Local and regional MMRV of greenhouse gasses with frequency combs

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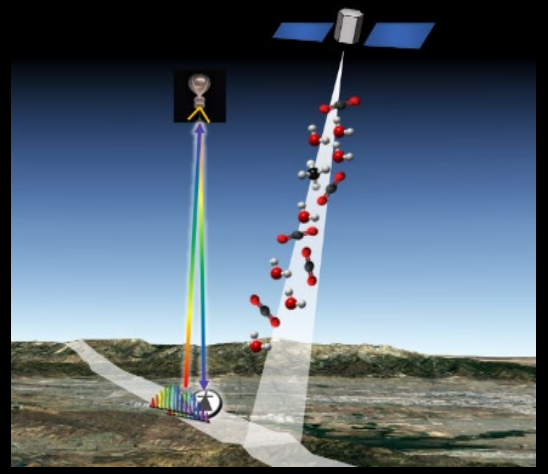
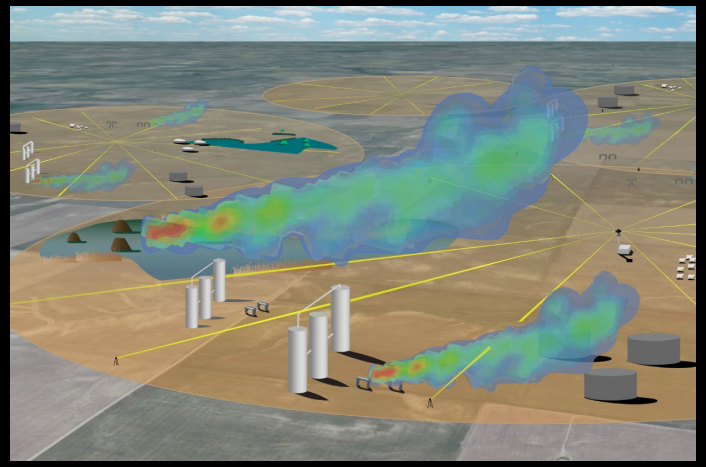
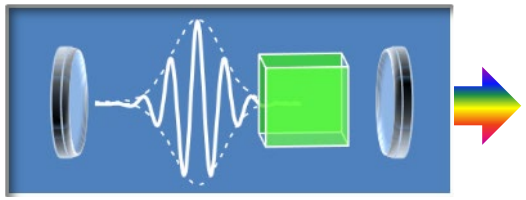
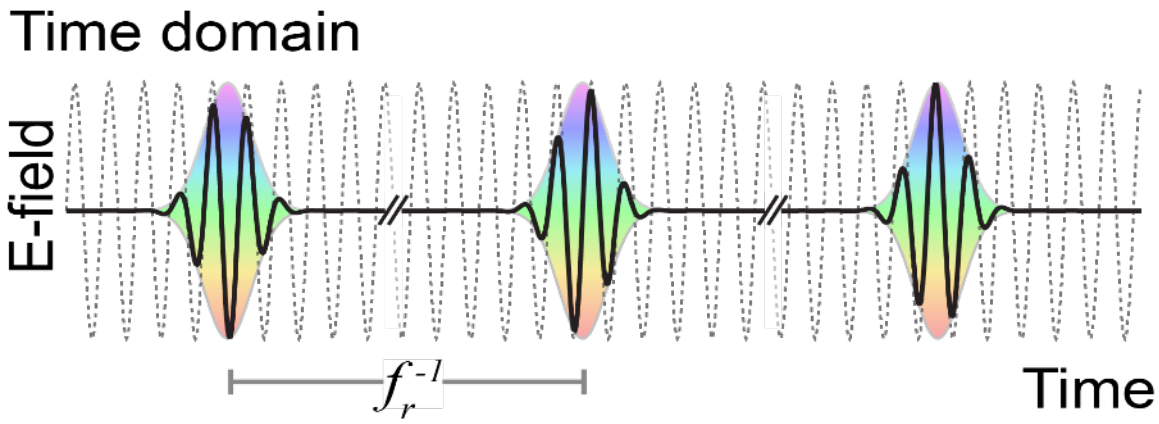


