Closing the Methane Budget for the US Corn Belt & Upper Midwest: An Overview of the GEM Study

GREENHOUSE GAS EMISSIONS IN THE MIDWEST

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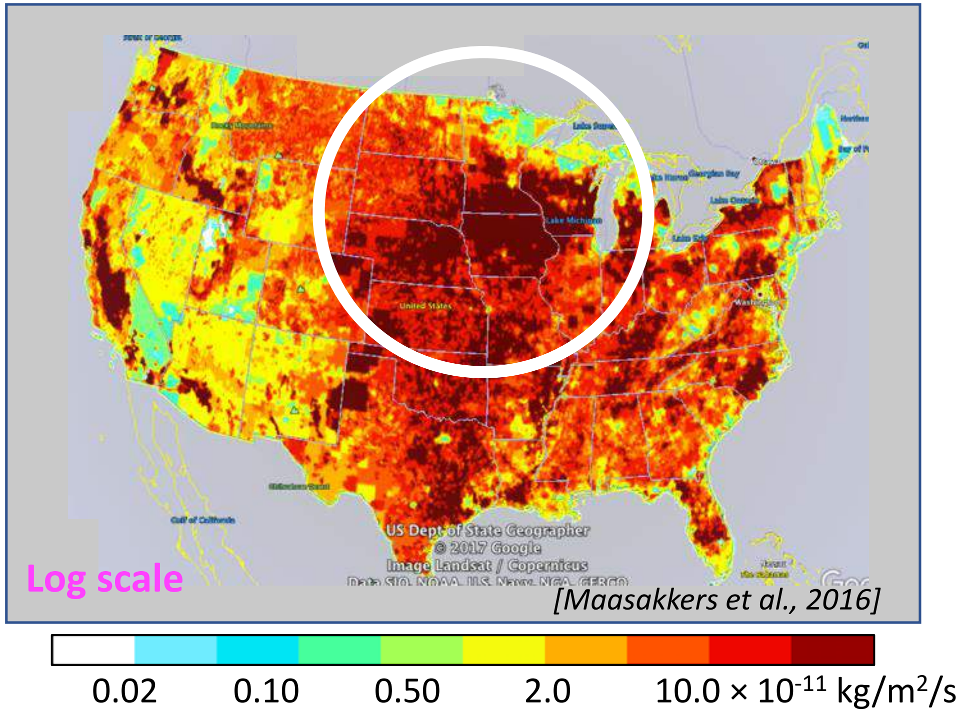
The Corn Belt & Upper Midwest: Key Component of the US Methane Budget

Major agricultural emissions

GEPA enteric + manure emissions



700 million livestock

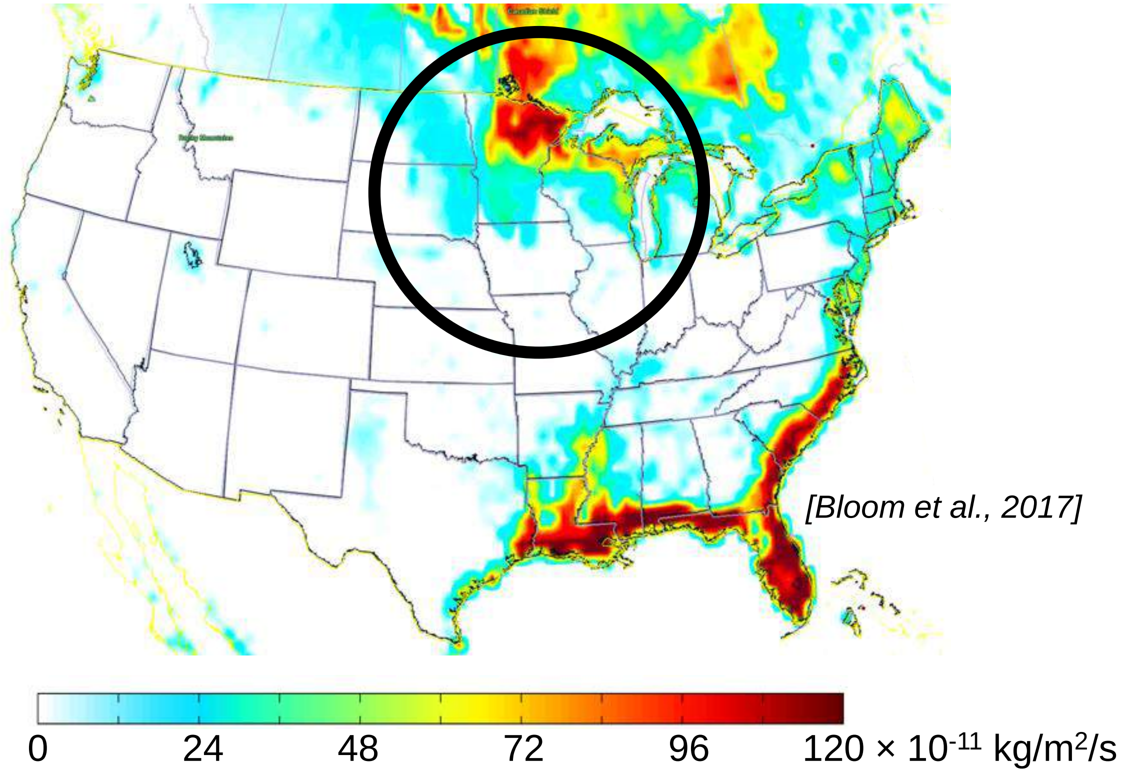
28 million cattle

IA + MN: ~75% of national hog production

~35% of NA livestock CH_4 flux based on current inventories

Also: among most wetland-rich areas in US

WetCHARTS wetland emissions

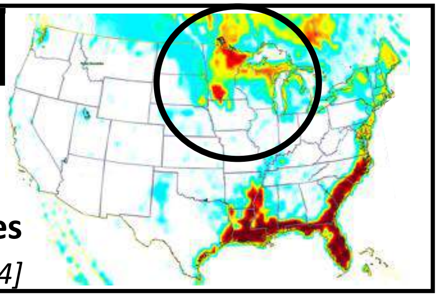


Region: ~30% of NA wetland CH_4 flux

But: uncertainties are large

SD of WetCHARTS ensemble

(same scale)

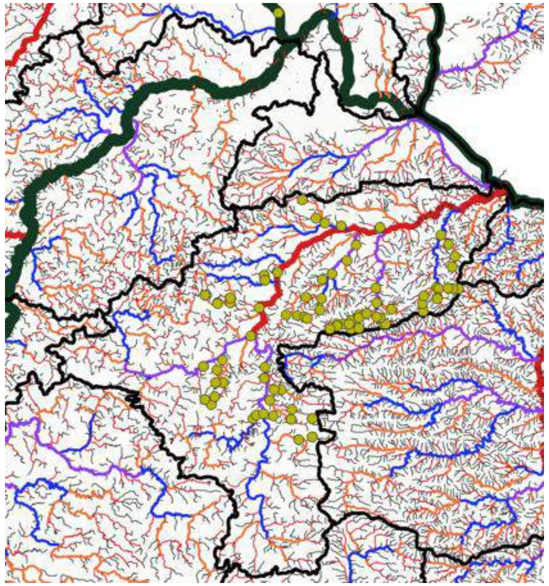


Large bottom-up vs. top-down discrepancies

[Zhang et al., 2014; Miller et al., 2014]

