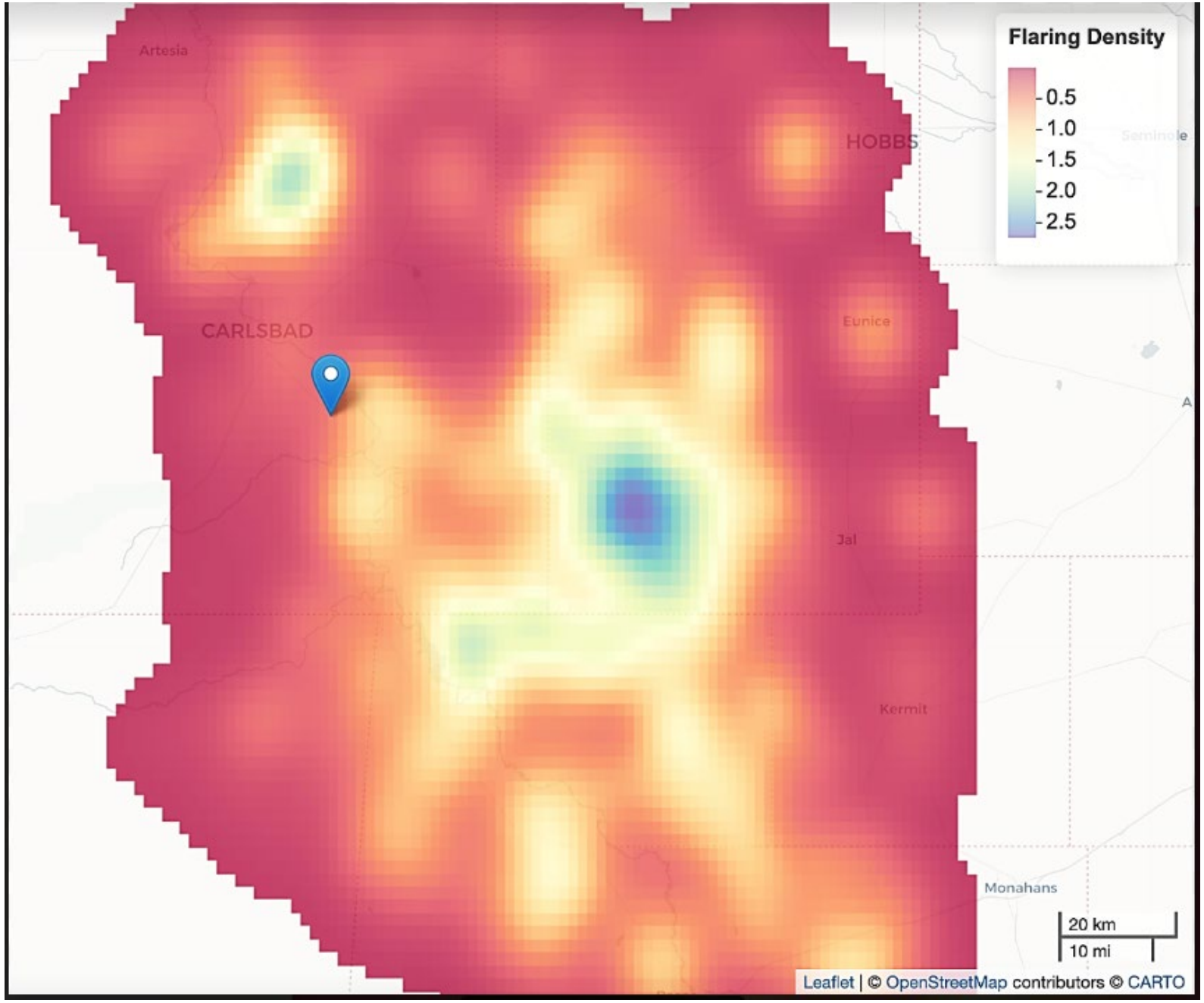
Cushing *et al* (2021) *Environ. Res. Lett.* **16** 034032

Air pollutants studied



The health effects of air pollution on the body. Media by Chantal Schromeda.

- Ozone
- Carbon Monoxide
- Sulfur Dioxide
- Hydrogen Sulfide
- Nitric Oxide, Nitrogen Dioxide
- Methane
- Volatile Organic Compounds (VOCs, ethane, propane, benzene, hexane, toluene, …)
- Airborne Gas and Particle Radioactivity (radon, thoron….)



Flaring density (#/km^2) around our site

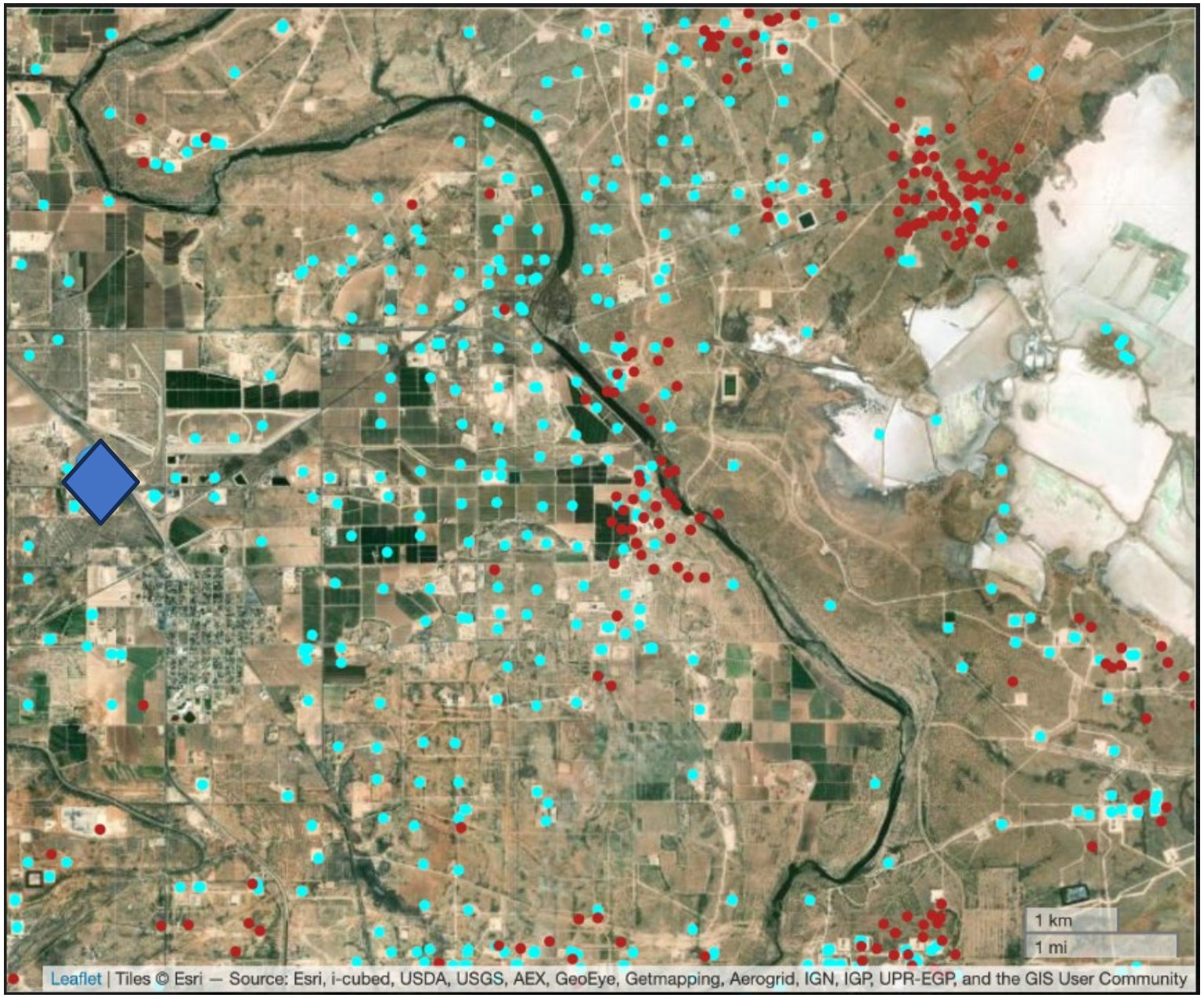
Study Objectives

Our study is designed to better understand emissions and population exposure to air pollutants and noise coming from Unconventional Oil and Gas Development (UOGD)

1) Use fixed-placed, active air quality monitoring to characterize the emissions and impacts from UOGD (stationary trailer)

2) Use distributed, passive sampling to understand the potentially uneven distribution of selected toxic air pollutants (volunteer-driven)

3) Focus on UOGD related flaring by combining our measured data with satellite observations



Blue marker is our site, cyan dots are wells, red dots are flares between 5/1/23 and 4/31/24.

What we are measuring in Loving, NM

Air Pollutants and Greenhouse Gases

- ***Ozone (O_3)***
- Volatile organic compounds (VOCs), 24 species, incl. *ethane*, propane, … acetylene, BTEX, ….
- Nitrogen Oxides (NO_x)
- Sulfur Dioxide (SO_2)
- Hydrogen Sulfide (H_2S)
- Carbon Monoxide (CO)
- *Methane (CH_4)*
- Carbon Dioxide (CO_2)

Radioactivity

- *Radon (Gas)*
- *Radon decay products (Particles)*

Noise

- Decibel levels at different frequencies

Ozone forms from:

- **VOCs as the fuel**
- **NO_x as the catalyst**
- **Sunlight as the driver**

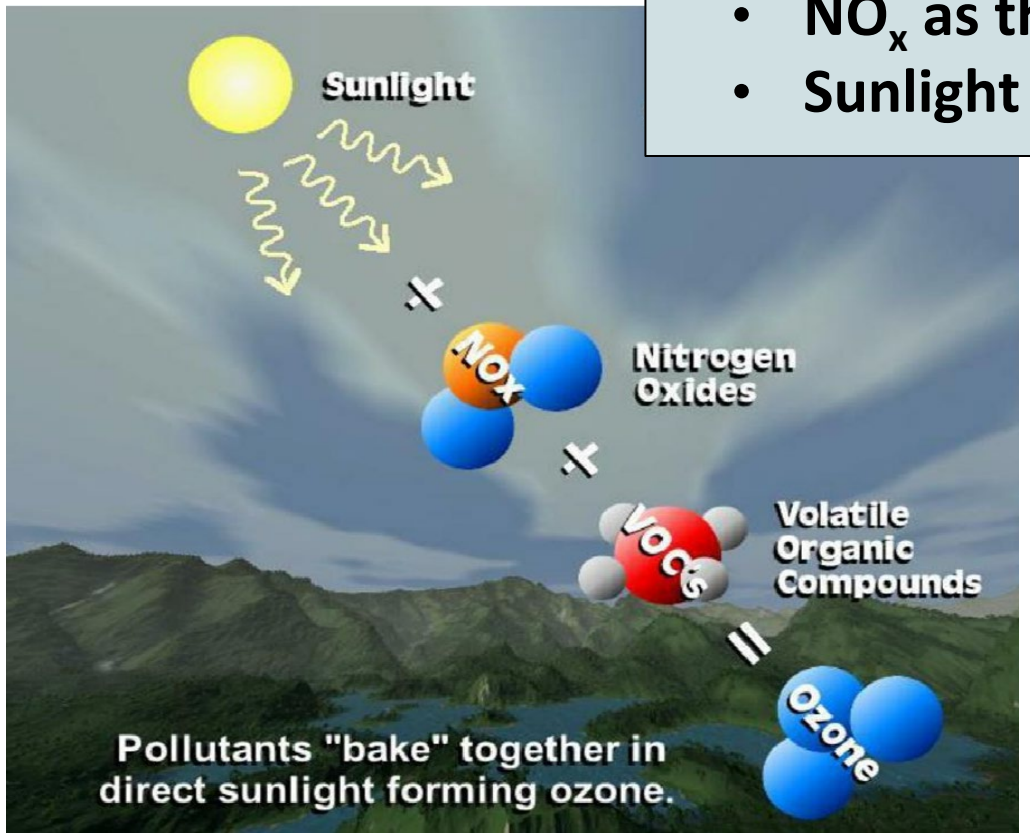
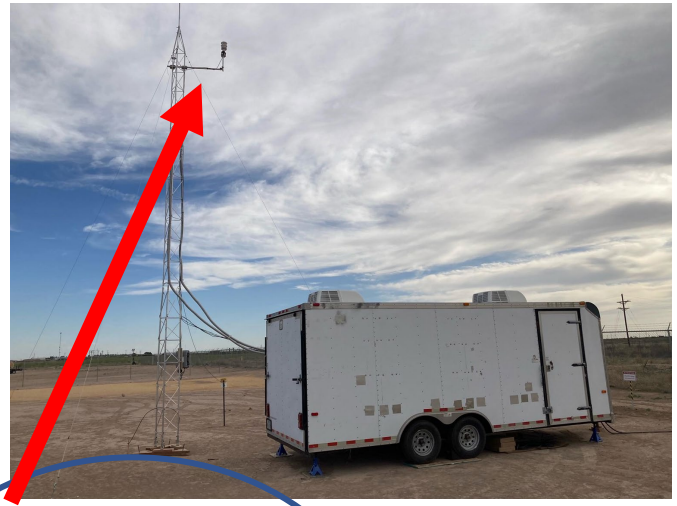


image credit: NASA/NSF

Real-Time (Continuous) Measurements



Wind Speed
Wind Direction
Rain
Relative Humidity
Temperature

Carbon Monoxide
Carbon Dioxide
Sulfur Dioxide Hydrogen Sulfide
Nitrogen Oxides Ozone
Methane

Volatile Organic Compounds (ethane, propane, … acetylene, benzene, toluene, ….)

Airborne gas and particle radioactivity

Measures to reduce exposure to air pollutants

Children, **workers,** and those with **pre-existing conditions** are most at risk

Individual-level

Wear a face covering outdoors.

Limit outdoor physical activity on bad air days.

Keep house windows closed.

Use home air purifiers to improve indoor air quality.

Avoid and safely store products that contain VOCs (paint, glues)

Community-level

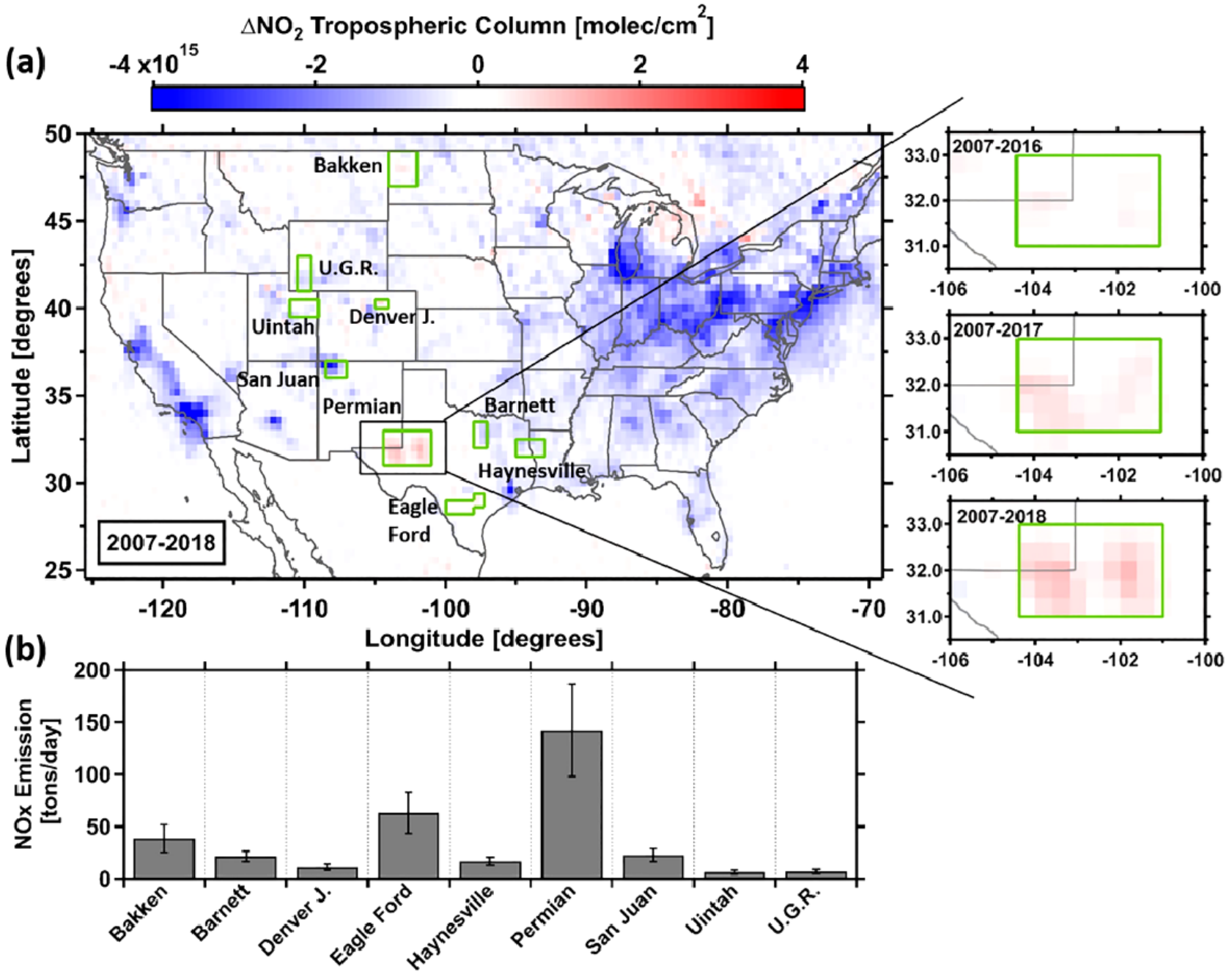
Increase buffers (setbacks) between homes & industry.

Reduce outdoor recess on bad air days.

Increase green space & vegetation.

Support investing in HVAC in schools & community centers.

Nitrogen Oxides

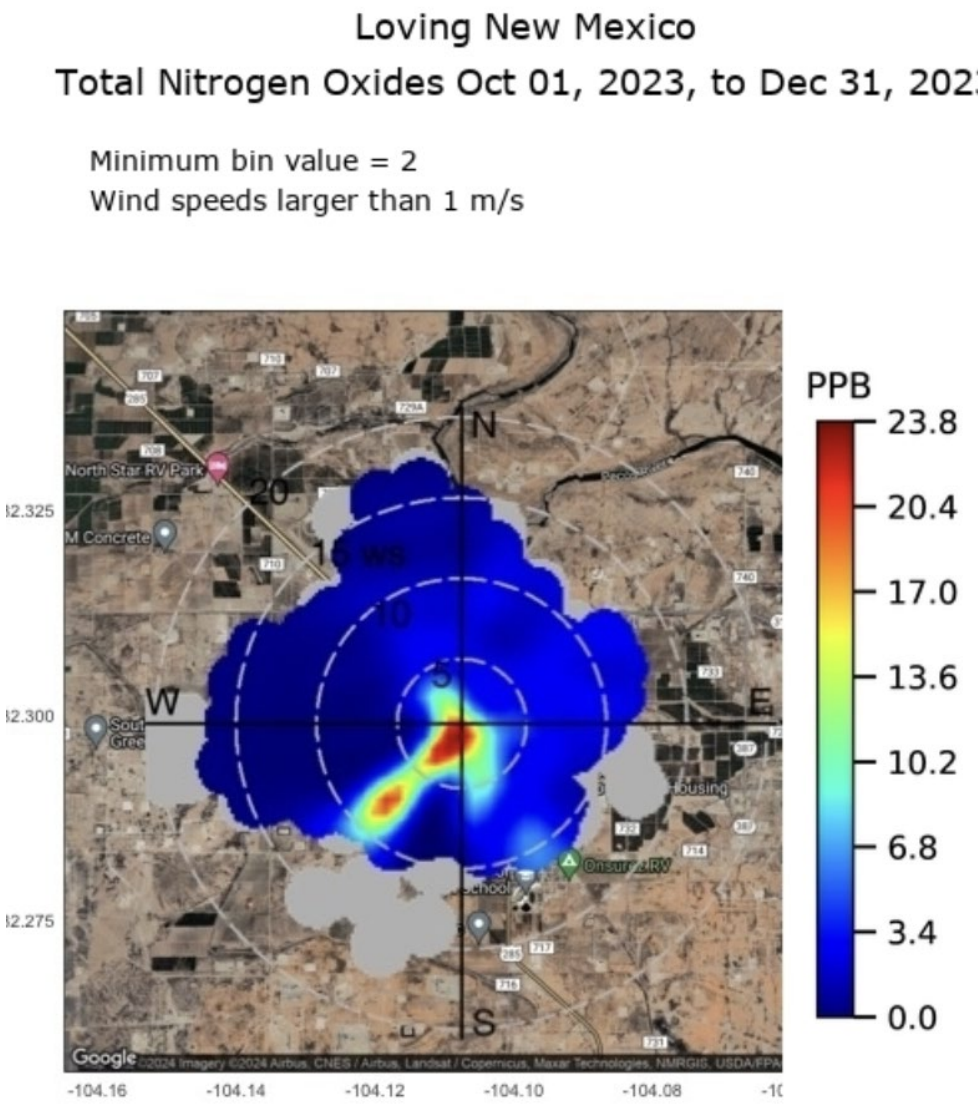


Upward NOx trend in the Permian as determined from satellite measurements

Dix et al., GRL 2019: *Nitrogen Oxide Emissions from U.S. Oil and Gas Production: Recent Trends and Source Attribution*

