

Reconciling Basin-Scale Top-Down and Bottom-Up Methane Emission Measurements for Onshore Oil and Gas Development

(RPSEA 12122-95)



Sponsors

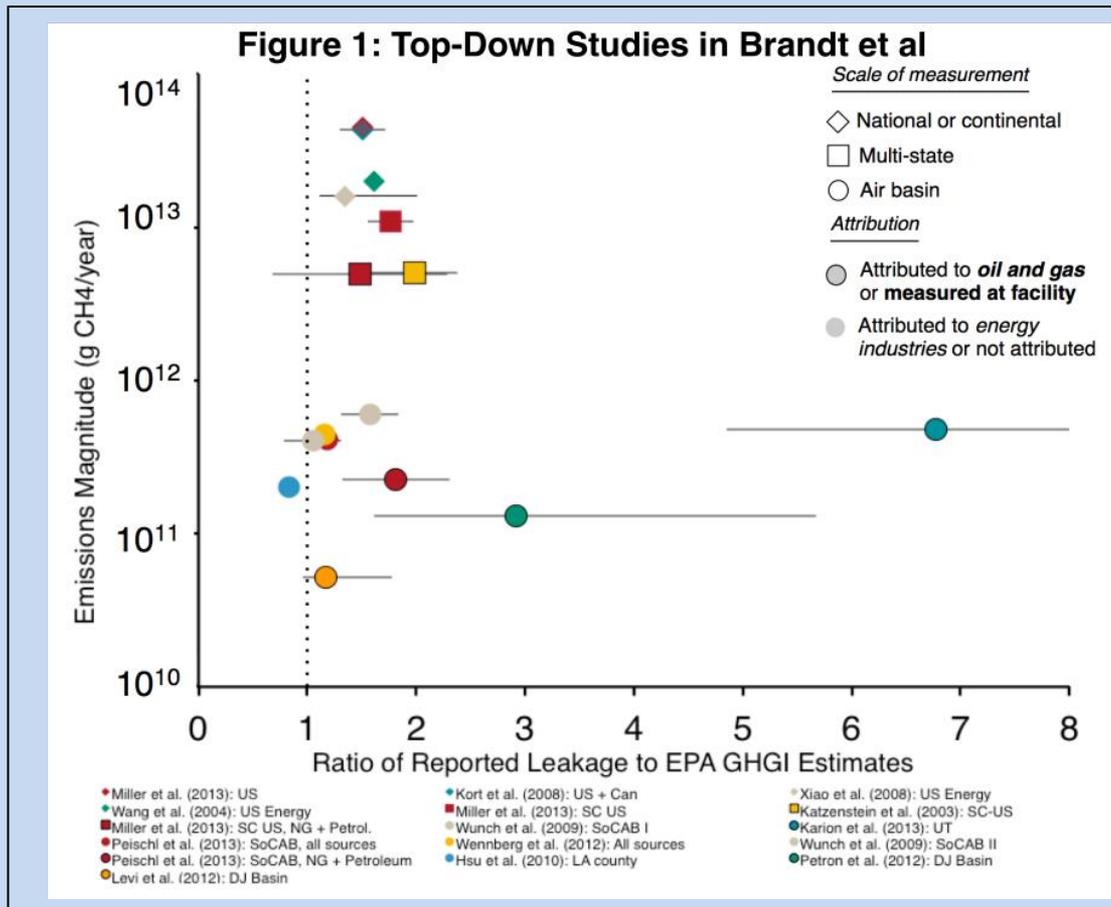


- 1. Problem Identification**
- 2. Combined Ground and Airborne Measurements**
- 3. Reconciliation**
- 4. Gas leakage from subsurface**
- 5. Comprehensive publication**

2014 State of the science

Multiple Top-Down studies estimate larger CH₄ emissions than EPA US GHG inventory: How do we close the gap?

Need to better understand CH₄ emissions, including from Oil and Gas systems



- Update EPA inventory
- Inform Life Cycle Assessment of Natural Gas
- Investigate potential for emission reduction

Colorado Project on Methane Emissions Reductions from Natural Gas

Top-Down Measurements



Aerodyne Research

AECOM

GHD

ARIA



Bottom-Up Measurements/Inventory



POWERHOUSE
ENERGY INSTITUTE
Colorado State University



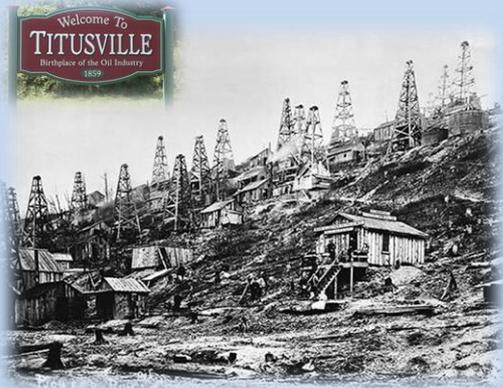
Center for Experimental Study of
Subsurface Processes



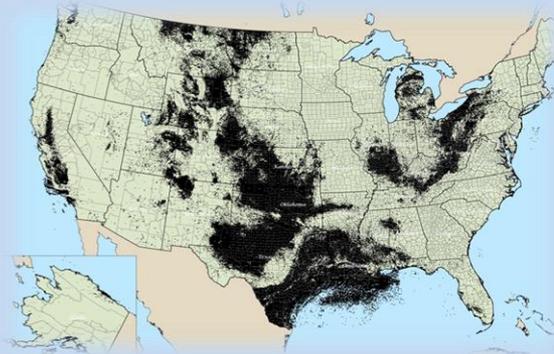
- NETL
- American Gas Association
- Four large oil and gas companies

