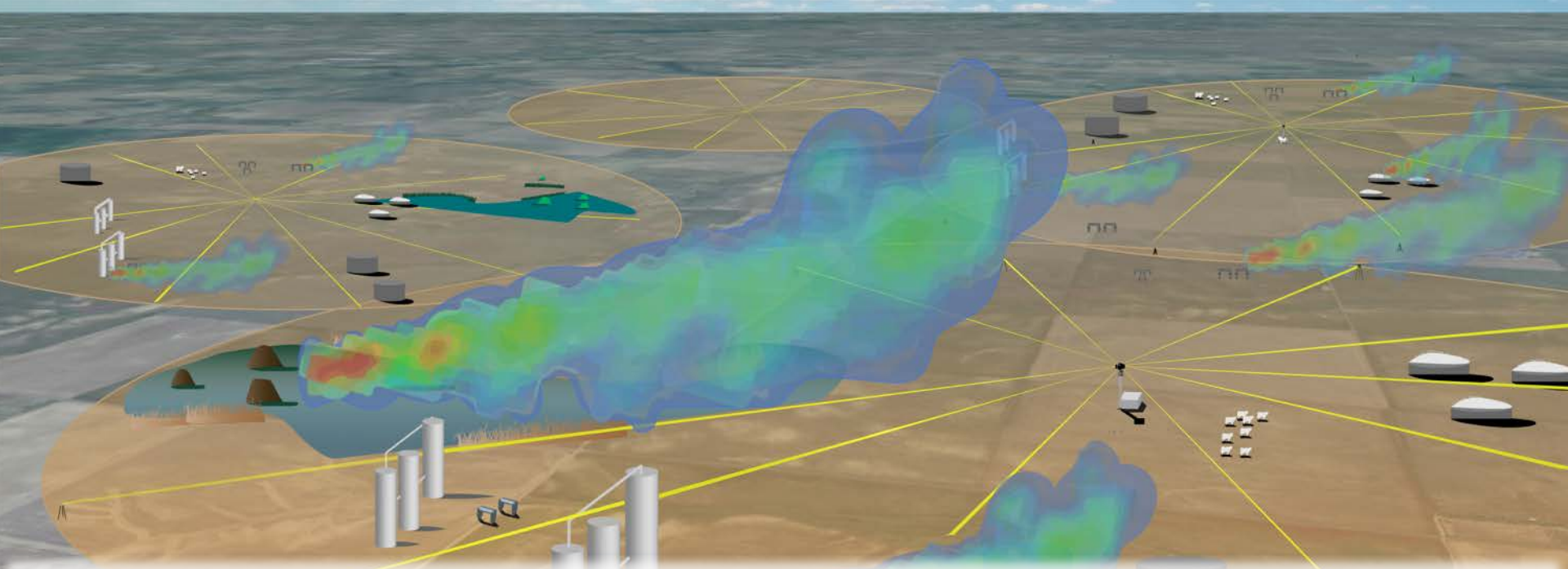


Single-blind testing of a regional, continuous monitoring system for finding methane leaks from oil and gas operations



Caroline Alden^{1,2}, Sean Coburn², Robert Wright², Esther Baumann³, Kevin Cossel³, Colm Sweeney⁴, Anna Karion³, Alex Rybchuk², Kuldeep Prasad³, Ian Coddington³, Gregory Rieker²

¹Cooperative Institute for Research in Environmental Sciences, ²University of Colorado, ³National Institute of Standards and Technology, ⁴National Oceanic and Atmospheric Administration



Precision Laser Diagnostics
for Energy and the Environment



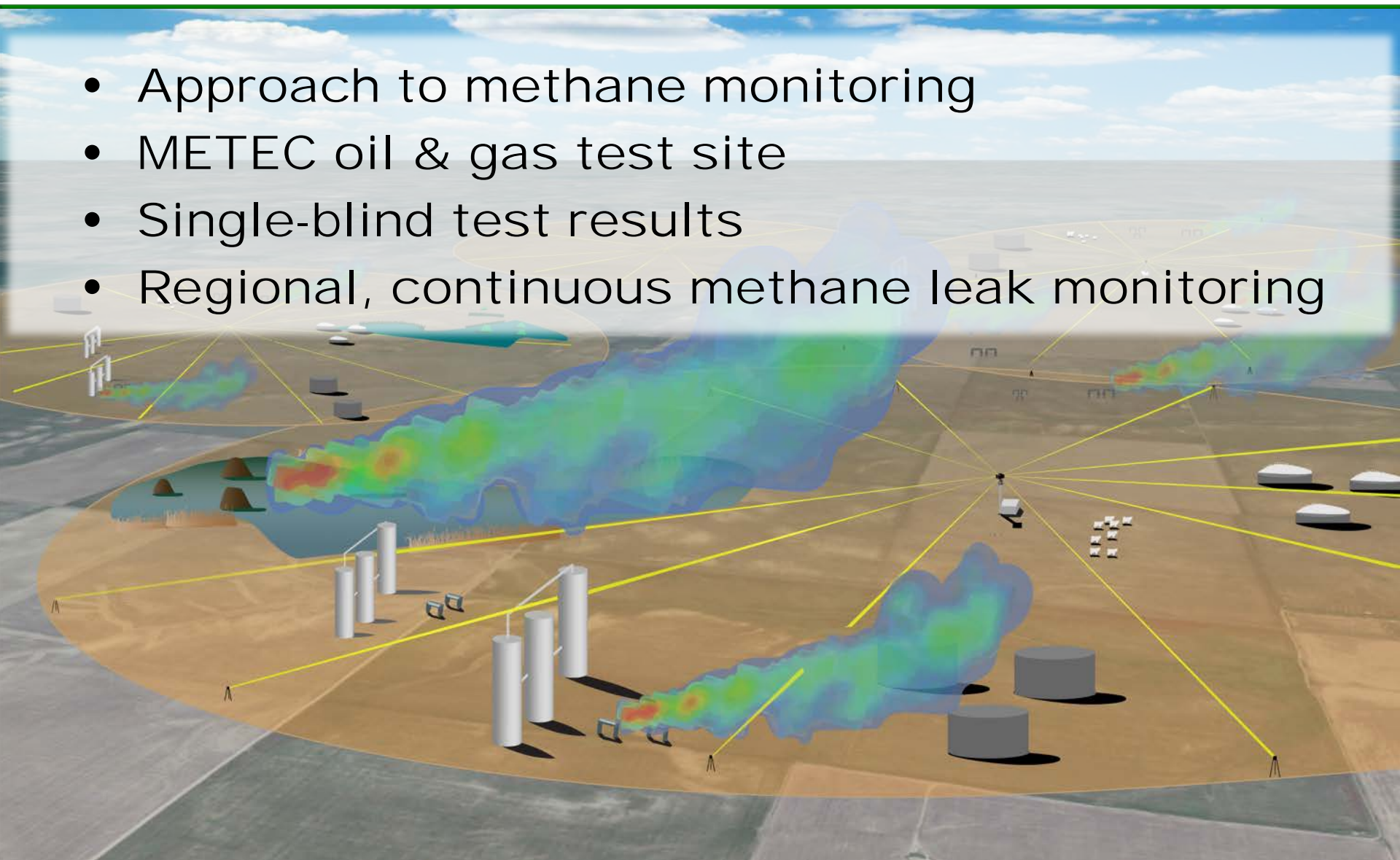
NIST



University of Colorado
Boulder

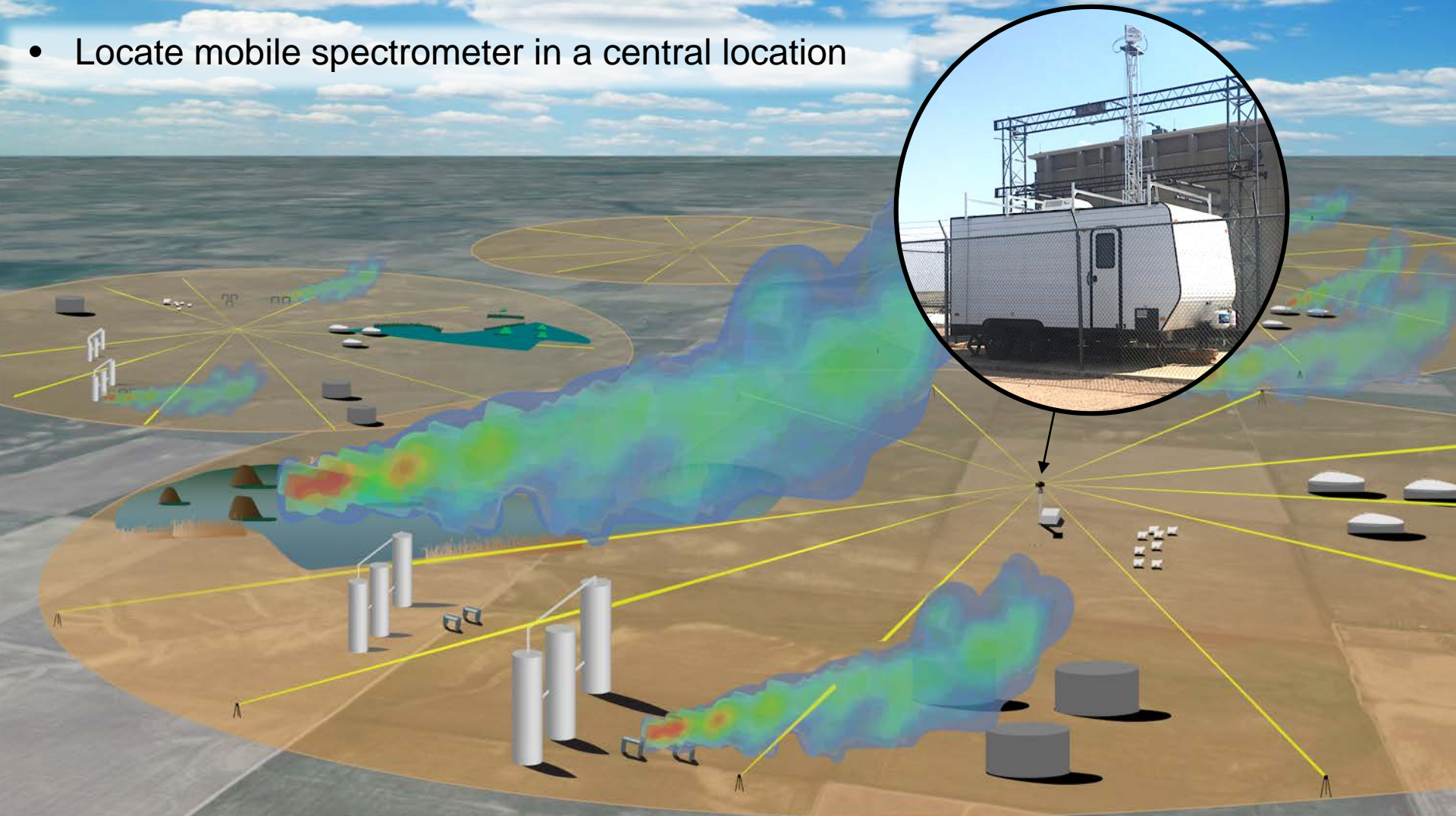
Outline

- Approach to methane monitoring
- METEC oil & gas test site
- Single-blind test results
- Regional, continuous methane leak monitoring



