

Wintertime Sources and Sinks of Volatile Organic Compounds in Fairbanks, Alaska

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Background

- Fairbanks, Alaska is highly polluted during the wintertime and is currently a non-attainment area for PM_{2.5}. Strong thermal inversions trap primary pollutants resulting in accumulation of volatile organic compounds (VOCs), NO_x, particulate matter, and other trace gases.

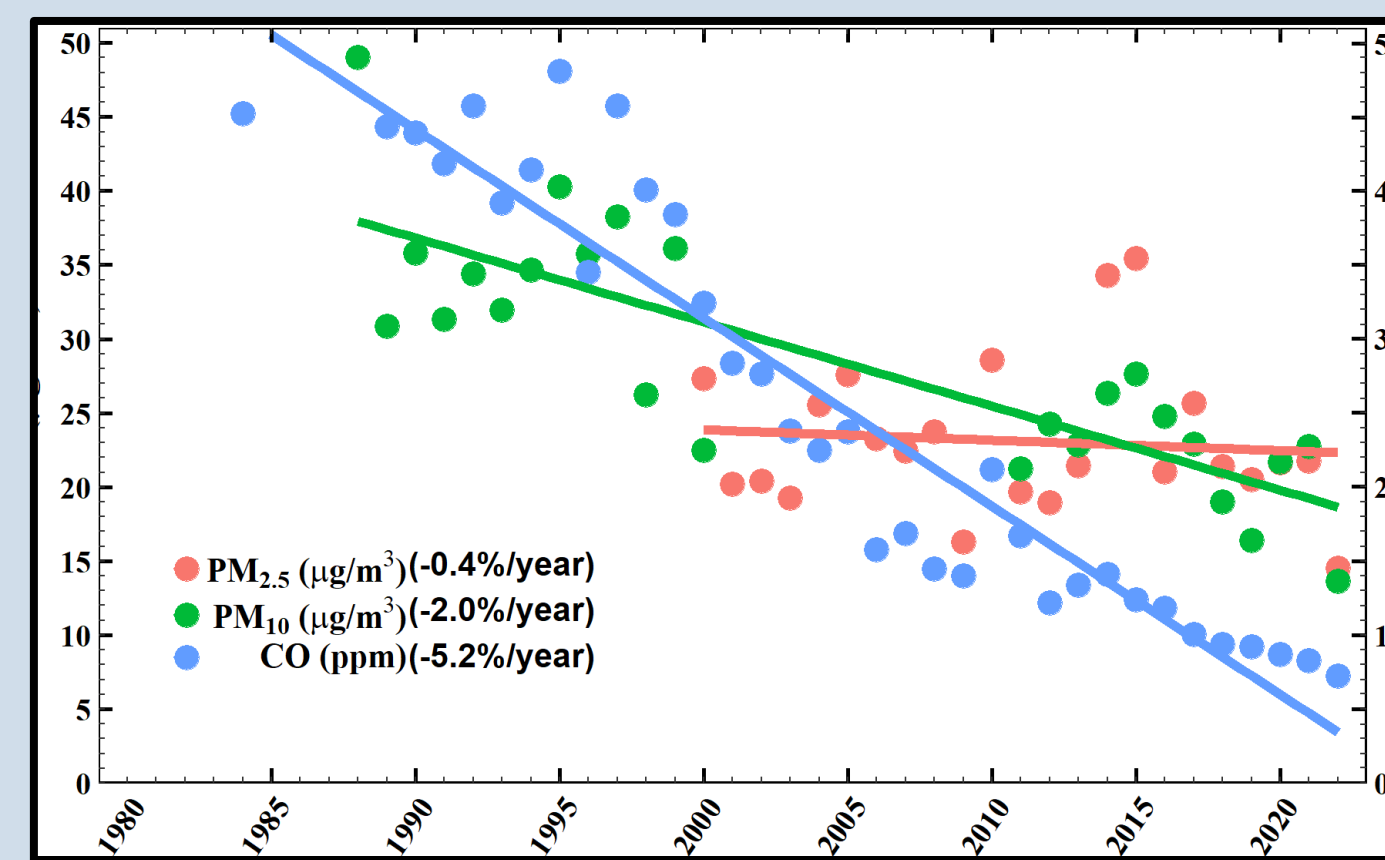


Figure 1. Historical trends of wintertime CO, PM₁₀, PM_{2.5} in Fairbanks, AK

- Due to the extreme cold, many individuals spend more of their time indoors. Residential wood combustion (RWC) is a popular choice for home heating, but fuel oil and natural gas are also prominent. The impact of these heat sources on the indoor environment is currently unknown.
- The impact of indoor VOCs from sources such as cooking, incense, and a combination of these sources is not fully understood.
- VOC oxidation mechanisms in extreme cold and dark environments remain unknown.
- The ALPACA field campaign provides the first comprehensive VOC measurements in Fairbanks, both indoor and outdoor to answer the following questions:

- How do outdoor VOC mixing ratios compare with indoor VOCs in cold and dark environments?
- How do daily activities, such as the operation of a pellet stove insert and other events, influence indoor VOC mixing ratios?
- Do regional and global emissions inventories accurately capture VOC emissions from these local sources?

Methods

- Indoor and outdoor measurements of VOCs were collected by a proton-transfer-reaction time-of-flight mass spectrometer (PTR-ToF-MS) as part of the ALPACA 2022 Field Intensive from January 19th to February 25th, 2022.
- Heated PTFE inlets were used to switch between indoor and outdoor sampling every 10 minutes.