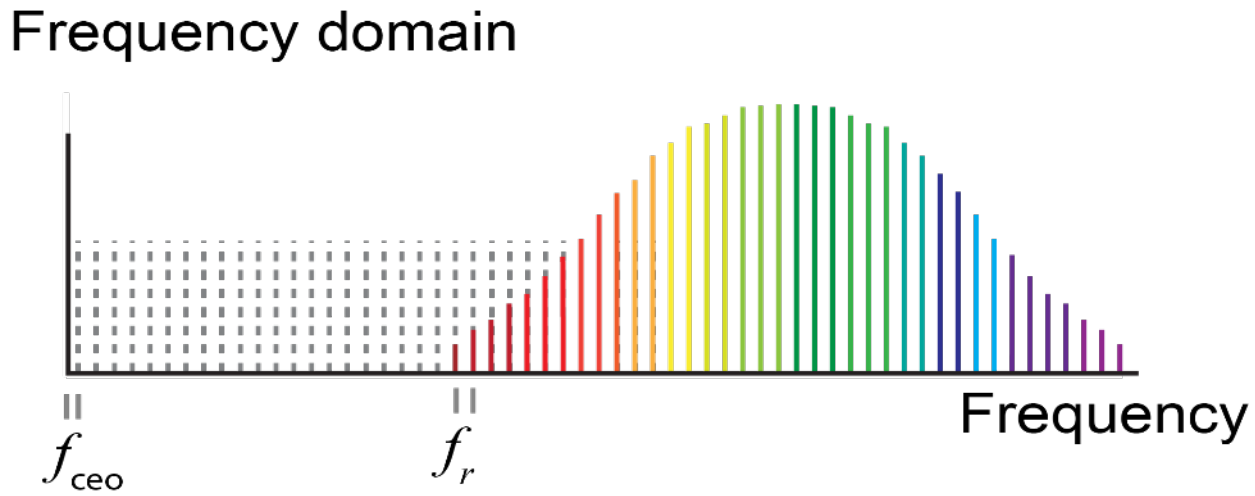


The frequency comb is a million lasers in one

Passively Modelocked Laser





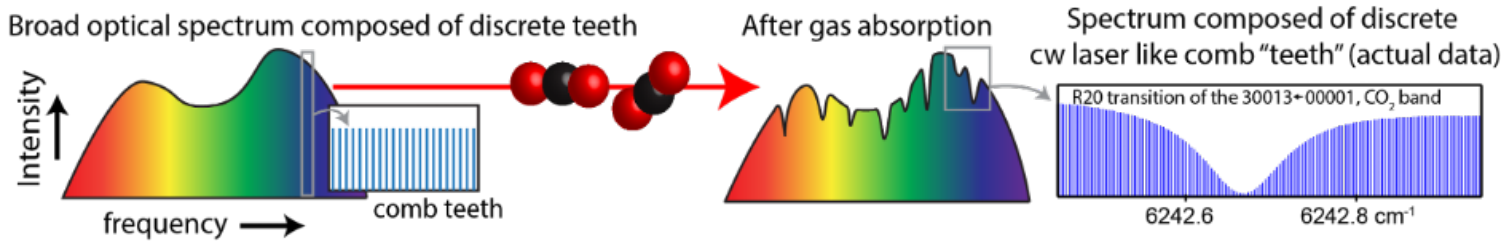


$$f_n = nf_{rep} + f_{ceo}$$

Frequency Combs are an important new tool for GHG monitoring

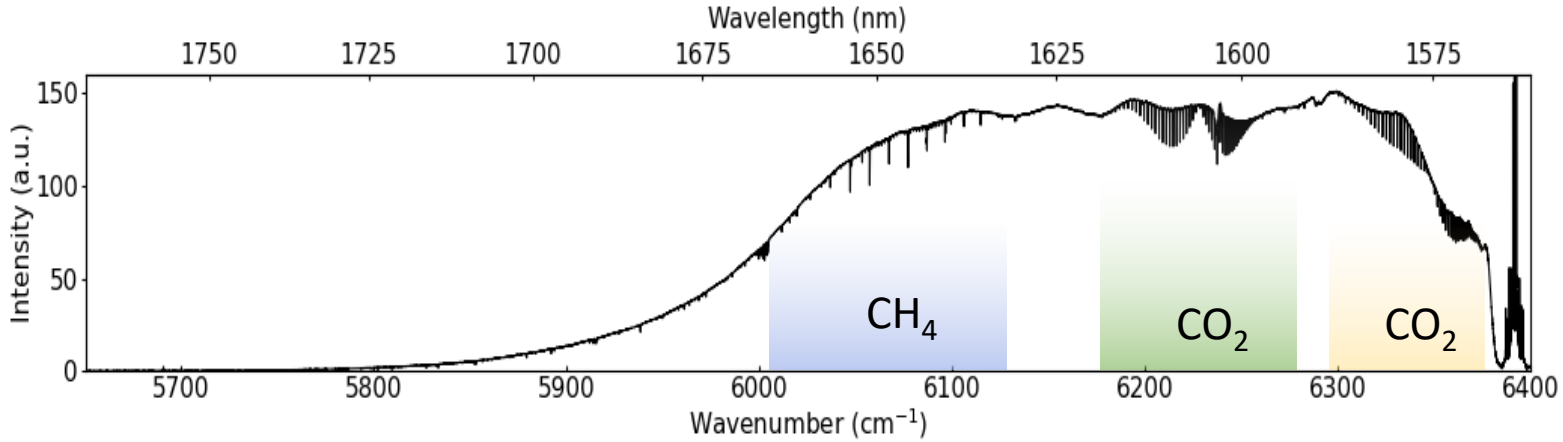
High precision concentration retrievals

- High frequency accuracy
- High resolution
- Negligible instrument lineshape



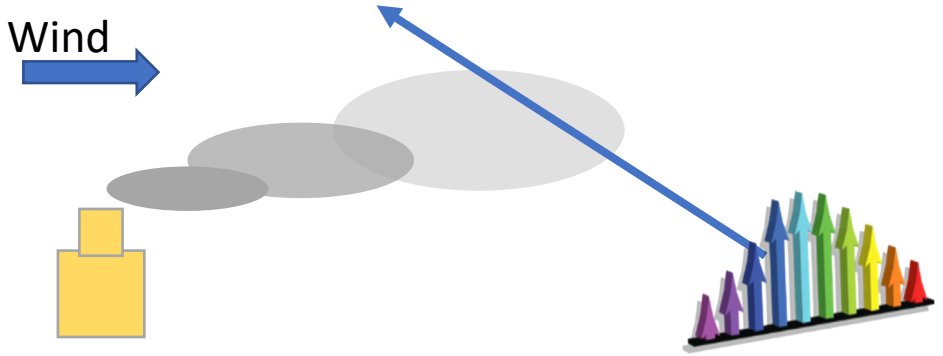
Broadband

- Multi species (CO_2, CH_4, N_2O, C_2H_6, NH_3, HCHO, HDO/H_2O)
- Path Temperature
- Low interference

