Methane emissions from natural gas extraction from the Haynesville, Fayetteville, and northeastern Marcellus shale regions

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B. M. Lerner,[1,2] R. Nadkarni,[3] M. Trainer,[2] and D. D. Parrish[2]

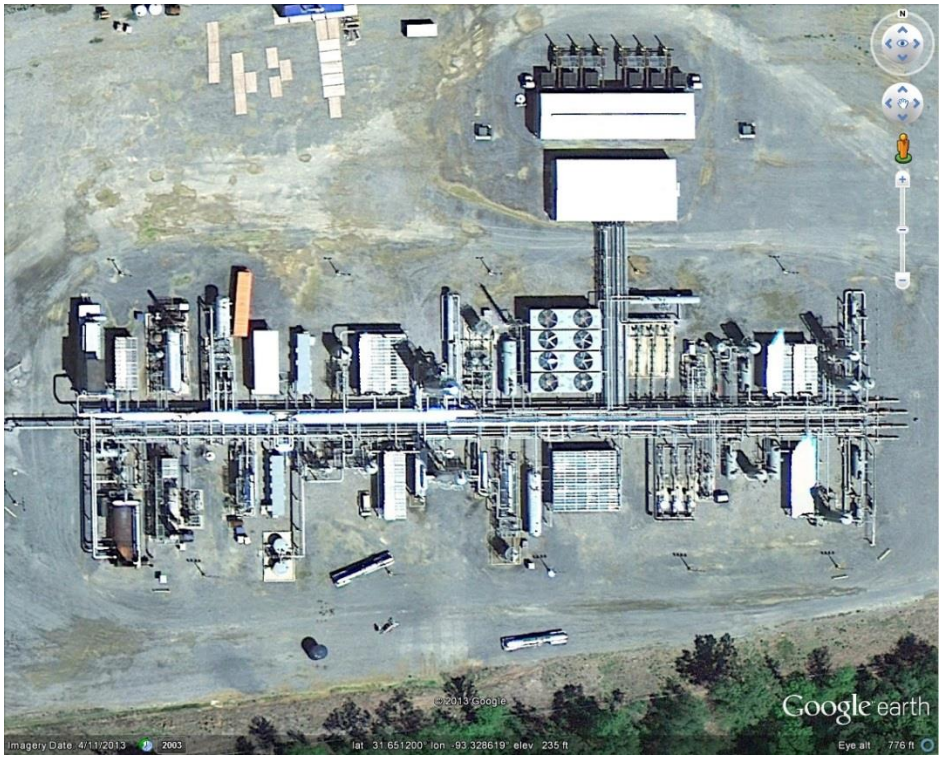
[1] Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder, Boulder, CO
[2] NOAA Earth System Research Laboratory, Chemical Sciences Division, Boulder, CO
[3] Texas Commission on Environmental Quality, Austin, TX

Outline:

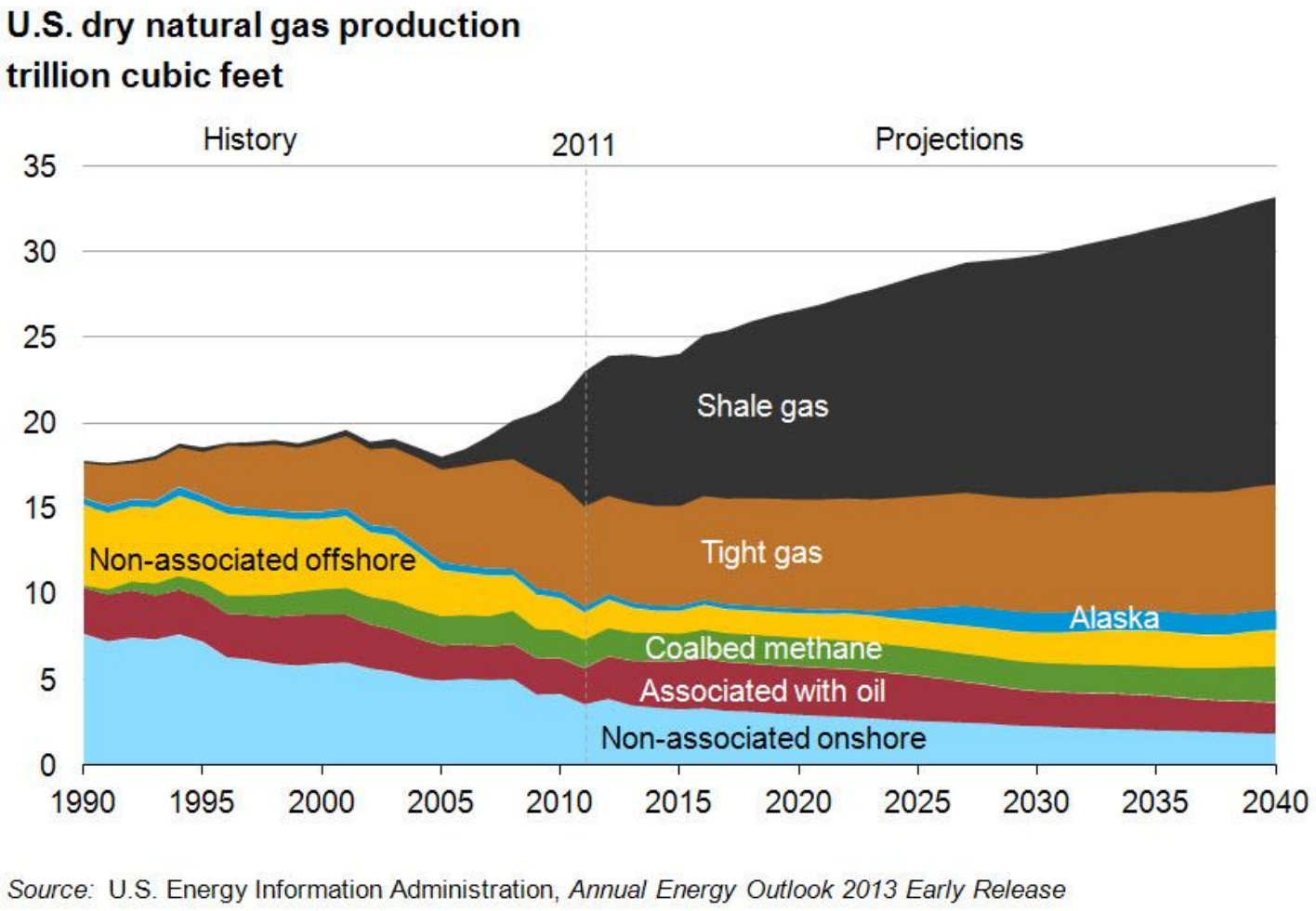
1. Shale gas production increasing – need top-down estimates of CH_4 leak rates
2. Southeast Nexus (SENEX) 2013 flights to three of the largest shale gas plays
3. Quantification method: mass balance
4. CH_4 emissions from these regions

well pad

natural gas processing plant



Shale gas increasing in importance as source of natural gas



Source: U.S. Energy Information Administration, *Annual Energy Outlook 2013 Early Release*

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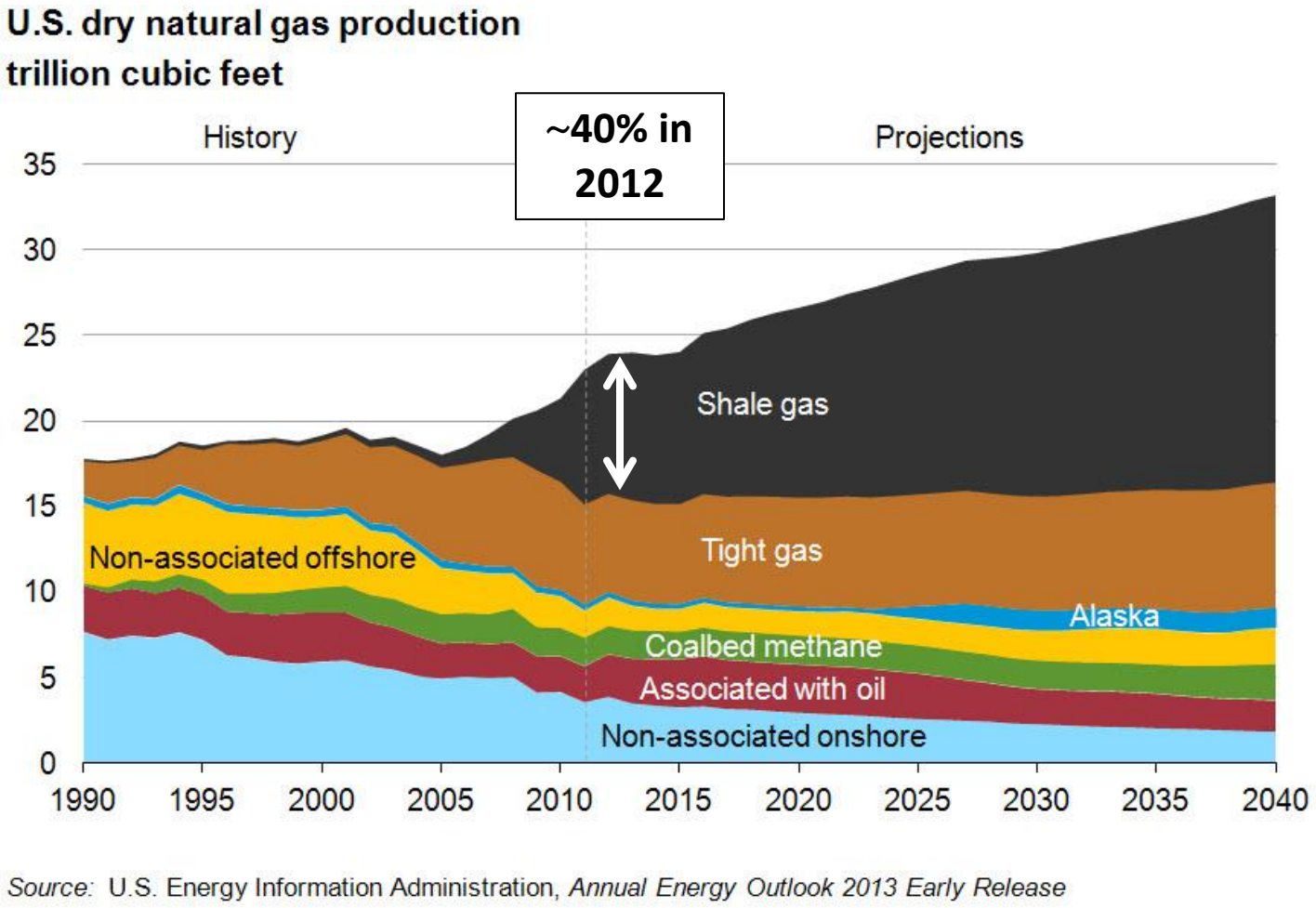

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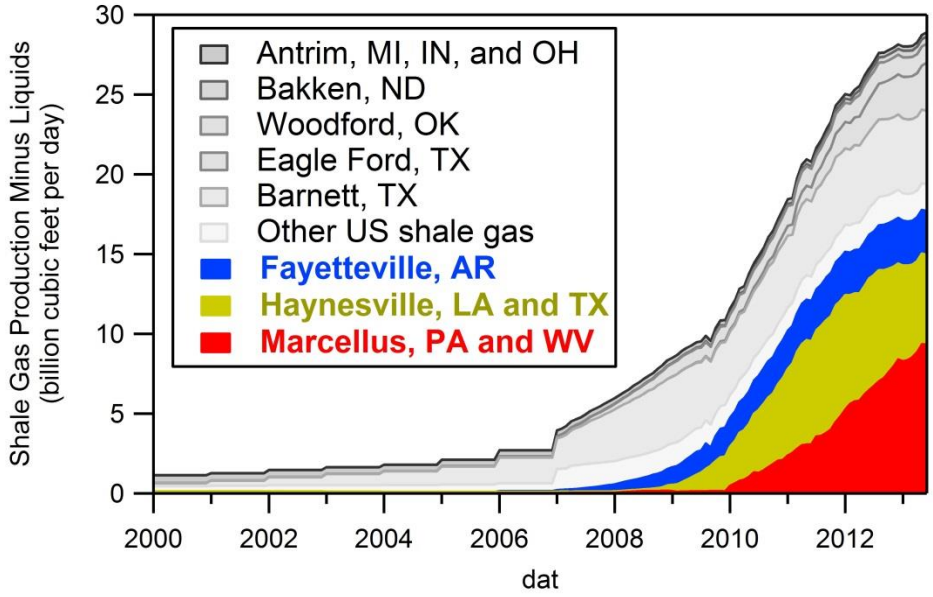

