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

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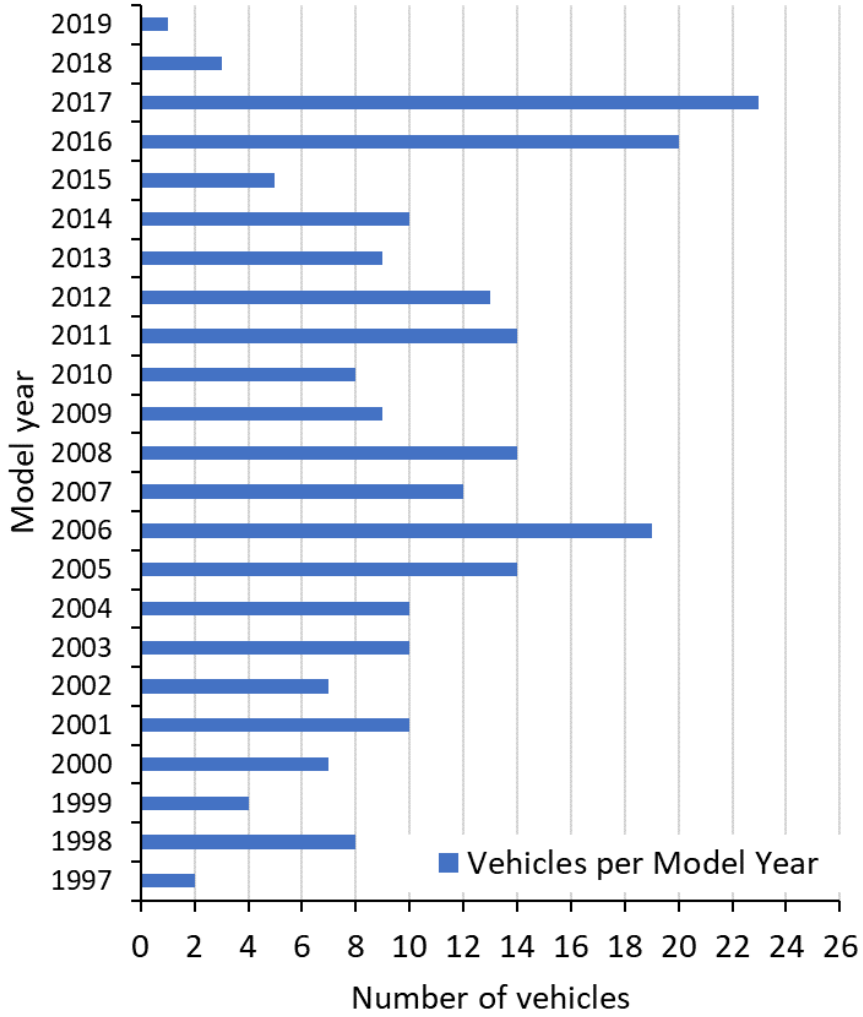
Background

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.

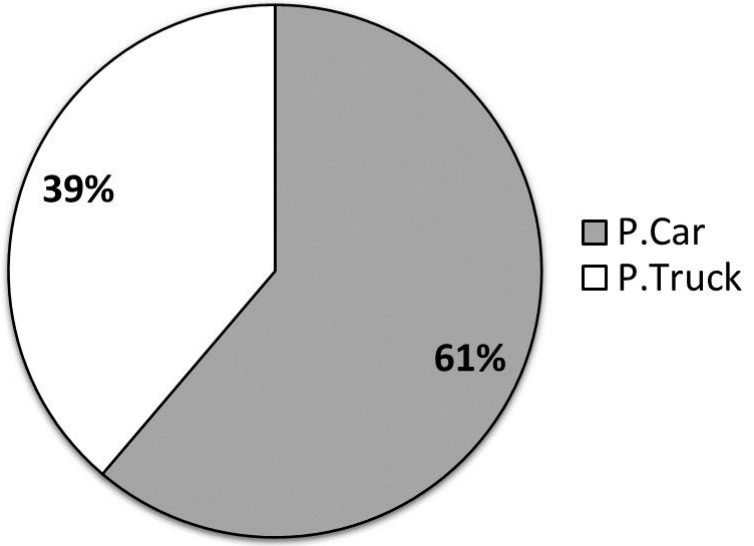
Research objective

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

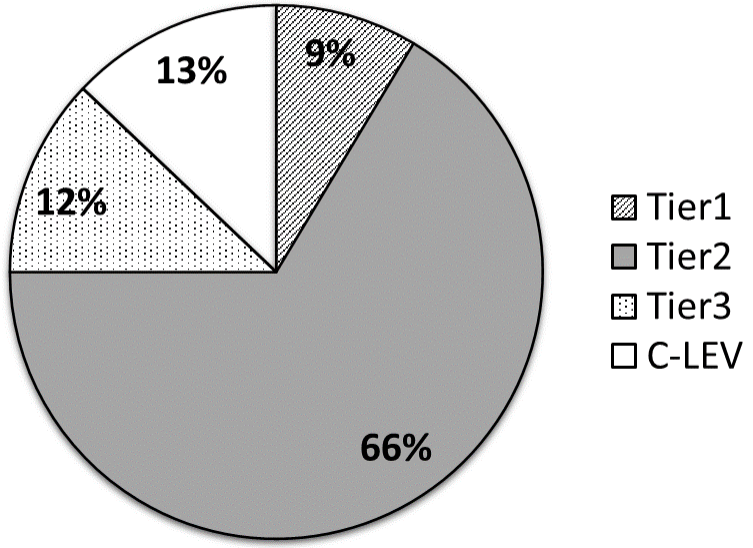
Case study: 232 Light Duty Gasoline Vehicles



