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

Anna Karion
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Photo: Uinta Basin, UT credit: David Oonk, CIRES
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

http://www.esrl.noaa.gov/gmd/dv/data/
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)

Health
Air Quality
Climate Forcing

Local-Regional Scale
Regional Scale
Global Scale

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

Distribution gas is >90% methane.
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, with a breakdown of emissions by distribution, transmission, processing, and production.]
So what are the CH$_4$ emissions from natural gas?

EPA Inventory of GHG Sources and Sinks
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
Utah, 2012

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
What we know

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)
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.]

What we know
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 (C₆H₆).

2. CH₄ 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 (O₃) production

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

VOCs, CO, CH₄

OH

NO₂

O₂

NO

O₃

HO₂

O₂

Sunlight

OVOCs, CO₂, H₂O
Photochemical Ozone ($O_3$) production

Nitrogen Oxides ($NO_x=NO + NO_2$):
engine exhaust, drill rigs, compressor engines

- $O_3$ production involves reactions with VOCs, CO, CH4, CO2, H2O.
- OH and HO2 radicals play key roles.
- NO and NO2 react with sunlight.

Slide: Jessica Gilman
Photochemical Ozone ($O_3$) production

Sunlight: UV from sunlight to trigger photochemistry

- VOCs, CO, CH4
- OVOCs, CO$_2$, H$_2$O
- OH
- NO$_2$
- NO
- HO$_2$
- O$_2$
- O$_3$

Slide: Jessica Gilman
Photochemical Ozone ($O_3$) production

Ingredients: VOC + NOx + Sunlight $\rightarrow$ 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.
Surface ozone pollution in winter

TOXIC TRANSPORT
Microbial mercury uptake

GLACIER DYNAMICS
Transient acceleration

EARTHQUAKES AT DEPTH
Thermal runaway

Schnell et al., 2009

Upper Green River Basin, Wyoming
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

Ozone Mixing Ratio at Fantasy Canyon, 2/5/2013

GMD Aircraft Flasks - Uinta Basin
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

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


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 relationship between C₂H₆ and CH₄ concentrations in Barnett Shale. The x-axis represents CH₄ (ppb) ranging from 1850 to 2050, and the y-axis represents C₂H₆ (ppb) ranging from 0 to 15. The graph includes a color gradient for longitude ranging from -96.5 to -98 degrees.]

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Ethane to Methane Ratio: Barnett Shale

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