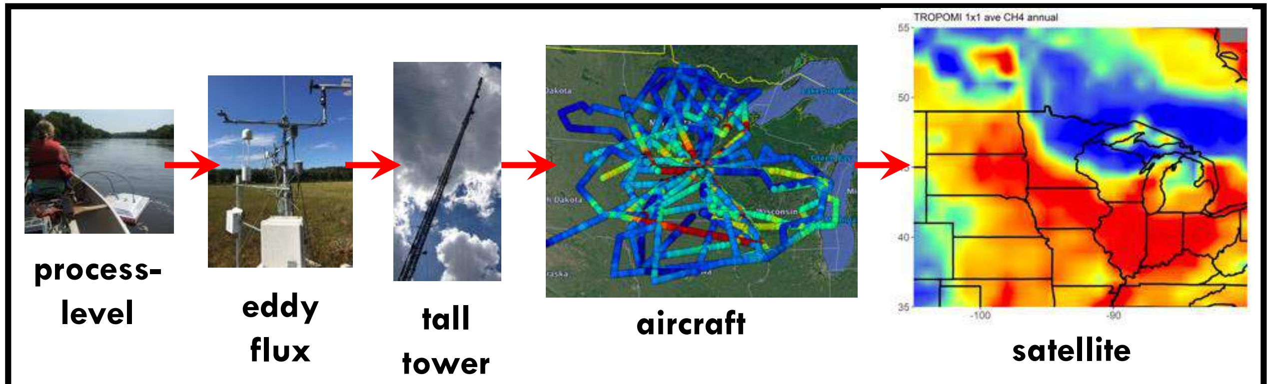
GEM Study: Targeted Uncertainties

<u>Wetlands.</u> The largest North American CH_4 source, but large divergence between estimates.



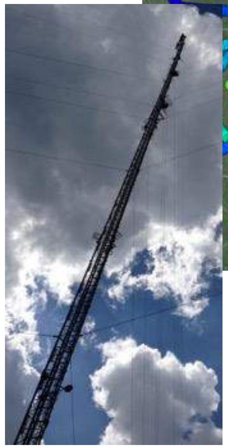
<u>Rivers and Streams.</u> Have shown elevated CH_4 (and N_2O) emissions in agricultural regions, but not well quantified into bottom-up inventories.

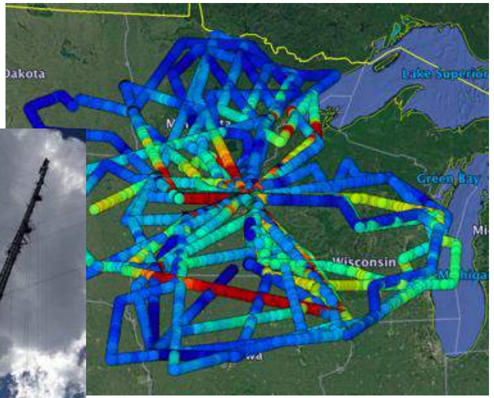
<u>Agriculture.</u> Bottom-up inventories uncertain due to sparse measurements, poor information on contribution from different sources, complicated site-specific management factors.

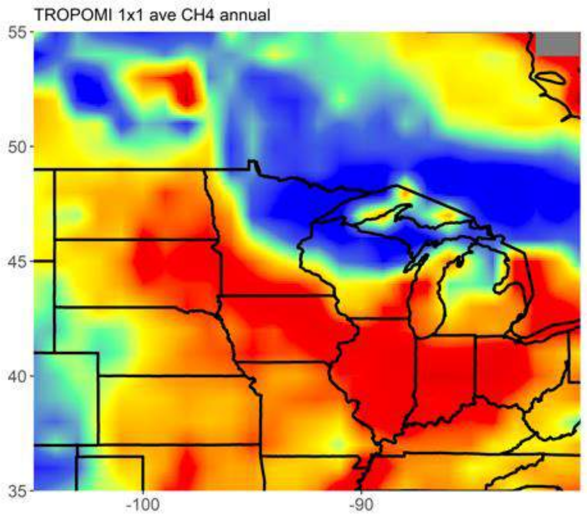


<u>Scaling.</u> Highly heterogeneous, discontinuous CH_4 sources, scaling challenges. Can we reconcile bottom-up process information with top-down constraints?

GEM: Multi-Scale Approach to Regional CH_4 Budget & Its National Context







Process-Scale
Quantifying river/stream and agricultural facility emissions →

Ecosystem-Scale
Multi-year eddy flux measurements over wetlands →

Regional-Scale
Aircraft and tall-tower measurements, forward & inverse modeling (GEOS-Chem) →

Scaling Up, National Context
Satellite data analysis, modeling

Role of Rivers and Stream in CH_4 Budget

Science Questions:

Lead: Ashish Singh

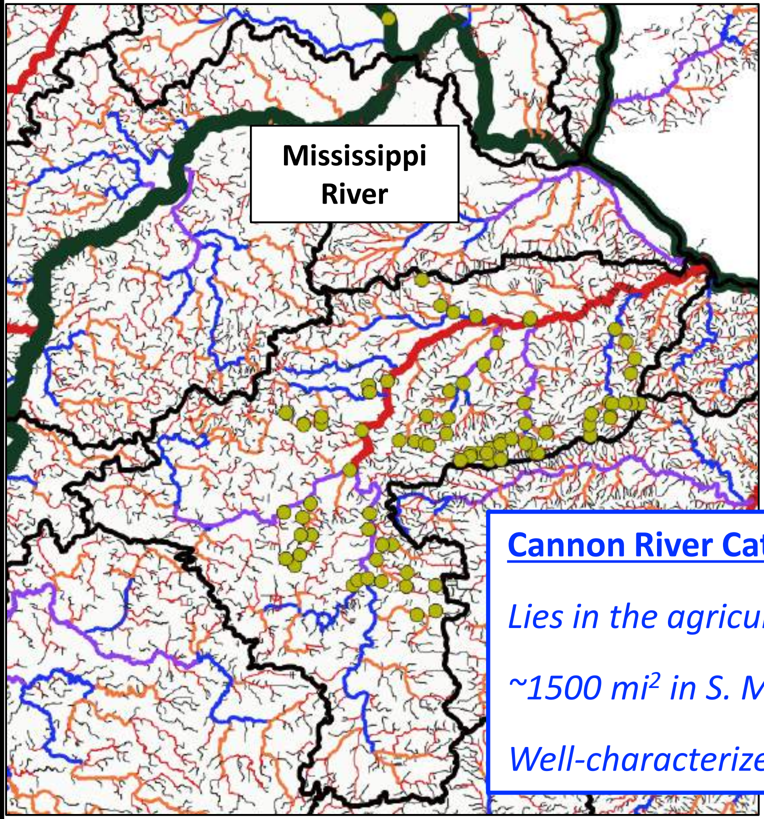
What is the role of streams & river CH_4 emissions in agricultural landscapes?

→ *Stream emissions found to double agricultural N_2O budget for the region [Turner et al., 2015]*

What are the underlying controls on this flux and its variability?