Approach to methane leak detection

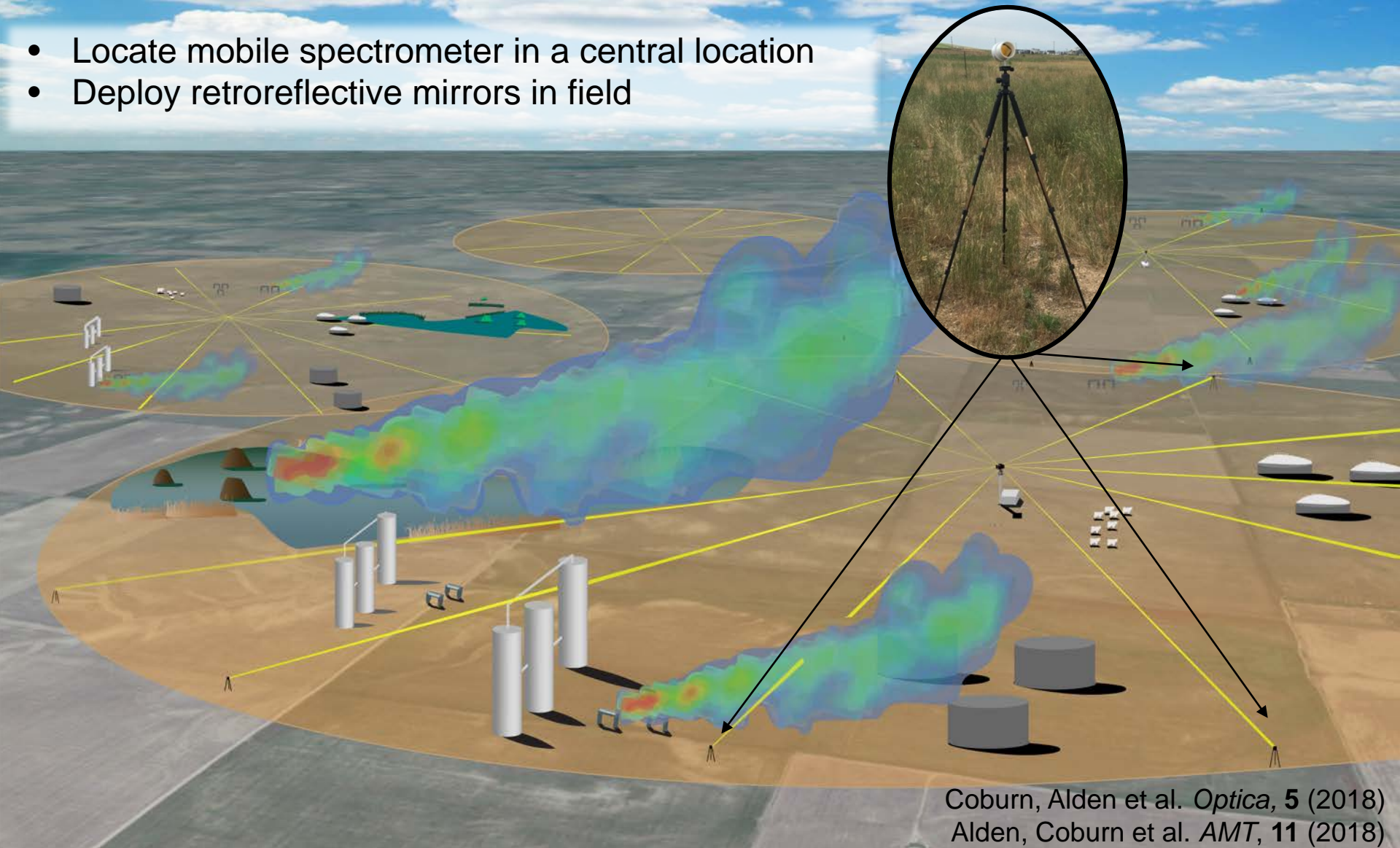
- Locate mobile spectrometer in a central location



Coburn, Alden et al. *Optica*, **5** (2018)
Alden, Coburn et al. *AMT*, **11** (2018)

Approach to methane leak detection

- Locate mobile spectrometer in a central location
- Deploy retroreflective mirrors in field

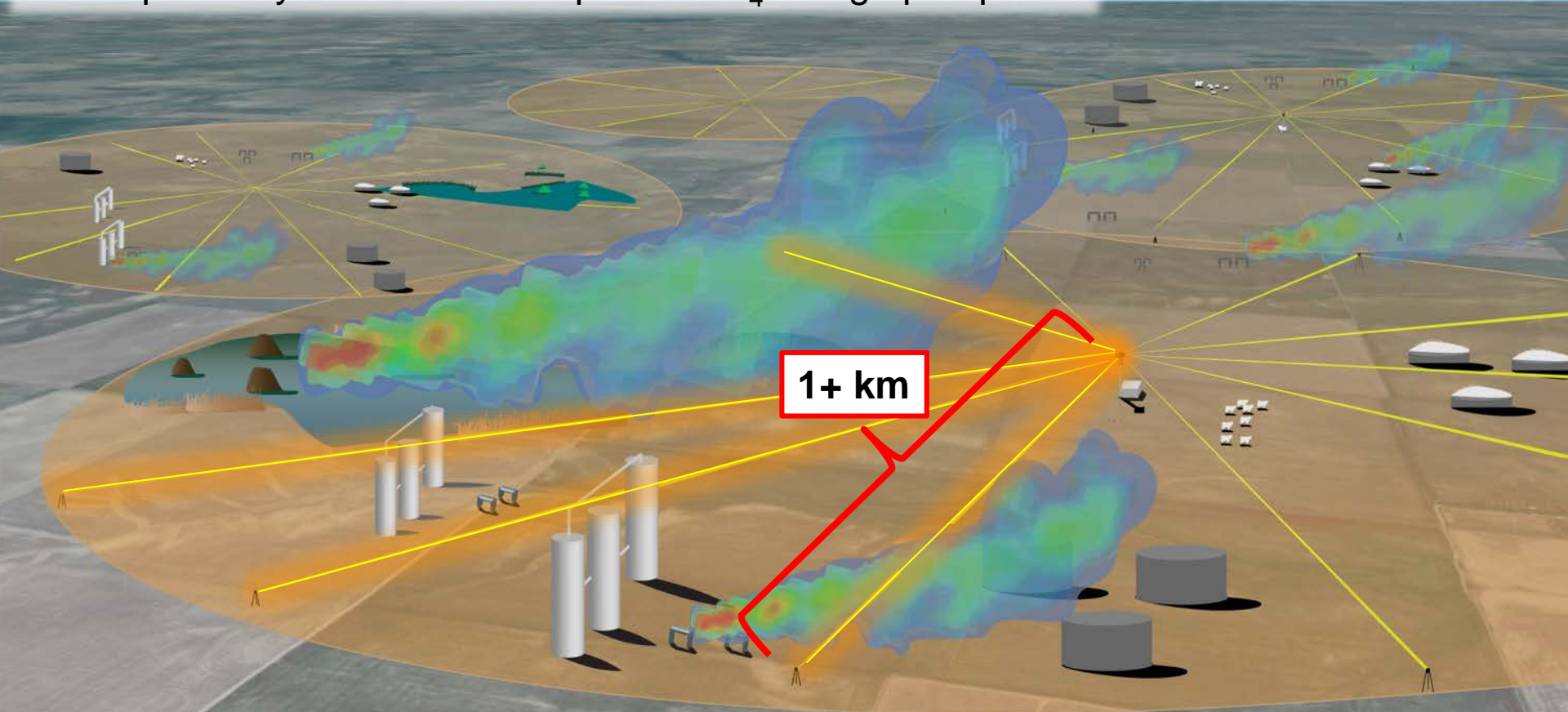


Coburn, Alden et al. *Optica*, **5** (2018)
Alden, Coburn et al. *AMT*, **11** (2018)



Approach to methane leak detection

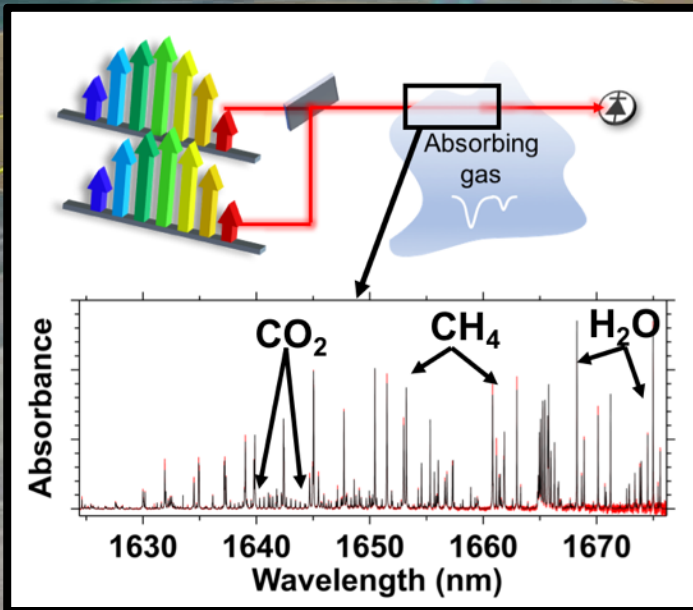
- Locate mobile spectrometer in a central location
- Deploy retroreflective mirrors in field
- Sequentially measure atmospheric CH_4 along open paths



Coburn, Alden et al. *Optica*, **5** (2018)
Alden, Coburn et al. *AMT*, **11** (2018)

