

Sources and variability of air toxics downwind of an oil and natural gas-producing well pad in a residential community

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Introduction
Research Objectives
 Our goal is to investigate the ambient levels of several air toxics near a new oil and natural gas (O&NG) well pad developed in a residential area near Greeley in northeastern Colorado.

A mobile laboratory (ML) was deployed to continuously monitor:
 • CH₄, CO₂, CO
 • CH₄, C₂H₆
 • Benzene, toluene, ethylbenzene, xylenes (BTEX)
 • ozone
 • Meteorological data (Wind speed and direction, temperature)

Our analysis will:
 • Investigate ambient level variability and contributions from various sources as well as the impact of variable meteorology
 • Compare with other data sets collected in the Colorado Front Range
 • Inform a health impact study led by the Colorado School of Public Health.

Background and motivation
Benzene and public health
 • Classified as an air toxic by the U.S. Environmental Protection Agency (EPA)
 • A known human carcinogen linked with leukemia
 • An ozone precursor
 • No National Ambient Air Quality Standard (NAAQS) for benzene in the U.S.

Major sources of BTEX in the atmosphere

	Gasoline exhaust
	Chemical production
	O&NG production

Benzene from O&NG
 Benzene is a naturally occurring component of O&NG and can be released from various pieces of equipment and stages of the production process.

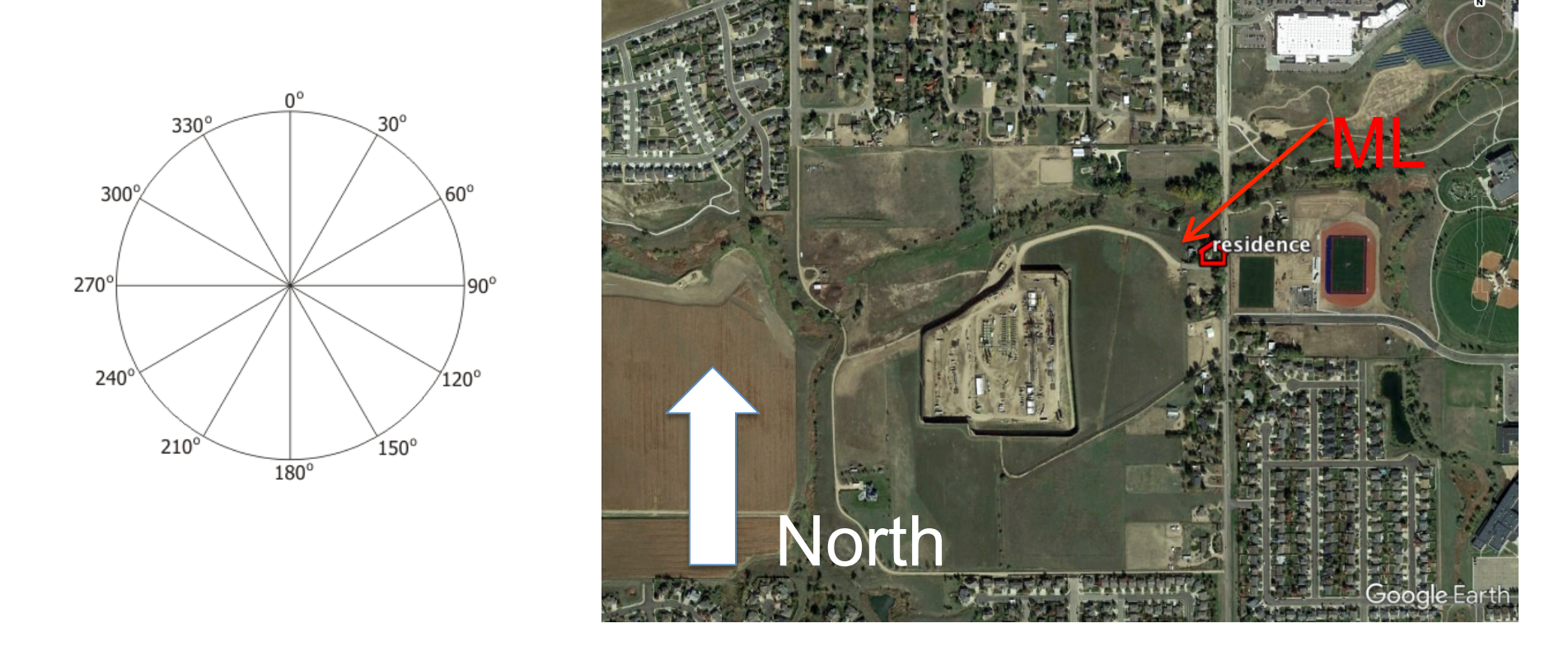


An O&NG well pad in the Colorado Front Range

Other trace gases for source apportionment
 The suite of compounds measured by the ML is critical for attributing observed benzene enhancements to different sources. Co-emitted CH₄ and C₂H₆ indicate O&NG emissions and CO₂ and CO are emitted through combustion.

