Quantifying Carbon Emissions from Oil and Gas Production Regions in the US

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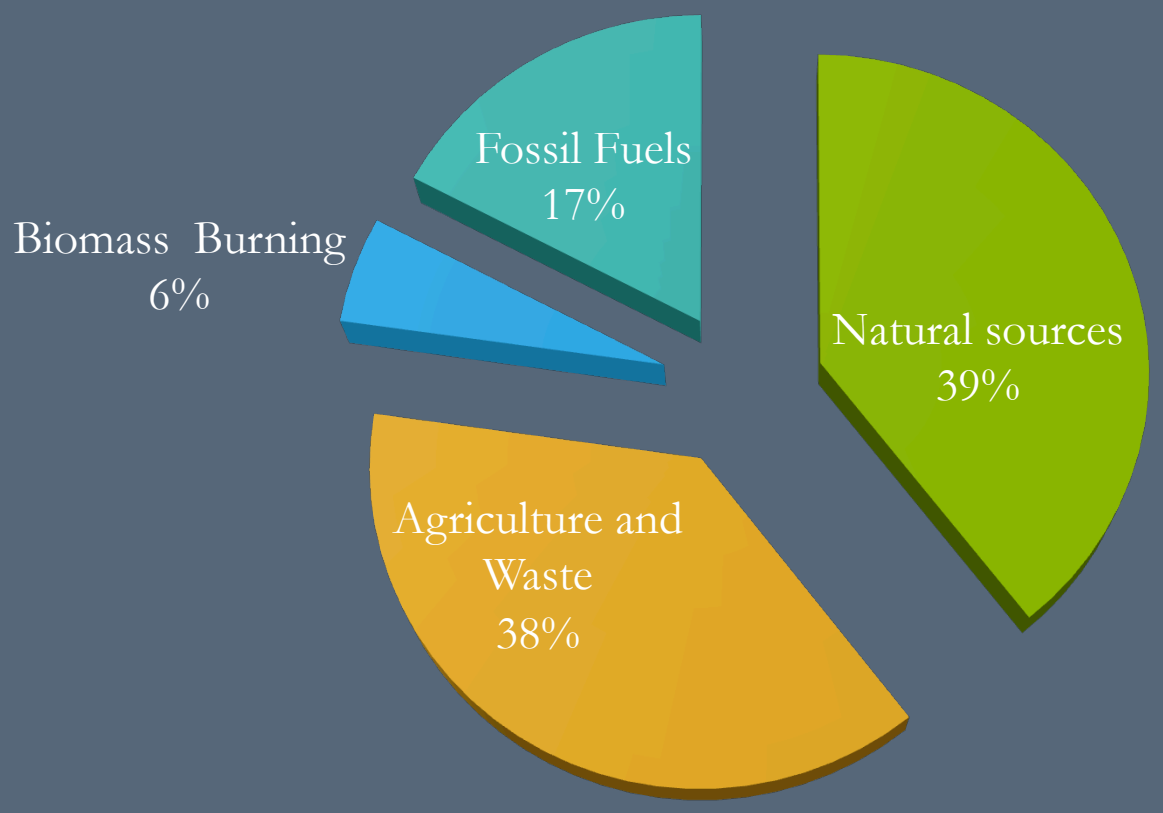
Thomas Lauvaux (NASA/JPL)

NACP All-Investigator Meeting, Jan 26-29, Washington, DC

Photo: Uinta Basin, UT credit: David Oonk, CIRES

Global Emissions of Methane



Total: 526-569 Tg yr^{-1}

Fossil: 77-123 Tg yr^{-1}

[Top Down Estimates for 2000-2009]

Kirschke et al., 2013, Nature Geo.

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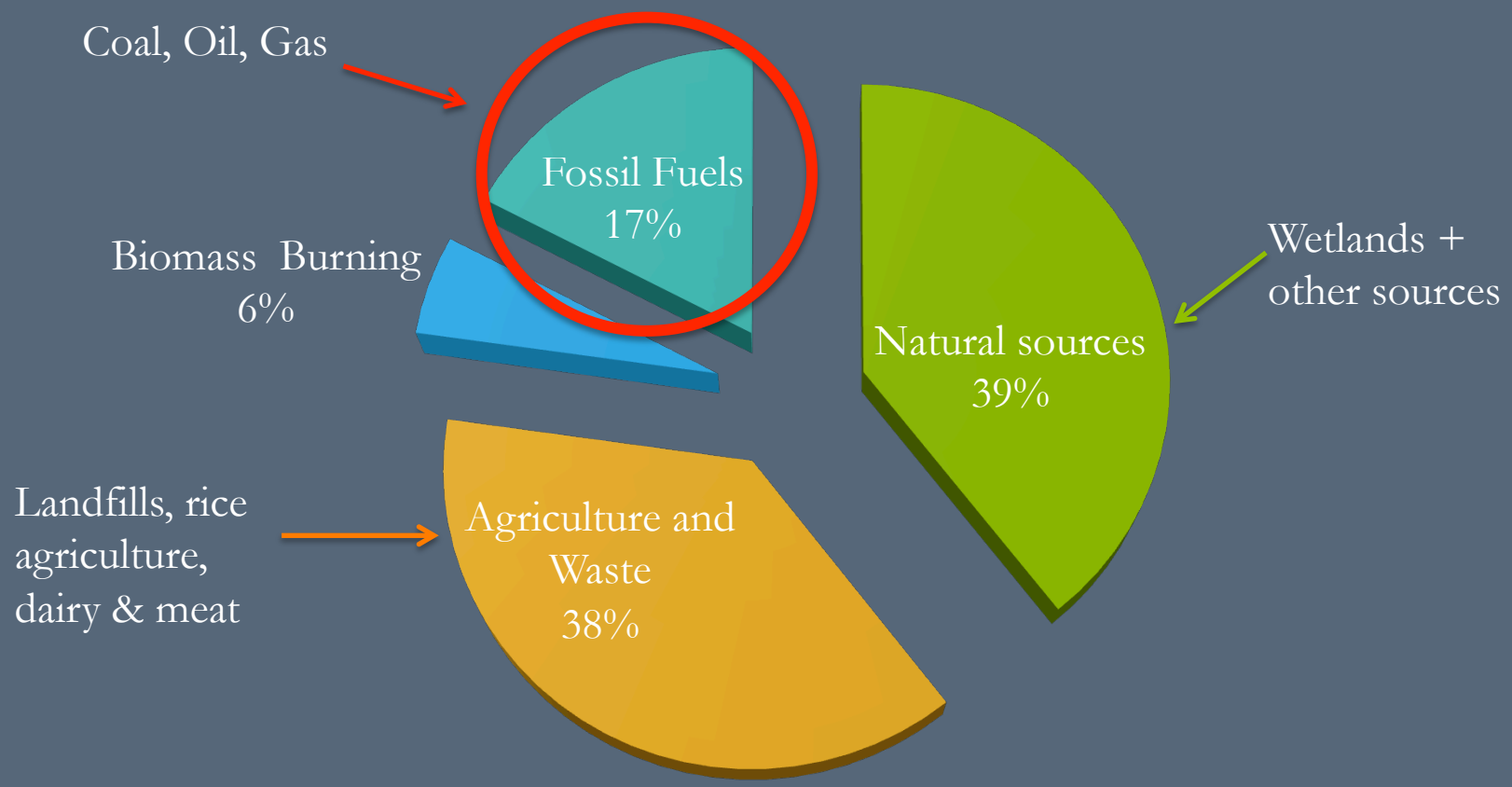

