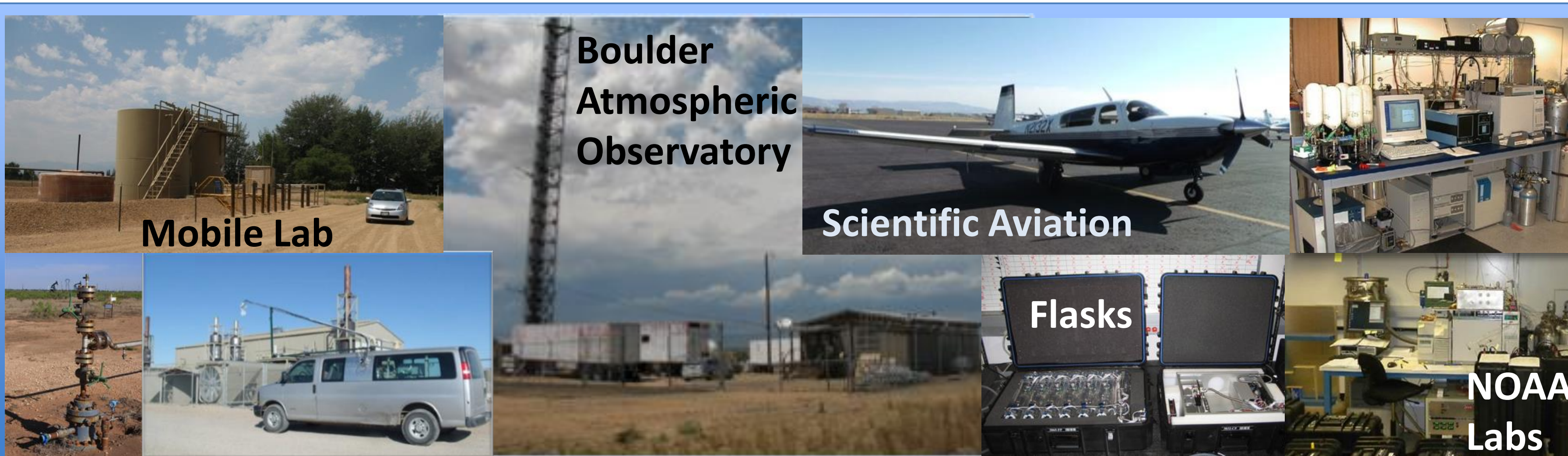
Implications of Top-Down Atmospheric Measurements in Oil and Gas Basins



Gabrielle Pétron and many colleagues

NOAA Global Monitoring Division

University of Colorado Cooperative Institute for Research in Environmental Sciences

Boulder, Colorado

Gabrielle.Petron@noaa.gov

AirWaterGas

Sustainability Research Network

NOAA

University of Colorado Boulder

RPSEA Research Partnership to Secure Energy for America

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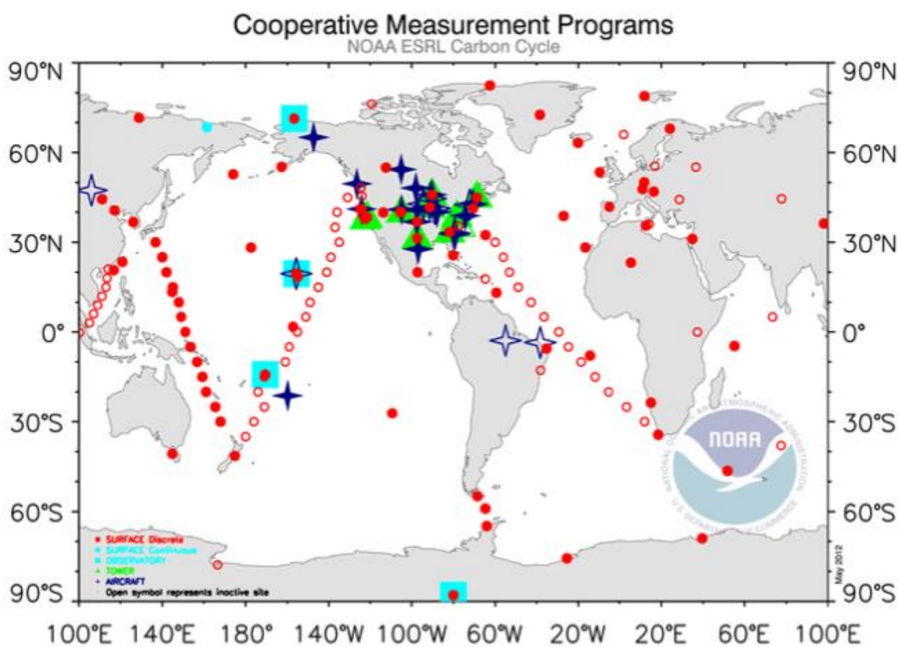
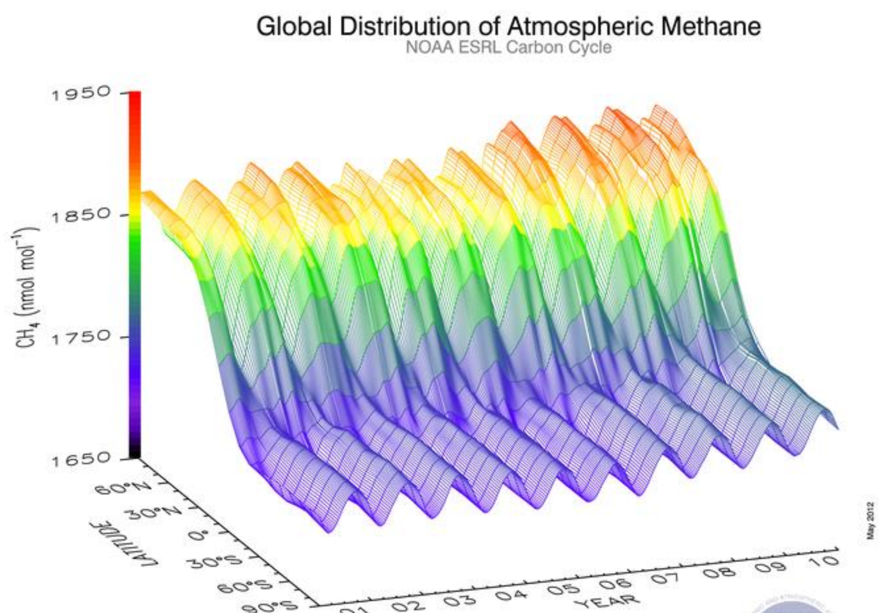
Global methane (CH_4) monitoring

- Lifetime ~ 9-10 years
- Potent GHG, GWP: 28 /100 years and 84 /20 years (IPCC 2013
- Background in northern hemisphere ~ 1850 ppb
- NOAA measurement uncertainty ±1ppb
- 17% of total direct radiative forcing from long-lived GHG in 2013