Proximity of O&NG and residential communities

- >350,000 people in NE Colorado live within 1 mile of an active O&NG well.
- New pads can have > 20 active wells (multi-well pads) and associated production equipment. Some sites pipe oil off-site and use electric power to reduce local emissions.
- Lifetime excess cancer risk for people living within 500 ft. of a well pad is 8 times the EPA upper threshold.



Measurement methods

Instrument	species	frequency
Baseline-Mocon 9100-HS GC-PID	BTEX	6 min
Aerodyne TILDAS (Tunable Infrared Laser Differential Absorption Spectroscopy)	CH ₄ , C ₂ H ₆	1 Hz
Picarro cavity ringdown spectrometer (CRDS)	CH ₄ , CO ₂ , CO, H ₂ O	0.5 Hz
2B ozone monitor	ozone	0.5 Hz
anemometers	Wind speed and direction	1 Hz
Sensaphone	Indoor and outdoor temps	1 min
flask samples	50+ gases	N/A



The GC-PID provides sub-ppb limits of detection for benzene and is linear over the 100 ppt - 54 ppb range for which it was tested in the NOAA GMD laboratory.

Measurement site

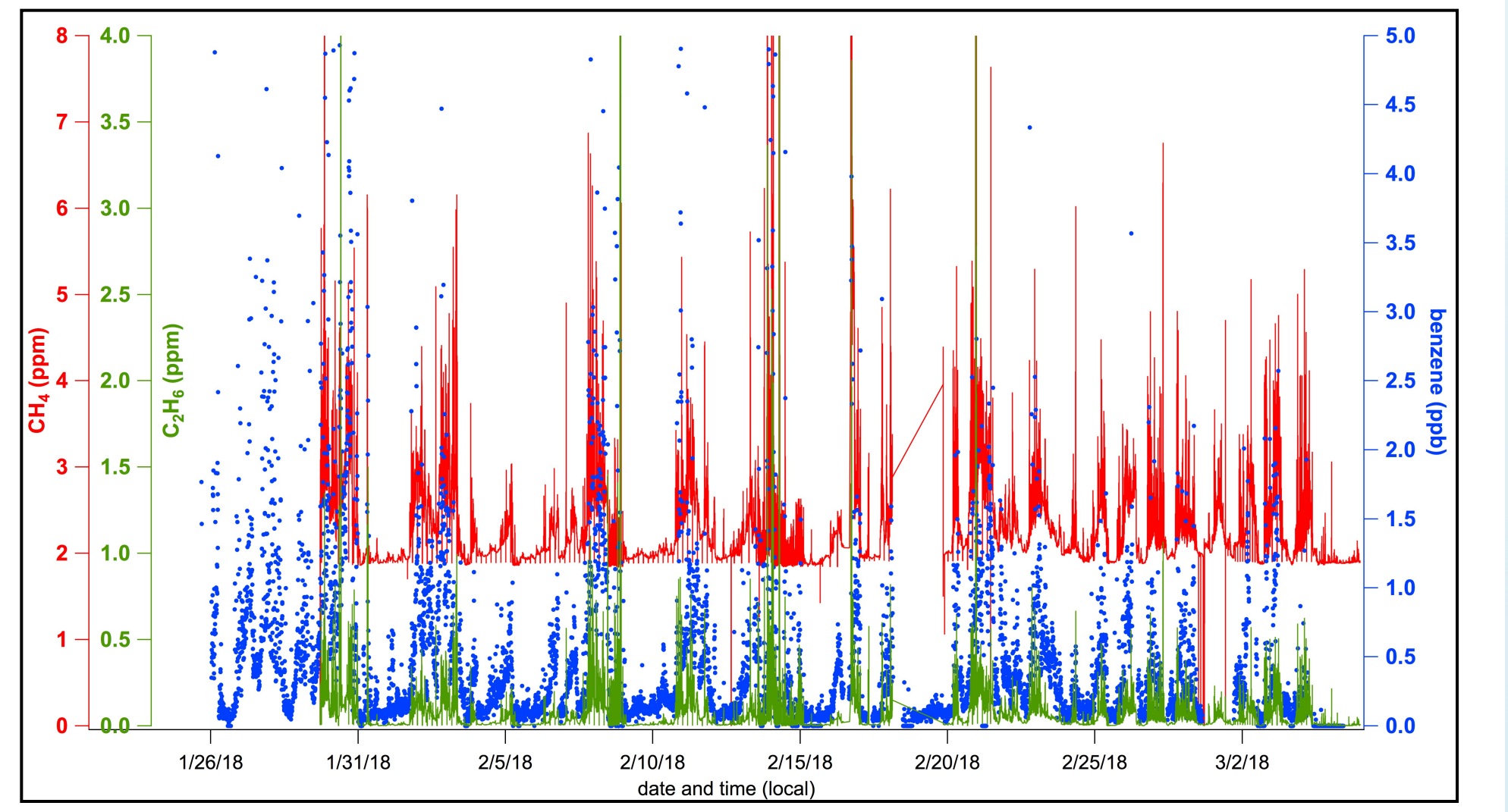
The 22-well pad was drilled in summer 2017, completed in fall 2017, and has been in production since October 2017. Continuous flaring of NG occurred during the campaign.