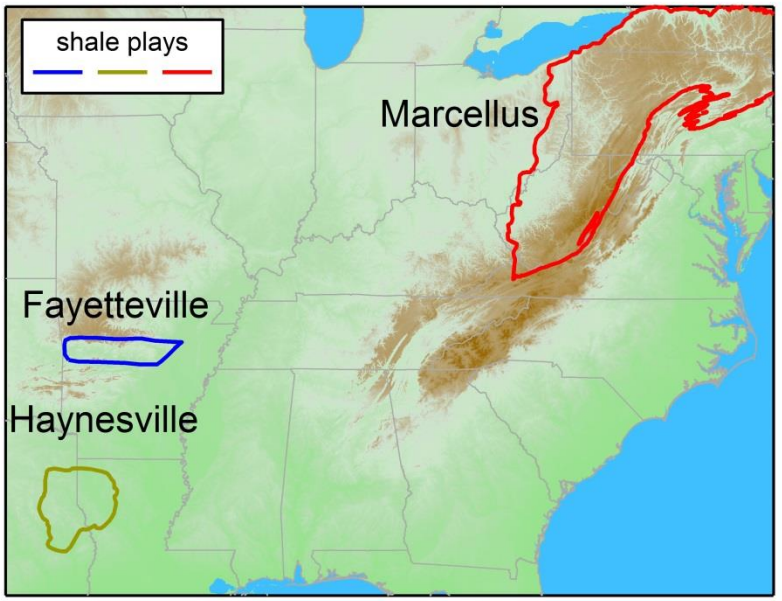

- U.S. shale gas production has increased 13-fold since 2005 [*EIA*]
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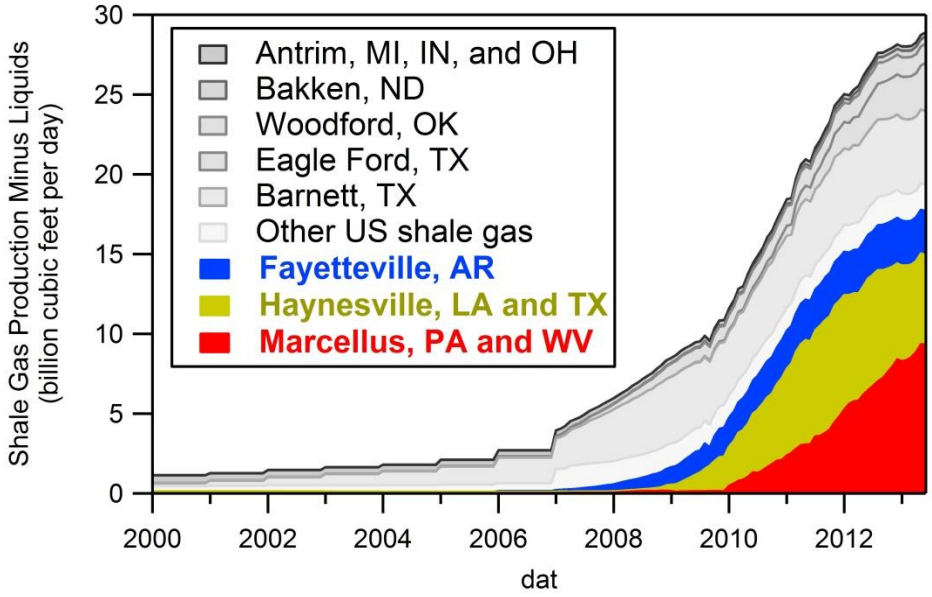

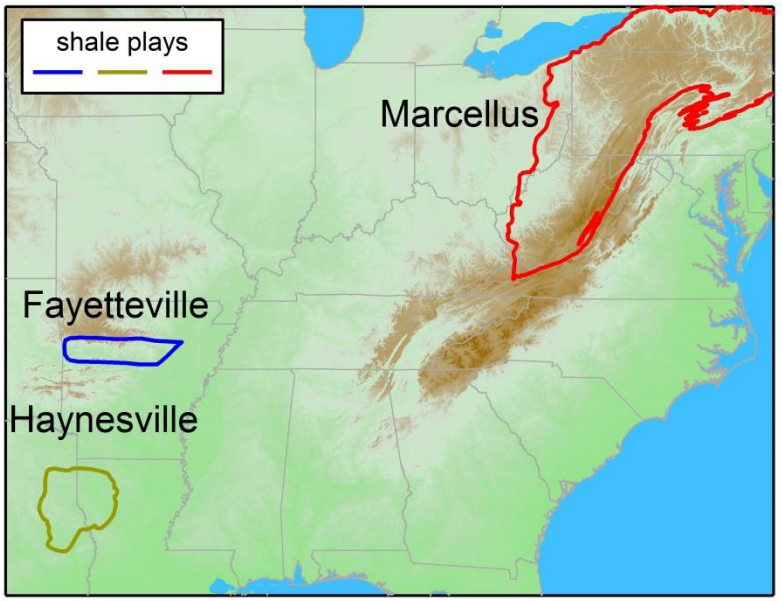

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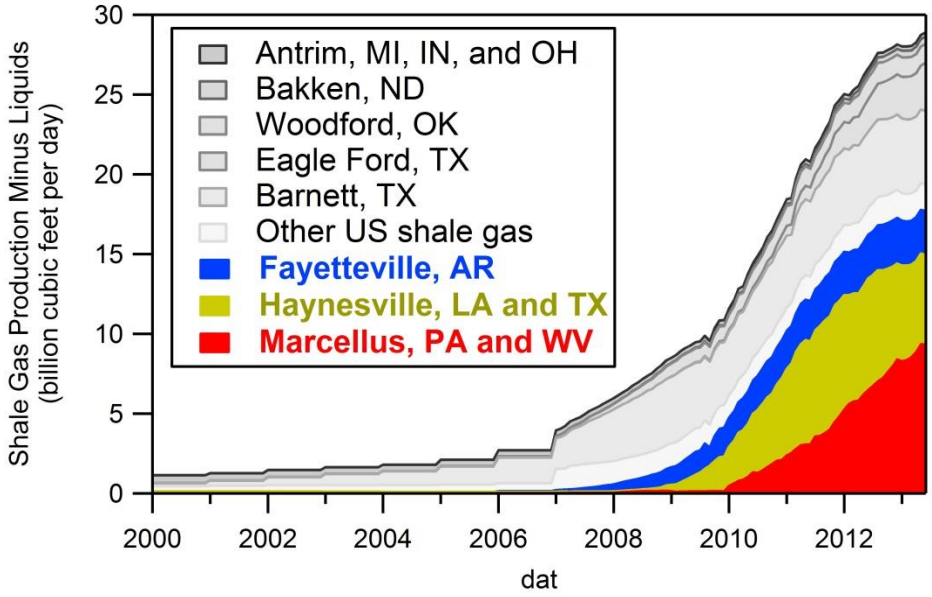

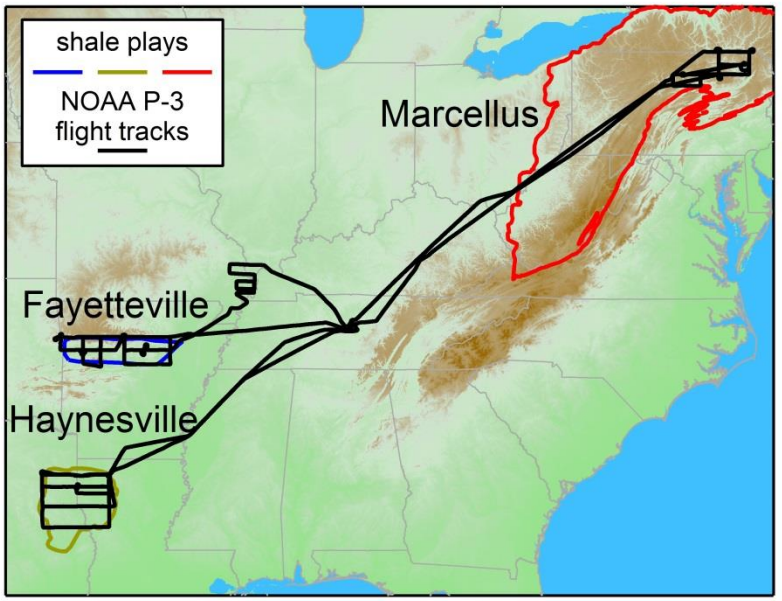

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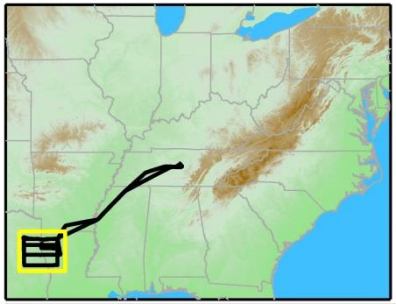
Will use NOAA P-3 data from SENEX to derive atmospheric CH_4 emissions from these regions

Aircraft CH_4 measurements higher downwind of **Haynesville** shale



- Two SENEX flights; both provide constraints for inverse modeling
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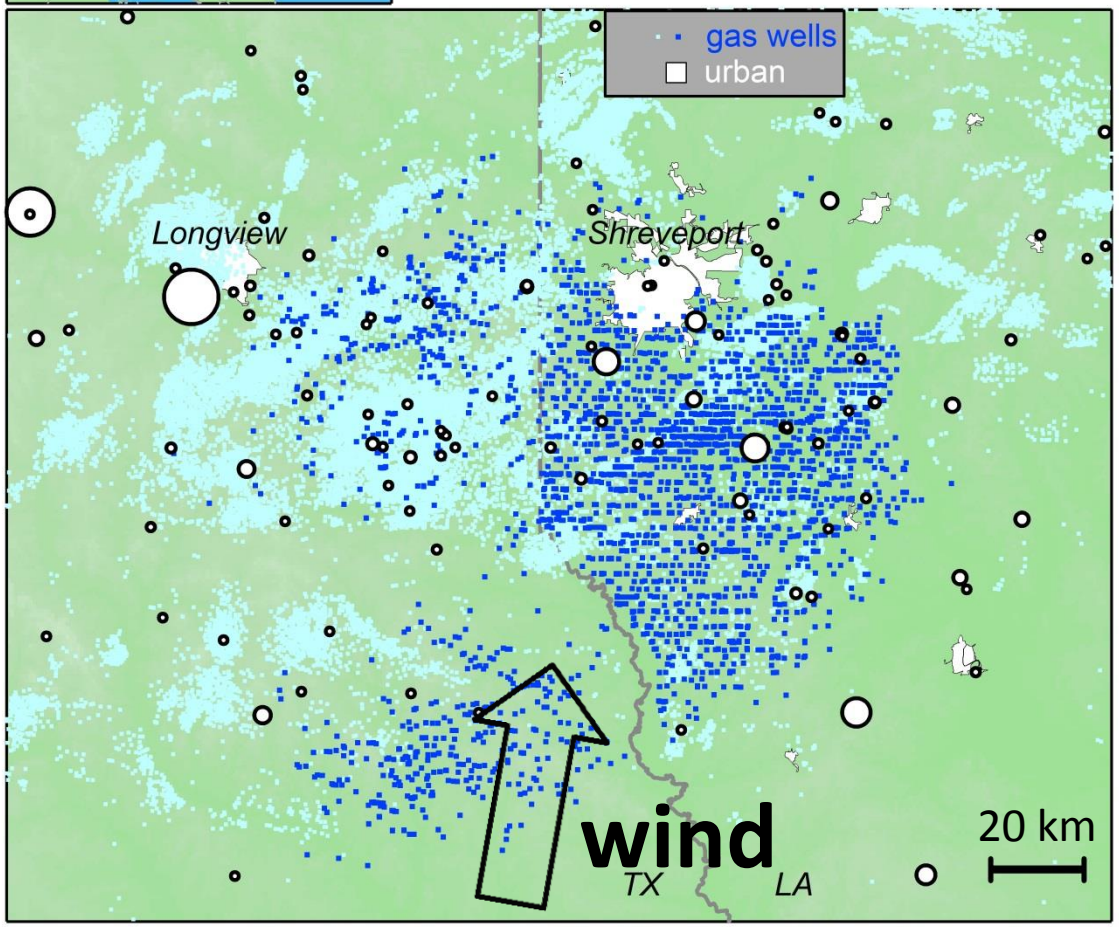