→ *N_2O emissions scale with stream order; are there emergent relationships for CH_4 that can be used for scaling?*

Approach: In-situ measurements through an agricultural watershed

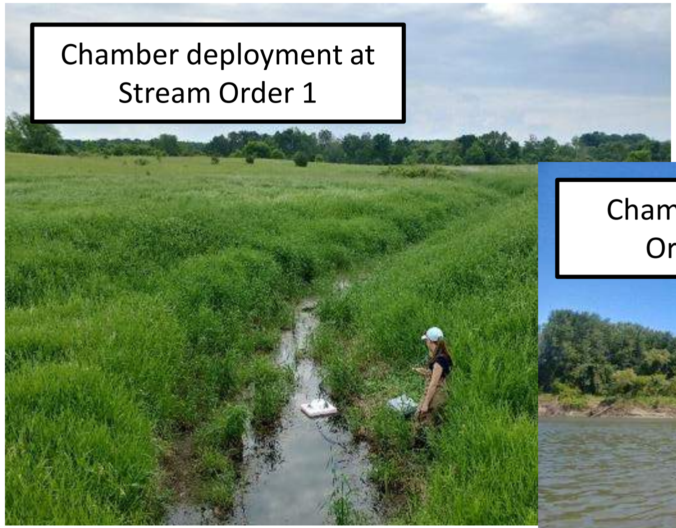


Cannon River Catchment

Lies in the agricultural Corn Belt of US Midwest

~1500 mi^2 in S. MN

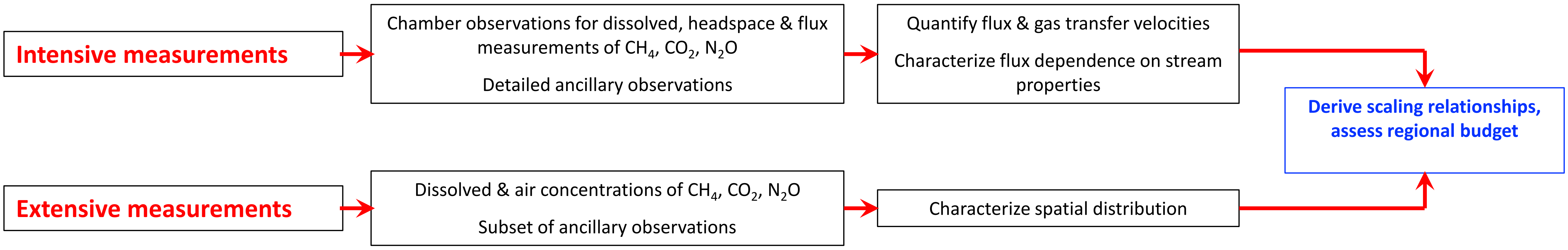
Well-characterized during past N_2O work



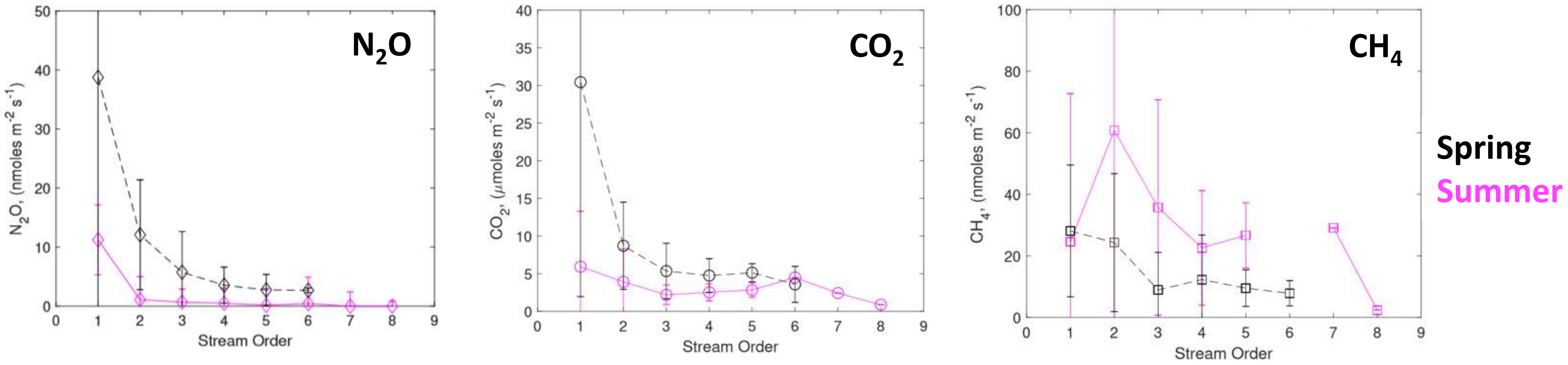
[Singh et al., in prep]

Role of Rivers and Stream in CH_4 Budget

Lead: Ashish Singh



Ongoing measurements!



Initial results point to:

Large, highly variable CH_4 fluxes
No clear link to stream order (contrasts with N_2O, CO_2)
Seasonality differs from N_2O, CO_2

[Singh et al., in prep]

Agricultural Emissions: Scaling Up

Leads: Xiang Li, Ashish Singh

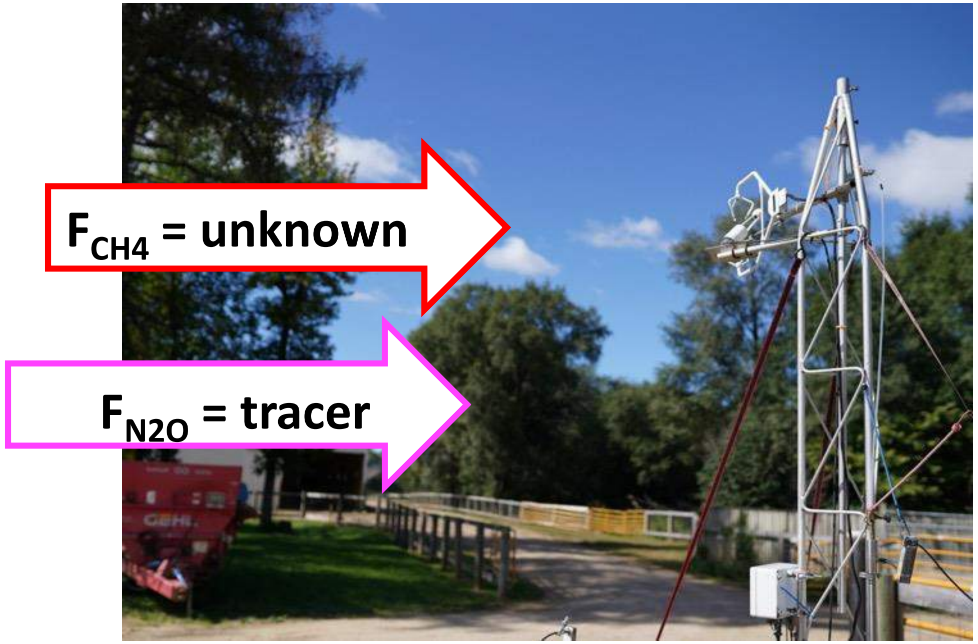
Science Question:

How accurately do current bottom-up methods scale-up to quantify the importance of agricultural CH_4 emissions?

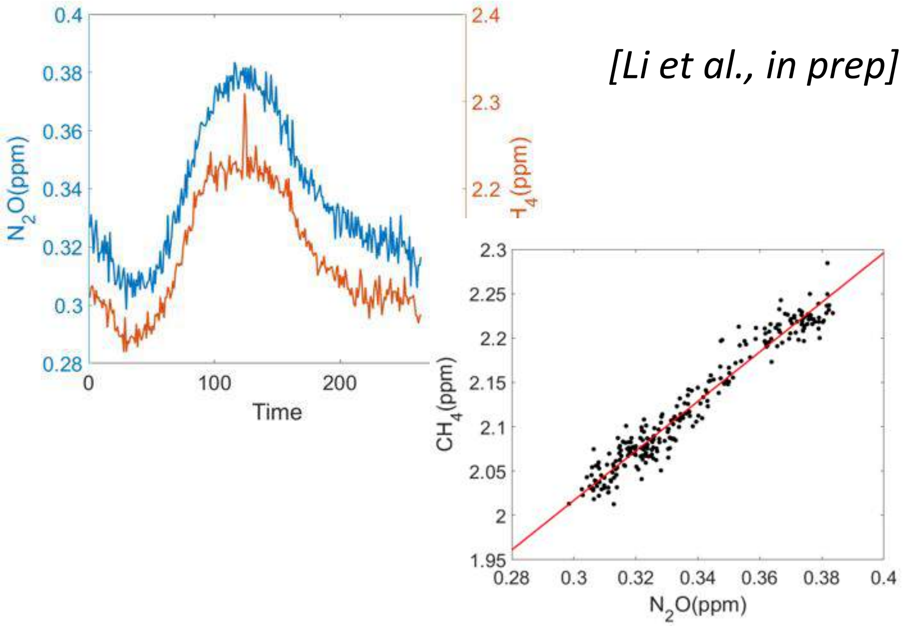
Approach:

Facility-level flux measurements to test bottom-up methodology.

