Assessment of Methane and VOC Emissions from Select Upstream Oil and Gas Production Operations Using Remote Measurements, Interim Report on Recent Survey Studies

2012-A-21-AWMA
105th Annual Conference of the Air & Waste Management Association
June 19-22, 2012, in San Antonio, Texas

E. D. Thoma, B. C. Squier - *EPA, ORD, National Risk Management Research Lab.*

D. Olson - *EPA, ORD, National Exposure Research Lab.*

A. P. Eisele - *EPA Region 8*

J. M. DeWees, R. R. Segall - *EPA, Office of Air Quality Planning and Standards*

M. S. Amin, M. T. Modrak - *ARCADIS Inc.*

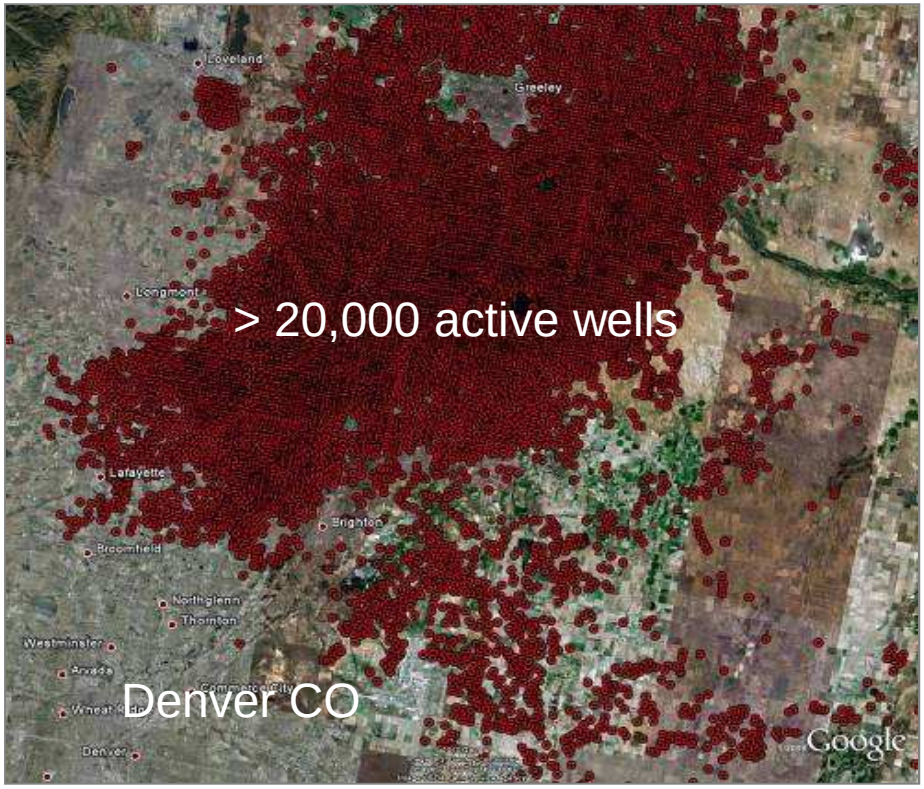
Office of Research and Development
National Risk Management Research Laboratory, Air Pollution Prevention and Control Division

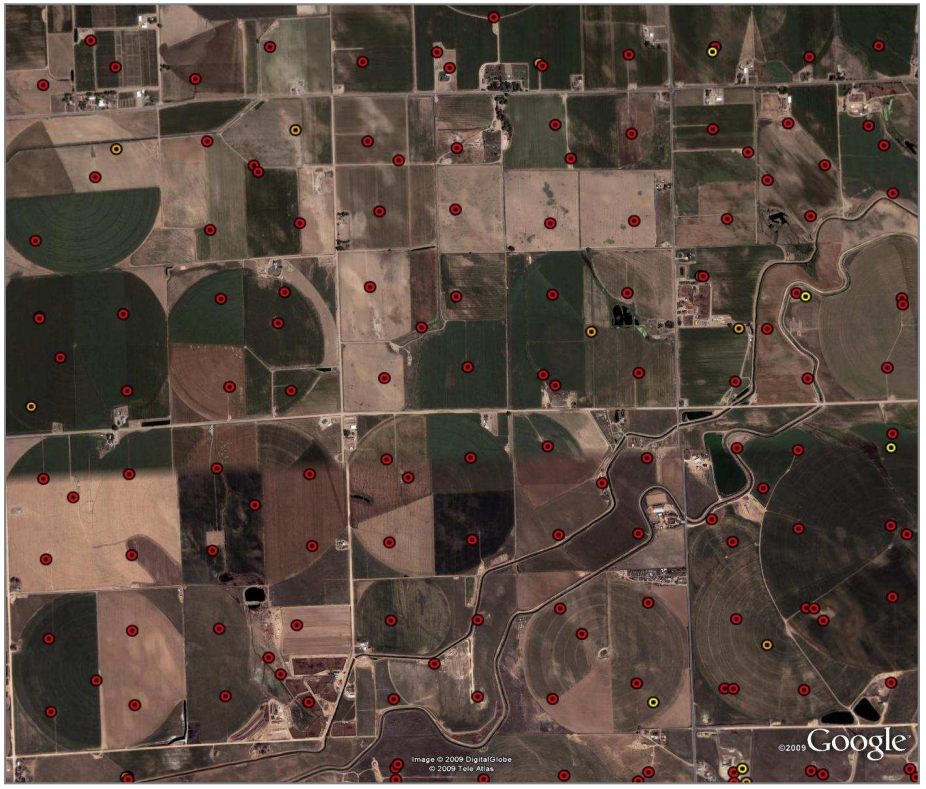
Motivation for oil and gas measurements

- Number of production facilities is increasing
  - *Impact of VOC emissions to ozone attainment is uncertain*
  - *GHG emissions estimates (fugitives and tanks) can be improved*
- Proximity of potential sources to populations is increasing
  - *Growing need to understand HAP emission potential*
- Limited measurement data, can be difficult to estimate emissions
  - *Many source types and engineering configurations*
  - *Significant variability in maintenance states and product composition*

Oil and gas production

large number of potential sources





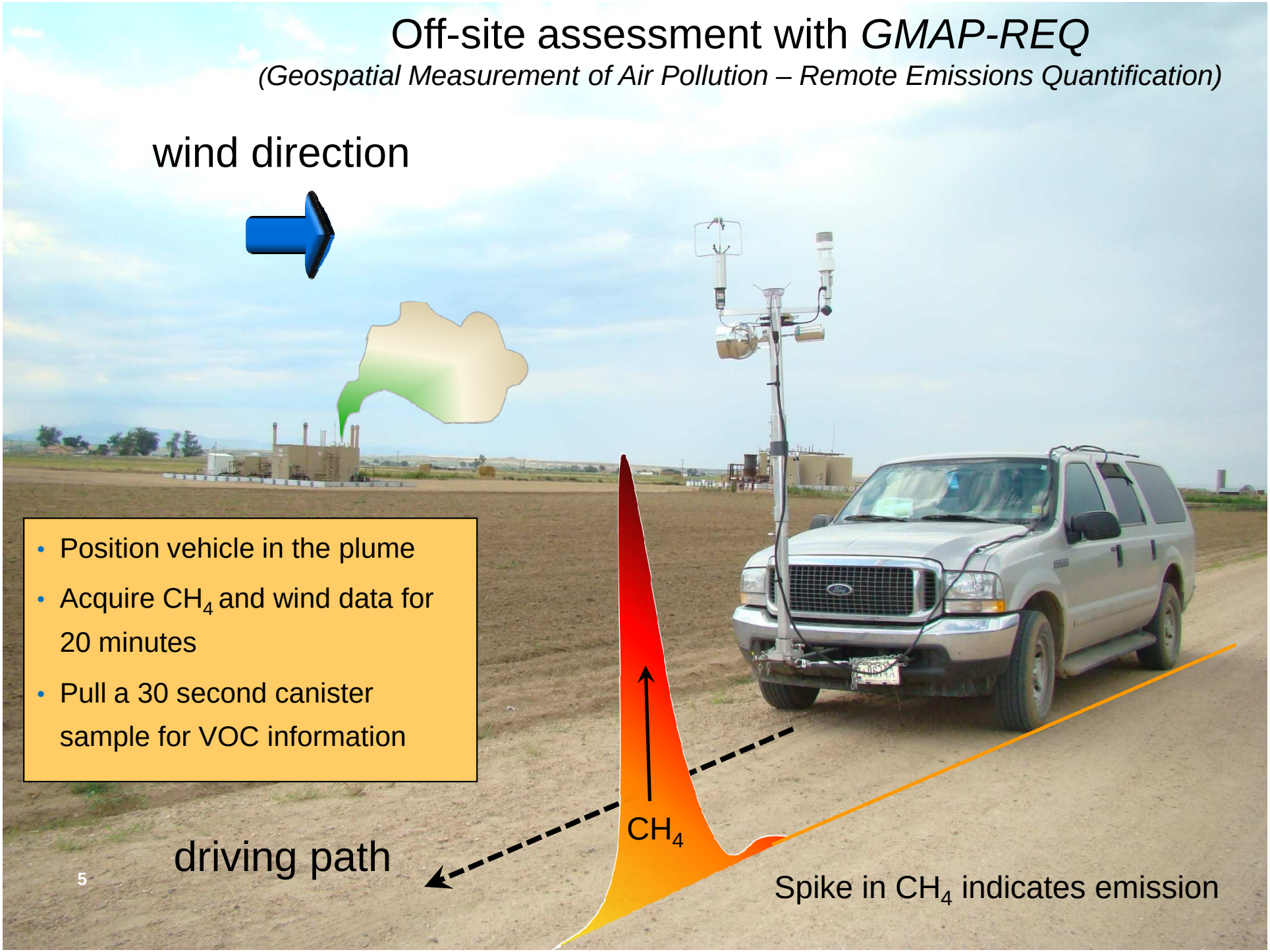

FLIR
ME OFF
AUTO
HIST
WH
Many types of emissions complicates assessment
FLIR Video File

