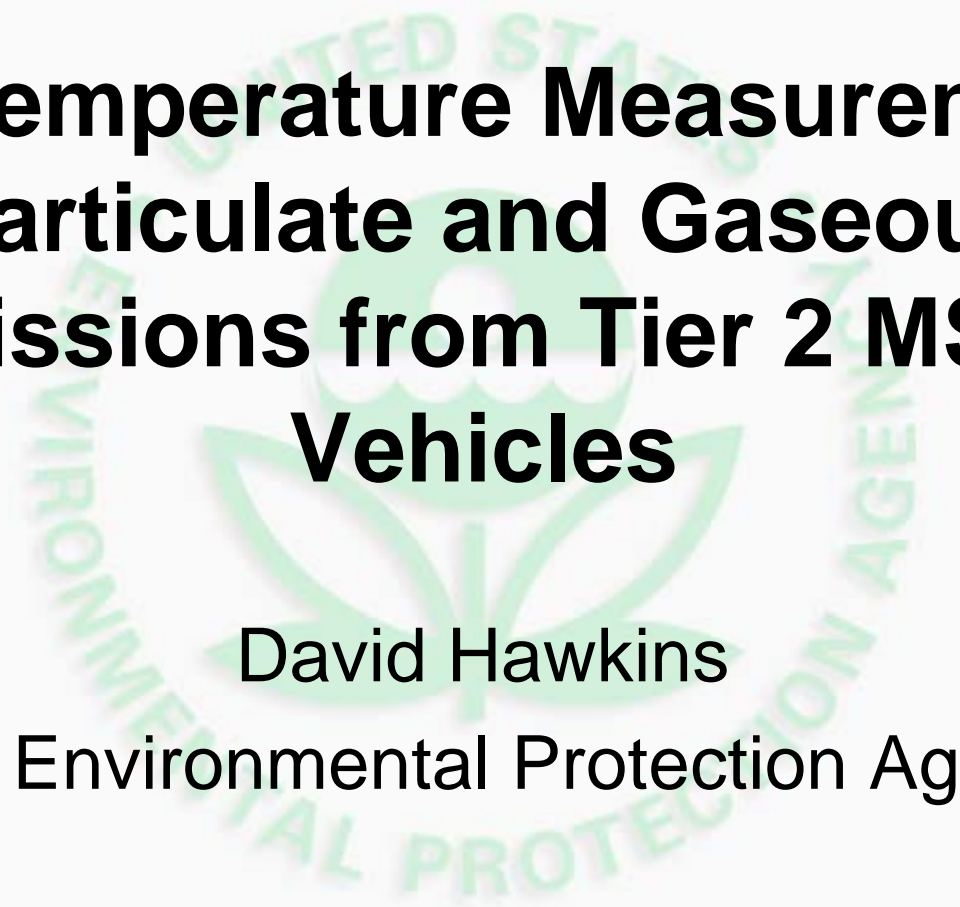




# **Cold Temperature Measurement of Particulate and Gaseous Emissions from Tier 2 MSAT Vehicles**

David Hawkins

U.S. Environmental Protection Agency

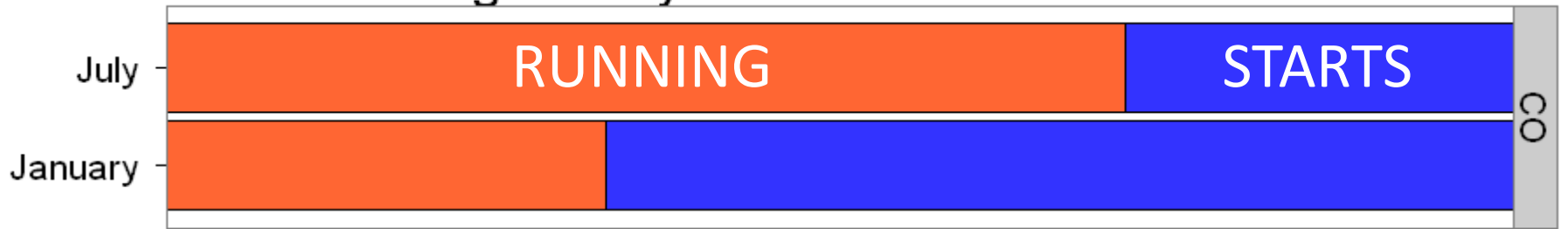


# Summary

- Background
- Modeling & Analysis Questions
- Test Program Design & Procedure
- Data & Analysis Summary
- Conclusions & Results

