6-6-2014

SLIDES: What We Know (and Don't Know) About Air Quality Impacts of Oil and Gas Development

Anna Karion

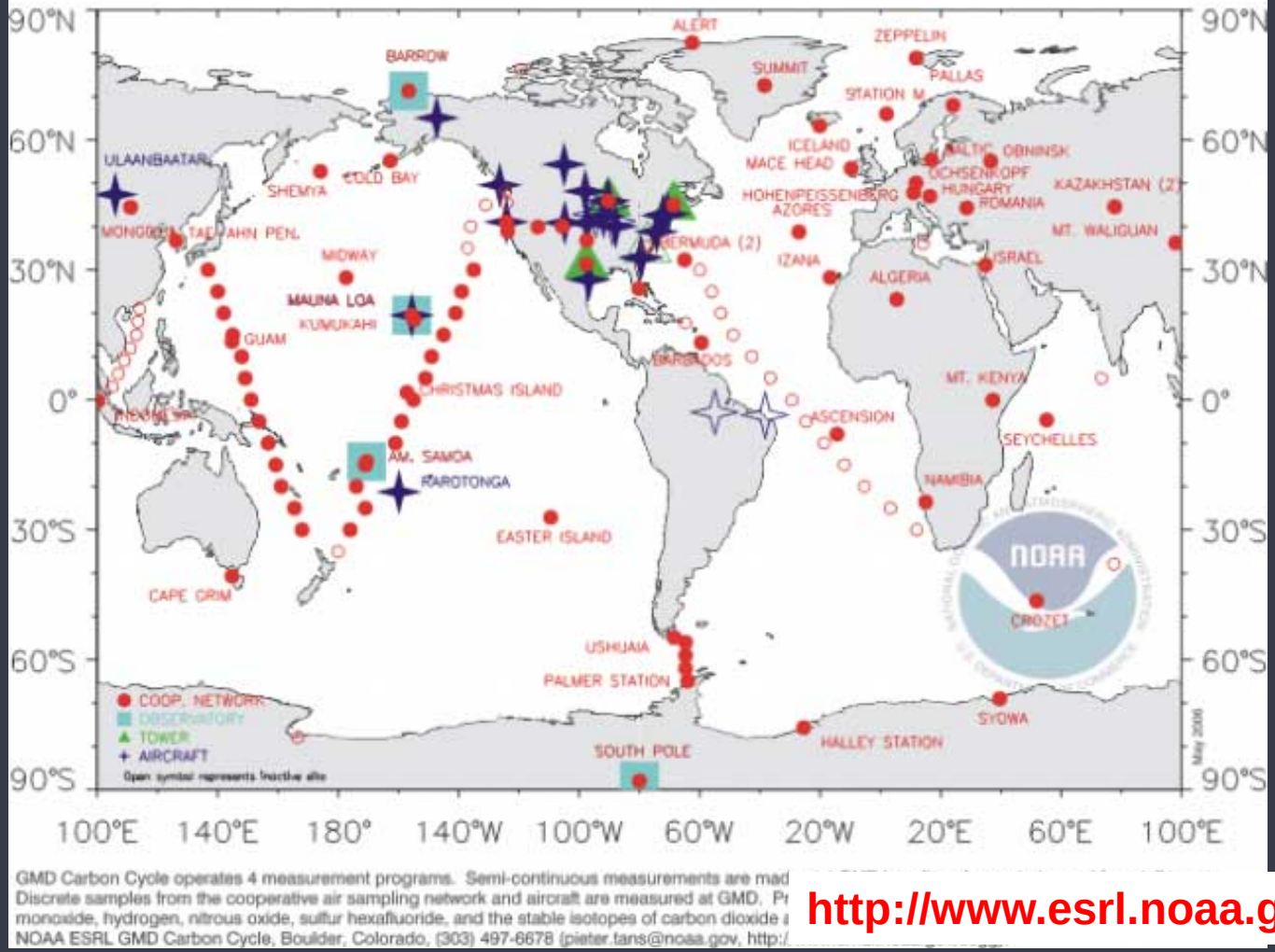
What we know (and don't know) about air quality impacts of oil and gas development

Anna Karion
NOAA/ESRL
University of Colorado/CIRES

Photo: Uinta Basin, UT credit: David Oonk, CIRES

NOAA Cooperative Global Air Sampling Network - Greenhouse Gases

http://www.esrl.noaa.gov/gmd/ccgg/flask.html



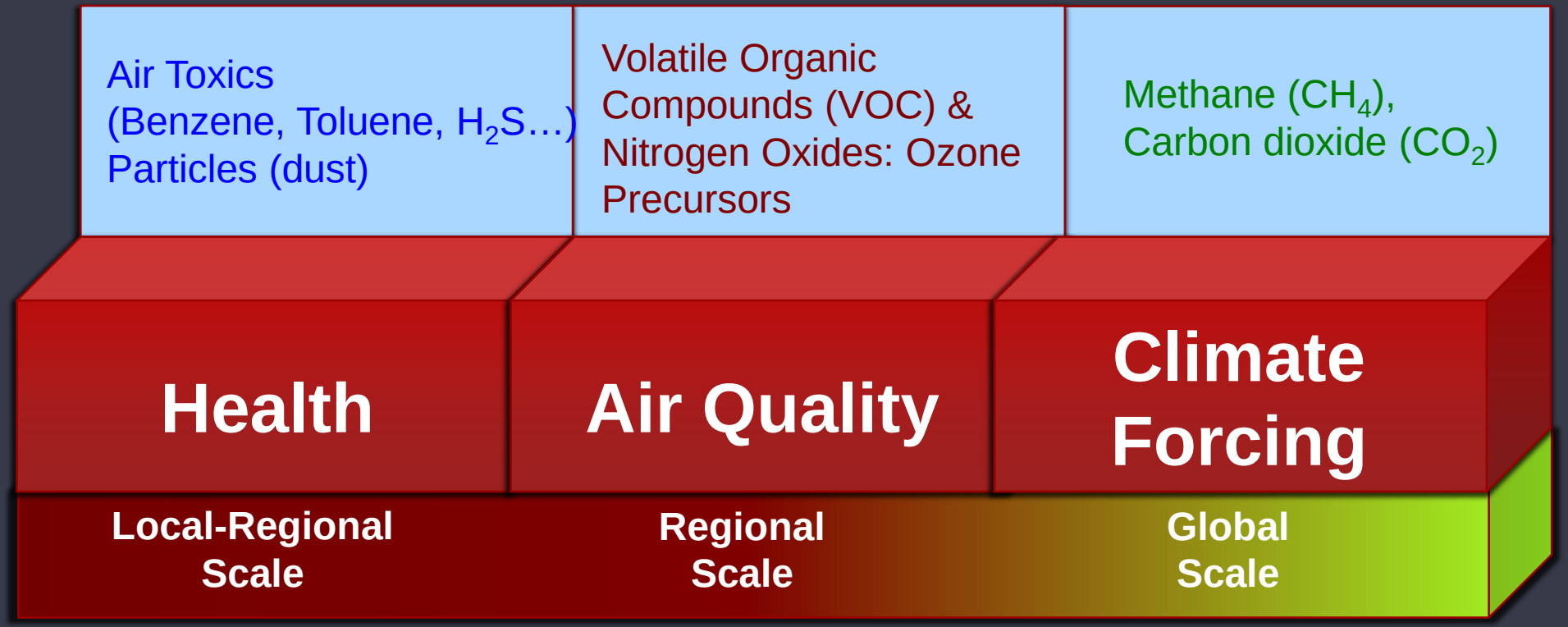
GMD Carbon Cycle operates 4 measurement programs. Semi-continuous measurements are mad
Discrete samples from the cooperative air sampling network and aircraft are measured at GMD. Pr
monoxide, hydrogen, nitrous oxide, sulfur hexafluoride, and the stable isotopes of carbon dioxide
NOAA ESRL GMD Carbon Cycle, Boulder, Colorado, (303) 497-6678 (pieter.tans@noaa.gov, http:/

GHGs (including methane) are measured in weekly air samples collected around the globe.

Data is free and available online at:

http://www.esrl.noaa.gov/gmd/dv/data/

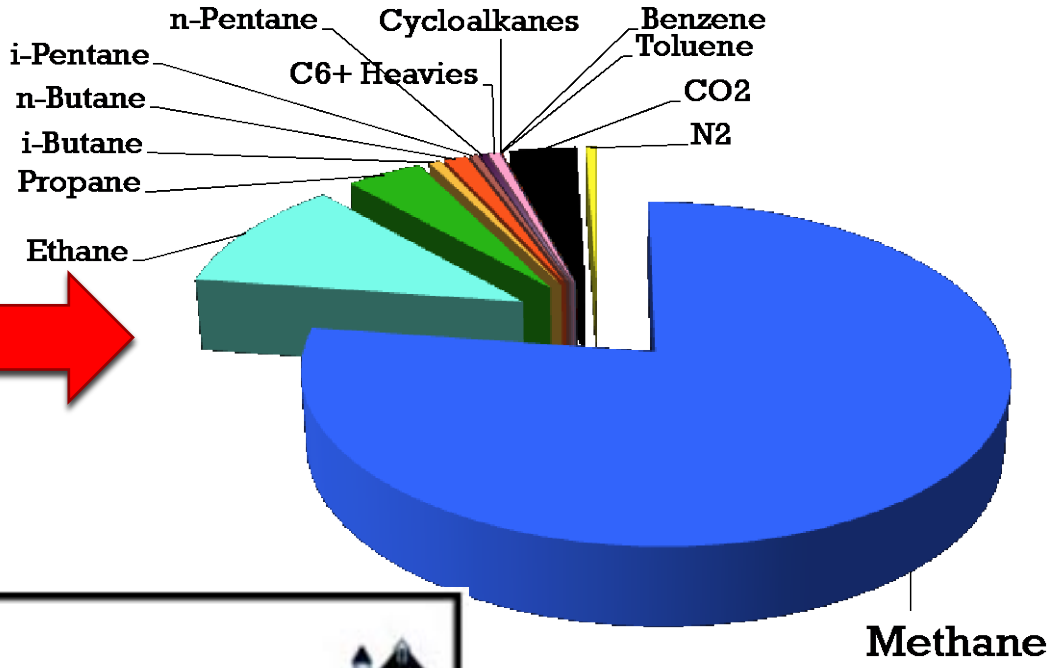
Potential Air Impacts of Unconventional Oil and Gas Development

