

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

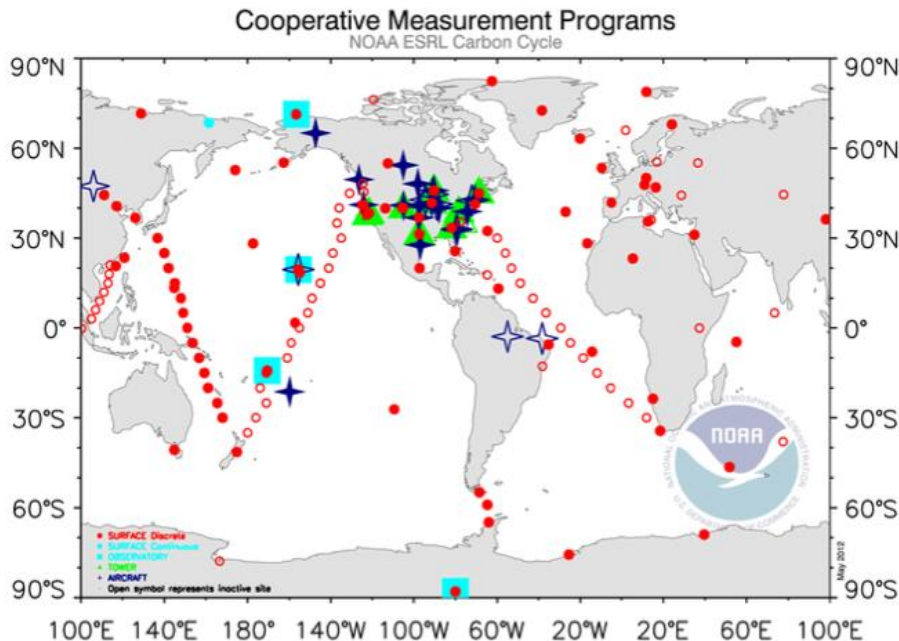
Gabrielle.Petron@noaa.gov

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of our employers and sponsors, including NOAA, NSF, CU Boulder, DOE, EDF.