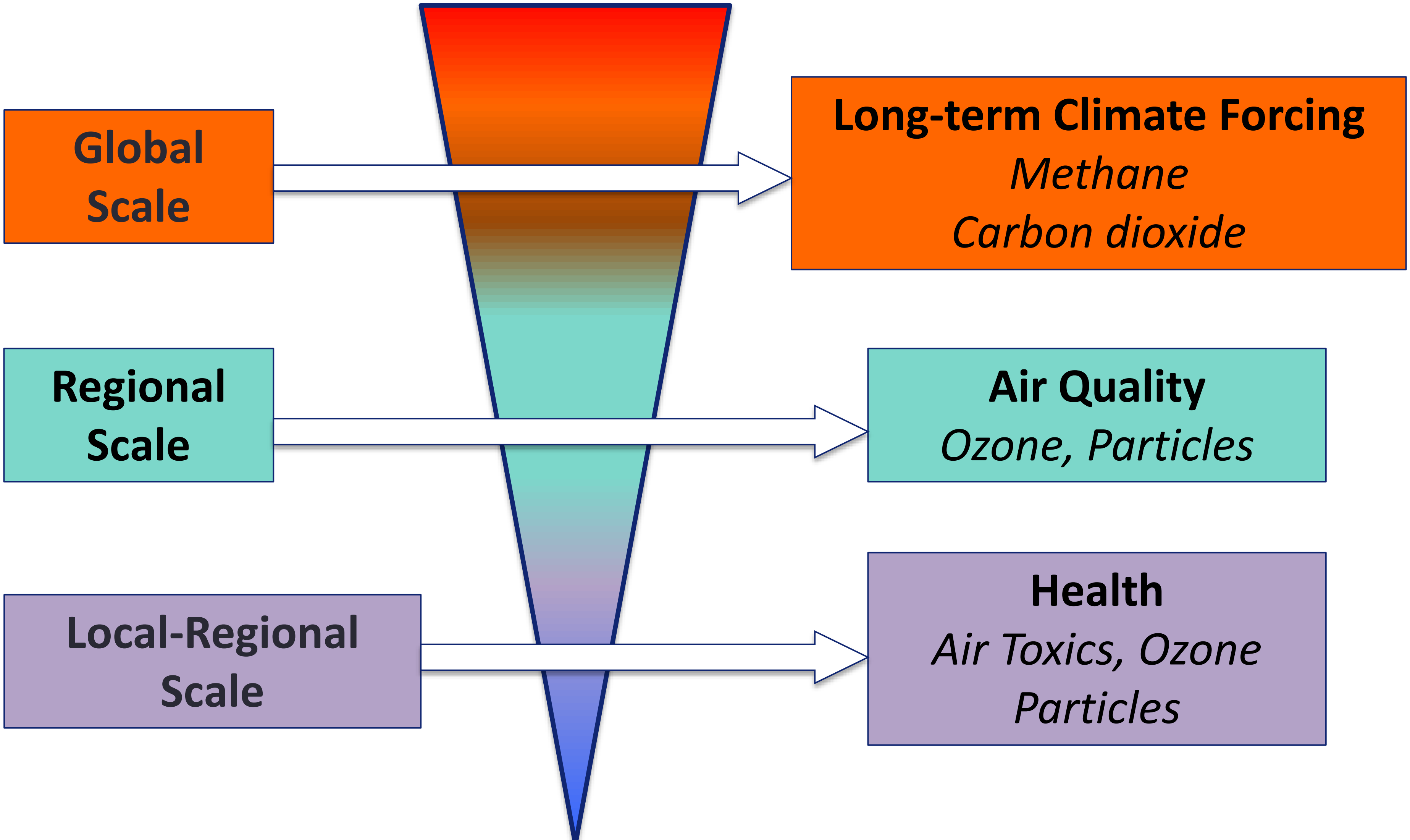


NOAA ESRL Carbon Cycle operates 4 measurement programs. Semi-continuous measurements are made at 4 baseline observatories, a few surface sites and from tall towers. Discrete surface and aircraft samples are measured in Boulder, CO. Presently, atmospheric carbon dioxide, methane, carbon monoxide, hydrogen, nitrous oxide, sulfur hexafluoride, the stable isotopes of carbon dioxide and methane, and halocarbon and volatile organic compounds are measured. Contact: Dr. Pieter Tans, NOAA ESRL Carbon Cycle, Boulder, Colorado, (303) 497-6678, pieter.tans@noaa.gov, http://www.esrl.noaa.gov/gmd/ccgg/.



Three-dimensional representation of the latitudinal distribution of atmospheric methane in the marine boundary layer. Data from the Carbon Cycle cooperative air sampling network were used. The surface represents data smoothed in time and latitude. Contact: Dr. Ed Dlugokencky, NOAA ESRL Carbon Cycle, Boulder, Colorado, (303) 497-6228, ed.dlugokencky@noaa.gov, http://www.esrl.noaa.gov/gmd/ccgg/.

