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

Abstract Control # 5
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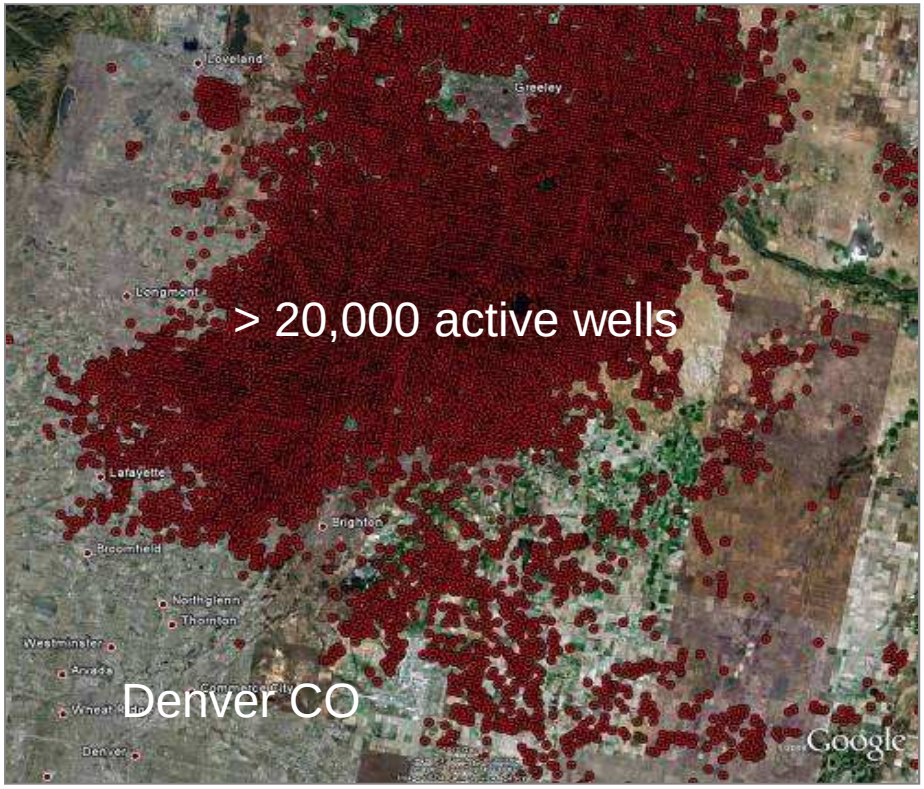
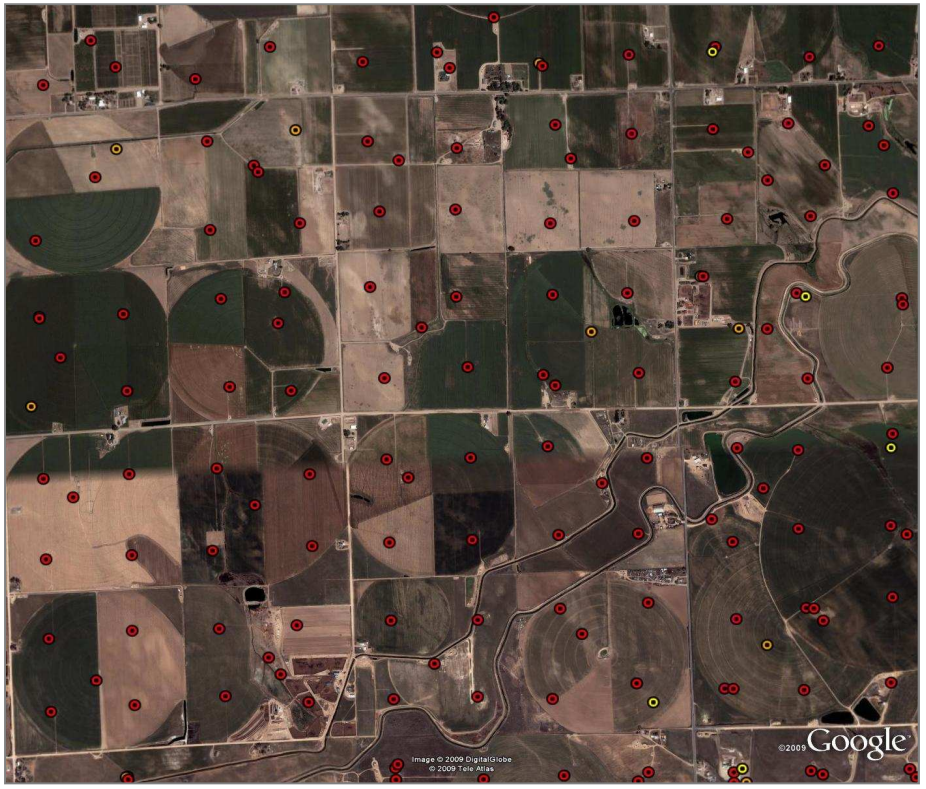
Motivation for oil and gas measurements

- Number of production facilities is increasing
  - *Impact of VOC emissions to ozone attainment is uncertain*
  - *GHG emissions estimates need improvement*
- 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

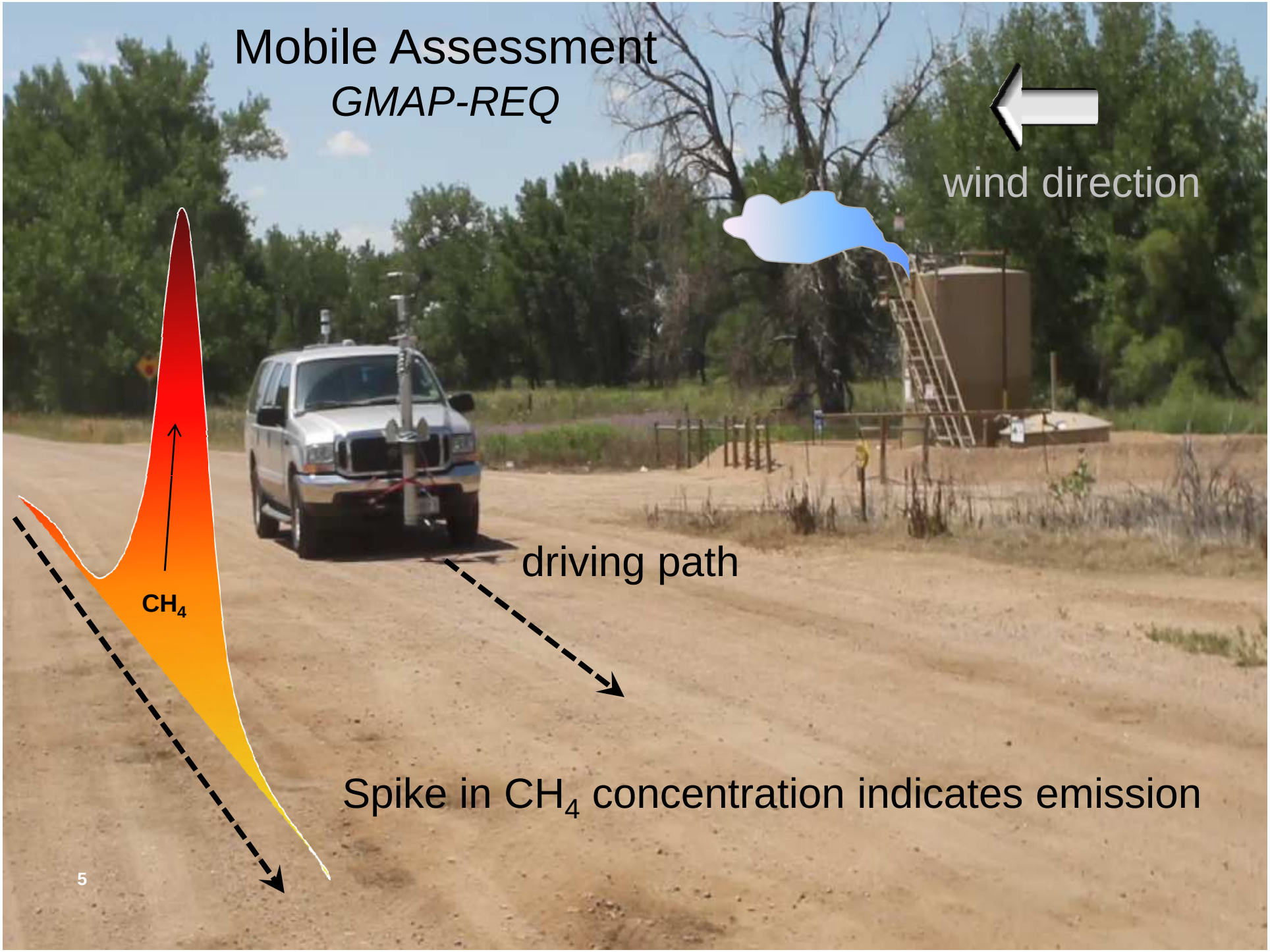





FLIR
ME OFF
AUTO
HIST
WH
Many types of emissions complicates assessment
FLIR Video File

