Oil and Natural Gas Operations in Colorado and Utah: Regional Characteristics & Potential Atmospheric Impacts

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Papers in Preparation – Internal slides

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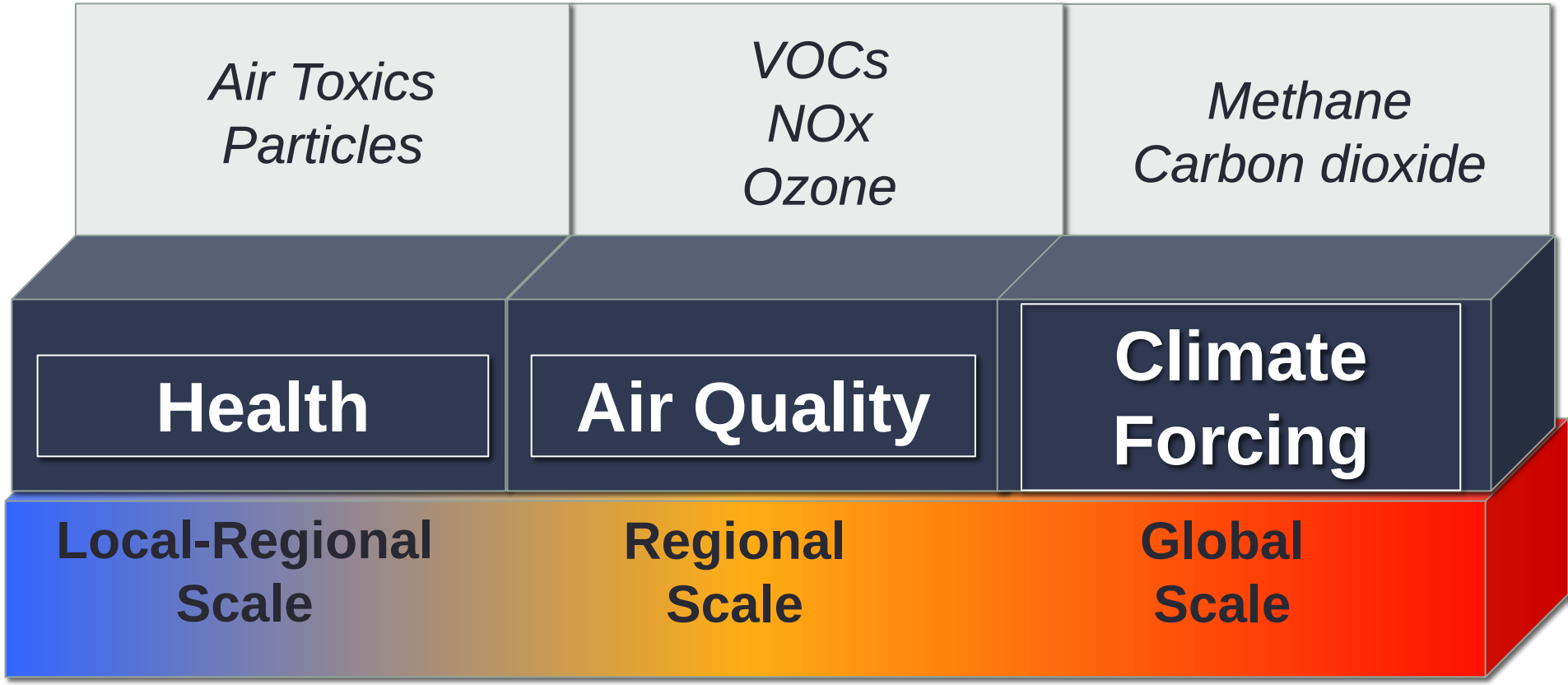
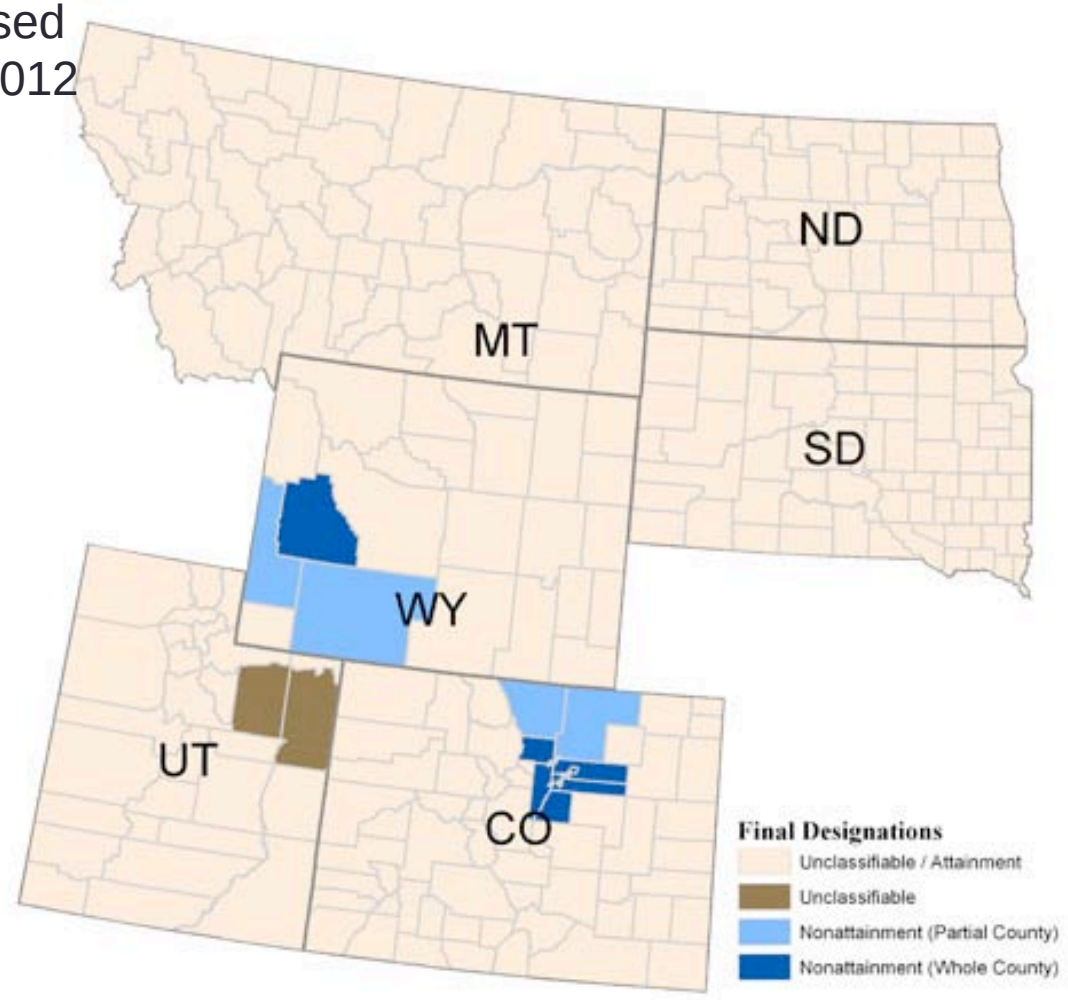
Potential Air Impacts of Shale Gas Development:



Where is air quality impacted?

EPA Region 8 Final Designations for Surface Ozone

Released
April 2012

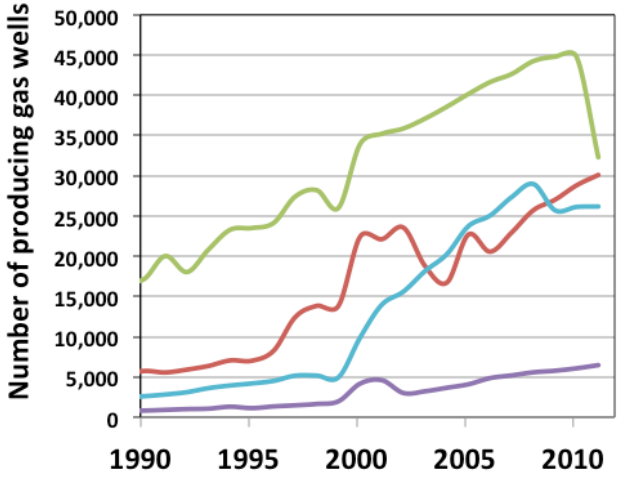


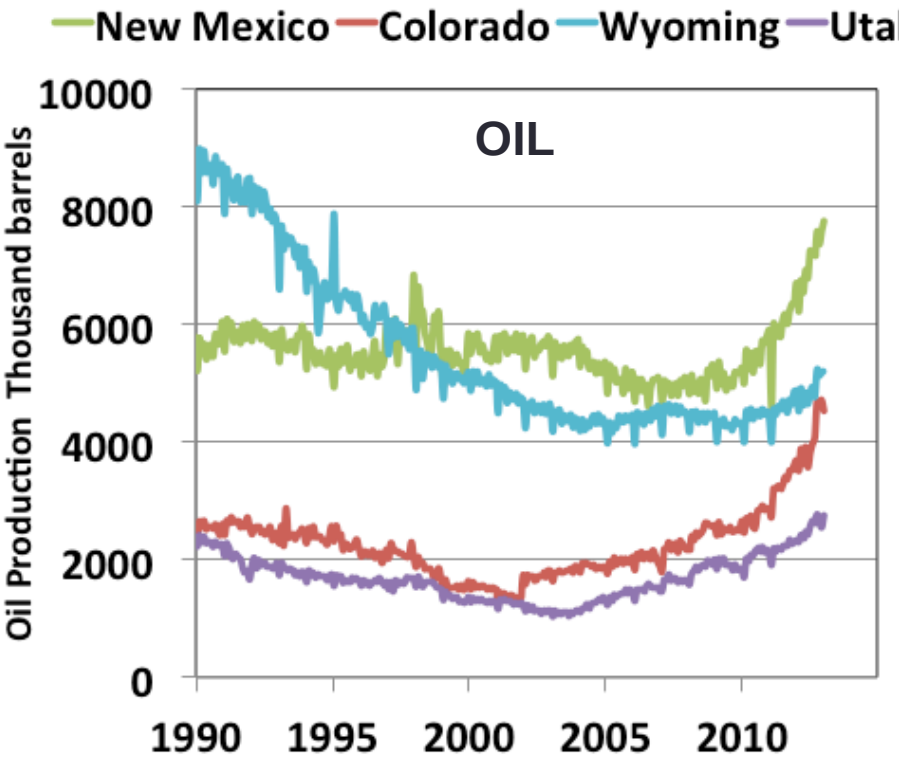
Wyoming:
Lincoln, Sublette, Sweetwater are non-attainment in the winter time

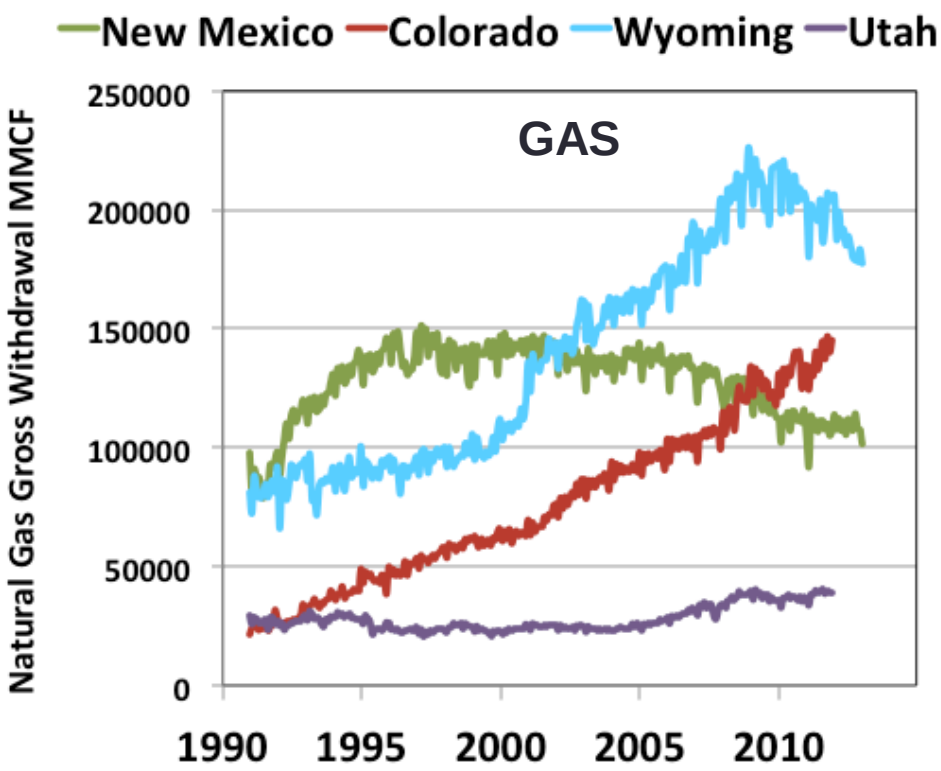
Colorado:
Adams, Arapahoe, Boulder, Broomfield, Denver, Douglas, Jefferson, Larimer, Weld are non-attainment in the summer time

Utah:
Uintah and Duchesne unclassifiable

Recent Trends in Rocky Mountain Region 1990-2011
EIA annual data

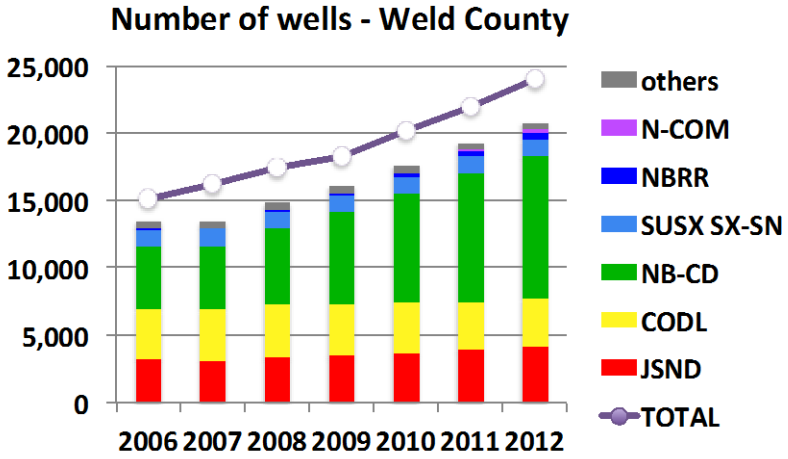


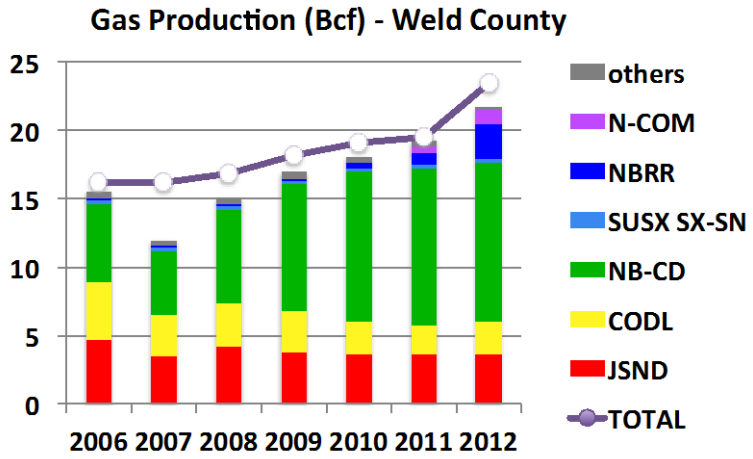


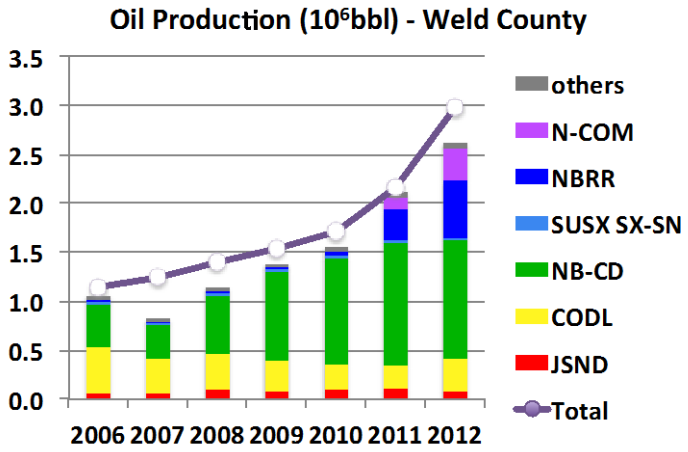


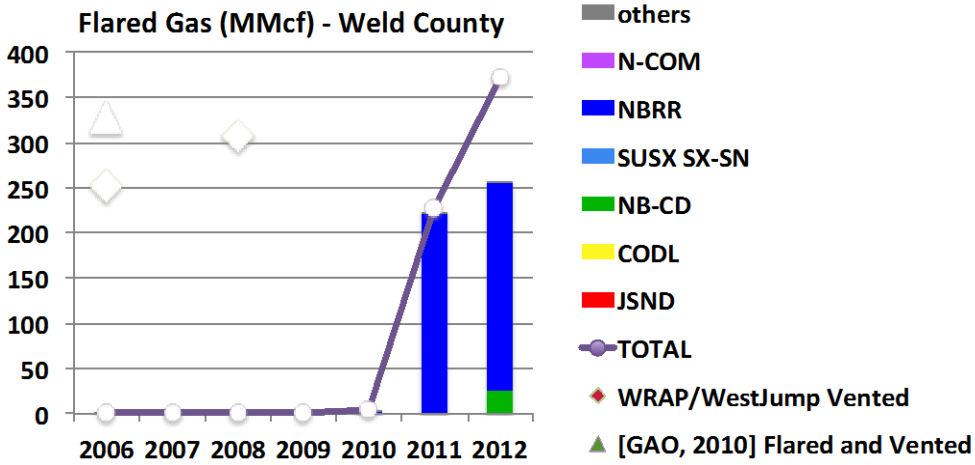
There has been a shift in recent years to produce natural gas and oil from unconventional formations (tight sand, shale and coal bed methane).

