Temporal Variability of Emissions at an Underground Natural Gas Storage Facility Revealed by Long-term Continuous Monitoring

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Presentation to:

Natural Gas & Petroleum Systems:

Updates Under Consideration for the 2021 GHGI

Environmental Protection Agency

November 12, 2020

Project Funding

The United States Department of Energy Office of Fossil Energy
National Energy Technology Laboratory
Methane Emissions Mitigation and Quantification from Natural Gas Infrastructure

Title: Emission Inventories from Natural Gas Storage Facilities using Regional Frequency Comb Laser Monitoring and Aircraft Flyovers
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Principal Investigator:
Dr. Gregory Rieker
Associate Professor

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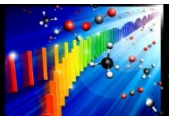
USDA NIFA
United States Department of Agriculture
National Institute of Food and Agriculture



Precision Laser Diagnostics for Energy and the Environment

UCDAVIS

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University of Colorado Boulder

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Study Site: Underground Natural Gas Storage

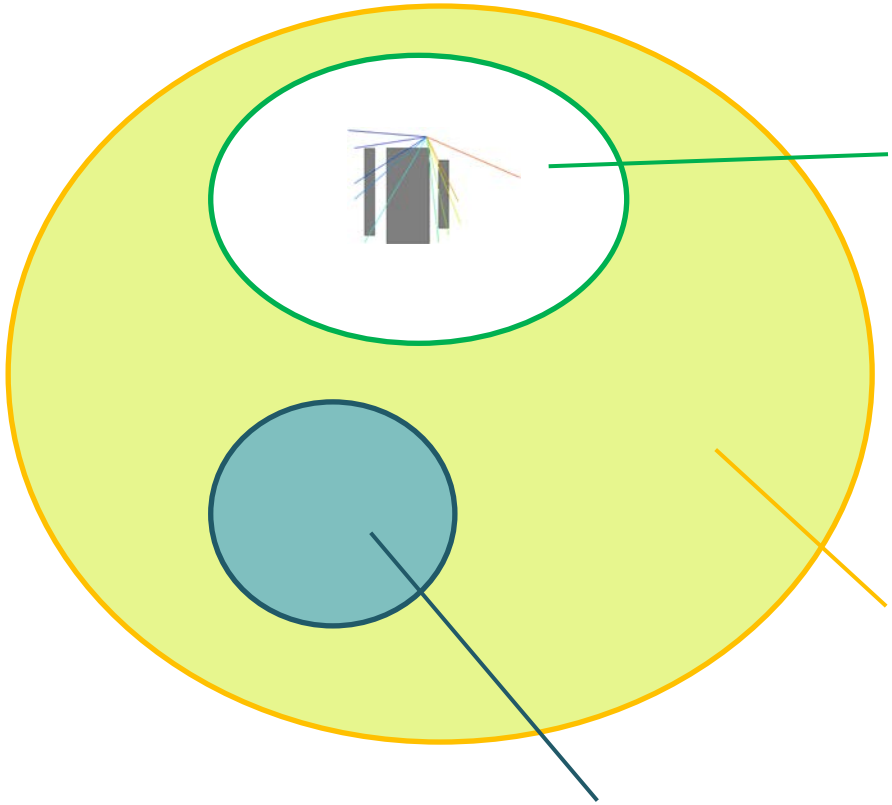
Area covered during Oct. ‘17 – Sept. ‘18 Campaign

Underground natural gas storage facility in EIA Pacific Region

Top quartile of US storage: base gas storage and total field capacity

Study Site: Underground Natural Gas Storage

Area covered during Oct. ‘17 – Sept. ‘18 Campaign



Smaller Study Area

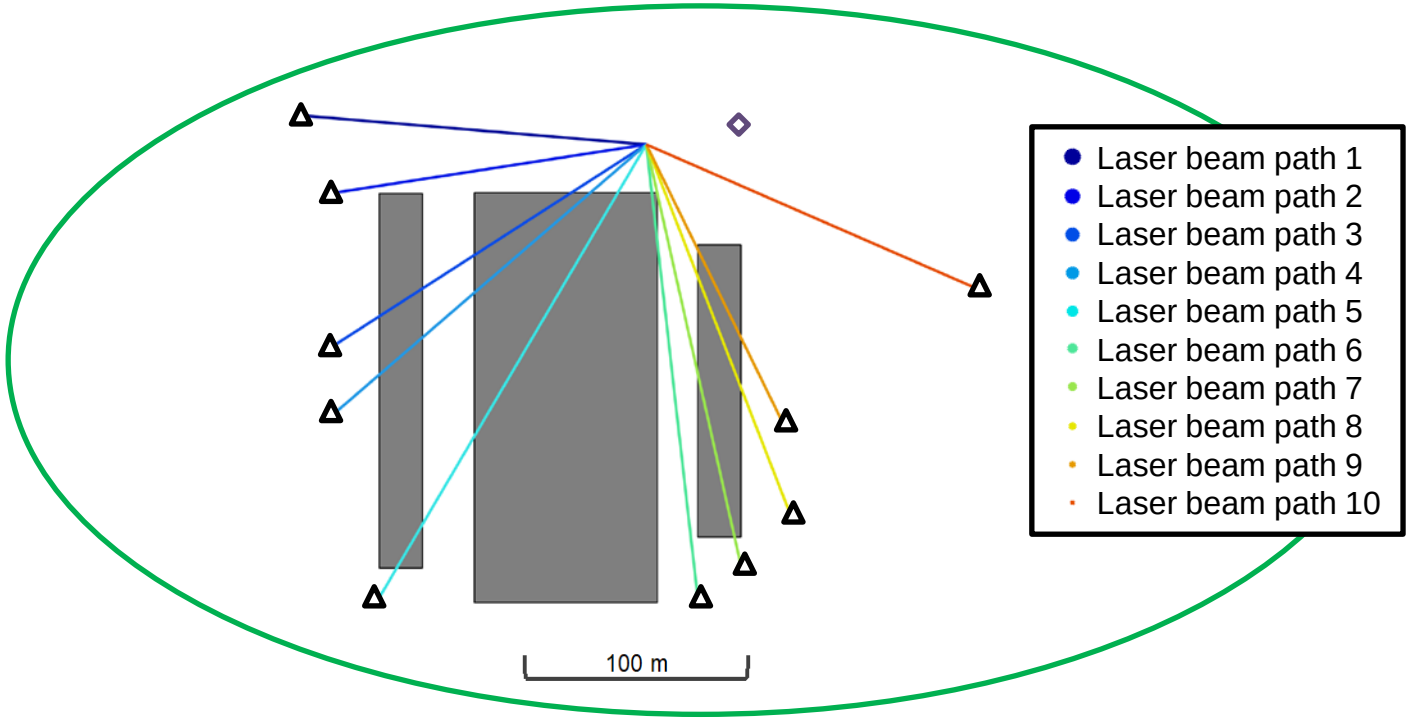
- Continuous monitoring with DCS laser system
- ~Monthly aircraft flights
- 36 wellheads, 2 reboilers, 4 contactor towers, 1 thermal oxidizer, 6 filter separators