Figure 2, 2007-2018 trend

Nitrogen oxides at Loving (LNM) probably has strong signal from nearby flaring



- Nitrogen oxides (NOx) are the catalyst for ozone formation
- Emitted from combustion processes
- 2–3 times higher mean than at Colorado comparison sites despite Colorado having a 10 times higher population (and traffic)
- However, wind analyses suggest that emissions are dominated by strong point source(s), possibly gas flaring

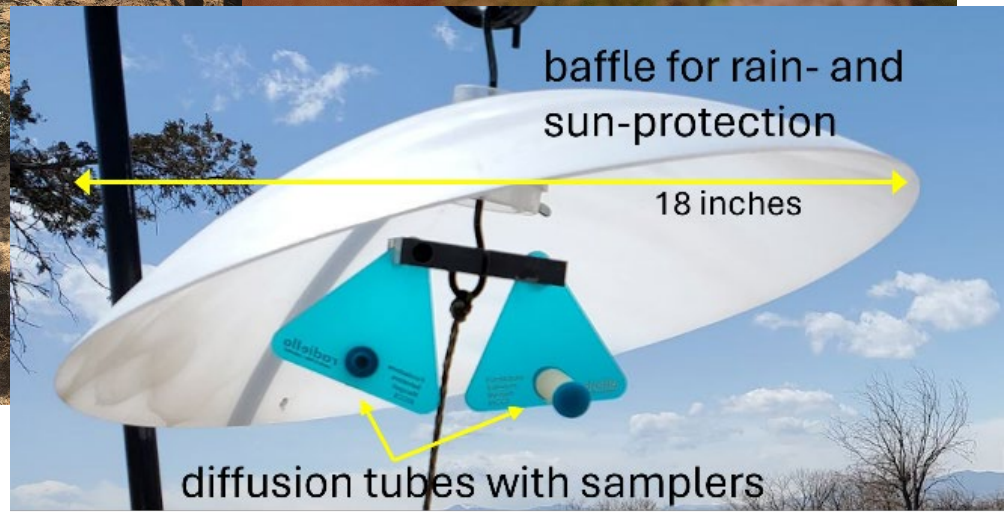
Passive Sampling Network and Benzene

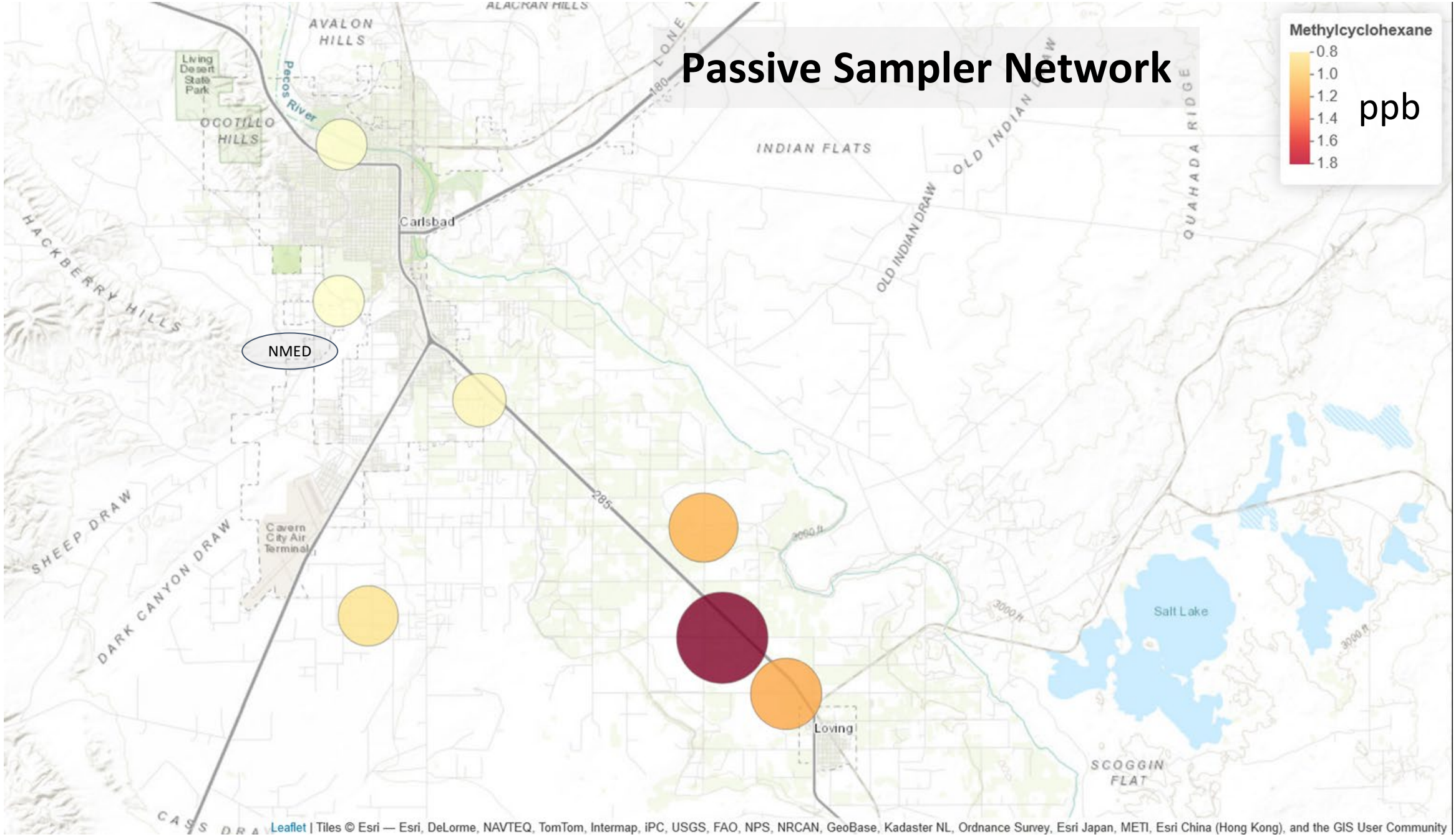
Volatile organic compounds

Passive sampling for VOCs like benzene and toluene, in areas where people live and work.

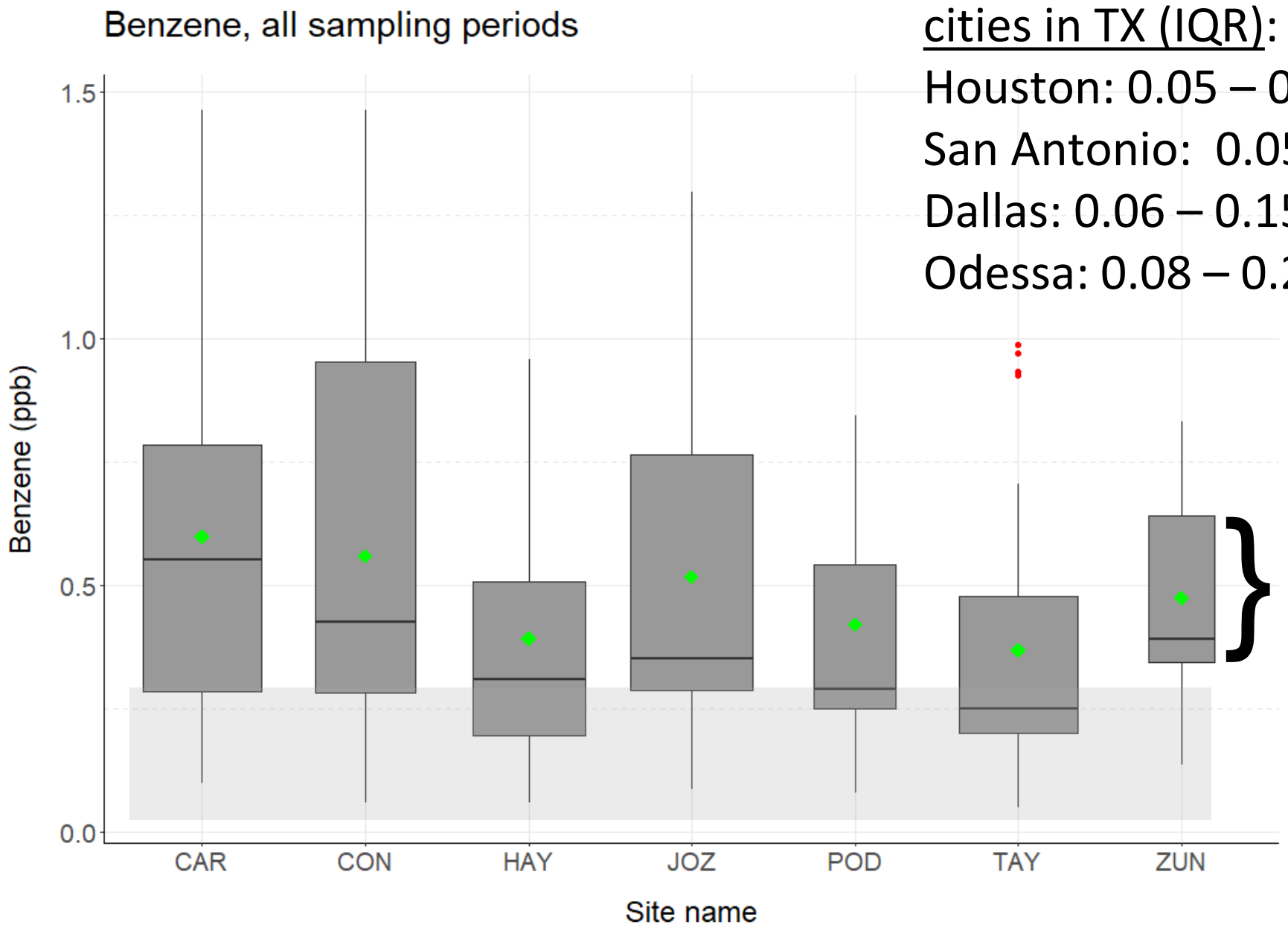
Ambient air average exposure during 5-10 days at a time

- two replicate samples
- white baffle as sampler protection from intense sunlight and rain
- samplers were shipped weekly to and from College Station, TX




Passive Sampler Network
Methylcyclohexane
0.8
1.0
1.2
1.4
1.6
1.8
ppb
NMED
Carlsbad
Loving
Salt Lake
AVALON HILLS
INDIAN FLATS
OCOTILLO HILLS
HACKBERRY HILLS
SHEEP DRAW
DARK CANYON DRAW
SCOGGIN FLAT
QUAHADA RIDGE
OLD INDIAN DRAW
Pecos River
Living Desert State Park
Cavern City Air Terminal
285
180
3000 ft
Leaflet | Tiles © Esri — Esri, DeLorme, NAVTEQ, TomTom, Intermap, iPC, USGS, FAO, NPS, NRCAN, GeoBase, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), and the GIS User Community

Exposure comparisons, I



<u>cities in TX (IQR)</u>:

Houston: 0.05 – 0.2 ppb

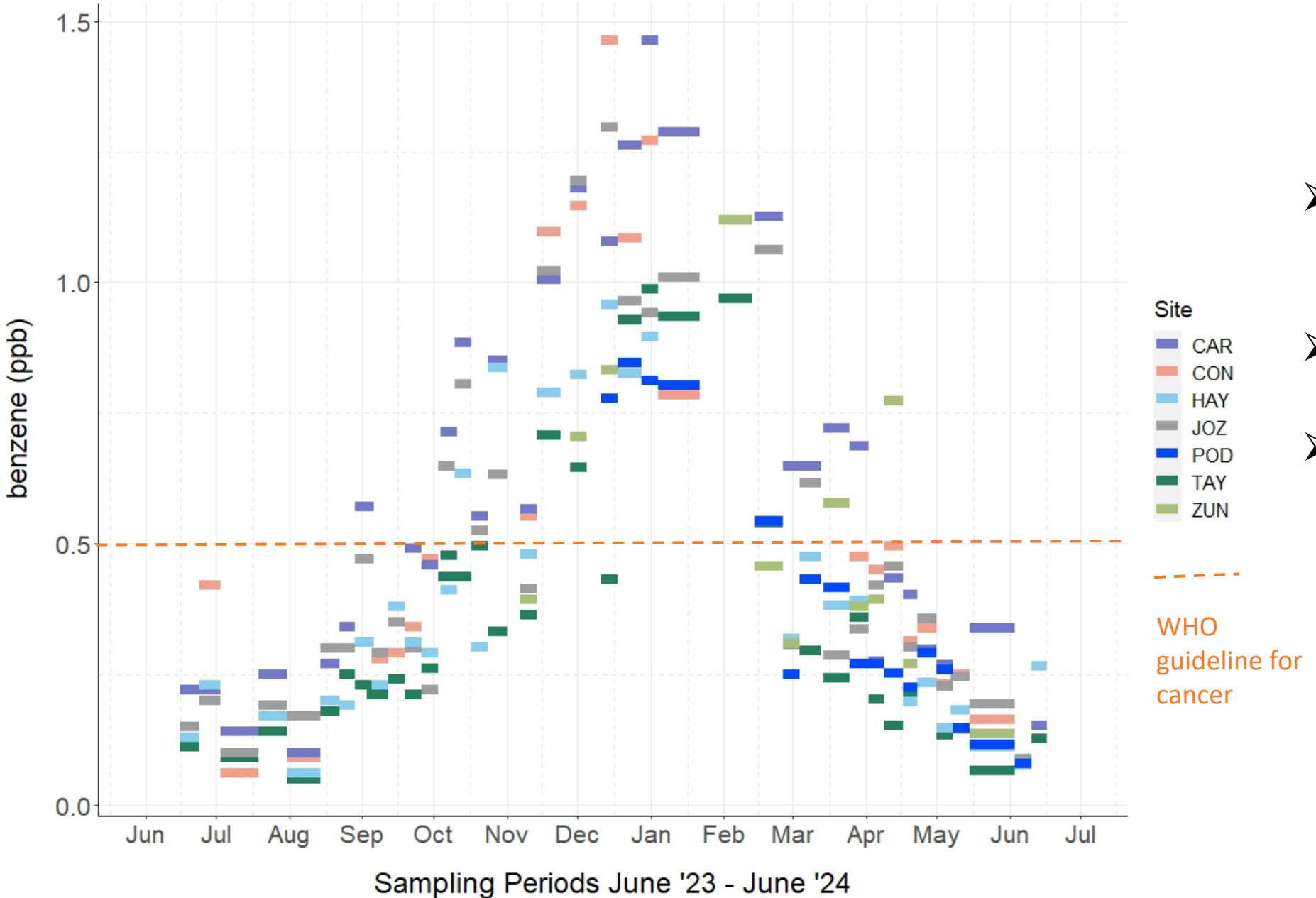
San Antonio: 0.05 – 0.1 ppb

Dallas: 0.06 – 0.15 ppb

Odessa: 0.08 – 0.29 ppb

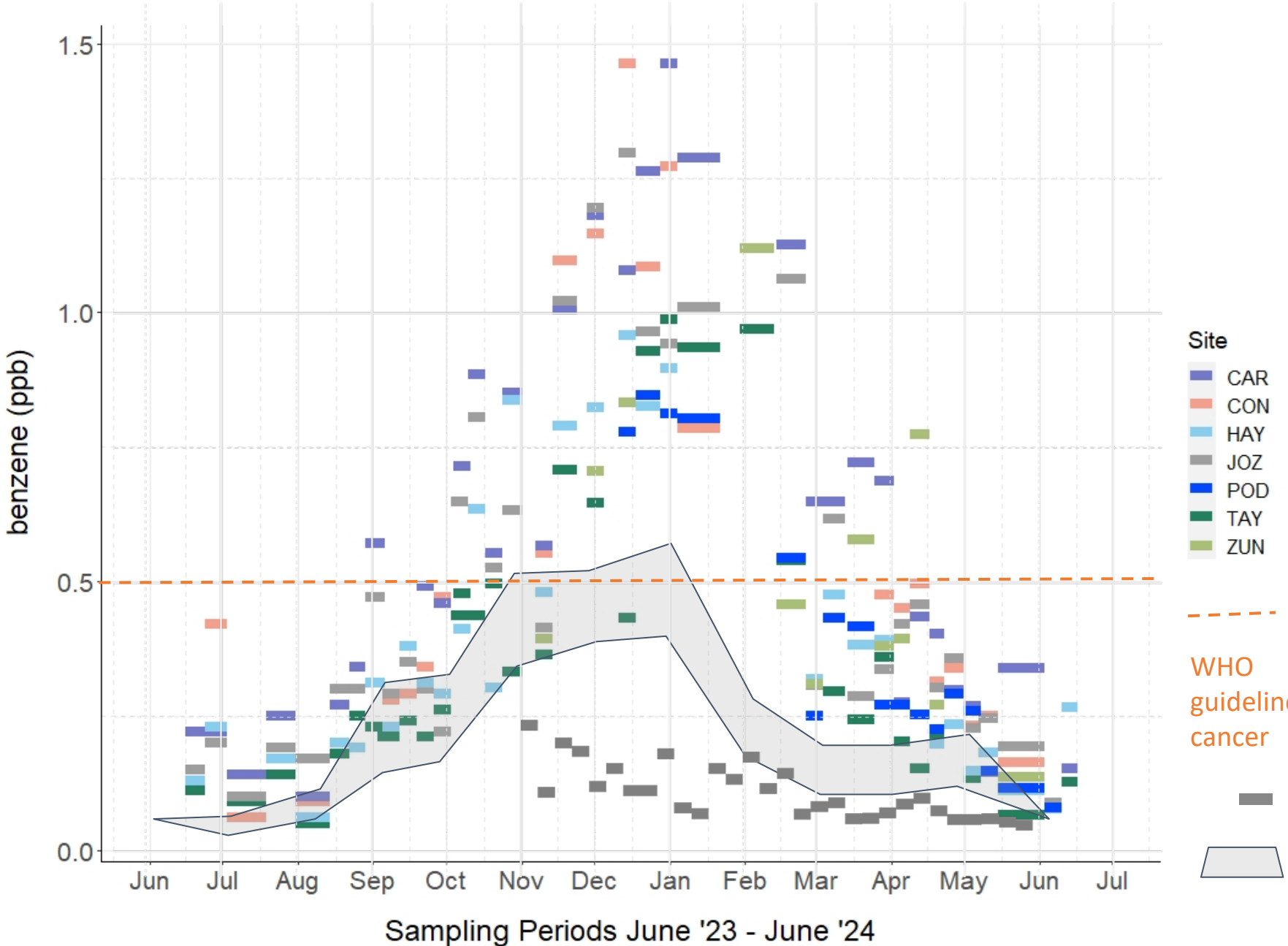
} interquartile range (IQR)

Passive sampling network: benzene concentrations



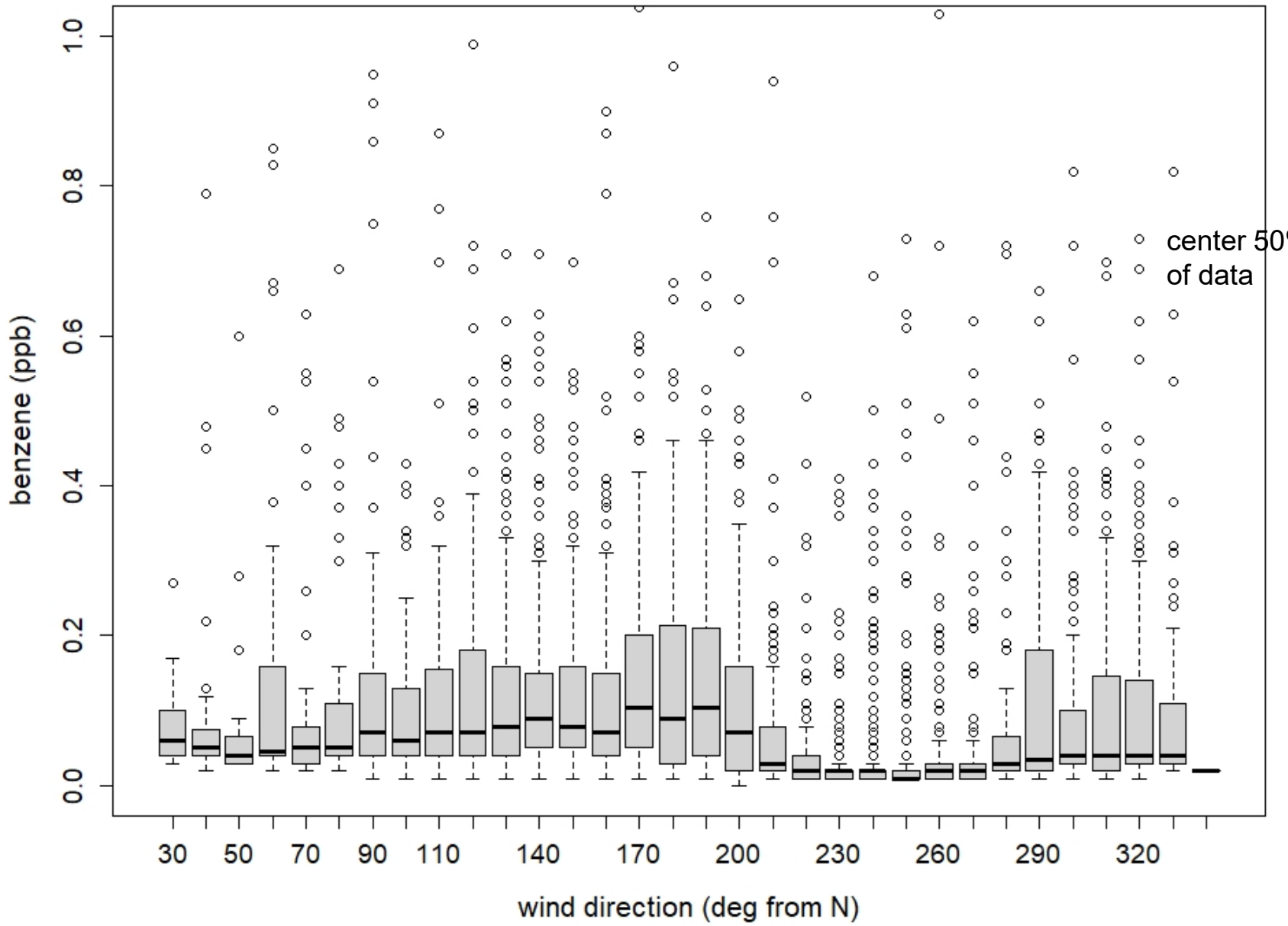
- Seasonal cycle (higher concentrations in fall and winter)
- Strong gradients between sites
- Some exceeding cancer risk guidelines for long-term exposure

