SLIDES: What We Know (and Don't Know) About Air Quality Impacts of Oil and Gas Development

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WHAT WE KNOW (AND DON’T KNOW) ABOUT AIR QUALITY IMPACTS OF OIL AND GAS DEVELOPMENT

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Photo: Uinta Basin, UT credit: David Oonk, CIRES
NOAA Cooperative Global Air Sampling Network - Greenhouse Gases

GHGs (including methane) are measured in weekly air samples collected around the globe.

Data is free and available online at:

http://www.esrl.noaa.gov/gmd/ccgg/flask.html
Potential Air Impacts of Unconventional Oil and Gas Development

- Air Toxics (Benzene, Toluene, H₂S…)
- Particles (dust)

- Volatile Organic Compounds (VOC) & Nitrogen Oxides: Ozone Precursors

- Methane (CH₄), Carbon dioxide (CO₂)

**Slide credit:** G. Pétron
Raw gas is composed of 70-90% methane.

Distribution gas is >90% methane.
So what are the \( \text{CH}_4 \) emissions from natural gas?

EPA Inventory of GHG Sources and Sinks

\[ \text{Tg CH}_4/\text{yr} \]

- 2010 Report
- 2011 Report
- 2013 Report

Year

\[ \text{Tg CH}_4/\text{yr} \]

- Distribution
- Transmission
- Processing
- Production

2010 Report
2011 Report
2013 Report

Characterizing Pivotal Sources of Methane Emissions from Unconventional Natural Gas Production
Summary and Analysis of API and ANGA Survey Responses

API
ANGA

June 1, 2012
So what are the CH$_4$ emissions from natural gas?

EPA Inventory of GHG Sources and Sinks

![Graph showing CH$_4$ emissions from natural gas across different years and sources.](image-url)
How can one assess atmospheric impacts of an industry?

**Inventory approach**
estimates emissions for various types of operations or equipment using activity data and emission factors

**Atmospheric evidence-based approach**
estimates emissions at various scales using atmospheric measurements
Can we detect emissions in the atmosphere?

Concentrations of pollutants measured by tower, instrumented van, or aircraft downwind of the area source reflect emissions from oil and gas production operations.

Slide: Gabrielle Pétron
Uinta Basin, Utah

- Horse Pool
- ~60 km
- oil wells
- gas wells
- Uinta Basin
High emissions (6-12% leak rate of NG), but this field only represents ~1% of US production. Best inventory: ~5%.

What we know

Katzenstein et al., PNAS 2003
Miller et al., PNAS 2013
Green River Basin, WY: high winter time surface ozone in natural gas field (Schnell et al., 2009)

Uinta Basin, UT: Jan/Feb 2012 winter-time ozone study (Feb. 2012: Karion et al., 2013.) - Feb. 2013 (Oltmans et al., in prep.)

Denver-Julesburg Basin, CO: Hydrocarbon emissions from oil and gas operations in Weld County (Pétron et al., 2012; Gilman et al., 2013; Pétron et al., 2014)
What we know

Barnett Shale, TX: Third largest shale gas field in the US.

Marcellus Shale, PA
[NOAA: Peischl, in prep.]

Haynesville Shale (LA/TX) & Fayetteville Shale (AR)
[NOAA: Peischl, in prep.]

[Zavala-Araiza et al, 2014; Karion et al, in prep.]
Upcoming work

Marcellus Shale, PA
[DOE Penn State]

Bakken, ND
[NOAA]

San Juan Basin, CO/NM
[NOAA]
Brandt et al., 2014: Emissions estimates from atmospheric measurements generally exceed inventories by ~50%.

Allen et al., 2013: On-site measurements show leakage similar to EPA estimates.
But… many production regions have not yet been sampled. (i.e. what we don’t know!)
What are inventories missing? (what we don’t know)

- Processes that emit that are not accounted for (e.g. Caulton et al., 2014)
- Long-tailed emissions distribution (a few sources causing the majority of leaks).
1. Top-down oil and gas emission estimates based on flight data in May 2012 are ~2 times larger than state inventory estimates for NMHCs and 7 times larger for the carcinogen benzene (C\textsubscript{6}H\textsubscript{6}).

2. CH\textsubscript{4} emissions are close to 3 times larger than an estimate based on EPA GHGRP data.

*Measured NMHC: propane, n-butane, i-pentane, n-pentane, benzene
Denver-Julesburg Basin

Pétron et al., 2014
Photochemical Ozone (O$_3$) production

Volatile Organic Compounds (VOC): venting, flashing, flaring, fugitive emissions

VOCs, CO, CH$_4$

OVOCs, CO$_2$, H$_2$O

OH

HO$_2$

NO$_2$

NO

O$_2$

O$_3$

Sunlight
Photochemical Ozone (O$_3$) production

Nitrogen Oxides (NO$_x$=NO + NO$_2$):
engine exhaust, drill rigs, compressor engines

VOCs, CO, CH4 (O$_2$)
O VOCs, CO$_2$, H$_2$O

OH
HO$_2$

NO$_2$
NO
O$_2$

O$_3$

Sunlight
Photochemical Ozone ($O_3$) production

Sunlight: UV from sunlight to trigger photochemistry

- VOCs, CO, CH4
- OVOCs, CO$_2$, H$_2$O
- NO$_2$, NO
- O$_2$, O$_3$, HO$_2$
Photochemical Ozone ($O_3$) production

Ingredients: VOC + NOx + Sunlight $\rightarrow$ Ozone

- VOCs, CO, CH4
- OVOCs, $CO_2$, $H_2O$
- OH
- $HO_2$
- $NO_2$
- NO
- $O_2$

O$_3$ = ozone

Summertime Ozone: Typical in urban areas. Weld County, Colorado is non-attainment in summer.

Wintertime Ozone: Rural western oil and gas basins, such as in Utah and Wyoming.
A NOAA study in 2011 estimated that 55% of OH reactivity in the DJ region was attributable to VOCs emitted by oil and gas operations.

Uinta Basin’s record surface ozone - 2013

- High emissions of ozone precursors
- Snow covered ground (reflected UV)
- Shallow inversion layer

75 ppb 8hr average standard

11am 4-6pm
Summary

What we know:

- Oil and gas production emissions affect air quality globally (greenhouse gases) and regionally (air toxics and ozone).
- Atmospheric measurements show that emissions are greater than inventory accounts.

What we don’t know:

- How inventories can be improved / what they are missing
- What the emissions from US oil and gas production are and how they will change.
Thanks to contributions from:

Gabrielle Pétron, Colm Sweeney, Jessica Gilman, Sam Oltmans, Russ Schnell, Eric Kort, Ben Miller, Stephen Montzka… and more

Contact: Anna.Karion@noaa.gov

Photo: sunset over the Denton, TX airport, courtesy S. Wolter
Thank you!
Some references


Studies of Uintah:


Ahmadov R., et al. (in prep). Understanding high wintertime ozone in an oil and natural gas producing region of the western U.S.
Barnett Shale, TX

~200 km

Upwind (Duchess)

Downwind (Mooney)
5 downwind transects

Karion et al., in prep.
Ethane to Methane Ratio: Barnett Shale

![Graph showing the ratio of ethane to methane in Barnett Shale with data points and a color scale representing longitude.](image-url)
Ethane to Methane Ratio: Barnett Shale

Kort et al., in prep.
Karion et al., in prep.