Entire Facility

- All wellheads, compressors
- Monitored with aircraft only

Continuous DCS Laser-Based Emissions Monitoring

New **Methane Leak Detection and Quantification** Technology & Methodology



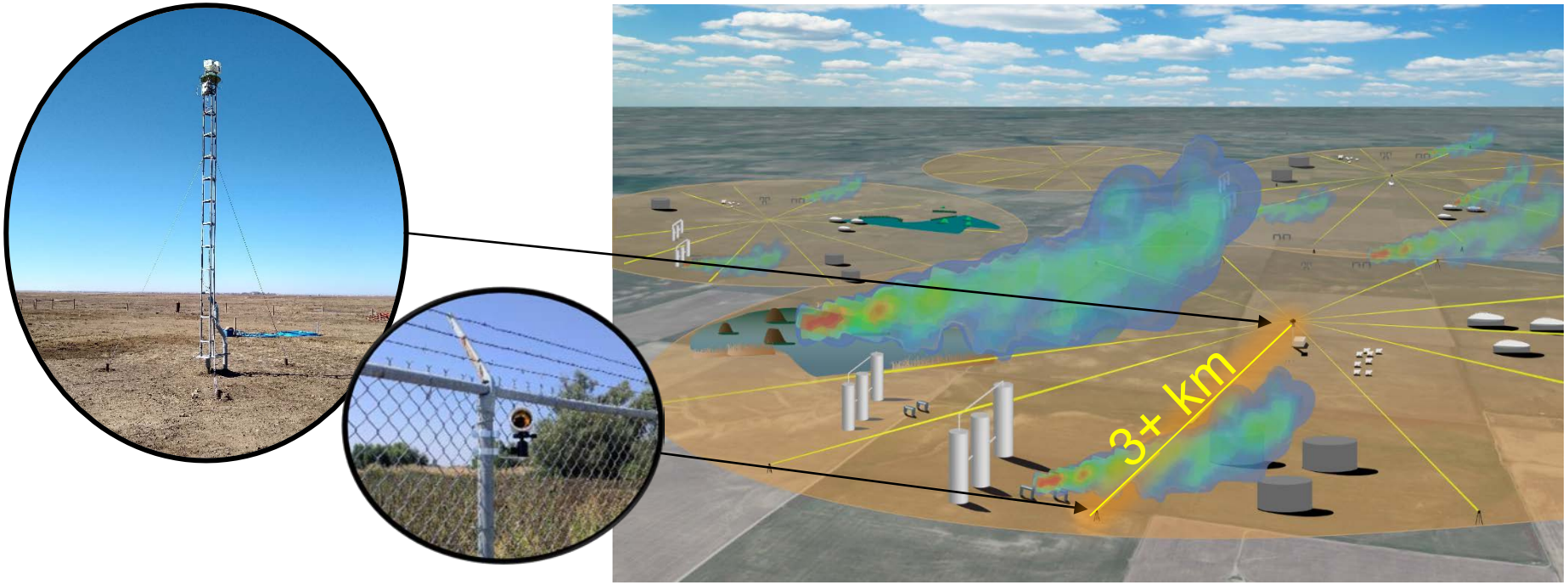
3+ km laser beam paths provide broad coverage of potential sources

Inverse modeling enables quantification of emissions

Autonomous continuous monitoring captures temporal variability

Low cost

Continuous DCS Laser-Based Emissions Monitoring

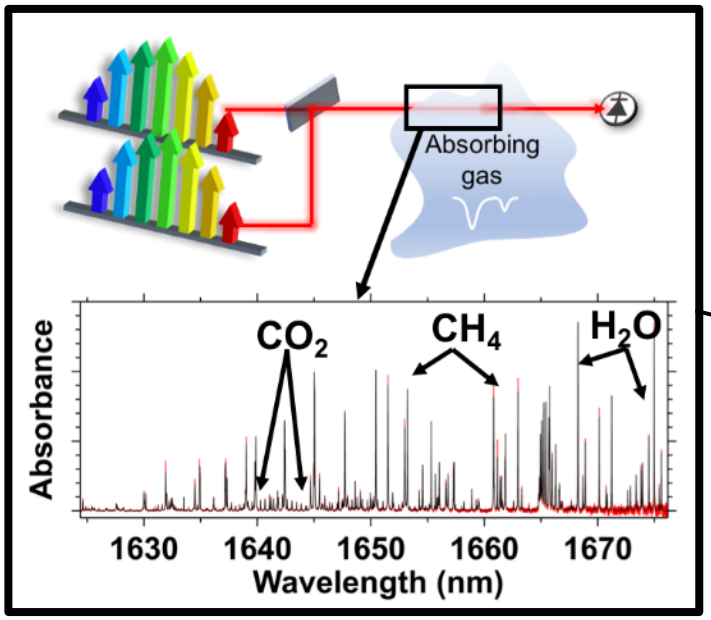


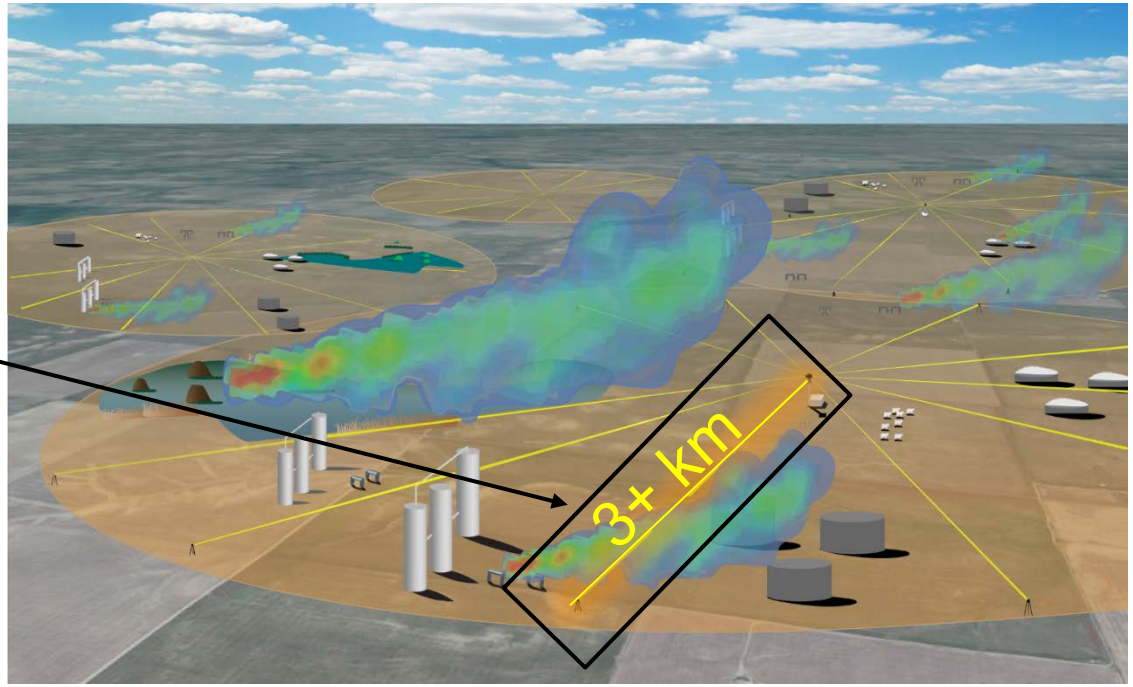
Dual Frequency-Comb Spectrometry

- < 5 ppb CH_4 precision over 3+ km paths
- Handles multi-species absorption interference
- Water measured directly → dry-air mole fractions
- High stability over time, no instrument drift, no calibration needed

