IMPROVING QUALITY ASSURANCE IN METHANE EMISSION MEASUREMENTS

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Qualifications

- Developer of the original Indaco High Flow in the early 1990's
  - Bacharach Hi-Flow based on the Indaco sampler
- Also developed the Vent Bag
- Both used for the EPA GHG Reporting program
- 25 years of methane measurements using tracer and high flow for organizations such as:
  - EPA Natural Gas Star
  - Gas Research Institute
  - European Commission
  - Environmental Defense Fund

Measurement Programs

- Two Broad Categories
  - Top Down
  - Bottom Up

Top Down Measurements

- Upwind and downwind concentrations over an area are measured by aircraft or towers
- Dispersion modeling used to estimate emission rates
- Should capture all emissions in an area
- Uncertainties:
  - Dispersion modeling
  - Source Apportionment
    - Oil and Natural Gas
    - Landfills
    - Wastewater Treatment
    - Cows

Bottom Up Measurements

- Point by point measurements within a facility
  - High flow sampler
  - Vent-Bags
  - Meters
- Total Facility Measurements
  - Atmospheric tracer
  - EPA OTM-33

Top Down vs. Bottom Up

- Top Down Measurements Consistently Higher than Bottom Up Measurements

- Current theory -
  - Bottom up measurements too low because super-emitters are not being captured in the current measurement programs

- More likely …..
  - Measurement programs are capturing the super-emitters, but are severely underreporting them

How Are Superemitters Under Reported?

- Bottom Up Measurement Methods Work Well When Carefully Done, But …..
  - When things do go wrong, measurements are usually biased low
  - In particular, the largest emitters are the ones most affected by low bias

Measurement Issues – Bacharach Hi-Flow Sampler

- Sensor Transition Failure
  - Sampler fails to transition from the low scale to the high scale, resulting in severe under reporting
- Confirmed by Bacharach in 2015 revision of Hi-Flow manual (after publication of Howard et al. (2015) study of the problem)
- https://www.mybacharach.com/wp-content/uploads/2015/08/0055-9017-Rev-7.pdf
- See Section 2.3

Measurement Issues – Bacharach Hi-Flow Sampler (cont'd.)

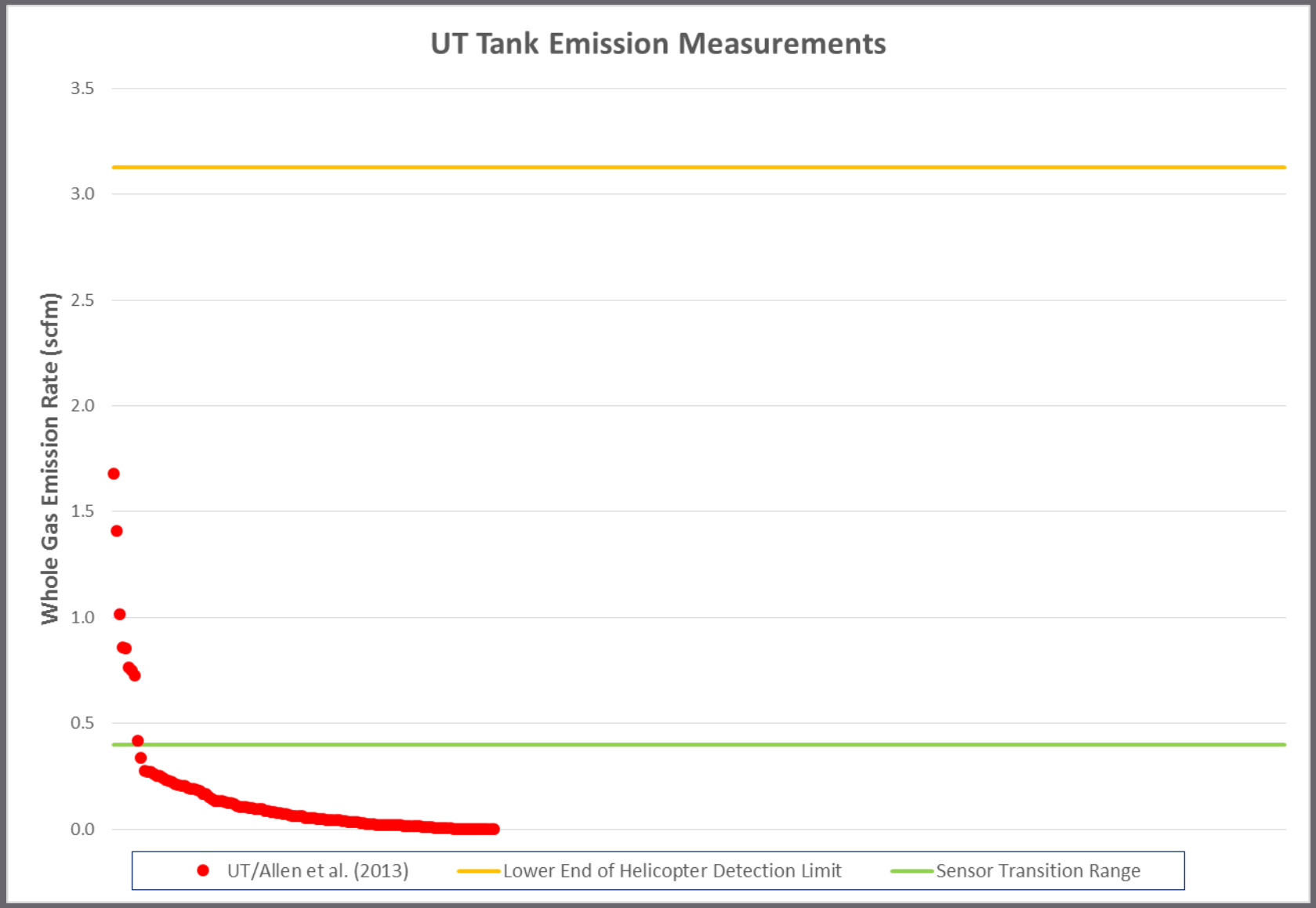
- Over Measurement Range
  - Emission rate is over the range of the sampler, but operator fails to recognize the need to switch to a higher range method
- Sources missed by measurement team