Potential air impacts of emissions at various scales



U.S. NG Systems: A large infrastructure

U.S. Statistics:
EIA, DOT, OGJ

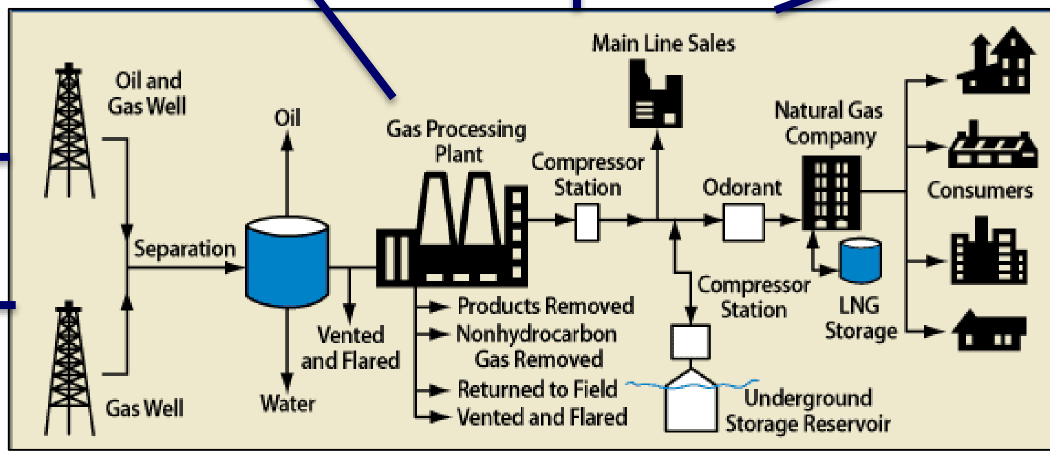
~ 500 processing plants

300,000 miles of transmission pipelines

> 1400 compressor stations

20,000 miles of gathering pipelines

>1 million oil and gas wells in US



DOE EIA

2,000,000 miles of distribution pipeline

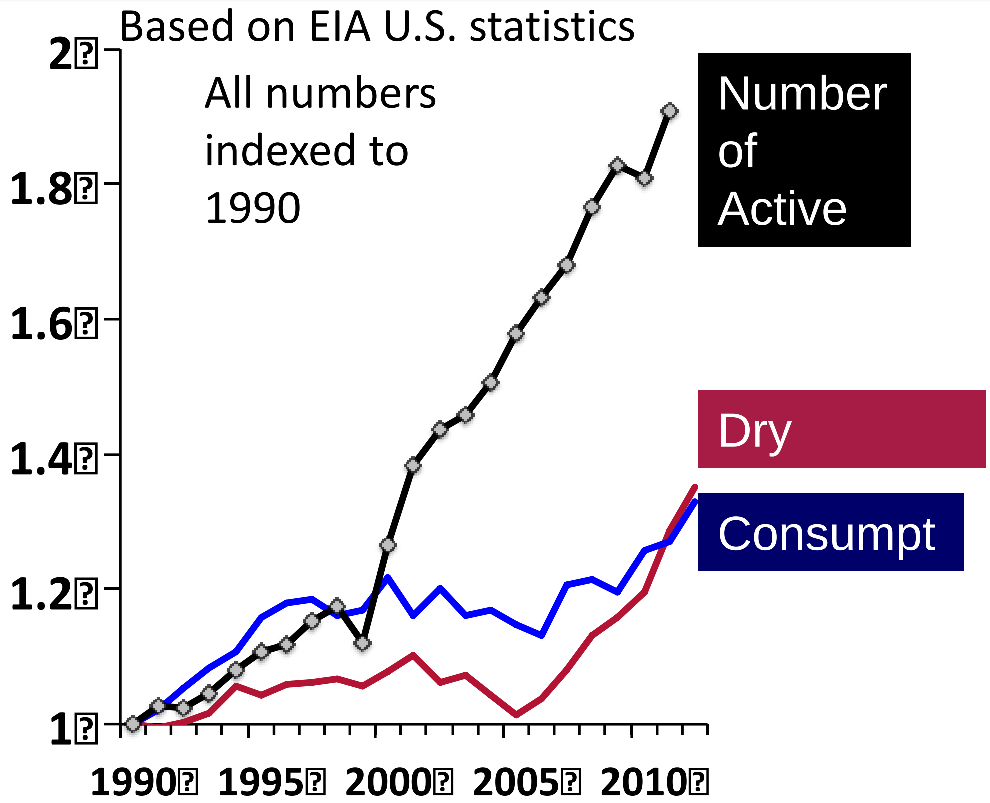
400 underground storage sites

Production → **Processing** → **Transmission** → **Distribution**

Raw Natural Gas > 70% methane in volume

Processed Natural Gas > 90% methane in volume

Multiplication of surface operations



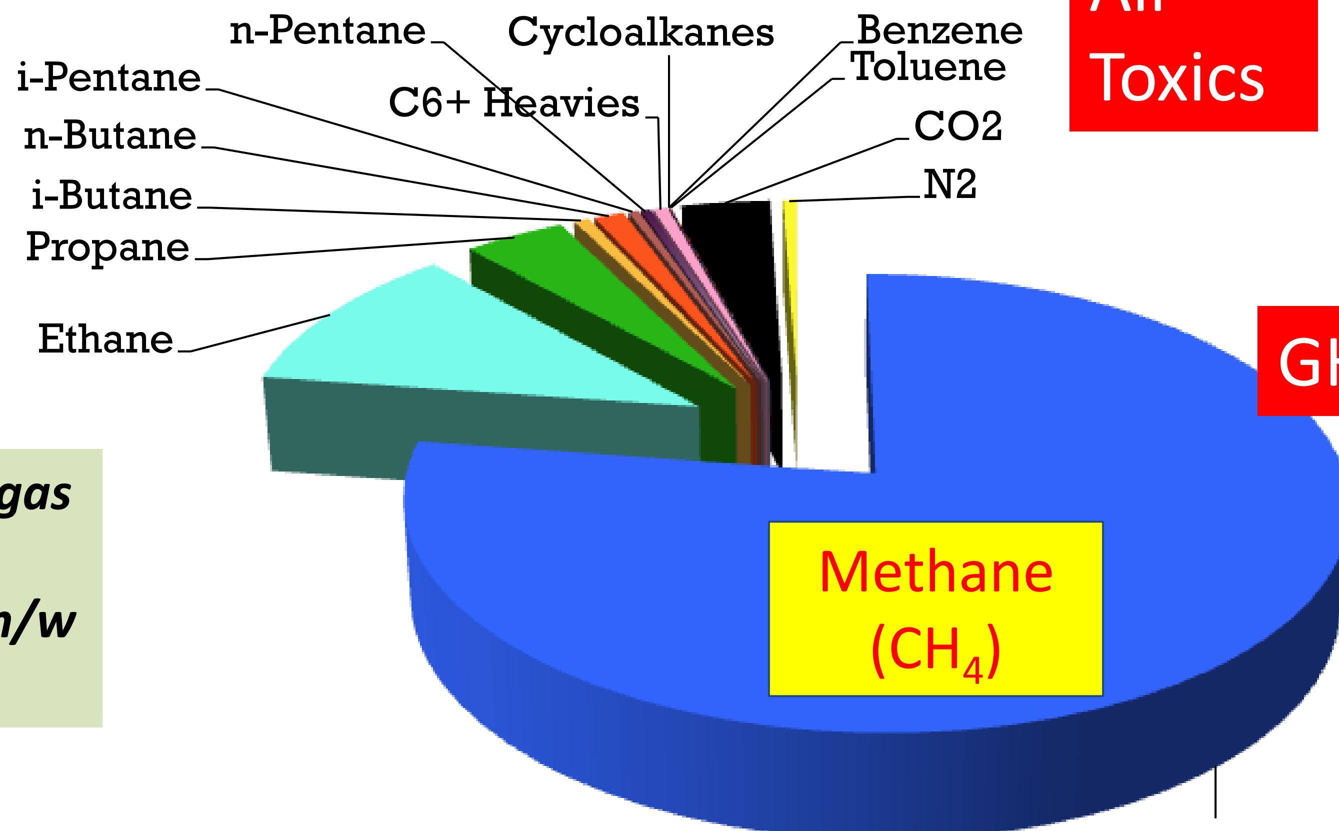
Well Pads Activities & Equipment:
Road/Pad construction
Well drilling and stimulation
Well head
Dehydrators
Separators
Liquid Storage Tanks
Additives (Methanol)
Servicing by trucks (oil, water)
Workover, Restimulation
Midstream Sector:
Pipelines
Compressor Stations
Processing Plants

What's in natural gas?