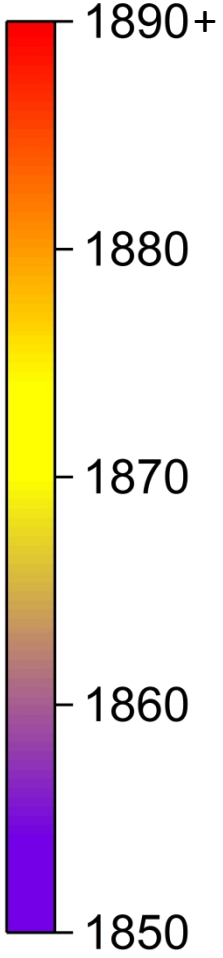

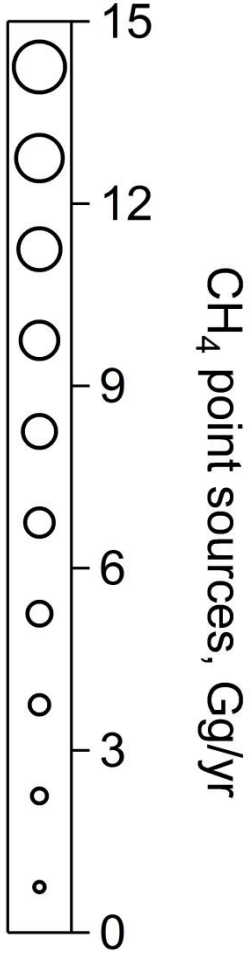

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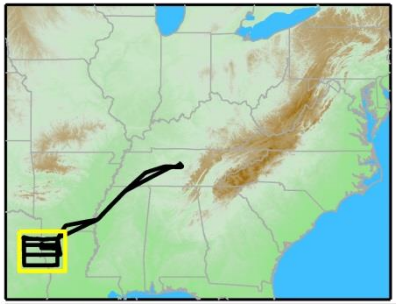

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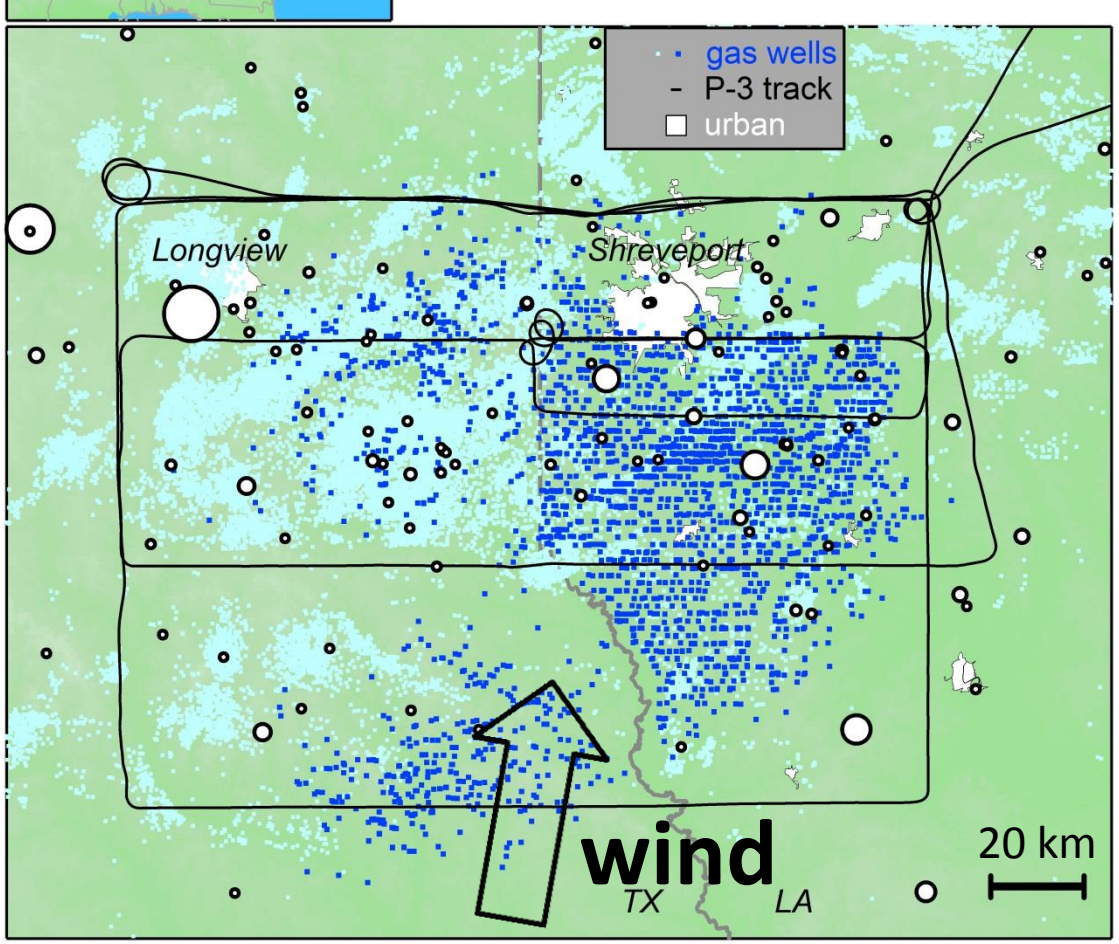

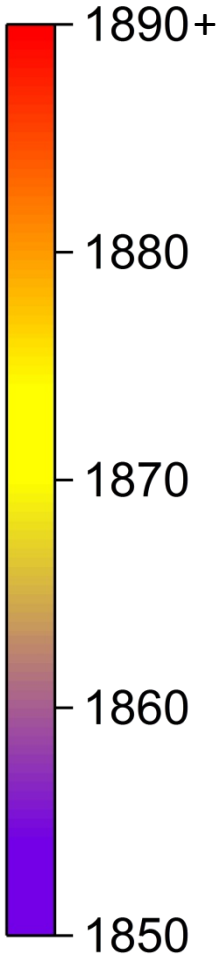

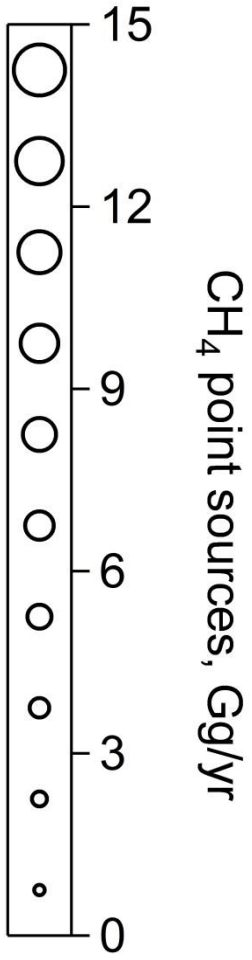

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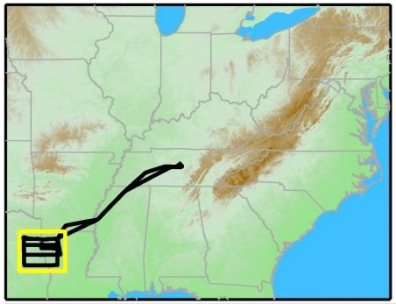

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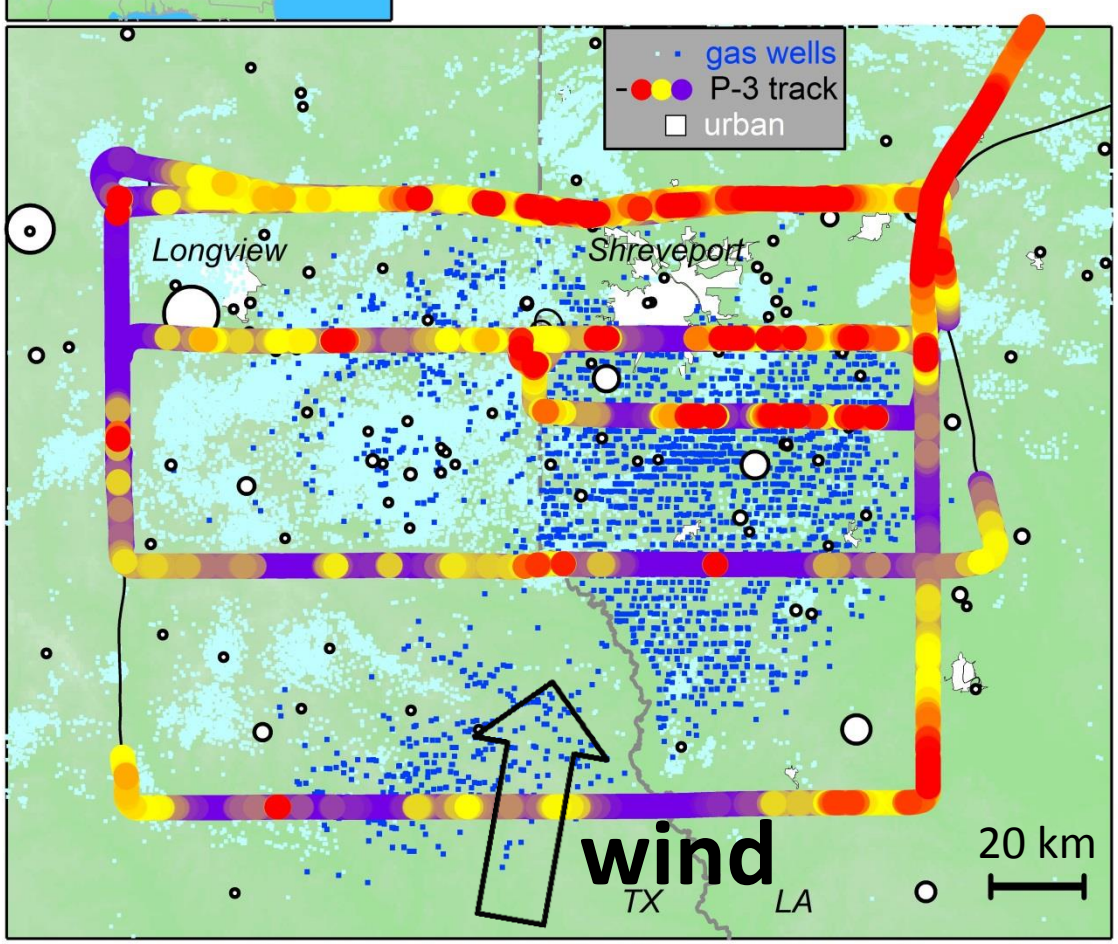

