Regional methane emissions estimates in northern Pennsylvania gas fields using atmospheric inversions

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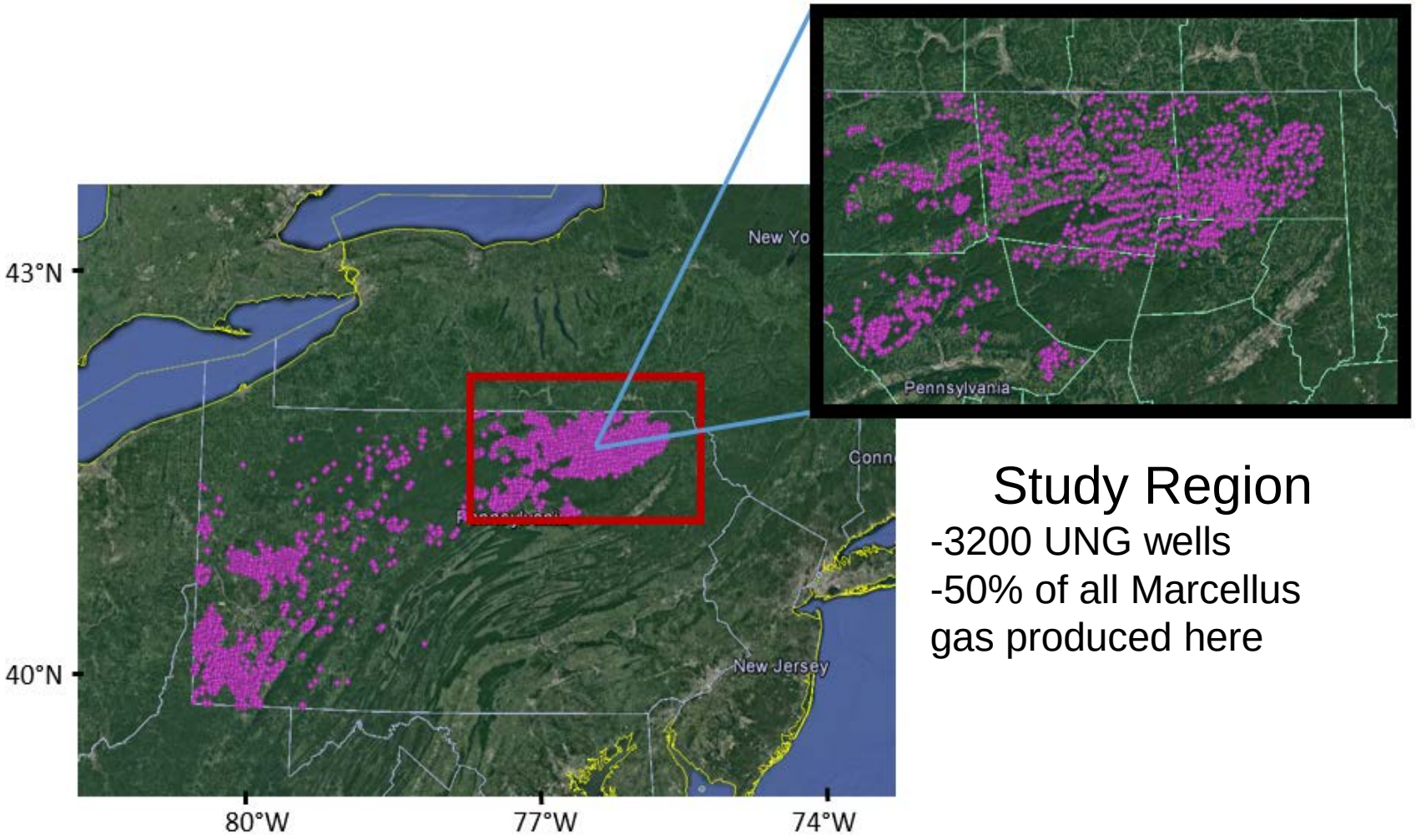
Project sponsored by the Department of Energy
National Energy Technology Laboratory

TA [2] Continuous, regional methane emissions estimates in northern Pennsylvania gas fields using atmospheric inversions



Study Region

-3200 UNG wells
-50% of all Marcellus gas produced here

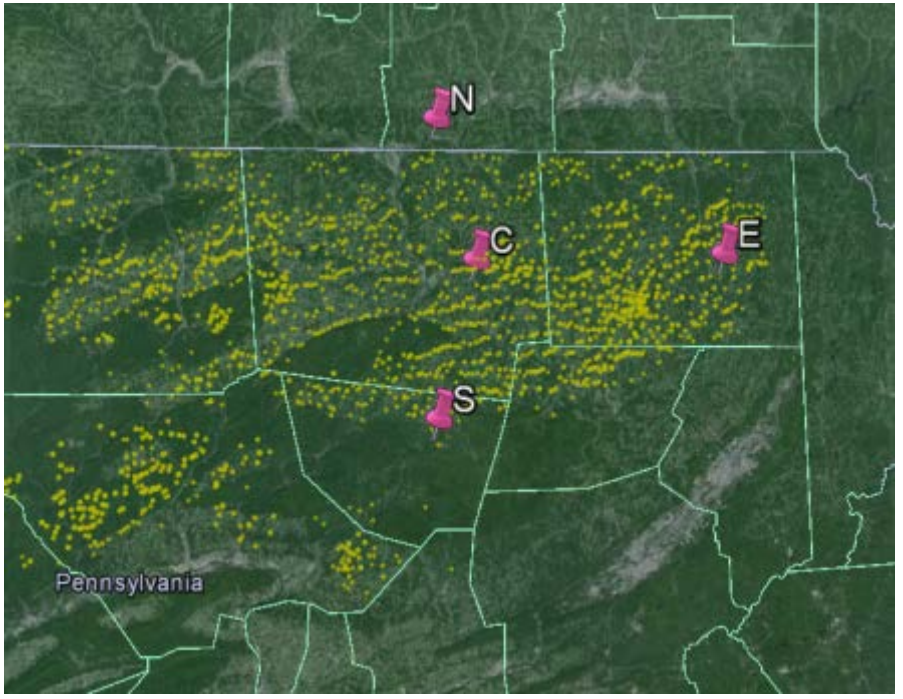
Objective: To quantify natural gas emissions from production in the northeastern Marcellus region

The Marcellus Projects: 2 approaches to estimating emissions

Aircraft Campaign

-Use CH_4 data from a series of flights in conjunction with a forward transport model to solve for the total emission rate from natural gas.

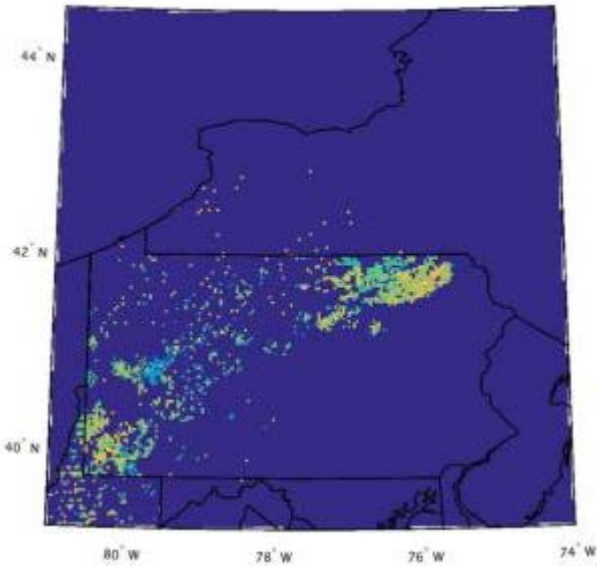
Tower-based Inversion



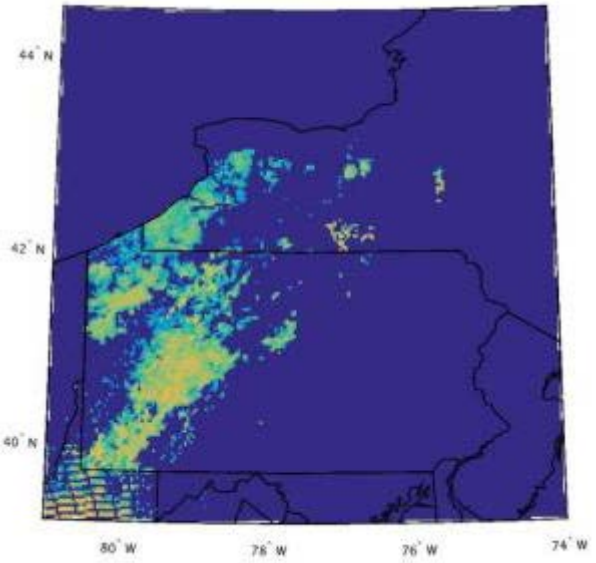
-Use a 2 year dataset of continuous CH_4 measurements from 4 points to detect spatial and temporal variability in emissions from natural gas using a Bayesian framework.

