Air Quality Research in the Carlsbad, NM, area

New Mexico Legislative Finance Committee Hearing
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Assessing source contributions to air quality and noise in unconventional oil shale plays

Funding and Monitoring Site Support

HEI energy

*** Results presented today have not yet undergone HEI Energy's rigorous review process.**

ConocoPhillips

Research Team

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Exposure assessment, statistics, data science

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unconventional oil and gas development measurement, distributed sampling

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unconventional oil and gas development measurement, fixed station monitoring

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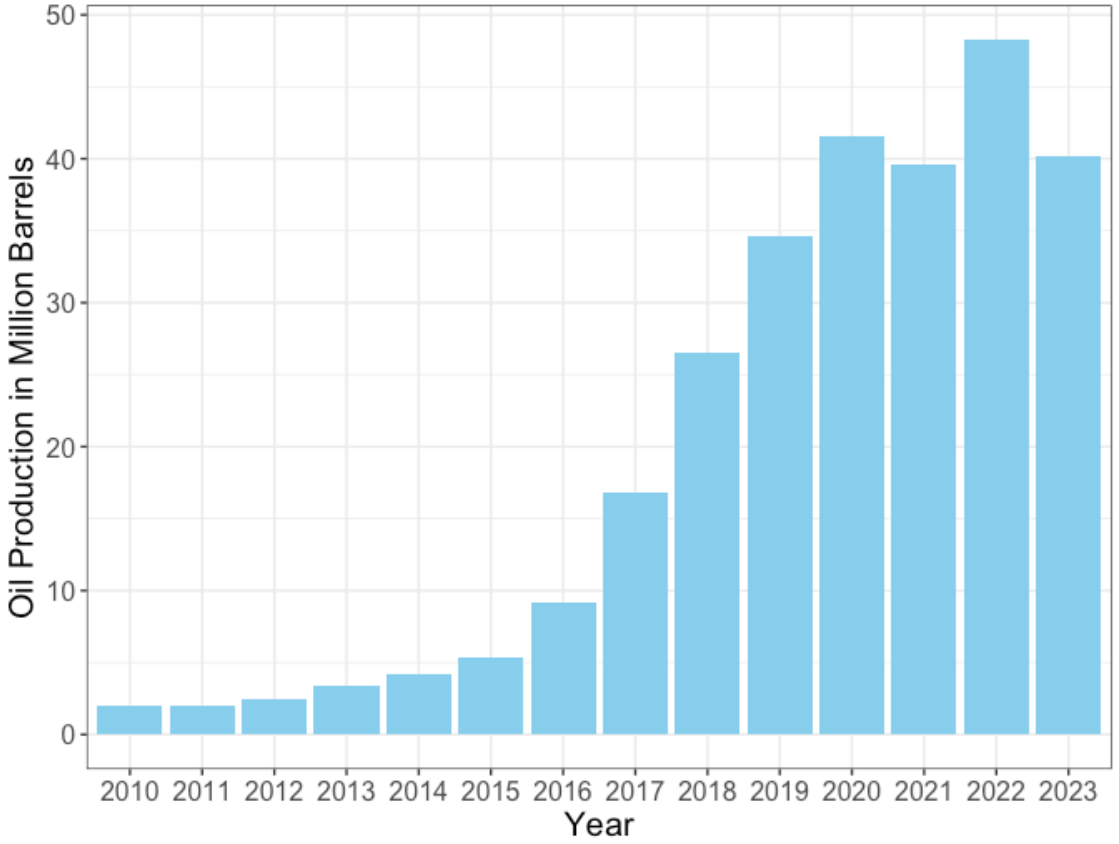
Environmental health and justice, community engagement

Lara Cushing (UCLA)
Environmental health and epidemiology, community engagement

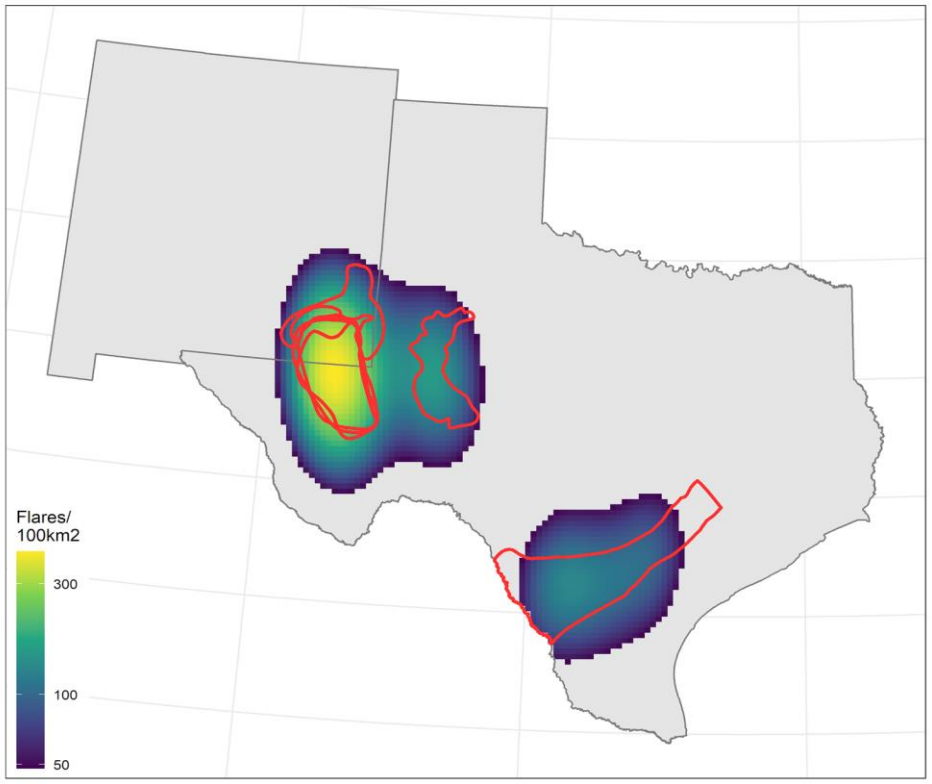
Study Motivation

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



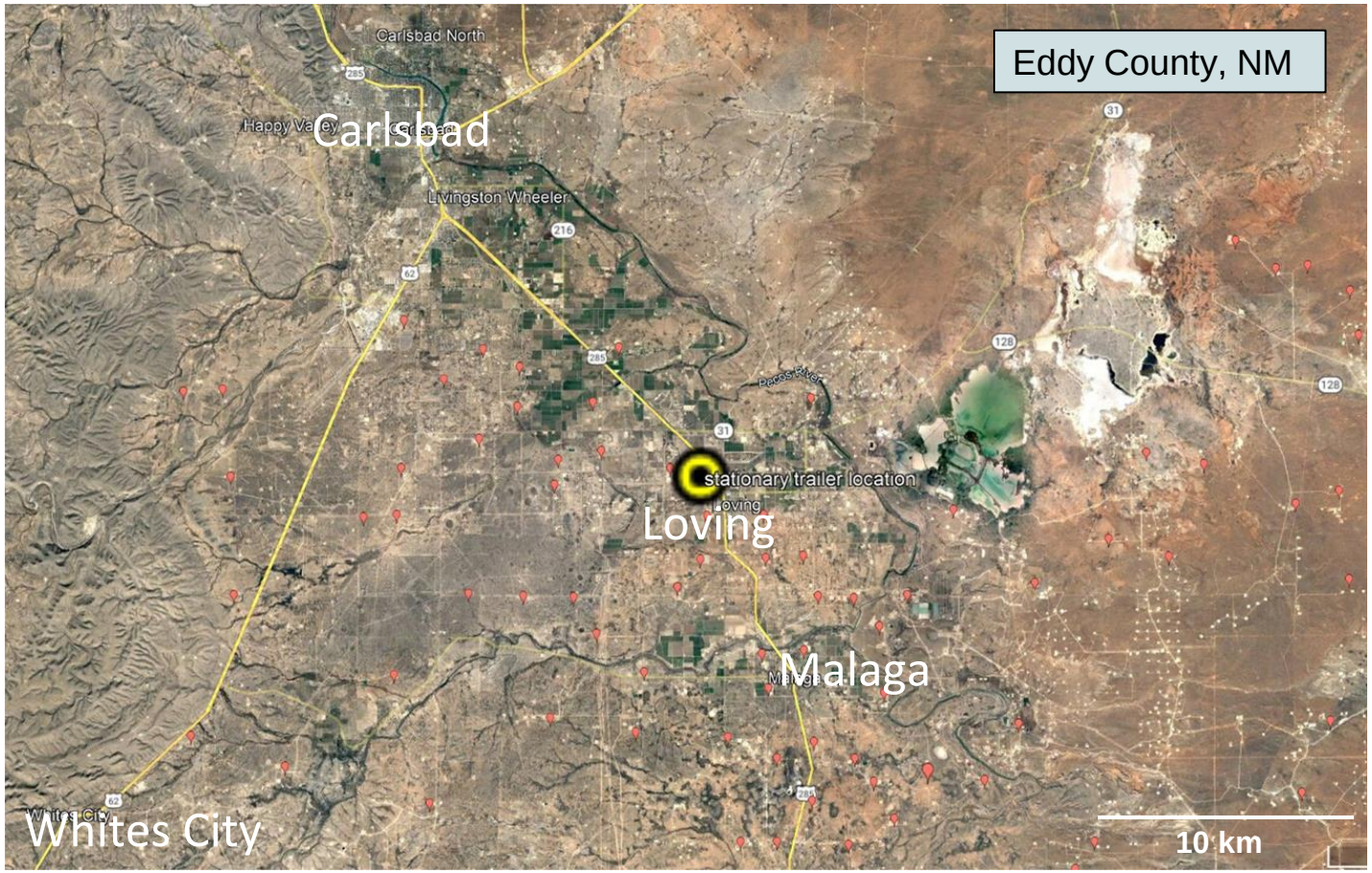
Data from Enverus (pulled 12/6/2023)