Evolution of Well Activity Data in Weld County 2006-2012









Vertical bars Based on monthly data in annual production reports posted online by COGCC
Used May for 2006, 2009-2012 and April for 2007 and 2008 as May was not covering as much of the total production
Circles and purple line: monthly data in COGCC searchable database for county level production numbers.

Risks Assessment and Mitigation

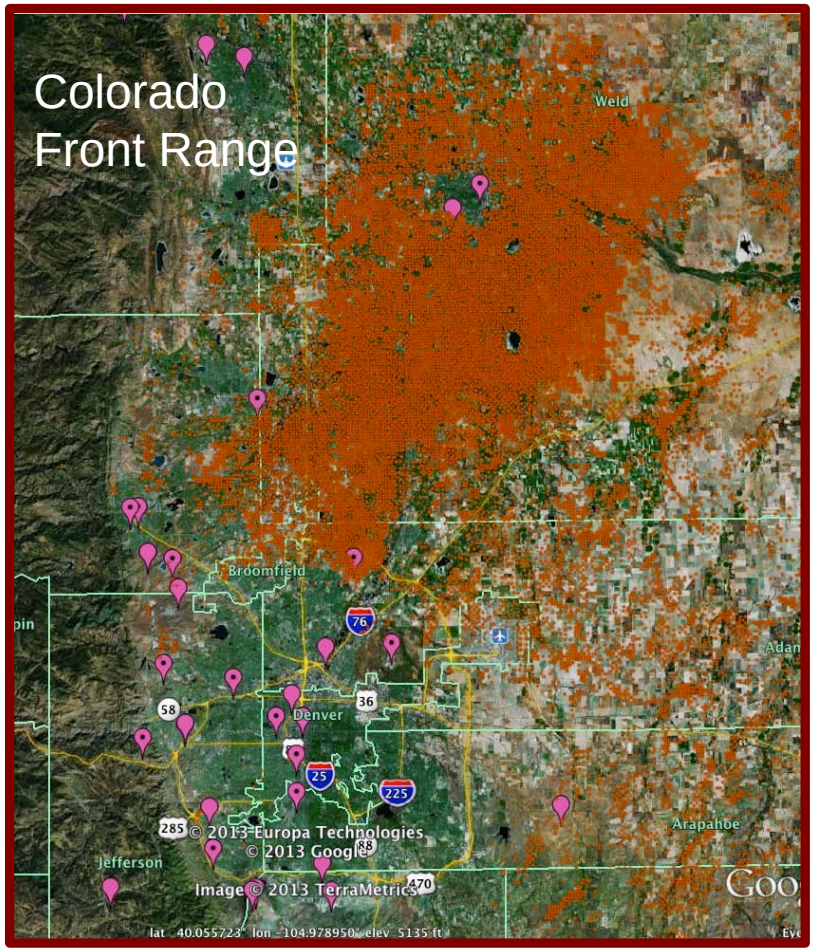
Questions

- Is the region in attainment for all AQ standards?
- What are the main sources of pollution?
- What sources should/could be regulated?
- What controls should/could be implemented?
- Can we assess mitigation success?

Tools

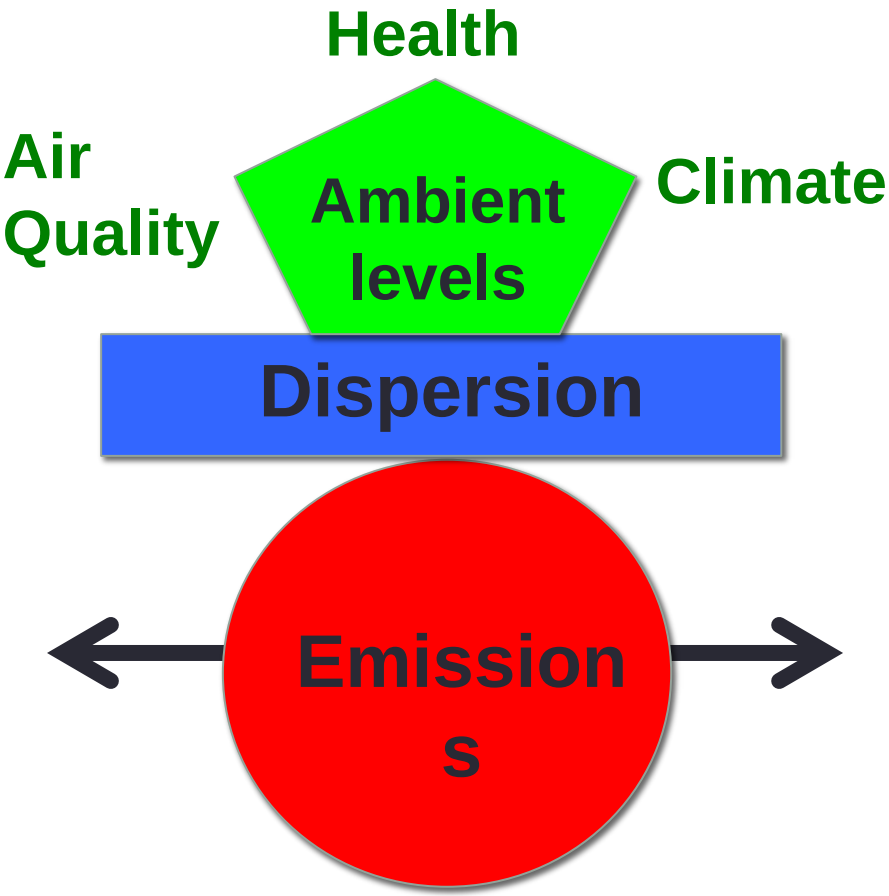
- Emission estimates
  - By source/process
  - Temporally and spatially resolved
  - Speciated composition profiles
- Atmospheric measurements
  - Primary and secondary pollutants
  - Meteorology
- Models
  - Chemical mechanisms
  - Dispersion conditions
  - Boundary conditions

Risks Assessment and Mitigation



Orange dots: active oil and gas wells
Pink: “Official” ozone monitors

Information chain should be adequate.

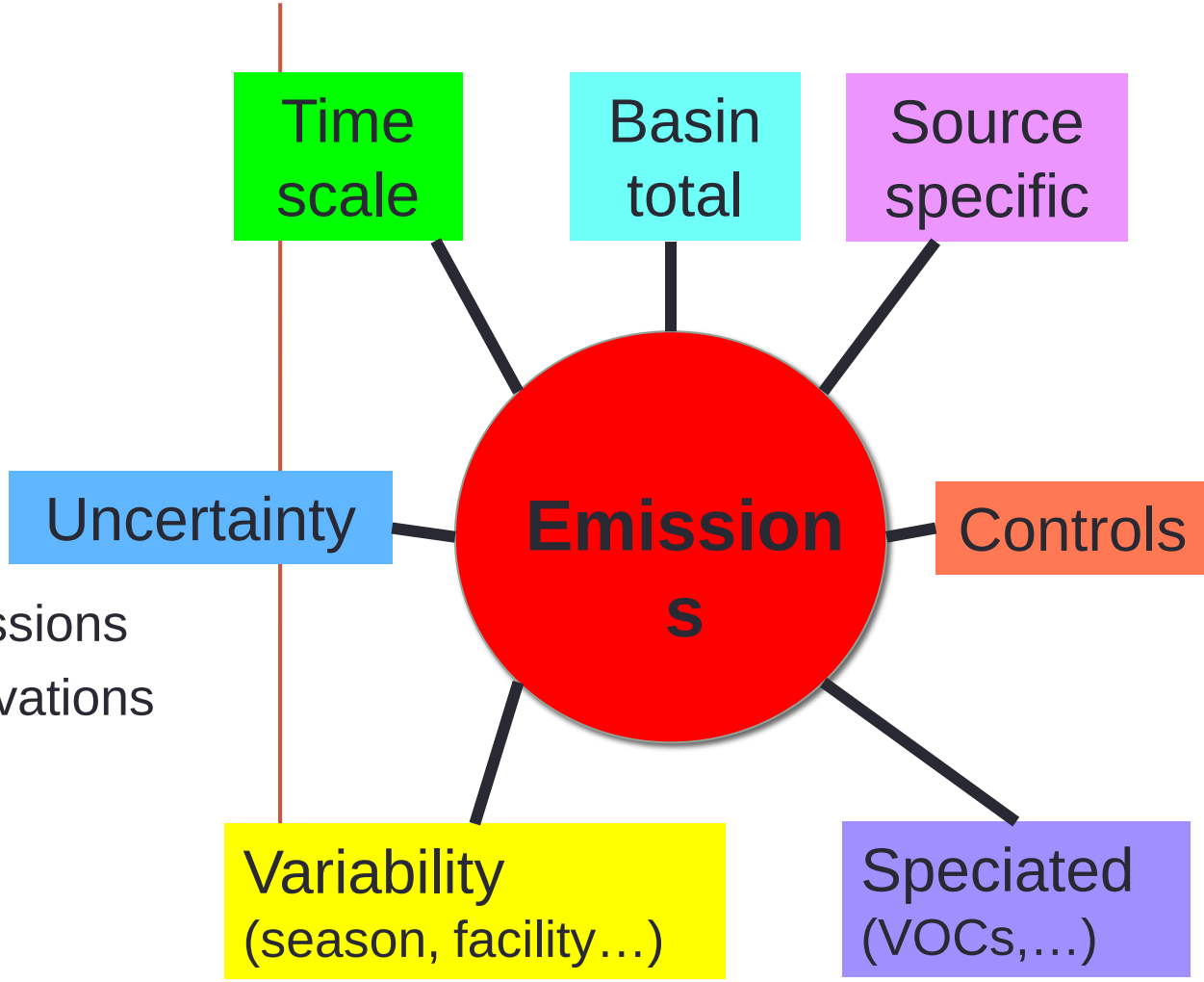


Emissions Assessment

Tools

- Inventories
  - Activity data
  - Emission factors
  - Emission Controls
- Atmospheric Measurements
  - Direct meas. of emissions
  - Ambient level observations

Information needed



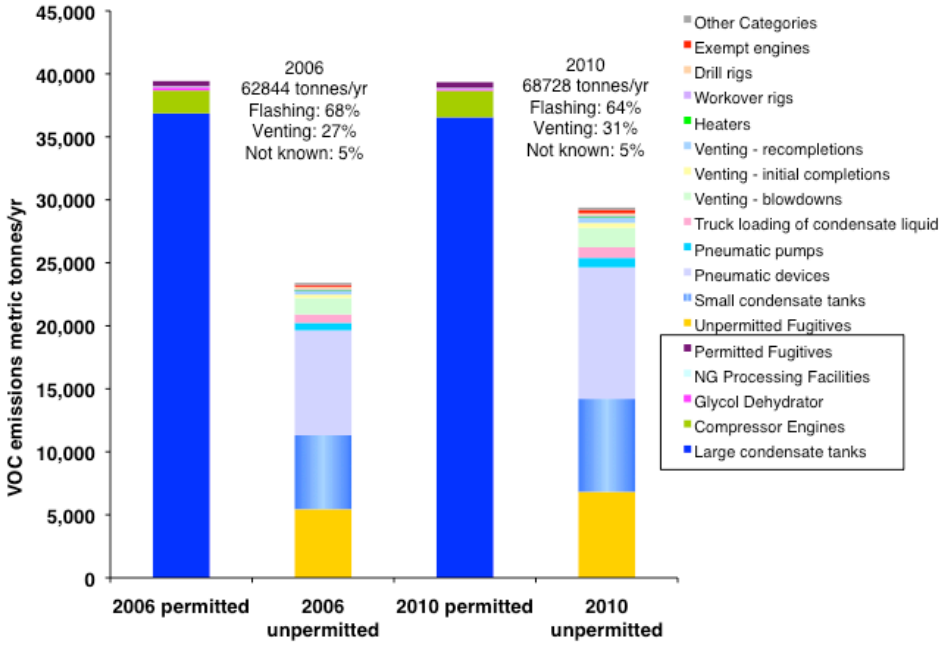
Key Emissions Data

Detailed source information

- Harmonized source categories for all pollutants from an industry and for all regions/years covered
- For each category:
  - Activity Data (year/month specific)
    - Activity/equipment counts
    - Production data
  - Emissions Statistics
    - Distribution ~~Mean~~
    - Variability
  - Composition Profile
  - Controls or not (effectiveness)
- Low threshold for permitting ensures inventory developers have information on small-medium facilities

➔Best knowledge & transparent bottom-up inventory

WRAP III inventories [Bar-Ilan et al, 2008]



http://www.wrapair2.org/PhaseIII.aspx

Current WRAP Oil & Gas Studies Source Categories

Source: Tom Moore, WGA

- Large Point Sources

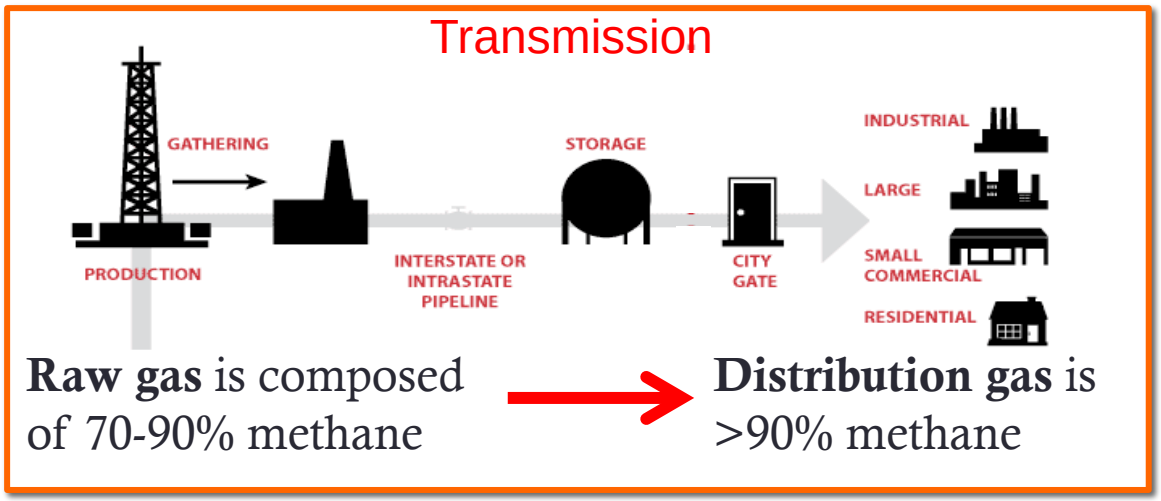
(Gas plants, compressor stations)

- Drill Rigs
- Wellhead Compressor Engines
- CBM Pump Engines
- Heaters
- Pneumatic Devices
- Condensate and Oil Tanks
- Dehydrators
- Completion Venting

- Lateral compressor engines
- Workover Rigs
- Salt- Water Disposal Engines
- Artificial Lift Engines (Pumpjacks)
- Vapor Recovery Units (VRU's)
- Miscellaneous or Exempt Engines
- Flaring
- Fugitive Emissions
- Well Blowdowns
- Truck Loading
- Amine Units (acid gas removal)
- Water Tanks