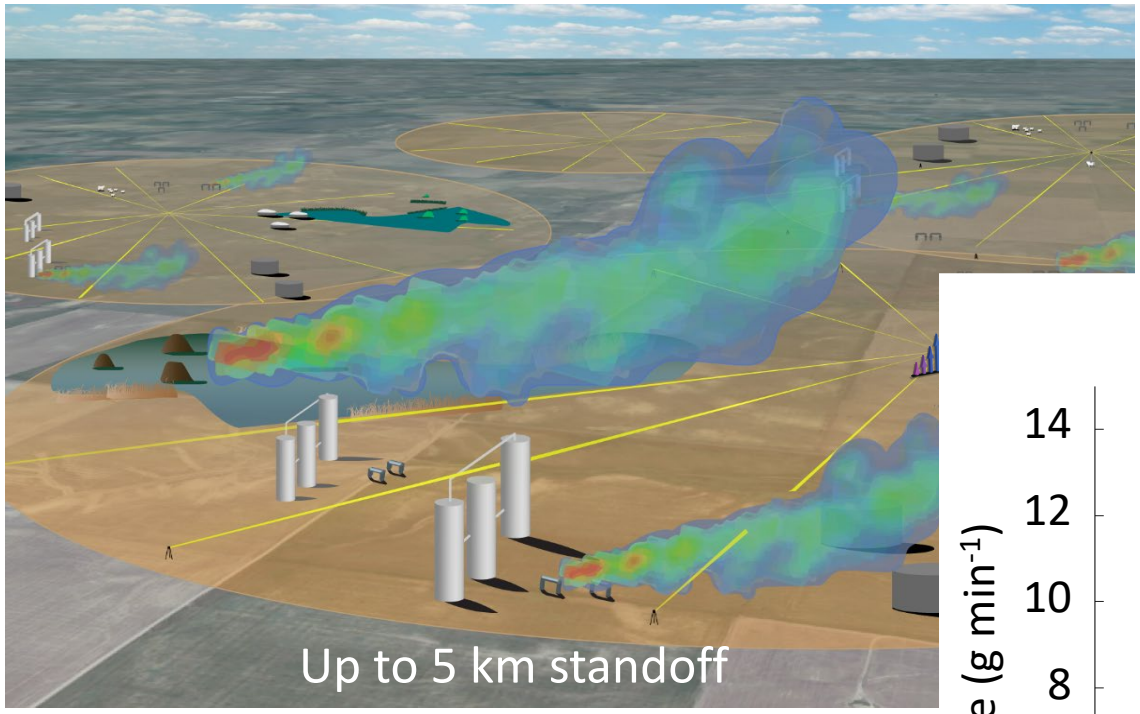


Long open-path measurements

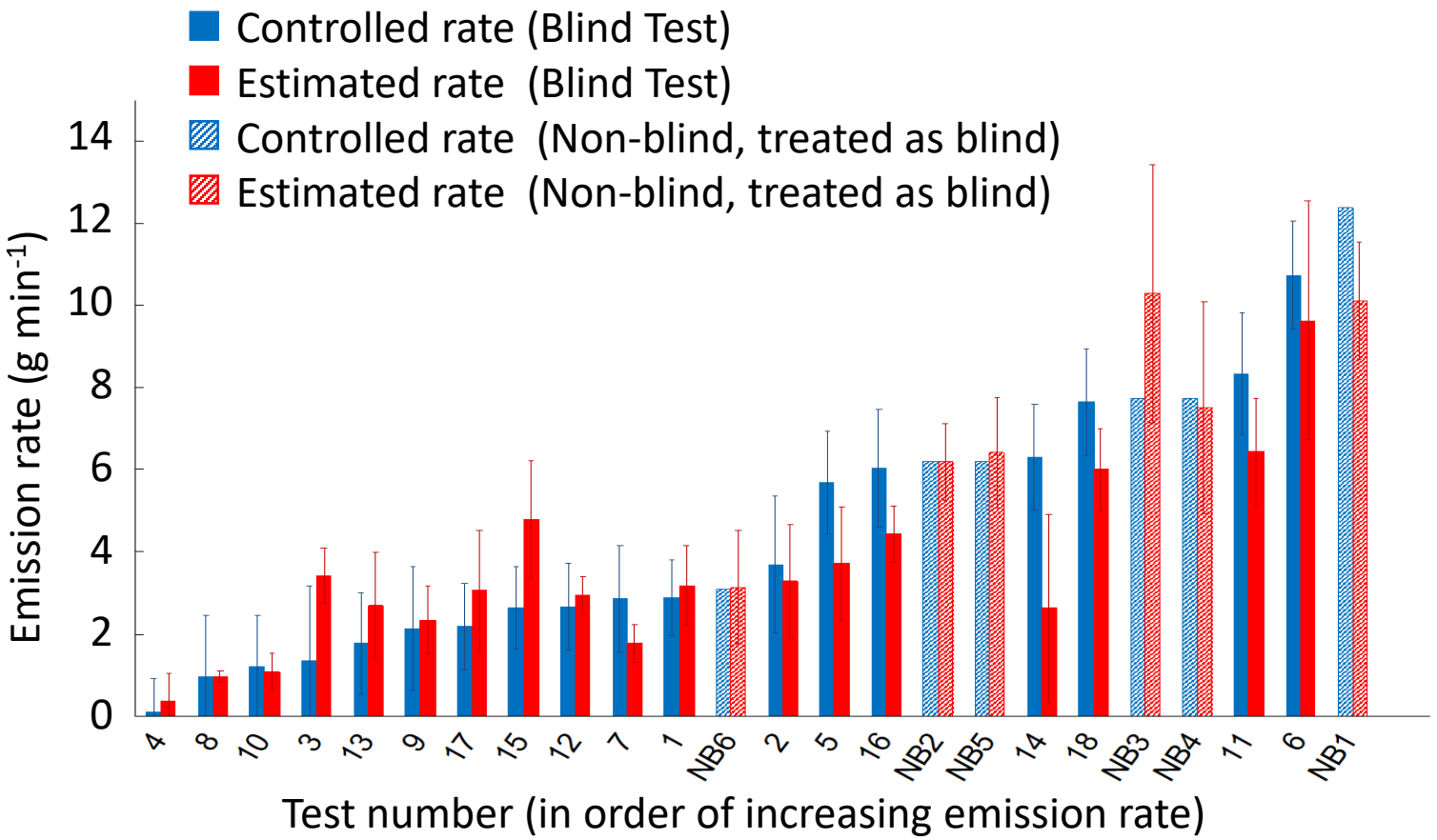
- High brightness single mode beam
- Simple detection scheme
- Turbulence immune