- Colorado State University
- Colorado School of Mines
- Colorado Energy Research Collaboratory

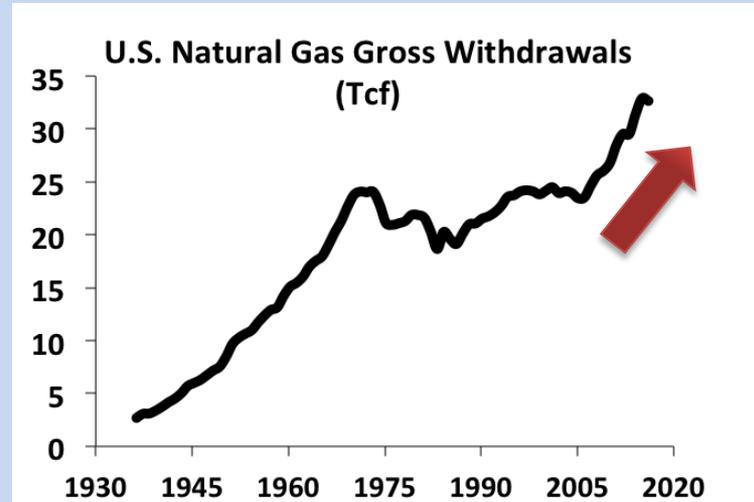
The Scale of the Temporal and Spatial Problem



1860's US first commercial oil field in PA



Today, US has over 1 million active oil and gas wells



In 2014 and 2015 US was world top oil and gas producer. Half of production now comes from shale or tight sand oil and gas formations

Gaby Pétron and colleagues at

NOAA Global Monitoring Division and Chemical Sciences Division

University of Colorado Cooperative Institute for Research in Environmental Sciences

Pétron - NAS methane workshop



US NG systems: complex mix of sources. Bottom-up studies cover spatial variability/sources

US Natural Gas Infrastructure

- ~1,000,000 active oil and gas wells
- 493 processing plants,
- > 20,000 miles of gathering pipelines,
- ~ 300,000 miles transmissions pipelines,
- NEW!> 4,500 gathering compressor stations [Marchese et al., 2015: 2.4 Tg CH₄/yr!]
- 1,758±20% (Zimmerle et al., 2015) vs 2147 (count from [EPA GHGI , 2014] based on 1992 data extrapolation) transmission compressor stations
- ~ 400 underground storage facilities
- ~ 2,000,000 miles of distribution pipelines

