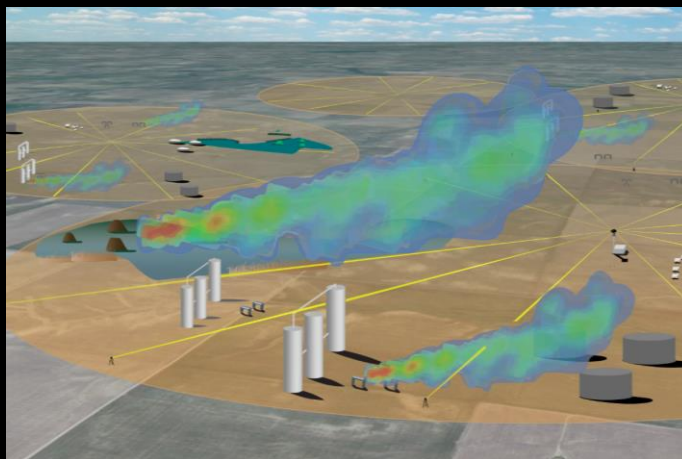
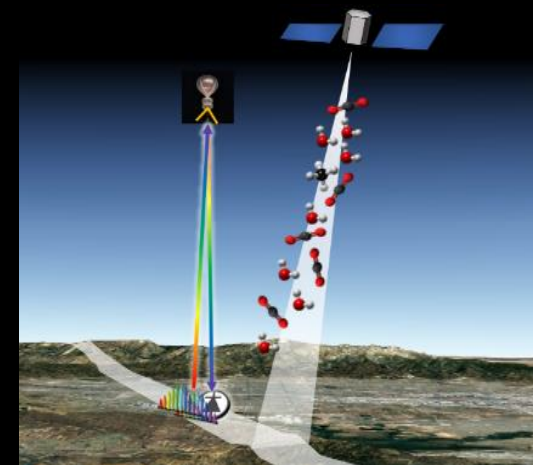


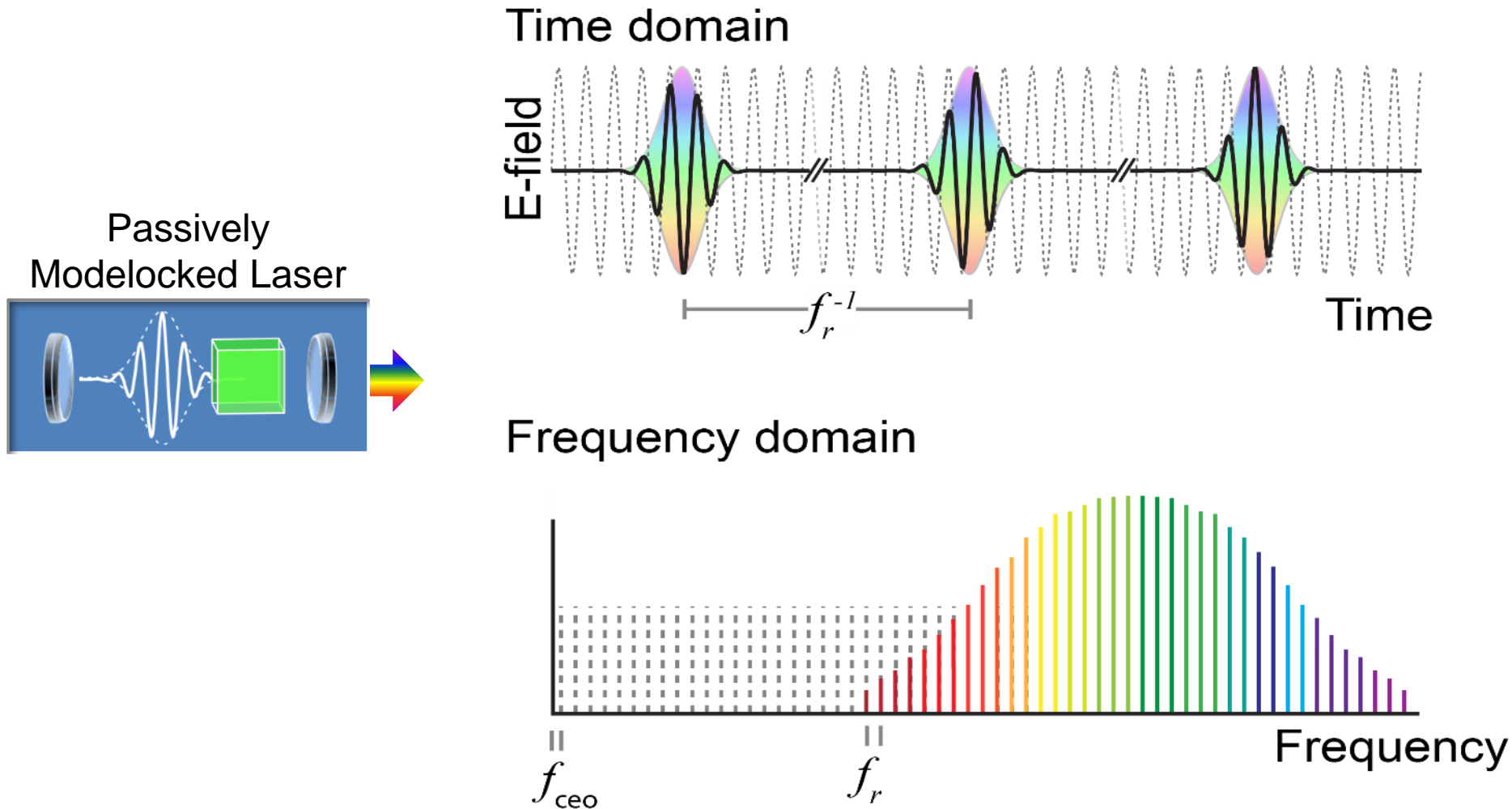
Local and regional MMRV of greenhouse gasses with frequency combs