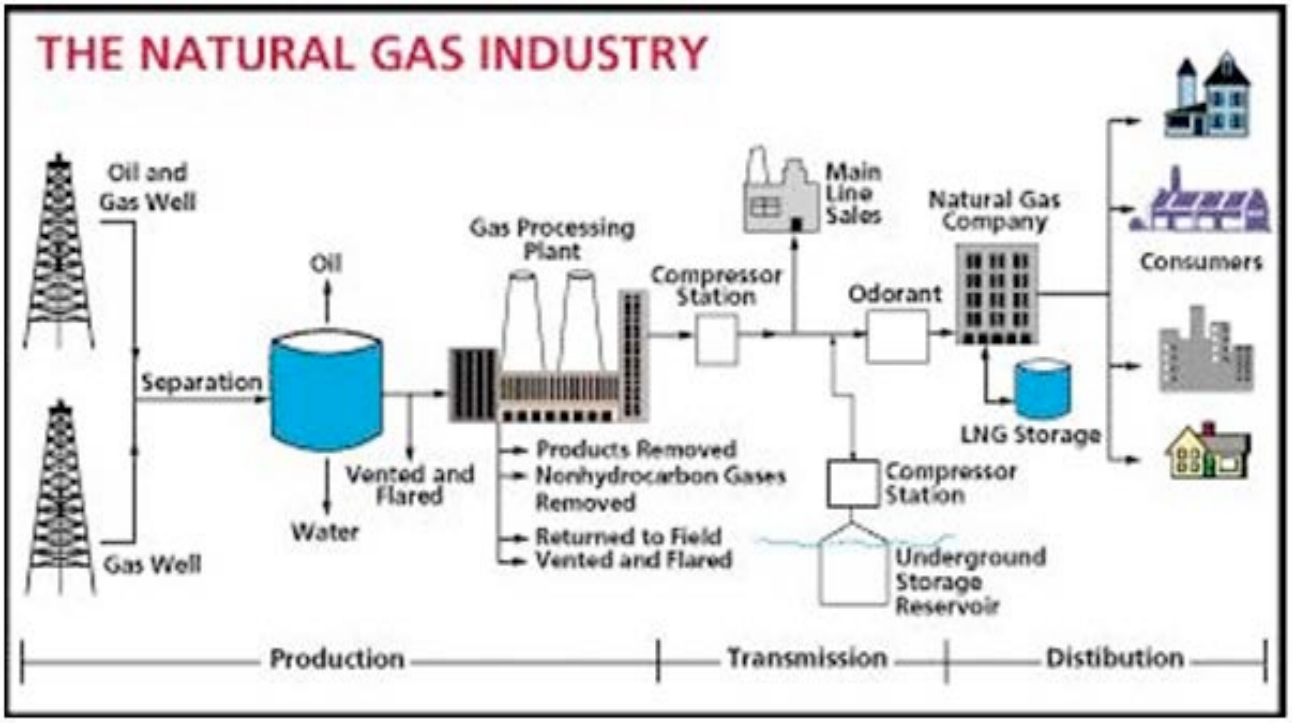


Slide credit: G. Pétron

Slide credit: G. Pétron

Raw gas is composed of 70-90% methane



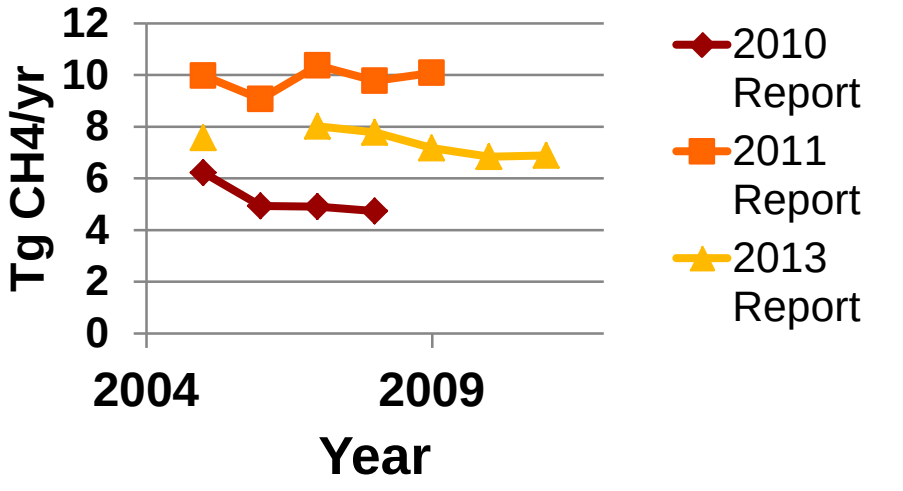


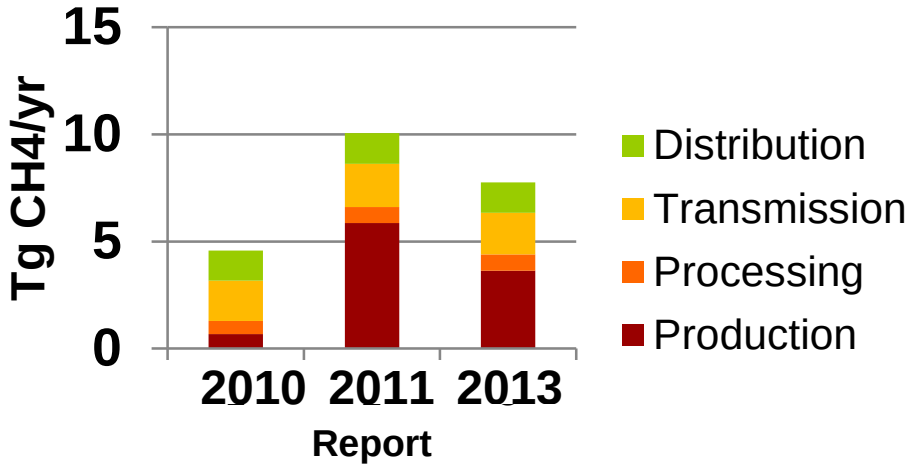
eia.gov

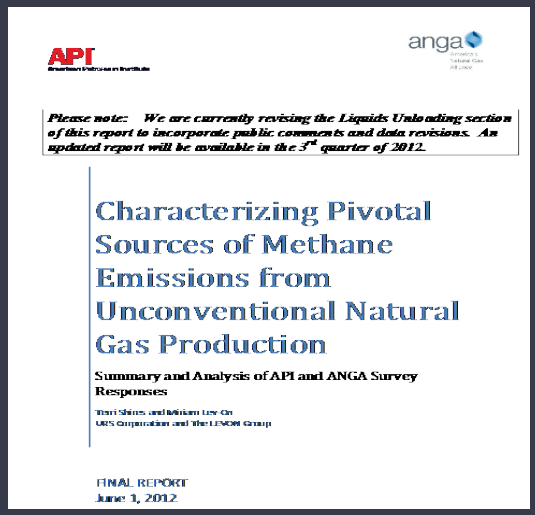
Distribution gas is >90% methane

So what are the CH_4 emissions from natural gas?

EPA Inventory of GHG Sources and Sinks







API

anga

Please note: We are currently revising the Liquids Unloading section of this report to incorporate public comments and data revisions. An updated report will be available in the 3rd quarter of 2012.

Characterizing Pivotal Sources of Methane Emissions from Unconventional Natural Gas Production

Summary and Analysis of API and ANGA Survey Responses

FINAL REPORT
June 1, 2012

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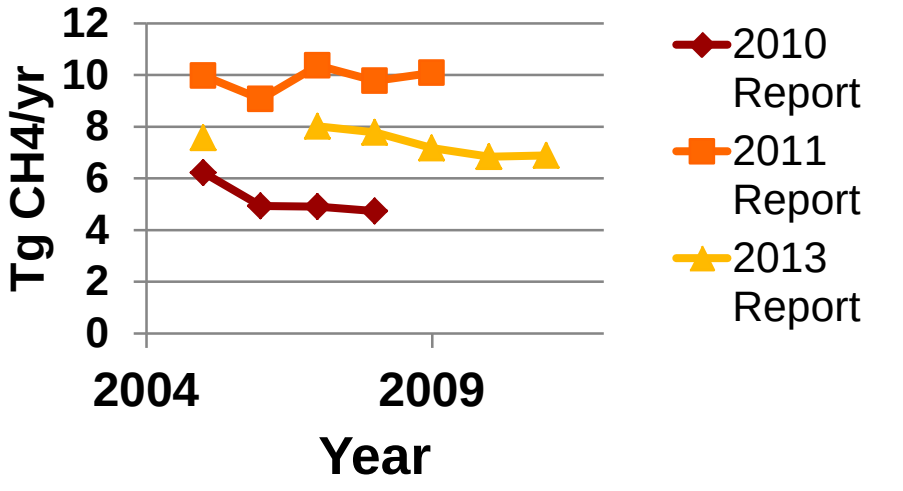

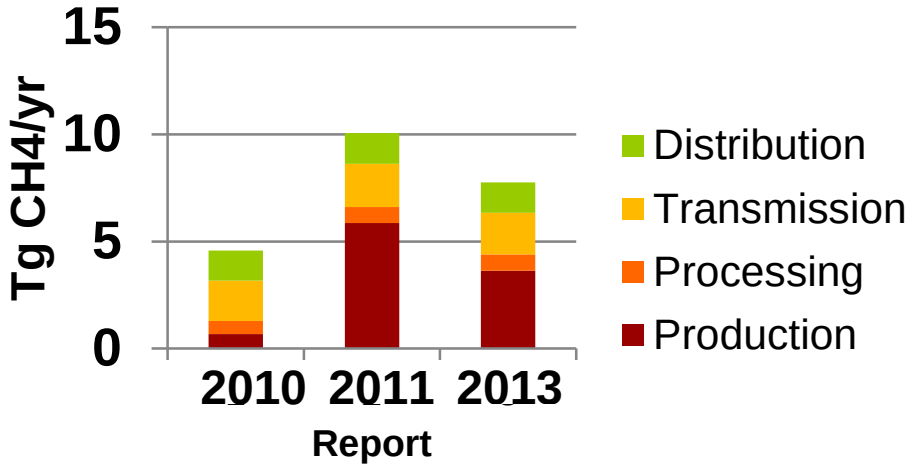

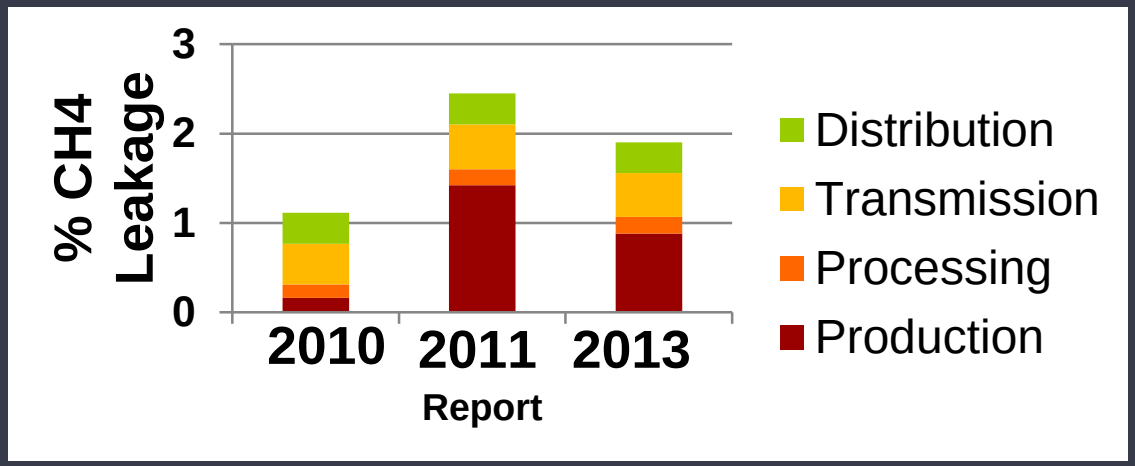

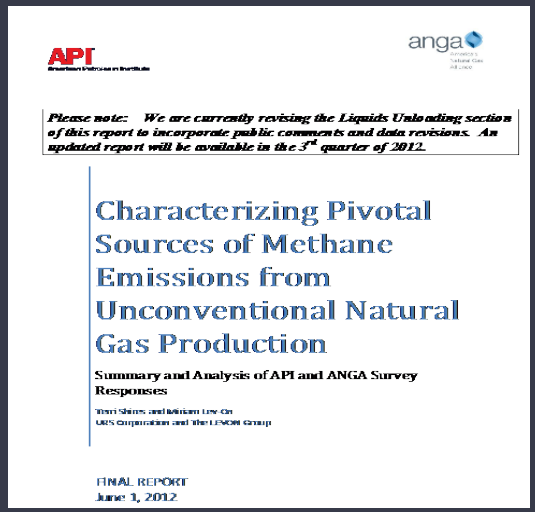
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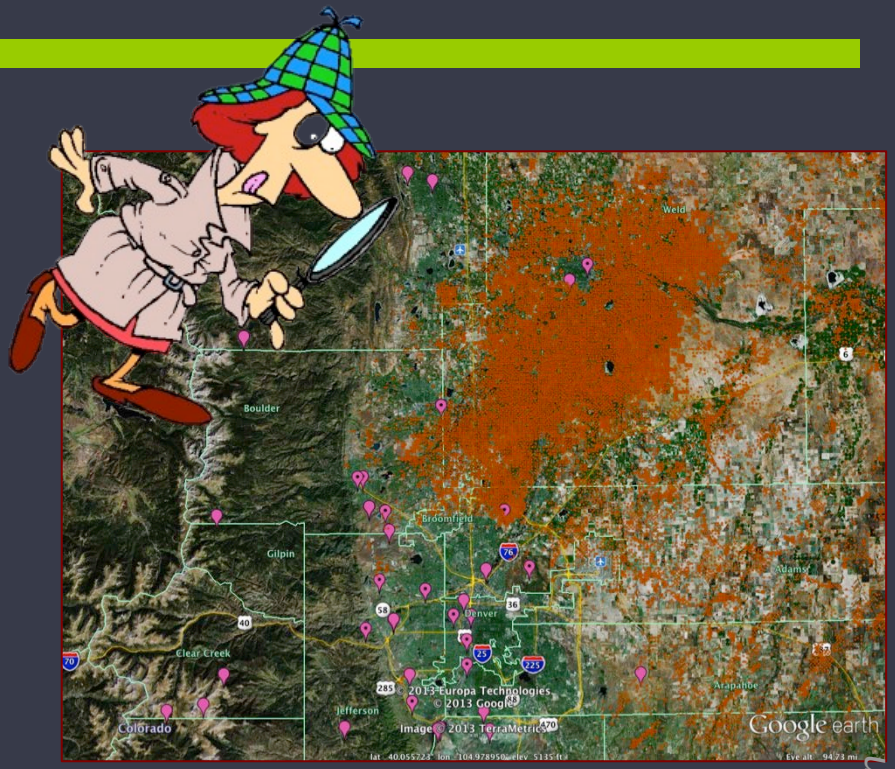
How can one assess atmospheric impacts of an industry?

Well completion
Well workover
Liquid unloading
Well normal fugitives
Separators
Dehydrators
Pneumatic Devices
Tank vents
Meters
Compressors
...



Inventory approach

estimates emissions for various types of operations or equipment using activity data and emission factors

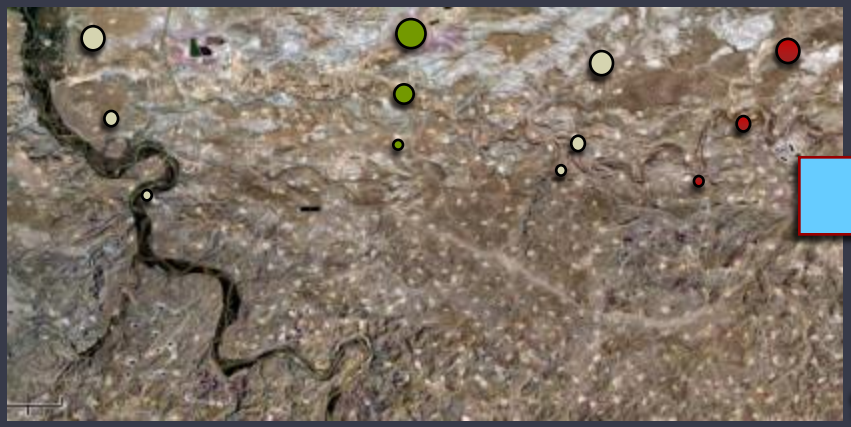
Atmospheric evidence-based approach

estimates emissions at various scales using atmospheric measurements

Slide: Gabrielle Pétron

Can we detect emissions in the atmosphere?

