Fine scale measurements of methane from ground sources (QLD, NSW and NT)

Stakeholder Roundtable Group Meeting

Cindy Ong | Principal Research Scientist | 4 November 2019
FOCUS: ONSHORE GAS

Fugitive Emissions: unintended releases of gas from industrial operations; includes exploration drilling, production testing and well completion, gas production activities, processing, transport, storage, transmission and distribution
Baseline Survey: Beetaloo Sub-Basin

- Quantify background atmospheric concentration levels of methane that are of interest for exploration;
- Identify & locate sources of methane & where applicable and feasible, quantify the fluxes related to sources.
Concentration And Emission Rate?

- Gas analysers measure concentrations (ppm, ppb);
- For greenhouse accounting we need to know emission rates;
  - Emission Rate (kg s\(^{-1}\)) = Concentration (kg m\(^{-3}\)) \times Flow (m\(^3\) s\(^{-1}\));
- Relatively easy in pipes and ducts (e.g. underground coal mines)
Determining Emissions Rates

● More difficult with diffuse sources
  • Open-cut coal mines
  • Agriculture
  • Gas fields

● Possible approaches
  • Top down – i.e. attempt to measure emissions over entire region
    • Atmospheric transport methods
    • Includes all sources; complicates interpretation
  • Bottom up – i.e. measure emissions from individual sources (e.g. wells) then add up to yield total emissions
    • May miss sources; provides information on emission routes
# Potential Sources of Methane Emissions in Beetaloo sub-Basin

<table>
<thead>
<tr>
<th>Source</th>
<th>Spatial Scale</th>
<th>Individual Concentration</th>
<th>Cumulative Concentration</th>
<th>Temporal Variation</th>
<th>Location</th>
<th>Quantification method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Livestock (cattle)</td>
<td>Small</td>
<td>Small</td>
<td>Large</td>
<td>NA</td>
<td>Dispersed</td>
<td>Estimates using emission factors well established</td>
</tr>
<tr>
<td>Fires</td>
<td>Large</td>
<td>NA</td>
<td>Large</td>
<td>Dry</td>
<td>Unknown</td>
<td>Total GHG inferred from fires mapped from satellite – CH₄ not discriminated</td>
</tr>
<tr>
<td>Termites</td>
<td>Small</td>
<td>Small</td>
<td>Unknown</td>
<td>Wet</td>
<td>Dispersed</td>
<td>Not well understood</td>
</tr>
<tr>
<td>Wetlands</td>
<td>Medium</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Wet</td>
<td>Not well understood</td>
<td></td>
</tr>
<tr>
<td>Natural geological seeps</td>
<td>Small</td>
<td>Small</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Unknown, not well characterised</td>
<td></td>
</tr>
<tr>
<td>Abandoned/old petroleum &amp; mineral, water bores</td>
<td>Small</td>
<td>Small-medium</td>
<td>Unknown</td>
<td>Continuous</td>
<td>Some knowledge                       As above; Monitoring methods established but not continuous</td>
<td></td>
</tr>
<tr>
<td>Future: Onshore operating wells</td>
<td>Small</td>
<td>Small</td>
<td>Unknown</td>
<td>Continuous</td>
<td>Well known                          Monitoring methods established but not continuous</td>
<td></td>
</tr>
<tr>
<td>Future: Oshore operating infrastructure</td>
<td>Medium</td>
<td>Medium - large</td>
<td>Unknown</td>
<td>Continuous</td>
<td>Well known                          Development required</td>
<td></td>
</tr>
<tr>
<td>Waste treatment facility</td>
<td>Medium</td>
<td>Small -Medium</td>
<td>NA</td>
<td>Well known</td>
<td>Methods well developed</td>
<td></td>
</tr>
</tbody>
</table>

**Source Spatial Scale**
- S < 1m
- M 10-30 m
- L > 250 m

**Individual Concentration**
- Small
- Medium - large
- Unknown

**Cumulative Concentration**
- Large
- Unknown

**Temporal Variation**
- Continuous
- Dry
- NA

**Location Quantification method**
- Dispersed
- Well known
- Not well understood

**Stakeholder Roundtable Group Meeting | 14 November 2019 | 7**
Mobile Surveys

- One of most widely used, reliable and well-developed techniques;
- Employ high sensitivity analysers deployed from 4WD drive;
- 3 mobile survey campaigns total ~15,000 km between July 2018 to February 2019.
  - 1\(^{\text{st}}\) campaign, dry season: total ~5,500 km between 29\(^{\text{th}}\) July – 10\(^{\text{th}}\) August 2018;
  - 2\(^{\text{nd}}\) campaign, fire season: ~5,300 km between 6\(^{\text{th}}\) – 15\(^{\text{th}}\) November 2018;
  - 3\(^{\text{rd}}\) campaign, wet season: ~4,050 km between 30\(^{\text{th}}\) January - 5\(^{\text{th}}\) February 2019
Summary of Mobile Survey in Beetaloo sub-basin