Rieker et al., *Optica* (2014)
Coburn et al. *Optica* (2018)
Alden et al. *AMT* (2018)
Alden et al., *ES&T* (2019)
Alden et al., *ES&T (2020)*

Continuous DCS Laser-Based Emissions Monitoring





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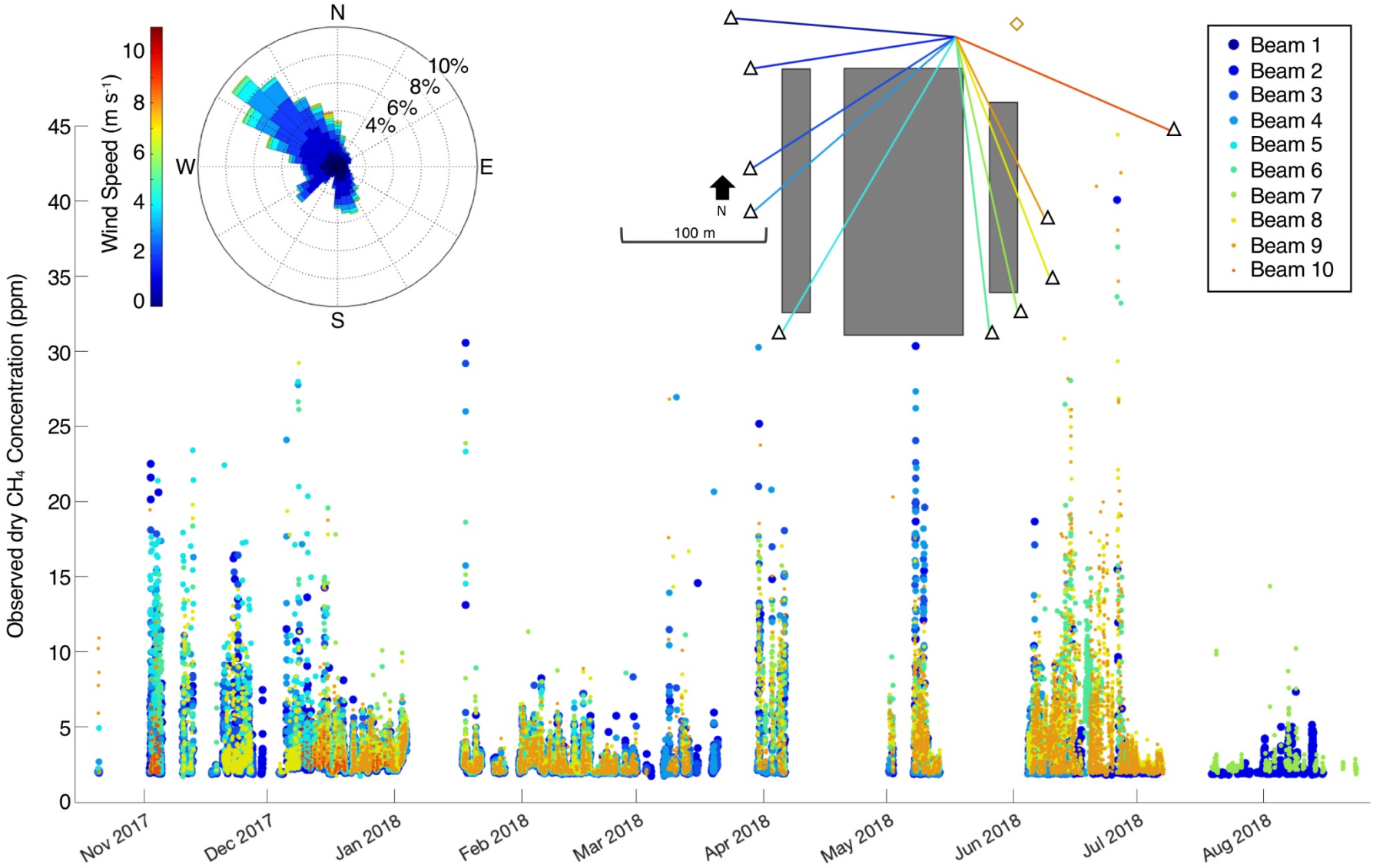
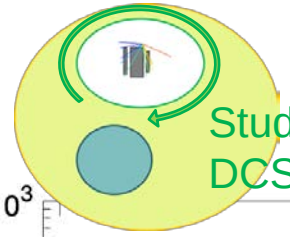
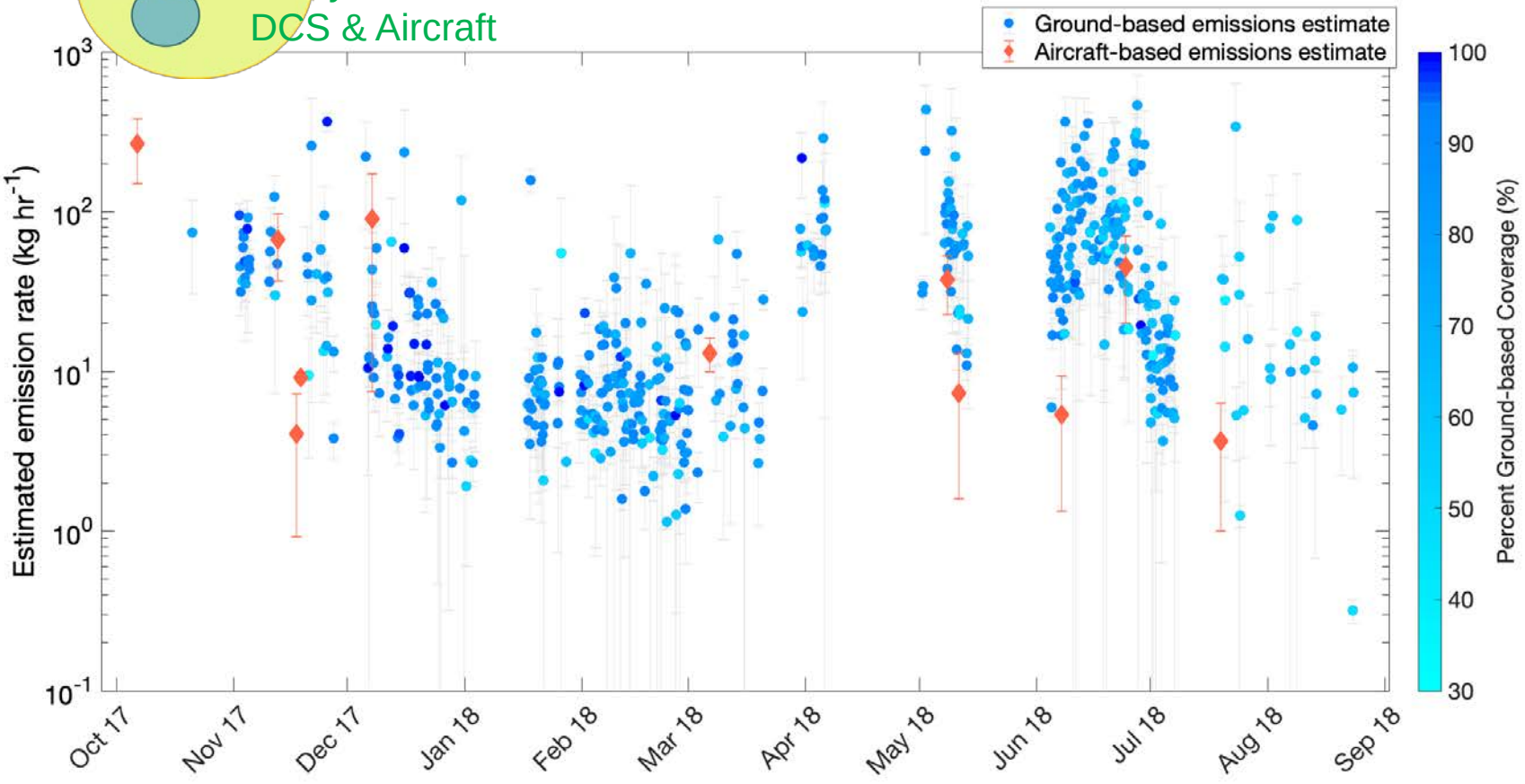
Continuous Concentration Timeseries