US Statistics: EIA, DOT, OGI

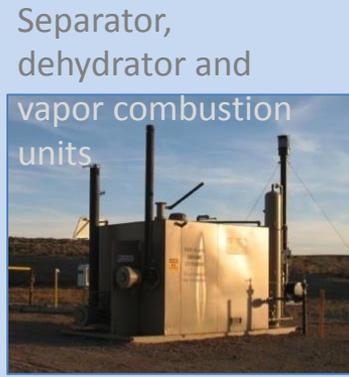


Drill rig

3/28/2017



wellhead



Separator, dehydrator and vapor combustion units

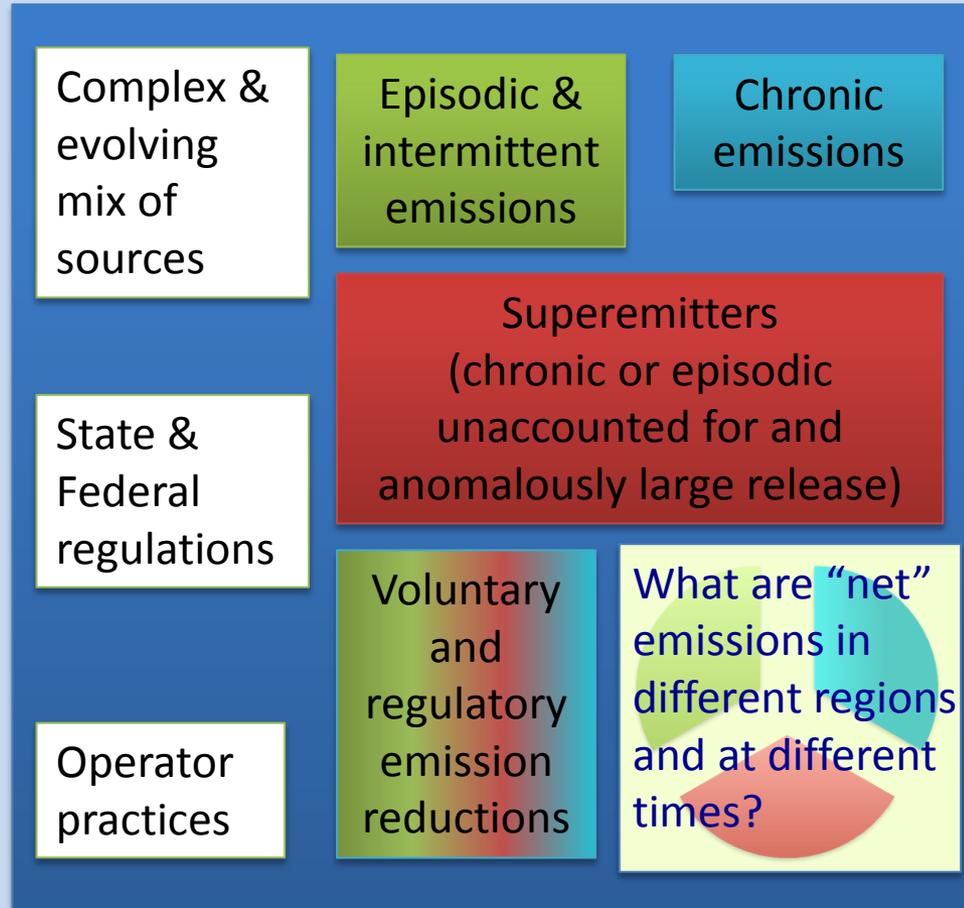
Petron - NAS methane workshop



Oil and water storage tanks in DJ Basin



Compressor station in UT



Top-Down studies cover a range of spatial scales

Process



1 process or facility
3 to 100s measured in 1 or multiple regions
Site access and site status

Facility



Region



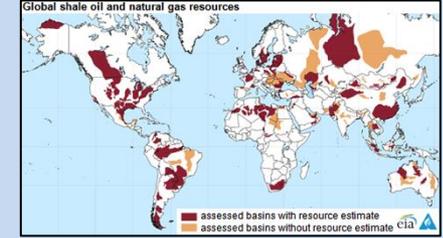
1000s Active Wells
10s Compressors
Processing Plants
1,000s Miles of Pipelines
10-100s Operators

Continent



1,000,000 Active Wells
1000s Compressors
100s Processing Plants
1,000,000 Miles Pipelines
1000s Operators

Global



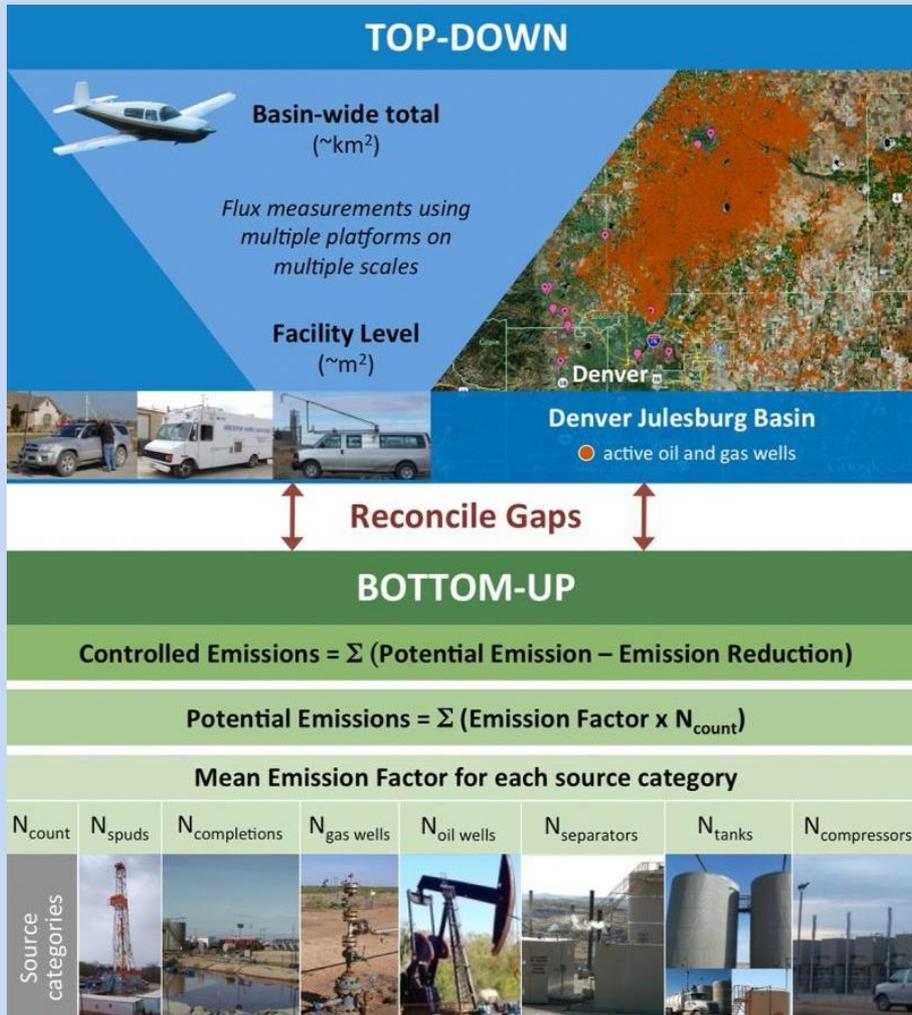
Large industry
Different practices & regulations
Small & Large Operators

PROCESS STUDIES

INTEGRATED EMISSIONS MONITORING

Emission source attribution more and more challenging

Top-down and Bottom-up Reconciliation of Quantitative Measures of Emissions from the Natural Gas Industry



Graphics: Gaby Petron (NOAA/CIRES)
and Garvin Heath (NREL)

- **Top-down:**
 - Source sector differentiation
 - Representative sampling
 - Accuracy
 - Gas composition profiles
 - Downscaling to sources
- **Bottom-up:**
 - “Fat tails” emission distribution
 - Missing sources
 - Representative samples
 - Activity data
 - Uncertainty characterization
- **The challenge:**
 - Reconcile Gaps

