On-Road Measurement of Running Losses by Remote Sensing

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Desire RSD method to measure Running Losses (RL)

Research Question

RL Lab Dyno Measurements: Certification use

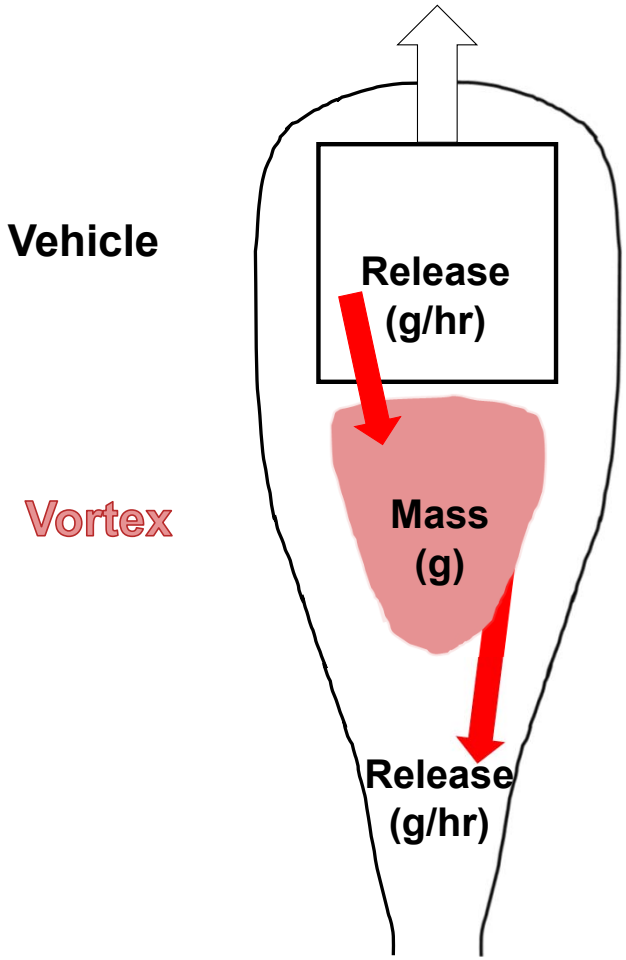
RL Modeling Unreliable: Non-Linear response of RLs to Vehicle Operation and Environmental Conditions

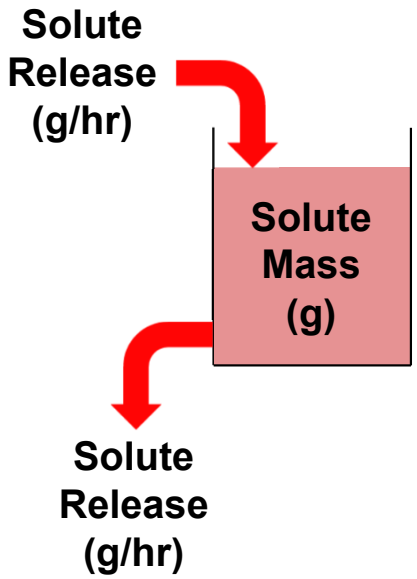
RL Model Validation: Existing on-road RL data?

Light-based Remote Sensing (RSD): High RL detection limits

Can HEAT Laser RSD data be processed to measure on-road RL?

Analogy: Swirling Vortex ↔ Stirred Tank





Relate Emission Rate to measurable quantities

Background

from ChemE analogy:

$$\text{Turnover Time (hr)} = \frac{\text{Mass in Vortex (g)}}{\text{Release Rate (g/hr)}}$$

what we want:

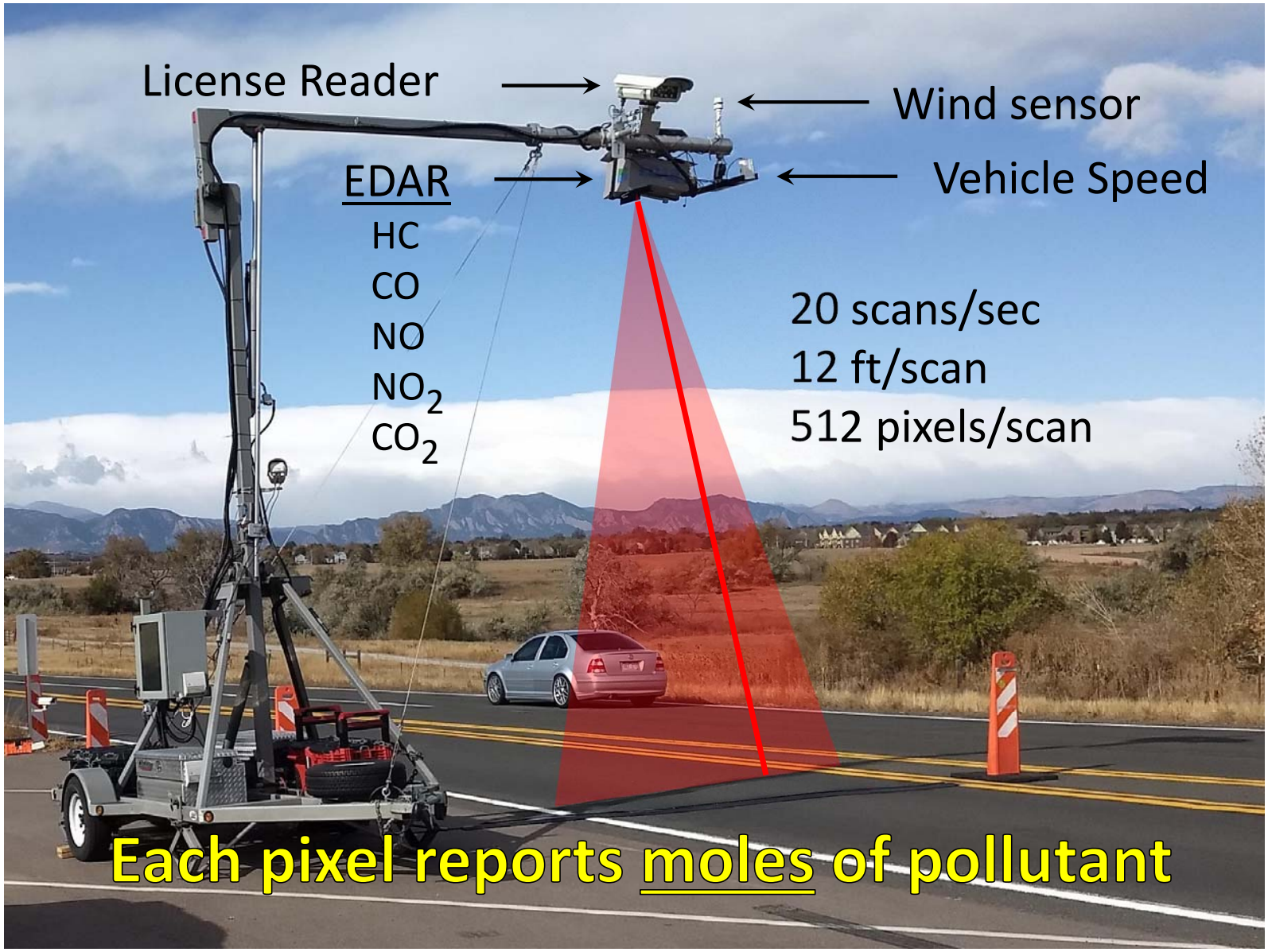
$$\text{Emission Rate (g/mile)} = \frac{\text{Release Rate (g/hr)}}{\text{Vehicle Speed (mile/hr)}}$$

with substitution:

$$\text{Emission Rate (g/mile)} = \frac{\text{Mass in Vortex (g)}}{\text{Turnover Time (hr)} * \text{Vehicle Speed (mile/hr)}}$$