As the separation distances of potential sources to populations decrease, the need for periodic inspection increases

Source: Microsoft Bing Maps (© Microsoft Corporation Pictometry Bird's Eye © 2010 Pictometry International Corp)

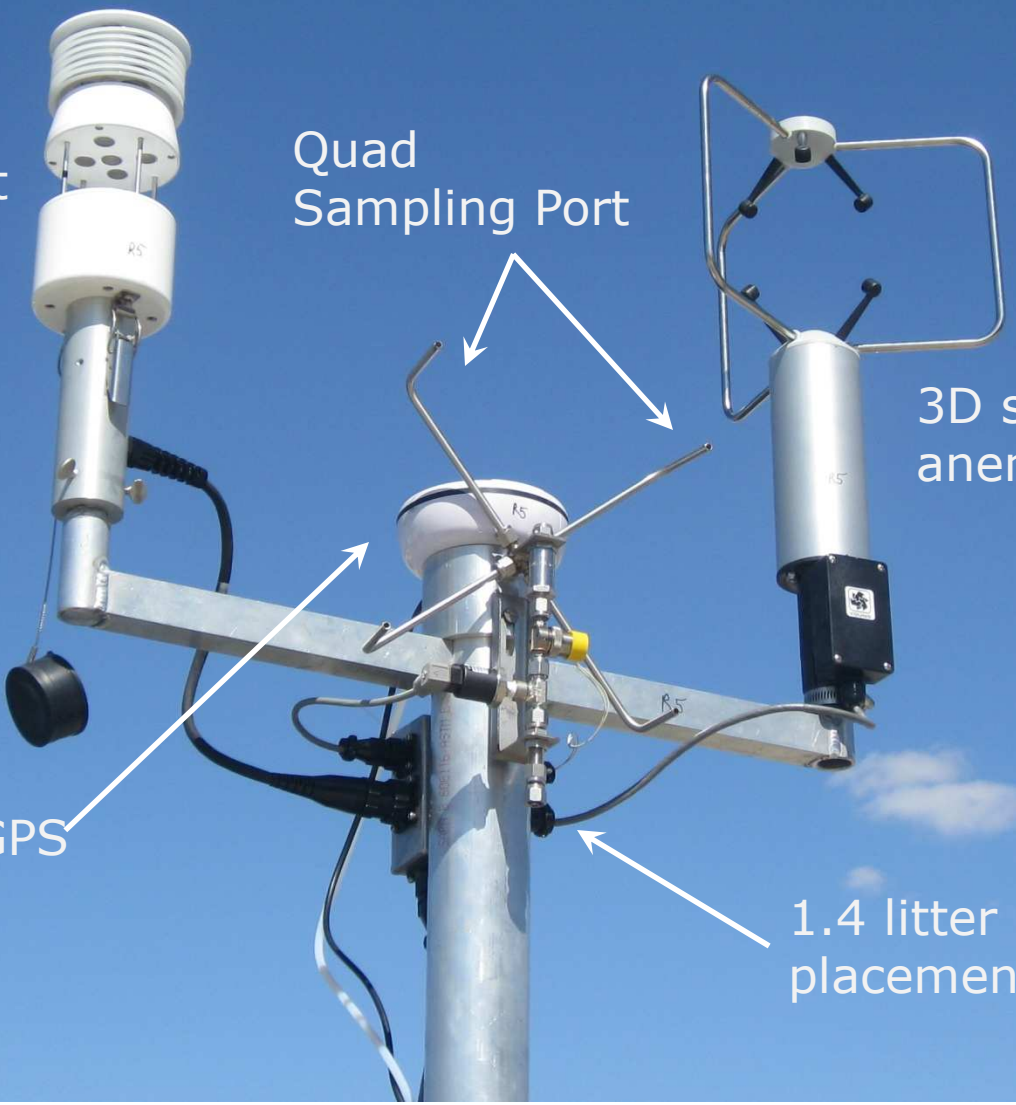
Off-site assessment with *GMAP-REQ*

(Geospatial Measurement of Air Pollution – Remote Emissions Quantification)



GMAP REQ measurement equipment

In the truck:
High-precision CH_4 Instrument *(critical component)*
Batteries, control system, IR camera, rangefinder



Auto-north met station

Quad Sampling Port

3D sonic anemometer

High-res GPS

1.4 litter canister placement

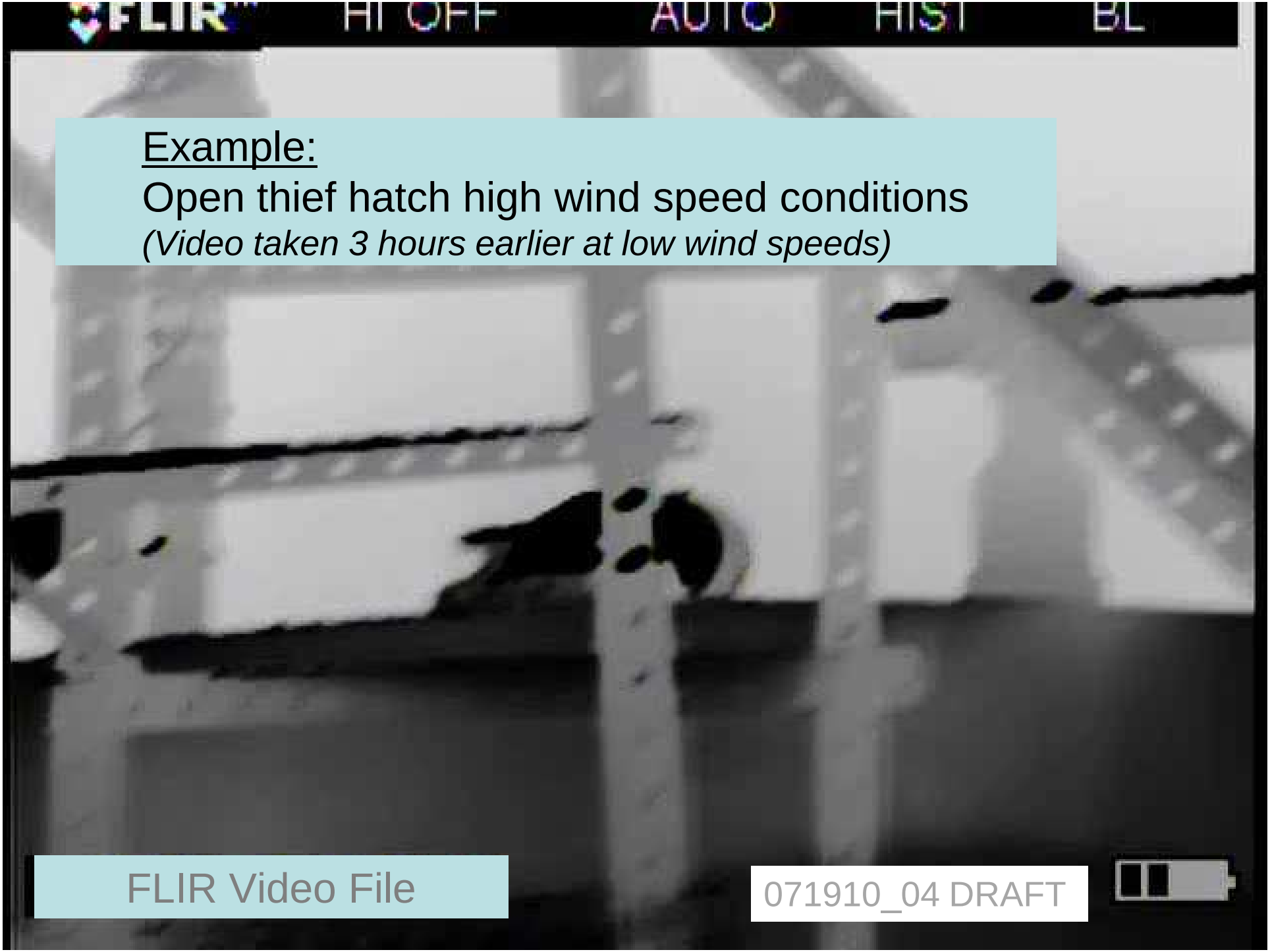
Estimating emissions with GMAP-REQ

(two methods: PSG and bLs)