Top-Down studies cover a range of temporal scales

Process



Facility



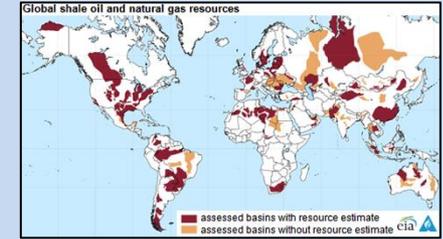
Region



Continent



Global



PROCESS STUDIES

Snapshot

A few sec- 30 min

Downwind Dual

Tracer

Aircraft in-situ or
remote sensing

On-site
HiFlow

midday hours,
1-several days

Aircraft Regional

Mass Balance

INTEGRATED EMISSIONS MONITORING

Longer time averages

In-situ long term observations or
remote sensing
& inverse modeling

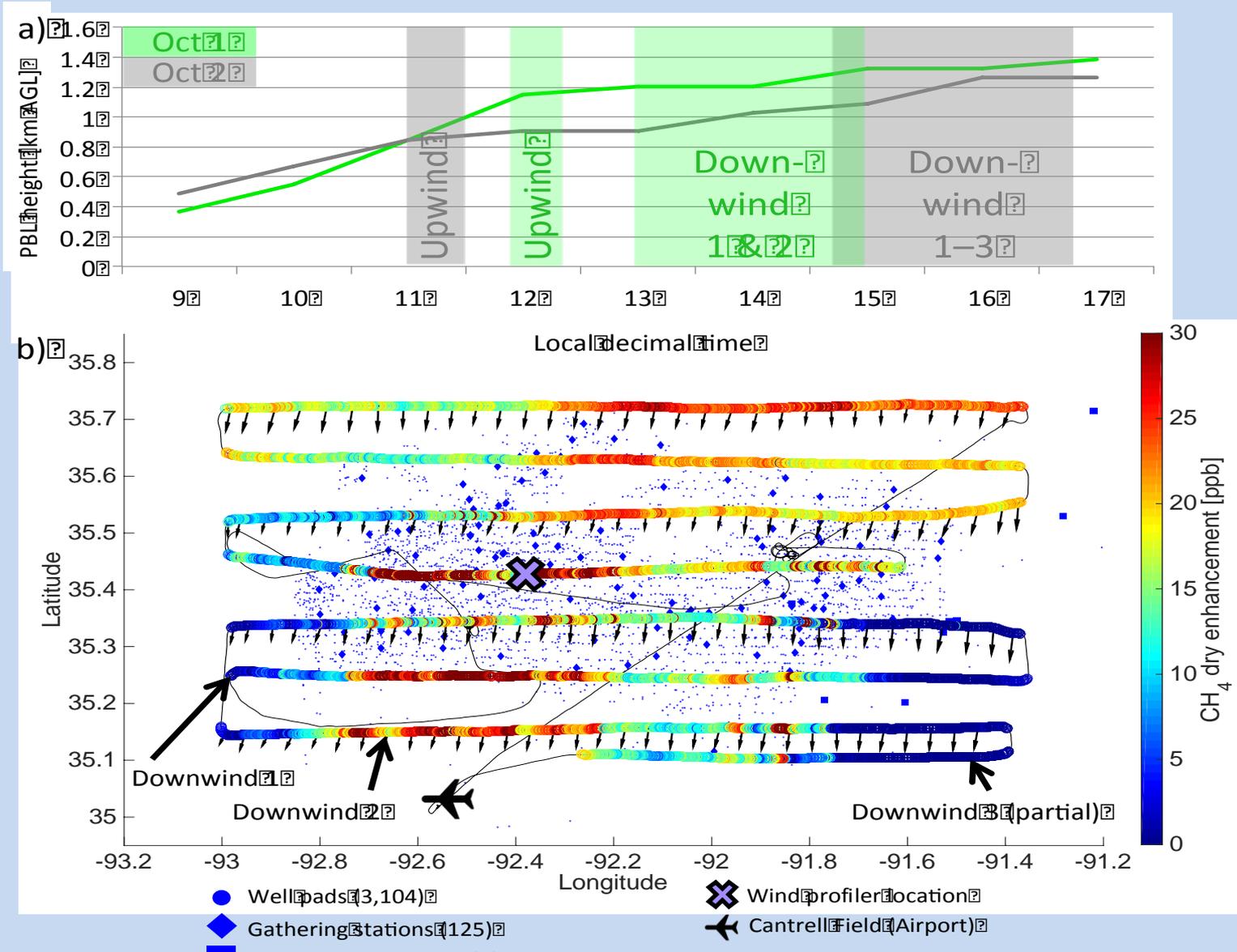
Available “official” EPA GHGI is annual and national.

EPA **GHGRP** is annual, non-exhaustive , at facility & county scales.