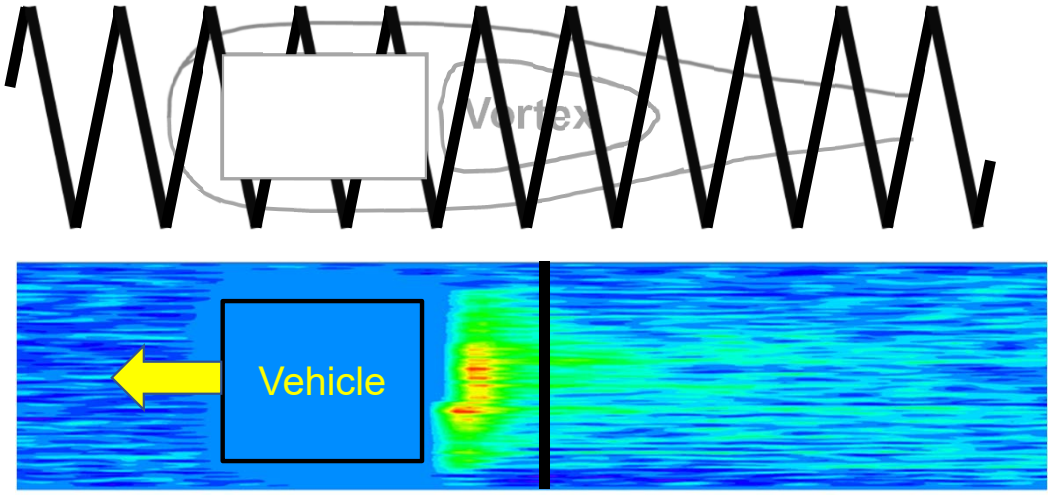
Use RSD to measure Mass in Vortex (g) and Speed (mile/hr)
Use Staged Testing with RSD to evaluate Turnover Time (hr)

Methodology



Methodology

EDAR illuminates a Zig-Zag to get its Signal



Portion of Vortex illuminated is inversely proportional to Speed:
5% at 40 mph, 10% at 20 mph, 100% at 2 mph

So, **RSD Signal (g) gets weaker as Speed increases.**

Mass in Vortex (g) → Emission Rate (g/mile)

Methodology

correct EDAR signal for speed:

$$\text{Mass in Vortex (g)} = \text{EDAR Signal (g)} * \frac{\text{Vehicle Speed (mile/hr)}}{\text{2 mile/hr}}$$

substituting the above into the "green" equation provides:

$$\text{Emission Rate (g/mile)} = \frac{\text{EDAR Signal (g)}}{\text{2 mile/hr} * \text{Turnover Time (hr)}}$$

Emission Rate is directly proportional to the EDAR signal – if Turnover Time is independent of test conditions

Test Design

	Vortex Dynamics Expt Use a Massive, Constant Emission Rate so we can see HC in vortex images (206 Tests)	Detection Limit Expt Go to lower Emission Rates where we can't see HC in vortex images (405 Tests)
RL Emission Rates (Butane)	Massive and Constant: 10,913 mg/mile	Wide Range: 6821 3411 1705 853 426 213 107 50* 0 mg/mile
RL Release Locations	fuel fill DOOR top of TANK under the HOOD rear wheel WELL	fuel fill DOOR top of TANK under the HOOD
Test Vehicles (drag area)	1: Camry (7.2 ft^2) 3: Highlander (10.7 ft^2) 4: Accent (6.7 ft^2) 5: Tahoe (13.4 ft^2)	3: Highlander (natural Exh: ~ 0ppmHC) 5: Tahoe (spiked Exh: ~ 400 ppmHC)
Speeds	12 25 37 50 mph	20 40 mph
Replicates	4	7

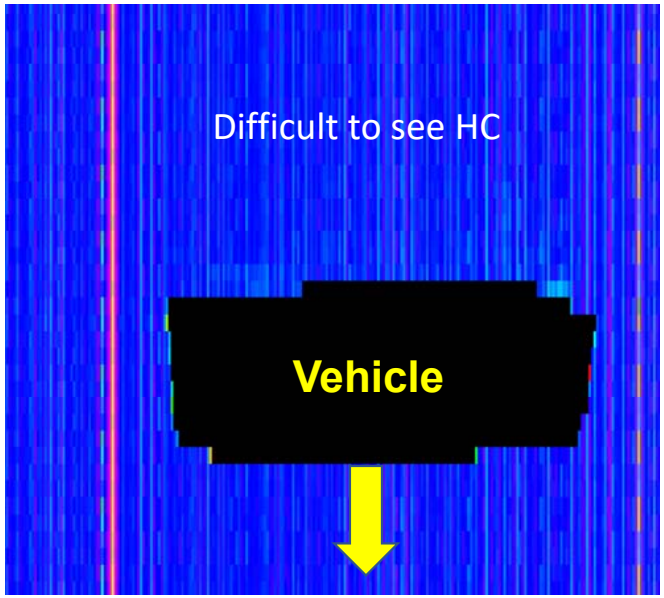
Note: Test Program conducted SEP 2016 at Bryan, TX

