



IRTEMS

H2020-MSCA-IF-2019,  
Grant Agreement 896417

CRC Real-World Emission Workshop

Long Beach, California

March 26-29, 2023



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# Evaluation of model predictions of real-world emission hotspots based on measured vehicle activity and emissions

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# Background

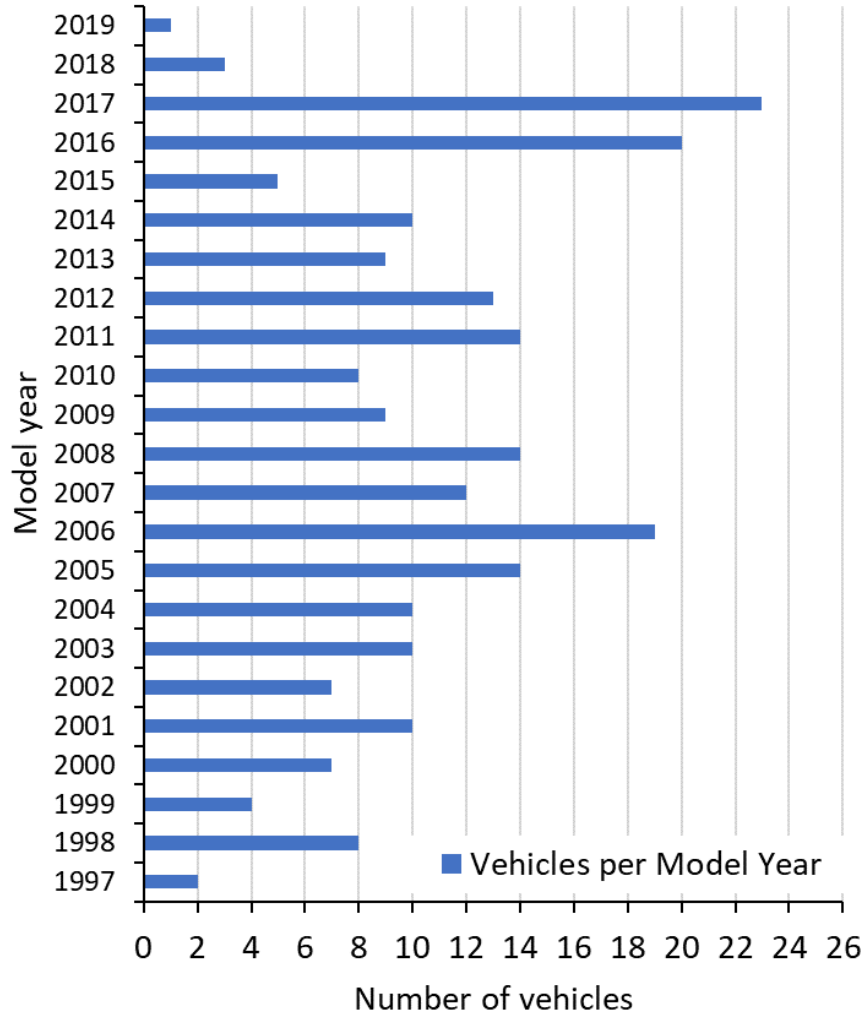
Quantification of spatial variability in on-road vehicle emission rates helps to identify locations of emission hotspots, which affect near-road air quality and human exposure.

## Research objective

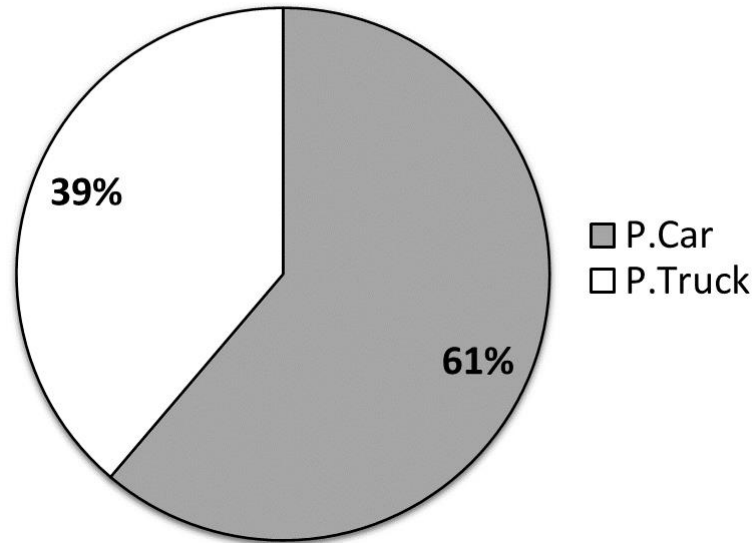
To evaluate the model predictions of real-world emission hotspots for a fleet of Light Duty Gasoline Vehicles.



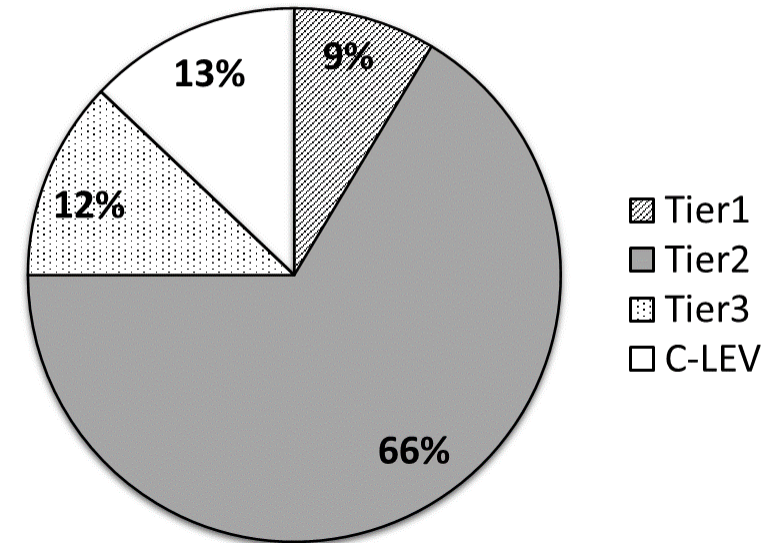
# Case study: 232 Light Duty Gasoline Vehicles