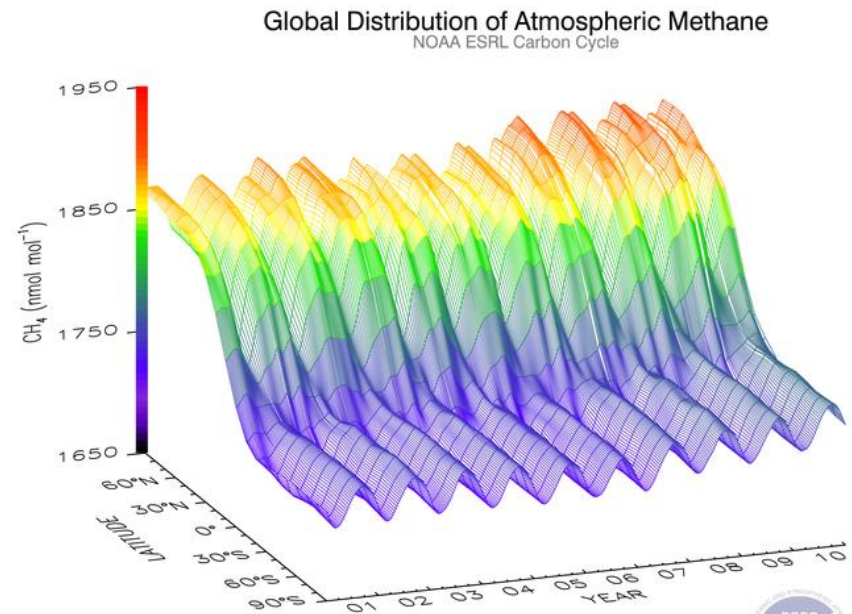


Global methane (CH₄) monitoring

- 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



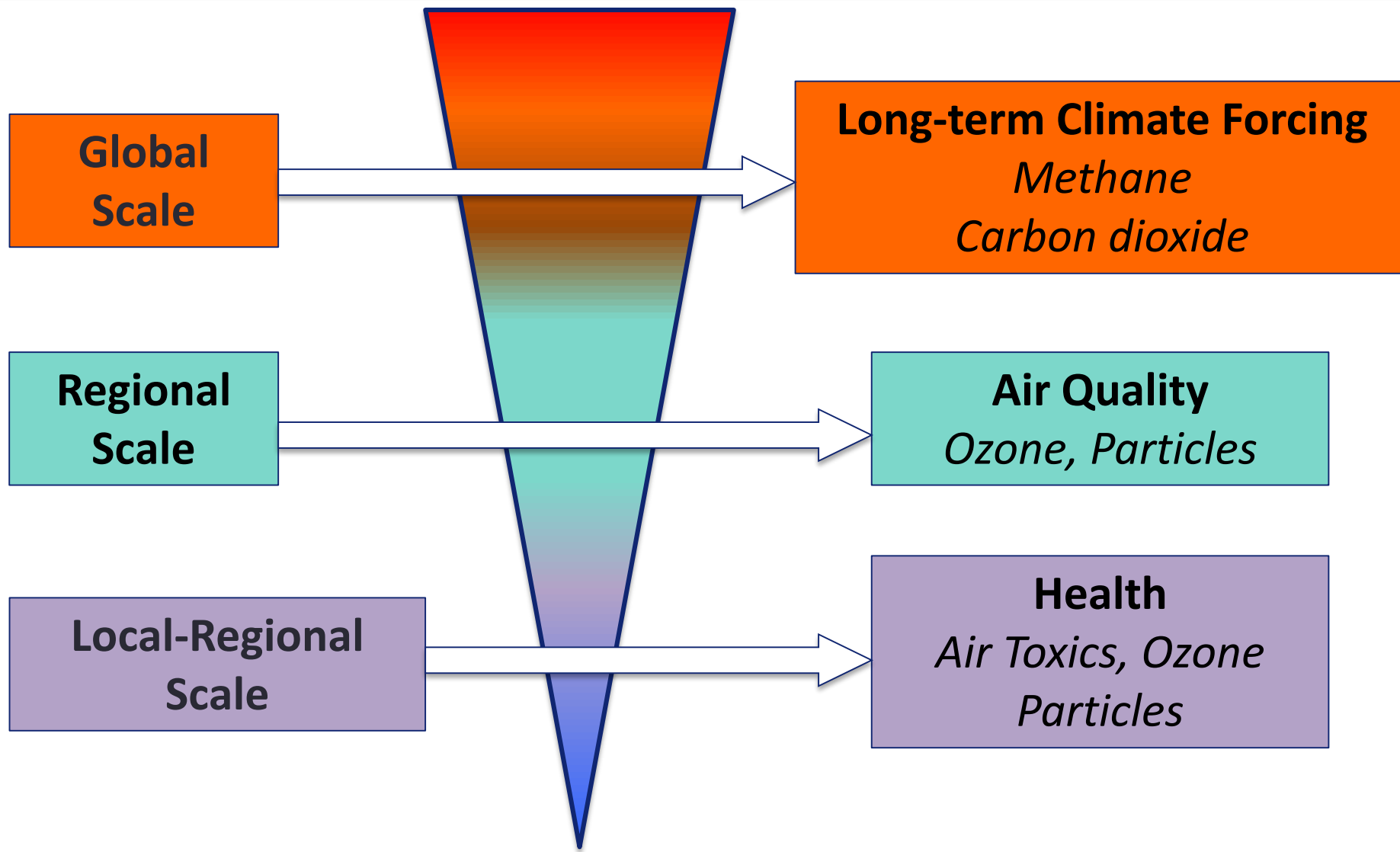
NOAA ESRL Carbon Cycle operates 4 measurement programs. Semi-continuous measurements are made at 4 baseline observatories, a few surface sites and from tall towers. Discrete surface and aircraft samples are measured in Boulder, CO. Presently, atmospheric carbon dioxide, methane, carbon monoxide, hydrogen, 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/>.