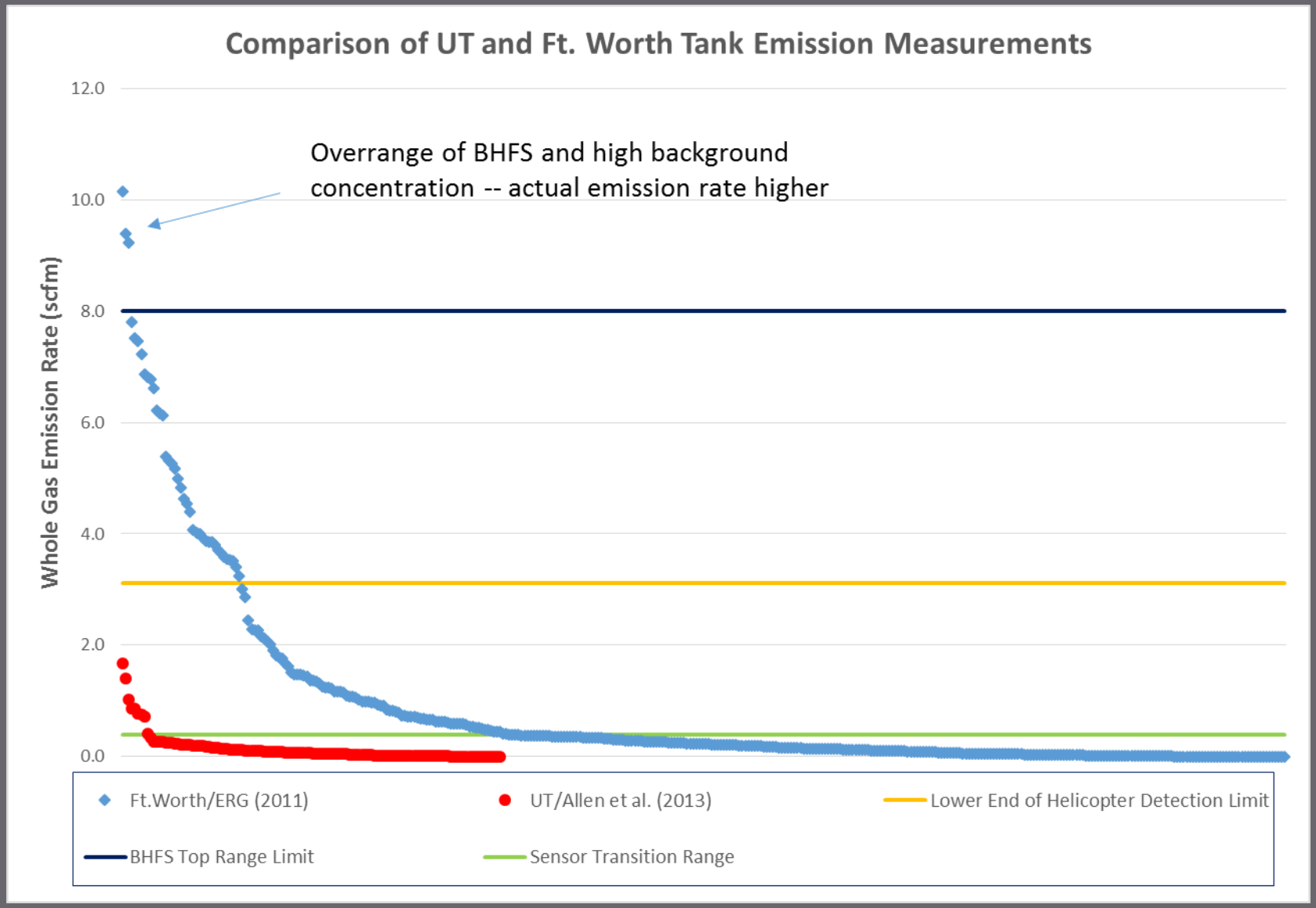
Hi-Flow Sampler Example

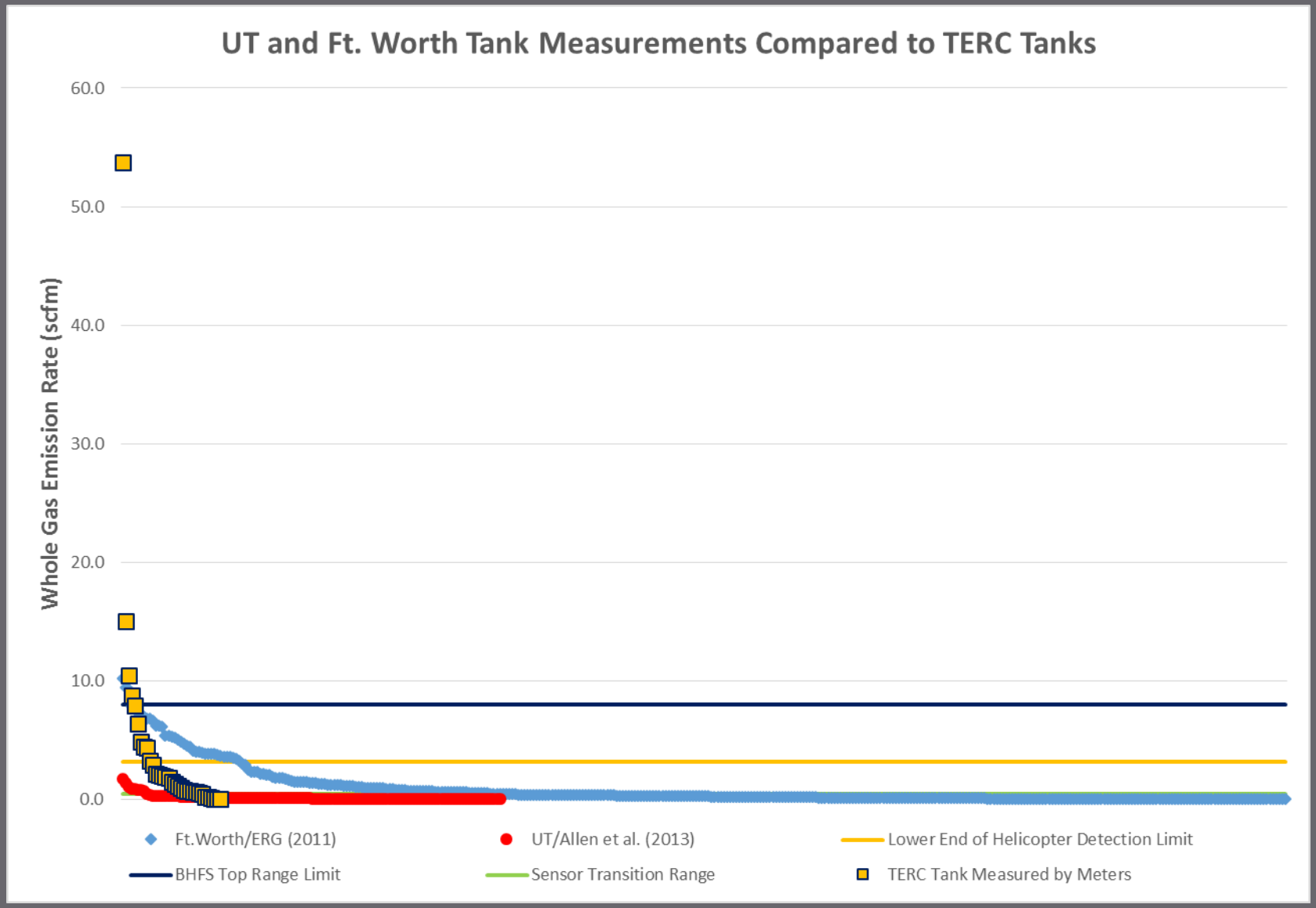
- Compressor Block Valve Leaking 20 scfm
- Hi-Flow sampler with Sensor Failure:
  - Leak Rate Reported = 0.2 scfm
  - Under Reporting by a factor of 100
- Over Range Hi-Flow Sampler
  - Leak Rate Reported = 8 scfm
  - Under Reporting by a factor of 2.5
  - If actual leak = 100 scfm, under reporting by over a factor of 10
- People will let instrument failure outweigh their judgement!