Continuous Emissions Timeseries, Study Site



Study Site:
DCS & Aircraft



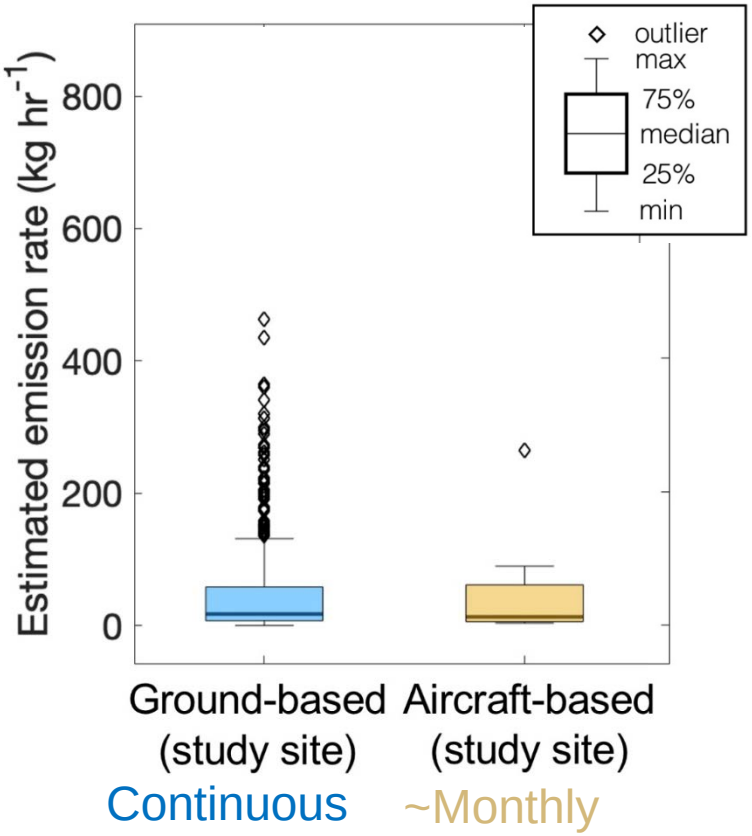
Alden et al., *ES&T* (2020)

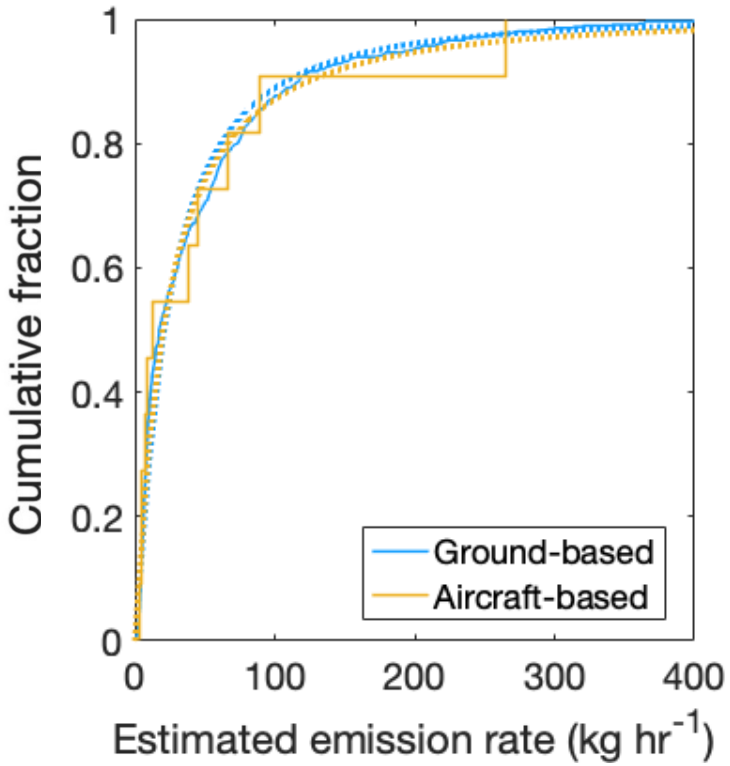
Continuous Emissions Timeseries, Study Site

Emissions lognormally distributed

DCS-based geometric mean: 20 [-2, +3] kg hr^{-1} (95% CI)

Aircraft-based geometric mean: 19.9 [-12.3, +32.0] kg hr^{-1} (95% CI)

