Comparison of Top-Down and Bottom-up O&G CH_4 Emission Estimates in Multiple U.S. Basins

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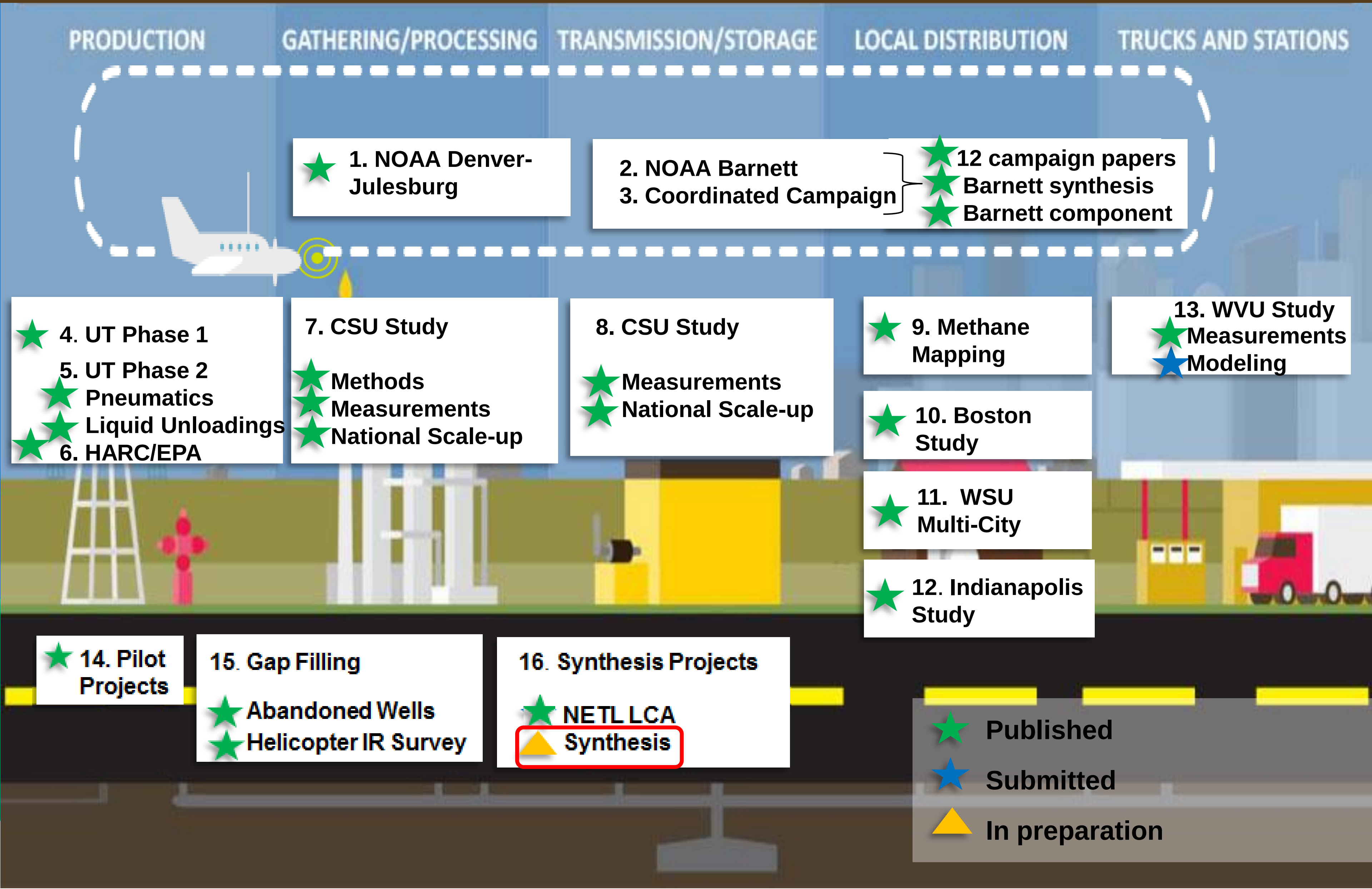
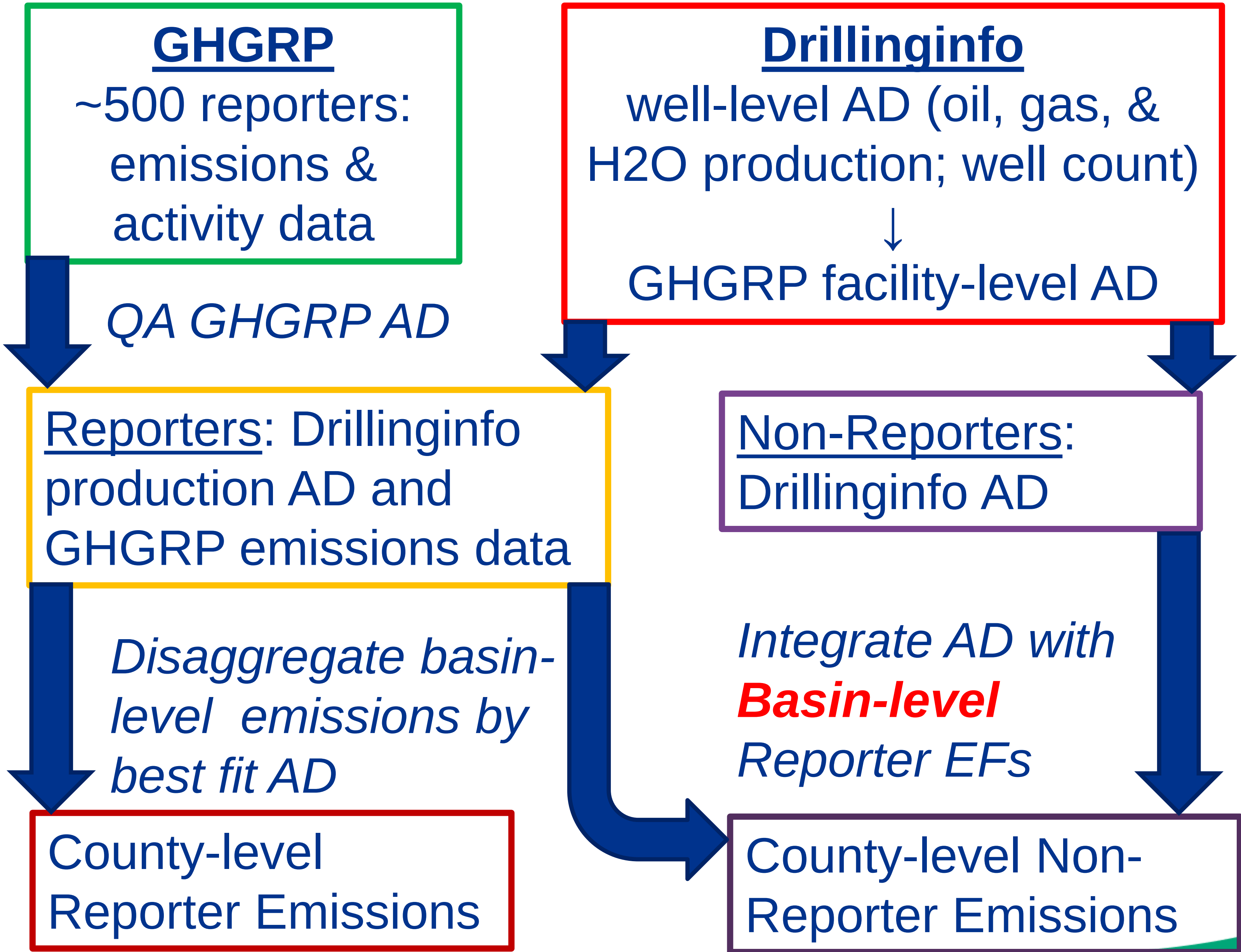
EDF Methane Studies