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)


Mobile Assessment
GMAP-REQ
wind direction
driving path
CH_4
Spike in CH_4 concentration indicates emission

Mobile Assessment - GMAP REQ

Geospatial Measurement of Air Pollution (GMAP)
Remote Emissions Quantification (REQ)

GMAP-REQ Measurement Sequence:

- Locate emission to be studied
- Observe with FLIR camera if possible (off-site)
- Position vehicle in the plume (head on)*
- Turn off engine (to avoid vehicle emissions)
- Set mast rotation and determine source distance
- Acquire CH_4 and wind data for 20 minutes
- Pull a 30 second canister sample for VOC information

* Safe, off-site location, usually roadway shoulders, deploy traffic cones

Measurement equipment

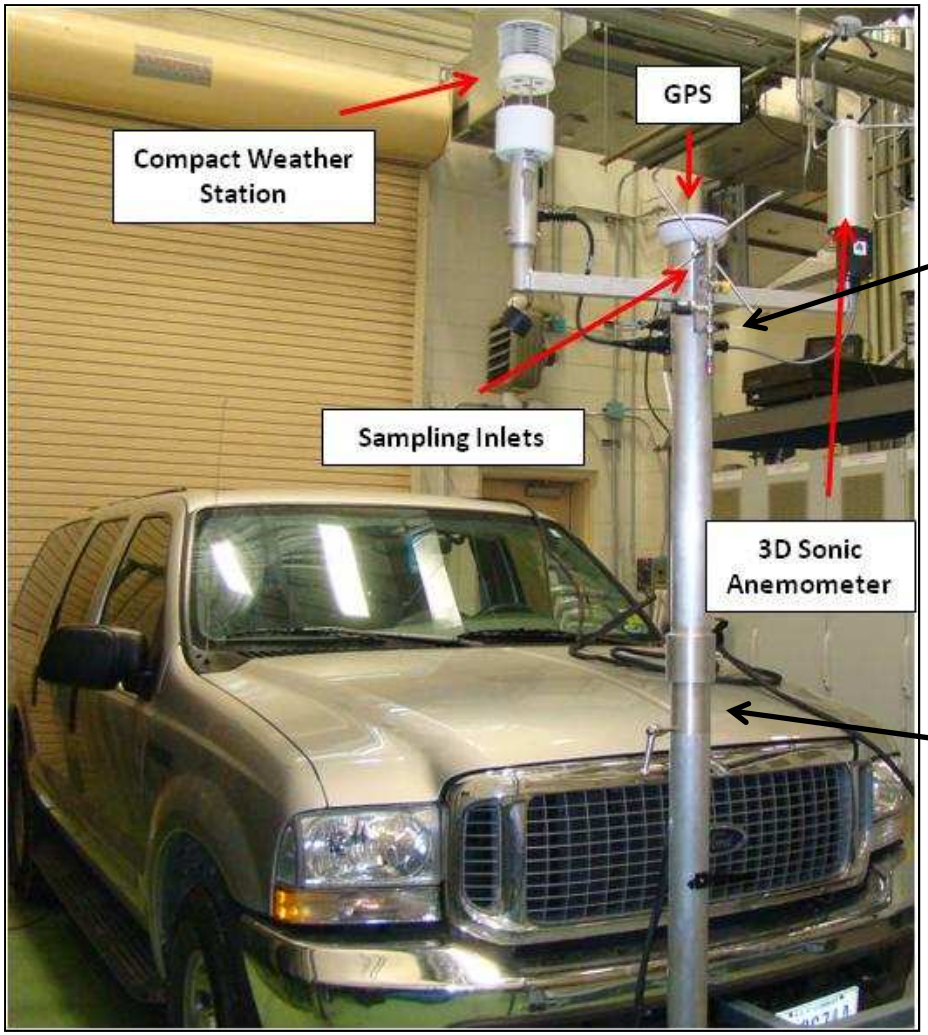
In the truck

- 10 Hz high precision methane analyzer
- Battery power system (to avoid vehicle exhaust issues)
- Computer/LabView data acquisition system
- FLIR Camera (if available)

On the mast

- Quad sampling port (0.2 m)
- Auto-north compact weather station
- 3-D sonic anemometer
- High precision GPS
- Evacuated canister draw system
- Distance and angle measurement