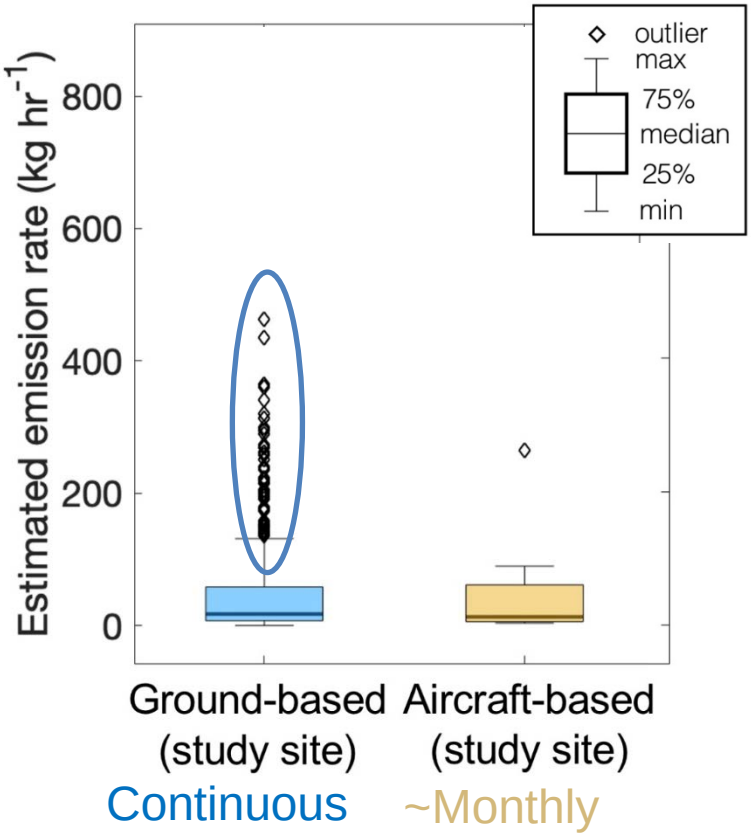


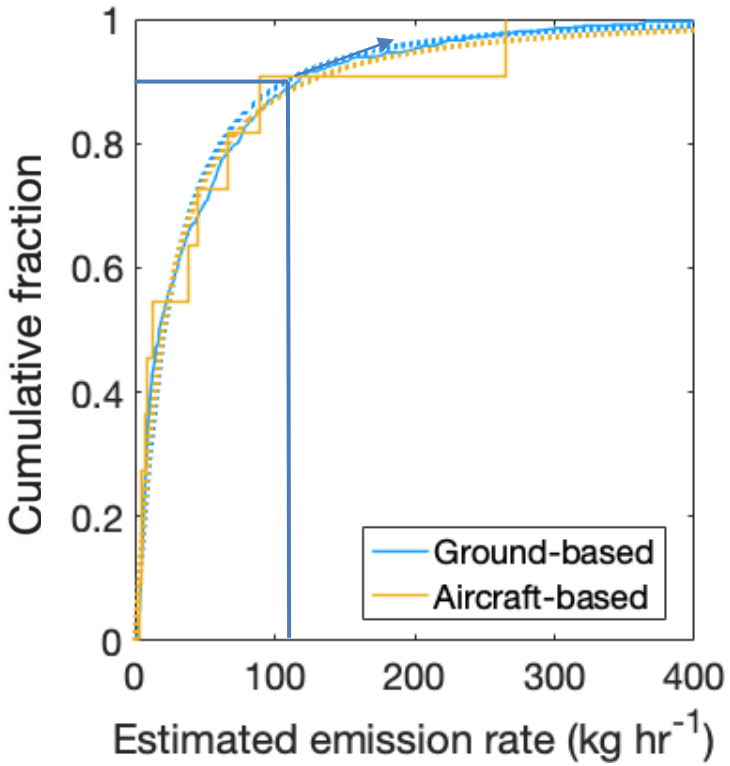


Alden et al., *ES&T* (2020)

Continuous Emissions Timeseries, Study Site

Continuous monitoring captures outliers that represent the top 10% largest emission events and 40% of total emissions





Alden et al., *ES&T* (2020)

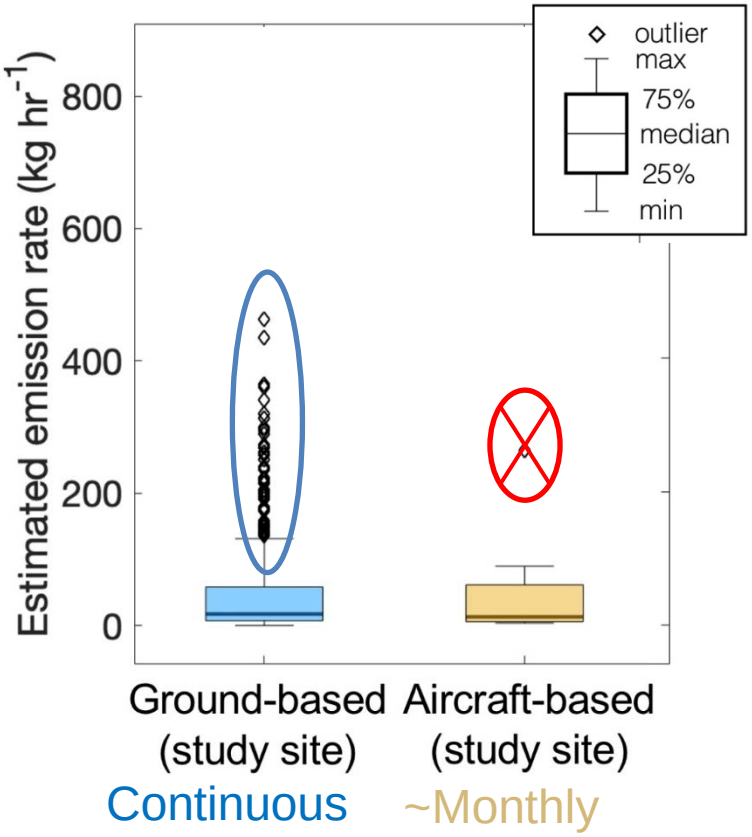
Continuous Emissions Timeseries, Study Site