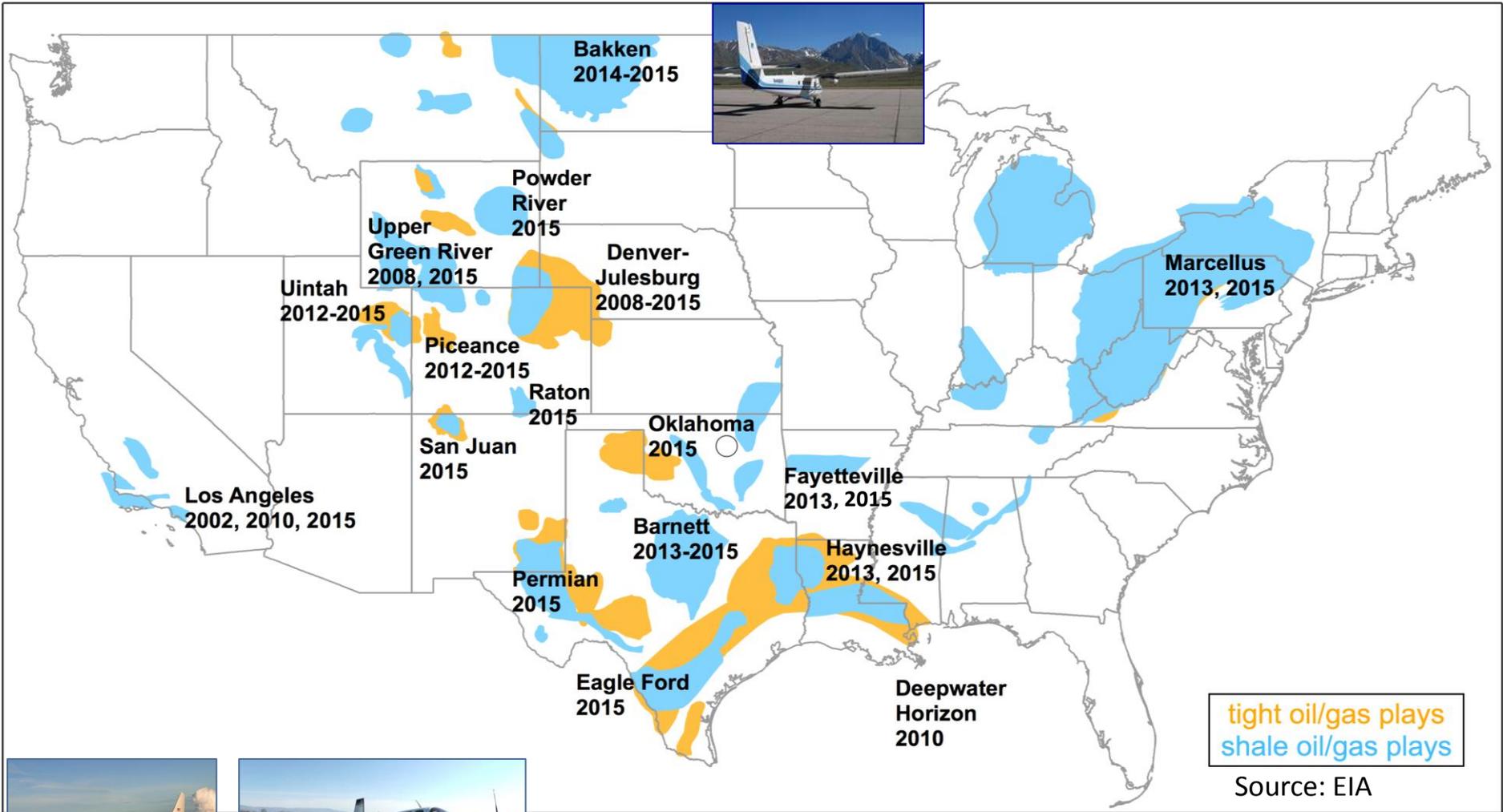
Research inventories : recent years coverage and updates are lagging.

All lack robust,
time & space
dependent
uncertainties

Example Flight and Ground Site Observations for Natural Gas Emissions Reconciliations (AR)



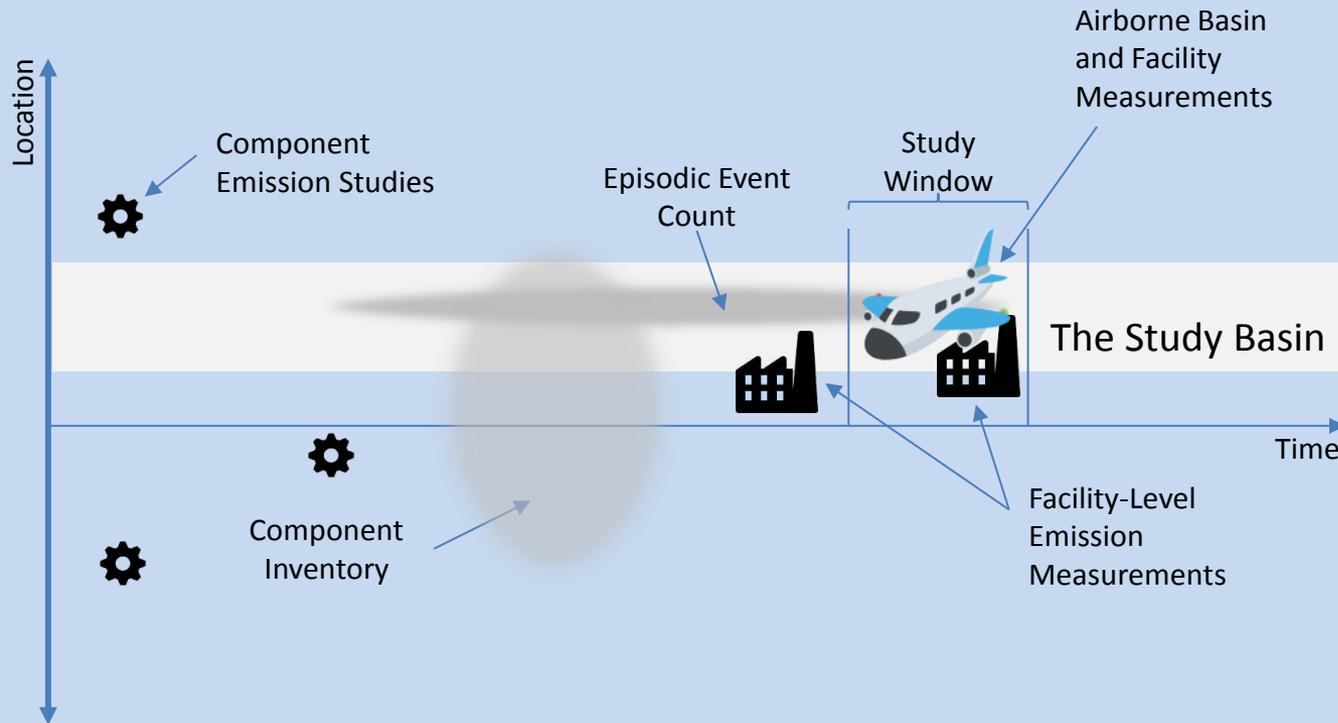
NOAA/CIRES Oil & Gas Research – Top Down National Coverage



