# Characterization of benzene emissions from a new multi-well pad in a Colorado Front Range residential community

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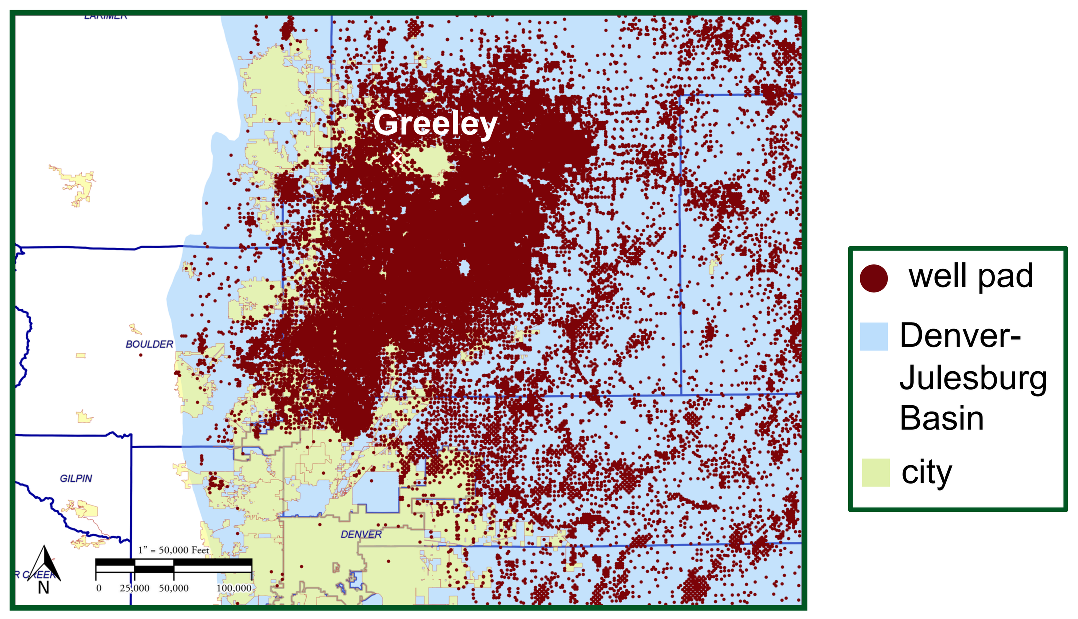
## Introduction

### Background and Motivation

The Colorado Front Range is an area with a steadily growing population and increasing land development for home construction. The Front Range also sits atop the Denver-Julesburg Basin, an oil and natural gas-rich geologic formation that has seen an increase in production over the past decade. As residences and well pads become closer in proximity, concerns about possible impacts on communities have arisen. In particular, the potential for human health impacts from benzene has received increased attention. A carcinogen linked to leukemia, benzene naturally occurs in crude oil and natural gas and can be emitted by equipment and processes on production pads.




Well pads in the Denver-Julesburg Basin in relation to Greeley, CO *(Colorado Oil and Gas Conservation Commission, 2019)*

### Research Objectives

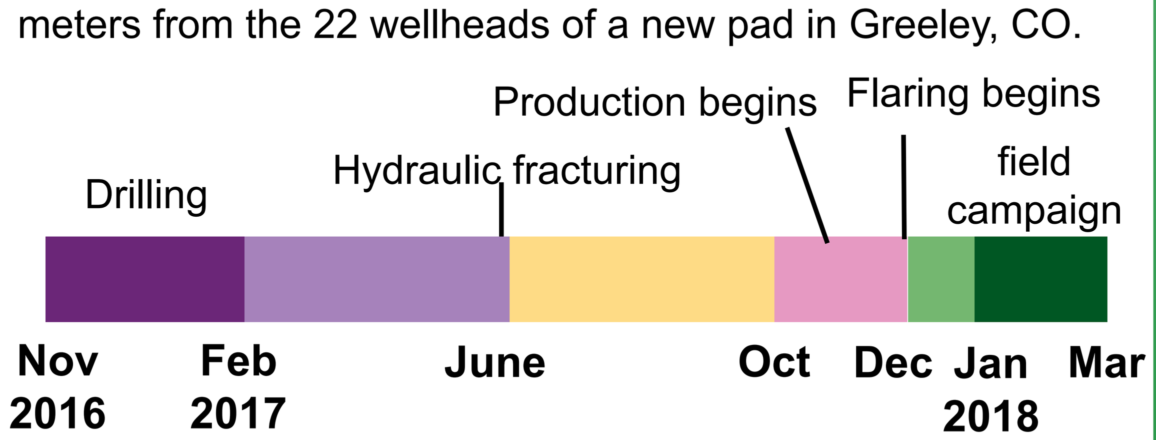
- Document benzene ambient mixing ratio diurnal and day-to-day variability
- Compare observed levels to other measurements in the Colorado Front Range
- Explain variability in benzene mixing ratios
- Identify the sources of benzene enhancements observed at the measurement site
- Use modeling to estimate mixing ratios at other residences for use in an initial health risk assessment