Custom inventory was developed by integrating recent data sources

- Drillinginfo
  - well-level production data
- GHGRP
  - 2015 onshore production emissions and activity data
- Harvard gridded GHGI (Maasakkers et al 2016)
  - midstream & downstream emissions by 0.1° x 0.1° cells
- Measurement studies
  - Allen et al 2013 (equipment leaks), Allen et al 2014 (pneumatic controllers), Marchese et al 2015 (gathering & processing), Zimmerle et al 2015 (transmission & storage)

Onshore Production Methods

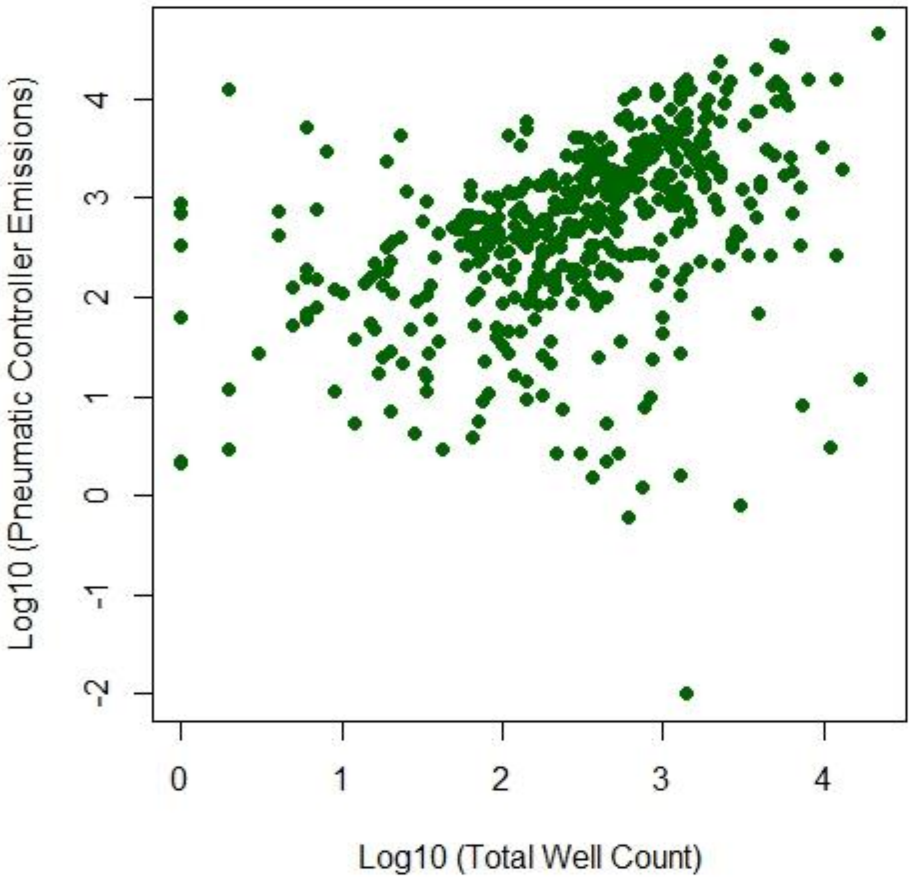


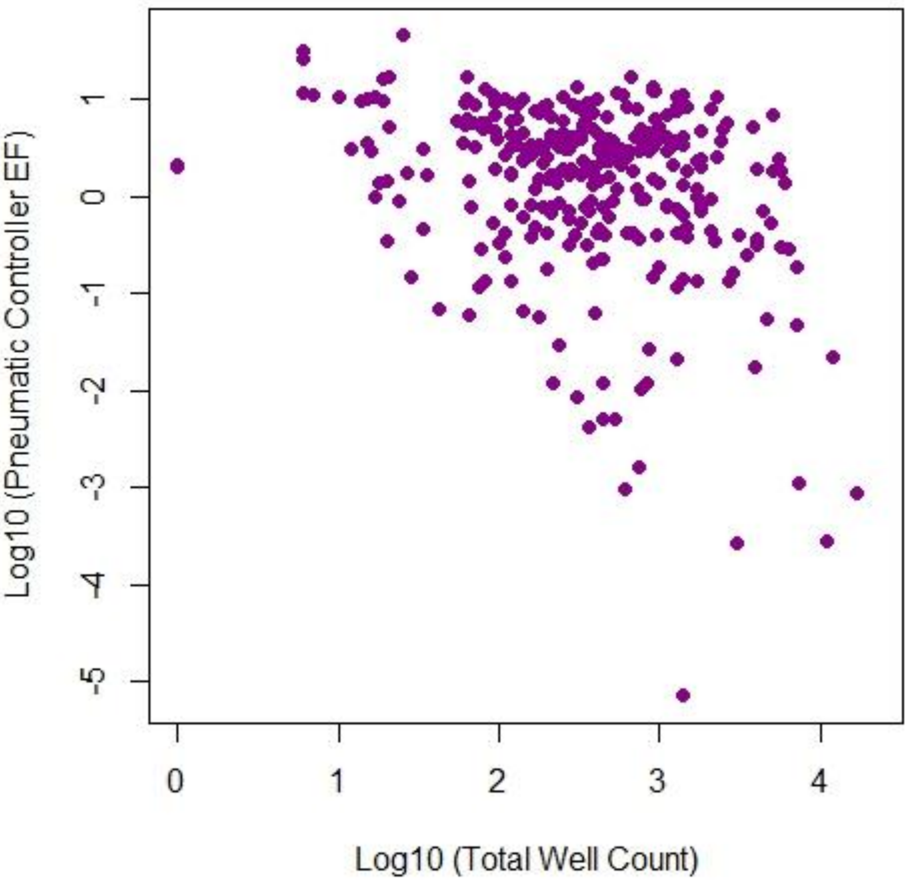
Reporters vs. Non-Reporters

- GHGRP reporters account for ~80% of U.S. O&G production and 50% of active wells
- Reporters' average O&G production per well is 4–5X higher than non-reporters'
- Within reporters, most emission sources have low to moderate *positive* correlation between emissions and at least one activity data parameter
- Within reporters, most emission sources have a *negative* correlation between activity data and AD-normalized EF
- <u>Conclusion</u>: Using reporter EFs for non-reporters results in conservatively low emission estimates

Example: Pneumatic Controllers

Within reporters, total well count is positively correlated with emissions (R = 0.49) and negatively correlated with EFs (R = -0.16)





Revised Emission Estimation Methods

- **Pneumatic controllers**
  - GHGRP AD (controllers by type per well)
  - Allen et al 2014 EFs: high-, low-, intermittent-bleed, and malfunctioning controllers = 2.0, 0.6, 0.2, and 7.3 MT/yr/device, respectively; 7% of devices malfunctioning
- **Equipment leaks**
  - Allen et al 2013 leak data applied using approach of Zavala-Araiza et al 2017
    - Wells aggregated to pads based on lat/long (50 m cluster radius)
    - For gas producing pads, site-level EFs based on Allen et al leak rate distribution and number of leaks per site (by well count)
    - For oil only pads, well-level EF based on GHGRP heavy crude leak emissions

Revised Emission Estimation Methods

- **Produced Water**
  - State-level bbl H_2O/well factors used for states without reported well-level H_2O production
  - TCEQ water flashing EFs (0.74 – 2.6 scf/bbl)
- **Abandoned Wells**
  - Drillinginfo AD and Townsend-Small et al 2016 EFs
- **Gathering Stations**
  - Marchese et al 2015 state-specific loss rates
  - Station emissions augmented ~20% based on Barnett Synthesis to account for underestimates from incomplete plume capture during tracer flux correlation