# MOVES2010b run - Detroit Metro 2015

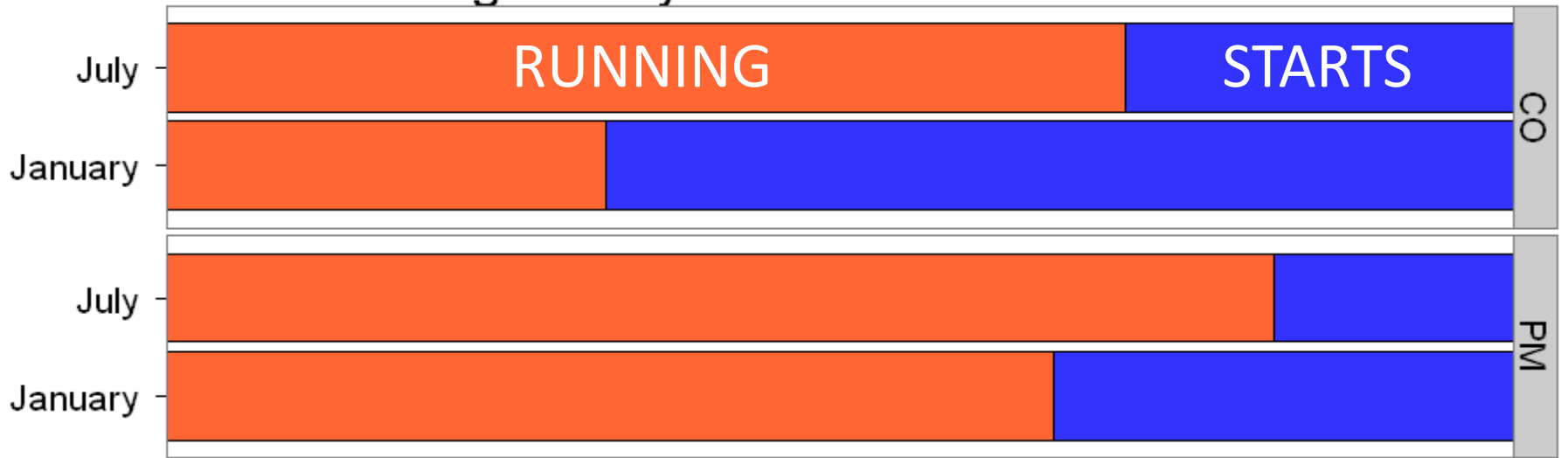
## Light-Duty Gasoline Vehicles



0.0 0.2 0.4 0.6 0.8 1.0  
Fraction of Emissions  
3

# MOVES2010b run - Detroit Metro 2015

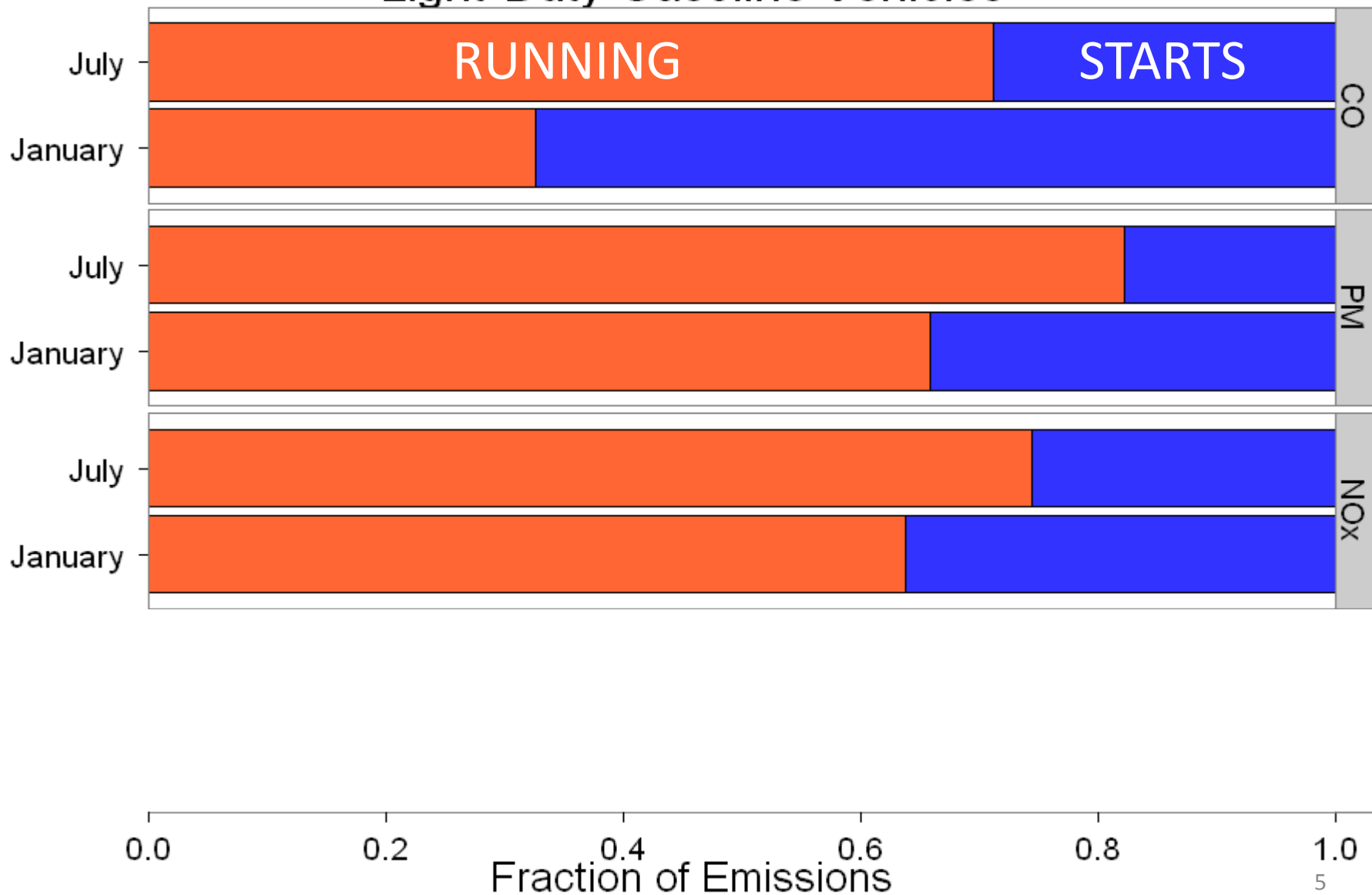
## Light-Duty Gasoline Vehicles



0.0 0.2 0.4 0.6 0.8 1.0  
Fraction of Emissions  
4

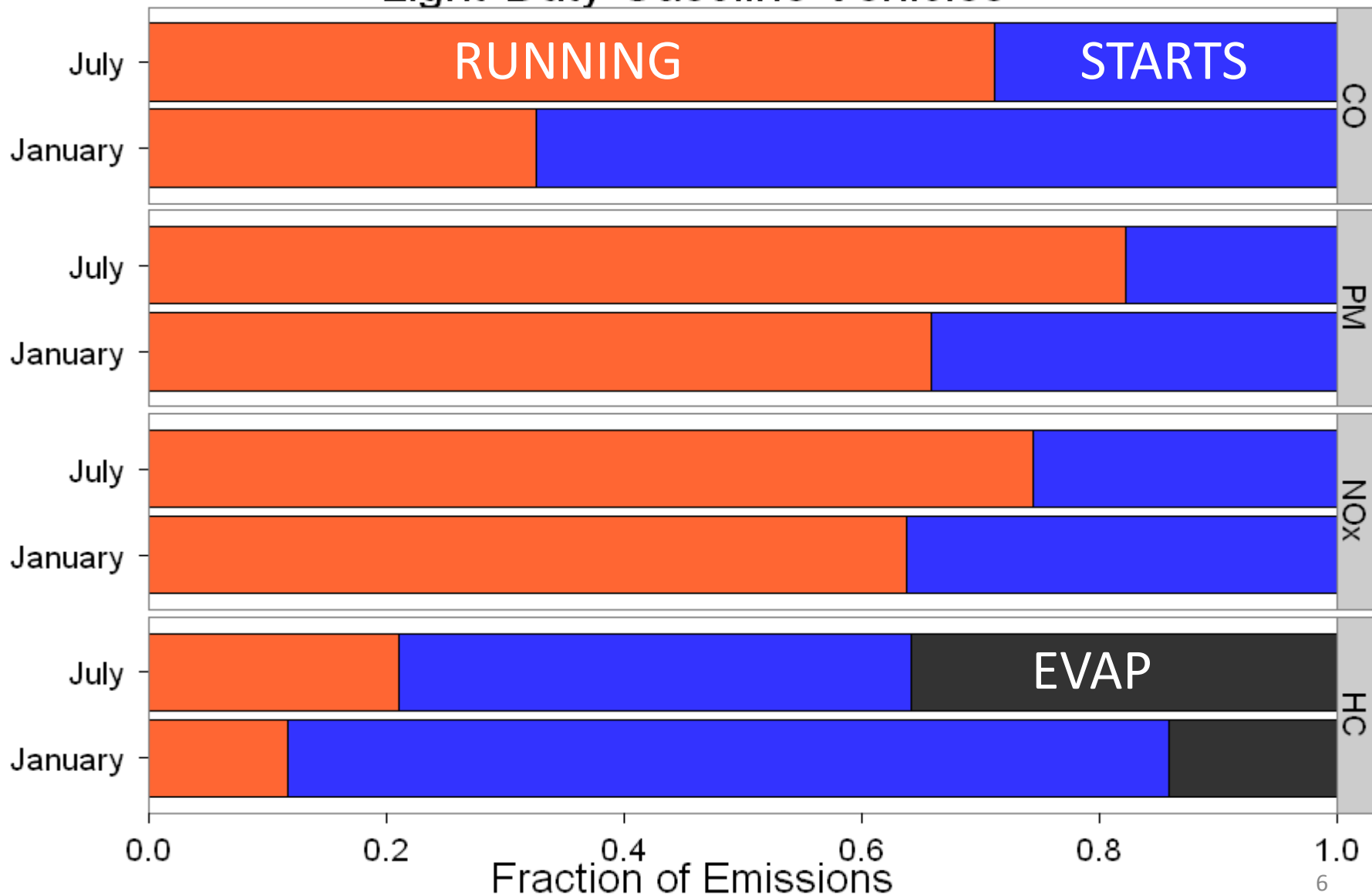
# MOVES2010b run - Detroit Metro 2015

## Light-Duty Gasoline Vehicles



# MOVES2010b run - Detroit Metro 2015

## Light-Duty Gasoline Vehicles



# Modeling Questions

- What is the ambient temperature effect on Tier 2/MSAT start emissions?
- Does ambient temperature affect running PM emissions for Tier 2/MSAT vehicles?

