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

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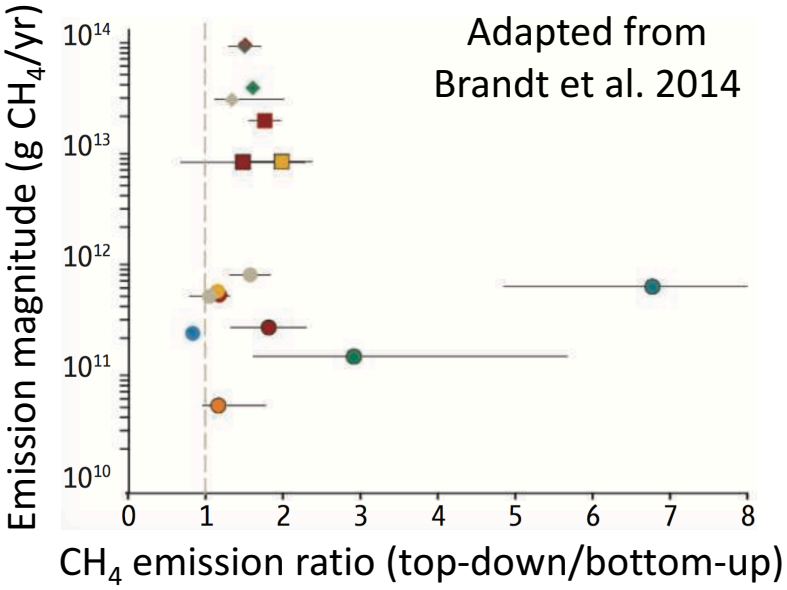
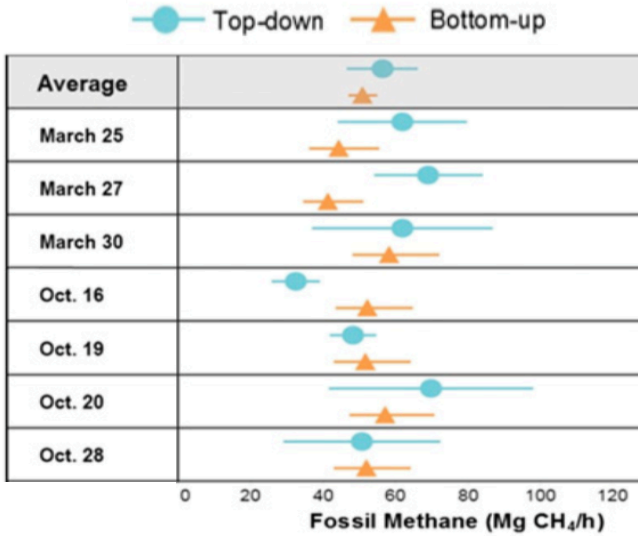
The oil and gas methane top-down (TD) vs. bottom-up (BU) phenomenon

Previous studies:

- CH_4 emission estimates from ***top-down*** (atmospheric) studies ***greater than bottom-up*** (inventory, component/facility) throughout the US
- ***Inventories may underestimate*** CH_4 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



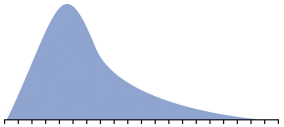
Adapted from Zavala-Araiza et al. 2015 Barnett study.

The Ugly Duckling: activity data from oil and gas production

Tier 1 Bottom-up

		g CH_4/hr		hr		yr^{-1}		g CH_4/yr
"Routine" emission event, facility type A	X	Emission rate	X	Duration	X	Frequency	X	# of sites	=	Emissions