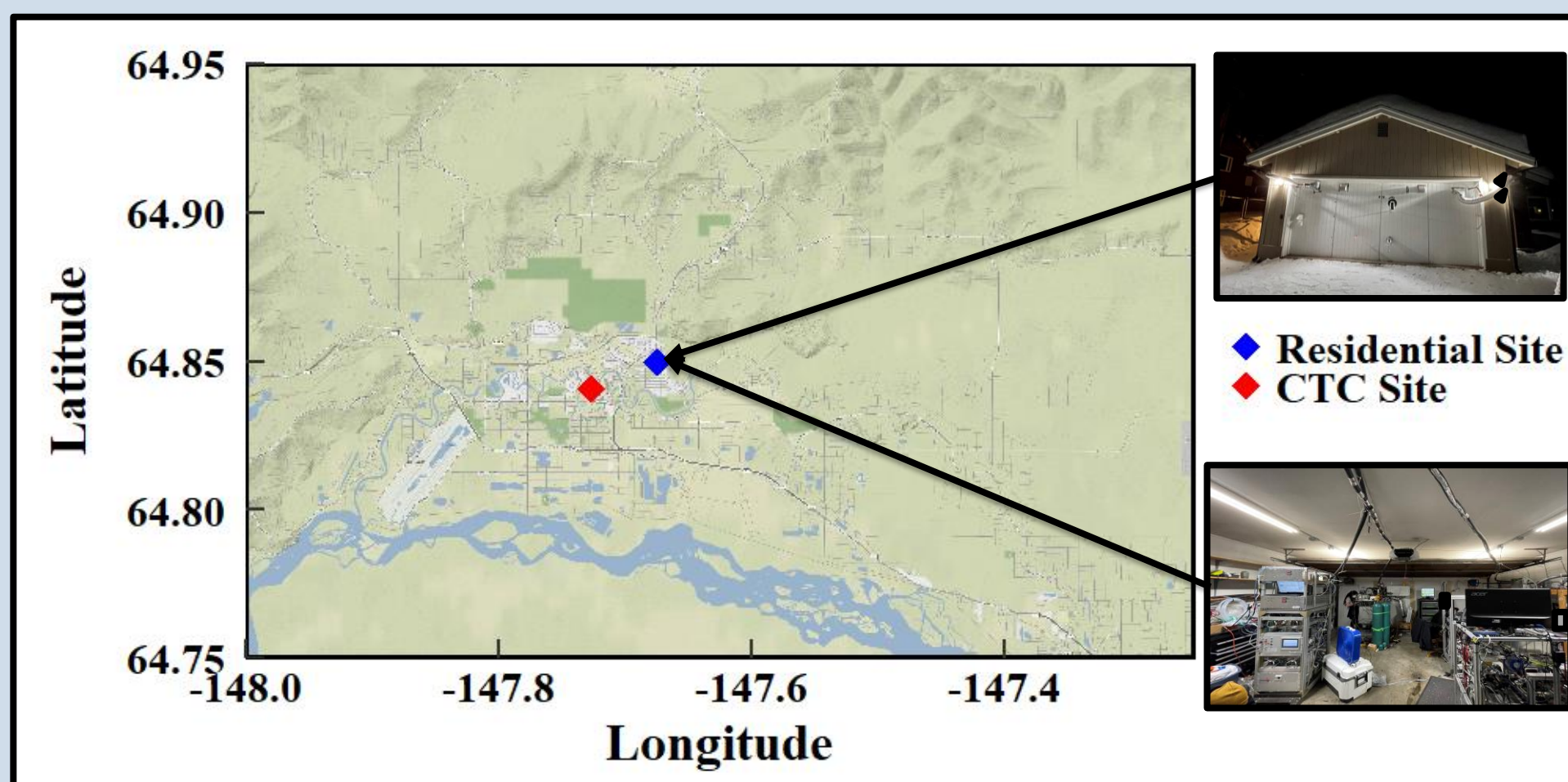


Figure 2. Map of Fairbanks, Alaska with residential and downtown sites labeled

- Indoor pellet stove experiments were conducted by operating the pellet stove insert for 3 hours, from ignition to 3 hours after extinguishing the flame.