Measurement equipment



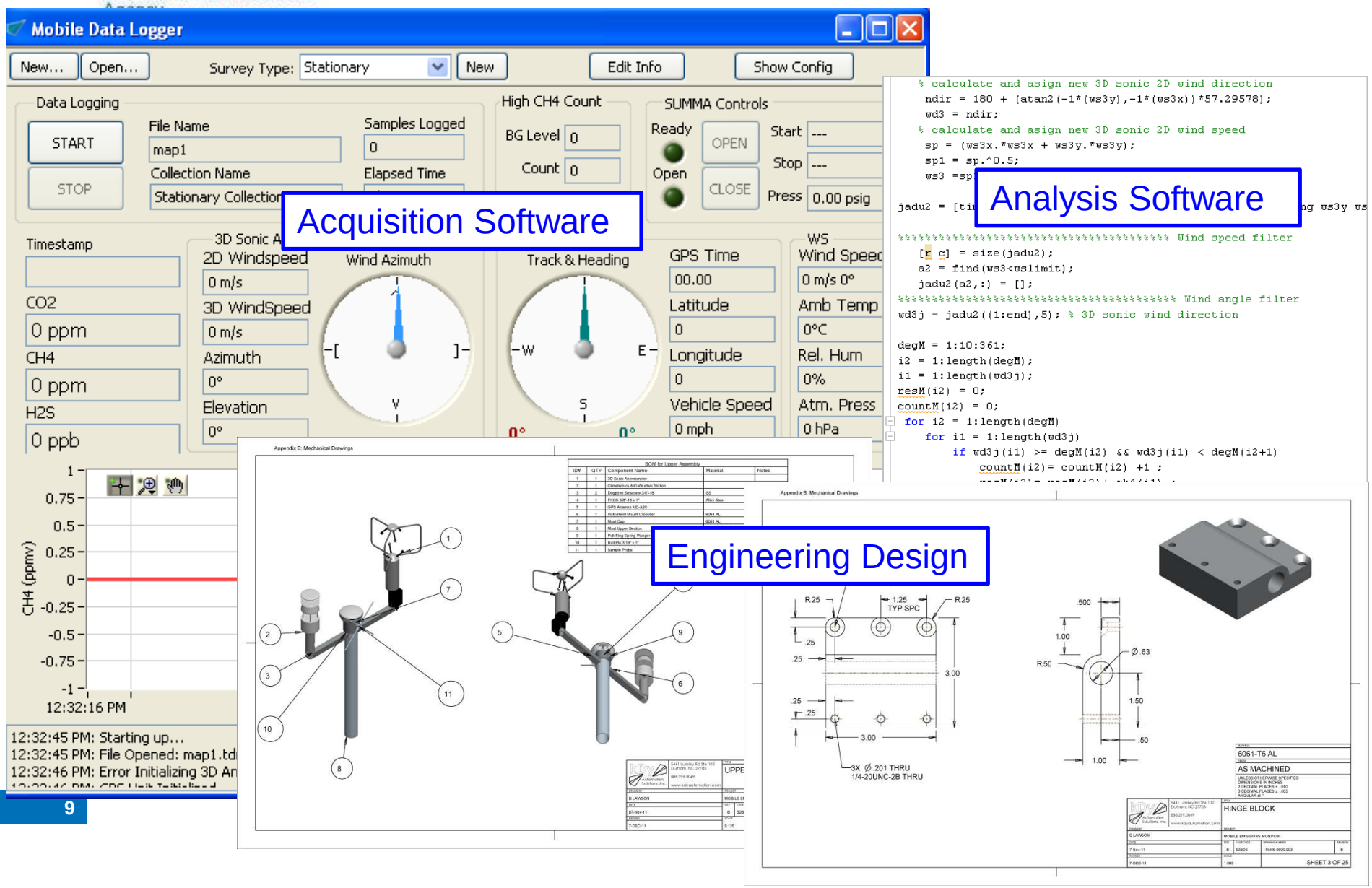
1.4 liter SUMMA Canister is placed here

Mast height range from 2.5 m to 5.0 m

Method and engineering package development

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

United States Environmental Protection Agency



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

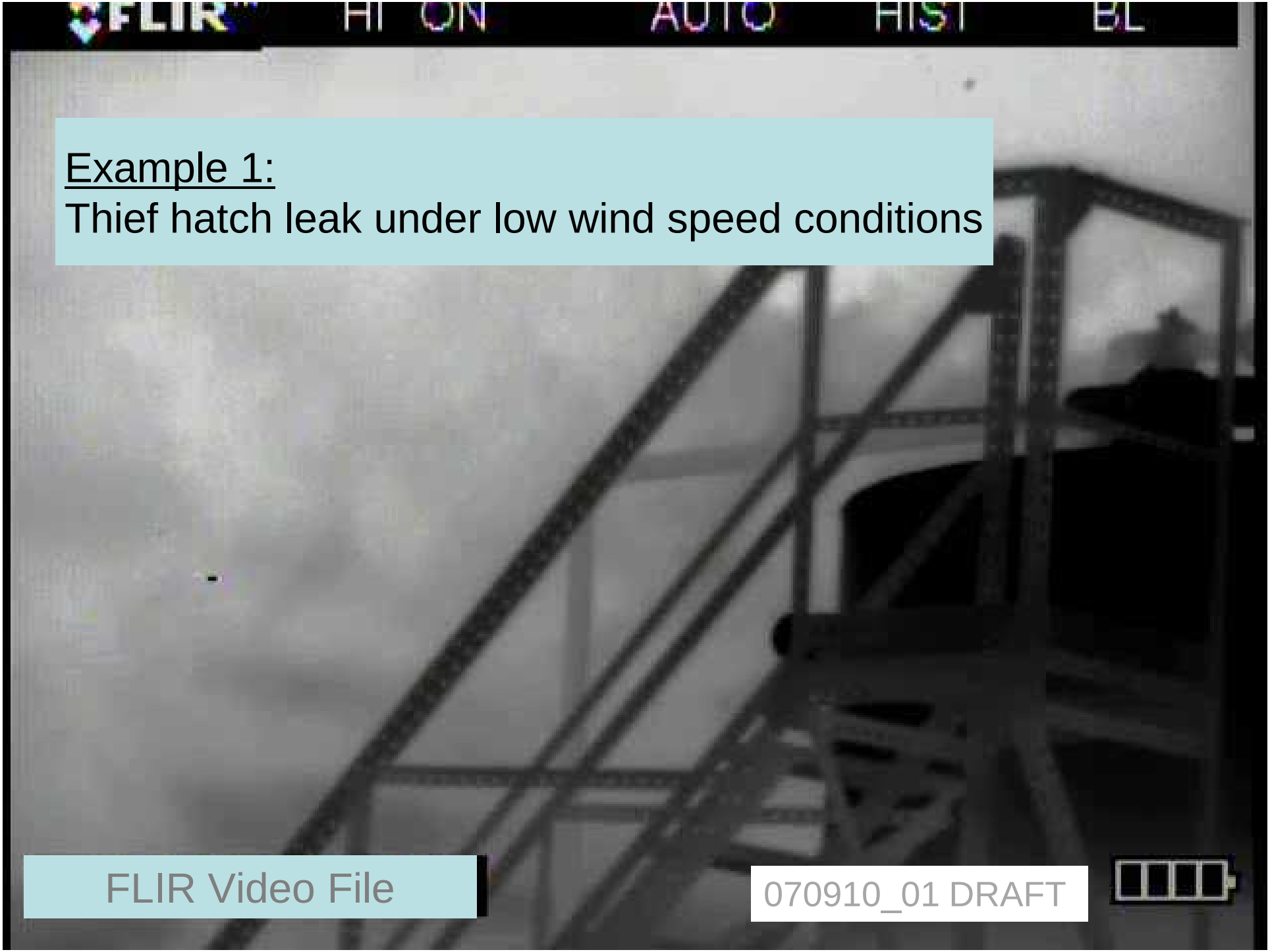
C_o =the measured methane concentration

M_t =the molecular weight of the target compound

M_o =the molecular weight of methane

Two basic emissions CH_4 estimation approaches
(PSG and bLs)

- CH_4 vs. wind angle in 10 deg bins
- Filters to remove off-axis wind information (+/- 60 deg)
- Determine CH_4 conc. by Gaussian fit
- Point Source Gaussian (PSG) approach
  - Use CH_4, and atmospheric stability to find expected σy,σz
  - Perform simple 2-D integration (no ground reflection term)
- Backwards Lagrangian Stochastic (BLS)
  - Use CH_4 and 3D sonic data in free use model WindTrax 2.0
- Estimate VOC emissions by canister ratio approach with CH_4

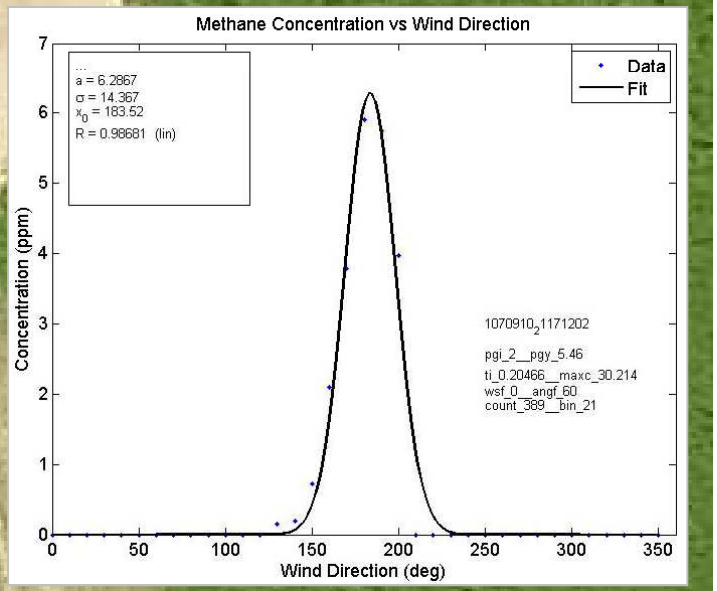

FLIR
HI ON
AUTO
HIST
BL
Example 1:
Thief hatch leak under low wind speed conditions
FLIR Video File
070910_01 DRAFT

Example 1
Distance = 28 m
Wind speed = 2.2 m/s
CH_4 bkg. = 1.78 ppm
CH_4 peak = 6.29 ppm (>bkg.)