Tier 2 Bottom up

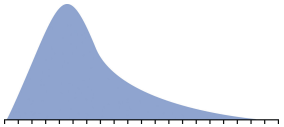


Basin-specific measurements, including fat tails

- 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



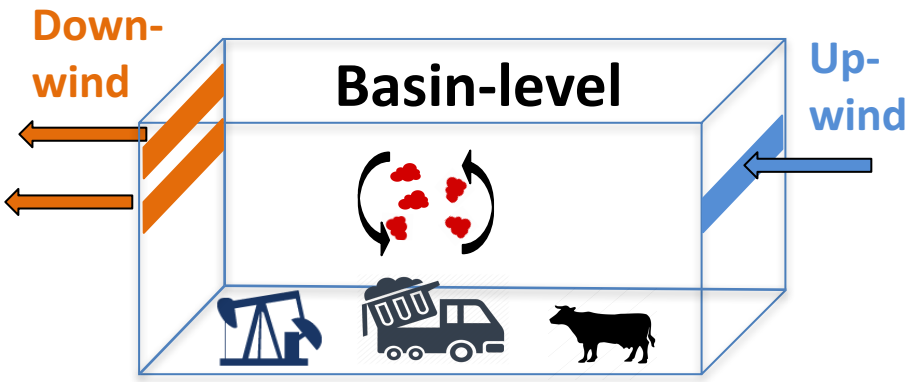
Basin-specific measurements, including fat tails