# Testing Summary

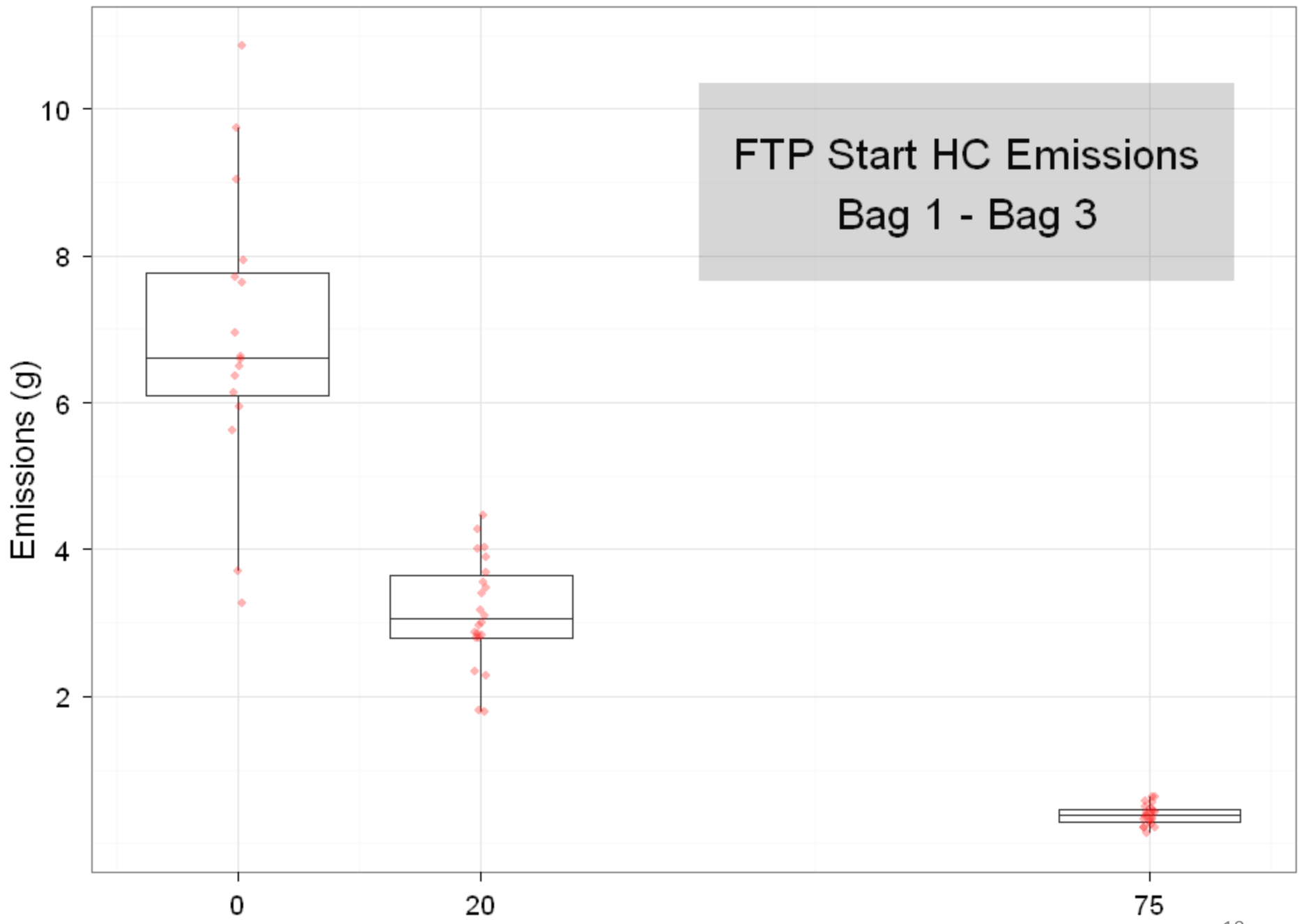
- Test Procedure
  - US06 & 3-bag FTP
  - 0, 20, 75 °F
  - E10 fuel
- Measured Fields
  - THC, NO<sub>x</sub>, CO, CO<sub>2</sub>
  - PM
    - Continuous (Soot Sensor)
    - Discrete (Filters)
  - VOC speciation
  - OBD 3 parameters
- Performed in 2012 at Mercedes, Ann Arbor



# Vehicle Summary

Vehicle Name	Model Year	Injection	Emissions Std	MSAT?	Odometer	Displ (L)	Cyl.
Buick Lucerne	2010	PFI	Tier 2/Bin 4	MSAT	22000	3.9	V-6
Honda Accord	2010	PFI	Tier 2/Bin 5	MSAT	24000	2.4	I-4
Hyundai Sante Fe	2010	PFI	Tier 2/Bin 5	MSAT	18000	2.4	I-4
Jeep Patriot	2010	PFI	Tier 2/Bin 5	MSAT	22000	2	I-4
Kia Forte EX	2010	PFI	Tier 2/Bin 5	MSAT	25000	2	I-4
Mazda 6	2010	PFI	Tier 2/Bin 5	MSAT	24000	2.5	I-4
Mitsubishi Gallant	2010	PFI	Tier 2/Bin 5	MSAT	38000	2.4	I-4
Cadillac STS	2010	GDI	Tier 2/Bin 5	MSAT	21000	3.6	V-6
VW Passat	2006	GDI	Tier 2/Bin 5	pre-MSAT	103000	2	I-4