*** 50 mg/mile = RL certification level**

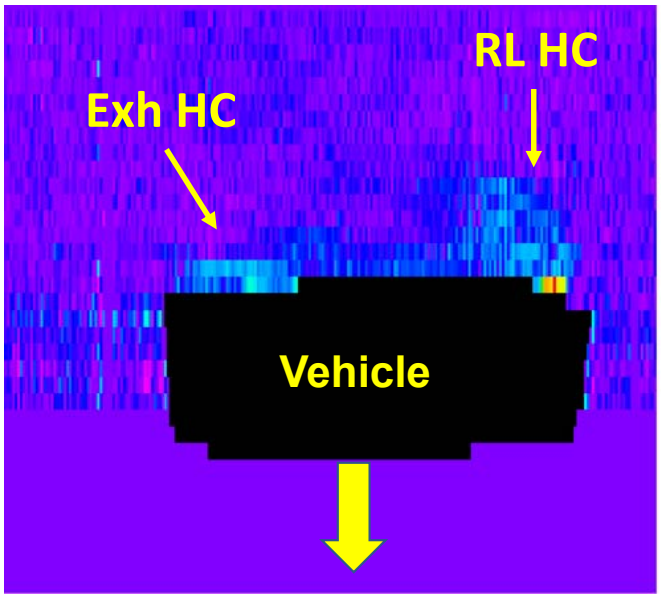
Signal Processing reveals HC Released and lowers Detection Limit

Analysis

Raw EDAR HC



De-Noised HC

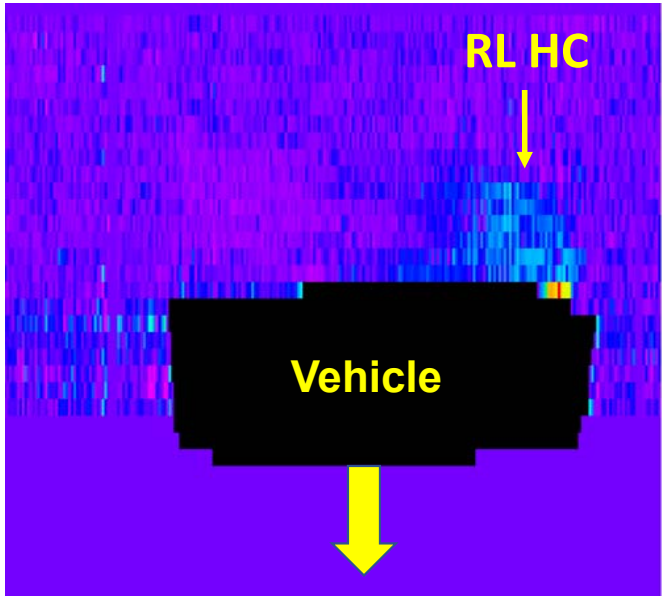


RL = 1565 mg/mile	RL from fuel fill DOOR
Exh = 400 ppmHC	Speed = 23 mph

Blind Source Separation splits De-Noised HC into:

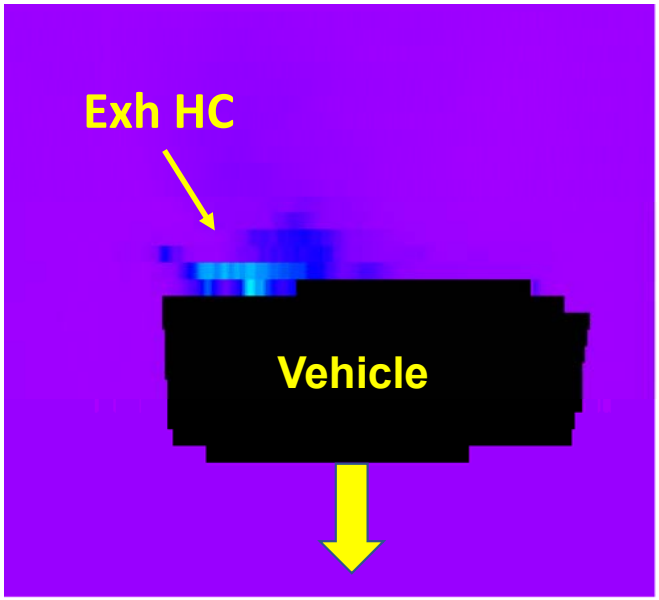
Analysis

Deduced RL HC



+

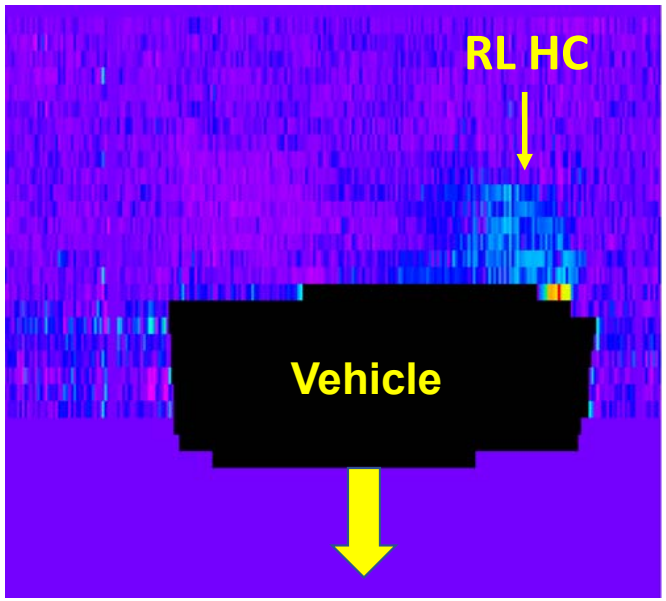
Deduced Exh HC