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

Overview of sampling site in Loving, NM



https://bouldair.com/loving.htm

What we are measuring in Loving, NM

Air Pollutants and Greenhouse Gases

- Ozone (O_3)
- *Volatile organic compounds (VOCs), including hydrocarbons*
- Nitrogen Oxides (NO_x)
- *Sulfur Dioxide (SO_2)*
- *Hydrogen Sulfide (H_2S)*
- *Carbon Monoxide (CO)*
- *Carbon Dioxide (CO_2)*
- *Methane (CH_4)*

Radioactivity

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

Noise

- *Decibel levels at different frequencies*

Ozone forms from:

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

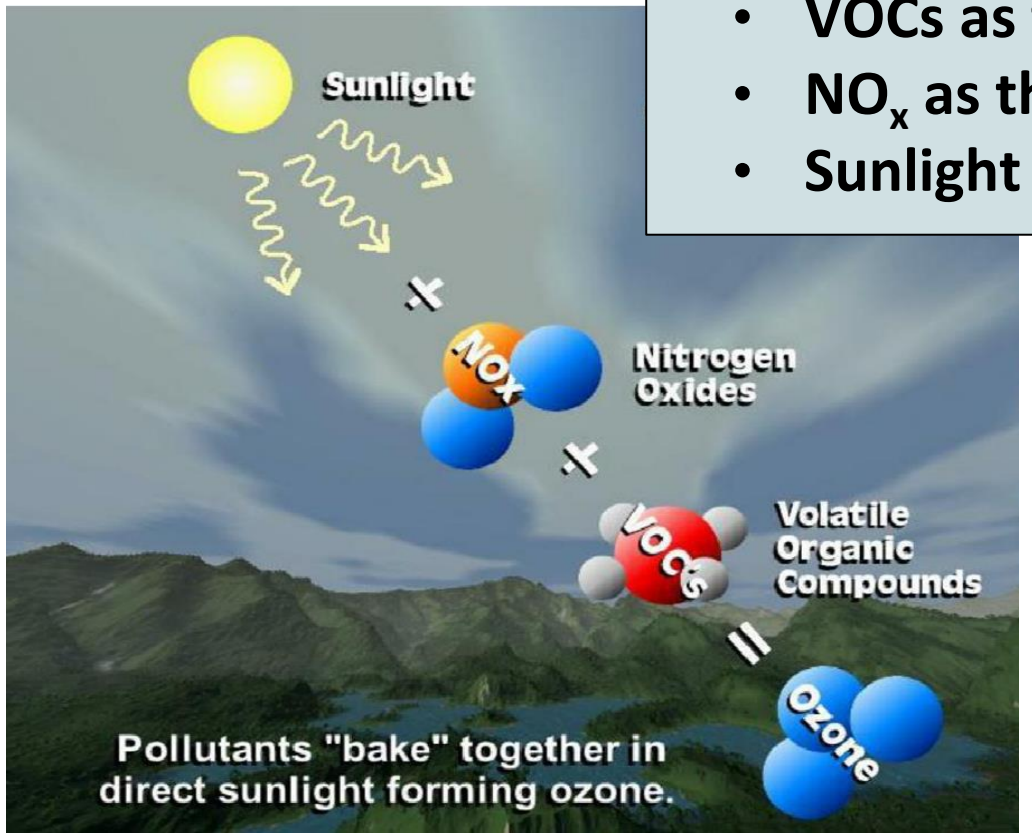


image credit: NASA/NSF

Air Quality in the context of oil and gas site setbacks

1. **Emissions and exposure**
2. **Emissions and ozone formation**
3. **Health effects**