Total VOC mixing ratios (tVOC) are ~5 times higher indoors than outdoors

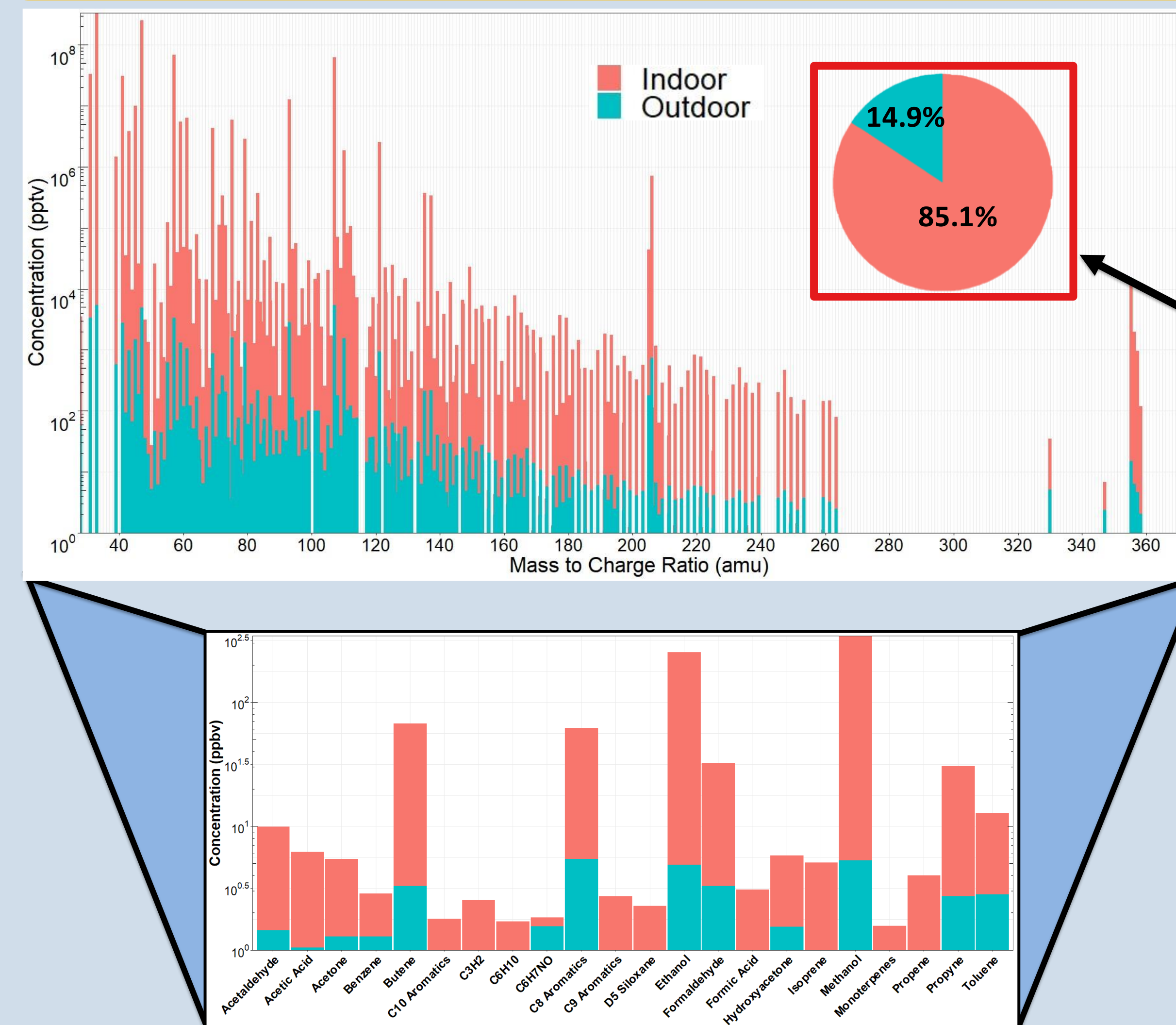


Figure 3. Top: Mass spectra of PTR-ToF-MS ions for indoor/outdoor sampling during ALPACA. Bottom: Most abundant VOCs measured indoor and corresponding outdoor concentrations

- Figure 2 represents the median VOC mixing ratios, both indoor and outdoor, during the ALPACA field intensive. This analysis excludes data during indoor experiments and a three-hour time buffer before and after each experiment.
- 192 unique masses were detected and quantified.
- 85.1% of the median tVOC mixing ratio was measured indoors.
- The median tVOC mixing ratio is 232 ppbv and 40.6 ppbv for indoor and outdoor, respectively.
- In a residential environment, exposure risk from hazardous air pollutants in the indoor environment is greater than outdoors. Indoor benzene mixing ratios are 75% higher than those measured outdoors, while HCHO is higher by a factor of 3 indoors.
- D5 siloxane and monoterpenes, both associated with personal care products, are significantly higher indoors due to researcher activity.