- Plot CH_4 vs. wind angle in 10 deg bins
- Filter off-axis information and determine plume CH_4 concentration
- Point Source Gaussian (PSG)
  - Use distance and atmospheric stability to find expected σ_y,σ_z (lookup)
  - Perform simple 2-D integration ($q = 2\pi \cdot \sigma_y \cdot \sigma_z \cdot u \cdot c$)
- Backwards Lagrangian Stochastic (bLs)
  - Use distance,CH_4, and 3D sonic data in model WindTrax 2.0
- Estimate VOC emissions by canister ratio approach with CH_4

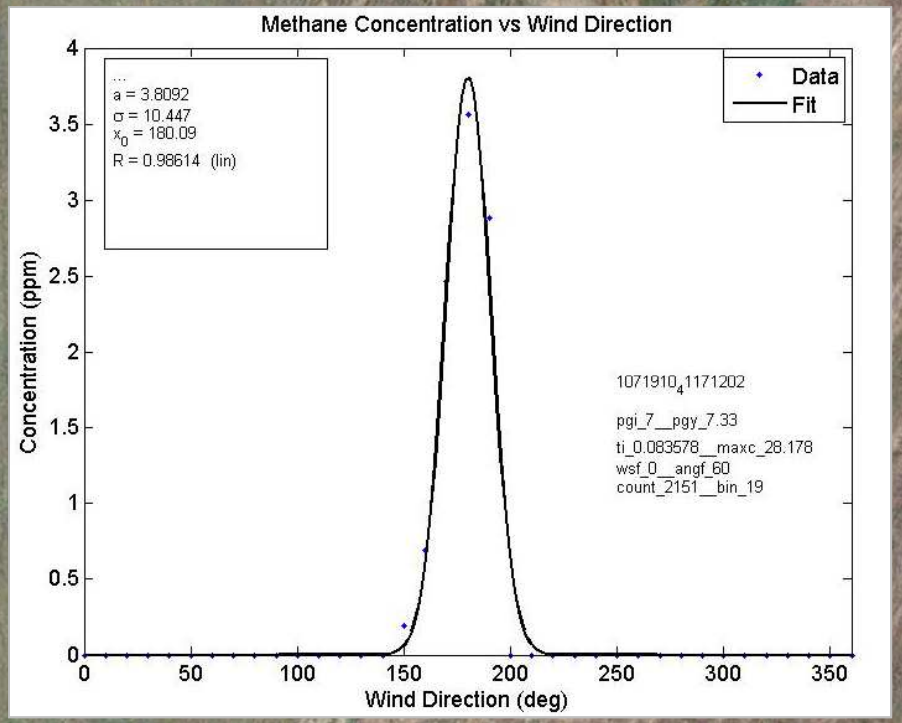
Description in:

Thoma, E.D.; Squier, B.C.; et al. *Assessment of Methane and VOC Emissions from Select Upstream Oil and Gas Production Operations Using Remote Measurements, Interim Report on Recent Survey Studies.* Proceedings of 105th Annual Conference of the Air & Waste Management Association, 2011-A-21-AWMA, June 19-22, 2012, San Antonio, TX.


FLIR
HI OFF
AUTO
HIST
BL
Example:
Open thief hatch high wind speed conditions
(Video taken 3 hours earlier at low wind speeds)
FLIR Video File
071910_04 DRAFT

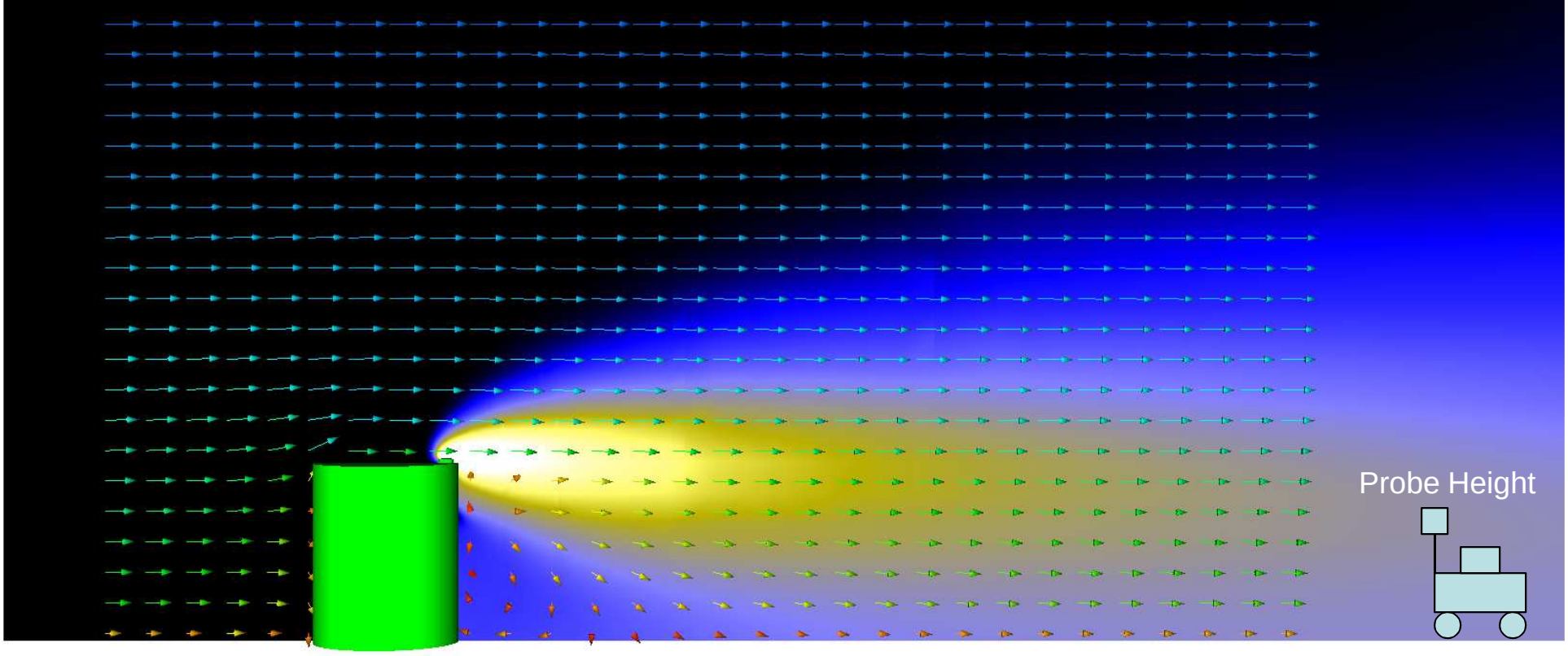
Example GMAP-REQ:
Distance = 90 m
Wind speed = 6.1 m/s
CH_4 bkg. conc.= 1.78 ppm
CH_4 plume conc. = 3.81 ppm (>bkg.)

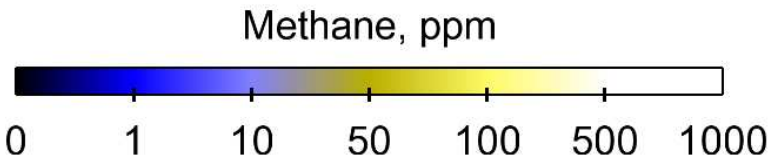
Snapshot emission estimates
CH_4 = 1.86 g/s
VOC = 1.08 g/s

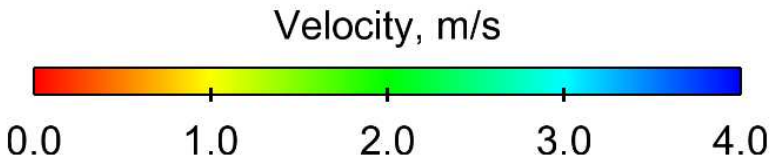


Wind Direction

- Method development includes computational simulations to understand flow
- With good winds, emissions from the tops of the tanks get mixed down by wake
- Measurements at about 3 m work pretty well in these cases