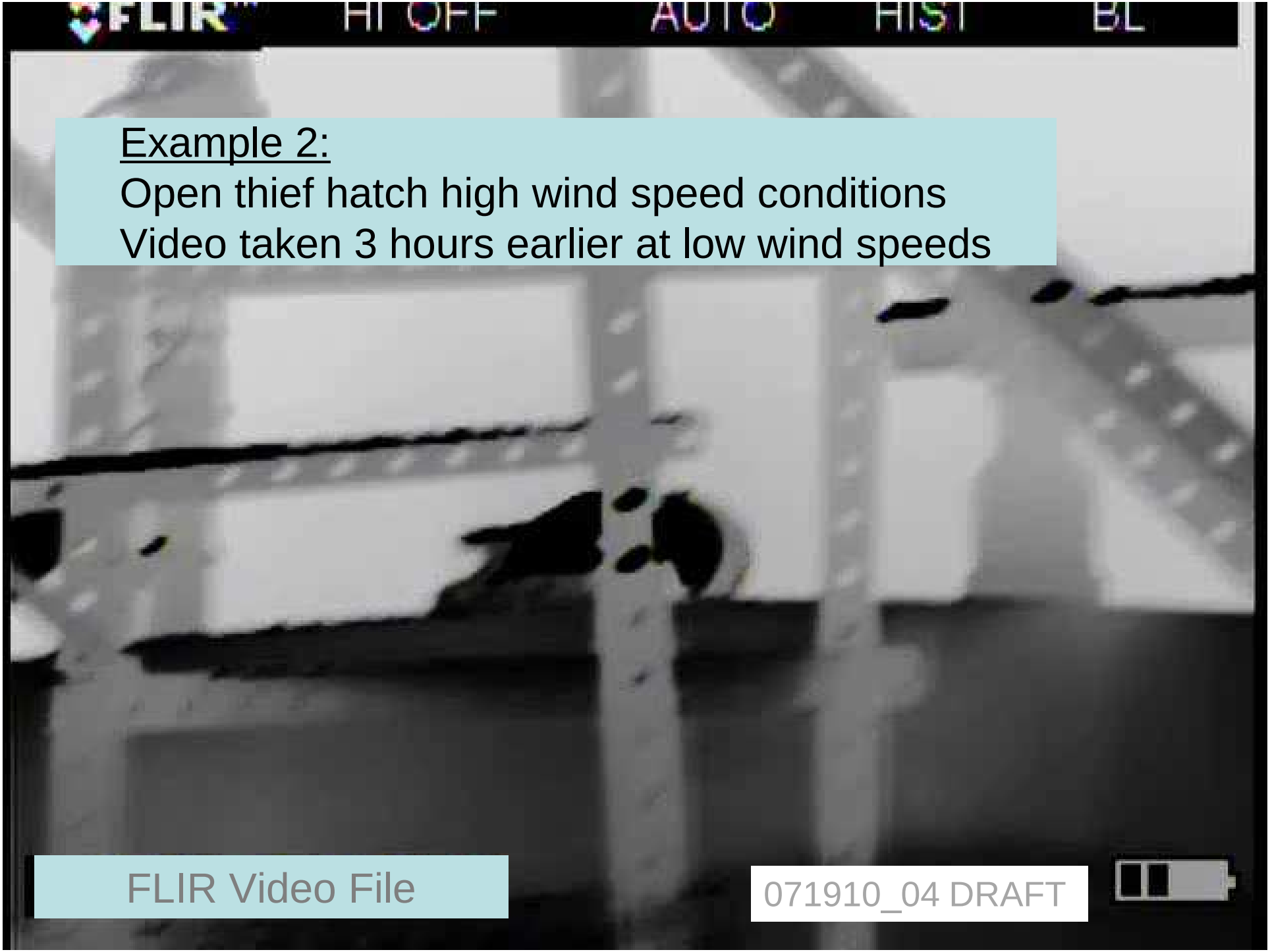
Snapshot emission estimate
CH_4 = 0.79 g/s
VOC = 0.31 g/s

Wind Direction

Observation point

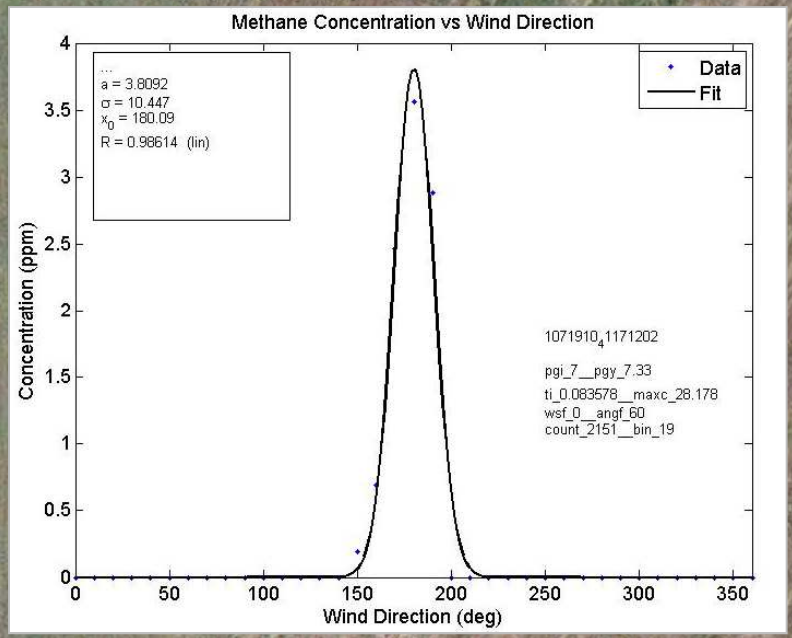


070910_02 DRAFT


FLIR
HI OFF
AUTO
HIST
BL
Example 2:
Open thief hatch high wind speed conditions
Video taken 3 hours earlier at low wind speeds
FLIR Video File
071910_04 DRAFT

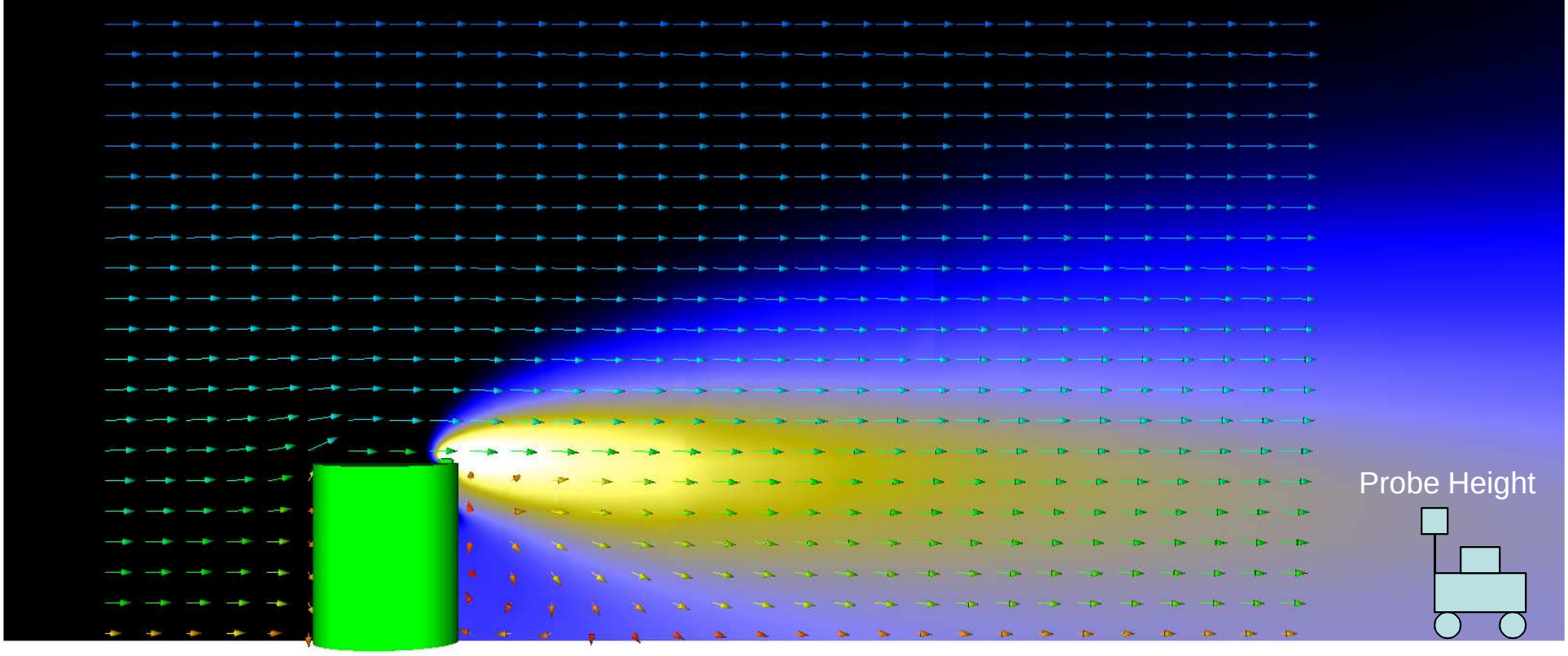
Example 2
Distance = 90 m
Wind speed = 6.1 m/s
CH_4 bkg. conc.= 1.78 ppm
CH_4 plume conc. = 3.81 ppm (>bkg.)