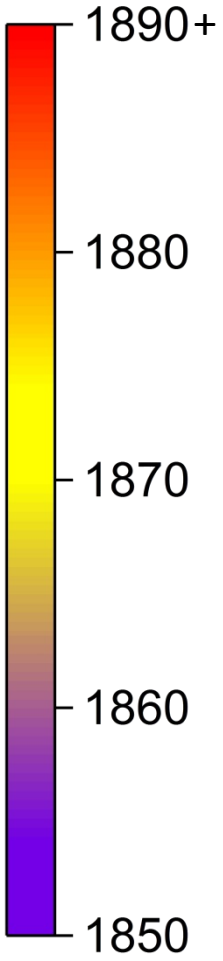

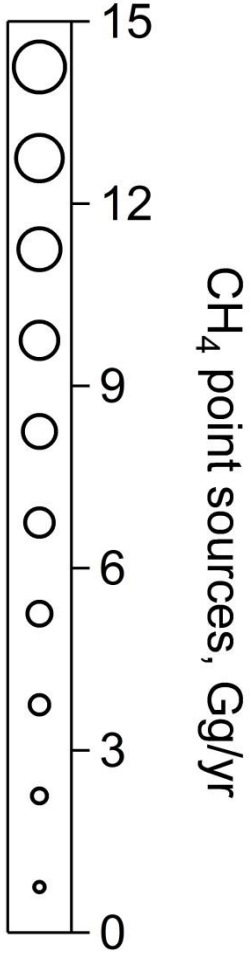

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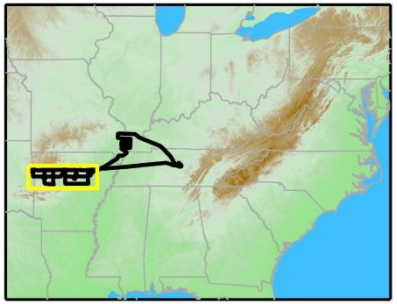

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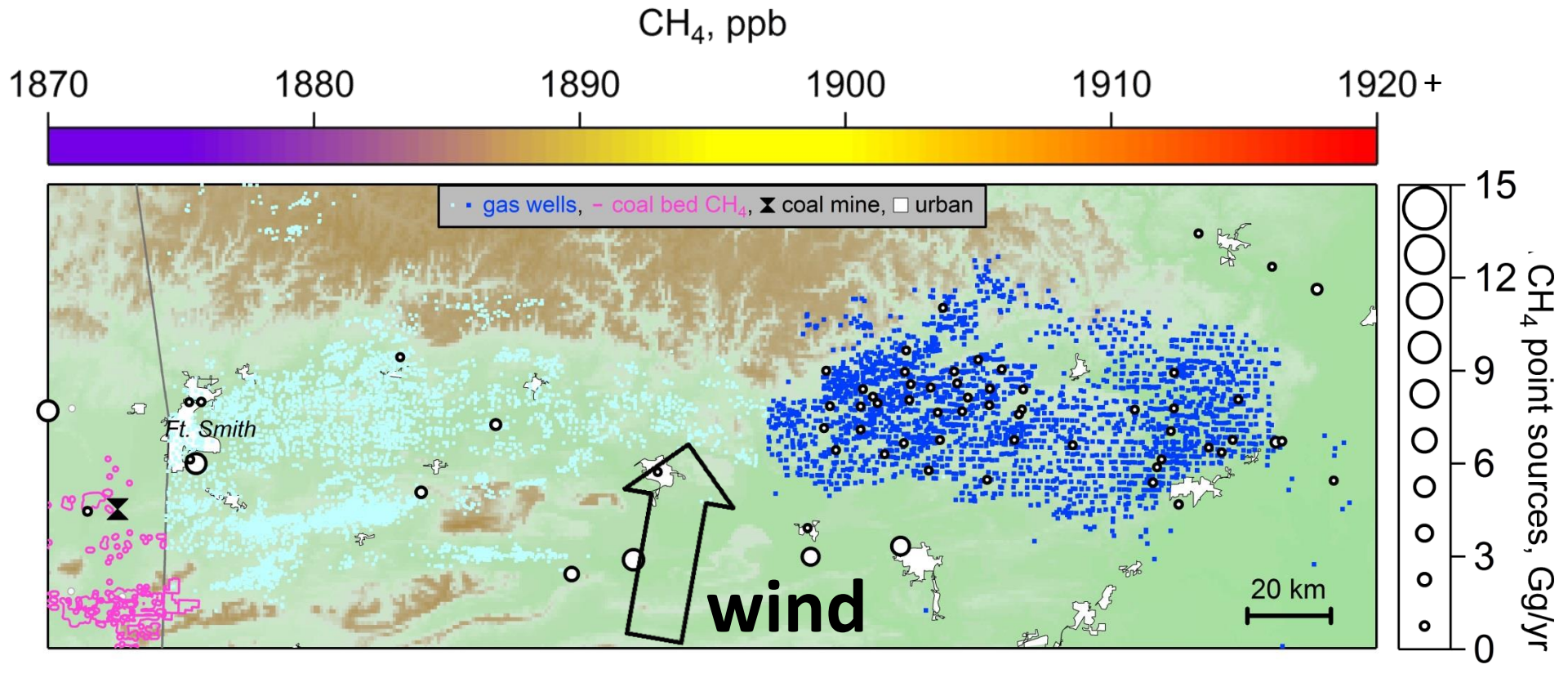

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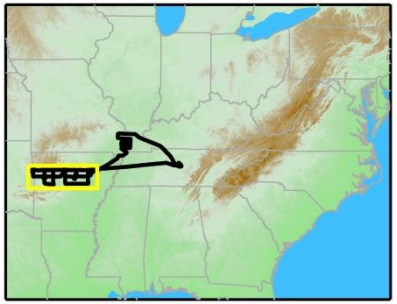

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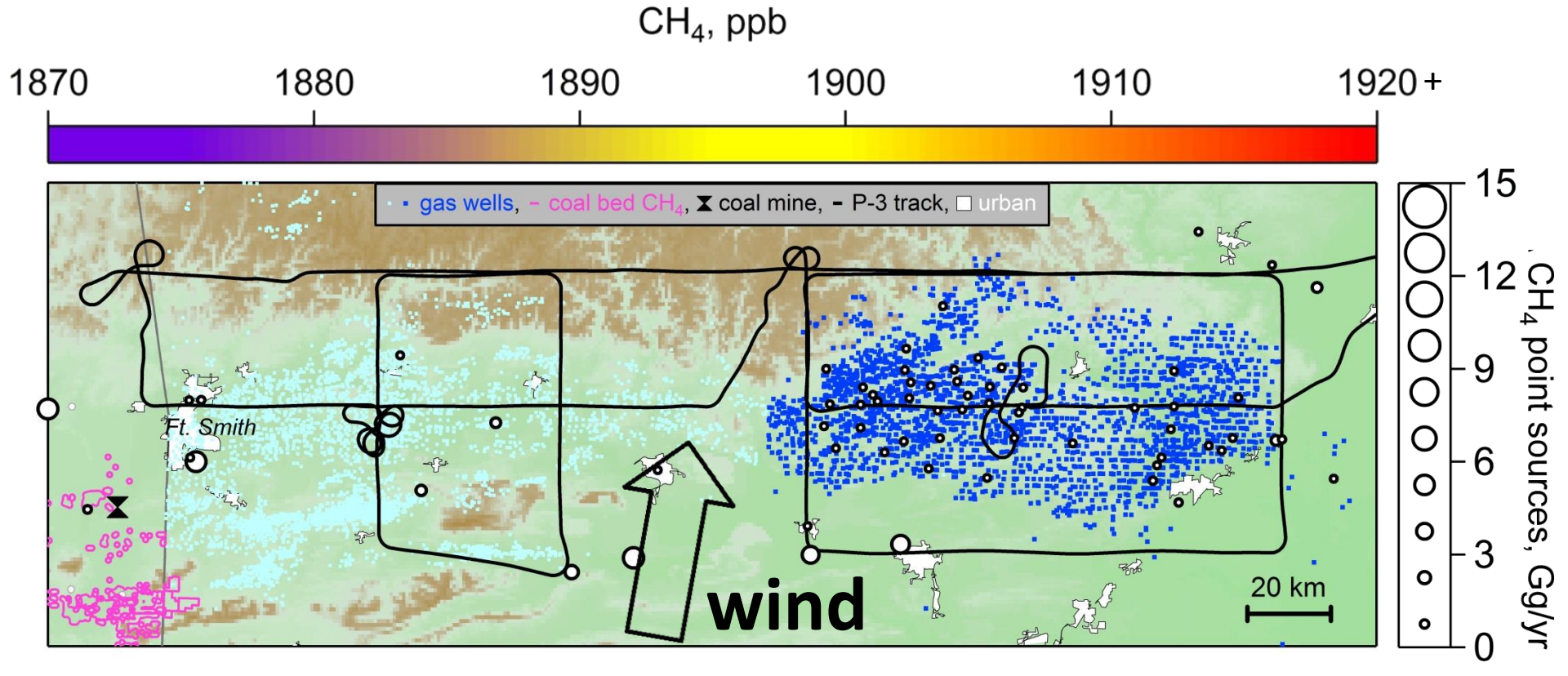

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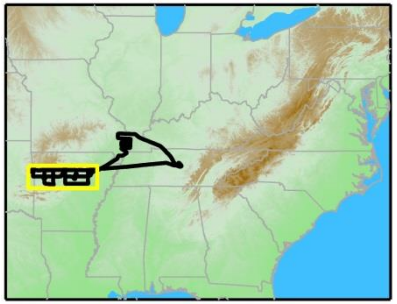

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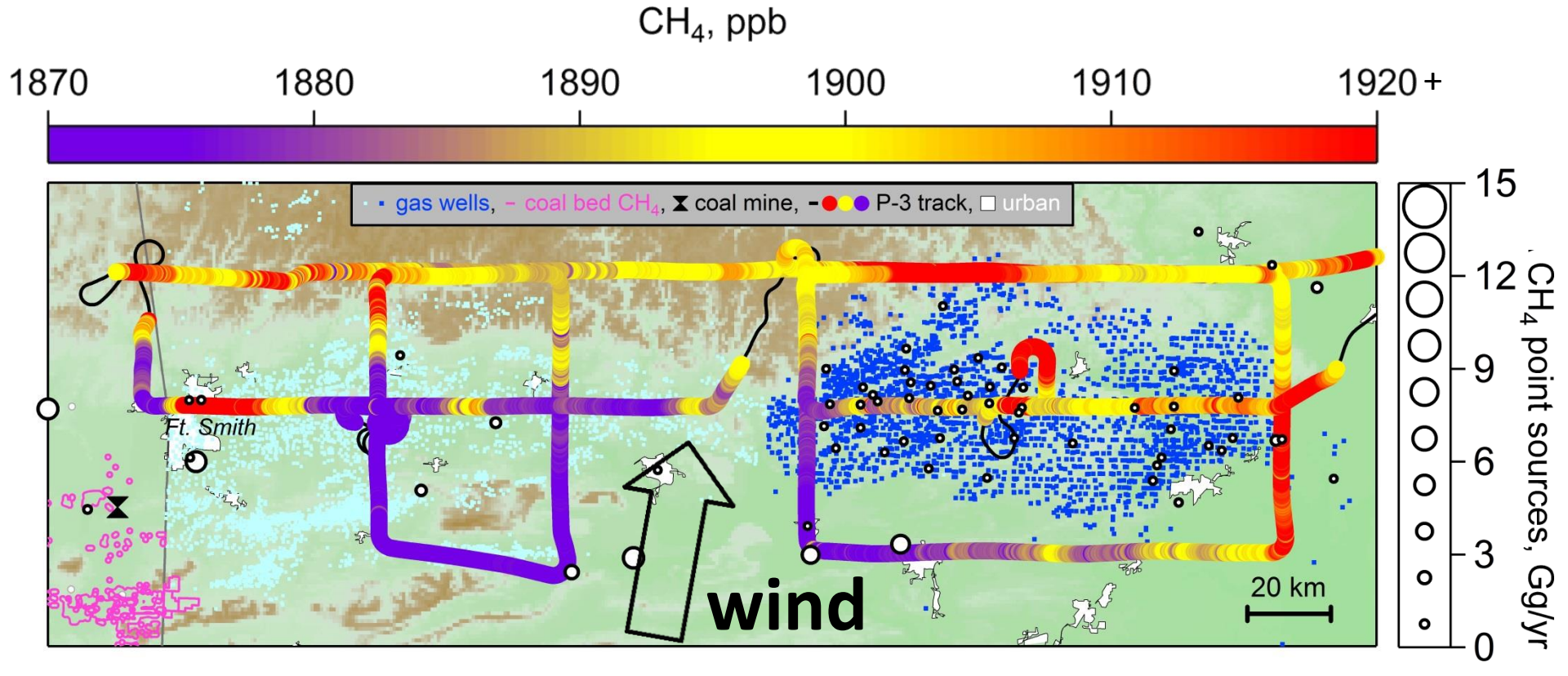
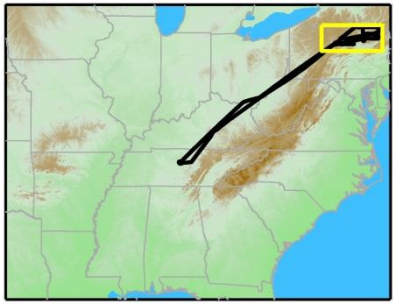


