Methane Emissions from Two Oil & Gas Regions in Alberta: What the inventory says. What an airplane says.

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EERL Methane Symposium, Carleton University, Ottawa, Canada, Nov. 21, 2017

Carleton UNIVERSITY
Canada's Capital University

SCIENTIFIC AVIATION

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE

EDF ENVIRONMENTAL DEFENSE FUND
Finding the ways that work

Why Methane?

- Short-lived climate pollutant
  - Atmospheric lifetime: ~9.2 years
  - Much less than CO_2 (~1000+ years)
- Methane Global Warming Potential:
  - IPCC AR4 (2007):
    - 72 / 25 (20- / 100-year time horizon)
  - IPCC AR5 (2013)
    - 84 / 28
  - Current (2017)
    - 96 / 34 (*Gasser et al., Earth System Dynamics, 2017)*

2

Official Estimates of Canada's Methane

- ECCC National Inventory Report (NIR)
  - Emission factor estimates combined with industry-reported production data
  - Fully updated approximately every 5-years
  - Current data is being projected from 2011 baseline

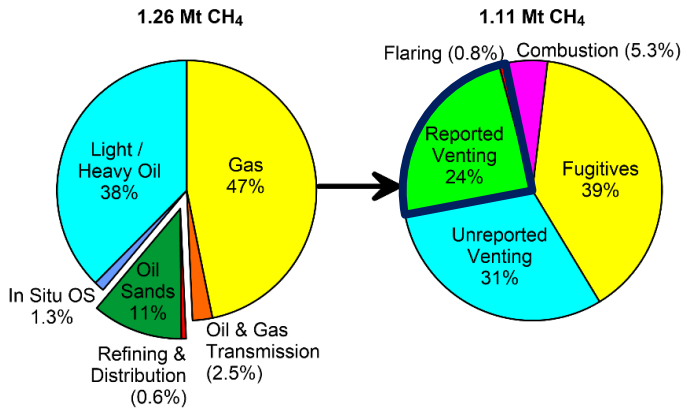
- National inventory methane estimates:
  - 44% of Canada's methane emitted by oil and gas sector
  - Oil and gas fugitive emissions are 42% of country total
    - Alberta: 29% of country total
    - Sask: 11% of country total

3

Commitments to Methane Regulation

- Federal Government / ECCC Regulations:
  - "Canada is committing to reduce methane emissions from the oil and gas sector by 40-45 percent below 2012 levels"
  - Final regulations anticipated in Spring 2018
- Alberta "Climate Leadership Plan"
  - "Methane emissions in Alberta will be reduced by 45% by 2025 under the Climate Leadership Plan"
  - Regulations being developed

2014 ECCC Methane Inventory Data for Alberta



- 88% of methane from "conventional" sources
- Only 1/4 is traced back to industry reported data

5

Top-Down / Bottom-up Analysis

Study Objectives:

I. Generate up-to-date, regional, bottom-up inventory estimates of Alberta UOG methane emissions
   - Follow approaches used in the ECCC NIR
   - Incorporate current well- and facility-level volumetric and activity data for 2016 as reported by industry to AER