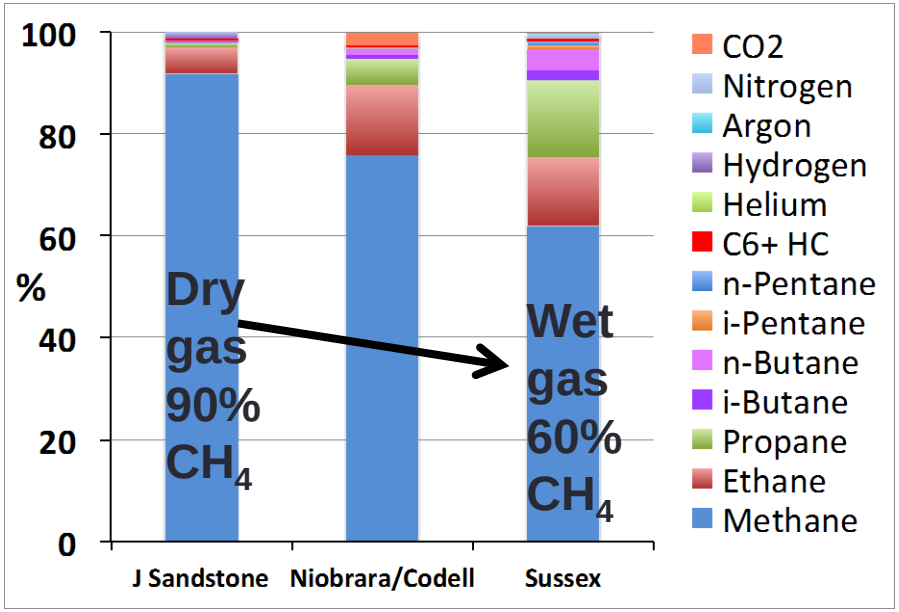
"green" completion

Natural Gas and Oil Systems



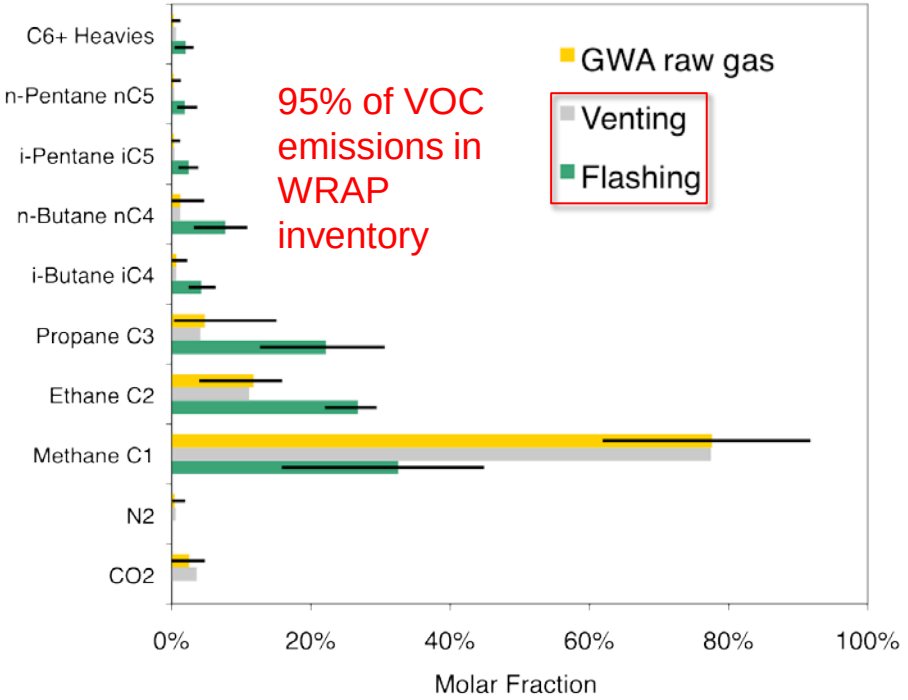
Fugitive emissions or leaks of natural gas along the production and supply chain result in direct emissions of CH_4 and VOCs (ozone precursors).

Example of raw gas molar composition



COGCC GWA gas composition data, 2007

WRAP venting and flashing profiles

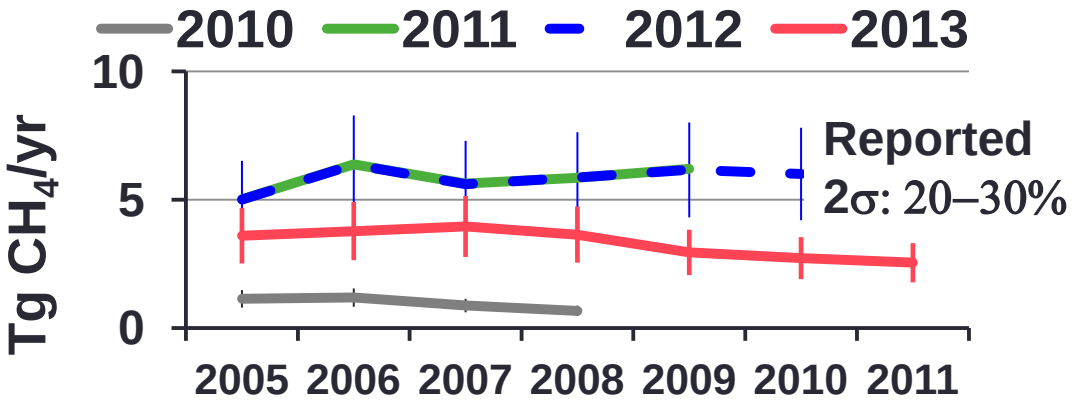


What is regulated?
Example: Colorado NE Front Range NAA

- VOC emissions controls (control start date)
  - Oil & Condensate Tanks (2008)
  - Glycol Dehydrators ()
  - Completion (2009)
  - Pneumatic devices (2009)
  - Compressor engines ()

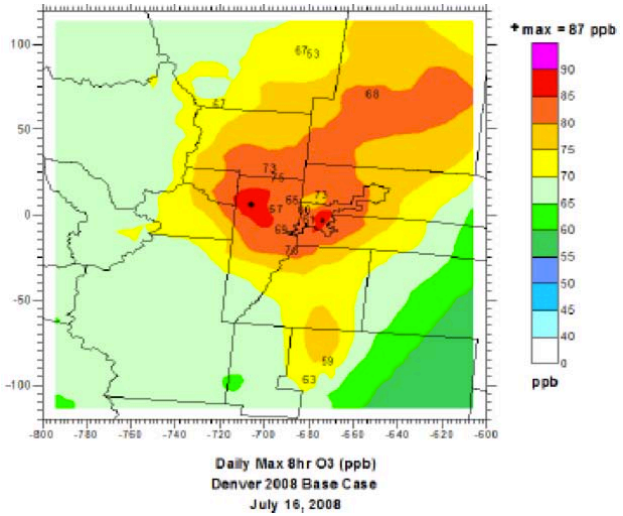
How well do we know emissions from oil and gas systems?

EPA GHG inventory, 2010-2013



Over the past 4 years, the EPA revised its methodology to calculate national level CH_4 emissions from natural gas production leading to major changes in emission estimates.

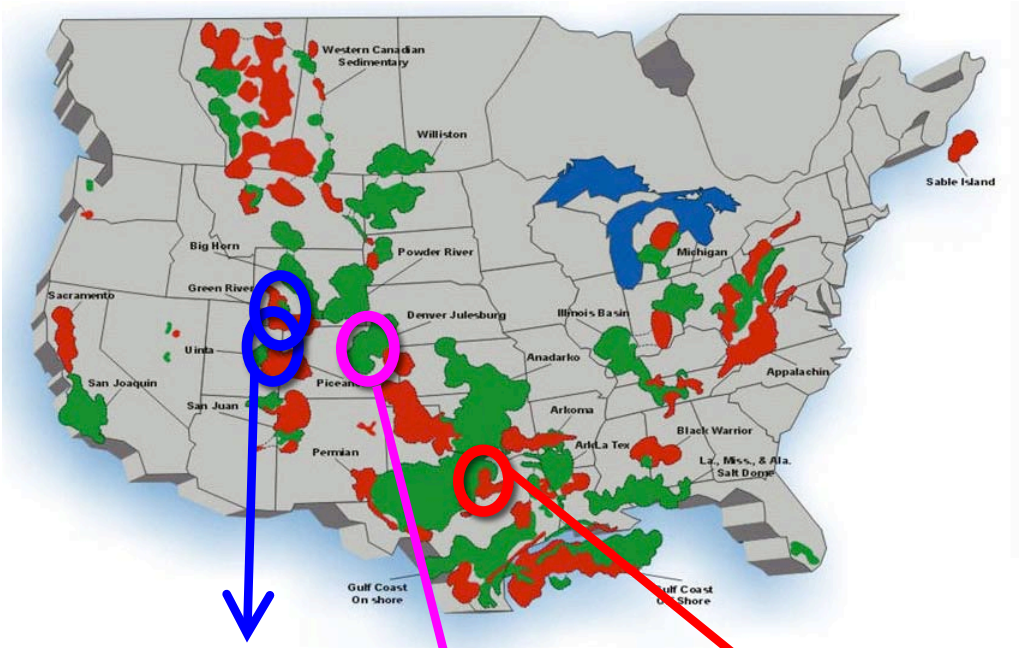
Colorado O_3 SIP modeling, CDPHE 2012



- In 2012, Colorado increased the estimate of total VOC emissions from tanks (x3), assuming that only 75% of flash emissions are captured by control equipment.
- A NOAA study in 2011 estimated that 55% of OH reactivity in the region was attributable to VOCs emitted by oil and gas operations [Gilman et al., 2013]

Location of past and on-going field intensive studies

Map of unconventional oil and gas reservoirs and dates of GMD campaigns



Wyoming 2008 Utah 2012, 2013

Colorado 2008-present

Texas 2013

Research Questions:

- Emissions of methane and non-methane hydrocarbons
- Summertime ozone
- Wintertime ozone

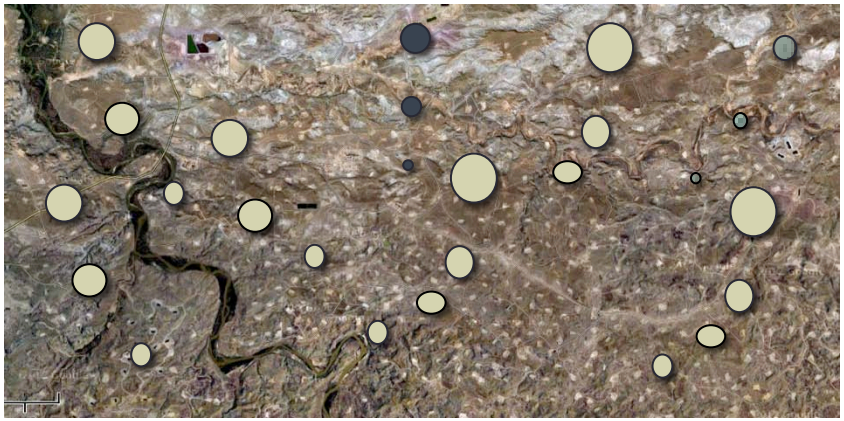
Instrumented airplane

Instrumented van

NOAA HRDL Wind Doppler Lidar

Can we detect NG emissions in the atmosphere?

CH_4 "cloud" from surface emissions



wind

Ambient levels of CH_4 measured by tower, instrumented van or aircraft downwind of the area source reflect emissions from oil and gas production operations

How do we measure or sample the air composition?

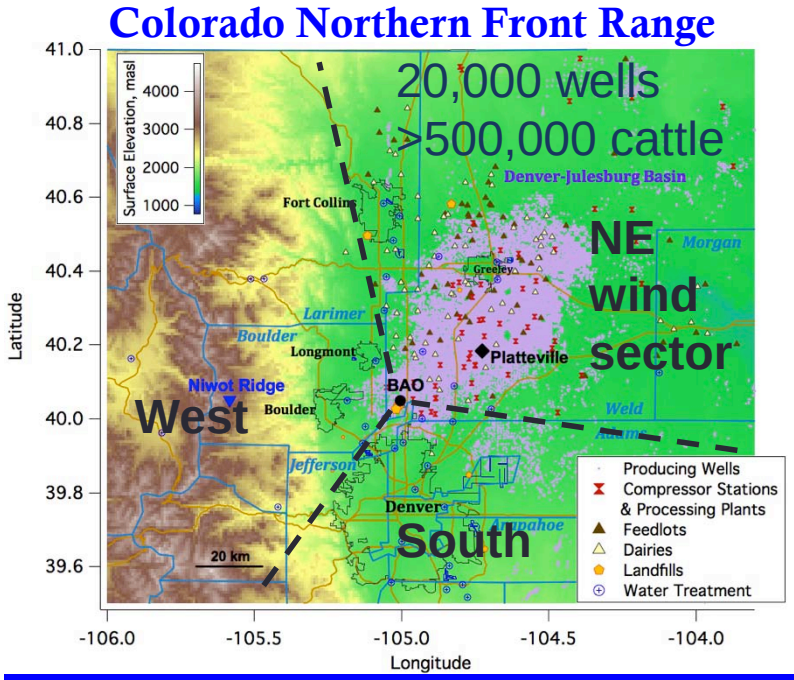
Tower, aircraft and van in-situ and canister