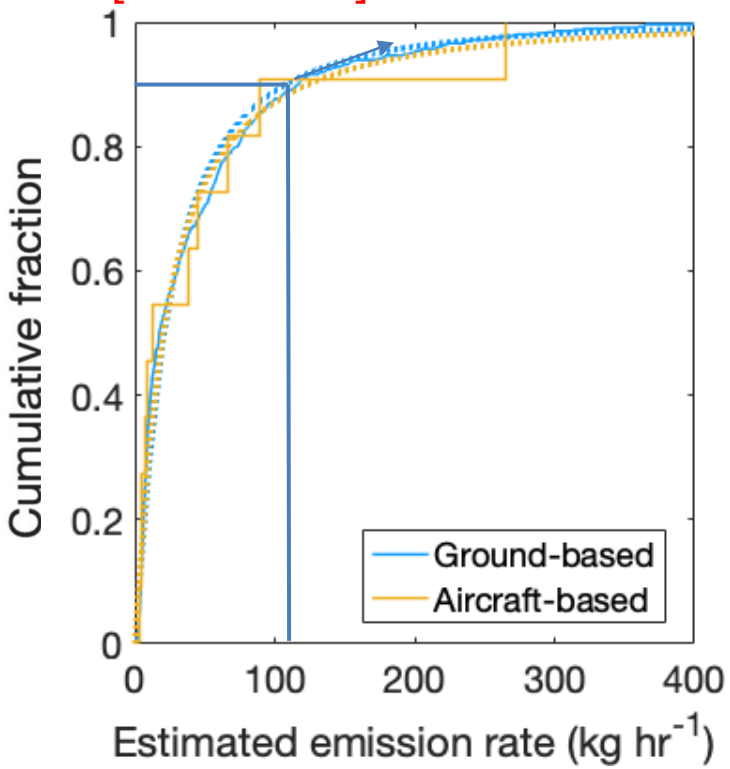
Emissions lognormally distributed

DCS-based geometric mean: 20 [-2, +3] kg hr^{-1} (95% CI)

Aircraft-based geometric mean: ~~19.9 [-12.3, +32.0]~~ kg hr^{-1} (95% CI)

15.3 [-8.8, +20.9]



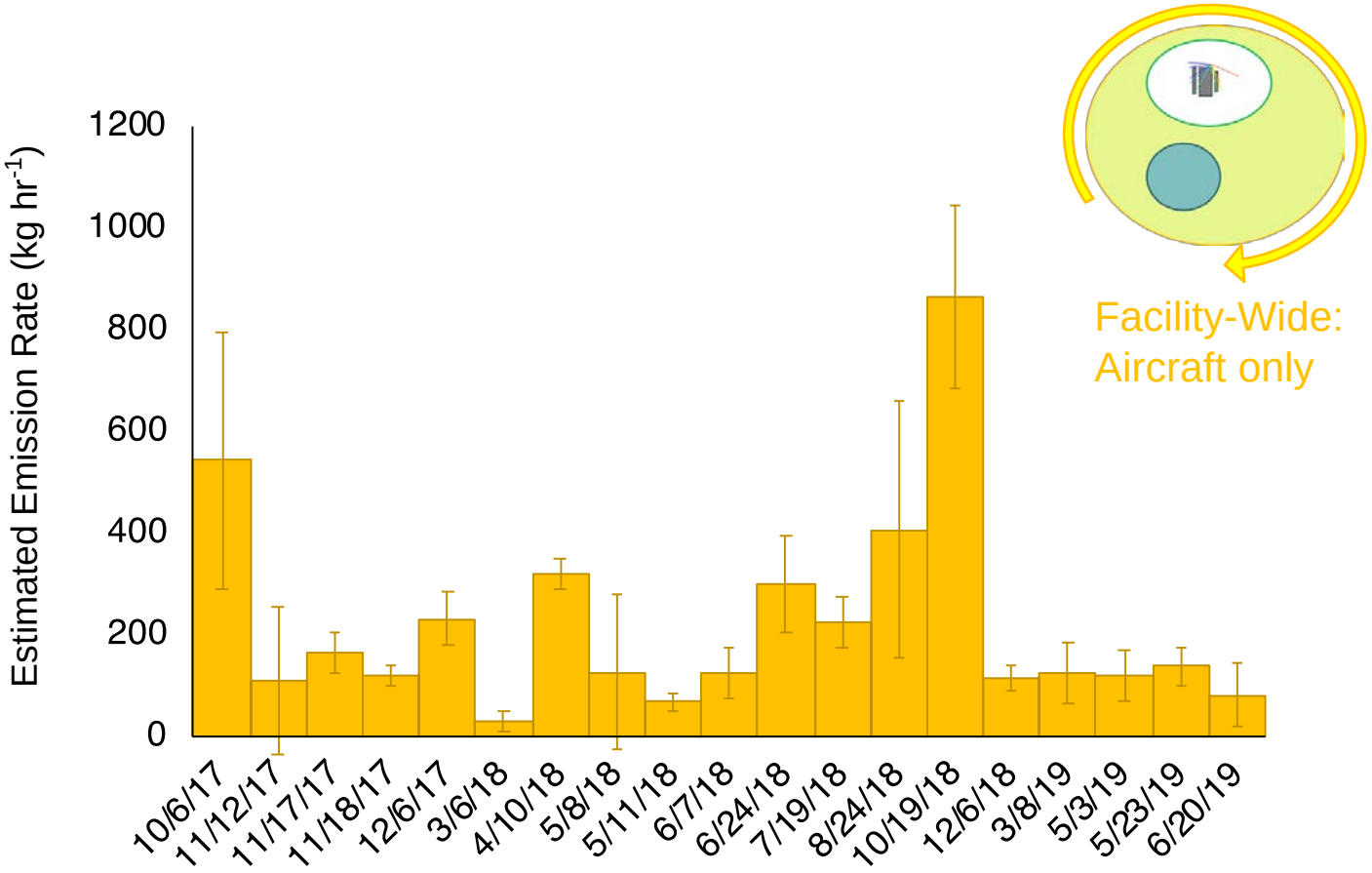


Alden et al., *ES&T* (2020)

Timeseries of Emissions, Site-Wide

Emissions lognormally distributed

Aircraft-based geometric mean: 164.6 [-51.8, +75.5] kg hr^{-1} (95% CI)