CH_4 Emissions Inventory

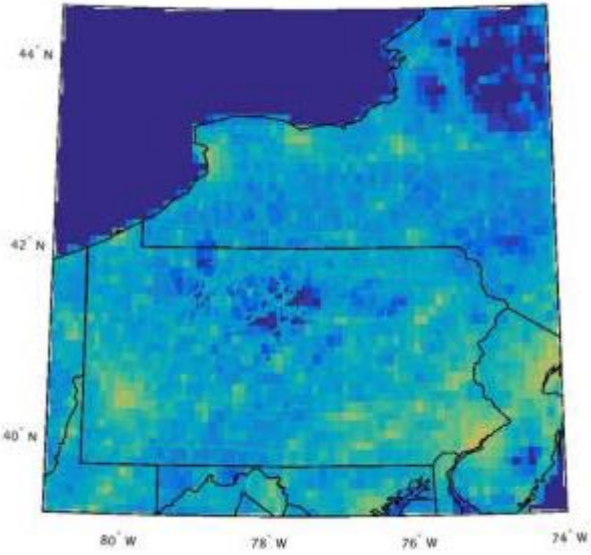
Unconventional Production



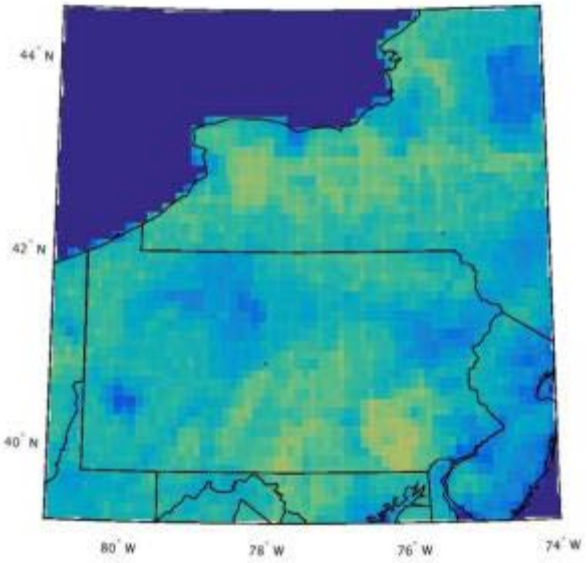
Conventional Production



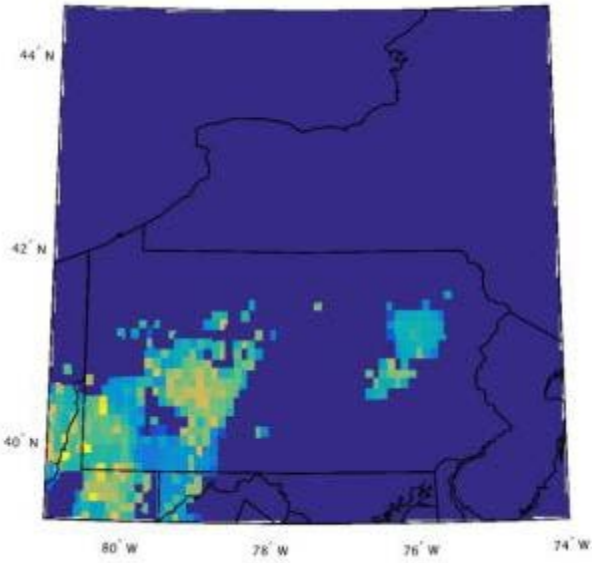
Distribution



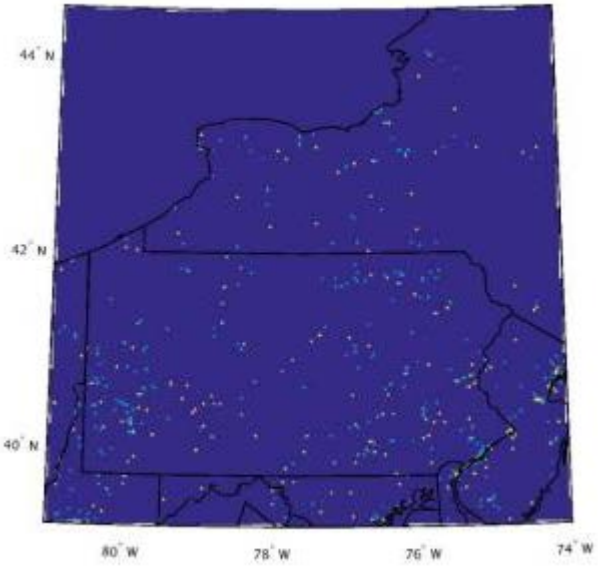
Animal Agriculture



Coal mines/beds

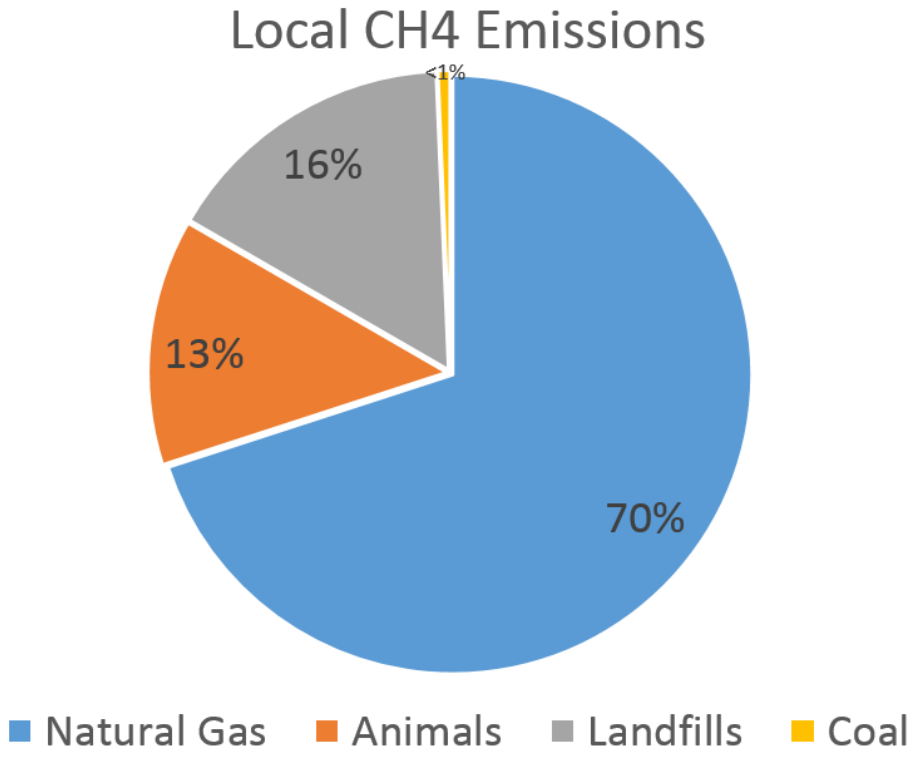


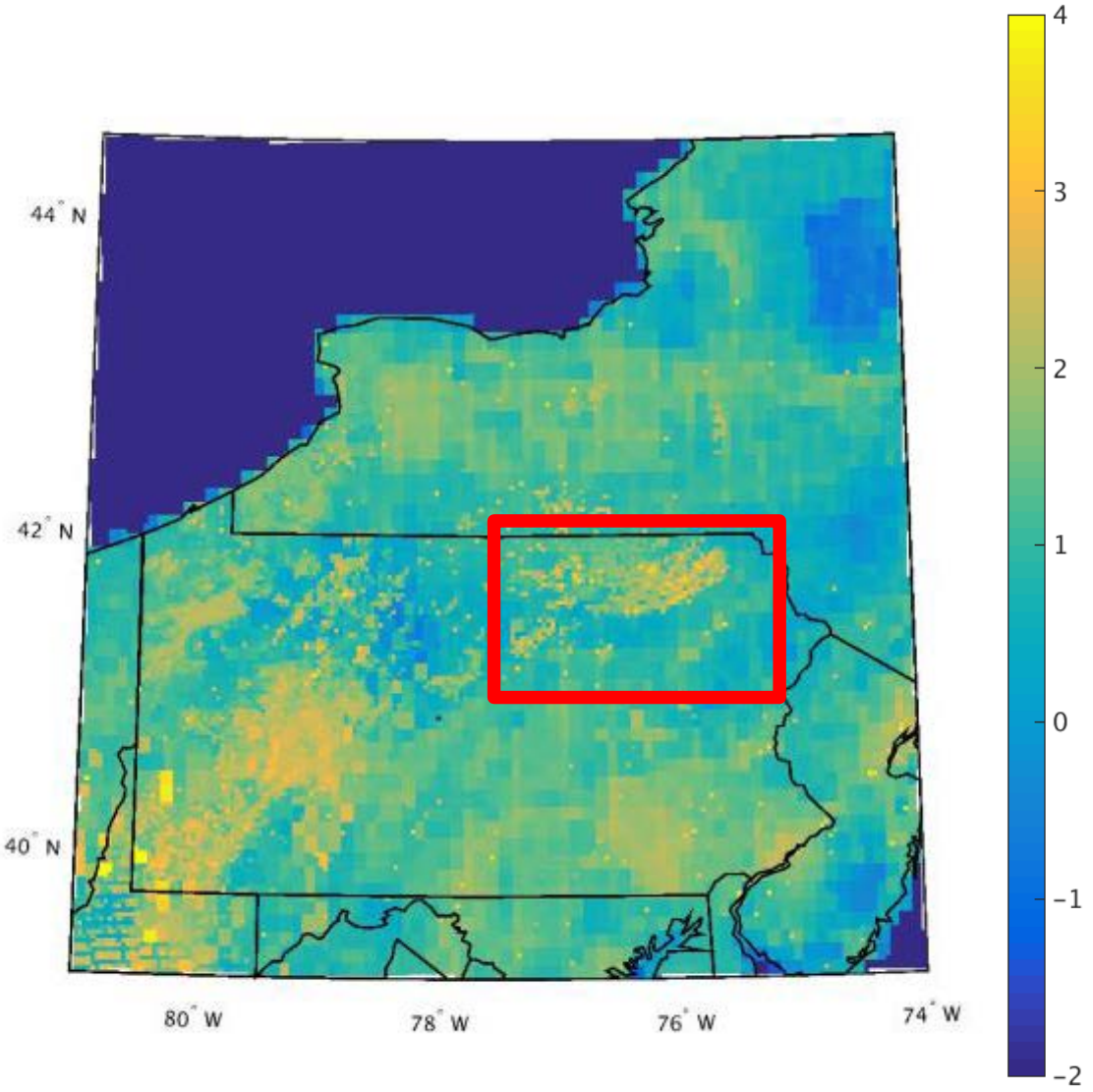
Landfill / Industry



from Barkley et al., under review

CH_4 Emissions Inventory

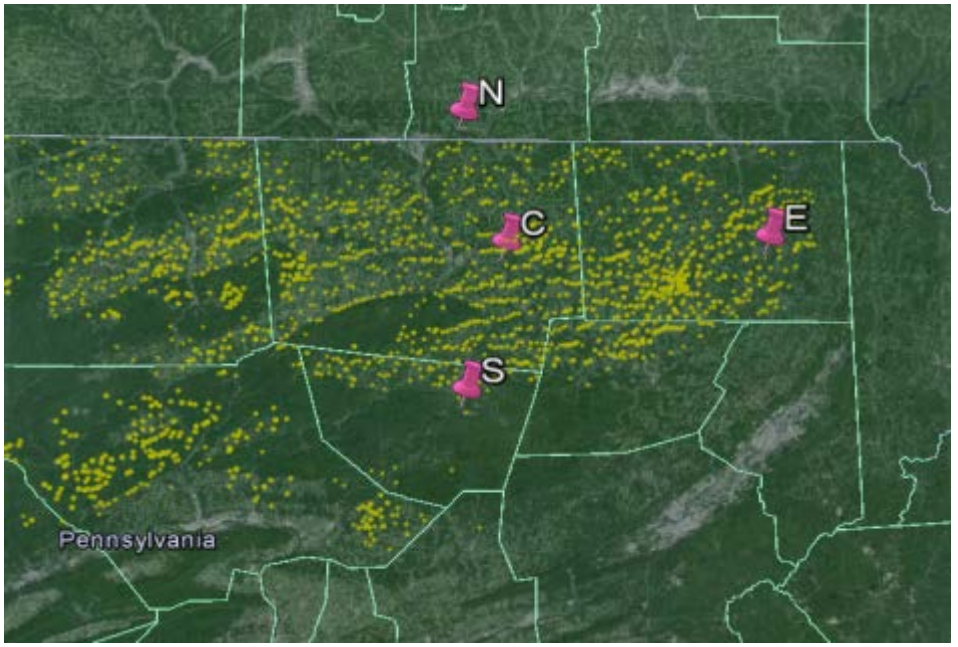




Map of the CH_4 emissions inventory for the extended Pennsylvania study domain in $mol.km^{-2}.hour^{-1}$ and our domain of interest (red box)

MARCELLUS TOWER NETWORK

Deployment of calibrated CRDS instruments at the four identified tower locations



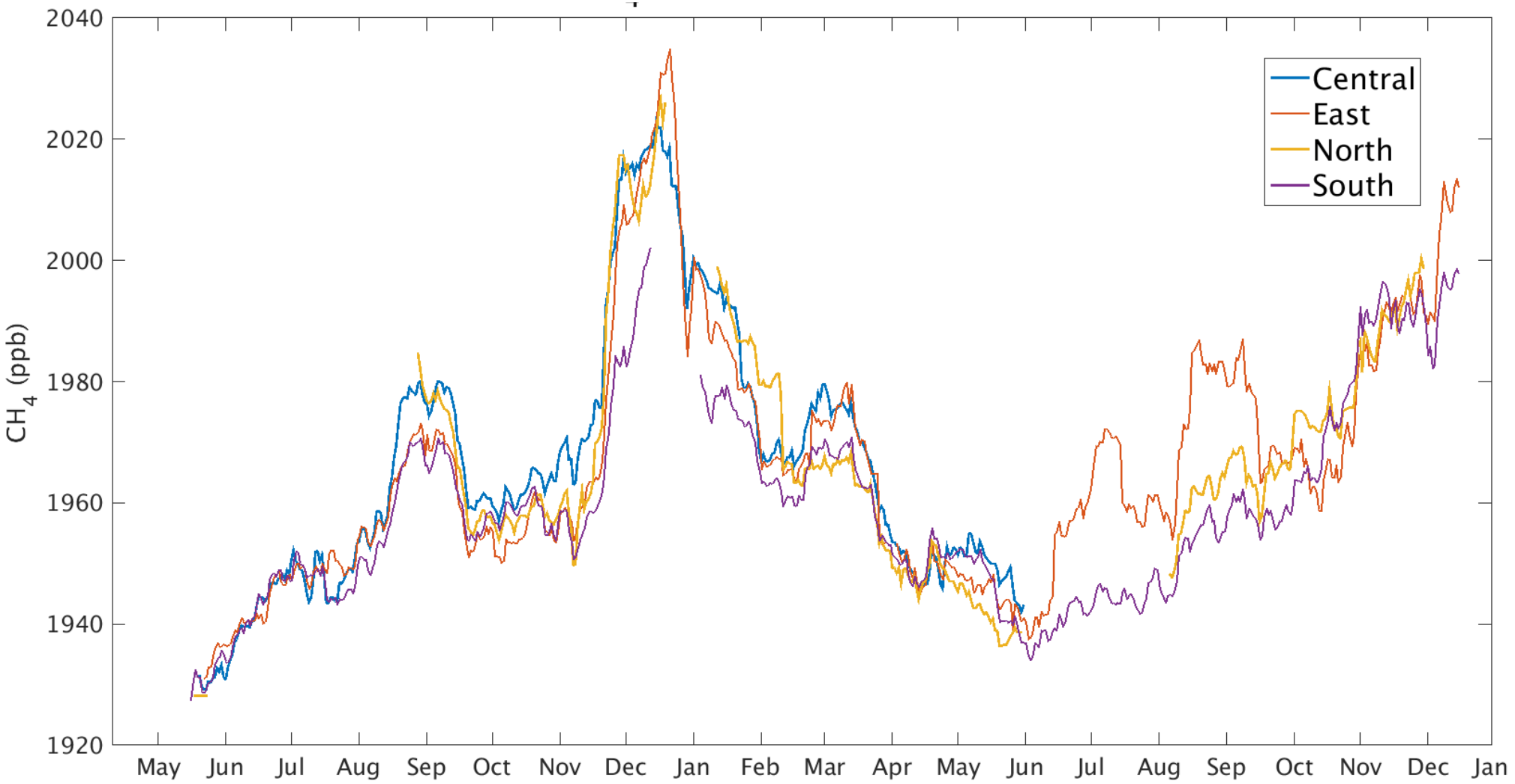
Definitive tower locations of the 4 towers called North (N), East (E), South (S), and Central (C). Unconventional wells are plotted in the background.

	Latitude	Longitude	Installation Date	Elevation (mASL)	Sampling height (mAGL)
Tower N-North	42.0159	-76.4333	05/08/15	476	46
Tower S-South	41.4662	-76.4188	05/07/15	591	61
Tower C-Central	41.7568	-76.3265	05/05/15	341	59
Tower E-East	41.7685	-75.6807	05/13/15	450	59

Coordinates, elevations, and sampling heights of the 4 towers

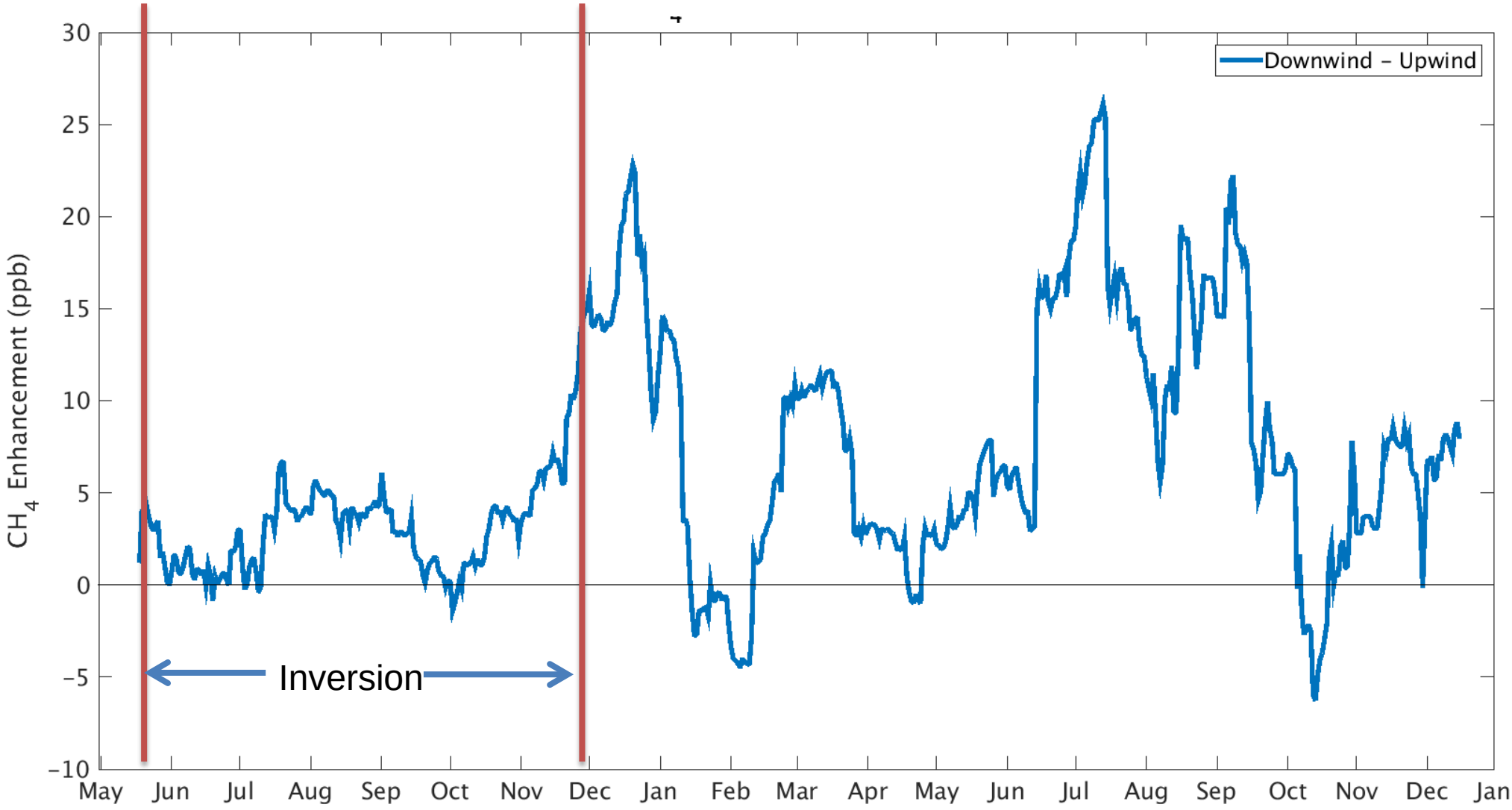
Photo of temporary shed (upper) and tube inlet at tower N, 46m AGL (lower)

Deployment of calibrated CRDS instruments at the four identified tower locations



CH_4 mixing ratio measurements over 2015-2017 from the four CRDS CH_4/$^{13}CH_4$ instruments (in ppb)

Downwind – Upwind CH_4



CH_4 mixing ratio enhancements over 2015-2017 from the four CRDS CH_4/$^{13}CH_4$ instruments (in ppb)