surface emissions

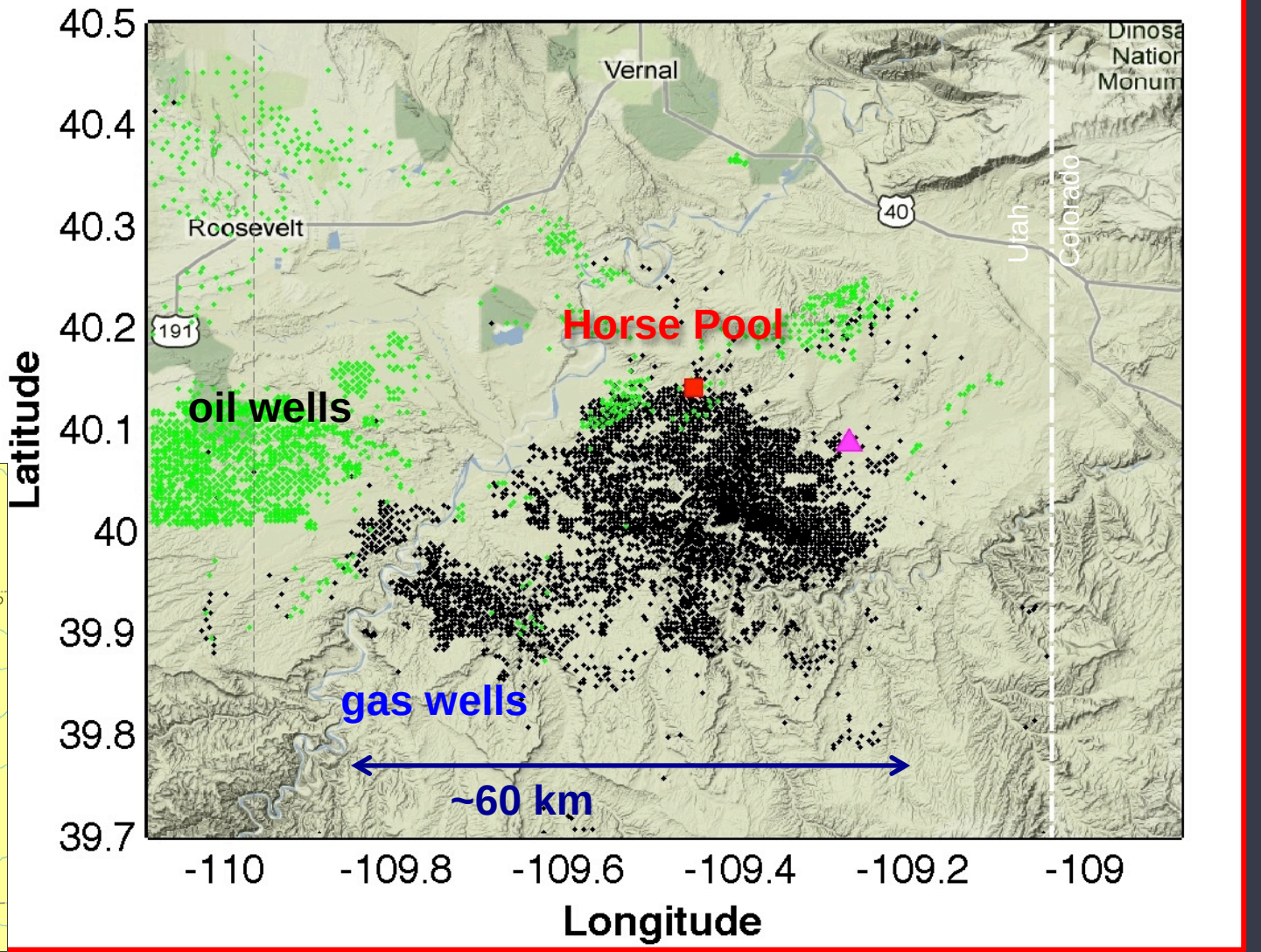


wind

Concentrations of pollutants measured by tower, instrumented van, or aircraft downwind of the area source reflect emissions from oil and gas production operations

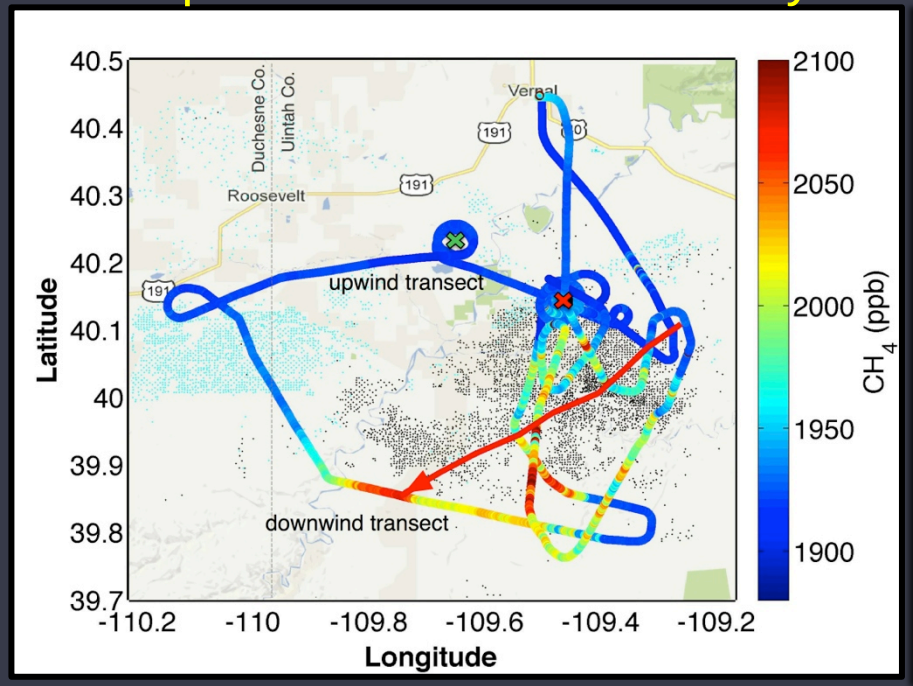
Slide: Gabrielle Pétron

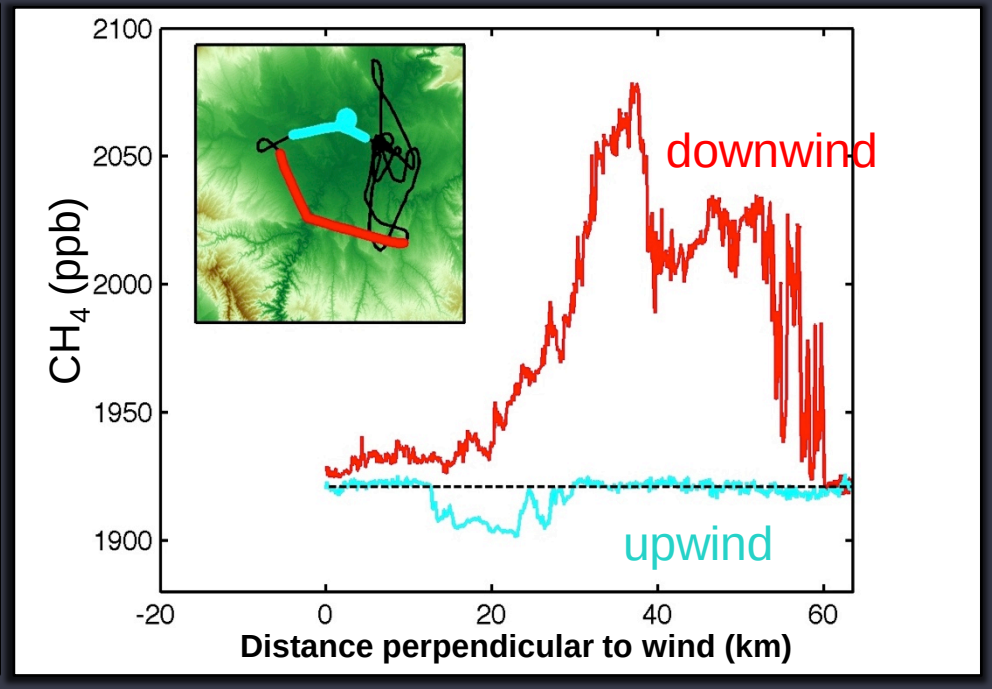
Uinta Basin, Utah



Utah, 2012

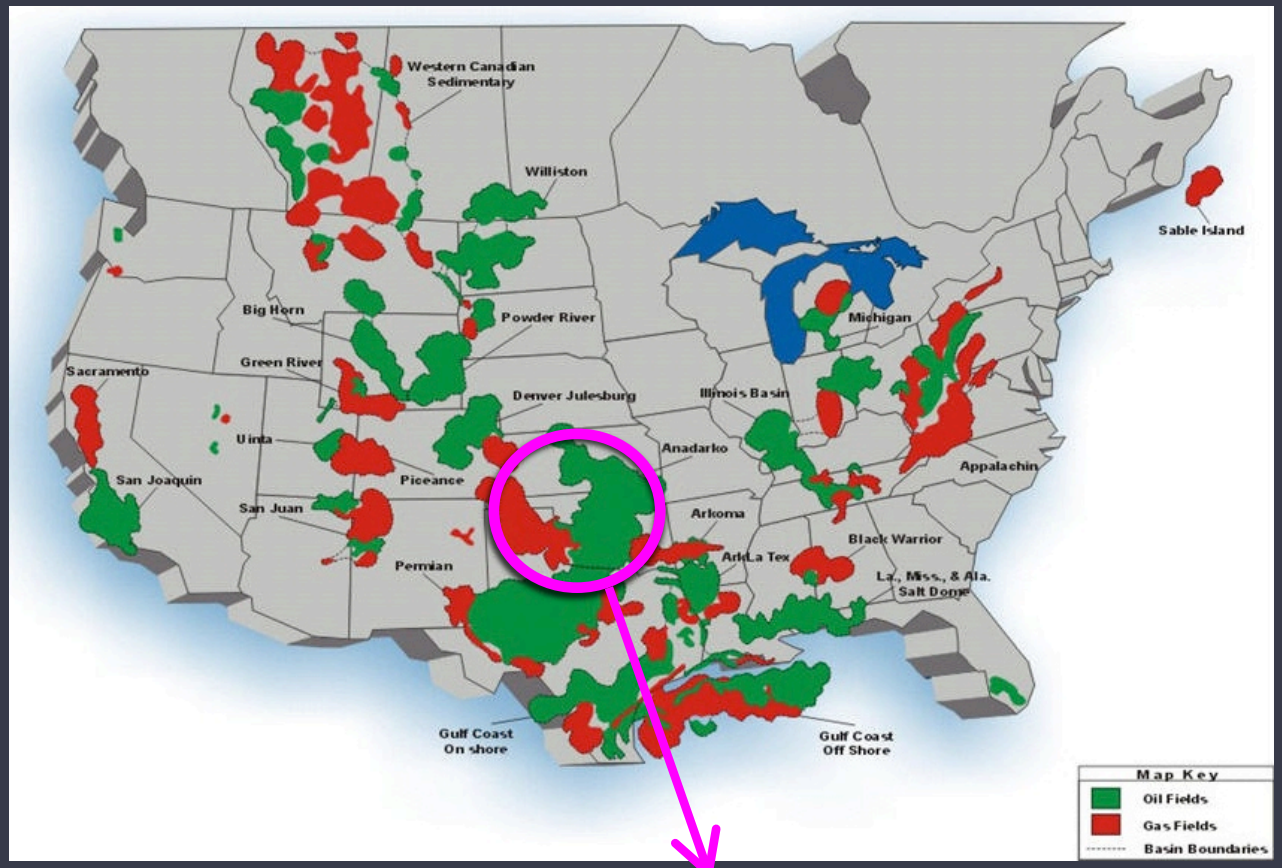
High emissions (6-12% leak rate of NG), but this field only represents ~1% of US production. Best inventory: ~5%.





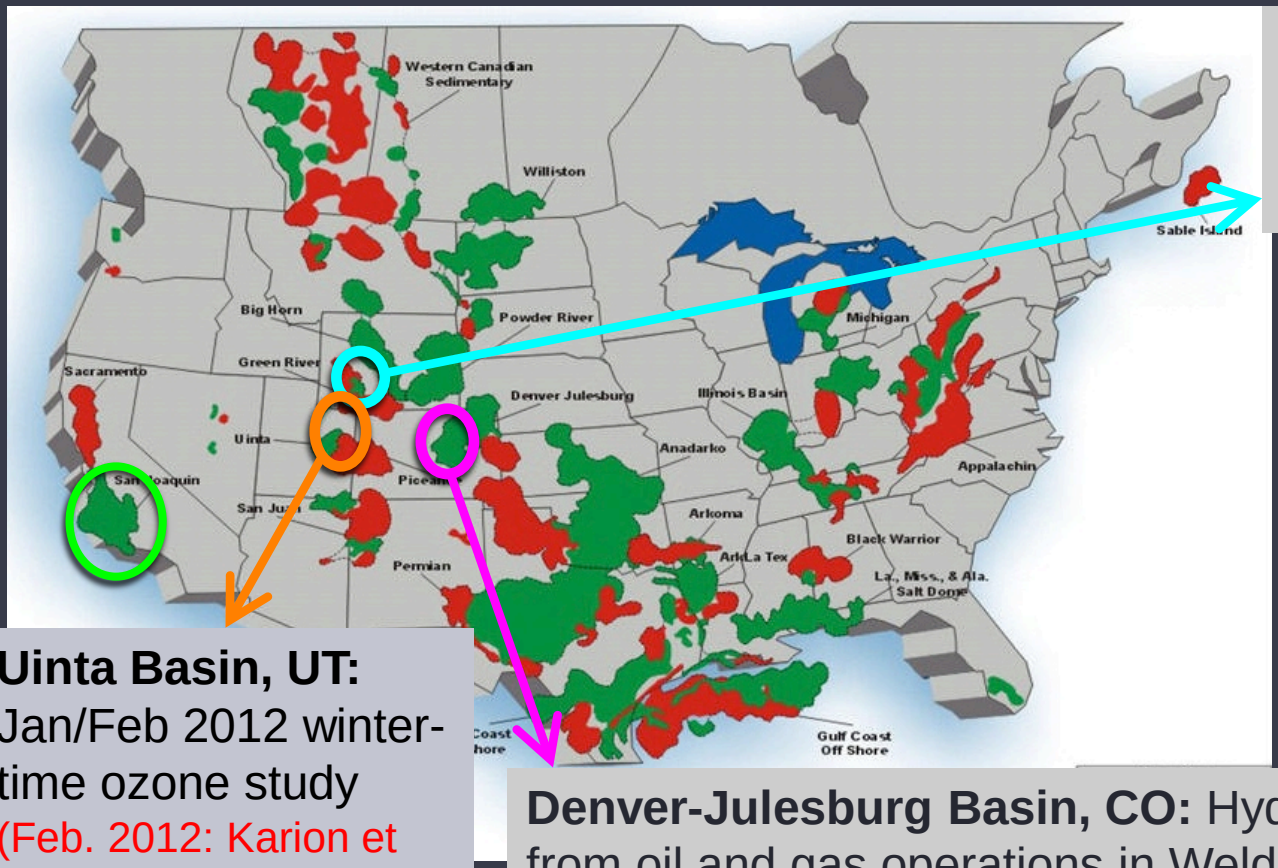
Karion, A., C. Sweeney, et al. (2013). Methane emissions estimate from airborne measurements over a western United States natural gas field. Geophysical Research Letters.

What we know



Katzenstein et al., PNAS 2003
Miller et al., PNAS 2013

What we know



Green River Basin, WY: high winter time surface ozone in natural gas field (Schnell et al., 2009)

Uinta Basin, UT: Jan/Feb 2012 winter-time ozone study (Feb. 2012: Karion et al., 2013.)
- Feb. 2013 (Oltmans et al., in prep.)

Denver-Julesburg Basin, CO: Hydrocarbon emissions from oil and gas operations in Weld County (Pétron et al., 2012; Gilman et al., 2013; Pétron et al., 2014)

What we know

Marcellus Shale, PA

[NOAA: Peischl, in prep.]