Surface ozone precursors

NGLs

Composition of gas varies from one basin/formation/well to another.



Air Toxics

GHG

Produced "raw gas" is composed of 70-90% methane

Distribution gas is >90% methane

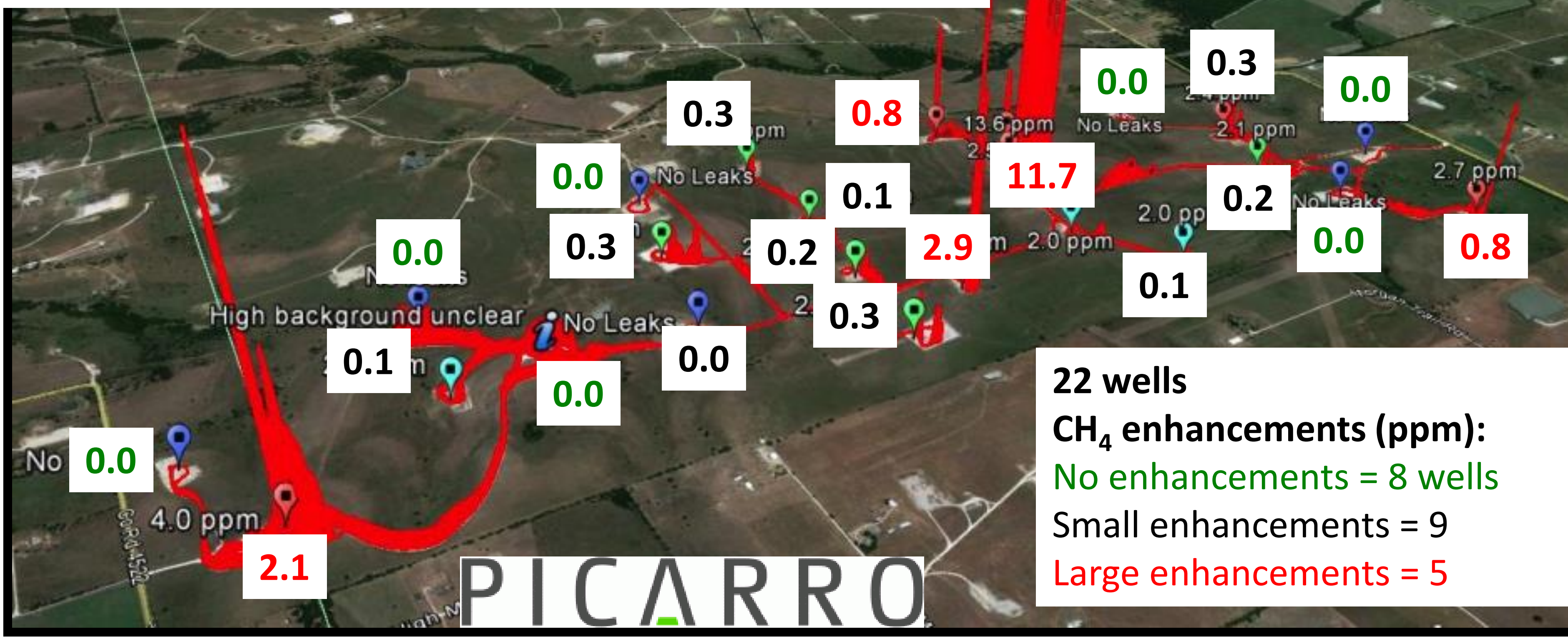
Emissions Assessment Tools
Inventory Approach

- Scalable, “easy” to update, information at process-level needed to prioritize mitigation efforts
- Components:
  - Activity Data
    - Not clear how accurate/up-to-date some of them are
      - Ex: pneumatic devices (comparing GHGRP 2012 reported emissions)
  - Emission Factors and Emissions Speciation Profiles
    - Many are old and based on a few snapshot measurements or model results
    - Assumes Gaussian distribution of emissions around a “mean value”
  - Emission Controls and their Actual Effectiveness
    - 2012: Colorado reevaluated the capture efficiency of oil/condensate tanks vapor recovery systems (100% to 75%) but Where is “true” problem?
    - Green completion required for gas wells (what about associated gas and oil wells?)

Is there a gross emitter problem ?

Are existing LDAR programs sufficient?

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.