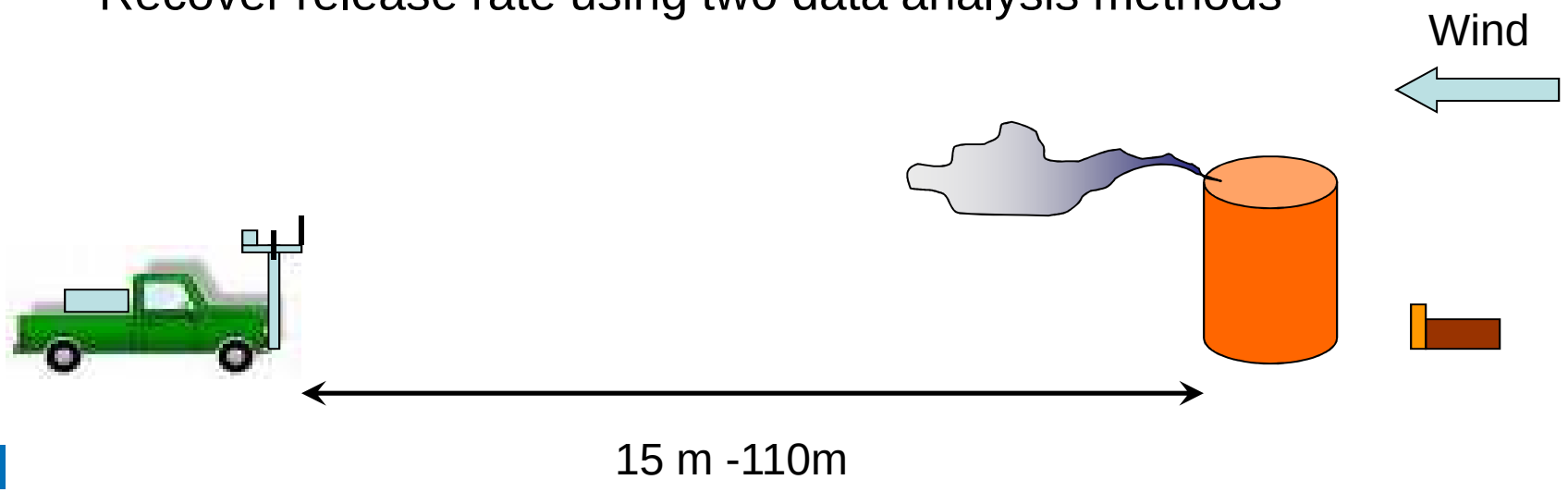






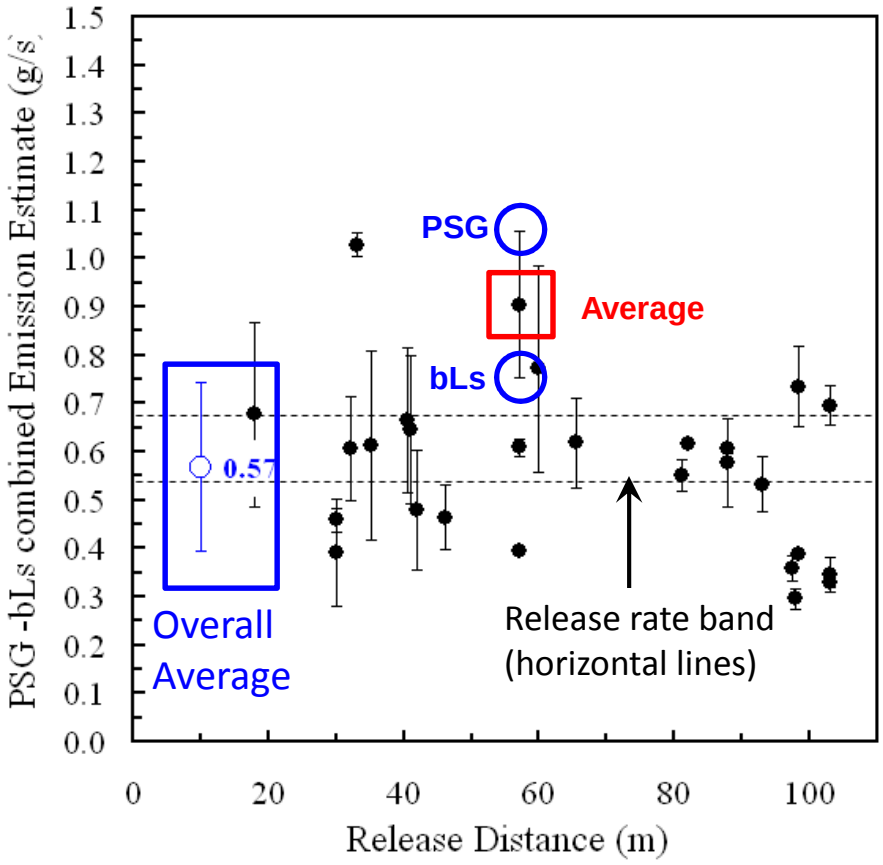
CH_4 release-recovery experiments *(testing the GMAP REQ approach)*

- Release methane gas from a variety of scenarios (0.6 g/s)
  - Free release (no wake effects)
  - Simulated tanks (top of trailer, two orientations : wake effects)
  - Different surfaces (pavement, hard ground, 0.3 m grass)
  - Different atmospheric conditions
  - Recover release rate using two data analysis methods

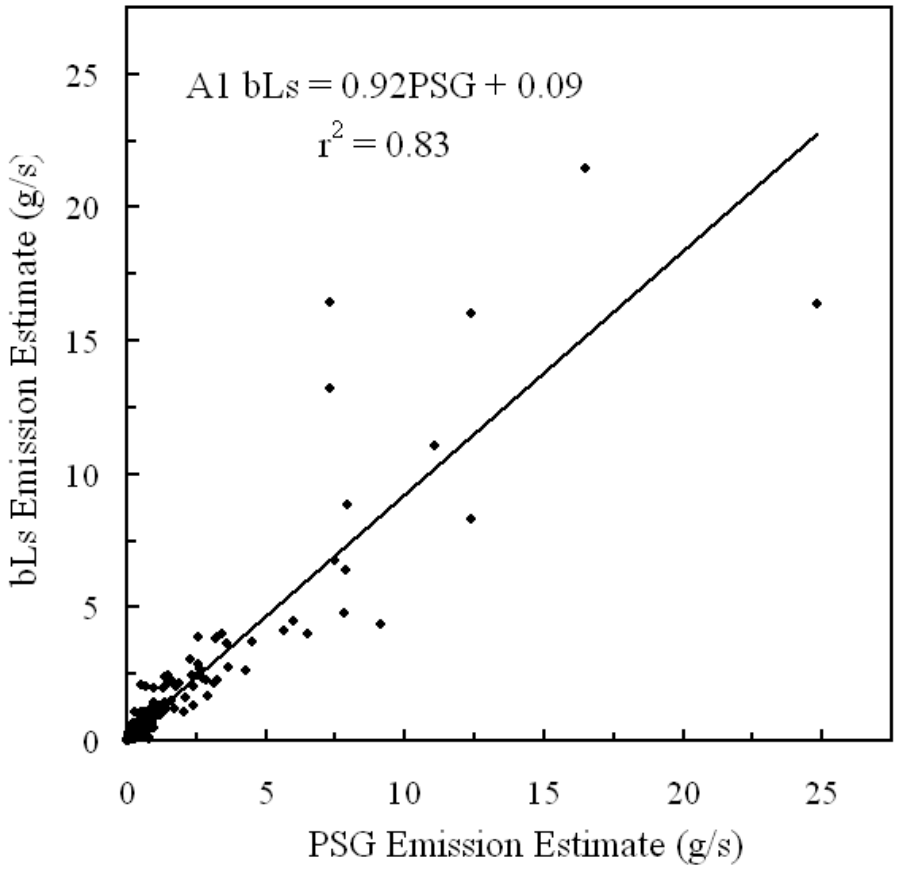


CH_4 release-recovery experiments and PSG to bLs model comparisons

PSG:bLs combined emission estimate results for CH_4 release experiments



Comparison of PSG and bLs results for release and field data (N=321)



Review of preliminary GMAP REQ results

(Interim report on 2010,2011 studies – ver. April 2012)

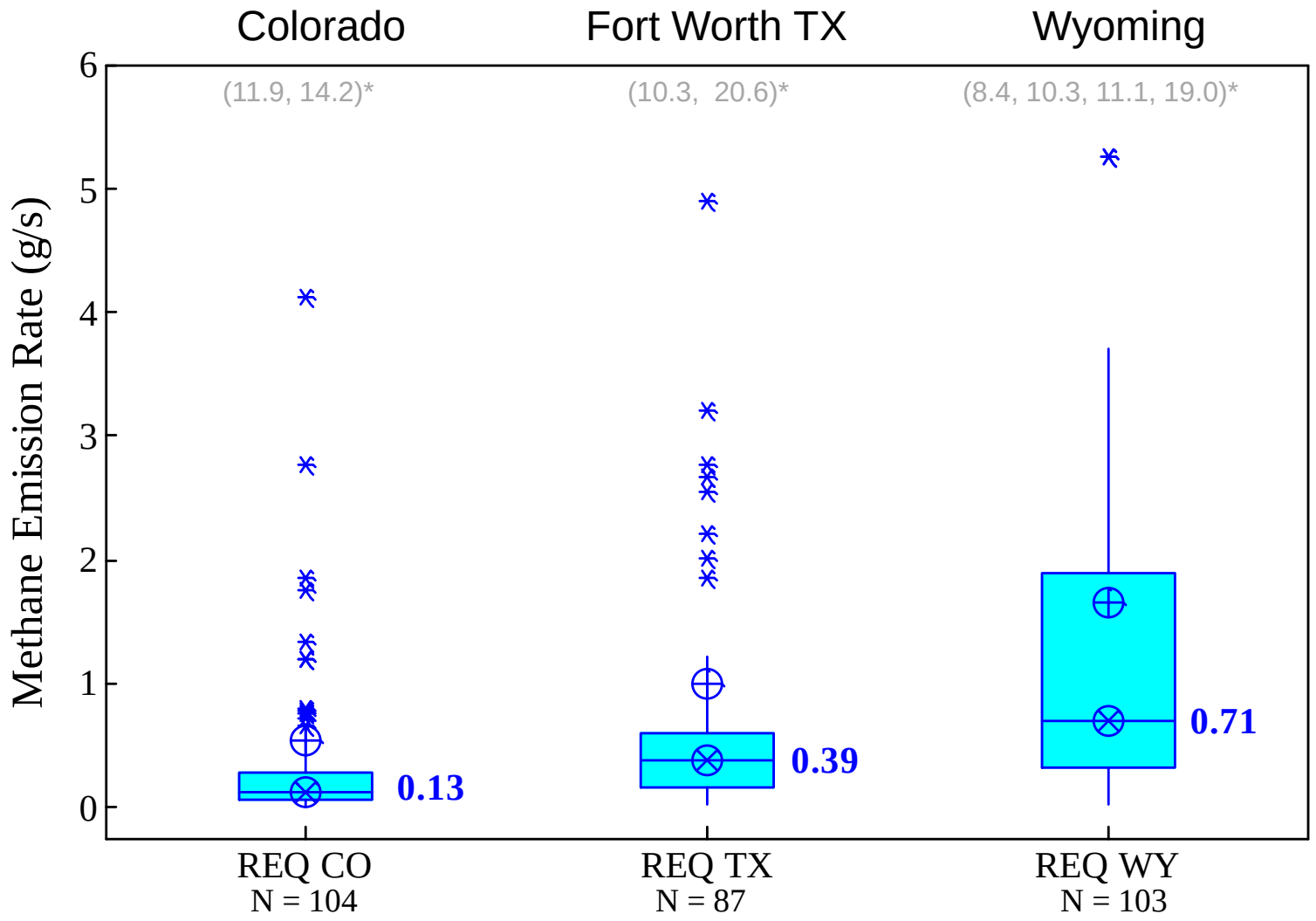
- Three GMAP REQ data groups:
  - Greeley Colorado area (REQ CO)
  - Fort Worth TX area (REQ TX)
  - Pinedale WY area (REQ WY)