II. Quantify regional methane emissions using airborne techniques in two distinct oil and gas producing regions

III. Directly compare these top-down and bottom-up methane emissions estimates.

6

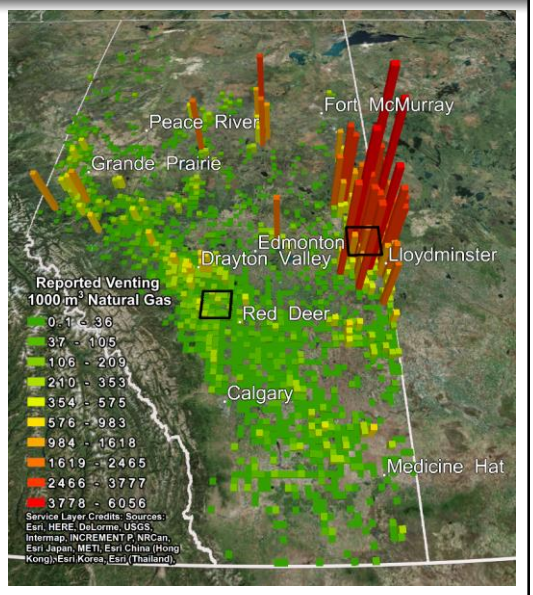
I. Inventory Development

- Industry-reported production accounting data
  - Up to date (2016) monthly from Petrinex reporting system
  - Reported flare, vent, and gas/oil production volumes
  - Additional Alberta monthly production data for 2002-2015
- Detailed activity data for individual wells
  - Current (Feb. 2017) version of AER general well file
- Well composition data
  - Individual well gas analyses containing 312,654 useable samples associated with 117,206 well segments (UWI)
- ECCC supporting data
  - As used by ECCC in creating projected inventories from 2011 data (most recent baseline year in NIR)

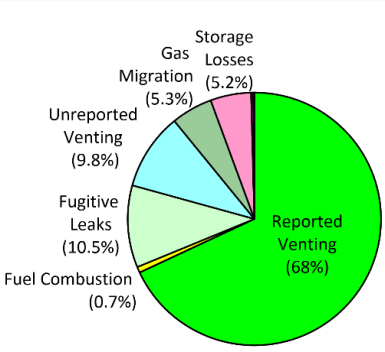
7

Reported Venting in Alberta in 2016

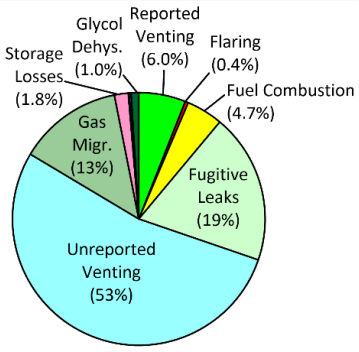
- 264 million m^3 of reported venting in 2016
- Lloydminster region dominates
  - Heavy oil production
- Additional hot spots east of Peace River and west of Grande Prairie



Inventory Expected Regional Distribution of Emissions



(a) Lloydminster Region

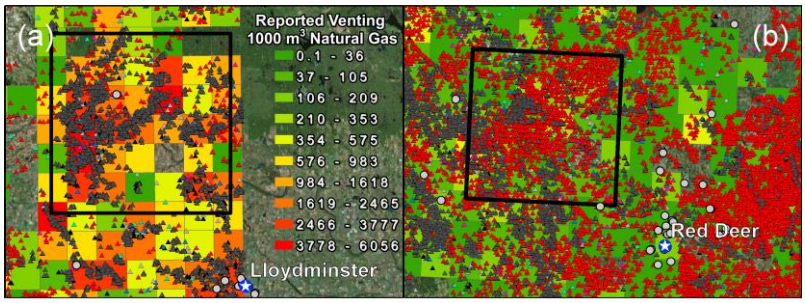


(b) Red Deer Region

- Significant differences in emissions profiles of different production regions

9

II. Measurement Region Selection



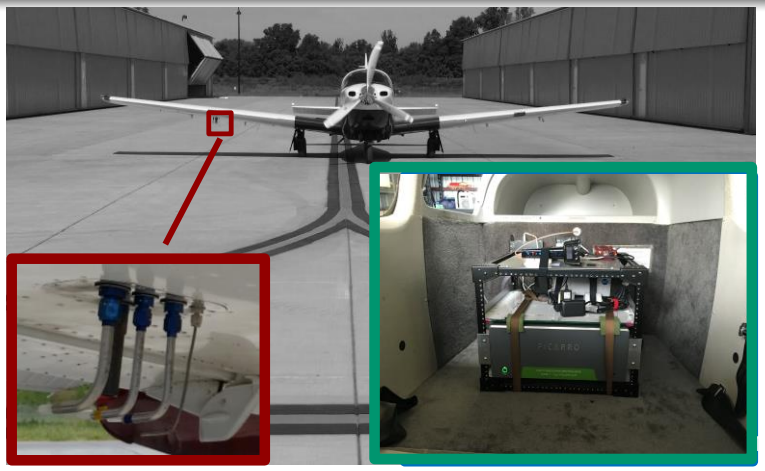
NPRI Facilities (Non-Oil and Gas) | Gas Battery | Gas Gathering System
Other Oil and Gas Facilities | Gas Well | Oil Battery
Compressor Station | Gas Plant | Oil Well