Vehicles body type



Vehicles emission standard



Vehicle	Age when measured (years)	Rated HP	Curb weight (lb)	RFE (mpg)	Mileage (mi*1000)
<b>Average fleet of 232 vehicles</b>	5.5	191	3489	25	75



# Methods: Activity and emission measurements



Portable Emission Measurement System (PEMS): CO<sub>2</sub>, NO<sub>x</sub>, HC, CO

On-Board Diagnostic scantool (OBD):  
1Hz vehicle activity data (e.g. speed)



Global positioning system (GPS) with  
barometric altimeter.

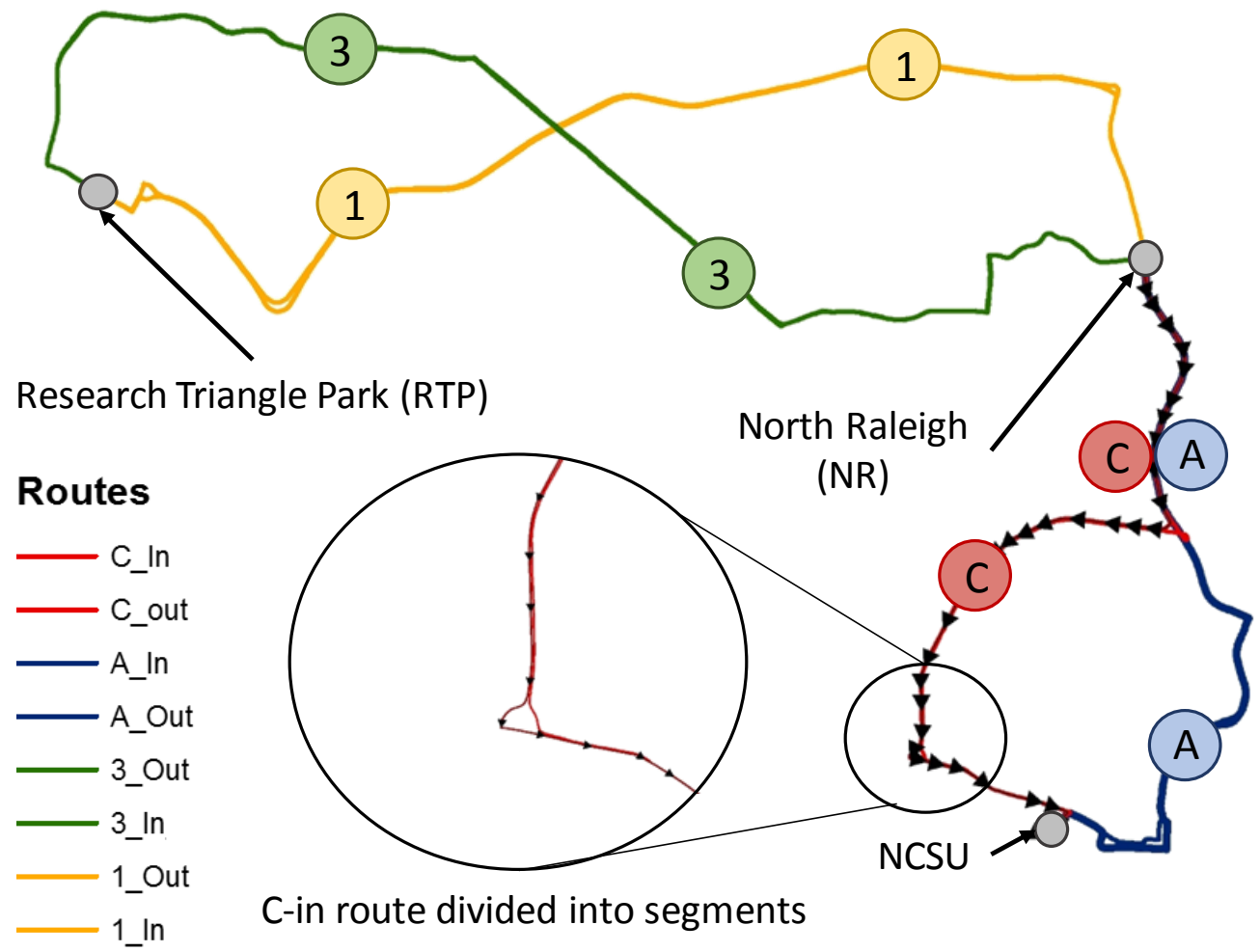


Road Grade (RG) estimation based on  
linear regression of elevation versus  
distance. Ranging from -5.3 to 5.7%



# Methods: Measured routes

- 8 one-way routes:
  - 4 out routes from NCSU to NR and from NR to RTP
  - 4 in routes from RTP to NR and from NR to NCSU
- Broad coverage of road types, speed limits and RG
- Total distance 110 mi
- 450 segments, based on:
  - constant RG
  - speed limits
  - road types
- Average length of 0.25 mi (0.005-0.49 mi)