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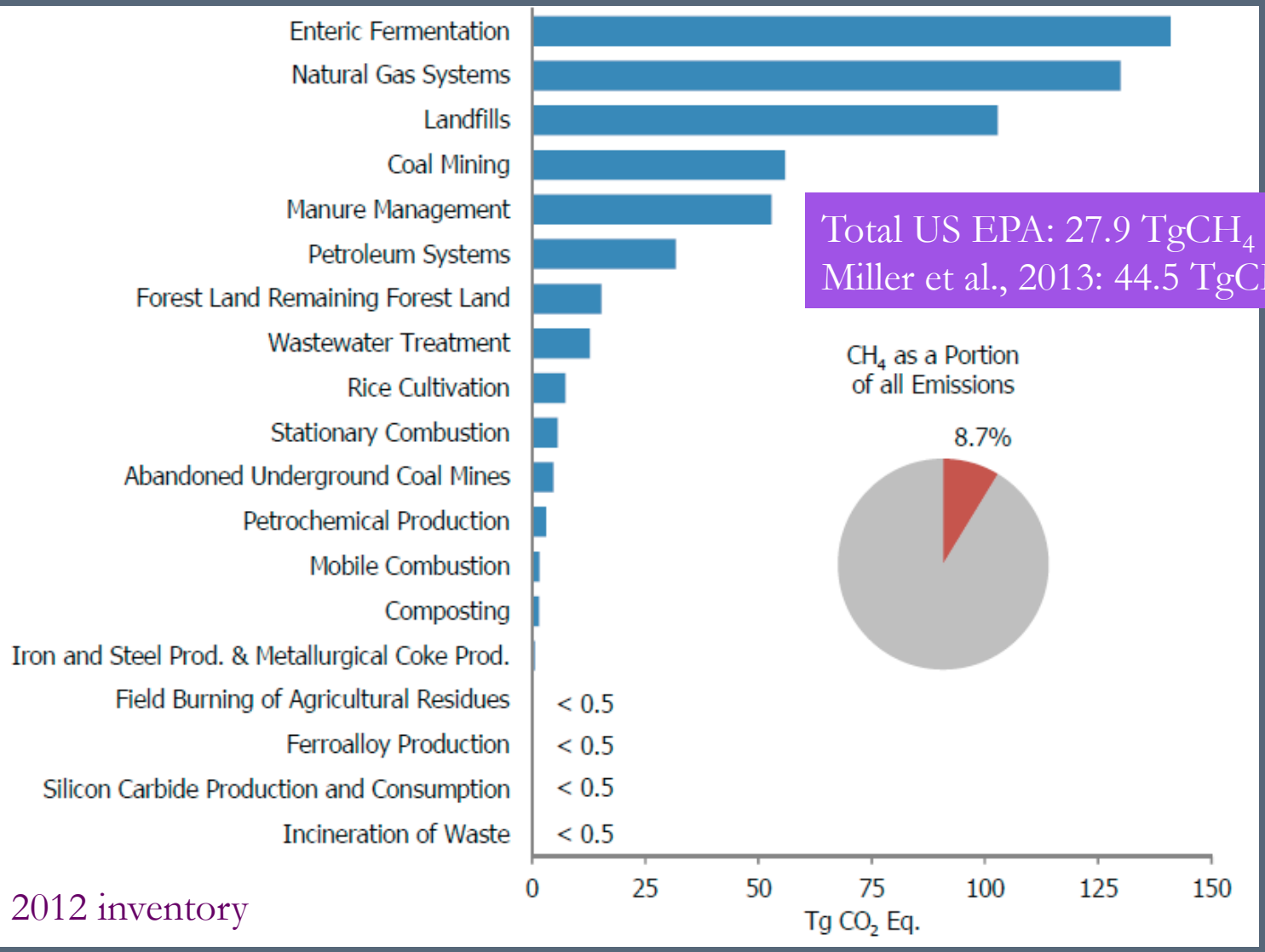
EPA GHG Inventory of US Emissions (Anthropogenic)

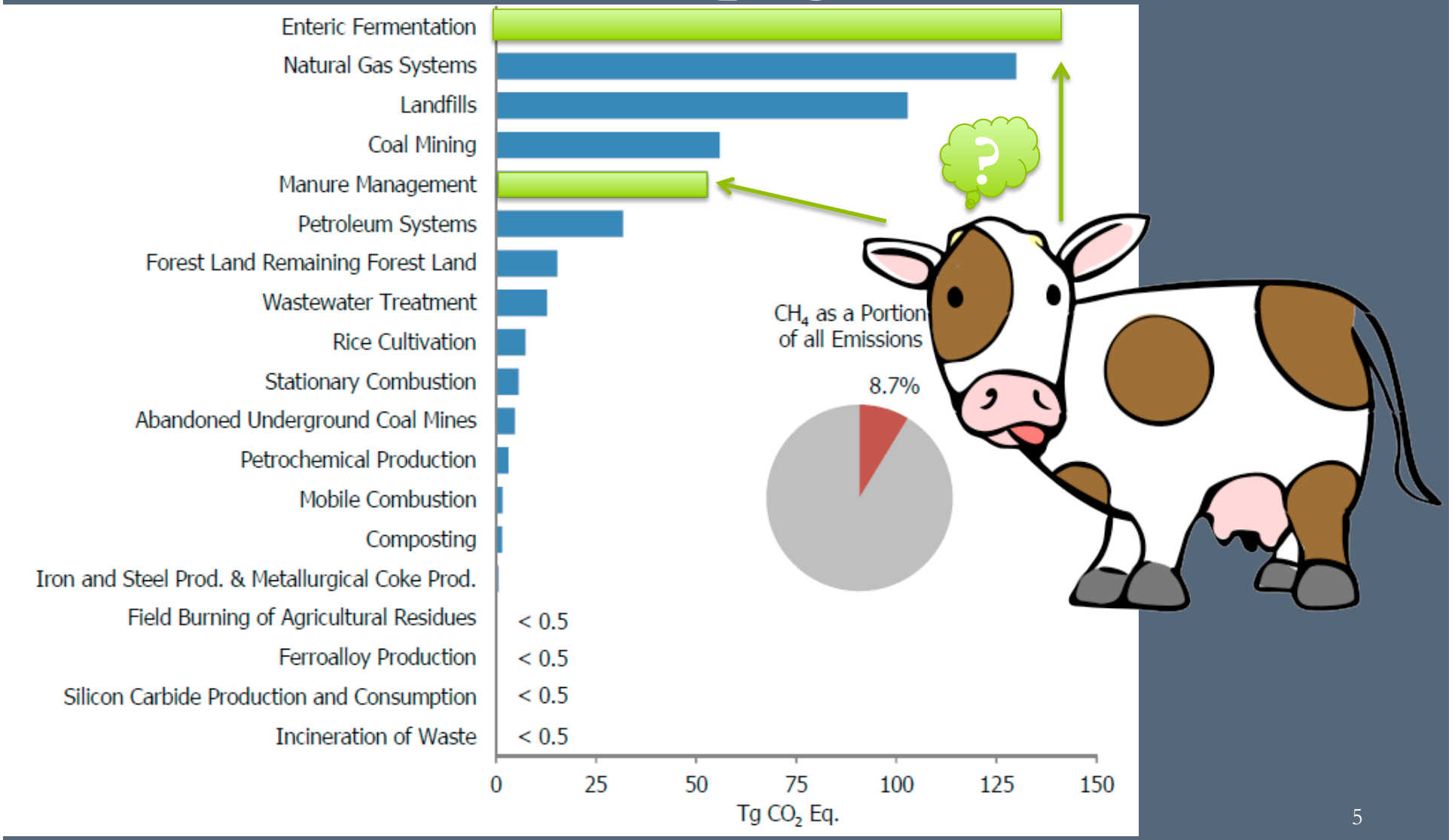


Total US EPA: 27.9 $TgCH_4$ (2010)
Miller et al., 2013: 44.5 $TgCH_4$ (2010)

2012 inventory

US EPA, 2014, Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2012

EPA GHG Inventory of US Emissions (Anthropogenic)