## Methods

### Measurement site


The location of the mobile laboratory relative to the well pad

Five weeks of continuous measurements were made using an instrumented van, the NOAA Global Monitoring Division mobile laboratory (ML), at a residence approximately 350 meters from the 22 wellheads of a new pad in Greeley, CO.




### Instrumentation

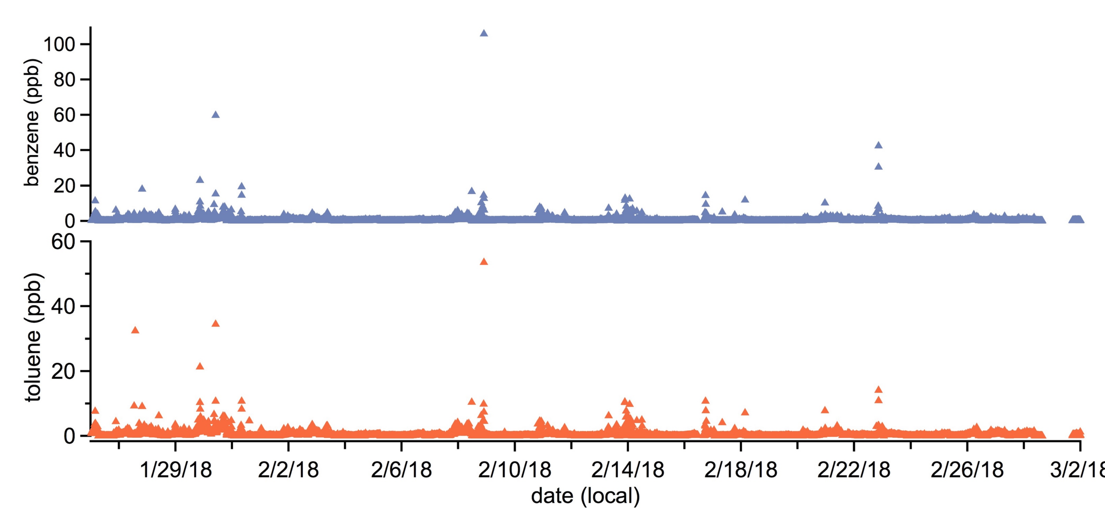
The ML was deployed near the residence for five weeks and collected the following measurements:

| measurements | instrument |
|---|---|
| benzene, toluene, ethylbenzene, xylenes (BTEX) | GC-PID |
| $CH_4$, $C_2H_6$ | Tunable infrared laser differential absorption spectroscopy |
| $CH_4$, $CO_2$, CO, water vapor | Cavity ringdown spectrometry |
| ozone | UV absorption |
| Wind speed and direction | anemometer |
| Indoor, outdoor temperatures | Sensaphone |
| 50+ trace gases | GMD flask sampling and analysis systems |