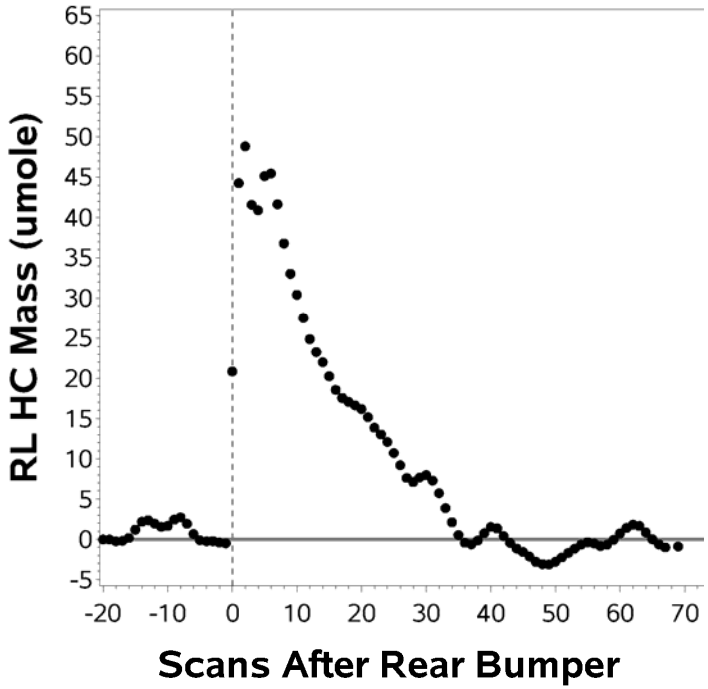


Analysis

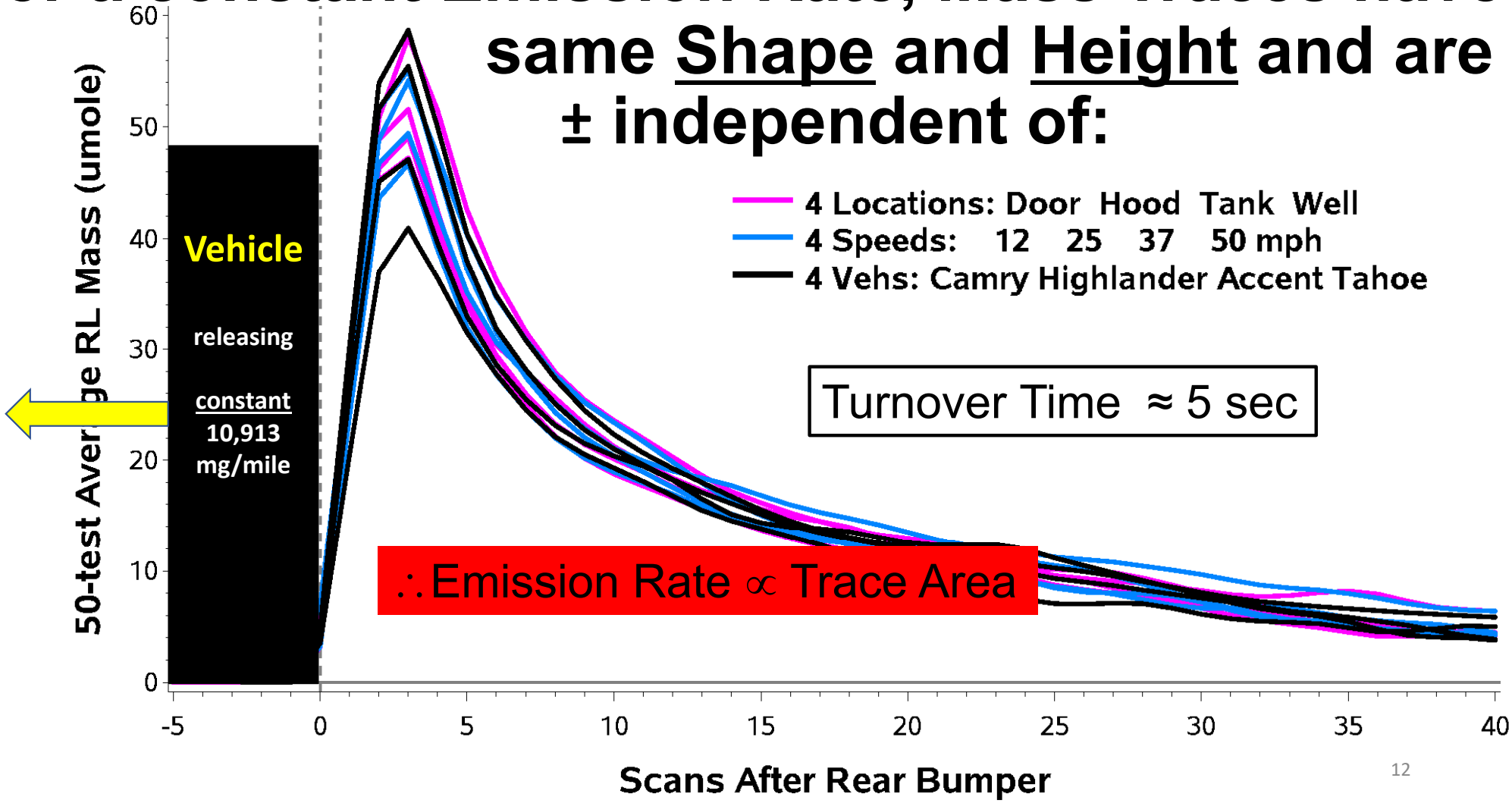
Sum the 512 Pixels in each Scan → RL Mass Trace