Tower-based Inversion

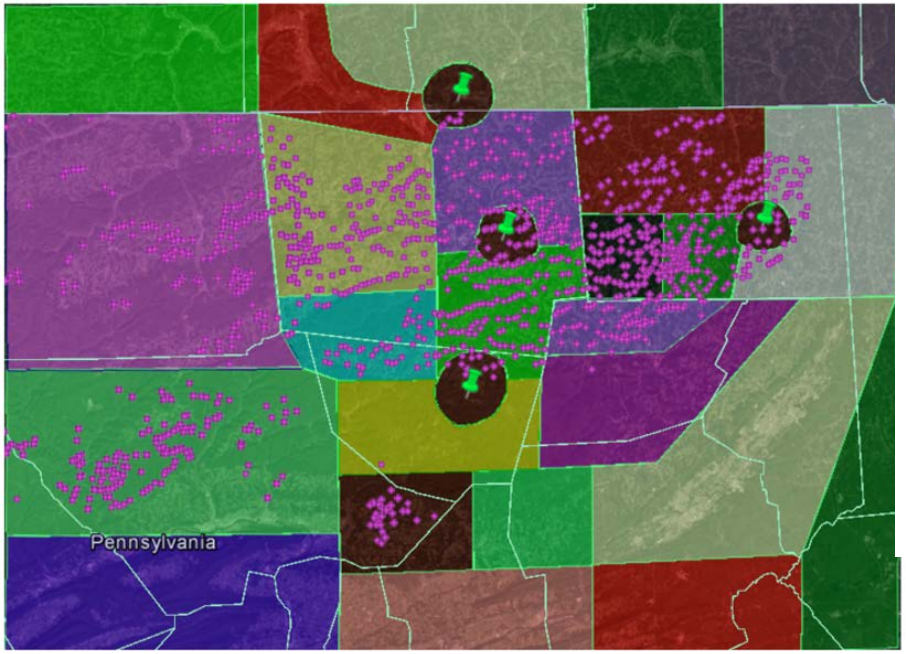
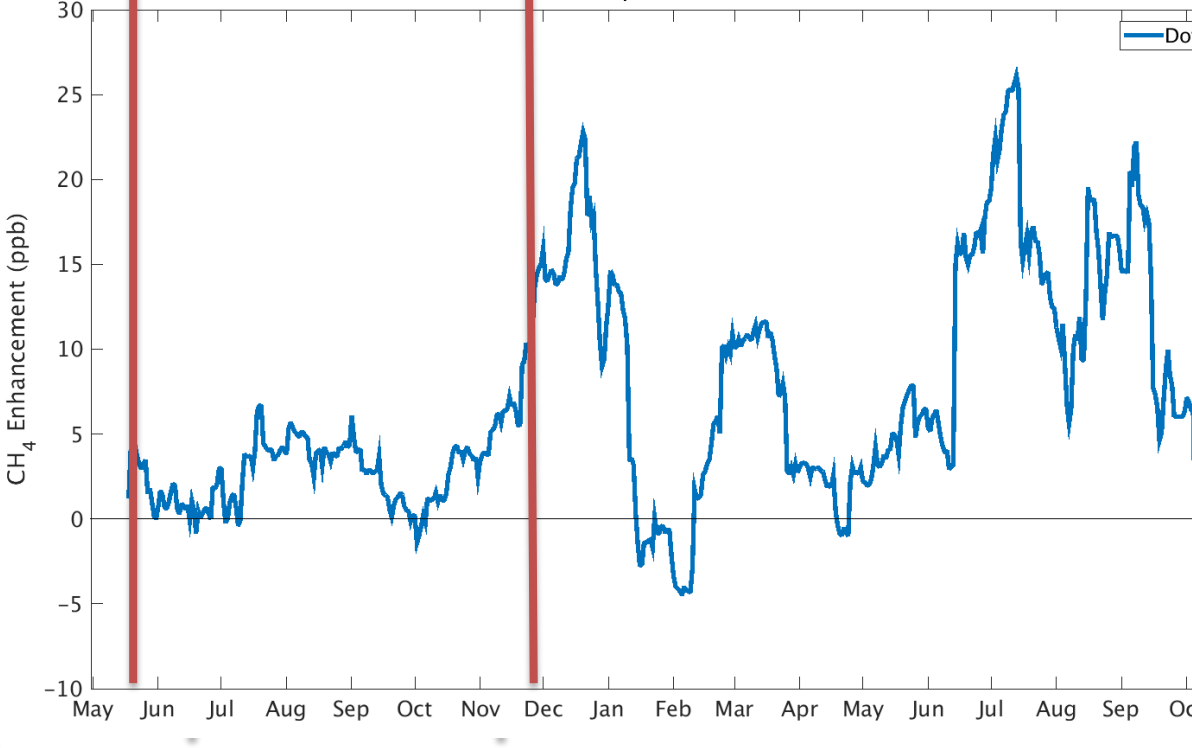
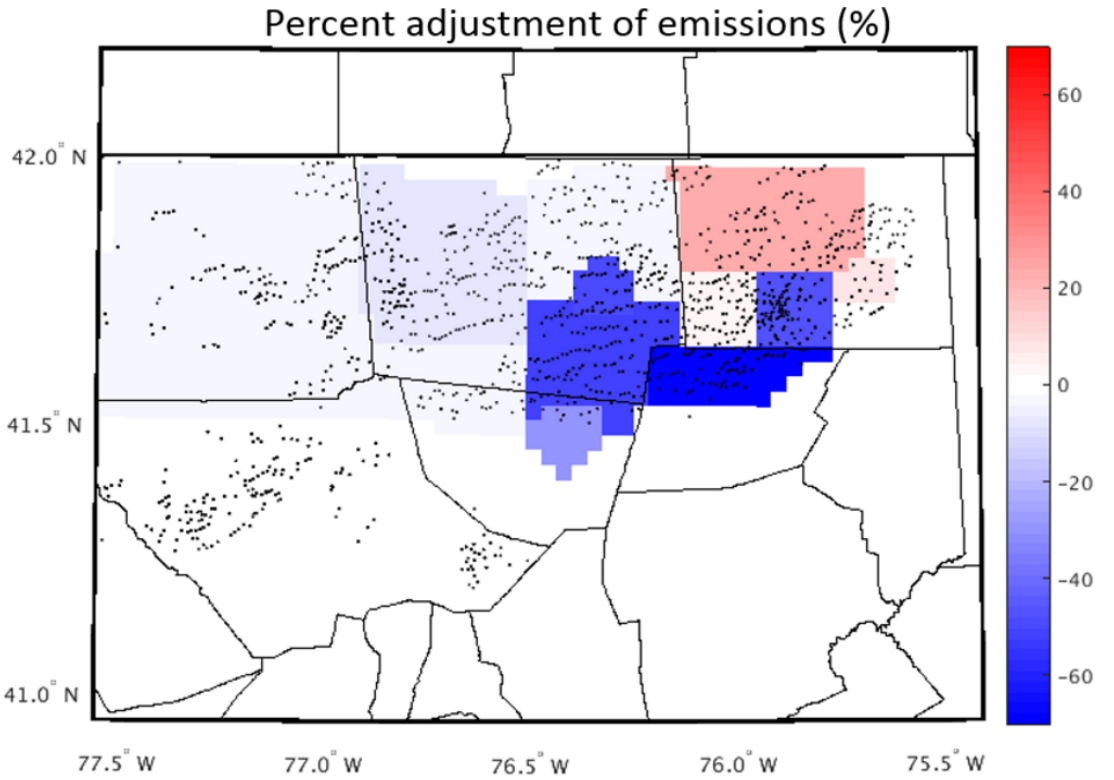


Diagram of the different flux sub-regions used in the inversion. Towers (green pins) and wells (pink dots) are plotted overtop



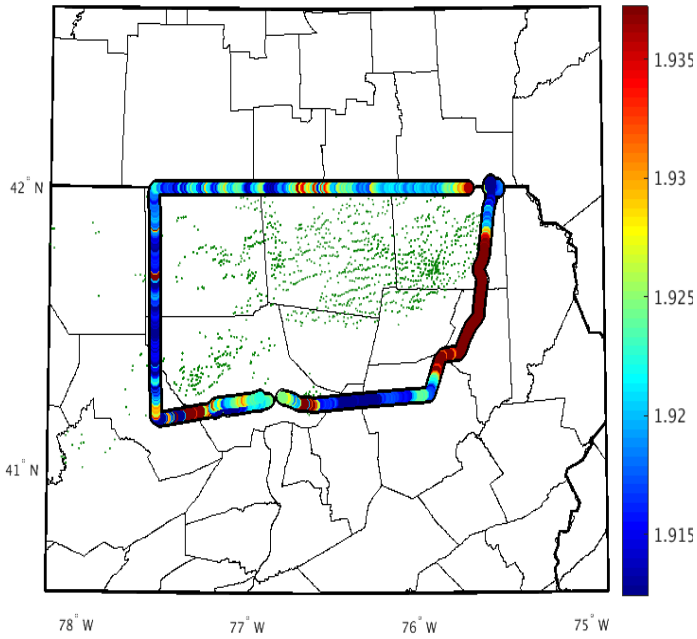


Map of the percent change in the posterior flux compared to the prior flux using tower observations from Oct-Dec 2015

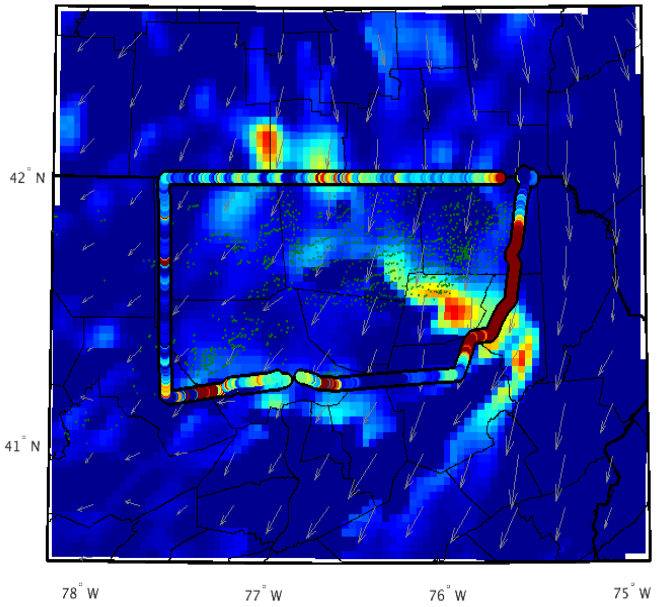
MARCELLUS AIRCRAFT CAMPAIGN

Deriving Natural Gas Emissions: 3 Steps

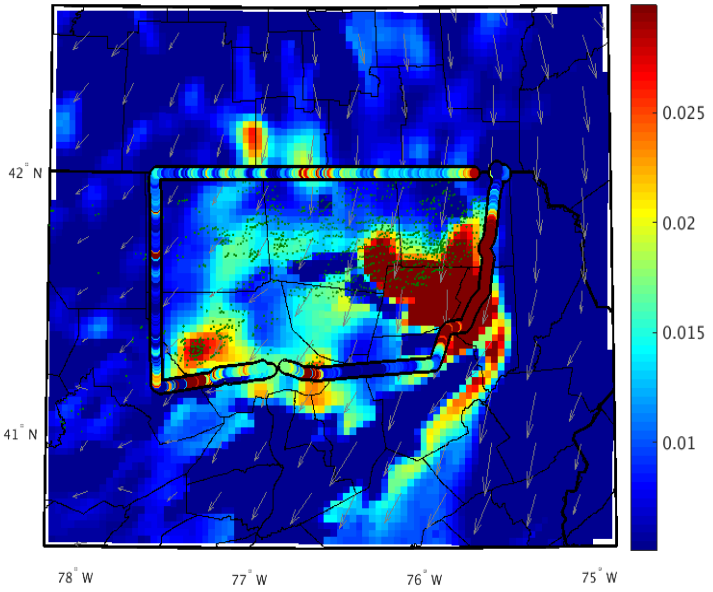
Get methane observations



Model methane enhancements



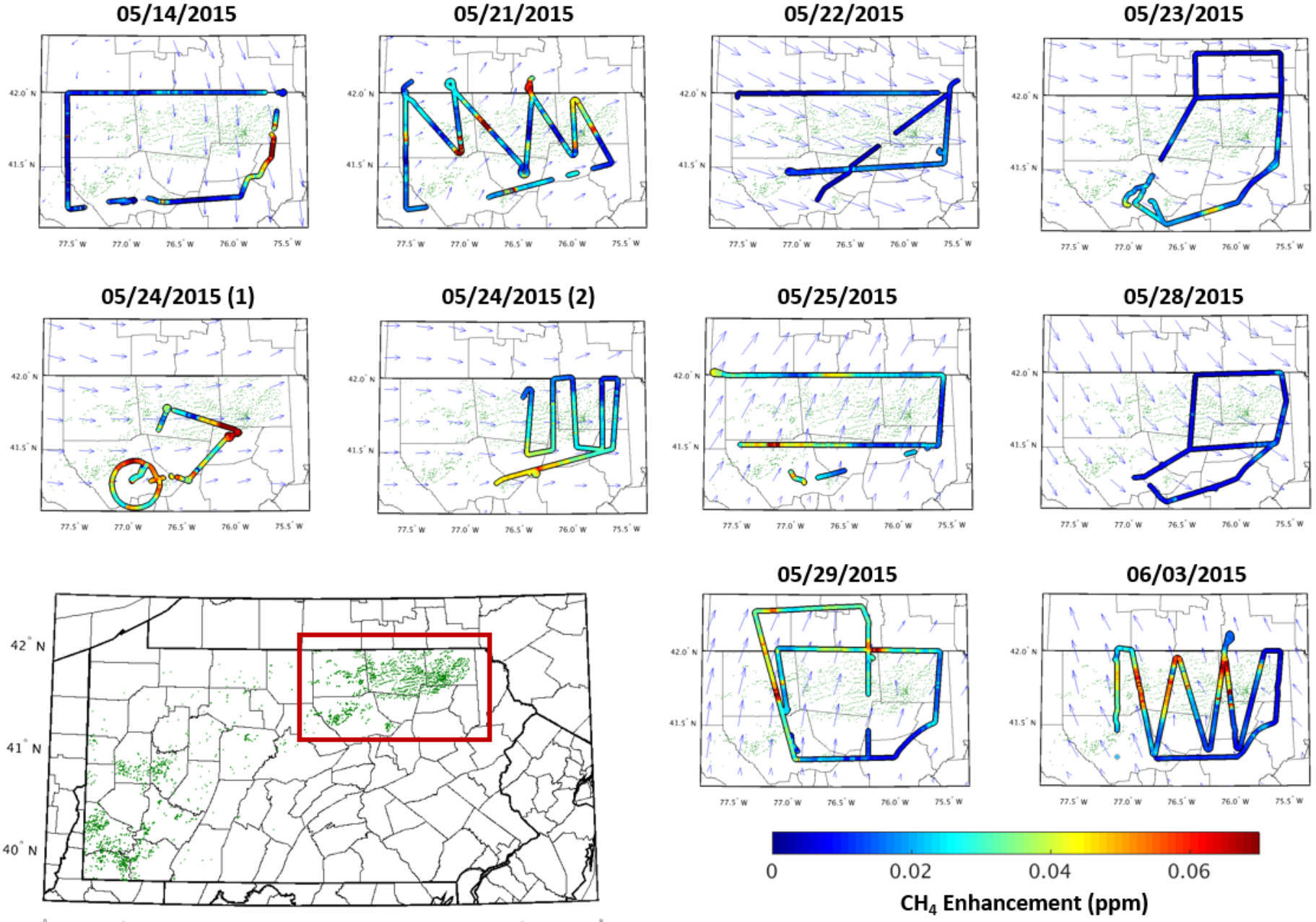
Optimize natural gas emissions



Step 1: Get methane observations

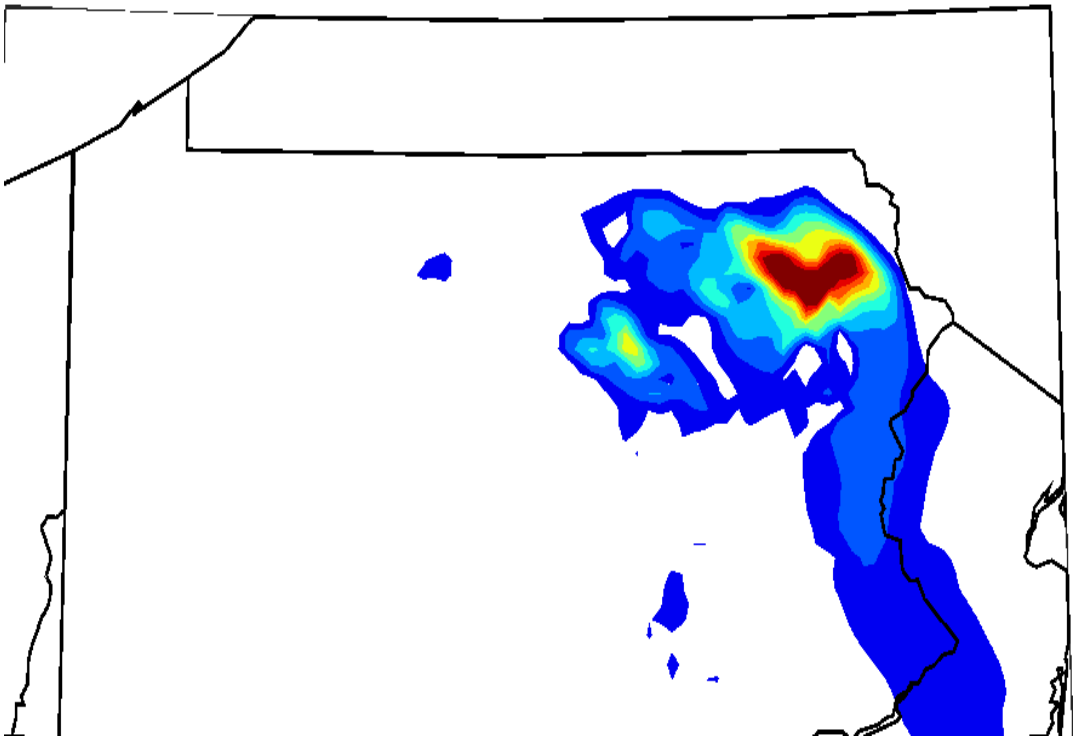
NOAA Twin Otter on the tarmac of the Williamsport airport