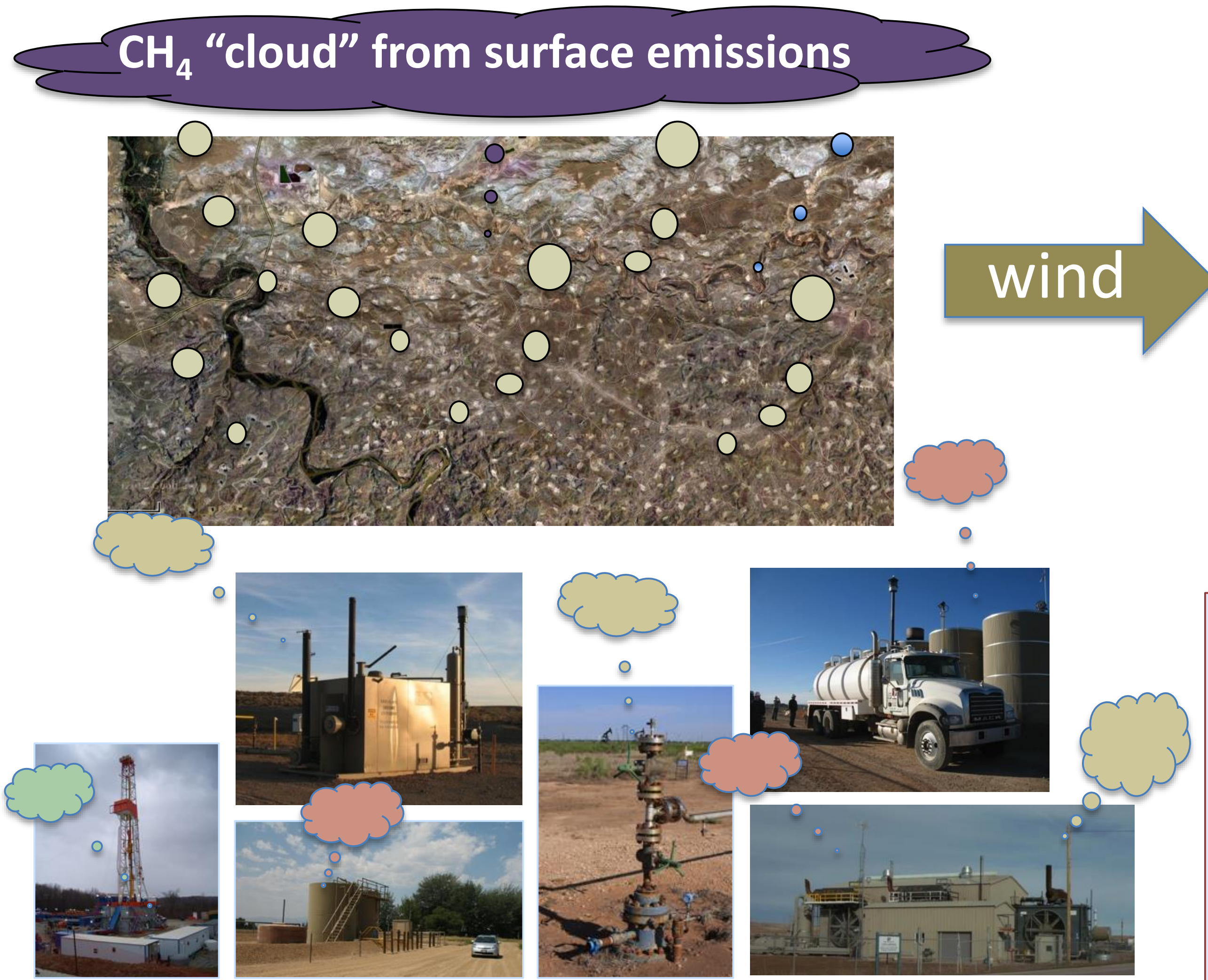


Eric Crosson, Picarro Inc,
Colm Sweeney, CU, 2013

Atmospheric studies: Top-Down Approach

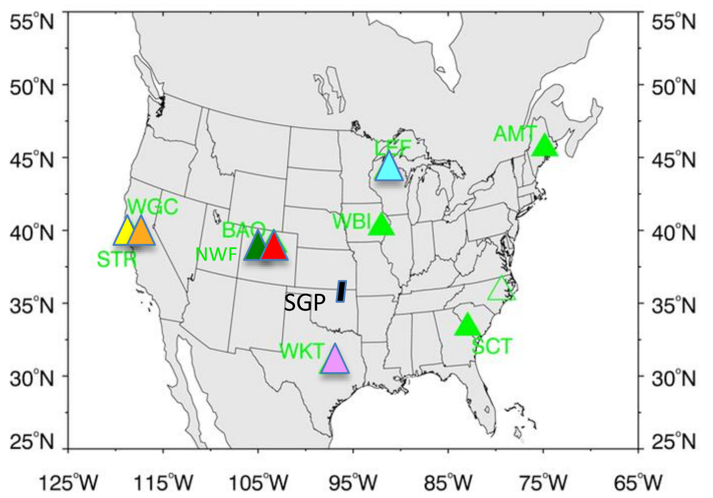
- Target questions: GHG, CAPs, HAPs
  - **Emissions**
  - Ambient levels
  - Chemistry
  - Dispersion
- Tools:
  - In situ measurements and sampling
  - Remote Sensing (Satellites)
  - Forward and Inverse modeling

Can we detect NG emissions in the atmosphere?

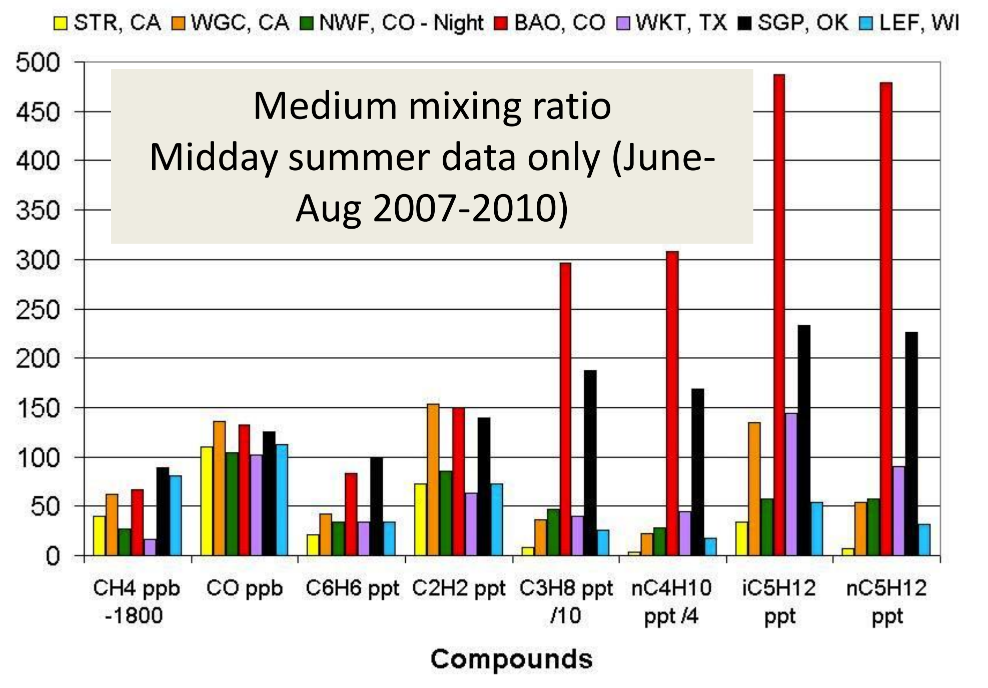


Ambient levels of CH_4 measured by tower, instrumented van or aircraft downwind of the area source reflect emissions from oil and gas production operations