Average, median, standard deviation and maximum CH$_4$ concentration values measured during the three mobile survey campaigns

<table>
<thead>
<tr>
<th></th>
<th>Campaign 1 (LGR)</th>
<th>Campaign 2 (LGR)</th>
<th>Campaign 3 (LGR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average (ppm)</td>
<td>1.839</td>
<td>1.827</td>
<td>1.808</td>
</tr>
<tr>
<td>Median (ppm)</td>
<td>1.835</td>
<td>1.826</td>
<td>1.807</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>0.019</td>
<td>0.013</td>
<td>0.017</td>
</tr>
<tr>
<td>Maximum (ppm)</td>
<td>2.604</td>
<td>2.206</td>
<td>2.920</td>
</tr>
</tbody>
</table>

Methane concentration measured at Cape Grim during survey periods

<table>
<thead>
<tr>
<th></th>
<th>August 2018</th>
<th>November 2018</th>
<th>February 2019</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.826</td>
<td>1.820</td>
<td>1.798</td>
</tr>
</tbody>
</table>
Beetaloo Baseline: Dry Season (29th July – 10th August)
Beetaloo Baseline: Grazing Cattle

- Elevated concentrations from cattle
- Estimated total emission = 7,402,159 kg CH₄ yr⁻¹ from 115K beast (NTCA, 2019)

Average emission factors 54.75-73.00 kg CH₄ per beast per yr⁻¹ Charmley et al. (2016). The average of this, 63.88 kg yr⁻¹ was used for the estimation.
Beetaloo Baseline: Fires (6th – 15th November 2018)
Fires

- Can be one of the largest sources of CH$_4$ emission;
- Spatially large, challenging to get close enough;
- Emission from fires currently estimated using satellite data and emission factors;
- Good candidate for GHG satellite with CH$_4$, CO, CO$_2$ capabilities;

CH$_4$ from mobile survey compared to fire scar from satellite data

TROPOMI CO total column mixing ratio averaged from November 13th to 19th, 2017 (from Borsdorff et al., GRL 2018).

Global XCH$_4$ distribution as obtained with TROPOMI (top) and GOSAT (bottom) measurements averaged over the period of 12 November to 30 December 2017 (from Hu, et al., AGU 2018)
Beetaloo Baseline: Termites

- No elevated values detected during dry campaign;
- Elevated values detected during wet campaign;
- Emission rate estimated $\sim 900,000$ kg CH$_4$ yr$^{-1}$ (based on (Jamali et al. 2011: 0.24 kg CH$_4$-C ha$^{-1}$ yr$^{-1}$ or 0.32 kg CH$_4$ ha$^{-1}$ yr$^{-1}$))
Beetaloo Baseline: Soils

- Soil fluxes were measured at 8 sites throughout 3rd mobile campaign;
- Estimated emission sink for Beetaloo sub-Basin ~ approximately 4,200,000 kg CH$_4$ yr$^{-1}$ based on Jamila et al. 2011: 1.52 kg CH$_4$ ha$^{-1}$ yr$^{-1}$

<table>
<thead>
<tr>
<th>Site Surface Description</th>
<th>Methane Emission Flux (mg CH$_4$ m$^{-2}$ day$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grassed edge of track – damp soil</td>
<td>-2.3</td>
</tr>
<tr>
<td>In free water on the grassed verge</td>
<td>-1.4</td>
</tr>
<tr>
<td>Dry ground without vegetation</td>
<td>-3.8</td>
</tr>
<tr>
<td>Dry ground without vegetation</td>
<td>0.5</td>
</tr>
<tr>
<td>Grassed edge of a large stagnant water body; Location 1</td>
<td>98.0</td>
</tr>
<tr>
<td>Grassed edge of a large stagnant water body; Location 2</td>
<td>5.1</td>
</tr>
<tr>
<td>Grassed edge of a large stagnant water body; Location 3</td>
<td>23.3</td>
</tr>
<tr>
<td>Stagnant water body – in the water</td>
<td>113</td>
</tr>
</tbody>
</table>
Beetaloo Baseline: Pipeline Riser

- Elevated values detected during all campaigns;
- Emission rates quantified during 3rd campaign - 43.8 kg CH₄ yr⁻¹;
- 60-80 % of a cattle;
- Under threshold of NT’s code of practice (5000 ppm at 150 mm).
Beetaloo Baseline: Petroleum Wells

- Visited or was close to 11 plugged & abandoned & suspended wells at least once during mobile survey campaigns;
- No elevated values measured
Beetaloo Baseline: Water Bores