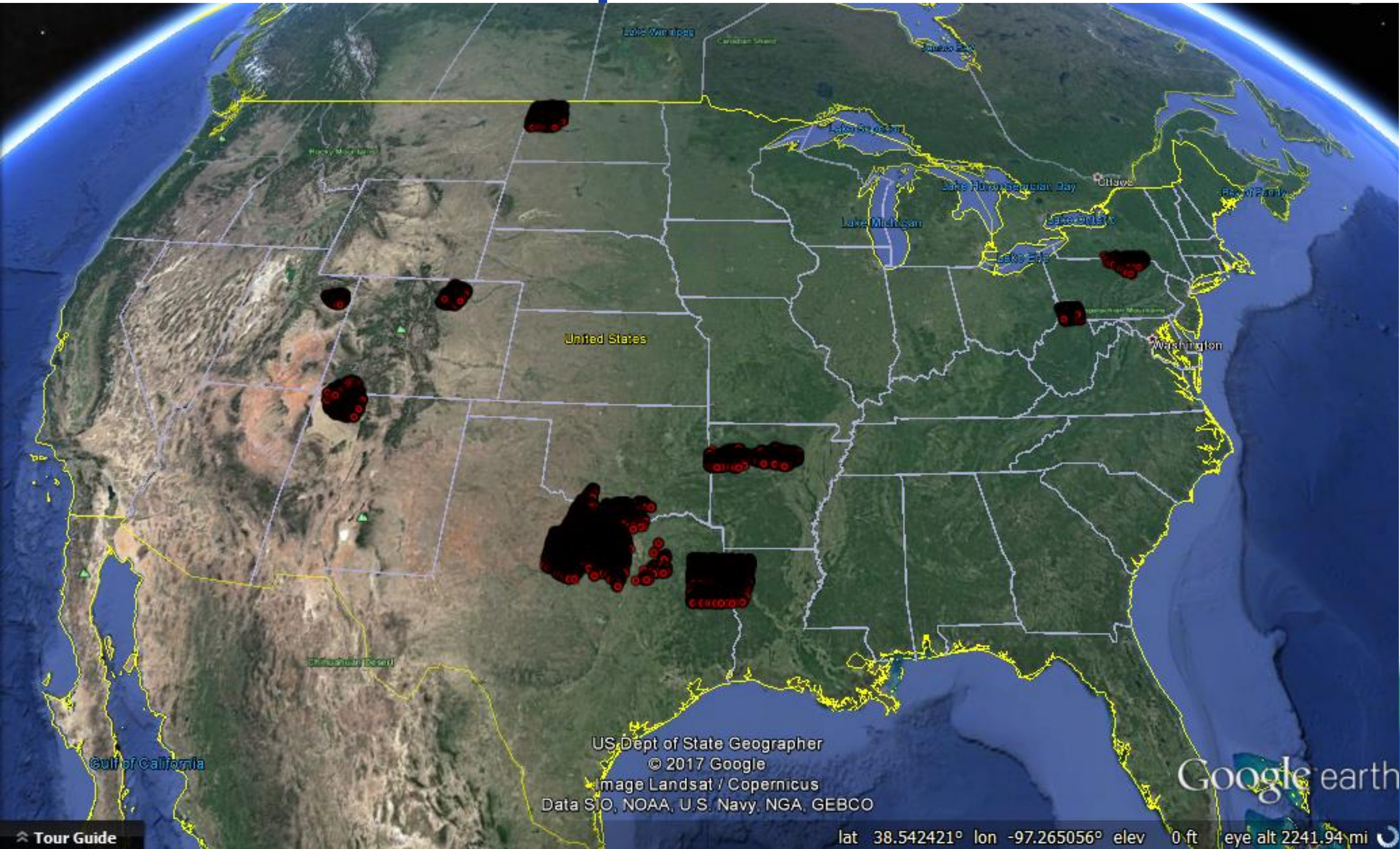
Revised Emission Estimation Methods

- Harvard gridded GHGI used for processing, transmission & storage, local distribution, other fossil, and biogenic sources.
- Gridded emissions for processing and T&S adjusted based on best estimate of national emissions
  - Processing: Marchese et al 2015 (~0.6 Tg)
  - T&S: Zimmerle et al 2015 including super-emitters (~1.8 Tg)

Top-Down/Bottom-Up Comparison

- Bottom-up emissions of 10 top-down flight envelopes were estimated by adjusting 2015 county-level inventory for spatiotemporal differences in AD
  - Bakken (Peischl et al 2016)
  - Barnett (Karion et al 2015)
  - Fayetteville (Peischl et al 2015; Schwietzke et al 2017)
  - Western Arkoma (Peischl et al 2015)
  - Haynesville (Peischl et al 2015)
  - Uintah (Karion et al 2014)
  - Denver-Julesburg (Petron et al 2014)
  - San Juan (Smith et al 2017)
  - Southwest PA (Ren et al 2017)
  - Northeast PA (Barkley et al, in review)

TD studies have quantified emissions in O&G basins accounting for ~40% of gas and 20% of oil production in the U.S.



Potential Causes of TD:BU Discrepancy

- Top-down O&G flux uncertainty
  - spatiotemporal domain
  - source apportionment
- Temporal patterns in emission sources
  - In the Fayetteville, liquids unloadings typically occur during the early day and therefore their emissions during TD flights may not be annually representative
- Inaccurate bottom-up data
  - Lower control efficiencies for tanks and flaring could account for the emissions gap in some basins
  - High uncertainty of estimates from sources with little empirical data such as gathering pipelines

Super-emitters

- Do bottom-up estimates fully account for super-emitters?
  - Zavala-Araiza et al 2017: empirically-based Barnett well pad emission rate is 50% than modeled component-level emissions
- After accounting for other issues like liquids unloading time compression, how much gas is lost through unknown, abnormal processes?
- Basins with the largest TD:BU discrepancy should be targeted for research, particularly related to the prevalence of super-emitters

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