Implications of Top-Down Atmospheric Measurements in Oil and Gas Basins

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Global methane (CH$_4$) monitoring

- Lifetime ~ 9-10 years
- Potent GHG, GWP: 28 /100 years and 84 /20 years (IPCC 2013)
- Background in northern hemisphere ~ 1850 ppb
- NOAA measurement uncertainty ±1ppb
- 17% of total direct radiative forcing from long-lived GHG in 2013
Potential air impacts of emissions at various scales

**Global Scale**

**Regional Scale**

**Local-Regional Scale**

**Long-term Climate Forcing**
- Methane
- Carbon dioxide

**Air Quality**
- Ozone, Particles

**Health**
- Air Toxics, Ozone
- Particles
U.S. NG Systems: A large infrastructure

**U.S. Statistics:**
- EIA, DOT, OGJ

- **~ 500 processing plants**
- **300,000 miles of transmission pipelines**
- **> 1400 compressor stations**

- **20,000 miles of gathering pipelines**
- **>1 million oil and gas wells in US**
- **2,000,000 miles of distribution pipeline**
- **400 underground storage sites**

**DOE EIA**

**Production**
- Raw Natural Gas > 70% methane in volume

**Processing**
- Processed Natural Gas > 90% methane in volume

**Transmission**

**Distribution**

Multiplication of surface operations

Based on EIA U.S. statistics
All numbers indexed to 1990

Number of Active

Dry

Consumpt

Well Pads Activities & Equipment:
- Road/Pad construction
- Well drilling and stimulation
- Well head
- Dehydrators
- Separators
- Liquid Storage Tanks
- Additives (Methanol)
- Servicing by trucks (oil, water)
- Workover, Restimulation

Midstream Sector:
- Pipelines
- Compressor Stations
- Processing Plants

Well pad in Utah, 2011

All numbers indexed to 1990

Based on EIA U.S. statistics
What’s in natural gas?

Produced “raw gas” is composed of 70-90% methane.

Distribution gas is >90% methane.

Composition of gas varies from one basin/formation/well to another.

Surface ozone precursors

Air Toxics

NGLs

GHG

Methane (CH₄)

- Methane
- Ethane
- Propane
- i-Butane
- n-Butane
- i-Pentane
- n-Pentane
- Cycloalkanes
- Benzene
- Toluene
- CO₂
- N₂
- C₆+ Heavies
- Benzene
- Toluene
- CO₂
- N₂
- C₆+ Heavies
- Benzene
- Toluene
- CO₂
- N₂
- C₆+ Heavies

Composition of gas varies from one basin/formation/well to another.
Emissions Assessment Tools

Inventory Approach

• Scalable, “easy” to update, information at process-level needed to prioritize mitigation efforts

• Components:
  – Activity Data
    • Not clear how accurate/up-to-date some of them are
      – Ex: pneumatic devices (comparing GHGRP 2012 reported emissions)
  – Emission Factors and Emissions Speciation Profiles
    • Many are old and based on a few snapshot measurements or model results
    • Assumes Gaussian distribution of emissions around a “mean value”
  – Emission Controls and their Actual Effectiveness
    • 2012: Colorado reevaluated the capture efficiency of oil/condensate tanks vapor recovery systems (100% to 75%) but Where is “true” problem?
    • Green completion required for gas wells (what about associated gas and oil wells?)
22 wells visited in DISH, TX all owned by the same company and likely built around the same time (by the same engineer?) suggest that the inventory method which assumes that these wells all have the same emissions will get it wrong.

Eric Crosson, Picarro Inc, Colm Sweeney, CU, 2013
Atmospheric studies: Top-Down Approach

• Target questions: GHG, CAPs, HAPs
  – Emissions
  – Ambient levels
  – Chemistry
  – Dispersion

• Tools:
  – In situ measurements and sampling
  – Remote Sensing (Satellites)
  – Forward and Inverse modeling
Can we detect NG emissions in the atmosphere?

CH₄ “cloud” from surface emissions

Ambient levels of CH₄ measured by tower, instrumented van or aircraft downwind of the area source reflect emissions from oil and gas production operations.
1. Air samples collected at the Colorado (BAO) and Oklahoma (SGP) sites have a distinctive strong hydrocarbon signature.

2. High quality (well calibrated) measurements show strong correlation between several of the hydrocarbons (see next slide).
300 magl level sampling at Colorado Tower: Multiple species analysis in midday discrete air samples

1. South Sector shows influence from urban emissions
2. N-E Sector shows influence from oil and gas operations
3. Based on a 3 week intensive with in-situ GC-MS measurements, Gilman et al. (2013) estimated that half of VOC reactivity in the region was due to O&G emissions
NOAA studies in U.S. oil and gas plays

Ozone nonattainment areas
- Light aircraft 2012 (UT, CO), 2013 (UT)
- 2014 NOAA Twin Otter
  - Bakken, ND
  - San Juan Basin, NM
- 2013 NOAA P3 (SENEX)
  - Haynesville (LA), Fayetteville (AR), Marcellus (PA) (Peischl, submitted)

2010 NOAA P3 (CALNEX)
- LA Basin
- Gas leaks from oil operations and natural gas distribution system

Light aircraft 2013
- EDF funded
  - Barnett, TX
  - Karion, in prep

2010 NOAA P3
- Deepwater Horizon Oil spill

http://shalebubble.org/the-map/
Methane and VOC emissions from oil and gas operations in Utah and Colorado estimated during aircraft intensives

- **NE Utah:** Large emissions from O&G operations (Karion et al., GRL, 2013)
  - Based on data from one flight in 2012: ~9% of the natural gas produced in the East (mostly gas) portion of the Uintah Basin was leaked (WRAP/GAO ~ 5%)
  - Use of the top-down emission estimate for 2013 winter campaign in WRF-Chem allowed model to match ambient VOC levels observed at fixed measurement site (Ahmadov et al., I review).

- **NE Colorado:** Official inventories underestimate oil and gas sector emissions (Pétron et al., JGR, 2014):
  - Methane x 3 (~4% of gas production)
  - VOCs (ozone precursors) x 2
  - Benzene (carcinogen) x 7
Example of Mobile Lab measurements: Not all pumpjack engines perform equally well, poorly.

Natural gas powered artificial lifts & their emission products in the Gilsonite Draw field, NE Utah

- Pumpjack engines in the oil field seem to be running with variable efficiency.
- Non-negligible fraction of the natural gas used to power these engines can leak to the atmosphere.
- See also Warneke et al. (2014)

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<td>19%</td>
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Challenges for top-down approach

• Partitioning between different sources within a target region
  – Use of multiple species
• Attribution to specific processes
  – Requires ground-based field work
• Interpretation of geographical differences not completely straight-forward
  – GAO 2010 report
  – Allen et al., 2013
  – NOAA top-down studies: dry vs wet gas?
• Need to combine different approaches at different scales to assess sources when/where needed
Complication
Scales of different emission estimation products often do not overlap

Spatial Scale

Global
National
Basin
Facility
Process/component

Snapshot Seasonal Annual Multi-year

Inverse modeling using well-calibrated long-term atmospheric observations

EPA NI WRAP EPA GHGRP

Mass-Balance Tracer Releases Emission Factors

CEMS

Source: G. Pétron

CEMS: Continuous Emissions Monitoring System
Final remarks

• There is a strong need to better understand emissions of GHG, CAP, and HAPs to
  – Assess emissions impacts
  – Support and evaluate effective emissions mitigation where needed

• High quality long-term atmospheric chemical measurements provide key information on sources influencing an air shed

• Targeted field campaigns can provide an independent check on inventory models and results and further diagnose sources contributions