- Comparisons are presented to help understand REQ approach and data
  - On-site direct measurement studies (DEM with references in paper)
  - Comparison to Greeley CO inventory (Inv.)

- Important to keep in mind:
  - GMAP REQ data are 20 minute “snapshots”
  - High values can be transient (can’t extrapolate to tons per year)
  - The median of the distribution is the best thing to focus on
  - Need to think of emissions in terms of production rates (next step)

GMAP REQ Field Data

CH_4 Emissions



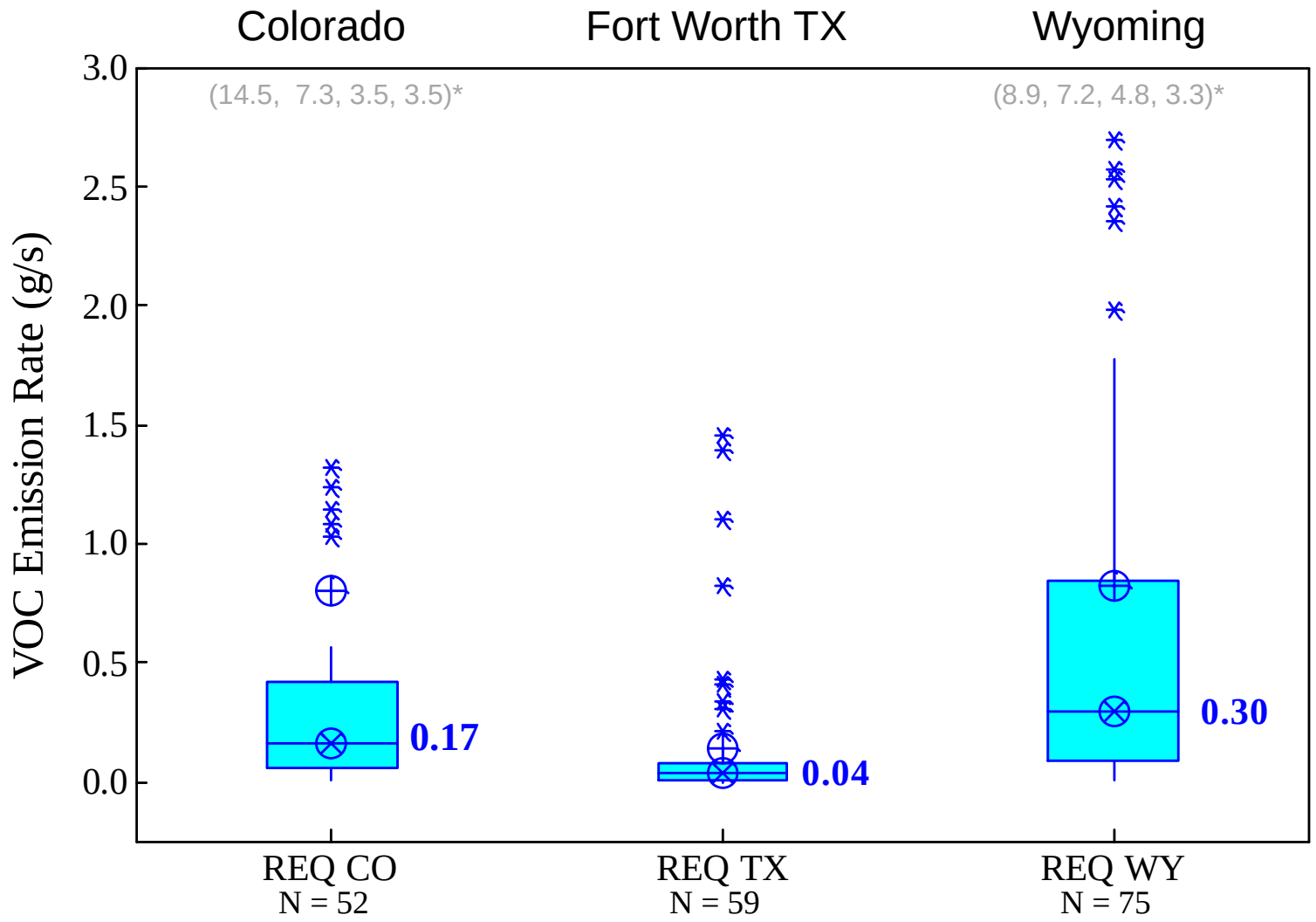
⊕ mean
⊗ median

Analysis based on GMAP REQ DA analytical and QA filter criteria as of February 2012