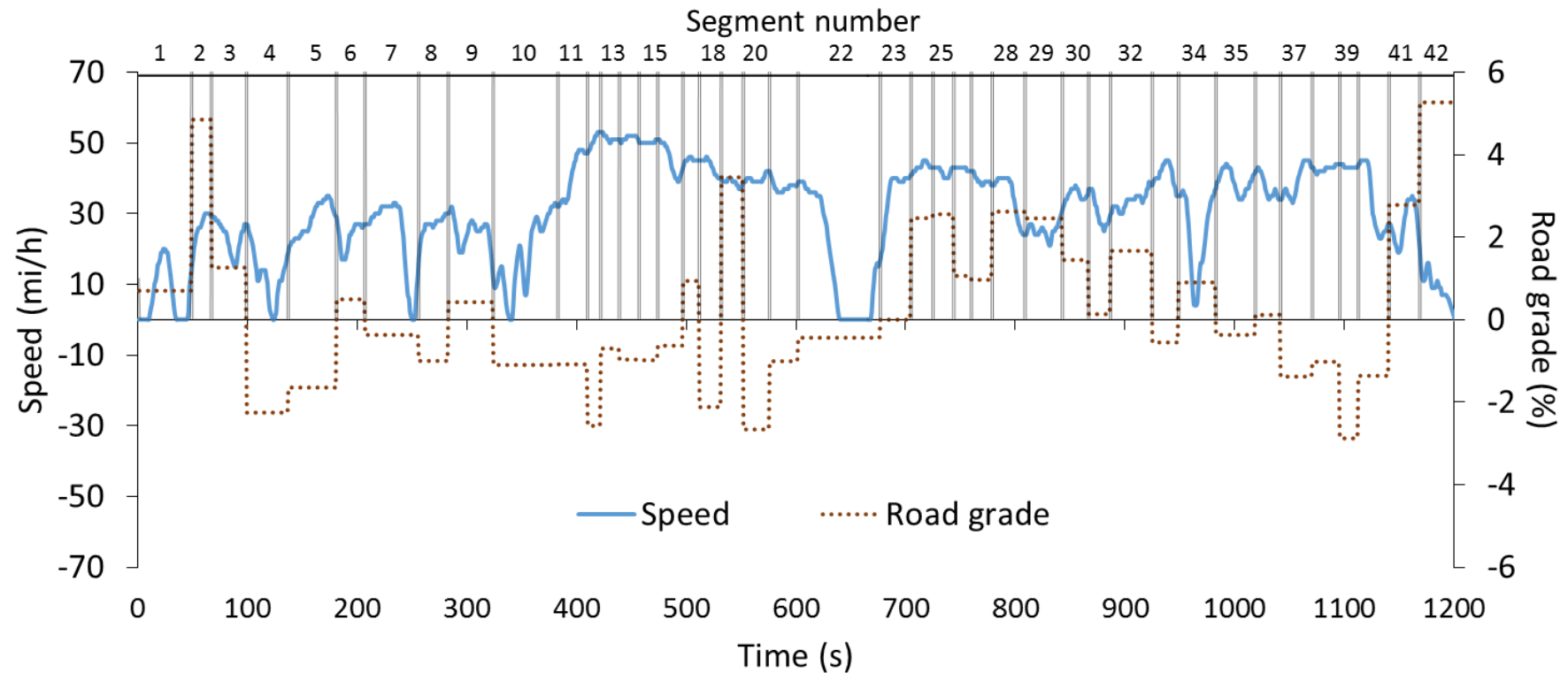




# Methods: segmented trajectories

Route A-out 42 segments with example trajectory for Ford Fusion vehicle

- Second by second vehicle speed
- Segment average road grade

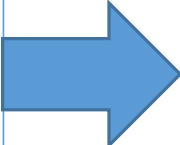




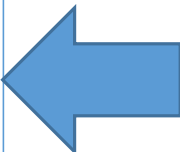
# Methods: On-road vehicles emission model

## US-EPA MOVES 3

Vehicle type  
Vehicle age  
Vehicle activity (1Hz speed profiles and RG) by segment  
Ambient condition



Fleet average segment based emission rates



The screenshot shows the MOVES 3 software interface with the 'Scale' settings panel open. The left sidebar contains a list of settings, all of which are checked with green checkmarks: Description (Alt+1), Scale, Time Spans, Geographic Bounds, Onroad Vehicles, Road Type, Pollutants and Processes, General Output, Output Emissions Detail, Create Input Database, and Advanced Features.

The 'Scale' panel is titled 'Scale' and contains the following sections:

- Model:**
  - Onroad** Estimate emissions from motorcycles, cars, buses, and trucks that operate on roads.
  - Nonroad** Estimate emissions from nonroad equipment used in applications such as recreation, construction, lawn and garden, agriculture, mining, etc. Nonroad does not include aircraft, railroads, or commercial marine vessels.
- Domain/Scale:**
  - Default Scale** Use the default national database with default state and local allocation factors.
 

**Caution:** Do not use this scale setting for SIP or conformity analyses. The allocation factors and other defaults applied at the state or county level have not been verified against specific state or county data and do not meet regulatory requirements for SIPs and conformity determinations.
  - County Scale** Use this scale for SIP and regional conformity analysis. This scale requires user-supplied local data for most activity and fleet inputs.
  - Project Scale** Use this scale for project-level analysis for conformity, NEPA, or other regulatory purposes where link-level analysis is needed. This scale requires user-supplied data at the link level for activity and fleet inputs that describe a particular transportation project.
- Calculation Type:**
  - Inventory** Mass and/or Energy within a region and time span.
  - Emission Rates** Mass and/or Energy per unit of activity.

At the bottom of the 'Calculation Type' section, there is a text box for 'MOVESScenarioID' containing the value '120120\_2005\_TOYOTA\_CAMRY'. A yellow warning icon is present at the bottom of the panel with the text: 'Caution: Changing these selections changes the contents of other input panels. These changes may include losing previous data contents.'