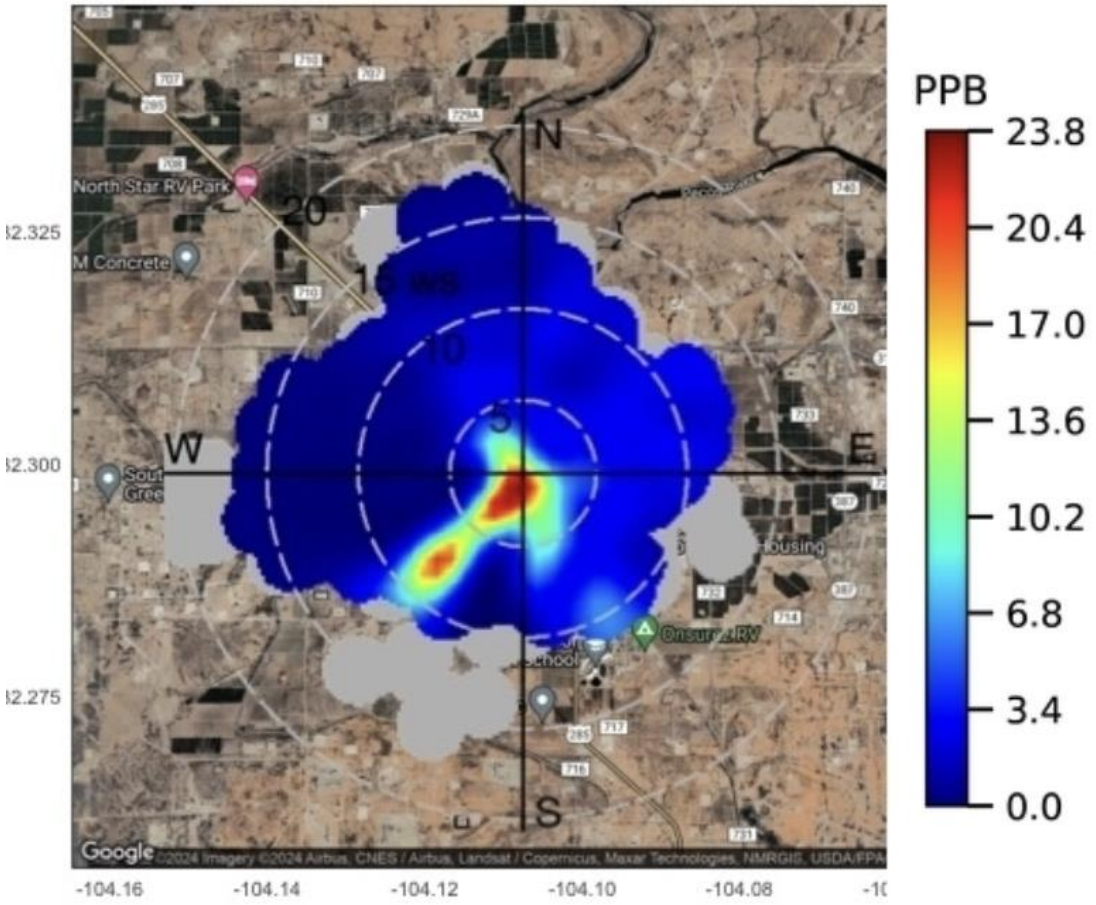
1. Pollutant Exposure

Loving New Mexico

Total Nitrogen Oxides Oct 01, 2023, to Dec 31, 2023

Minimum bin value = 2

Wind speeds larger than 1 m/s



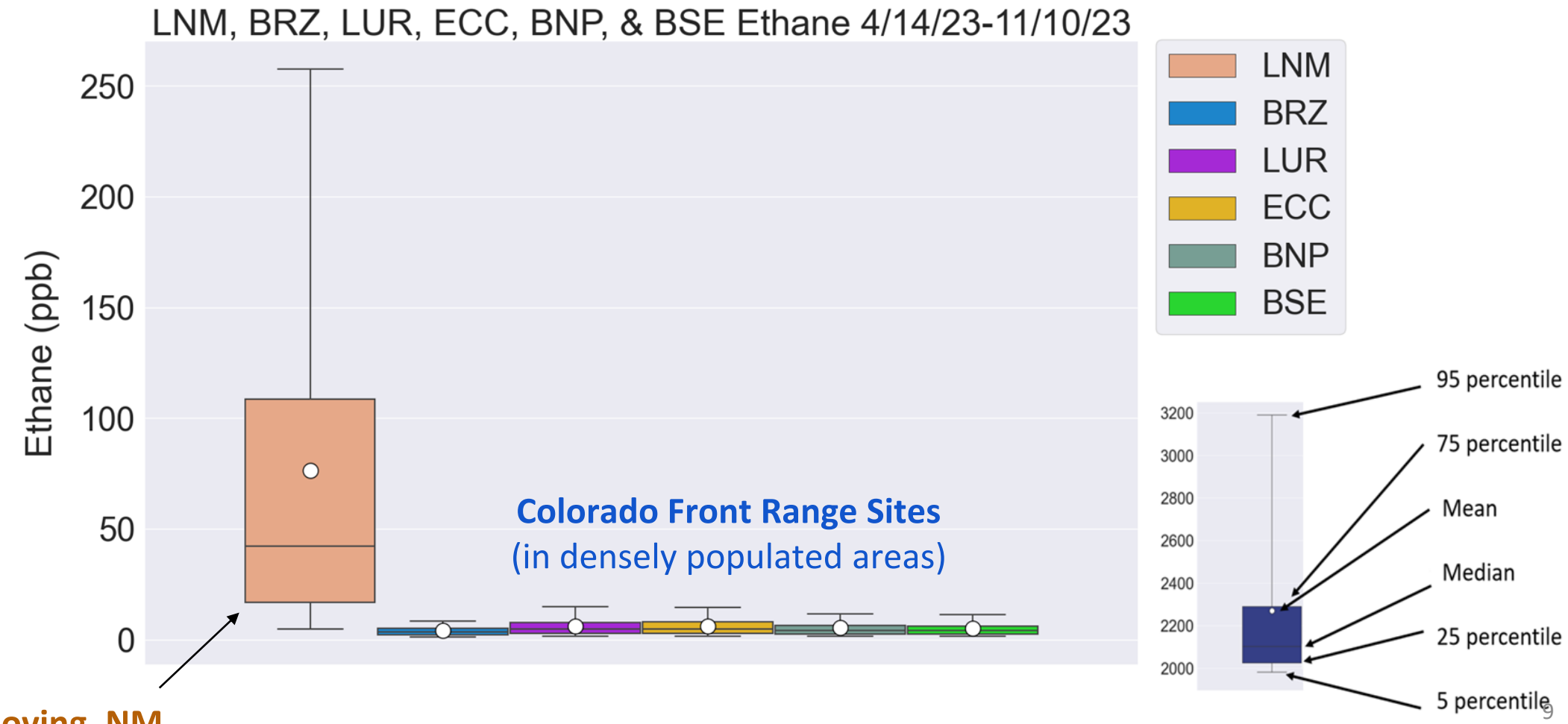
Nitrogen Oxides (NO_x) emissions

- **Nitrogen oxides (NOx) are the catalyst for regional ozone formation**
- **Emitted from combustion processes**
- **Wind analysis suggests that emissions are dominated by a strong point source at our site,**

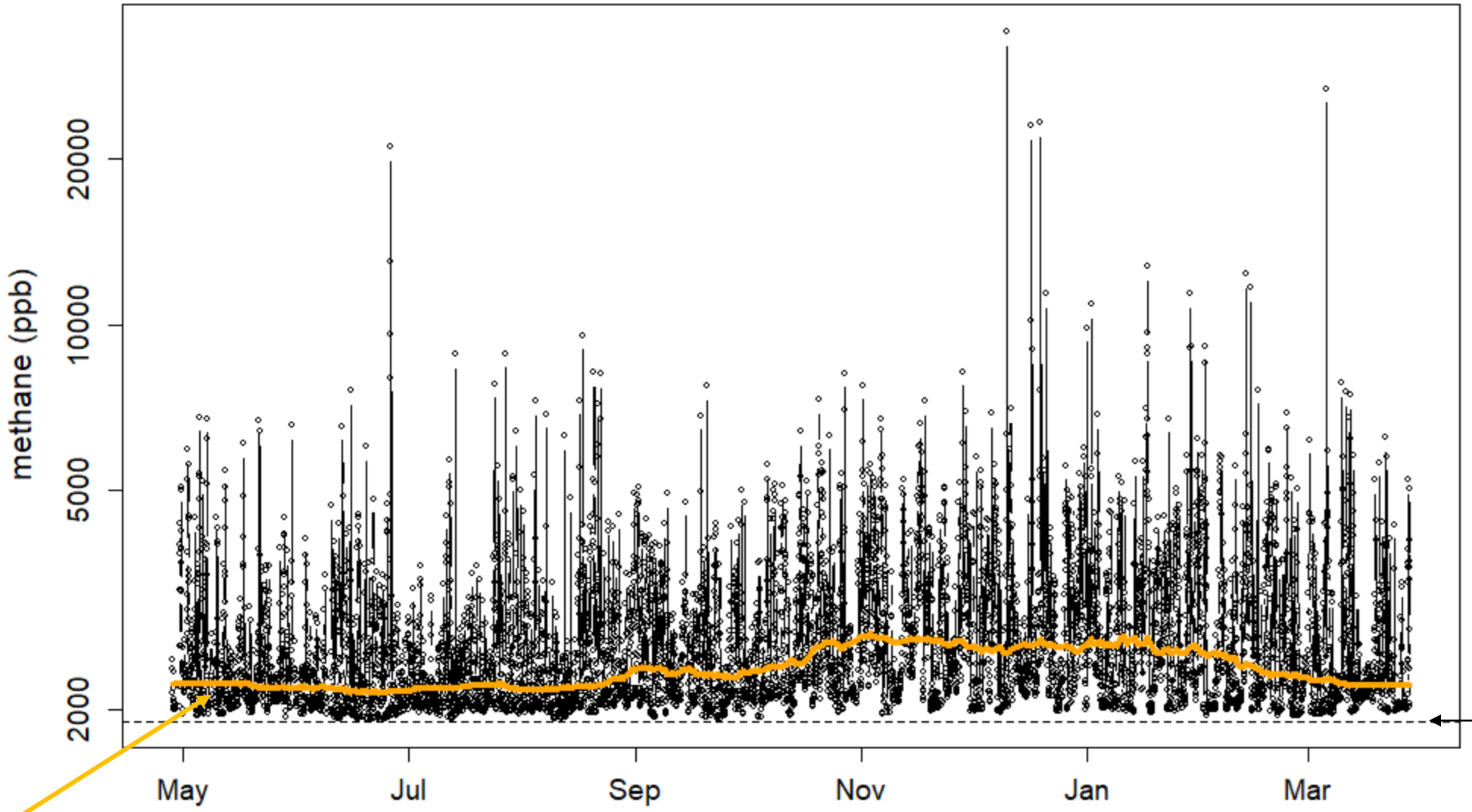
  <u>here: gas flaring on neighboring pad site</u>

Exposure statistics: Ethane at the Loving, NM site in 2023

Ethane is an important oil and gas emissions tracer



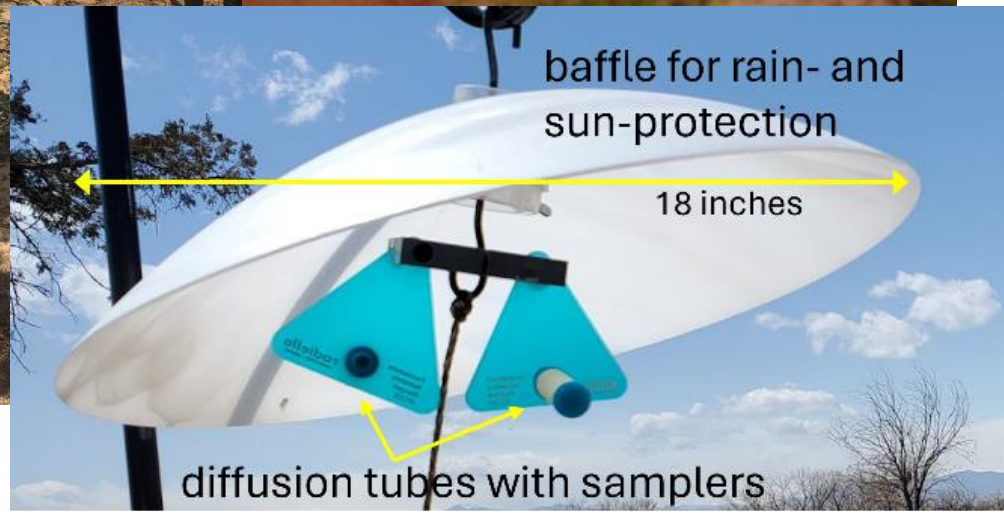
Methane time series to illustrate pollution plumes