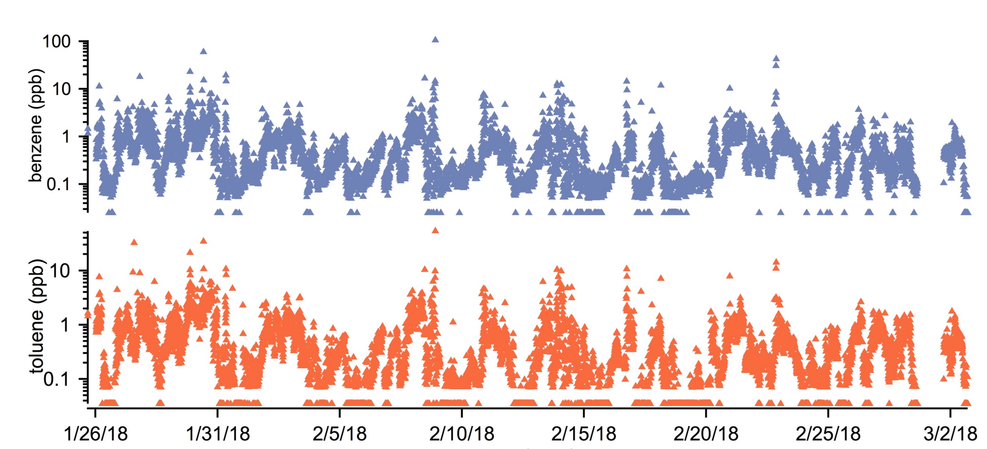
## Results

### Full campaign time series

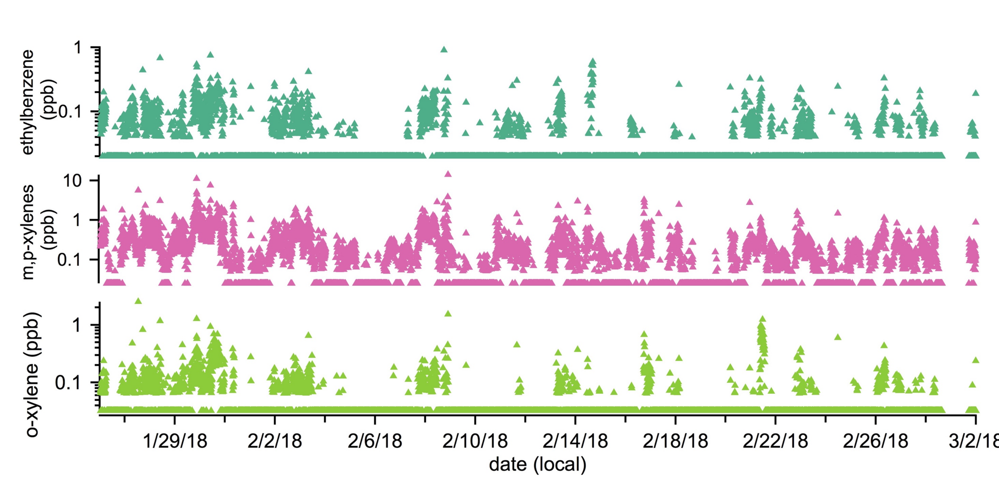
BTEX (15 sec air sample measured every 6 minutes) results are shown below. Ethylbenzene and o-xylene were often below the limit of detection of the GC-PID. Mixing ratios of benzene, toluene, and m+p-xylenes show a fair amount of variability but track together, suggesting a shared source or sources. Throughout the campaign, several periods during which benzene was greatly enhanced occurred, with benzene reaching tens of ppb and a maximum of 106 ppb.



Benzene and toluene mixing ratios measured during the course of the field campaign. Non-detects are shown as zeros.



Benzene and toluene mixing ratios shown on a log scale.



Ethylbenzene, m+p-xylenes, and o-xylene mixing ratios on a log scale.