The Colorado Methane Project Goals (CSM, CSU, CU, NOAA, NREL)

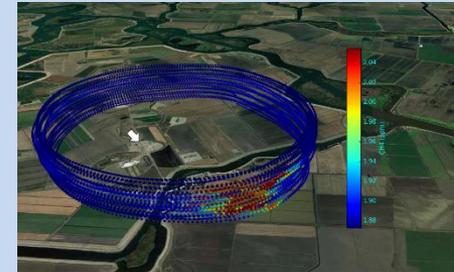
- Develop and reconcile independent top-down and bottom-up methane emission measurements (same basins, same time!)
 - At facility and basin levels for a US shale gas play
 - Using multiple state-of-the-science measurement methods at the same time
 - Scaling bottom-up estimates using spatially- and temporally-resolved activity data

What Has Been Compared in Past Studies



- Facility measurements not statistically representative
- Episodic data from annualized counts aggregated at basin level (at best)
- Vague component inventory values
- Component measurements from distant times & places

Key Objective of Colorado study: Reconciliation and Comparisons of Different Measurements (in Denver-Julesburg basin, CO, and Fayetteville Shele, AR)



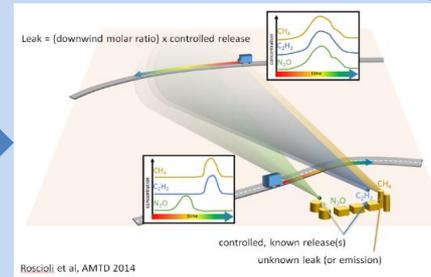
Facility "Spiral Flight"



Onsite

X

Emission
source
count
and timing

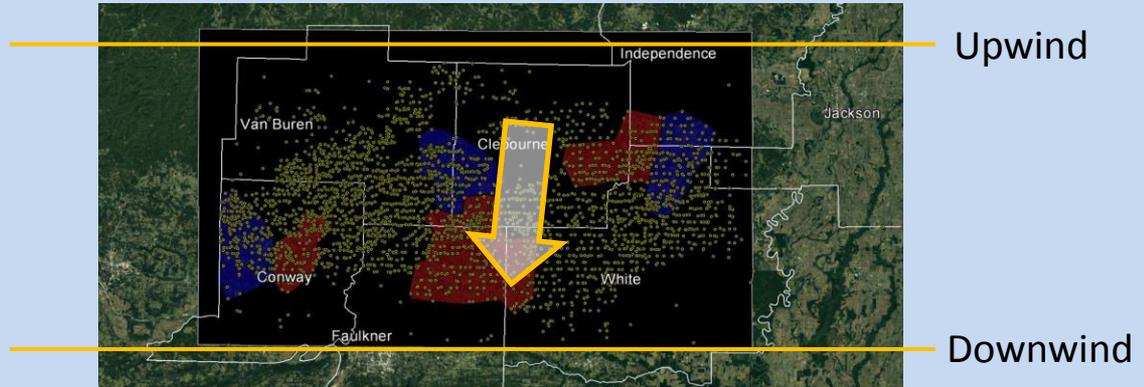
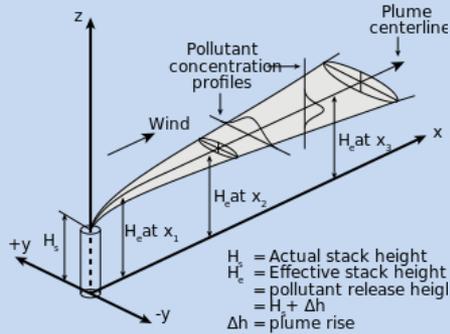