Method 1: Tracer-Release



[Li et al., in prep]



Use CH_4:tracer relationship to compute facility-level flux, compare with bottom-up prediction

Agricultural Emissions: Scaling Up

Method 2: Airborne quantification

Leads: Xueying Yu, Ashish Singh

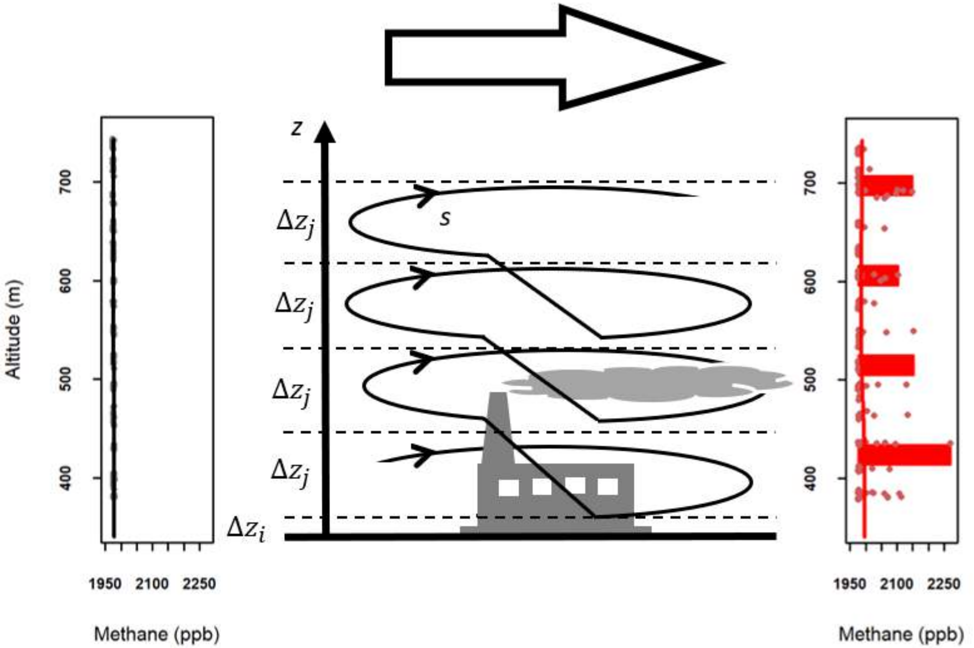
[Yu et al., in review]

Airborne facility-level flux measurements for:

9 of largest CAFOs in region
(dairies, beef, swine)

>100,000 animals combined

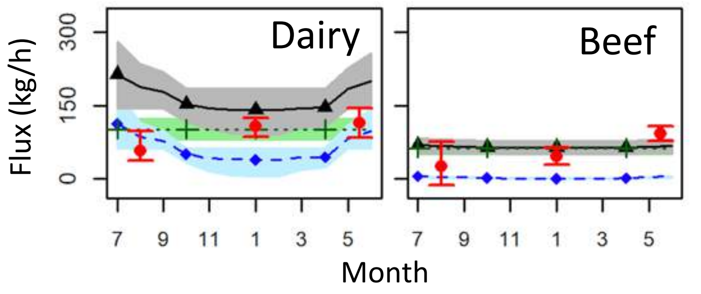
Multiple re-visits across seasons



Example finding:

Airborne + tracer release results support bottom-up enteric flux estimates

Large gap for manure emissions



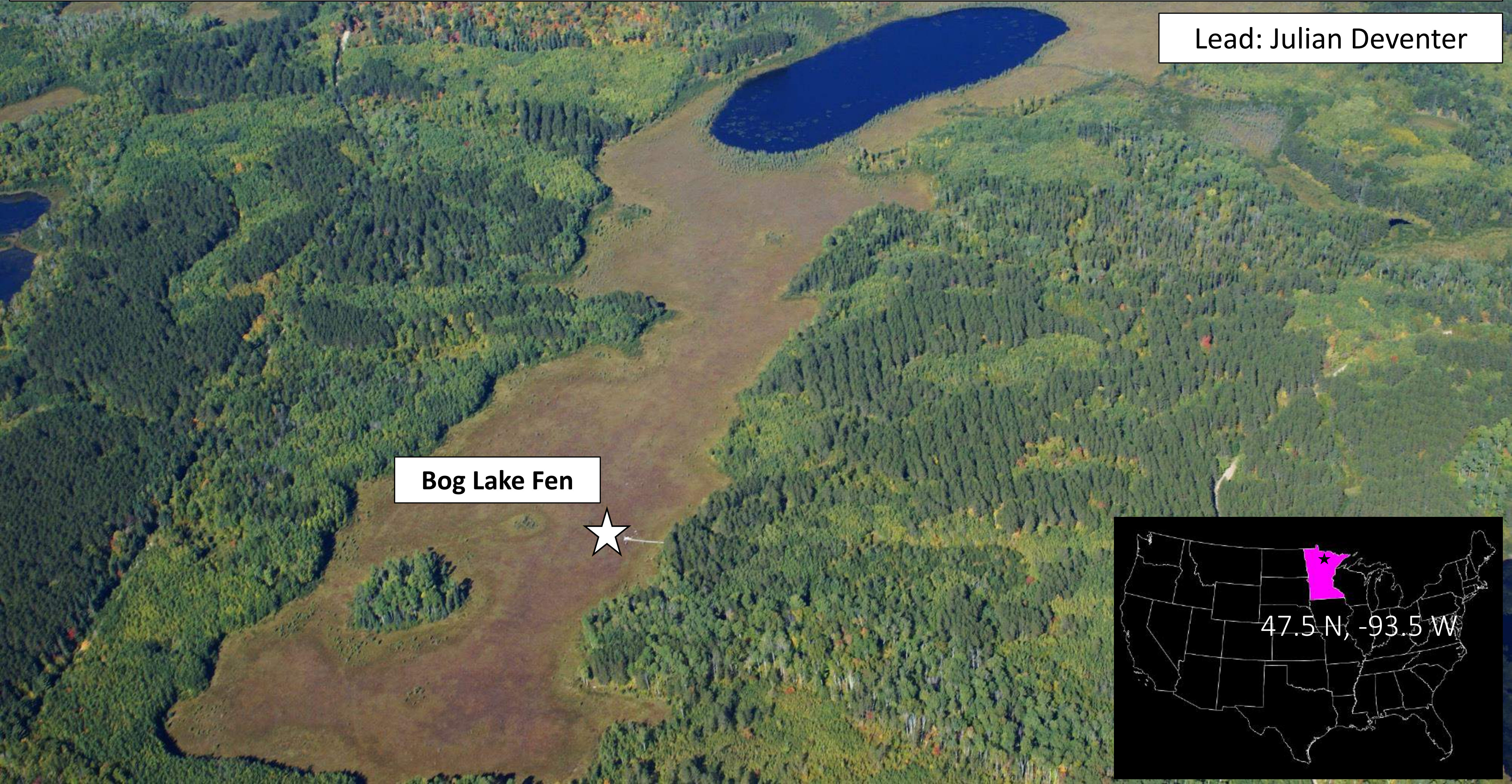
→ *management factors affecting emissions that are not well-captured in inventories*