Ian Coddington
6/7/2024

Esther Baumann, Kevin Cossel, Fabrizio Giorgetta,
Daniel Herman, James Kasic, Liang Chun Lin,
Griffin Mead, Nathan Malarich, Nathan Newbury,
Nathan Sweet, Brian Washburn



The frequency comb is a million lasers in one

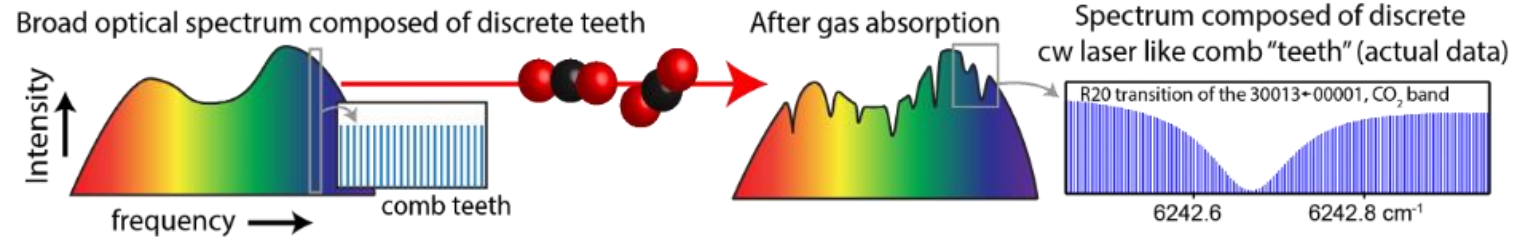


$$f_n = n f_{rep} + f_{ceo}$$

Frequency Combs are an important new tool for GHG monitoring

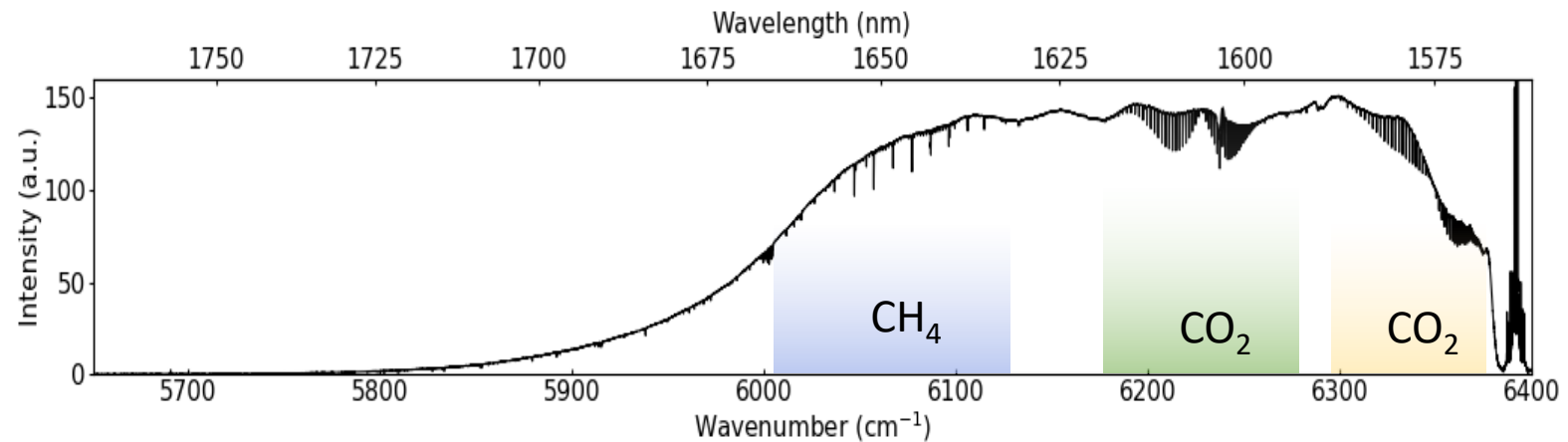
High precision concentration retrievals

- High frequency accuracy
- High resolution
- Negligible instrument lineshape



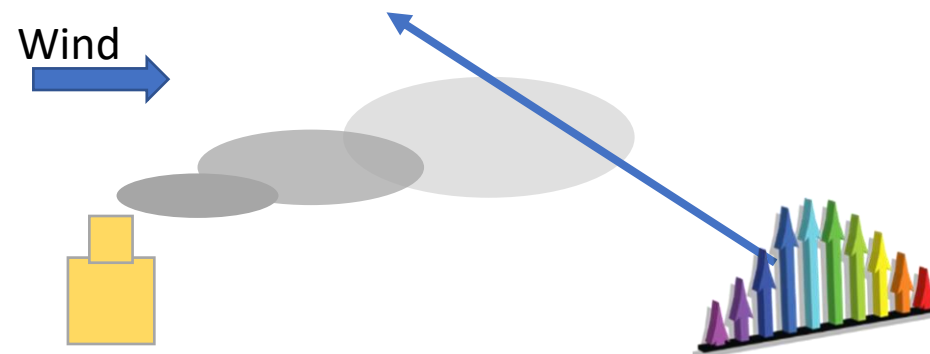
Broadband

- Multi species (CO₂, CH₄, N₂O, C₂H₆, NH₃, HCHO, HDO/H₂O)
- Path Temperature
- Low interference