- 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

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



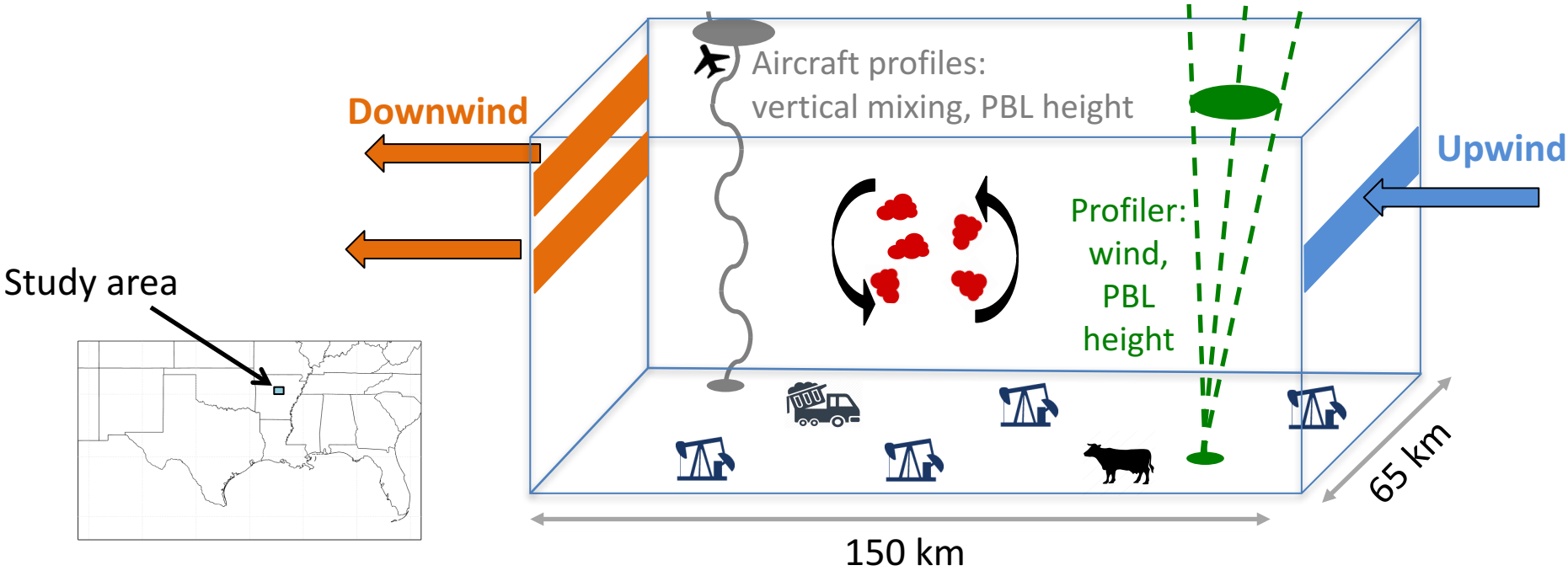
Bottom-up

Facility-level

Component-level

Fayetteville Shale 2015 study aircraft sampling overview

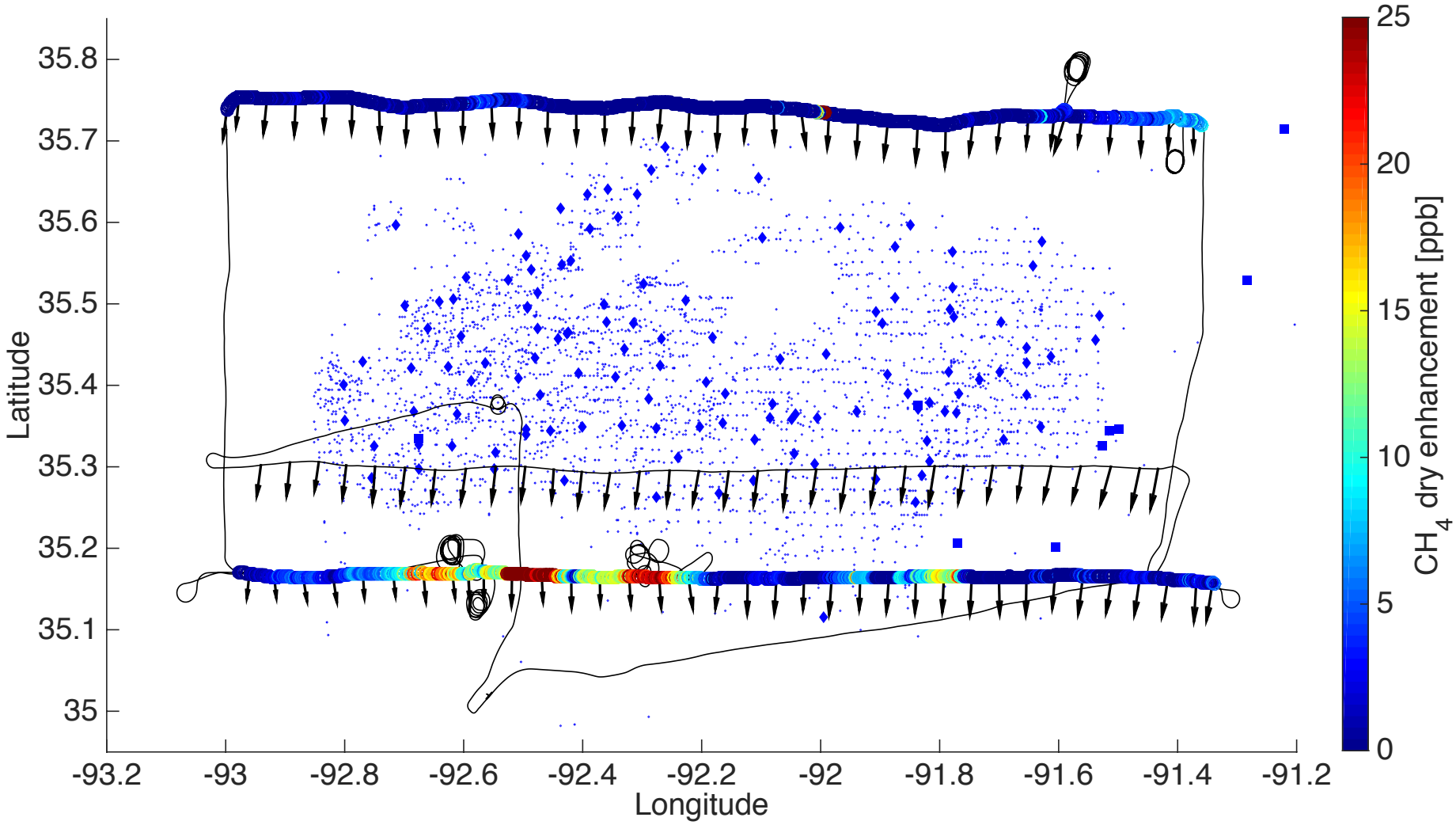
- 15 flights in 23 days (Sep/Oct)
- 2 flights (Oct 1 & 2) with ideal meteorological conditions for aircraft mass balance