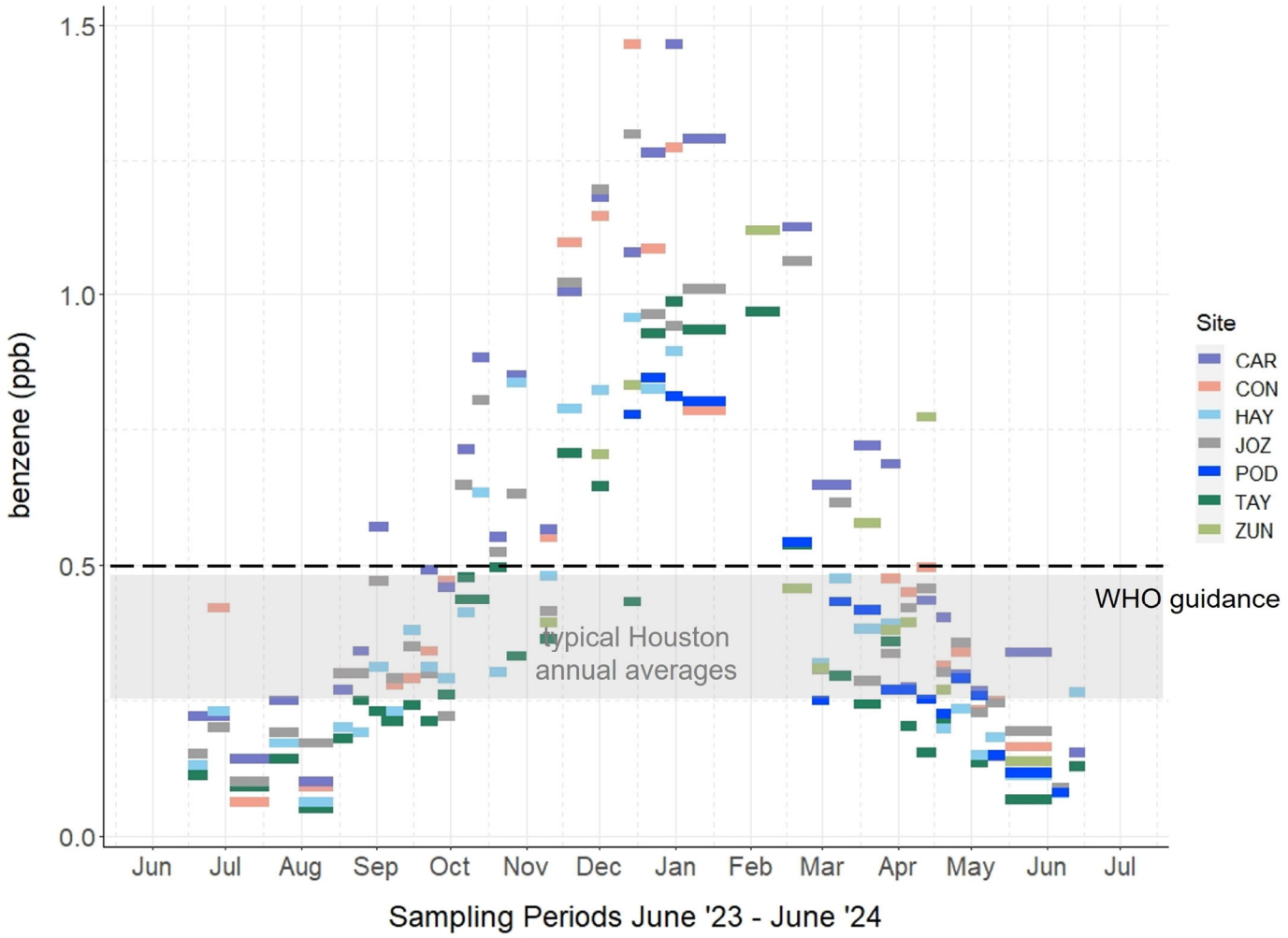
Passive Sampling

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 are shipped weekly to and from College Station, TX

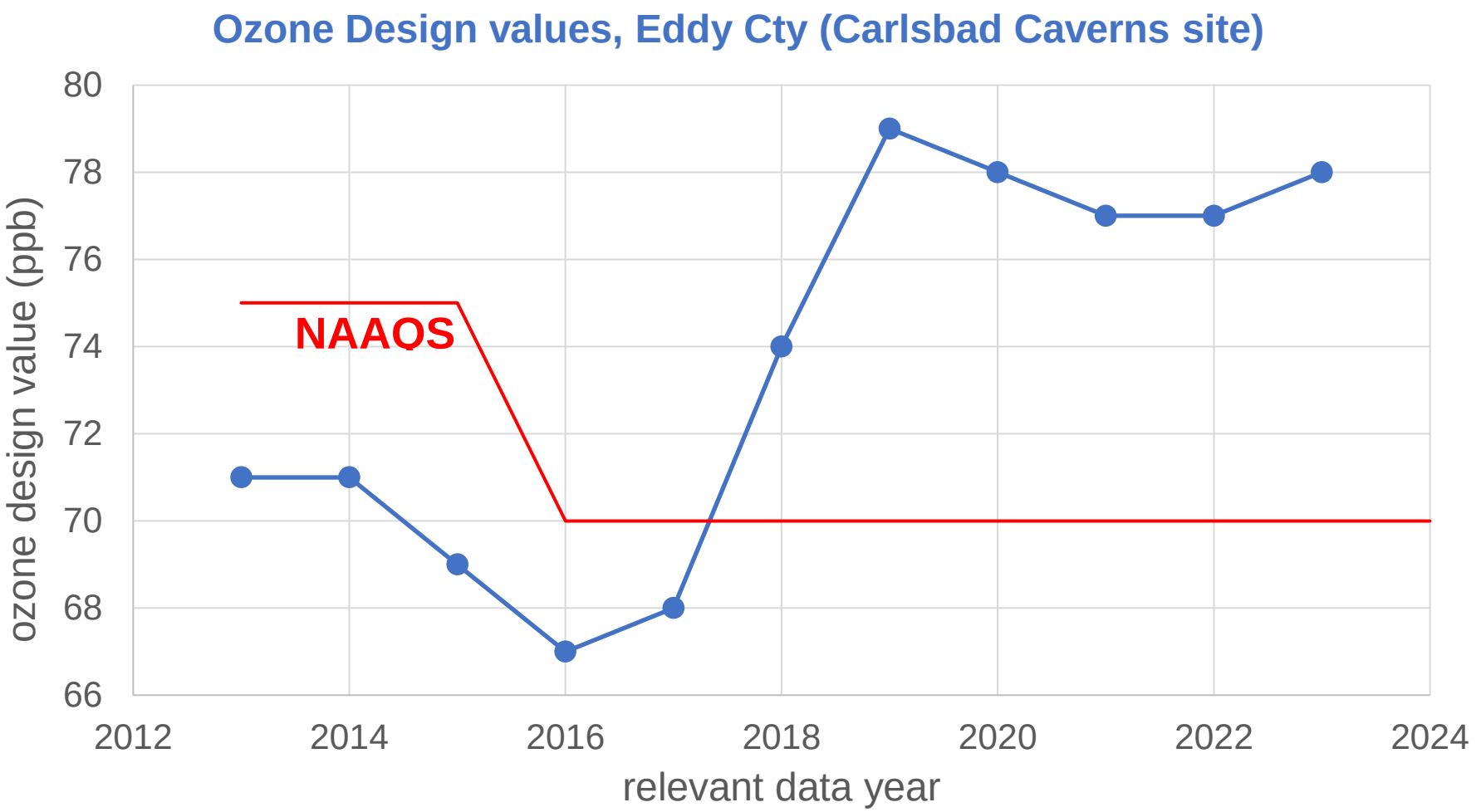


Passive sampling network: benzene concentrations

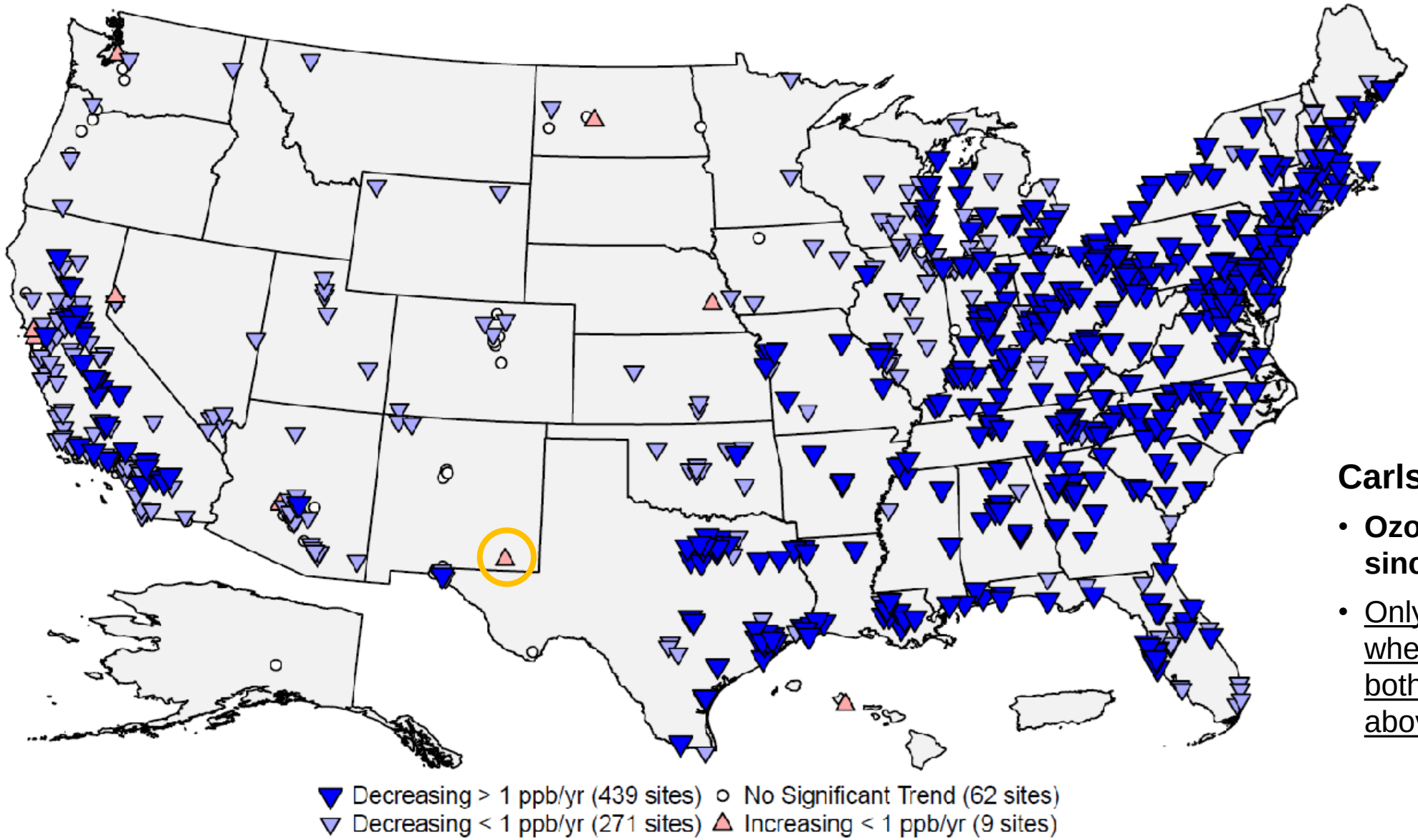


- Seasonal cycle (higher concentrations in fall and winter)
- Strong gradients between sites
- Higher levels than in Houston
- Exceeding WHO long-term exposure guidance level