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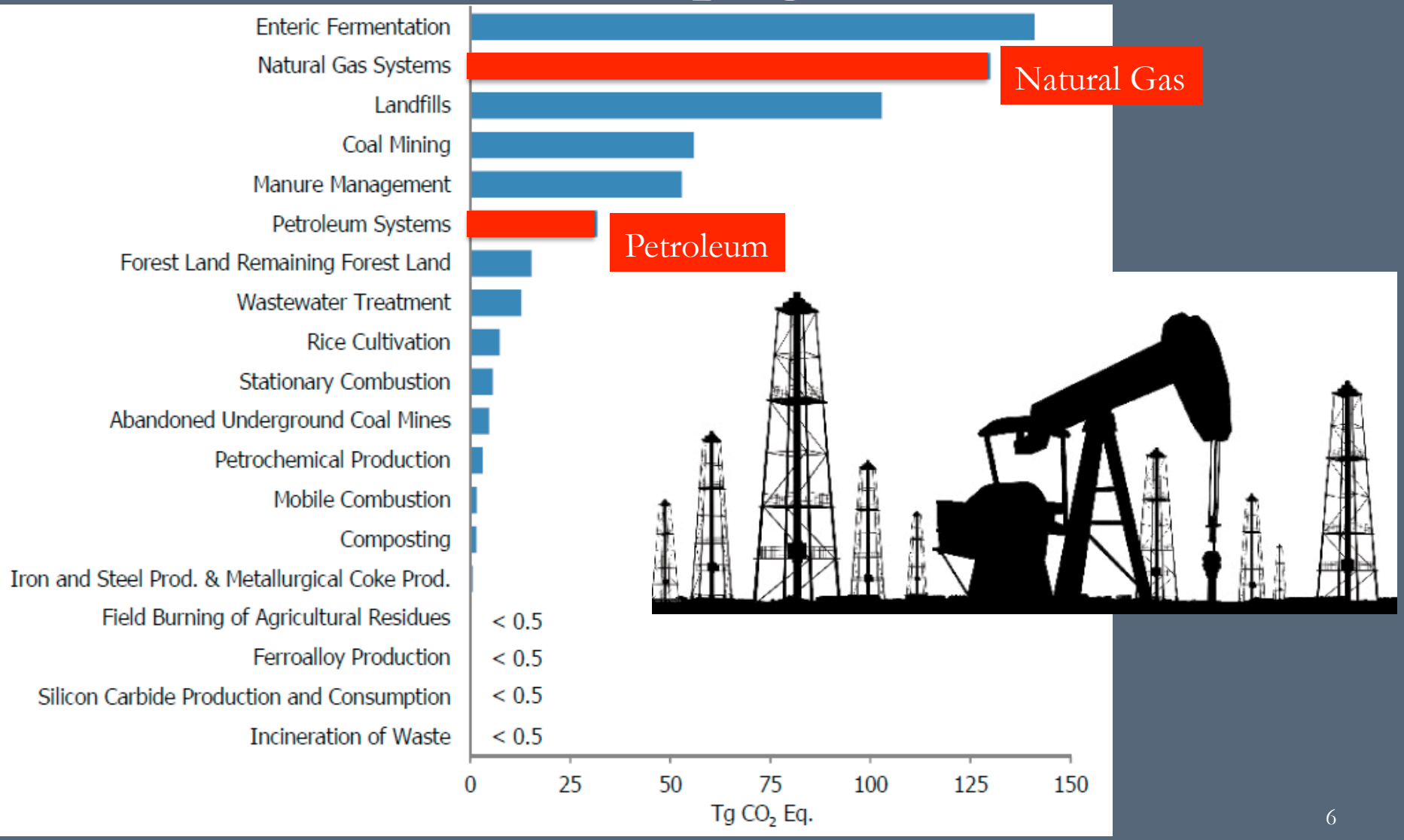
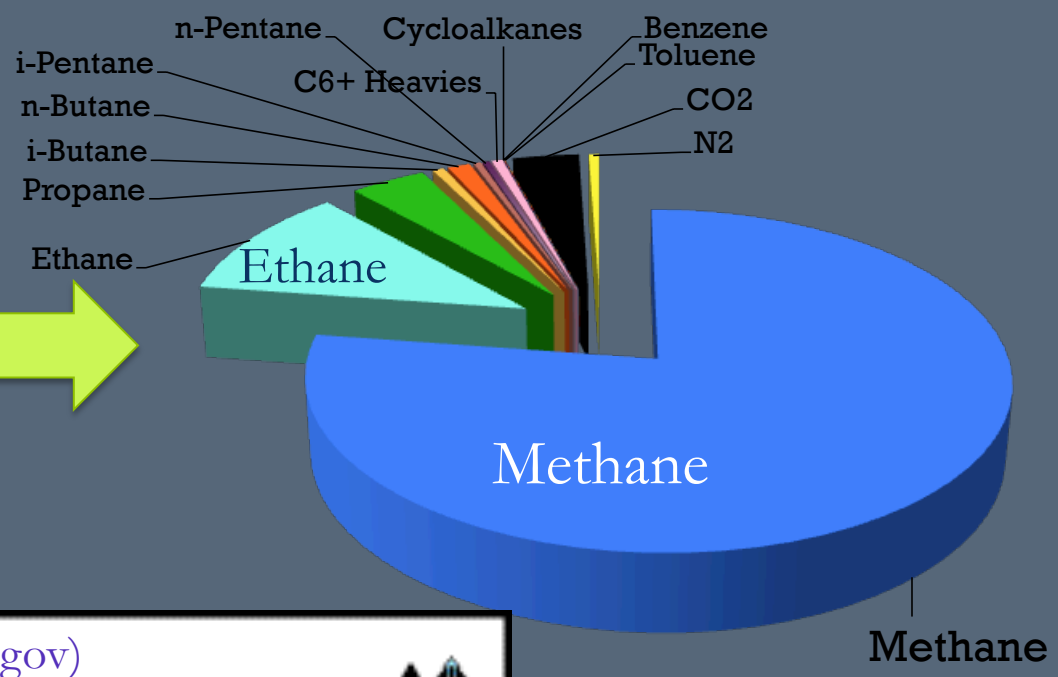
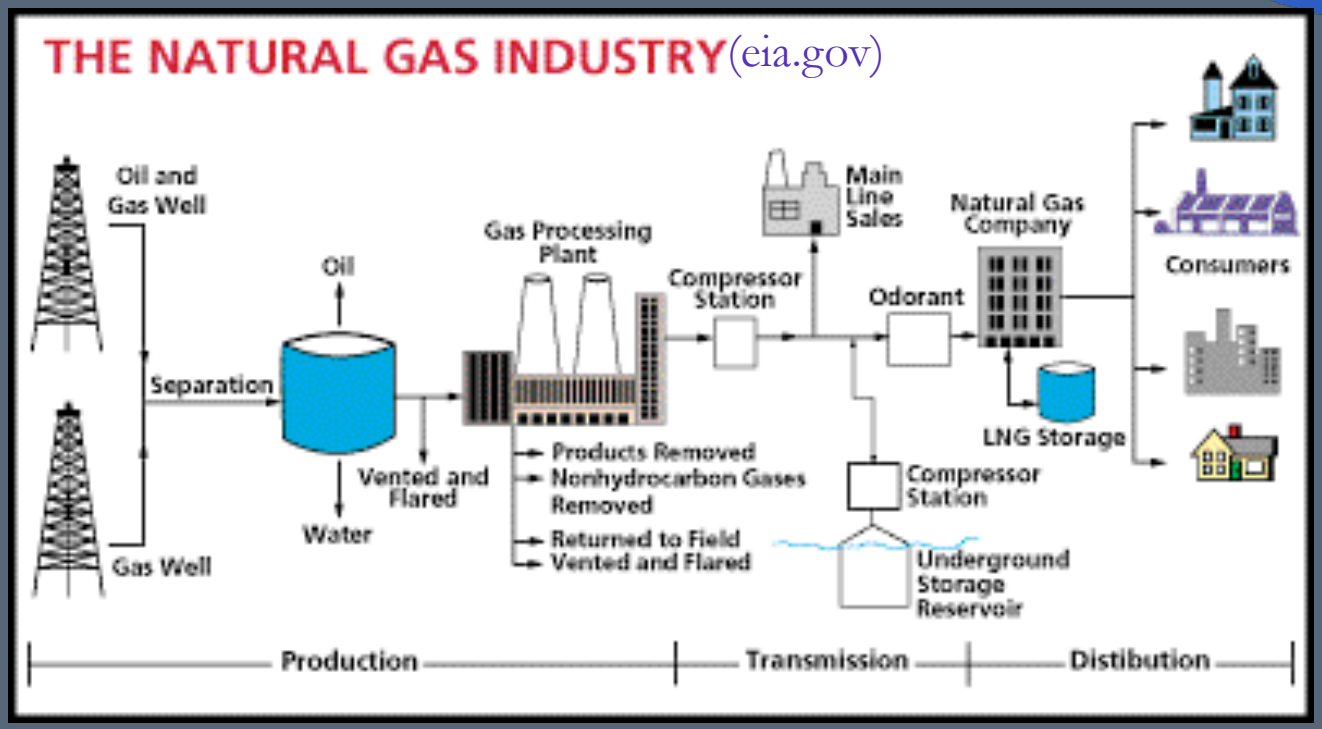