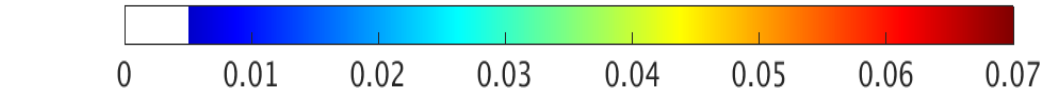
Aircraft Campaign: 10 flights



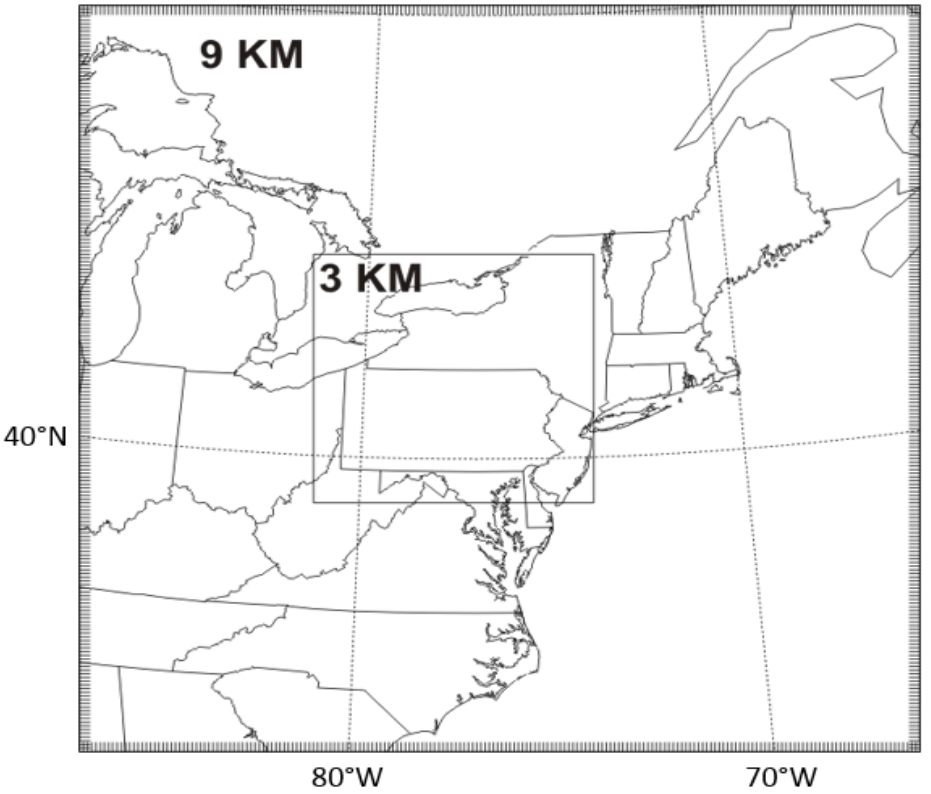
Step 2: Model Methane Enhancements

-Use Weather Research and Forecasting Model (WRF-Chem) to model methane emissions throughout region at 3 km resolution



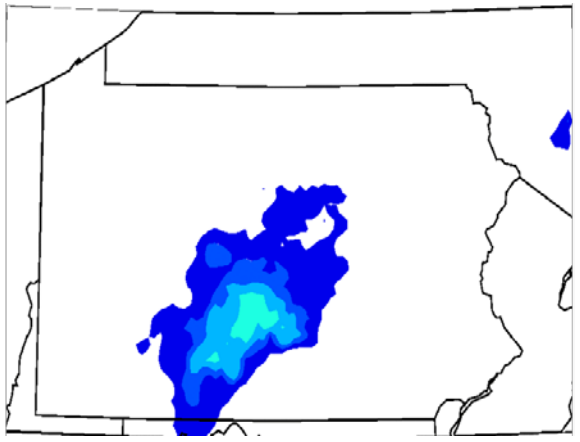


CH_4 Enhancement (ppb)

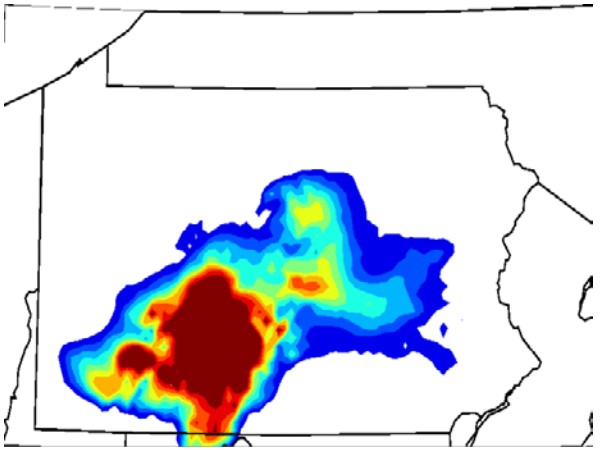


Modeling domain to simulate the atmospheric conditions during the deployment period (2015-2017) WRF

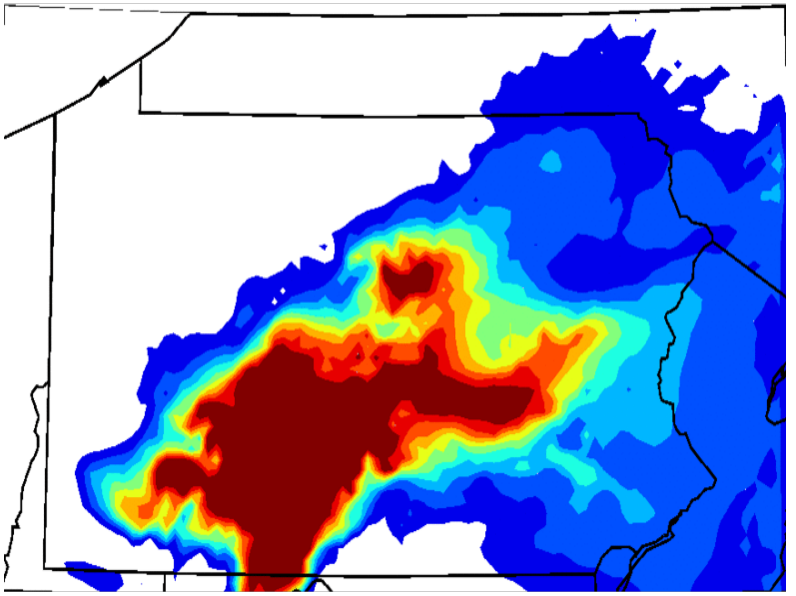
Unconventional Production/Gathering



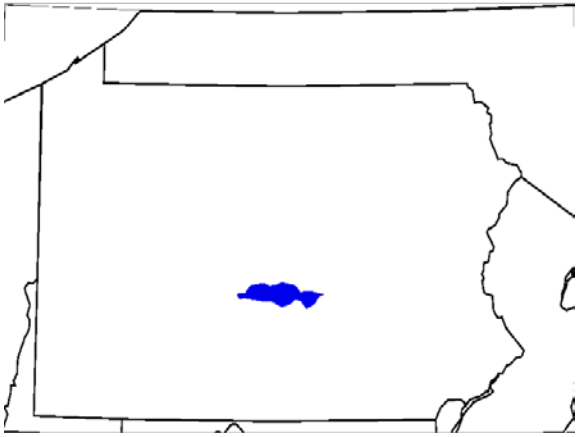
Coal Mines



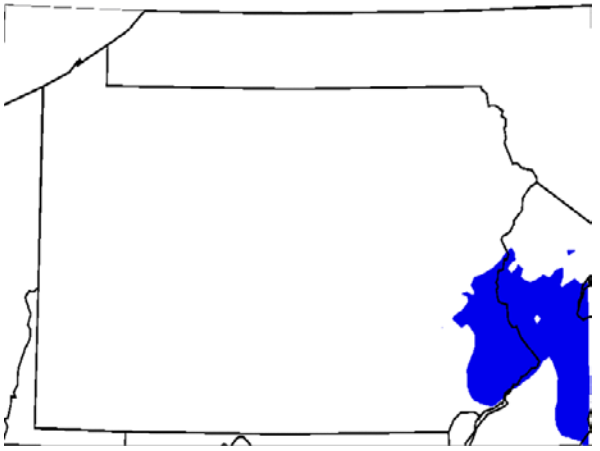
May 24th 2015 Total Enhancement



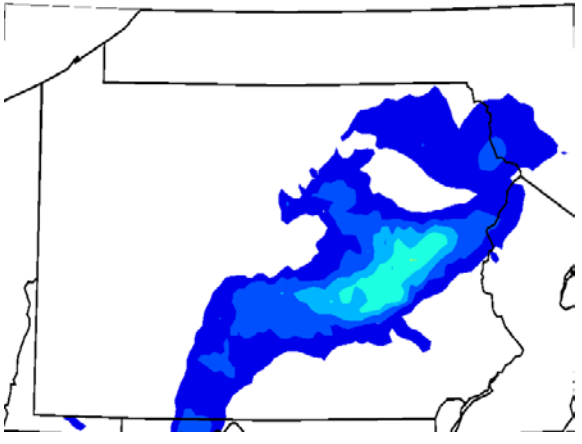
NG Transmission/Distribution



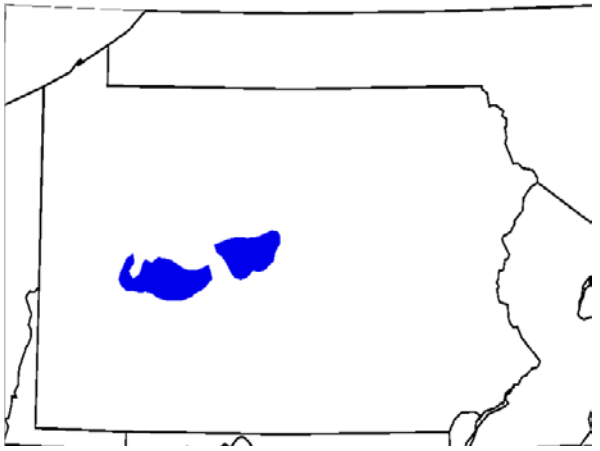
Enteric Fermentation

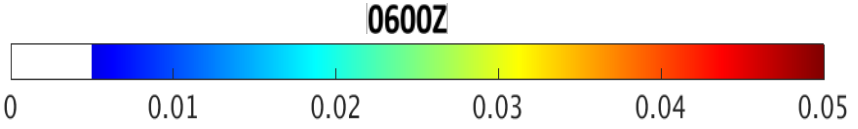


Conventional Wells



Landfills and Other





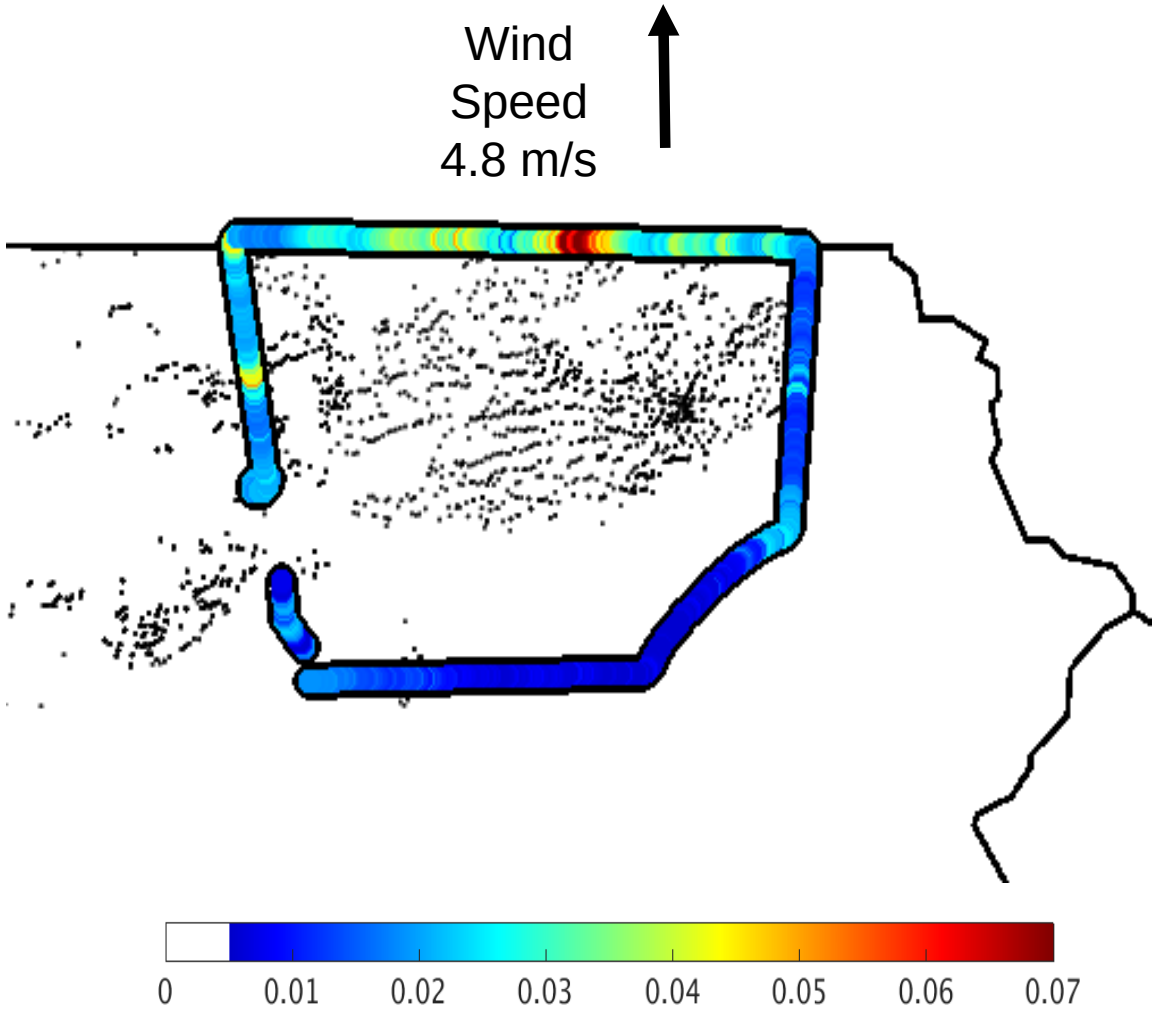
Modeled Methane Enhancement (in ppm)

Step 3: Optimize Natural Gas Emissions

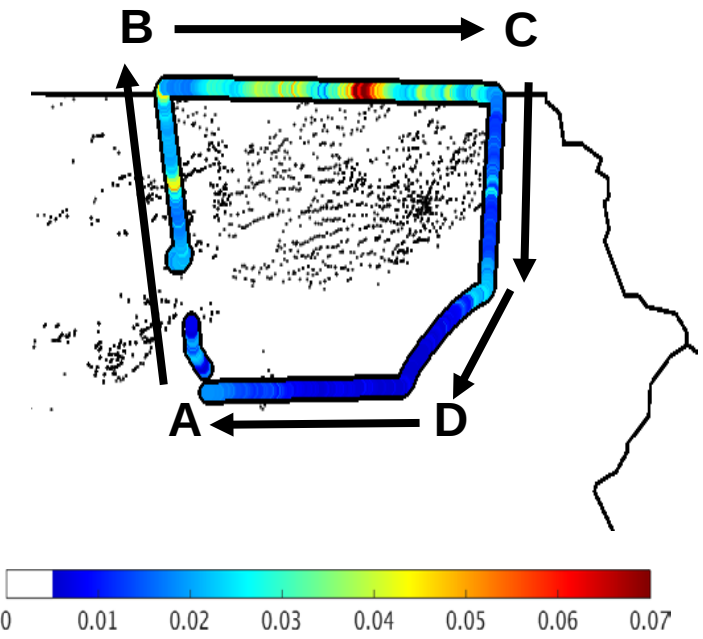
…let’s just run through some examples

Example 1:

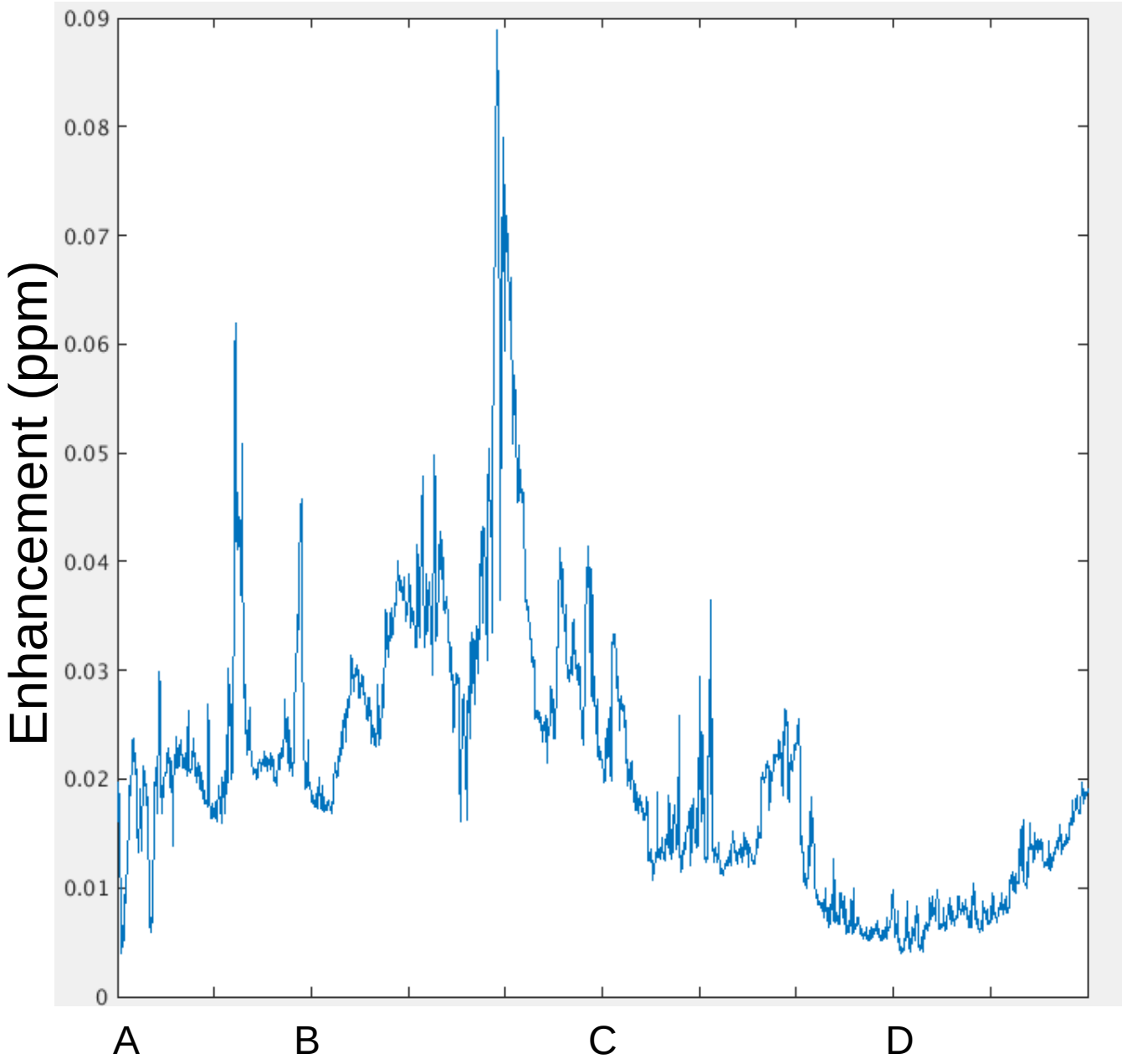
May 29th 2015: A rare day where science works.