*off scale

GMAP REQ Field Data

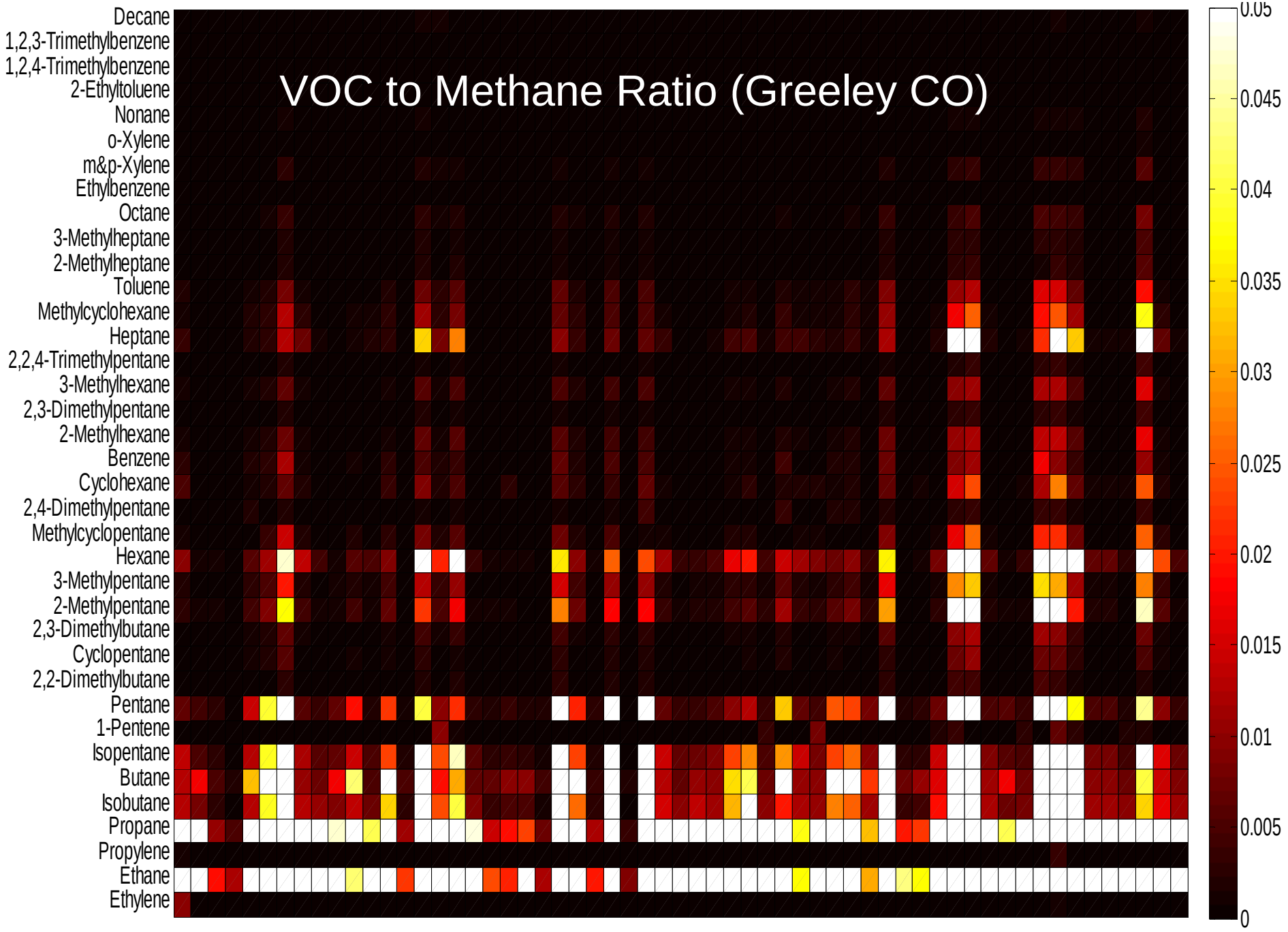
VOC Emissions

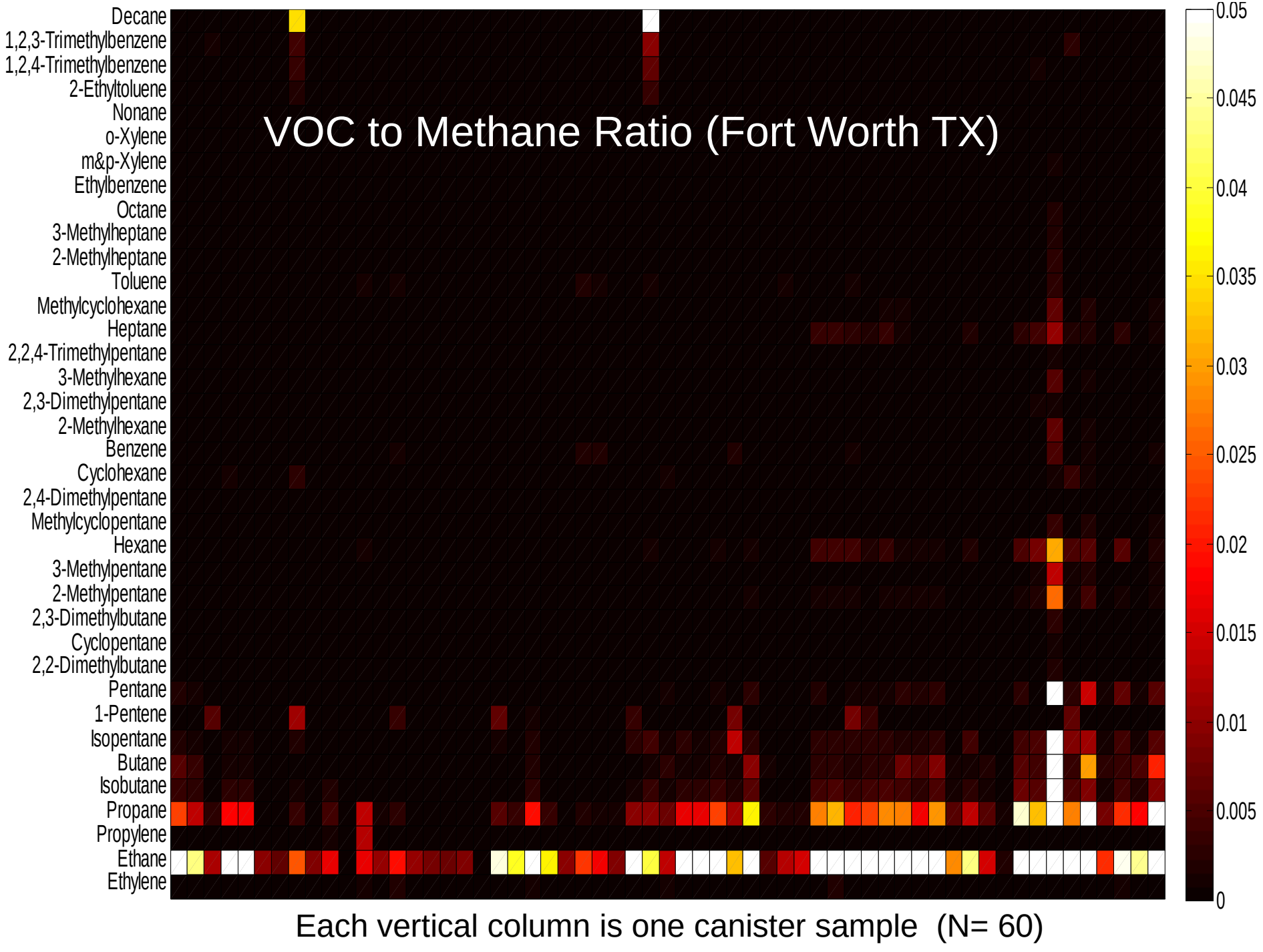


⊕ mean
⊗ median

Analysis based on GMAP REQ DA analytical and QA filter criteria as of February 2012

*off scale


VOC to Methane Ratio (Greeley CO)
Decane
1,2,3-Trimethylbenzene
1,2,4-Trimethylbenzene
2-Ethyltoluene
Nonane
o-Xylene
m&p-Xylene
Ethylbenzene
Octane
3-Methylheptane
2-Methylheptane
Toluene
Methylcyclohexane
Heptane
2,2,4-Trimethylpentane
3-Methylhexane
2,3-Dimethylpentane
2-Methylhexane
Benzene
Cyclohexane
2,4-Dimethylpentane
Methylcyclopentane
Hexane
3-Methylpentane
2-Methylpentane
2,3-Dimethylbutane
Cyclopentane
2,2-Dimethylbutane
Pentane
1-Pentene
Isopentane
Butane
Isobutane
Propane
Propylene
Ethane
Ethylene
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Each vertical column is one canister sample (N= 60)


VOC to Methane Ratio (Fort Worth TX)
Decane
1,2,3-Trimethylbenzene
1,2,4-Trimethylbenzene
2-Ethyltoluene
Nonane
o-Xylene
m&p-Xylene
Ethylbenzene
Octane
3-Methylheptane
2-Methylheptane
Toluene
Methylcyclohexane
Heptane
2,2,4-Trimethylpentane
3-Methylhexane
2,3-Dimethylpentane
2-Methylhexane
Benzene
Cyclohexane
2,4-Dimethylpentane
Methylcyclopentane
Hexane
3-Methylpentane
2-Methylpentane
2,3-Dimethylbutane
Cyclopentane
2,2-Dimethylbutane
Pentane
1-Pentene
Isopentane
Butane
Isobutane
Propane
Propylene
Ethane
Ethylene
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Each vertical column is one canister sample (N= 60)

EPA and City of Forth Worth studies approximate measurement areas

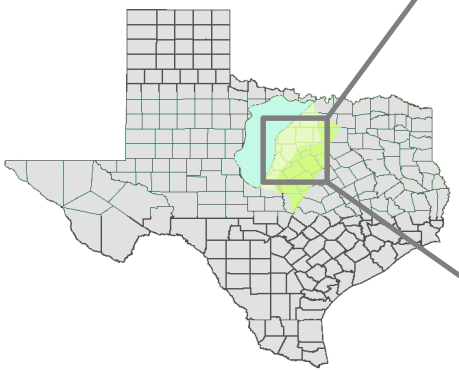
United States Environmental Protection Agency