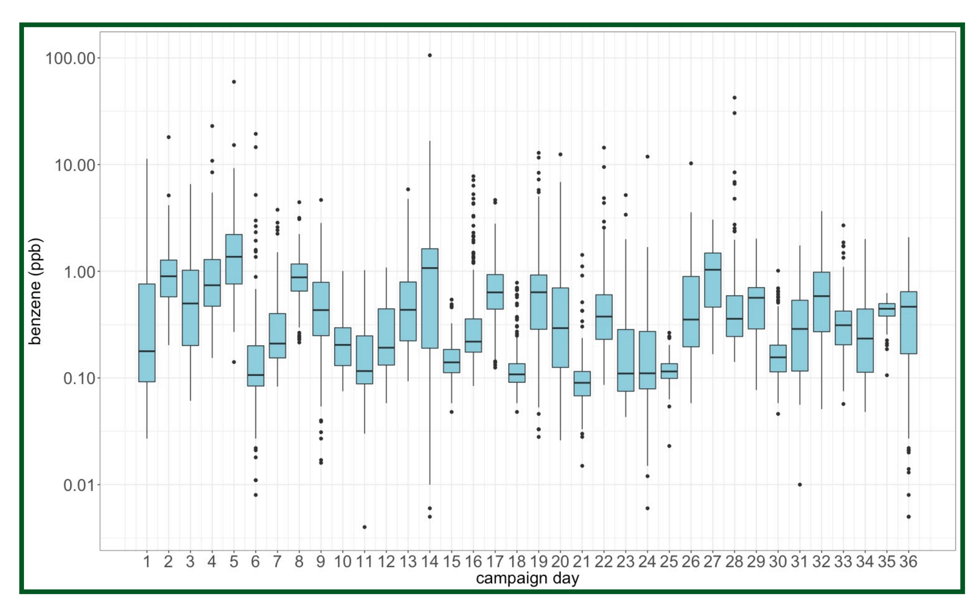
### Variability of BTEX mixing ratios

The mean benzene mixing ratio of 0.621 ppb observed at the residence is about 3 times the mean reported in other O&G studies in the Front Range (Abeleira, 2017; Collett, 2016; Gilman, 2013; Thompson, 2014; Swarthout, 2013) Our mean is closer to the 0.53 ppb reported by Halliday from measurements near the surface (5.6 m AGL) at Platteville Observatory, 25 km south of Greeley. Though our mean exceeds those from other studies, the field campaign benzene median of 0.300 ppb is closer to the ~0.2 ppb reported in earlier studies. However, our campaign maximum of 106 ppb far exceeded even the 30 ppb maximum reported in Platteville by Halliday. This is not surprising given that the mobile lab was positioned much closer to a potential source than the instrumentation in Platteville.

| Species | mean (ppb) | std dev | median (ppb) | maximum (ppb) |
|---|---|---|---|---|
| benzene | 0.621 | 1.820 | 0.300 | 105.825 |
| toluene | 0.523 | 1.179 | 0.255 | 53.543 |
| ethylbenzene | 0.037 | 0.050 | < LOD | 1.332 |
| m,p-xylenes | 0.196 | 0.371 | 0.094 | 14.110 |
| o-xylene | 0.053 | 0.077 | < LOD | 2.520 |

Statistics for BTEX mixing ratios measured 1/26/2018-3/2/2018.

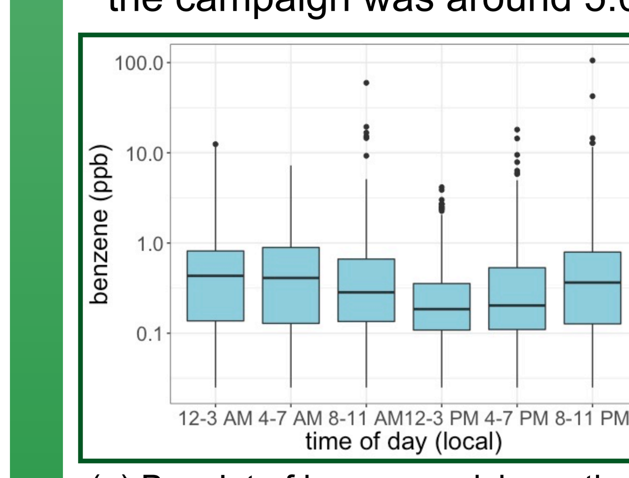
The measured benzene mixing ratio displays a great deal of day-to-day variability, which could be a result of meteorology and/or activities on the well pad. Results from a single day of sampling or measurements collected over a short time period may not be representative of more long-term patterns at a site, which are important for researchers evaluating human exposure to pollutants.