Space-time distribution of ag emissions mis-represented

Implications for source attribution, inverse modeling

Constraints on Wetland Fluxes From Eddy Covariance Measurements

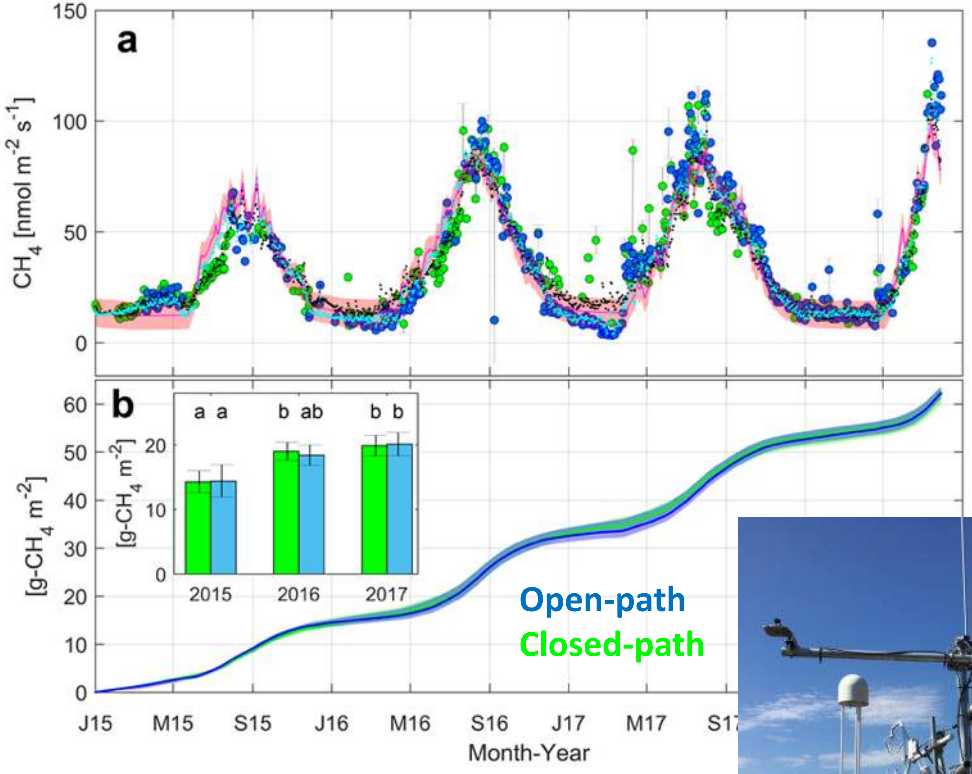
Lead: Julian Deventer



Constraints on Wetland Fluxes From Eddy Covariance Measurements

Lead: Julian Deventer

Quantifying uncertainties in wetland CH_4 budgets

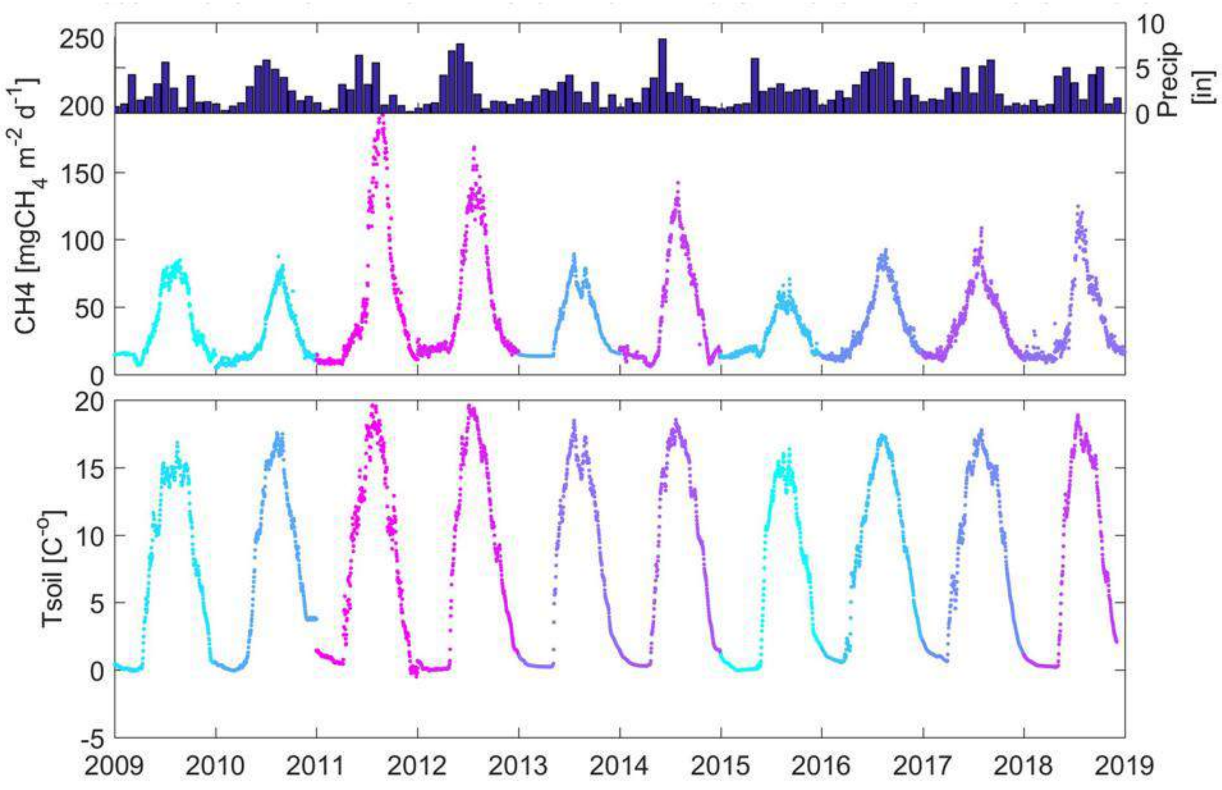


Multi-year flux measurements with independent instruments for error quantification

[Deventer et al., 2019]