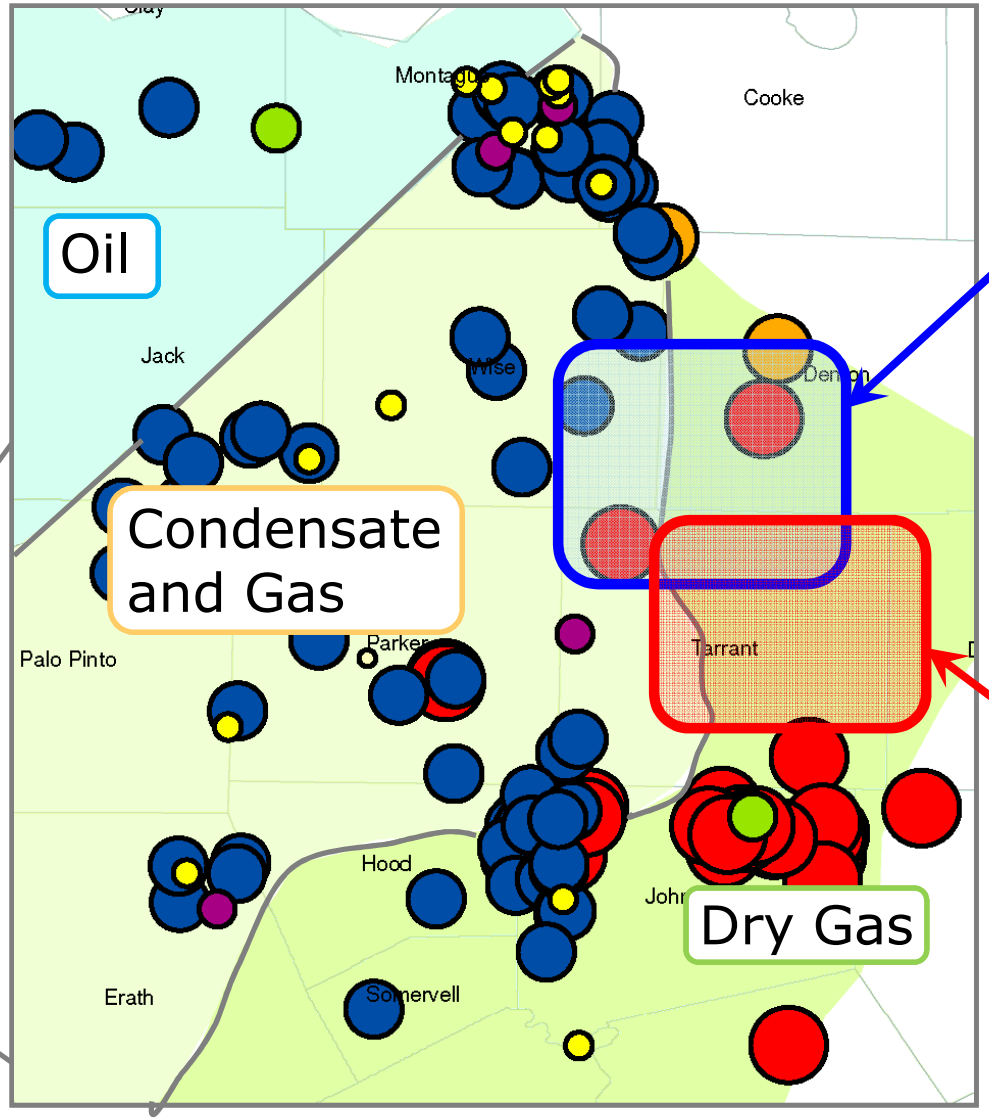
EXPLANATION

Methane mol% From production data

- 0.01 - 10
- 10.01 - 40.00
- 40.01 - 70.00
- 70.01 - 75.00
- 75.01 - 80.00
- 80.01 - 90.00
- Greater than 90

TEXAS



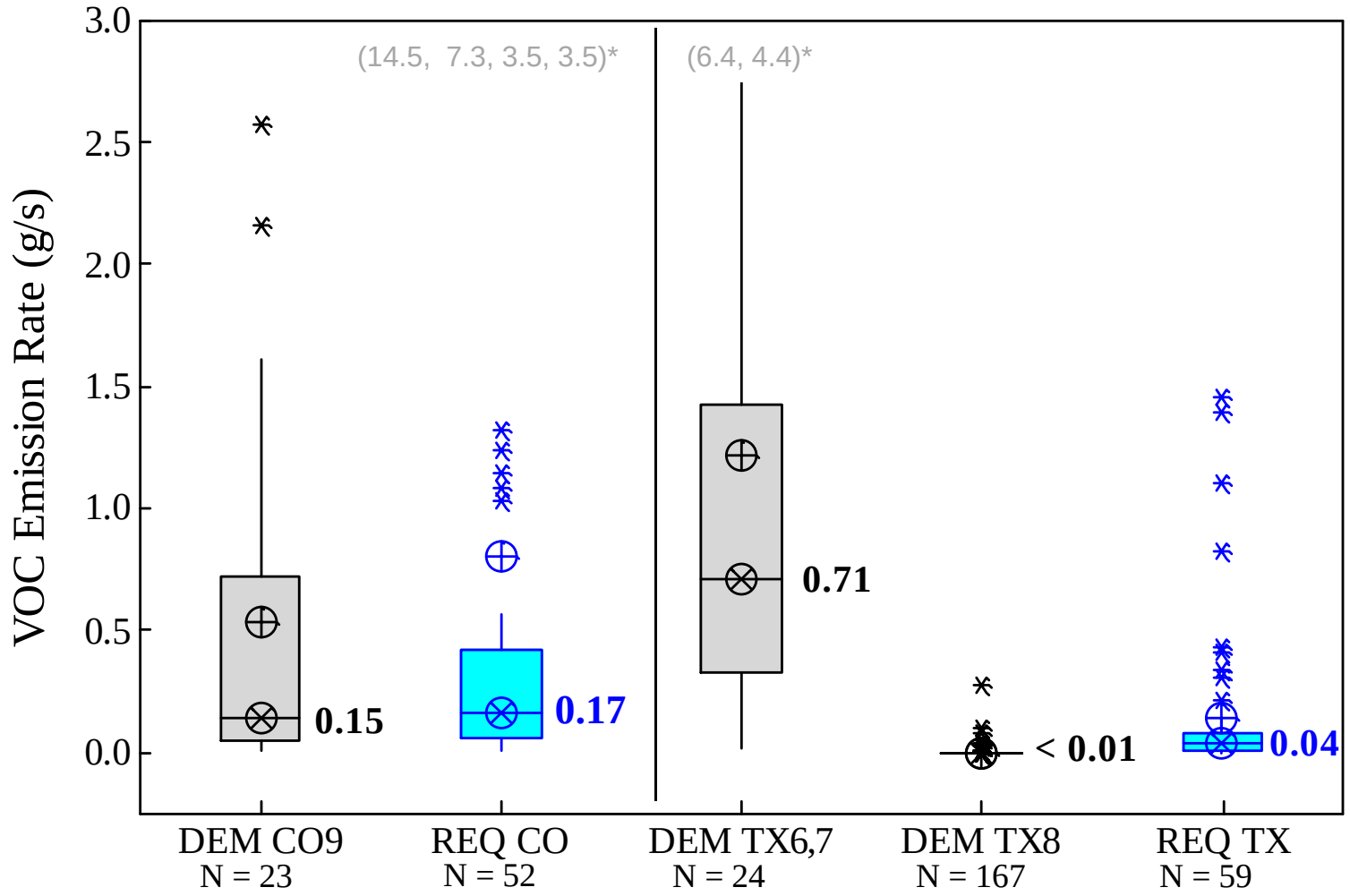


EPA
(some wet gas)

City of Forth Worth
(mostly dry gas)

GMAP REQ compared to on-site measurements

VOC Emissions



⊕ mean
⊗ median

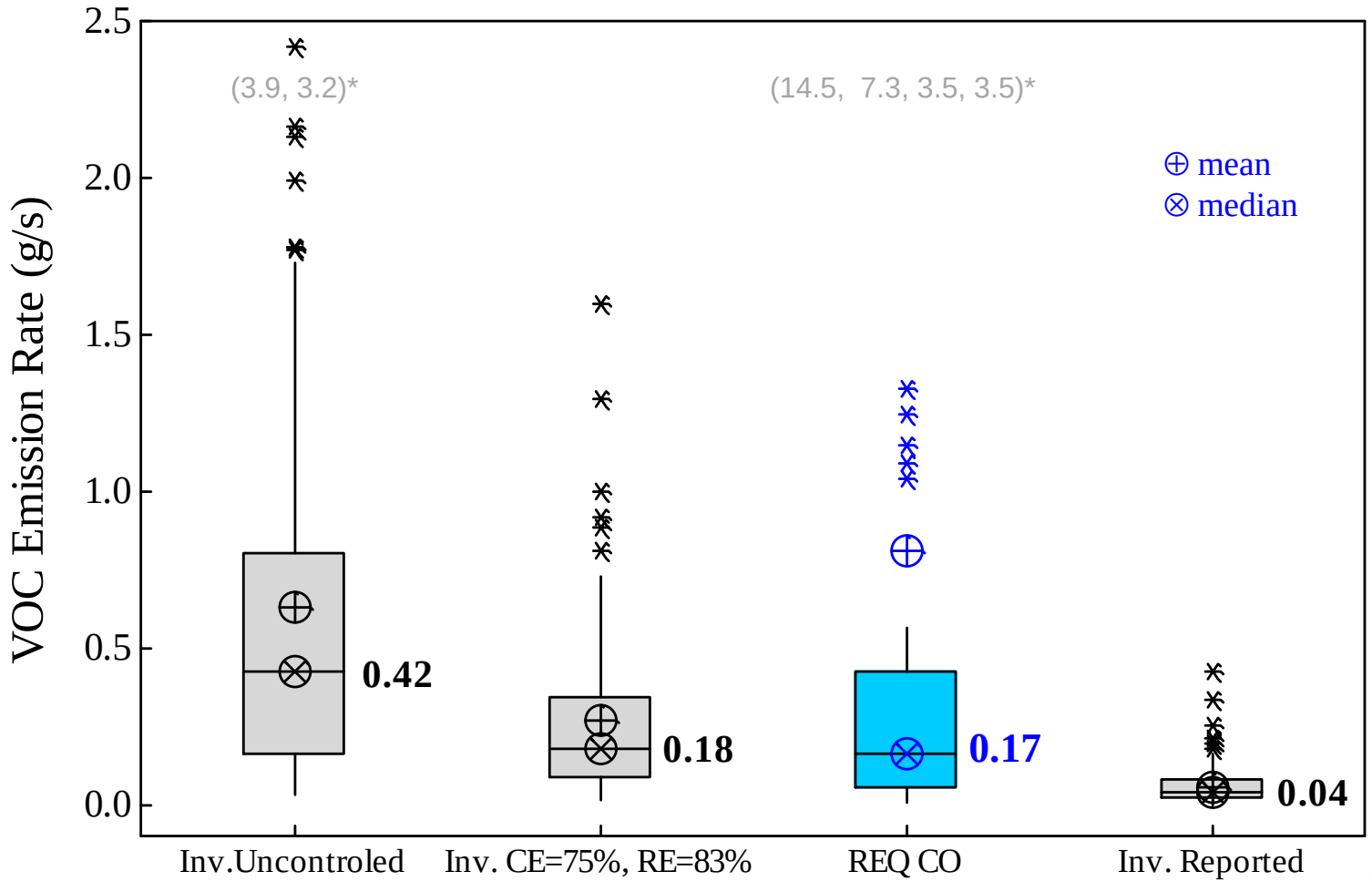
Analysis based on GMAP REQ DA analytical and QA filter criteria as of February 2012

*off scale

GMAP REQ "VOC snapshot measurements" compared to CO condensate tank emissions inventory expressed in g/s.