Comb technology is well suited to monitoring industrial releases



71% of emissions estimated to within 2 g/min



S. Coburn, Optica. **5**, 320 (2018).
C.B. Alden, Atmospheric Meas. Tech. **11**, 1565

Successful commercial deployment

LONGPATH TECHNOLOGIES

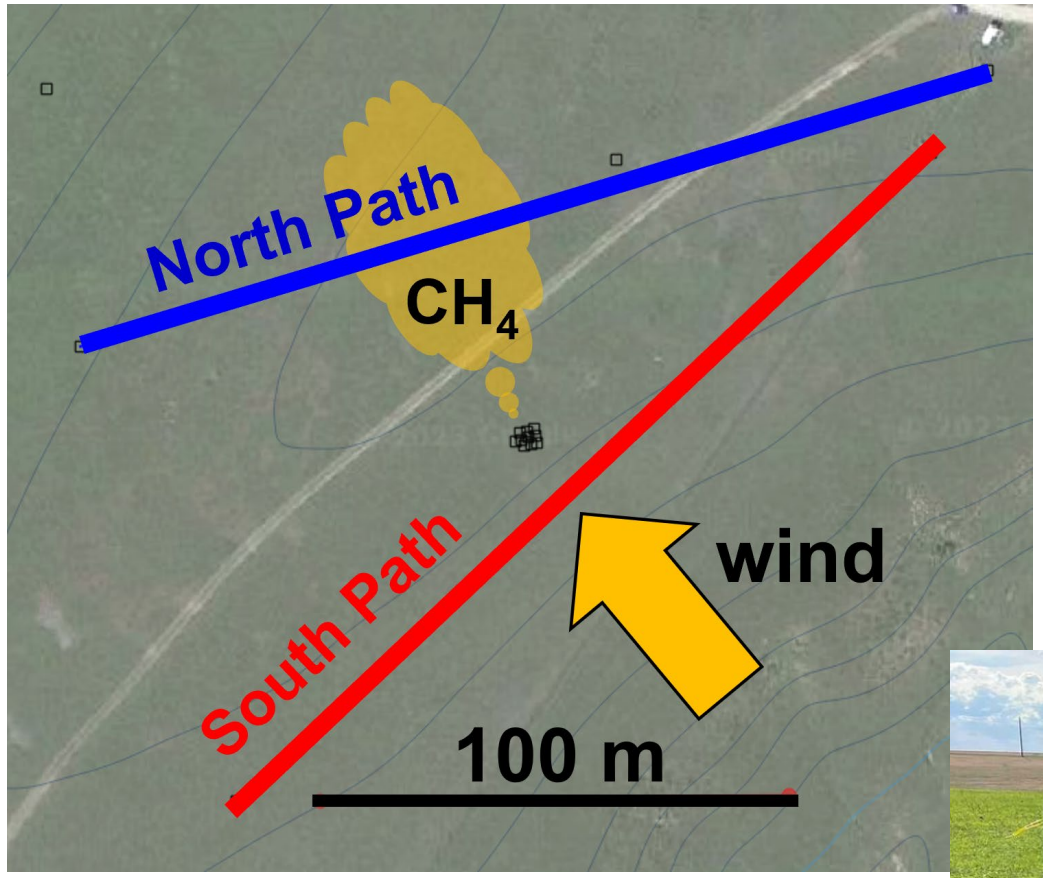
~350 facilities