UT Tank Data Example

- UT/Allen et al. (2013) study was affected by Hi-Flow Sensor Failure (Howard, 2015)
- Tank data not used for emissions estimate, but still reported as part of study data


UT Tank Emission Measurements
Whole Gas Emission Rate (scfm)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
UT/Allen et al. (2013)
Lower End of Helicopter Detection Limit
Sensor Transition Range


Comparison of UT and Ft. Worth Tank Emission Measurements
Overrange of BHFS and high background concentration -- actual emission rate higher
Whole Gas Emission Rate (scfm)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Ft.Worth/ERG (2011)
UT/Allen et al. (2013)
Lower End of Helicopter Detection Limit
BHFS Top Range Limit
Sensor Transition Range


UT and Ft. Worth Tank Measurements Compared to TERC Tanks
Whole Gas Emission Rate (scfm)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Ft.Worth/ERG (2011)
UT/Allen et al. (2013)
Lower End of Helicopter Detection Limit
BHFS Top Range Limit
Sensor Transition Range
TERC Tank Measured by Meters

UT Tank Data Example

- UT/Allen et al. (2013) reported tank emission measurements but used EPA GHG Inventory data instead of field data
- Since field teams had IR cameras to survey, they would have seen that tank emissions dominated all other site emissions
- Underreporting Hi-flow must have outweighed the IR camera evidence

Measurement Issues – Atmospheric Tracer/OTM-33

- Ground Level Sampling
- Elevated Emissions
- Bulk of methane emissions plume can be missed

Measurement Issues

- Overall effect of these issues – super-emitters will be under reported
- Key emitters will exceed the range of the high flow sampler, so both sensor transition failure and over range conditions can cause severe underreporting of emissions
- Key emitters are also usually elevated (coming from compressor vents or tank vents), so tracer and OTM-33 may also under report them

Evaluating QA by Comparing Methods

- How close should methods agree?
- Hi-Flow sampler (correctly operating)
  - ± 15%
- Atmospheric Tracer
  - Tracer Release Rate: ± 5%
  - Tracer Concentration: ± 5%
  - Methane Background Concentration: ± 5%
  - Methane Downwind Concentration: ± 5%
  - Total Tracer Uncertainty = ± 20%

Quality Assurance Expectations

- So if all the random experimental error lines up wrong for a site with 100 scfm emission rate:
  - Hi-Flow sampler could report 115 scfm
  - Atmospheric Tracer could report 80 scfm
  - Largest expected ratio of results would be
    - 115 scfm/80 scfm = 1.44
- So if everything is working well, results from a site measured by two different methods should not vary more than a ratio of 1.5
- Now we have an easy and objective benchmark to evaluate QA

Is this QA Benchmark Achievable?