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



Ozone Design Value trends across the United States (EPA, 2023)



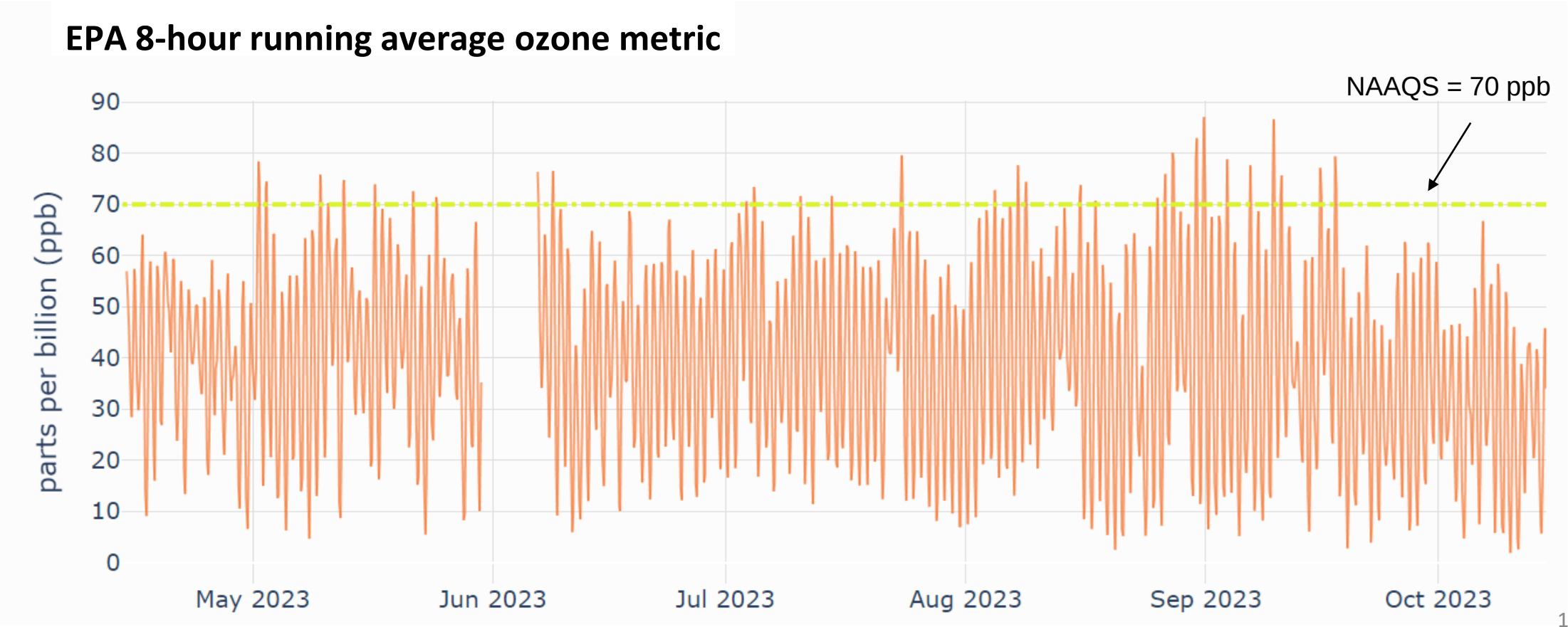
Carlsbad-Artesia:

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

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

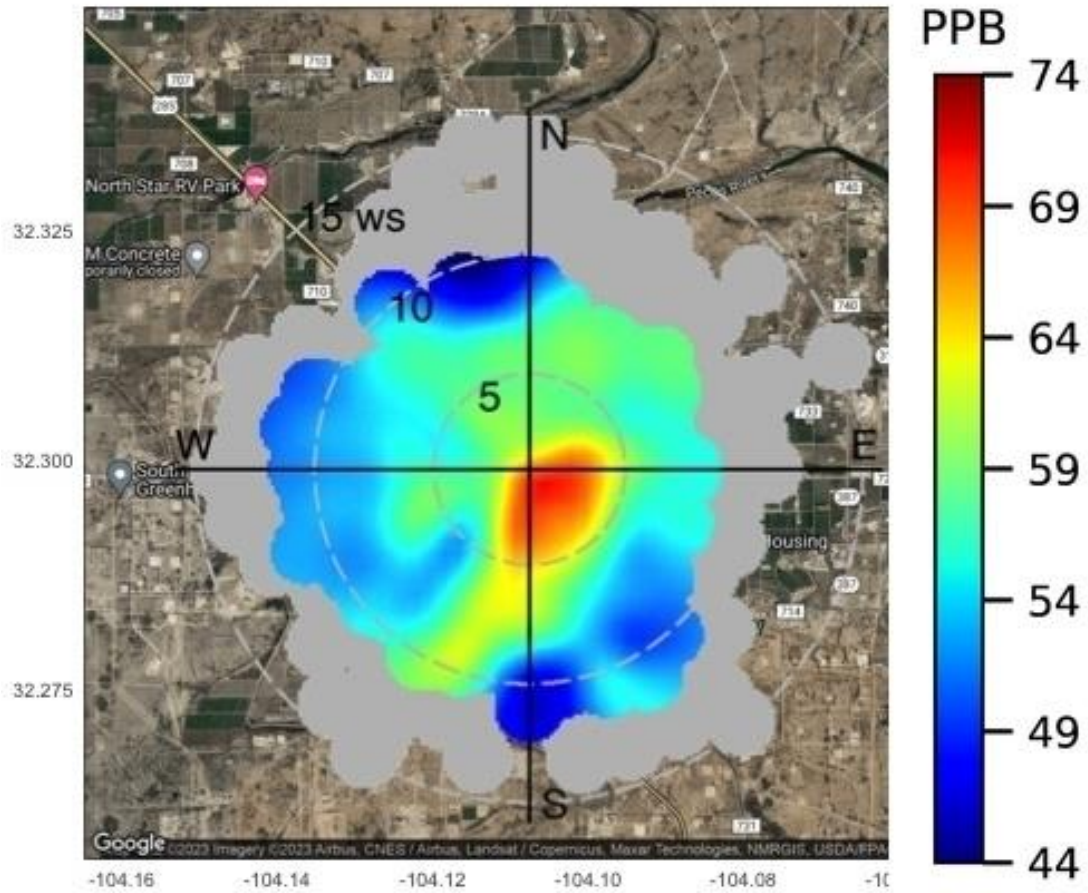


Loving New Mexico

Ozone May 01, 2023, to Sep 30, 2023

Minimum bin value = 6

Wind speeds larger than 1 m/s, time window 11am to 7pm



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.**
- **Virtually all “fuel” for ozone formation comes from oil and gas industry hydrocarbon emissions (not shown here)**

3. Health effects of air pollution

	Nitrogen oxides	Ozone	Benzene & other VOCs
• Asthma	X	X	
• Coughing, wheezing, difficulty breathing	X	X	
• Airway inflammation, reduced lung function	X	X	
• Susceptibility to infections	X	X	X
• Cardiovascular effects (heart attacks)	X		
• Metabolic effects		X	
• Damage to kidneys, liver, and nervous system			X
• Anemia			X
• Cancer			X

- Effects depend on the level and duration of exposure
- **Children**, **outdoor workers**, and those with **pre-existing conditions** are most at risk

American Lung Association, US EPA, US CDC, IARC

Photo: Nenad Stojkovic

Health effects observed in populations living near oil and gas production

- Respiratory effects such as asthma & reduced lung function
- Adverse birth outcomes like premature birth and birth defects
- Childhood leukemia
- Increased blood pressure
- Complaints of nosebleeds, wheezing, sore throat and dizziness