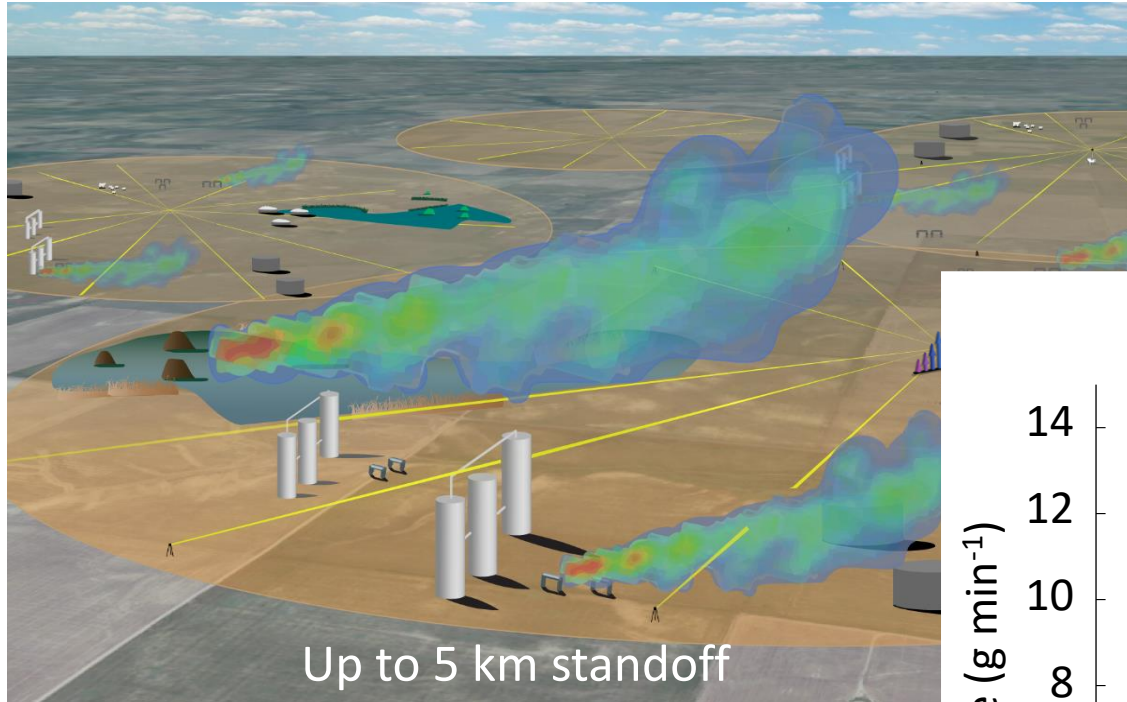
Long open-path measurements

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

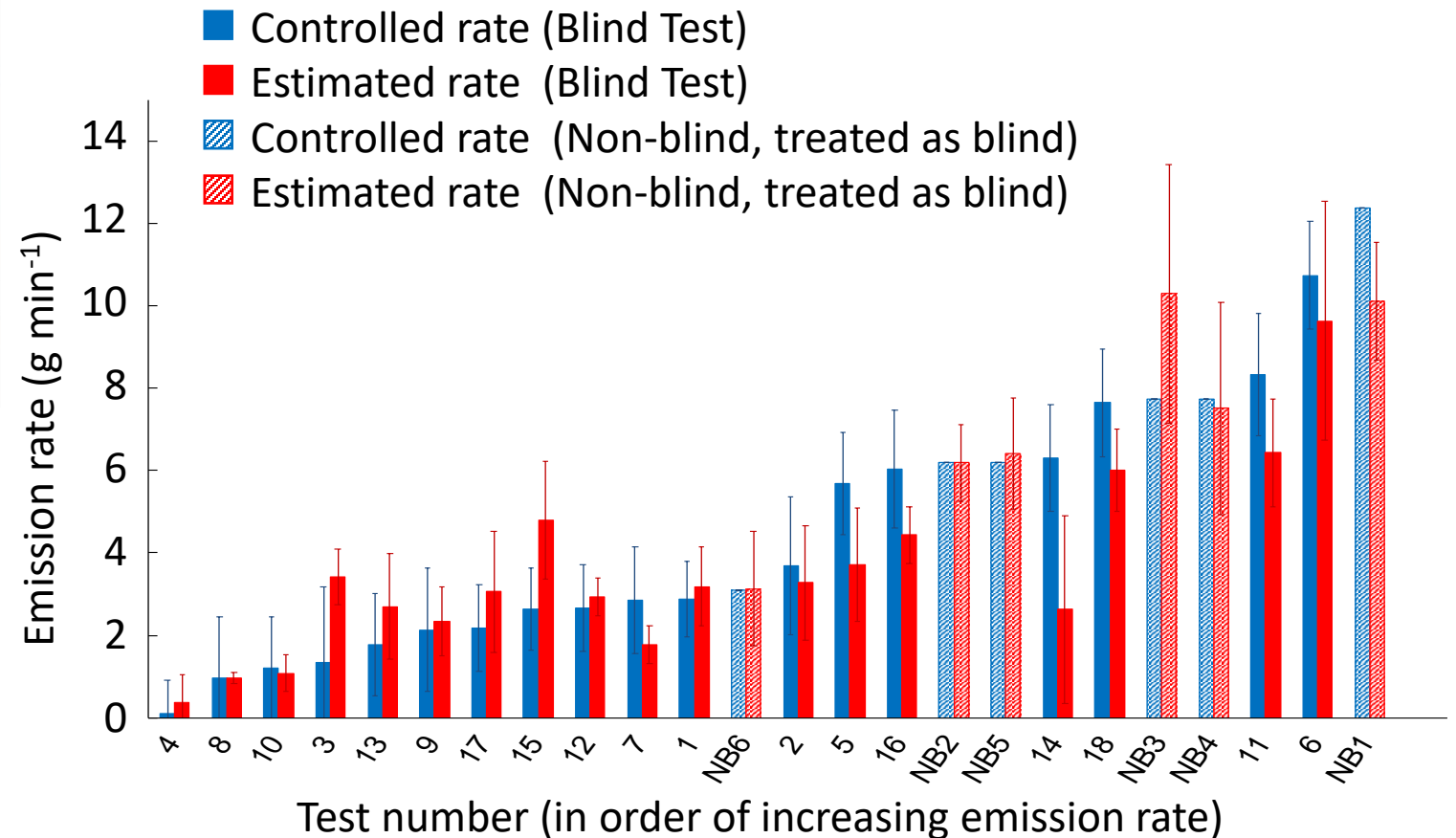


Comb technology is well suited to monitoring industrial releases

NIST