Approach to methane leak detection

- Locate mobile spectrometer in a central location
- Deploy retroreflective mirrors in field
- Sequentially measure atmospheric CH_4 along open paths
- Determine species concentration

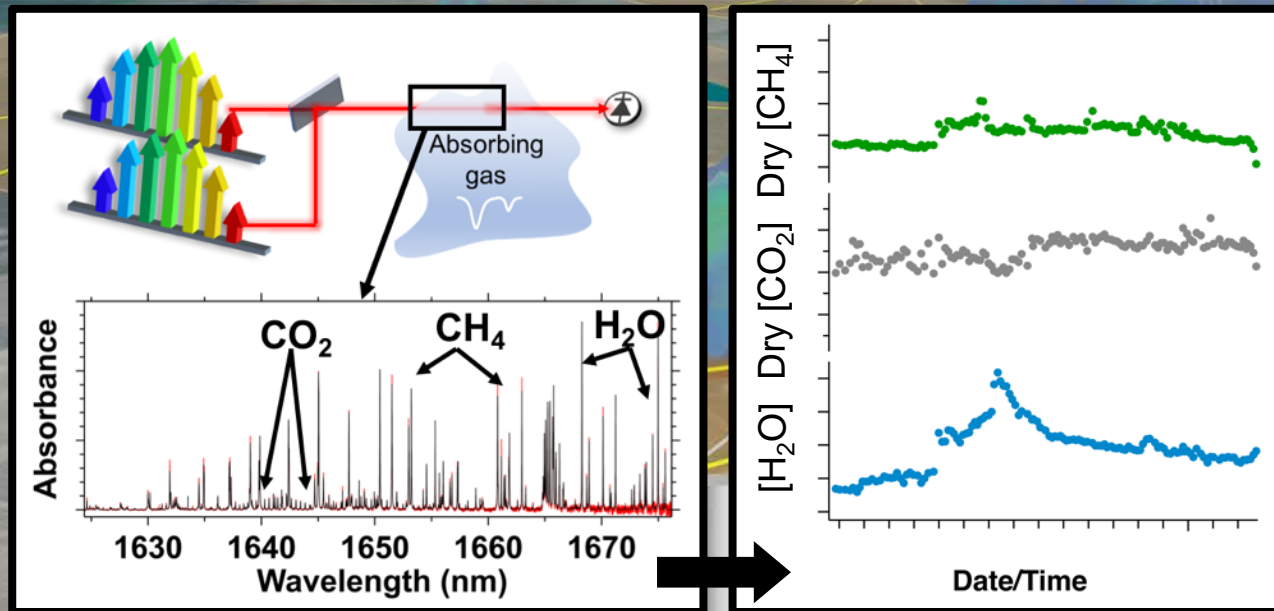


- < 5 ppb CH_4 precision over 1+ km paths in 2 mins
- Handles multi-species absorption interference
- Water measured directly \rightarrow dry-air mole fractions
- High stability over time, little to no instrument drift

Coburn, Alden et al. *Optica*, **5** (2018)
Alden, Coburn et al. *AMT*, **11** (2018)

Approach to methane leak detection

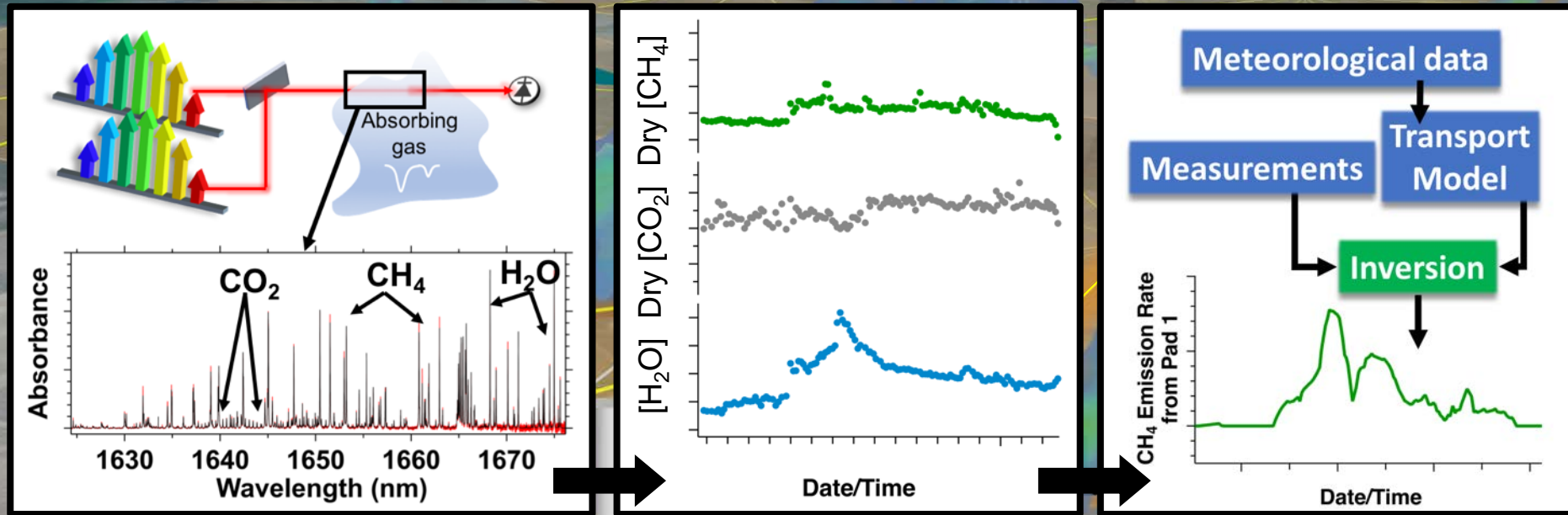
- Locate mobile spectrometer in a central location
- Deploy retroreflective mirrors in field
- Sequentially measure atmospheric CH_4 along open paths
- Determine species concentration, track variability through time



Coburn, Alden et al. *Optica*, **5** (2018)
Alden, Coburn et al. *AMT*, **11** (2018)

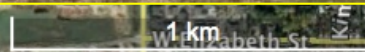
Approach to methane leak detection

- Locate mobile spectrometer in a central location
- Deploy retroreflective mirrors in field
- Sequentially measure atmospheric CH_4 along open paths
- Determine species concentration, track variability through time, couple with atmospheric modeling and inversions



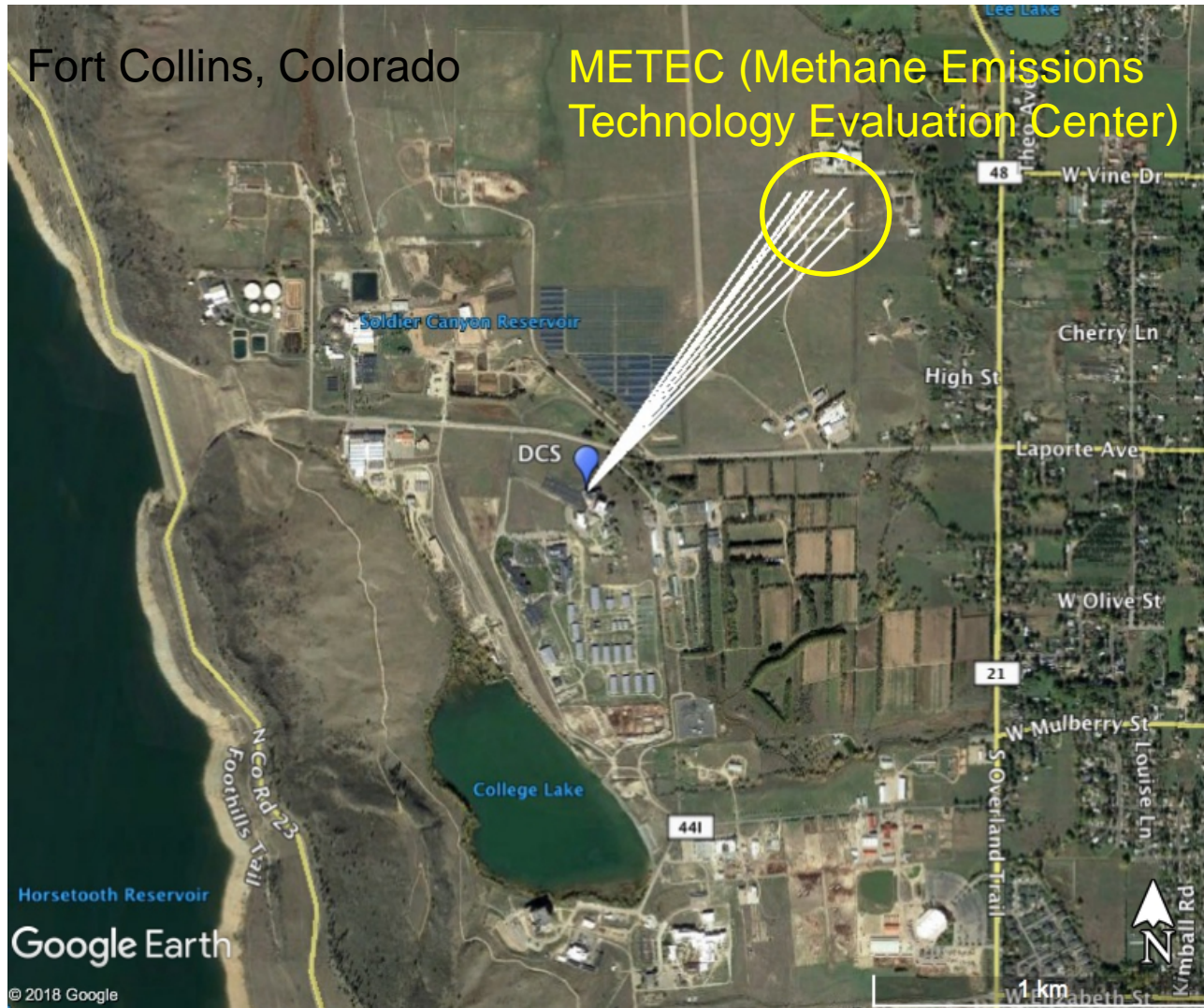
Coburn, Alden et al. *Optica*, **5** (2018)
Alden, Coburn et al. *AMT*, **11** (2018)