Deziel et al. 2020, Johnston et al. 2021 & 2023, Clark et al. 2022

Photos: Kin Man Hui & Jerry Lara, DXJ Gonzalez

Summary

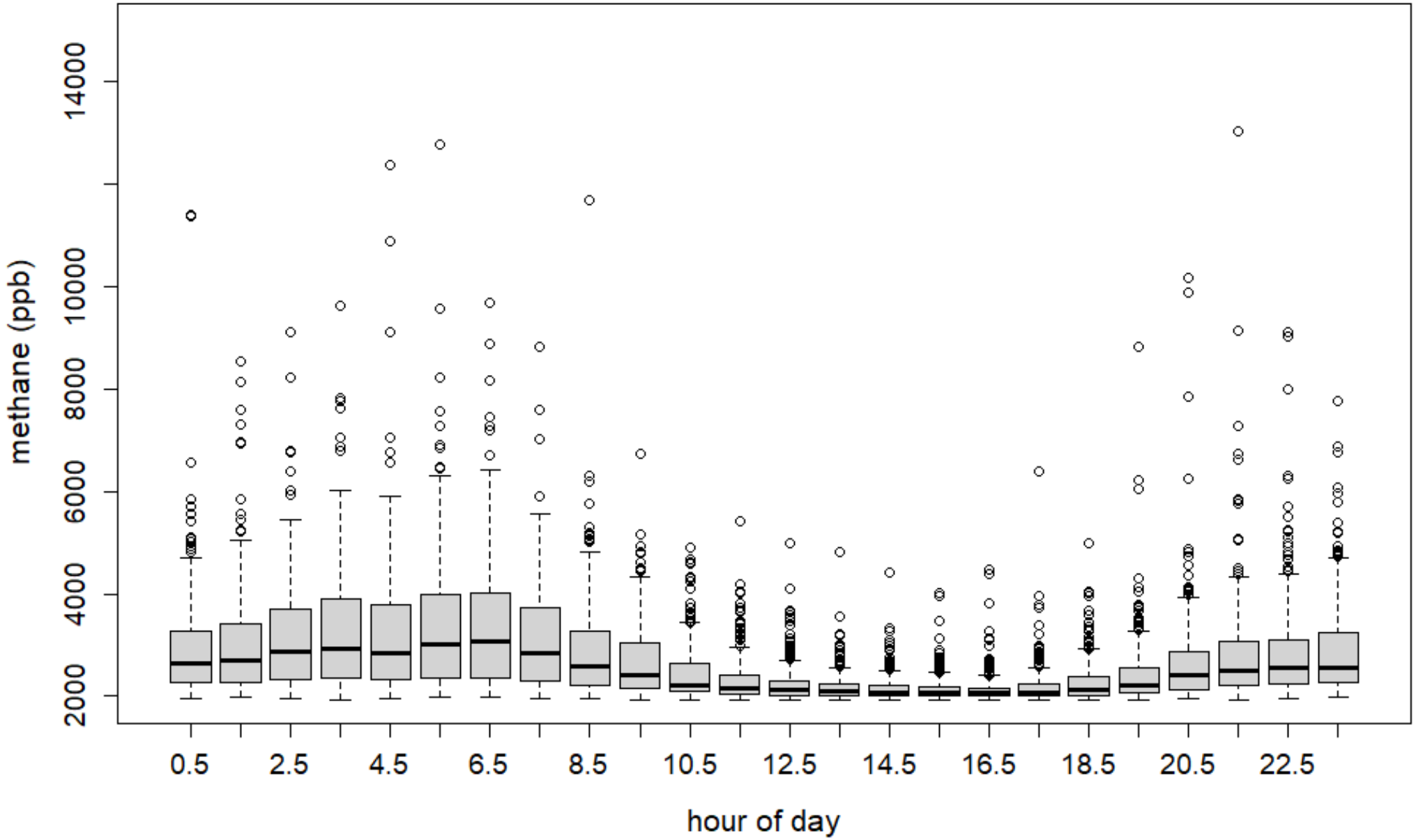
- A good neighbor?

- <u>Regional air quality is poor</u>
  - Frequent pollution plumes (from all directions, especially prominent at night)
  - Benzene, among most toxic compounds measured, exposure is comparatively high, worse than in big cities (e.g. Houston)
  - Significant ozone problem, very likely created by oil & gas industry (VOC and NO_x) emissions

Reserve slides

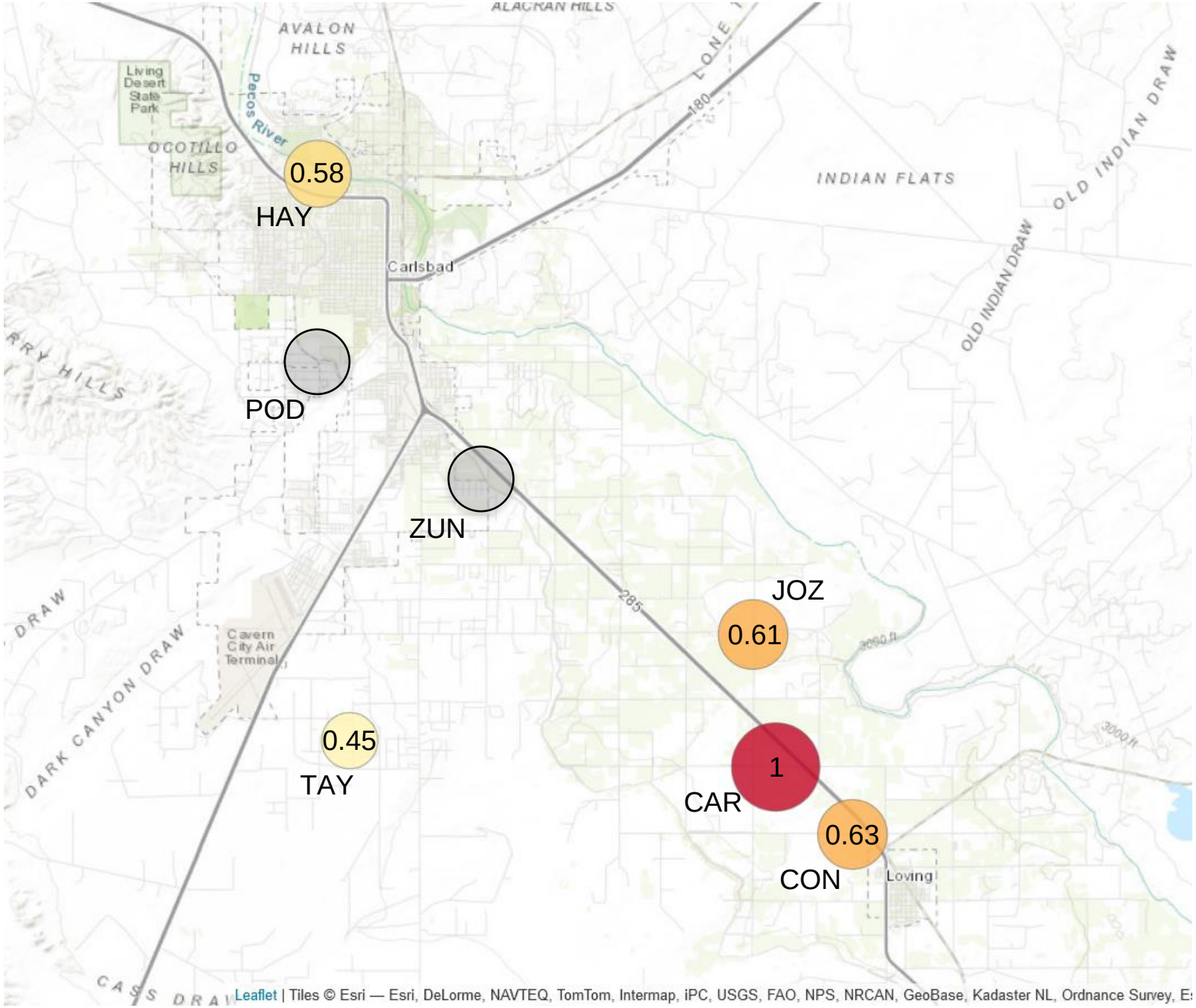
Flaring as waste disposal

- Flaring is used during the flowback, production and processing stages
- Nearly 5% of the world's gas consumption is flared annually
- Gas Flares often burn continuously for weeks or months
- Common in oil-producing shale plays
- Release VOCs, such as benzene
  - also PAHs, NOx, sulfur dioxide, and black carbon (soot)


methane (ppb)
2000
4000
6000
8000
10000
14000
0.5
2.5
4.5
6.5
8.5
10.5
12.5
14.5
16.5
18.5
20.5
22.5
hour of day

Passive sampling network

relative exposure levels for toluene across the network



Where are hydrocarbons coming/emitted from?