The NOAA ML was parked on a homeowner's property east of the multi-well pad for five weeks. The residence is <1000 ft. from the well pad.

Results

Full campaign time series



All campaign ML benzene, CH₄, and C₂H₆ data, including reference tank runs. The y axes are scaled so that variability is more easily shown and the highest data points are not shown.

- The timescale of background variability observed for all species indicates local sources of gas species, as opposed to regional influence.
- Correlation of C₂H₆ and CH₄ suggests an O&NG source such as the multi-well pad or another, smaller pad in the area.
- Periods of enhanced benzene tend to correlate with C₂H₆ and CH₄ enhancements.

Results are compared with February 2008-2016 data from GMD discrete flask samples collected at the Boulder Atmospheric Observatory (BAO) tower in Erie, CO. February 2018 benzene data collected by INSTAAR at the Boulder Reservoir (background conditions) show similar statistics.

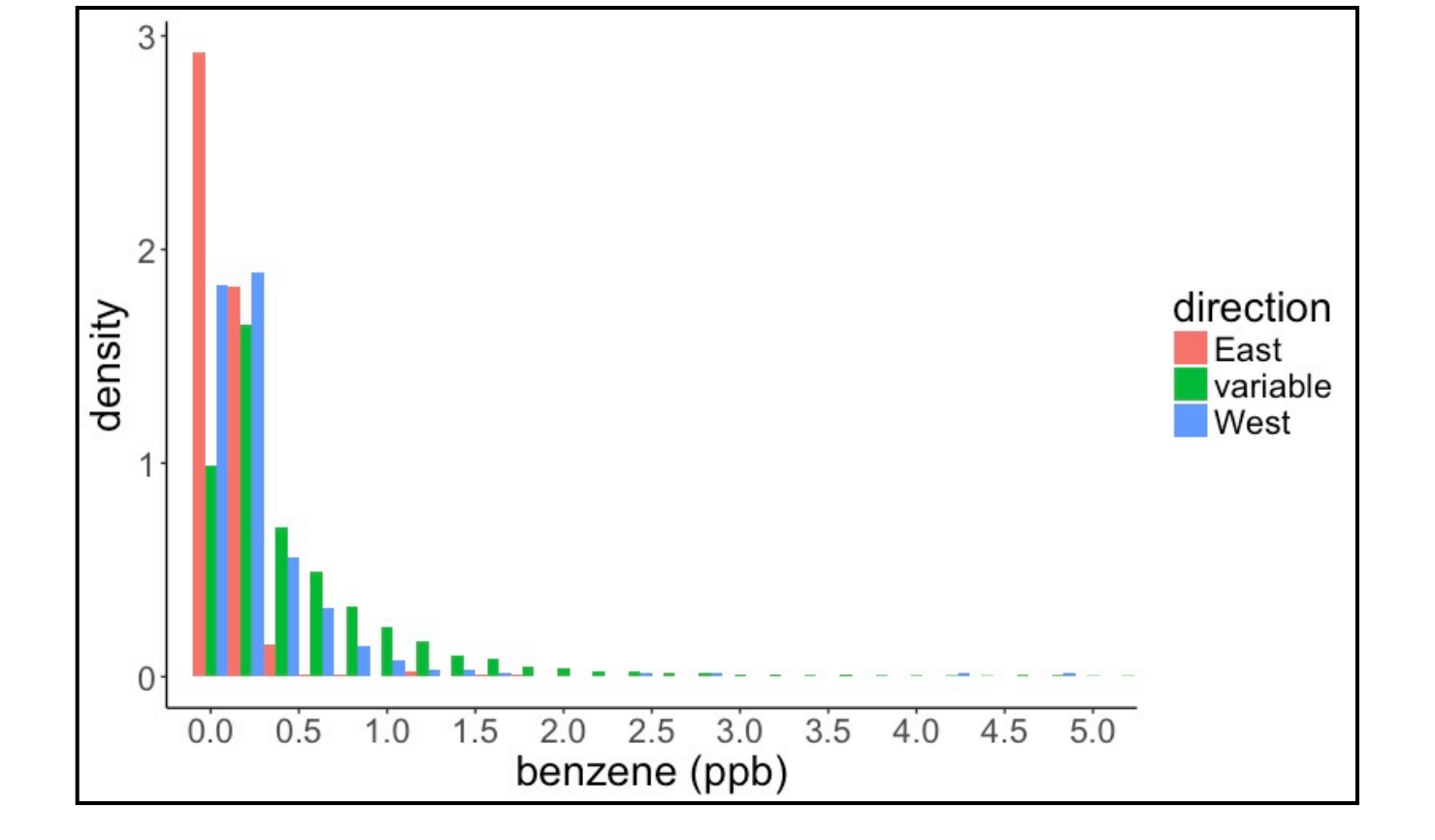
species	mean	median	maximum