METEC oil & gas test site



Alden, Coburn et al., *In Prep*

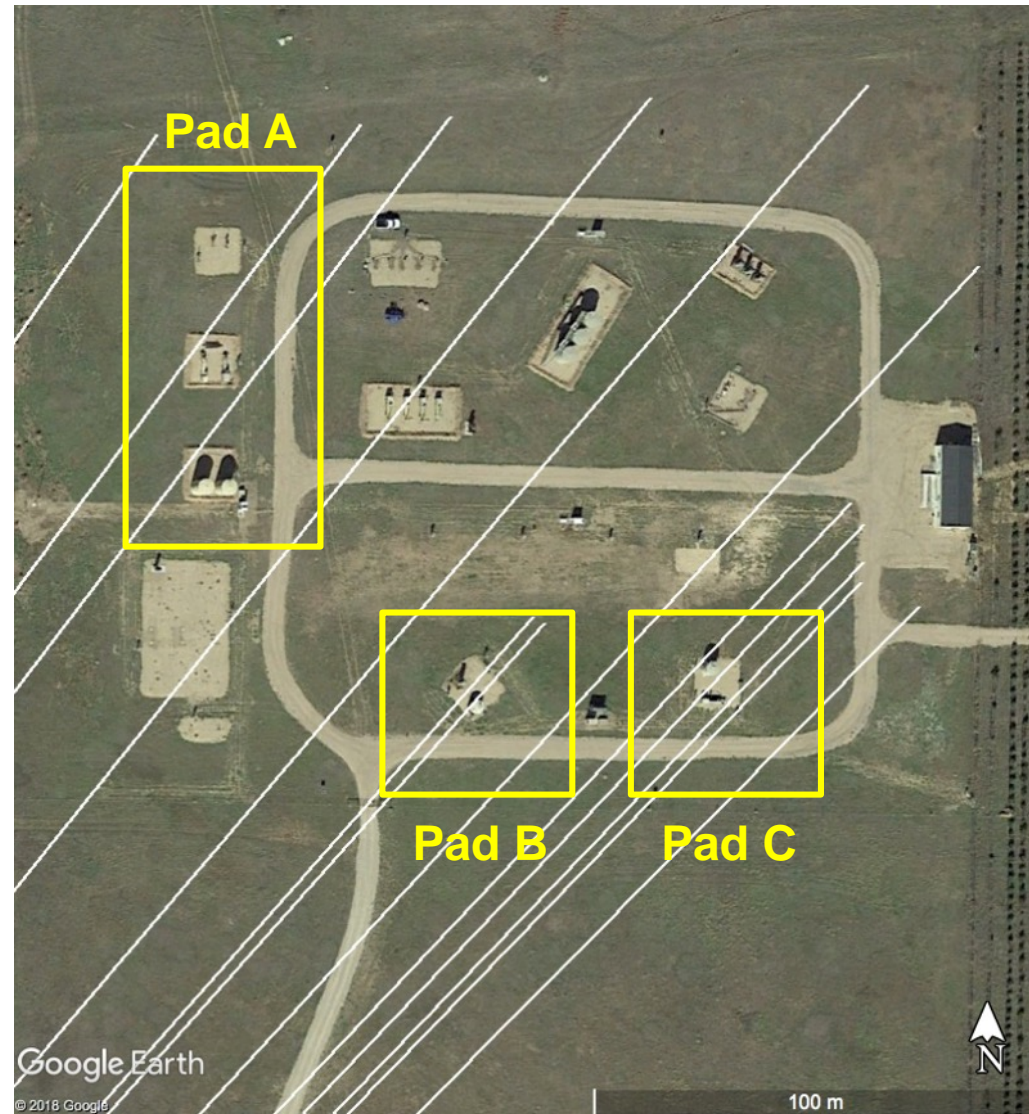
METEC oil & gas test site



Spectrometer located
>1 km away to the SW

Alden, Coburn et al., *In Prep*

METEC oil & gas test site



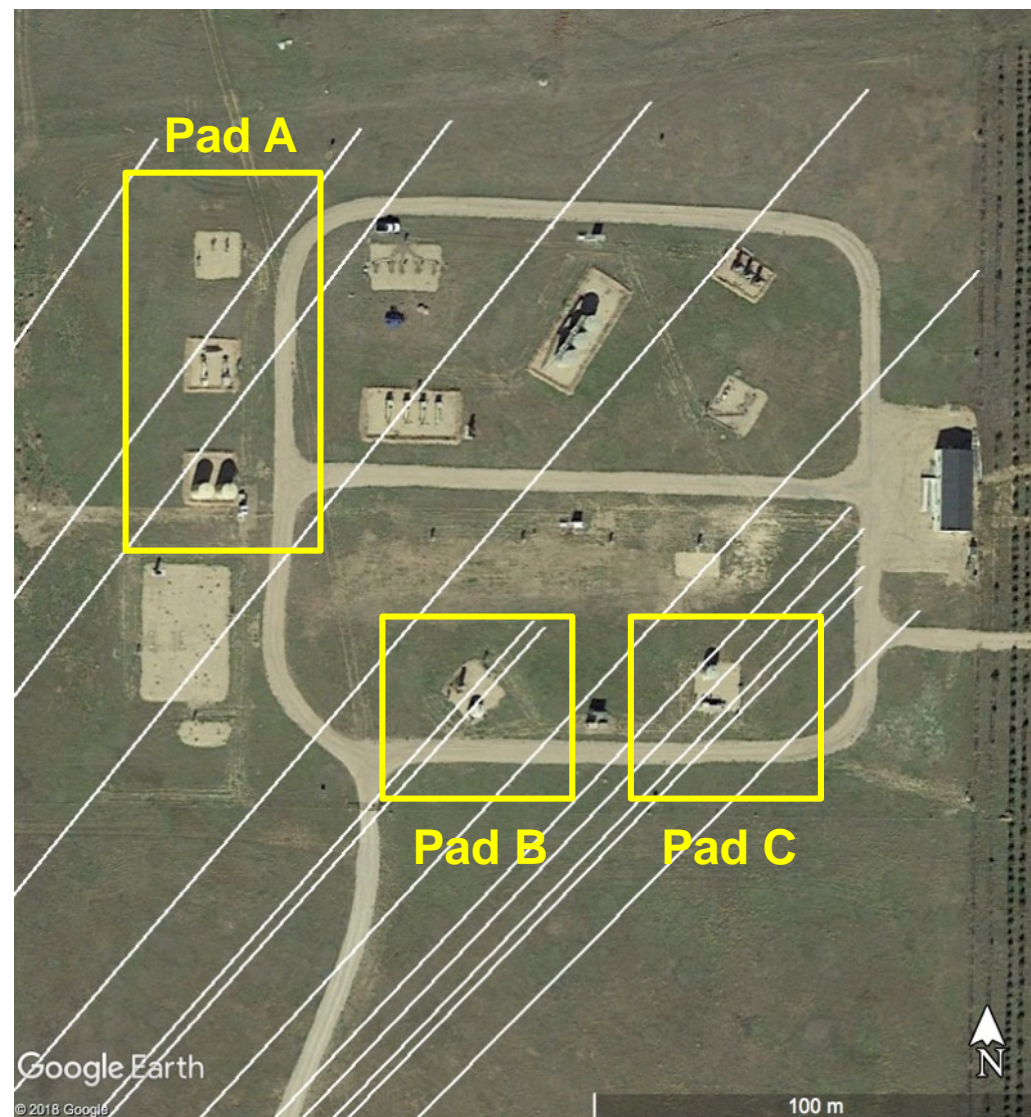
Detection: is there a leak?

Attribution: where is the leak?

Quantification: how big is the leak?