- 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

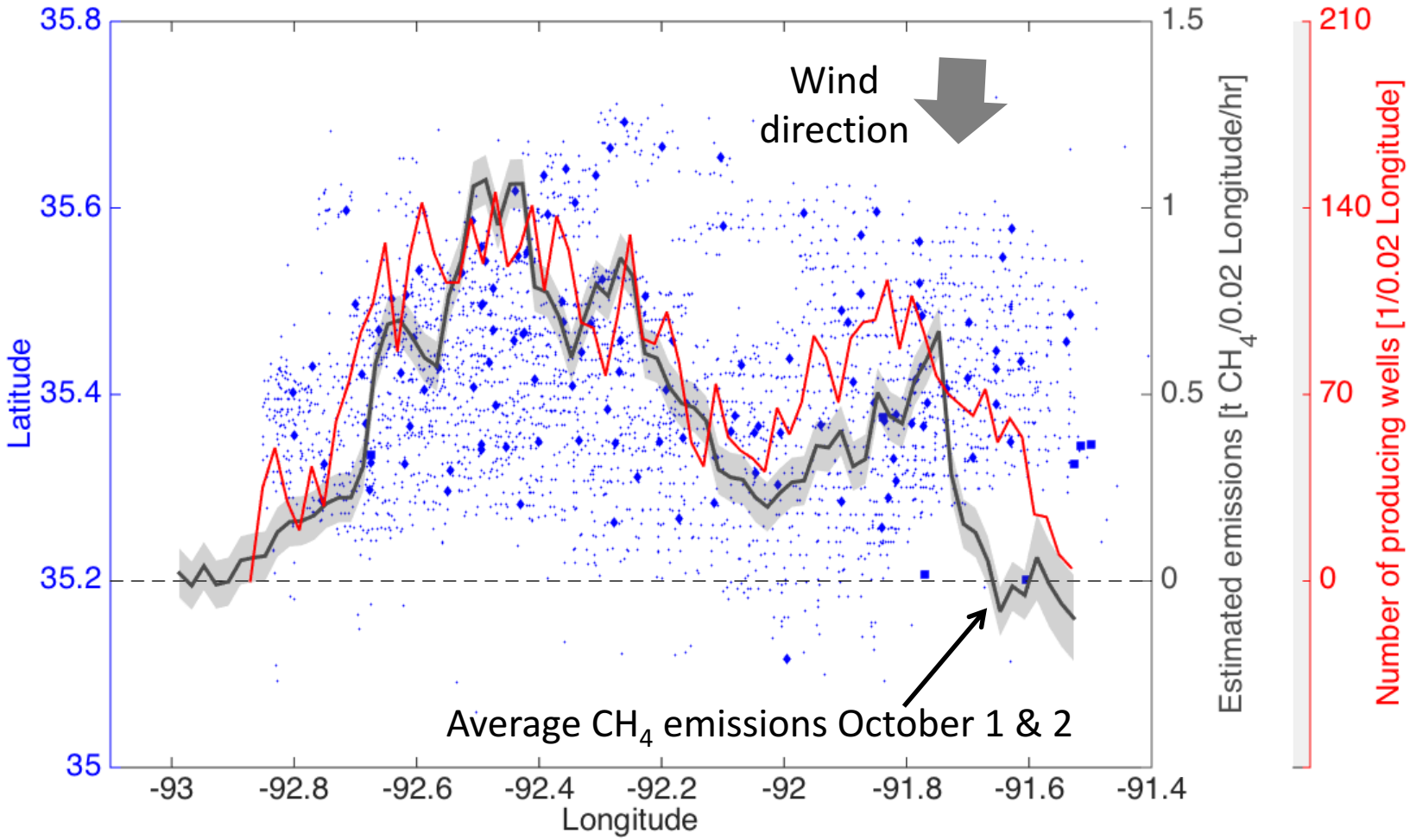
October 1, 2015 flight overview