# Methods: Hotspots definition

Emission **hotspots** are defined as segments within the top 10% ( $\geq 90^{\text{th}}$  percentile) of the measured or modelled segments average emission rates for each pollutant.

**Near misses** of measured hotspots: segments which have segment average modeled emission rates that are below the top 10%, but are in the top 20% (between  $80^{\text{th}}$  to  $90^{\text{th}}$  percentile).





# Methods: Model hotspot prediction analysis

- Confusion matrix: summary of prediction results per pollutant:

	Modeled positive (Hotspot [+])	Modeled negative (Non-hotspots [-])
Measured positive (Hotspot [+])	<b>True positive (TP)</b>	<b>False negative (FN)</b>
Measured negative (Non-hotspots [-])	<b>False positive (FP)</b>	<b>True negative (TN)</b>

TP: Model correctly identifies a real world hotspot

TN: Model correctly identifies real world non-hotspot

FP: Model identifies as hotspot a real world non-hotspot

FN: Model identifies as non-hotspot a real world hotspot



# Methods: Model hotspot prediction analysis

- Accuracy (Acc): model probability to correctly identify hotspots and non-hotspots:

$$\text{Acc (\%)} = \left( \frac{\text{TP} + \text{TN}}{\underbrace{\text{TP} + \text{FN}}_{\text{Actual positives}} + \underbrace{\text{TN} + \text{FP}}_{\text{Actual negatives}}} \right) \times 100$$

- Precision (P): model probability to correctly identify hotspots:

$$\text{P (\%)} = \left( \frac{\text{TP}}{\underbrace{\text{TP} + \text{FP}}_{\text{Model positives}}} \right) \times 100$$

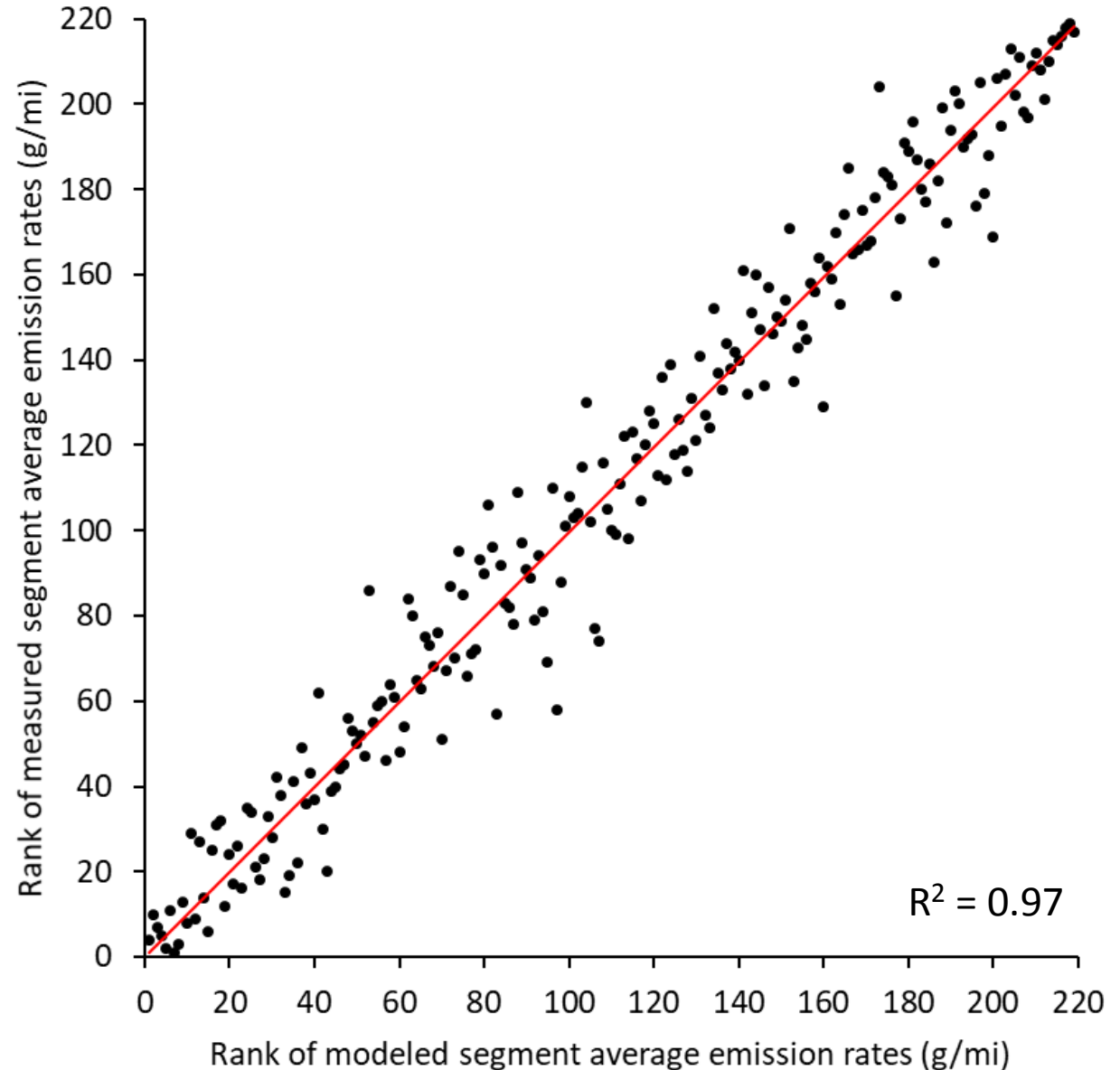
TP = True Positives  
TN = True Negatives  
FP = False Positives  
FN = False Negatives