May 2012

Potential air impacts of emissions at various scales



U.S. NG Systems: A large infrastructure

U.S. Statistics:
EIA, DOT, OGI

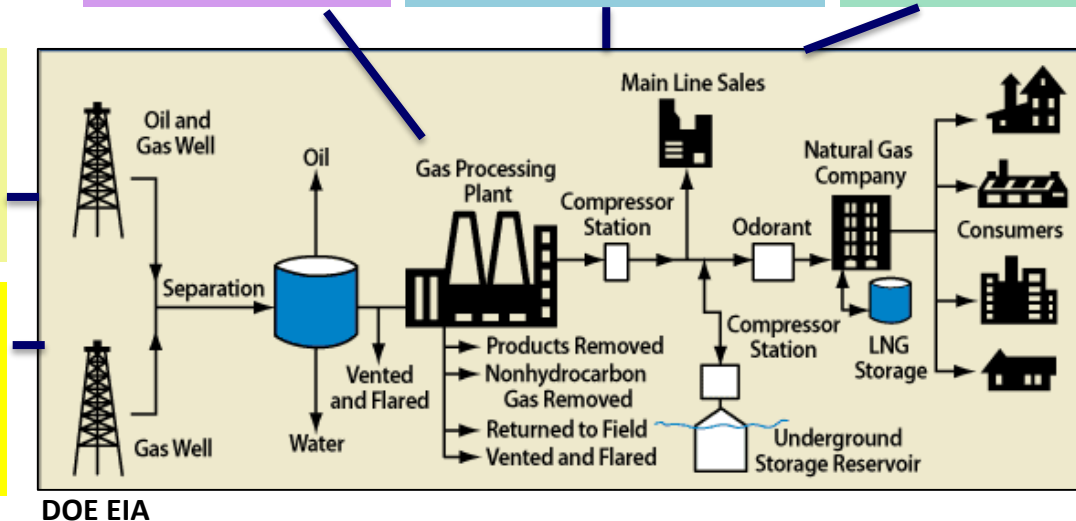
~ 500
processing
plants

300,000 miles of
transmission
pipelines

> 1400
compressor
stations

20,000 miles
of gathering
pipelines

>1 million
oil and gas
wells in US



2,000,000
miles of
distribution
pipeline

400
underground
storage sites

Production

Processing

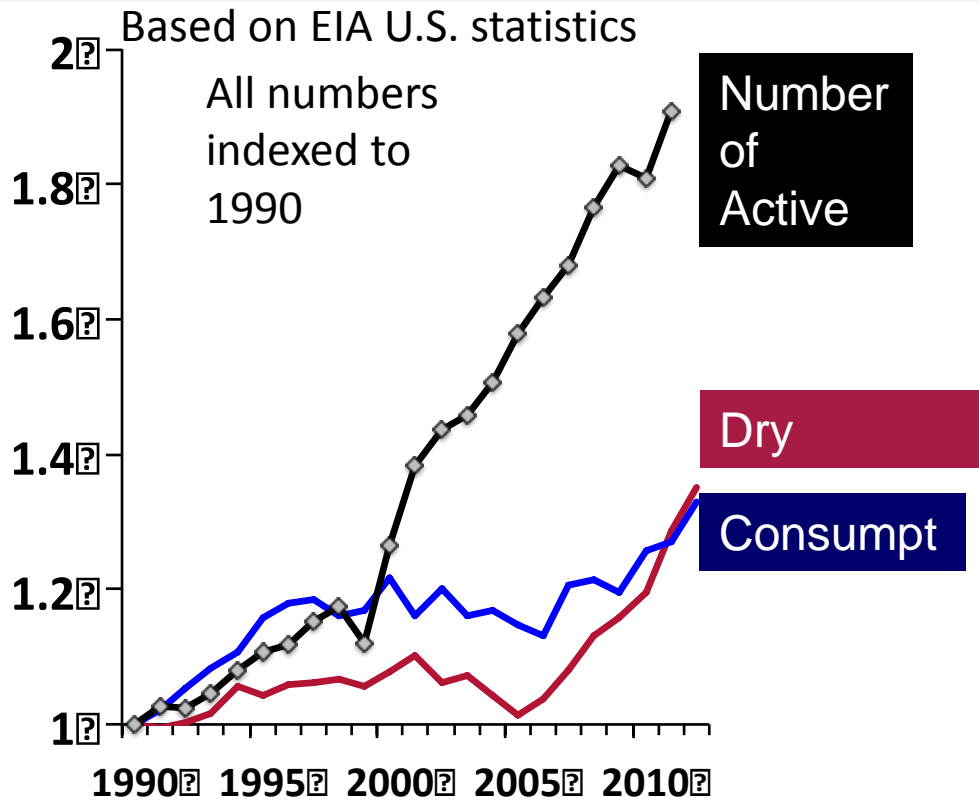
Transmission

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



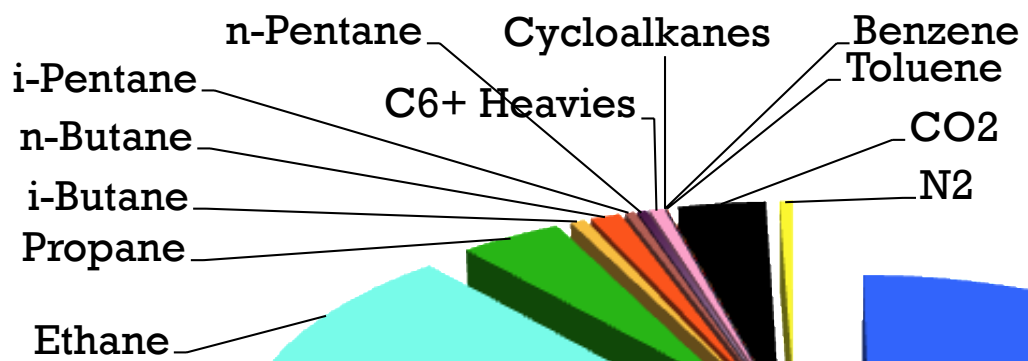
What's in natural gas?