benzene	campaign: 0.56 ppb	0.28 ppb	107 ppb
	BAO: 0.17 ppb	0.14 ppb	0.89 ppb
CH₄	campaign: 2313 ppb	2146 ppb	74270 ppb
	BAO: 1940 ppb	1915 ppb	2568 ppb
C₂H₆	campaign: 57 ppb	26 ppb	13753 ppb
	BAO: 9 ppb	4 ppb	76 ppb
CO₂	campaign: 434 ppm	426 ppm	2746 ppm
	BAO: 399 ppm	400 ppm	414 ppm
CO	campaign: 0.238 ppm	0.187 ppm	36 ppm
	BAO: 0.151 ppm	0.145 ppm	0.311 ppm

Summary statistics for BAO data collected 2008-2016 (2015-2016 for C₂H₆) and the five-week campaign measurements.

- Large enhancements relative to the assumed background (based on BAO data) are observed for all species.
- 55% of the benzene concentration data points were \geq 0.2 ppb (the expected background).

Benzene as a function of wind direction

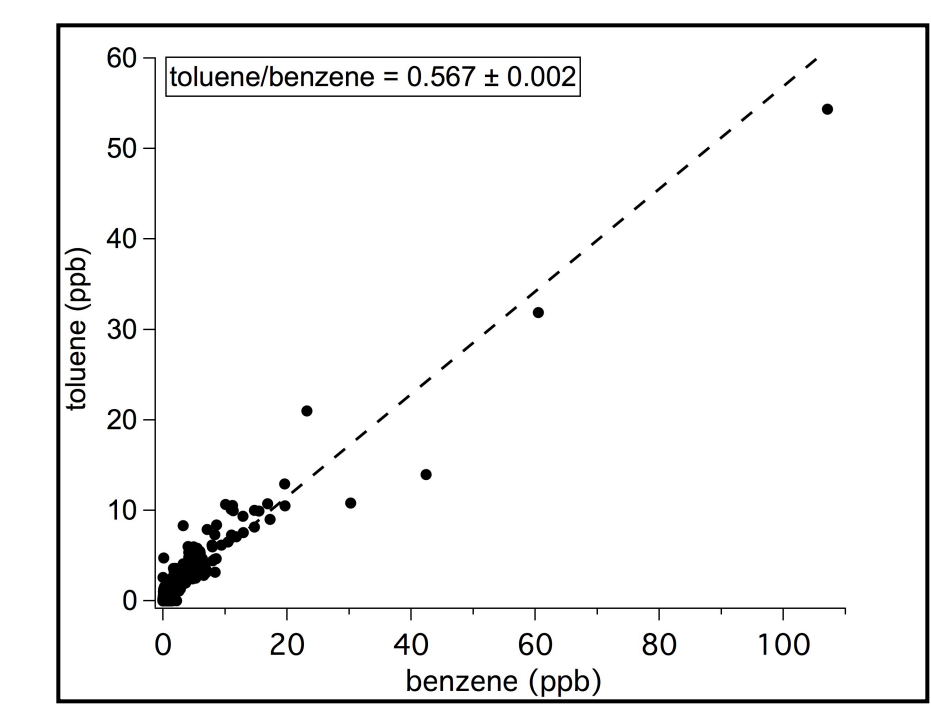
- BTEX data were filtered by wind direction to separate the west (multi-well pad) and east (high traffic road).
- 1 Hz wind speed and direction were averaged over 30 seconds. A wind speed threshold of 2.5 m/s was used.
- 5% of benzene observations were below the limit of detection and were removed from the analysis below.