Raw gas is composed of 70-90% methane

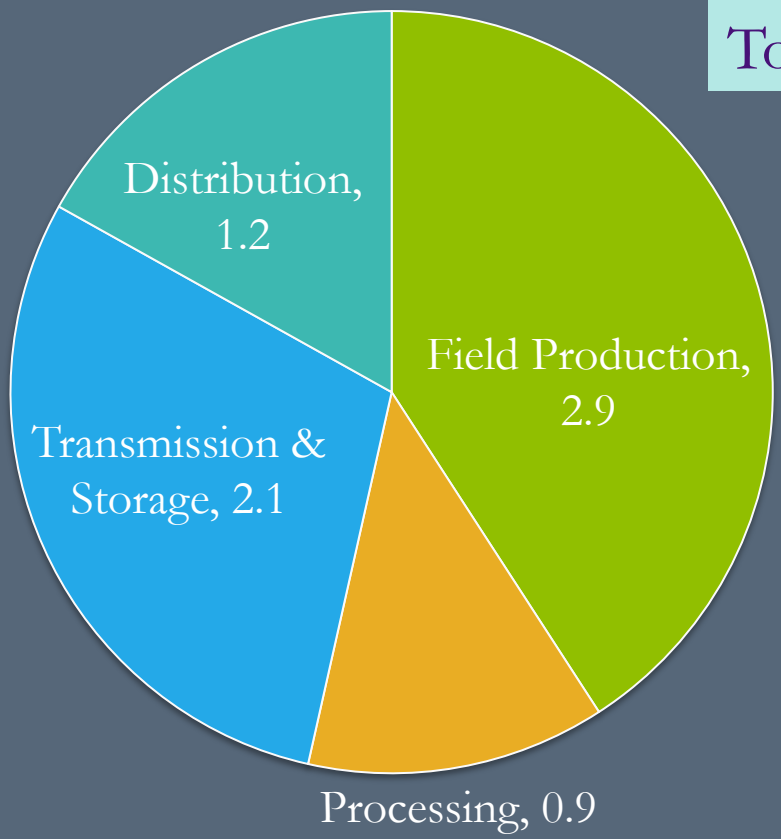




Slide: G. Pétron

Distribution gas is >90% methane

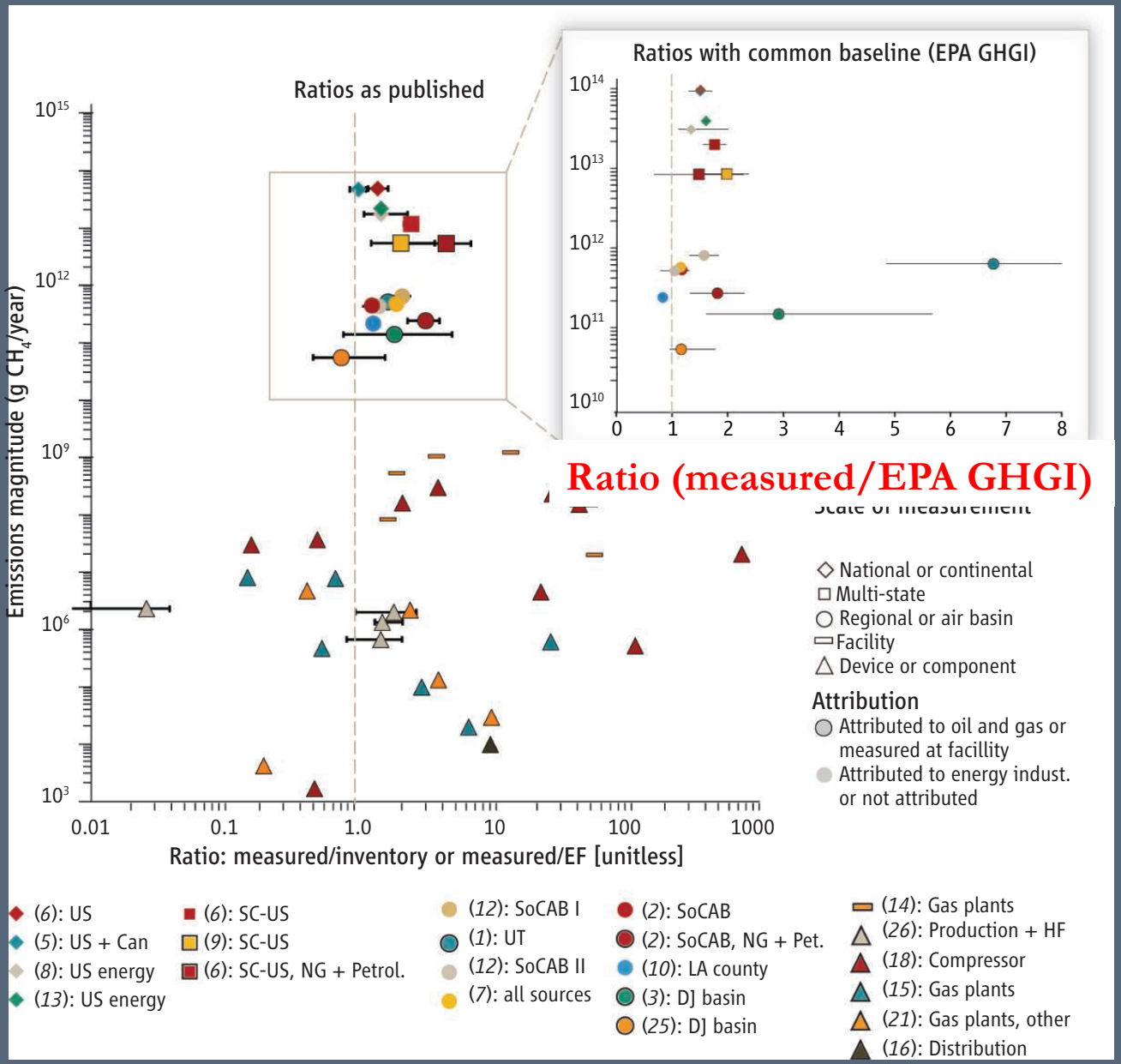
CH_4 Emissions (Tg/yr) from Natural Gas Systems (EPA GHGI 2012)



Total NGS (EPA): 6.2 Tg CH_4/yr

Total US EPA: 27.0 TgCH_4 (2012)
Miller et al., 2013: 44.5 TgCH_4 (2010)

Inventories and emissions factors consistently underestimate actual measured CH_4 emissions from natural gas across scales.



Brandt et al., 2014, Science

NOAA aircraft mass balance study regions

Bakken, ND
Oil

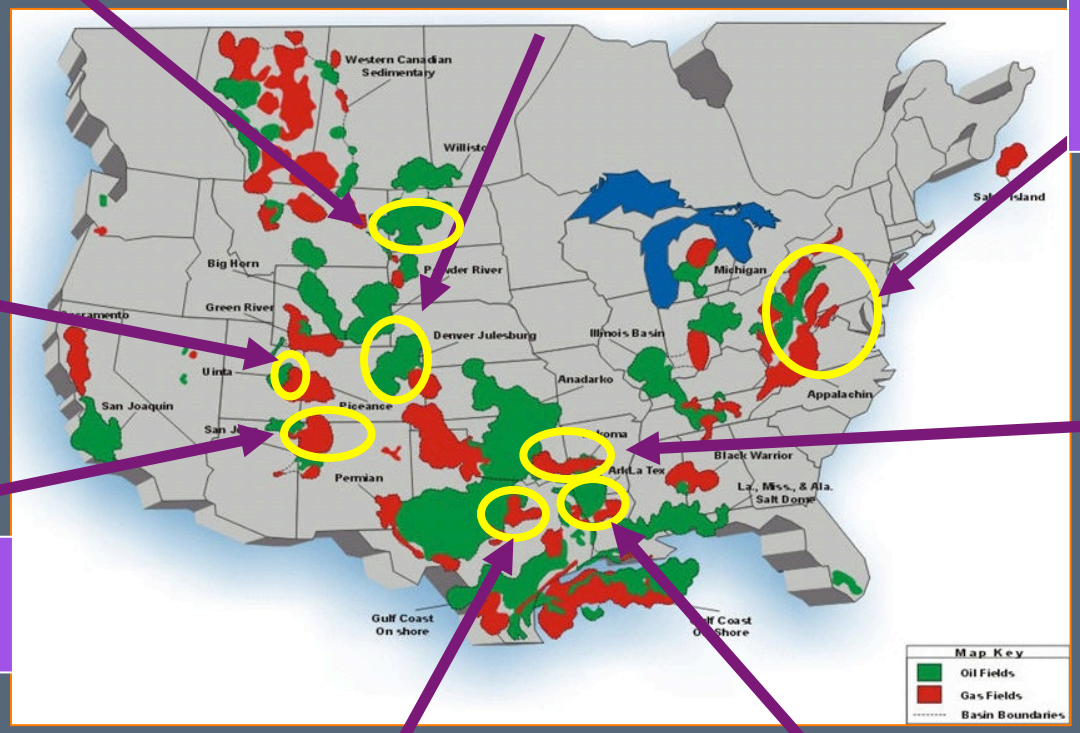
Denver Julesburg, CO
1% of national production

