Methane Emissions from Marcellus Shale Natural Gas Operations: Results from Summer 2015 Aircraft Observations

Xinrong Ren[1,2,*], Dolly Hall[1], Timothy Vinciguerra[3], Sayantan Sahu[1], Hao He[1], Alexa Chittams[3], Sheryl Ehrman[3], and Russell Dickerson[1]

1. Dept. of Atmos. & Oceanic Sci., University of Maryland ; 2. NOAA Air Resources Laboratory; 3. Dept. of Chem. & Biomolecular Engineering, University of Maryland *Contact: ren@umd.edu

Introduction

- Quantification of methane (CH_4) emissions from oil and gas operations is important for establishing scientifically sound and cost-effective policies for mitigating greenhouse gases (GHGs).
- Discrepancies between observation-based (top-down) and inventory-based (bottom-up) CH_4 emissions suggests more observations are needed.
- In this work, we quantified CH_4 emissions from the Marcellus Shale natural gas operations in SW PA and Northern WV using the mass balance approach based on 3 flights conducted in August/September 2015.

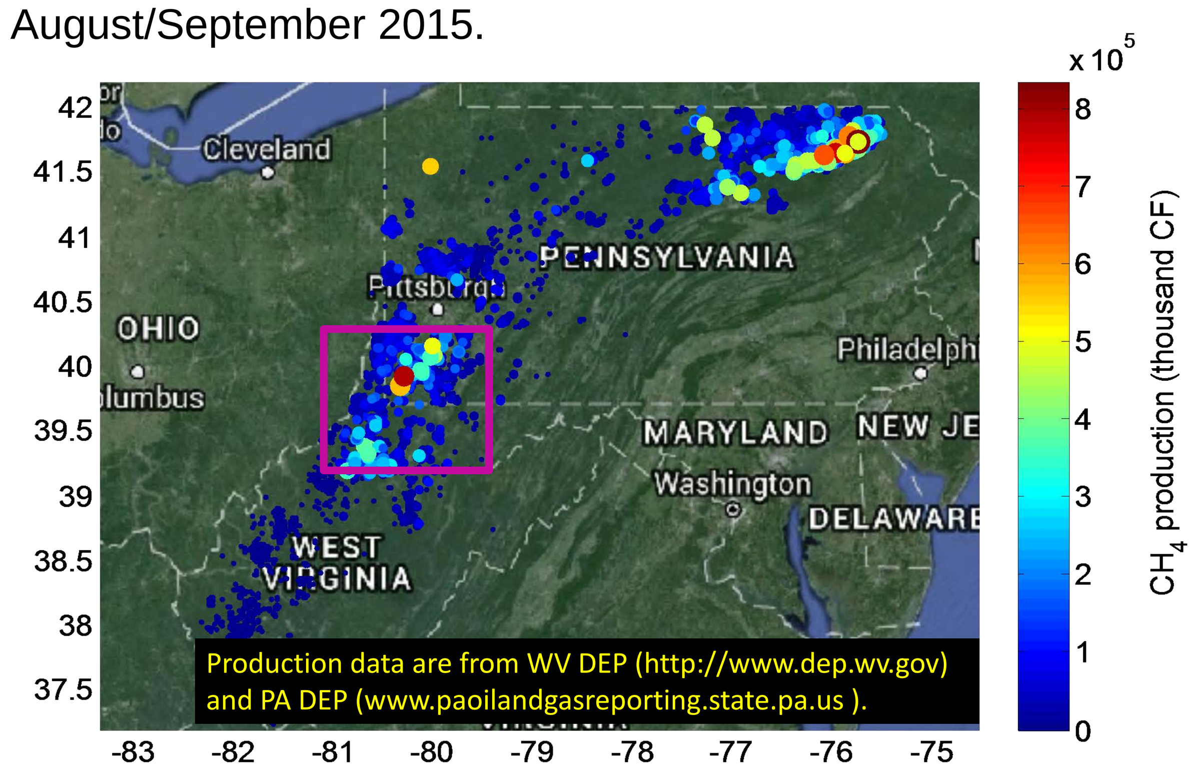

Fig. 1. Marcellus Shale gas production in PA in August 2015 and in WV in August 2014. The purple rectangle represents the area we surveyed.

Measurements

UMD research aircraft observations to quantify CH_4 emissions:
-- what: aircraft observations of GHGs, other trace gas, and aerosol scattering, absorption.
-- when: August/September, 2015
-- where: over the Marcellus Shale natural gas operation area

Flight Design and Mass Balance Approach

- The flights was designed based on the mass balance theory.
- Wind carrying background concentrations of CH_4 blows over the Marcellus Shale area, where it picks up CH_4 emissions.
- We flew horizontal transects perpendicular to the prevailing wind direction downwind of the area and enhancements in CH_4 above background were intercepted and detected.