Tested at 0°F



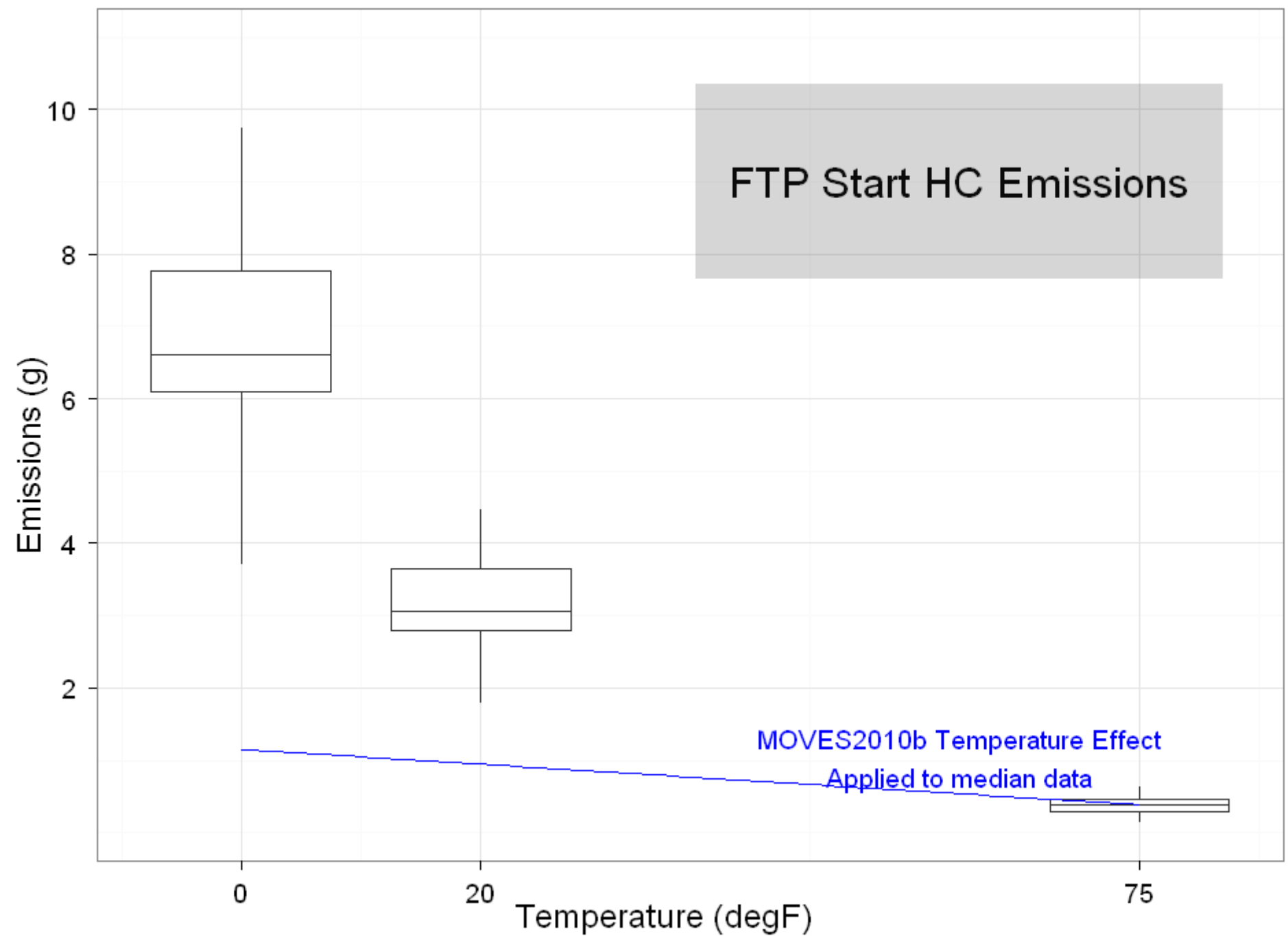
FTP Start HC Emissions  
Bag 1 - Bag 3

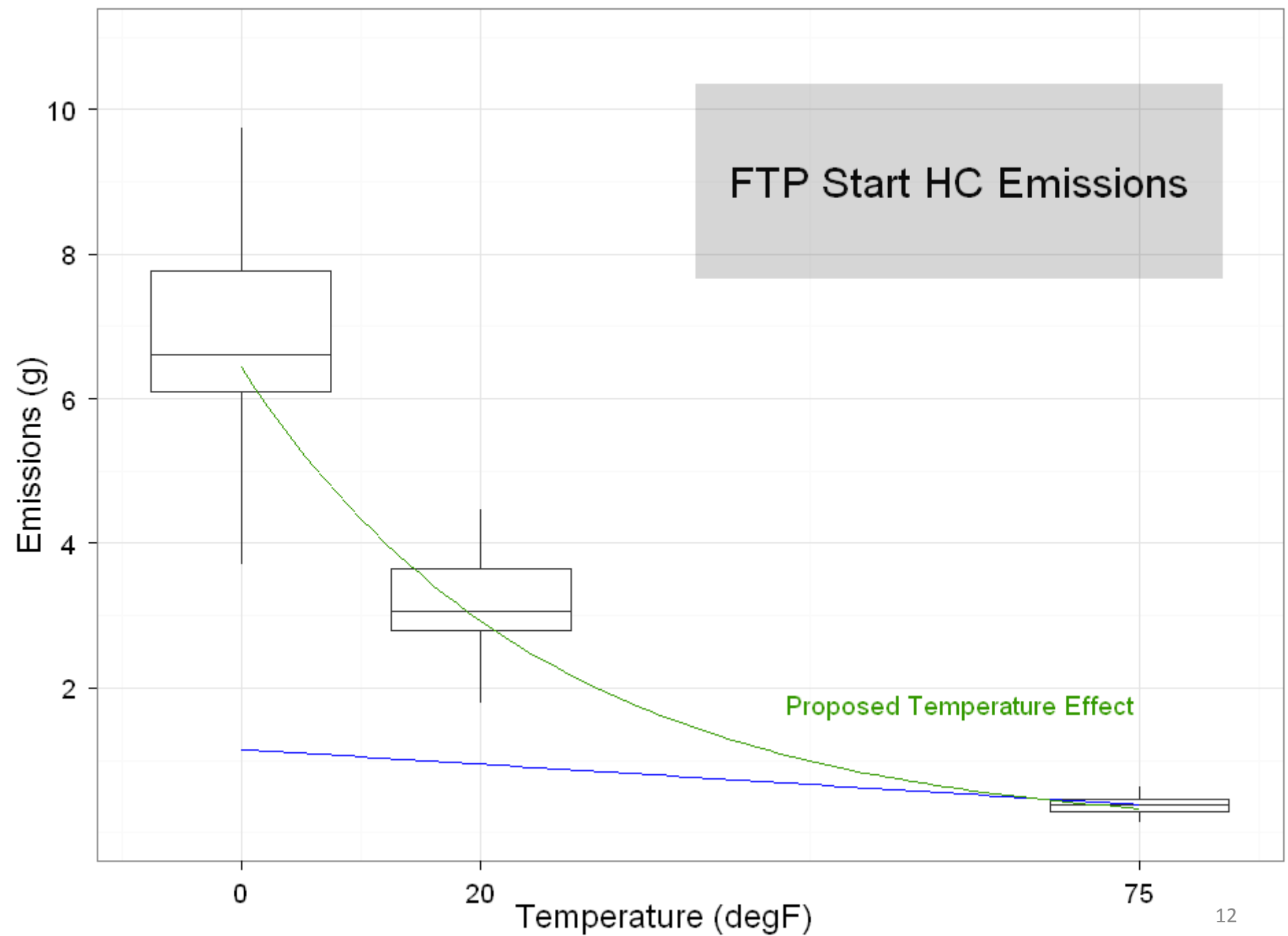
Emissions (g)