Marcellus, PA/NY
17% of national production

Uinta, UT
1.5%

Fayetteville, AR
6%

San Juan, CO/NM
Coal bed



Barnett, TX
7%

Haynesville, LA/TX
9%

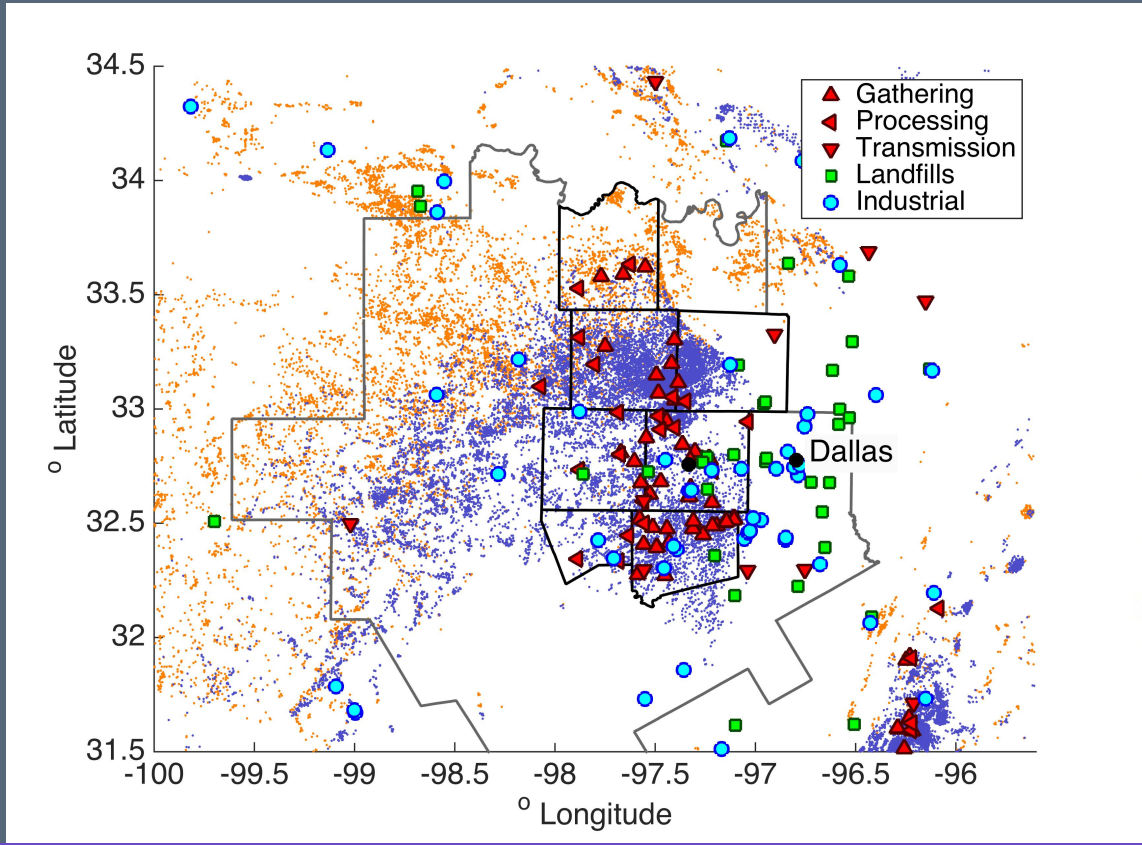
>35% US total natural gas production

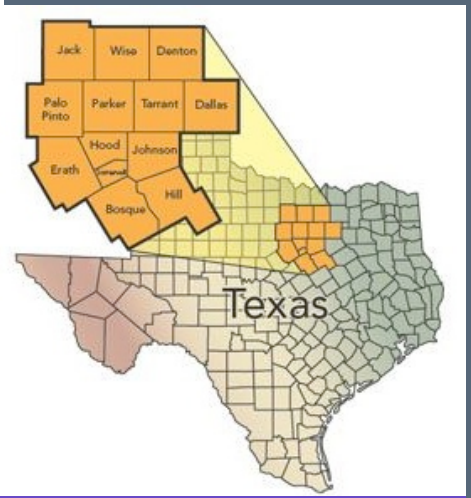
>70% of shale gas production

Environmental Defense Fund's

Barnett Coordinated Campaign

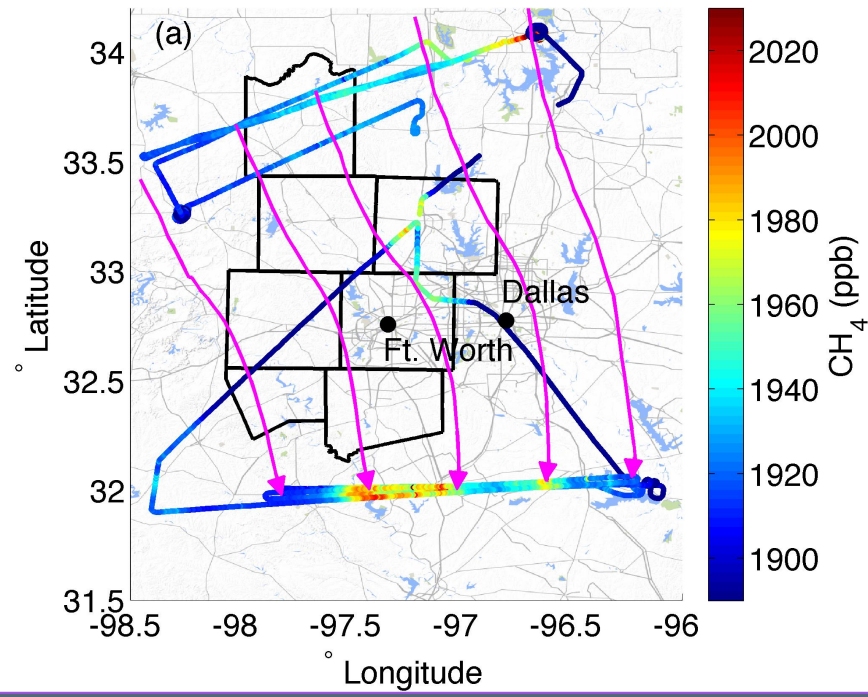
Top-down and bottom-up reconciliation effort with intensive ground measurements.

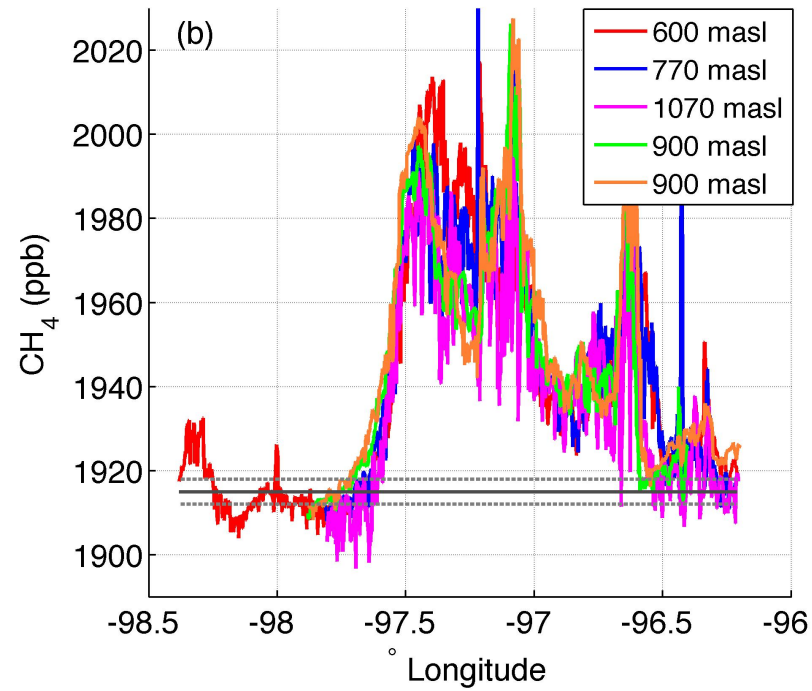




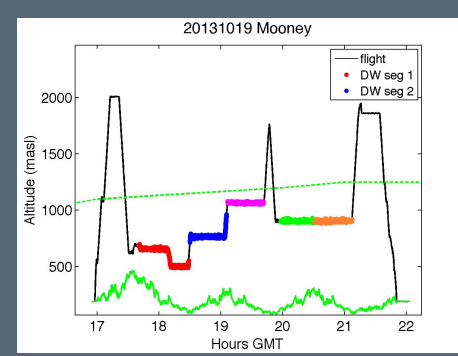
Variety of source types are spatially overlapping, making attribution difficult.

Barnett Top-Down CH_4 Emissions Estimate





$$\dot{n}_{CH_4} = V\cos\theta \int_{-b}^{+b} \Delta X_{CH_4} \left(\int_{z_{gnd}}^{z_{PBL}} n_{air}\, dz \right) dx$$



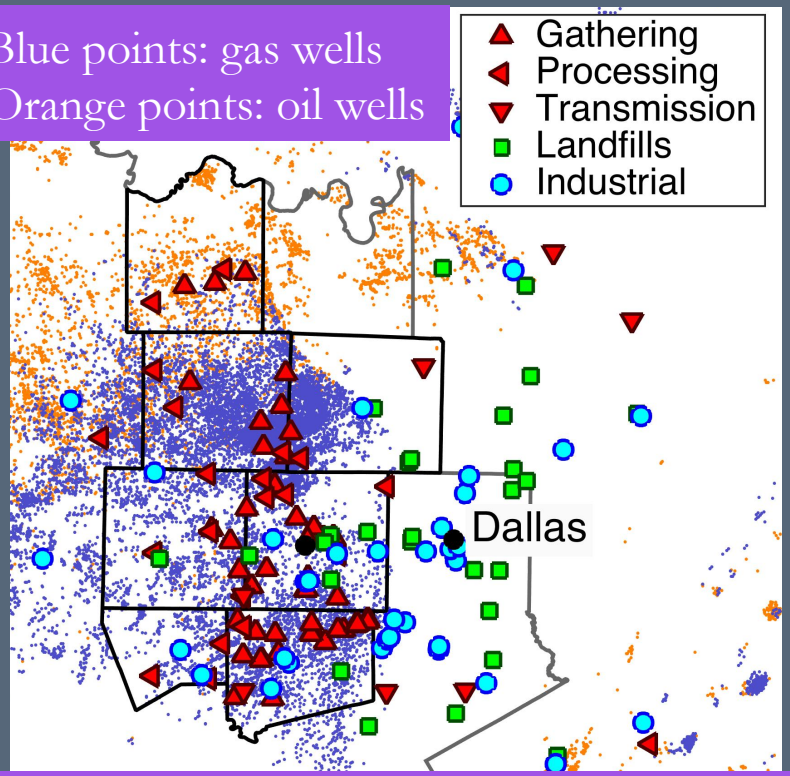
Karion et al., submitted.

Environmental Defense Fund's

Barnett Coordinated Campaign

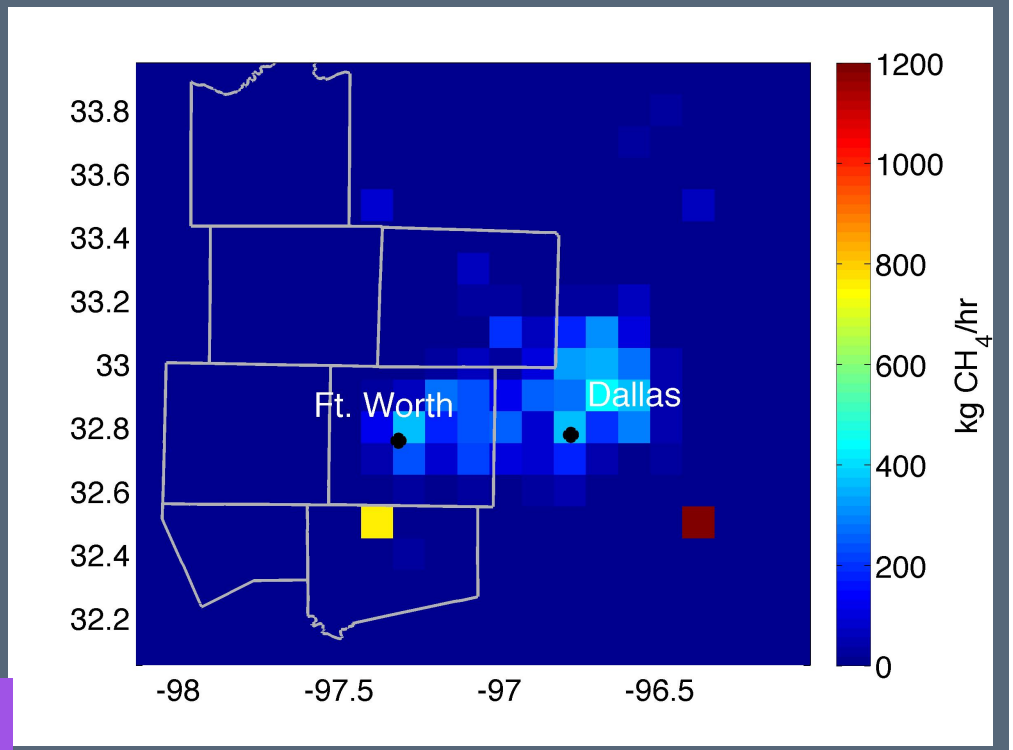
Top-down and bottom-up reconciliation effort with intensive ground measurements.