150 km x 65 km box



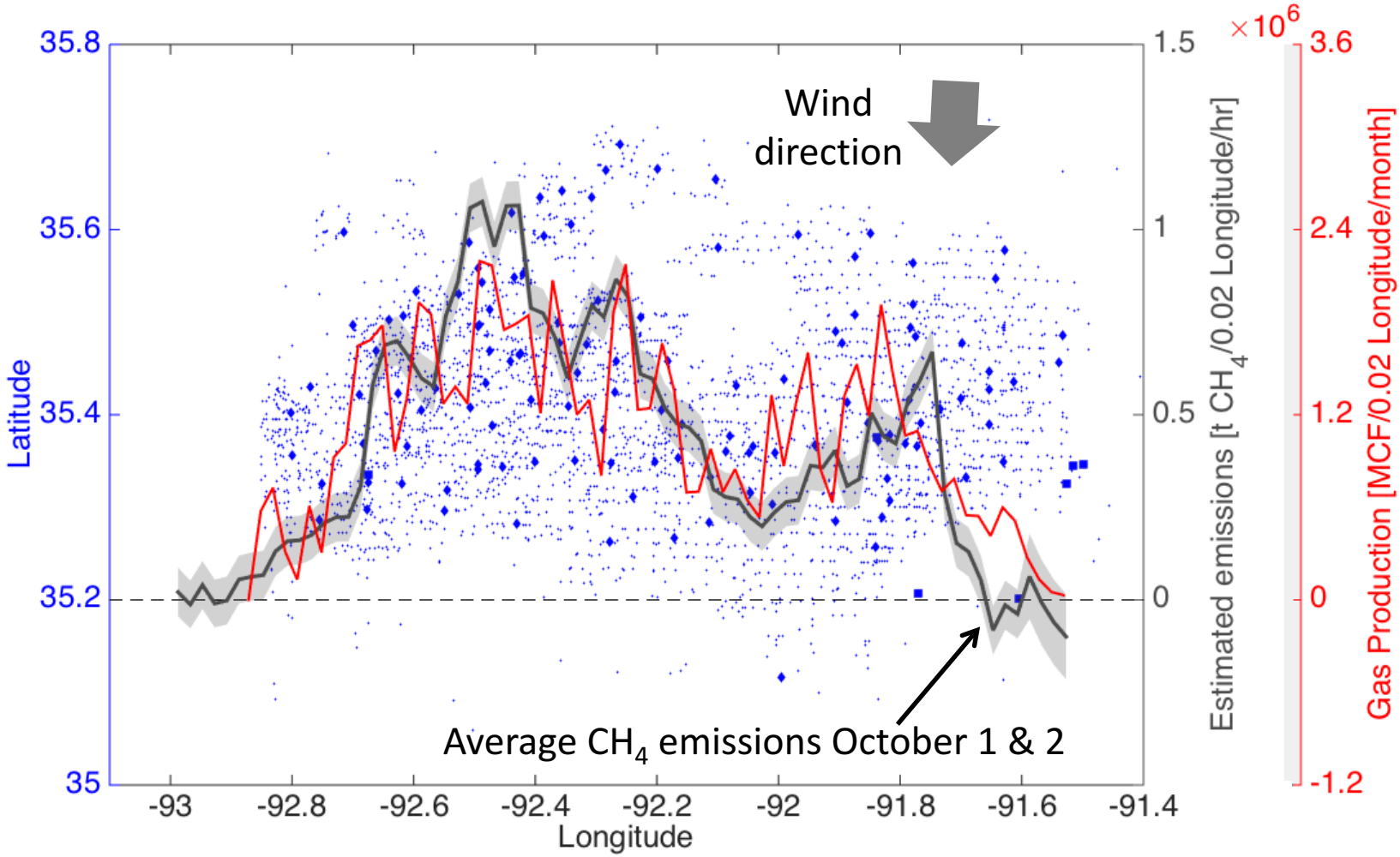
First spatially-resolved aircraft-based CH_4 emission estimates for a basin