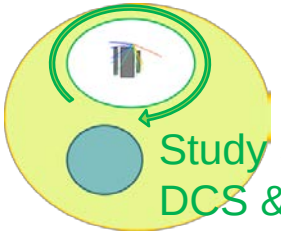
Facility-Wide:
Aircraft only

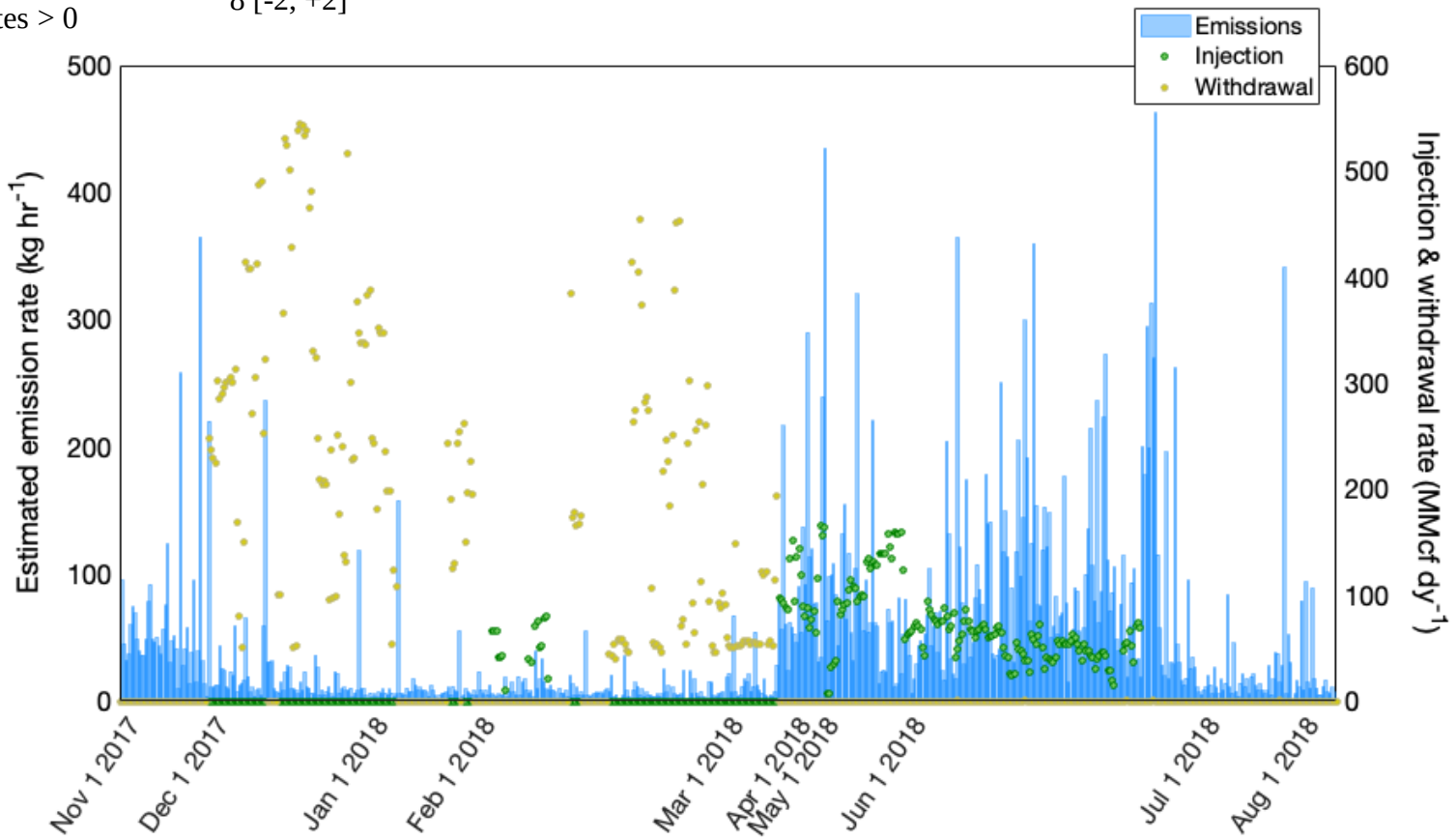
Alden et al., *ES&T* (2020)

Links Between Operations & Emissions

Grouped Data	Geometric Mean Emission Rate [95% CI] (kg hr^{-1})
Injection rates > 0 & withdrawal rates = 0	58 [-8, +9]
Injection rates = 0 & withdrawal rates > 0	8 [-2, +2]

- Higher emissions during injection
- No compressors on study site
- Emissions associated with higher system pressures during injection?

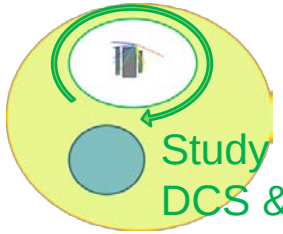




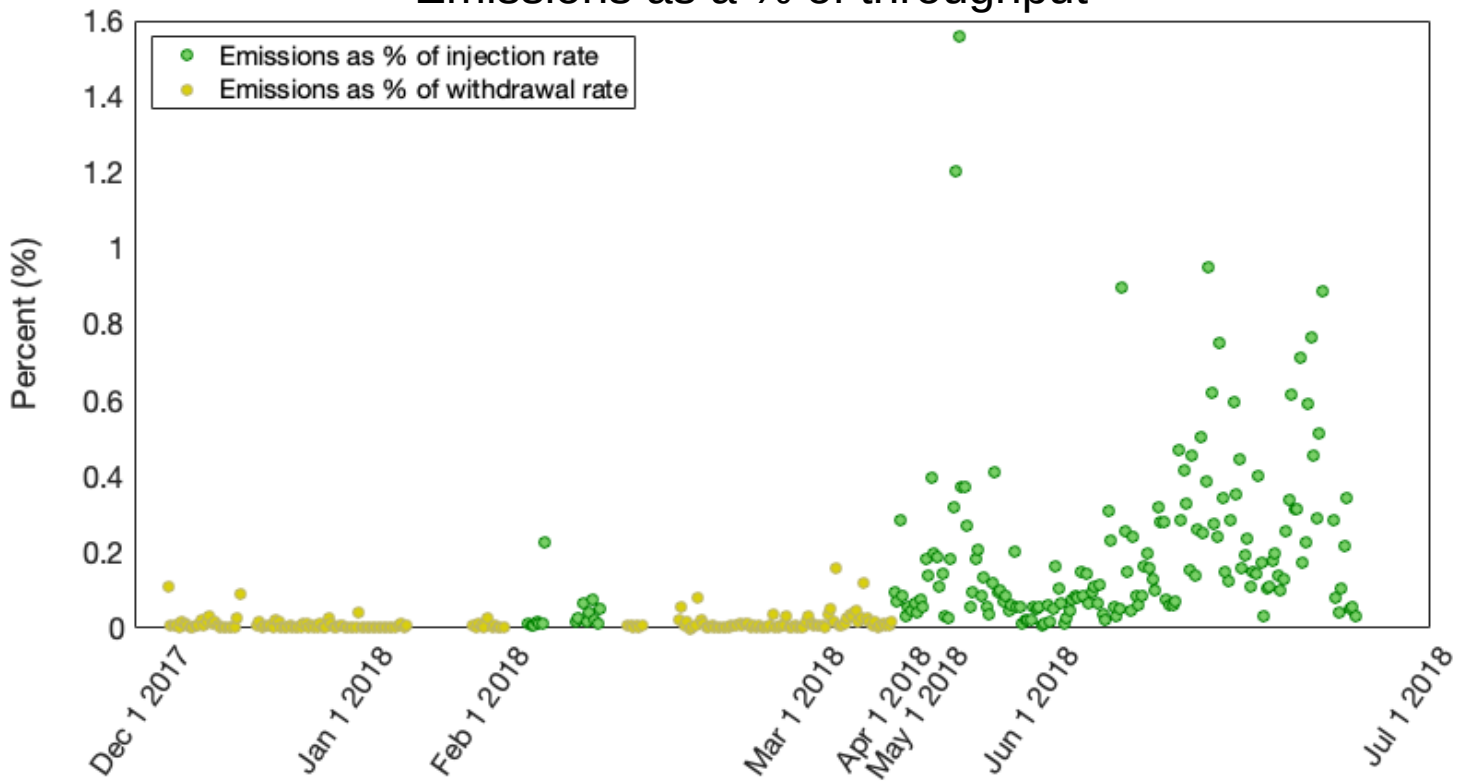
Links Between Operations & Emissions

Grouped Data	%
Emissions as % of Injection Rate	0.19
Emissions as % of Withdrawal Rate	0.01

- Higher emissions during injection
- No compressors on study site
- Emissions associated with higher system pressures during injection?