Aircraft emissions estimate on May 29th 2015

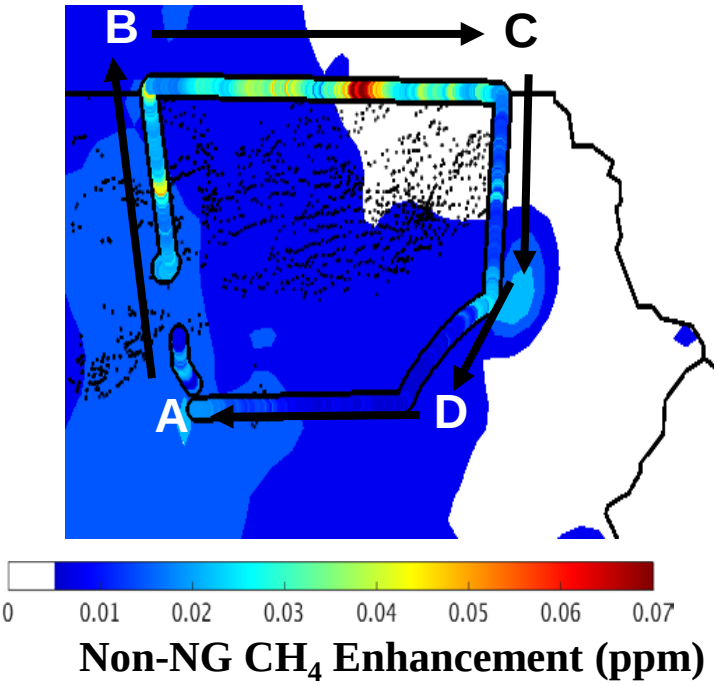


Observed CH_4 Enhancement (ppm)

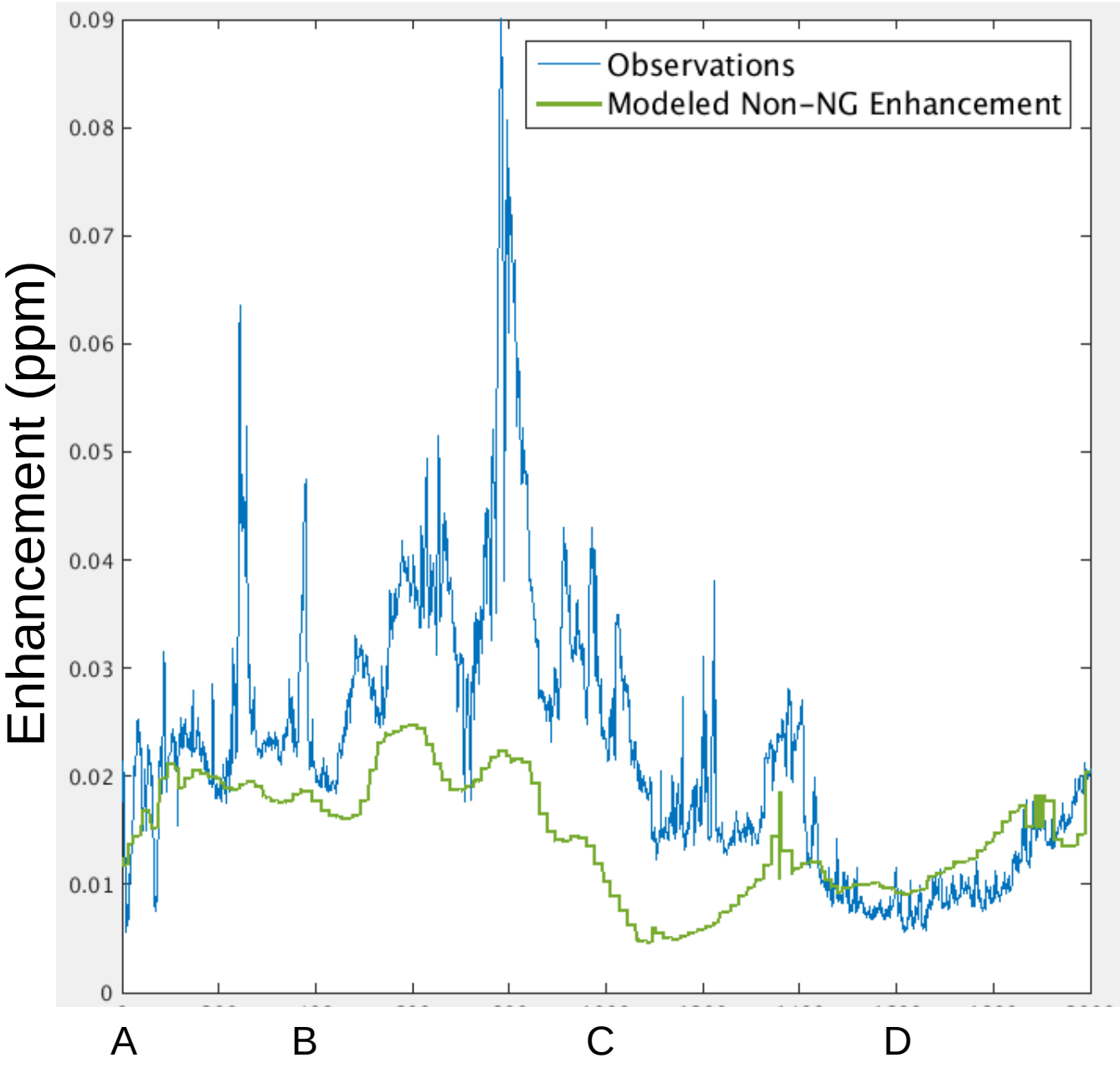


Observed CH_4 Enhancement measured during the flight (in ppm)

Aircraft emissions estimate on May 29th 2015

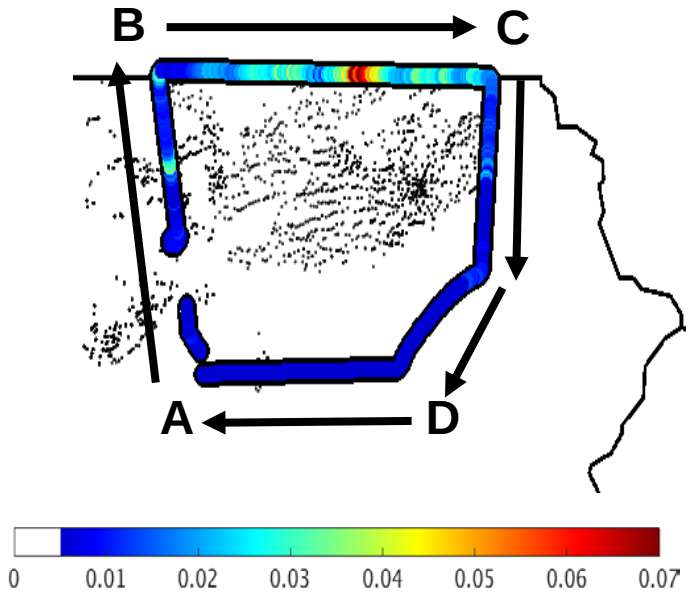


Non-NG CH_4 Enhancement (ppm)

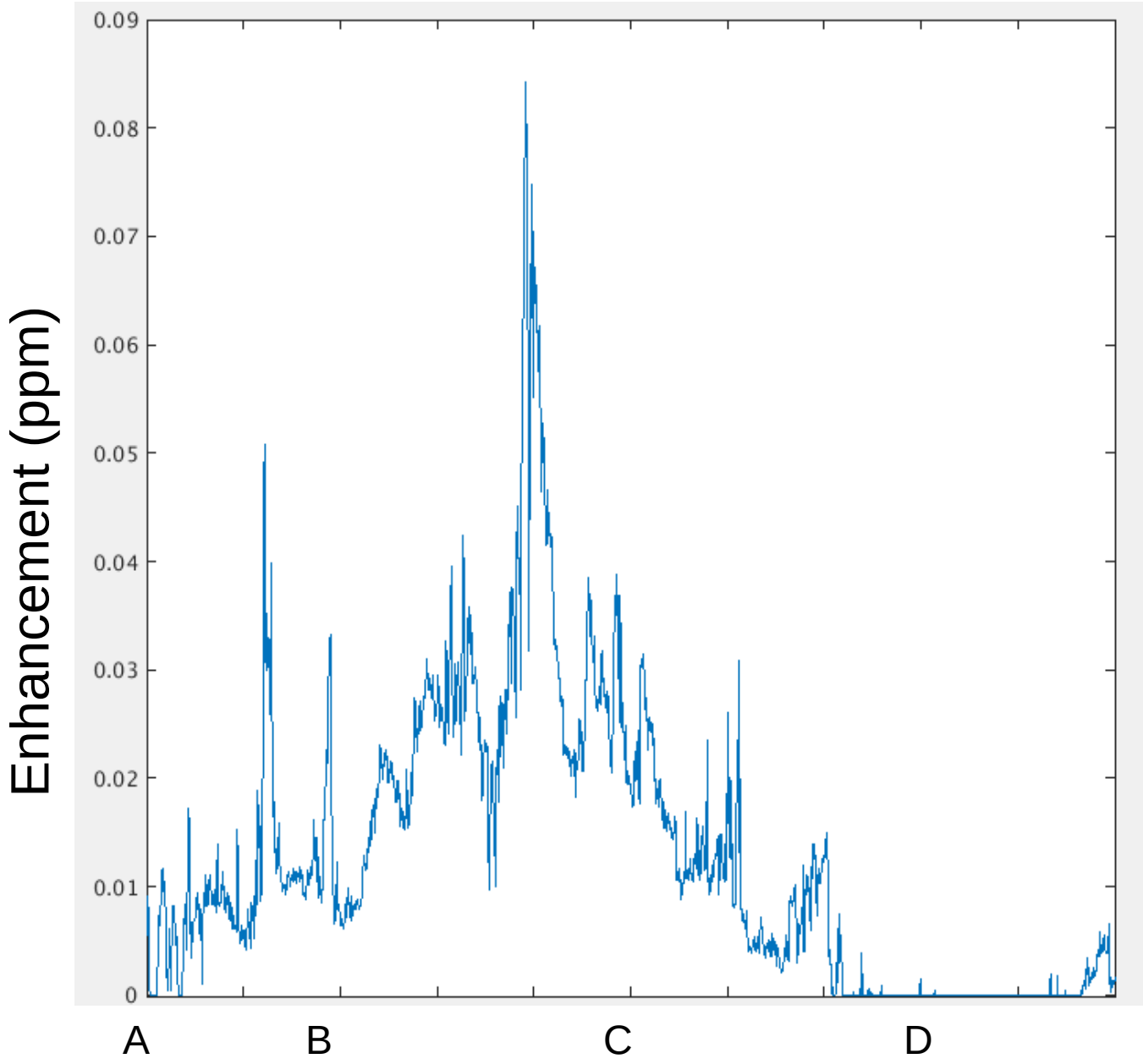


Observed and modeled Non-Natural Gas CH_4 enhancement for the May 29th flight (in ppm)

Aircraft emissions estimate on May 29th 2015

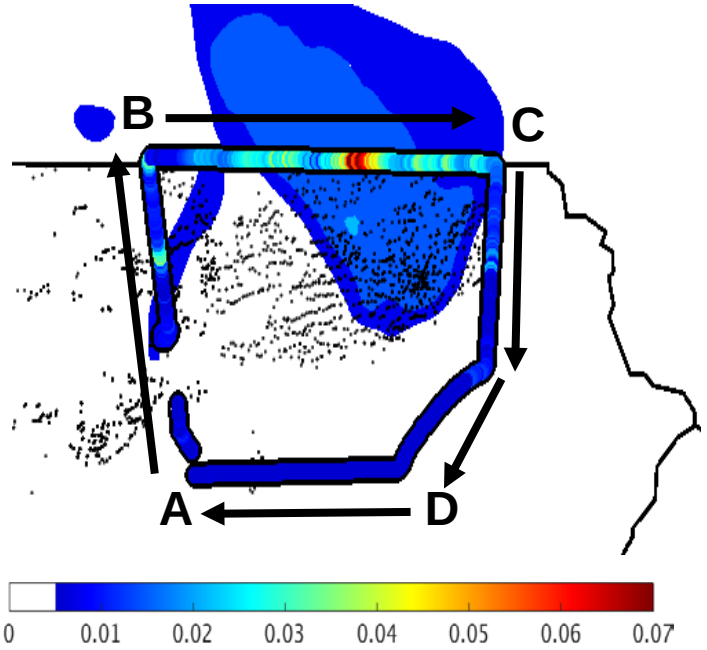


Natural Gas CH_4 Enhancement (ppm)



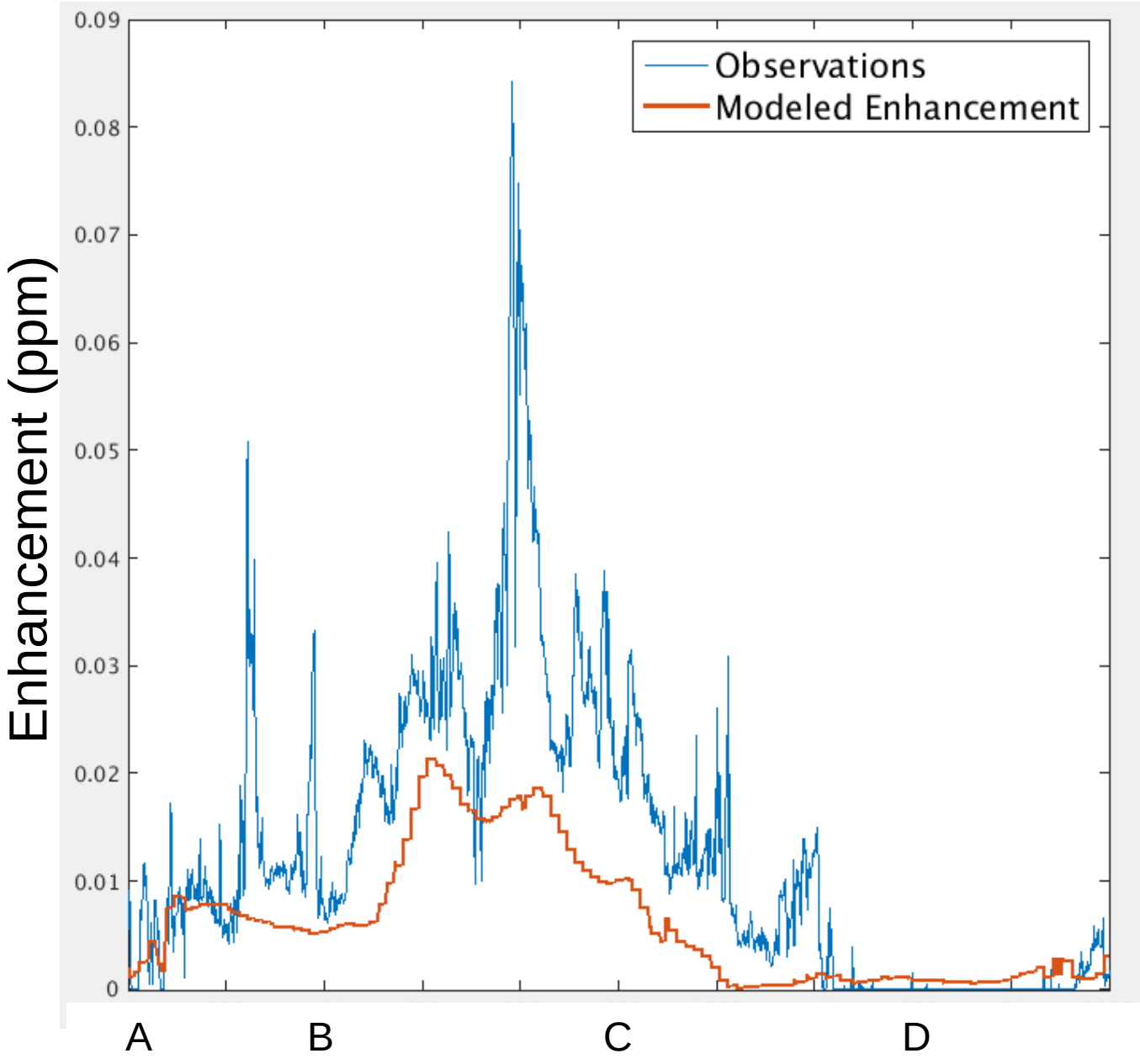
Observation-derived natural gas CH_4 enhancement for the May 29th flight (in ppm)