Large interannual variability in emissions

→ Argues for strong climate sensitivity



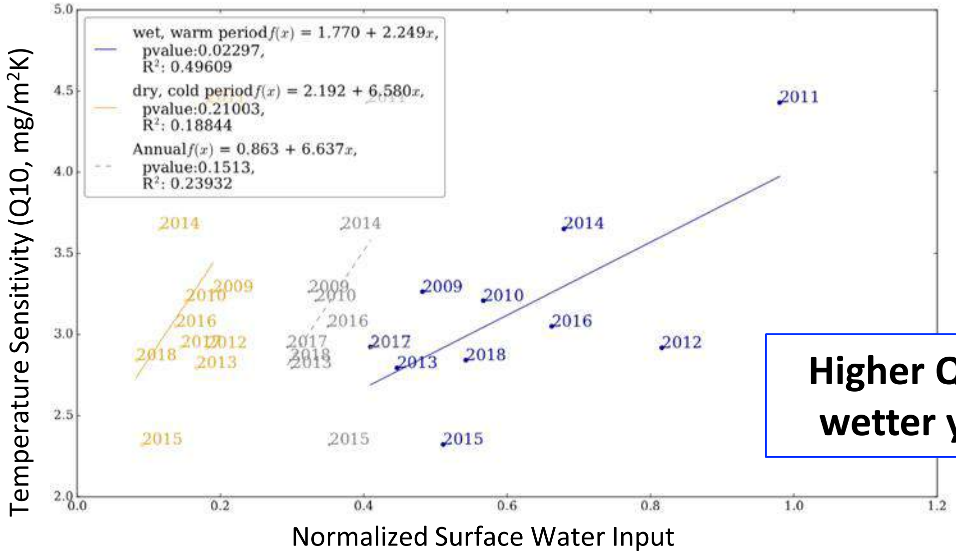
Consecutive years can vary to 2x

Inter-annual flux variability much greater than in soil T

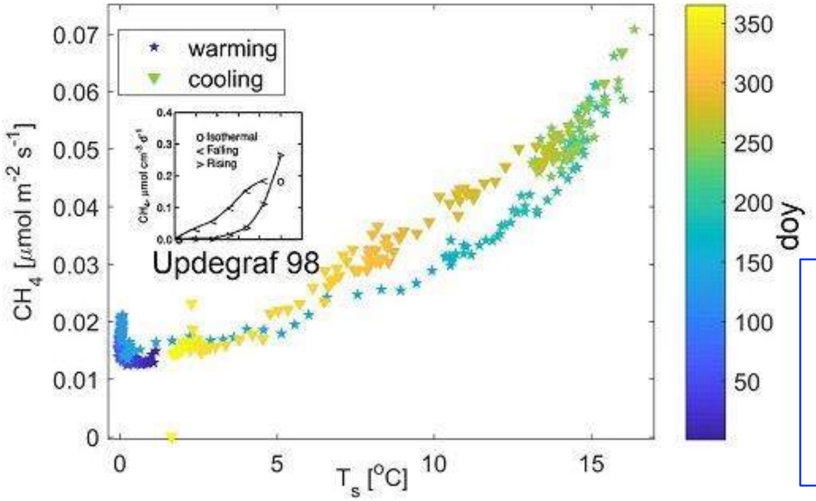
Constraints on Wetland Fluxes From Eddy Covariance Measurements

Example results: CH_4 flux dependence on interactions between T, hydrology, snow cover

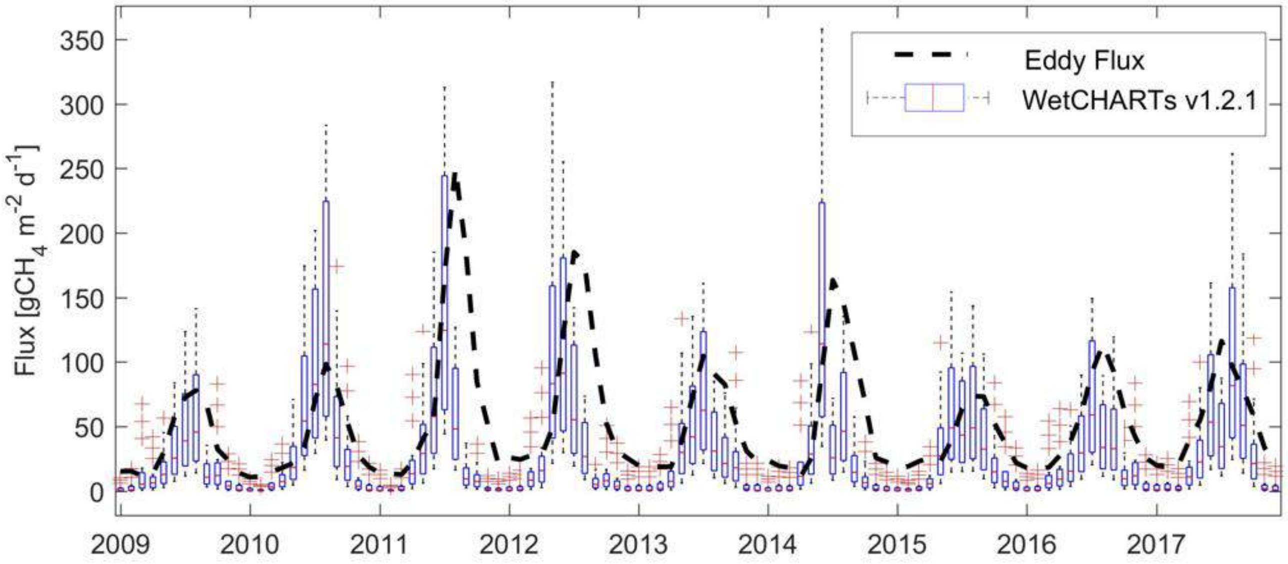
Lead: Julian Deventer



Higher Q10 in wetter years



Hysteresis: higher emissions, T-sensitivity in latter phase of year



Ongoing - testing current emission models:
Flux measurements versus WetCHARTs

Long-term flux data to evaluate modeled climate sensitivities for CH_4 emissions

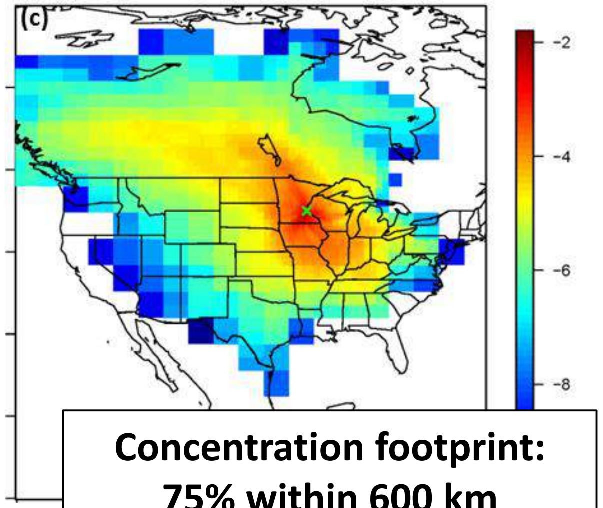
WetCHARTs ensemble: comparable IAV to observations

Biased seasonality

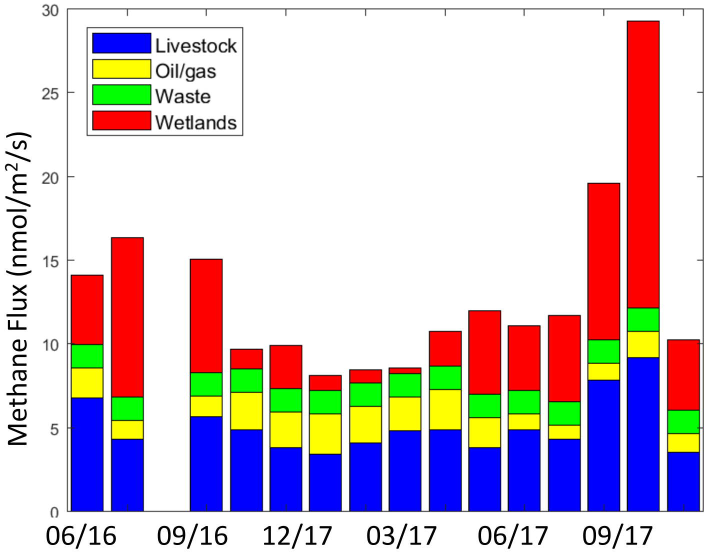
[Deventer et al., 2019; Deventer et al. in prep]

Tall Tower Measurements to Quantify Regional CH_4 Flux Through Time

Lead: Tim Griffis



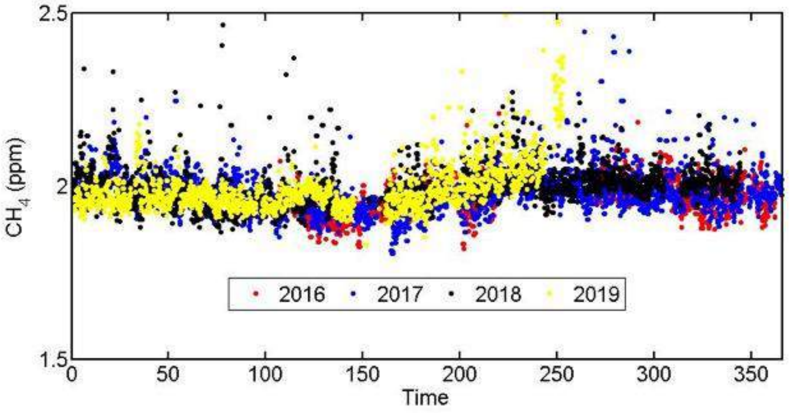
Concentration footprint: 75% within 600 km