Blue points: gas wells
Orange points: oil wells



Point sources as reported to EPA's GHGRP Wells from DI Desktop

EDGAR 4.2 2010 Oil and NG Emissions

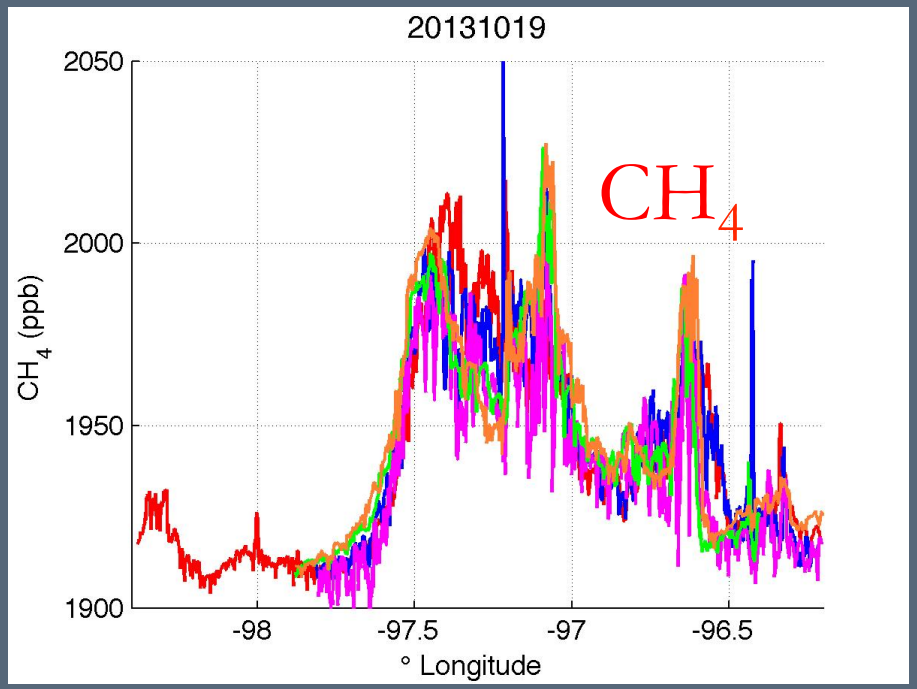


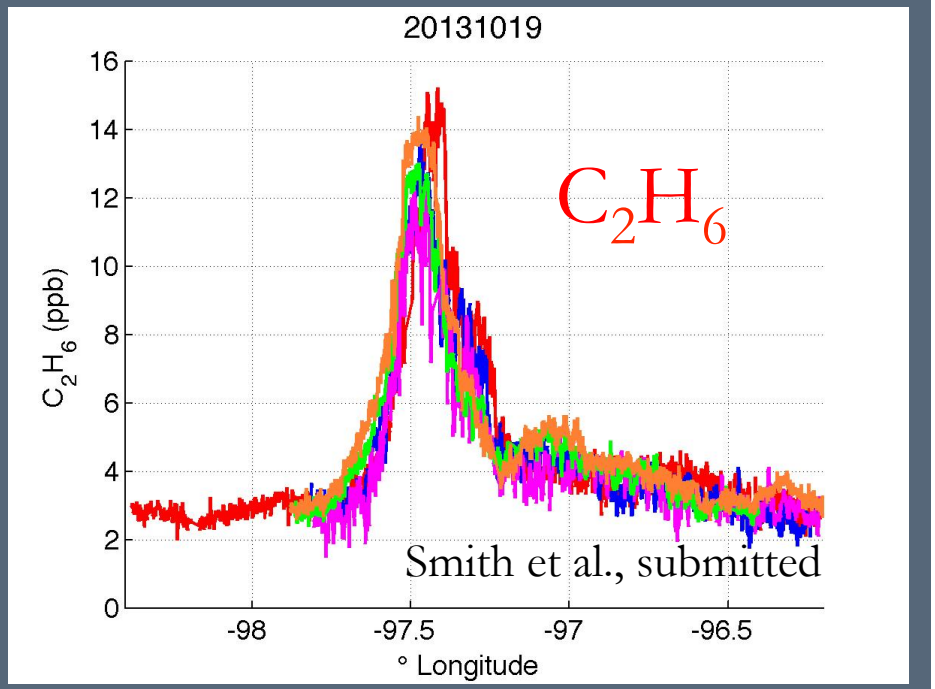
Various CH_4 sources are nearly co-located. Within the NG system, emissions in this region include all segments of the production chain, down to local distribution in urban areas.

Top-down Source Type Attribution

- Prior CH_4 estimates based on inventories often have incorrect spatial patterns
  - introduce uncertainty in the source attribution of top-down estimates.
- Top-down source type attribution
  - trace gas information and measurements (e.g. ethane or methane isotopes).
  - measurements at different scales

Top-down Source Type Attribution





Continuous ethane measurements from aircraft in the Barnett Shale.
(Yacovitch et al., ES&T, 2014; Smith et al., submitted.)

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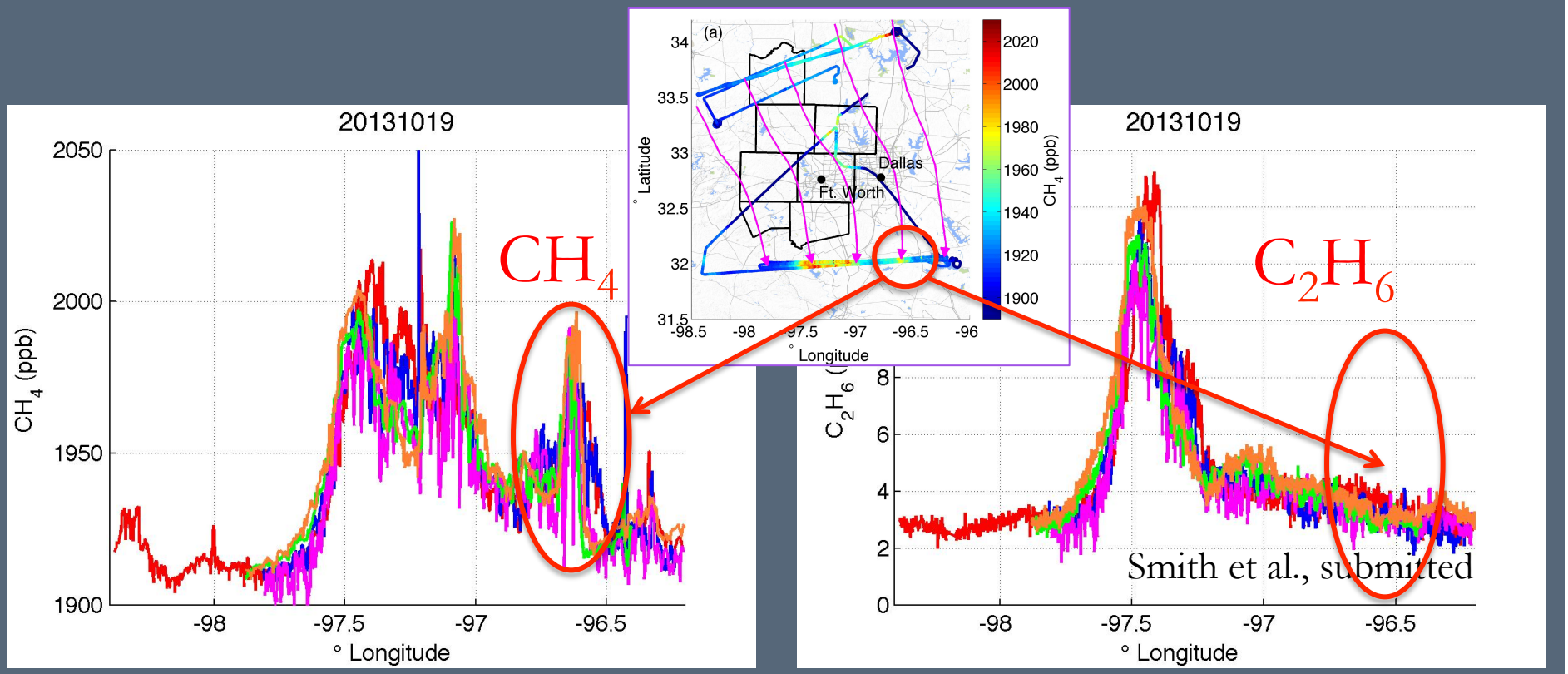