Aircraft emissions estimate on May 29th 2015



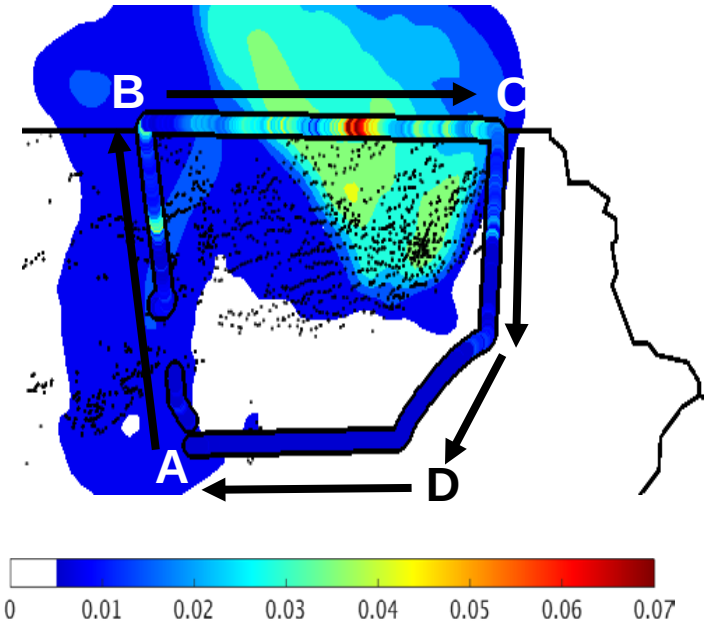
Natural Gas CH_4 Enhancement (ppm)

Emission Rate = **0.13%**



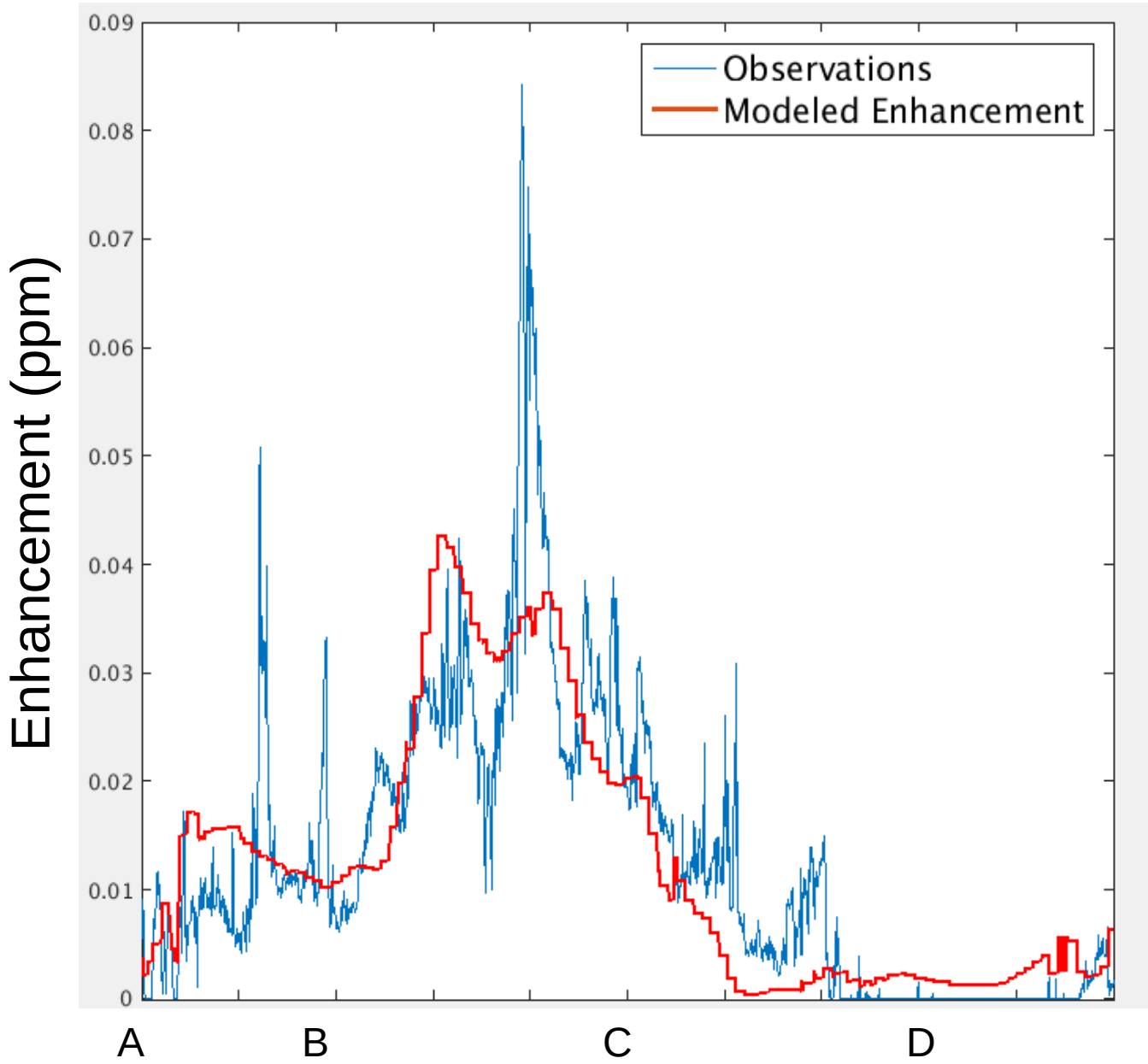
Observed and modeled Natural Gas CH_4 Enhancement for the May 29th flight (in ppm)

Aircraft emissions estimate on May 29th 2015



Natural Gas CH_4 Enhancement (ppm)

Emission Rate = **0.26%**

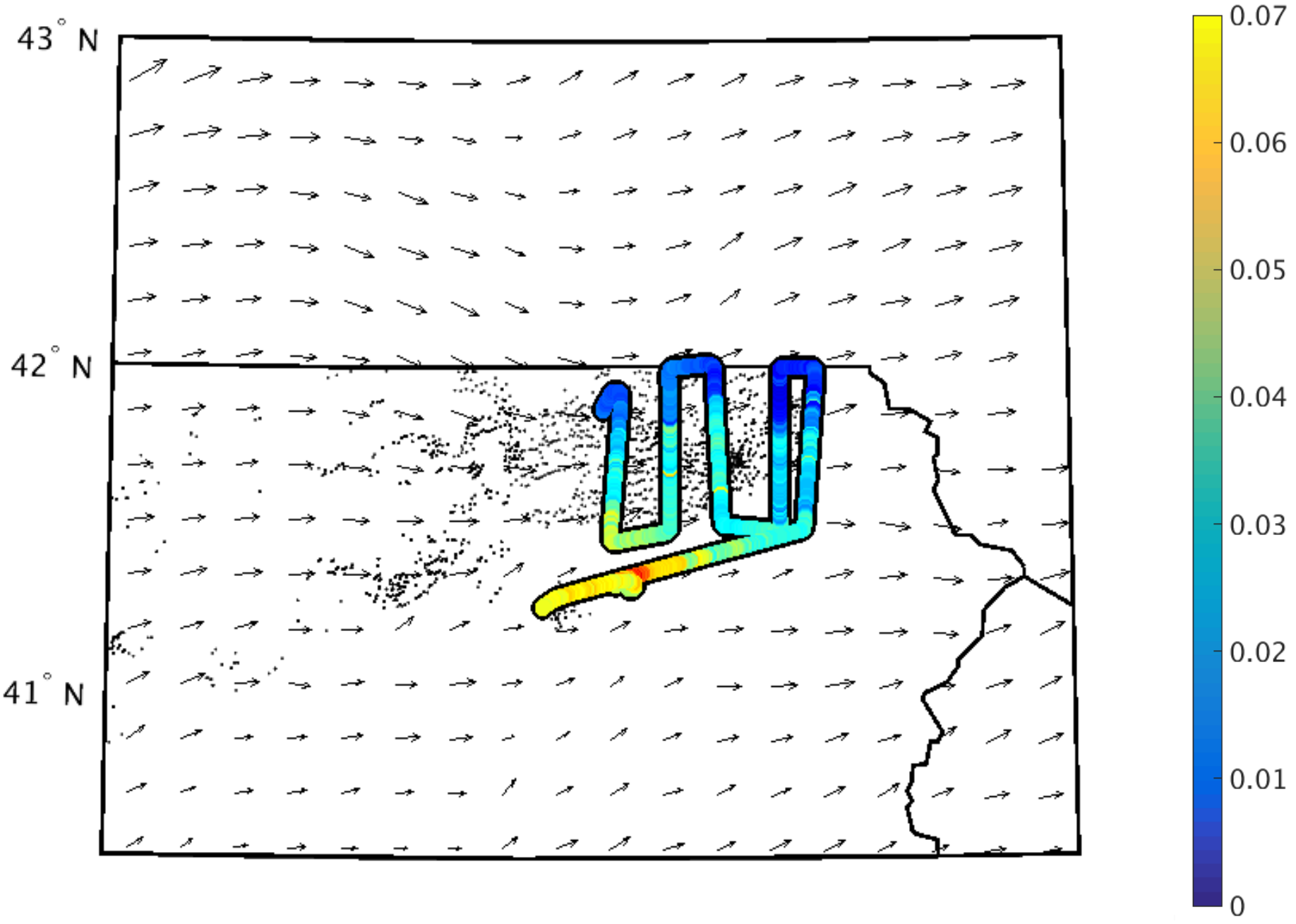


Observed and optimized Natural Gas CH_4 enhancement for the May 29th flight (in ppm)

EXAMPLE 2: MAY 24th, 2015

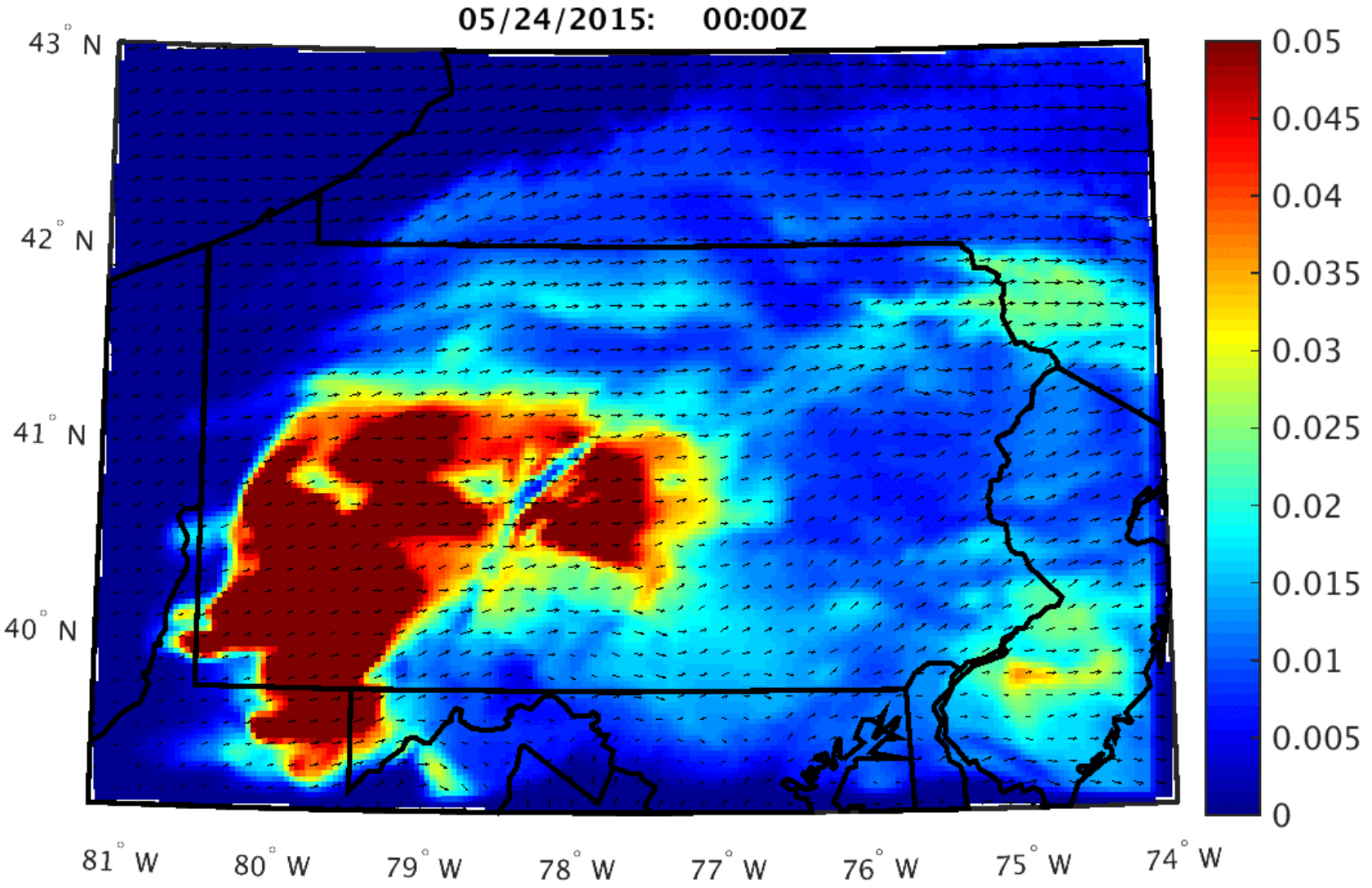
The Importance of a Good Methane Inventory

Aircraft emissions estimate on May 24th 2015



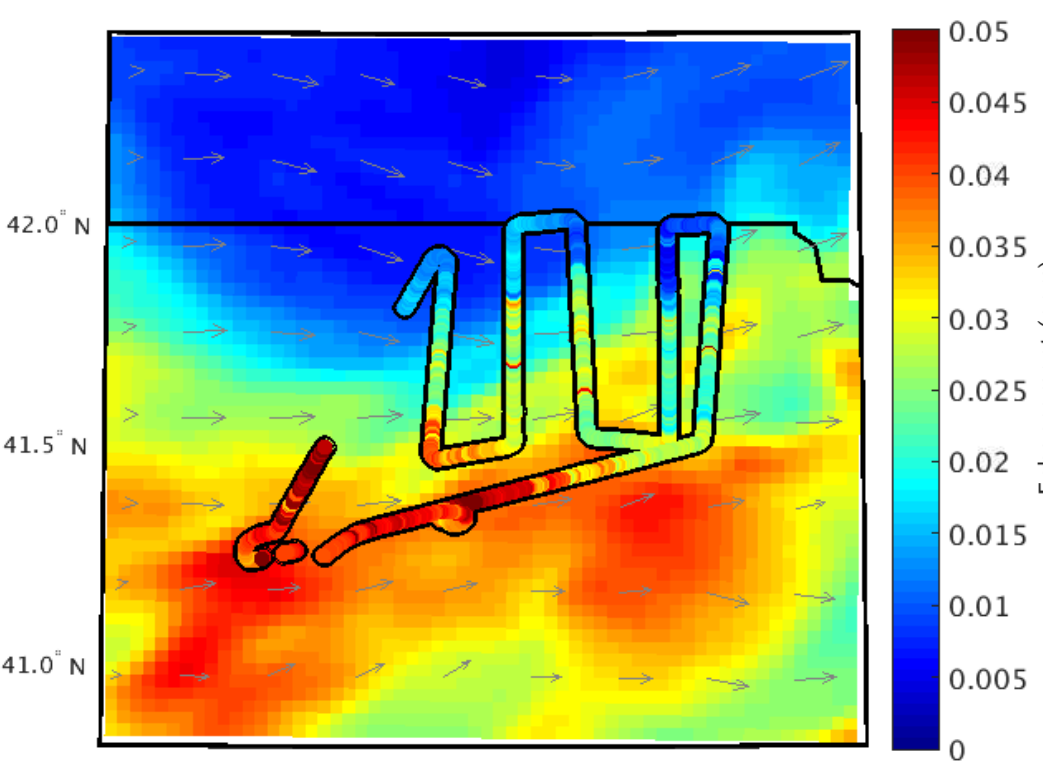
Observed CH_4 enhancement for the May 24th flight at 20z (in ppm)