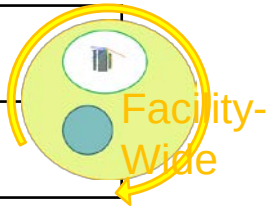


Emissions as a % of throughput

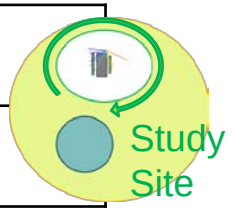


New Values to Consider for GHGI

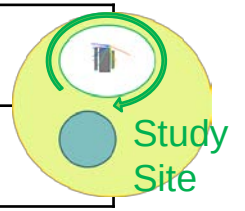
Facility-Wide Emission Rate	**Geometric Mean [-, + 95% CI]**
	164.6 [-51.8, +75.5] kg hr^{-1}



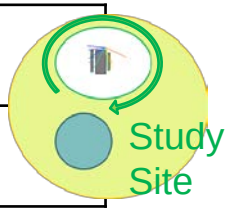
Emission Rate Variability (3-hrly; study site only)*	**Parameters of Lognormal Fit**
	μ = 3.0, σ = 1.3



Emission rate during withdrawal as percent of emission rate during injection*	**Geometric Mean**
	14%



Emissions as % of Injection & Withdrawal Rates*	**Injection**	**Withdrawal**
	0.19%	0.01%



*From non-compressor equipment

New publication out 10/27

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Article

Temporal Variability of Emissions Revealed by Continuous, Long-Term Monitoring of an Underground Natural Gas Storage Facility

Caroline B. Alden,* Robbie J. Wright, Sean C. Coburn, Dani Caputi, Griffith Wendland, Alex Rybchuk, Stephen Conley, Ian Faloona, and Gregory B. Rieker

Cite This: https://dx.doi.org/10.1021/acs.est.0c03175

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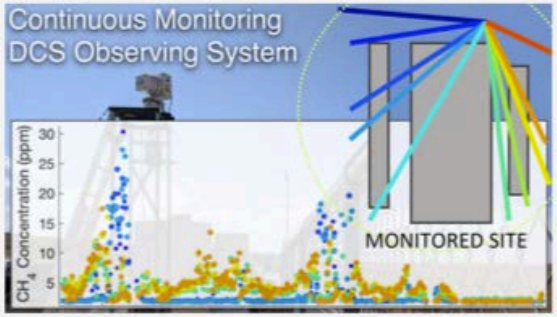
ABSTRACT: Temporal variability contributes to uncertainty in inventories of methane emissions from the natural gas supply chain. Extrapolation of instantaneous, "snapshot-in-time" measurements, for example, can miss temporal intermittency and confound bottom-up/top-down comparisons. Importantly, no continuous long-term datasets record emission variability from underground natural gas storage facilities despite substantial contributions to sector-wide emissions. We present 11 months of continuous observations on a section of a storage site using dual-frequency comb spectroscopy (DCS observing system) and aircraft measurements. We find high emission variability and a skewed distribution in which the 10% highest 3 h emission periods observed by the continuous DCS observing system comprise 41% of the total observed 3-hourly emissions. Monthly emission rates differ by >12×, and 3-hourly rates vary by 17× in 24 h. We find links to the operating phase of the facility—emission rates, including as a percentage of the total gas flow rate, are significantly higher during periods of injection compared to those of withdrawal. We find that if a high frequency of aircraft flights can occur, then the ground- and aircraft-based approaches show excellent agreement in emission distributions. A better understanding of emission variability at underground natural gas storage sites will improve inventories and models of methane emissions and clarify pathways toward mitigation.



Relevant Publications

- Alden, C. B., Wright, R., Coburn, S., Caputi, D., Wendland, G., Rybchuk, A., Conley, S., Faloona, I., Rieker, G. B., **2020**, Temporal variability of emissions revealed by continuous, long-term monitoring of an underground natural gas storage facility. *Environmental Science & Technology*, DOI: 10.1021/acs.est.8b06259
- Alden, C. B., Coburn, S. Wright, R., Baumann, E., Cossel, K., Perez, E., Hoenig, E., Prasad, K., Coddington, I. Rieker, G., **2019**, Single-blind quantification of natural gas leaks from 1 km distance using frequency combs. *Environmental Science & Technology*, DOI: 10.1021/acs.est.8b06259
- Alden, C. B., Ghosh, S., Coburn, S., Sweeney, C., Karion, A., Wright, R., Coddington, I., Prasad, K., Rieker, G., **2018**, Bootstrap inversion technique for atmospheric trace gas source detection and quantification using long open-path laser measurements, *Atmospheric Measurement Techniques*, DOI: 10.5194/amt-11-1565-2018
- Coburn, S., Alden, C. B. Wright, R., Cossel, K., Baumann, E., Truong, G.-W., Giorgetta, F., Sweeney, C., Newbury, N., Prasad, K., Coddington, I., Rieker, G. B., **2018**, Regional trace-gas source attribution using a field-deployed dual frequency comb spectrometer, *Optica*, DOI: 10.1364/OPTICA.5.000320
- Rieker, G. B., Giorgetta, F. R., Swann, et al., **2014**, Frequency-comb-based remote sensing of greenhouse gases over kilometer air paths, *Optica*, DOI: 10.1364/OPTICA.1.000290
- A. Rybchuk, C. Alden, J.K. Lundquist, G. Rieker, ***In Review*** at *Monthly Weather Reviews,* A Statistical Evaluation of WRF-LES Dispersion Against Project Prairie Grass
- Coburn, S., Alden, C. B., Wright, R., Wendland, G., Rybchuk, A., Seitz, N., Coddington, I., Rieker, G. B., ***In Prep,*** Long Distance Continuous Methane Emissions Monitoring with Dual Frequency Comb Spectroscopy: Deployment and Blind Testing in Complex Emissions Scenarios
- A. Rybchuk, C. Alden, I. Faloona, J.K. Lundquist, G. Rieker, ***In Prep,*** LES-Simulated Trace Gas Emissions Estimates from Concurrent Ground-Based Lasers and Aircraft Measurements

Summary & Questions

- Emissions change rapidly through time
- Continuous monitoring captures large emission events and lognormal distribution of emissions, both of which are missed by intermittent aircraft sampling
- Emissions vary according to operating phase (injection / withdrawal) even in areas without compressors
- New numbers available describing distribution of emissions, emissions variability and links to operating phase

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