- Past comparisons of Indaco Hi-Flow versus atmospheric tracer
  - Ranged from 1.2 to 1.5
- WSU EDF controlled methane releases versus tracer
  - Within 1.06

Applying the QA Benchmark

- Remember that if comparisons lie outside of routine experimental error, something has gone wrong
- In that case, the lower measurement is most likely biased low by whatever the problem is
- Higher number is most likely closest to the correct result

Applying the QA Benchmark

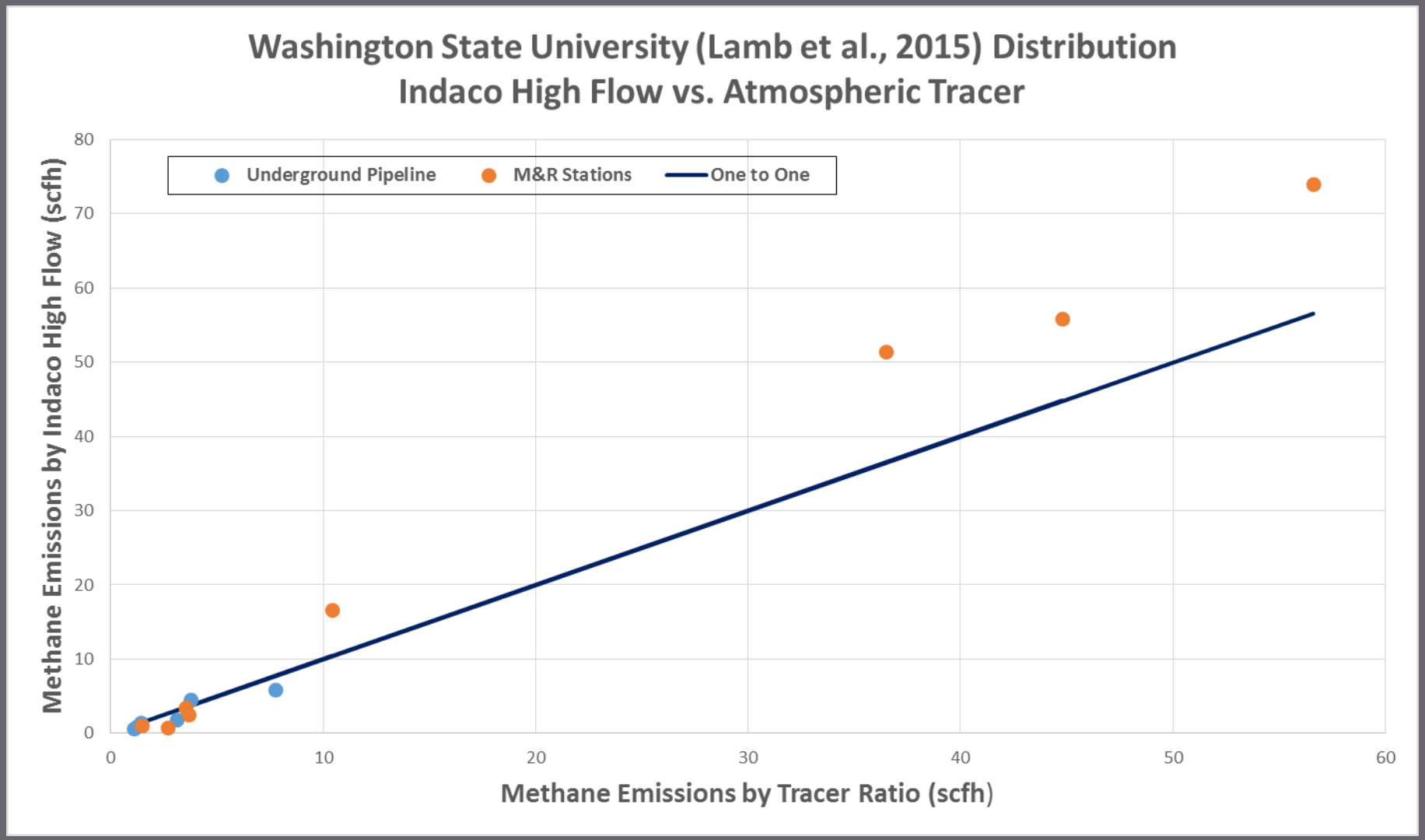
- Three EDF sponsored studies
  - Washington State University Distribution (Lamb et al., 2015)
  - Carnegie Mellon/Colorado State University Transmission and Storage Compressor Stations (Subramanian et al., 2015)
  - University of Texas Pneumatics (Allen et al., 2014)

WSU Distribution

- For full disclosure:
  - Direct measurements were made by Indaco Sampler
  - I conducted training, measurements, and QA procedures for the high flow measurements
  - I assisted with tracer measurements and their QA
- Any problems are my responsibility