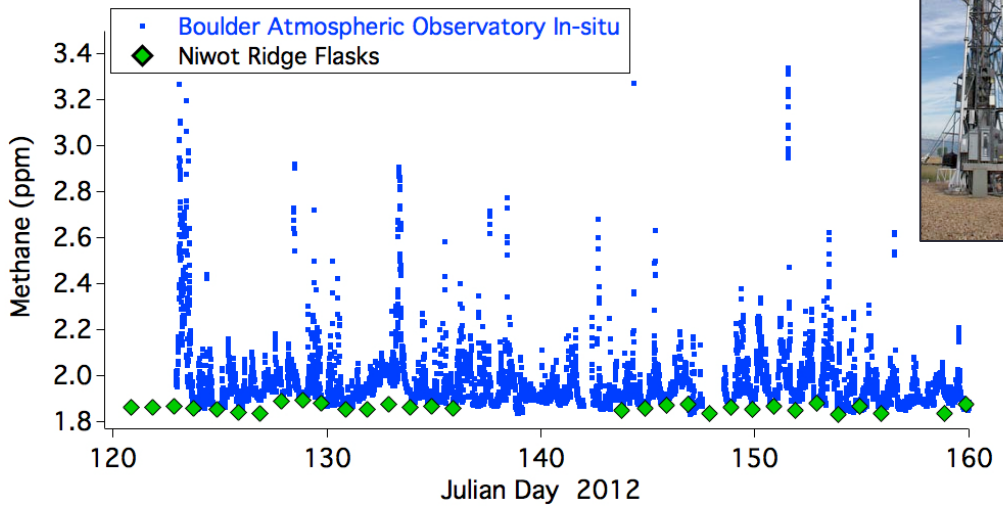
CCGG MAGICC

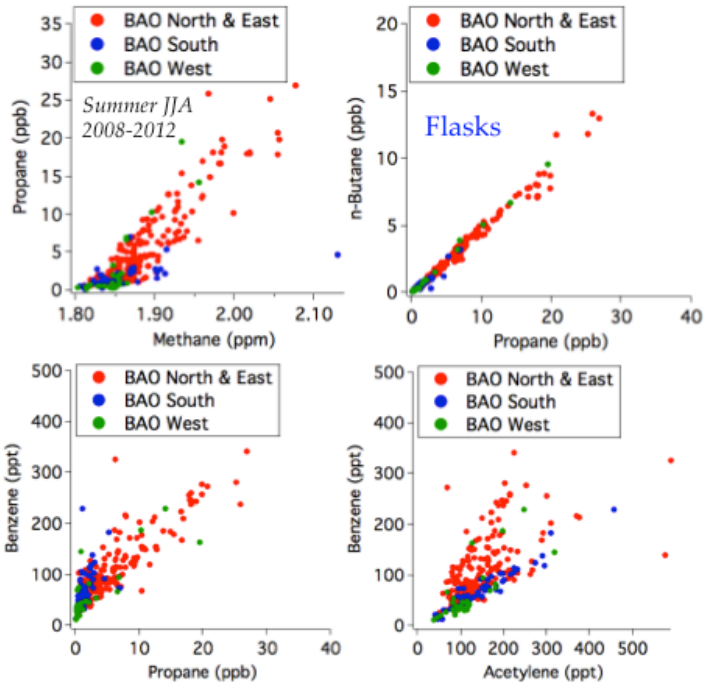
CO_2 CH_4 N_2O SF_6 CO H_2

HATS GC/MS
43 species

Denver-Julesburg Basin, Colorado



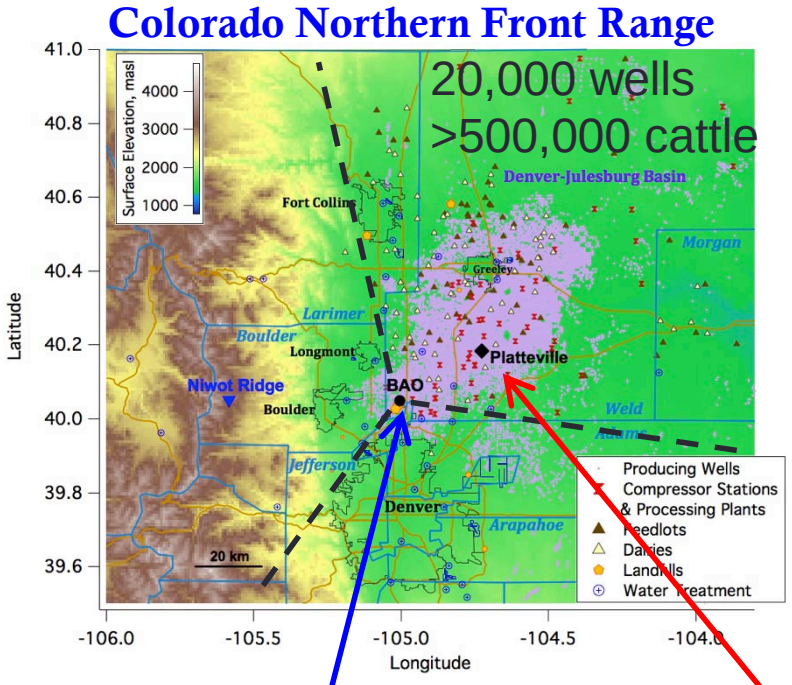


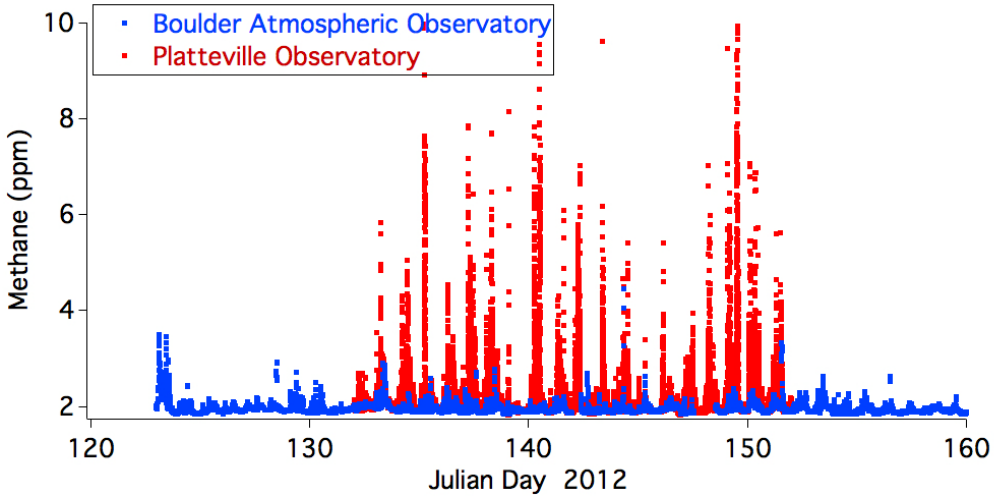


NOAA measurements have shown evidence of local emissions of methane and VOCs from oil and gas operations (Pétron et al., JGR, 2012).

55% of OH-VOC reactivity attributable to emissions from oil and gas operations (Gilman et al, ES&T, 2013).

Denver-Julesburg Basin, Colorado



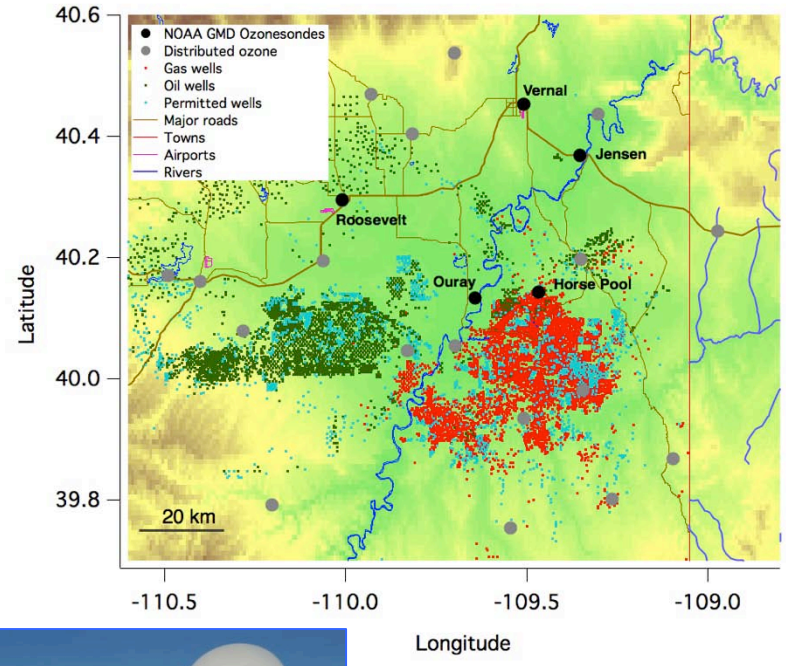


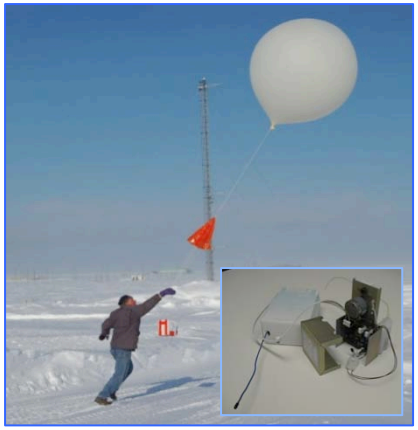
Methane at the surface is much higher at night at the Platteville site, located in the middle of the Basin.

Do we know the magnitude of fugitive emissions at the Basin level?

Uintah Basin Study- Jan/Feb 2012

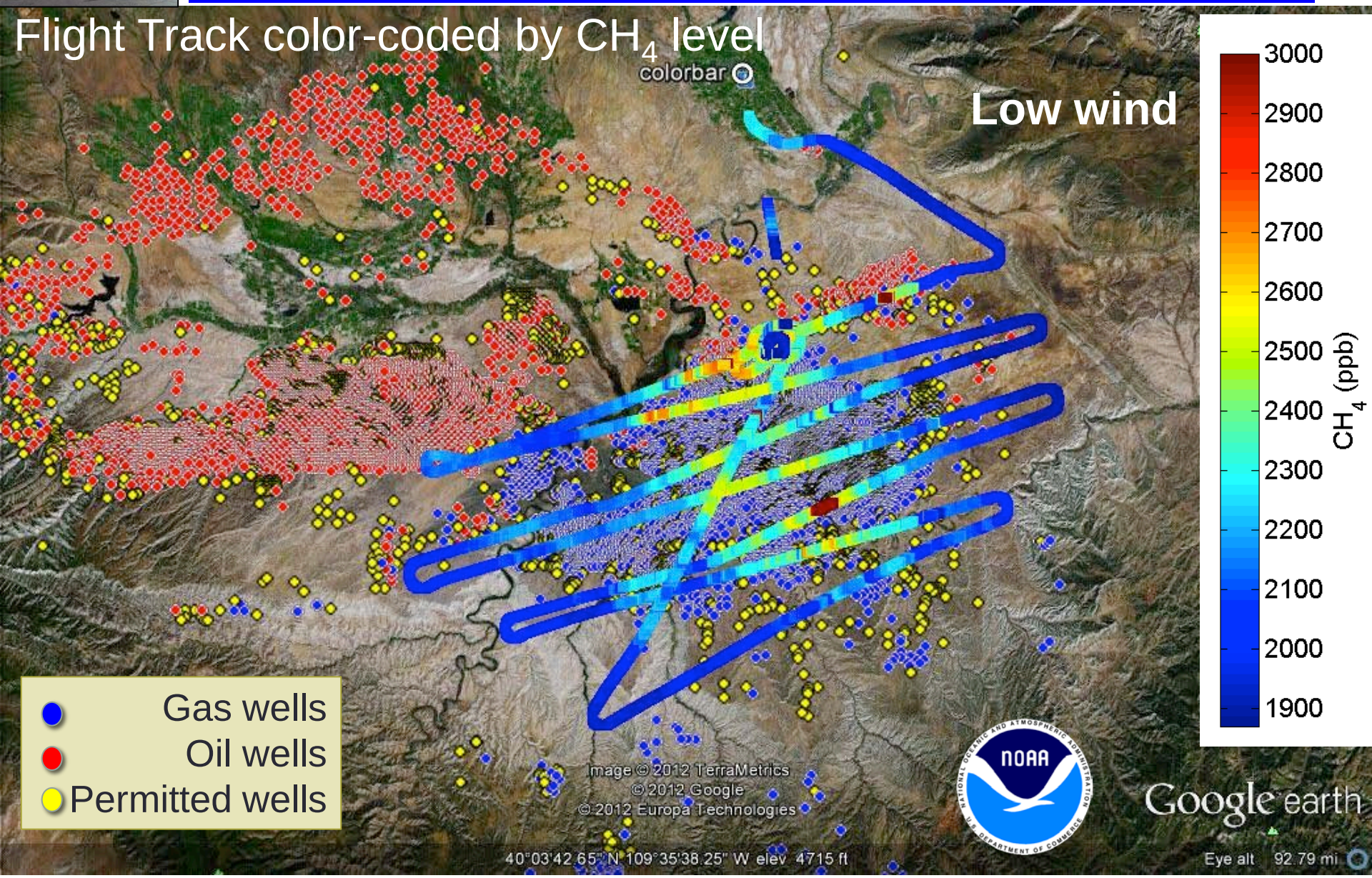
NOAA Global Monitoring Division and Chemical Sciences Division
University of Colorado, CIRES and INSTAAR



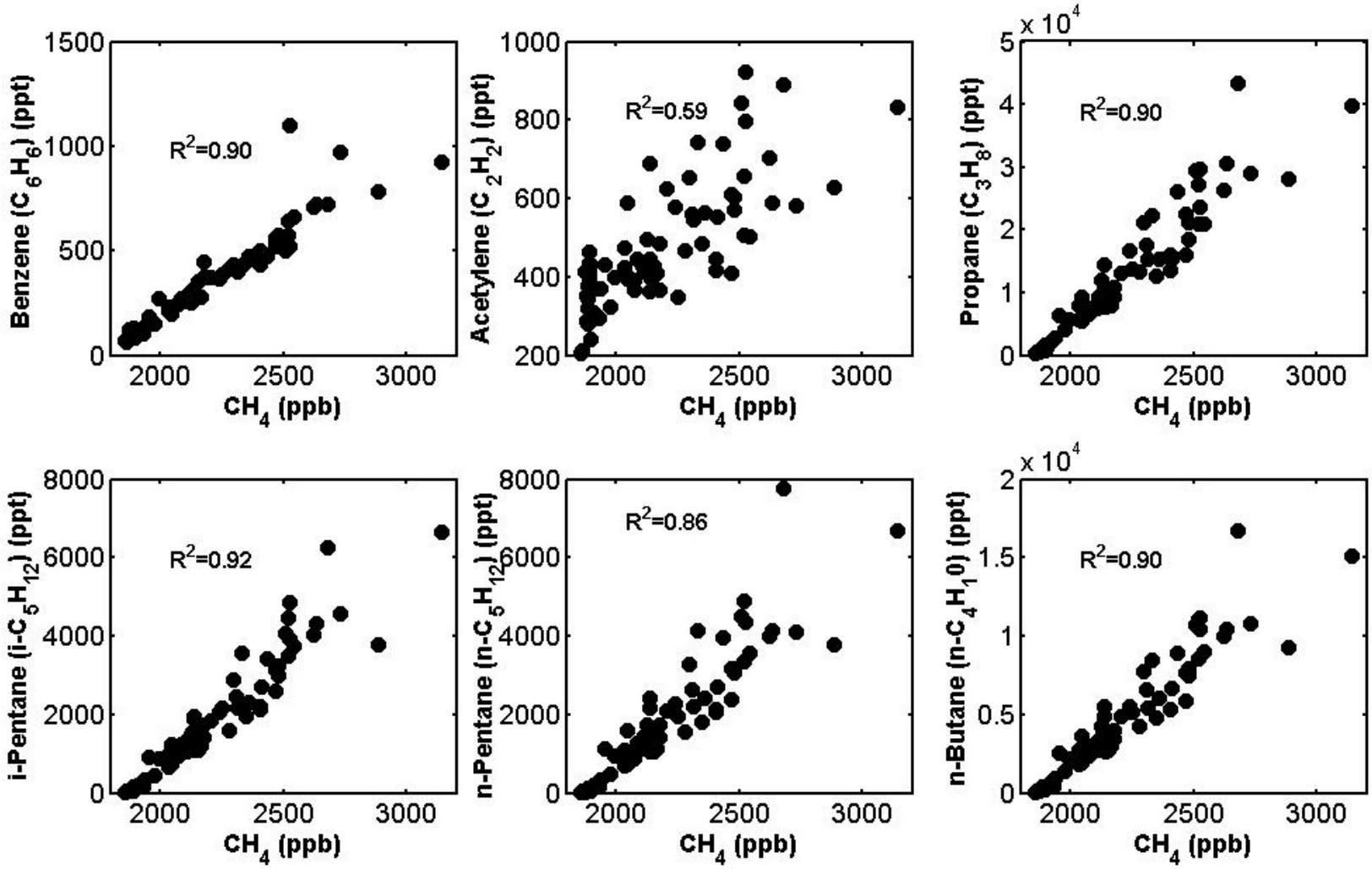


- Mapping O_3 structure
  - Ozonesondes
    - At 3 sites: Roosevelt, Jensen, Ouray
    - On D. Helmig's tethered balloon at Horse Pool
    - O_3, P, T, RH
  - Ozone Lidar at HorsePool
- Mapping NO_X and VOC distribution across the Basin
  - Mobile Lab
    - 2B Ozone 10 sec
    - NOxCaRD NO/NO_2 or O_3/NO_2 1 sec
    - Picarro CH_4, CO, CO_2, H_2O 2 sec
    - Met fields 10 sec
    - GPS 1sec
  - Aircraft
    - 2B Ozone 10 sec
    - NO2
    - Picarro CH_4, CO, CO_2, H_2O 2 sec
    - GPS 1sec
- Characterization of NOx and VOC sources
  - Targeted sampling of canisters for VOCs analysis
- Wind fields and PBL: HRDL Lidar