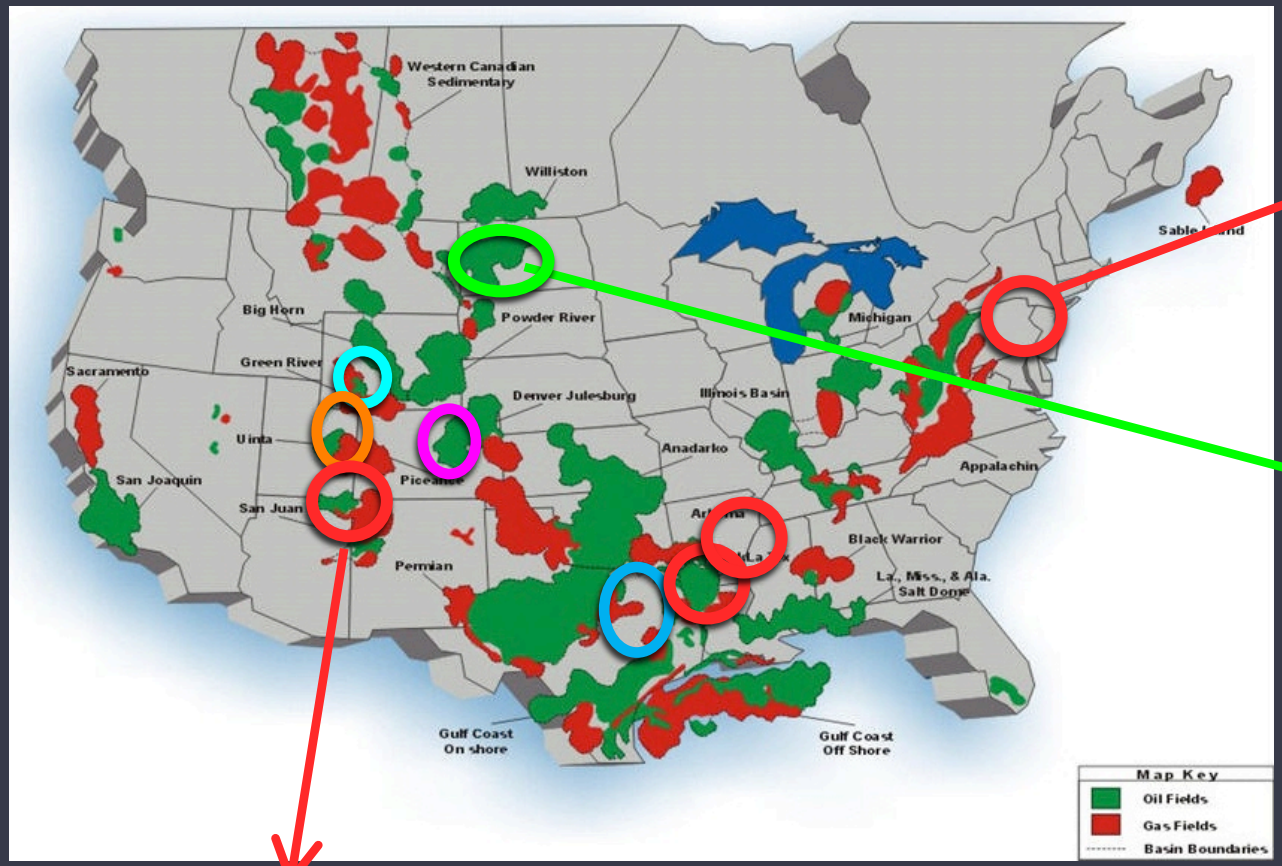
Haynesville Shale (LA/TX) & Fayetteville Shale (AR)

[NOAA: Peischl, in prep.]

Barnett Shale, TX: Third largest shale gas field in the US.

[Zavala-Araiza et al, 2014; Karion et al, in prep.]

Upcoming work



Marcellus Shale, PA

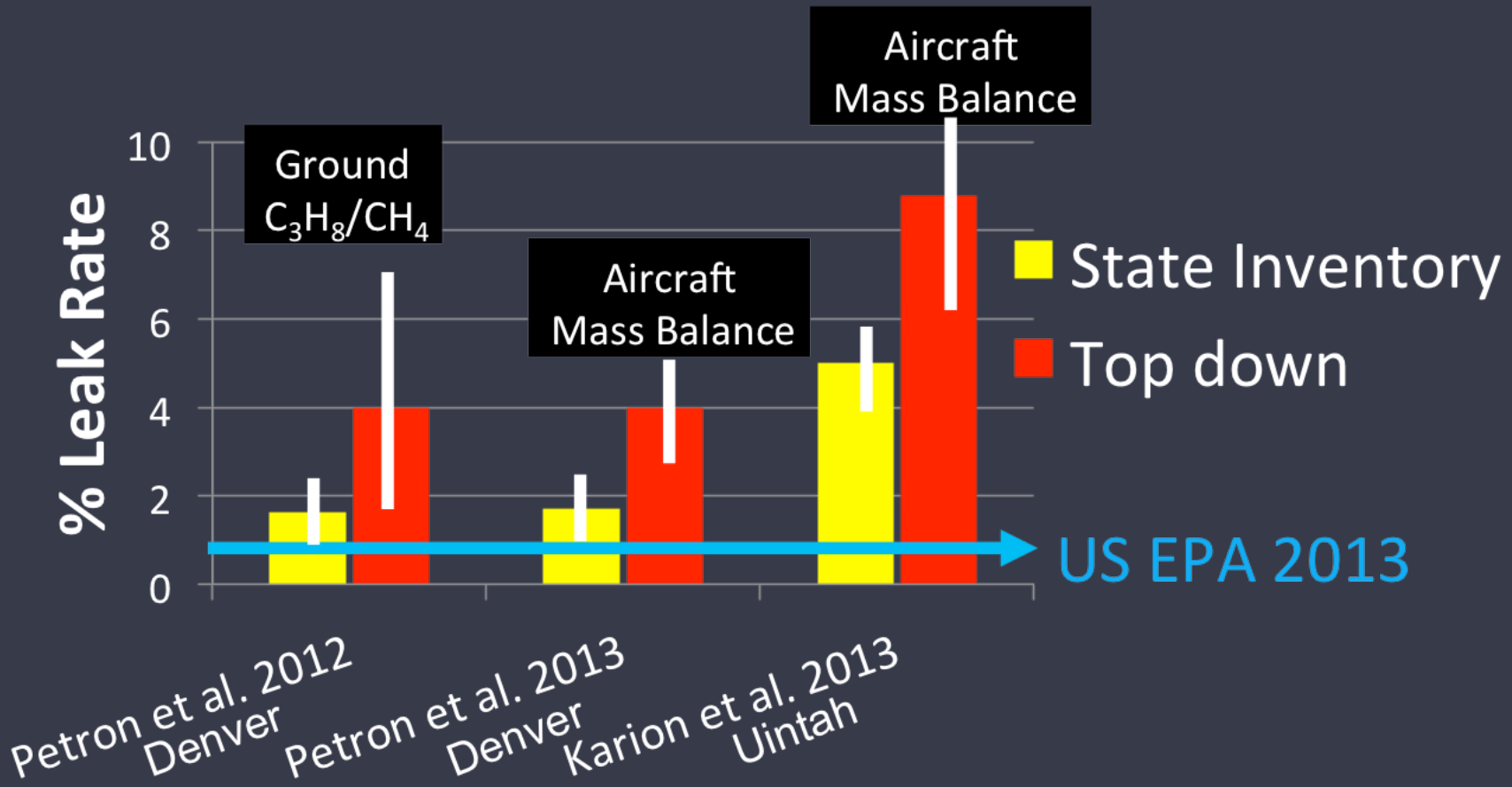
[DOE Penn State]

Bakken, ND

[NOAA]

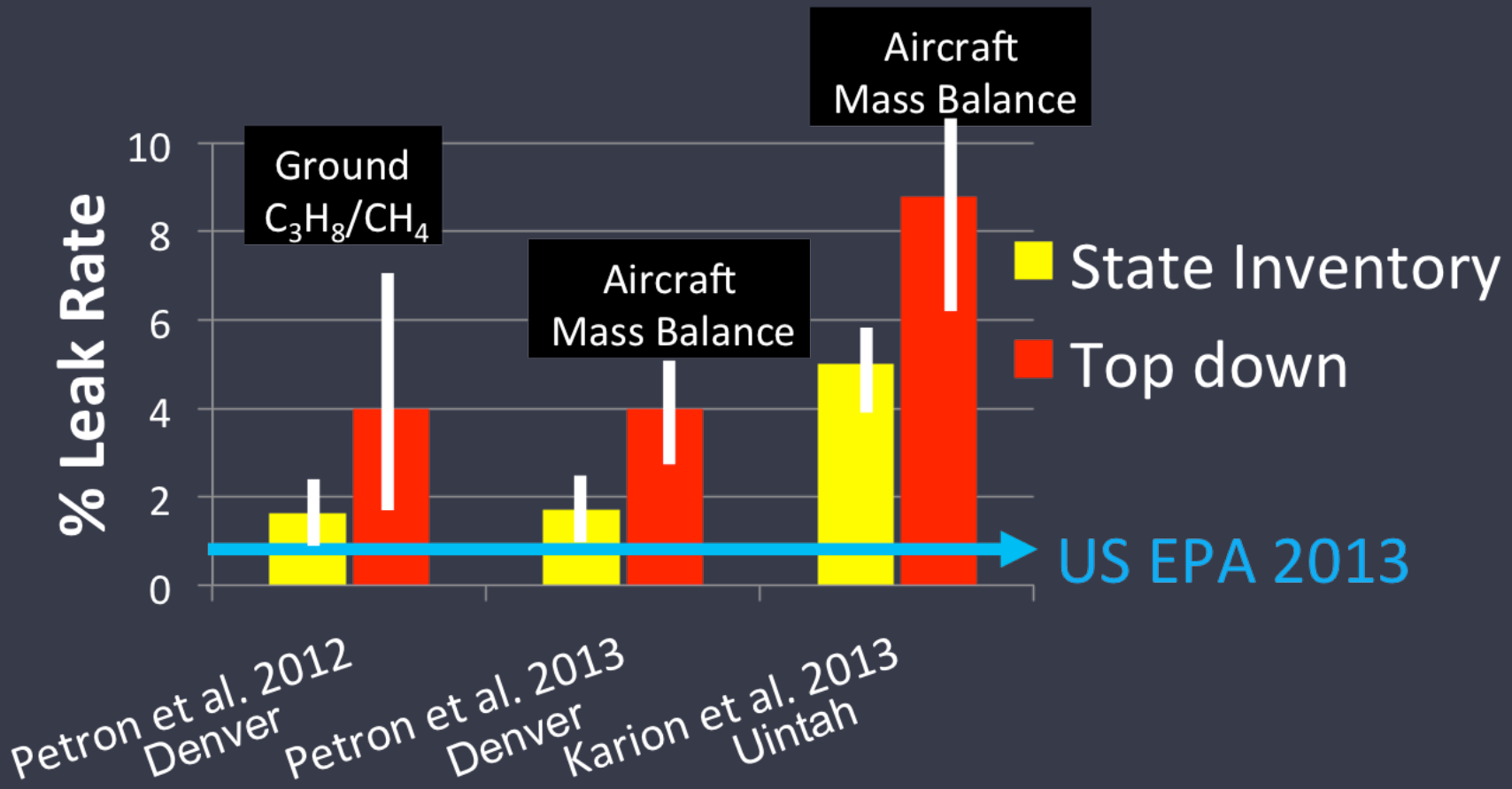
San Juan Basin, CO/NM

[NOAA]

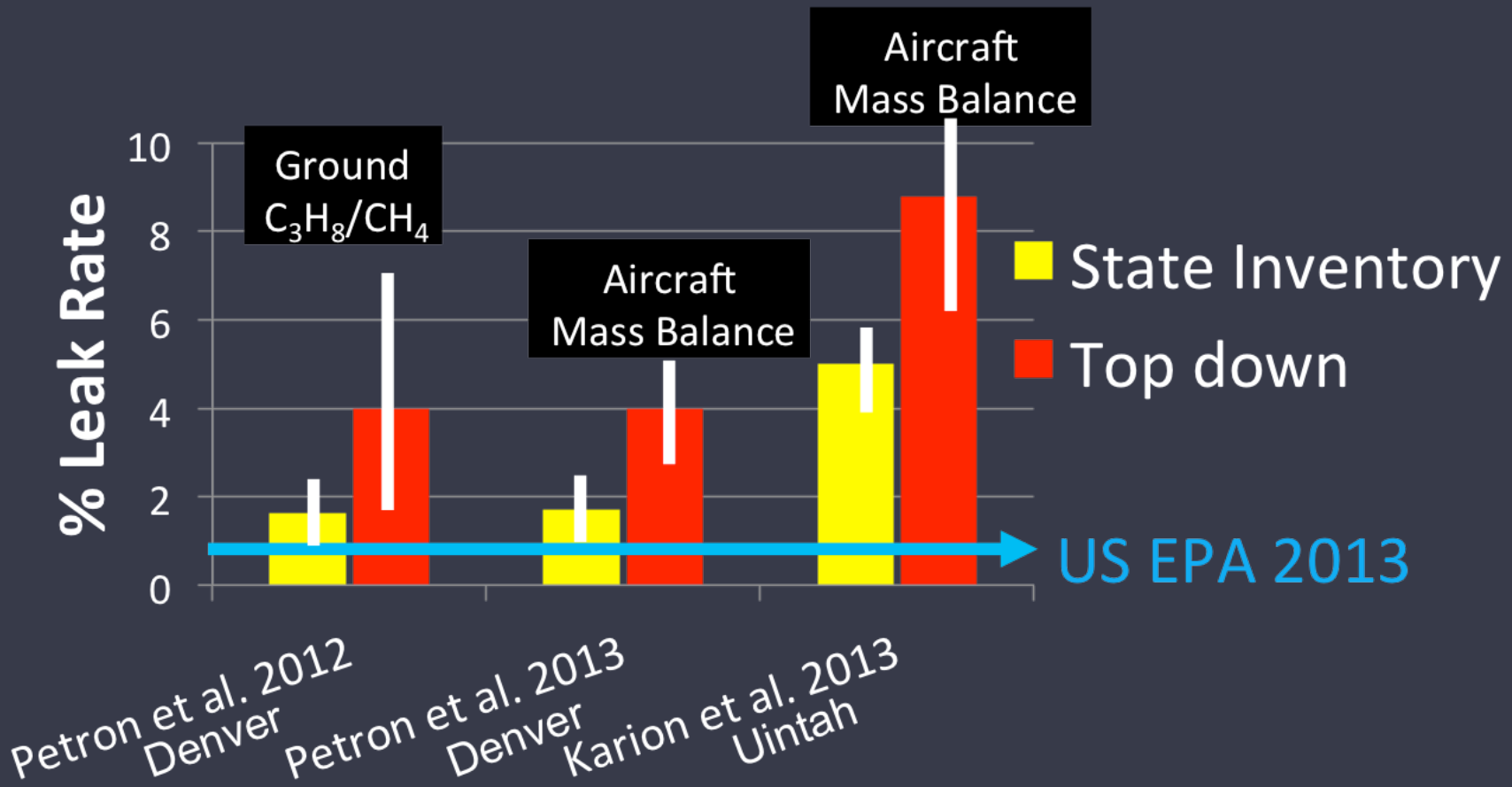


Brandt et al., 2014: Emissions estimates from atmospheric measurements generally exceed inventories by ~50%.