Aircraft CH_4 measurements around **Marcellus** shale affected by upwind sources



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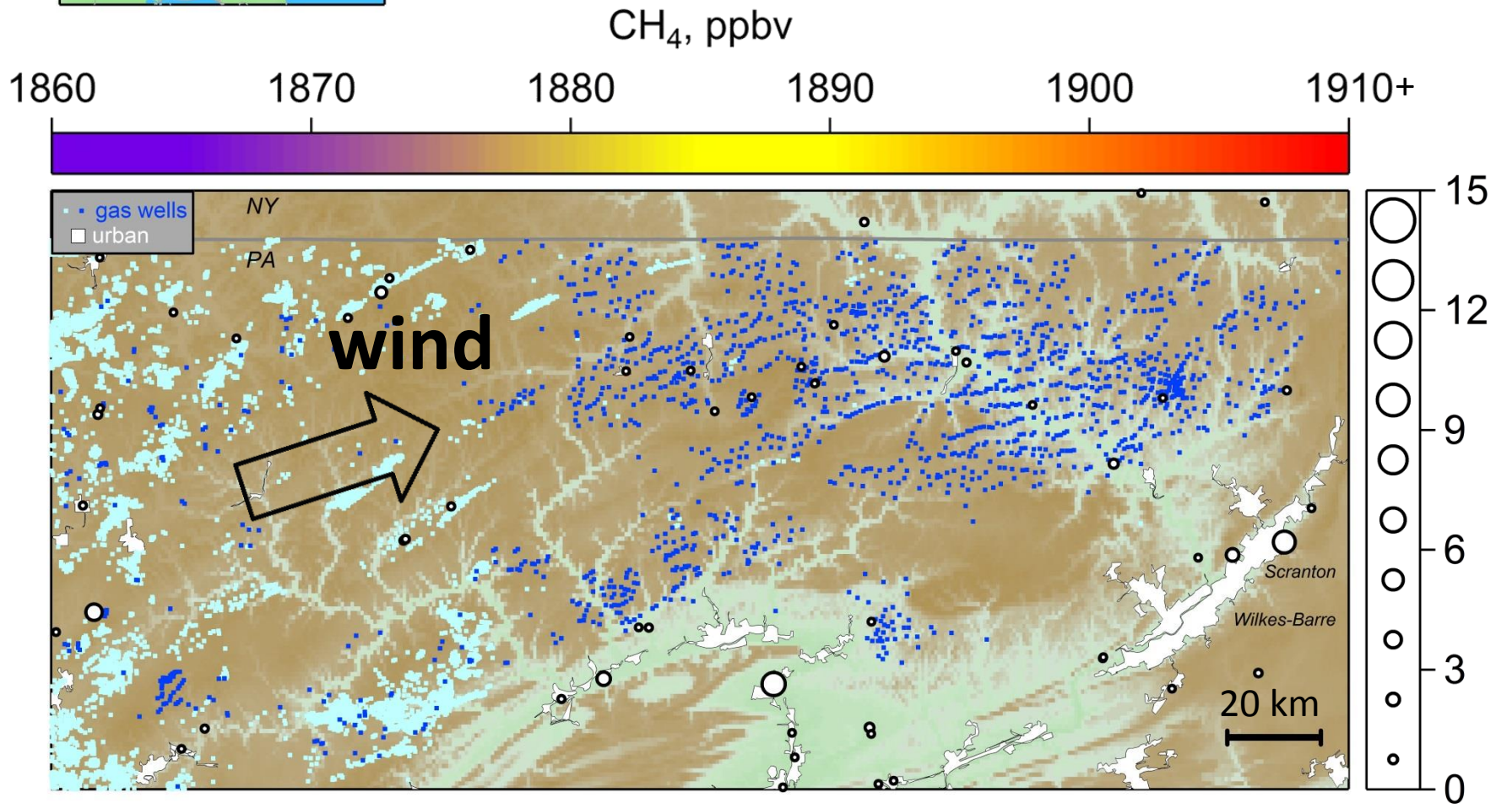

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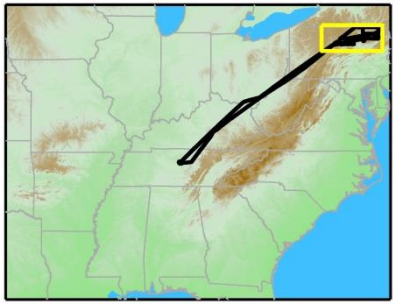

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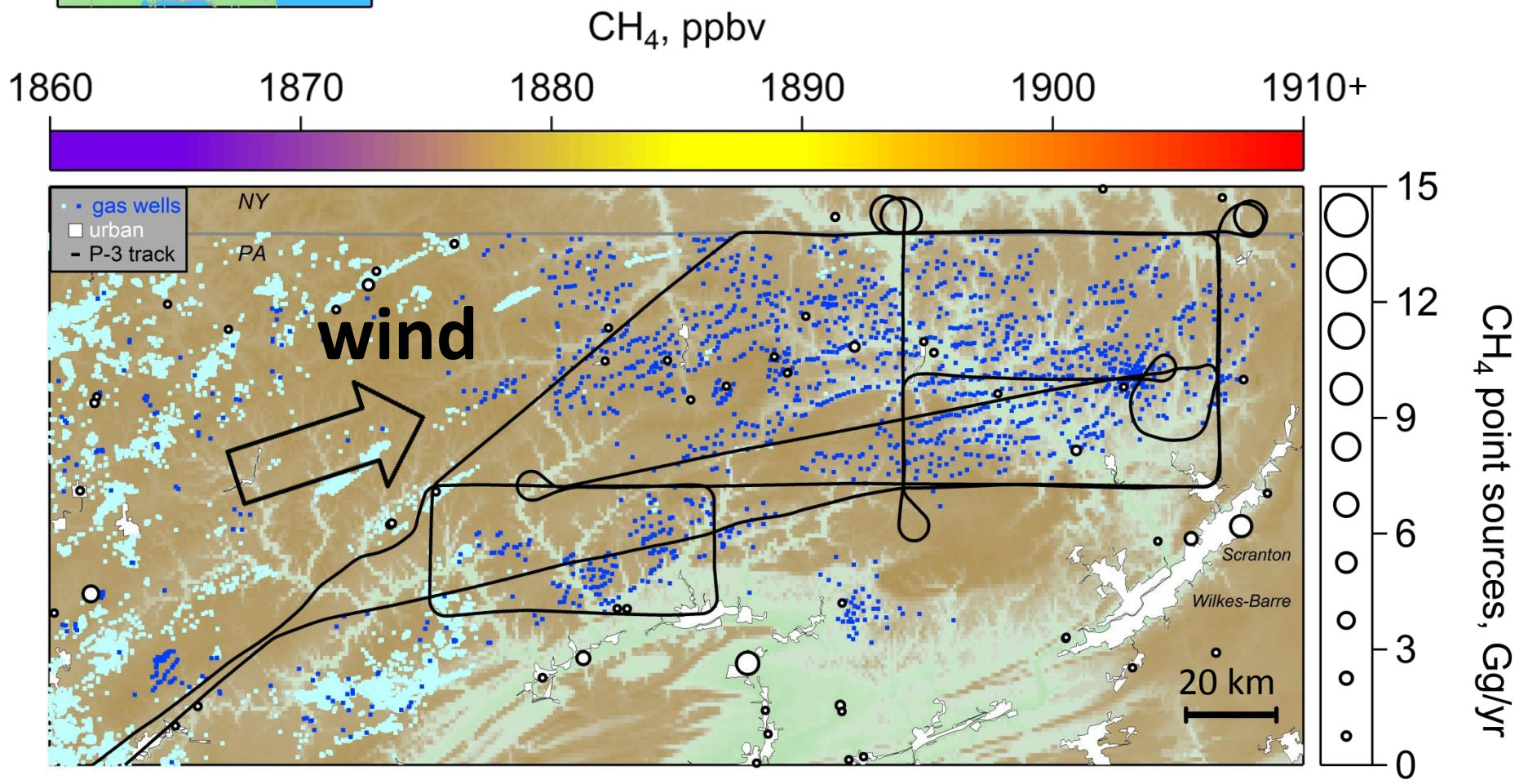

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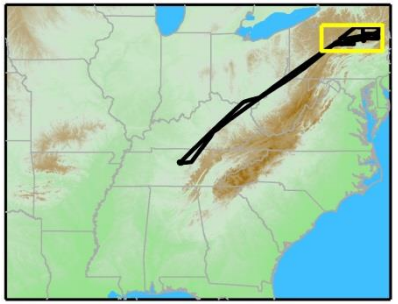

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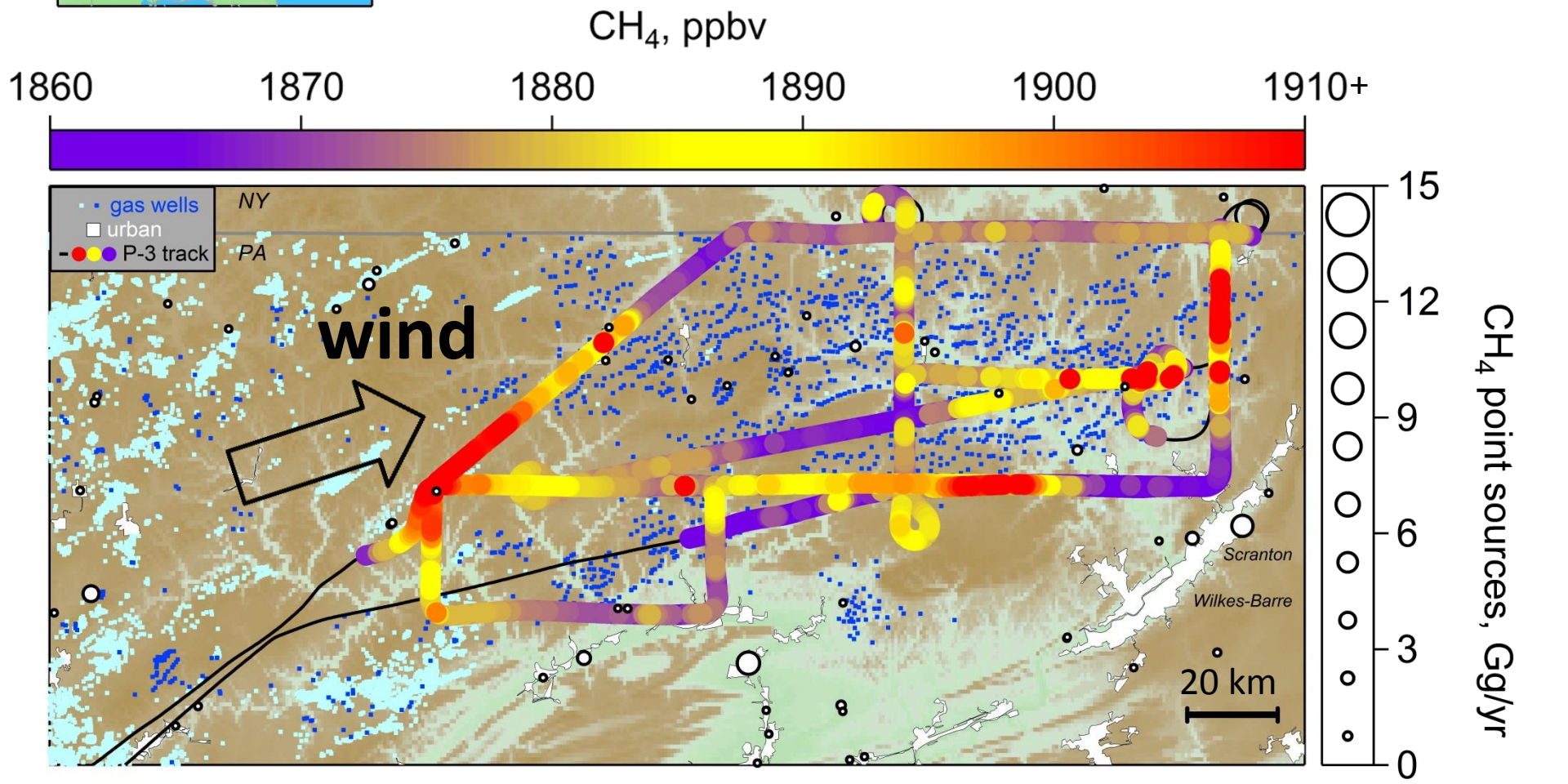