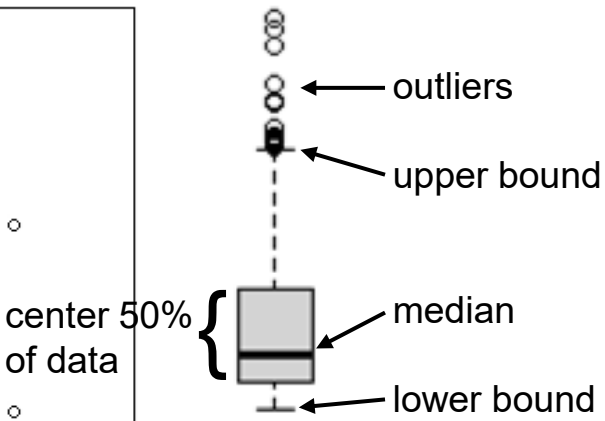
Passive sampling network: benzene concentrations



- Seasonal cycle (higher concentrations in fall and winter)
- Strong gradients between sites
- Higher levels than in Houston
- Higher than NMED reference site

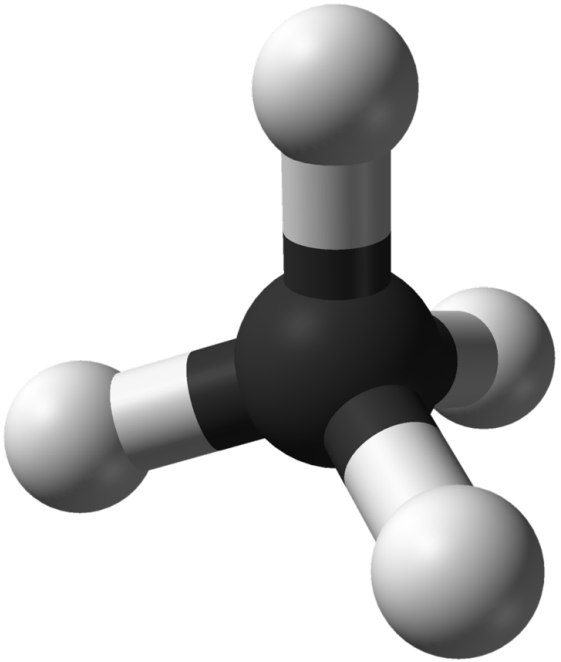
Benzene data (Nov ‘23 - Jun ‘24) from the NMED Carlsbad site





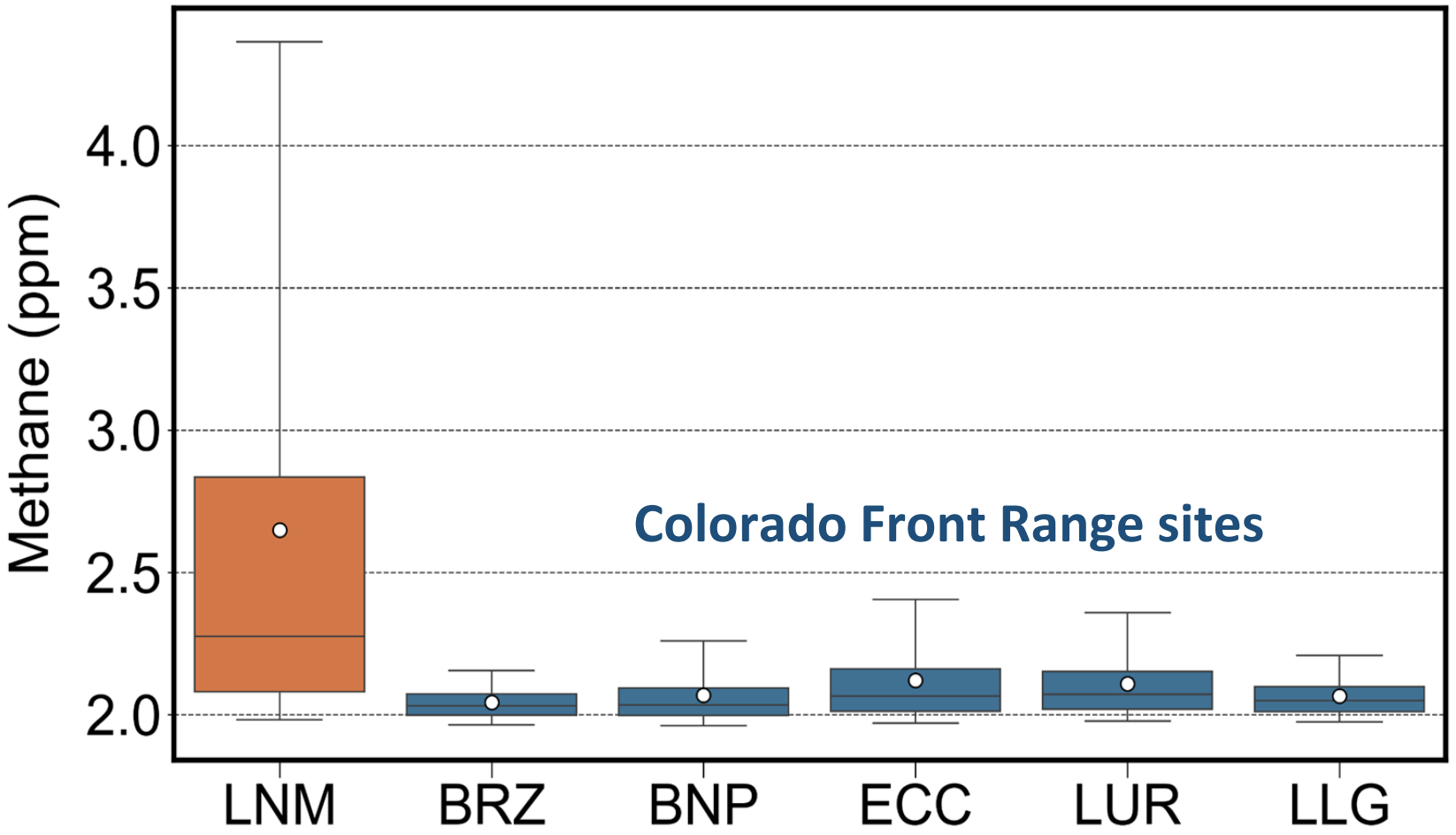
Methane

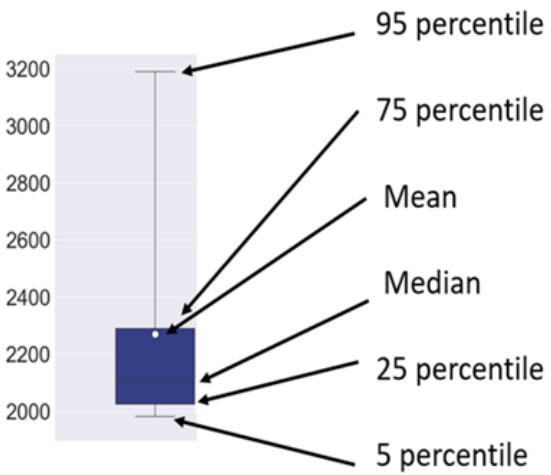
4. Methane

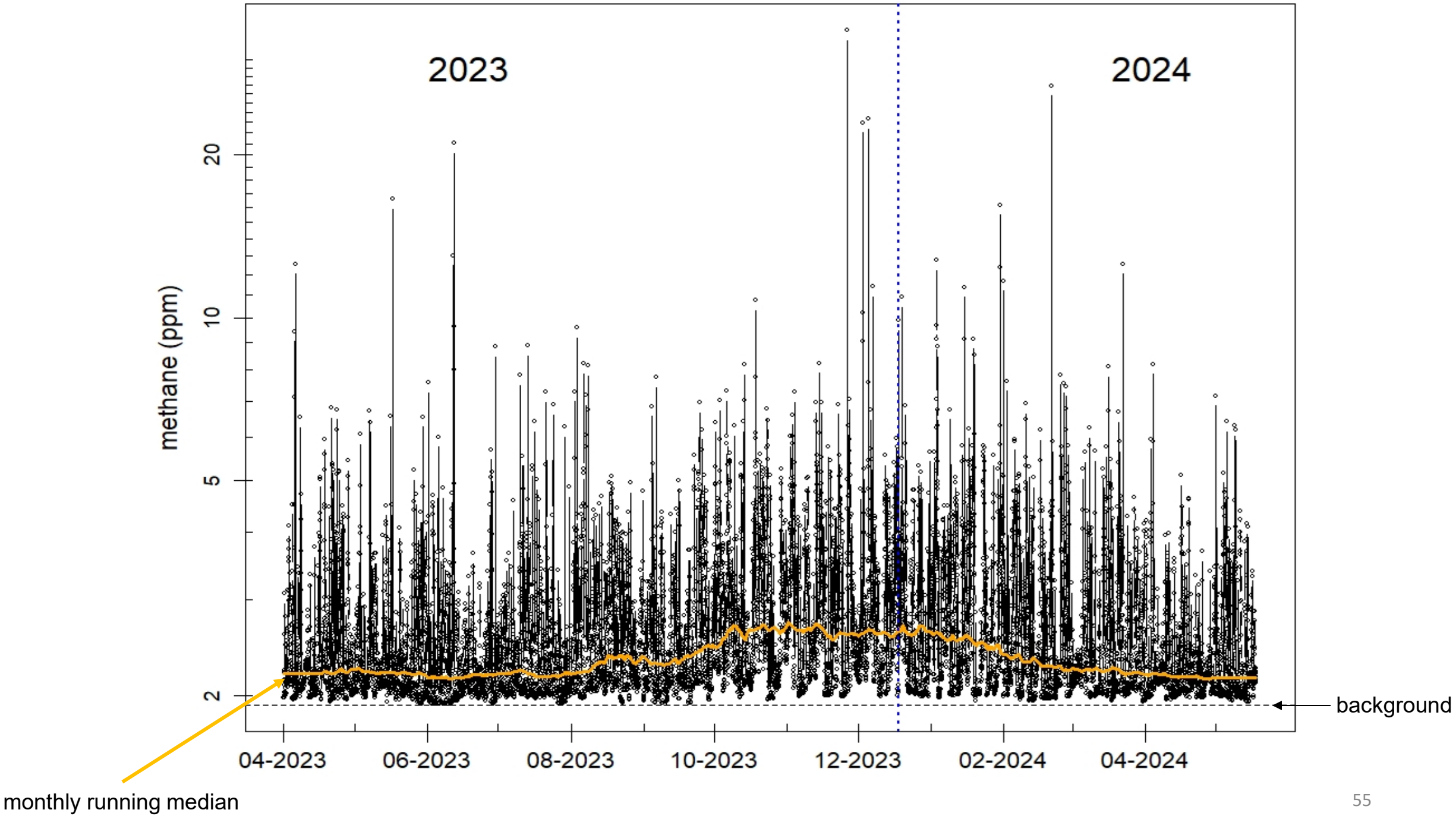


- potent Greenhouse Gas (GHG)
- major component of *natural gas*
- common atmospheric constituent
  - “background” of 1.9 ppm (pre-industrial: 0.7 ppm)
- non-toxic except at very high concentrations

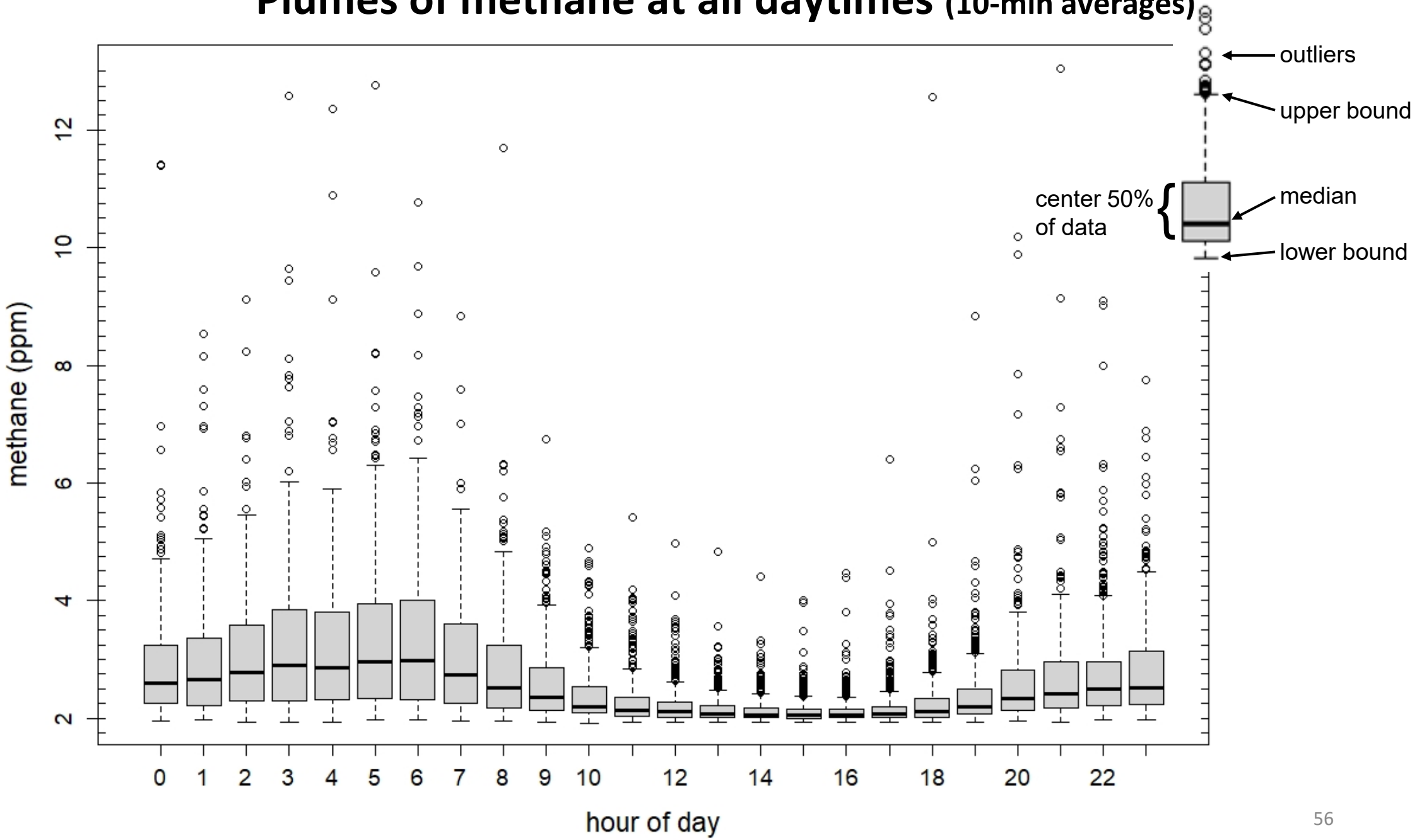
Methane at Loving, NM, compared to Colorado sites



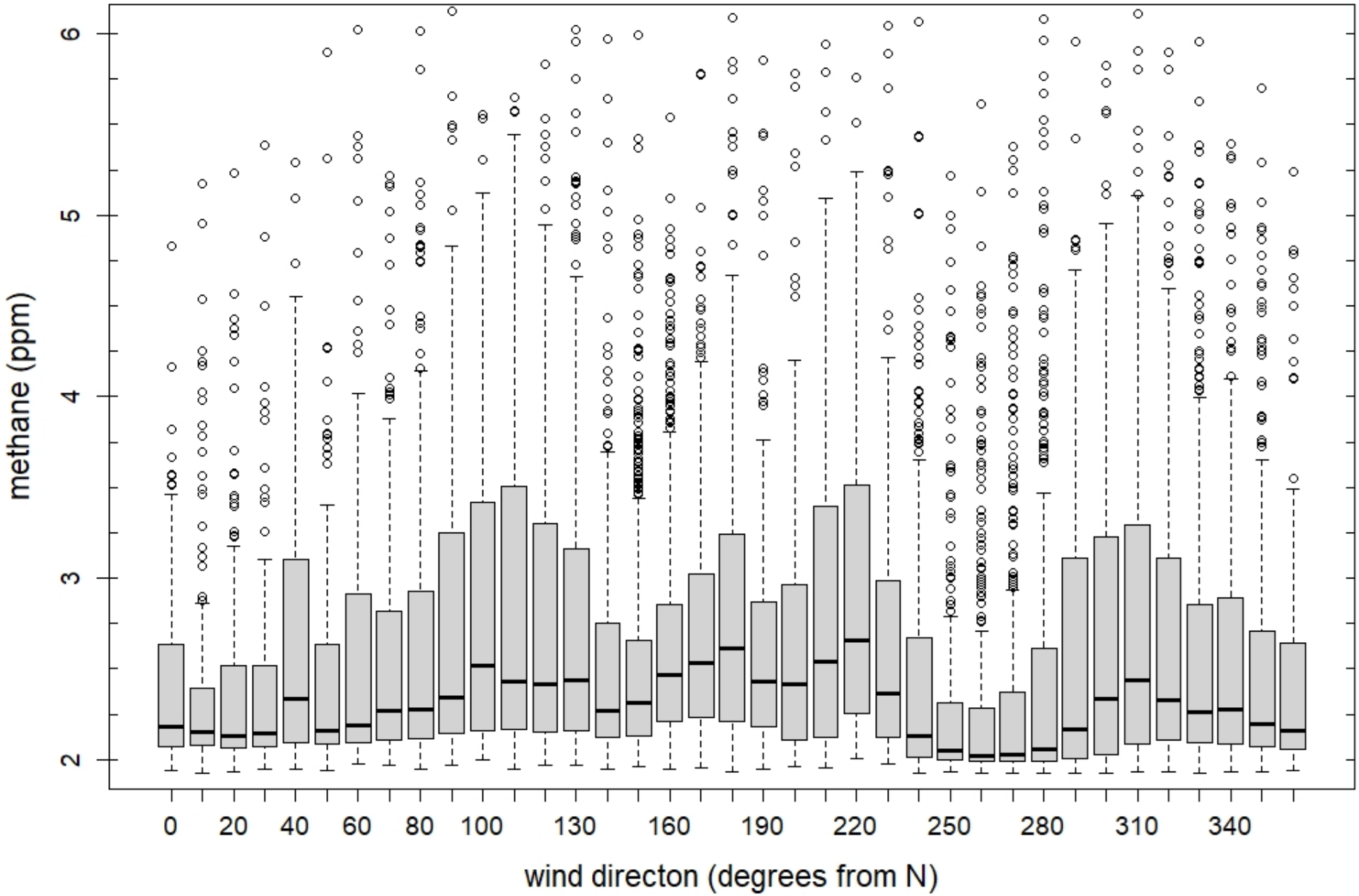


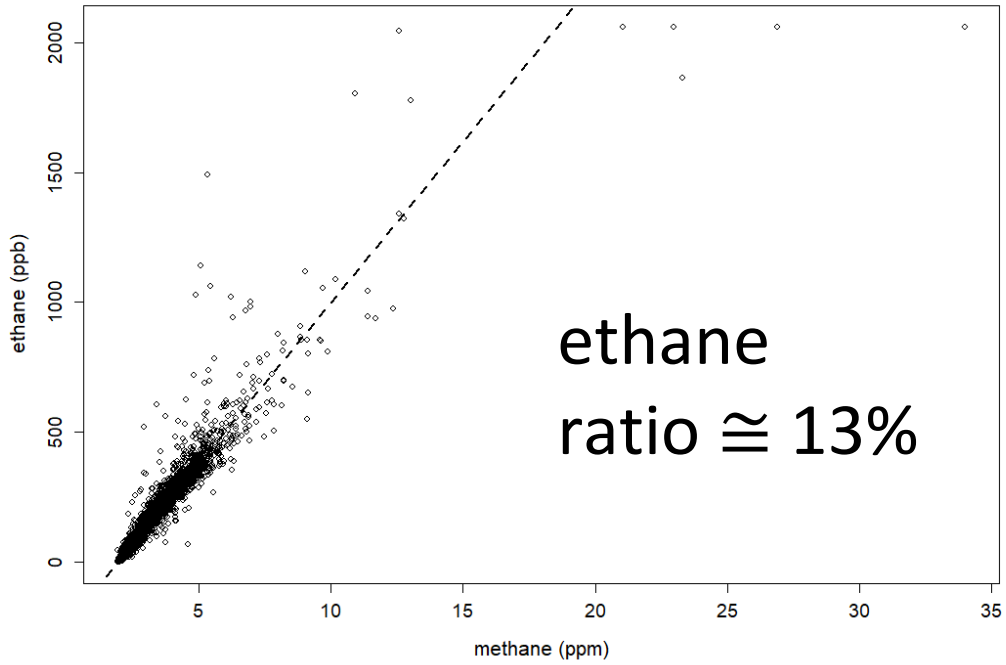

2023
2024
methane (ppm)
2
5
10
20
04-2023
06-2023
08-2023
10-2023
12-2023
02-2024
04-2024
background
monthly running median