Deduced RL HC

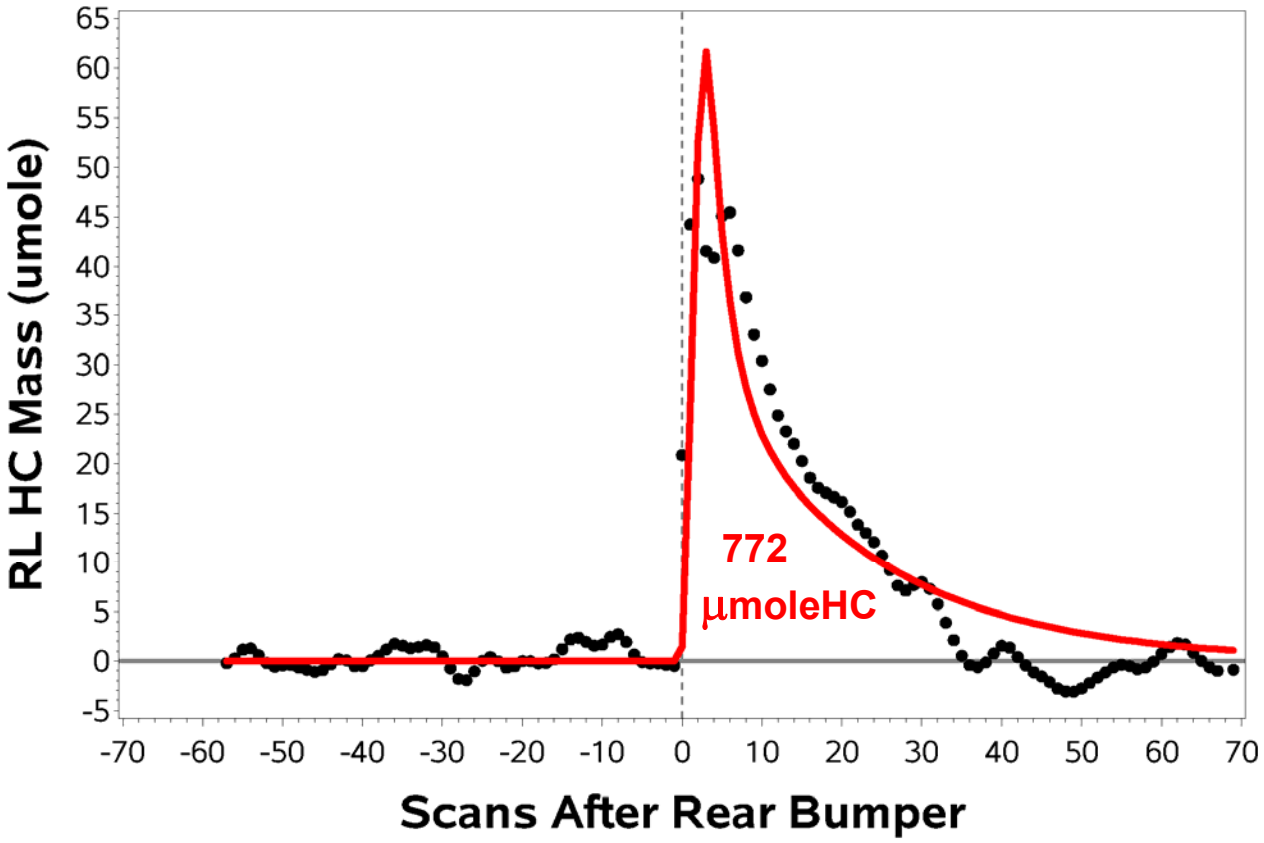




For a constant Emission Rate, Mass Traces have same Shape and Height and are ± independent of:



For each individual test:
Calculate Area under a Fit of the RL Mass Trace



Traces vary because of Turbulence, Noise, Emissions Vortex-Entrainment Efficiency.