Surface ozone precursors

Air Toxics

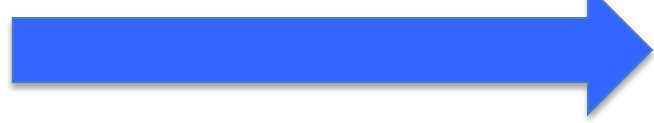
NGLs

GHG



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

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



Distribution gas is >90% methane

Emissions Assessment Tools

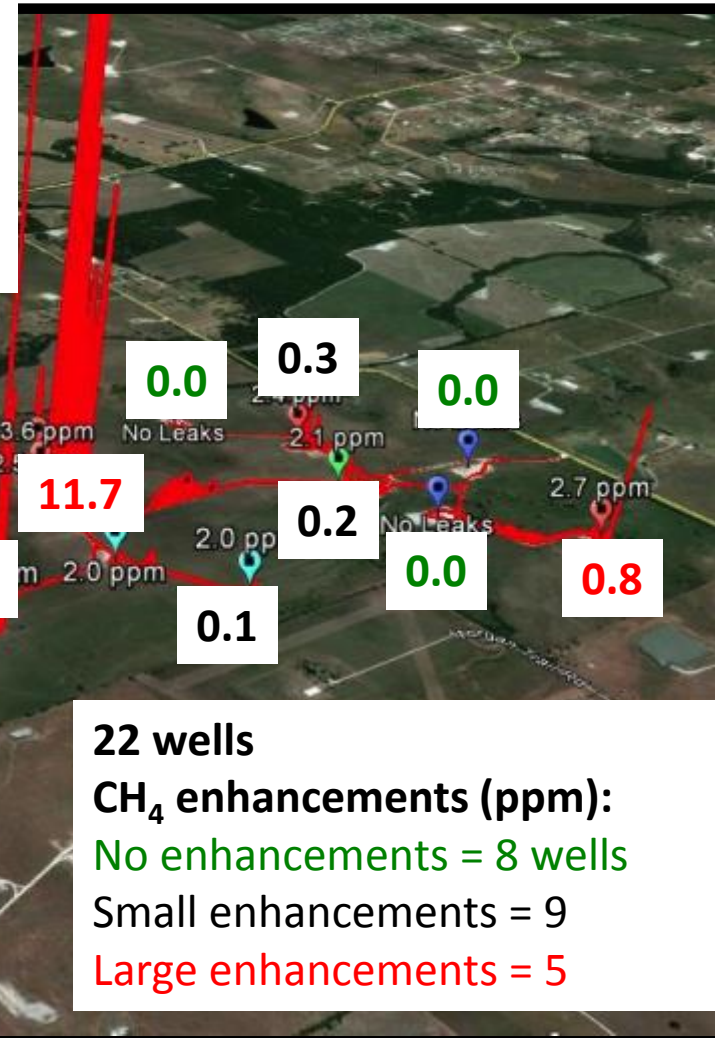
Inventory Approach

- 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

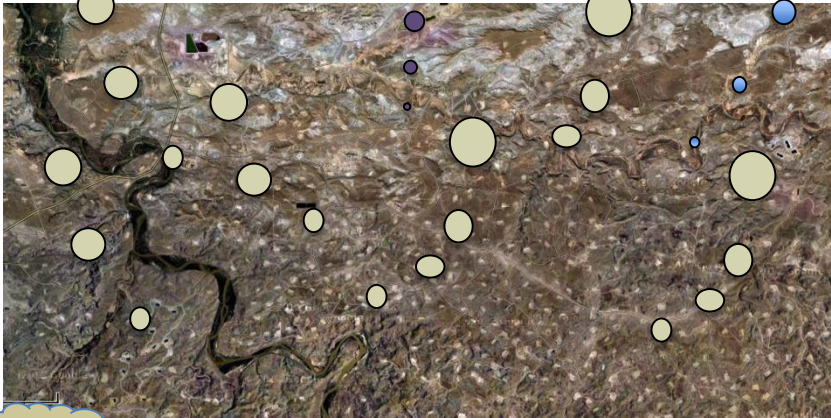


Atmospheric studies: Top-Down Approach

- 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?