0

20

75

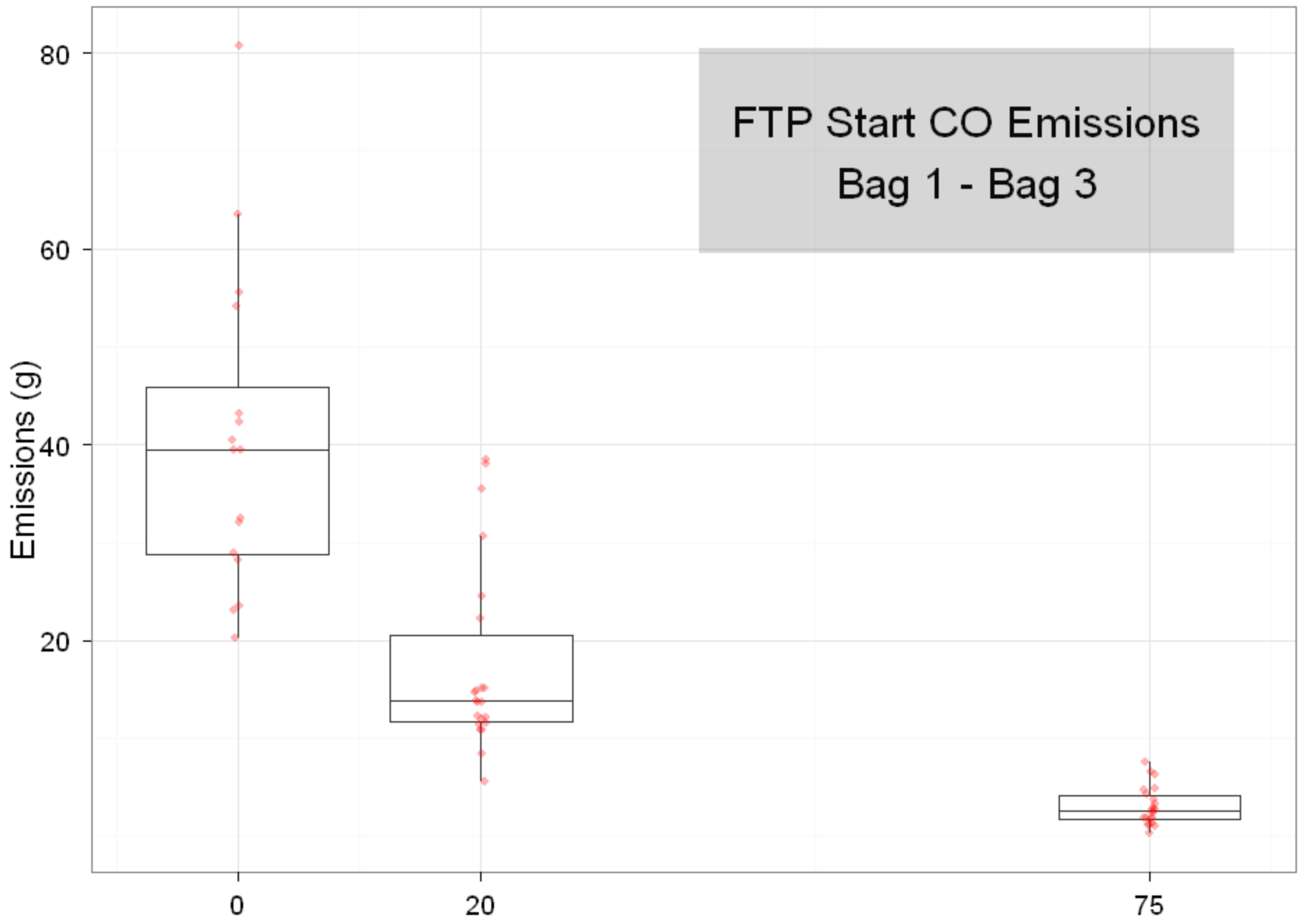


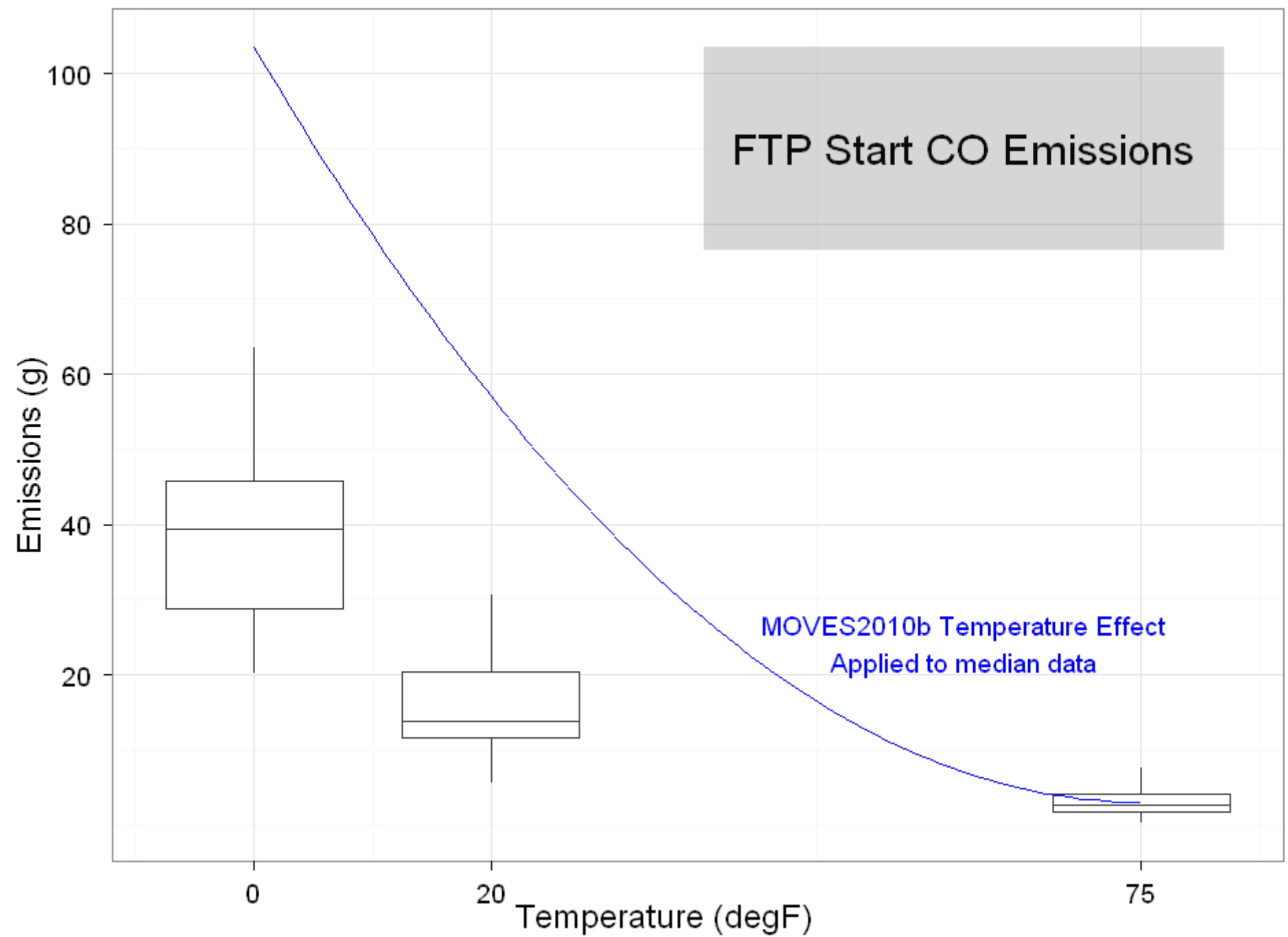


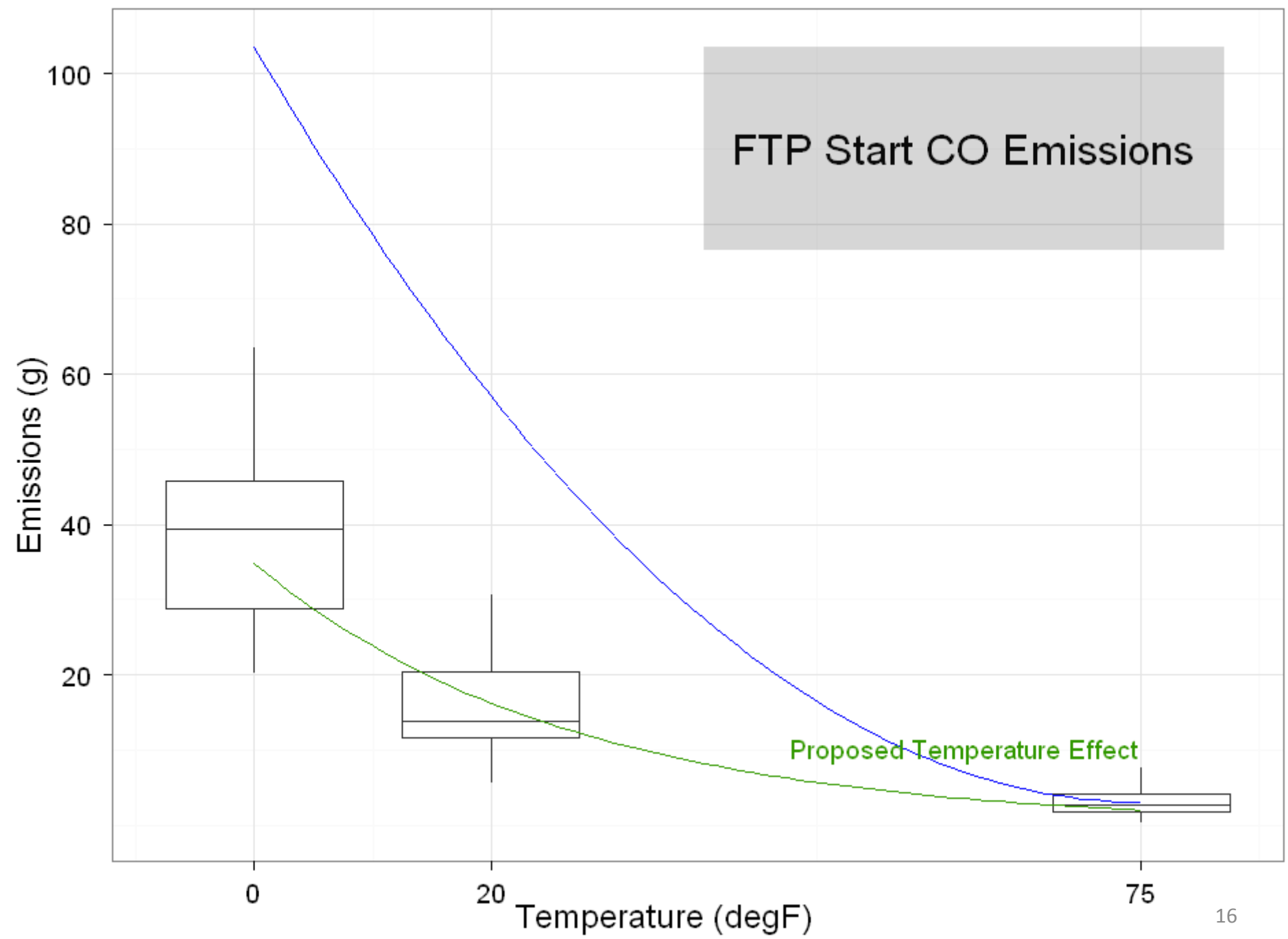
# HC emissions

- MSAT / Tier 2 vehicles projected to have minimal temperature effect
- Tested vehicles have higher temperature effect than expected.
  - Vehicles are in compliance with standard

FTP Start CO Emissions  
Bag 1 - Bag 3









# CO emissions

- MSAT / Tier 2 vehicles were predicted to have large temperature effect
- Tested vehicles have a lower temperature effect than expected.
- Newer vehicles no longer have higher CO emissions than older vehicles at low temps.