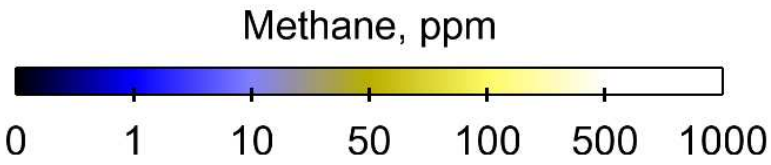
Snapshot emission estimates
CH_4 = 1.86 g/s
VOC = 1.08 g/s

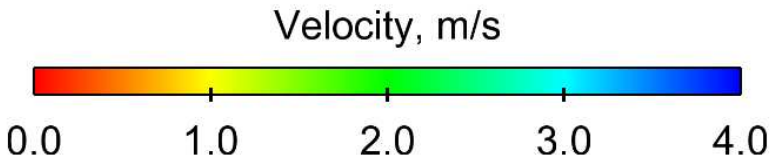


Wind Direction

- 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

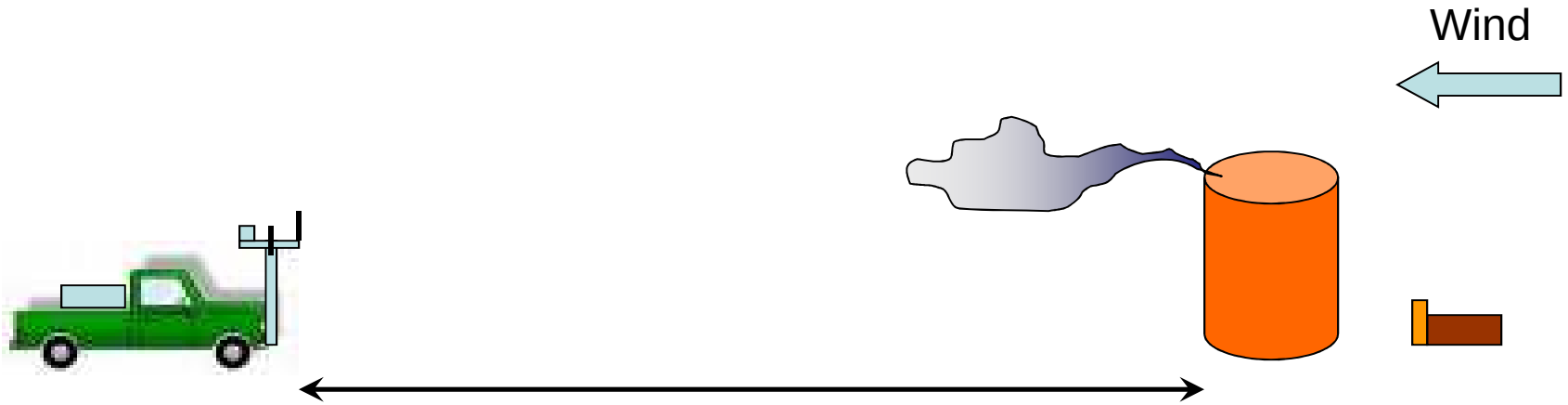






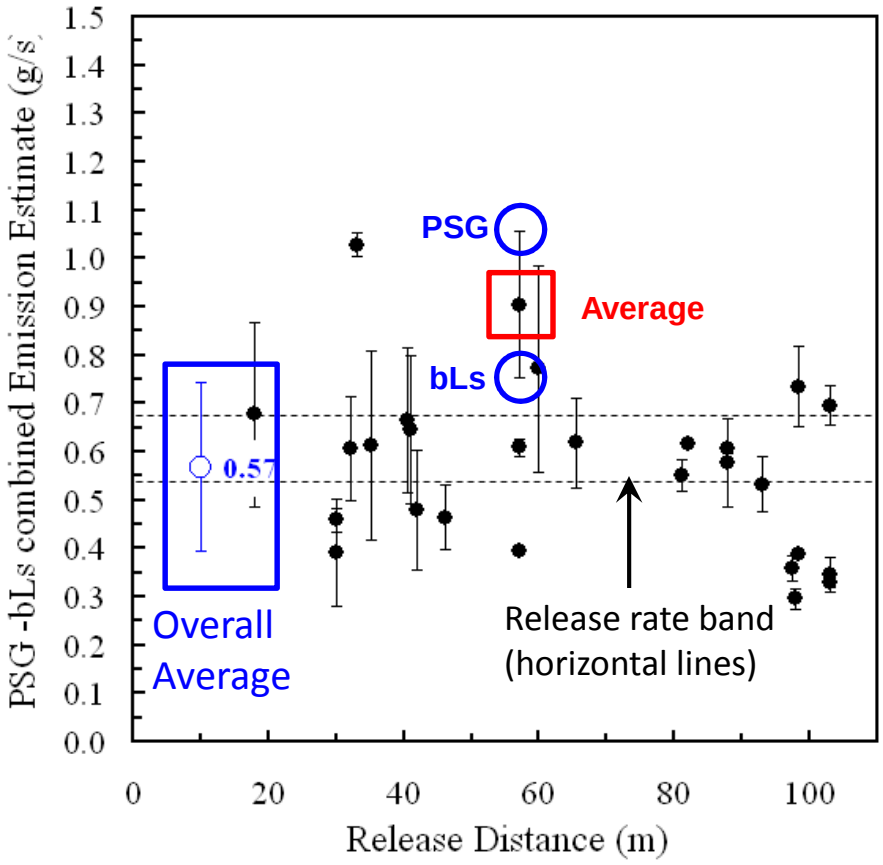
CH_4 release-recovery experiments

- 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

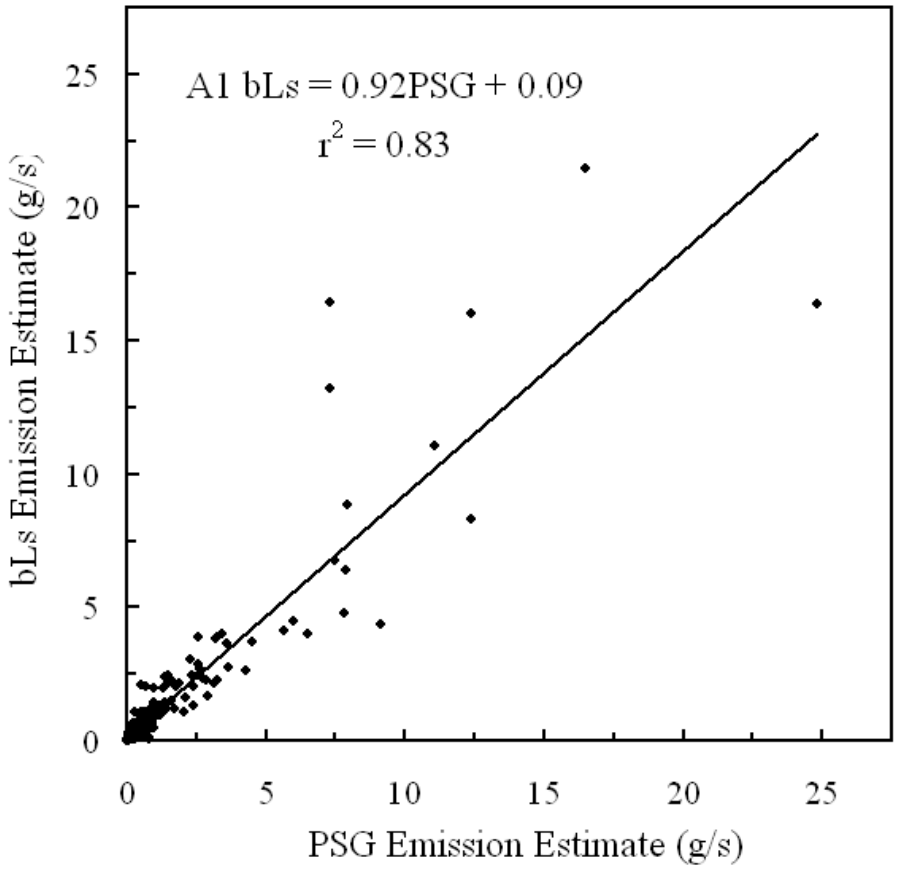


CH_4 release-recovery experiments and PSG to bLs model comparisons

PSG:bLs combined emission estimate results for CH_4 release experiments



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