Pellet stove operation enhances indoor VOCs

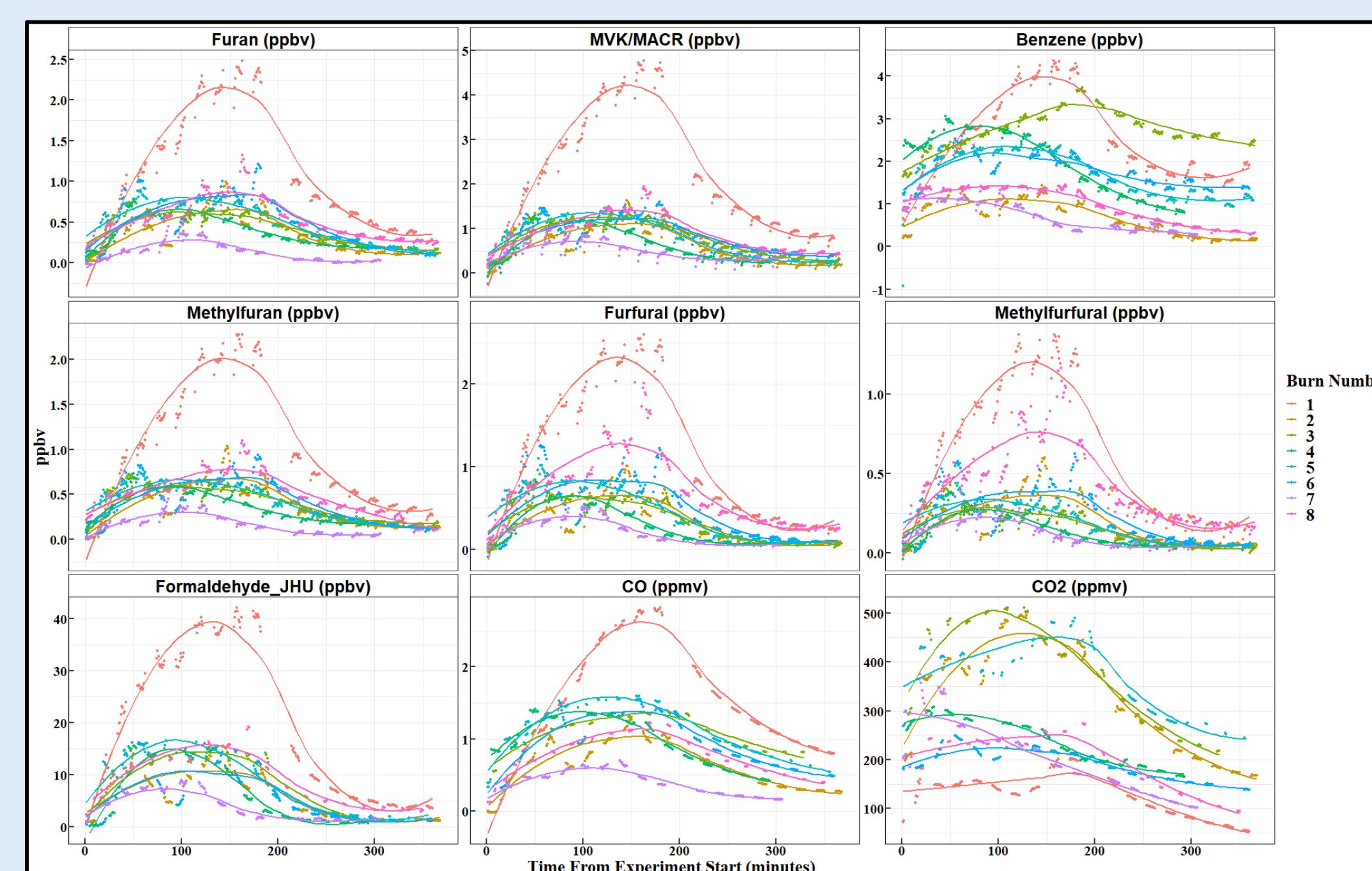


Figure 4. Indoor VOC enhancements during 8 pellet stove experiments

- Experiment 1 resulted in the largest enhancement for most species, potentially due to off-gassing from the new stove's paint.
- Furanic species were all elevated during each burn, while acetonitrile only showed appreciable enhancement during a single burn.
- Hazardous VOCs such as benzene and formaldehyde exhibit and maintain high concentrations during pellet stove use.
- Emission ratios derived from measurements of the stove exhaust will be compared to regional and global emissions inventories



Figure 5. Researchers conducting pellet stove experiment 1. Photo Credit: Peter F DeCarlo

RWC is a major source of VOCs in Fairbanks, AK

$$\text{Fraction of VOC from RWC} \rightarrow [VOC]_{RWC} = \frac{ER_{VOC}}{F} [F] \leftarrow \text{Furfural Mixing Ratio}$$