Allen et al., 2013: On-site measurements show leakage similar to EPA estimates.



But… many production regions have not yet been sampled.
(i.e. what we don't know!)

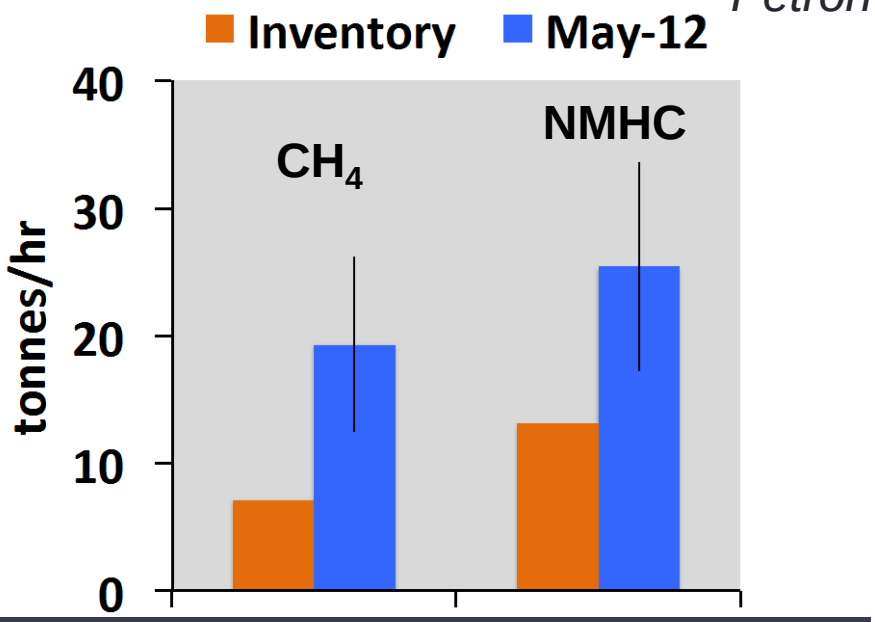


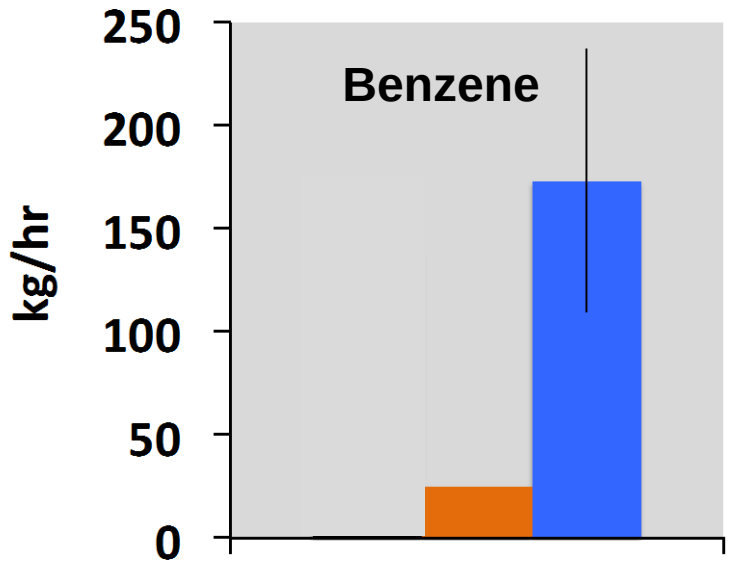
What are inventories missing? (what we don't know)

- Processes that emit that are not accounted for (e.g. Caulton et al., 2014)
- Long-tailed emissions distribution (a few sources causing the majority of leaks).

Air Toxics and Methane in Colorado

Pétron et al., 2014



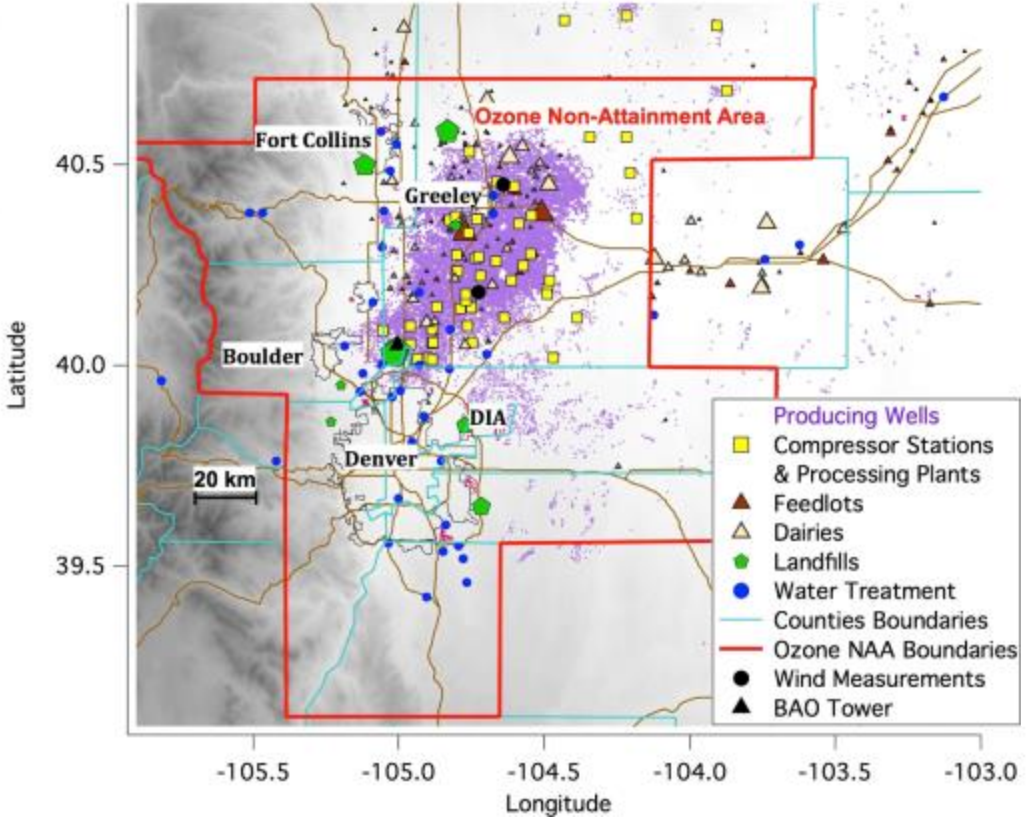


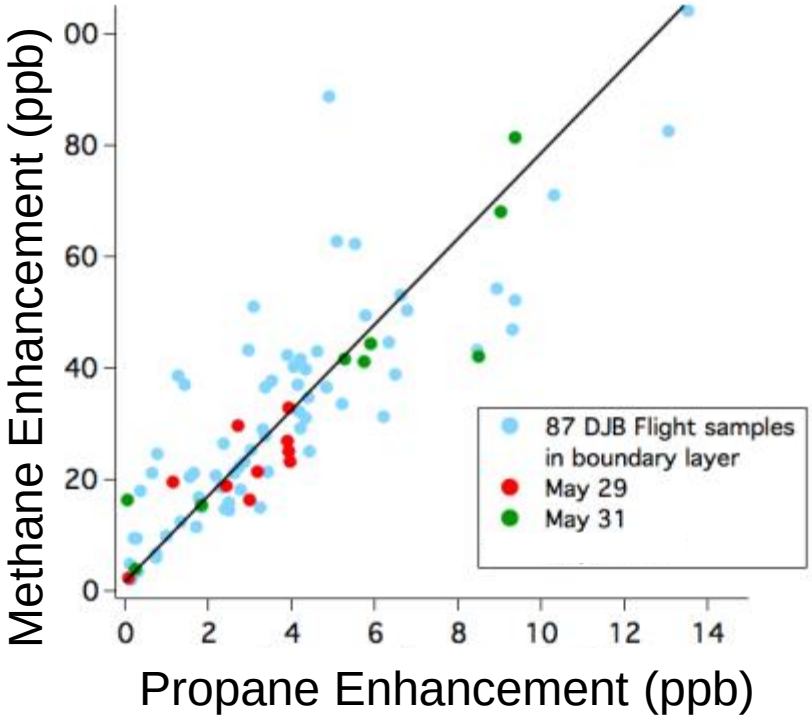
1. Top-down oil and gas emission estimates based on flight data in May 2012 are ~2 times larger than state inventory estimates for NMHCs and 7 times larger for the carcinogen benzene (C_6H_6).

2. CH_4 emissions are close to 3 times larger than an estimate based on EPA GHGRP data.

*Measured NMHC: propane, n-butane, i-pentane, n-pentane, benzene

Denver-Julesburg Basin



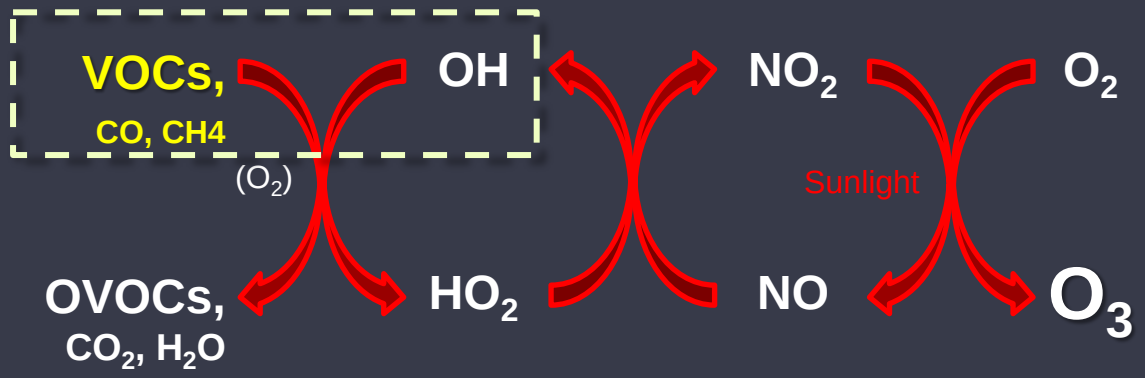


Pétron et al., 2014

Photochemical Ozone (O_3) production

Volatile Organic Compounds (VOC):

venting, flashing, flaring, fugitive emissions

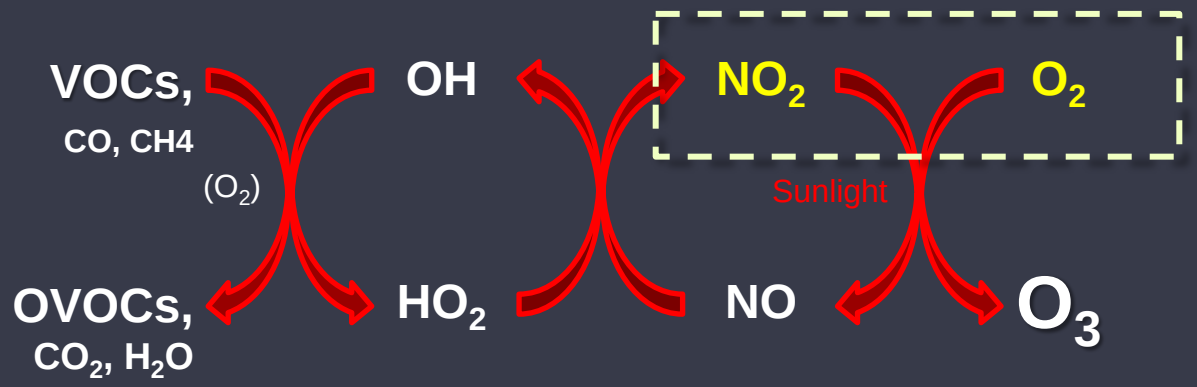


Slide: Jessica Gilman

Photochemical Ozone (O_3) production

Nitrogen Oxides (NO_x=NO + NO_2):

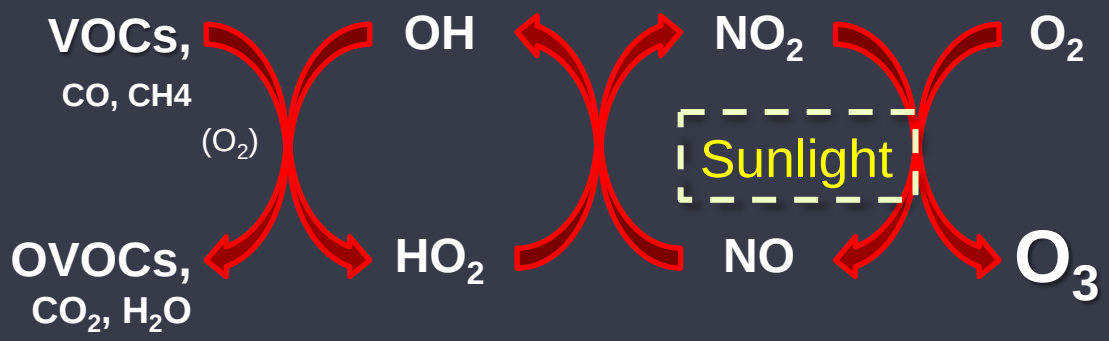
engine exhaust, drill rigs, compressor engines