Example result - Seasonal inversions for 2016/17 show dominance of wetlands, ag CH_4 sources

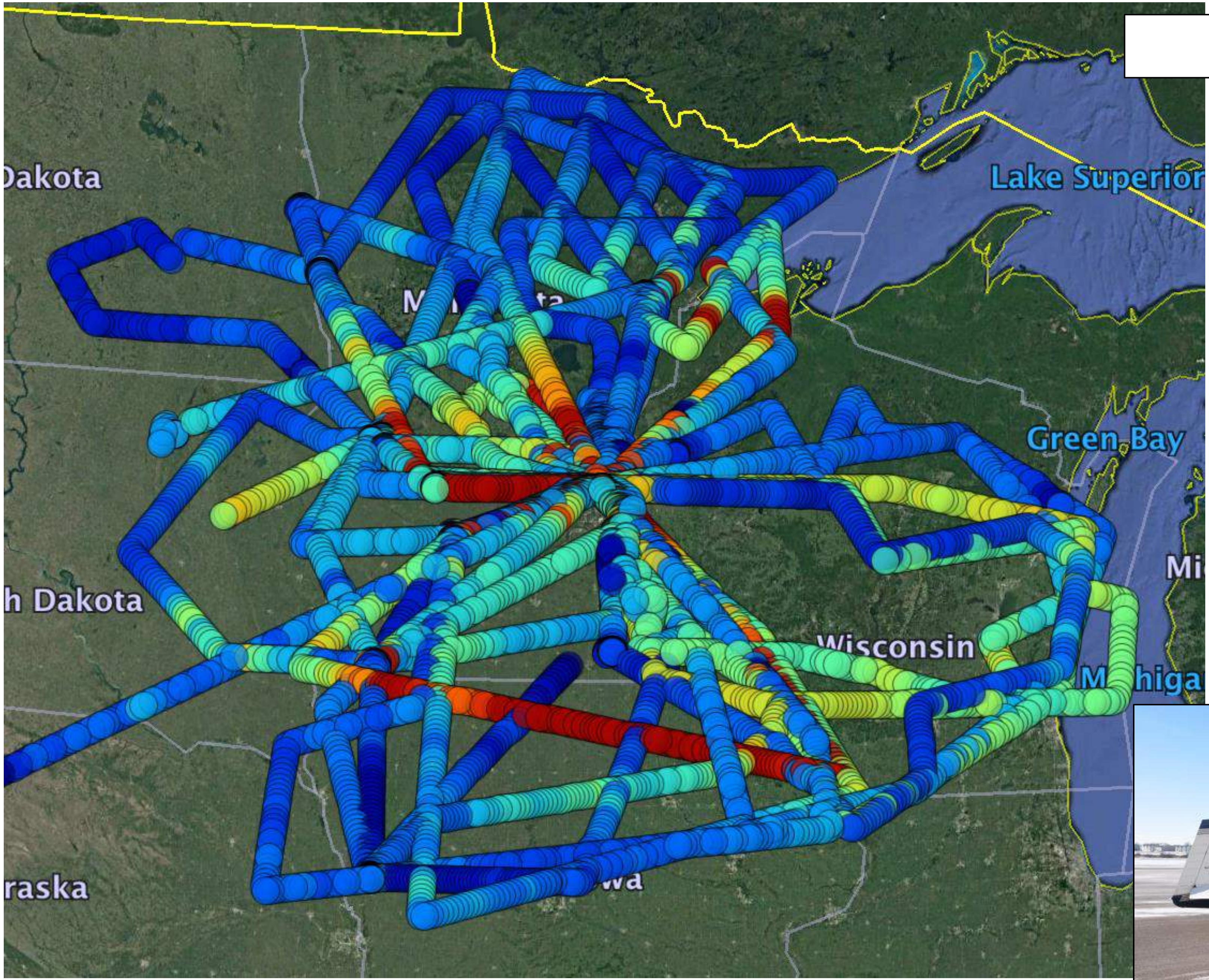
[Chen et al., 2018]

Ongoing: Apply 4+ year dataset to quantify regional trends through time



[Griffis et al. in prep]

Airborne Measurements Across Seasons to Derive Spatial Constraints



Leads: Dylan Millet, Eric Kort, Xueying Yu

Measurements span summer, winter, spring

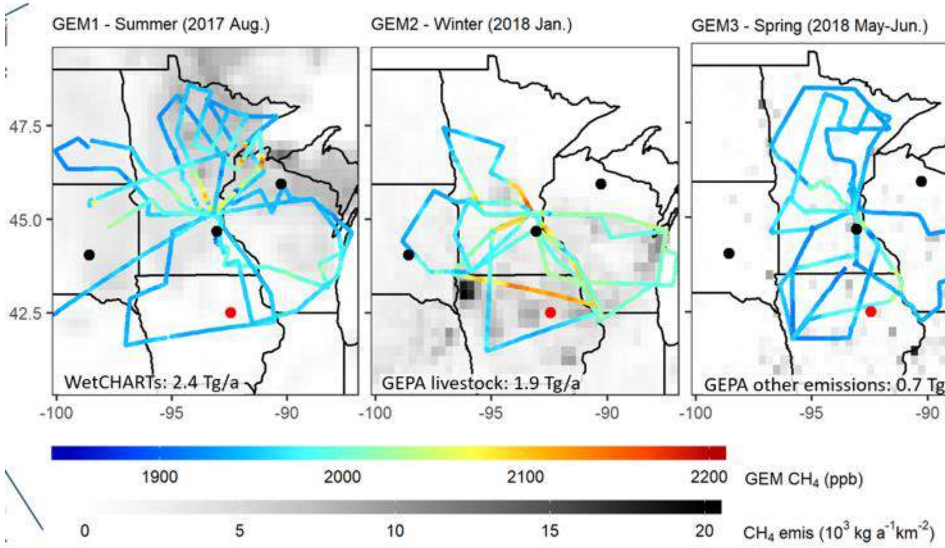
Suite of trace gases: CH_4, CO_2, N_2O, CO, O_3, H_2O

Regional surveying for wetland, agriculture, urban emissions, point sources

Ongoing: inverse analysis of CH_4 and N_2O emissions

Multiple Inversion Frameworks to Quantify Midwest Methane Fluxes

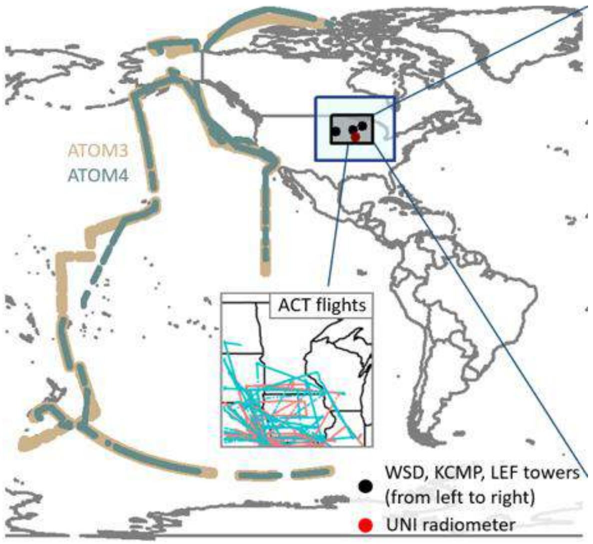
Lead: Xueying Yu



1) High-resolution adjoint optimization (GEOS-Chem @ 0.25° × 0.3125°)

2) Sector-based analytical inversions for source attribution

3) Gaussian Mixture Model (GMM) to spatially cluster grid cells prior to optimization.