Long Term Measurements in the Boundary Layer over the US

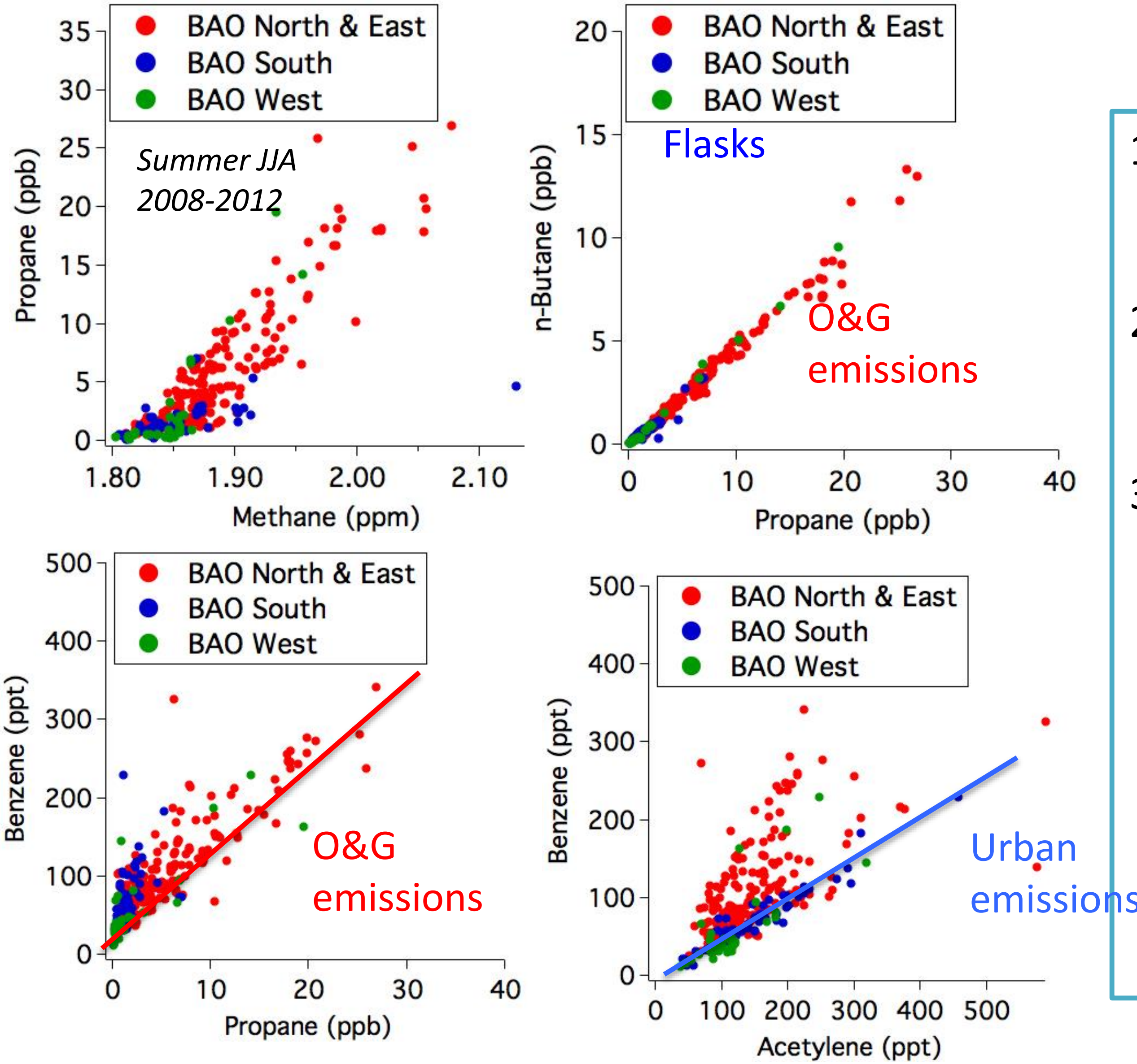


NOAA Tall Tower Measurement and Sampling Network
(PI Arlyn Andrews)



1. **Air samples collected at the Colorado (BAO) and Oklahoma (SGP) sites have a distinctive strong hydrocarbon signature.**
2. **High quality (well calibrated) measurements show strong correlation between several of the hydrocarbons (see next slide).**

300 magl level sampling at Colorado Tower: Multiple species analysis in **midday** discrete air samples



1. South Sector shows influence from urban emissions
2. N-E Sector shows influence from oil and gas operations
3. Based on a 3 week intensive with in-situ GC-MS measurements, Gilman et al. (2013) estimated that half of VOC reactivity in the region was due to O&G emissions

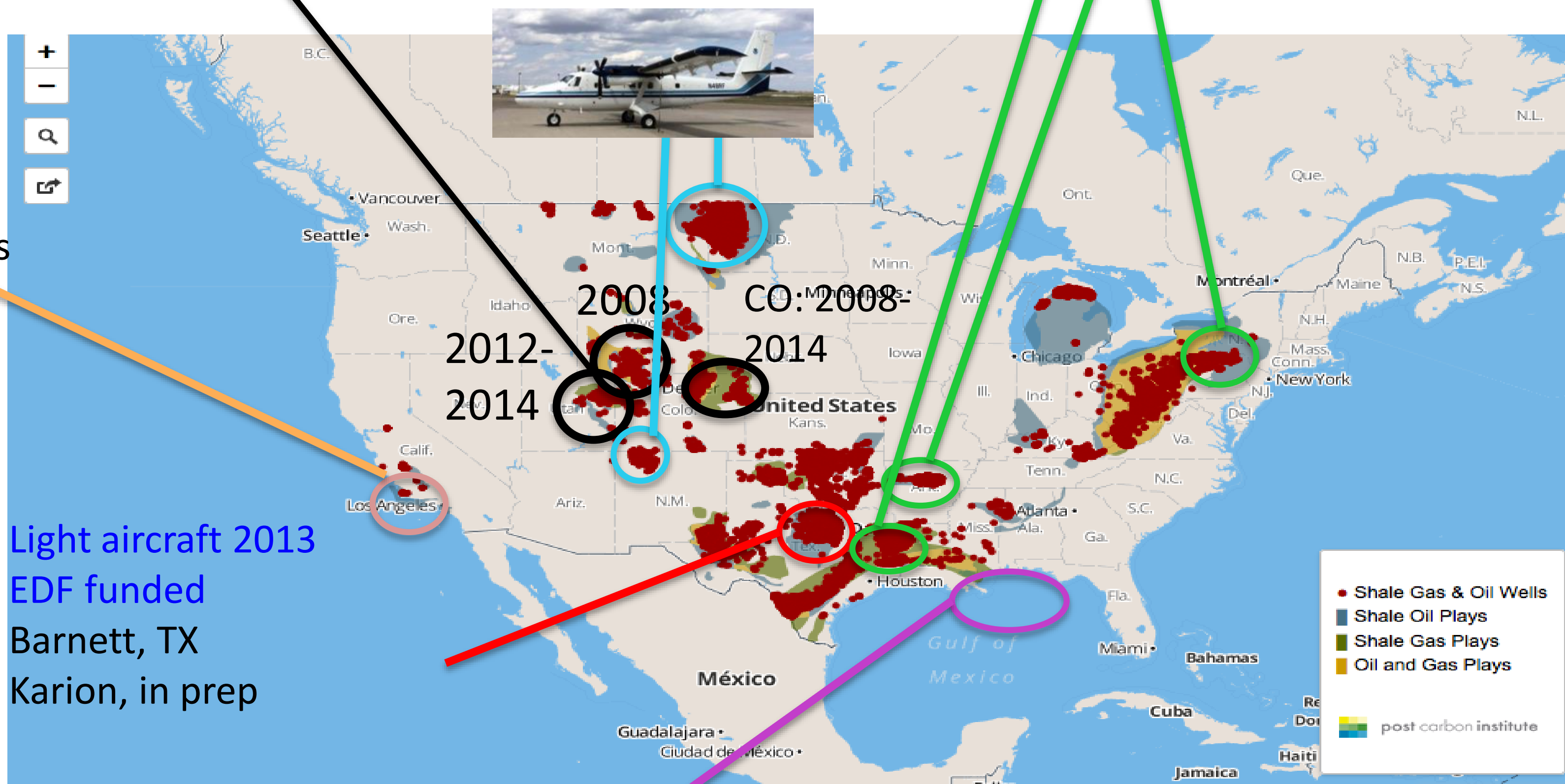
NOAA studies in U.S. oil and gas plays

Ozone nonattainment areas Light aircraft 2012 (UT, CO), 2013 (UT)