Colorado, Texas, New Mexico, Oklahoma, Louisiana

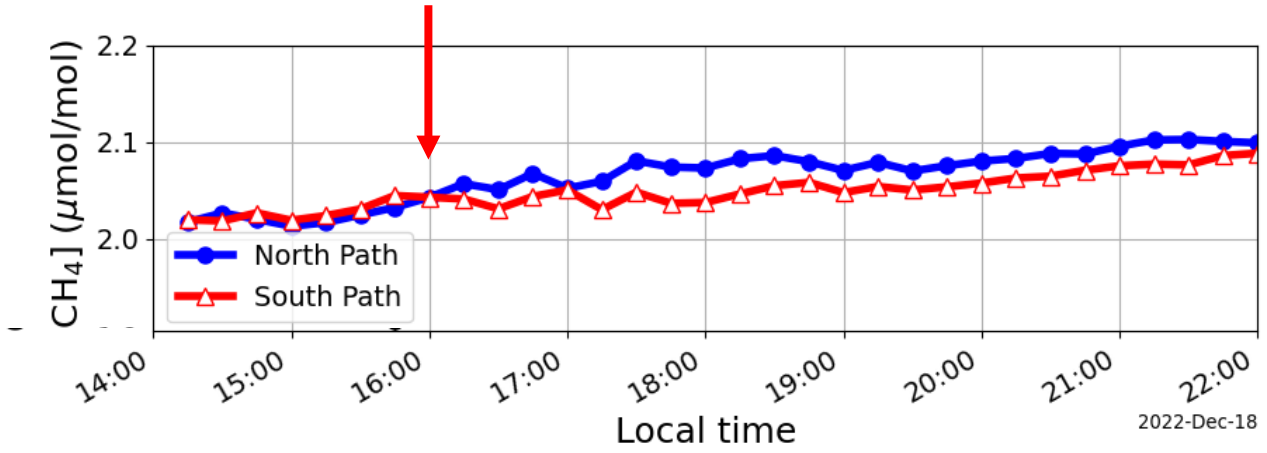
Average emissions abatement: **>40,000,000 cubic feet of natural gas per system per year**

Frequency combs

Ultra low emissions can be quantified



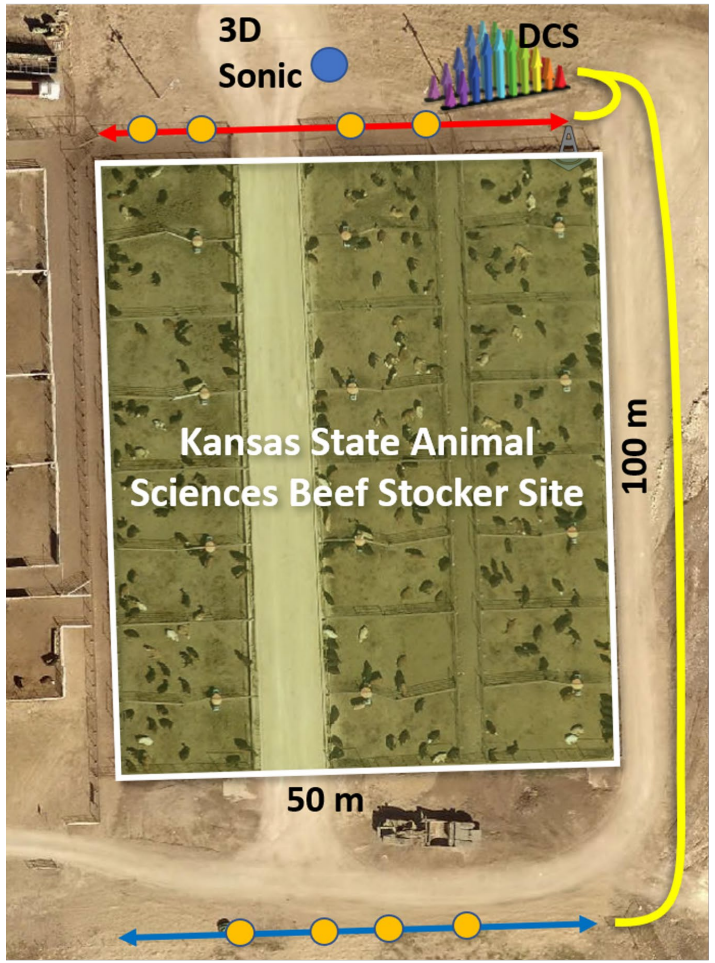
Release on (~27 head of cattle)