Flux calculation method [*White et al.*, *Science*, 1976]

Emission rate, and its uncertainty, calculated from:

$$\text{net } \mathrm{CH_4} \text{ flux} = v \bullet \cos(\alpha) \bullet \int_0^z n(z)\, dz \int_{-y}^{y} X_m(y)\, dy$$

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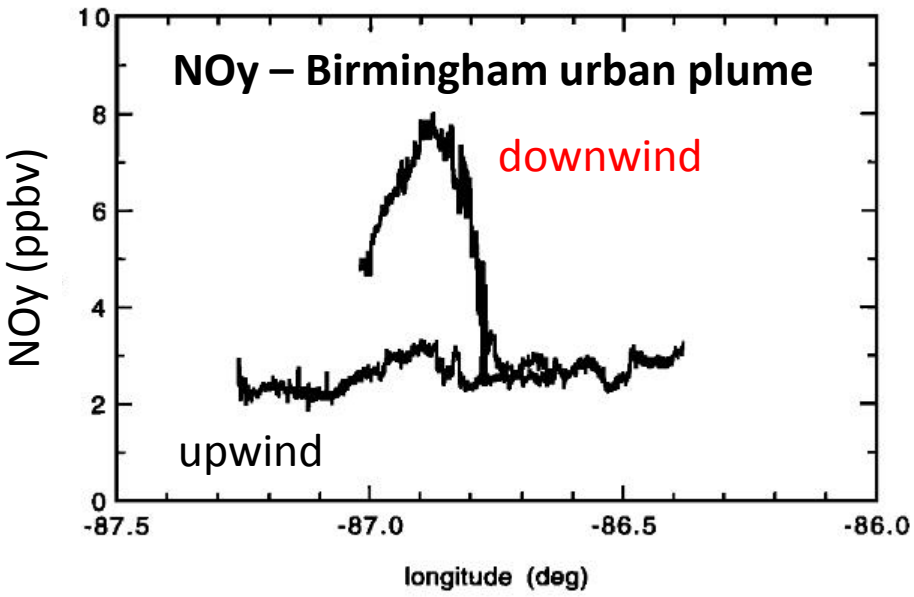

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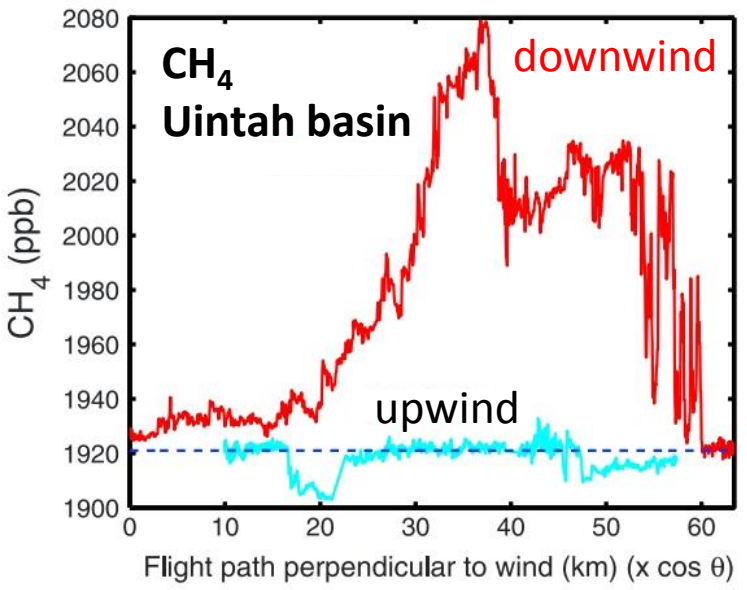
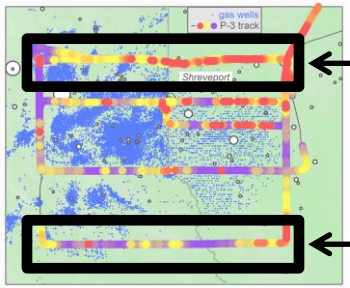


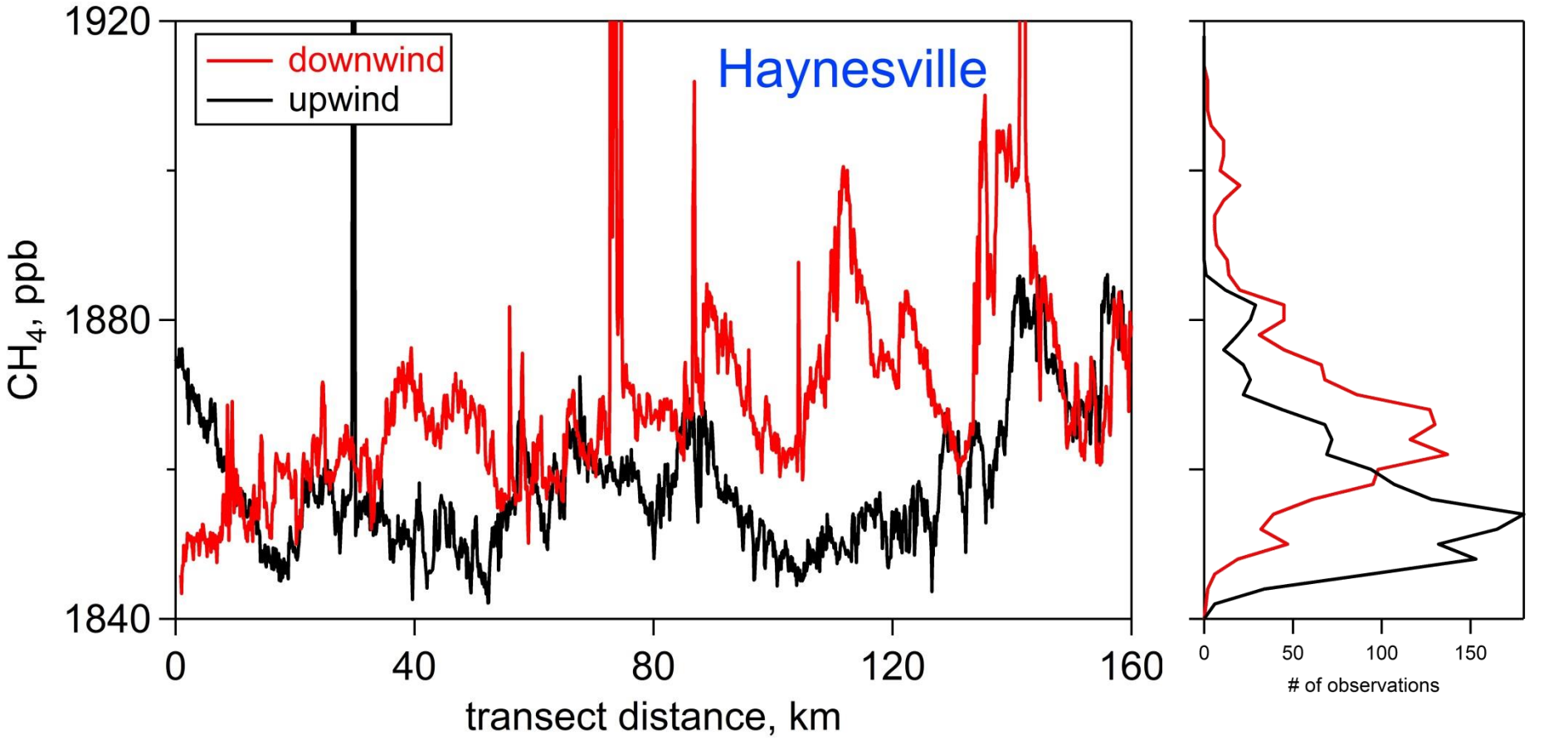
Emission rates and uncertainties driven by downwind CH_4 enhancements vs. upwind variability



downwind

upwind

Enhancement downwind vs. upwind
Haynesville
Fayetteville
Marcellus



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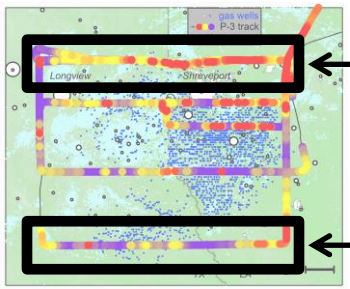

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upwind

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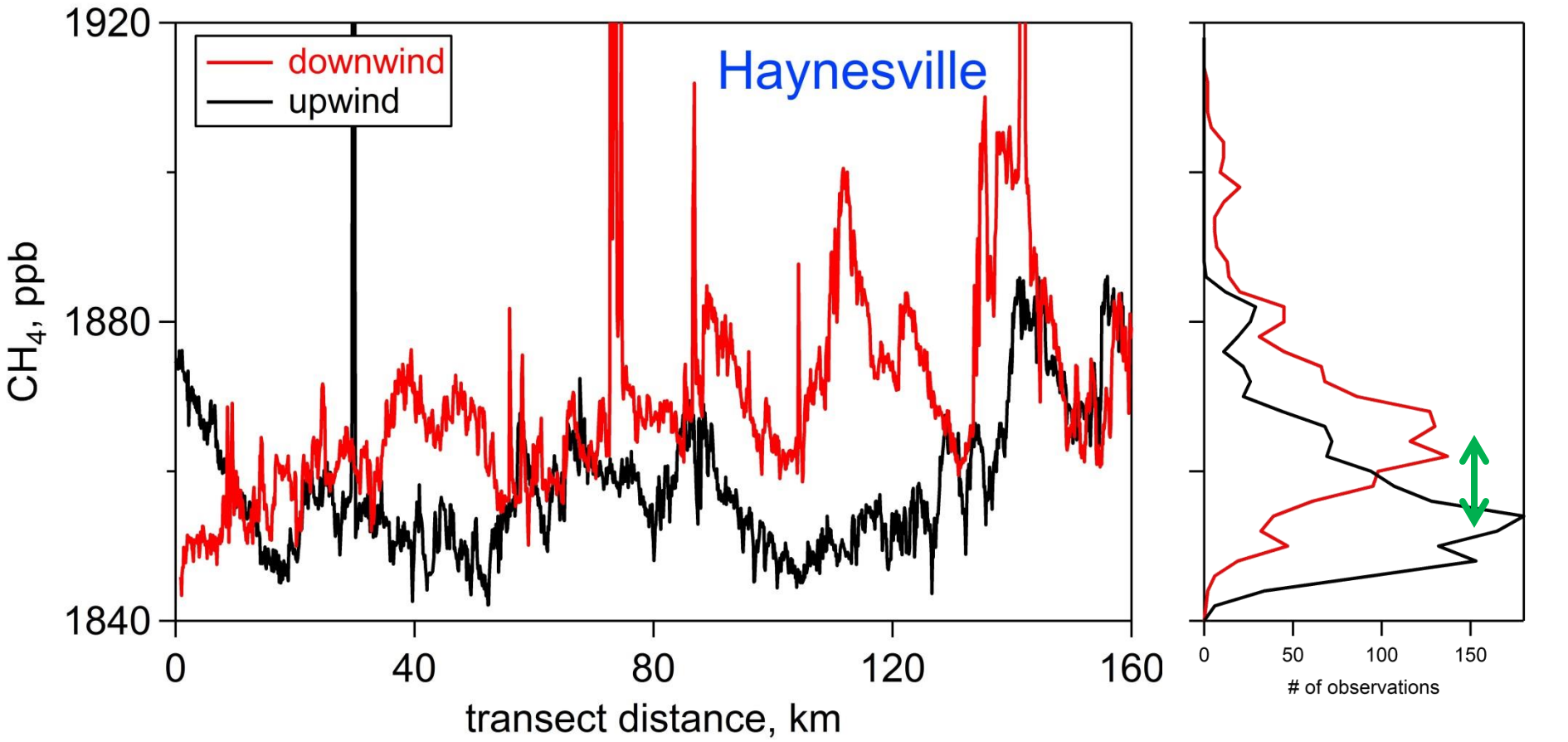
	Fayetteville
	Marcellus



