Fugitive Emissions from Unconventional Wells in Northeastern Pennsylvania: Tower Network Design and Regional Methane Inventory

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Motivation

-Methane (CH_4) is a greenhouse gas with 25 times the potency of CO_2 over a 100 year period (IPCC 2007)

-Though natural gas is often praised as a cleaner energy source than coal, methane leaks within the production and distribution system reduce the energy's overall effectiveness for reducing greenhouse gas emissions

-A global leakage rate in the natural gas infrastructure of 3.4% or greater from production to distribution would result natural gas having a more negative impact on climate change compared to simply using coal (Schwietzke et al. 2013)

-Various studies have produced contradictory results on what this emission rate is, with some exceeding this 3.4% threshold.

-This project will perform the first multi-year, top-down study on fugitive emissions from the natural gas industry

-A network of four towers will be set up in the Marcellus Shale region in northeastern Pennsylvania, continuously measuring methane concentrations over a two-year period.

Research Questions

(I) What are the major sources of CH_4 emission in Pennsylvania?

(II) What is a tower-network design that can capture background CH_4 concentrations as well as the enhancement from natural gas production in the region?

(III) What is a reasonable first-guess fugitive emission rate from wells in northeastern PA based on observations?

Methods

INVENTORY:
-Emission rates for wells were estimated as a percentage of monthly production values. In this study, unconventional wells are given a 0.4% leakage rate and conventional wells are given a 2% leakage rate.
-Emissions from enteric fermentation were obtained by taking the number of cows, goats, sheep, and pigs in each county and multiplying them by emission factors provided by the EPA.
-Emissions from anthropogenic sources outside of those described were obtained from the EPA Greenhouse Gas Reporting Program for 2013.

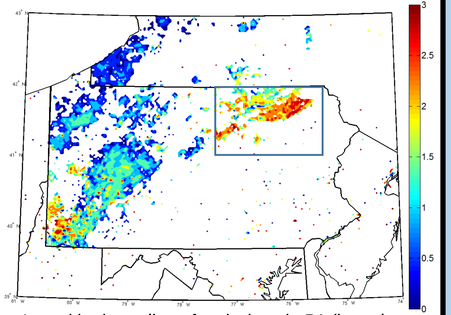
OBSERVATIONS:
-Regional field measurements from driving campaigns were gathered across 4 days in July 2014 using a Picarro CH_4 instrument.
-In addition to automobile measurements, observations from a July 2013 flight over the region (detailed in Peischl et al. 2013) were used.

SIMULATIONS:
-Emissions data from the inventory was entered into WRF-Chem and concentration fields were simulated and compared to observations.
-Leakage rates from unconventional wells were adjusted accordingly to match simulations with observations and provide a first-guess fugitive emission rate.

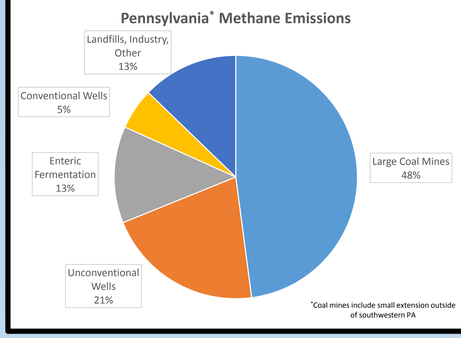
Inventory

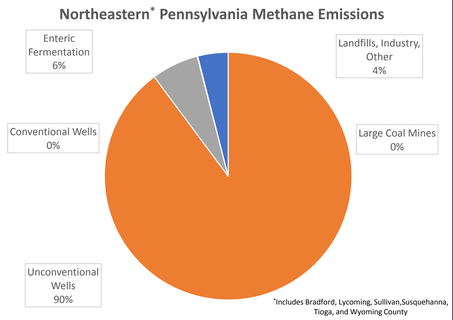
From a localized perspective, fugitive emissions from the natural gas industry make up nearly all of CH_4 emissions in northeast PA. The area is rural, livestock populations are small, and there are few large emitters identified in the EPA's Greenhouse Gas Report.

An inventory for the entire state paints a different picture. Emissions from coalbeds in southwestern PA, northwestern WV, and southeastern OH are large methane sources. The addition of conventional wells in western PA also adds an additional variable to the mix.