Slide: Jessica Gilman

Photochemical Ozone (O_3) production

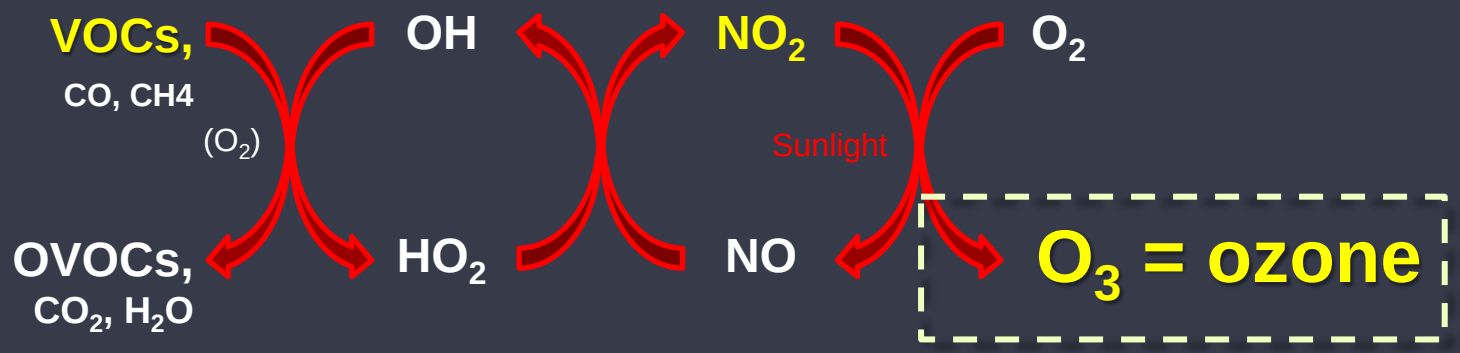
Sunlight: UV from sunlight to trigger photochemistry



Slide: Jessica Gilman

Photochemical Ozone (O_3) production

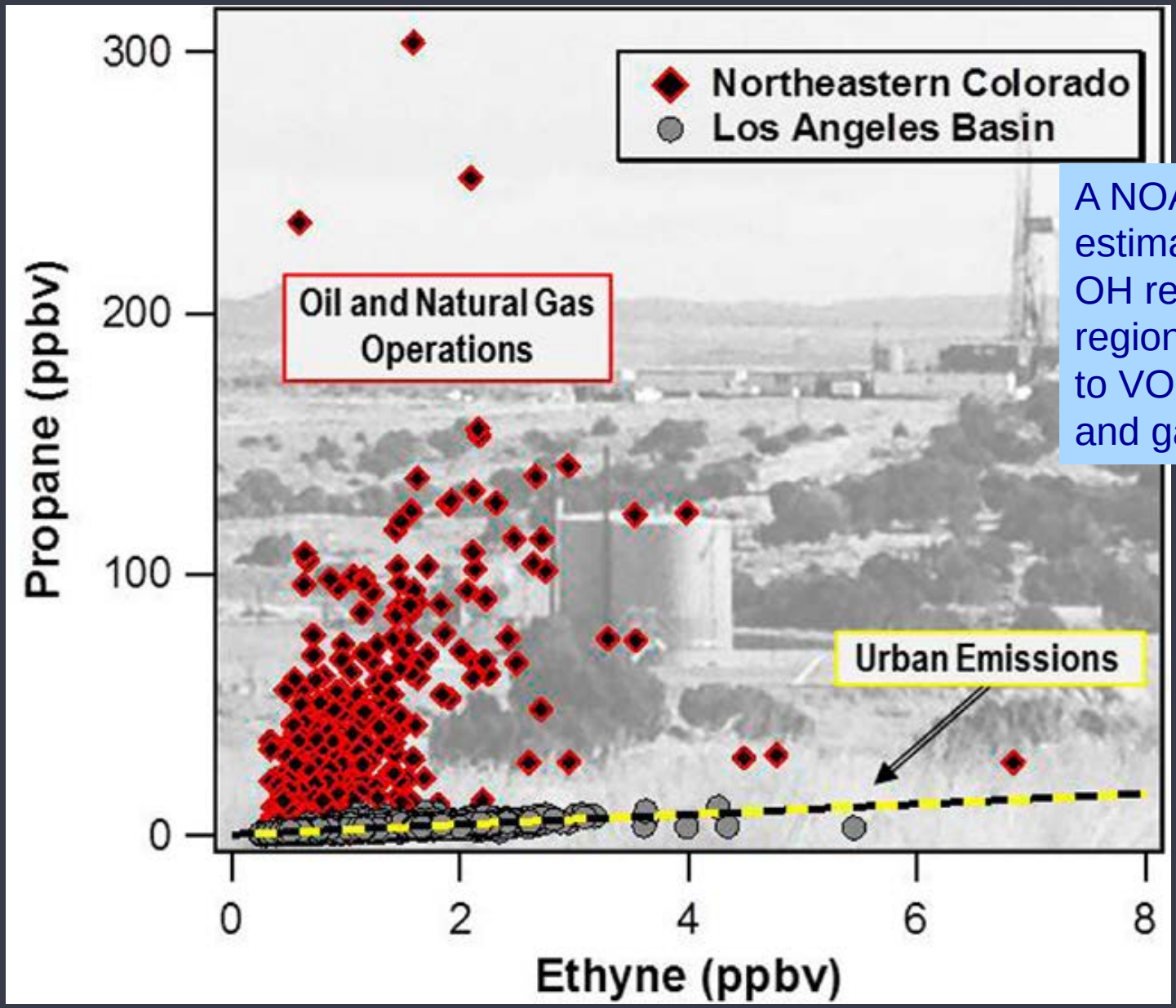
Ingredients: VOC + NOx + Sunlight → Ozone



Summertime Ozone: Typical in urban areas. Weld County, Colorado is non-attainment in summer.

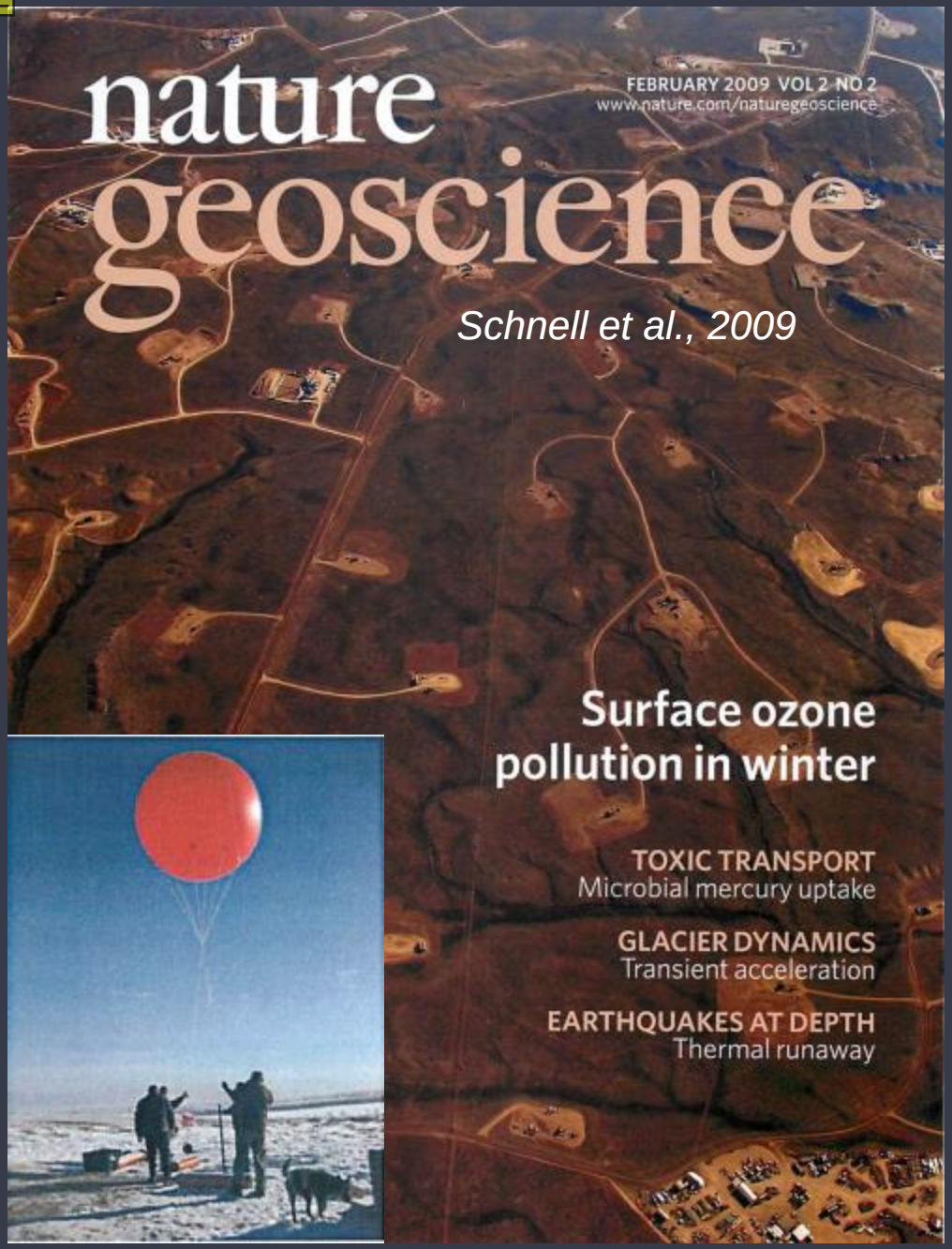
Wintertime Ozone: Rural western oil and gas basins, such as in Utah and Wyoming.

Slide: Jessica Gilman

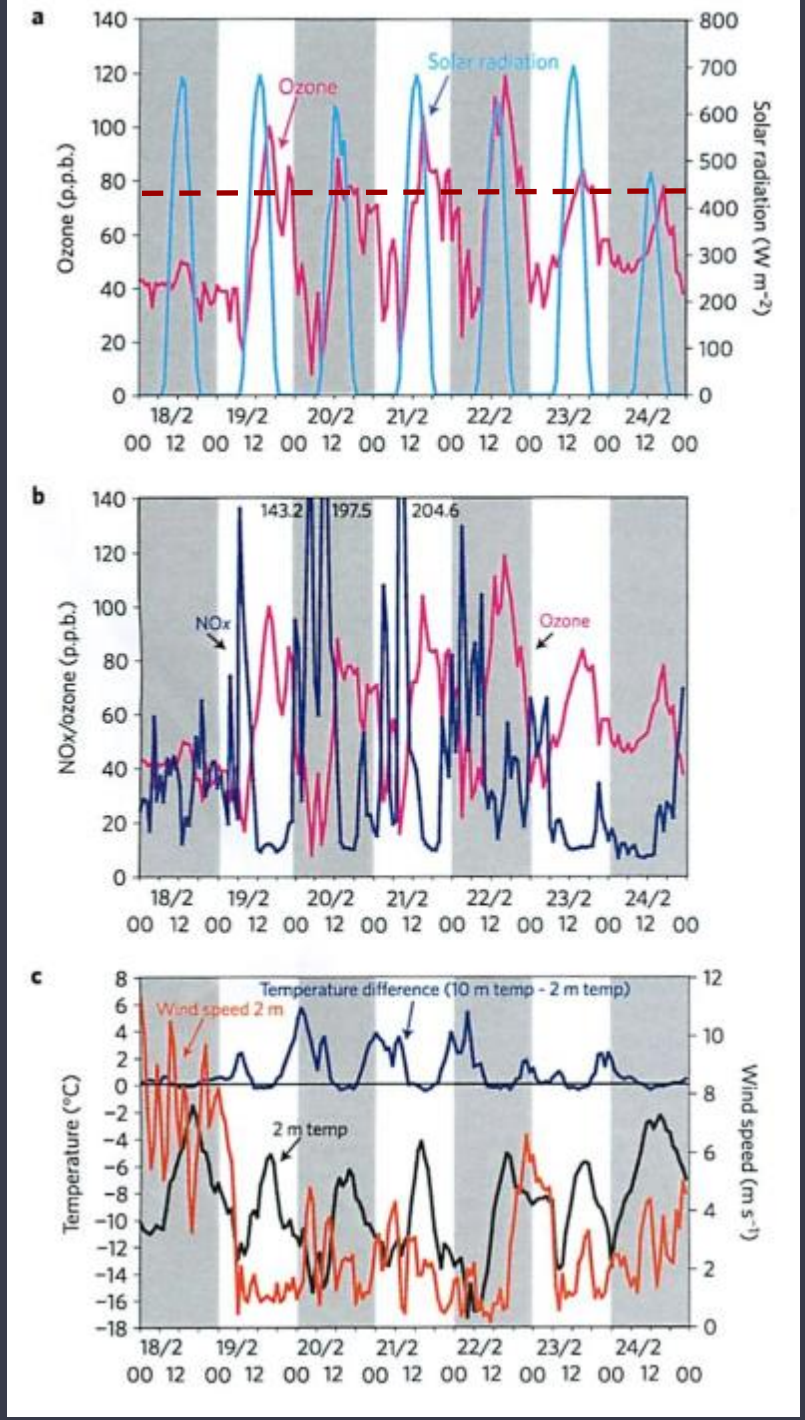


A NOAA study in 2011 estimated that 55% of OH reactivity in the DJ region was attributable to VOCs emitted by oil and gas operations.