# Results: Measured vs. modeled ranked emission rates per segment

## CO<sub>2</sub>

- Fleet average results based on 232 vehicles data
- Outbound routes
- 219 segments (points)

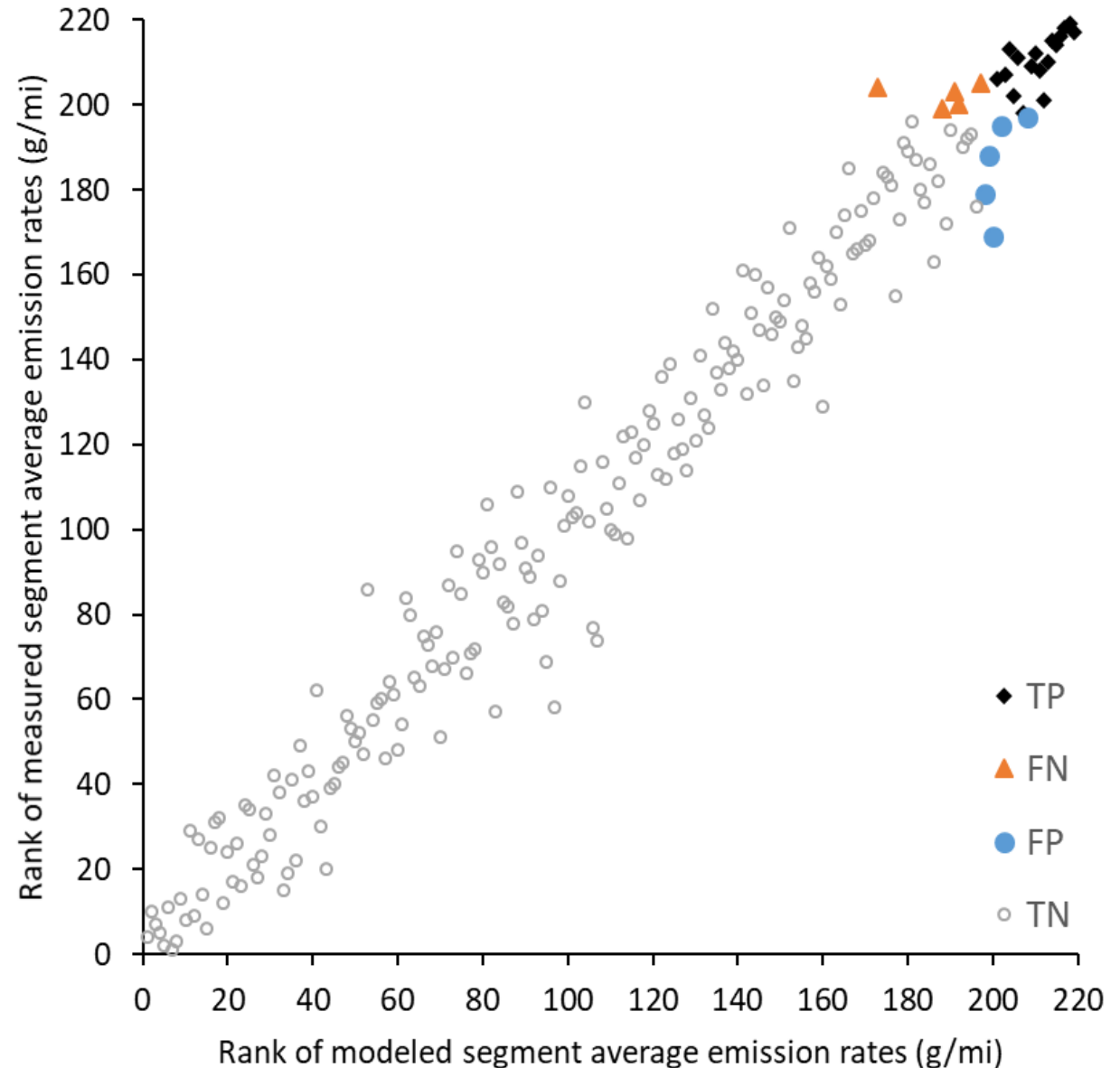




# Results: Measured vs. modeled ranked emission rates per segment – Identification of hotspots

## CO<sub>2</sub>

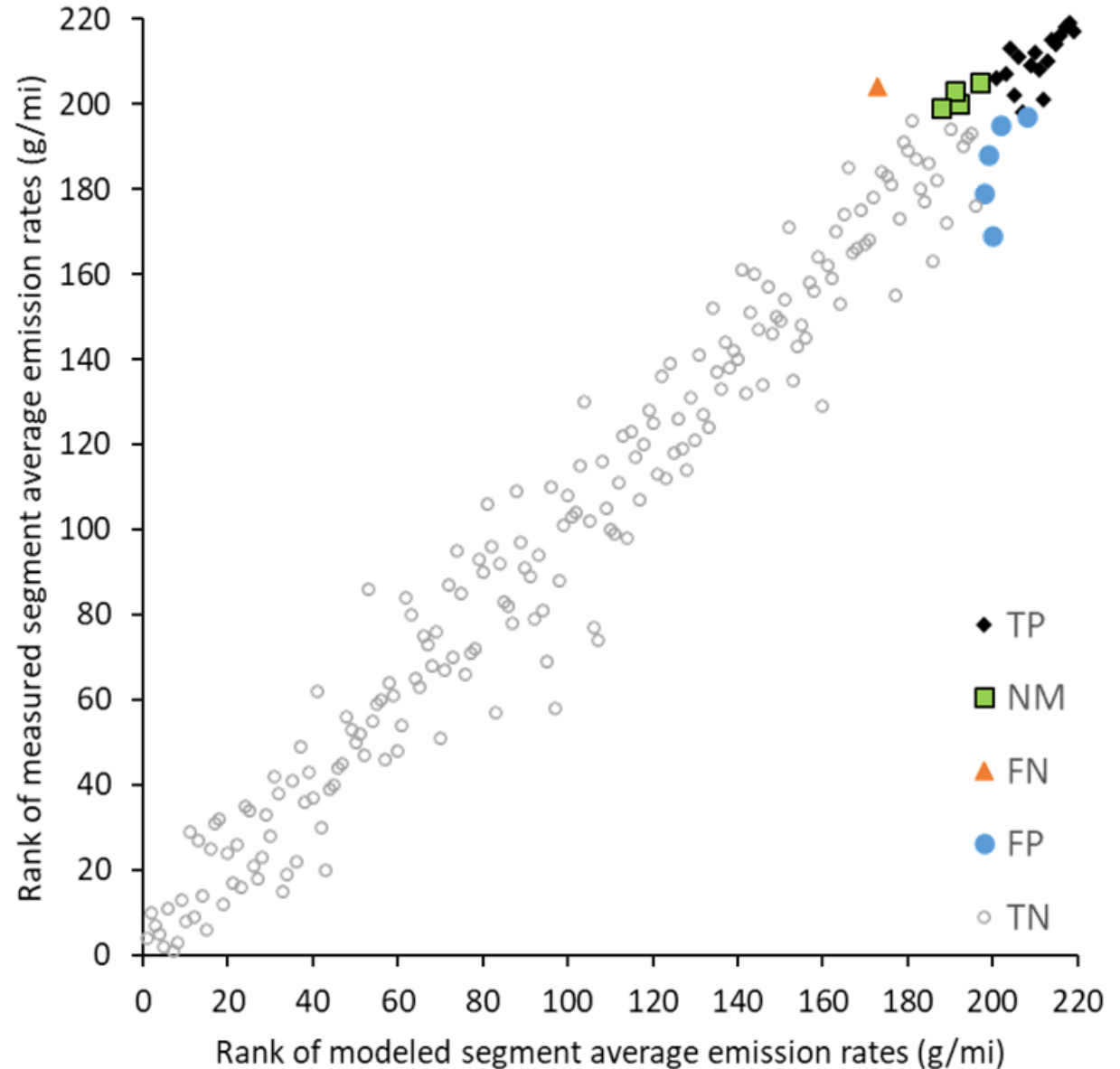
- Fleet average results based on 232 vehicles data
- Outbound routes
- 219 segments (points)





# Results: Measured vs. modeled ranked emission rates per segment – Identification of hotspots and near misses CO<sub>2</sub>

- Fleet average results based on 232 vehicles data
- Outbound routes
- 219 segments (points)