February 7, 2012: Uinta Basin Sea of CH_4



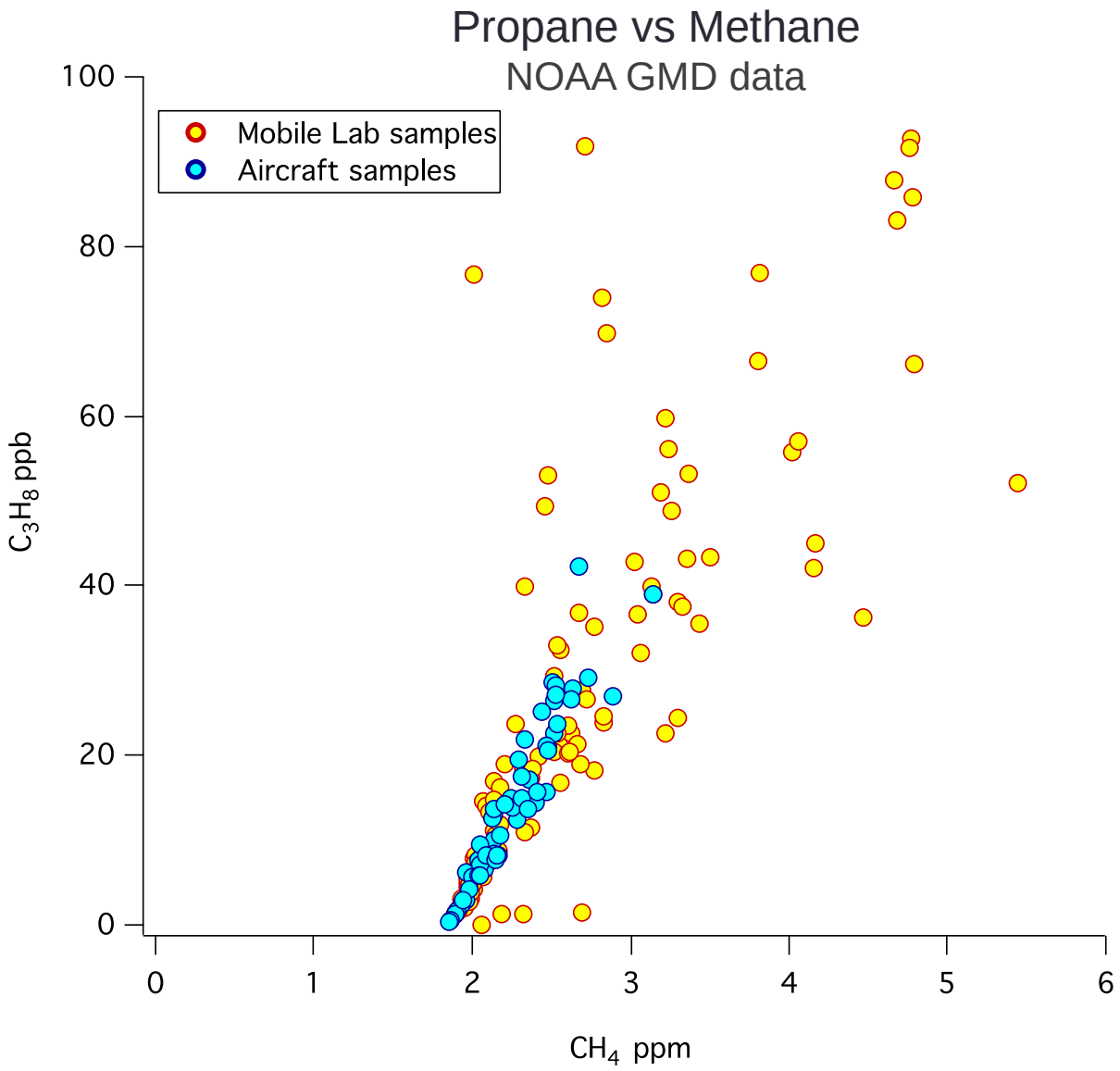
Airplane flask samples show that several hydrocarbons correlate well with CH_4



Uinta Basin, February 2012

One area source: oil and gas operations

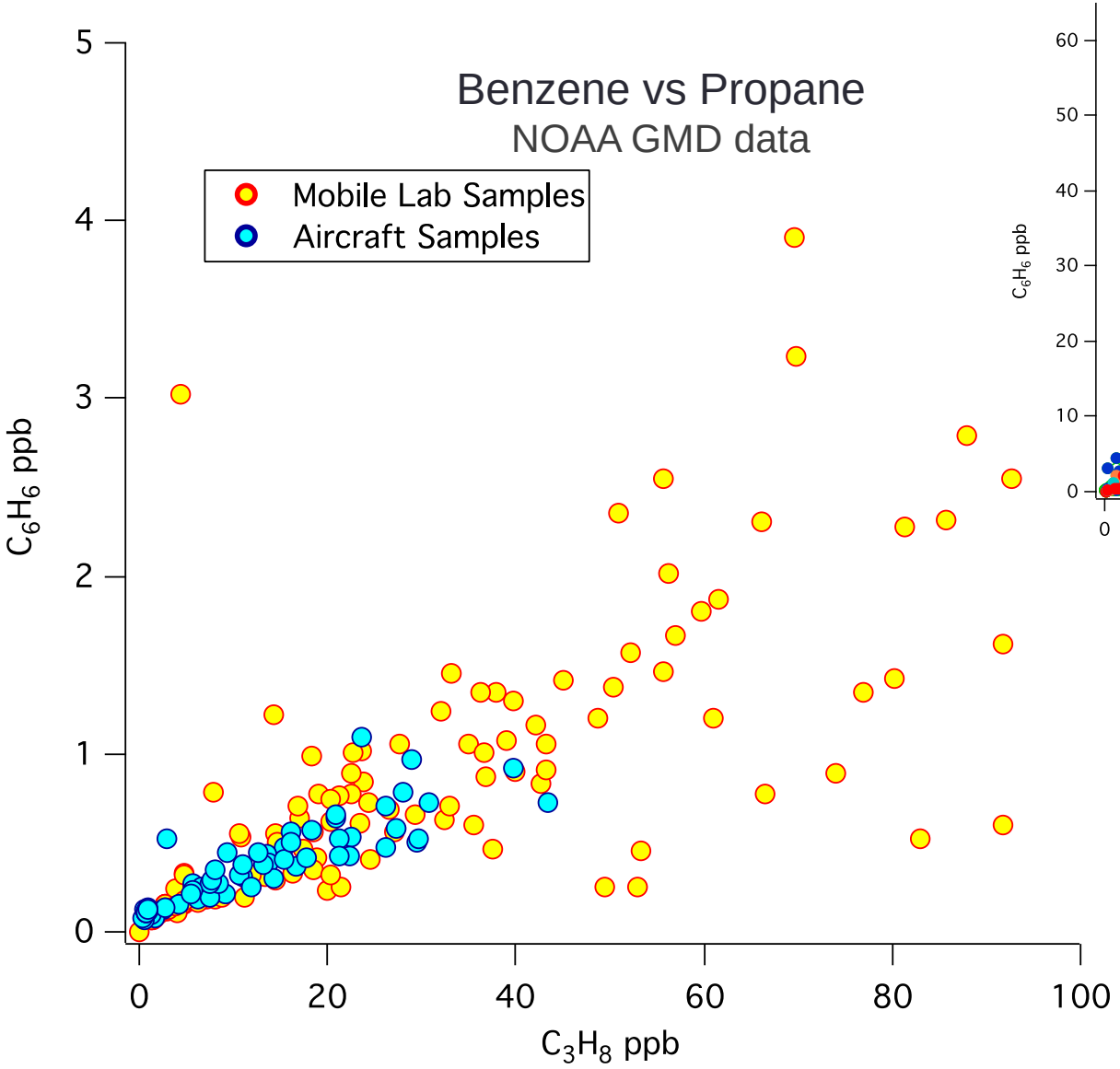
Discrete air samples measurements

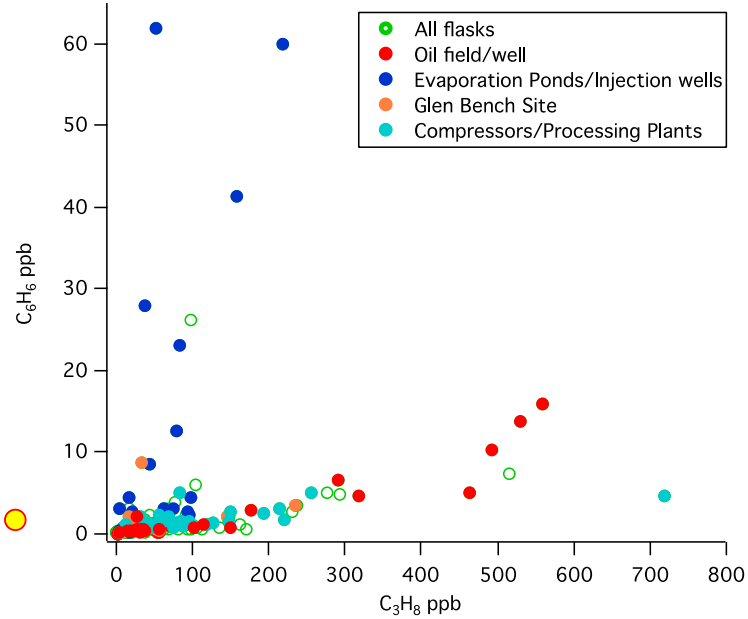


The Mobile Lab data show different chemical signatures depending on the point sources sampled.

The Aircraft data reflect more the overall mix of emissions in the region.

Discrete air samples measurements

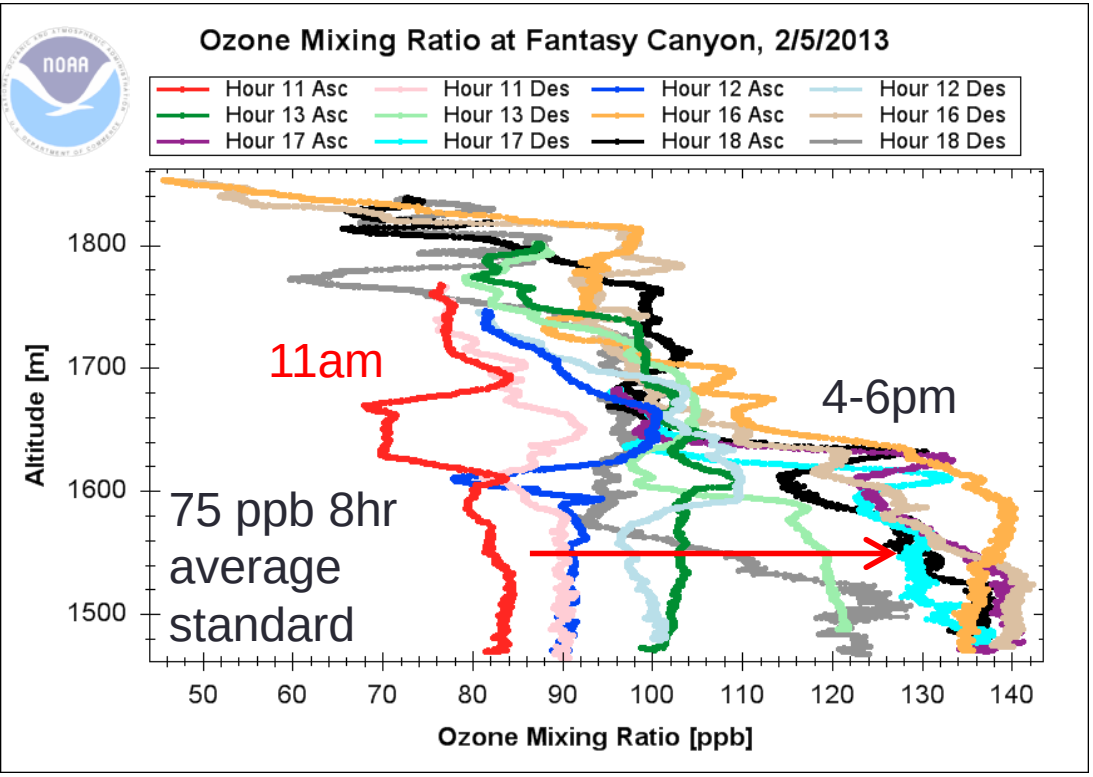


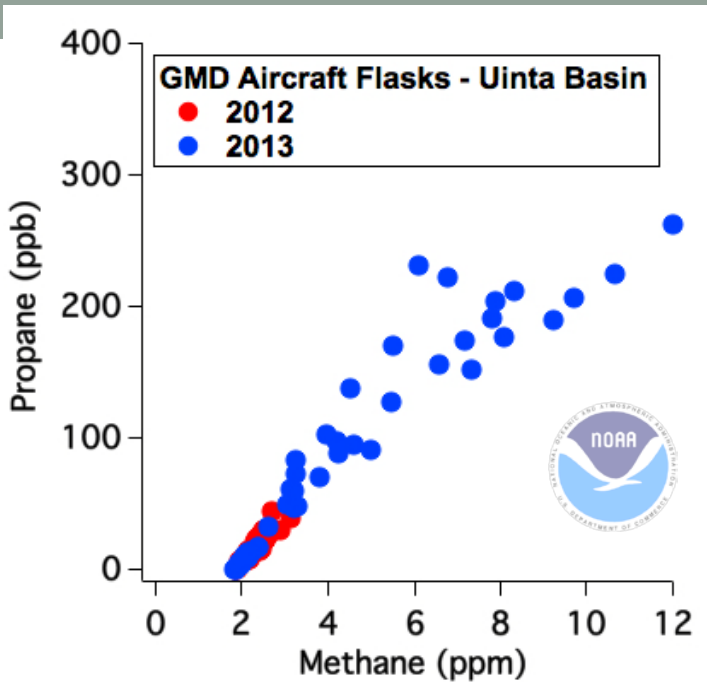


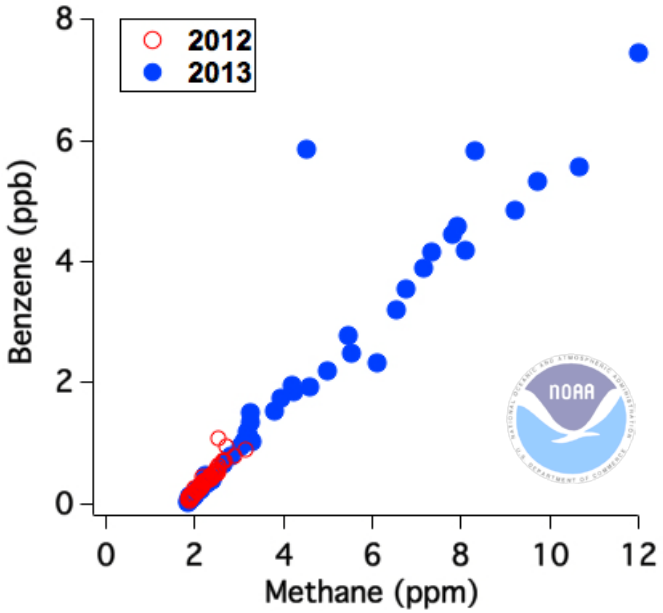
The Mobile Lab data show different chemical signatures depending on the point sources sampled.

The Aircraft data reflect more the overall mix of emissions in the region

Uinta Basin's record surface ozone - 2013



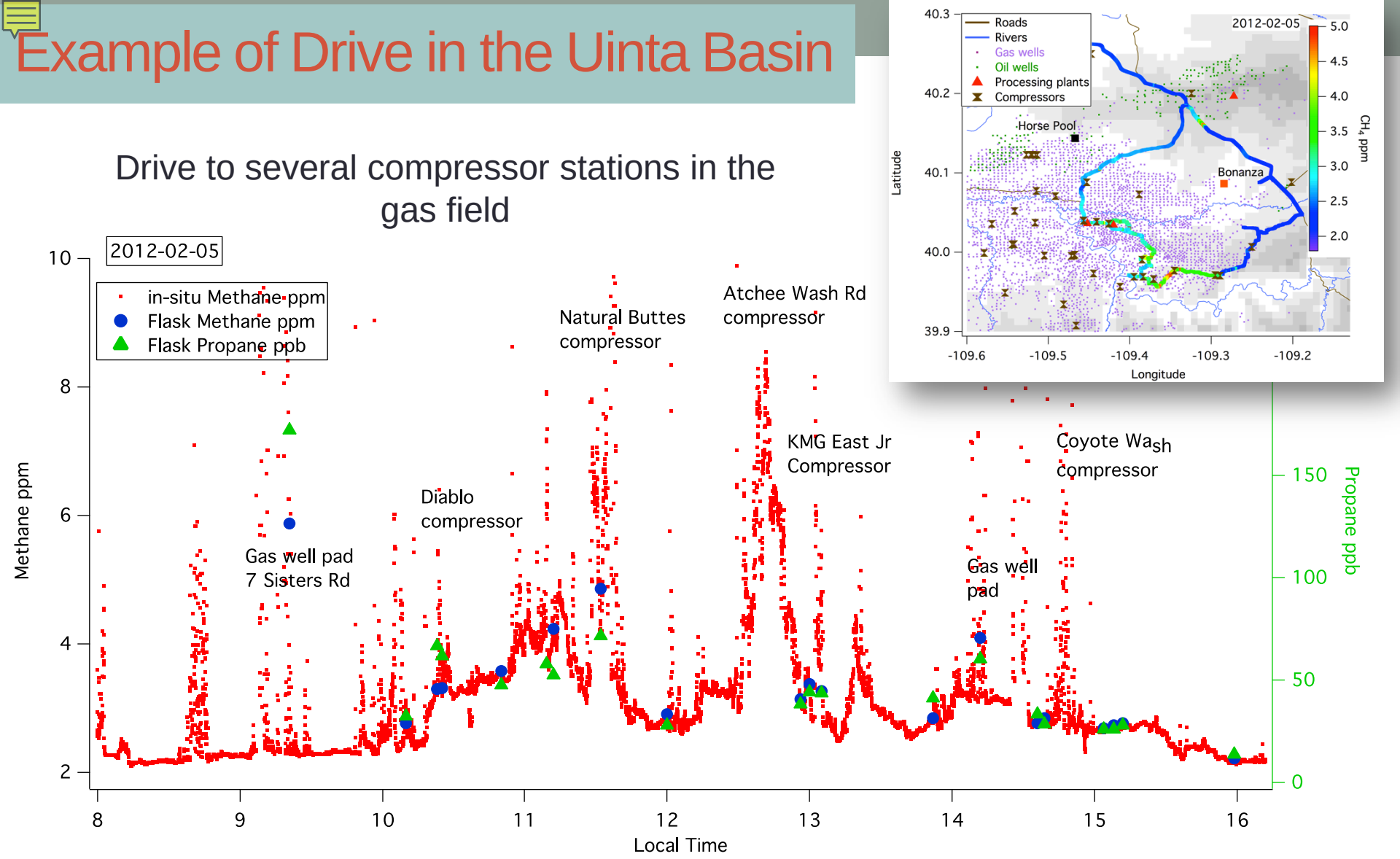




The Perfect Storm:

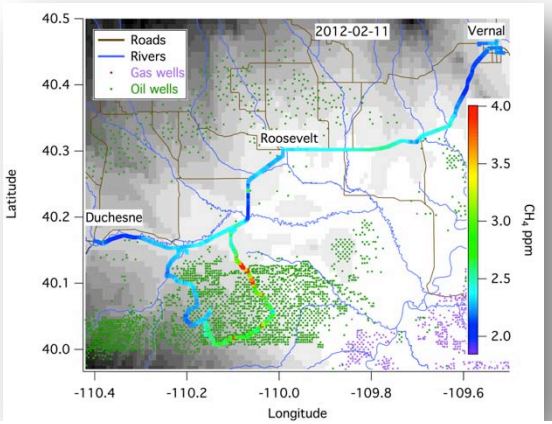
- High emissions of ozone precursors
- Snow covered ground (reflected UV)
- Shallow inversion layer

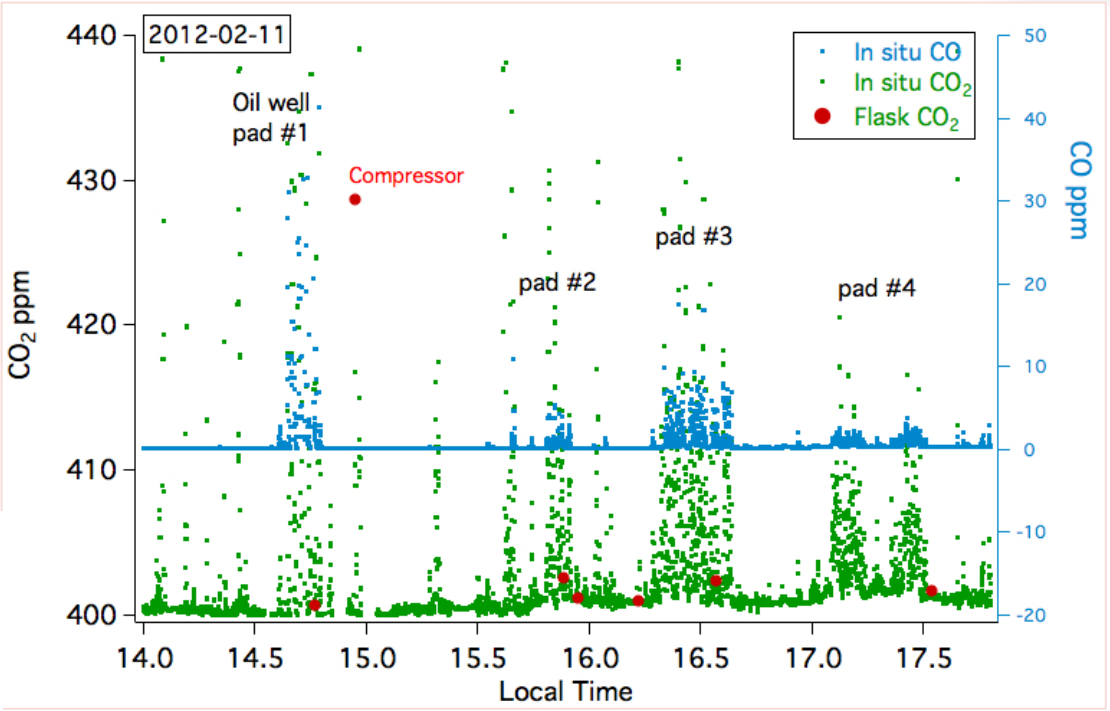
Example of Drive in the Uinta Basin

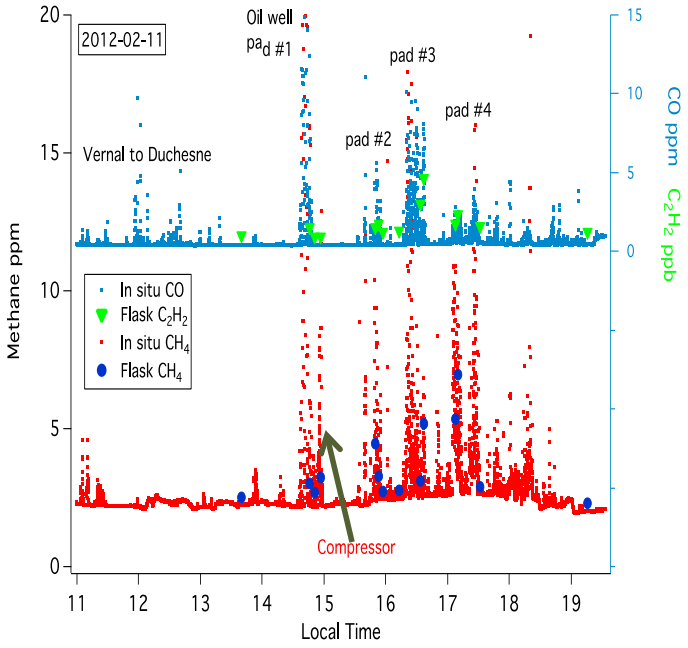


Fugitive emissions of natural gas are substantial at several locations in the oil & gas fields.

Example of drive in oil field, Duchesne County

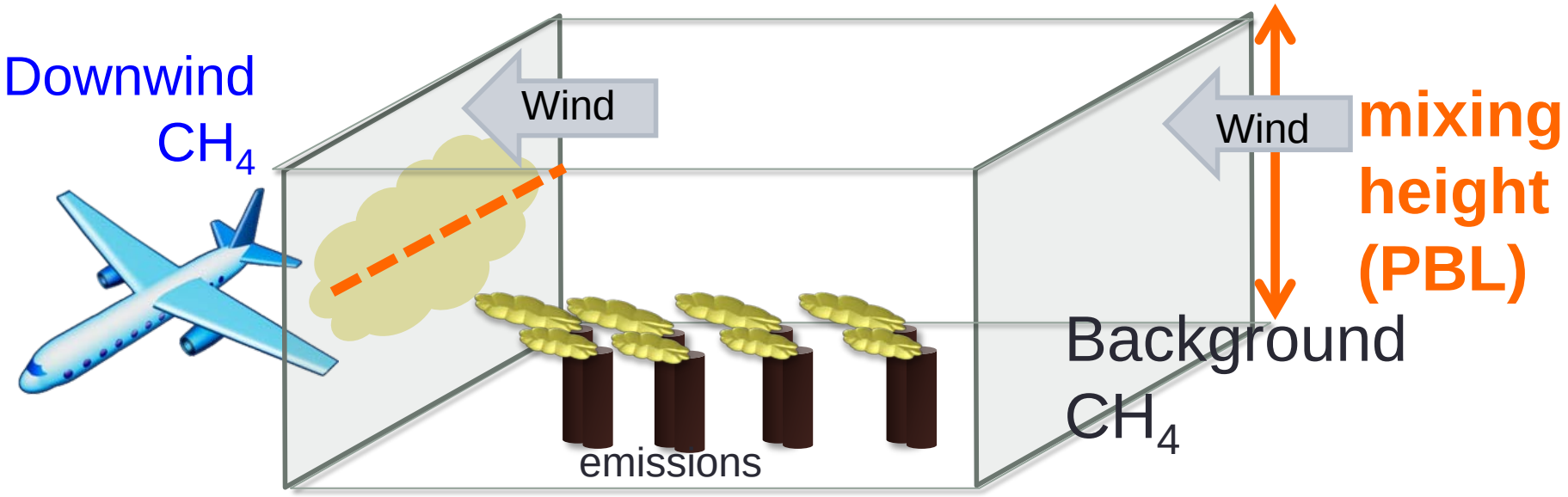






Molar ratio at Oil Pad #	CO/CO_2	$(CO_2+CO)/(CO_2+CO+CH_4)$
1	85%	81%
2	23%	80%
3	52%	79%
4	19%	58%

Aircraft Mass Balance Method



CH_4 flux

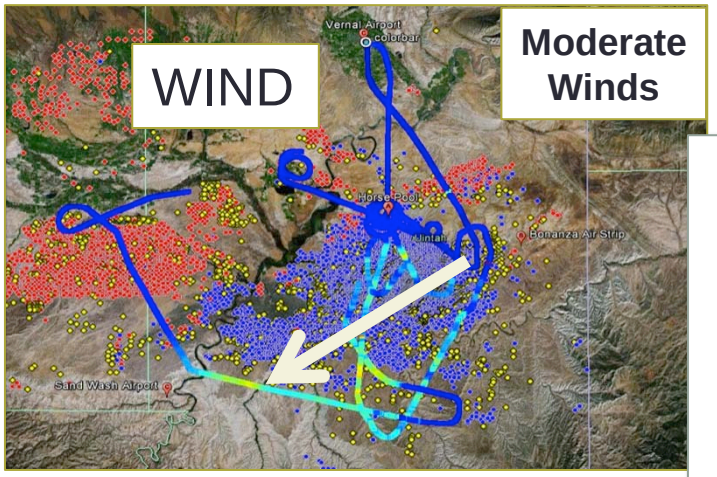
Molar CH_4 enhancement in PBL

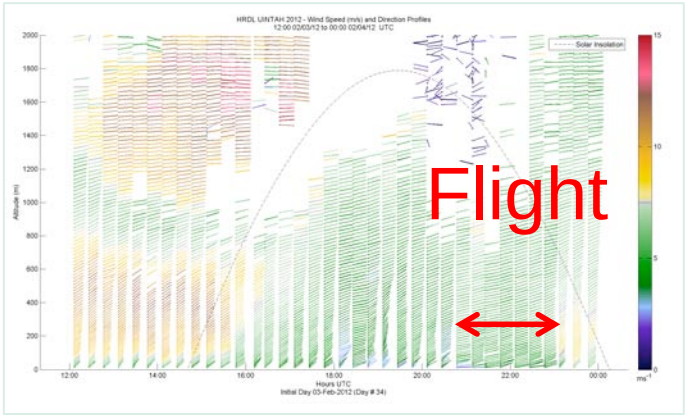
$$\dot{n}_{CH_4} = V\cos\theta \int_{-b}^{+b} \Delta X_{CH_4} \left(\int_{z_{gnd}}^{z_{PBL}} n_{air}\, dz \right) dx$$