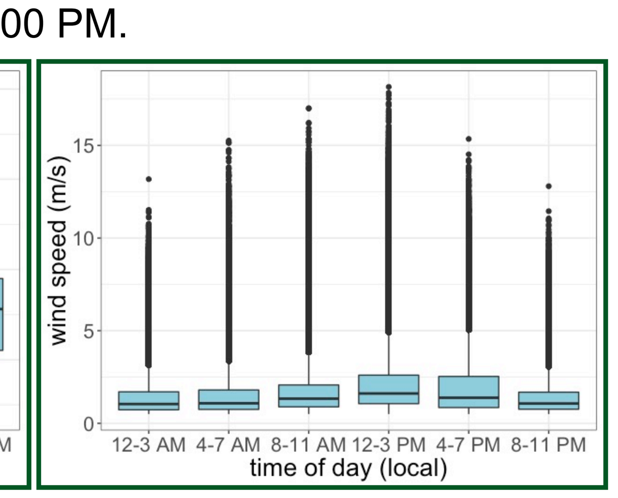
A boxplot (outliers are 1.5 times the interquartile range) showing the distribution of benzene mixing ratios on each day of the field campaign.

### Benzene by time of day and wind

Benzene mixing ratios tend to be lowest in the afternoon (~12:00-3:00 PM MST). Though surface wind speeds were often low (< 2 m/s) during this wintertime campaign, they were generally higher in the afternoon. Afternoon is also when the boundary layer depth peaks. Sunset time during the campaign was around 5:00 PM.

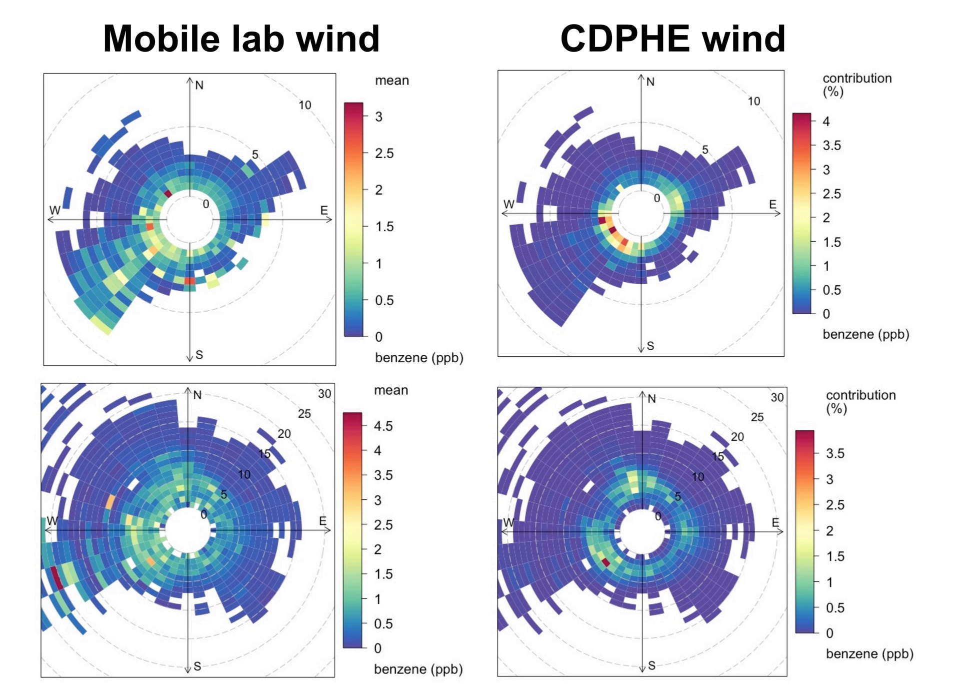


(a) Boxplot of benzene mixing ratio by local time of day



(b) Boxplot of wind speed from the mobile lab anemometer by time of day

The Colorado Department of Health and Environment (CDPHE) operated a monitoring station ~6 km southeast of the field campaign site. Wind data from the 10 m CDPHE tower are compared with those collected using the mobile lab, as tower data may better reflect wind regimes in the neighborhood as a whole.