Emission Ratio of VOC/Furfural

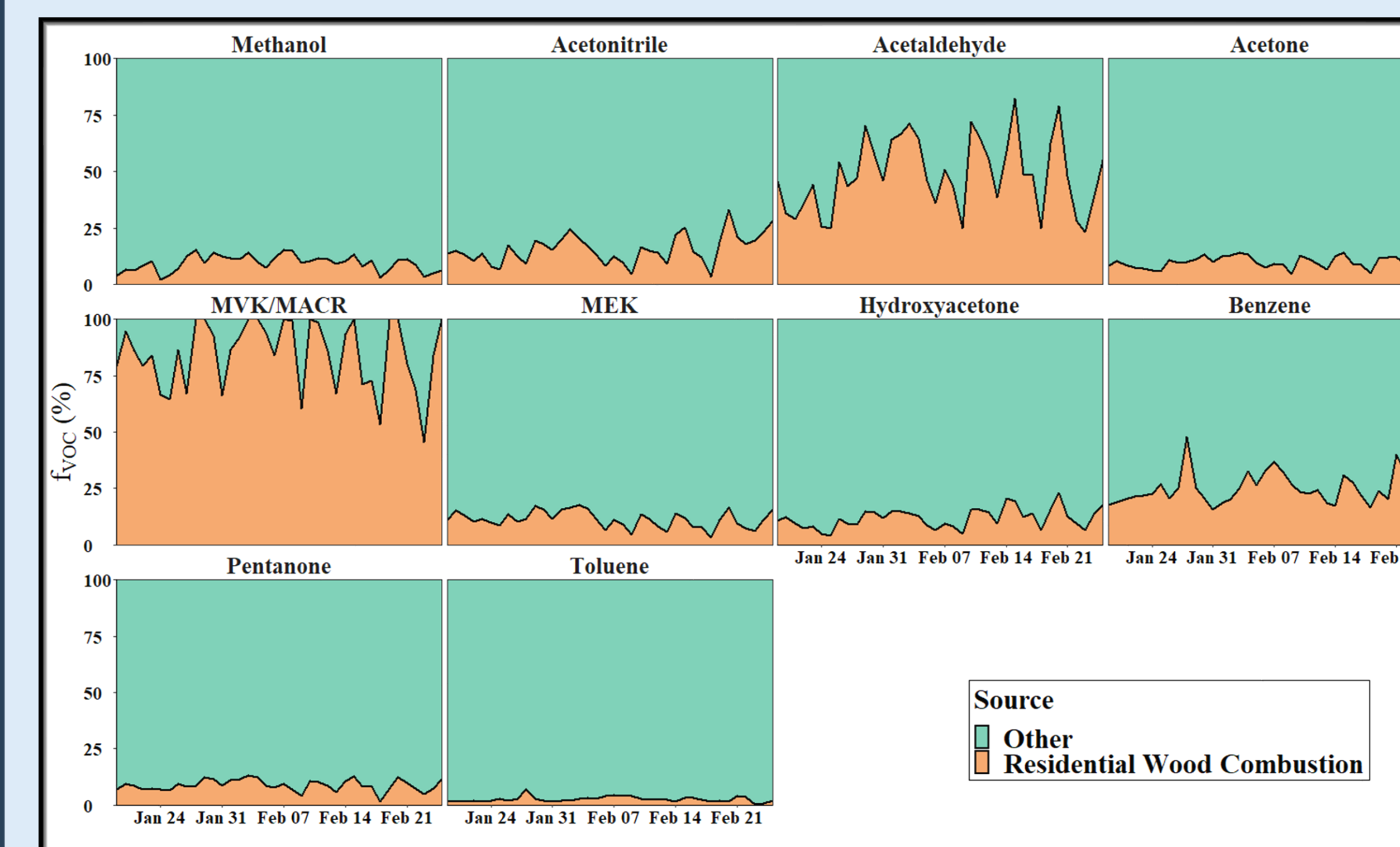


Figure 6. Contribution of RWC to outdoor VOC abundance in Fairbanks

- It is estimated that RWC contributes between 10% and 25% for most measured VOCs.
- RWC may be the main source of acetaldehyde (48.7%) and MVK/MACR (84.3%) during the wintertime.
- Using furan and methylfuran as tracers produced similar results; PMF will be used to compare with this method.