Tracer Flux

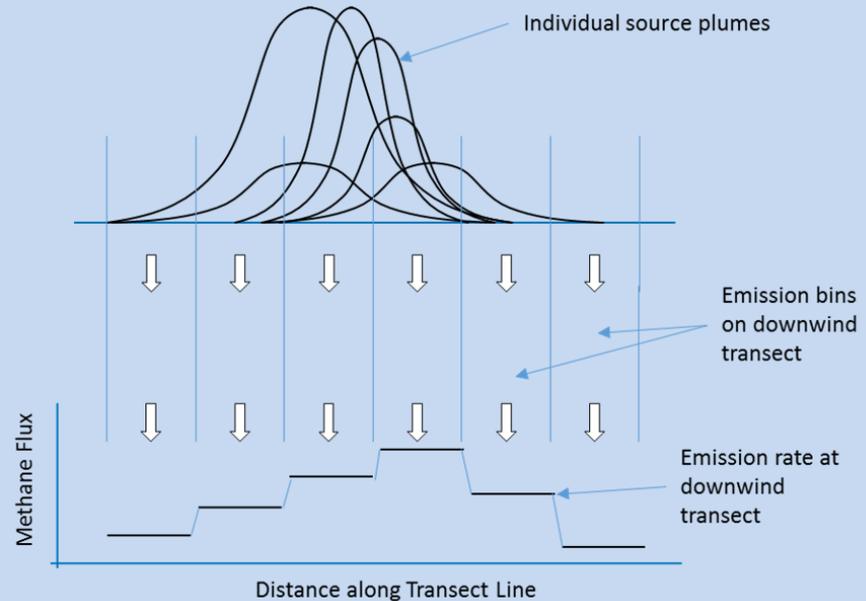


OTM33A

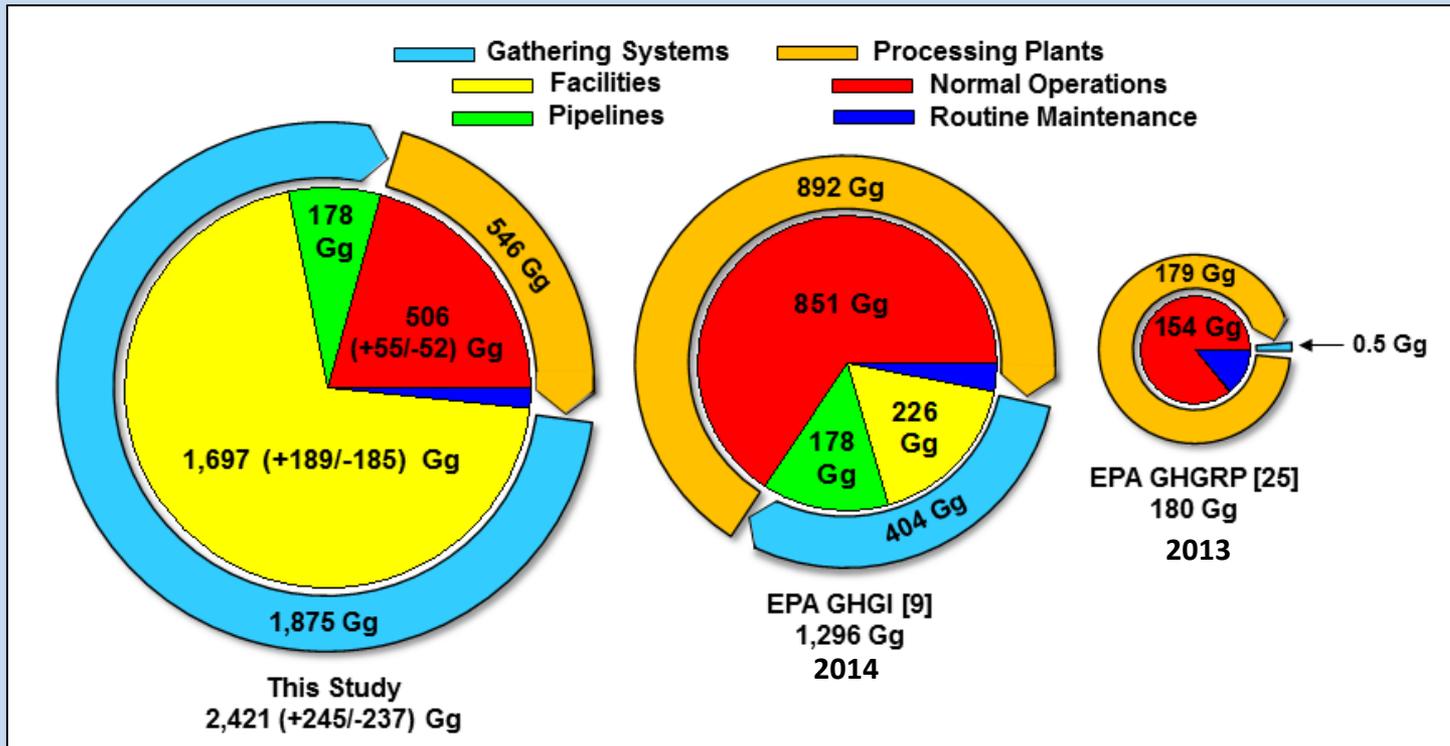
Basin Study Results



- Both top-down (aircraft) and bottom-up models show significant structure
- Structure is strongly related to activity data (known & unknown)