Measurement Region	Lloydminster	Red Deer
# of active wells in 2016	2631	2672
# gas wells / # oil wells / # oil CHOPS wells	*214 / 2350 / 2291*	*2053 / 613 / 0*
Total volume of gas produced [10^6 m^3]	467	3511
Total volume of oil produced [10^3 m^3]	3906	403
Vol. weighted mean CH_4 / C_2H_6 in produced gas	97.2% / 0.675%	82.1% / 7.65%

II. Airborne Measurements Oct. – Nov. 2016

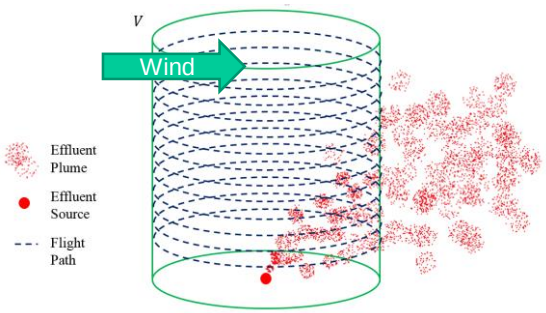
11

The Instrumented Aircraft



- Picarro Greenhouse gas analyzer
- Aerodyne Ethane TDL Analyzer
- Whole air samples (NOAA, UCI)
- Mooney Ovation & Mooney TLS
- Horizontal wind system
- Temperature & relative humidity

How are sources quantified from the air?



Principle of mass conservation:
Emission = Out - In

Start with mass continuity

$$Q_c = \langle \frac{\partial m}{\partial t} \rangle + \iiint \nabla \cdot \boldsymbol{F}_c dV$$

Use Gauss' theorem to replace volume integral with surface integral

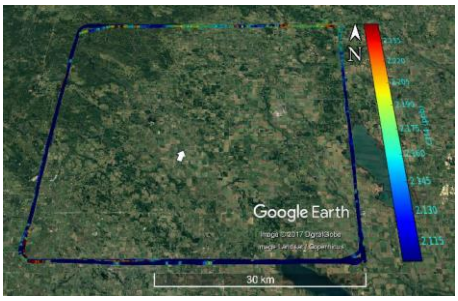
$$Q_c = \left\langle \frac{\partial m}{\partial t} \right\rangle + \oiint \boldsymbol{F_c} \cdot \hat{\boldsymbol{n}}\, dS$$

More details:

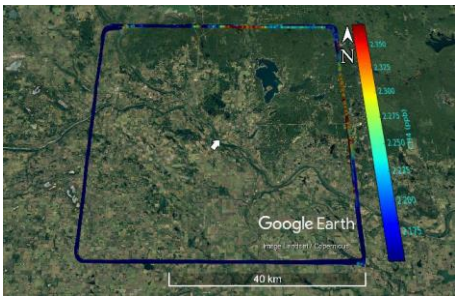
- Conley et al., *Atmos. Meas. Tech.,* 2017.
- Conley et al., *J. Atmos. Ocean. Technol.,* 2014.