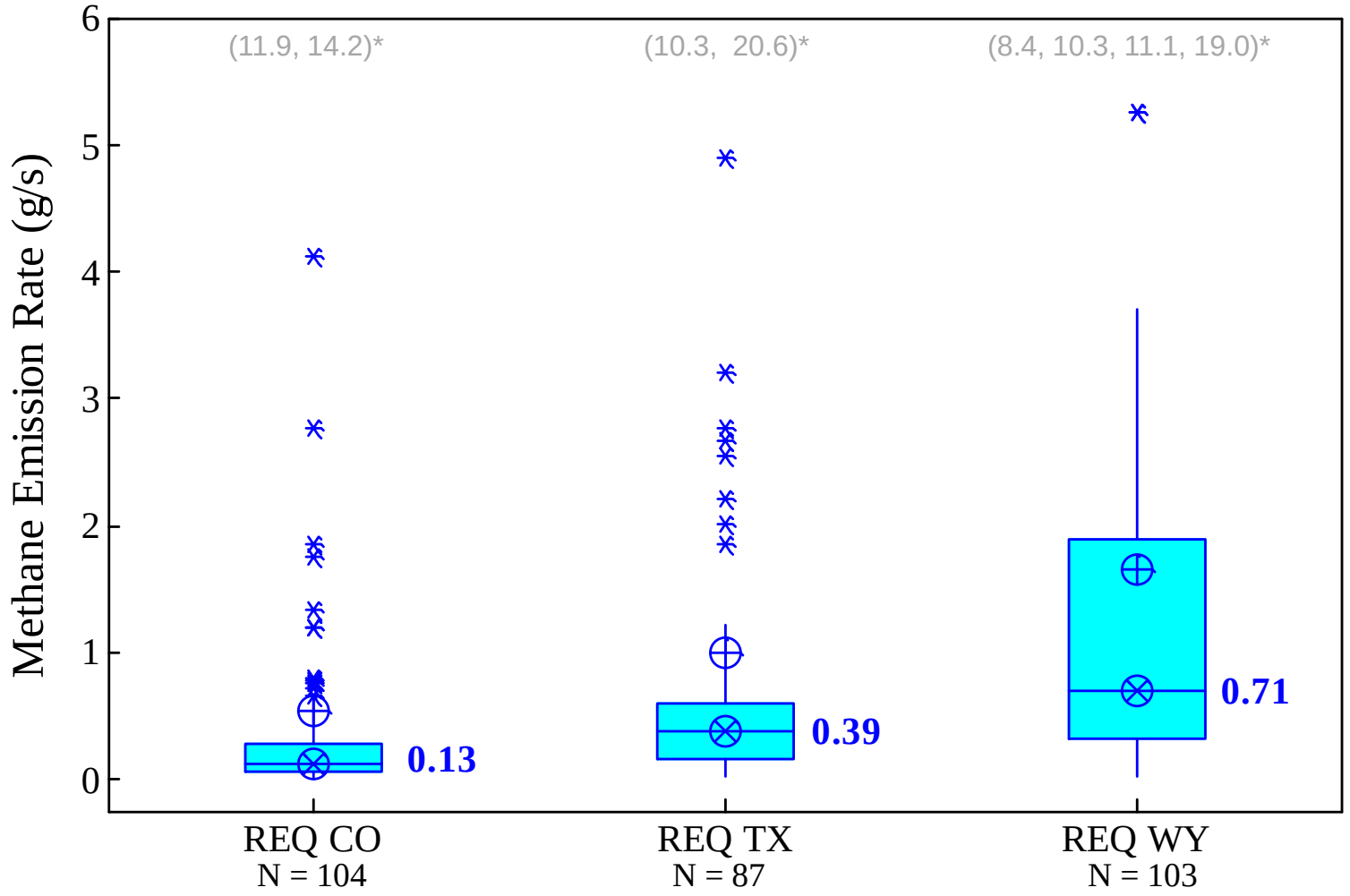
Review of Preliminary GMAP REQ Results

(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 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 are can be transient (can’t extrapolate to tons per year)
  - With further data set analysis, some high values may be revised
  - The median of the distribution is the best to thing to focus on
  - Emissions data needs to be related to production levels (next step)

GMAP REQ Field Data

CH_4 Emissions



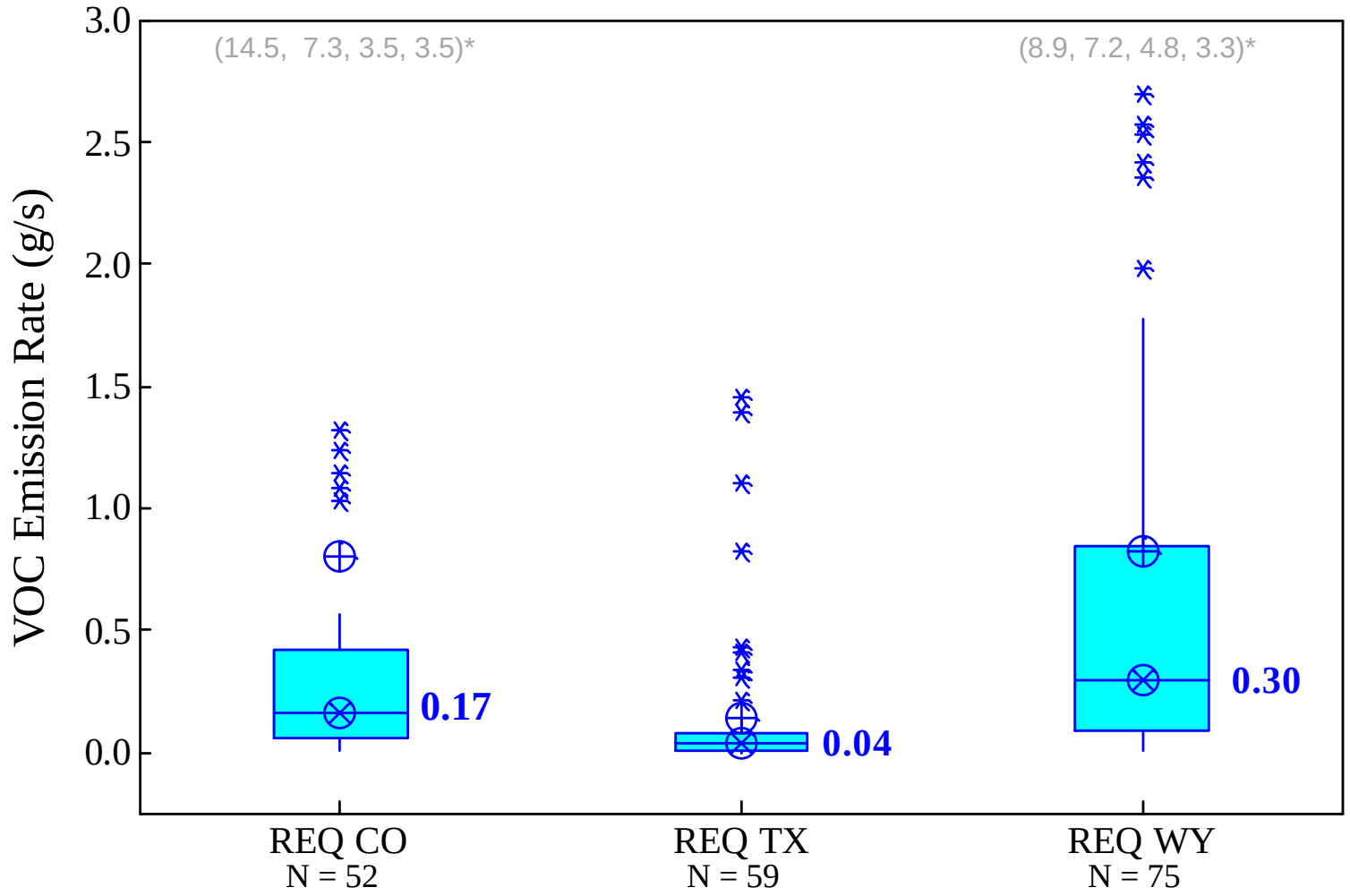
⊕ mean
⊗ median

Preliminary result: analysis based on GMAP REQ DA analytical and QA filter criteria as of February 2012