Alden, Coburn et al., *In Prep*

Single-blind test results: **Detection**



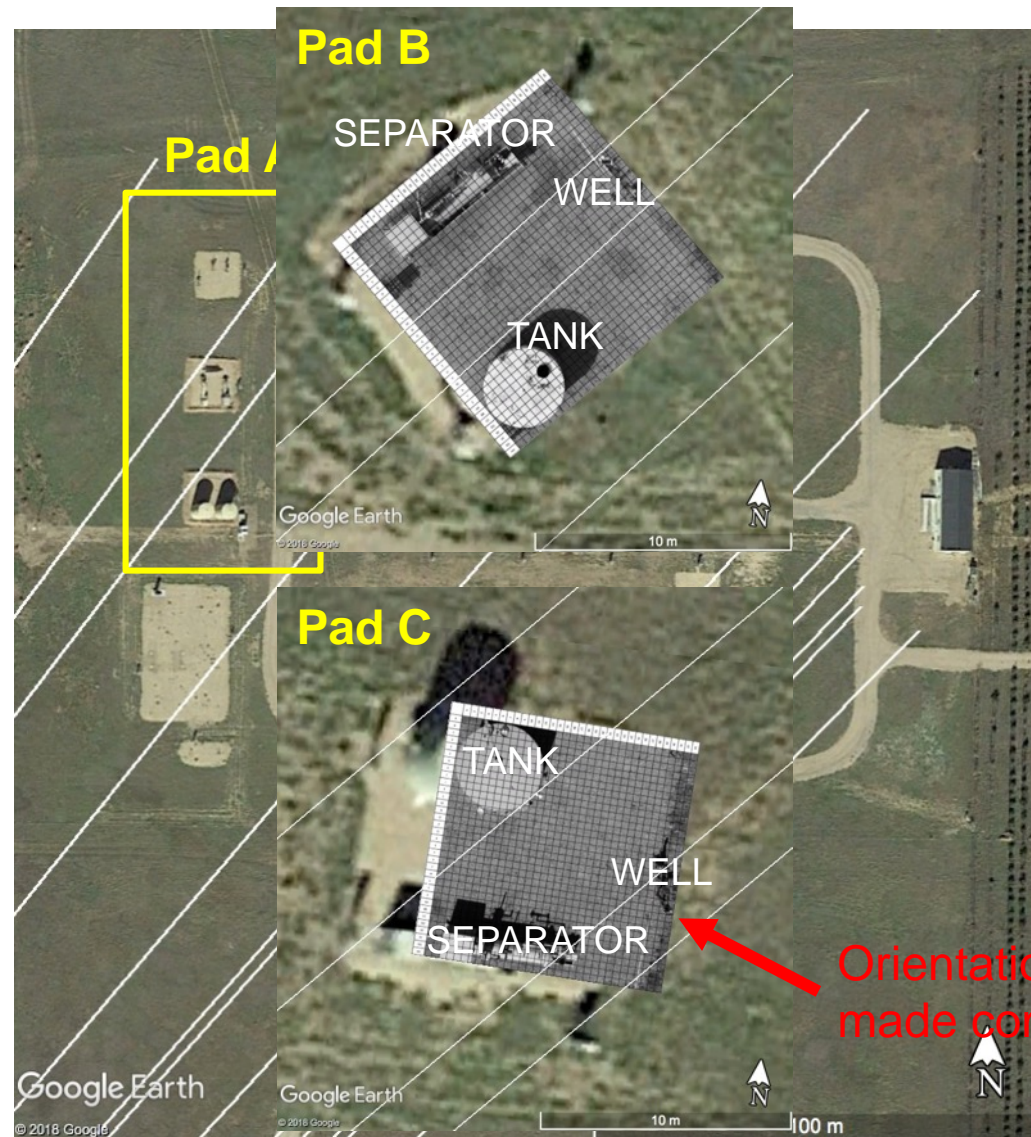
Pad A:
6/6 leaks detected at pad A ✓

Pad B:
6/6 leaks detected at pad B ✓

Pad C:
5/5 leaks detected at pad C
1/1 false detection avoided ✓

Alden, Coburn et al., *In Prep*

Single-blind test results: Attribution



Pad A: **Sub-pad level**
sub-pad identified in 6 of 6 cases ✓

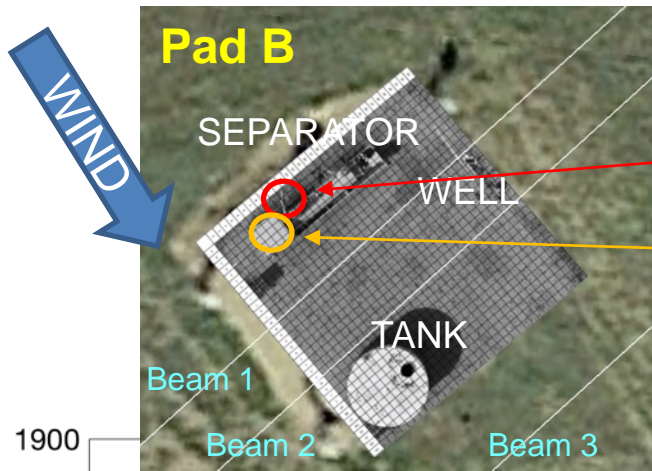
Pad B: **Component-level**
component identified in 6 of 6 cases ✓

Pad C: **Component-level**
component identified in 2 of 5 cases

Orientation of pad C with respect to spectrometer made component-level detection difficult

Alden, Coburn et al., *In Prep*

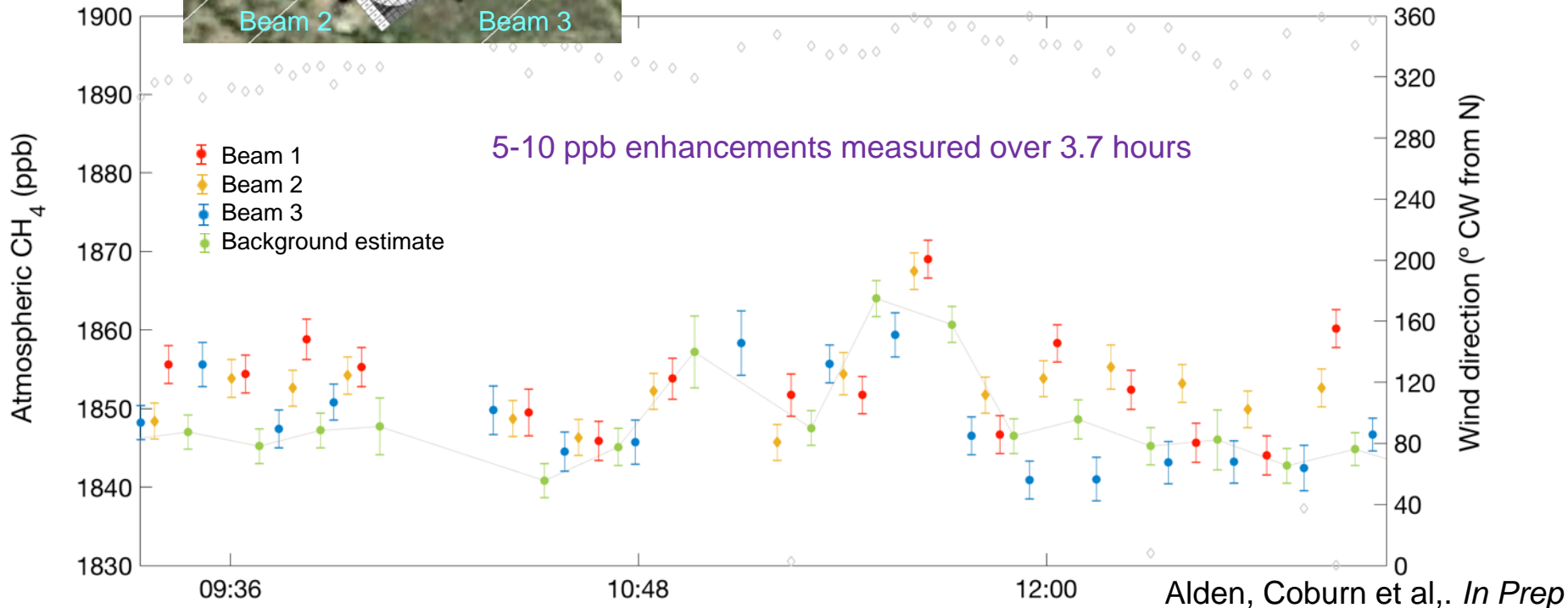
Single-blind test results: Quantification



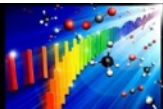
Test 10

True leak 3.9 ± 2 scfh (**0.7 kg/hr**) leak from separator regulator flange

Leak estimate 3.5 ± 1 scfh (**0.6 kg/hr**) from separator house pressure-reducing valve



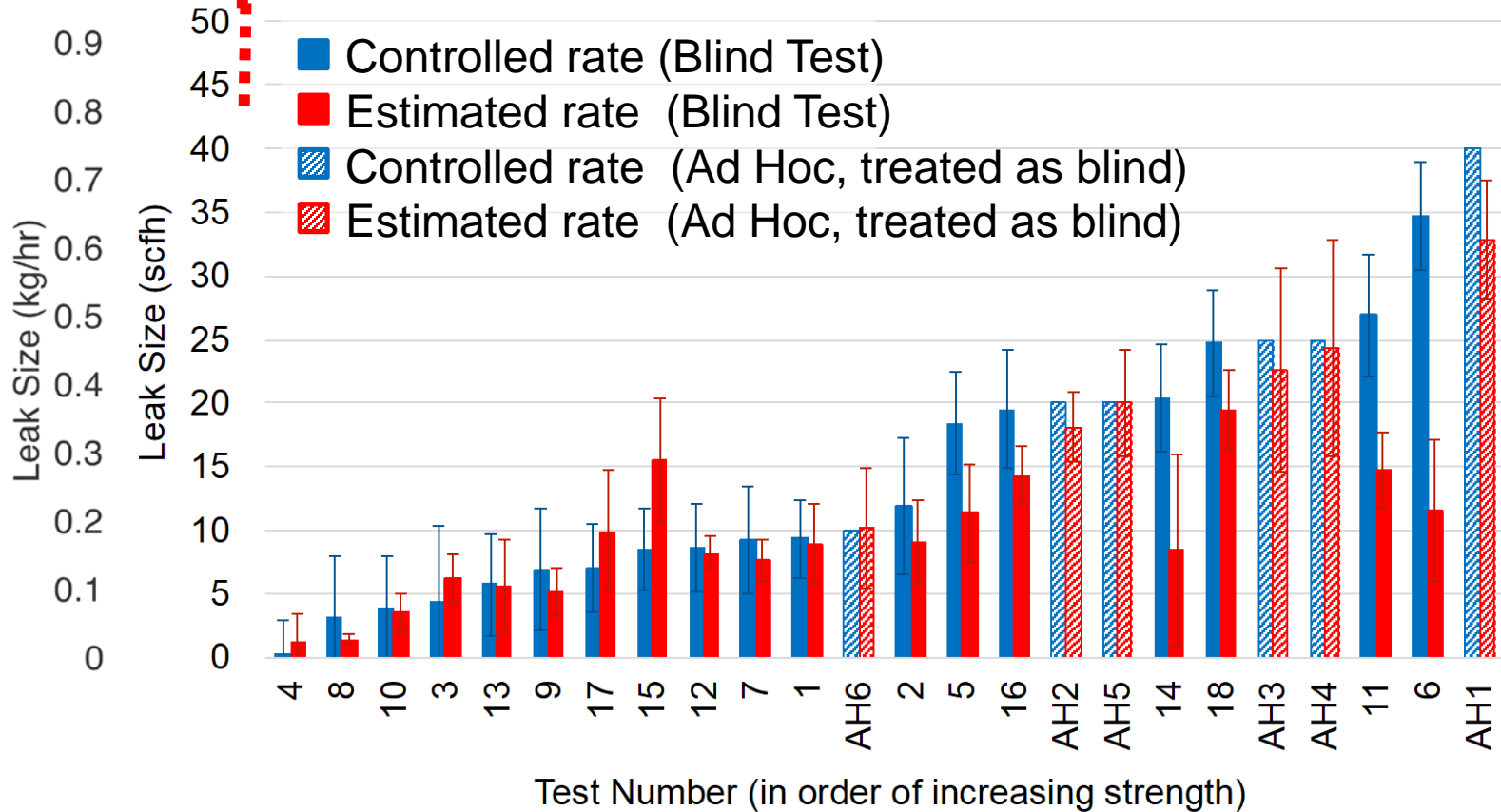
Alden, Coburn et al., *In Prep*



Single-blind test results: Quantification



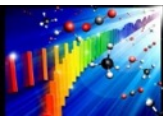
Device-level measurements suggest
90% of all emissions come from leaks **> 135 scfh (2.5 kg/hr)!**



Test Number (in order of increasing strength)

Brandt et al., *ES&T*, **50** (2016)