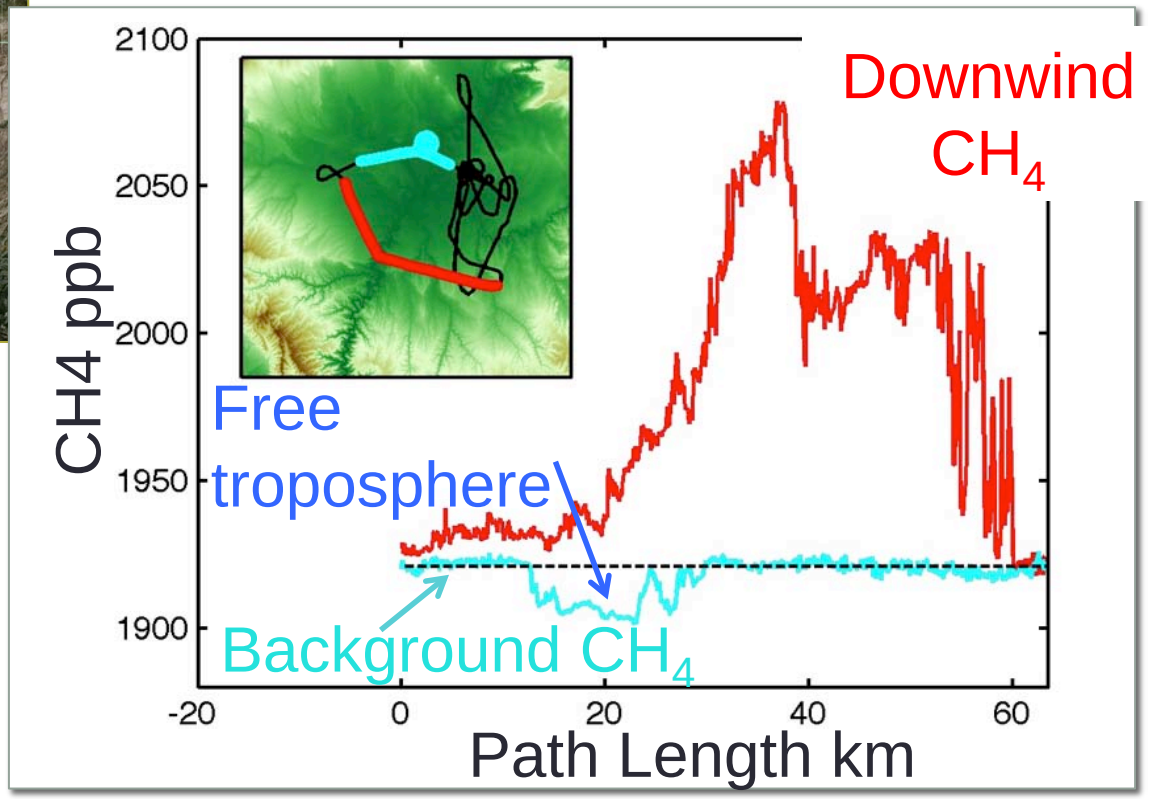
Perpendicular wind speed in PBL

References: White et al., 1976; Ryerson et al., 2001; Mays et al., 2009

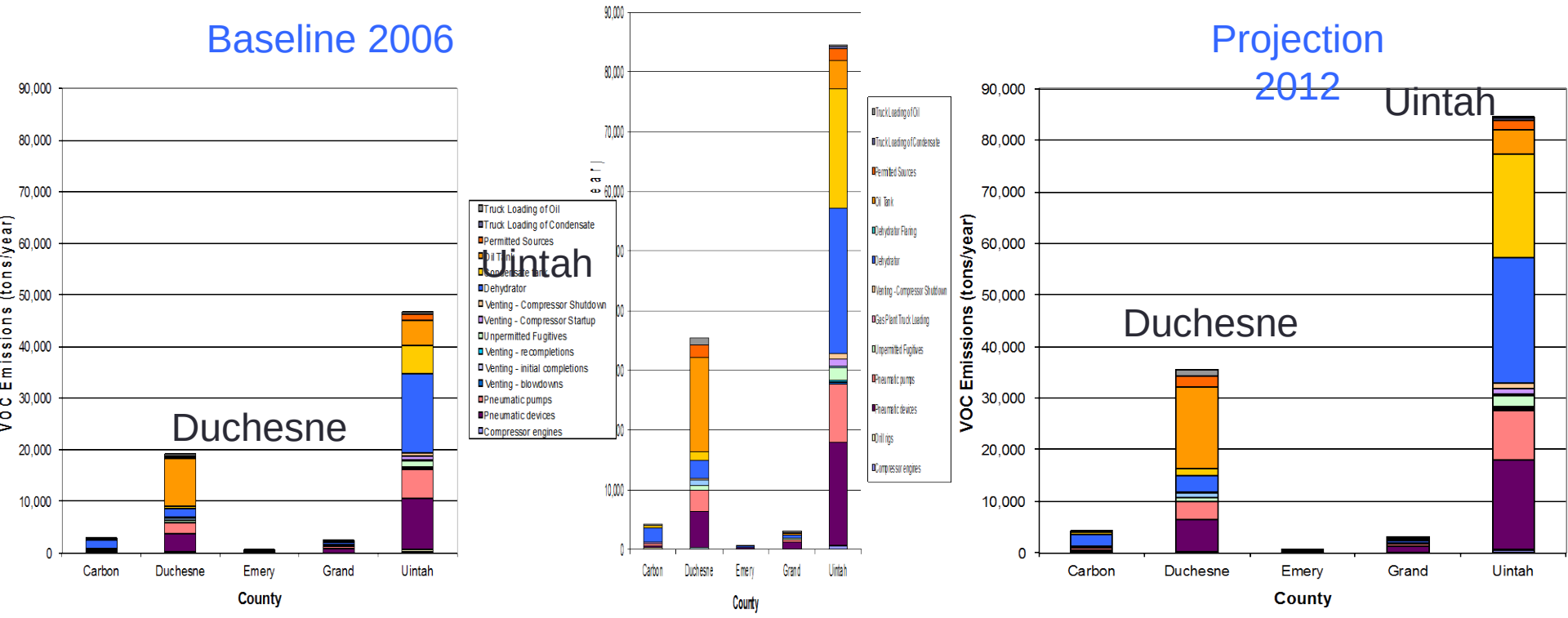
Utah February 3 ,2012







WRAP Phase III Bottom-up Inventories

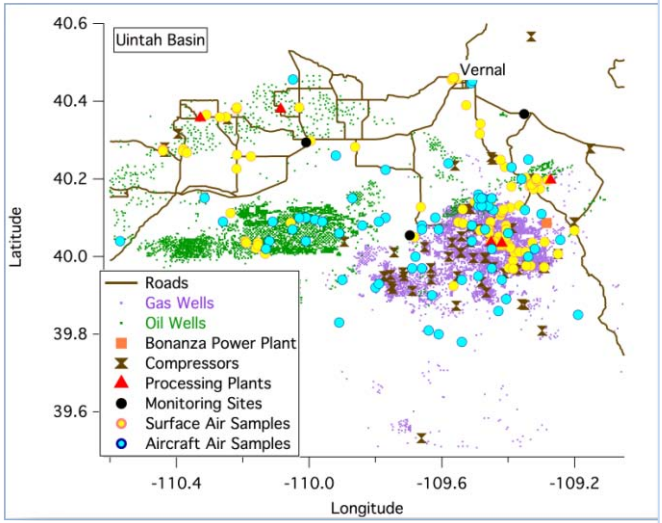


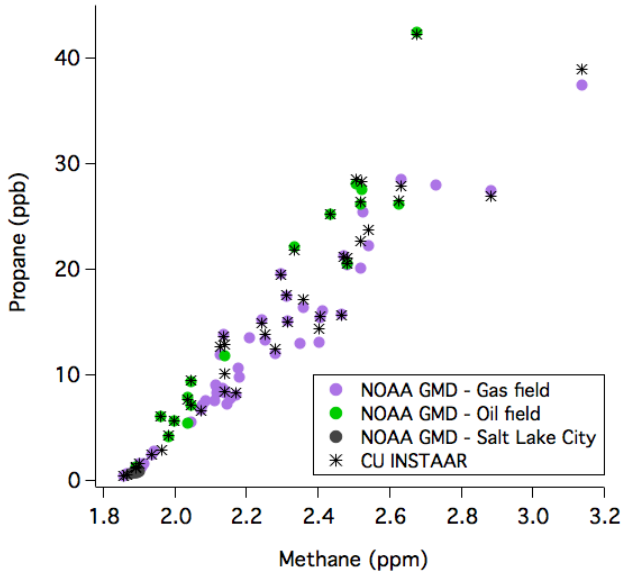
- 2006 Baseline inventory [Friesen et al., 2009] based on:
  - Reported activity levels
  - Surveys of industry operations

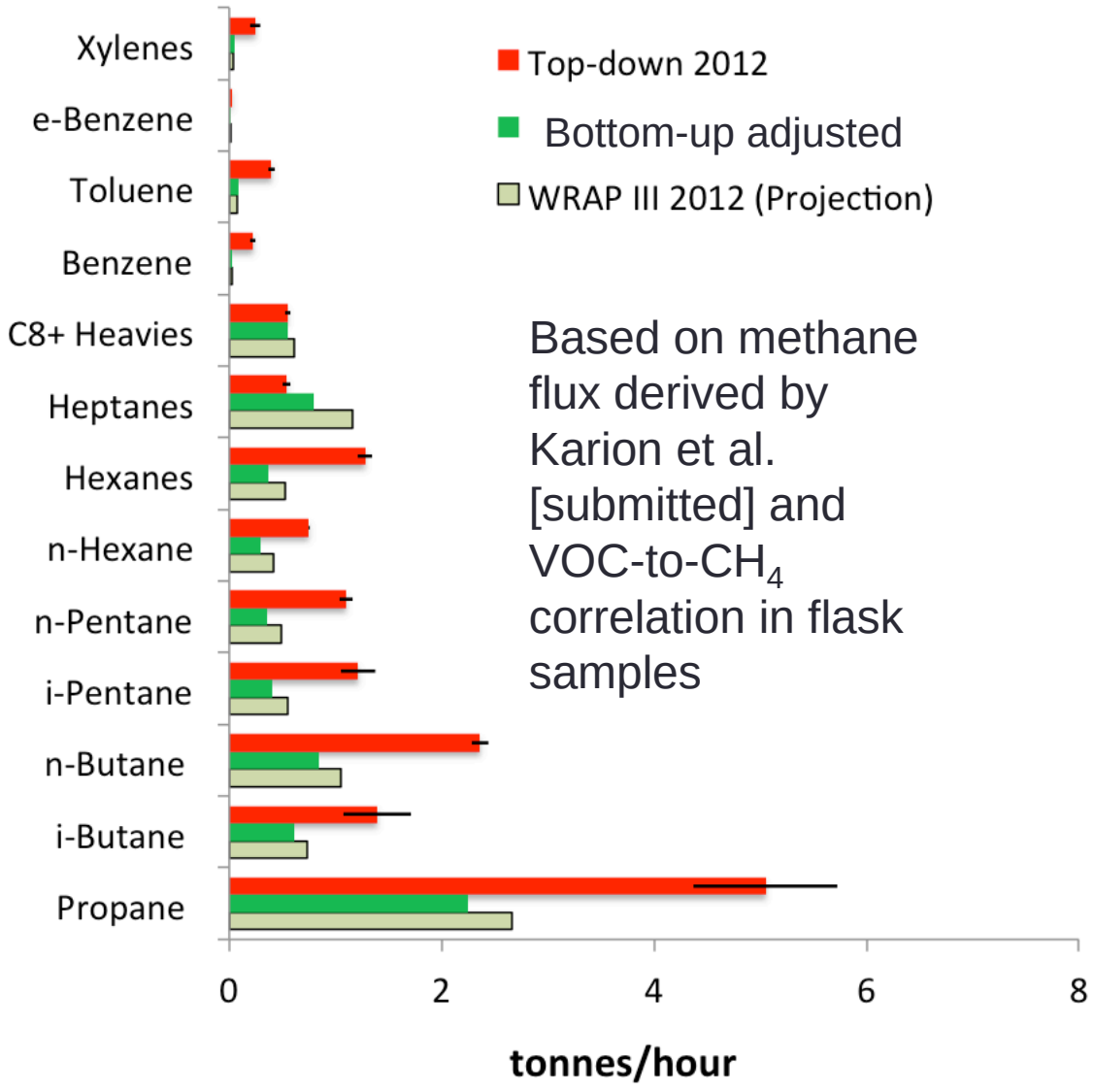
- 2012 Projection inventory [Bar-Ilan et al., 2009] based on:
  - 2006 Baseline inventory
  - Projected activity growth

Note: growth was likely over-estimated

Uinta County Emission Evaluation

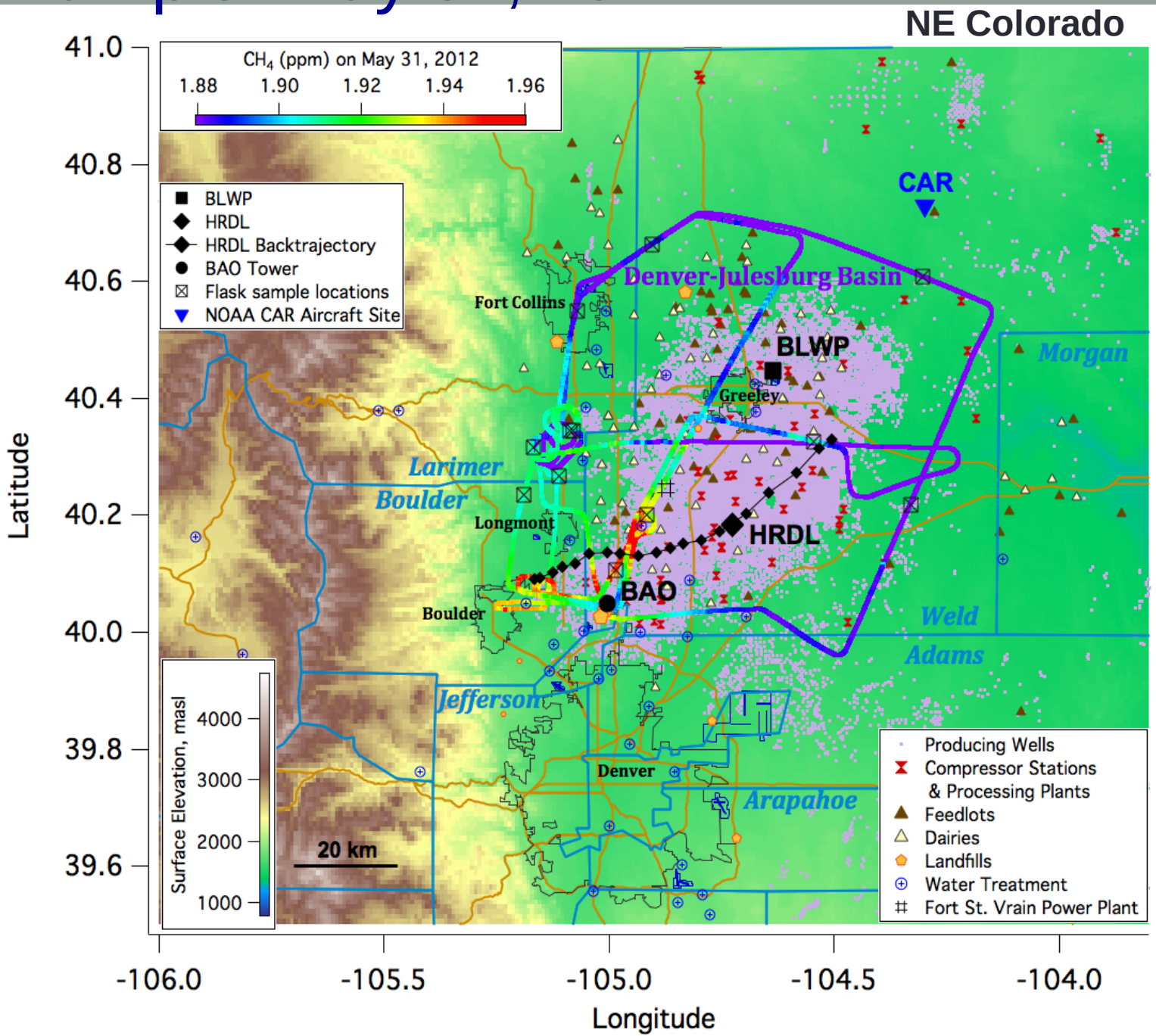






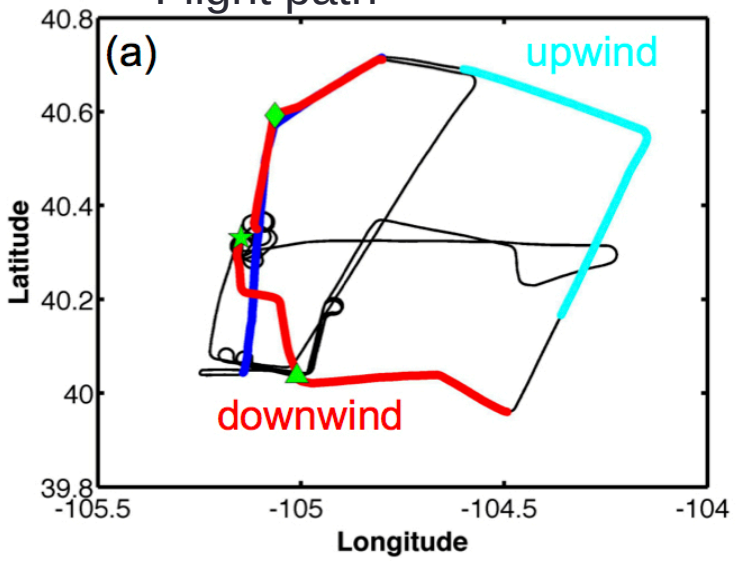
Based on methane flux derived by Karion et al. [submitted] and VOC-to-CH_4 correlation in flask samples