*off scale

GMAP REQ Field Data

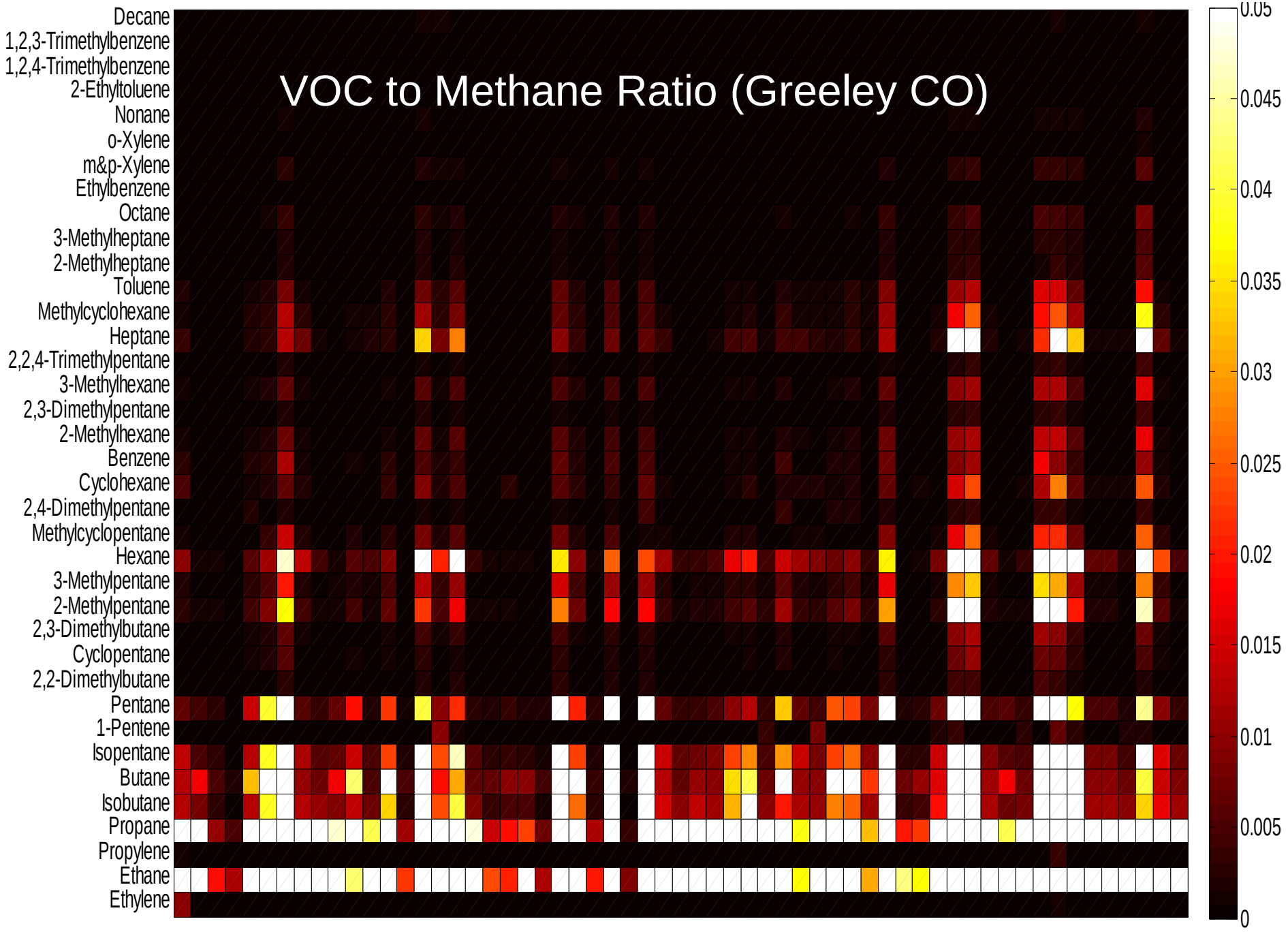
VOC Emissions

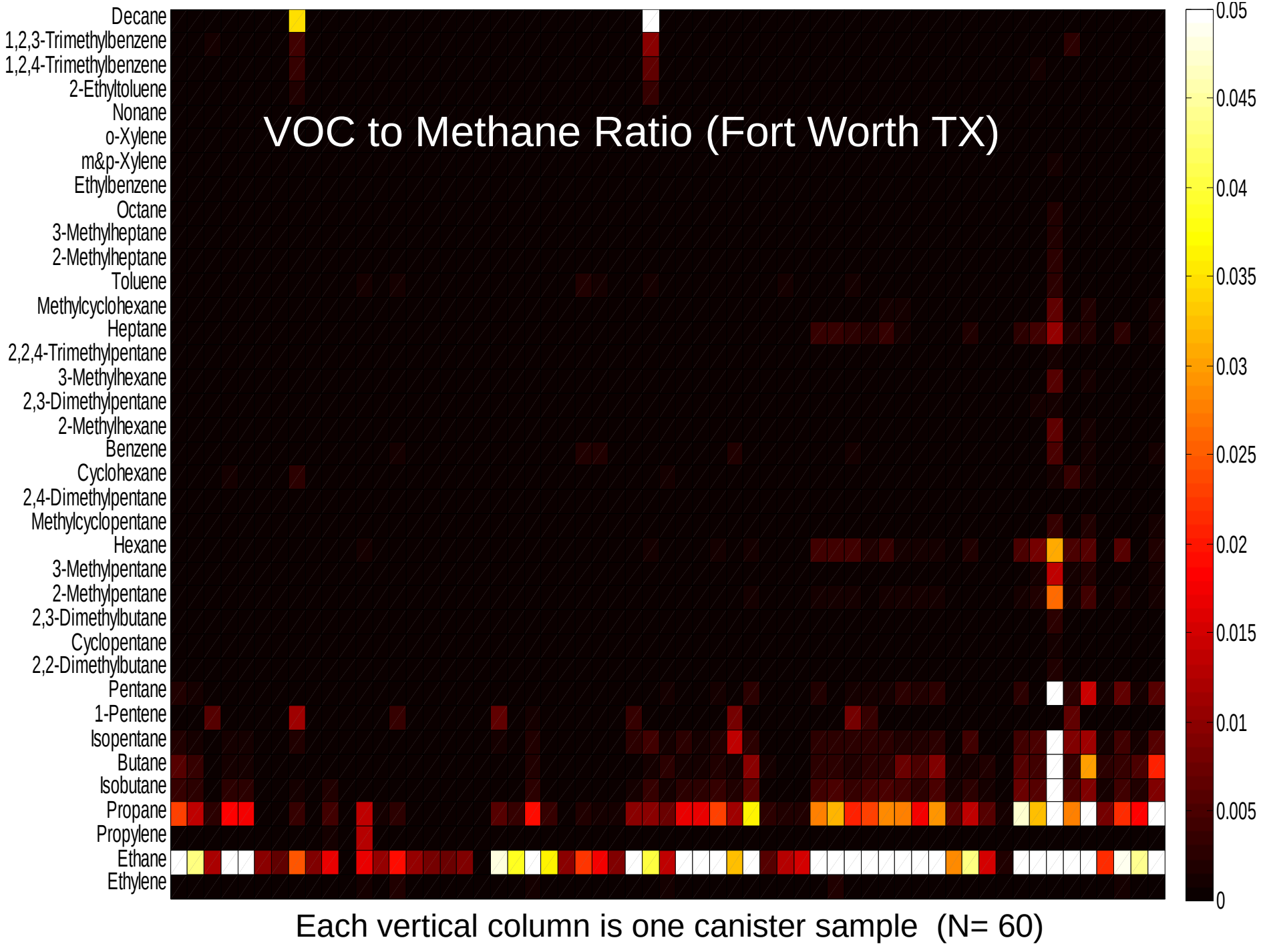


⊕ mean
⊗ median

Preliminary result: analysis based on GMAP REQ DA analytical and QA filter criteria as of February 2012