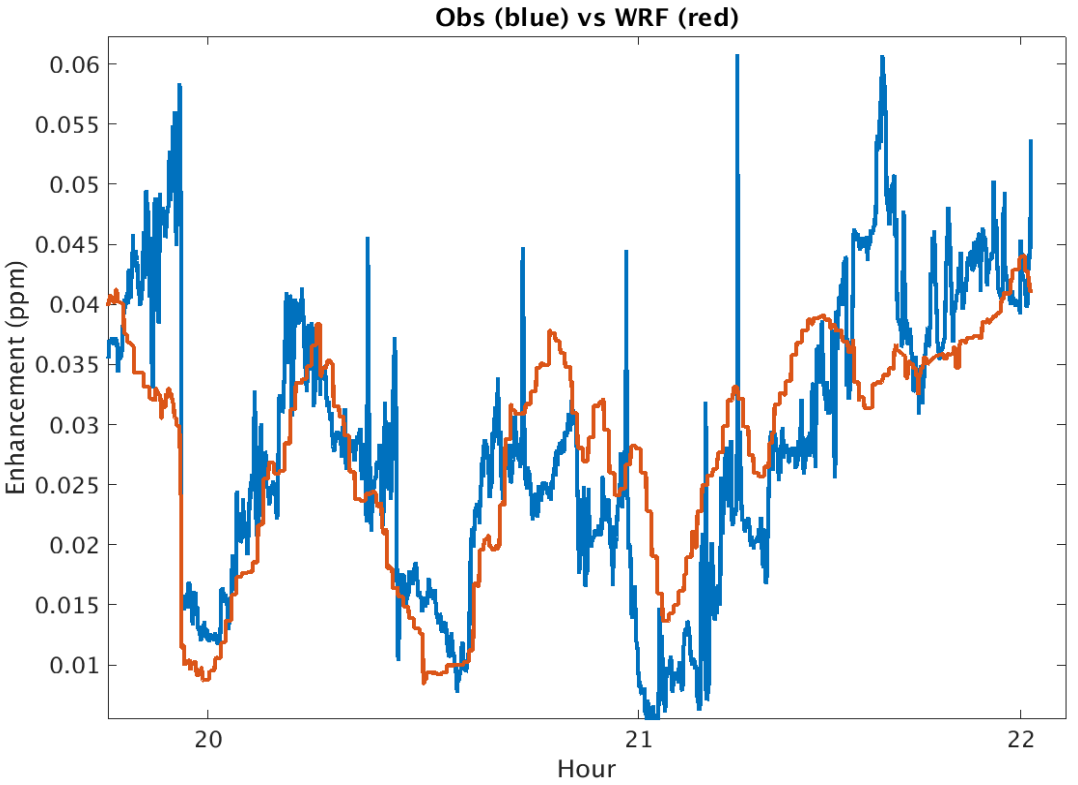
Modeled CH_4 Enhancement for May 24th, 2015



Coal plume has a significant impact on the regional measurements

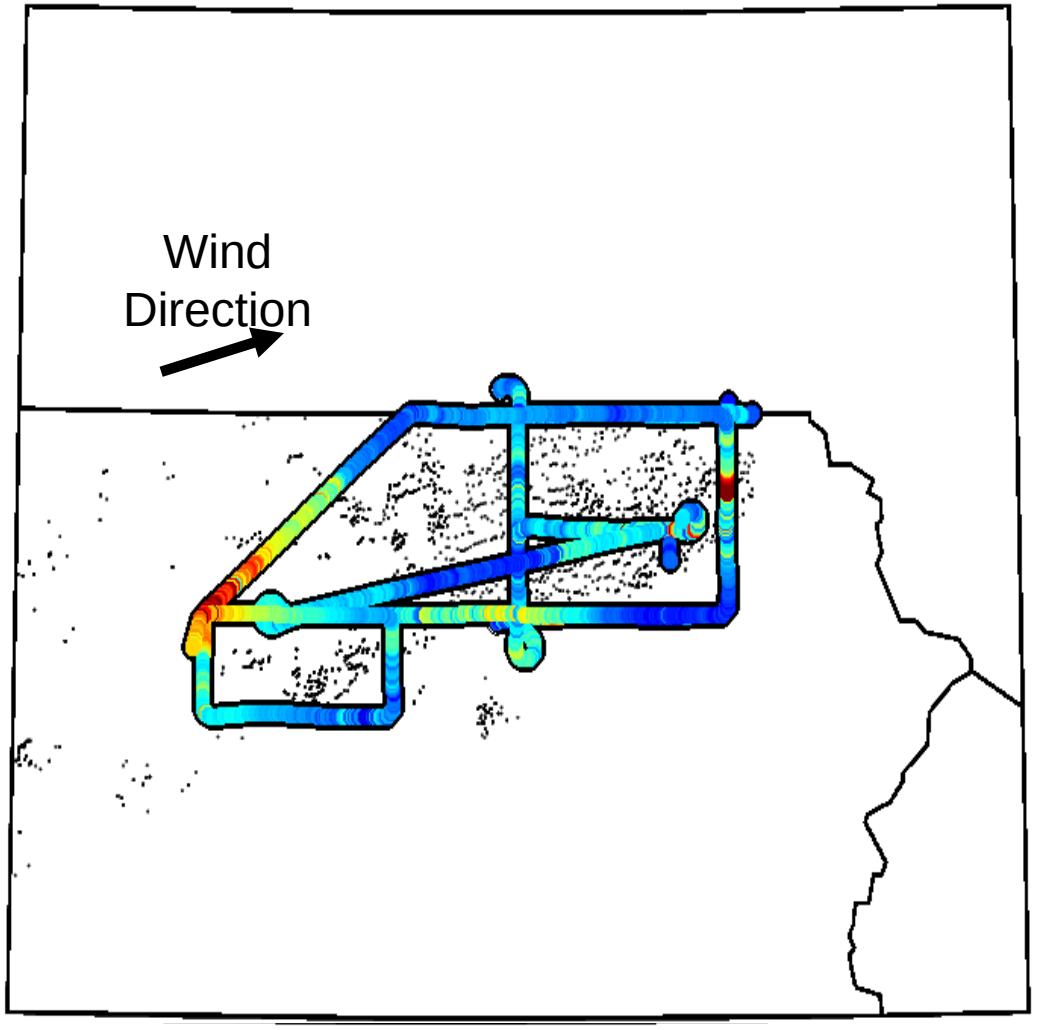
May 24th 2015: WRF vs Obs All sources

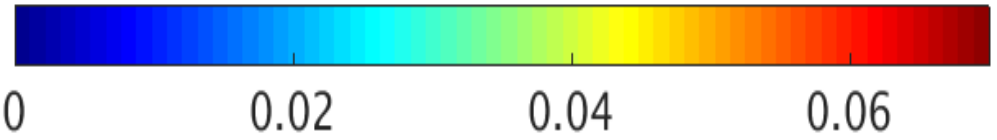




Optimized Natural Gas Emission Rate = 0.29%

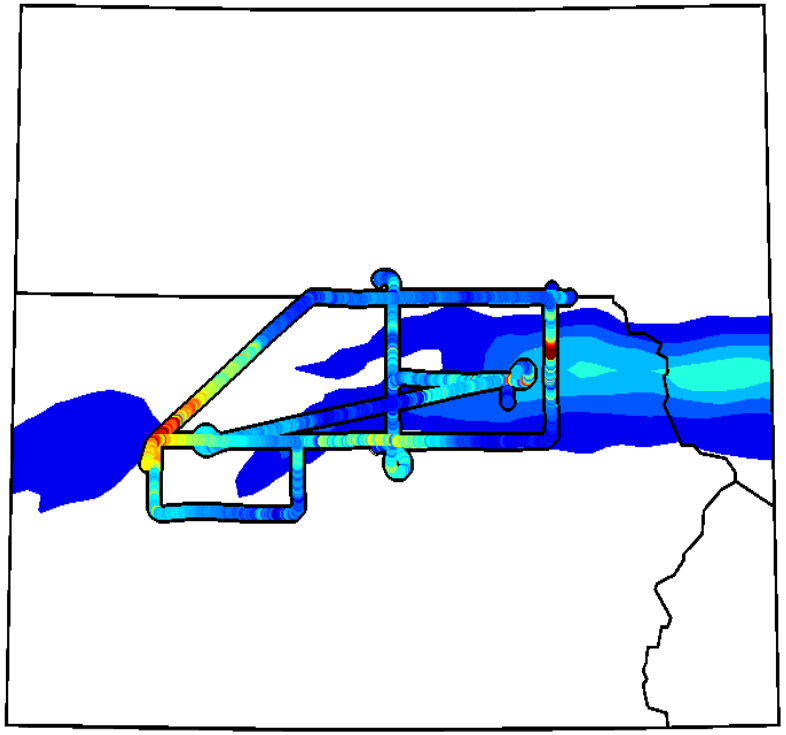
Peischl Flight: July 6, 2013



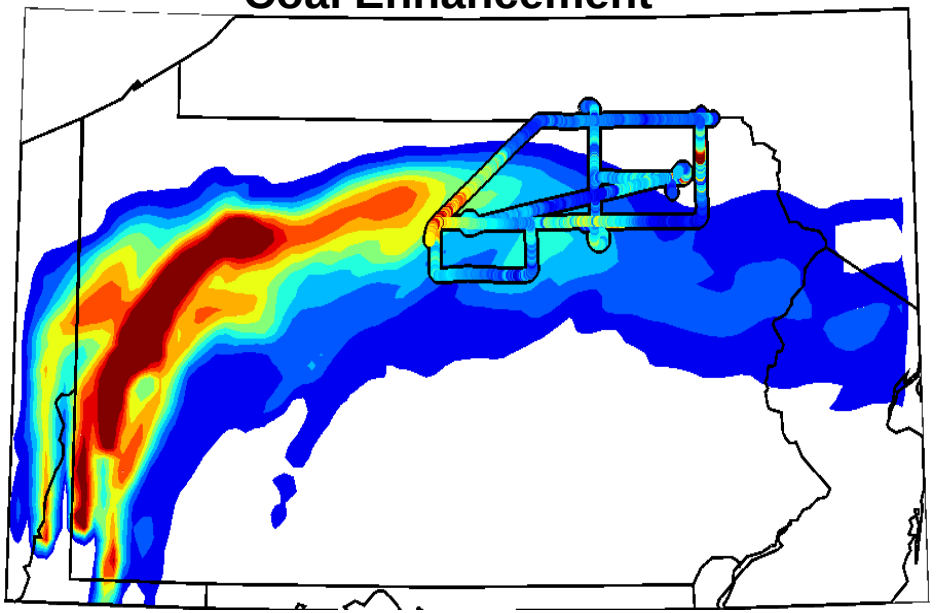


CH_4 Enhancement (ppm)