Example: May 31, 2012

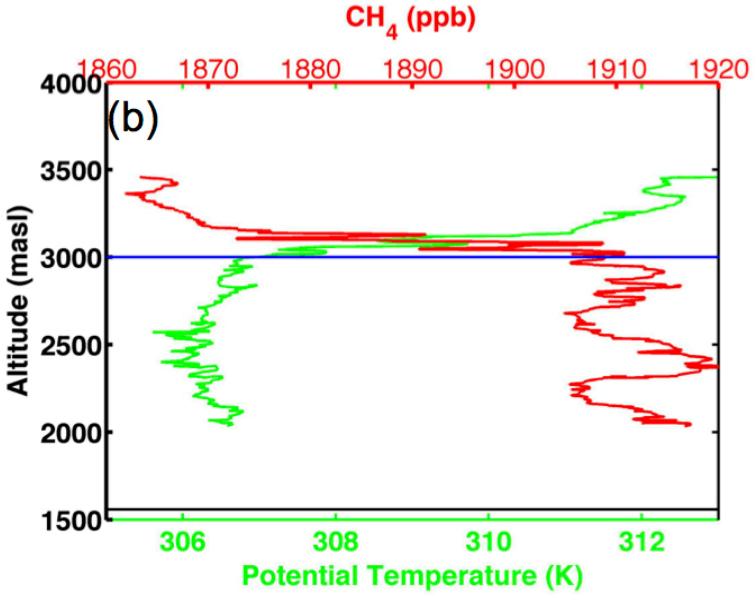


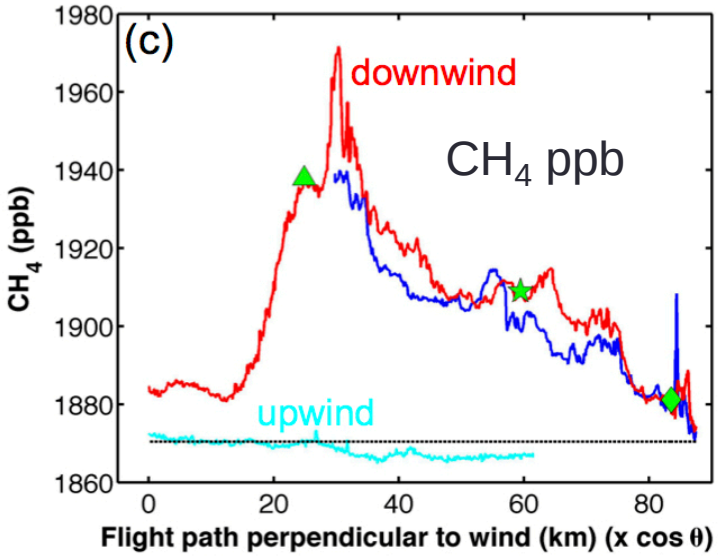
DJB Flight May 31, 2012

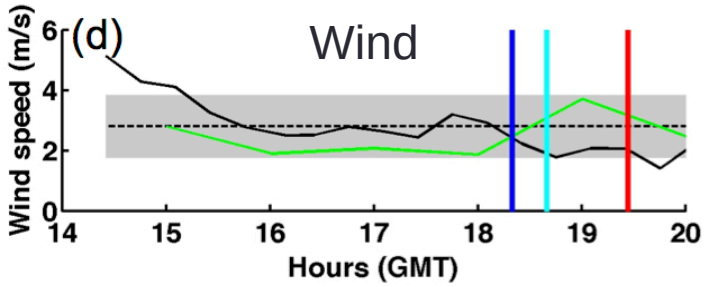
Flight path

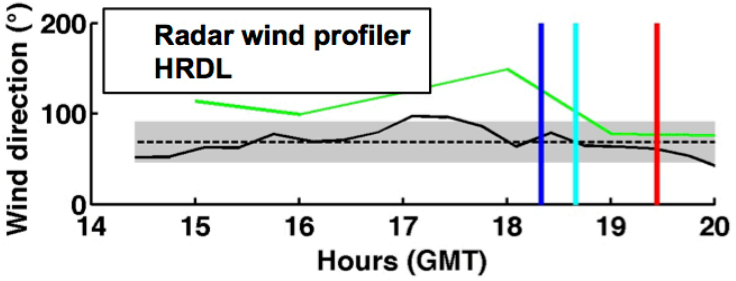


Vertical profile



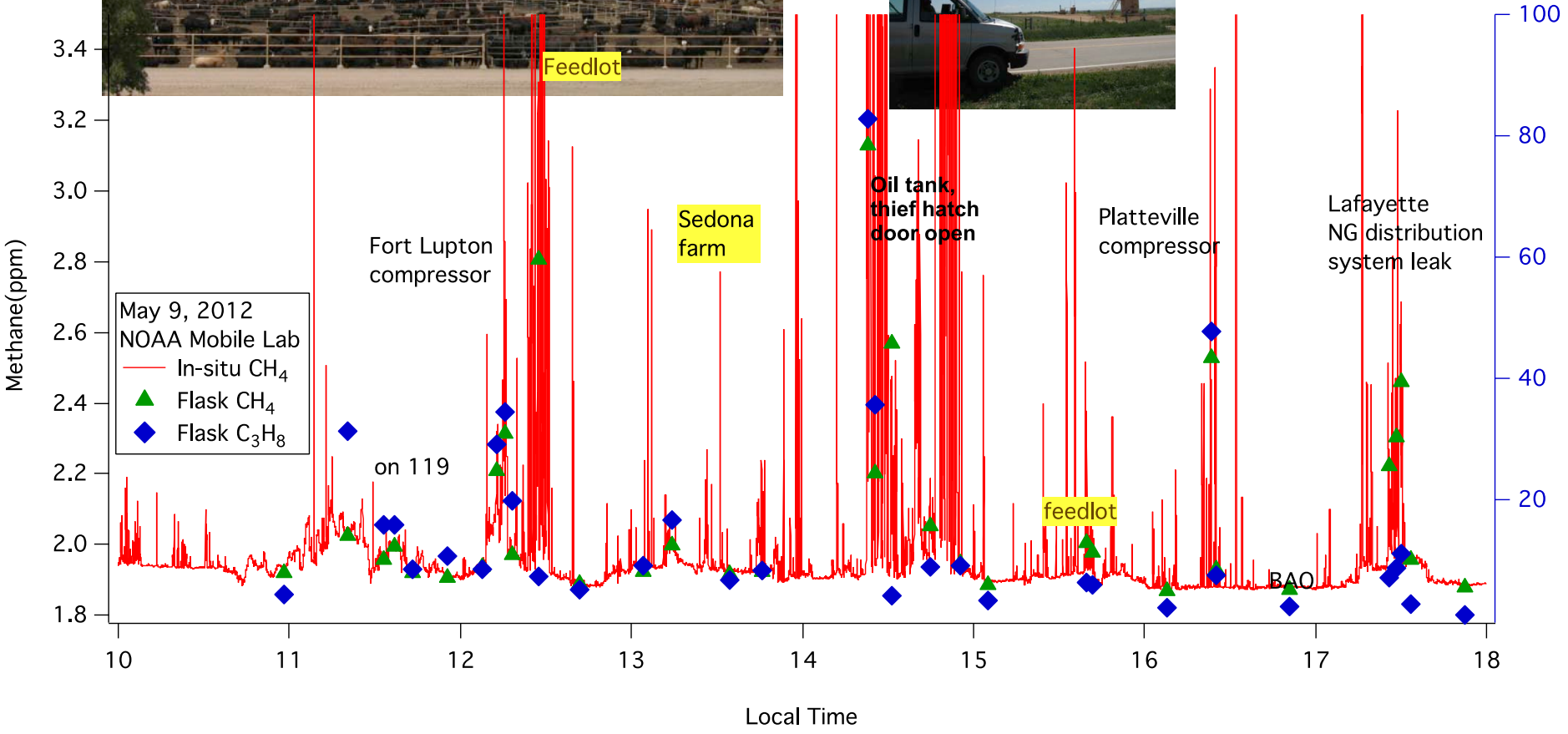






Petron et al., in prep

Open thief hatch door

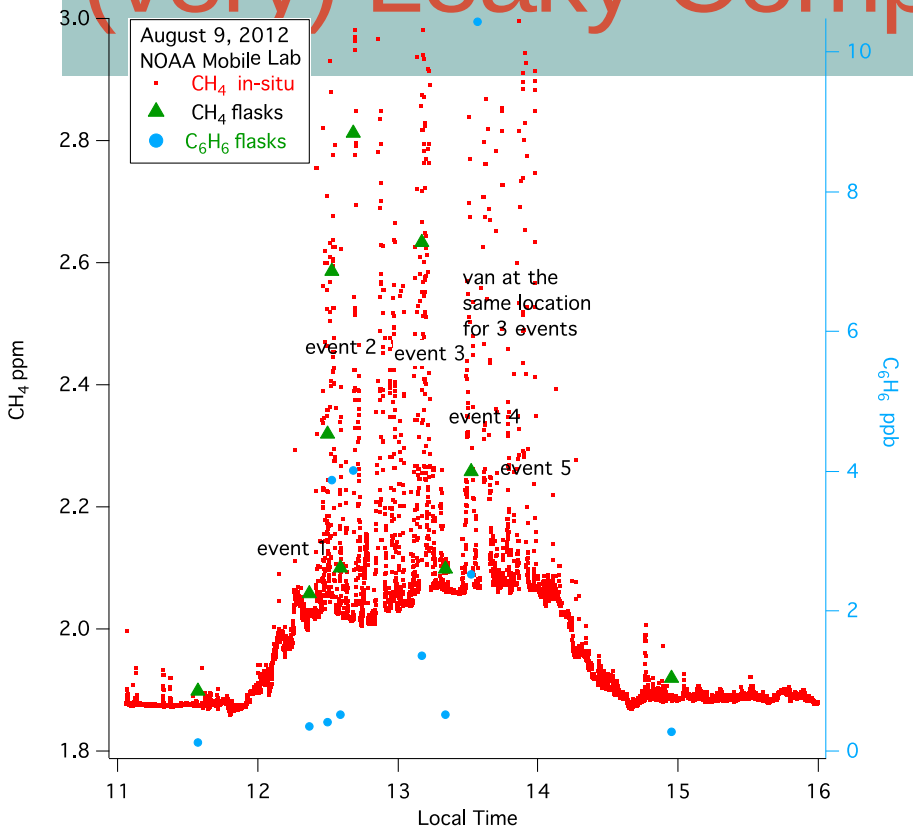


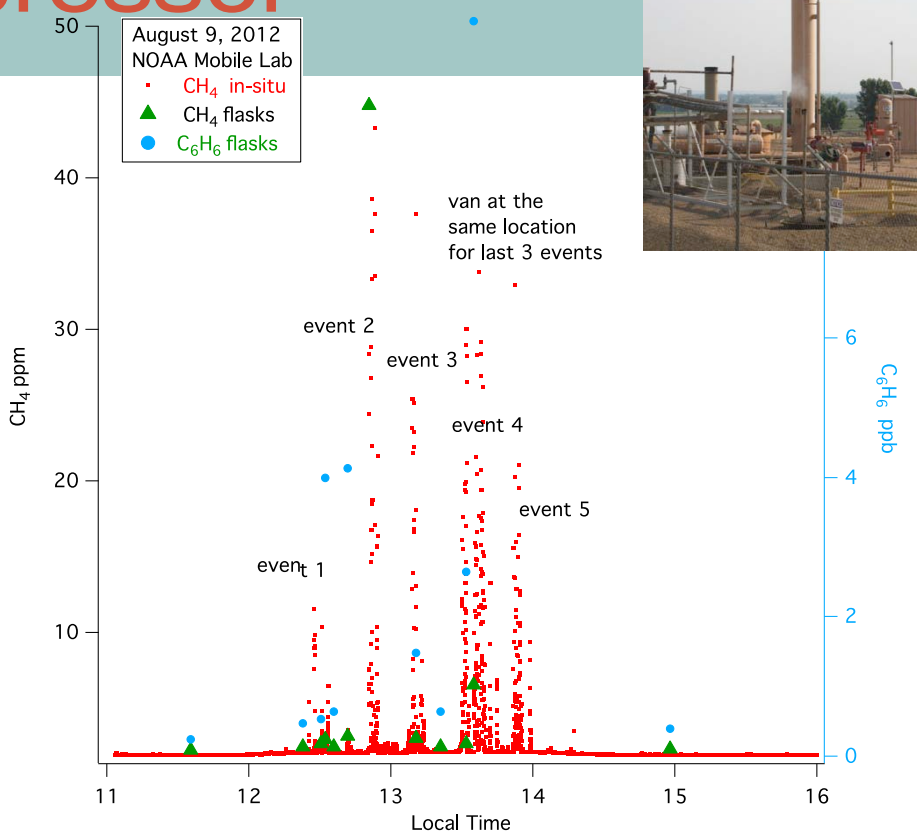
Enhanced methane (>2.2 ppm) near feedlots, compressor stations, oil tank with thief hatch door open... Which one has the largest detected signal?

Same time series – different methane scale

"System upsets" (accidents) do happen...

(very) Leaky Compressor





High levels have been measured downwind of this compressor on 3 different drives (July 27, 2011, August 9 2012, October 17 2012)

Key Emissions Data

Detailed source information

- Harmonized source categories for all pollutants from an industry and for all regions/years covered
- For each category:
  - Activity Data
    - Activity/equipment counts
    - Production data
  - Emissions Statistics
    - Distribution ~~Mean~~
    - Variability
  - Composition Profile
  - Controls or not
- Low threshold for permitting ensures inventory developers have information on small-medium facilities

➔Best knowledge & transparent bottom-up inventory

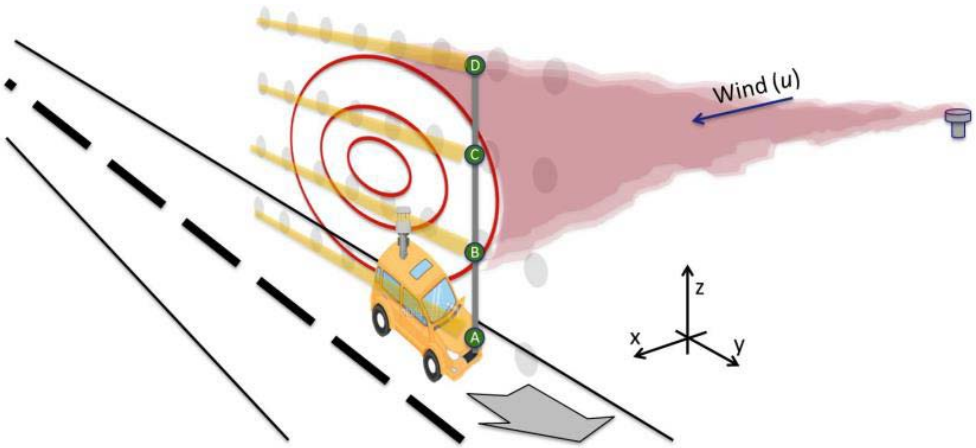
Expand on WRAP/WestJump work and include more atmospheric measurements to assess emissions statistics, aggregated emissions totals, mitigation effectiveness

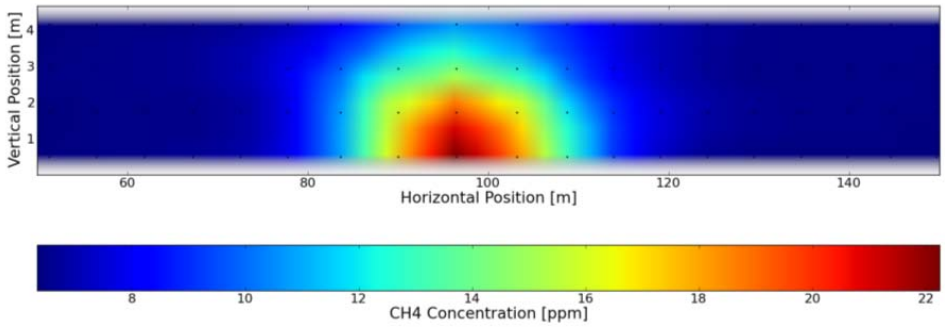
Summary

- Regional atmospheric studies of CH_4 and VOC emissions from oil and gas producing fields in CO and UT indicate that current inventories are too low by a factor of 2 to 3.
- Emissions to the atmosphere can vary greatly from one Basin to another depending on practices, regulations, composition of raw gas.
- There are large emitters in every field.
  - Why do they leak more than the rest? (age, maintenance level,…)
  - How much do they contribute to the total?
  - Are existing LDAR techniques effective at finding them and verifying repairs?
- Atmospheric measurements from vehicle and aircraft platforms are a reliable and quantitative method to detect leaks and estimate emissions.
- More research should be conducted to explore the full potential of these techniques for different scales and assess how they could effectively supplement existing leak detection and repair programs.

Emitters Statistics: Picarro Plume Scanner

Tracy Tsai
& Eric Crosson



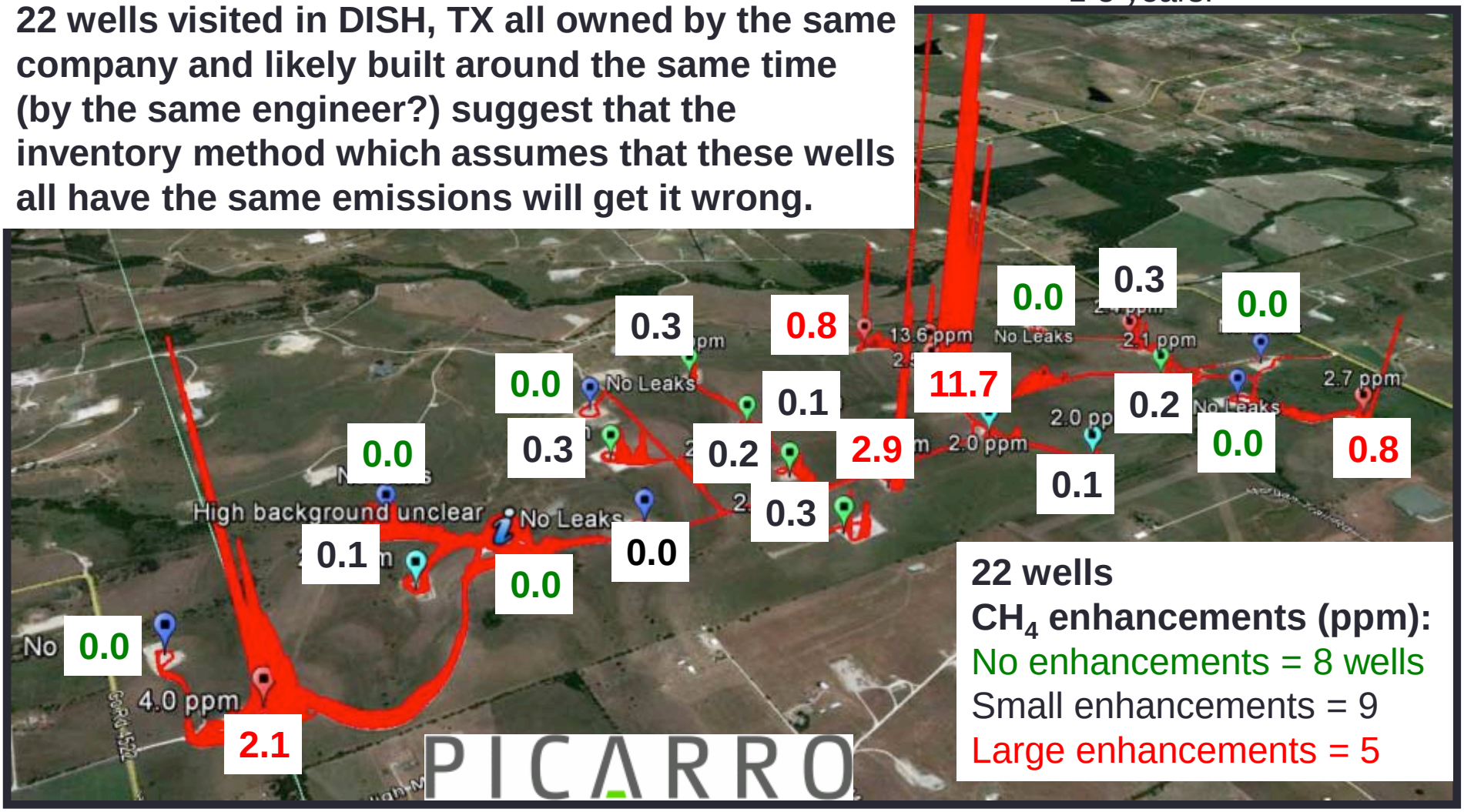


PICARRO

Where are the big leaks ?

Well pads are typically inspected by State every 1-5 years.

22 wells visited in DISH, TX all owned by the same company and likely built around the same time (by the same engineer?) suggest that the inventory method which assumes that these wells all have the same emissions will get it wrong.



22 wells
CH_4 enhancements (ppm):
No enhancements = 8 wells
Small enhancements = 9
Large enhancements = 5

Eric Crosson, Picarro Inc,
Colm Sweeney, NOAA, 2013