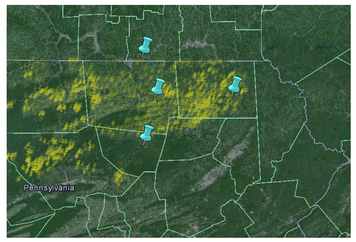
Logarithmic scaling of emissions in PA (in moles CH_4/hour) and surrounding area. The blue box highlights northeastern PA, the area of interest for this study. Animal emissions are not included in figure for visual purposes.





Tower Network Design

-As of May 2015, methane sensors have been set up at four sites across northeastern PA (blue placemarkers on map)

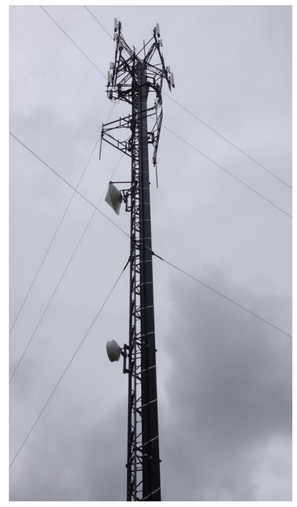


-Towers are equipped with Picarro measuring CH_4 and $^{13}CH_4$ isotope to distinguish sources of concentration.

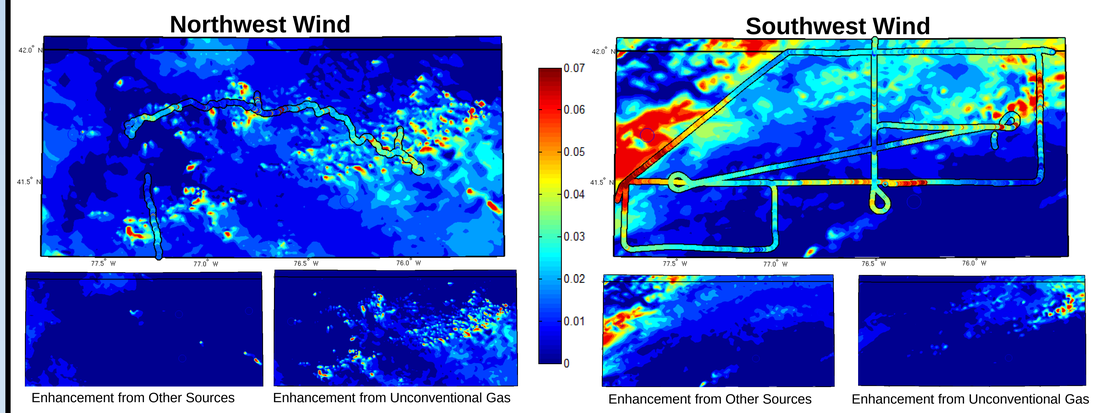
-Central and eastern tower are located directly in well region to measure enhancement from natural gas activity.

-Northern and southern towers are located along outer fringe of wells, and will measure background values or enhancement depending on wind direction.

-Tower network design is tight knit, covering ~100km^2 area. Background sites located close to enhancement sites, limiting noise from sources outside of Marcellus region.



Observations vs Simulations:



Projected CH_4 concentration enhancement (in ppm) with observations plotted overtop

Left Figure: Surface observations from driving campaign on July 17th, 2014 compared to afternoon concentrations calculated using WRF-Chem. Winds were steady from the northwest.

In this situation, concentrations from sources other than Marcellus gas production are minimal and all enhancements are attributed to natural gas production/transmission.

Right Figure: Observations from aircraft campaign on July 6th, 2013 compared to afternoon 1000m concentrations calculated using WRF-Chem. Winds were mostly from the southwest during afternoon hours.

In this situation, large intrusions from sources other than unconventional gas can be seen, with the coalbeds in southwestern PA acting as the largest contributors.

Conclusion: Wind direction in NE Marcellus region may play a large role in background conditions

Conclusion

DISCUSSION
-Observations from driving campaign show a 40ppb enhancement downwind of natural gas production.
-A CH_4 enhancement pattern similar to those seen in observations can be modeled in WRF-Chem if emissions from unconventional wells are set to 0.4% of production.
-Large emitters in southwestern PA can lead to l shifts in background CH_4 equal or greater in magnitude to emissions from wells. Correctly defining a background value for the region becomes very important

FUTURE WORK:
-Instrumentation at tower sites will be deployed over the next two years, continuously monitoring methane in the region
-These measurements will be combined with a high-resolution, regional-scale atmospheric transport model with a Bayesian inversion to trace methane concentrations back to their source.
-This data will be combined with information from the inventory and a more thorough analysis of the fugitive emission rate for natural gas in the Marcellus region will be performed.

Acknowledgments

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