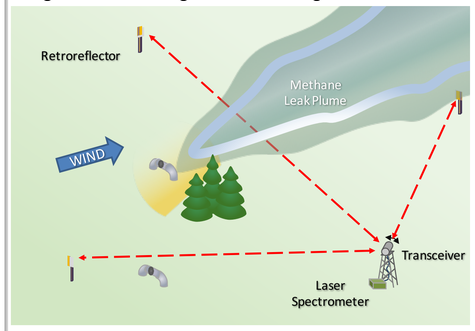
Continuous Monitoring of Pollutant Emissions at Site- to Regional- Scales

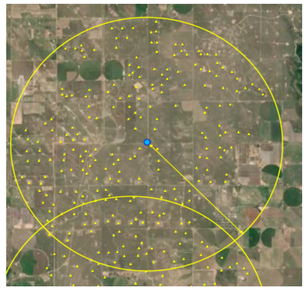
University of Colorado Boulder

Overview

Approach:

Regional monitoring service covering Oil & Gas infrastructure in 5-30 square mile regions



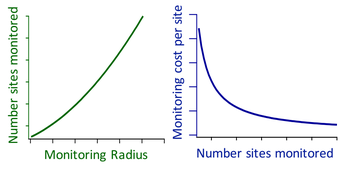


Monitor 100s of sites from a central location. Customers pay an annual fee for monitoring.

Leak Detection and Sizing

- To date, ability to find up to 2 leaks
- Ability to approximate source strength
- Coverage of areas up to 2km x 2km
- Future regulatory reporting service

Per site monitoring costs well below ARPA-E cost targets ($3000/site/year)



Technology Impact

Capable of meeting MONITOR goals, with enhanced functionality

- Multispecies sensing: CH_4, $^{13}CH_4$, H_2O, propane, ethane
  - Reports dry CH_4, immune to variable H_2O dilution
  - Methane selectivity
  - Potential for thermogenic/biogenic differentiation
- High sensitivity
  - Capable of sensing leaks downwind, from a distance
- Drift-free intrinsic calibration
  - Absorption model serves as 'calibration' for all instruments
- Extremely low long-term instrument drift
  - Concentrations can be compared over time and among instruments

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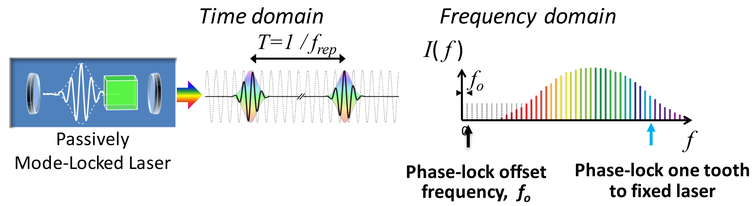
Tech-to-Market: Ted Weaver, Marta Zgagacz

Dual Comb Spectroscopy (DCS)

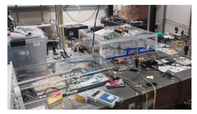
Frequency Comb: a stabilized mode-locked laser

Output acts as **>100,000 well behaved CW lasers**



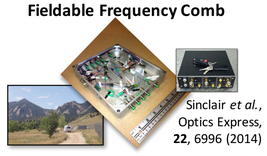
Frequency Comb lasers are ready to move out of the laboratory:

Proof-of-Concept Dual Comb Spectrometer



- Sensitive mode-locking
- Stabilized optical table
- >$500,000

Fieldable Frequency Comb



Sinclair *et al.*, Optics Express, **22**, 6996 (2014)

- 0.7 liter package
- Simple reproducible design
- FPGA control electronics
- Low cost

Our Combs

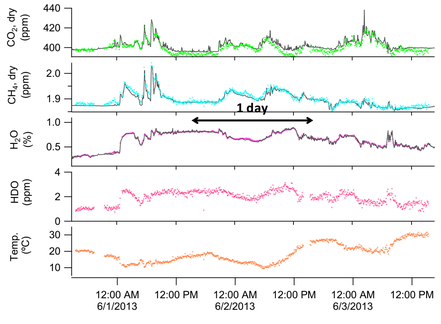
- Portable DCS
- 10x cost reduction
- Ruggedized for field