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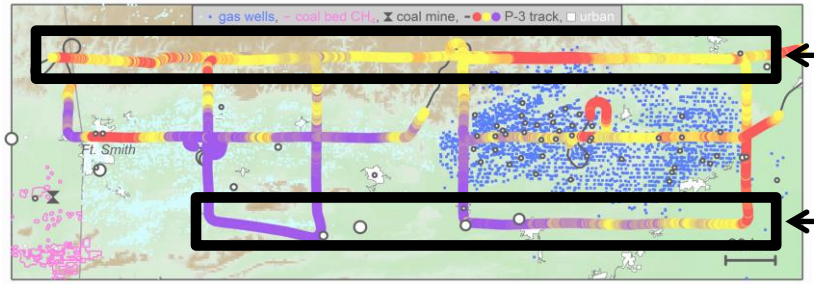

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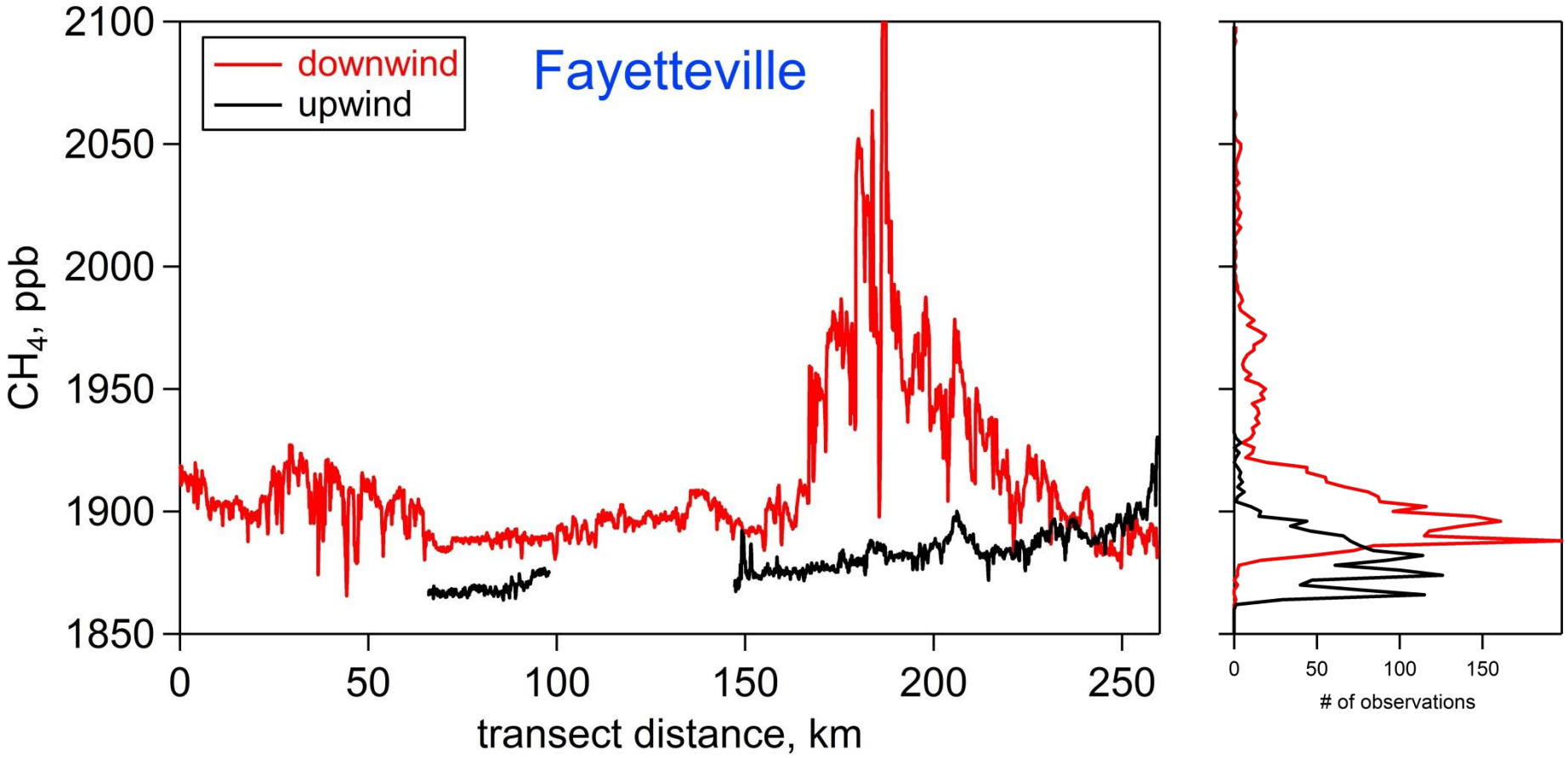

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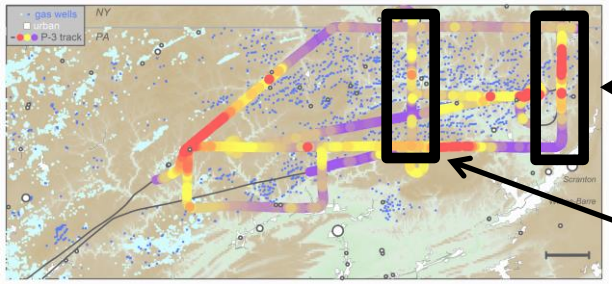

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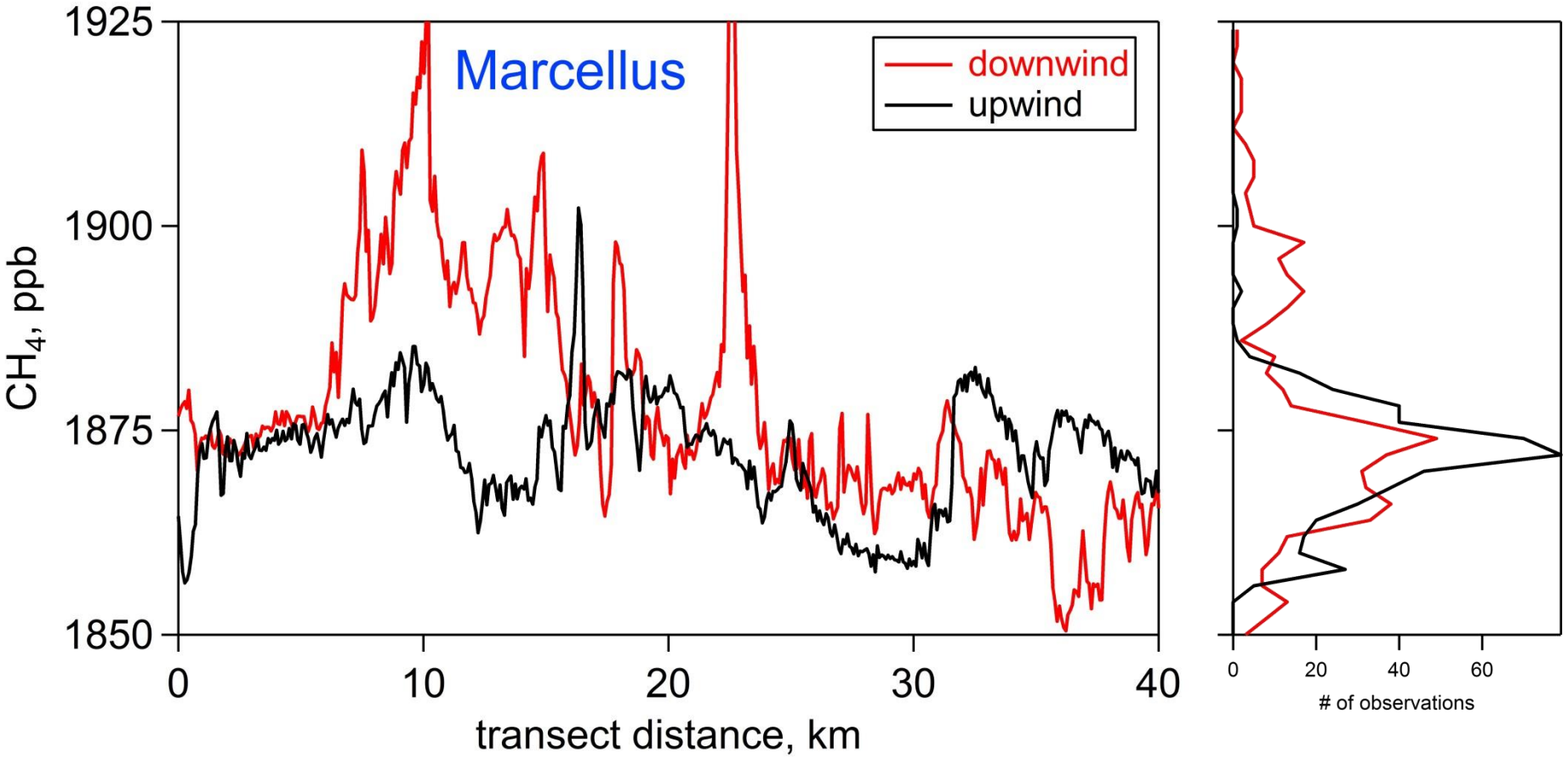
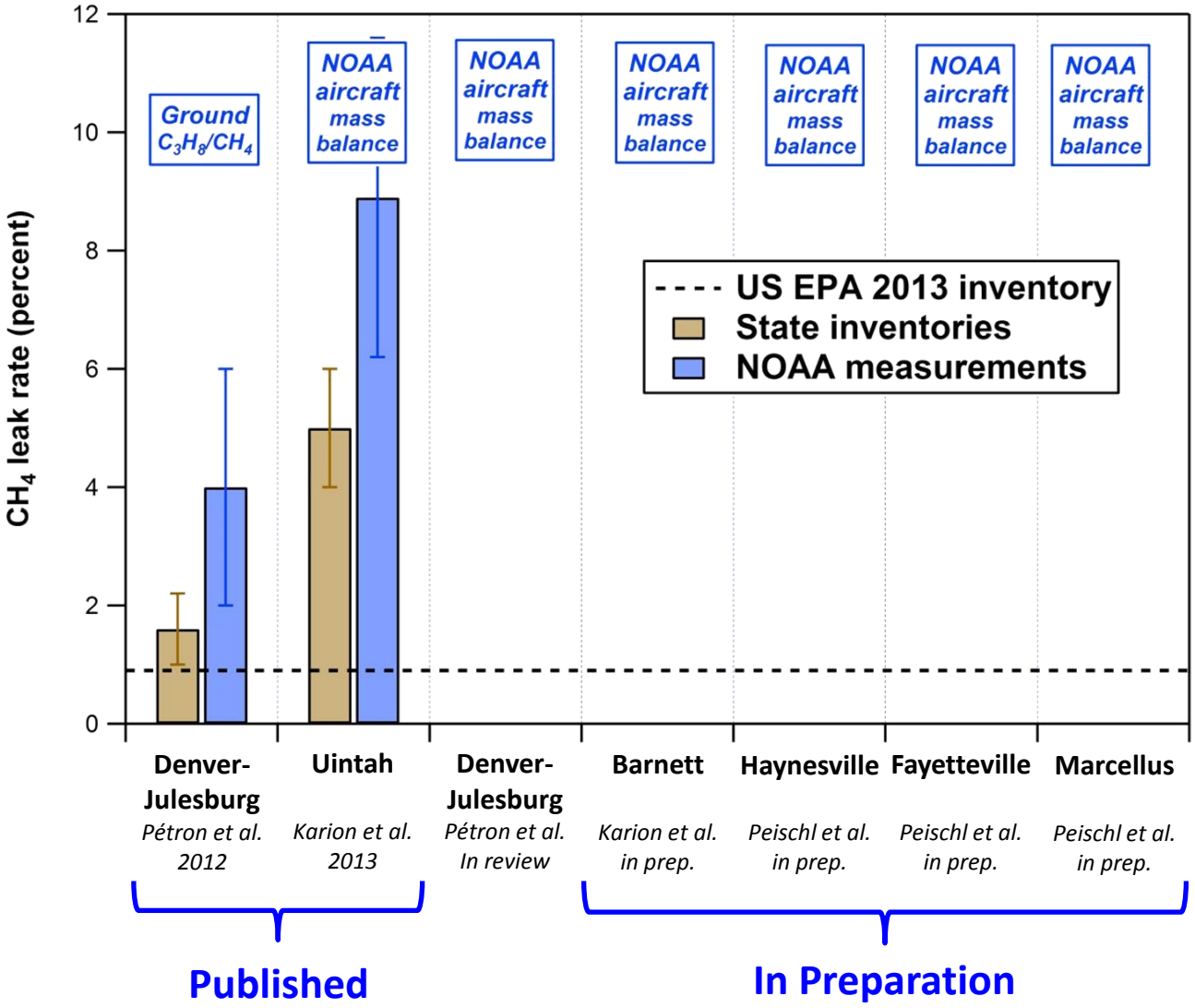