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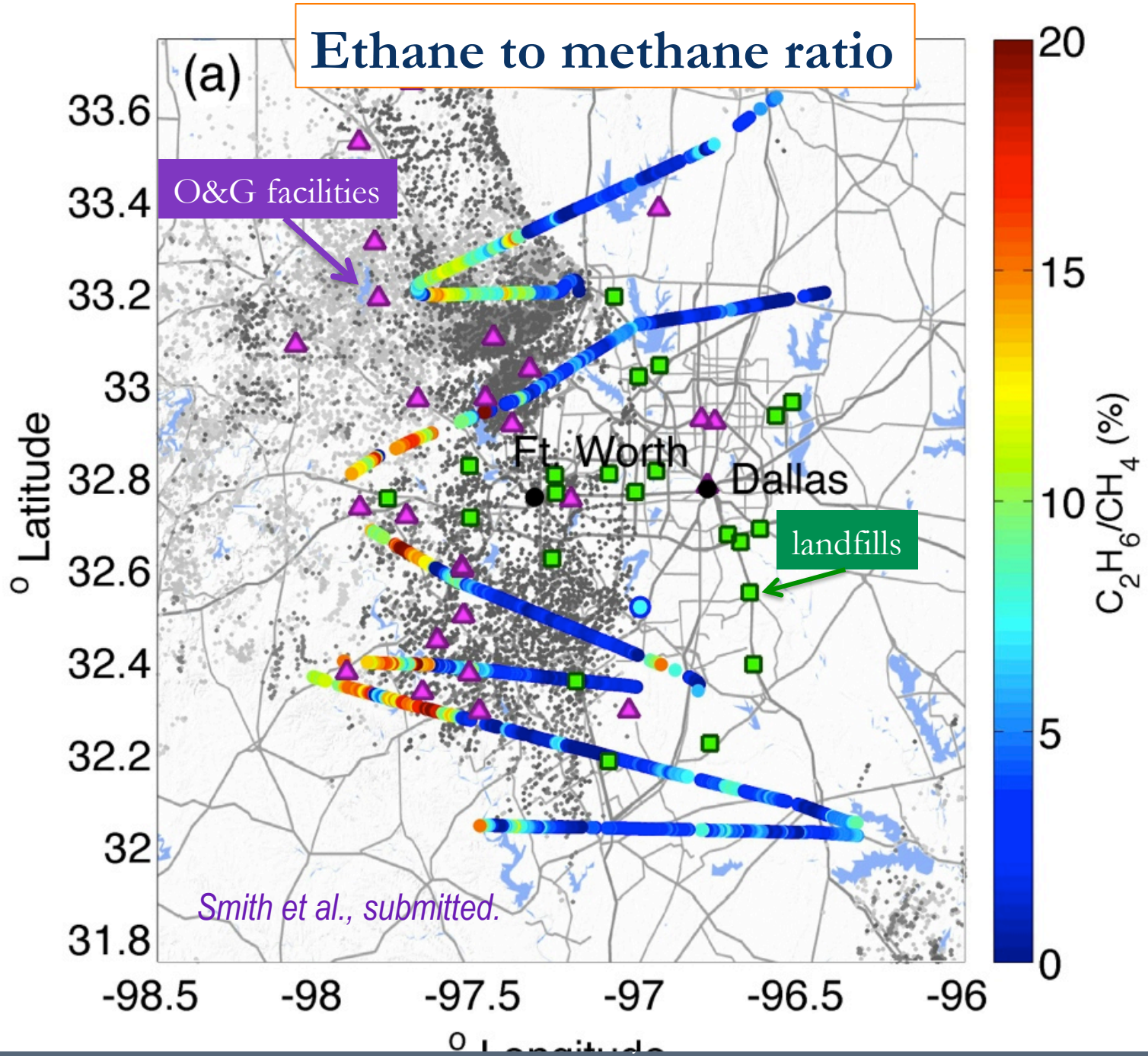
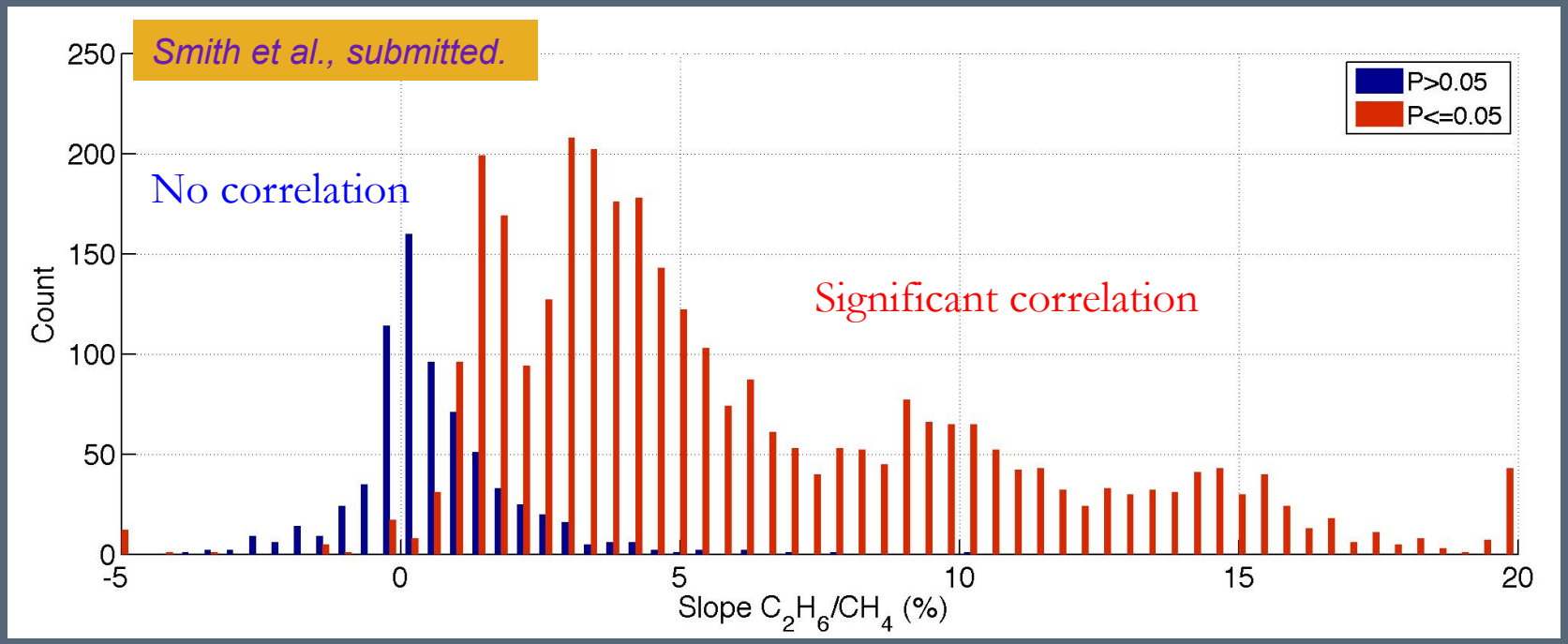
Ethane to methane ratio



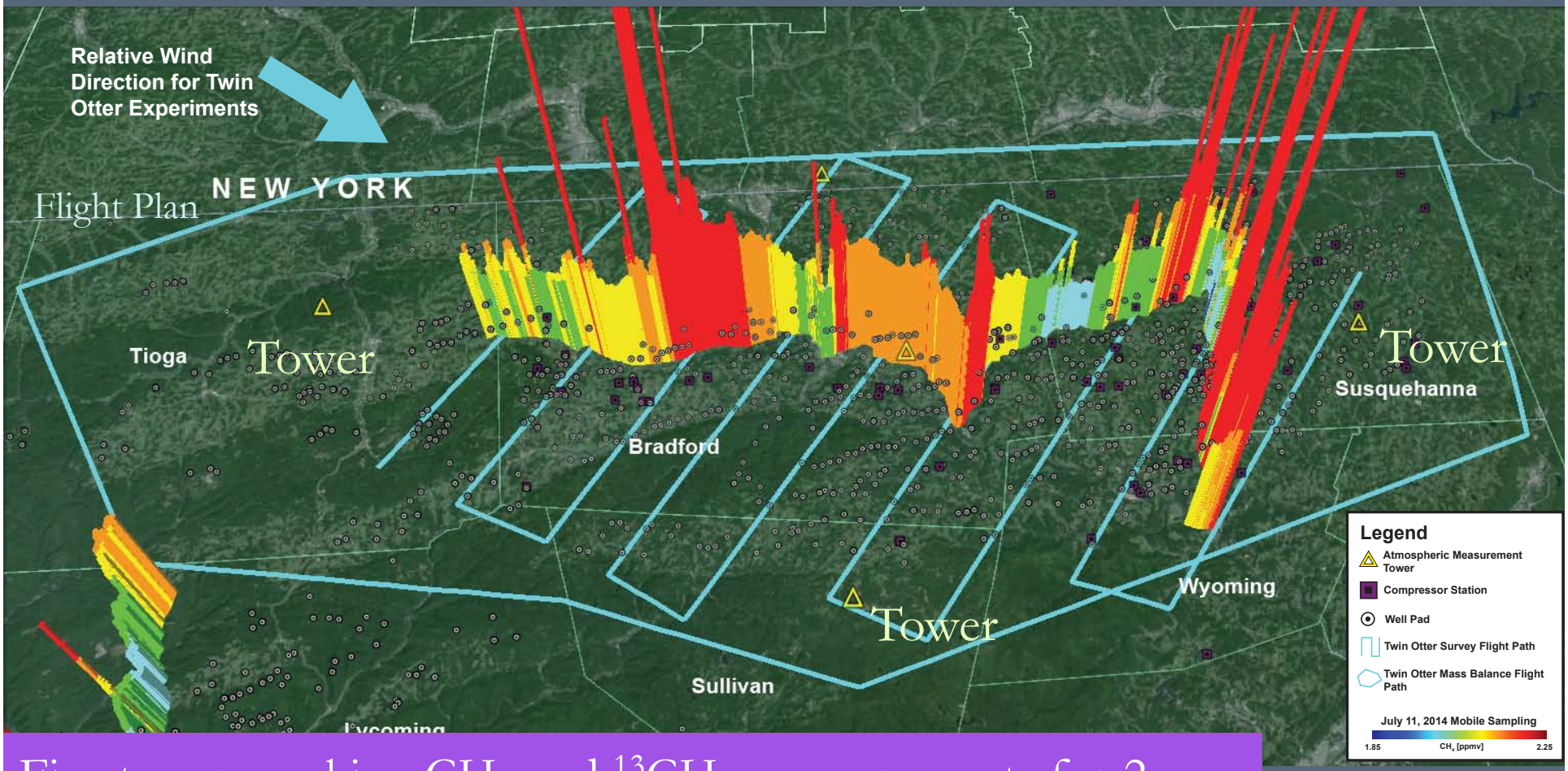
Gray dots = wells with gas production

Correlations of C_2H_6 with CH_4



Use the sum of CH_4 that does NOT correlate with C_2H_6 (blue) to establish contribution from biogenic sources: 15-29%.