Proof-of-Concept: Open path measurements

Rieker *et al.*, Optica, **1**, 290 (2014)

Results

- Excellent overall tracking between frequency comb and tower sensor measurement across multiple days
- Deviations likely represent real differences between 2km path and point sample
- 0.2% absolute CH_4 accuracy against WMO-calibrated sensor during well-mixed conditions



CH_4 Inversions for leak detection

Synthetic Data Testing:

Model-data-mismatch (R):

- Measurement Uncertainty: 4 ppm-m
- Transport Uncertainty: plume vs. LES

Transport Model:

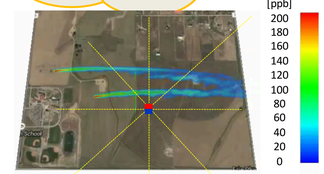
- Gaussian plume
- Large Eddy Simulation (LES)
- Particle dispersion modeling

Background CH_4:

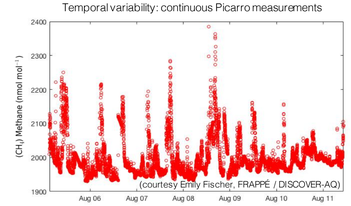
- "far-field" affects whole domain
  - Key: temporal variability
  - Estimated from in situ continuous msmts made at BAO in 2014
- "near-field" heterogeneous across domain
  - Key: spatial variability
  - Estimated by simulating leaks at nearby wells outside domain

4 ppm-m = 2 ppb over 1 km folded path

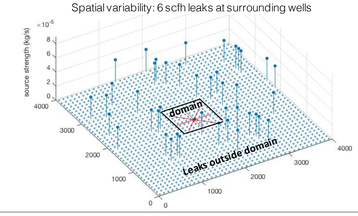
This is conservative! New data suggests precision of ~0.7 ppb on 1 km folded beam path in 100 seconds



Temporal variability: continuous Picarro measurements

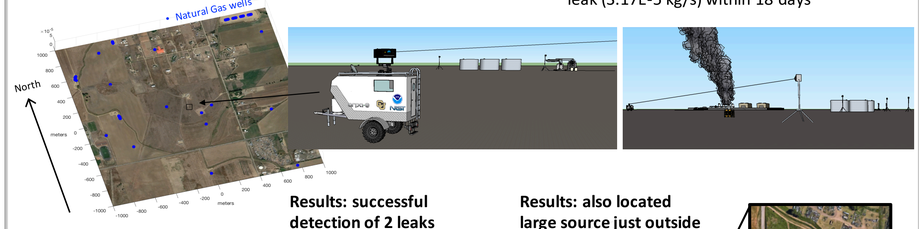


Spatial variability: 6 scfh leaks at surrounding wells

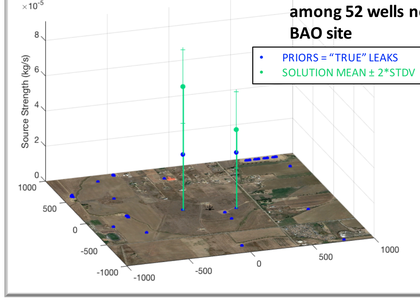


BAO Site & Synthetic Inversion Results

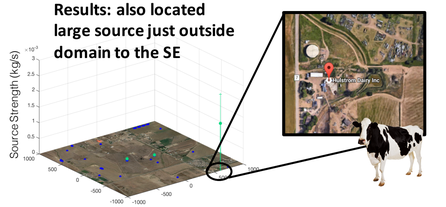
MONITOR Program Goal: detect 6 scfh leak (3.17E-5 kg/s) within 18 days



Results: successful detection of 2 leaks among 52 wells near BAO site



Results: also located large source just outside domain to the SE



- Leak strength of 1.5E-3 kg/s
- Divided by 3.9E-6 kg/s per cow (McGinn and Beauchemin, 2012)
- Estimated 390 ± 120 head cattle at Hulstrom

Good example of near-field source we can anticipate & account for using perimeter monitoring approach!