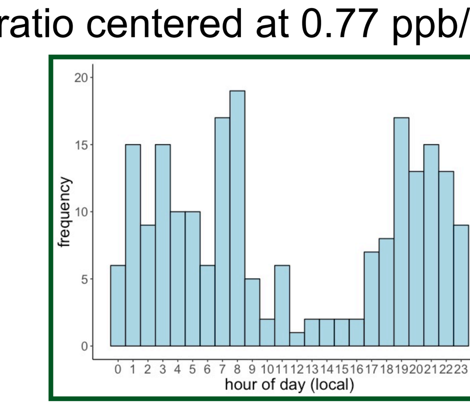



Polar frequency plots showing the mean and weighted mean benzene mixing ratio using wind data from the mobile lab and CDPHE tower.

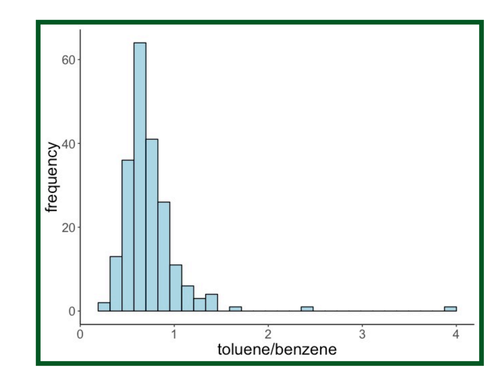
The highest benzene levels tend to originate from the southwest. Benzene > 1 ppb is observed from all wind directions, but typically when wind speeds are low, which likely reflects pooling of air that occurs during stagnant atmospheric conditions.

### Benzene enhancement events

Benzene enhancement events were defined as the time during which benzene reached 1.26 ppb (90th percentile of the dataset). Events ranged in duration from 18 minutes to 2 hours and occurred least often in the afternoon. Toluene and benzene were correlated in 99% of these events, with a ratio centered at 0.77 ppb/ppb.



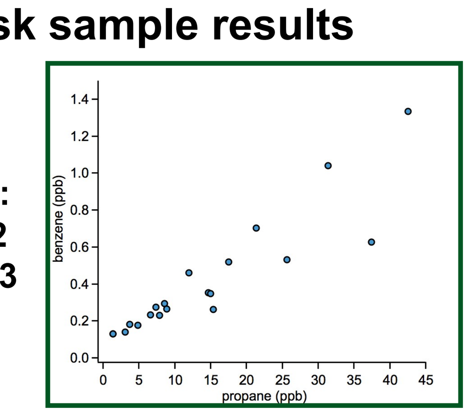
(a) Frequency of benzene plume events by time of day

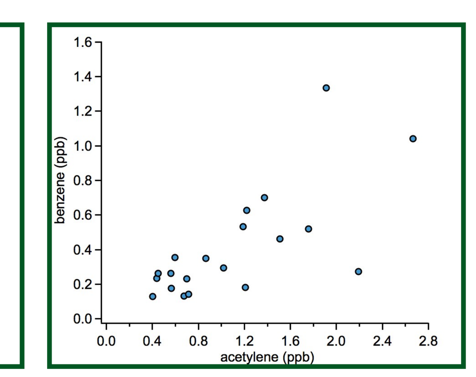


(b) Frequency of toluene/benzene ratio during each enhancement event

### Flask sample results

slope : 0.0242 $R^2$: 0.83





slope : N/A $R^2$: 0.51

Benzene in 19 flask samples collected March 3&4 shows stronger correlation with propane, an O&G-related compound, than acetylene, which is associated with combustion.

## Future work

AERMOD, a Gaussian plume dispersion model, will be used to determine emission rates from the well pad and simulate mixing ratios throughout the neighborhood. It will be used to evaluate the impact of meteorology on the observations.

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