(tanks within 500 m of GMAP measurement, Inv. data provided by Dale Wells, Colorado DPHE)

In Greeley Colorado, condensate tank emissions are controlled by flares



*off scale

Inv. Uncontrolled: modeled inventory assuming 0% control Capture Efficiency (CE),
Inv. CE=75%, RE=83%: State of CO estimate of 75% control CE and 83% Rule Effectiveness (RE), 95% control effectiveness
Inv. Reported: Reported inventory assuming 100 % CE, 100% RE and 95% control effectiveness

Continuing work on dataset and method

Geospatial visualization database

United States Environmental Protection Agency

Google Earth database
Allow viewing of field Data and IR videos

Source

Wind QA Chart
(needs magnetic declination correction)

Observation

ST3_090711

Developing Wind QA Chart to help confirm source location and distance

© 2012 Google
Imagery Date: 6/13/2011 33°04'12.26" N 97°28'08.30" W elev 0 ft Eye alt 958 ft

ST3_090711

Collection Summary

Latitude:	33.0699 °N
Longitude:	-97.469 °E
CH4 BG Conc:	1.83 ppm
CH4 Peak Conc:	2.89 ppm
CH4 Emission Rate:	0.54 g/s
Wind Speed Avg:	3.96 m/s
Wind Dir Avg:	10.4 °
Distance:	125 m

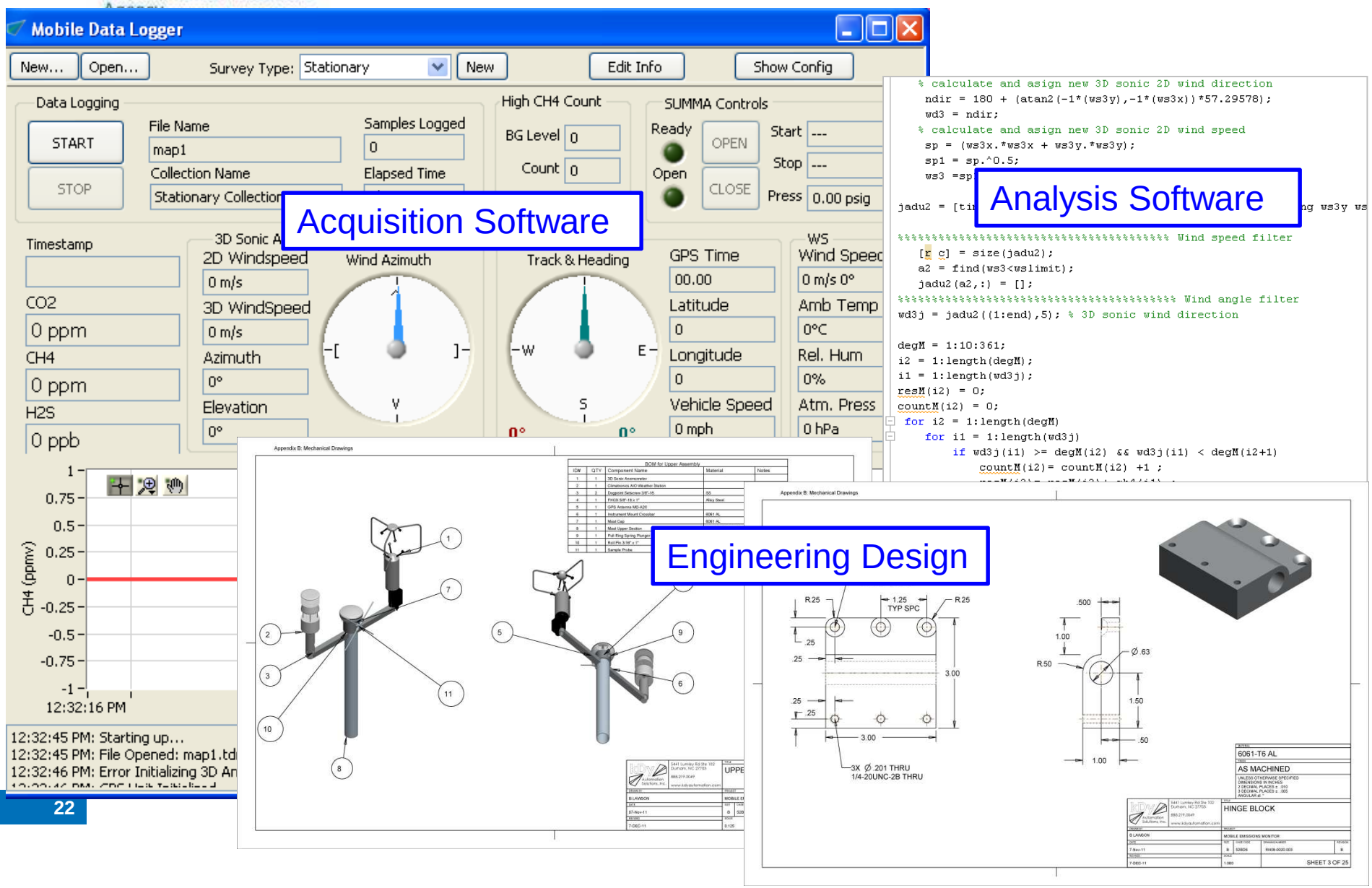
Links

Right-click and select "open link" to view files

Method and engineering package development

(to be submitted to EPA OAQPS for posting consideration as preliminary method)

United States Environmental Protection Agency



Four GMAP REQ systems in the field

EPA United States Environmental Protection Agency

Summary and next steps

- The GMAP REQ approach is a useful tool to complement developing on-site measurements for oil and gas and other sectors
- Preliminary results from field studies provide interesting comparisons with direct emissions measurements and inventory estimates
- Data analysis continues in 2012
  - Development of QA checks and comparisons with CFD modeling
  - Google-earth based visualization and infrared camera database
- GMAP REQ method development activities continue in 2012
  - New user interface software with source location indicators
  - Expand to UV detection for BTEX (facility LDAR applications)

EPA oil and gas measurement team and contractor and vendor acknowledgments

- Eben Thoma, Bill Squier, Bill Mitchell - *EPA Office of Research and Development, National Risk Managment Research Laboratory*
- Dave Olson, Sergey Napelenok, Matt Landis, Karen Oliver - *EPA Office of Research and Development, National Risk Managment Research Laboratory*
- Robin Segall, Jason DeWees , Roy Huntley - *EPA Office of Air Quality Planning and Standards*
- Adam Eisele, Cindy Beeler, Carl Daly - *EPA Region 8*
- Mike Miller, Michael Morton, Ruben Casso - *EPA Region 6*
- Marta Fuoco, Chad McEvoy, Loretta Lehrman - *EPA Region 5*
- Rich Killian, CarolAnn Gross-Davis, Ron Landy, Howard Schmidt - *EPA Region 3*
- Armando Bustamante, Ken Garing - *EPA NEIC*
- **M. Shahrooz Amin, Mark Modrak -** *ARCADIS (Contractor EPA)*
- Chris Lehmann, Joe Ibanez, Buzz Harris, David Ranum - *Sage Environmental Consulting Inc.*
- Chris Rella, Eric Crosson - *Picarro Inc.*
- Wei Tang, Matt Freeman, Mike Uhl - *Lockheed Martin*
- Working with City of Forth Worth TX, States of CO, WY, and TX

United States Environmental Protection Agency

Backup Slides

Basic Data Analysis Approach

- Estimate CH_4 emissions using concentration and wind data
- Obtain emission information for other compounds by a ratio of canister to CH_4 data

$$F_t = [(C_t * F_o)/C_o]\ [M_t/M_o]$$

Where:

F_t =the flux of the target compound (VOC)

C_t =the measured concentration of the target compound

F_o =the calculated methane flux

C_o =the measured methane concentration

M_t =the molecular weight of the target compound

M_o =the molecular weight of methane