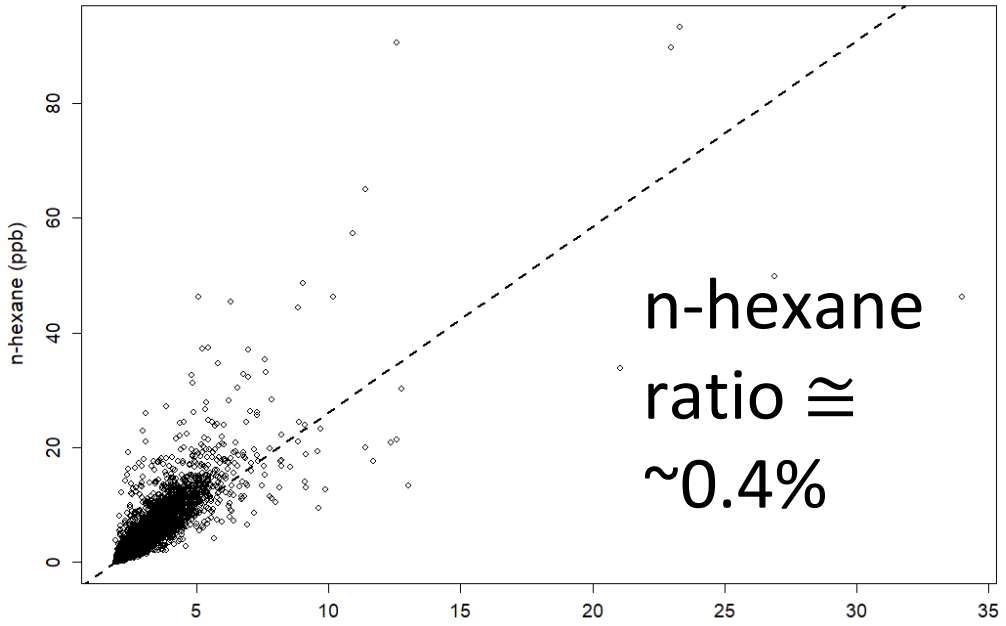
Plumes of methane at all daytimes (10-min averages)

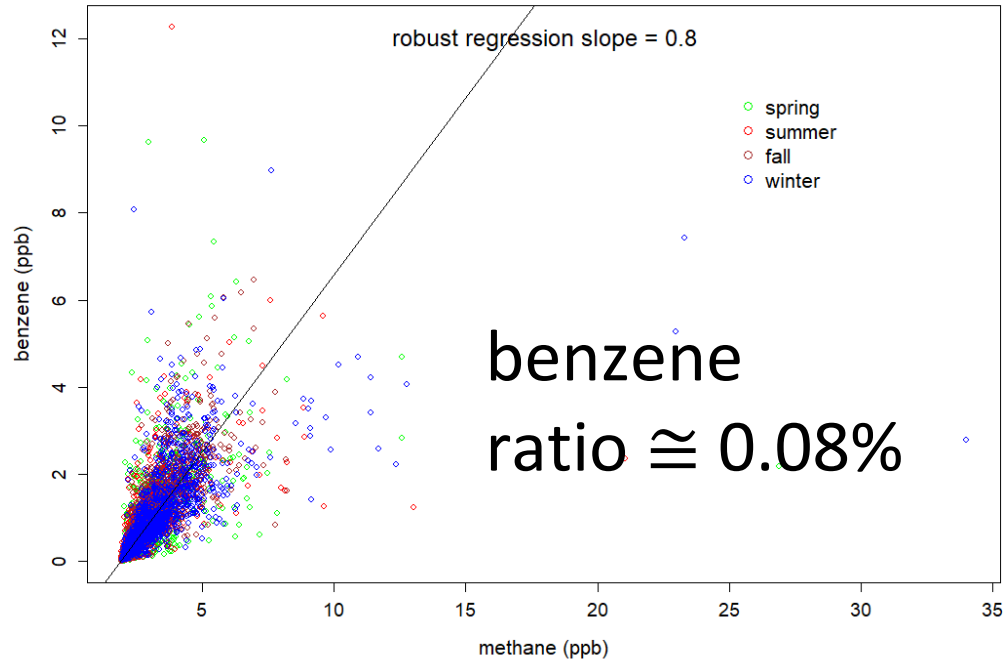


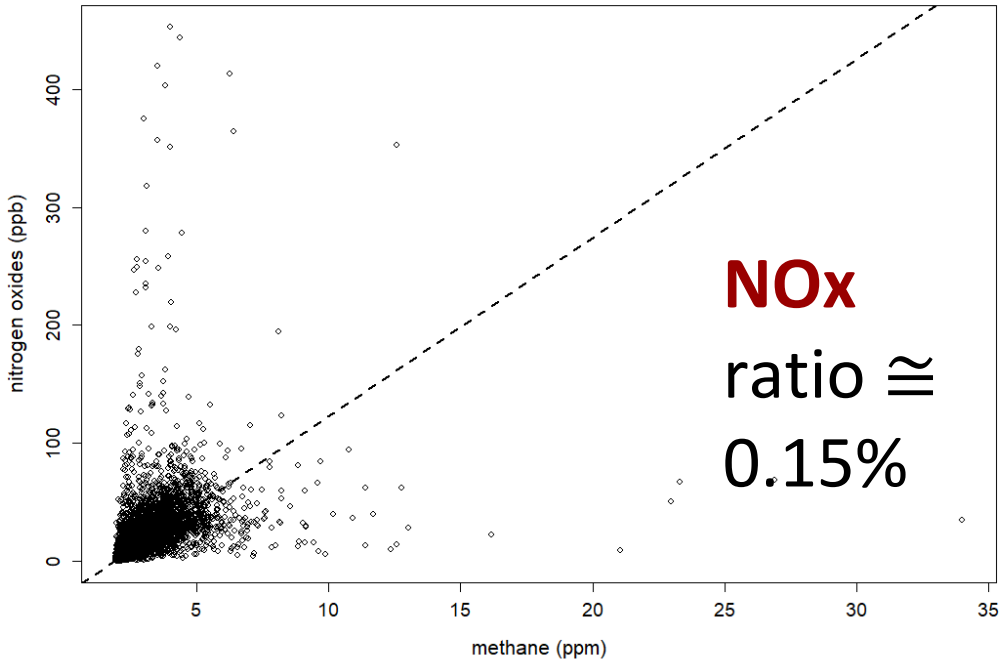
Plumes from all directions (10-min averages)




ethane (ppb)
methane (ppm)
ethane
ratio ≅ 13%


n-hexane (ppb)
n-hexane
ratio ≅
~0.4%


robust regression slope = 0.8
spring
summer
fall
winter
benzene (ppb)
methane (ppb)
benzene
ratio ≅ 0.08%


nitrogen oxides (ppb)
methane (ppm)
NOx
ratio ≅
0.15%

Ozone

Health Effects of Ozone

Elevated ozone can cause:

- Asthma attacks, aggravated asthma
- Coughing, wheezing, difficulty breathing
- Reduced lung function
- Reduced resistance to infections
- Emphysema and bronchitis

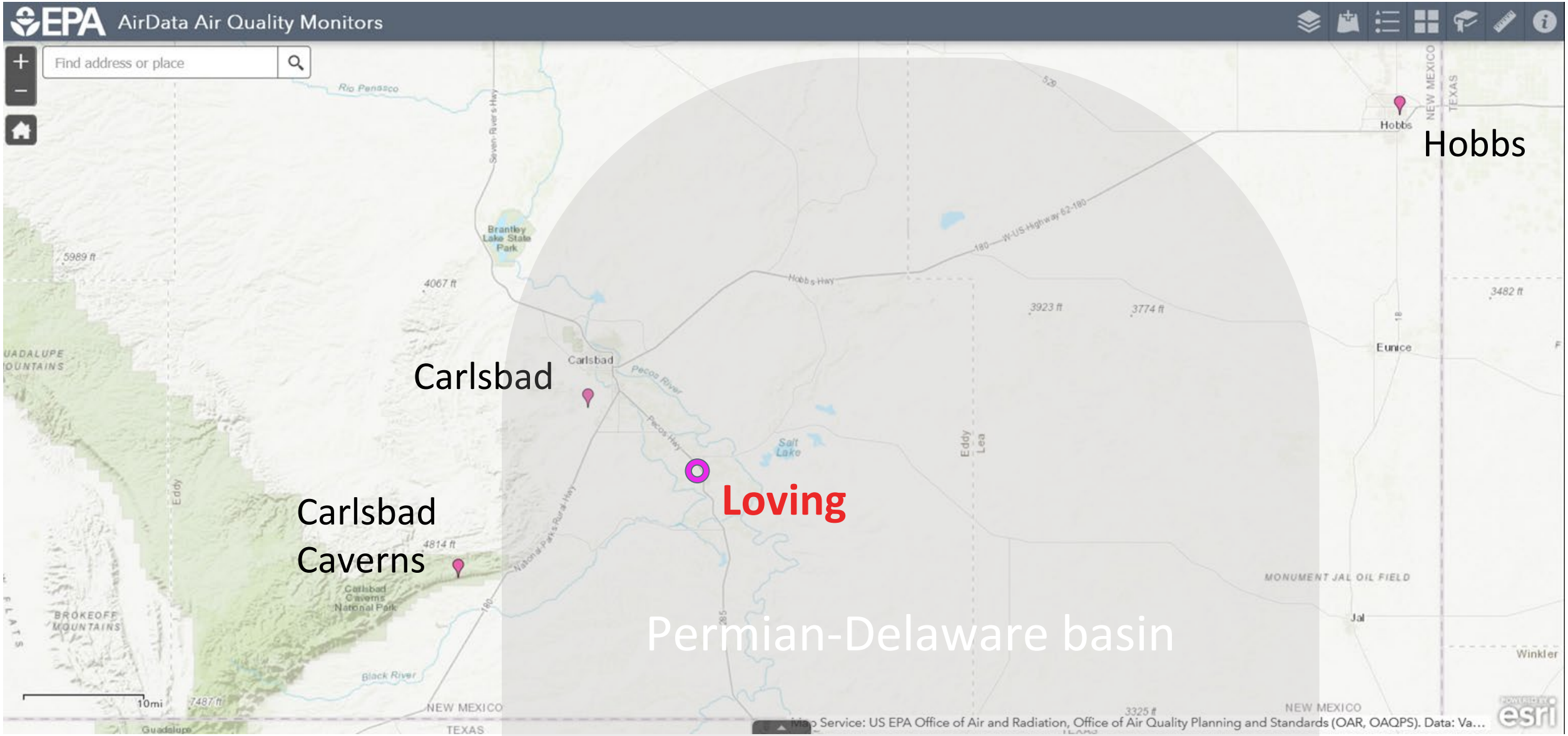
EPA National Ambient Air Quality Standard (NAAQS):

- Regulatory standard under the Clean Air Act
- Level EPA deems protective of public health, including children and asthmatics
- Annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years, should not exceed **70 parts per billion (ppb)**

Source: American Lung Association, US EPA

Photo: Nenad Stojkovic

Regional ozone monitoring stations



2023 occurrences of 8-hour ozone > 70 ppb at Loving, NM and Carlsbad NMED

Loving, NM, 8-hour Ozone Occurrences

2023 (full year)			
O3_8hr (ppb)	day-month	year	# days > 75/70 ppb NAAQS
87.1	31-Aug	2023	
86.7	9-Sep	2023	
84.3	30-Aug	2023	
82.1	27-Aug	2023	
81.6	17-Sep	2023	
79.7	23-Jul	2023	
78.9	3-Sep	2023	
78.6	1-May	2023	
77.9	26-Aug	2023	
77.8	6-Sep	2023	
77.7	7-Aug	2023	
77.7	6-Jun	2023	
77.3	15-Sep	2023	
77.2	10-Sep	2023	
76.6	2-May	2023	
76.6	8-Jun	2023	
76.0	4-Jul	2023	17
75.8	9-May	2023	
75.7	12-May	2023	
75.7	15-Aug	2023	
75.6	8-Aug	2023	
74.0	16-May	2023	
73.5	24-May	2023	
72.9	4-Aug	2023	
72.6	21-May	2023	
72.0	6-Aug	2023	
71.8	14-Jul	2023	
71.7	10-Jul	2023	
71.3	25-Aug	2023	
71.2	2-Sep	2023	
71.0	3-Jul	2023	31
70.9	17-Aug	2023	
70.4	10-May	2023	
70.3	18-Jun	2023	

Carlsbad, NMED, 8-hour Ozone Occurrences

2023 (full year)			
O3_8hr (ppb)	day-month	year	# days > 75/70 ppb NAAQS
18-Sep	81.8	2023	
17-Sep	80.4	2023	
10-Sep	79.9	2023	
1-Sep	79.0	2023	
31-Aug	78.0	2023	
9-Sep	77.4	2023	
7-Jul	76.6	2023	7
6-Jun	75.9	2023	
24-Jul	75.6	2023	
28-Aug	75.4		
13-May	74.1		
5-Aug	73.8		
25-May	73.3		
5-Jul	73.1		
23-Jul	73.0		
16-Aug	72.9		
24-May	72.8		
9-Jun	72.8		
4-Aug	72.5		
11-Sep	72.4		
8-Aug	72.3	2023	
2-May	72.0	2023	
12-Apr	72.0	2023	
4-Jul	71.9	2023	
27-Aug	71.8	2023	
7-Sep	71.7	2023	
12-May	71.6	2023	
30-Aug	71.0	2023	28
3-Jul	70.9	2023	
8-Jun	70.5	2023	
13-Apr	70.4	2023	

	Loving	Carlsbad NMED
8-hour max	87.1 ppb	81.8 ppb
4th -highest 8-hour	82.1 ppb	79.0 ppb
# days > 75 ppb	17	7
# days > 70 ppb	31	28

2023 and 2024 occurrences of 8-hour ozone > 70 ppb at Loving, NM

2023 (full year)			
O3_8hr (ppb)	day-month	year	# days > 75/70 ppb NAAQS
87.1	31-Aug	2023	
86.7	9-Sep	2023	
84.3	30-Aug	2023	
82.1	27-Aug	2023	
81.6	17-Sep	2023	
79.7	23-Jul	2023	
78.9	3-Sep	2023	
78.6	1-May	2023	
77.9	26-Aug	2023	
77.8	6-Sep	2023	
77.7	7-Aug	2023	
77.7	6-Jun	2023	
77.3	15-Sep	2023	
77.2	10-Sep	2023	
76.6	2-May	2023	
76.6	8-Jun	2023	
76.0	4-Jul	2023	17
75.8	9-May	2023	
75.7	12-May	2023	
75.7	15-Aug	2023	
75.6	8-Aug	2023	
74.0	16-May	2023	
73.5	24-May	2023	
72.9	4-Aug	2023	
72.6	21-May	2023	
72.0	6-Aug	2023	
71.8	14-Jul	2023	
71.7	10-Jul	2023	
71.3	25-Aug	2023	
71.2	2-Sep	2023	
71.0	3-Jul	2023	
70.9	17-Aug	2023	
70.4	10-May	2023	
70.3	18-Jun	2023	

31

2024 (until Oct 25th)			
O3_8hr (ppb)	day-month	year	# days > 75/70 ppb NAAQS
99.8	25-Jul	2024	
97.7	24-Jul	2024	
92.4	23-Jul	2024	
91.5	6-Jul	2024	
86.8	26-Jul	2024	
86.3	9-Jul	2024	
85.4	8-Aug	2024	
85.4	15-May	2024	
82.7	7-Aug	2024	
82.5	12-Jun	2024	
80.4	28-Sep	2024	
79.6	30-Sep	2024	
78.3	28-Aug	2024	
78.3	30-May	2024	
78.1	1-Aug	2024	
77.7	10-Jul	2024	
77.5	11-Jul	2024	
77.2	20-Jul	2024	
76.3	27-Jul	2024	
76.1	2-Oct	2024	
76.0	31-Jul	2024	21
75.8	27-Sep	2024	
75.6	6-Jun	2024	
75.2	12-Jul	2024	
75.1	23-May	2024	
75.1	13-Jun	2024	
74.7	3-Jul	2024	
74.7	9-Aug	2024	
74.6	15-Aug	2024	
74.6	31-May	2024	
74.3	19-Jul	2024	
74.2	24-May	2024	
73.6	29-Sep	2024	
73.5	10-Sep	2024	
73.2	7-Sep	2024	
73.0	24-Jun	2024	
73.0	10-Jun	2024	
73.0	9-Sep	2024	
72.6	14-May	2024	
72.1	24-Sep	2024	
72.0	8-Jul	2024	
71.9	29-May	2024	
71.6	5-Jun	2024	
71.4	6-Apr	2024	
71.3	28-Jul	2024	
71.0	27-Aug	2024	
70.7	7-Apr	2024	
70.7	14-Oct	2024	
70.6	6-Aug	2024	
70.5	17-Apr	2024	
70.4	23-Jun	2024	
70.4	30-Jul	2024	
70.2	3-Jun	2024	
70.1	5-May	2024	

46

Loving 2023-2024 mean 4th:
86.8 ppb

Carlsbad 2020-2022 mean 4th:
78 ppb

Carlsbad Caverns 2020-2022 mean 4th:
78 ppb

Hobbs 2020-2022 mean 4th:
71 ppb

Number of ozone NAAQS exceedance days

Carlsbad area Ozone is high …

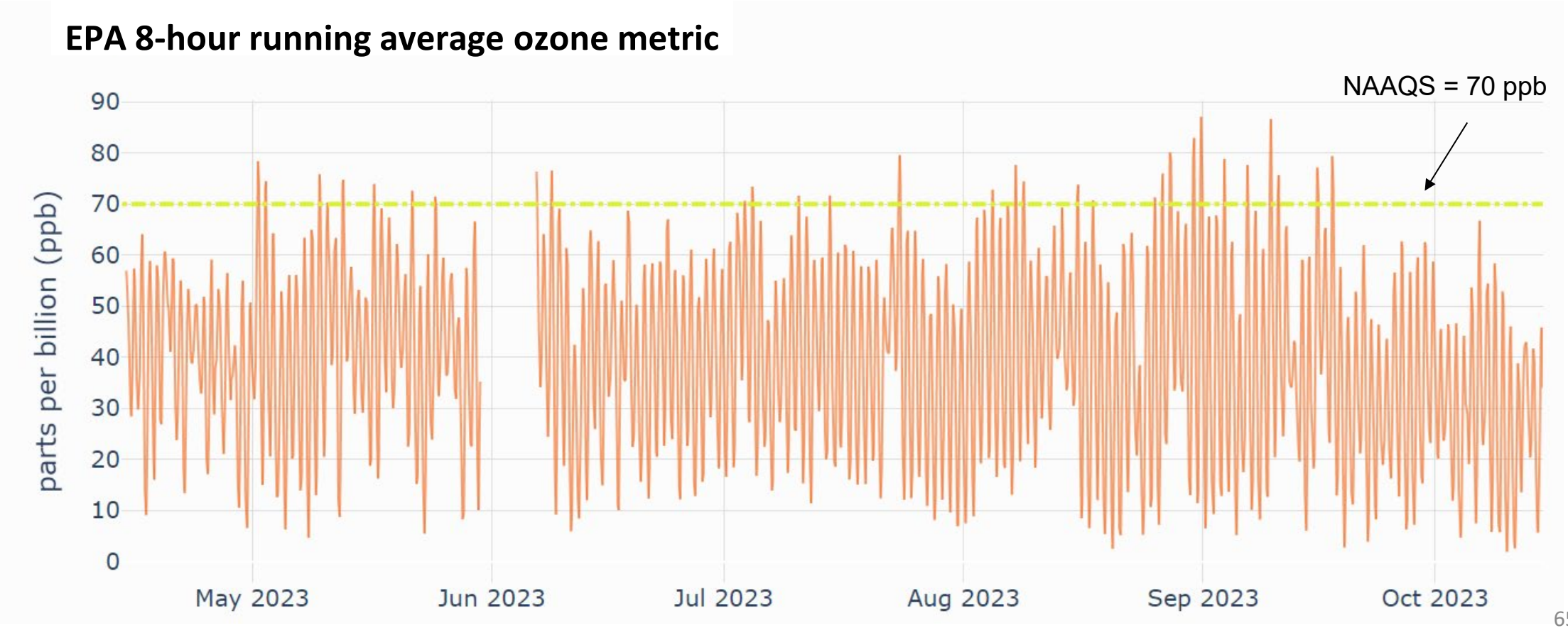
- … during daytime, especially noon to 6 pm, and for clear-skies
- … on spring and summer days, from April into October
  - … when it is dry, i.e. humidity is low
  - … when temperatures exceed 90 deg F.
  - … when winds are weak
  - … and air moves slowly from southerly to easterly directions