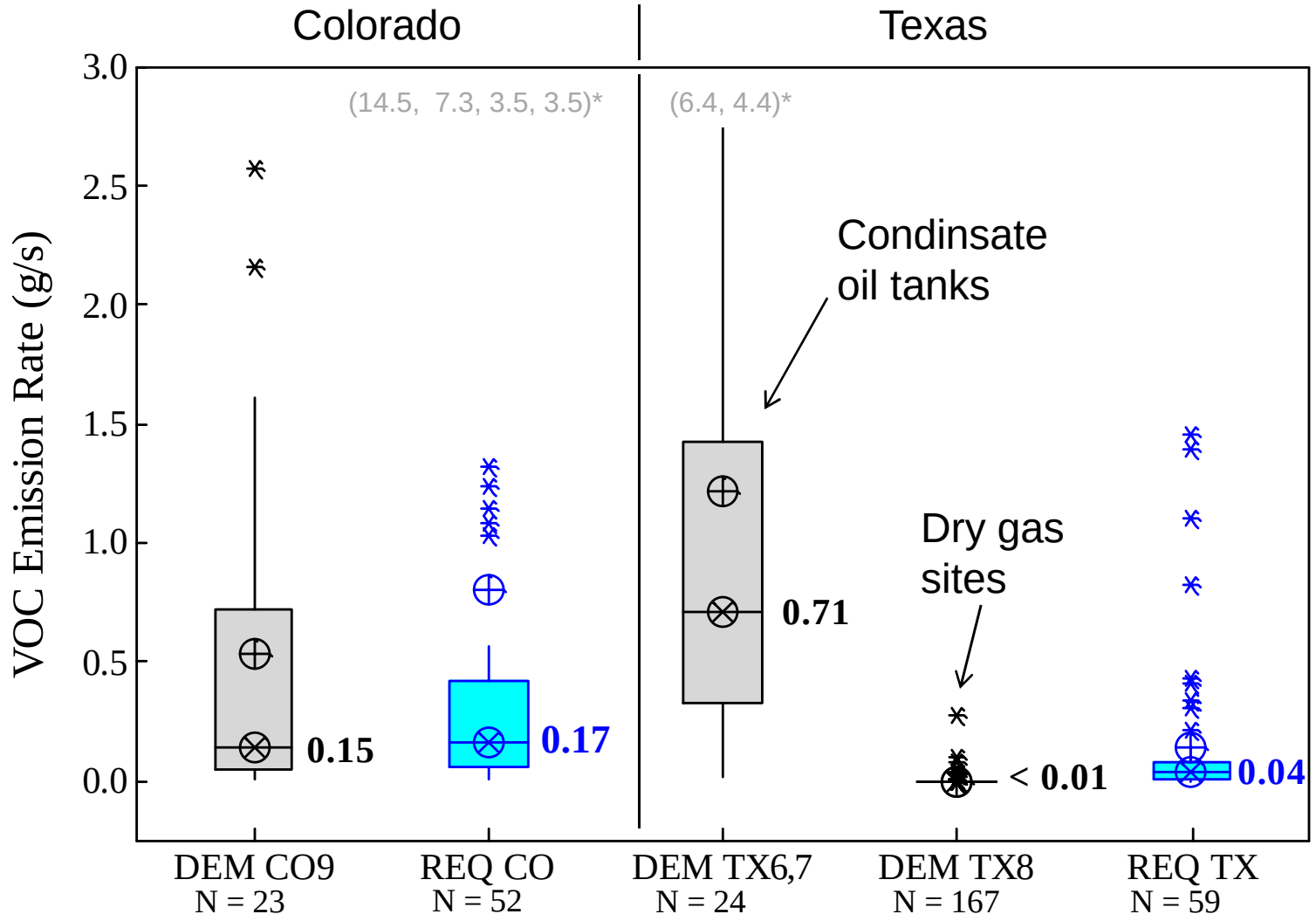
*off scale


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)

GMAP REQ compared to on-site measurements

VOC Emissions



⊕ mean

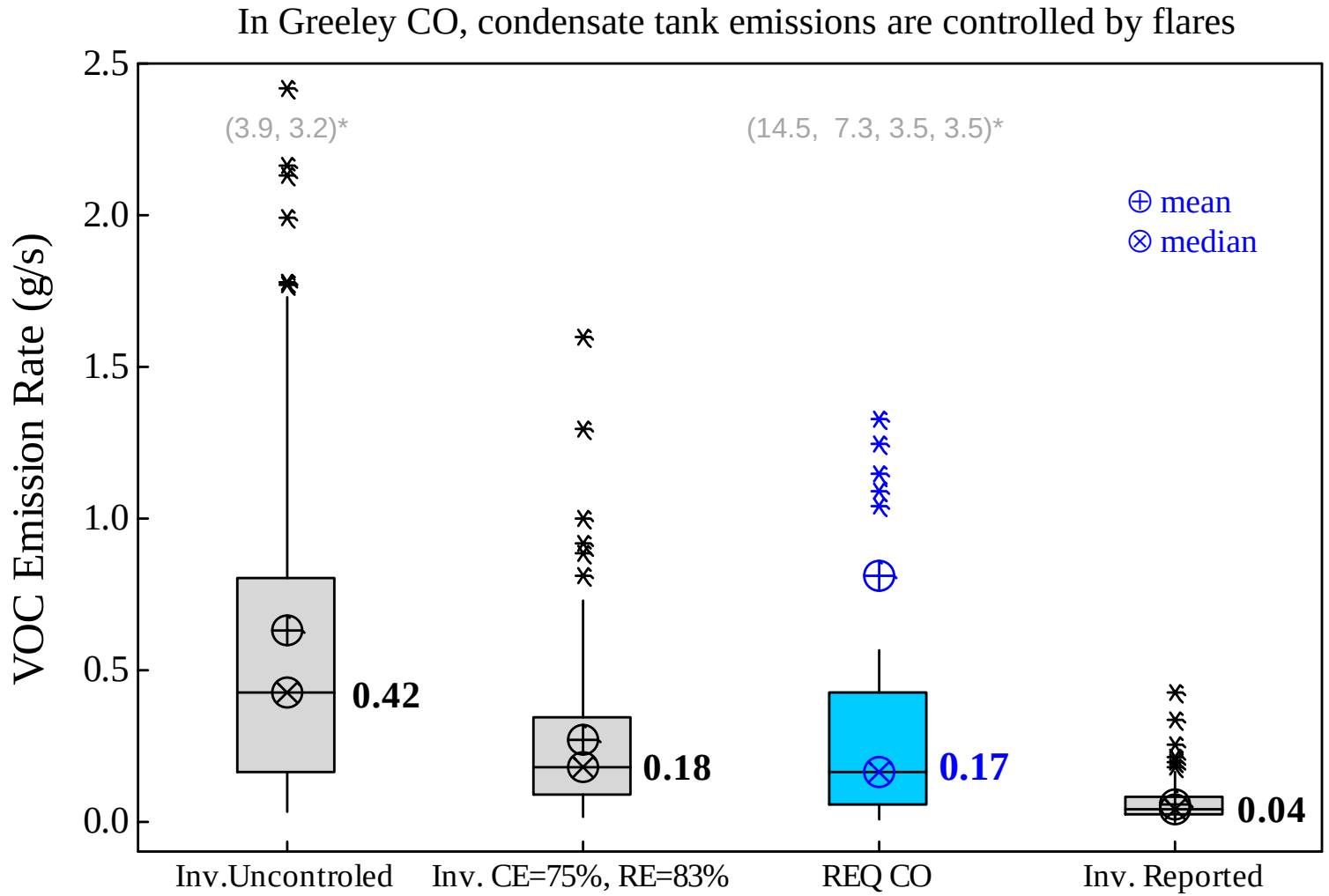
⊗ median

Preliminary result: 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)



*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

Preliminary 040212

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

Summary and next steps

- The GMAP REQ DA approach may be a useful tool to complement developing on-site measurements for oil and gas and other areas
- Preliminary data analysis from 2010 and 2011 studies provide interesting comparisons with direct emissions measurements
- Data analysis continues in 2012
  - Development of QA checks comparisons with CFD modeling
  - Google-earth based visualization software
  - Infrared camera database
- GMAP REQ DA method development activities continue in 2012
  - New user interface software with source location indicators
  - Enhanced real-time data quality indicators
  - Expand to UV detection for BTEX

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