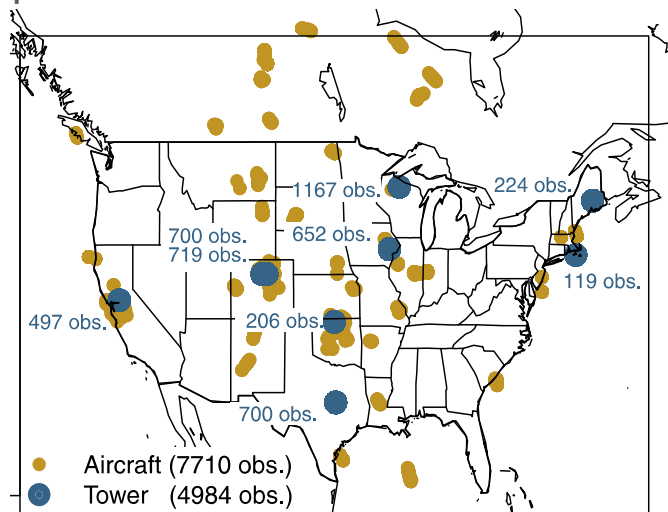
Alden, Coburn et al., *In Prep*



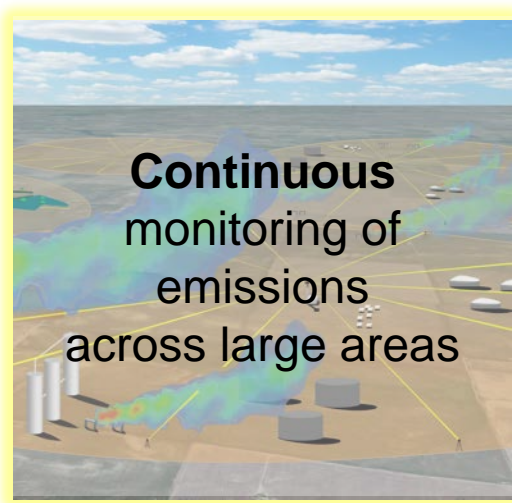
Regional, continuous methane leak monitoring

Methane emissions from oil and gas intermittent, unpredictable, and heavy-tailed: a small fraction of sources cause most of the emissions (“super-emitters”)

Continuous NOAA/GMD data provide nation-wide statistics



Miller et al., 2013 *PNAS*

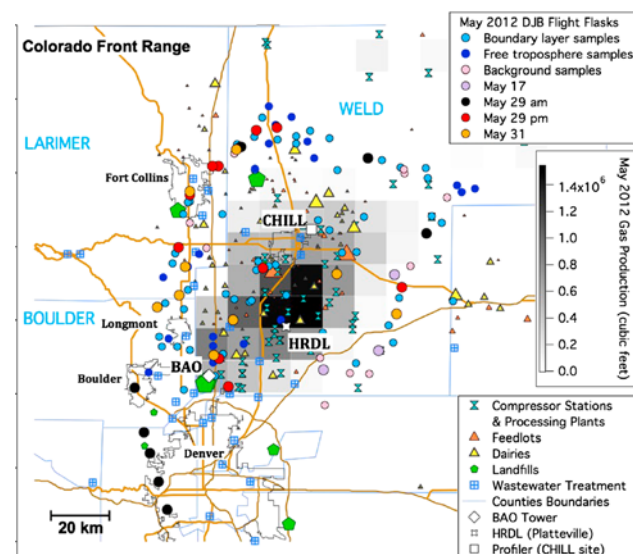


Continuous monitoring of emissions across large areas



“Missing Link”

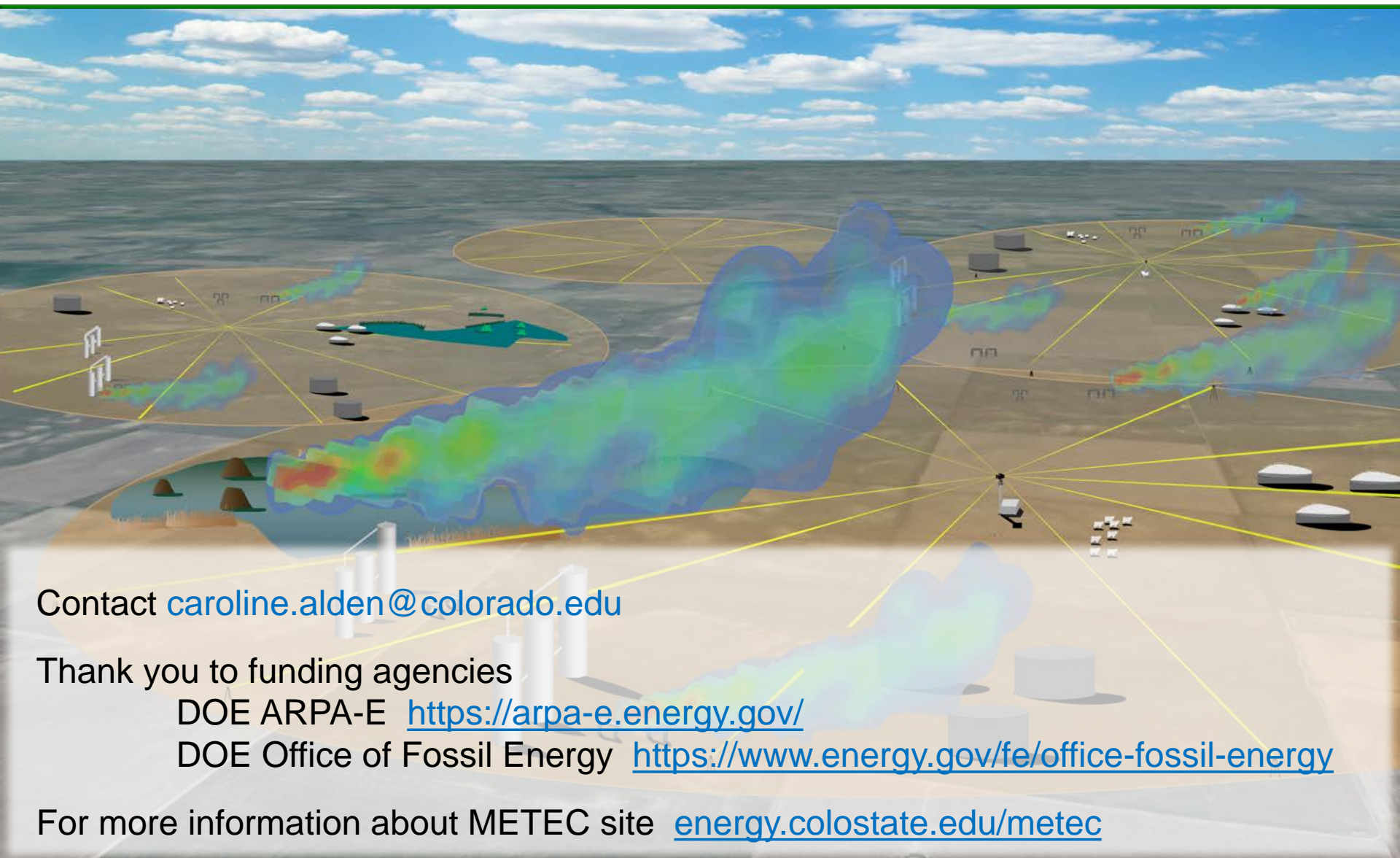
Campaigns provide snapshots, reconciliation of emissions estimates



Pétron et al., 2014 *JGR*

Continuous monitoring of many sites will provide critical, missing information about time variability of emissions and distributions of “super-emitters”

Thank You



Contact caroline.alden@colorado.edu

Thank you to funding agencies

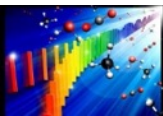
DOE ARPA-E <https://arpa-e.energy.gov/>

DOE Office of Fossil Energy <https://www.energy.gov/fe/office-fossil-energy>

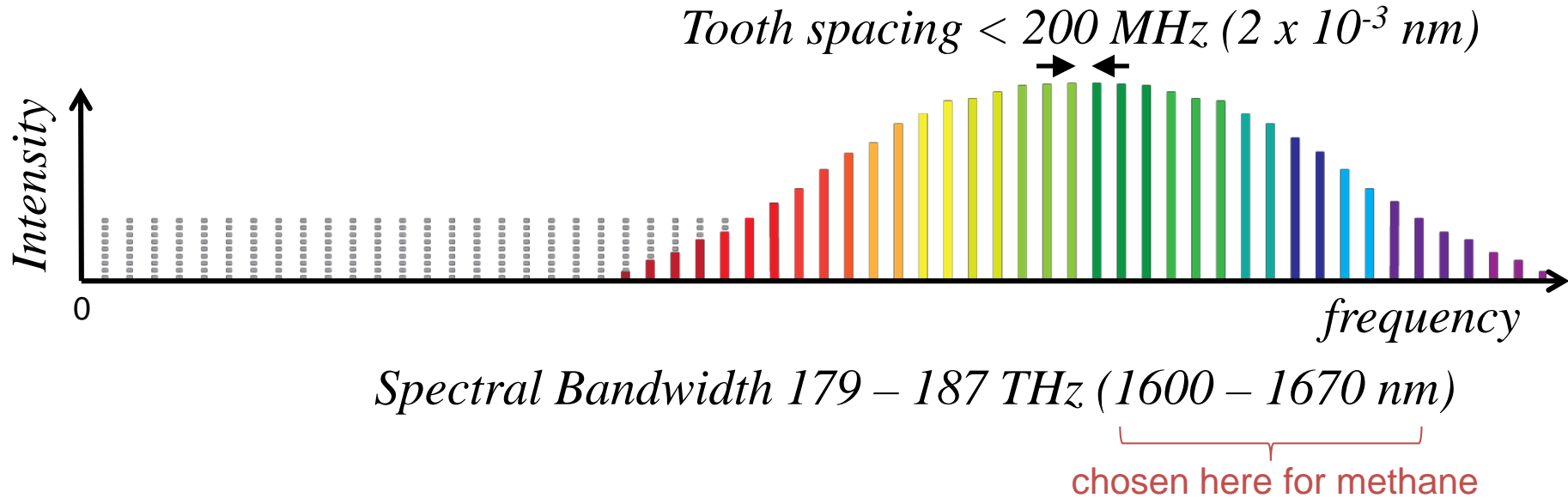
For more information about METEC site energy.colostate.edu/metec