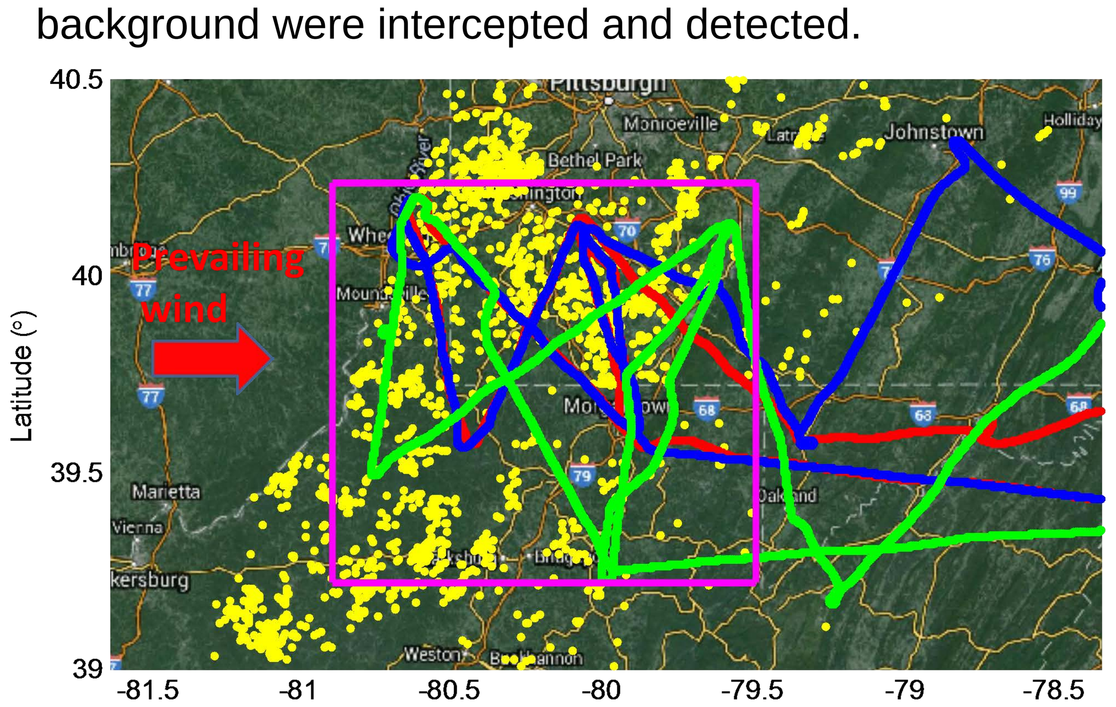

Fig. 2. Three flight paths (blue, red, and green) in August/September 2015. The purple rectangle represents a 110x120 km area that covers surveyed oil and gas operation area. Yellow dots show the locations of the wells.

- The mass balance approach:

$$Flux = \int_0^z \int_{-x}^{+x} \left([C]_{ij} - [C]_b \right) \times U_{\perp ij} \, dx dz \qquad (1)$$

where, $[C]_{ij}$: concentration at a downwind location(xi, zi)
$[C]_b$: background concentration detected upwind
$U_{\perp ij}$: perpendicular wind speed at a downwind location (xi, zi)

Results

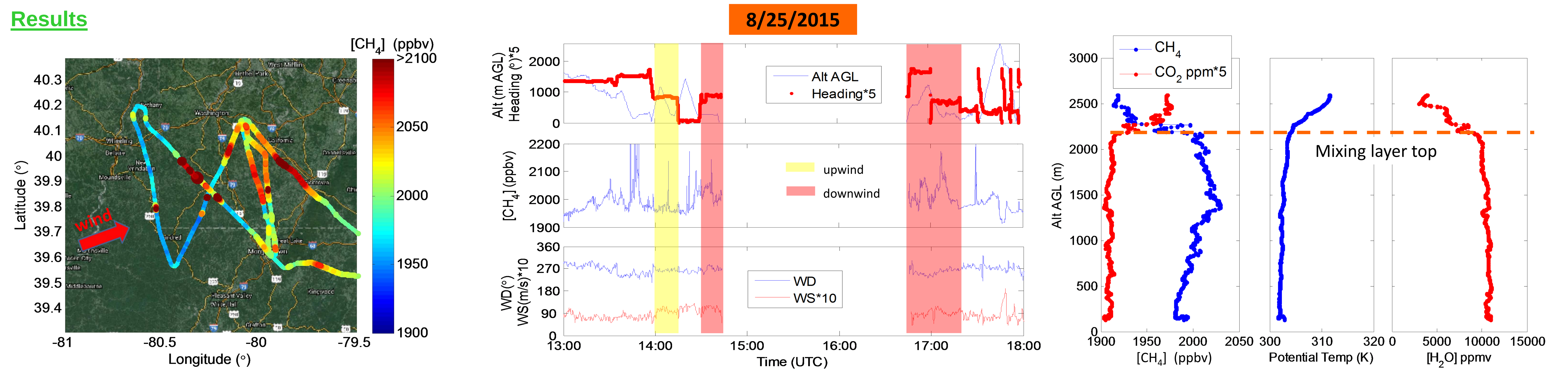

Fig. 3. *Left:* $[CH_4]$ along the flight track; *Middle:* Time series of altitude, $[CH_4]$, wind speed and direction ; *Right:* vertical profiles of $[CH_4]$, $[CO_2]$, potential temp and H_2O mixing ratio for the flight on 8/25/15.