71% of emissions estimated to within 2 g/min



Successful commercial deployment



NIST



~350 facilities

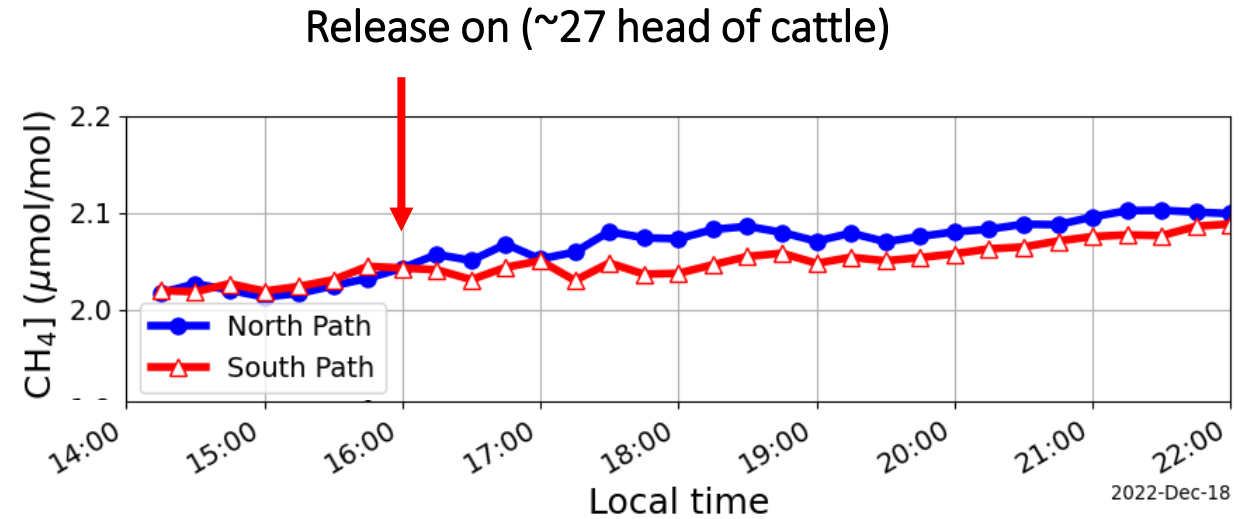
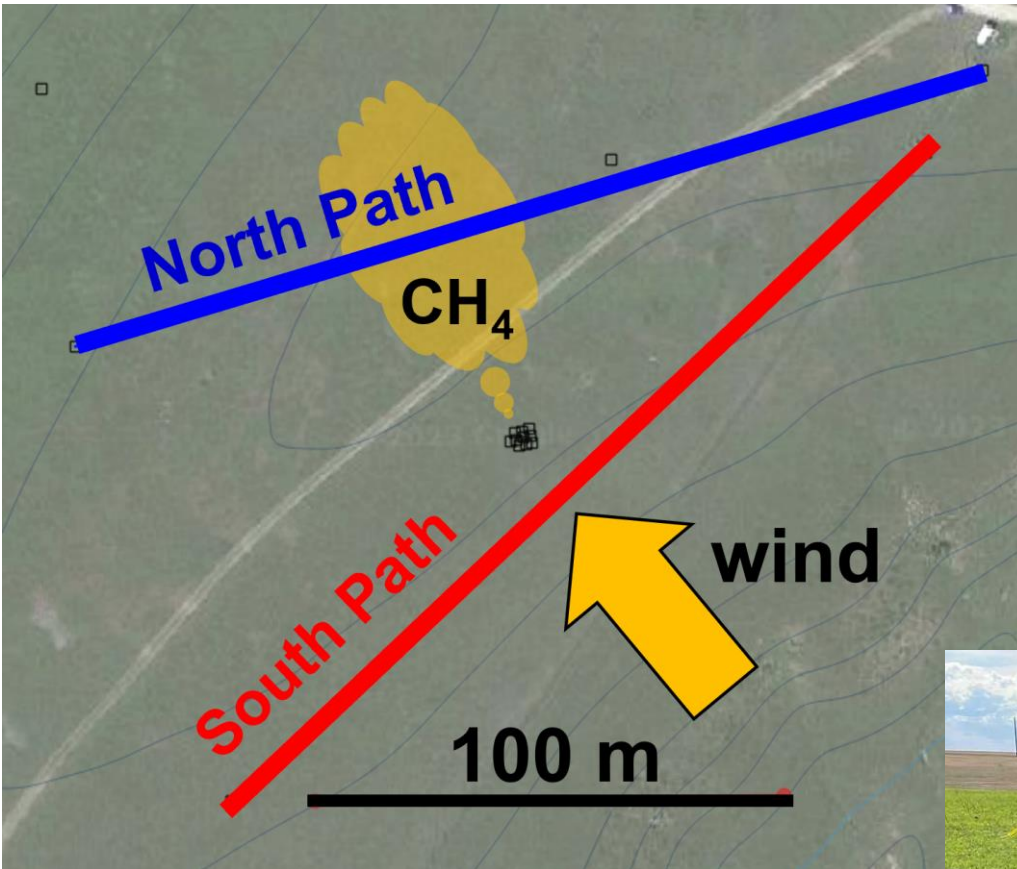
Colorado, Texas, New Mexico, Oklahoma,
Louisiana