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

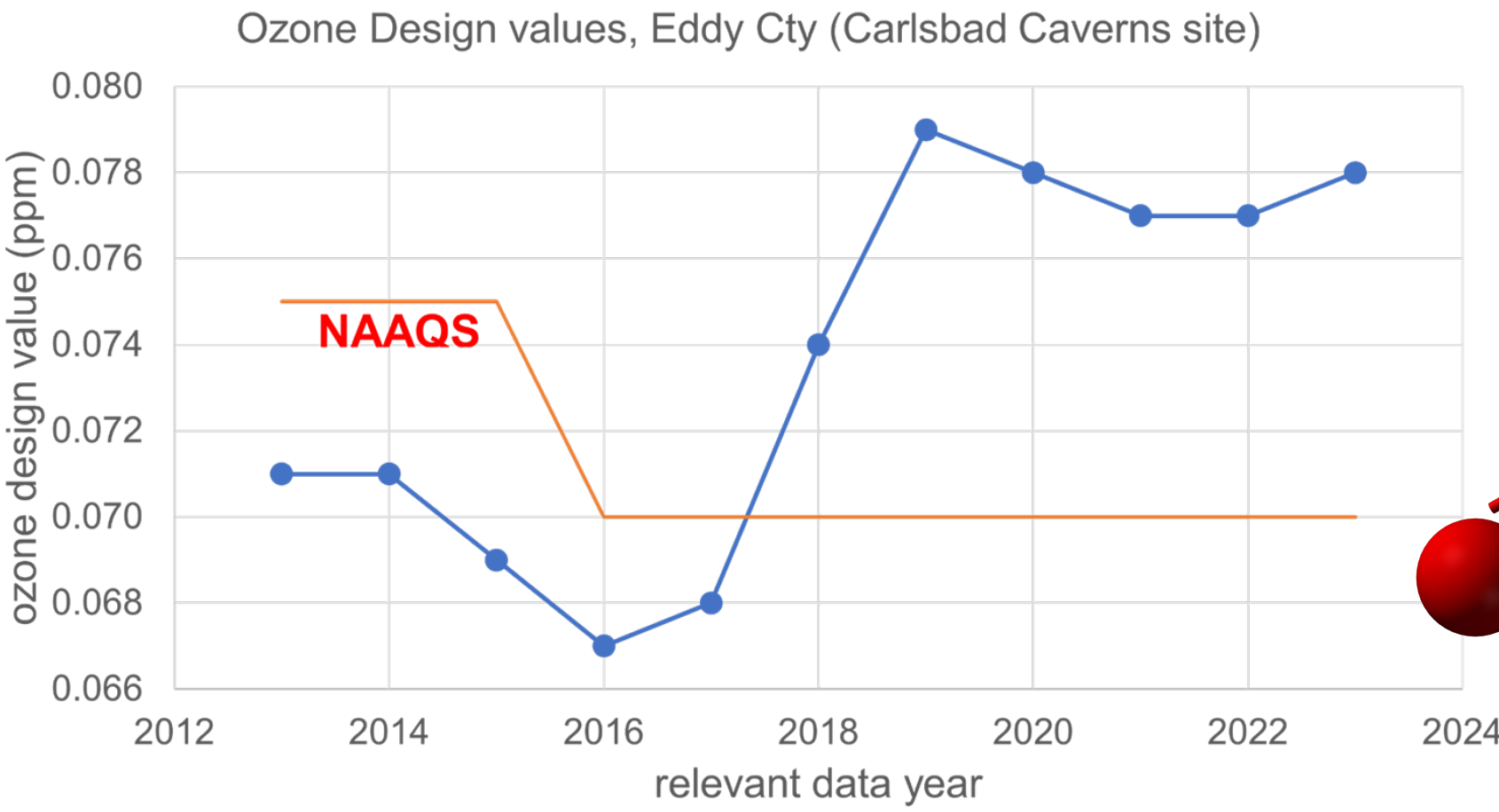
Ozone at the Loving, NM site in 2023

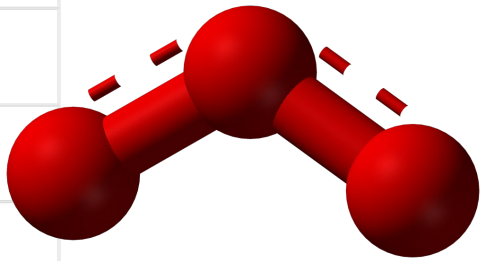
Ozone levels exceeded the current U.S. EPA NAAQS* of **70 ppb** on ***31 of 155*** days measured.
Similar exceedances have been observed for several years at Carlsbad Caverns.

* NAAQS = National Ambient Air Quality Standard



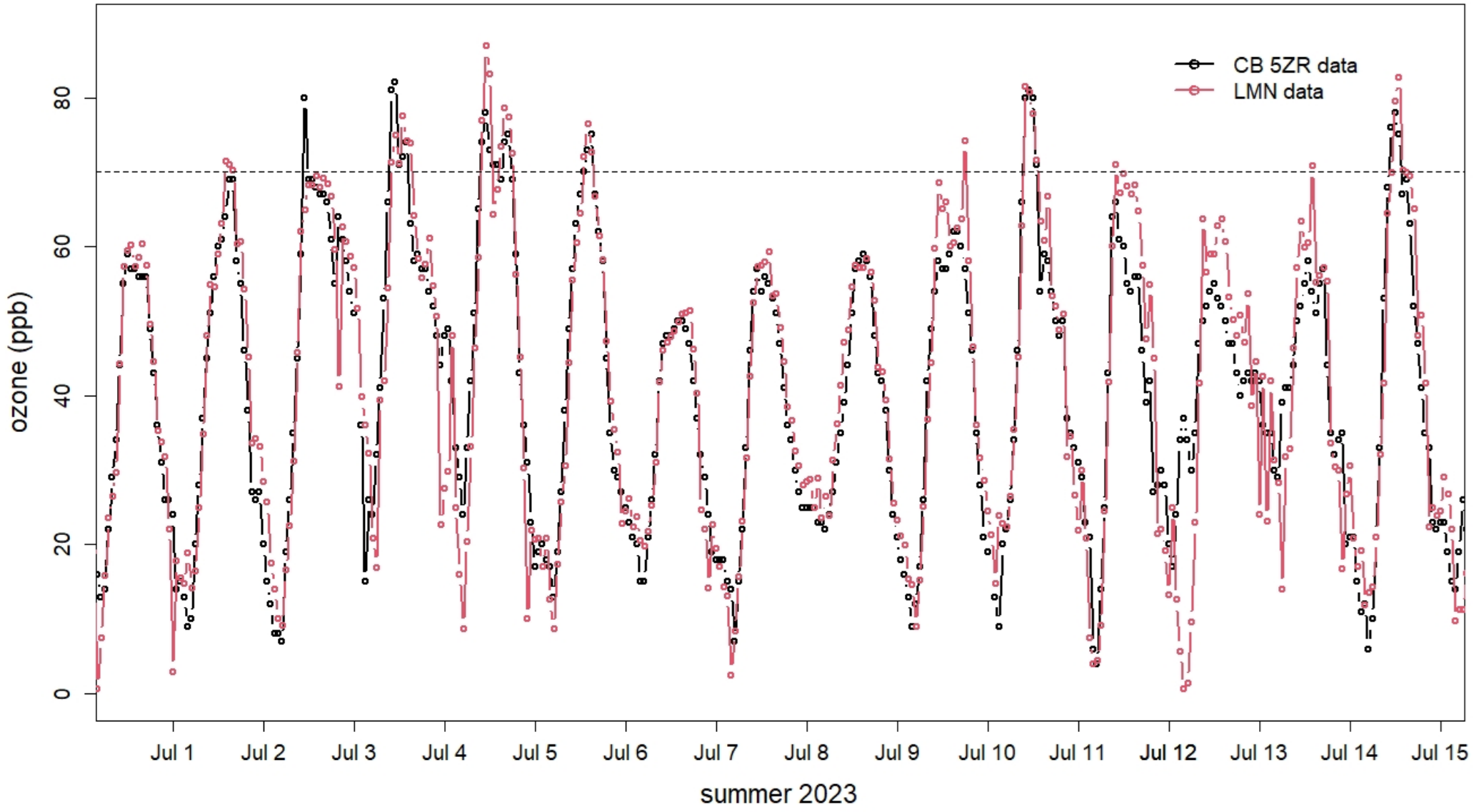
1. Ozone above the *National Ambient Air Quality Standard* (NAAQS)





https://www.env.nm.gov/air-quality/my-air-quality/#ozone

Comparing the local NMED site data to data at our LMN site



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

Health Effects of Ozone

Elevated ozone can cause:

- Asthma attacks, aggravated asthma
- Coughing, wheezing, difficulty breathing
- Reduced lung function
- Reduced resistance to infections
- Emphysema and bronchitis

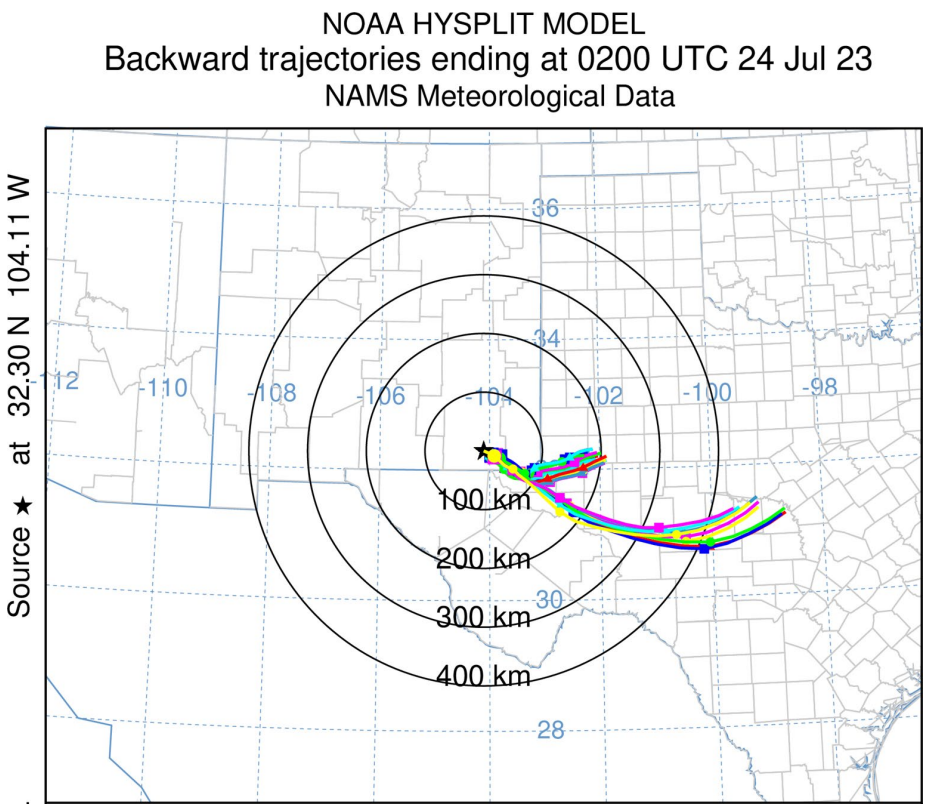
EPA National Ambient Air Quality Standard (NAAQS):

- Regulatory standard under the Clean Air Act
- Level EPA deems protective of public health, including children and asthmatics
- Annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years, should not exceed **70 parts per billion (ppb)**

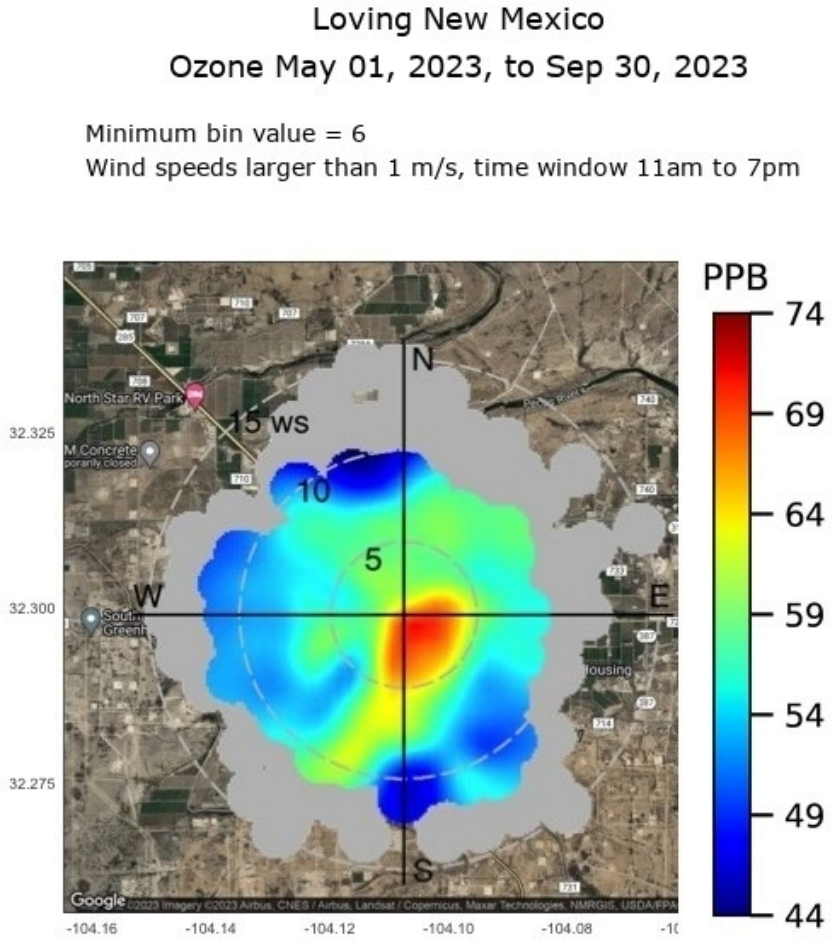
Source: American Lung Association, US EPA

Photo: Nenad Stojkovic

Where is the high ozone coming from?



Example air mass origins for 23 July (7 pm local time), a high ozone day (80 ppb).



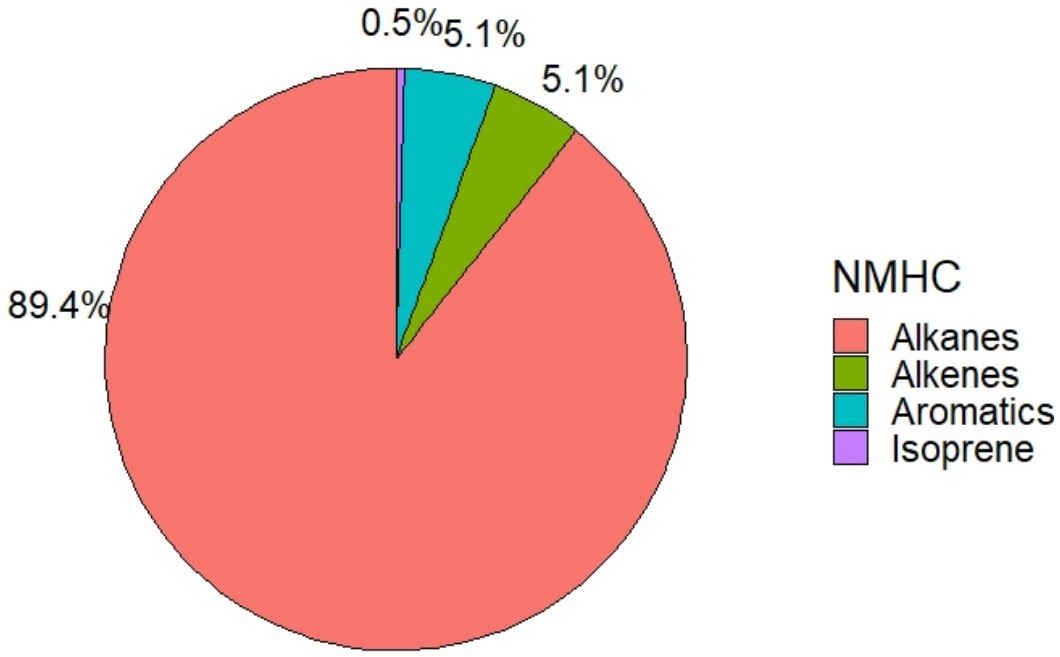
- ➔ **Weak southeast winds associated with highest daytime ozone.**
- ➔ **On average, air transported from the southeast sector had 10–15 ppb higher ozone than air from other directions.**

Ozone (O_3) statistics at the LNM site

2023 May 1st - October 1st					2024 May 1st - October 1st			
O3 Value (ppb)	# Hours, O3 1hr avg > val	# Hours, max O3 minute > val	# Days, max 8hr avg O3 > val		O3 Value (ppb)	# Hours, O3 1hr avg > val	# Hours, max O3 minute > val	# Days, max 8hr avg O3 > val
120	0	0	0		120	0	0	0
115	0	0	0		115	0	1	0
110	0	1	0		110	0	4	0
105	0	4	0		105	5	13	0
100	3	5	0		100	13	25	0
95	4	17	0		95	23	40	2
90	13	36	0		90	38	68	4
85	35	103	2		85	63	106	8
80	86	191	5		80	106	199	11
75	190	324	21		75	226	367	24
70	327	515	34		70	391	570	48
65	488	736	60		65	623	822	75
60	730	1000	89		60	850	1084	100

What compounds drive ozone formation?

Measured hydrocarbon reactivity → ozone formation potential



- May – October means, 11 – 19 hours

→ 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.

cf. Pan et al., JAWMA 73(12), Nov. 2023

VOCs

Airborne Radioactivity

3. Airborne Radioactivity

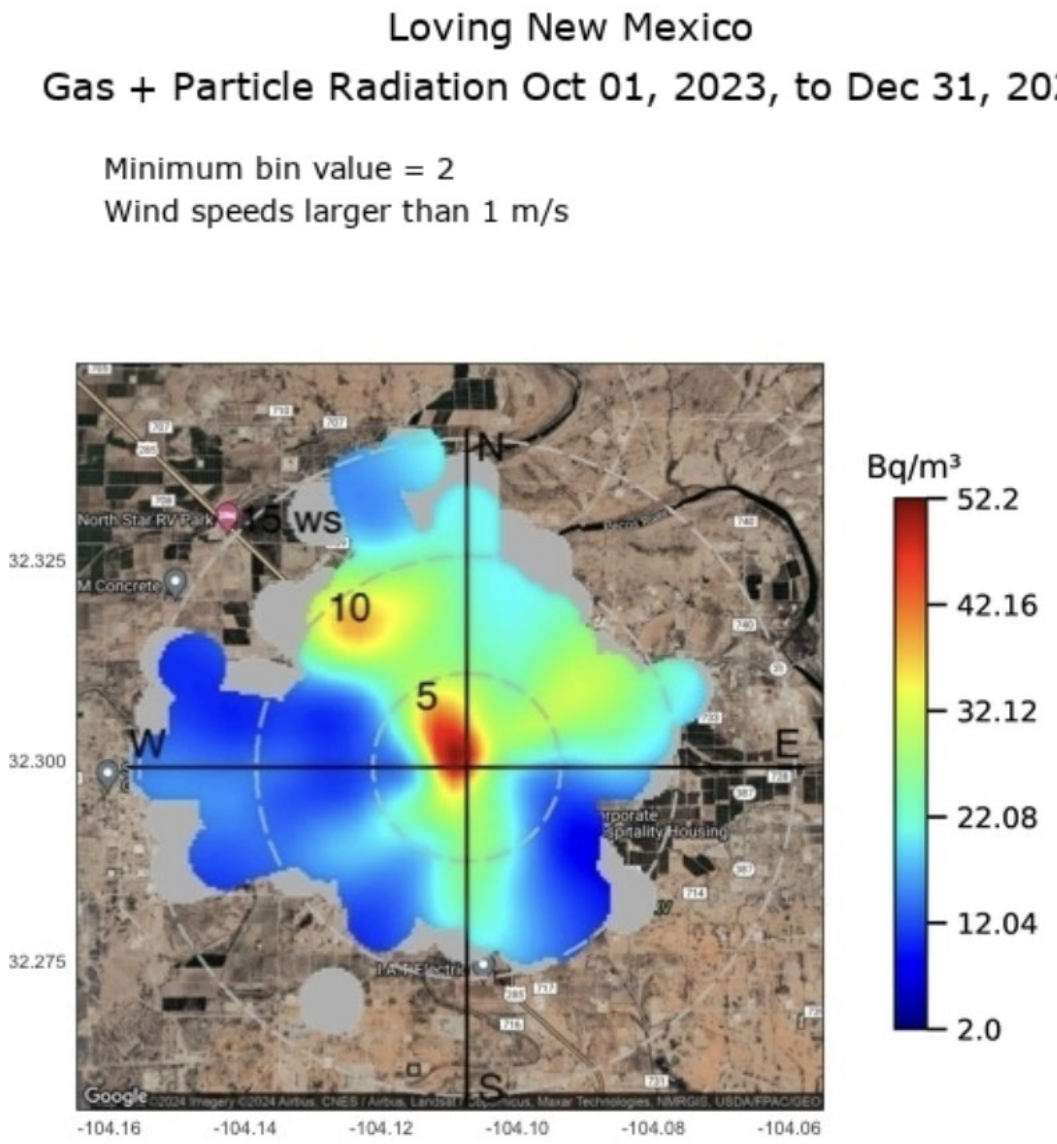
Radon in the atmosphere …

… is mostly due to emissions from the ground, creating a natural background level of radioactivity in air.