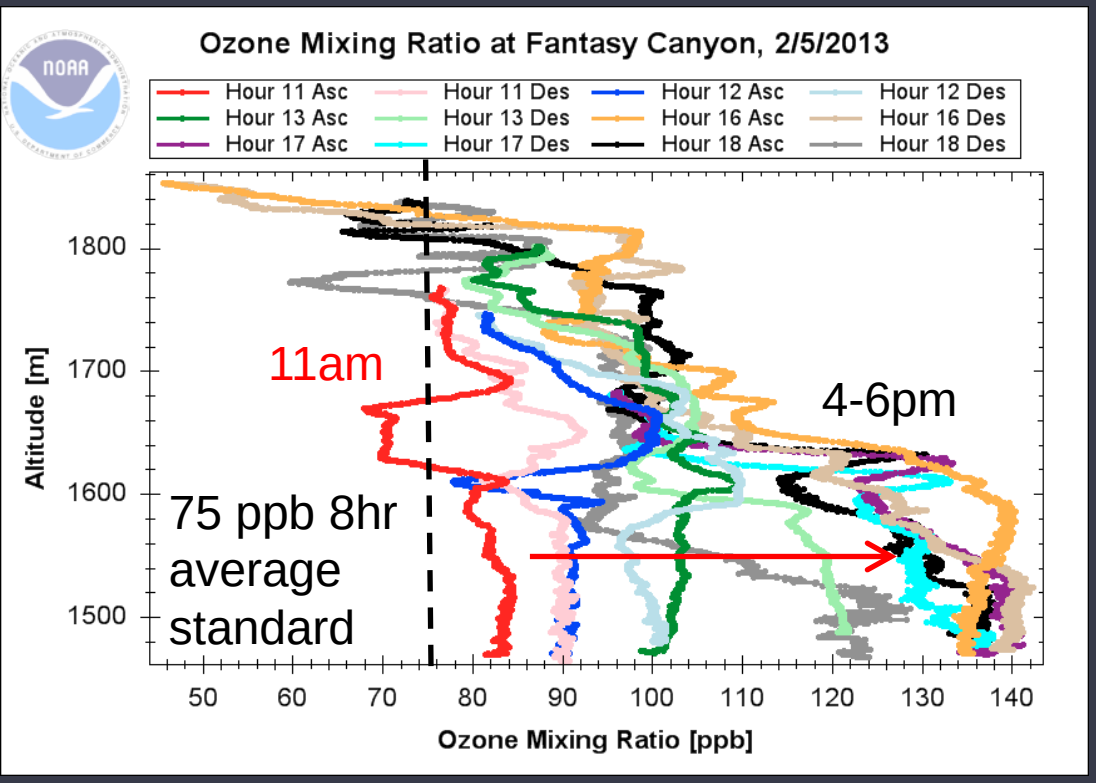
Gilman et al., "Source Signature of Volatile Organic Compounds from Oil and Natural Gas Operations in Northeastern Colorado", ES&T, 2013

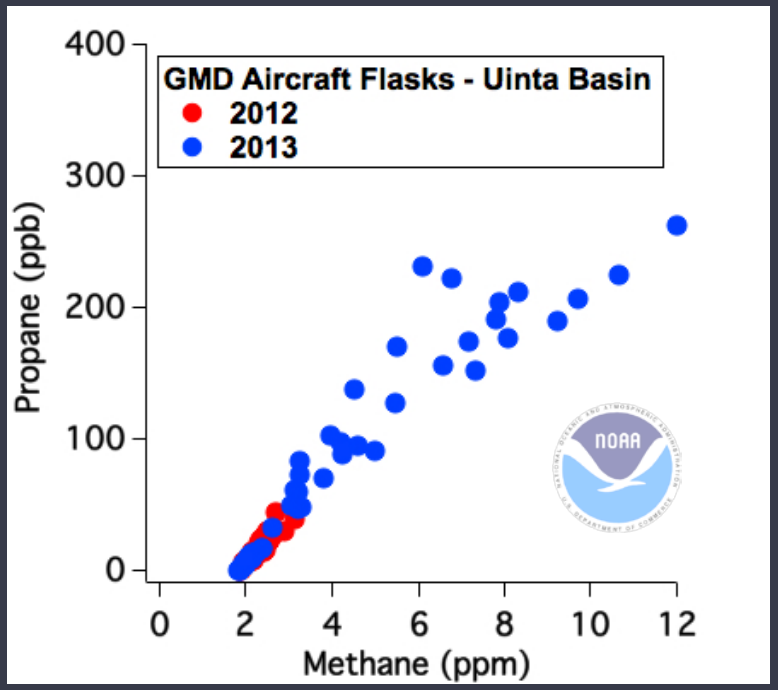


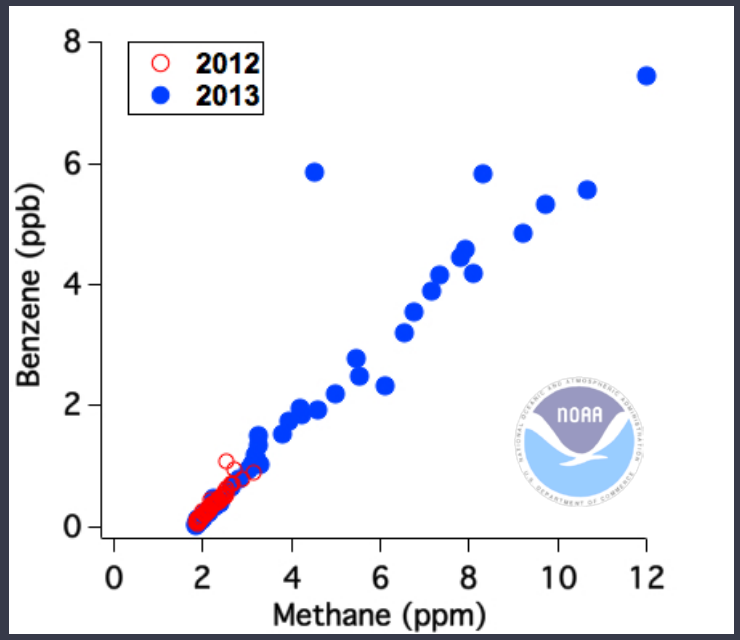
Upper Green River Basin, Wyoming



Uinta Basin's record surface ozone - 2013







- High emissions of ozone precursors
- Snow covered ground (reflected UV)
- Shallow inversion layer

Summary

- What we know:
  - Oil and gas production emissions affect air quality globally (greenhouse gases) and regionally (air toxics and ozone).
  - Atmospheric measurements show that emissions are greater than inventory accounts.
- What we don't know:
  - How inventories can be improved / what they are missing
  - What the emissions from US oil and gas production are and how they will change.

Thanks to contributions from:

Gabrielle Pétron, Colm Sweeney, Jessica Gilman, Sam Oltmans, Russ Schnell, Eric Kort, Ben Miller, Stephen Montzka… and more

Contact: Anna.Karion@noaa.gov

Photo: sunset over the Denton, TX airport, courtesy S. Wolter

Thank you!

Some references

Daniel Zavala-Araiza, David W. Sullivan & David T. Allen, *Atmospheric Hydrocarbon Emissions and Concentrations in the Barnett Shale Natural Gas Production Region*, 48 ENVTL. SCI. TECH. 5, 314, 5,315-5,319 (2014).

Carter & Seinfeld, *Winter Ozone Formation and VOC Incremental Reactivities in the Upper Green River Basin of Wyoming*, 50 ATMOSPHERIC ENVT. 255, 255 (2012).

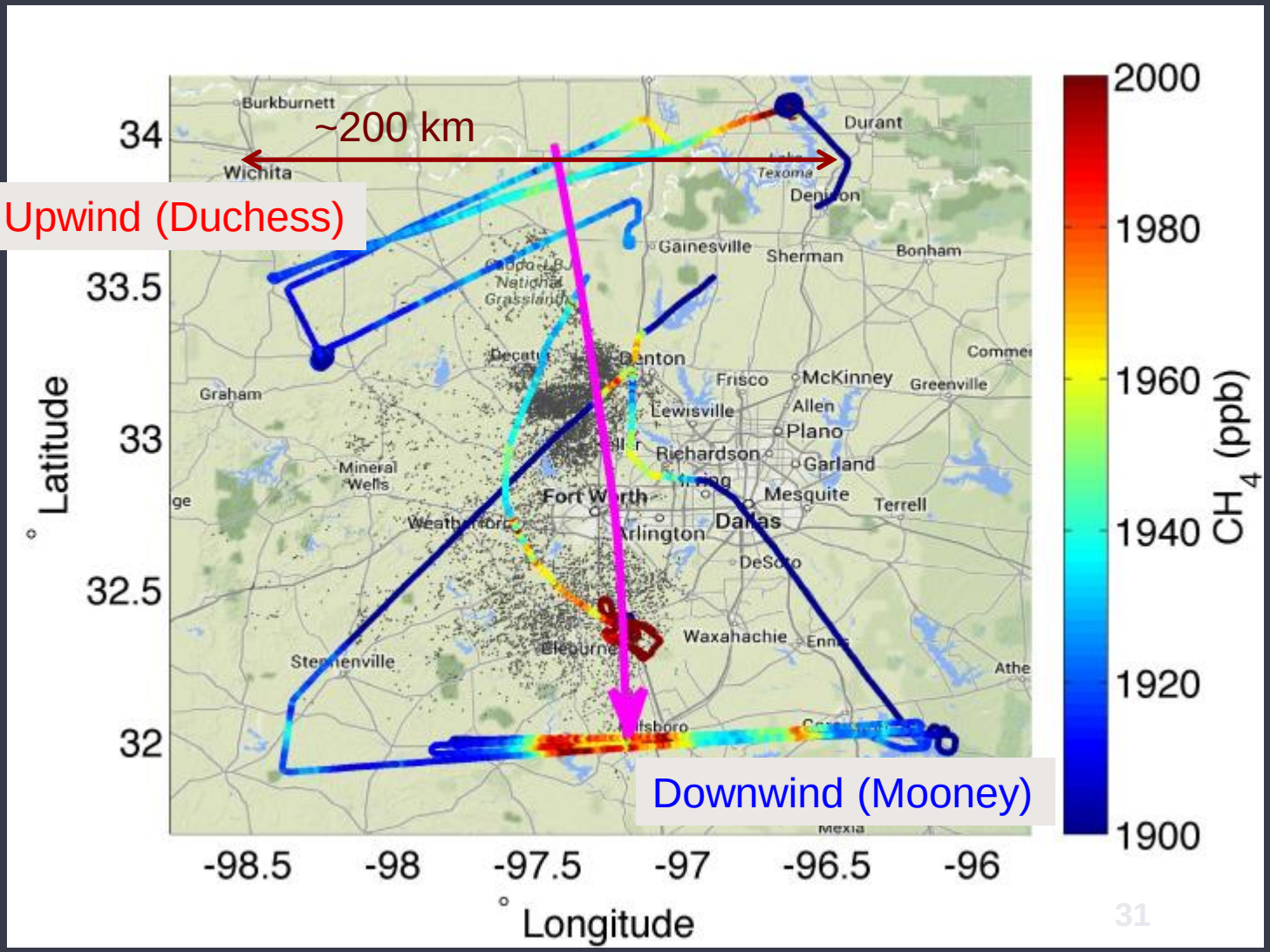
Studies of Uintah:

Edwards, P. et al., (2013). Ozone photochemistry in an oil and natural gas extraction region during winter: simulations of a snow-free season in the Uintah Basin, Utah. Atmospheric Chemistry and Physics.

D. Helmig et al., (2014) Highly Elevated Atmospheric Levels of Volatile Organic Compounds in the Uintah Basin, Utah, 48 ES & T.

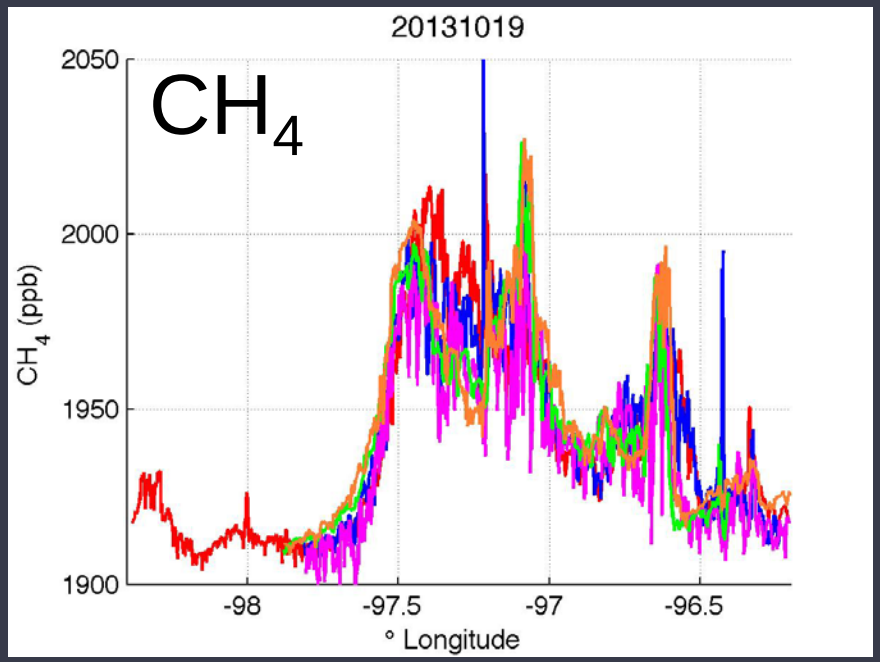
Ahmadov R., et al. (in prep). Understanding high wintertime ozone in an oil and natural gas producing region of the western U.S.

