Top-down estimation of CH$_4$ emissions from oil and natural gas operations in the Denver and Uintah oil and gas Basins

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US CH₄ emissions (Tg/yr) from natural gas systems
Impact of change in EPA inventory methodology

How accurate are these numbers?

2010 EPA US GHG inventory

2011 EPA US GHG inventory

Field production emissions X 9

Reported uncertainty for CH₄ national emissions from NG systems: 20-30%.
Can we detect CH$_4$ emissions in the atmosphere?

CH$_4$ “cloud” from surface emissions

Ambient levels of CH$_4$ measured by instrumented tower, van or aircraft downwind of the area source reflect emissions from oil and gas production operations.
Can we use multiple species measurements for source attribution?

Different sources of $\text{CH}_4$ have different chemical signatures. Here flight measurements in the Denver Basin in May 2012 show two distinct plumes downwind of Denver (red) and downwind of the oil and gas field (black).

Denver Basin, home to > 20,000 oil and gas wells.

A multi-species approach is needed to determine the significance of different $\text{CH}_4$ sources as well as to separate different emission processes within the NG industry.
Methane is strongly correlated with propane.

Samples collected downwind of feedlots, a landfill, and a waste water treatment plant have enhanced methane compared to the other samples.

We use the measured atmospheric propane-to-methane enhancement ratios observed at the BAO tall tower and at the surface across the Front Range to evaluate the proportion of flashing (condensate/oil tanks) and venting (fugitive) emissions.

Top-down Estimates versus Inventory

- Fugitive emissions of CH$_4$ in Weld County are likely underestimated in bottom-up inventory for 2008.
- Still very large uncertainties on top-down estimates.
- **We need a truly independent method to evaluate inventories!**
Mass Balance Approach for Area Flux Estimation

Under ideal meteorological conditions, we can calculate the area CH$_4$ flux with a low uncertainty.
Aircraft Measurements of CH$_4$

Uintah Basin
February 3 2012
Moderate wind
Methane enhancement in plume downwind of field is integrated over the horizontal extent to calculate the CH$_4$ surface flux.

**Downwind CH$_4$ Plume Integration**

- **Background condition**
- **Downwind leg**
- **Oil and gas plume**
- **Free troposphere**
- **Path length (km)**
Flux uncertainty calculation for February 3 2012

- This is the uncertainty of a single day observation.
- Consistent winds lead to a relatively low uncertainty on this observation.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>% Uncertainty</th>
</tr>
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<tbody>
<tr>
<td>Wind Speed</td>
<td>13%</td>
</tr>
<tr>
<td>Cosine of angle between wind direction and normal to heading</td>
<td>19%</td>
</tr>
<tr>
<td>Methane enhancement</td>
<td>6.4%</td>
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<tr>
<td>Mixing layer height</td>
<td>6%</td>
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<td>Total Flux (CH$_4$)</td>
<td>25%</td>
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Karion et al., in prep.
Concluding remarks

- Atmospheric measurements can be used to quantitatively assess emissions from oil and gas upstream and midstream activities
  - Our top-down emission estimates are
    - for a specific location and time
    - integrated fluxes from various O&G operations
- This type of study provides an objective evaluation of bottom-up inventories
  - Specifically it can be used to assess at the regional scale
    - new inventory methodologies
    - impact of new regulation/practices
- VOC emission reduction strategies most likely also reduce CH$_4$ emissions
  - Example of co-benefit: Air quality/Climate
- Results from on-going experiments should be available later this year.

Pictures from Uintah Basin February 2012
Supplementary Slides
Flux calculation for February 3 2012

\[
\dot{n}_{CH_4} = V \cos \alpha \int_{-b}^{+b} \Delta X_{CH_4} \left( \int_{h(x)}^{PBL} n_{air} \, dz \right) \, dx
\]

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NOAA Boulder Atmospheric Observatory

- 300 meter tall tower
- Located in Erie, Weld County
- Instrumented with LICOR (CO$_2$) and TECO (CO) in April 2007: sampling from 3 intake heights (22m, 100m, 300m)
- 30 sec - Met Data at three levels
- Equipped to collect discrete air samples from 300 meter level in August 2007. Analyses performed in NOAA Boulder lab.


Most oil and gas E&P operations have been regulated so far at the state level. New EPA rule into effect by 2015.

http://www.esrl.noaa.gov/gmd/ccgg/towers/index.html
Field study to investigate methane sources chemical signatures in the Front Range

- Mobile Platform to sample close to sources
- High-frequency stable analyzers to detect plumes and target flask sampling
- Discrete air sampling for multi-species chemical analyses in the NOAA lab

Toyota Prius equipped with:
- Fast response CO₂ and CH₄ analyzer (Picarro)
- Real Time Display of Measurements
- GPS
- Programmable Flask Package (PFP with 12 sampling glass flasks) and Programmable Compressor Package (PCP) with GPS
BAO: Distinct alkane signature compared to other continental sites in the US

Air samples collected at the BAO and at Oklahoma site (SGP) have a strong alkane signature.

* SGP is a NOAA aircraft site in Northern Oklahoma. Samples collected below 650 meters were used for this analysis.
Midday Data from the BAO (August 2007-April 2010).
Wind sector designation based on 30-min average (prior to sample collection) wind direction and wind speed (data retained if $|w\text{.speed}| > 2.5$ m/s).
Regional Scale enhancement of CH₄

Example of Mobile Lab Survey (July 9, 2008)

The size of the symbols along the survey track are proportional to the measured CH₄ mixing ratio.

The CH₄ mixing ratio increased suddenly when the wind direction shifted and we started sampling air coming from the NE.