CH₄ "cloud" from surface emissions

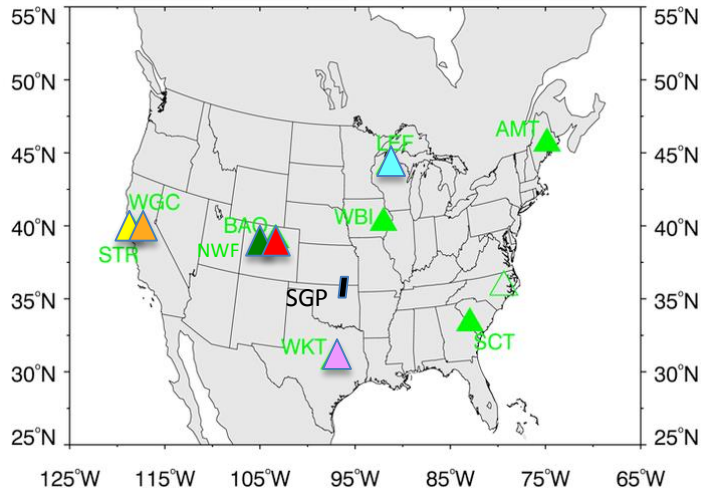


wind

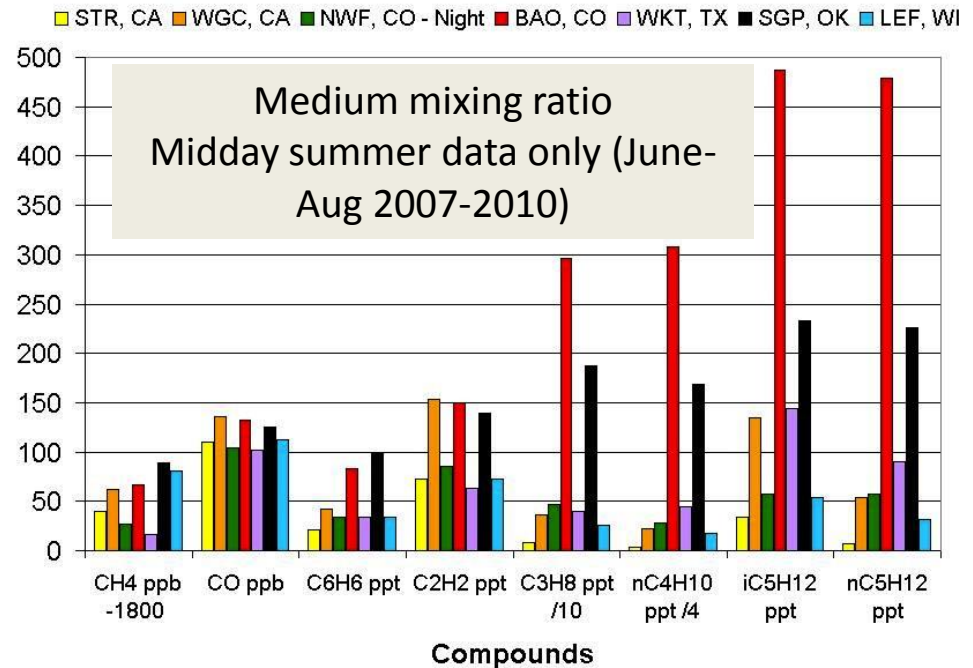


Ambient levels of CH₄ measured by tower, instrumented van or aircraft downwind of the area source reflect emissions from oil and gas production operations

Long Term Measurements in the Boundary Layer over the US

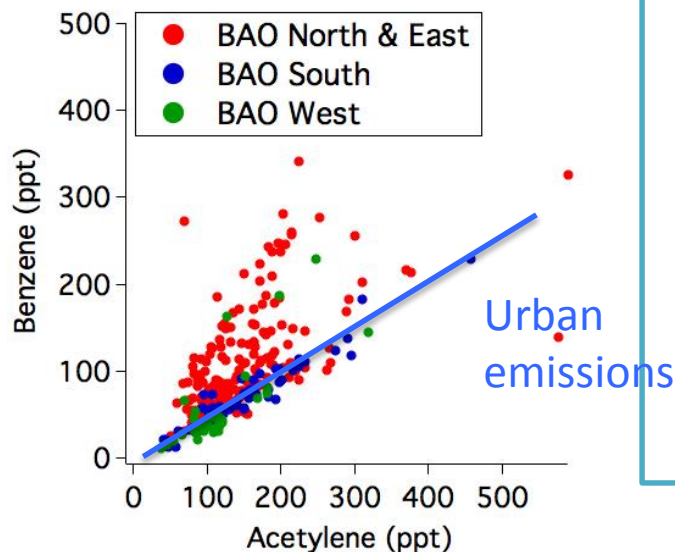
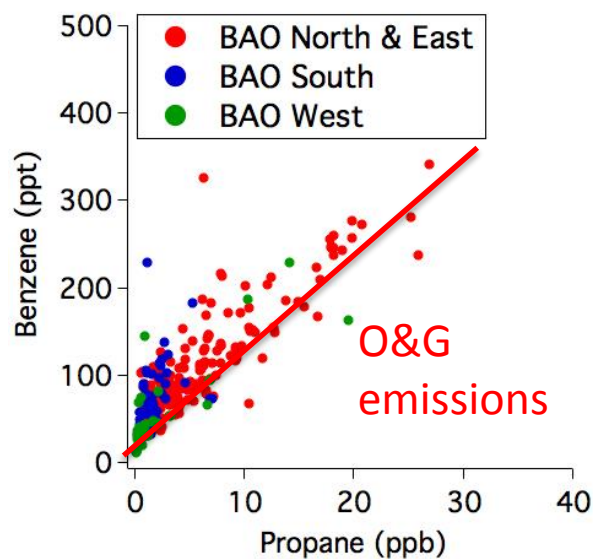
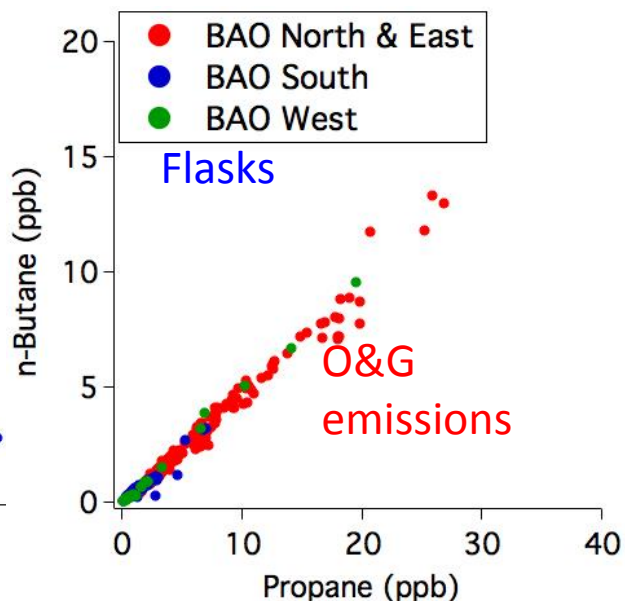
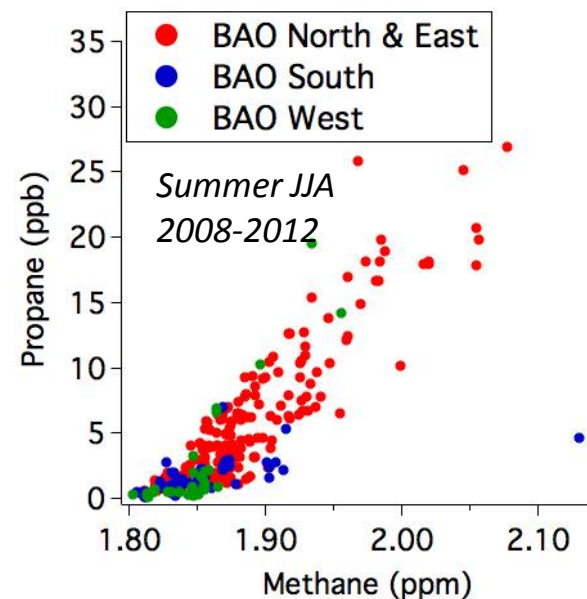