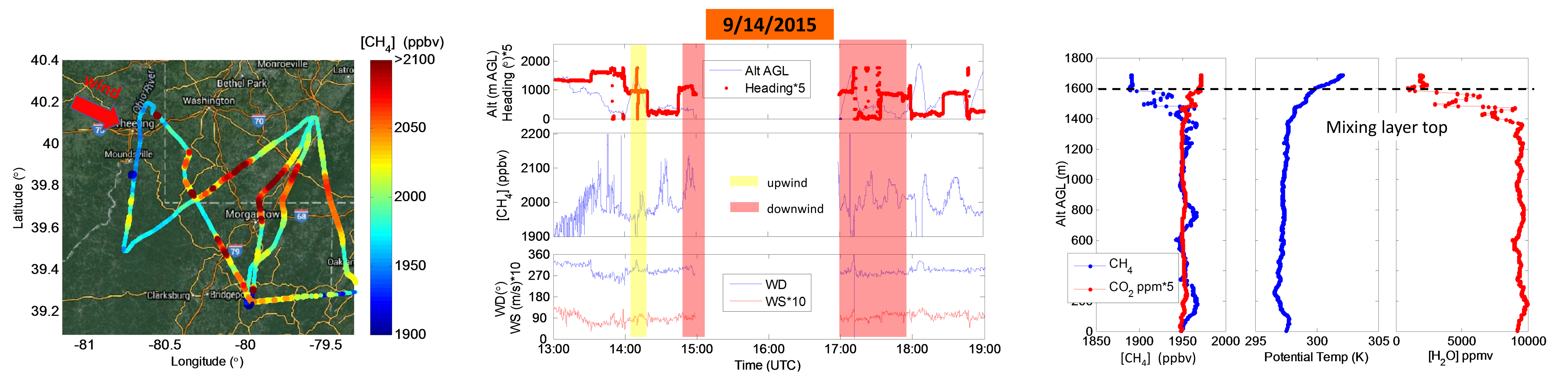

Fig. 4. *Left:* $[CH_4]$ along the flight track; *Middle:* Time series of altitude, $[CH_4]$, wind speed and direction ; *Right:* vertical profiles of $[CH_4]$, $[CO_2]$, potential temp and H_2O mixing ratio for the flight on 9/14/15.

Table 1. Data used in Equation (1) and derived CH_4 fluxes from the 3 flights over Marcellus Shale in SW PA and Northern WV

Flight Date	$[CH_4]_{upwind}$ (ppbv)	$[CH_4]_{downwind}$ (ppbv)	WS (m/s)	WD (deg)	PBL Height (m AGL)	CH_4 flux* (mol/s)	NG prod** (mol/s)	CH_4 flux / NG prod
8/25/2015	1,967±22	2,024±78	8.5±1.4	251±11	2,250±200	4,036	69,200	5.8%
8/29/2015	2,130±116	2,202±140	6.6±1.4	250±25	2,000±200	5,245	69,200	7.6%
9/14/2015	1,960±28	2,018±39	9.4±1.2	282±12	1,500±200	3,201	72,800	4.4%

* A horizontal distance of 110 km is assumed to cover the entire oil and gas operation area surveyed.
** Mean natural gas production within the purple rectangle of Fig. 2. Data for August and September 2014 in WV are used.

- Average flux = 4,160±1,030 moles s^{-1} , or 5.0±1.2 g CH_4 km^{-2} s^{-1}, consistent with the results (2.0-14 g CH_4 km^{-2} s^{-1}) by Caulton et al. (2014) in SW PA, but larger than the results (1.2±0.6 g CH_4 km^{-2} s^{-1}—measurements made in 2012) in SW PA by Swarthout et al. (2015) and an order of magnitude larger than the results (~0.4 g CH_4 km^{-2} s^{-1}) by Peischl et al. (2015) in the Marcellus Shale region in NE PA.
- CH_4_flux/NG_production = 5.9±1.6%, much greater than the loss rate (0.18–0.41%) estimated for the Marcellus region in northern PA by Peischl et al. (2015)