North-East PA: Marcellus Shale Project



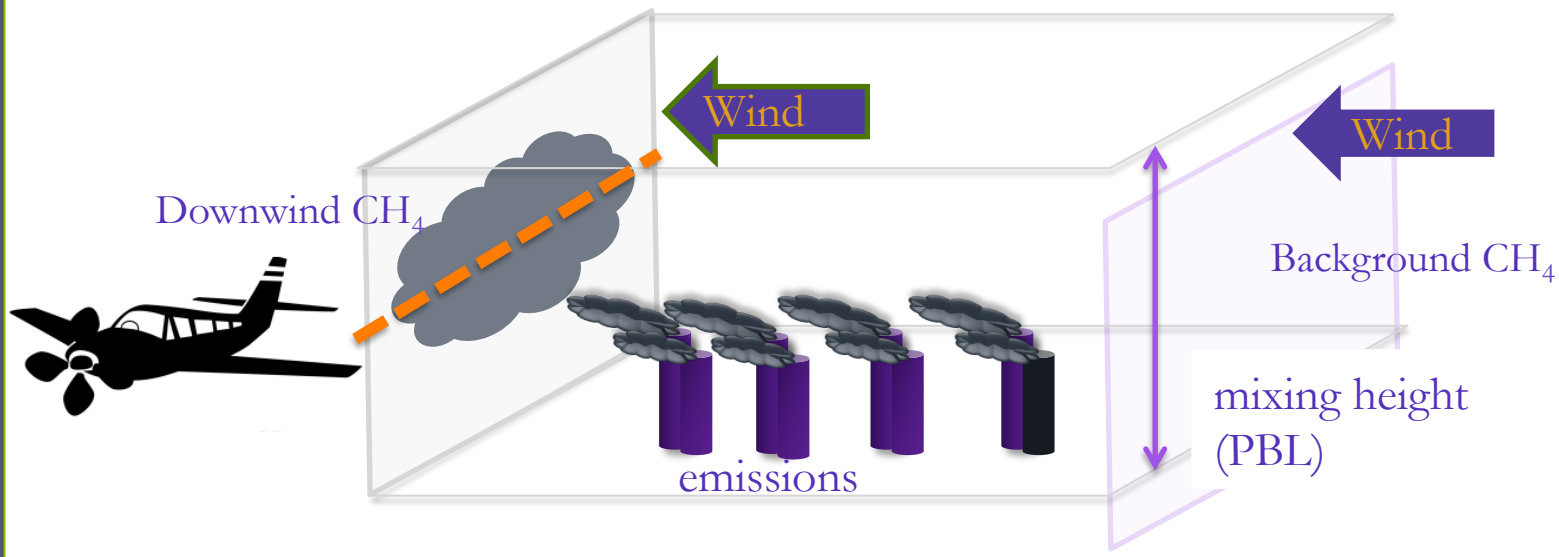
Five towers making CH_4 and $^{13}CH_4$ measurements for 2 years; one aircraft intensive campaign; regional modeling.

Figure: Doug Martins. See Poster.

Summary

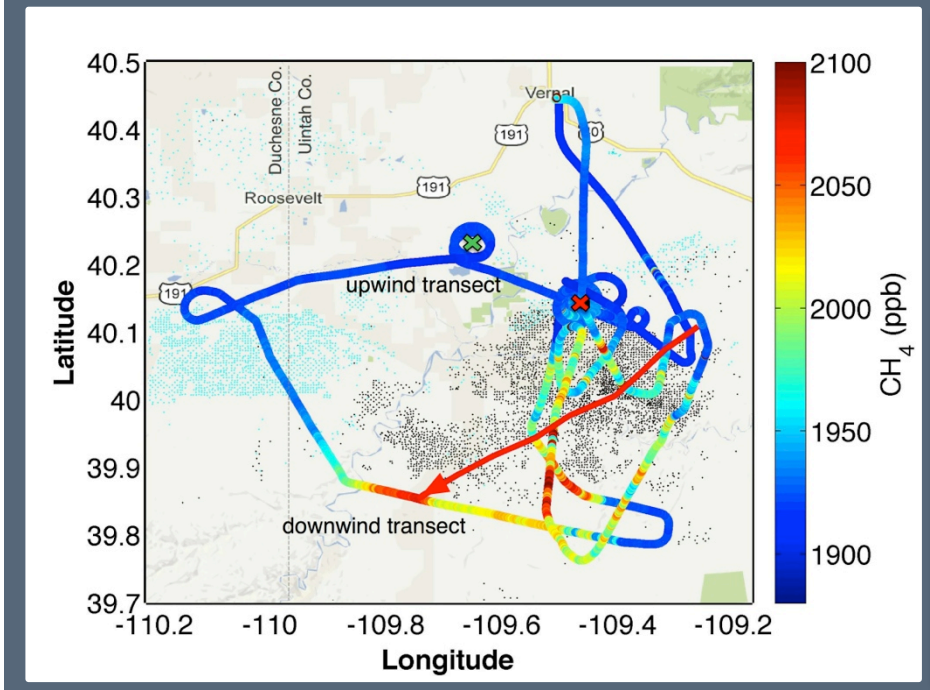
- Top-down measurements are essential for verifying bottom-up inventories.
- Tracer gases ($^{13}CH_4$ or higher hydrocarbons) are the most robust way to accomplish attribution given a lack of spatial separation between different source categories (biogenic vs. fossil).
- Measurements at different scales are necessary to distinguish between different fossil sources (production, processing, distribution).
- Detailed bottom-up inventories are needed to determine where emissions are coming from down to a component level, in order to produce actionable information for policy makers.

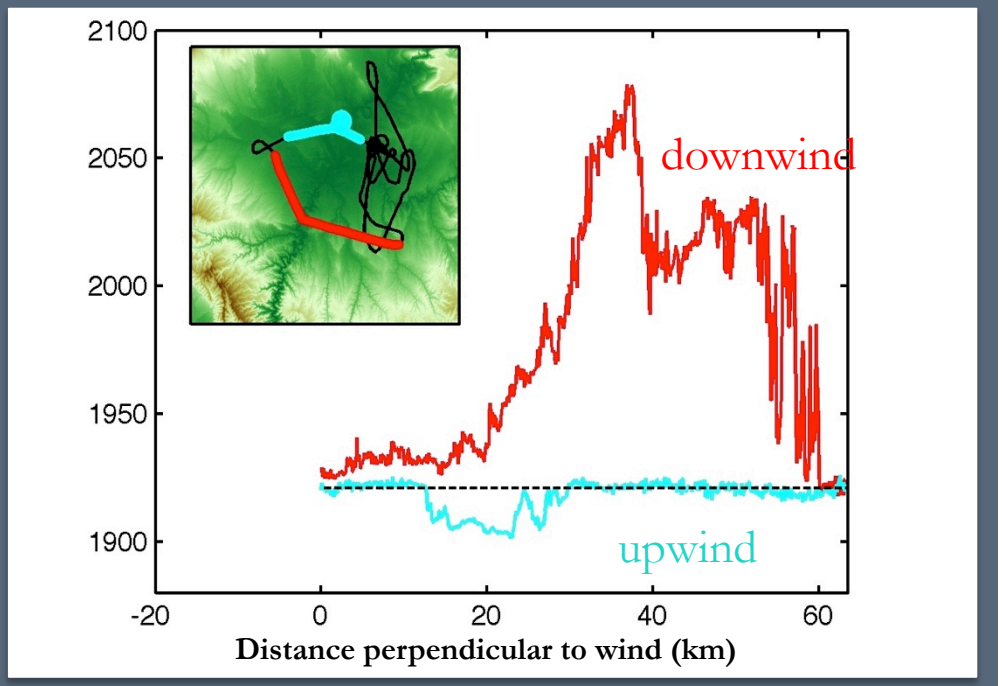
Mass Balance Approach for Emissions Estimation



$$\underbrace{\dot{n}_{CH_4}}_{CH_4\text{ flux}} = \underbrace{V\cos\theta}_{\text{Perpendicular wind speed}} \overbrace{\int_{-b}^{+b} \Delta X_{CH_4} \left(\int_{z_{gnd}}^{z_{PBL}} n_{air}\, dz \right) dx}^{\text{Molar } CH_4 \text{ enhancement in PBL}}$$

Uinta Basin, Utah 2012





Karion, et al., GRL, 2013