WSU Distribution

- Fourteen comparisons of tracer vs Indaco high flow
- Ten (71%) within the 1.5 QA benchmark
- Only one (7.1%) exceeded a ratio of 2


Washington State University (Lamb et al., 2015) Distribution
Indaco High Flow vs. Atmospheric Tracer
Underground Pipeline
M&R Stations
One to One
Methane Emissions by Indaco High Flow (scfh)
Methane Emissions by Tracer Ratio (scfh)
0
10
20
30
40
50
60
70
80

WSU Distribution

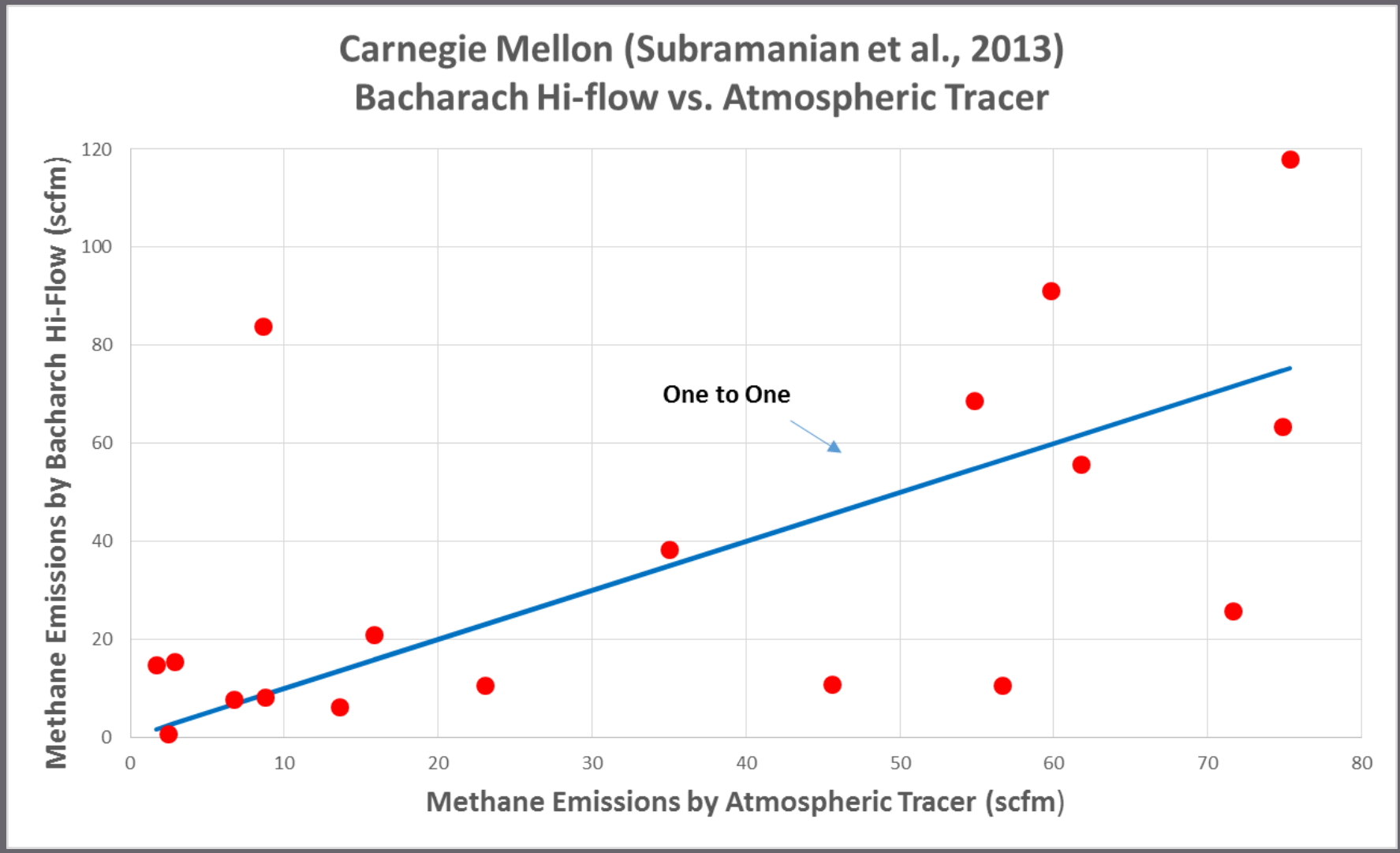
- Tracer > High Flow at lower emitting sites
  - High Flow biased low most likely due to a missed leak
  - A single missed leak could influence low emitting sites
- Hi-Flow > Tracer at higher emitting sites
  - Tracer may be biased low due to vented emissions at meter station sites
  - No low bias observed in high flow measurements at higher emitting sites which are the most important
  - Most WSU measurements done by high flow