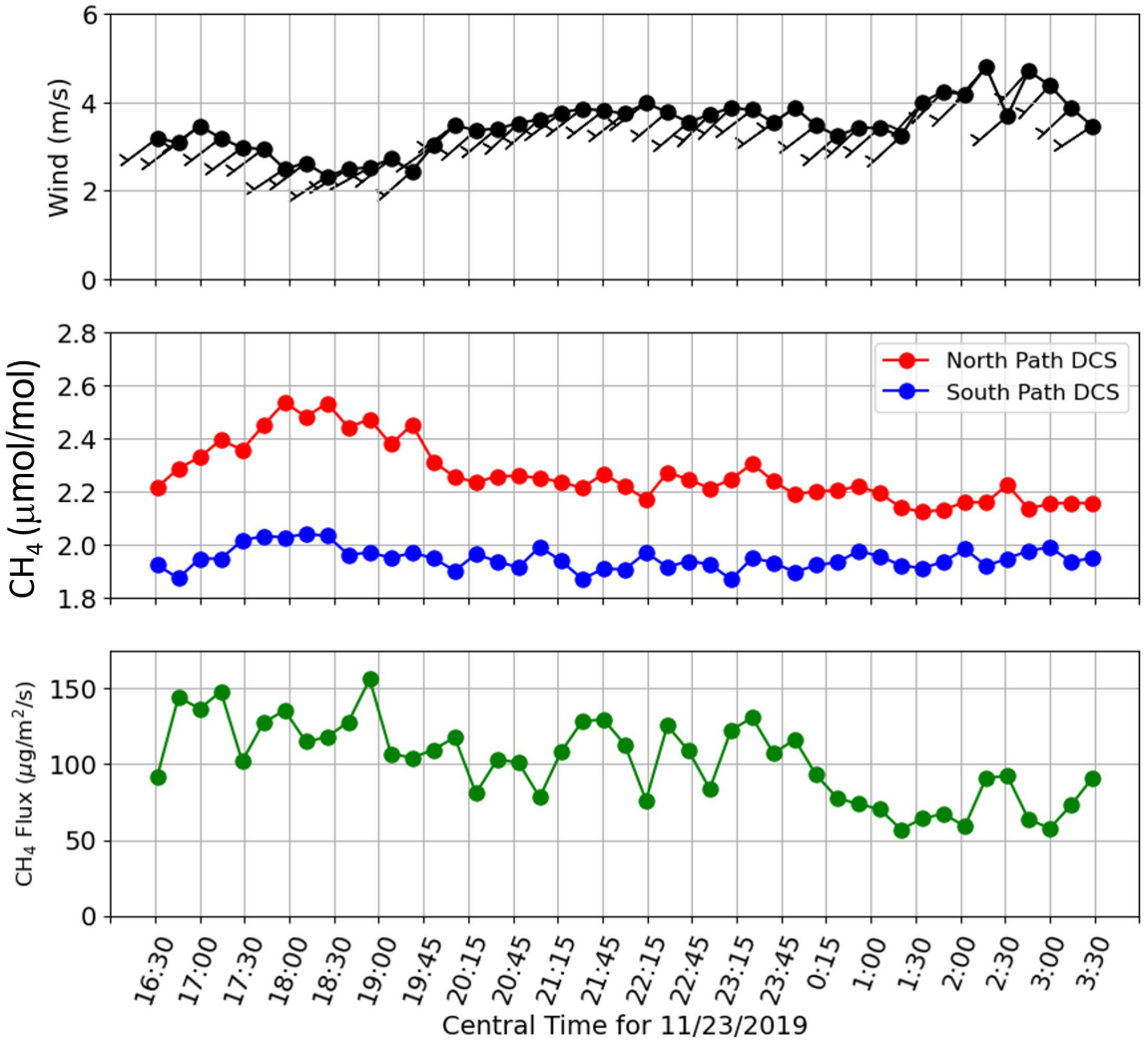


Observing 4000g/day emissions

KANSAS STATE UNIVERSITY

Feed testing in partnership with Kansas State





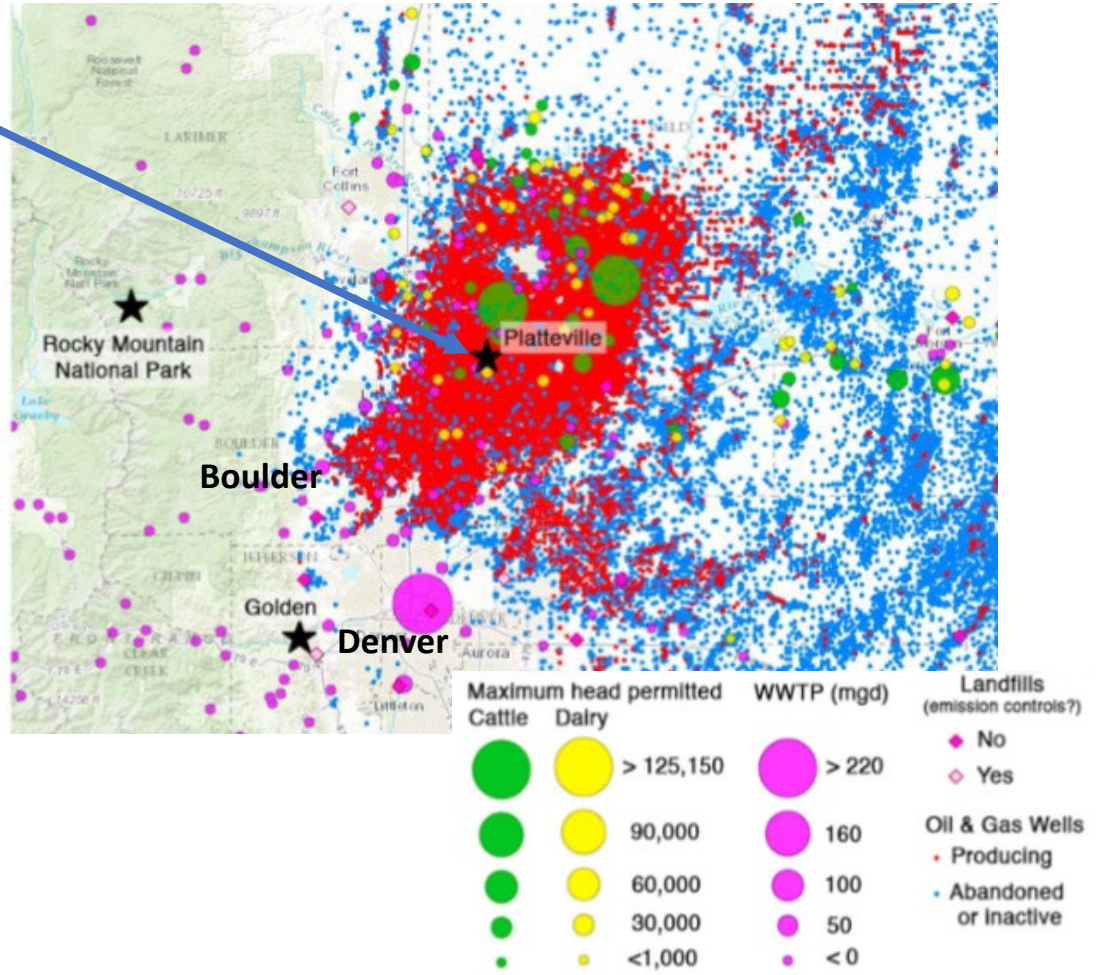
Actively testing the impact of feed on emissions

- Sustainable sorghum
- Lower carbon emission?
- Nitrogen impact?

D. Herman et al., Science Advances 7(14), (2021).

Multi-species observation allows regional monitoring in complex environments

Northern Colorado Front Range contains complex mix of sources