FTP Start NOx Emissions  
Bag 1 - Bag 3

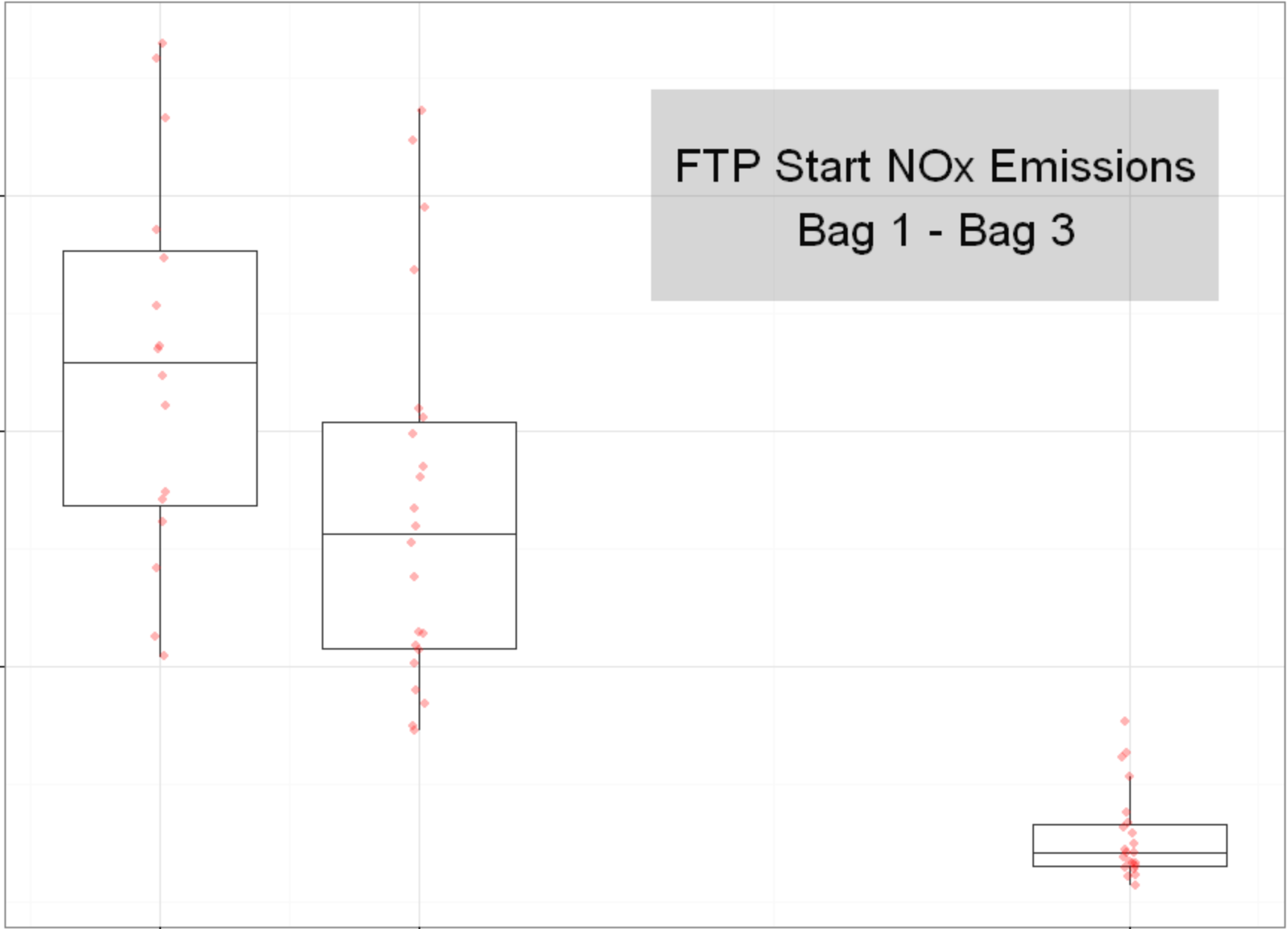
Emissions (g)