NOAA Tall Tower Measurement and Sampling Network
(PI Arlyn Andrews)



- 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

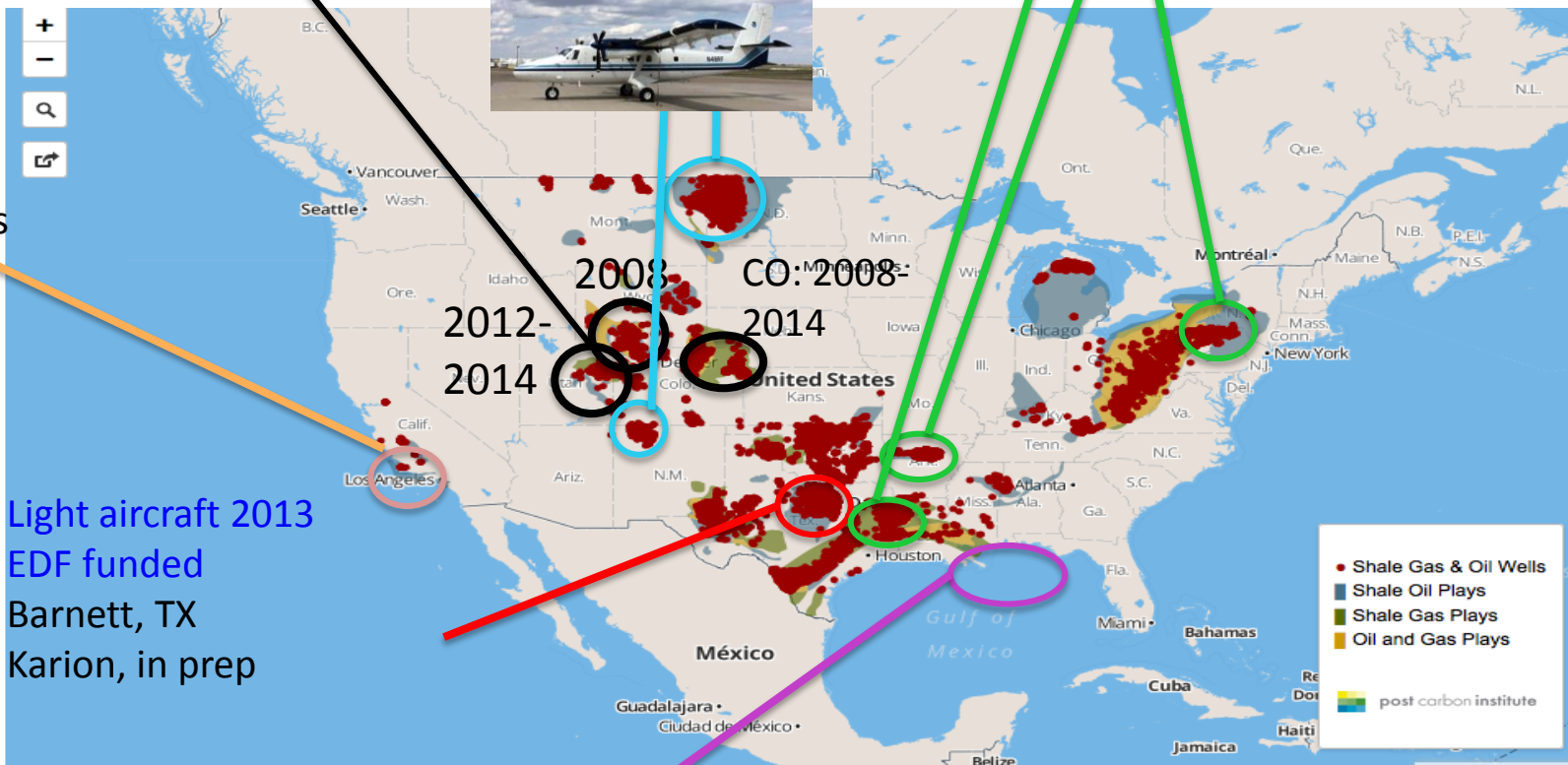
NOAA studies in U.S. oil and gas plays

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



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

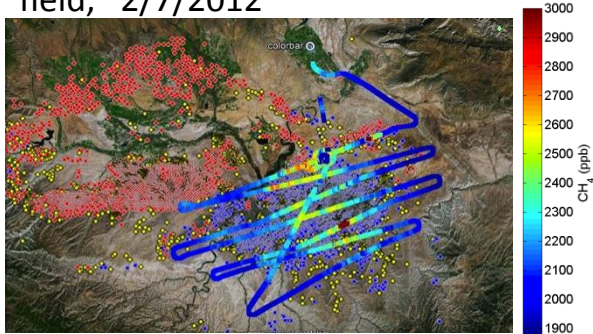


2010 NOAA P3
Deepwater Horizon Oil spill

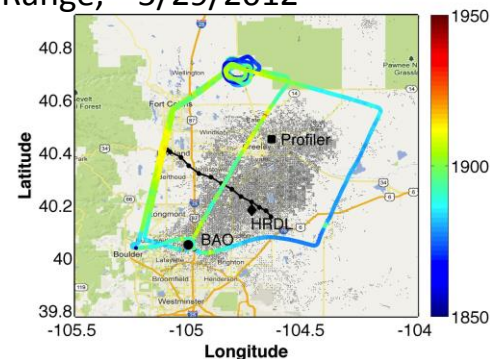
<http://shalebubble.org/the-map/>