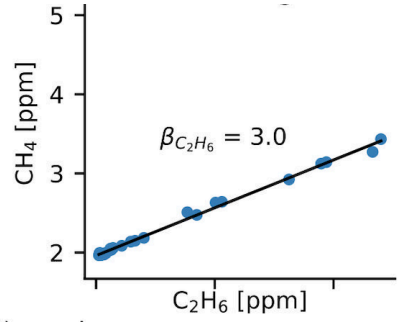


G. Mead, *et.al.*, Geophysical Research Letters, 51, e2023GL105973 (2024)

Regional flux estimation and source sector assignment possible over an 800 km^2 region

Multi-month time series of CH_4, C_2H_6 and NH_3

Sector apportion methane using tracer gas correlations



O&G prior

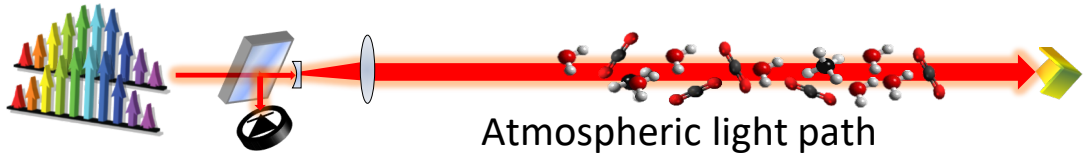
O&G posterior

Posterior - prior

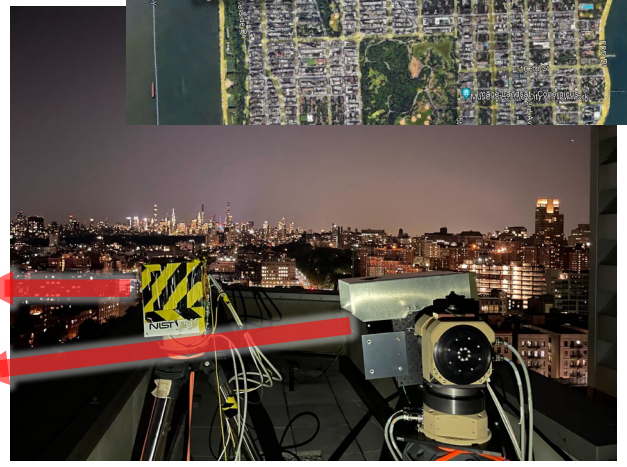
Sector-specific optimization of regional oil and gas (O&G) and agriculture CH_4 fluxes