WSU High Flow QA Program

- Verified Indaco High Flow did not exhibit sensor failure
- Daily pre- and post-sampling calibrations of methane sensors
- Daily pre- and post-sampling flow system leak and single point checks
- Weekly full flow system calibrations
- 10% replicate measurements
- Should have compared field teams at same facility

Carnegie Mellon Transmission/Storage

- Eighteen comparisons of tracer vs Bacharach Hi-Flow (sites in same mode for both methods)
- Seven (39%) within the 1.5 QA Benchmark
- 50% exceeded a ratio of 2
- 22% exceeded a ratio of 5


Carnegie Mellon (Subramanian et al., 2013)
Bacharach Hi-flow vs. Atmospheric Tracer
Methane Emissions by Bacharch Hi-Flow (scfm)
Methane Emissions by Atmospheric Tracer (scfm)
One to One
0
20
40
60
80
100
120
0
10
20
30
40
50
60
70
80

Carnegie Mellon Transmission/Storage Issues

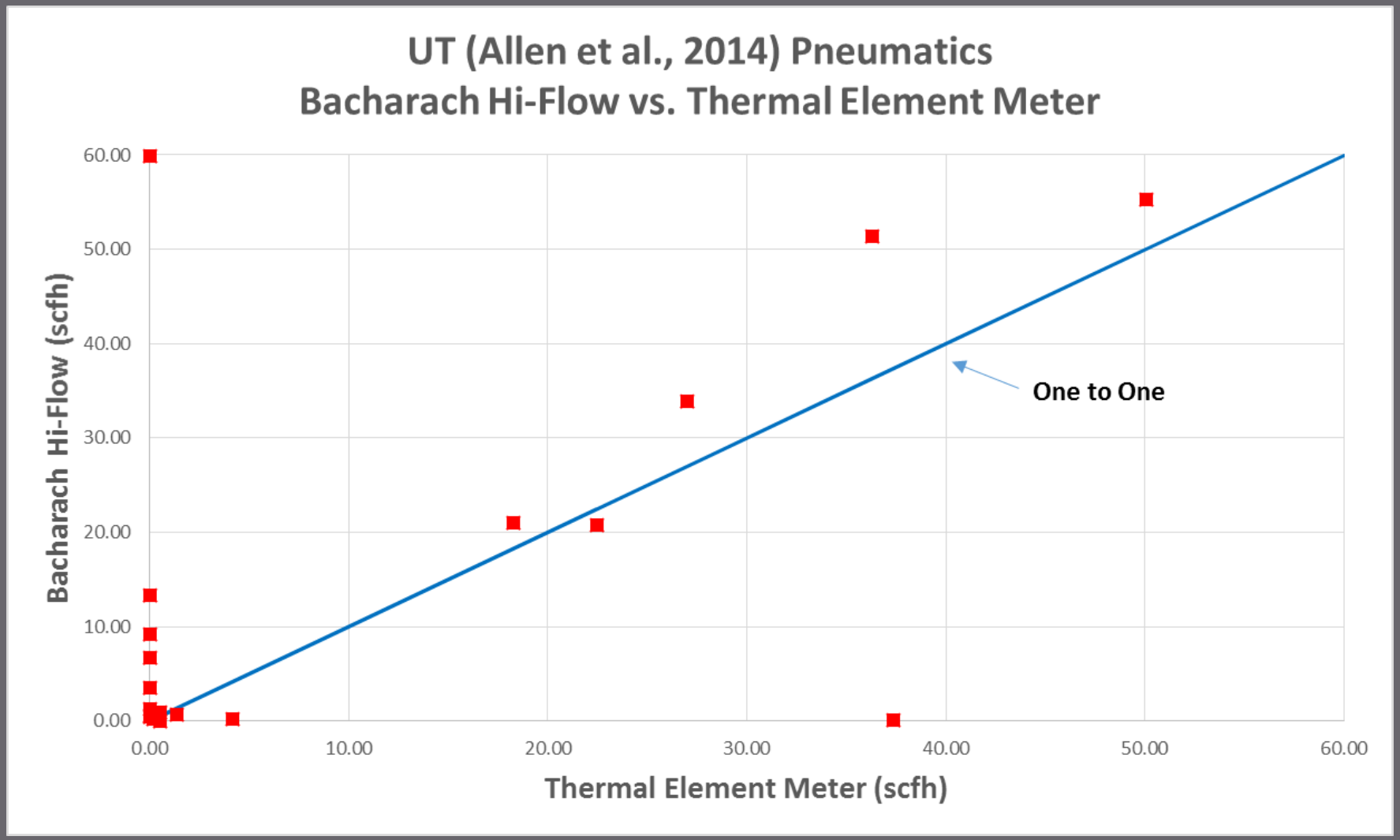
- When High Flow > Tracer (exceeding QA benchmark)
  - Tracer biased low
  - Most likely due elevated sources missed by tracer measurements
- For this case, emissions reported by tracer were only 46% of Hi-Flow (actual) emissions
- Possible implications for other tracer or OTM-33 studies at sites with elevated sources such as EDF Gathering and Processing