2014
NOAA Twin Otter
Bakken, ND
San Juan Basin, NM

2013 NOAA P3 (SENEX)
Haynesville (LA), Fayetteville (AR), Marcellus (PA)(Peischl, submitted)

2010 NOAA P3 (CALNEX)
LA Basin
Gas leaks from oil operations and natural gas distribution system



2008
2012-
2014
CO: 2008-
2014

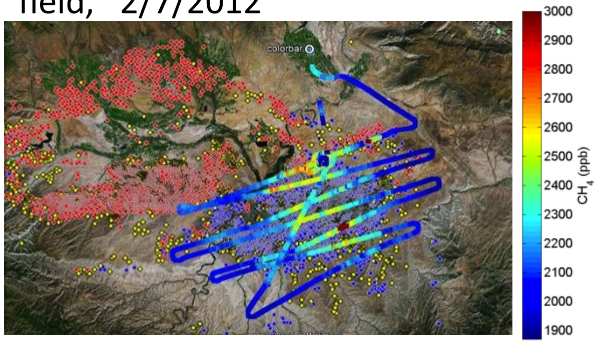
Light aircraft 2013
EDF funded
Barnett, TX
Karion, in prep

http://shalebubble.org/the-map/

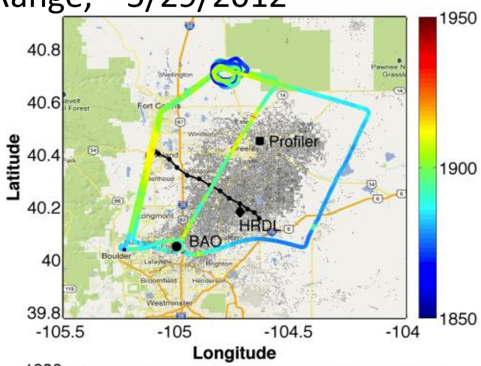
2010 NOAA P3
Deepwater Horizon Oil spill

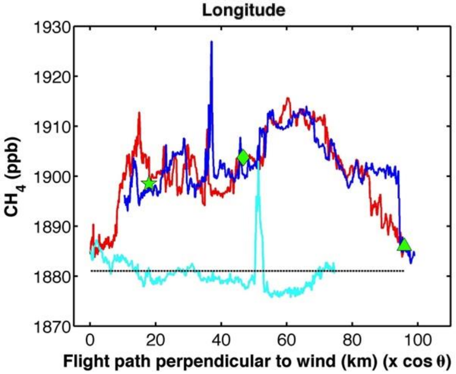
Methane and VOC emissions from oil and gas operations in Utah and Colorado estimated during aircraft intensives