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



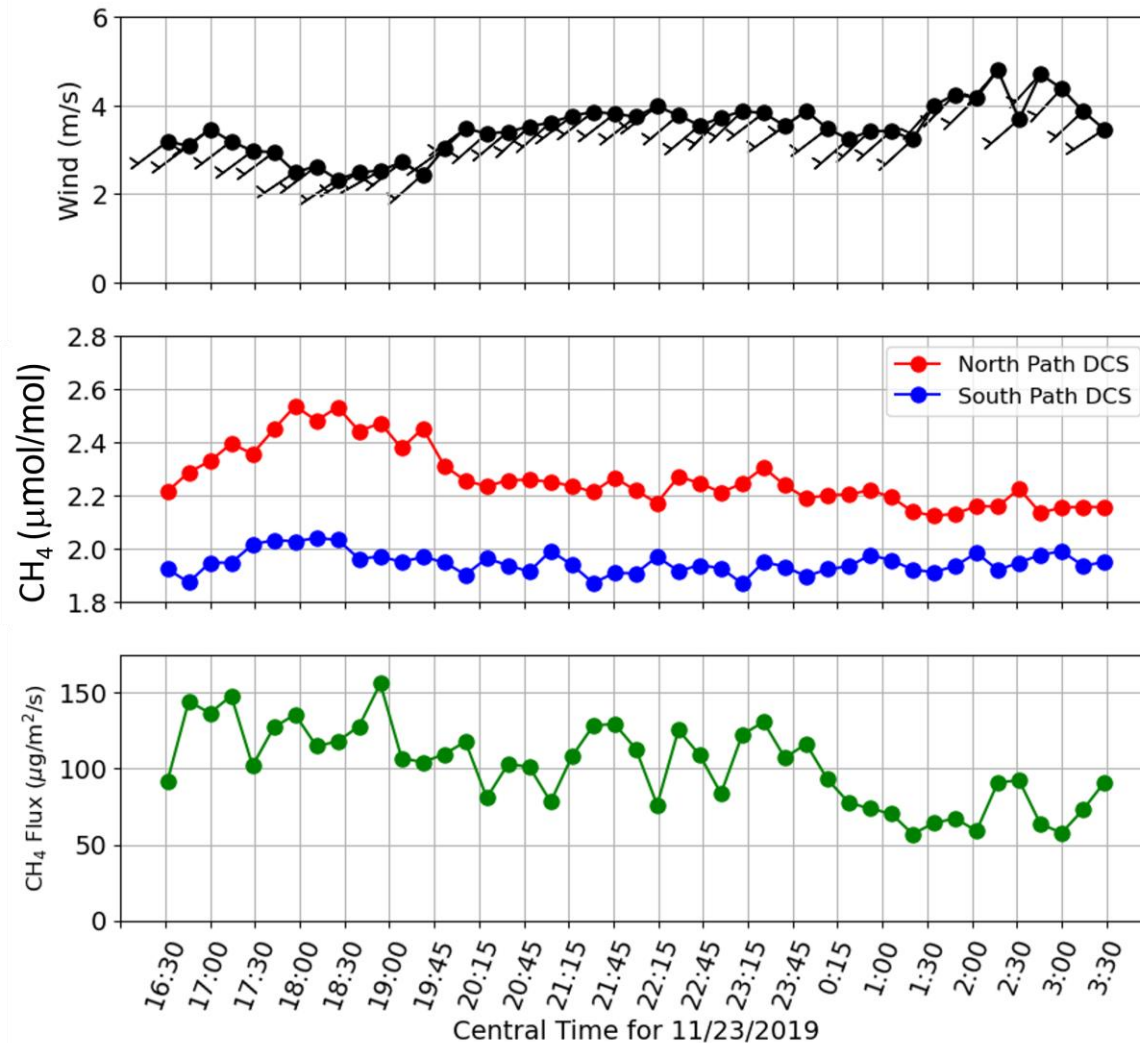
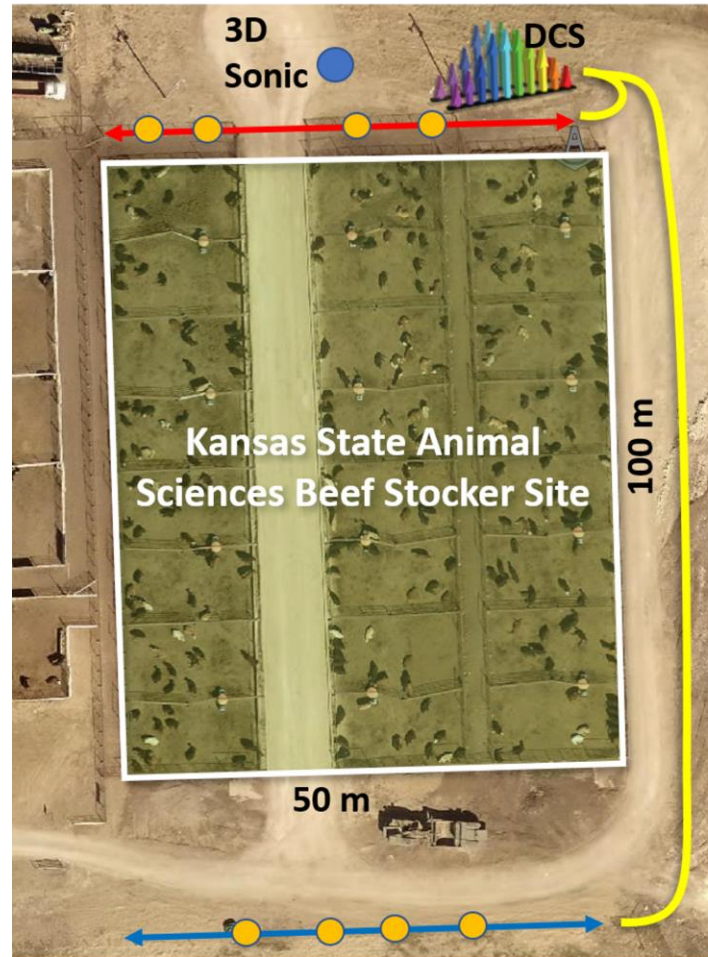
Frequency combs

Ultra low emissions can be quantified