CEDS compares well with source measurements

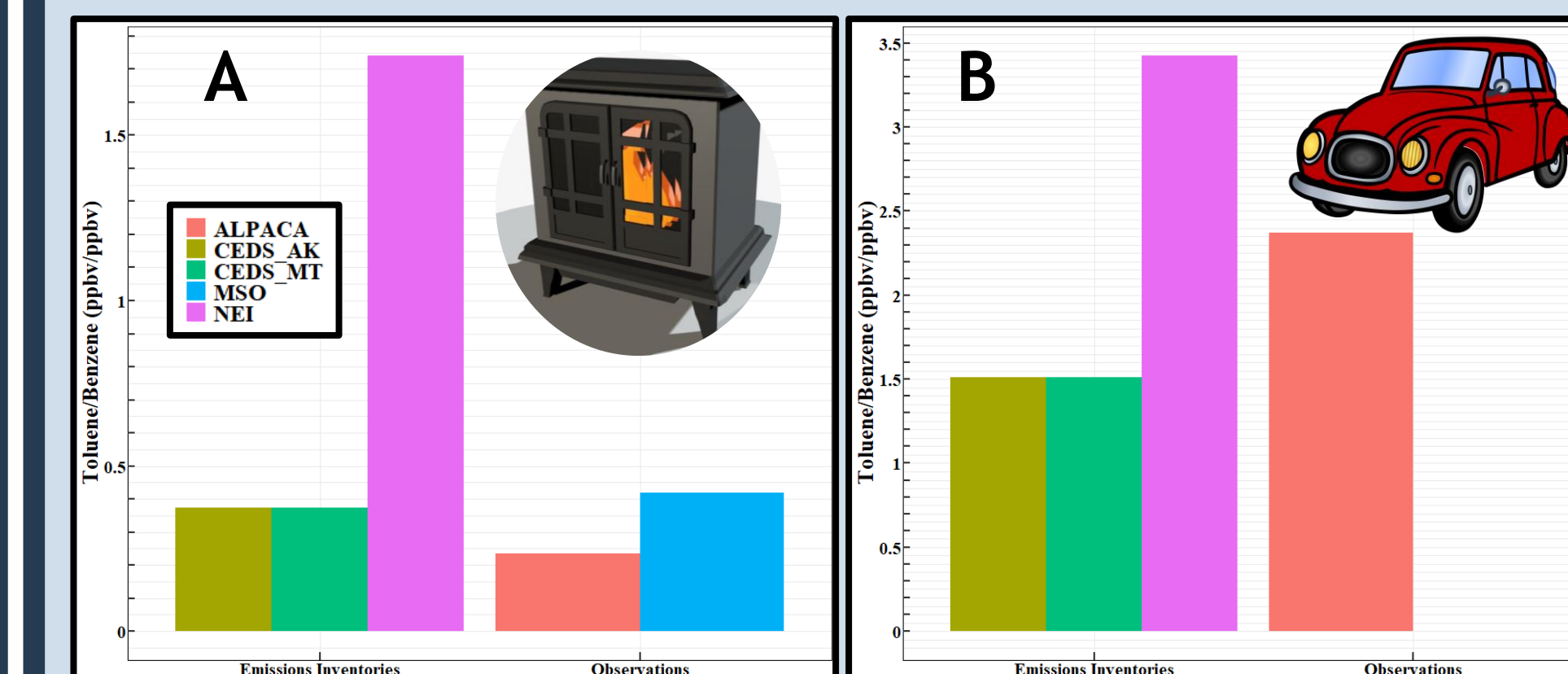


Figure 7. Comparison of Observed Toluene/Benzene Emission Ratios from RWC (A) and on road sources (B) with the Community Emissions Data System (CEDS) and the National Emissions Inventory (NEI)

- The RWC emission ratio from CEDS agrees well with conventional wood stove emissions (MSO) but is slightly higher than those derived from the pellet stove insert.
- The on-road T/B emission ratio from CEDS is lower than observed cold start emission ratios.
- NEI T/B ratios are consistently higher than CEDS and observations.