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

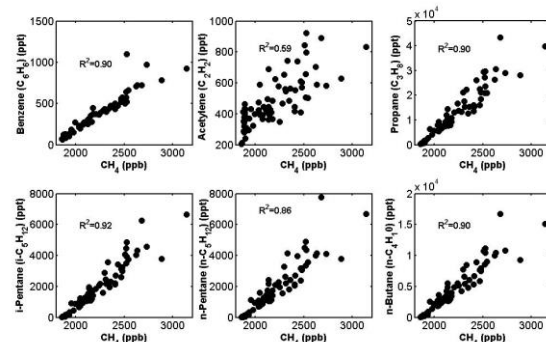
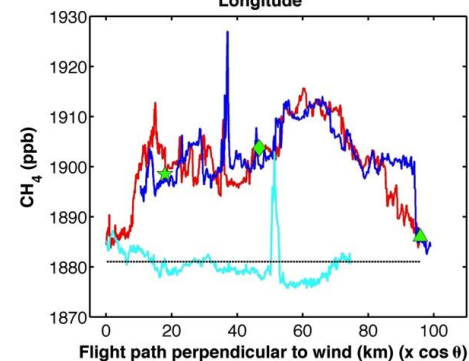


Methane in Colorado's Front Range, 5/29/2012



- 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).

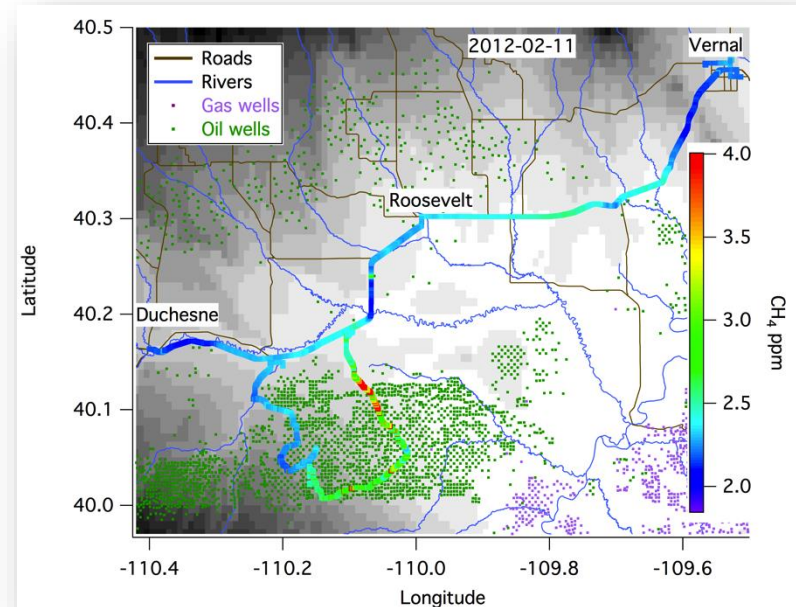
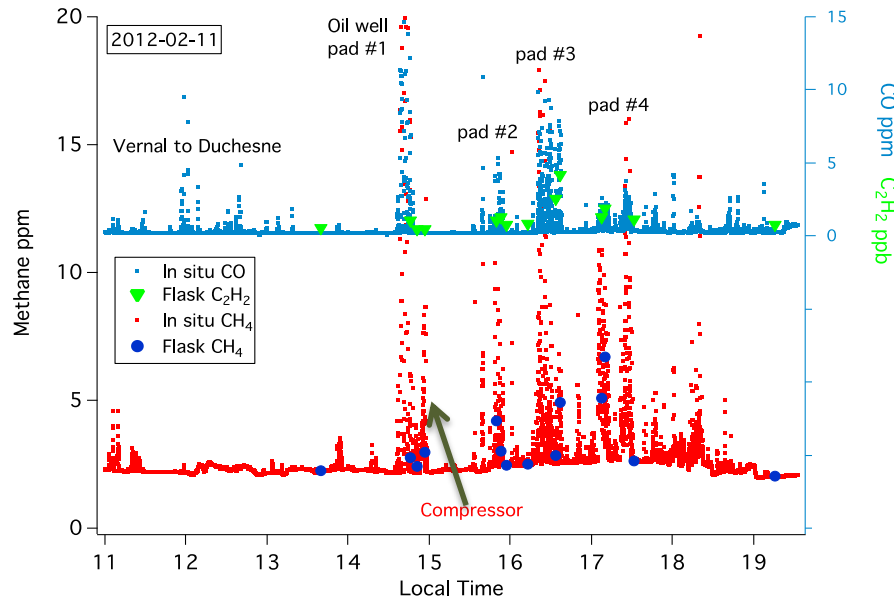
- NE Colorado: Official inventories underestimate oil and gas sector emissions (Pétron et al., JGR, 2014):
 - Methane x 3 (~4% of gas production)
 - VOCs (ozone precursors) x 2
 - Benzene (carcinogen) x 7