Observing 4000g/day emissions

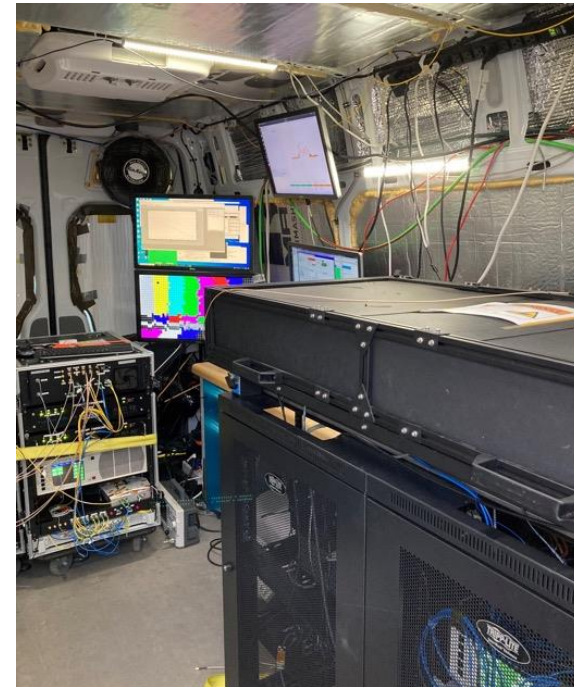
Feed testing in partnership with Kansas State



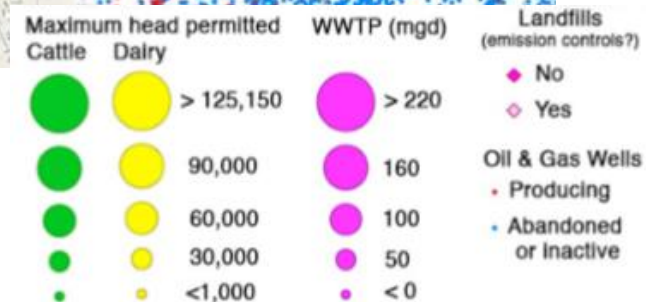
Actively testing the impact of feed on emissions