Extra Slides



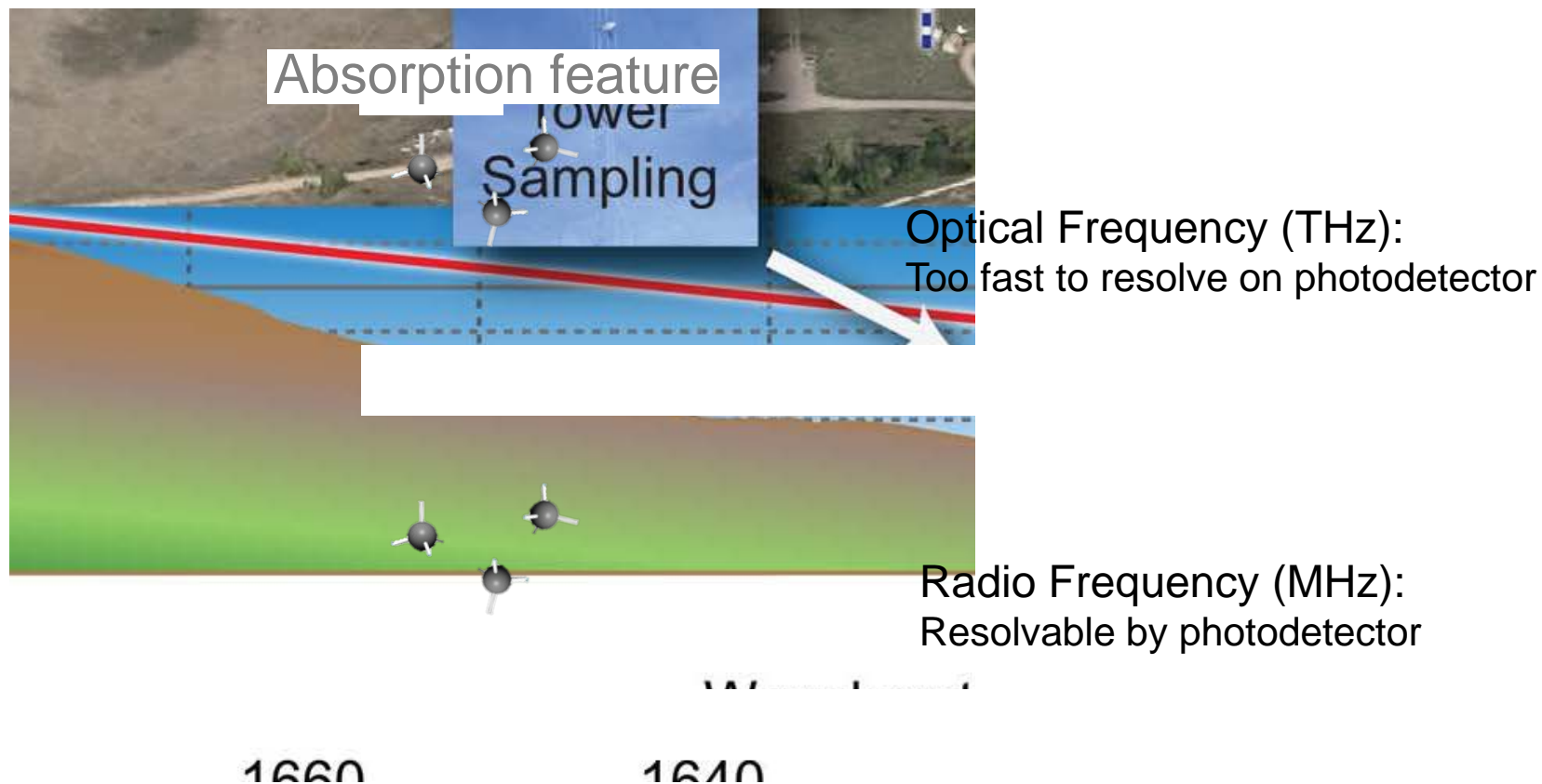
Frequency Comb Spectroscopy



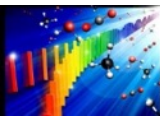
Equivalent to ~80,000 well-behaved continuous wave lasers

Dual Frequency Comb Spectroscopy

Two frequency comb lasers with slightly offset tooth spacing, give rise to a third comb in the radio frequency (rf) regime

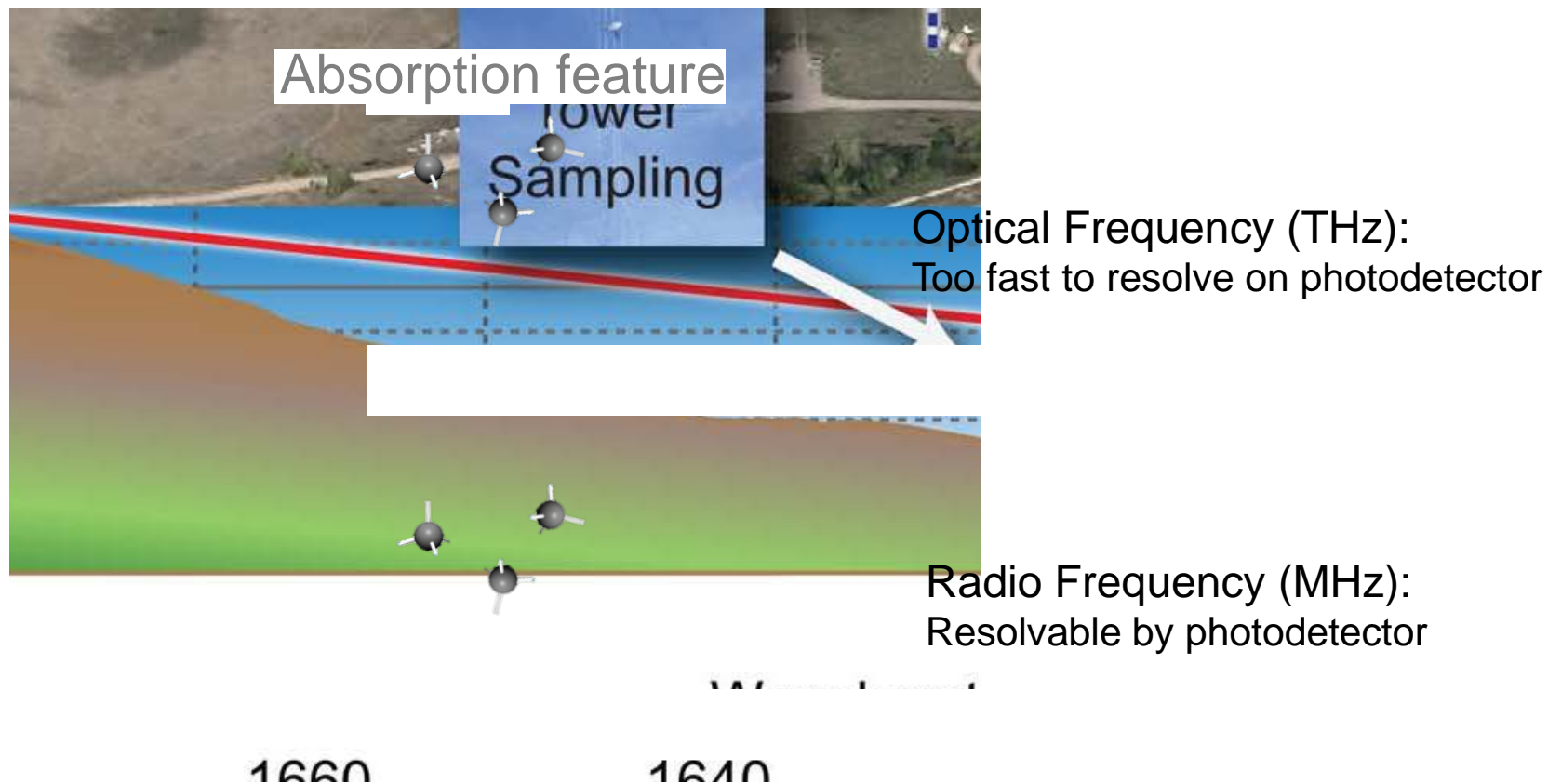


Rieker et al. *Optica*, 1 (2014)

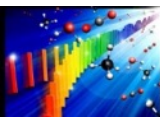


Dual Frequency Comb Spectroscopy

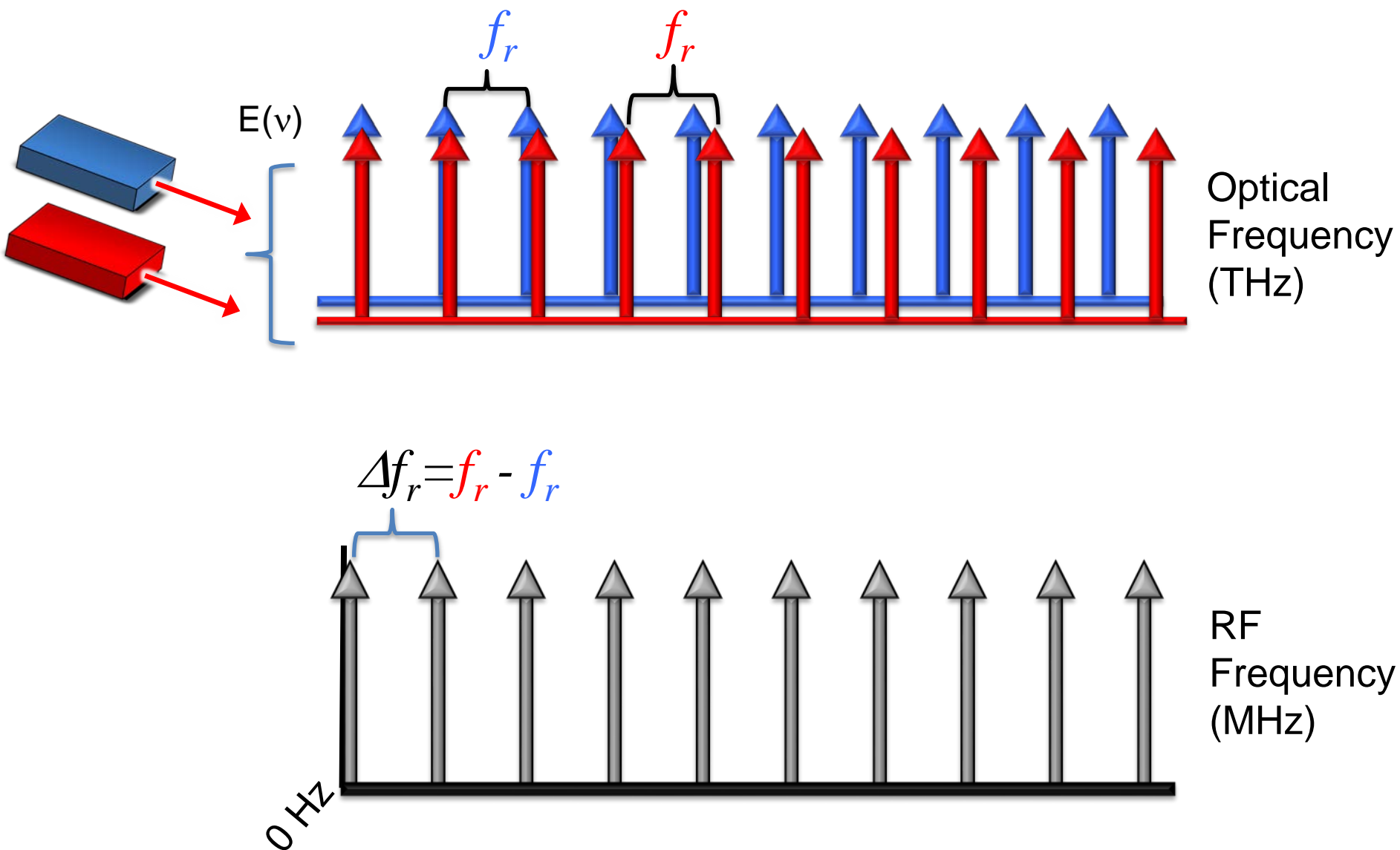
- Dry-air mole fractions CO₂, CH₄, H₂O, HDO and ¹³CO₂
- Minimal to no instrument drift
- Very high precision: < 5 ppb CH₄ over 1 km path in 2-5 minutes
- Measurement of long, open paths through the atmosphere (up to several km)