Sample Flight Data

Red Deer, Nov. 2, 2016

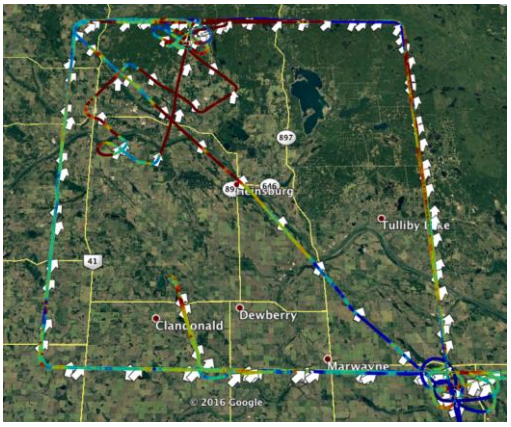


Lloydminster, Nov. 4, 2016

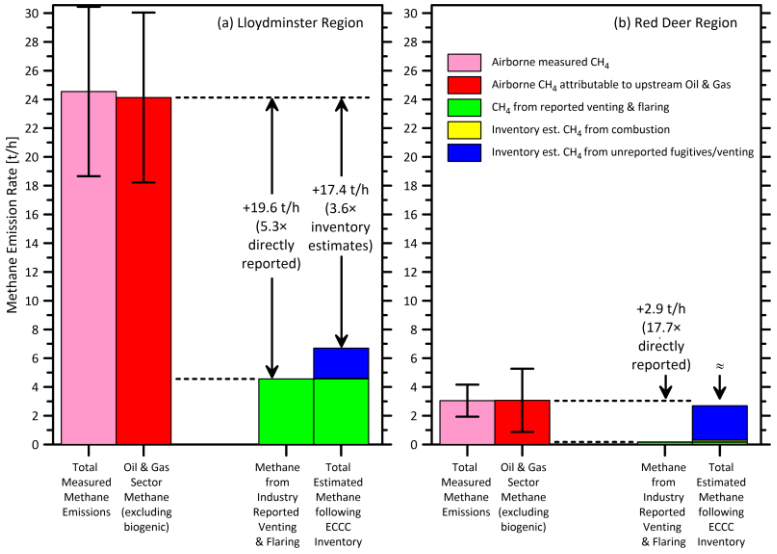


The Unpredictability of Field Work!

- Additional laps on November 5, 2017 interrupted by curious CF-18...

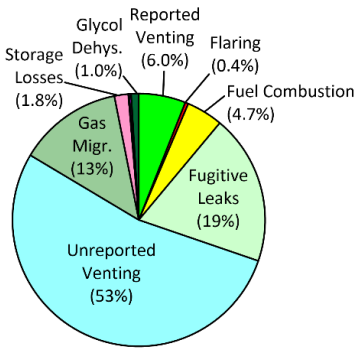


III. Top-Down vs. Bottom-up Comparison



Implications

- Current reporting requirements capture much less than one-quarter of emitted methane
- Regional variations can be quite significant
- In regions like Red Deer:
  - Unreported emissions account for 94% of total released methane
  - ***Majority of reductions must come from sources not yet identified and/or not being measured***
    - >70% likely from unreported venting and fugitive leaks

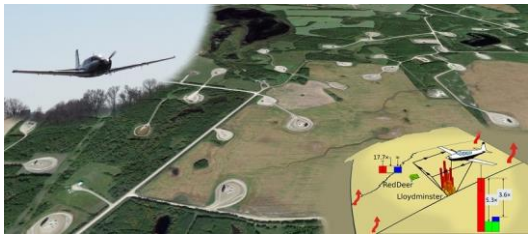


(b) Red Deer Region

17

Implications

- Measured methane 3−5× greater than both reported and inventory estimates in the Lloydminster
  - Contrasts with Red Deer region, where combined reported and unreported emissions matched airborne measurements
  - Suggests unexplained emissions in Lloydminster are attributable to unique operating practices in that area
    - Underreported venting of casing gas from CHOPS sites



18

Implications

- Extended to other CHOPS production sites in Alberta *while leaving current inventory estimates for all other types of facilities unchanged*:
  - Reported venting in Alberta is likely low by a factor of ~2.5 (range 2.0–3.1).
  - Suggests actual methane emissions from the conventional oil and gas sector at least 25–50% greater than estimated
- 45% cut in the current inventory methane emissions totals implies a decrease of ~500 $ktCH_4/y$.
  - **Present results suggest 924 $ktCH_4/y$ reduction is actually required to reach the same absolute emissions target**

19

Acknowledgements

NSERC CRSNG

Natural Resources Canada

EDF ENVIRONMENTAL DEFENSE FUND

Carleton UNIVERSITY
Energy & Emissions Research Lab

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Journal Article: Johnson et al., *Environmental Science & Technology*, 2017 (doi: 10.1021/acs.est.7b03525).