… may be elevated by mining, creating more pathways of Radon to escape into the lower atmosphere.

… is the second leading cause of lung cancer after smoking

New insights from airborne radioactivity measurements



Radioactive <u>Radon is a gas</u> and <u>Radon decay products are on particles</u>

Radon emanation is enhanced as it is brought to the surface via drilling and gas production

- Elevated levels (yellow to red colors) are detected from various directions, especially under moderate northerly, especially NNW wind directions.
  - Under these conditions, levels are on average 2-3 times higher than background* levels (cyan and blue colors).
- Correlation with sulfur compounds may suggest a shared “sour gas” source.

* cf. Gäggeler, *Radiochimica Acta* 70/71, 1995

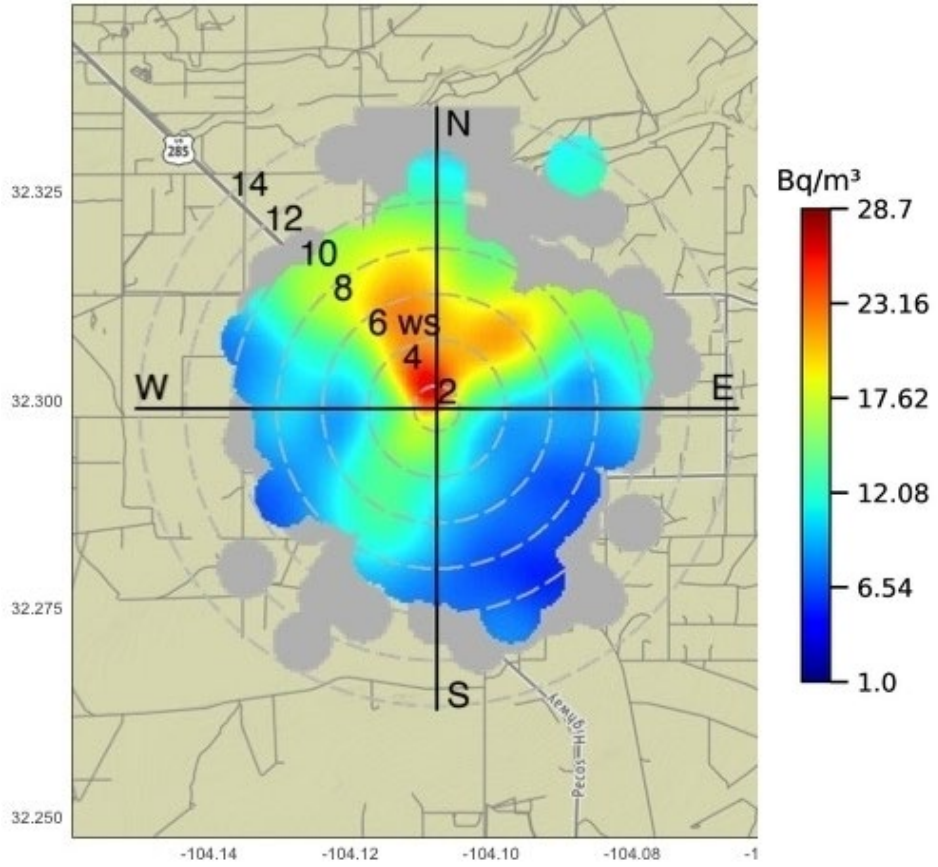
Airborne Radioactivity at Loving, NM (LNM)

Loving New Mexico

Gas Phase Radiation Jul 01, 2023, to Sep 12, 2023

Minimum bin value = 2

Wind speeds larger than 1 m/s

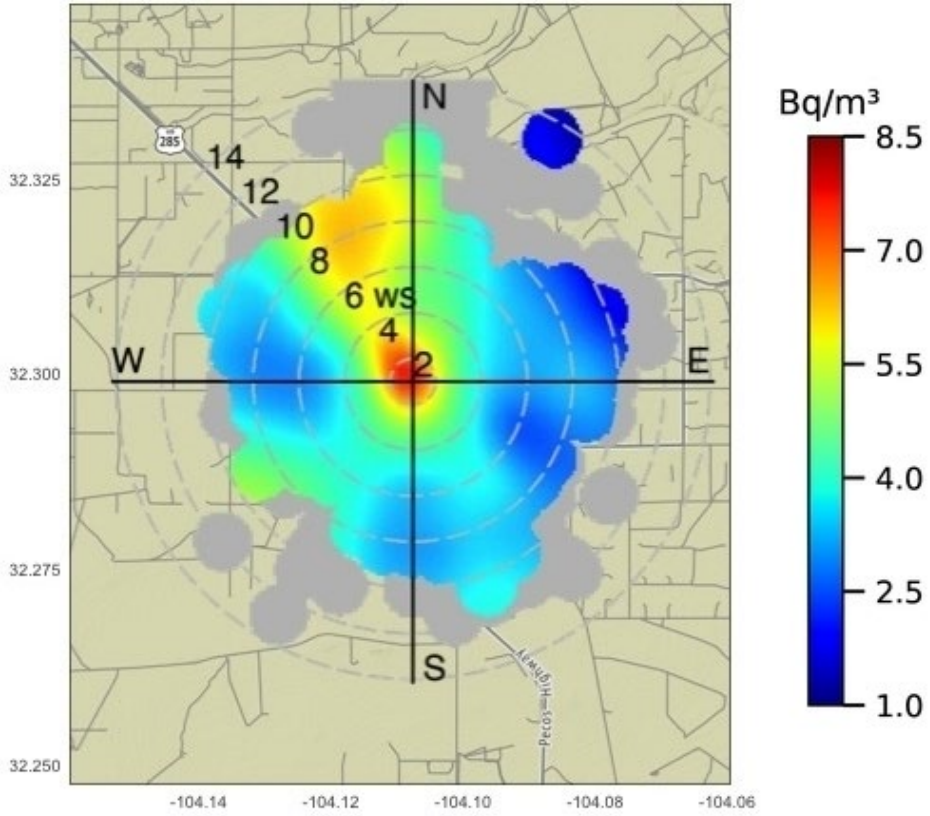


Loving New Mexico

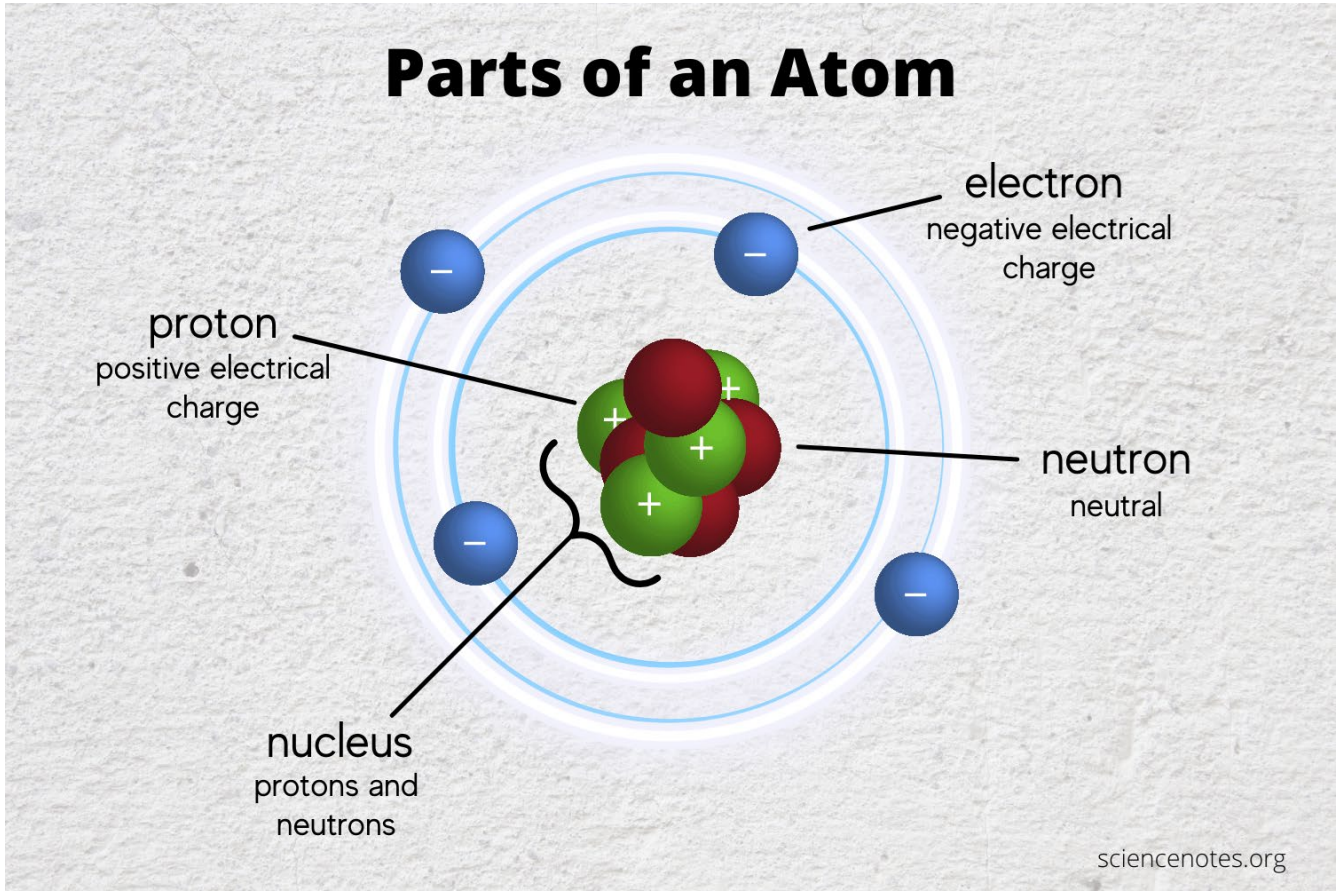
Particle Radiation Jul 01, 2023, to Sep 12, 2023

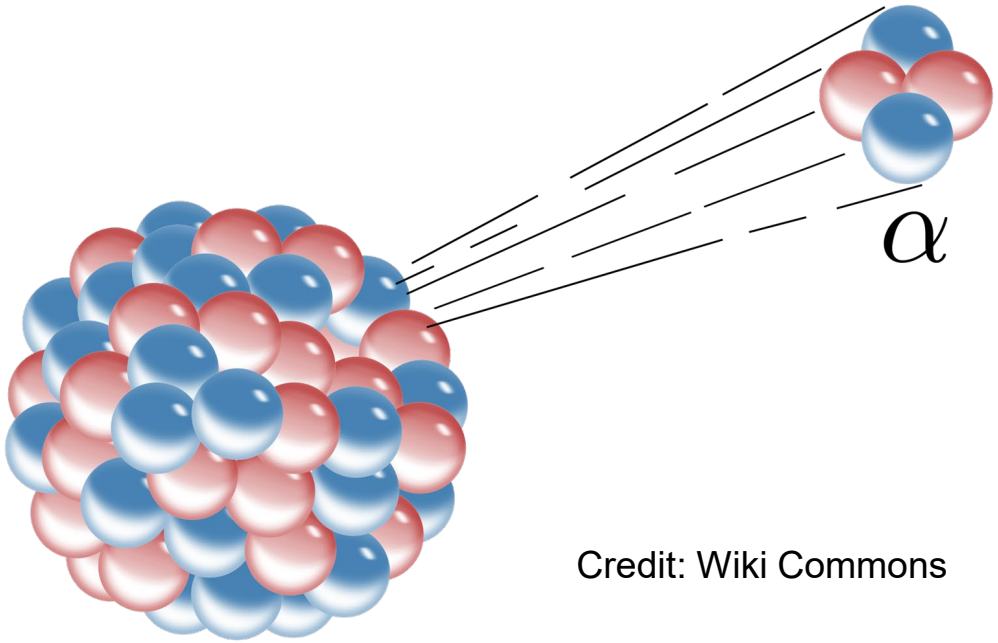
Minimum bin value = 2

Wind speeds larger than 1 m/s



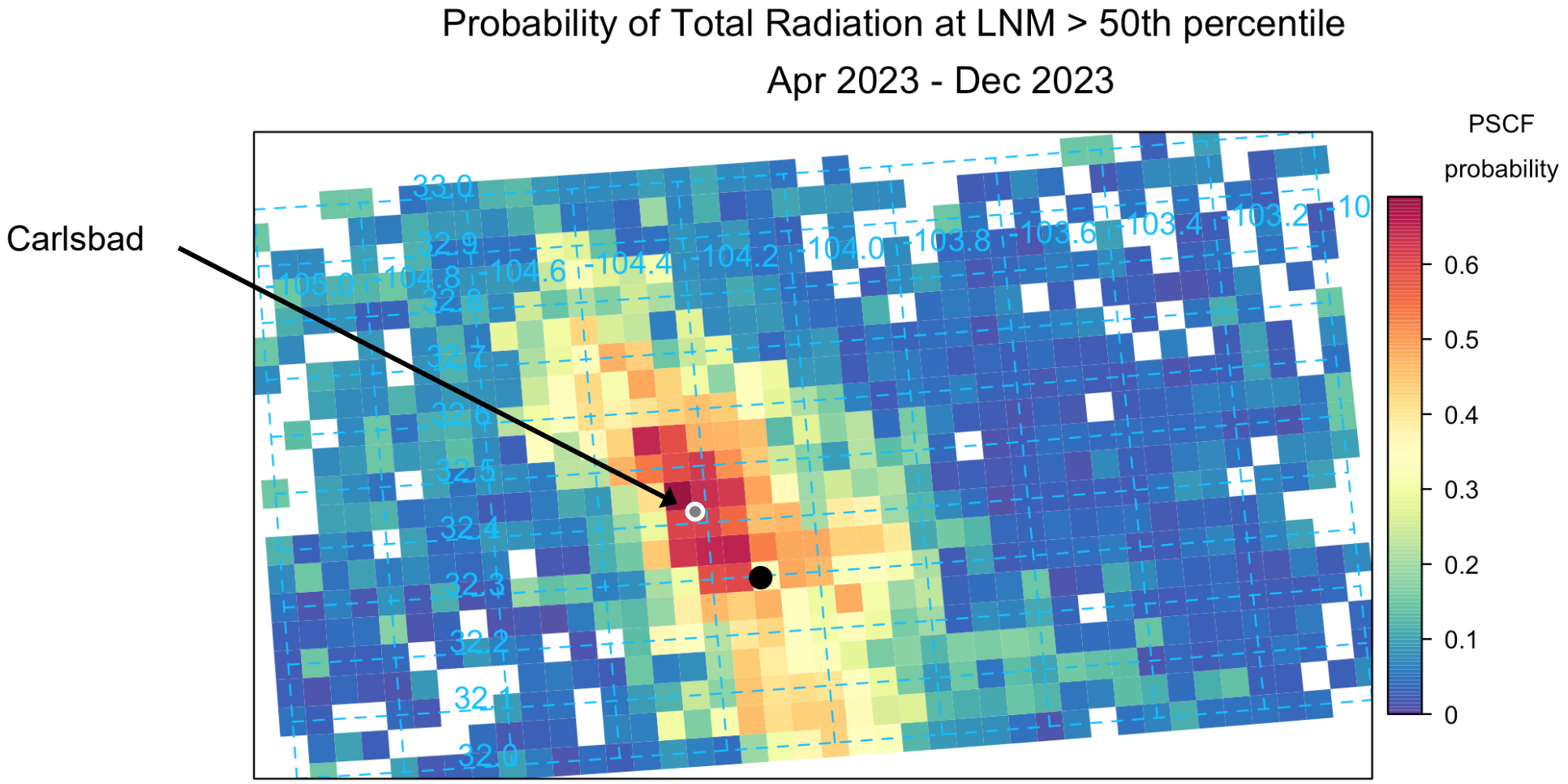
What is Radioactivity?

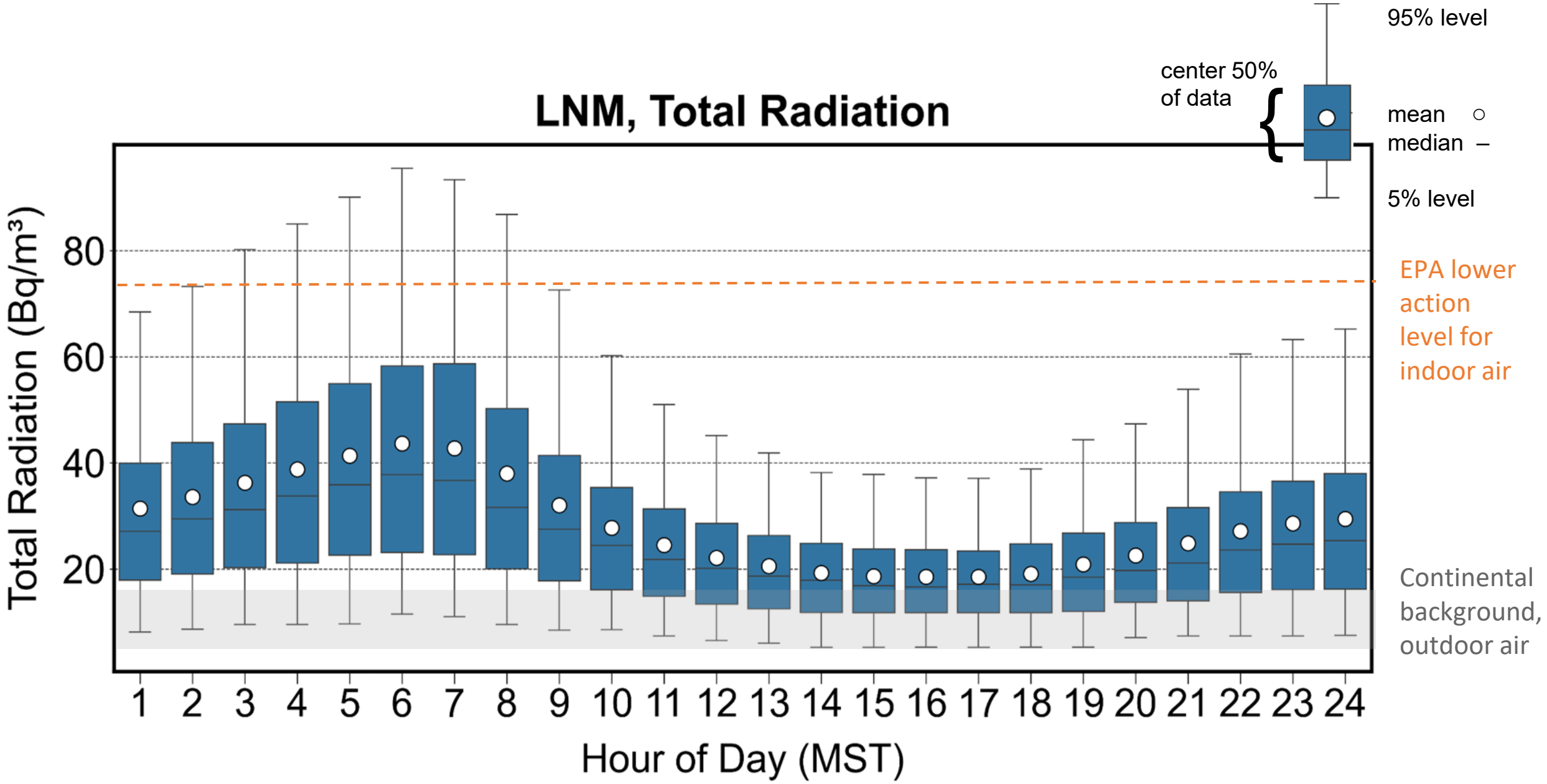




Credit: Wiki Commons

Potential Source Contribution Function Results – Uses Correlation Analyses with HYSPLIT Trajectories




LNM, Total Radiation
Total Radiation (Bq/m³)
80
60
40
20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour of Day (MST)
95% level
center 50%
of data
mean ○
median –
5% level
EPA lower action level for indoor air
Continental background, outdoor air