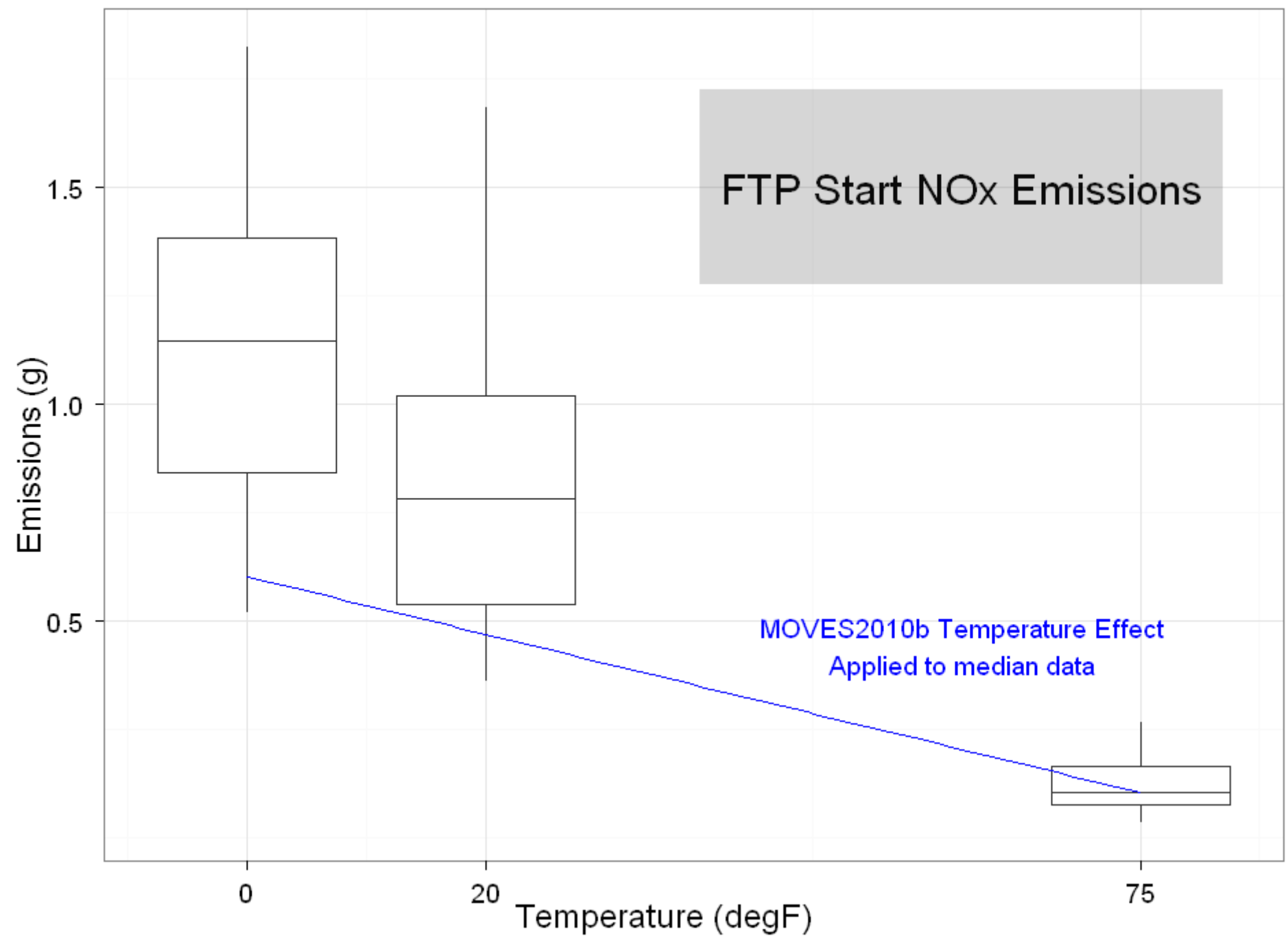
1.5  
1.0  
0.5

0

20

75

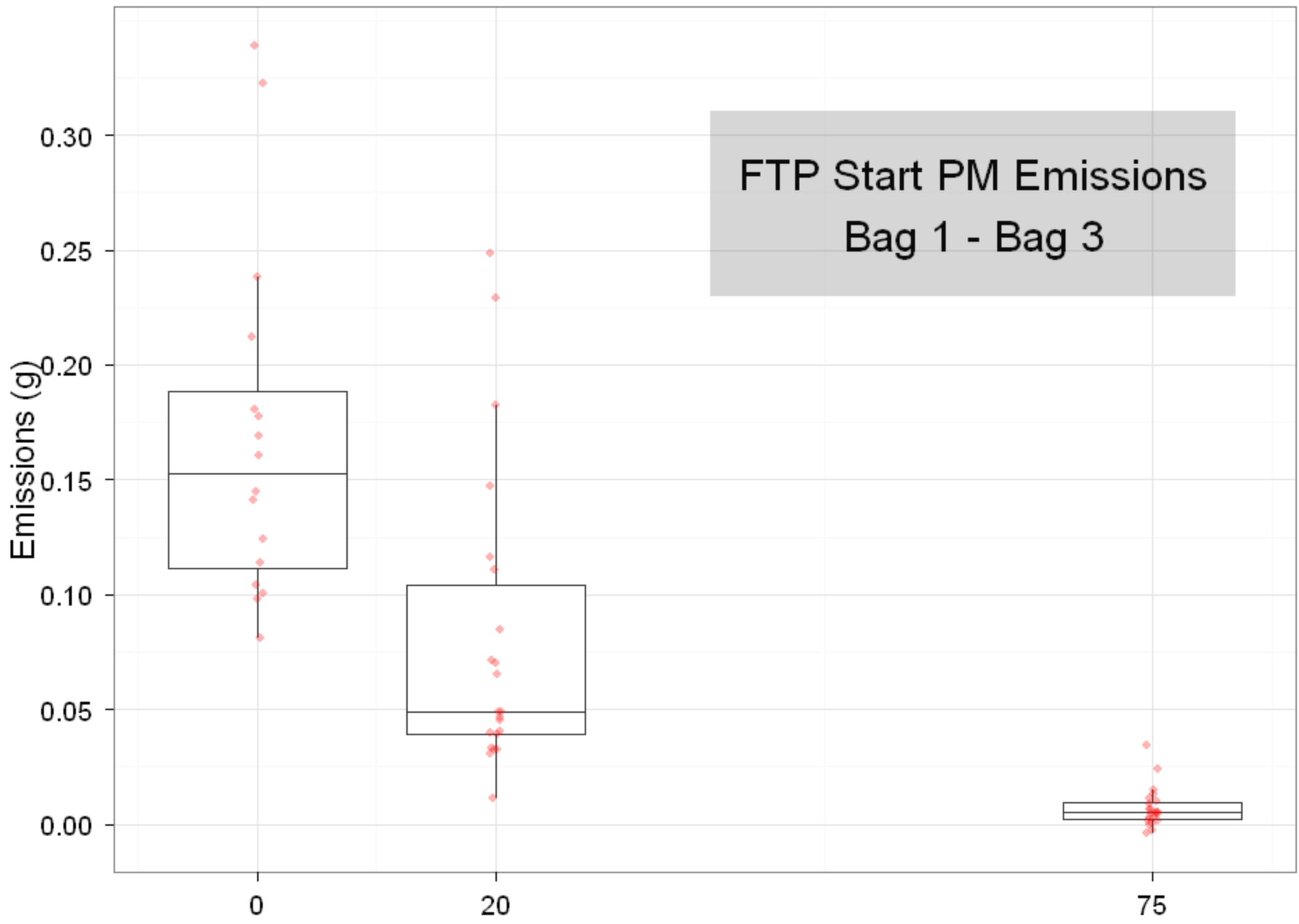


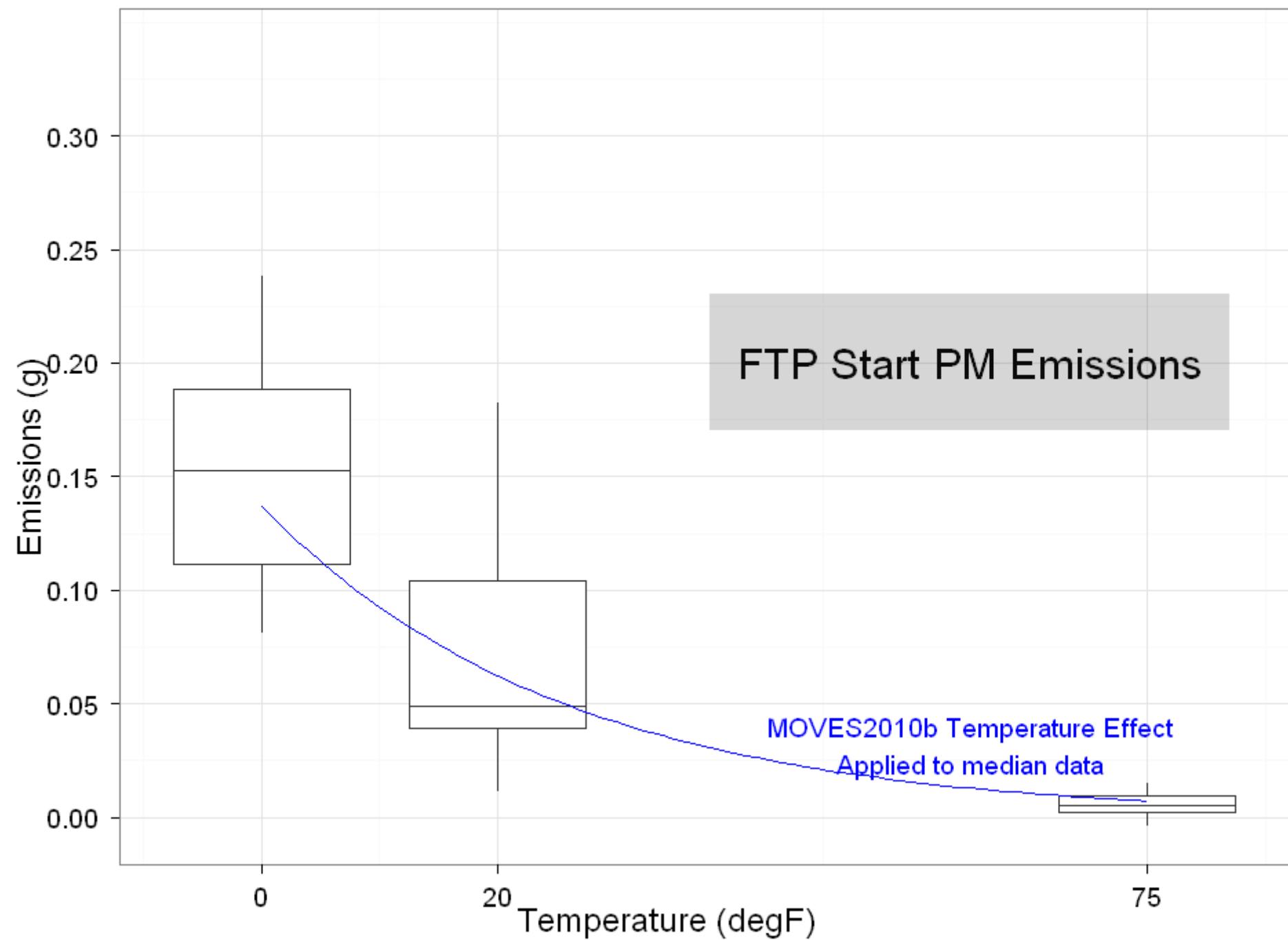


# NOx Emissions

- NOx temperature effect is very minimal
- Updating MOVES NOx temperature effect still tentative