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

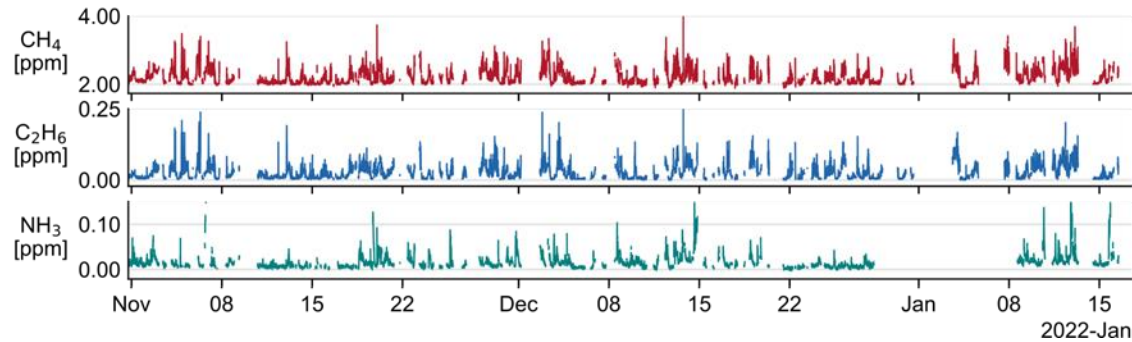
NLST



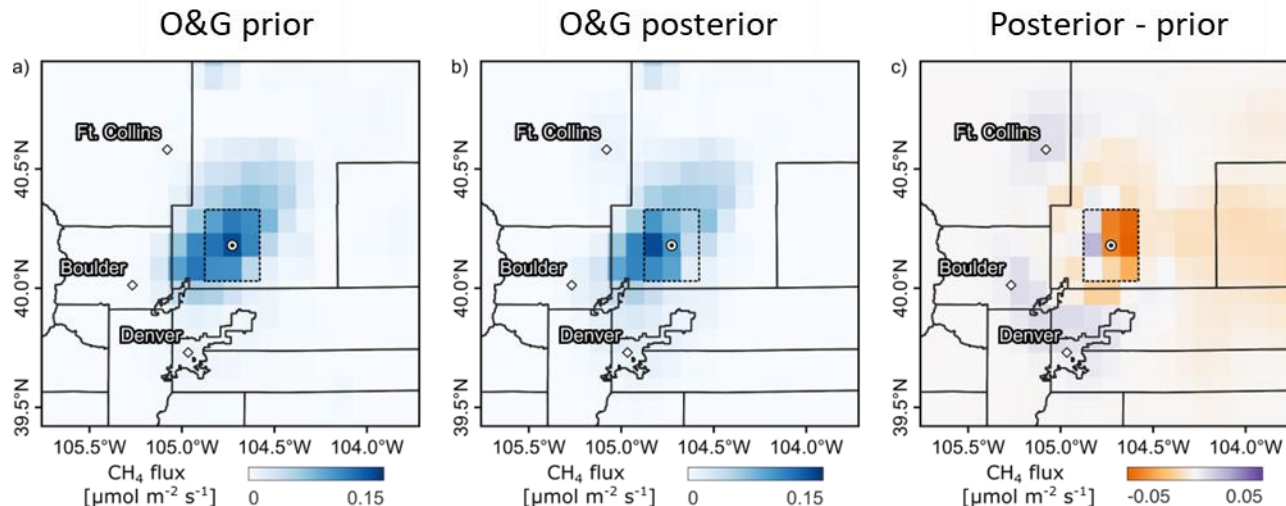
A map of Colorado showing sampling locations for the study. The map includes major cities like Boulder, Denver, and Platteville, and geographical features like Rocky Mountain National Park. Sampling locations are marked with colored dots (red, blue, green, yellow, purple) and circles of varying sizes. A blue arrow points from the text 'Platteville' to a specific sampling location.



Regional flux estimation and source sector assignment possible over an 800 km² region

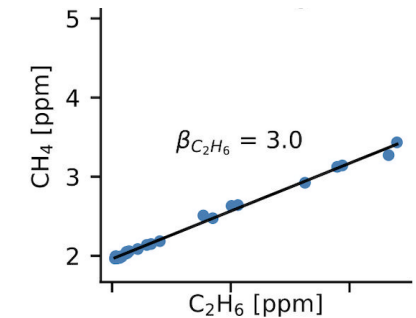


Multi-month time series of CH₄, C₂H₆ and NH₃

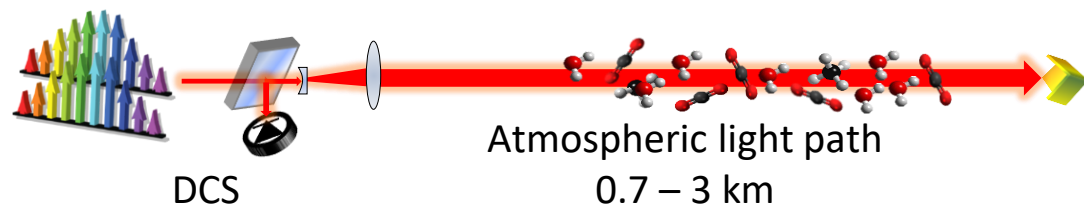


Sector-specific optimization of regional oil and gas (O&G) and agriculture CH₄ fluxes

