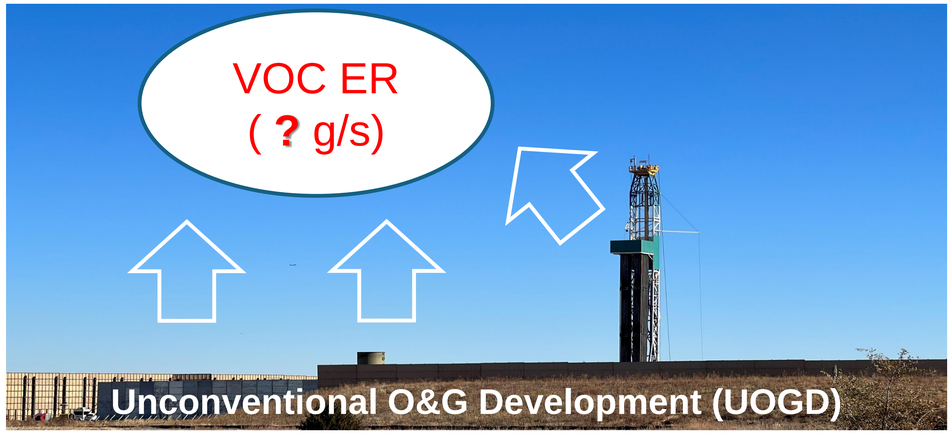
Using Ambient Concentration Measurements to Quantify Volatile Organic Compound Emissions from Oil and Gas Operations

Weixin Zhang[1], Da Pan[1, 2], I-Ting Ku[1], and Jeffrey Collett[1] (collett@colostate.edu)
[1]Department of Atmospheric Science, Colorado State University
[2]School of Civil and Environmental Engineering, Georgia Institute of Technology

Background



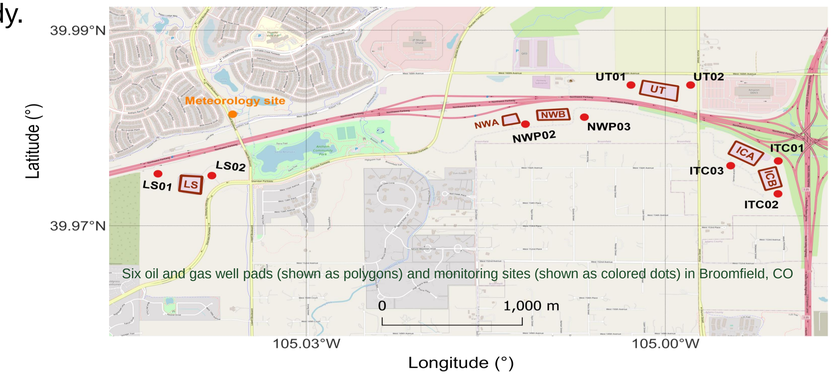
- The O&G industry is a large volatile organic compound (VOC) emission source. Some VOCs from O&G activities pose environmental & health risks.
- Knowledge of VOC emissions from individual UOGD operations remains limited.

EPA 2020 Nonpoint Oil and Gas Emission Estimation Tool
- Values might not be representative for present-day technologies and practices.

Hecobian et al. (2019)
- Emission rates of 46 individual VOCs for drilling, fracking, flowback (green-completion operations), and production operations.

Ambient Concentration Measurement

- Six large O&G well pads were developed between 2019 and 2022 in Broomfield, Colorado.
- Four years of weekly whole air canister (1,274) measurements (50 VOCs) from 10 monitoring sites were used in this study.



Six oil and gas well pads (shown as polygons) and monitoring sites (shown as colored dots) in Broomfield, CO

Emission Inversion Method

- Observation (weekly canister samples at multiple locations).
- AERMOD dispersion model simulation.
- Derive VOC emission rates (ER) through Multiple Linear Regression (MLR).

$$\begin{pmatrix} C_1 \\ \vdots \\ C_n \end{pmatrix} = C_{bg} + \begin{pmatrix} M_{1,1} & \cdots & M_{1,m} \\ \vdots & \ddots & \vdots \\ M_{n,1} & \cdots & M_{n,m} \end{pmatrix} \cdot \begin{pmatrix} e_1 \\ \vdots \\ e_m \end{pmatrix}$$

