Improved mechanistic understanding of natural gas methane emissions from spatially-resolved aircraft measurements

Stefan Schwietzke\textsuperscript{1,2}, Gabrielle Pétron\textsuperscript{1,2}, Stephen Conley\textsuperscript{3,4}, Cody Pickering\textsuperscript{5}, Ingrid Mielke-Maday\textsuperscript{1,2}, Edward J. Dlugokencky\textsuperscript{2}, Pieter P. Tans\textsuperscript{2}, Tim Vaughn\textsuperscript{5}, Clay Bell\textsuperscript{5}, Daniel Zimmerle\textsuperscript{5}, Sonja Wolter\textsuperscript{1,2}, Clark W. King\textsuperscript{2}, Allen B. White\textsuperscript{2}, Timothy Coleman\textsuperscript{1,2}, Laura Bianco\textsuperscript{1,2}, Russell C. Schnell\textsuperscript{2}

\textsuperscript{1}CIRES/CU Boulder, \textsuperscript{2}NOAA/ESRL Boulder, \textsuperscript{3}Scientific Aviation, \textsuperscript{4}UC Davis, \textsuperscript{5}Colorado State Univ.


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Previous studies:

- CH₄ emission estimates from top-down (atmospheric) studies greater than bottom-up (inventory, component/facility) throughout the US
- Inventories may underestimate CH₄ emissions, miss sources

- Reconciliation of top-down & bottom-up through statistical accounting of “super-emitters”
- E.g., 2% of facilities responsible for half of the emissions

Adapted from Zavala-Araiza et al. 2015 Barnett study.
The Ugly Duckling: activity data from oil and gas production

**Tier 1 Bottom-up**

- "Routine" emission event, facility type A
- Emission rate
- Duration
- Frequency
- # of sites

\[ \text{Emissions} = \text{g CH}_4/\text{hr} \times \text{hr} \times \text{yr}^{-1} \times \text{# of sites} \]

**Tier 2 Bottom-up**

- Publicly available activity data, average day
- Routine vs. episodic vs. chronic event?
- Merge with measurements, event types

**Barnett: statistical TD-BU reconciliation**

**Tier 3 Bottom-up**

- Industry/operator supplied activity data
  - Match each flight period
  - Categorize facility types at finer level
  - Characterize events (episodic, chronic, routine)
- Site access for component measurements

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Fayetteville Shale 2015 study design (Tier 3 approach)

- Hourly activity data from nearly all operators in study area (99% of natural gas production and infrastructure)
- Simultaneous measurements at multiple scales/techniques

**Top-down**

**Bottom-up**

- Facility-level
- Component-level
Fayetteville Shale 2015 study aircraft sampling overview

- 15 flights in 23 days (Sep/Oct)
- 2 flights (Oct 1 & 2) with ideal meteorological conditions for aircraft mass balance

Aircraft profiles:
- Vertical mixing, PBL height
- Profiler: wind, PBL height
- Upwind
- Downwind

Study area

- Remaining flights:
  - Identify larger emitting sub-regions incl. repeats to check consistency
  - Sample ethane:methane ratios for source attribution
  - Quantify CH$_4$ emissions from individual facilities

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October 1, 2015 flight overview

150 km x 65 km box

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First spatially-resolved aircraft-based CH$_4$ emission estimates for a basin

- Strong spatial correlation with well count (R$^2 = 0.81$ for ~2 km wide longitudinal bins)

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First spatially-resolved aircraft-based CH$_4$ emission estimates for a basin

- Strong spatial correlation with well count ($R^2 = 0.81$ for $\sim$2 km wide longitudinal bins)
- Also strong spatial correlation with natural gas production ($R^2 = 0.75$)

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Raster flights on other days further confirm the spatial emission pattern.
Substantial episodic emissions midday during aircraft sampling

Gas production normalized CH₄ emissions (“leak rate”) in the West double compared to East

- About 1/3 of total CH₄ emissions → Explains ~2/3 of W-E difference in leak rate
- Midday peak vs. annual average!
- Episodic sources partially responsible for day-to-day emission variability (can’t tell without spatial analysis)

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Summary

• First spatially-resolved aircraft-based CH$_4$ emission estimates for a basin
  - Used for a spatially/temporally resolved TD-BU comparison to understand TD-BU differences mechanistically rather than statistically
  - Important for prioritizing mitigation targets

• Episodic sources are large contributor to midday CH$_4$ emissions and drive “leak rate” difference in the basin
  - Temporal interpretation of TD estimates is key (peak emissions)
  - Cooperation / data sharing with local operators is essential (reported activity levels and equipment/facility counts)
  - Site access allows for measurement methods comparison

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