The winter of our oil & gas emissions, made glorious by measurements

Seasonality oil & gas emissions?
Uncertainties in methane emissions
Method to quantify: tracers flux ratio
Tracers to identify emissions or air mass
Mobile lab in Western US Wintertime Study
Seasonal Natural Gas Use

Natural gas deliveries to customers by end use, Jan 2010 - Jun 2015

Source: U.S. Energy Information Administration, Natural Gas Monthly
Note: Does not include natural gas as a vehicle fuel.

= 29 million kg hr\(^{-1}\)

Anecdote: unattended production at sites with additional treatment (e.g. ‘wet’ gas) fare poorly in cold weather
Utah Wells

Site Level (bottom-up) vs Basin Scale (top-down)
Component scale vs Flight Mass Balance
Actual Site scale* vs Emission Inventory
Activity Factors $\Phi$ Emission Intensities

*multi-tracer flux ratio

Pneumatic valves, liquids unloading, condensate tank top emissions

ozone precursor emissions
Aerodyne Mobile Laboratory (AML)

Instrument subset
- CH₄, C₂H₆, N₂O, HCN, C₂H₂, CO₂, O₃, CO, HCHO
- Vocus
- HR-AMS

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Industrial Emissions Characterization

Method to quantify: tracers flux ratio

\[
\text{Emission CH}_4 = \left( \frac{\text{downwind CH}_4}{\text{tracer}} \right) \times \text{Emission tracer}
\]

Want to know known

Measured in transects

Lamb et al, 1995; Czepiel et al, 1996, 2003; Börjesson et al, 2009; Mønster et al., 2014; Roscioli et al., 2015; Yacovitch et al., 2017;
Method to quantify: tracers flux ratio

Methane Emission Rate

\[ F(\text{CH}_4) = \frac{\text{CH}_4}{\text{C}_2\text{H}_2} \times F(\text{C}_2\text{H}_2) \]

\[ F(\text{CH}_4) = 7.2 \times F(\text{C}_2\text{H}_2) \]

“dry gas” region
Texas
September 2019
Site ID 59

The dominant source at this site is the north well (with an unusual sounding pneumatic). The second well is emitting much less. The tanks are also emitting, with aromatics.

Tracer at Well N

With unusual sound

Tracer at Tank
Emission intensity linked to on-site activity

Activity Factors $\Phi$ Emission Intensities

$C_2H_6$ (kg hr$^{-1}$)

$CH_4$ (kg hr$^{-1}$)

on site compressor blowdown

Additional staged release $+1.07$ kg hr$^{-1}$

Site normal $1.0$ kg hr$^{-1}$

UTC, Site 003

4/25/18
Like the deliberate ‘tracers’ the chemical dimension brought by other measurements enhances CO₂, CH₄, N₂O measurements.

Inspired by -> Observed iso- and n-pentane mixing ratios at various sites in Colorado and two cities (Houston, TX and Pasadena, CA). [Gilman et al., 2013]
Example of urban source attribution: Boston manhole CH$_4$ and C$_2$H$_6$ concentrations

- Ethane content provides information about the sources (biogenic vs NG) in urban settings
- Manholes with high CH$_4$ are dominated by natural gas, not biogenic “sewer” gas
Like the deliberate ‘tracers’ the chemical dimension brought by other measurements enhances CO₂, CH₄, N₂O measurements.
Mobile ground measurements resolve substantial changes in atmospheric composition

Relevant to wintertime vertical gradients in SLC
Using topography to advantage

Mobile Lab can measure within an urban boundary layer and quantify the residual layers above by using topography.

DOE/NSF Milagro 2006
In addition to on road travel at different altitudes, mobile measurement will be coupled to drone-based transect to explore vertical gradient when road access is unavailable.
Identifying and Apportioning Ozone Producing Volatile Organic Compounds in Central Texas

Aerodyne Research, Inc.
Drexel University
Montana State University
Environment Canada
University of Texas (Austin/San Antonio)
University of Houston
Baylor University

AQRP
May 2017
Seasonality oil & gas emissions?
Yes and no

Uncertainties in methane emissions
on-site activity factors & emissions with research endeavor can match top-down

Method to quantify: tracers flux ratio
on-site/whole-site can be quantified

Tracers to identify emissions or air mass
chemical signatures are inherent ‘tracers’

Mobile lab in Western US Wintertime Study
AML could be used to look at spatial and vertical composition gradients
AML Schematic, 2019

Dual TILDAS
Tunable Infrared Direct Absorption Spectrometer
NO, NO₂

Mini TILDAS
HCHO, H₂O

Mini TILDAS
CO, N₂O, H₂O

Mini TILDAS
CH₄, C₂H₆

CO₂
Licor N.D. IR

CO₂
Licor N.D. IR

O₃
UV Absorption

ARISense
PM₂.₅, PM₁₀, CO, NO, NO₂, etc.

GPS

Wind

Power and Volume
(optional, see me)

PTR-MS
Proton-Transfer Mass Spec.
H₂S, HCN, aromatics, other VOCs

VOCUS
Aromatics (BTEX), acetone, methyl & ethyl mercaptans, other VOCs

Live Display

RH, Press. Temp.
Industrial Emissions Characterization

South Coast Air Quality Management District
March 2018

Los Angeles, CA
FIREX – August, 2018 Field Deployment, Idaho & Washington

Twisp
AML ground track
Cougar
450 mi.
350 mi.
Rattlesnake
50 mi.
Rabbit Foot
200 mi.
Missoula
McCall
Boise
Base at Activity Barn
Lon. -> -120 -119 -118
Lat. -> 48 47 46 45 44
Tracer Flux Ratio quantifies CH$_4$ through correlation with tracer

Emission CH$_4$ = (downwind CH$_4$ / tracer) * Emission tracer

Want to know

Measured in transects

Lamb et al, 1995;
Czepiel et al., 1996, 2003;
Börjesson et al, 2009;
Mønster et al., 2014;
Roscioli et al., 2015

Early, this work employed one tracer, N$_2$O we took single cylinder of aux. tracer C$_2$H$_2$
Correlated Methane and Nitrous Oxide Plumes

- CH₄
- C₂H₆
- N₂O

Map with transect

NAL 102 MEDR 2-19-39-3 Production Site 52.36506916, -114.417315