Benzene observations \leq 5 ppb separated by east, west, or variable/low wind (< 2.5 m/s), which included all directions.

- Benzene associated with a west wind tends towards higher values than benzene associated with a west wind.
- Larger benzene enhancements tend to occur when wind speeds are low or variable, often representative of stagnant atmospheric conditions.

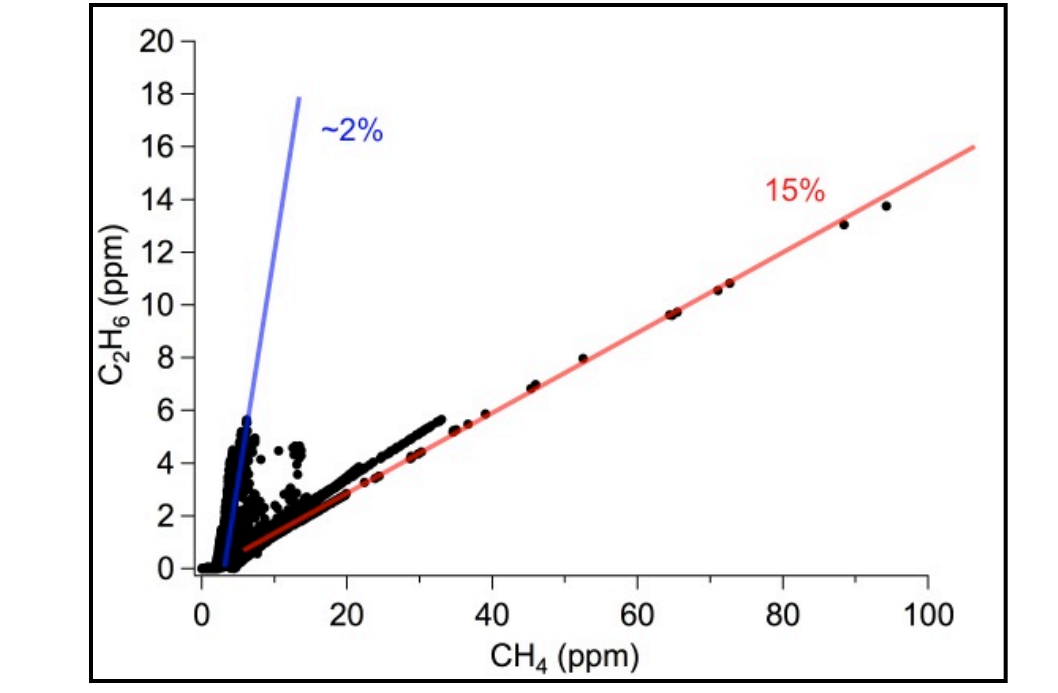
Multispecies analysis
Toluene vs. benzene



- A ratio \geq 2 is characteristic of combustion (Barletta et al., 2002; Heeb et al., 2000; Bravo et al., 2002)
- The full data set is characterized by a toluene-to-benzene ratio < 2, which suggests a dominant benzene source other than traffic.
- Plumes will need to be investigated individually.

C₂H₆ vs. CH₄

- Correlation indicates an O&NG source
- Data points with several different regression slopes reveals the presence of multiple sources at the measurement site.



Future work

- Individual benzene plumes will be examined with other gases to gain additional information about sources.
- ML measurements at a second residence downwind of a new multi-well pad will be collected to document benzene trends during all phases of the production process.
- Results from both sites will be used in dispersion modeling to calculate daily emission rates from the multi-well pads and simulate the expected benzene mixing ratio at other locations in the neighborhoods.