Exploit combined constraints from GEM, ACT-America, ATom

	Total	Oil & Gas	Livestock	Waste	Rice	Fires	Wetlands	Other
Sector	0.94	1.03	1.01	1.02	1.01	1.00	0.83	1.00
Sector + BC	0.95	1.03	1.01	1.02	1.01	1.00	0.83	1.00
GMM	0.99	1.05	1.07	1.05	1.01	1.00	0.89	1.00
GMM + BC	0.93	1.02	1.03	1.03	1.00	1.00	0.77	1.00
GMM-Adj	0.99	1.05	1.02	1.02	1.03	1.01	0.92	1.01
GMM-Adj + BC	0.95	1.03	0.99	1.01	1.02	0.98	0.85	0.99
Adjoint	0.99	1.02	1.03	1.02	1.07	0.99	0.93	1.02

Example finding:

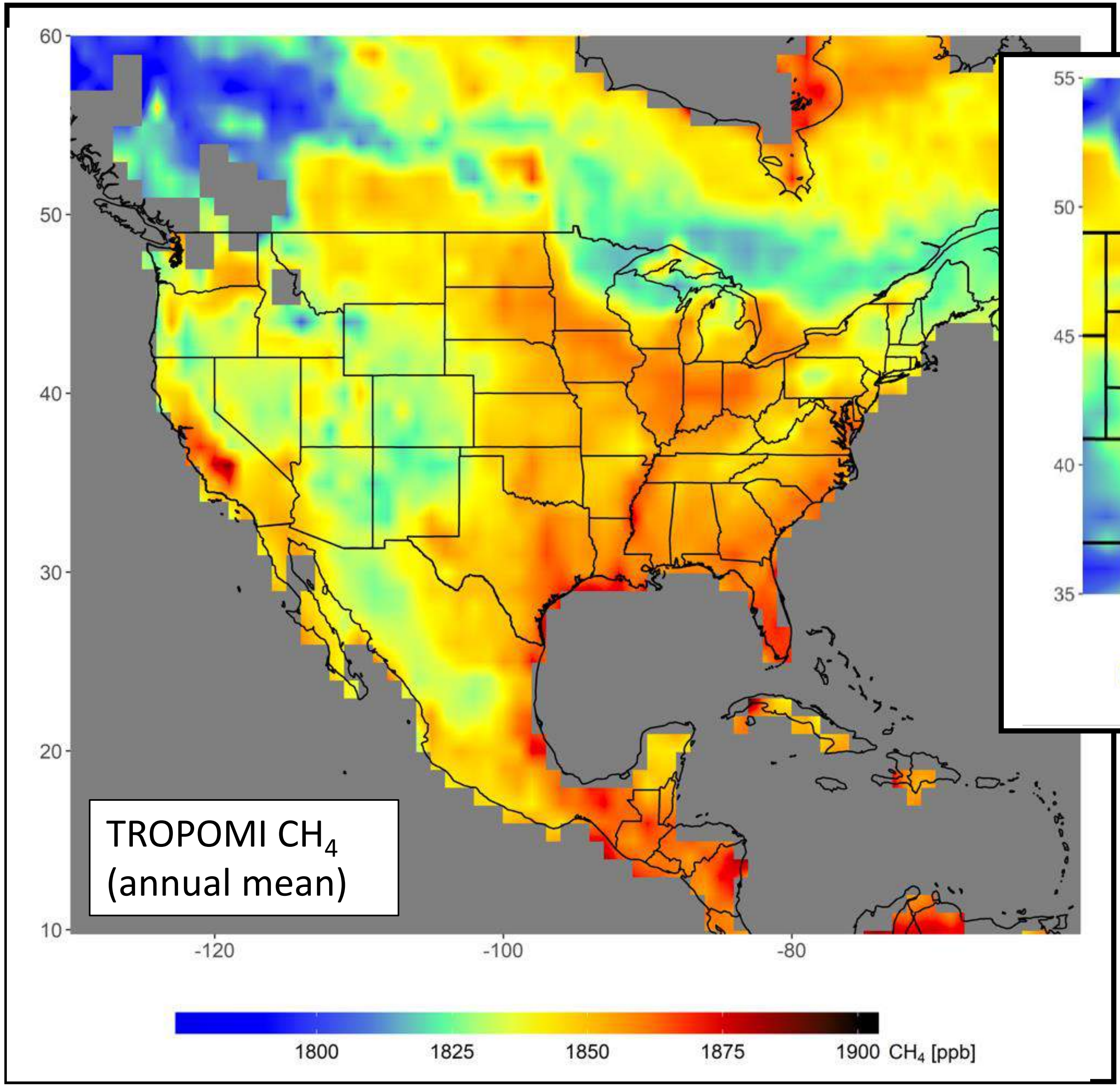
Bottom-up overestimate of springtime wetland CH_4 flux

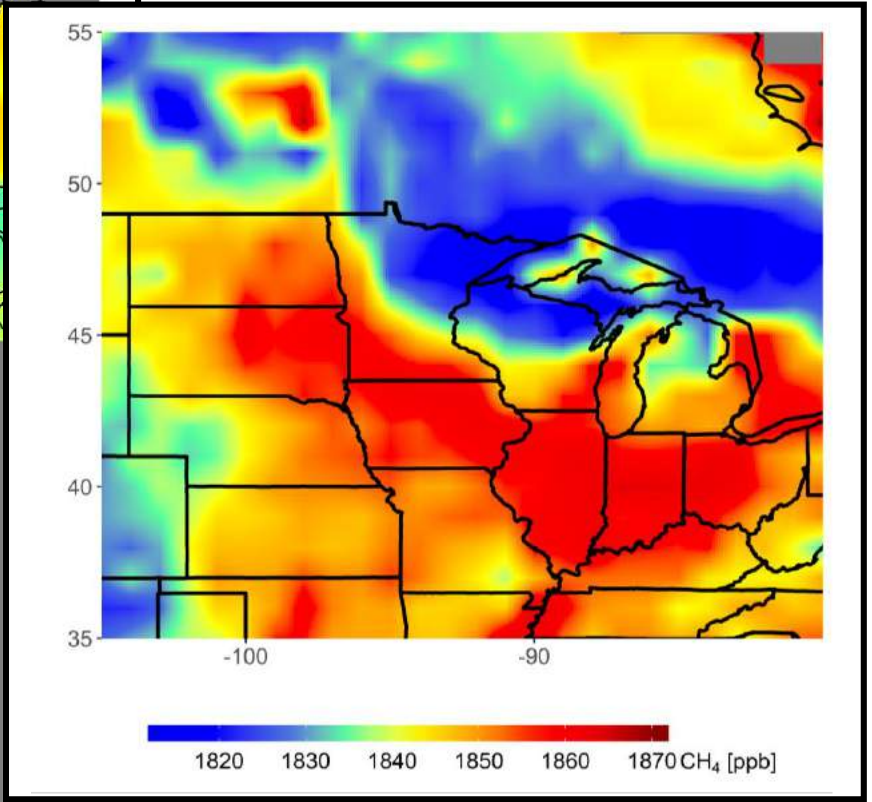
Robust across inverse frameworks

Consistent with GEM eddy flux measurements

Next Steps:

Lead: Xueying Yu





Application of new TROPOMI CH_4 data

Retrieval evaluation

Assess consistency with constraints from GEM datasets; place regional findings in broader context