1. Evaporation from tank batteries, and other leaky oil field equipment.

Leaks

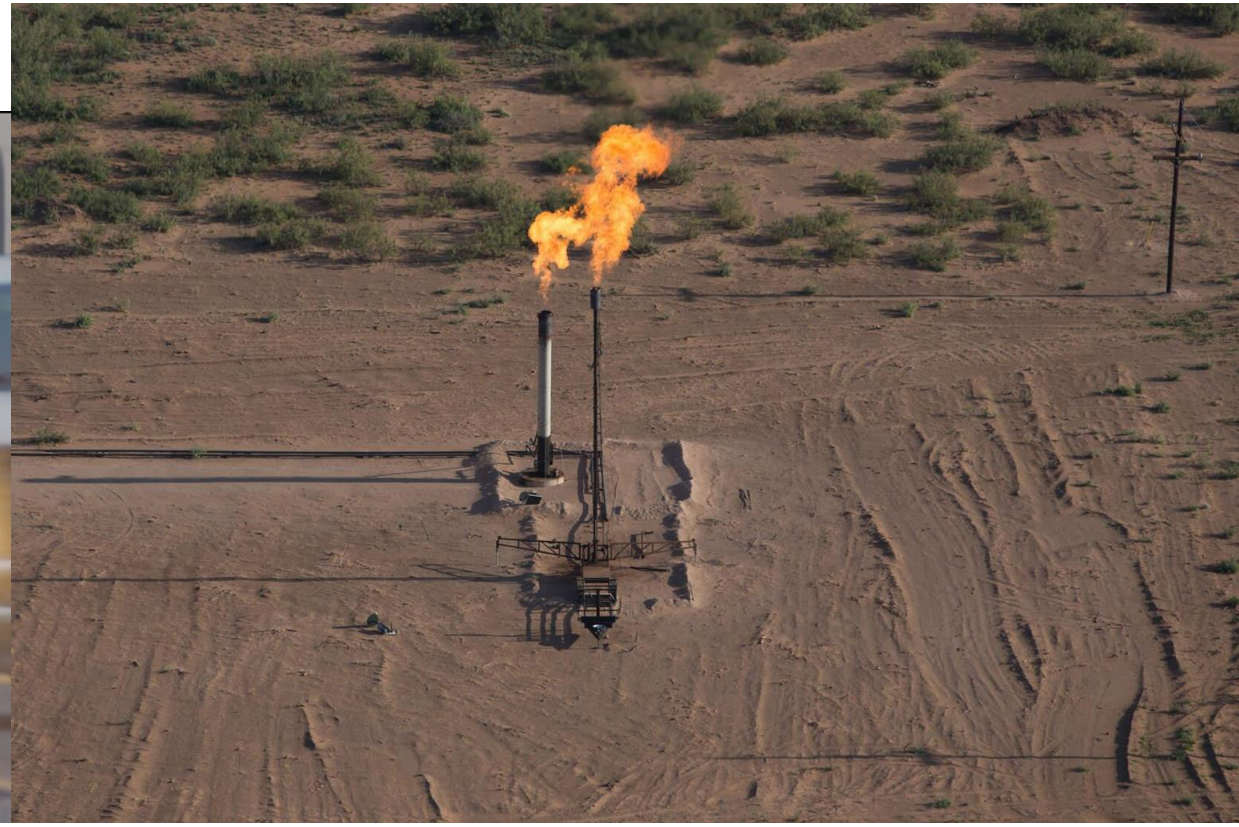
2. Incomplete (Gas) Combustion in flares and compressor engines

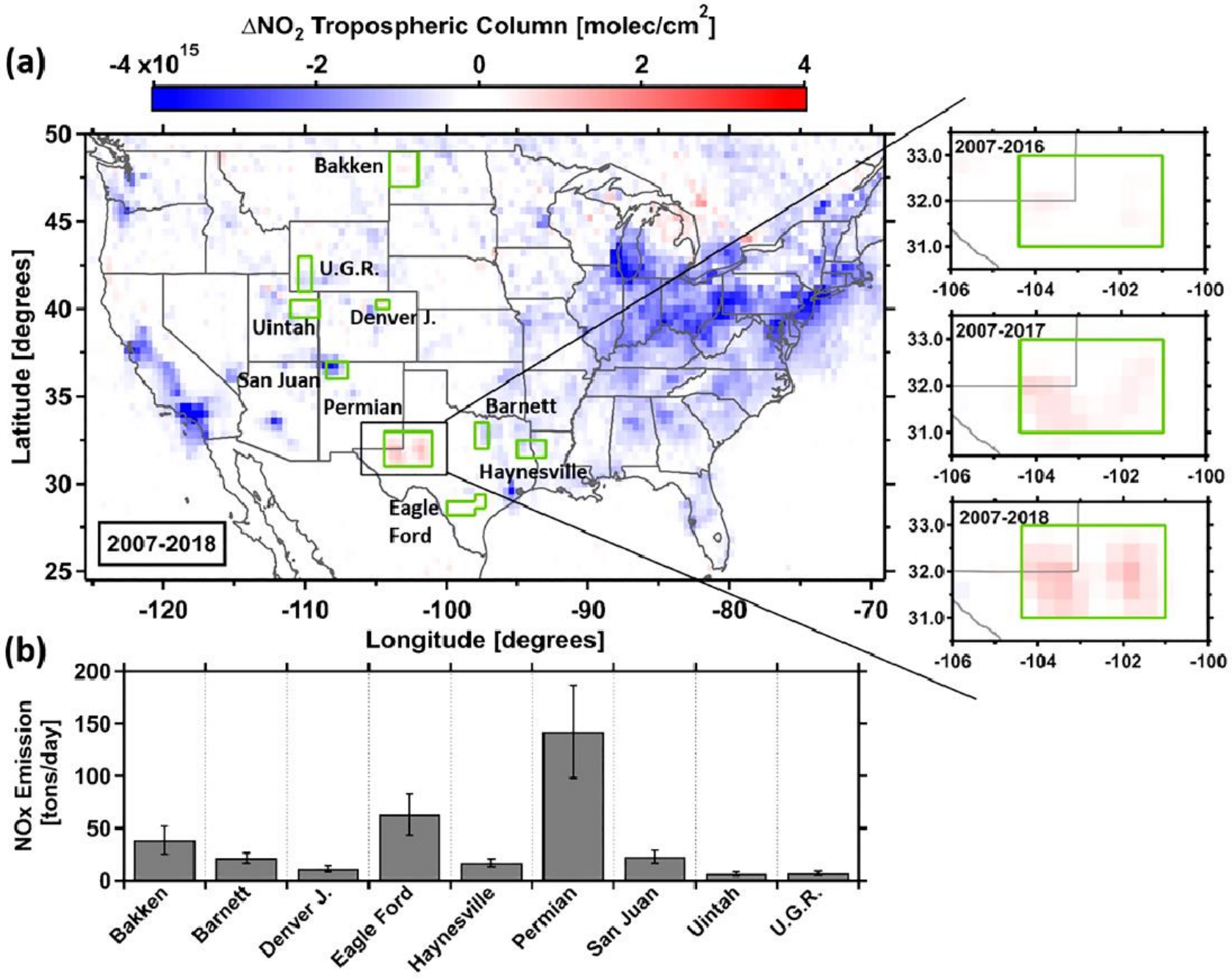
Incomplete combustion

Where are hydrocarbons coming/emitted from?

3. Oil field and regular car traffic (exhaust and evaporation)

4. Gas flares (aside incomplete combustion, new emissions are formed, like benzene!)





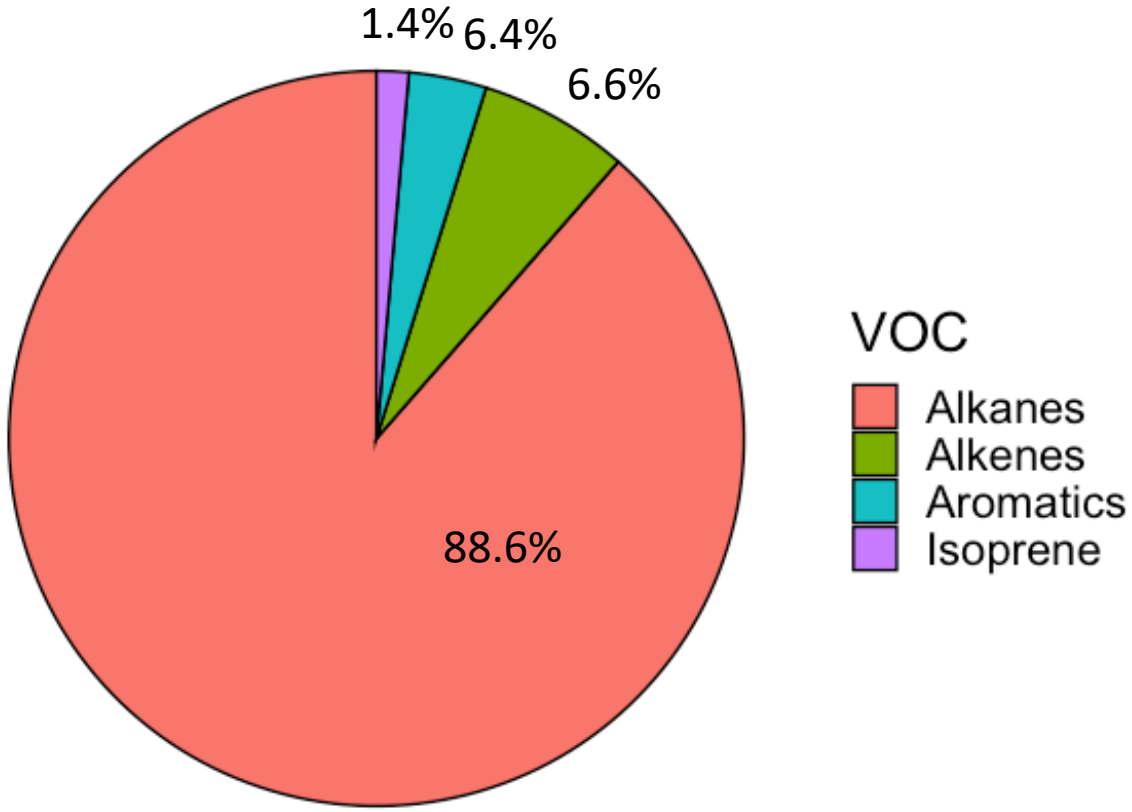
Upward NOx trend in the Permian as determined from satellite measurements

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

What compounds drive ozone formation?