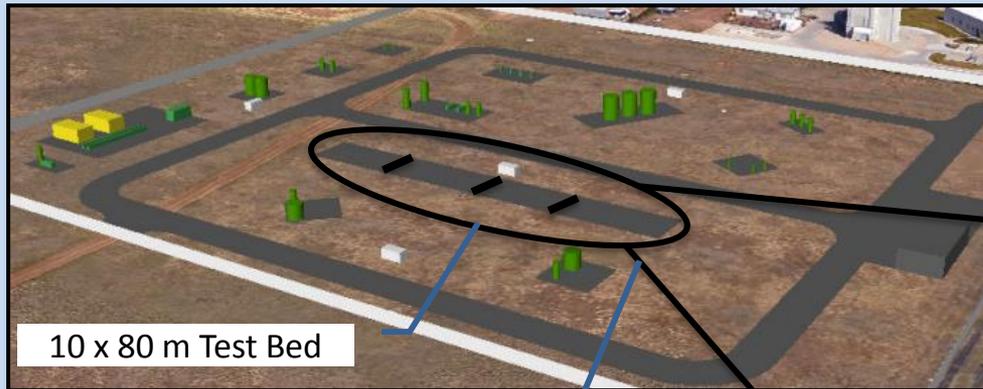
CH₄ Estimate for Gathering and Processing



New emissions data + substantial update to activity estimates

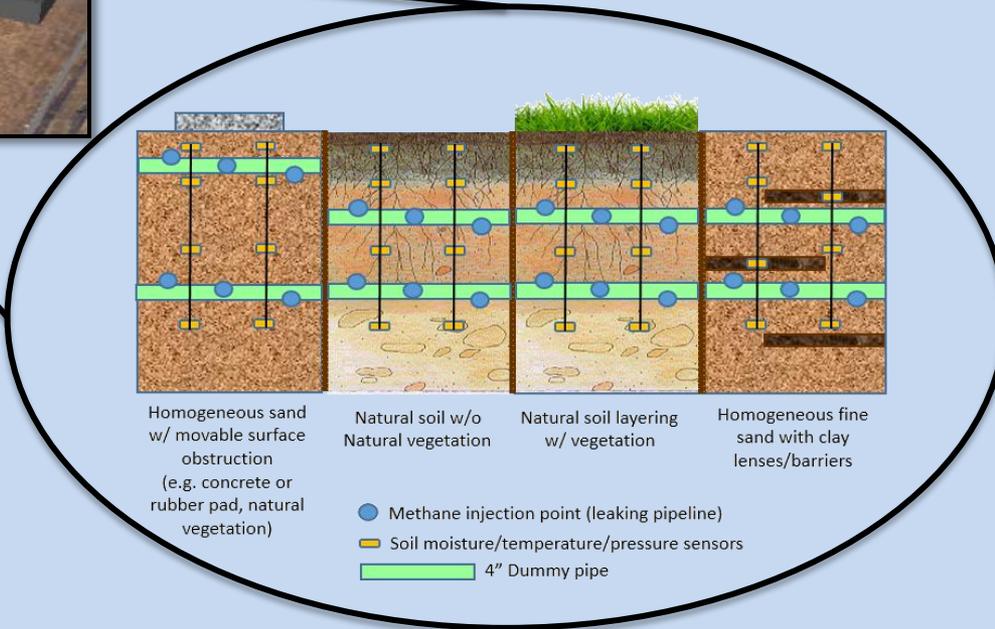
Marchese, A.J., Zimmerle, D.J., Vaughn, T. L. et al (2015). Methane emissions from United States natural gas gathering and processing. *Environ. Sci. Technol.* 10.1021/acs.est.5b02275.

METEC Emissions Testbed. At CSU



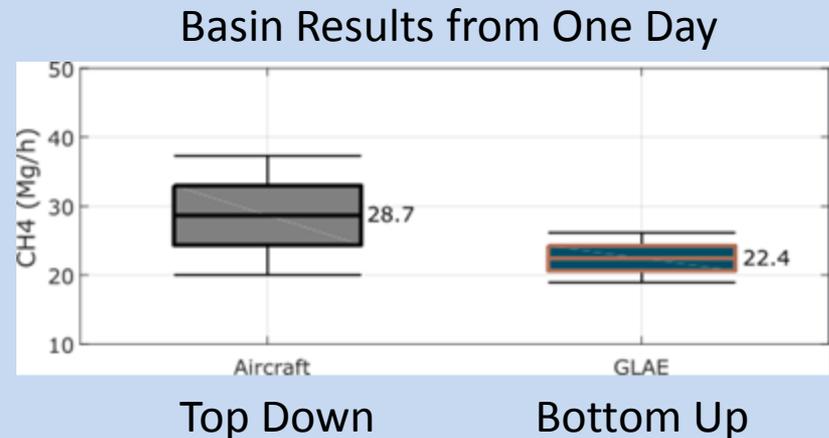
10 x 80 m Test Bed

Test bed separated into 4 separate test locations, varying based on soil type and surface conditions



Main Conclusion of Basin Study

- Reasonable agreement between TD & BU estimates
- Relies on very complete activity data
- No special modeling of BU emissions required



- 8 papers in press/progress (incl. Proc. Nat'l Academy of Sciences, October 29th, 2018. Embargo in effect till then.
- DC Federal Agencies (EPA, USGS, and ?) presentation to coincide with Academy release.

Other Conclusions

Shift from coal to unconventional gas implies:

- Move towards even greater US energy self reliance
- Decreasing greenhouse gas emissions
- Further decrease in GHGs also by methane emissions reductions

New opportunity: Create new carbon-based materials from CO₂! Potentially very large market