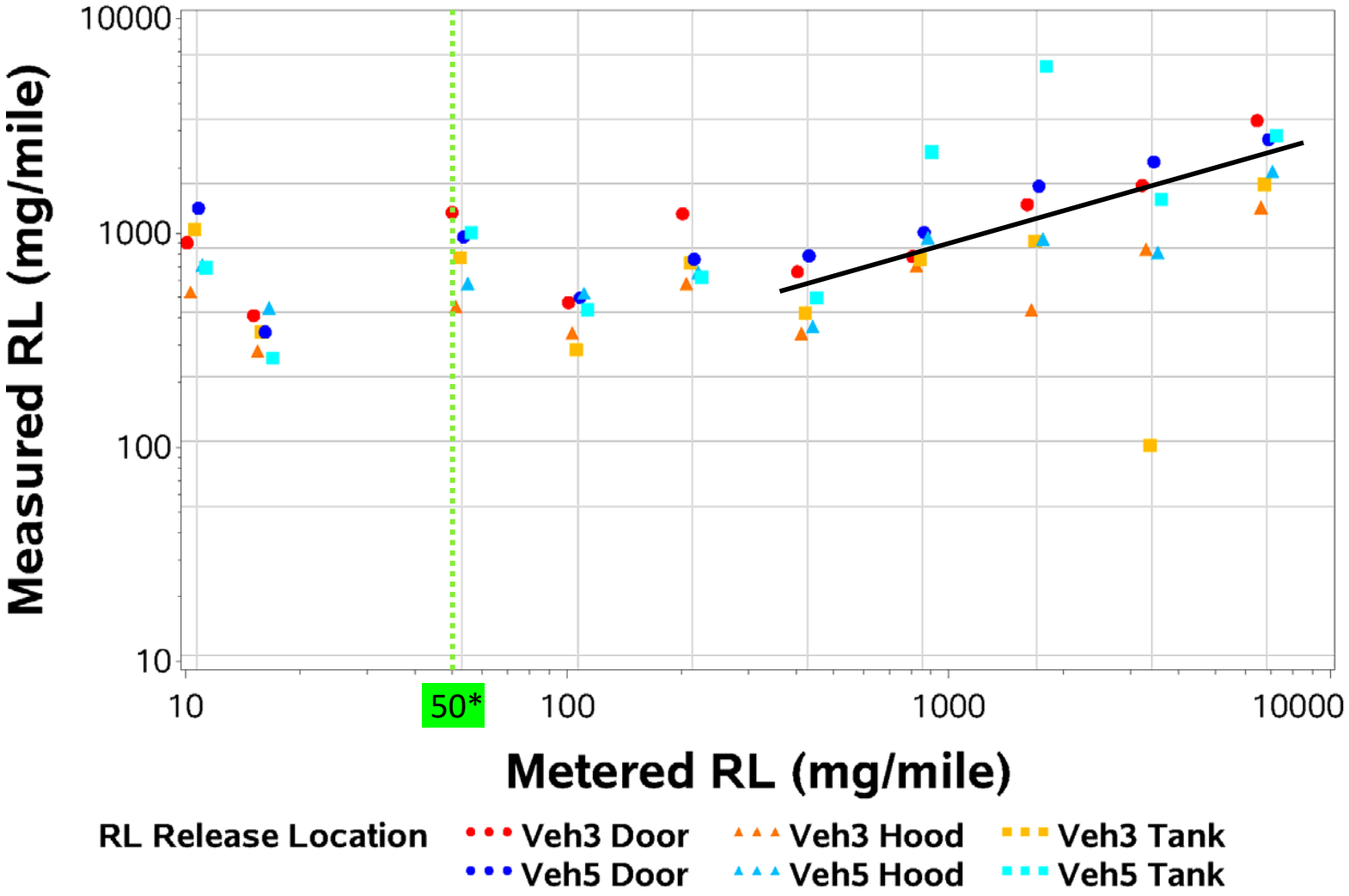
Fit the measured RL mass trace to the condition-independent Mass Trace Shape.

Calculate the Area under the Fit to get the EDAR Signal (g) – further reducing noise.

$$\text{Emission Rate (g/mile)} = \frac{\text{EDAR Signal (g)}}{\text{2 mile/hr} * \text{5 s}}$$

Analysis

Evaluate Measured RL Emission Rate



Conclusions

Simple relationship:

$$\text{Emission Rate (g/mile)} = \frac{\text{EDAR Signal (g)}}{\text{2 mile/hr} * \text{5 s}}$$

Large variability in measured RL Emission Rate (g/mile):

A consequence of Noise, Turbulence, Emissions Vortex-Entrainment Efficiency
RL determination on Individual Tests will be uncertain

However, Average RL should be reliable for large fleet segments:

Model Year Groups
Traffic Modes (congested, flowing)
Ambient Temperatures
Gasoline Volatility (RVP)

Further Work:

Improve linearity and detection limit
Quantify RL of 30,000 EDAR measurements from Denver in OCT 2019

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