Measured hydrocarbon reactivity → ozone formation potential



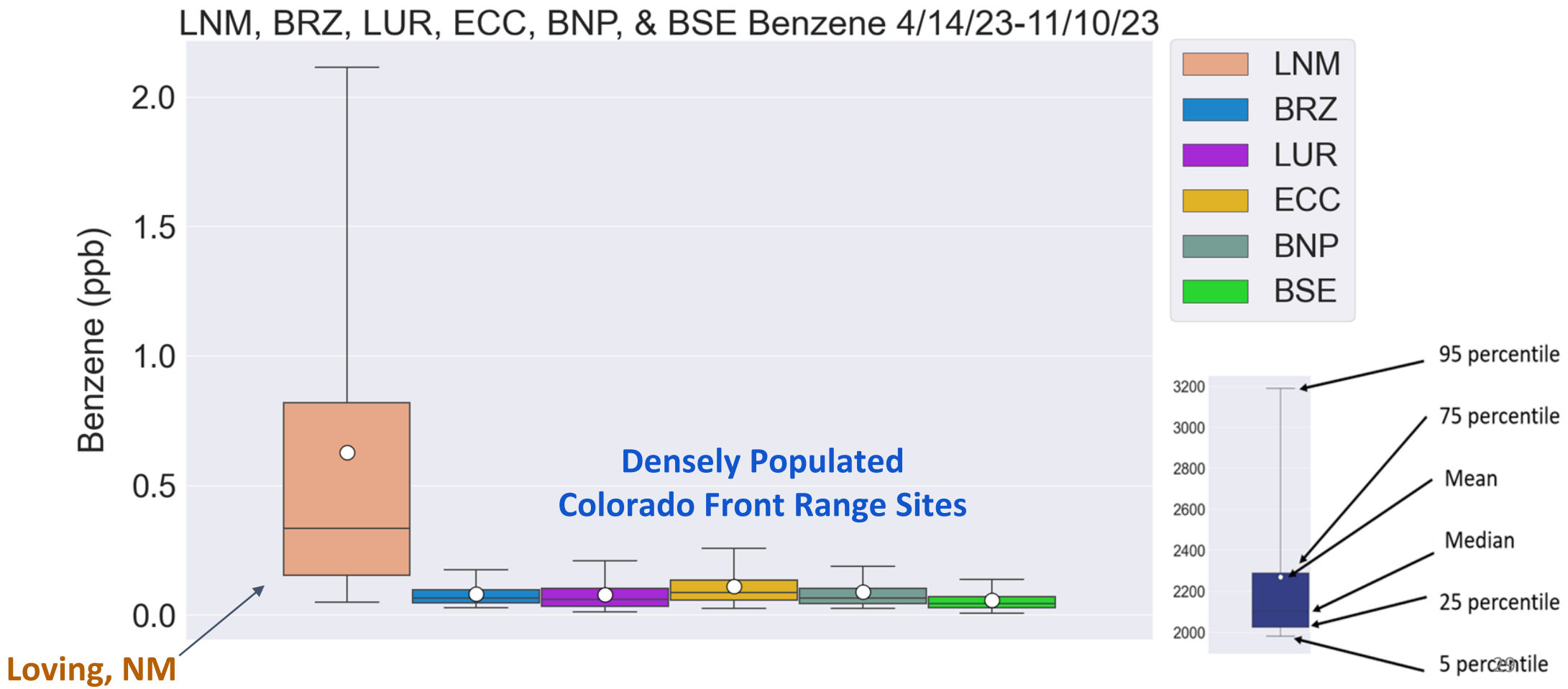
→ The largest contributor to regional photochemical ozone formation is petroleum hydrocarbons.

→ Combined, hydrocarbons associated with oil and gas production contribute more than 90% to the measured ozone formation potential.

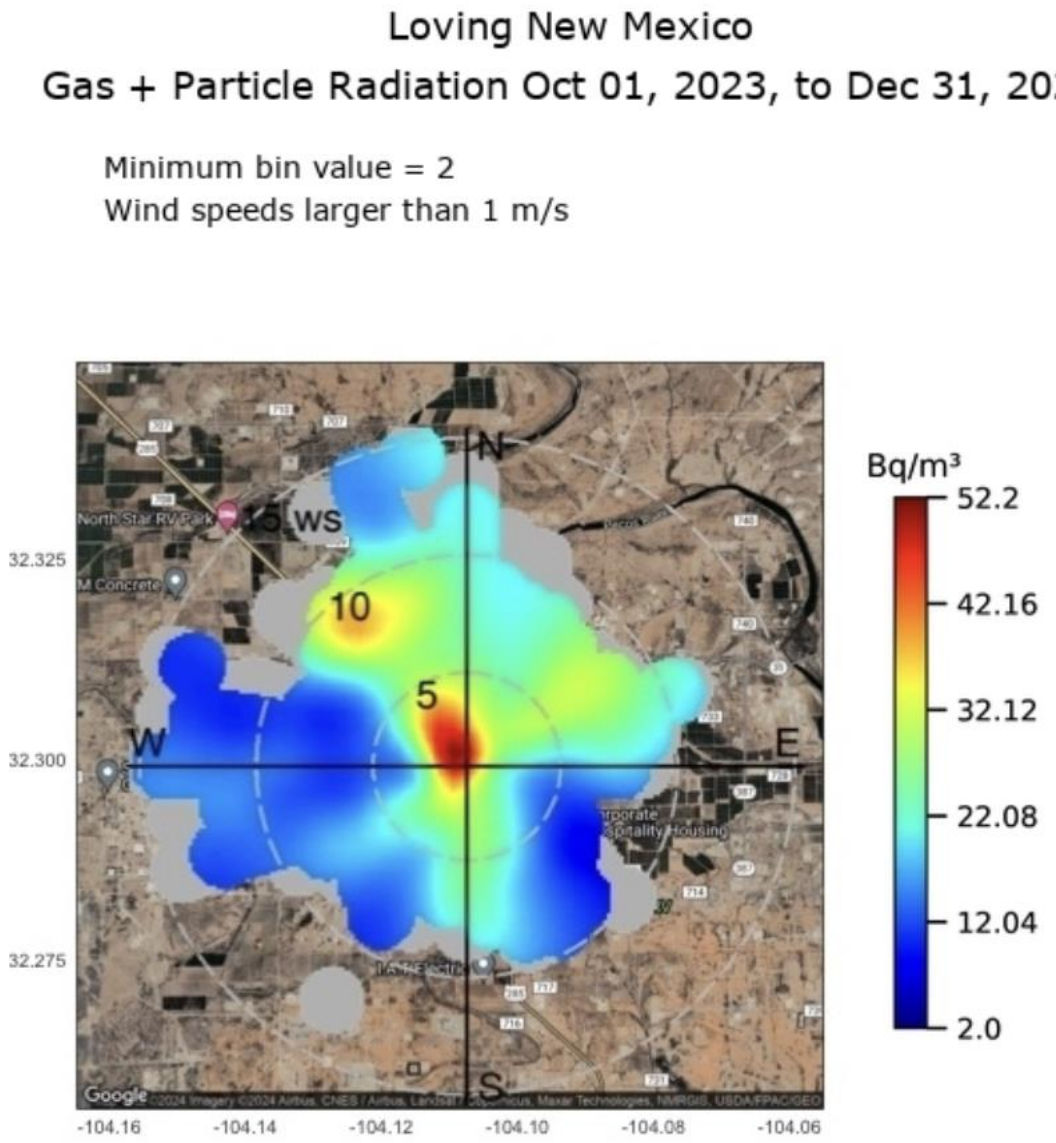
cf. Pan et al., JAWMA 73(12), Nov. 2023

Hydrocarbons: Benzene at the Loving, NM Site in 2023

Benzene is a toxic air contaminant, and a known carcinogenic.
Average was 9–11 times higher in Loving, NM than at Colorado comparison sites.



New insights from airborne radioactivity measurements



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

Radon in the ground is brought to the surface via drilling and gas production

- <u>EPA-recommended action level is 150 Bq/m^3</u>.
- Elevated levels (yellow to red colors) are detected under moderate northerly, especially NNW wind directions.
  - Under these conditions, levels are on average 3-4 times higher than background* levels (blue colors).
- Correlation with sulfur dioxide and hydrogen sulfide suggests a shared “sour gas” source.

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

How to protect yourself from air pollution

Personal level

- Limit outdoor activities
- Keep house windows closed
- Use home air purifiers

Images: Quang Nguyen Vinh, Dimitri Svetsikas

Community level

- Increase setbacks between homes and industry
- Reduce outdoor recess on bad air days
- Increase green space and vegetation
- Support investing in ventilation and filtration systems in schools and community centers