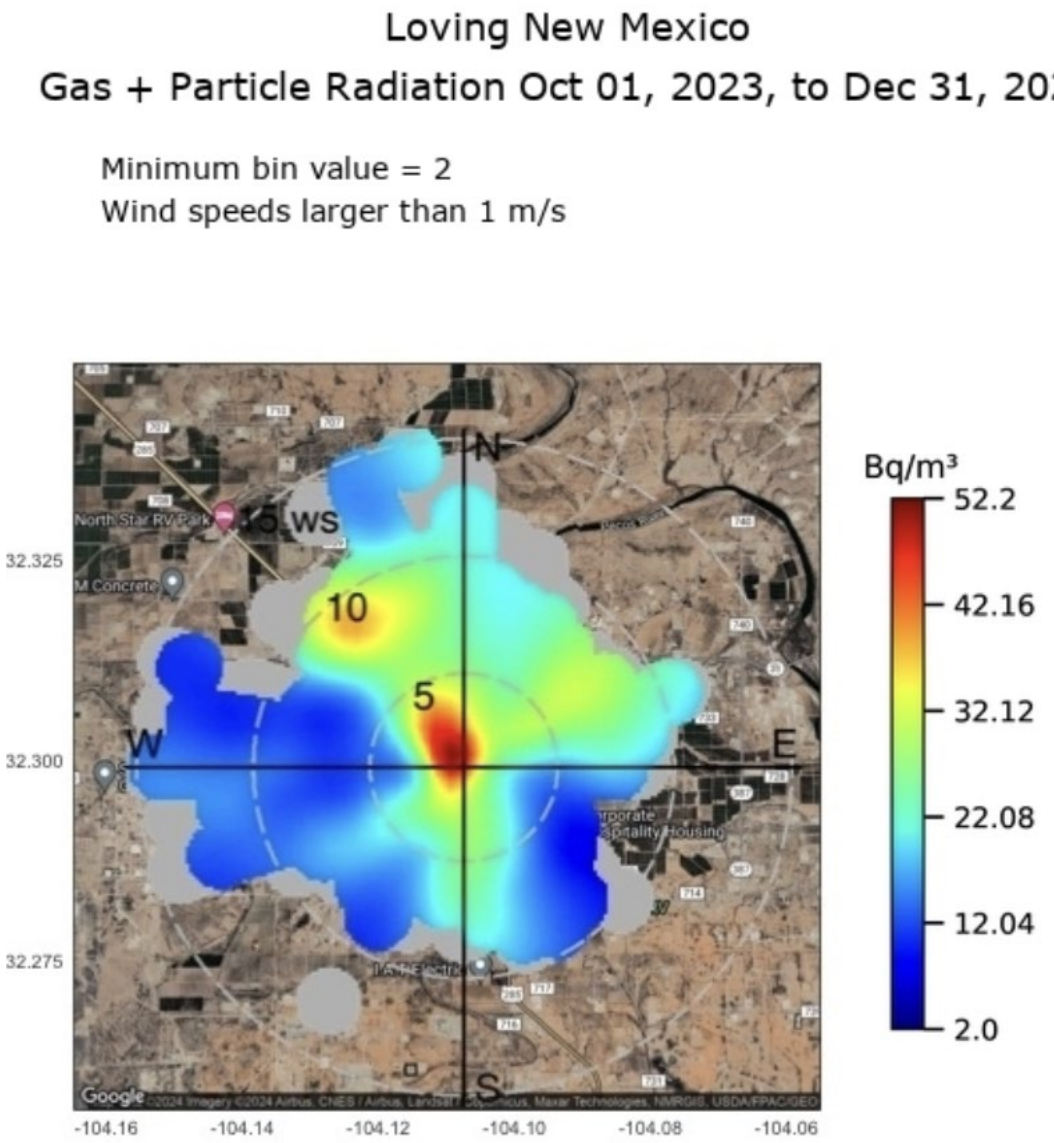
The Periodic Table of Elemer

scientificgems.wordpress.com

1 H Hydrogen																	2 He Helium
3 Li Lithium	4 Be Beryllium											5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon
11 Na Sodium	12 Mg Magnesium											13 Al Aluminium	14 Si Silicon	15 P Phosphorus	16 S Sulfur	17 Cl Chlorine	18 Ar Argon
19 K Potassium	20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton
37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon
55 Cs Cesium	56 Ba Barium	57–71 La–Lu Lanthanides	72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Ac–Lr Actinides	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

57 La Lanthanum	58 Ce Cerium	59 Pr Praseodymium	60 Nd Neodymium	61 Pm Promethium	62 Sm Samarium	63 Eu Europium	64 Gd Gadolinium	65 Tb Terbium	66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	70 Yb Ytterbium	71 Lu Lutetium
89 Ac Actinium	90 Th Thorium	91 Pa Protactinium	92 U Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

New insights from airborne radioactivity measurements



Radioactive <u>Radon is a gas</u> and <u>Radon decay products are on particles</u>

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- Correlation with sulfur compounds may suggest a shared “sour gas” source.

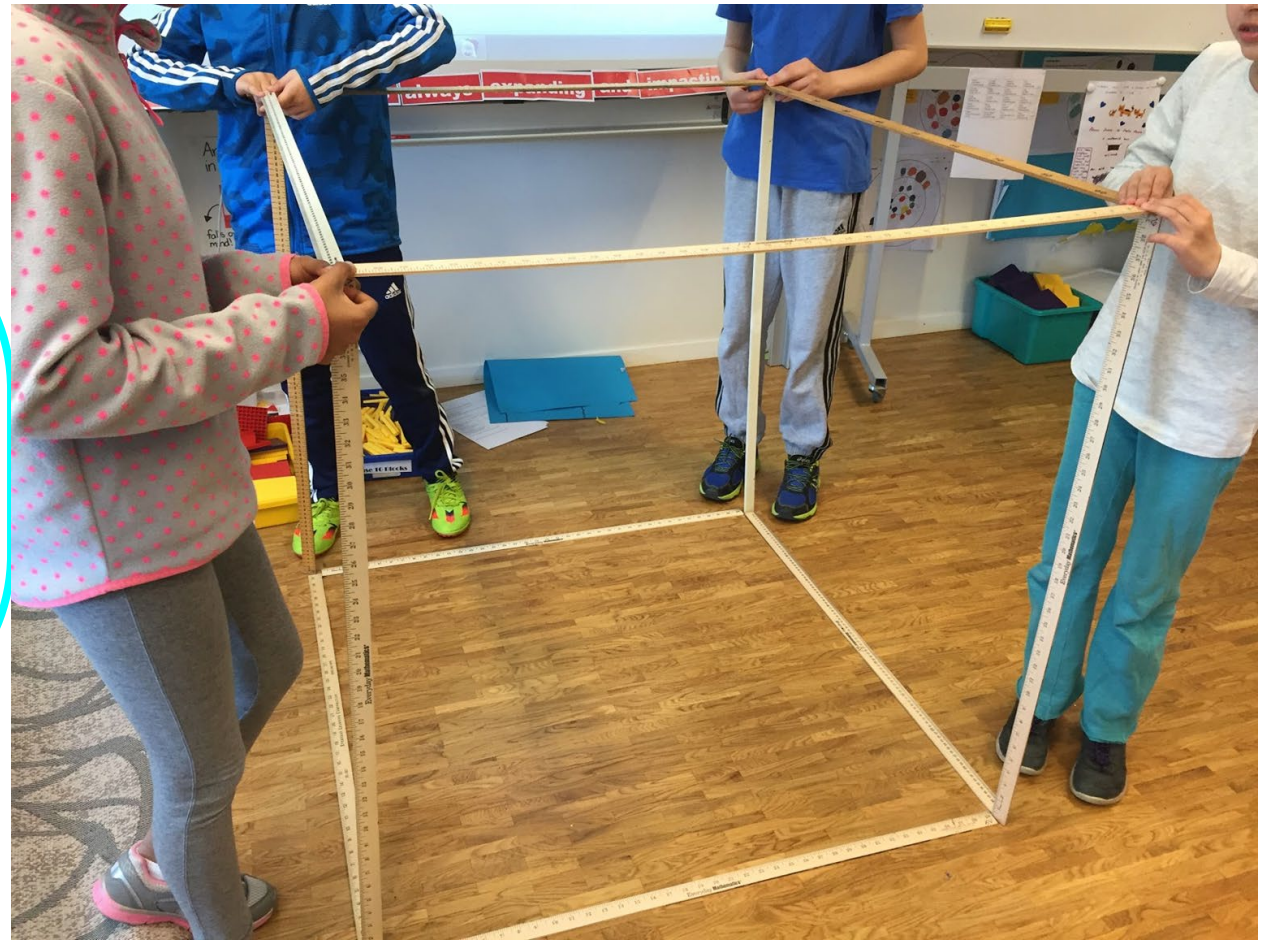
* cf. Gäggeler, *Radiochimica Acta* 70/71, 1995

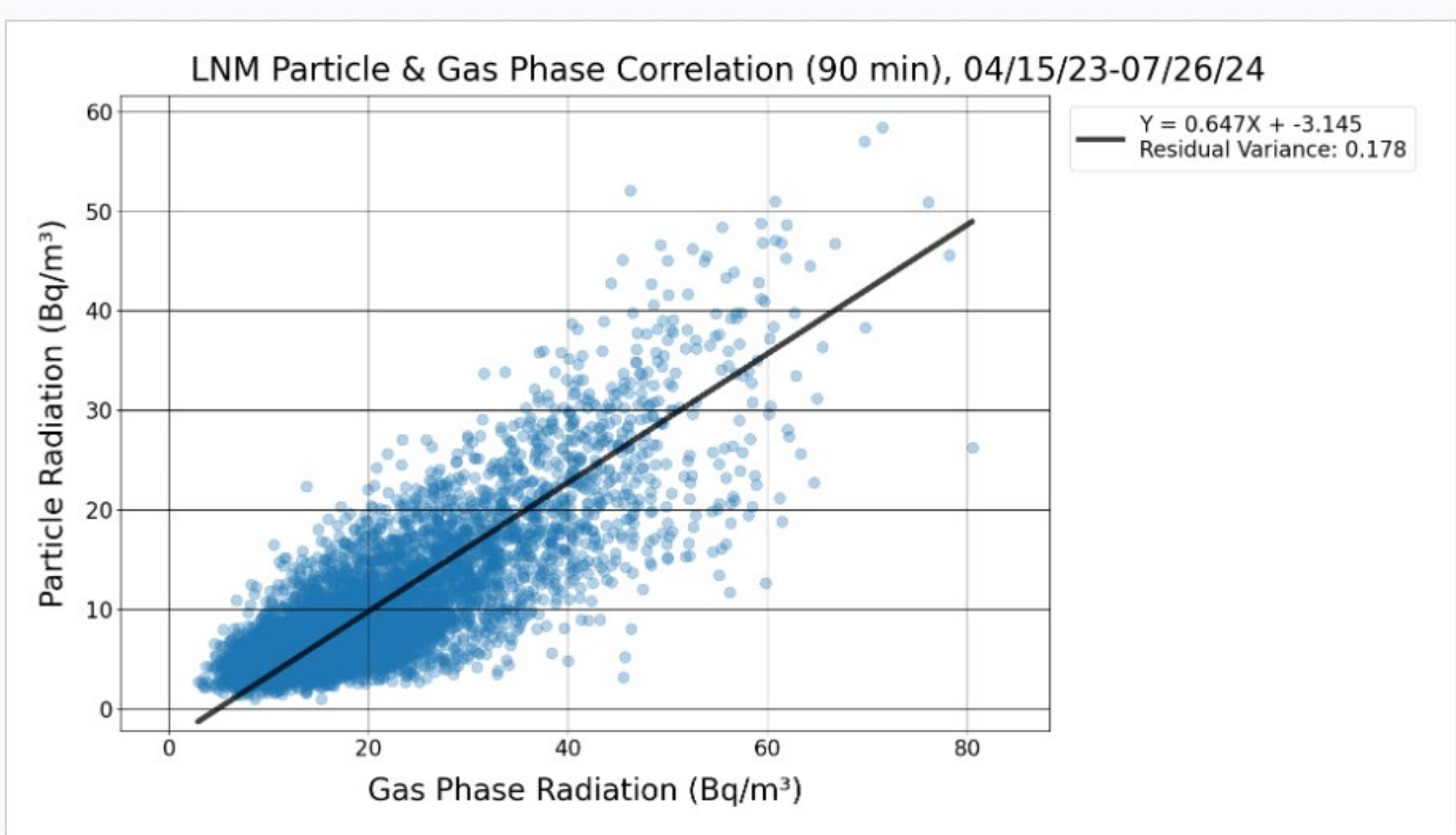
Blue to cyan colors represent normal, background radioactivity levels.

Units for Ambient Radioactivity Monitoring

- **Becquerel per cubic meter: Bq/m³**
  - How many radioactive decays there are in a cubic meter every second

- Continental background, outdoor air: **5-15 Bq/m³**
- Action levels for indoor air:
  - **100 Bq/m³** (World Health Organization)
  - **75-150 Bq/m³** (U.S. Environmental Protection Agency)




LNM Particle & Gas Phase Correlation (90 min), 04/15/23-07/26/24
Y = 0.647X + -3.145
Residual Variance: 0.178
Particle Radiation (Bq/m³)
Gas Phase Radiation (Bq/m³)
0
10
20
30
40
50
60
0
20
40
60
80

Bertin Technologies AlphaGUARD DF2000 + AlphaPM

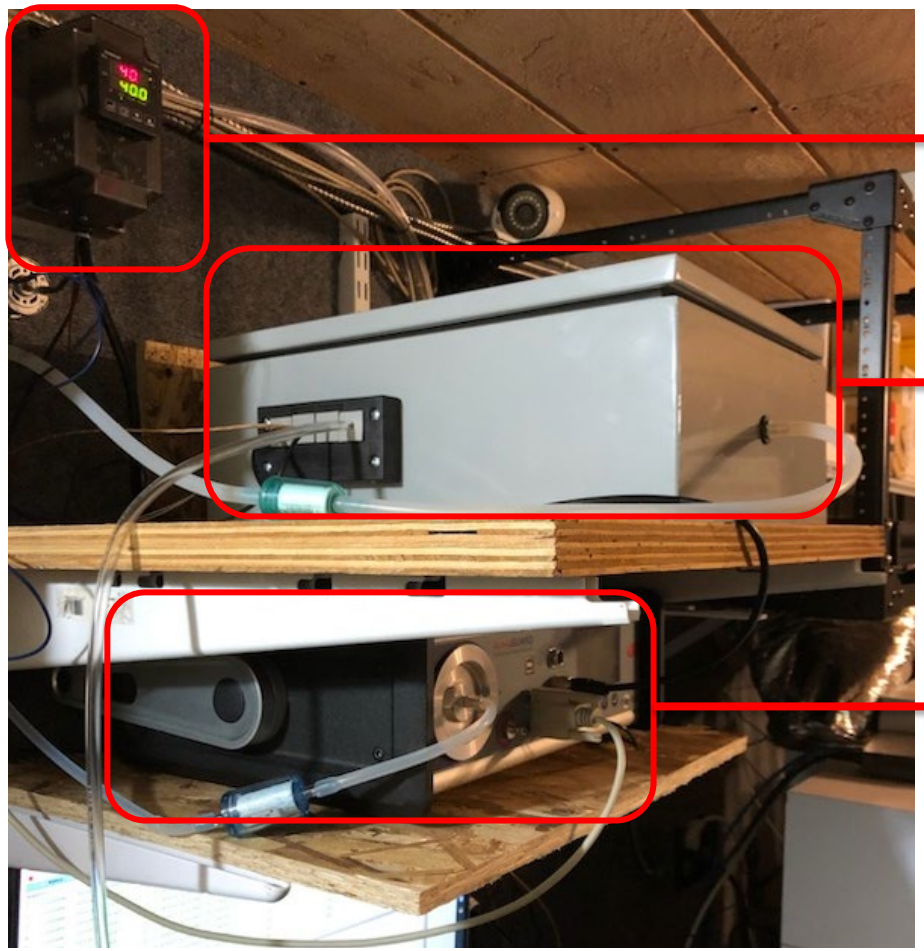
AlphaGUARD DF2000 Radon gas alpha decay

Detector: Ionization chamber
Range: <0.05 pCi/l to 54,000 pCi/l (2 to 2,000,000 Bq/m3)
Flow rate 0.05 – 0.5, 1, 2 L/min; 620 mL chamber volume
1 min or 10 min measurement cycle
5-year calibration factor, traceable

AlphaPM Radon progeny on PM alpha decay

Detector: Semiconductor (PIPS)
Range: 0.5 to 1,000,000 Bq/m3 EEC (0.02 to 35,000 MeV/cm3)
Lower detection limit at 10 min and 2 L/min flow: 2 Bq/m3 EEC (0.07 MeV/cm3)
Flow rate 0.1, 0.5, 1.0, 1.5, 2.0 L/min
10 min measurement cycle, synchronized automatically with connected AlphaGUARD

The radioactivity monitors (inside the trailer):

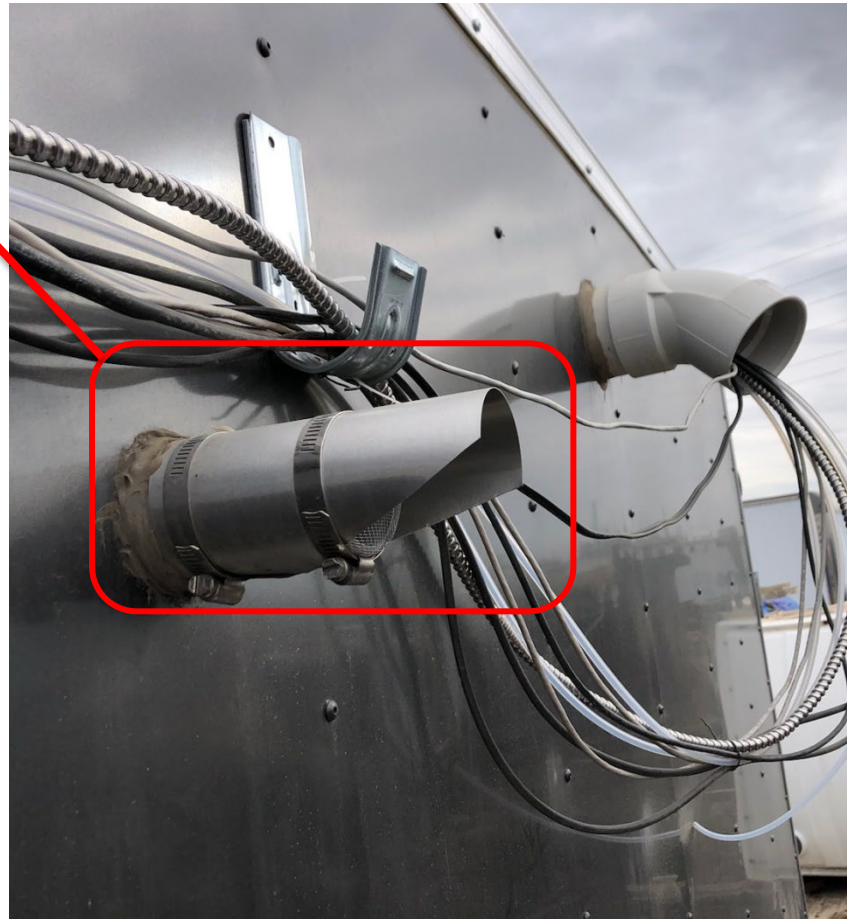


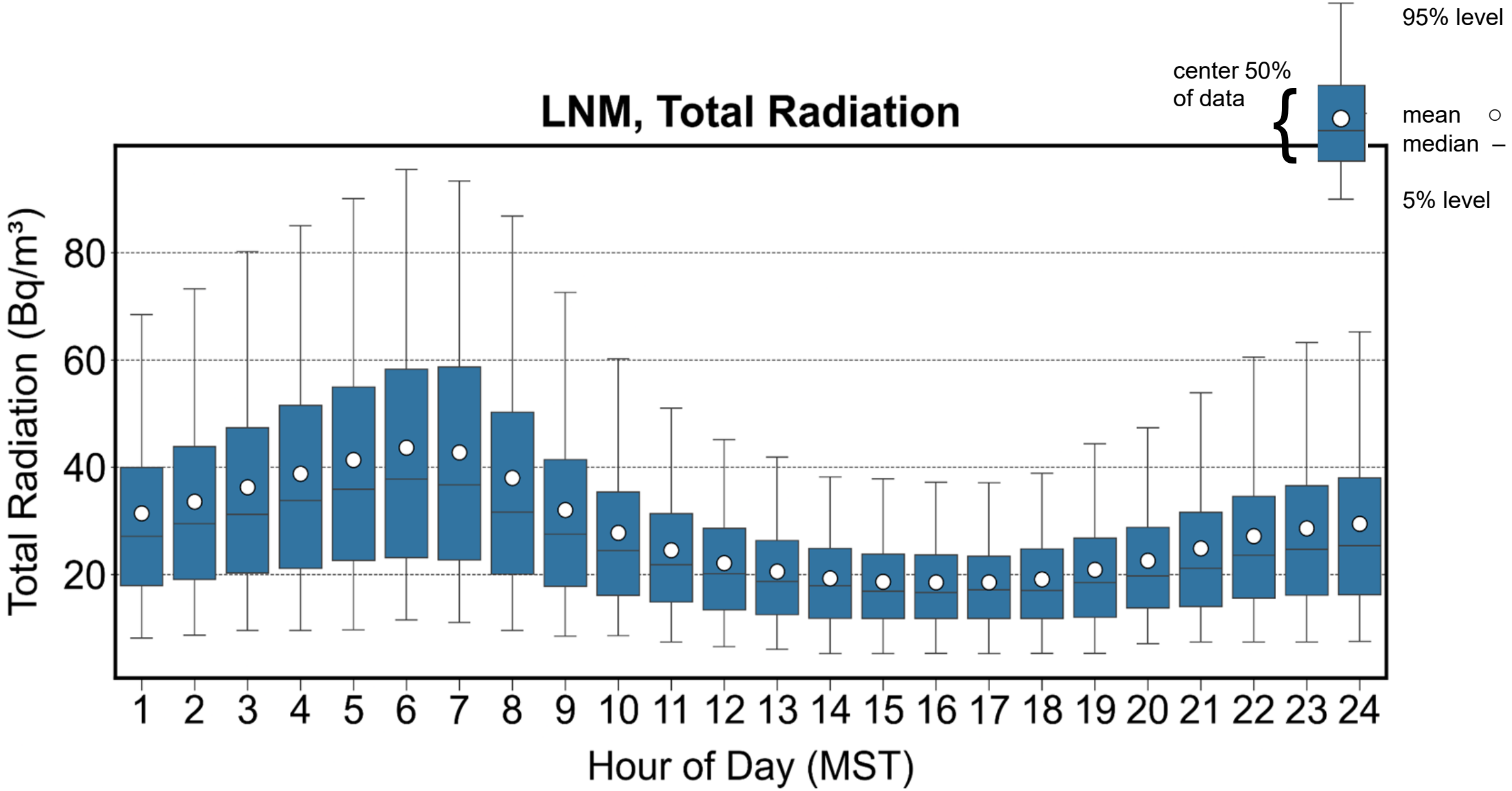
Particle radioactivity monitor inlet temperature controller