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)

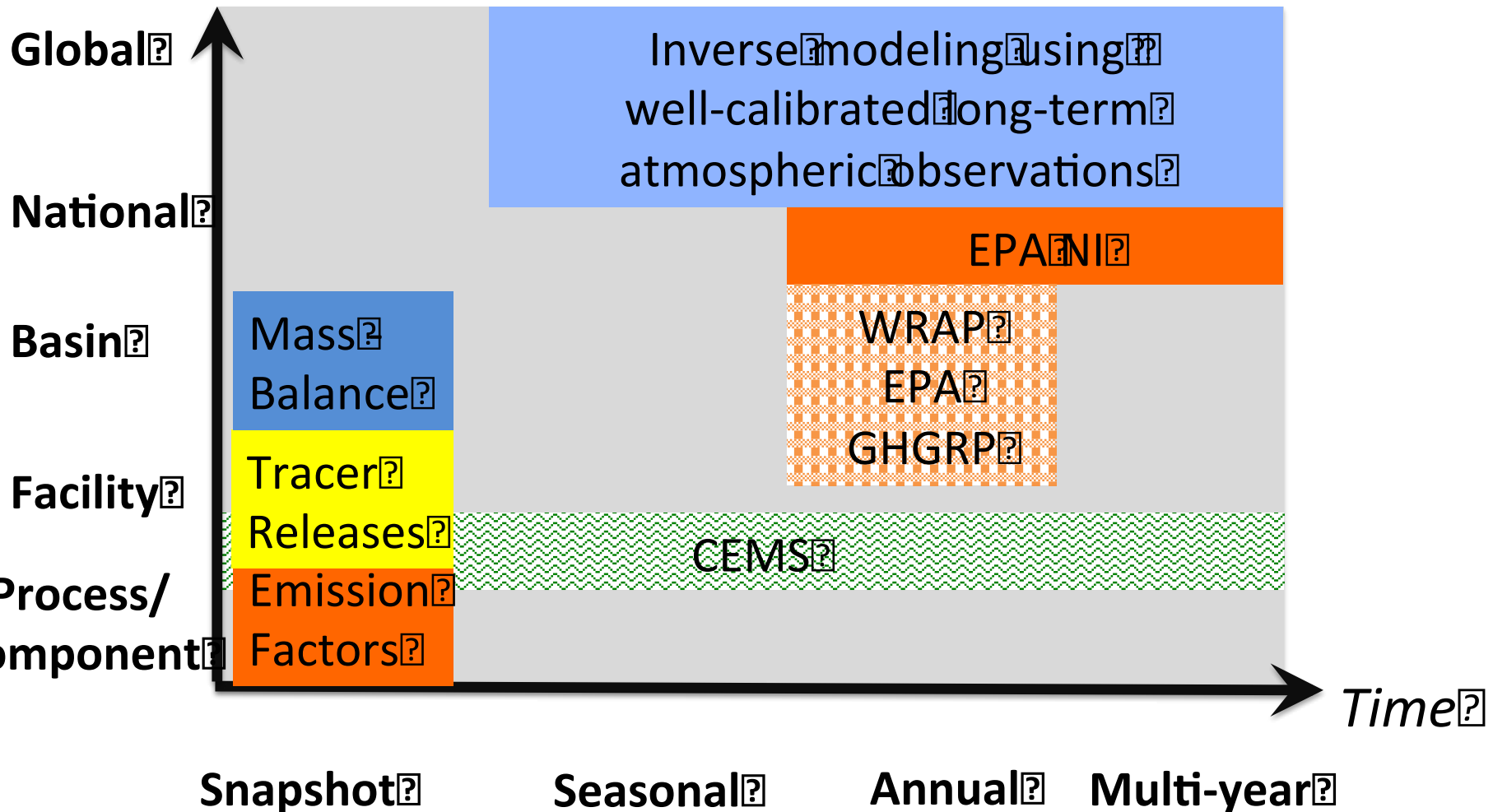
Challenges for top-down approach

- 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

Spatial
Scale



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