- Visited or close to 25 bores at least once during 3 campaigns;
- No elevated values measured at most bores; small number have small levels above background but cattle close by; elevated values close of Daly Waters Motel bore near septic tank;
Infrastructure

- CSG Wells;
- Wells Workover;
- Wells Completion;
## Infrastructure: CSG Wells

<table>
<thead>
<tr>
<th>Year</th>
<th>No Wells</th>
<th>Location</th>
<th>Mean</th>
<th>Max</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013-14</td>
<td>43</td>
<td>NSW &amp; QLD</td>
<td>5 L/min</td>
<td>67 L/min</td>
<td>&lt;0.05 % production</td>
</tr>
<tr>
<td>2014-16</td>
<td>24</td>
<td>NSW</td>
<td>~ 5 L/min</td>
<td>33.8 L/min</td>
<td></td>
</tr>
<tr>
<td>2019</td>
<td>300+</td>
<td>QLD</td>
<td>1.7 L/min</td>
<td>17.5 L/min</td>
<td>Preliminary from &gt; ½ measurements</td>
</tr>
</tbody>
</table>
Infrastructure: CSG Well Workover Emissions

- Well cleaned to improve gas flow after some period of production
- One workover in 2015 - flushing the well with compressed air for 24 hours
  - Significant $\text{CH}_4$ since drilling fluid was not present; total amount vented was $\sim 22$ t;
  - $\text{CH}_4$ flow stopped when well was ‘killed’.
- Air injection is not typical for workovers
  - Likely that workovers without air injection have lower emissions;
  - Needs to be tested in the field.
Infrastructure: CSG Well Completion

- Well completion activities; i.e. installation of water pump, tubing etc. into the well
- Emission measurements at 9 well sites in 2015-2016
  - Little or no emissions while well is filled with drilling fluid
  - Most emissions after unloading and during operations where air is injected into the well
  - Max emission from completion ~370 kg CH₄

<table>
<thead>
<tr>
<th></th>
<th>Number of Wells</th>
<th>Mean Emission (kg CH₄)</th>
<th>Median Emission (kg CH₄)</th>
<th>Minimum Emission (kg CH₄)</th>
<th>Maximum Emission (kg CH₄)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company A</td>
<td>4</td>
<td>128</td>
<td>98</td>
<td>0</td>
<td>315</td>
</tr>
<tr>
<td>Company B</td>
<td>5</td>
<td>175</td>
<td>126</td>
<td>25</td>
<td>373</td>
</tr>
<tr>
<td>Combined</td>
<td>9</td>
<td>154</td>
<td>126</td>
<td>0</td>
<td>373</td>
</tr>
</tbody>
</table>
Legacy: Surface Seeps (Abandoned Bores)

- Most emissions within about 2 x 2 m square
- Emission > 60 L min$^{-1}$
- Numerous other boreholes emission rates 0.1 to 100 L min$^{-1}$
Legacy: Surface Seeps (Source Unknown)

- Localised emission
  - No obvious source
  - Gas seeping from ground
  - Nearest CSG well > 2.5 km away

- Traversed to estimate flux
  - Up to 18 ppm CH$_4$
  - ~50 L min$^{-1}$
Detection & Location Of Unknown Seepages

Results from Fruitland Outcrop, San Juan Basin

Figure 4: Site 1 plume images. Left and center plumes are from single-pass data taken on Feb. 26th. The image on the right is from the Feb. 27th flight. The color bars scale from 0 to 1,000 ppm-v.

Table 1: Best effort estimation of CH4 flux for the detected sites. The values are total fluxes for each area.

<table>
<thead>
<tr>
<th></th>
<th>Longitude</th>
<th>Latitude</th>
<th>26-Feb</th>
<th>27-Feb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site 1</td>
<td>-107.85205</td>
<td>37.31519</td>
<td>19,200</td>
<td>0,000</td>
</tr>
<tr>
<td>Site 2</td>
<td>-107.64201</td>
<td>37.31287</td>
<td>48,000</td>
<td>72,000</td>
</tr>
<tr>
<td>Site 3</td>
<td>-107.65773</td>
<td>37.31390</td>
<td>7,200</td>
<td>7,200</td>
</tr>
<tr>
<td>Site 4</td>
<td>-107.66257</td>
<td>37.31504</td>
<td>2,400</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Note: Data were acquired at reduced sensitivities. Could potentially double in sensitivities; Different configurations such as lower flying height, etc. could increase detection.
Regional Monitoring: Multi-Temporal

- 6 year of satellite (SCIAMACHY) data;
- Regional trends in Surat Basin compared to whole of Australia
Thank you

Cindy Ong
Principal Research Scientist

+61 8 6436 8677
cindy.ong@csiro.au
gisera.org.au