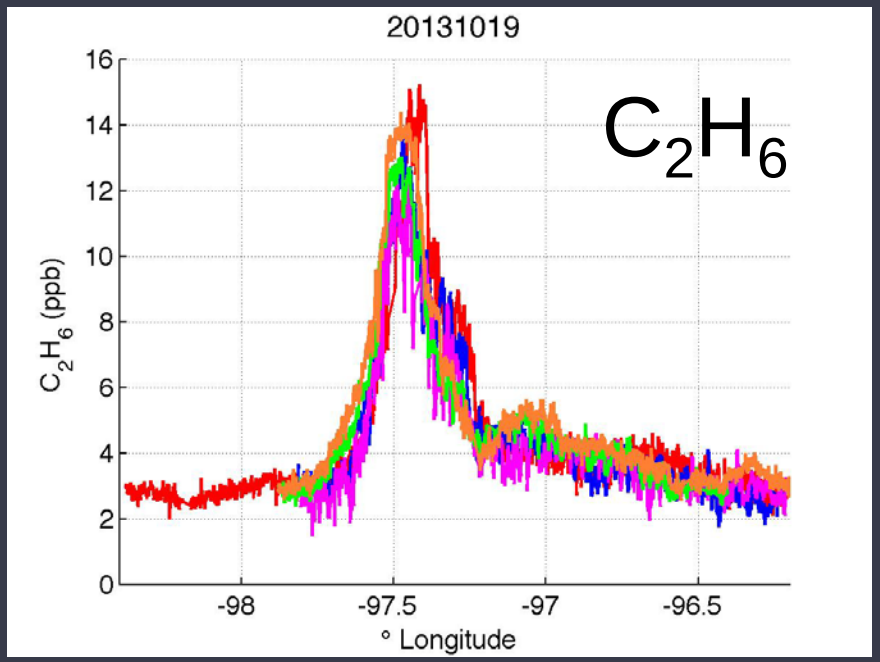
Barnett Shale, TX



5 downwind transects

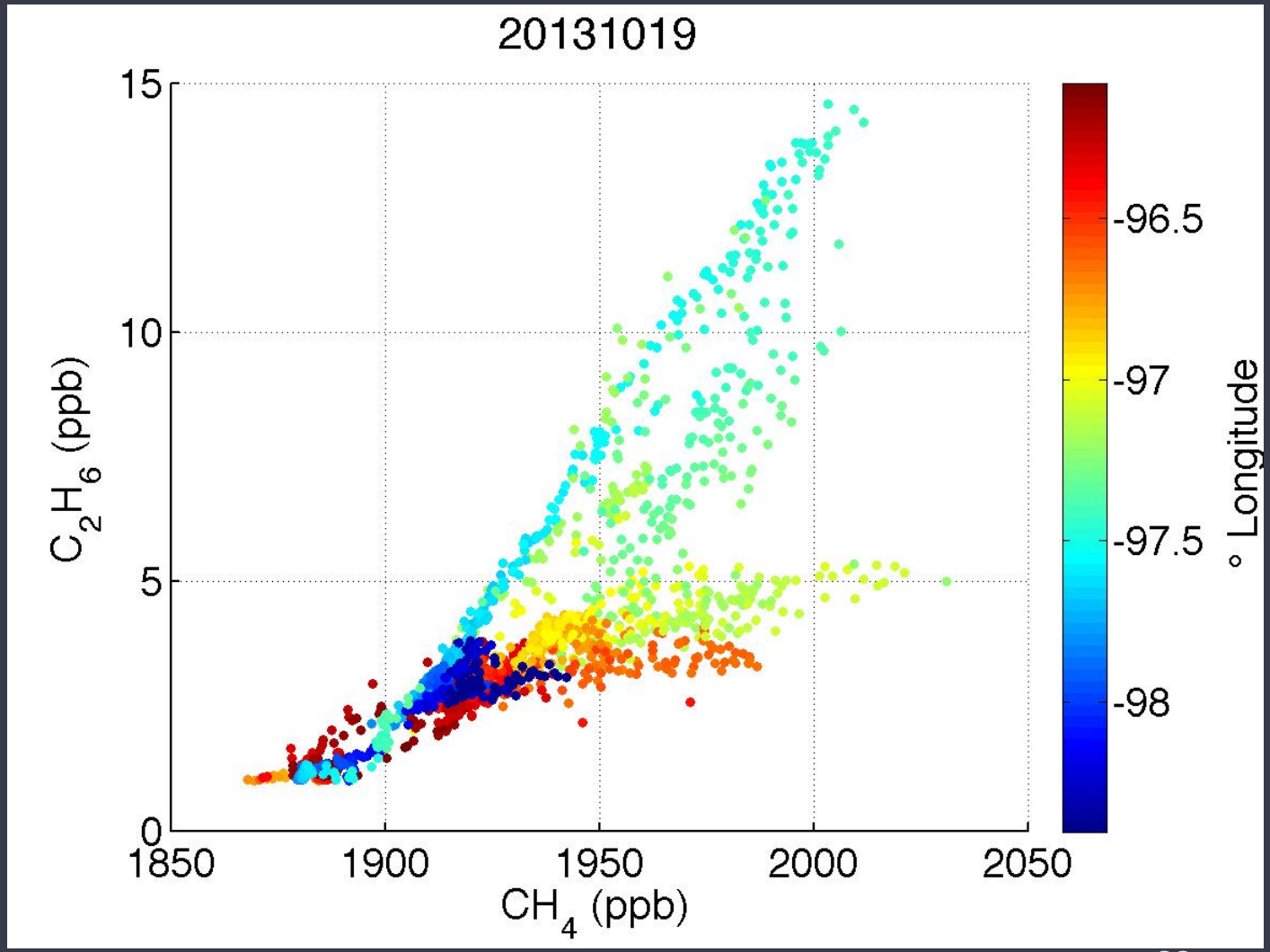
19 Oct 2013





Karion et al., in prep.

Ethane to Methane Ratio: Barnett Shale



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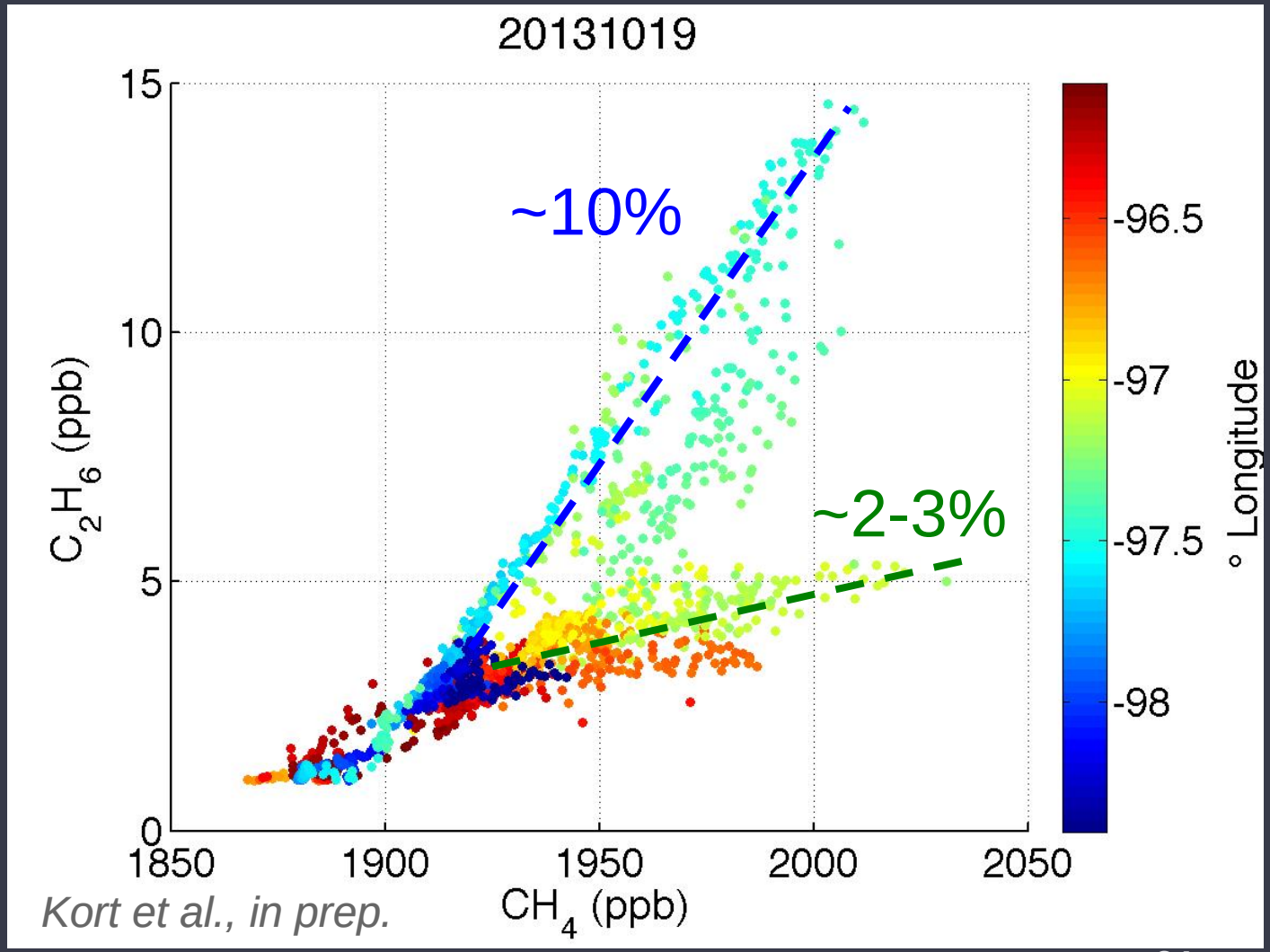
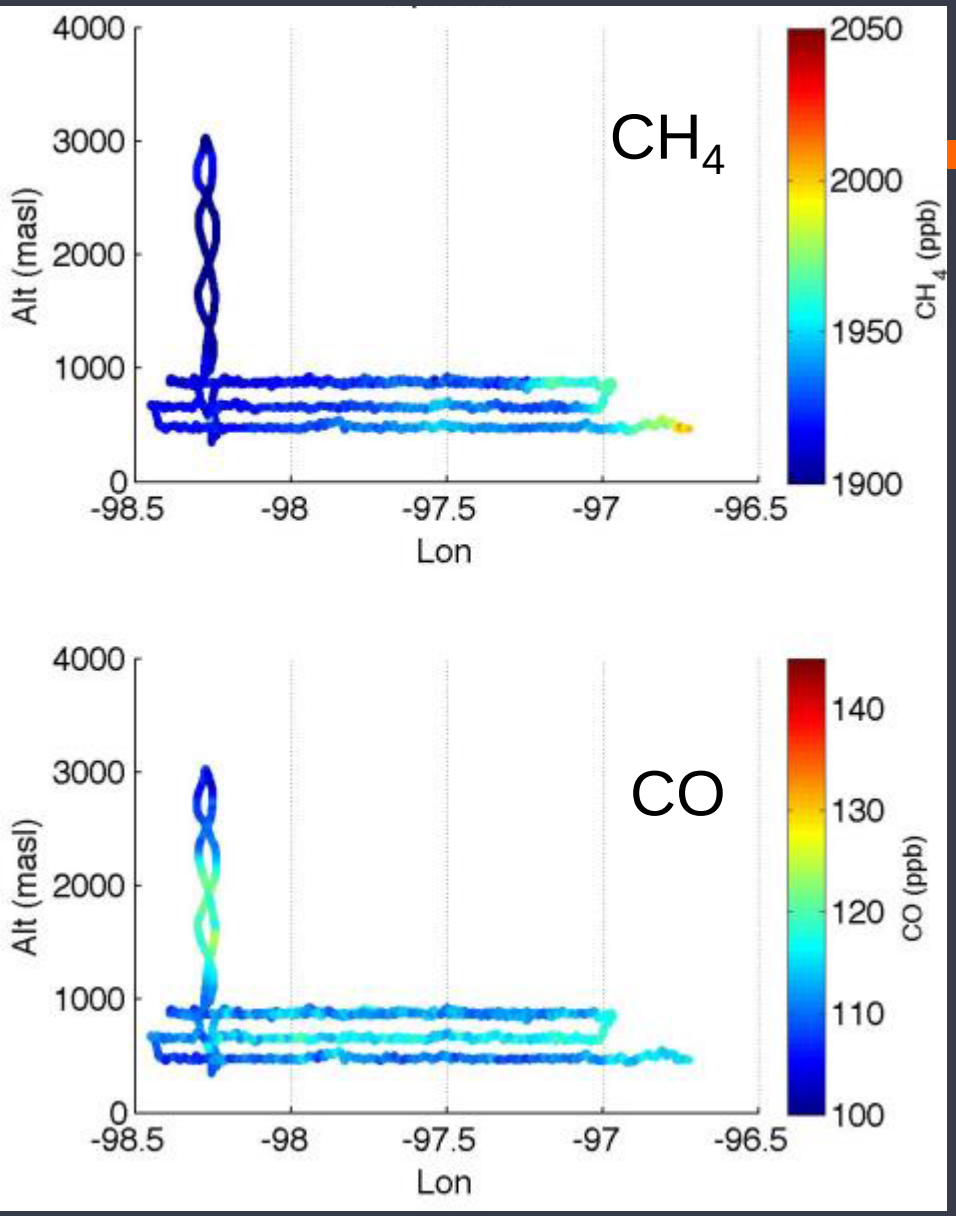
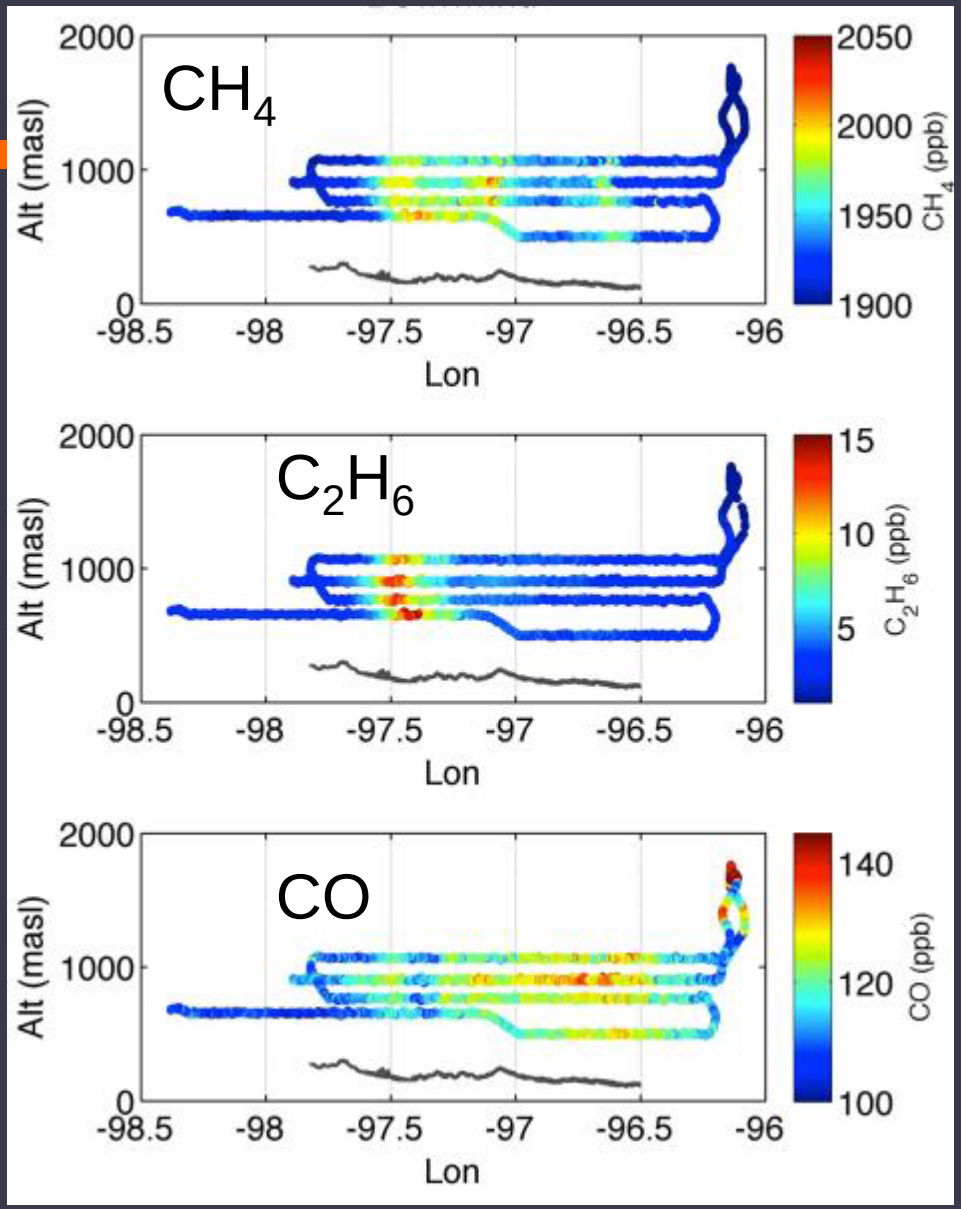


Upwind (Duchess)

Downwind (Mooney)





Karion et al., in prep.