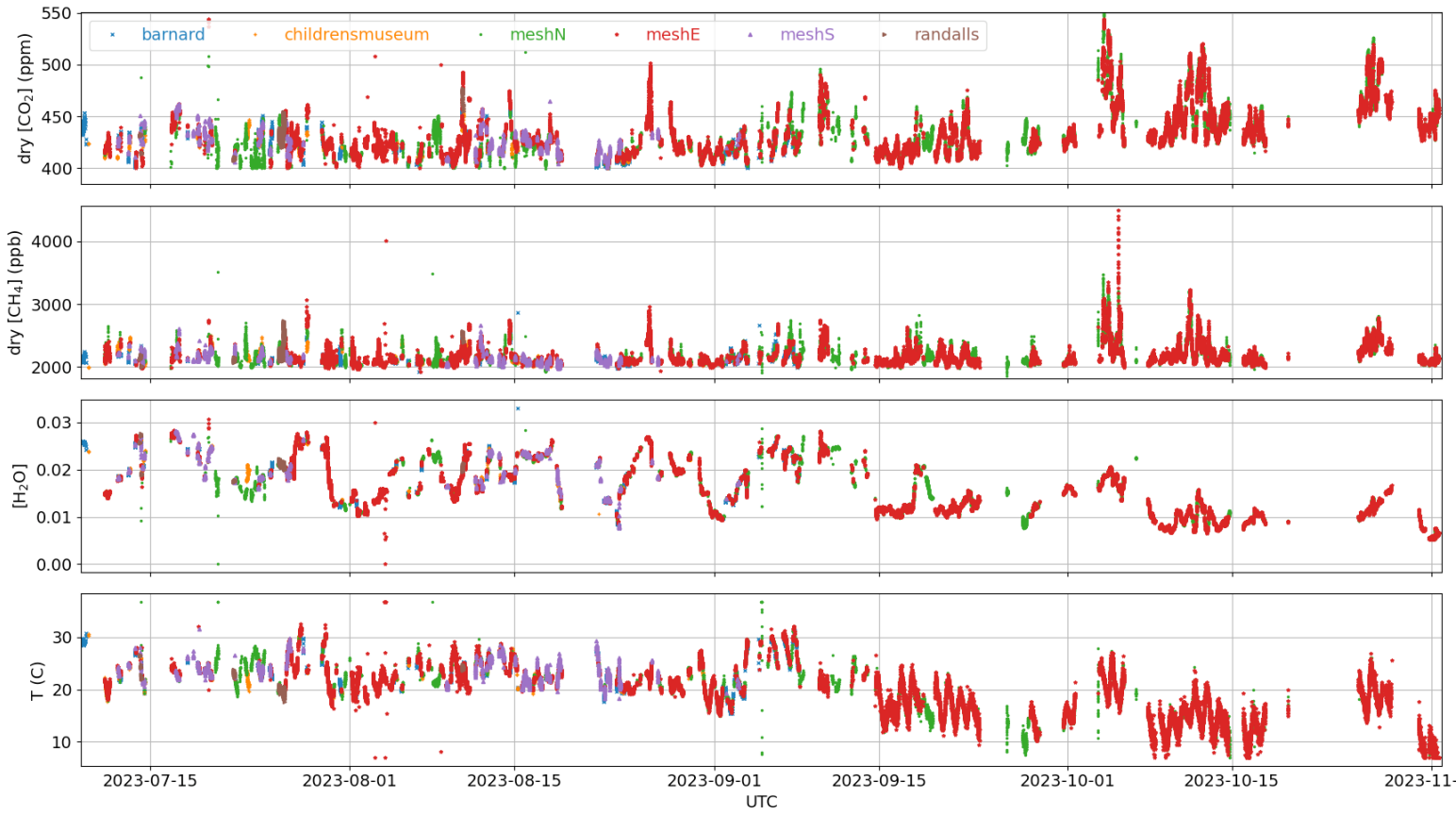
G. Mead, *et.al.*, Geophysical Research Letters, 51, e2023GL105973 (2024)

Regional measurement also possible in urban environments



- CH_4 and CO_2, minute time resolution
- Characterize urban emissions of GHGs and spatial-temporal variability: are plumes local or widespread?
- Compare point and open-path measurements
- Compare with airborne remote sensing





Summary

Future spectroscopy work includes

- Facility scale: Oil and Gas, Cattle emission mitigation studies (exploring opportunities for landfills and wastewater treatment)
- Regional scale: Urban monitoring and DJ basin monitoring using co-emitted species.
- Satellite calibration: Ongoing efforts to support databases, ongoing balloon trials, exploratory work in ground-truth measurements