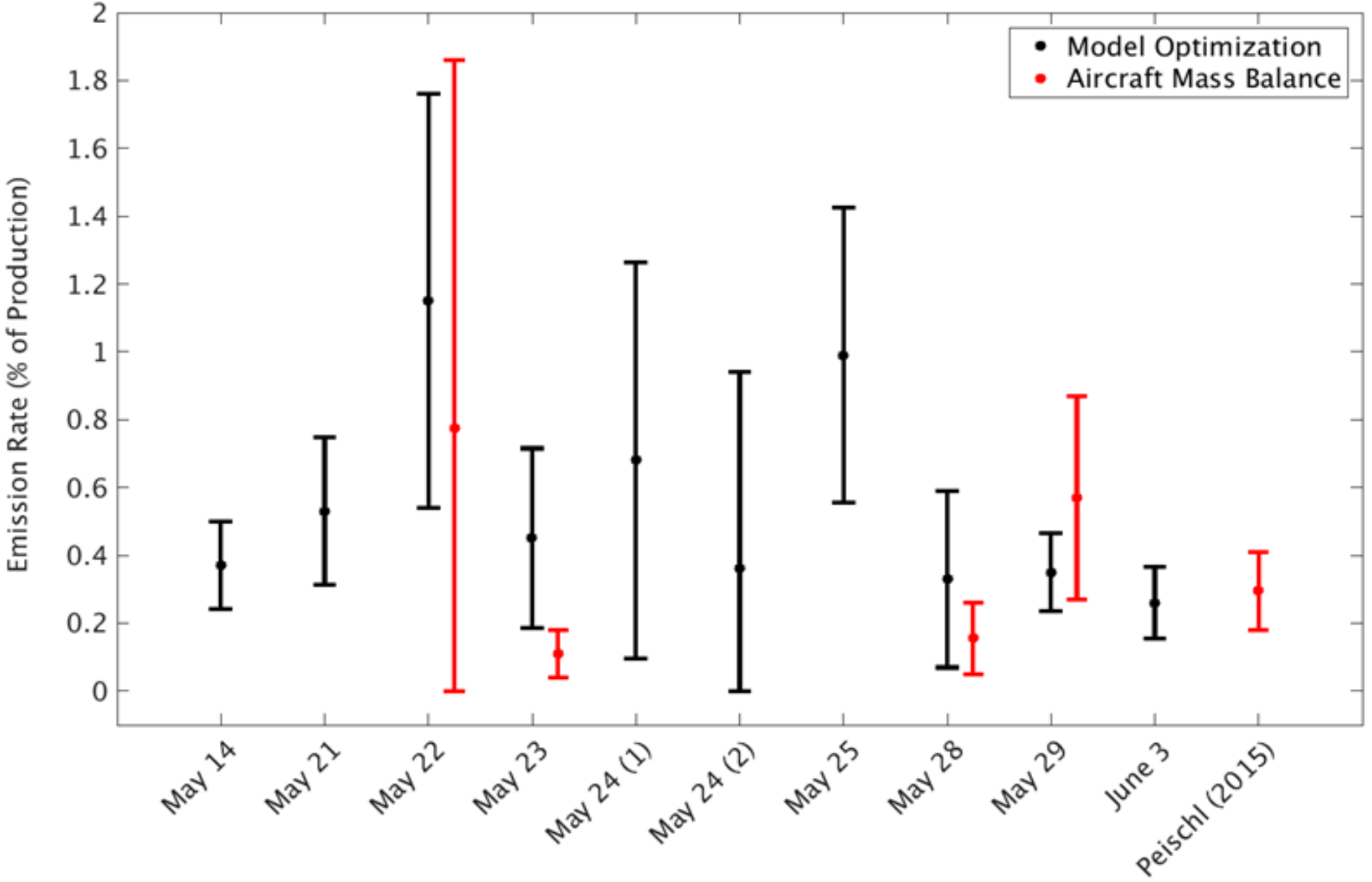
Natural Gas Enhancement



Coal Enhancement

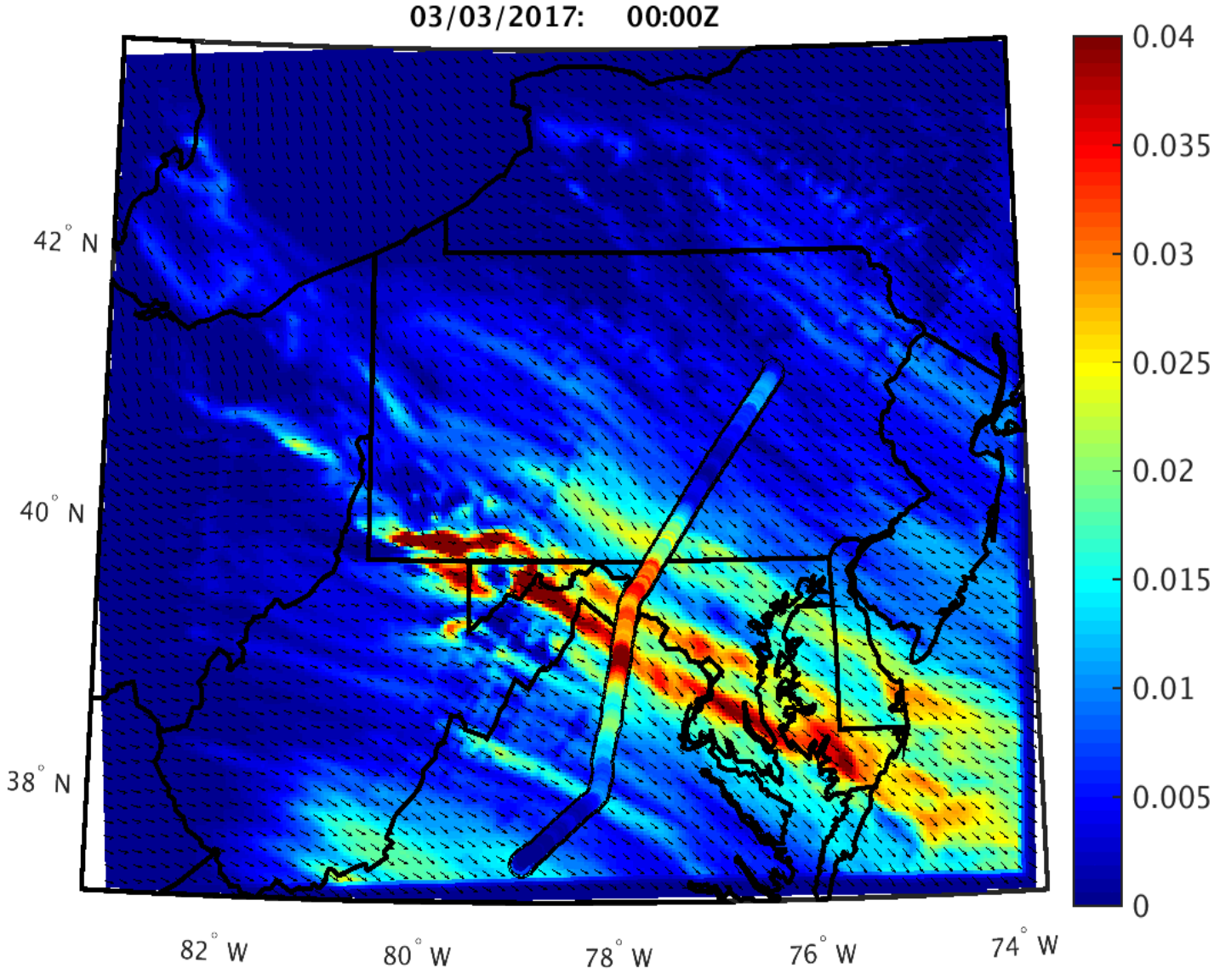


Best-guess upstream emission estimates



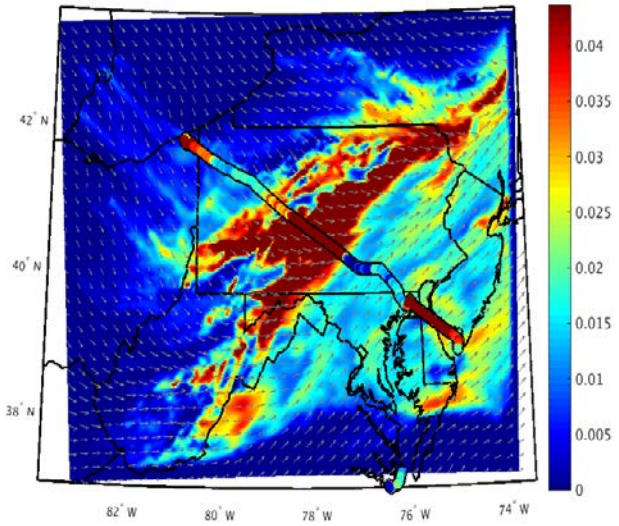
Optimal mean leakage rate based on 10 flights in May 2015: **0.39% of production**

Moving Forward: Using what we've learned for ACT-America

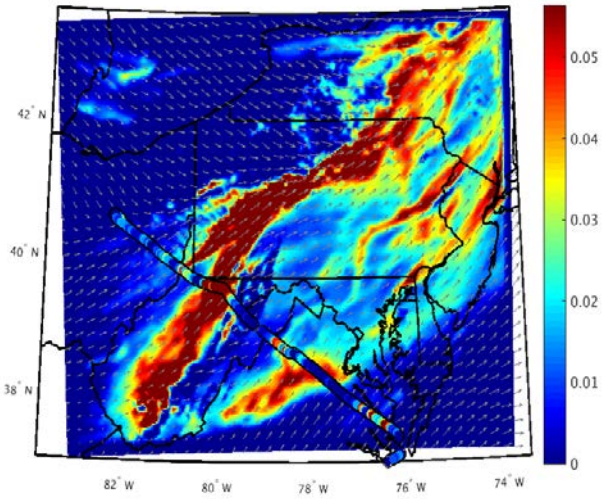


Lots of ACT flights to work with

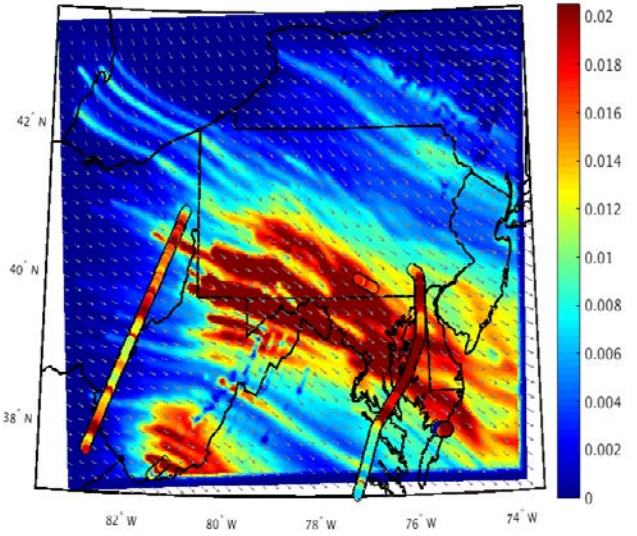
07/18/16 B200



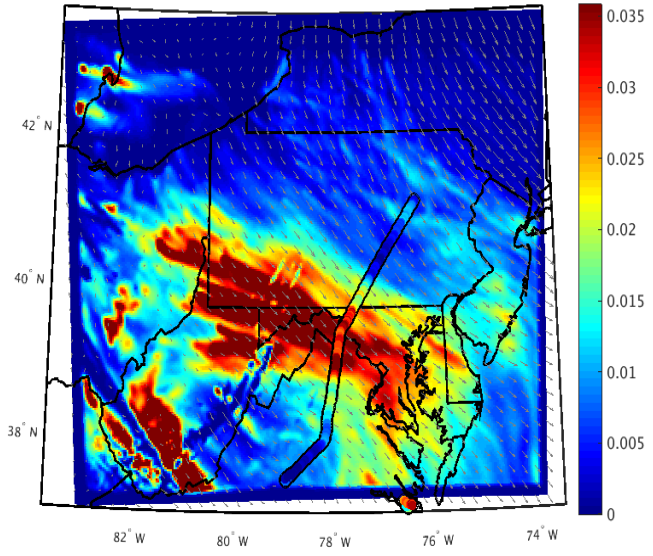
07/25/16 B200



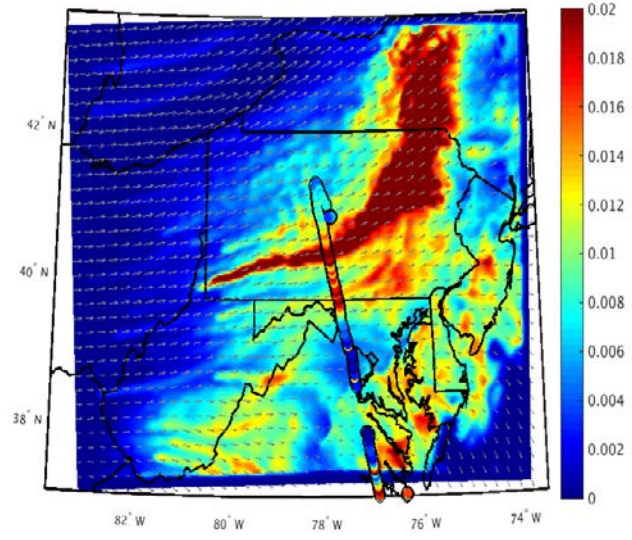
03/02/17 C130



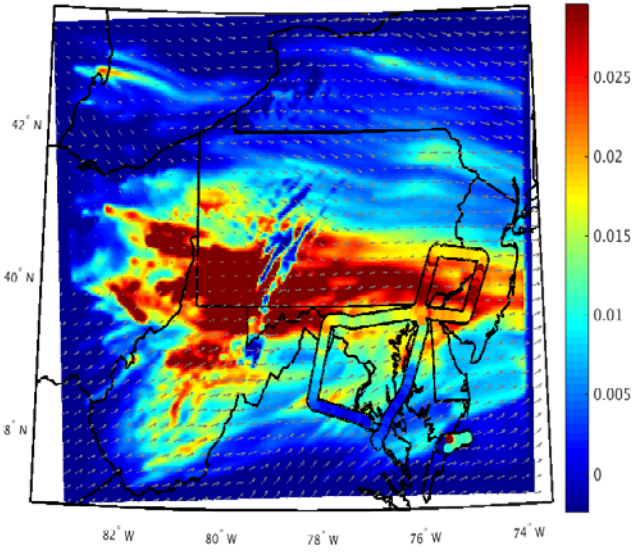
03/04/17 B200



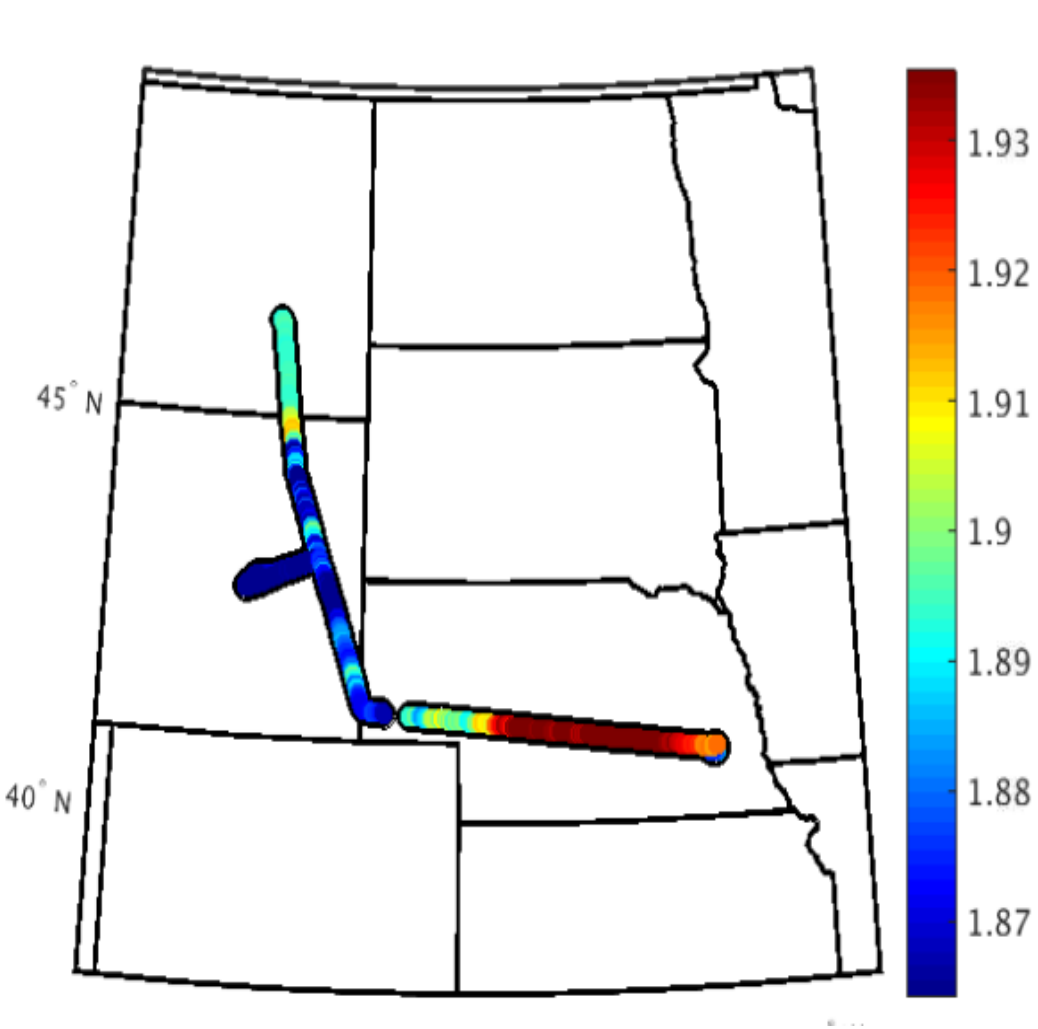
03/08/17 B200

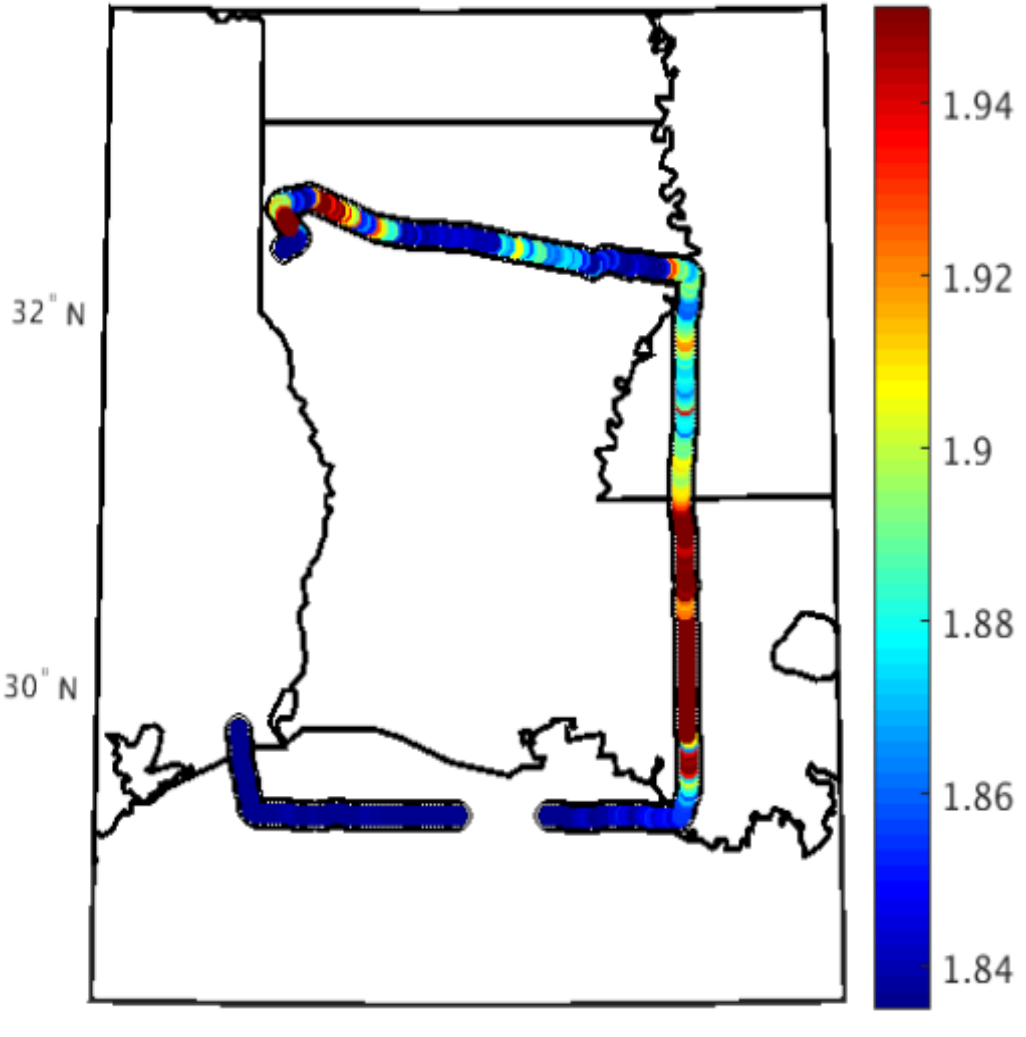


03/09/17 C130



Apply methodology in other methane hotspot regions?





Conclusions

-Emissions as a percent of production from natural gas production/gathering facilities are low in the Marcellus (but tower data indicates there is temporal variability!)

-Running a transport model on flight days can:

1. Provide an alternative method to solving for emissions.
2. Help identify and separate out observed plumes associated with different sources.
3. Reveal days in which the background CH_4 fields are complex and derived emission rates may be unreliable.

-With the new U.S. gridded CH_4 inventory (Maasakkers et al 2016), running the transport model in other regions is easier than ever!