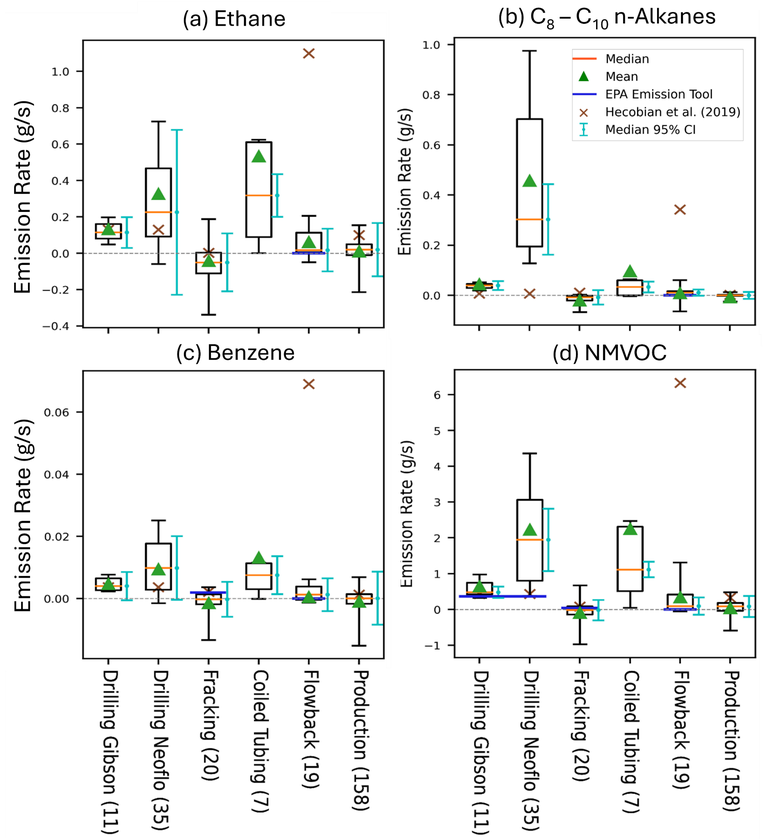
Observation — Background concentration — AERMOD simulation — VOC ER

- We characterize VOC emission rates for 50 species for well drilling, fracking, coiled tubing/millout, flowback, and production operations.

Results

- Here we focus on 4 VOC compounds/groups.
- Emission rate values are compared to those from the EPA Emission Tool and Hecobian et al. (2019).

Emission rates during different oil and gas operations



- Ethane, benzene & NMVOC (nonmethane VOC) - highest median emission rates from drilling and coiled tubing/millout operations.
- Flowback emissions in Broomfield were not the largest VOC emission source – a contrast to Hecobian et al. (2019)
- High emission rate of C_8-C_{10} n-alkanes associated with Neoflo drilling mud outgassing.

Conclusions

- We provide the first report of VOC emissions from coiled tubing/millout operations.
- High VOC emissions during drilling and coiled tubing/millout operations represent an opportunity for future emission reductions.
- EPA O&G Emission Tool underestimates VOC emissions from drilling mud degassing and flowback green-completion operations.
- Flowback VOC and benzene ERs > 95% lower than reported by Hecobian et al. (2019), indicating significant improvements through use of closed-loop, tankless fluid handling systems.

References

Hecobian, A., Clements, A.L., Shonkwiler, K.B., Zhou, Y., MacDonald, L.P., Hilliard, N., Wells, B.L., Bibeau, B., Ham, J.M., Pierce, J.R., Collett, J.L.Jr., 2019. Air Toxics and Other Volatile Organic Compound Emissions from Unconventional Oil and Gas Development. Environ. Sci. Technol. Lett. 6, 720–726. https://doi.org/10.1021/acs.estlett.9b00591

Ku, I.-T., Zhou, Y., Hecobian, A., Benedict, K., Buck, B., Lachenmayer, E., Terry, B., Frazier, M., Zhang, J., Pan, D., Low, L., Sullivan, A., Collett, J.L., 2024. Air quality impacts from the development of unconventional oil and gas well pads: Air toxics and other volatile organic compounds. Atmospheric Environment 317, 120187. https://doi.org/10.1016/j.atmosenv.2023.120187

Eastern Research Group, Inc., 2022. 2020 Nonpoint Oil and Gas Emission Estimation Tool Version 1.3.

Acknowledgements: We thank Yong Zhou and Jeffrey Pierce for their feedback on this work. This research was funded by HEI Energy. Air monitoring was funded by the City and County of Broomfield and conducted in collaboration with Ajax Analytics.