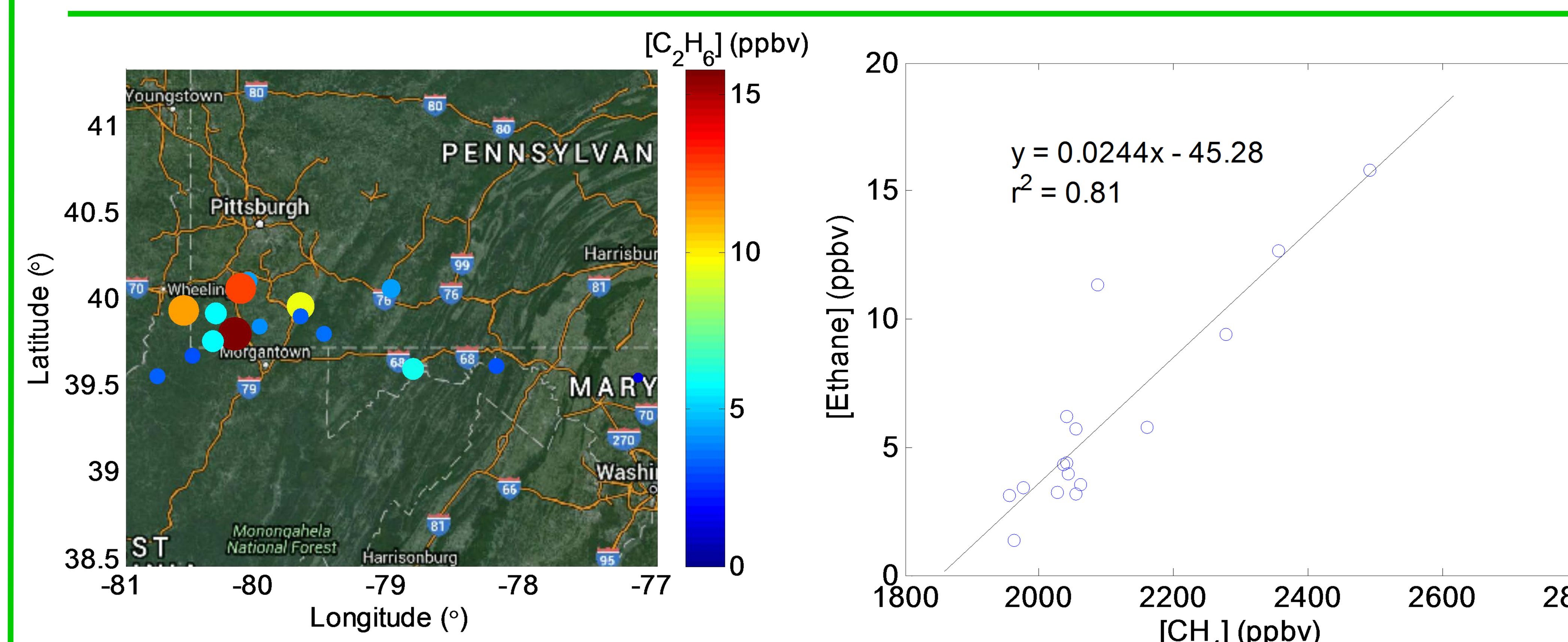

Fig. 5. Ethane concentrations in 16 whole-air samples (left panel) and ethane versus methane (right panel). The ethane-to-methane ratio (slope) could potentially be used for identification and quantification of methane sources.

Summary

- The averaged CH_4 flux from a 110x120 km area in the Marcellus Shale region in SW PA and Northern WV was estimated to be 4,160±1,030 moles s^{-1}.
- CH_4_flux/NG_production = 5.9±1.6%.
- The observed ethane/CH_4 = 2.4%, agrees with the USGS ethane/CH_4 composition ratio (2.3%) of for this region, but is smaller than what (3.3%) was obtained in the DC-Baltimore area in winter 2015. More investigation of this is needed.

Future Work

- To obtain other CH_4 sources in the surveyed area to derive CH_4 leak rate.

Acknowledgements

- NSF (Grant #: CBET1438400), MDE, NIST, and NASA/AQAST for funding
- Crew at University Research Foundation, Greenbelt, MD for help to conduct flights
- Students at UMD for helping with the flights and emission data

References

- Caulton et al. (2014), Toward a better understanding and quantification of methane emissions from shale gas development, PANS, 111 , 6237–6242.
- Peischl et al. (2015), Quantifying atmospheric methane emissions from the Haynesville, Fayetteville, and northeastern Marcellus shale gas production regions, J. Geophys. Res. Atmos., 120, 2119–2139.
- Swarthout et al. (2015), Impact of Marcellus Shale Natural Gas Development in Southwest Pennsylvania on Volatile Organic Compound Emissions and Regional Air Quality, Environ. Sci. Technol., 49, 3175−3184