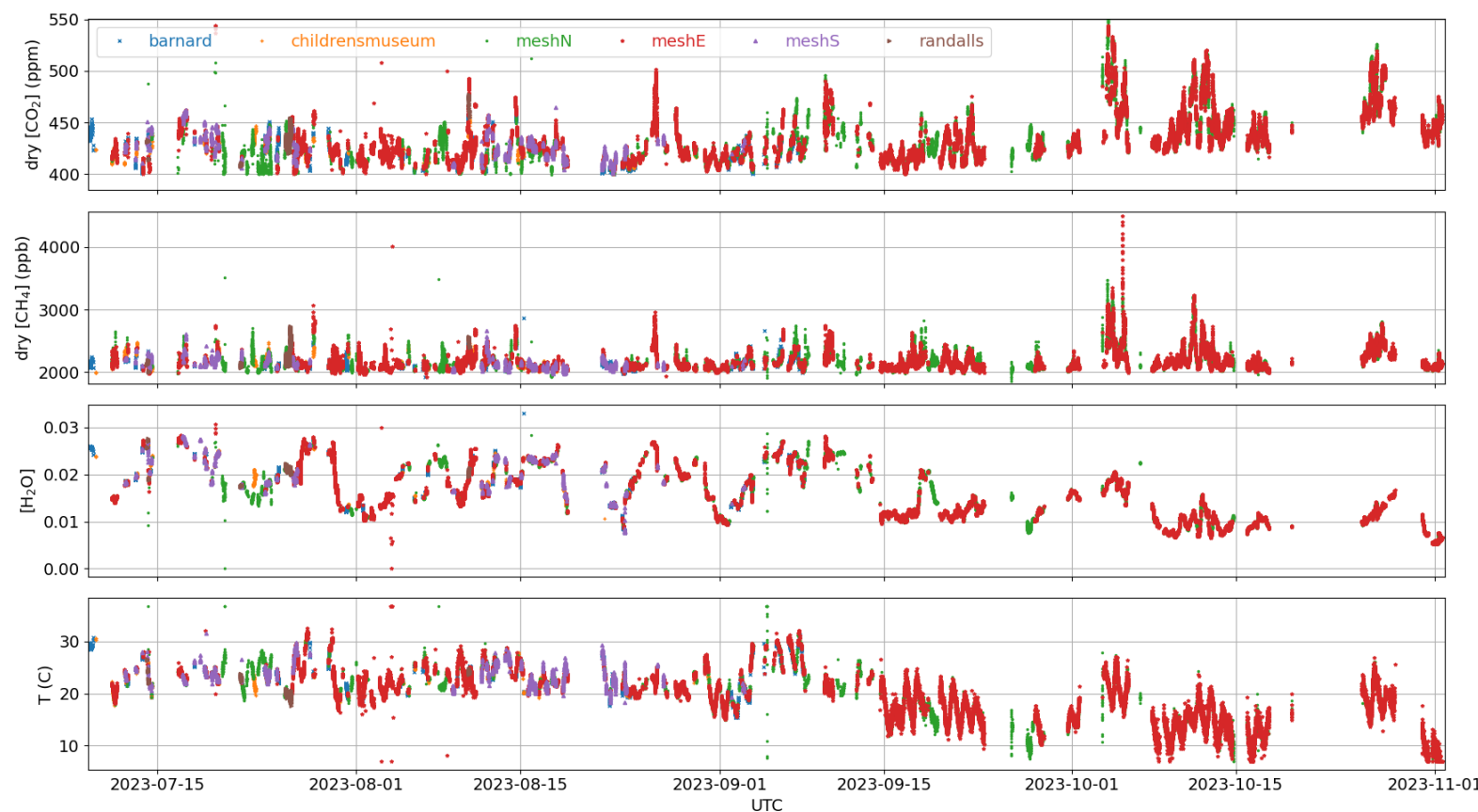
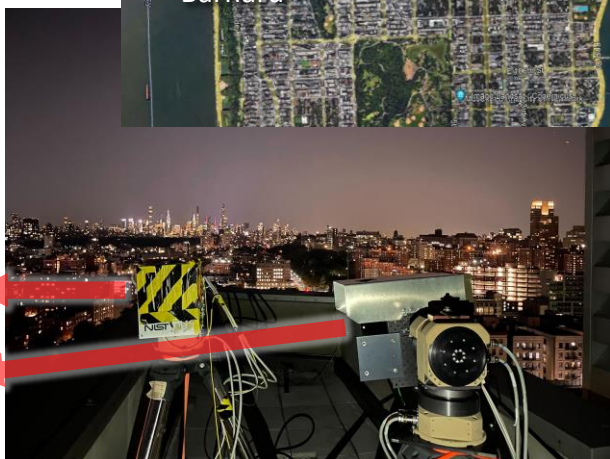
Sector apportion methane using tracer gas correlations



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



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