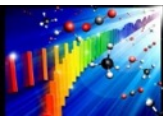
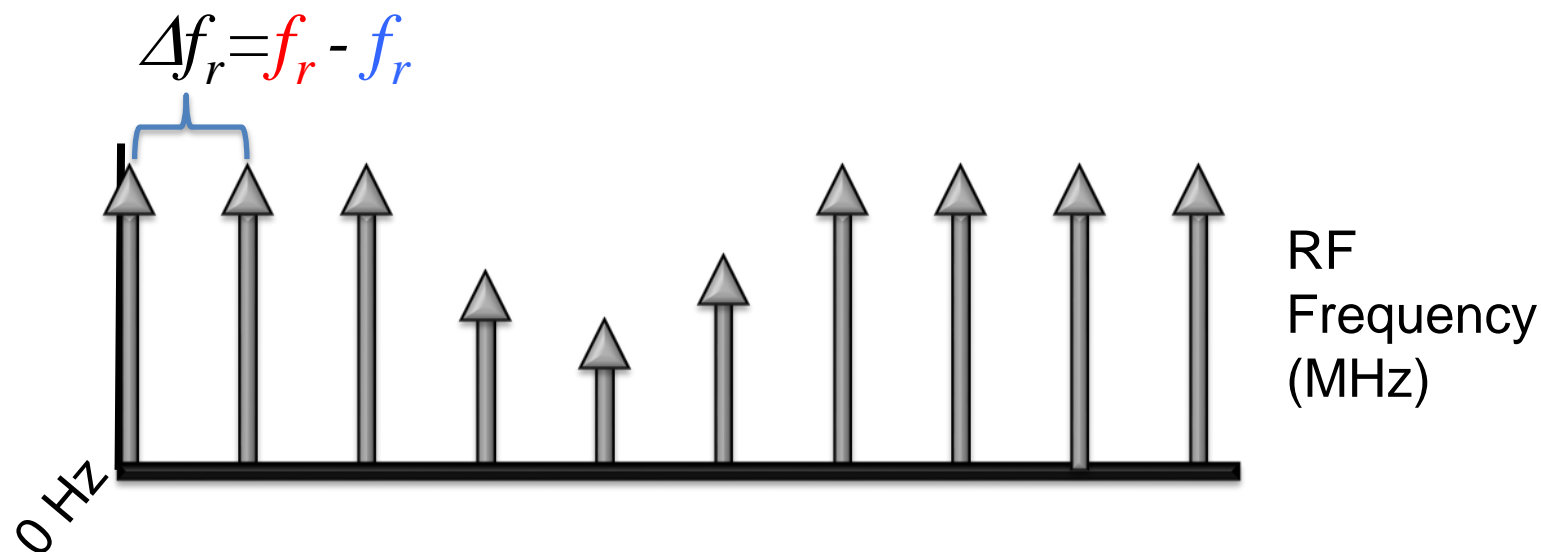
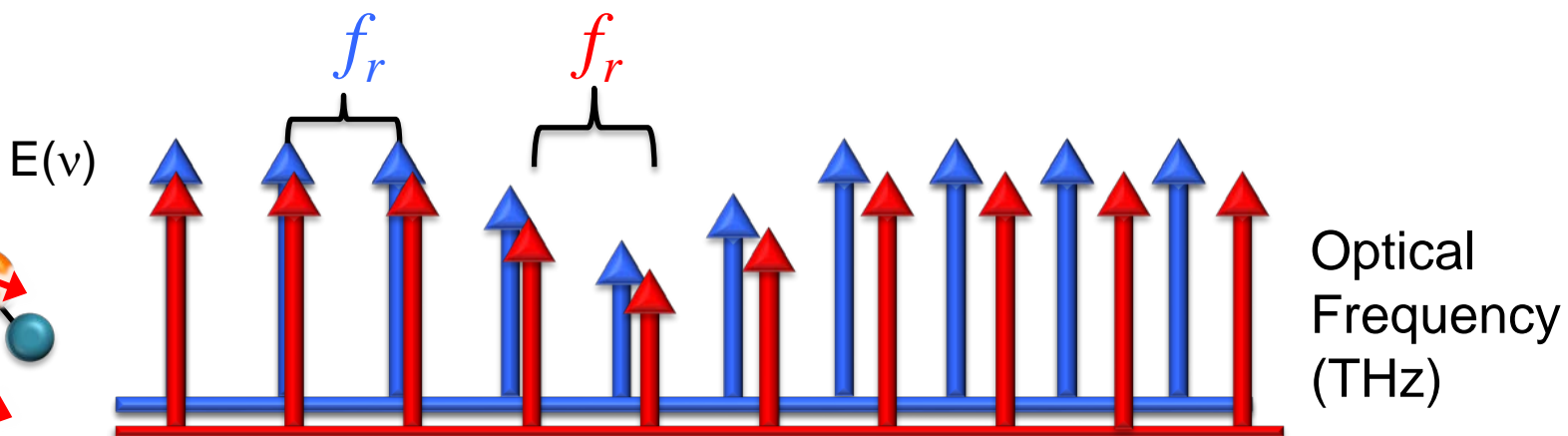
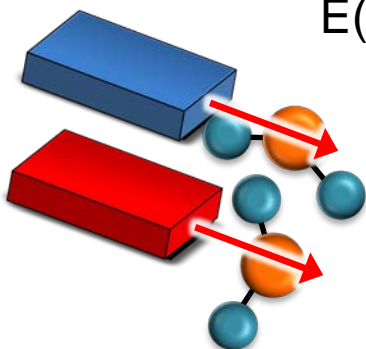
Rieker et al. *Optica*, 1 (2014)



Dual Frequency Comb Spectroscopy

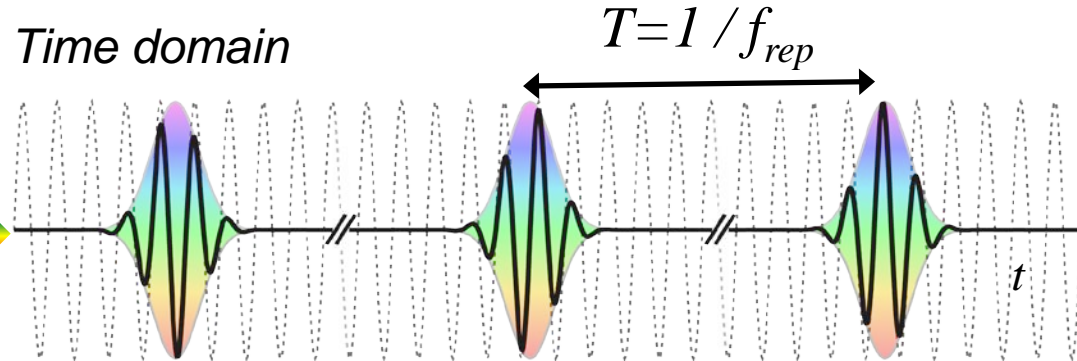
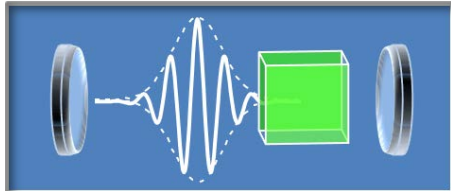


Dual Frequency Comb Spectroscopy

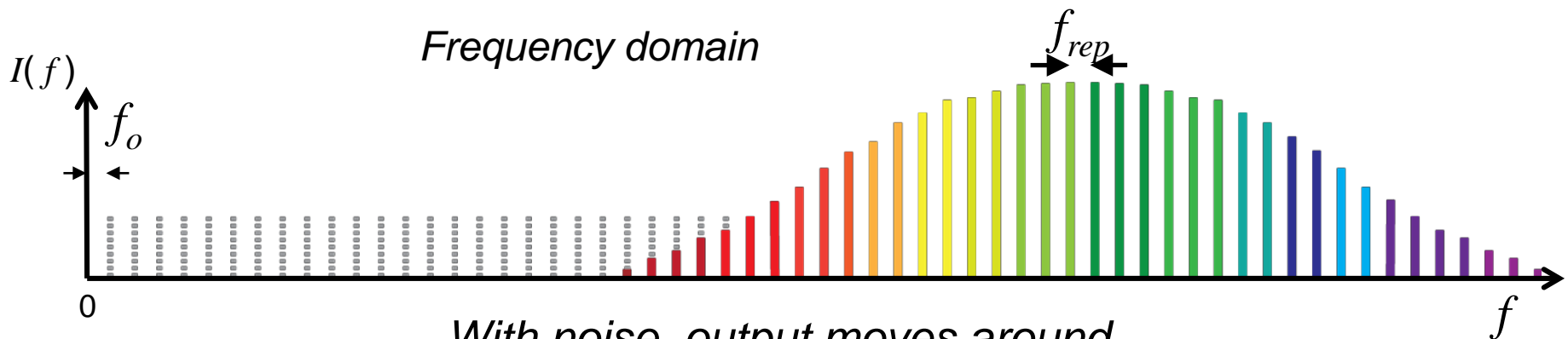


Frequency Comb Spectroscopy

Passively Mode-locked Laser



>100,000 well-behaved Continuous Wave lasers



*With noise, output moves around...
but basic comb structure is preserved.*

Comb can only “translate” and “breathe”