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

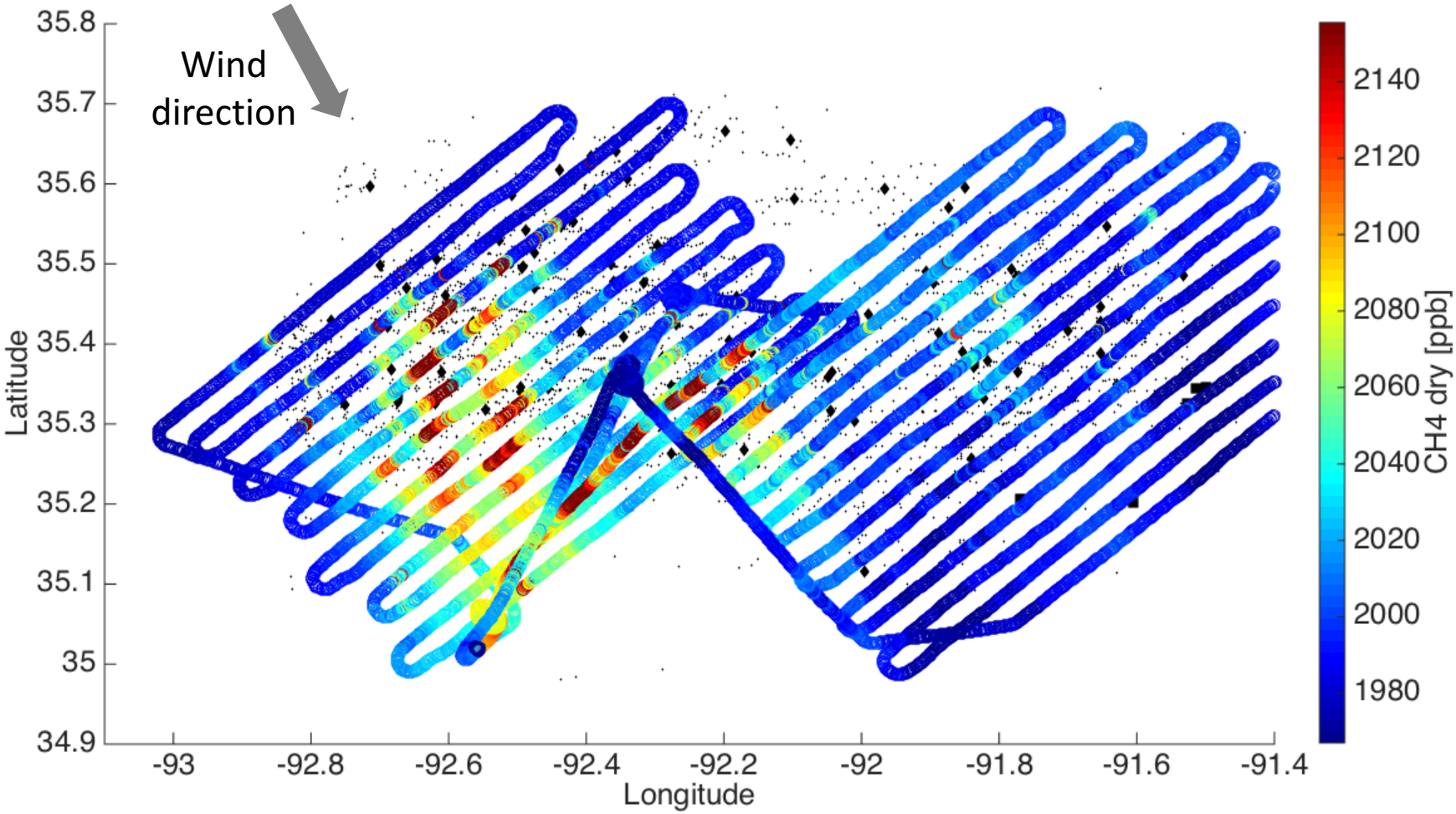


First spatially-resolved aircraft-based CH_4 emission estimates for a basin

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

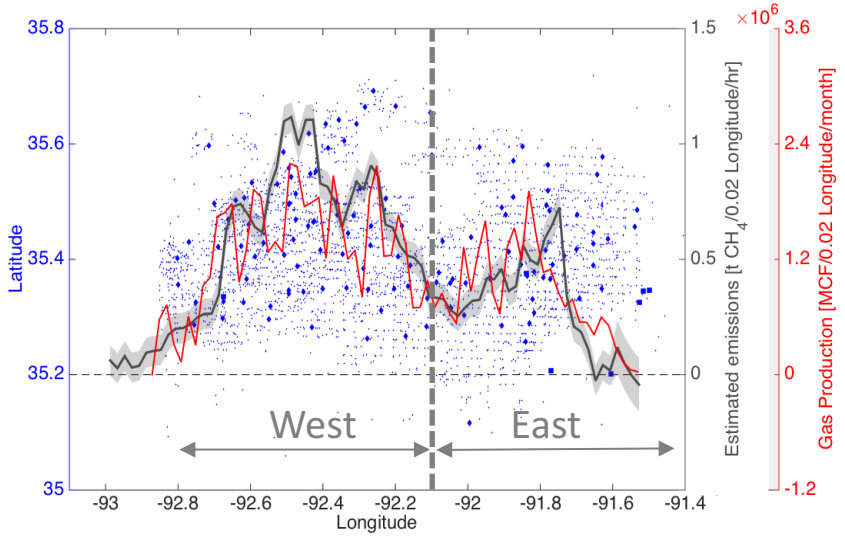


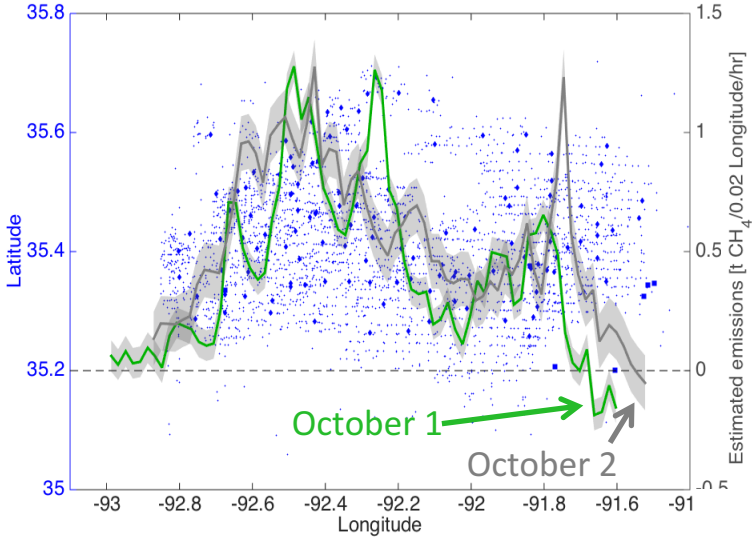
Raster flights on other days further confirm the spatial emission pattern

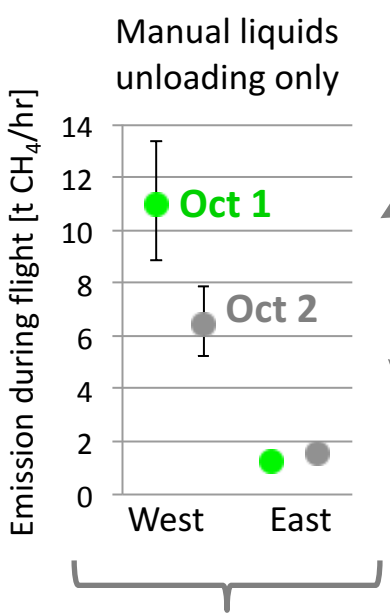


Substantial episodic emissions midday during aircraft sampling

Gas production normalized CH_4 emissions ("leak rate") in the West double compared to East







Hourly activity data

Allen et al. (2014) manual liquids un-loadings measurem.

- About 1/3 of total CH_4 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)

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