FTP Start PM Emissions  
Bag 1 - Bag 3

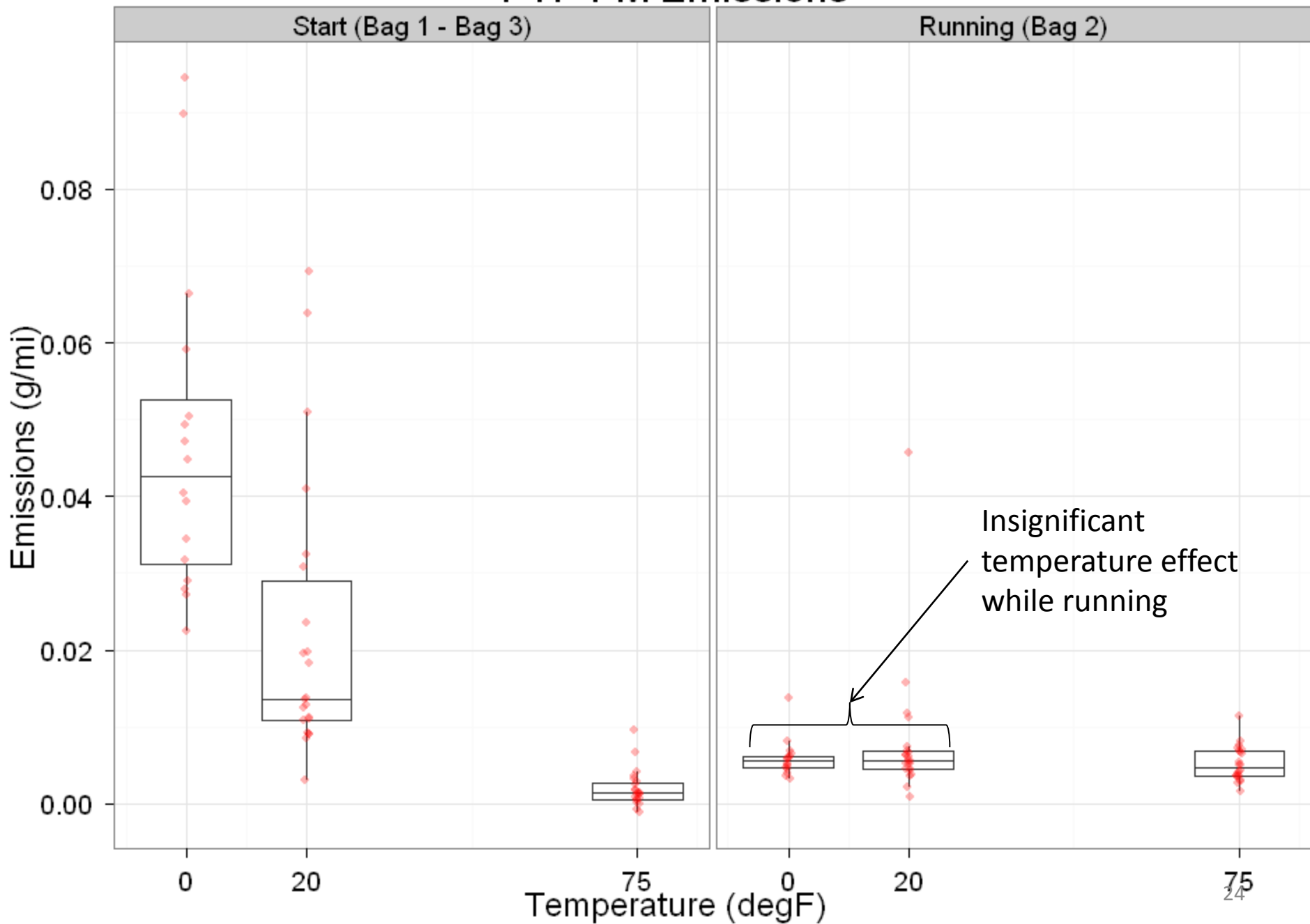




# PM Emissions

- PM temperature effect in MOVES fits data well for MSAT-2 compliant vehicles.
- No plans to change start emissions temperature effect for PM emissions
- NOTE: Vehicles tested with TX40 filters

# FTP PM Emissions





# Running PM

- FTP Bag 2, Hot US06, and continuous PM measurement suggest no ambient temperature effect on running PM emissions
- Consistent with findings from a 2005 EPA/SwRI test program conducted on four 2005 MY light-duty gasoline Tier 2 vehicles
- In contrast, the Kansas City Light-Duty Vehicle Study showed a significant temperature effect on the LA-92 bag 2

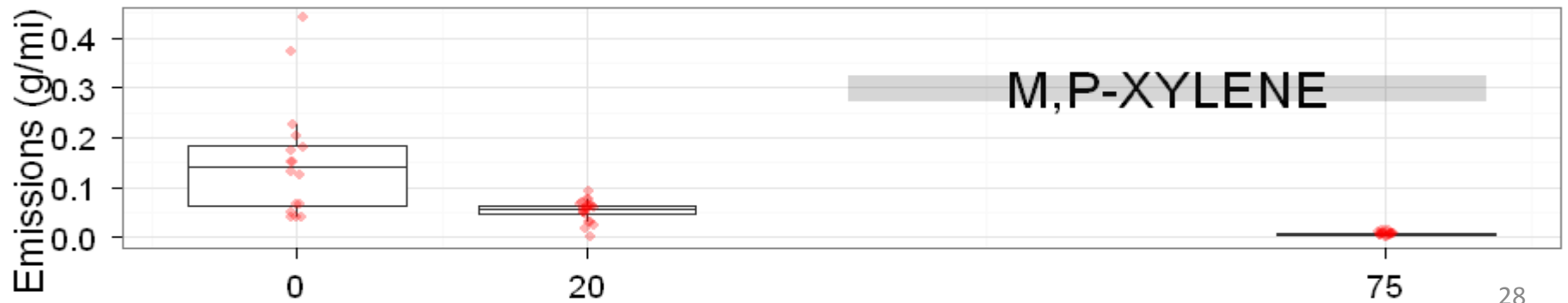
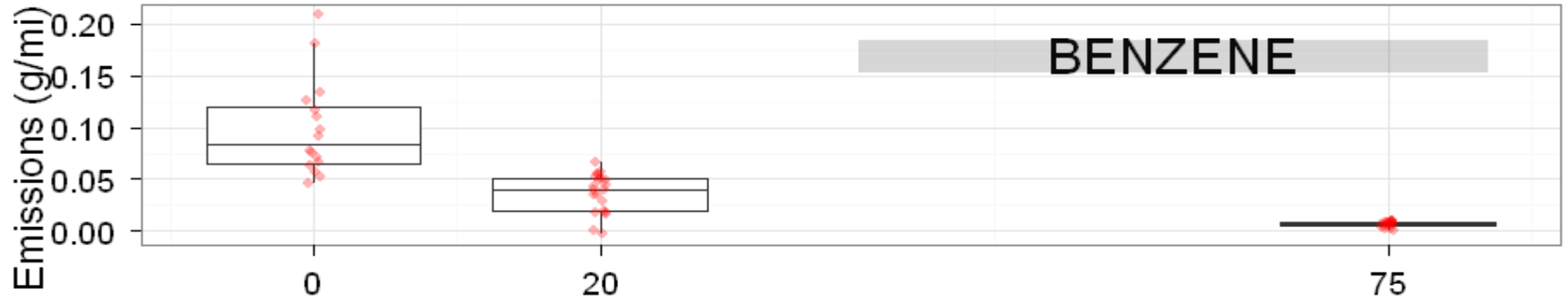
# Running PM Effects for MOVES2013

- Maintain PM running temperature effect for pre-Tier 2 vehicles (pre-2005)
  - Kansas City Study vehicles include 1960-2004 MY vehicles (no Tier 2 vehicles)
- Remove PM temperature running effect for Tier 2 vehicles (2005 and later)
  - Data from test programs does not show temperature effect on Bag 2 on the FTP (2005 and later model year vehicles)
  - MOVES provides good fit to the start emissions from recent test programs on the FTP

# VOC Speciation

- VOC species results available for each temperature
- As expected, generally follow HC temperature effect

# VOC species, FTP Starts



# Conclusions / Proposals

- **HC**
  - Higher temp effect in MOVES2013 for MSAT starts
- **CO**
  - Lower temp effect in MOVES2013 for MSAT starts
- **PM**
  - No PM temp effect in MOVES2013 for Tier 2 & later running
- **NOx**
  - *No proposal to change for MOVES release*

# New Questions

- Do other GDI data exist at low temperature?
- How to approach VOC speciation data analysis?
- How do start effects vary by soak length?
  - This program measured starts at 12 hours

# Acknowledgements

- Chuck Schenk
- Joseph McDonald
- Darrell Sonntag



# Questions?







# Appendix

# Additional Information:

## PM temperature effect for running emissions

- PM running temperature effect based on Kansas City Light-duty Vehicle Emissions Study
  - Based on bag 2 from LA-92 cycle from Kansas City Study
  - Largely attributed to the short warm-up
    - LA-92 Bag 1 : 1.2 miles
    - FTP Bag 1: 3.59 miles
- Re-analysis of Kansas City Study (2013)
  - Magnitude of the PM running temperature effect decreases as the vehicle warms up
  - Significant temperature effect persists on the running emissions, even for the end of bag 2
  - Temperature effect significant
    - after FTP bag 1 length (505 seconds)
    - after 1025 seconds (17 minutes)

# Additional Information: PM temperature effect for running emissions

- Analysis suggested that the running temperature effect can persist up to the length of the bag 1 + bag 2 of the LA-92
  - Average trip length in MOVES < 9 miles
  - LA-92 bag 1 + bag 2 length = 9.82 miles
- If, the running temperature were removed from the model, we believe we would be underestimating the temperature effect on total PM emissions.
- Analysis suggests that running temperature effect should remain in the model for pre-2005 vehicles
- More data needed to understand relationship of technology and drive cycles on cold start emissions