Atmospheric measurements to quantify CH_4 leak rates from regions of natural gas extraction



Atmospheric measurements have assessed fields accounting for **65%** of the total U.S. shale gas production

NOAA studies planned for:

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(several) (May 2015)
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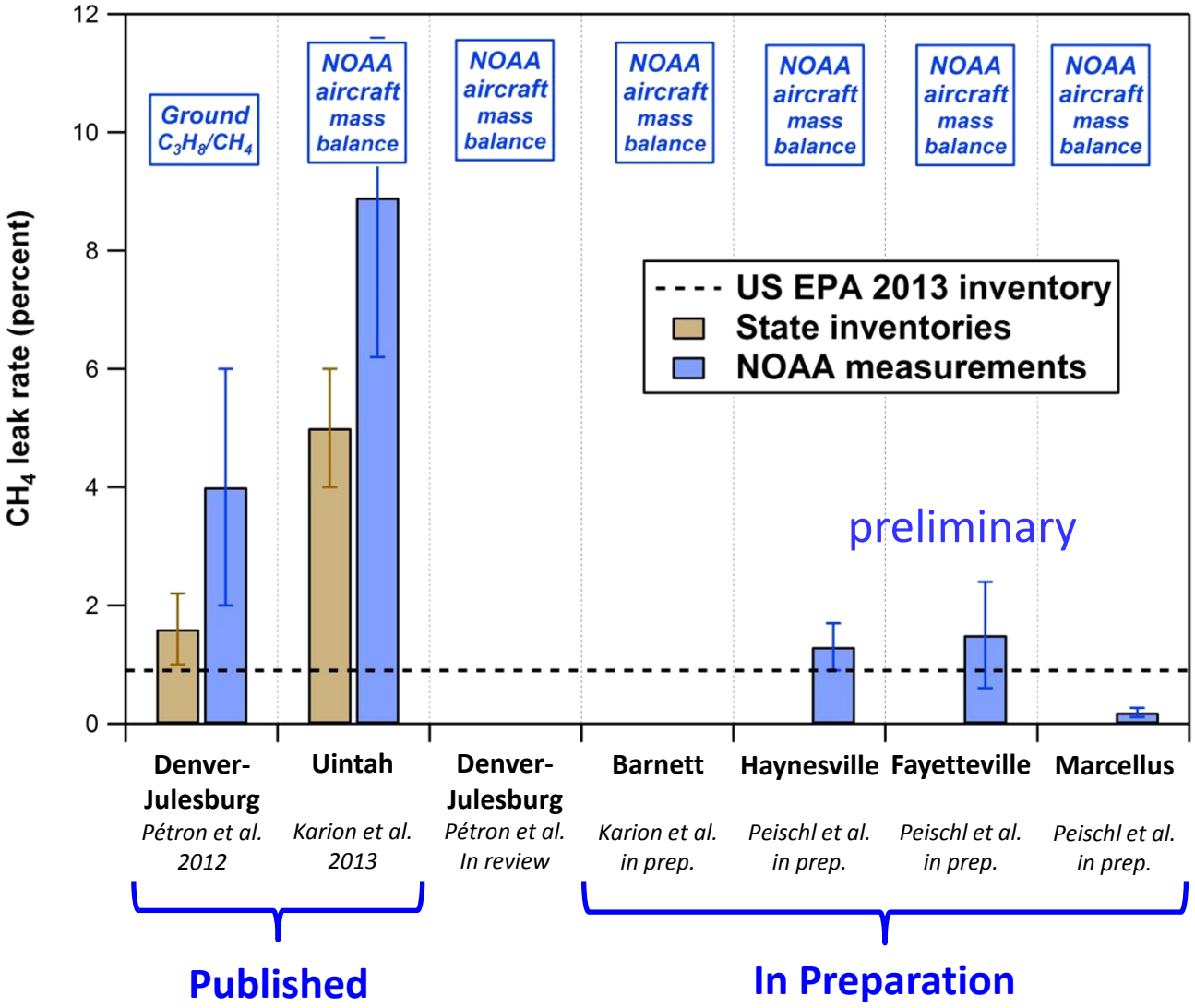

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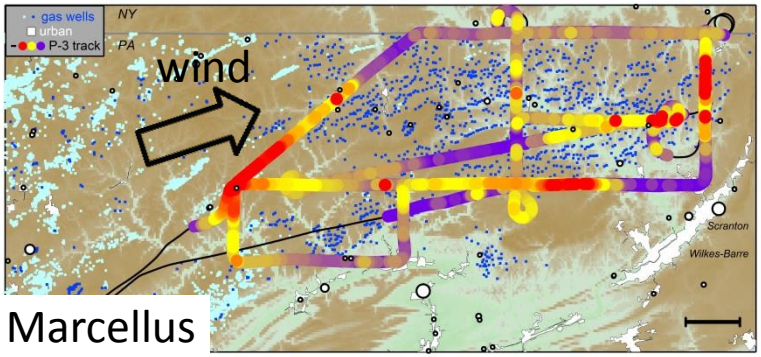
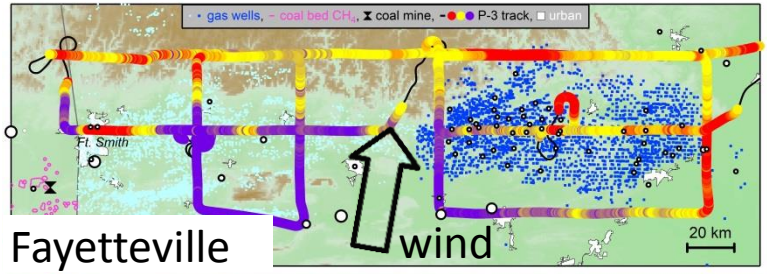
Marcellus (2015)

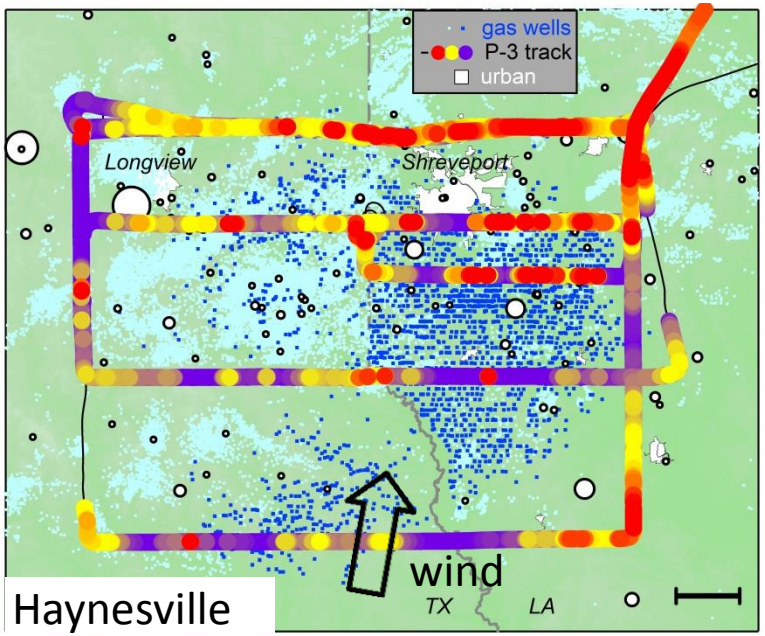
Conclusions



Marcellus



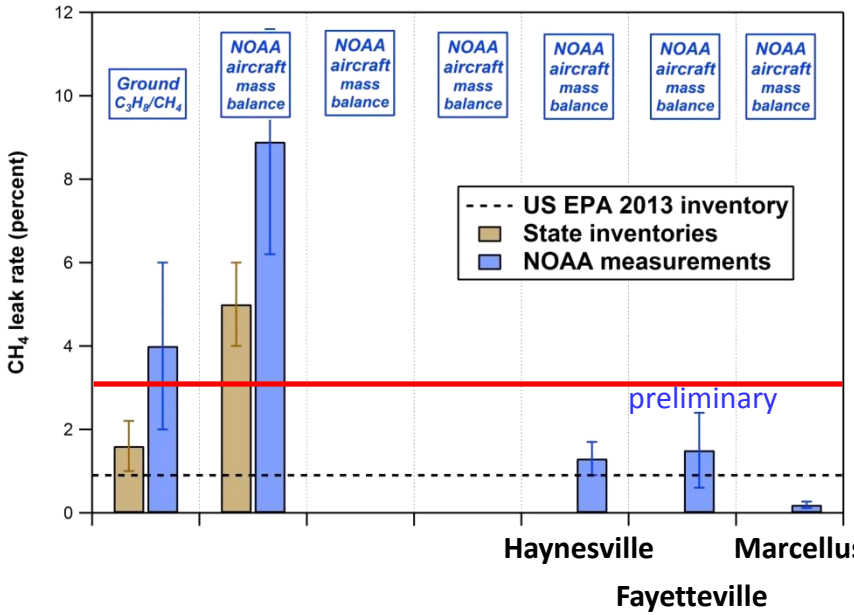
Fayetteville



Haynesville

- NOAA P-3 flew to three of the largest shale gas producing regions of the U.S. in June and July 2013 and determined maximum CH_4 emissions attributable to oil and gas exploration

- One-day natural gas leak rates from all three shale plays are ***less than***
  - **3.2%**, <u>immediate</u> net climate benefit for use as power plant fuel vs. coal [*Alvarez et al.*, 2012]
  - **3.7%**, net climate benefit in <u>20 yrs</u> [*Ibid.*]
  - **8%**, net climate benefit in <u>100 yrs</u> [*Ibid.*]



3.2%