Particle radioactivity monitor enclosure

Gas phase radon monitor

Particle radioactivity monitor inlet




LNM, Total Radiation
Total Radiation (Bq/m³)
20
40
60
80
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour of Day (MST)
95% level
center 50%
of data
mean ○
median –
5% level

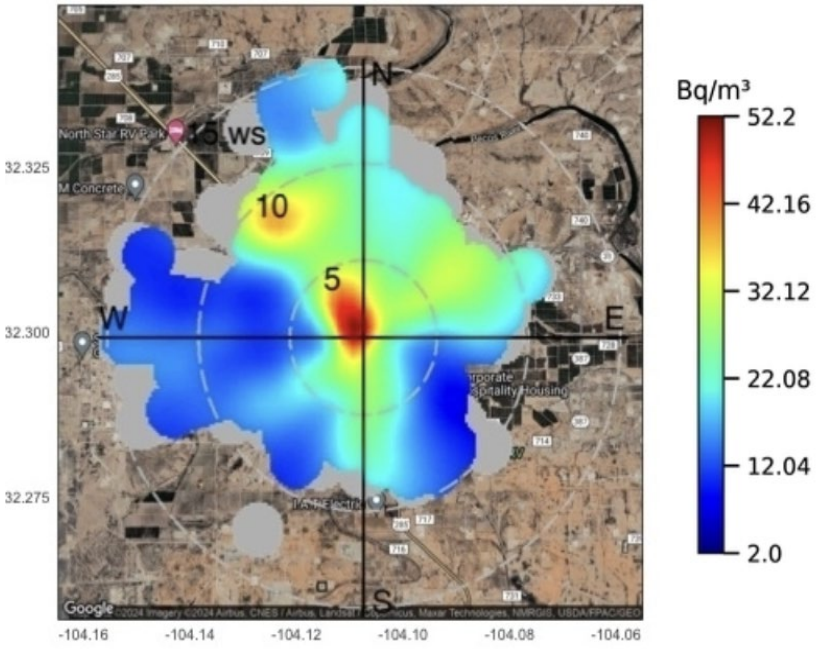
Airborne gas and paraticle radioactivity at Loving, NM

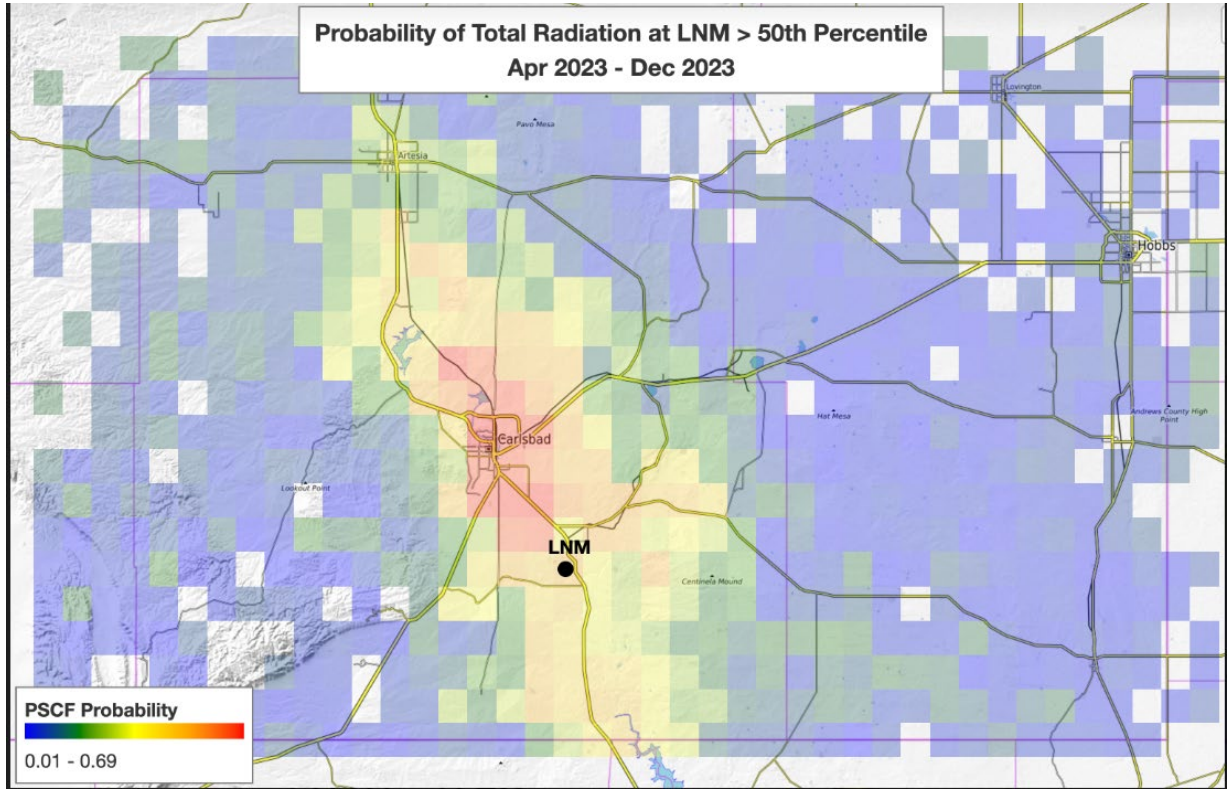
Loving New Mexico

Gas + Particle Radiation Oct 01, 2023, to Dec 31, 2023

Minimum bin value = 2

Wind speeds larger than 1 m/s



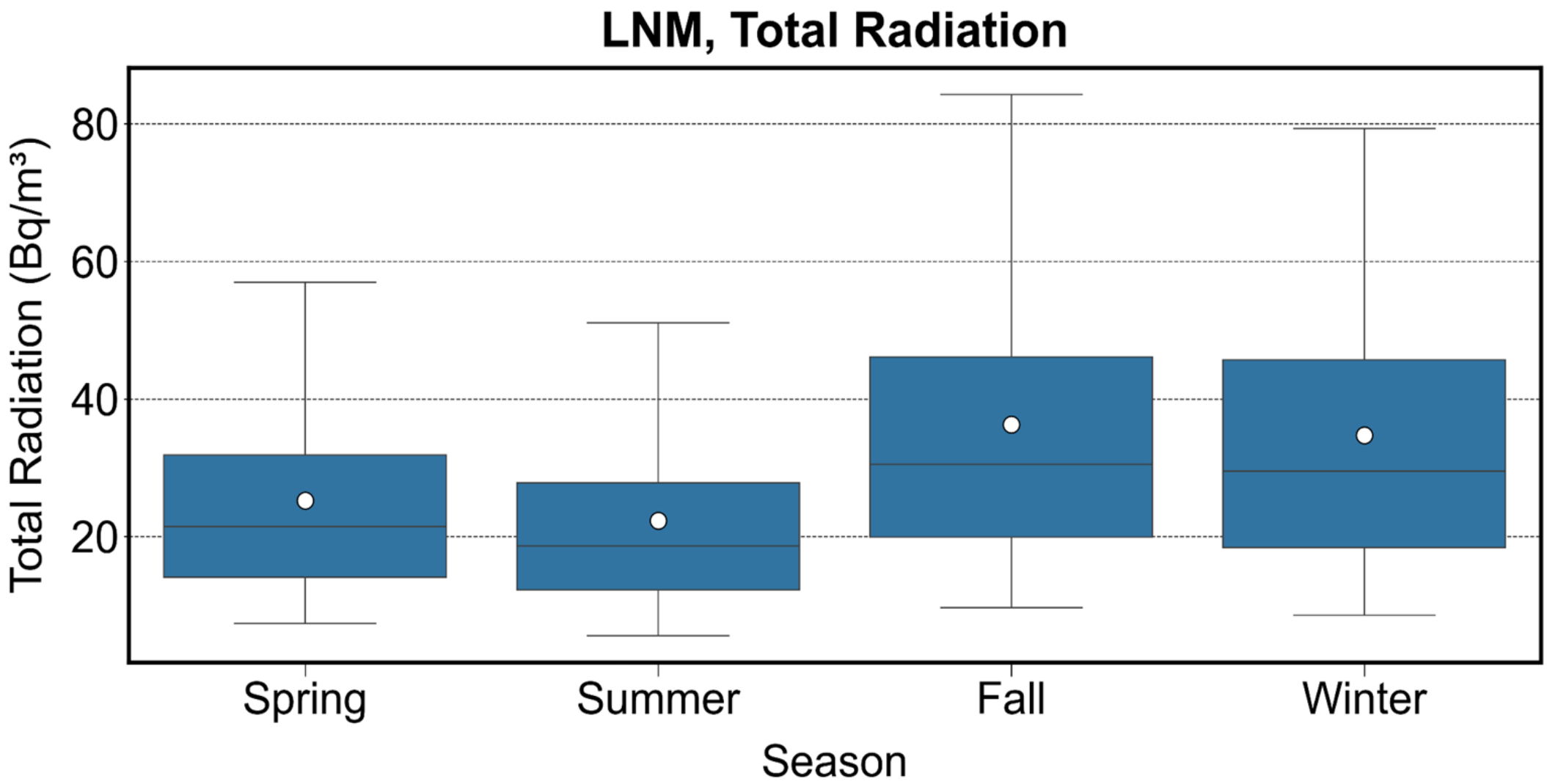


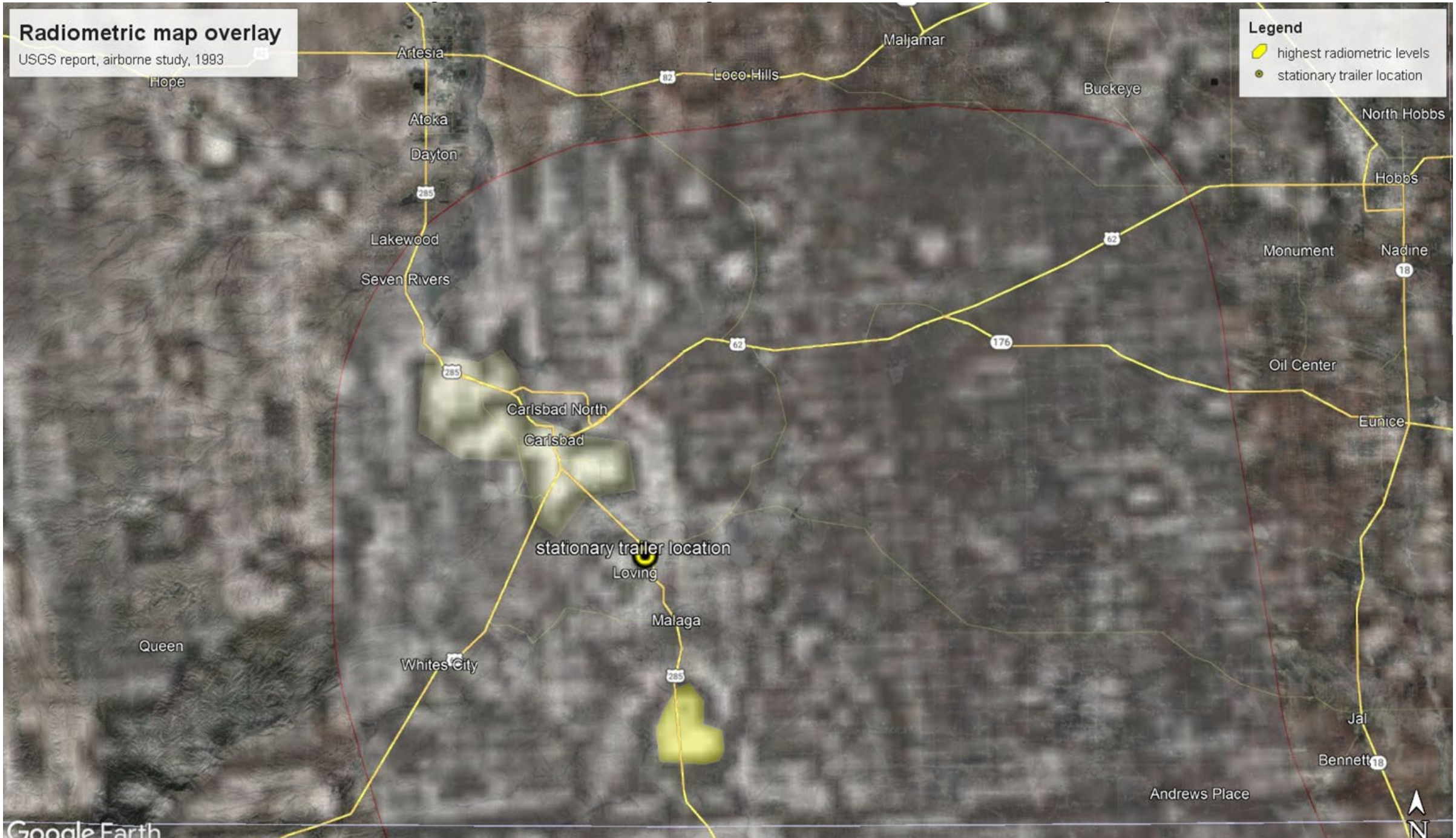
Units for Ambient Radioactivity Monitoring

- Pico-Curie per Liter : pCi L^{-1}
- **Becquerel per cubic meter: Bq m^{-3}**

1 pCi L^{-1} is equivalent to 37 Bq m^{-3}

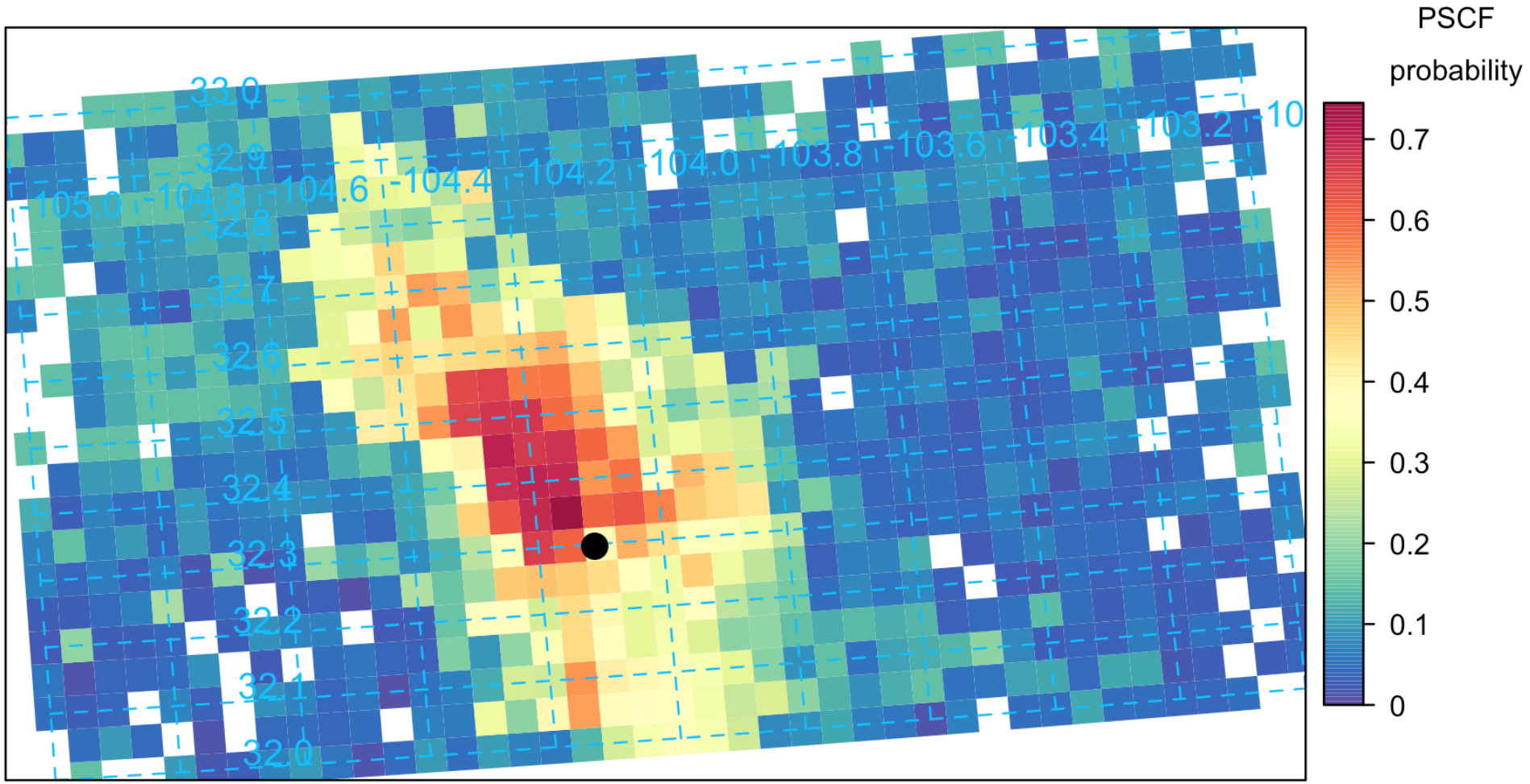
- Continental background, outdoor air: **5-15 Bq/m^3** (0.135-0.405 pCi/L)
- World Health Organization action level for indoor air: **100 Bq/m^3** (2.7 pCi/L)
- US EPA action level for indoor air: 4 pCi/L (~**150 Bq/m^3**)


LNM, Total Radiation
Total Radiation (Bq/m³)
80
60
40
20
Spring
Summer
Fall
Winter
Season


Radiometric map overlay
USGS report, airborne study, 1993
Legend
highest radiometric levels
stationary trailer location
Artesia
Hope
Maljamar
Loco Hills
Buckeye
North Hobbs
Atoka
Dayton
Hobbs
Lakewood
Seven Rivers
Monument
Nadine
Oil Center
Carlsbad North
Carlsbad
Eunice
stationary trailer location
Loving
Malaga
Queen
Whites City
Jal
Bennett
Andrews Place
Google Earth
N

Probability of Gas Phase Radiation at LNM > 50th percentile

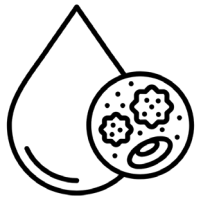
Apr 2023 - Dec 2023



Health effects of volatile organic compounds (VOCs)

Central nervous system

- Dizziness, drowsiness, headaches, nausea, confusion
- Numb feet and hands
- Hearing and vision loss
- Nerve and brain damage



Blood (benzene)

- Anemia
- Increased chance of infections
- Leukemia

Reproduction & development

Source: EPA IRIS, EPA 2012, ATSDR

Images: Cedric Villain, Dhalia Nuraini, and Mahmure Alp for the Noun Project

What levels of benzene in air are considered safe?

ATSDR chronic minimal risk level (MRL)	**3 ppb** (non-cancer)
EPA reference concentration & inhalation unit risk	**9 ppb** (immune system) **0.4 to 1.4 ppb** (1 in 100,000 excess cancer risk)
WHO guidelines	**0.5 ppb** (1 in 100,000 excess cancer risk)

ATSDR = Agency for Toxic Substances and Disease Registry
EPA = Environmental Protection Agency
WHO = World Health Organization