Carnegie Mellon Transmission/Storage

- When Tracer > Hi-Flow (exceeding QA benchmark)
- Hi-Flow is biased low
  - Unlikely due to missed sources – IR camera tells measurement team where to look for large sources
  - Most likely due to Hi-Flow sensor failure or over range conditions
- For this case, emissions reported by Hi-Flow were only 30% of tracer (actual) emissions
- Since these research grade measurements have this level of uncertainty, routine measurements reported to the EPA GHGRP may be far worse

UT (Allen et al., 2014) Pneumatics

- Nineteen comparisons of Bacharach Hi-Flow vs. Thermal Element Meter
- Six (32%) within the 1.5 QA benchmark
- Eleven (58%) exceed a ratio of 10
- Note: For Hi-flow vs. meter, a better QA Benchmark = 1.25 since meter more accurate than tracer


UT (Allen et al., 2014) Pneumatics
Bacharach Hi-Flow vs. Thermal Element Meter
Bacharach Hi-Flow (scfh)
Thermal Element Meter (scfh)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
One to One

UT (Allen et al., 2014) Pneumatics Calibration Issues

- No meter calibrations during field work
- Only pre- and post-project calibrations
- Corrected data based on post project check that showed faulty meter too low by factor of 1.5
- Used Hi-Flow data to pinpoint where problem started
- Unfortunately – UT team knew this could not be correct ……

UT (Allen et al., 2014) Pneumatics Calibration Issues

- UT failed to report a field test during the project showing that faulty meter under reporting by a factor of 3
- UT field team member reported: "Everyone knows that meter is screwed up. You can hook it up to a pneumatic, hear it fire, and not see anything on the meter."
- Meter response clearly changed over time
- Single correction factor could not be accurate

UT (Allen et al., 2014) Pneumatics Calibration Issues

- Thermal meter may have become oily early in the project and slowly cleaned up over time
  - Would explain why meter response improved between the field tests and end of project calibration
  - Would also explain why the meter was well known to not respond when measuring an actuating pneumatic
- Hi-Flow data far too uncertain to track meter calibration

UT (Allen et al., 2014) Pneumatics Calibration Issues

- Most critically, the meter problem was not addressed when UT became aware of it
- Meter should have been tested and fixed
- All measurements should have been repeated
- Daily calibration checks should have been instituted

UT (Allen et al., 2014) Pneumatics Calibration Issues

- Implications: UT liquids unloading (Allen et al., 2014) used same type of meter
- Meter calibrations only done prior to project
- No field or post project calibrations
- Even harsher environment than pneumatics

Consequences of Poor Quality Assurance

- Safety issues due to Hi-Flow sensor failure have been disregarded
- Emissions from production segment have been severely under reported
- Emissions from other segments must also be reviewed
- Highly publicized studies have given policy makers and the public the wrong information
- EPA Office of Inspector General may help bring clarity to some issues

Steps Forward

- EPA can take immediate steps to restore accuracy and credibility of measurement programs
- Implement simple standards of QA for:
  - GHG Inventory
  - GHG Reporting program

Steps Forward

- Any instrumentation with demonstrated variable response must have daily field calibrations
  - Hi-Flow
  - Meters
  - Downwind instrumentation as appropriate
- Measurements not meeting this standard should be excluded or removed from the EPA GHGI and GHGRP data

CONTACT INFORMATION

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