NEI overestimates contributions of RWC VOCs, underestimates PM_{2.5} fraction

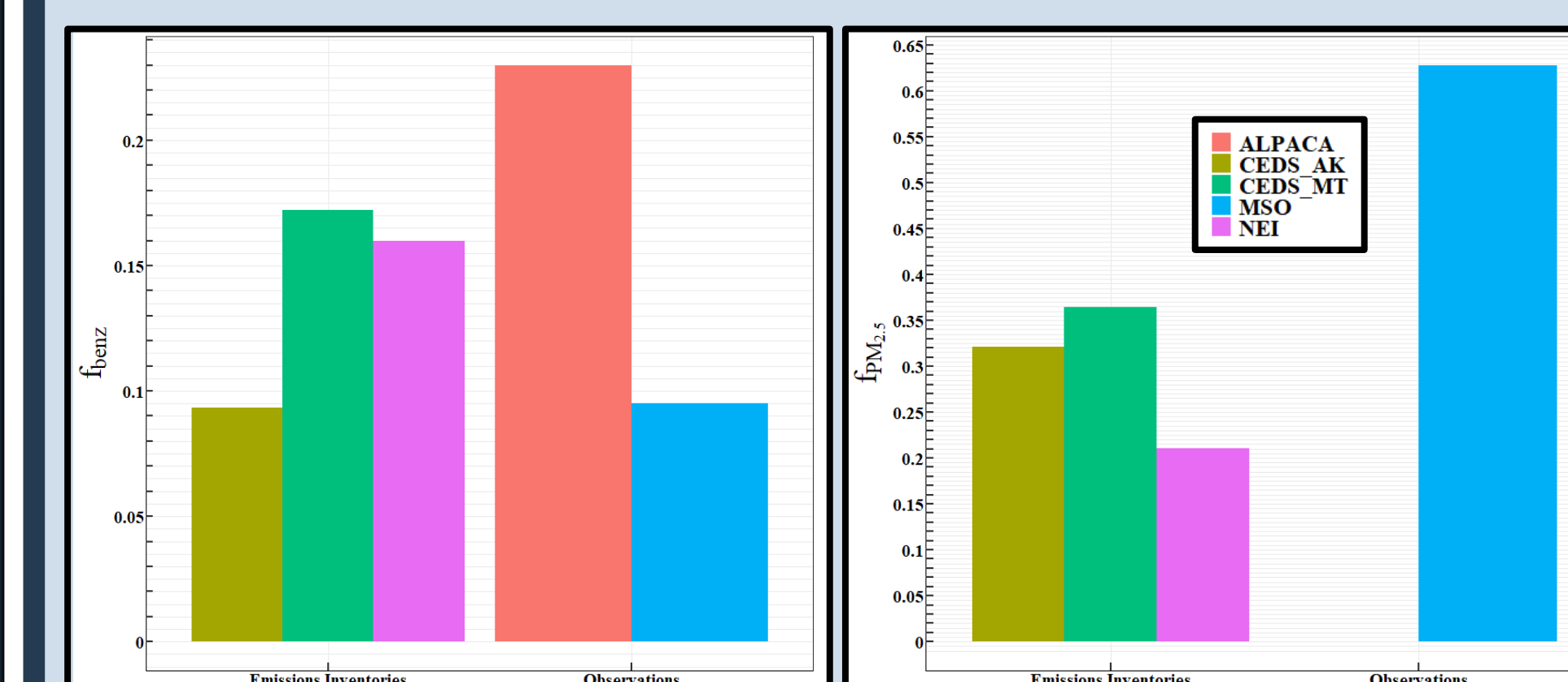


Figure 8. Comparison of observed RWC contributions to benzene and PM_{2.5} with CEDS and NEI

- The fraction of benzene attributed to RWC is 2.5 times lower in CEDS than observed during ALPACA.
- Benzene from RWC in MSO is overestimated by a factor of 2 in CEDS and NEI.
- PM_{2.5} contributions from RWC are underestimated in both CEDS (2x) and NEI (3x) compared to observations in MSO.

Future Directions

- Analysis of mixed, cooking, and incense experiments
- FOAM: FOAM box modeling to examine fates of outdoor VOCs in the cold/dark environment
- Source attribution of outdoor VOCs at the house site

Acknowledgements

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