Lake of Methane over Utah gas field, 2/7/2012

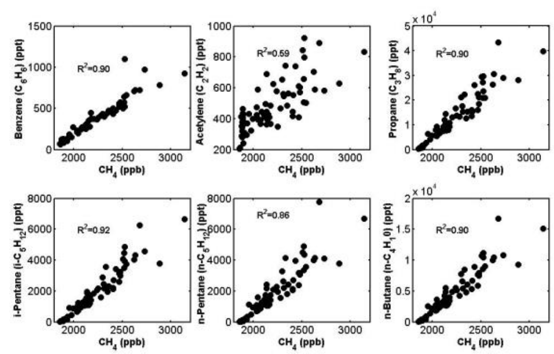


Methane in Colorado's Front Range, 5/29/2012



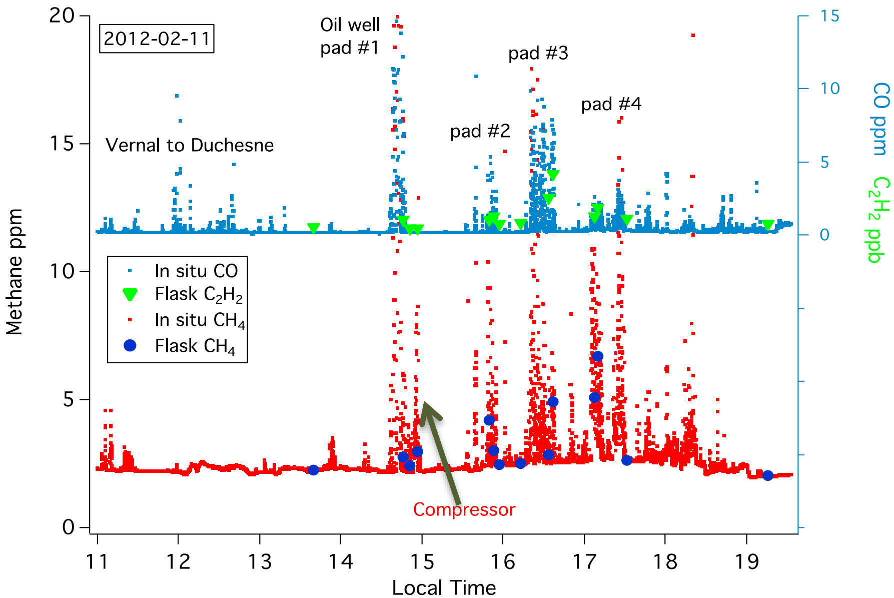


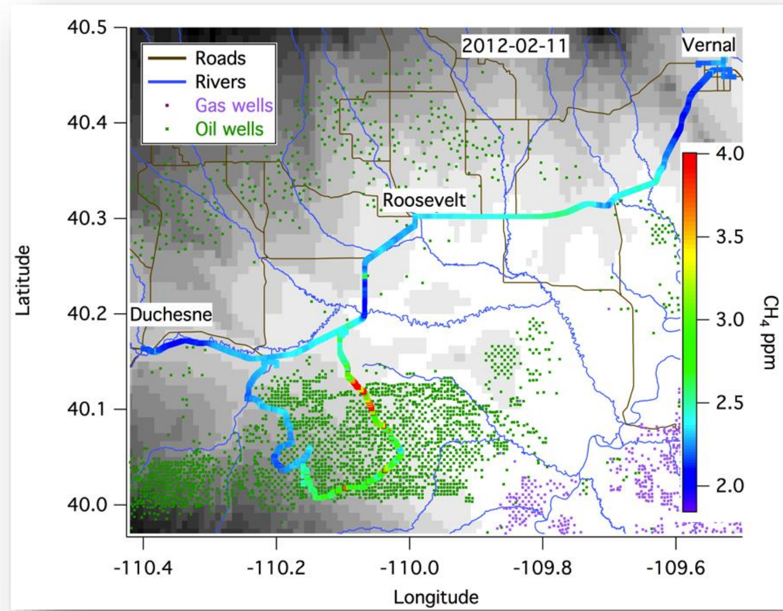
- NE Utah: Large emissions from O&G operations (Karion et al., GRL, 2013)
  - Based on data from one flight in 2012 : ~9% of the natural gas produced in the East (mostly gas) portion of the Uintah Basin was leaked (WRAP/GAO ~ 5%)
  - Use of the top-down emission estimate for 2013 winter campaign in WRF-Chem allowed model to match ambient VOC levels observed at fixed measurement site (Ahmadov et al, I review).
- NE Colorado: Official inventories underestimate oil and gas sector emissions (Pétron et al., JGR, 2014):
  - Methane x 3 (~4% of gas production)
  - VOCs (ozone precursors) x 2
  - Benzene (carcinogen) x 7



Example of Mobile Lab measurements:Not all pumpjack engines perform equally ~~well~~ poorly

Natural gas powered artificial lifts & their emission products in the Gilsonite Draw field, NE Utah





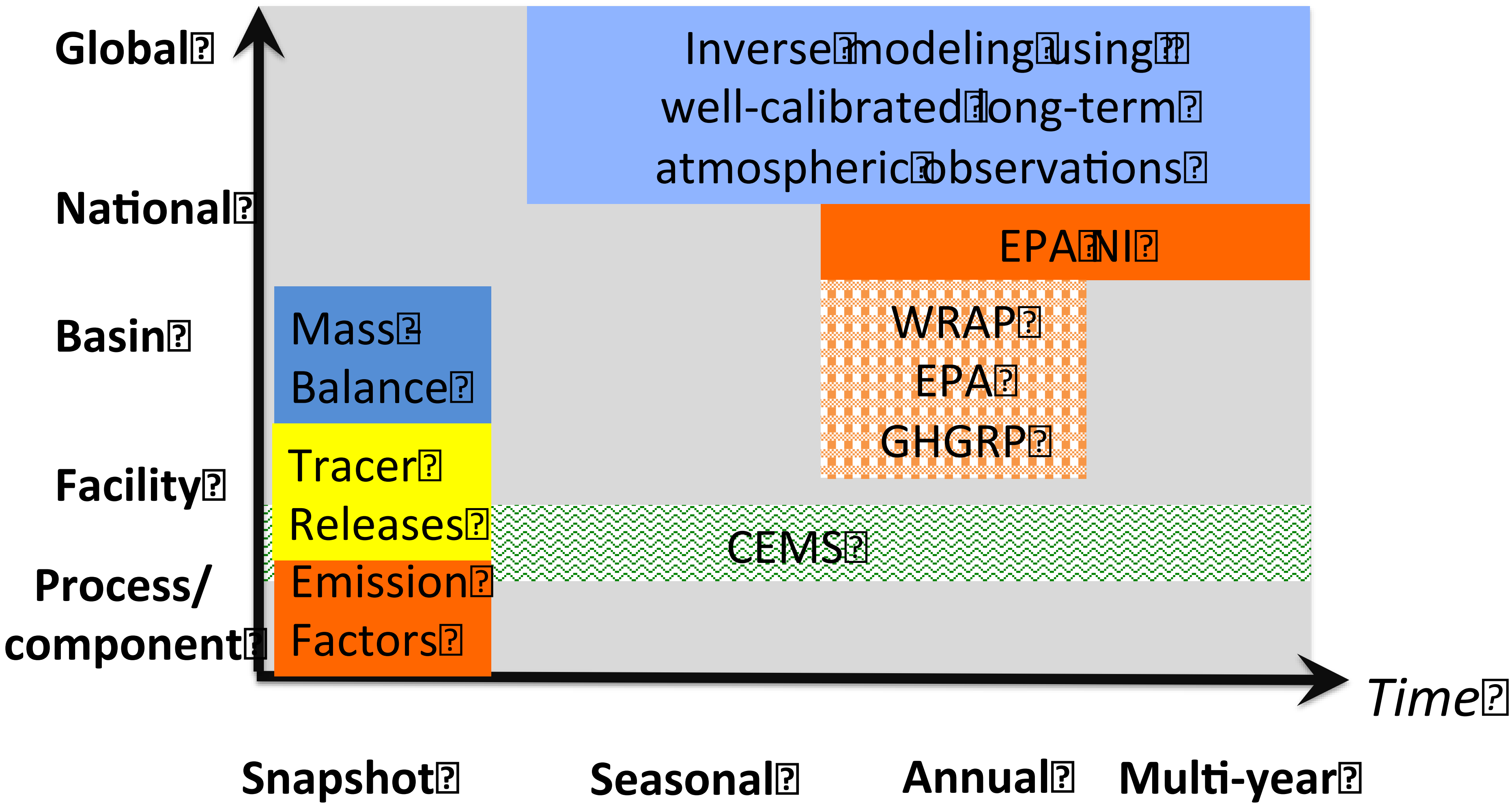
Molar ratio Pad #	CO/CO_2	$(CO_2+CO)/(CO_2+CO+CH_4)$
1	85%	81%
2	23%	80%
3	52%	79%
4	19%	58%

- Pumpjack engines in the oil field seem to be running with variable efficiency.
- Non-negligible fraction of the natural gas used to power these engines can leak to the atmosphere.
- See also Warneke et al. (2014)

Challenges for top-down approach

- Partitioning between different sources within a target region
  - Use of multiple species
- Attribution to specific processes
  - Requires ground-based field work
- Interpretation of geographical differences not completely straight-forward
  - GAO 2010 report
  - Allen et al., 2013
  - NOAA top-down studies: dry vs wet gas?
- Need to combine different approaches at different scales to assess sources when/where needed

Complication
Scales of different emission estimation products often do not overlap



Source: G. Pétron

CEMS: Continuous Emissions Monitoring System

Final remarks

- There is a strong need to better understand emissions of GHG, CAP, and HAPs to
  - Assess emissions impacts
  - Support and evaluate effective emissions mitigation where needed
- High quality long-term atmospheric chemical measurements provide key information on sources influencing an air shed
- Targeted field campaigns can provide an independent check on inventory models and results and further diagnose sources contributions