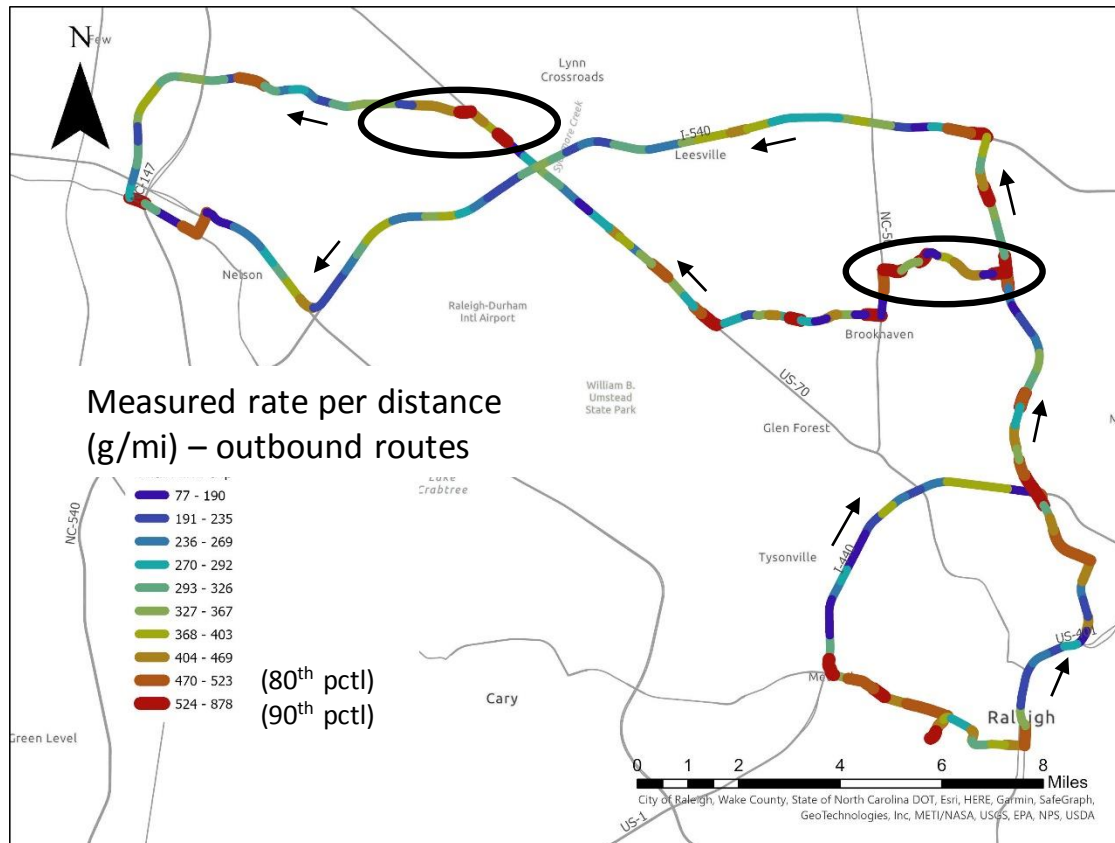




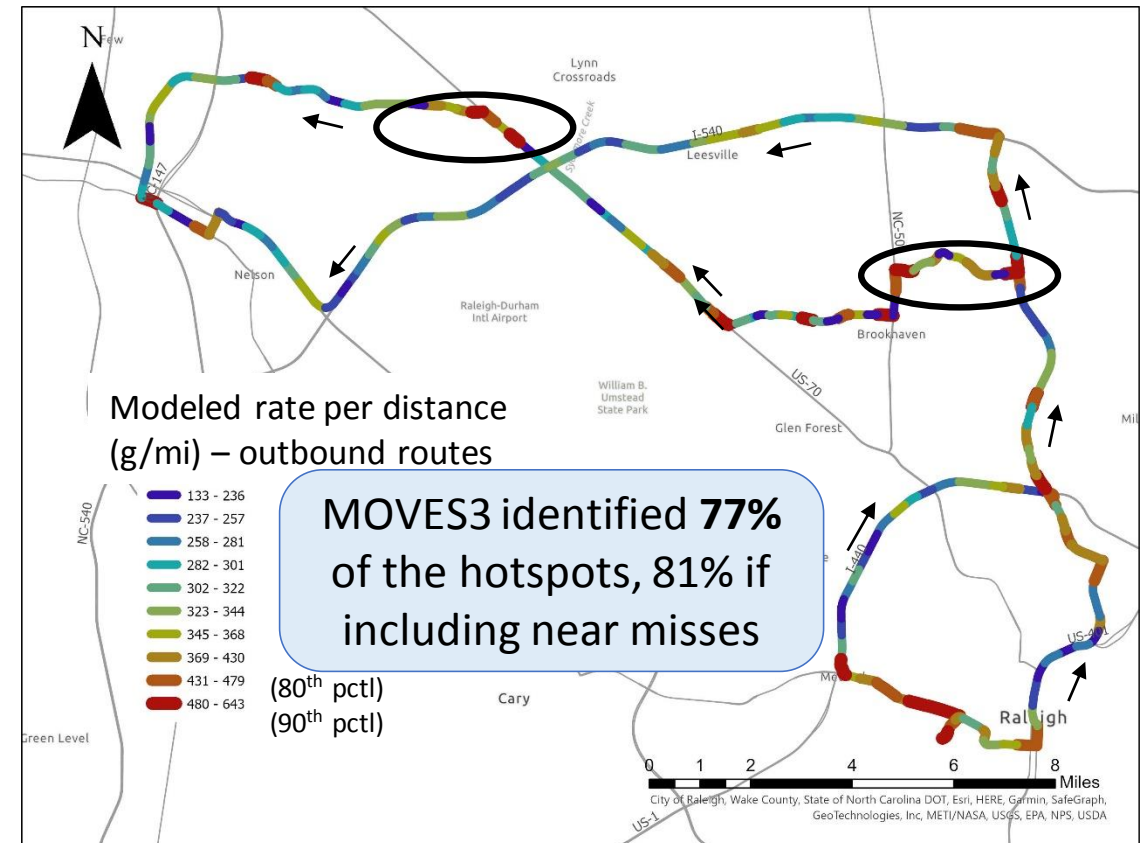


# Results: MOVES3 modeled and measured emission rates per segments – average for 232 vehicles – CO<sub>2</sub>

## Measured hotspots



## Model predicted hotspots

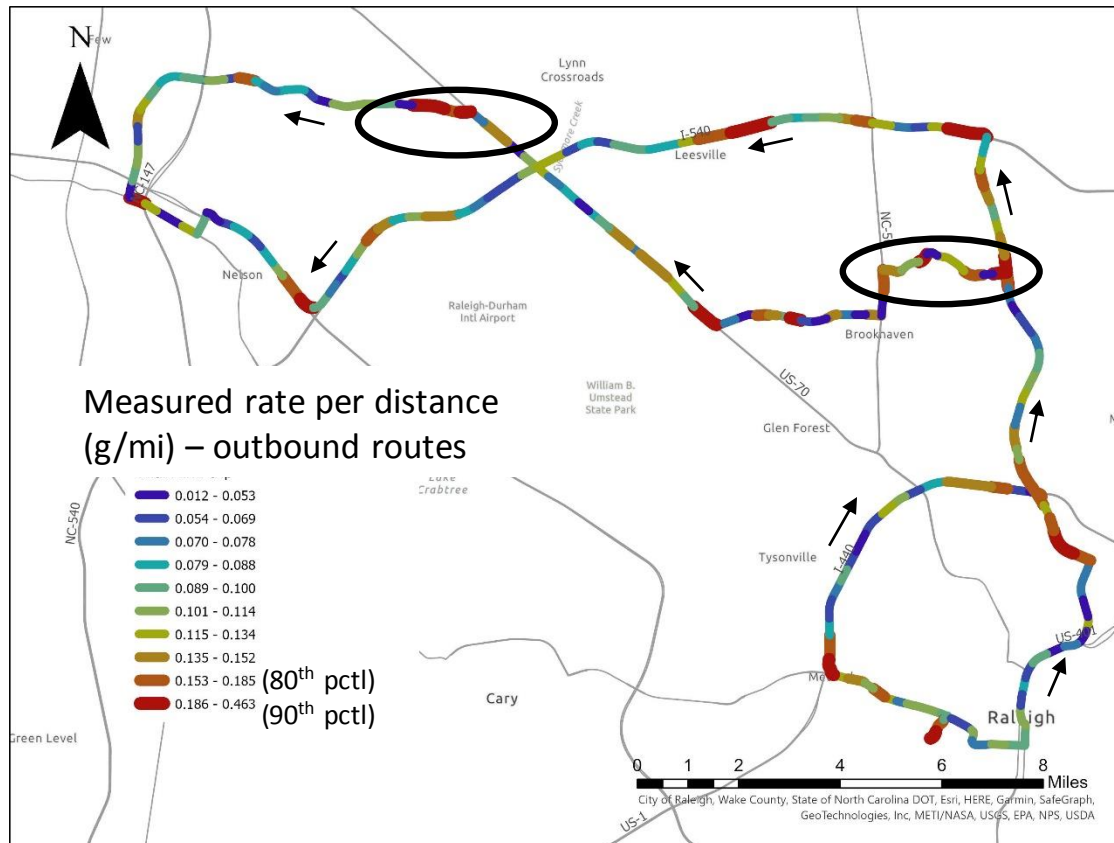


**MOVES3 identified 77% of the hotspots, 81% if including near misses**

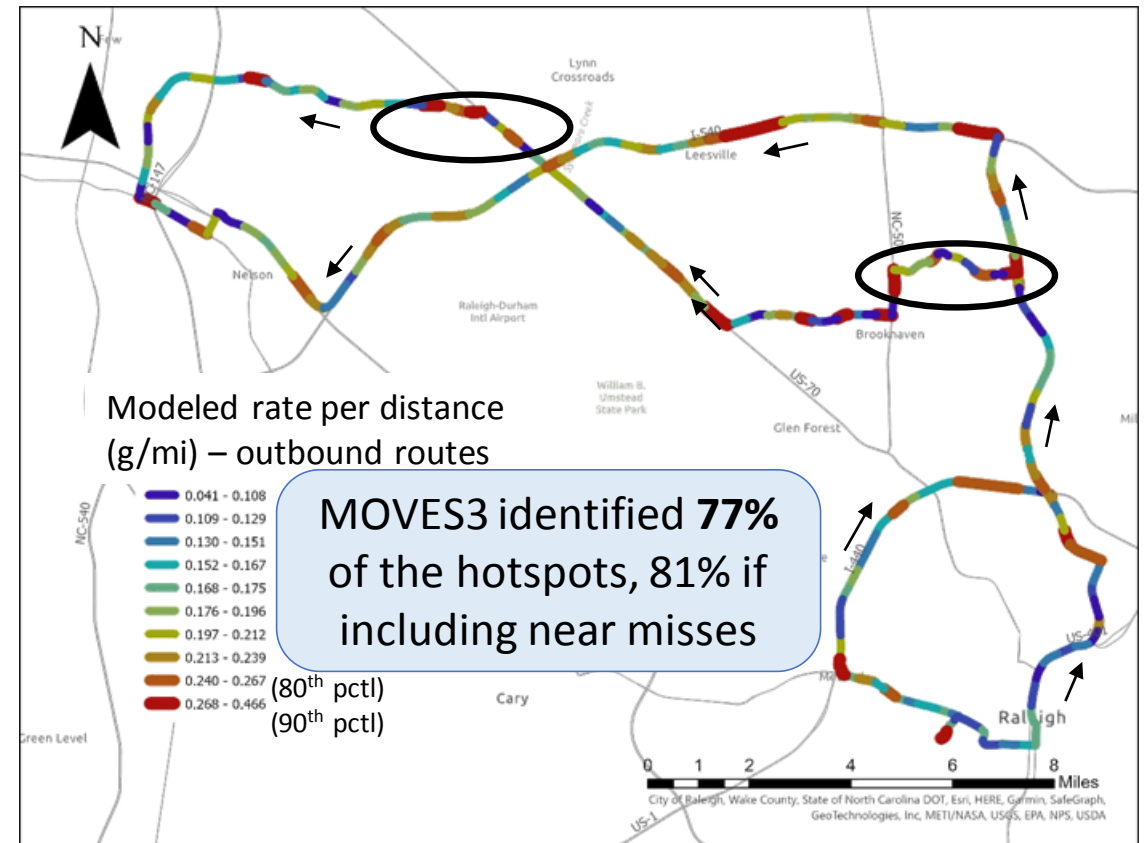


# Results: MOVES3 modeled and measured emission rates per segments – average for 232 vehicles – NO<sub>x</sub>

## Measured hotspots



## Model predicted hotspots



MOVES3 identified **77%** of the hotspots, 81% if including near misses



# Results: Accuracy and precision of model predictions for several pollutants over 219 outbound segments

## Accuracy and precision per pollutant

	CO <sub>2</sub>	NO <sub>x</sub>	HC	CO
Accuracy	95%	95%	95%	93%
Precision	77%	77%	73%	64%

Results are based on a fleet of 232 vehicles over 219 outbound segments



# Results: Accuracy and precision of model predictions for several pollutants – including near misses

## Accuracy and precision per pollutant

	CO <sub>2</sub>	NO <sub>x</sub>	HC	CO
Accuracy	97%	97%	97%	94%
Precision	81%	81%	78%	67%

Results are based on a fleet of 232 vehicles over 219 outbound segments



# Conclusions

- The model is performing better for CO<sub>2</sub> and NO<sub>x</sub>, followed by HC and finally for CO.
- The model is highly accurate, at 93% to 95% across pollutants, in locating the measured hotspots and non-hotspots. When including near misses the accuracy increases to 94% to 97%.
- The high values of accuracy and precision indicate that the model is performing well and has a high level of agreement with the measurements.





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# Thank you!

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