Vehicles body type

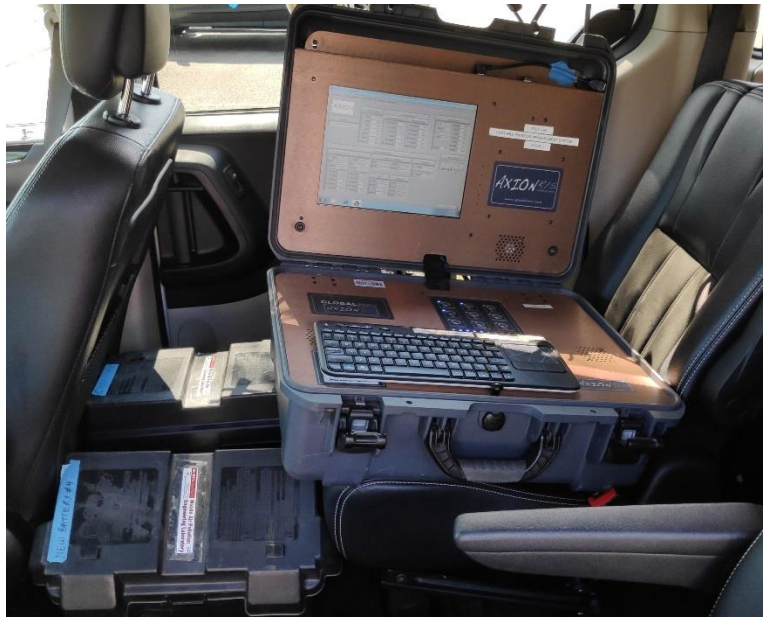


Vehicles emission standard



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

Methods: Activity and emission measurements



Portable Emission Measurement System (PEMS): CO_2, NO_X, HC, CO

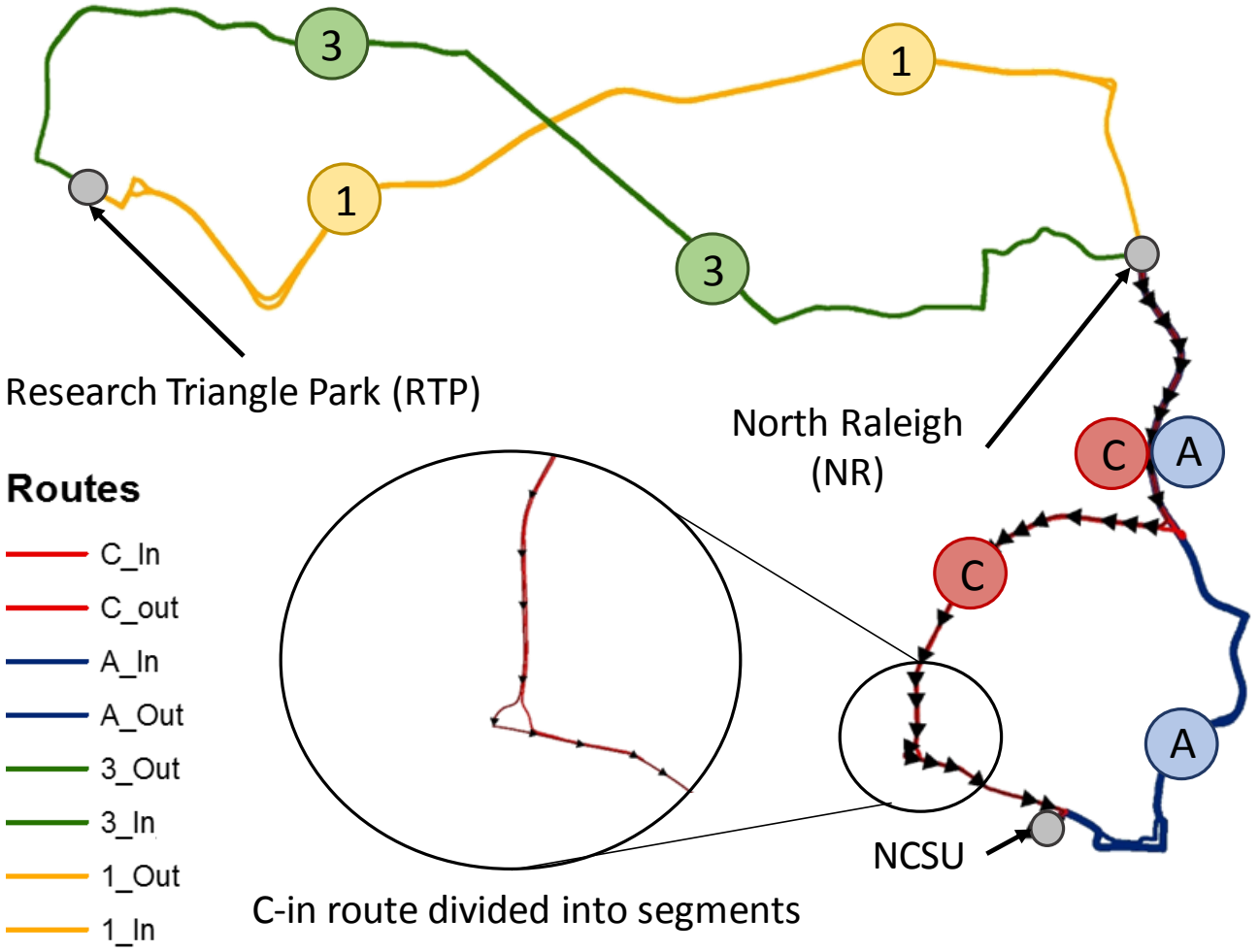
On-Board Diagnostic scantool (OBD): 1Hz vehicle activity data (e.g. speed)

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)

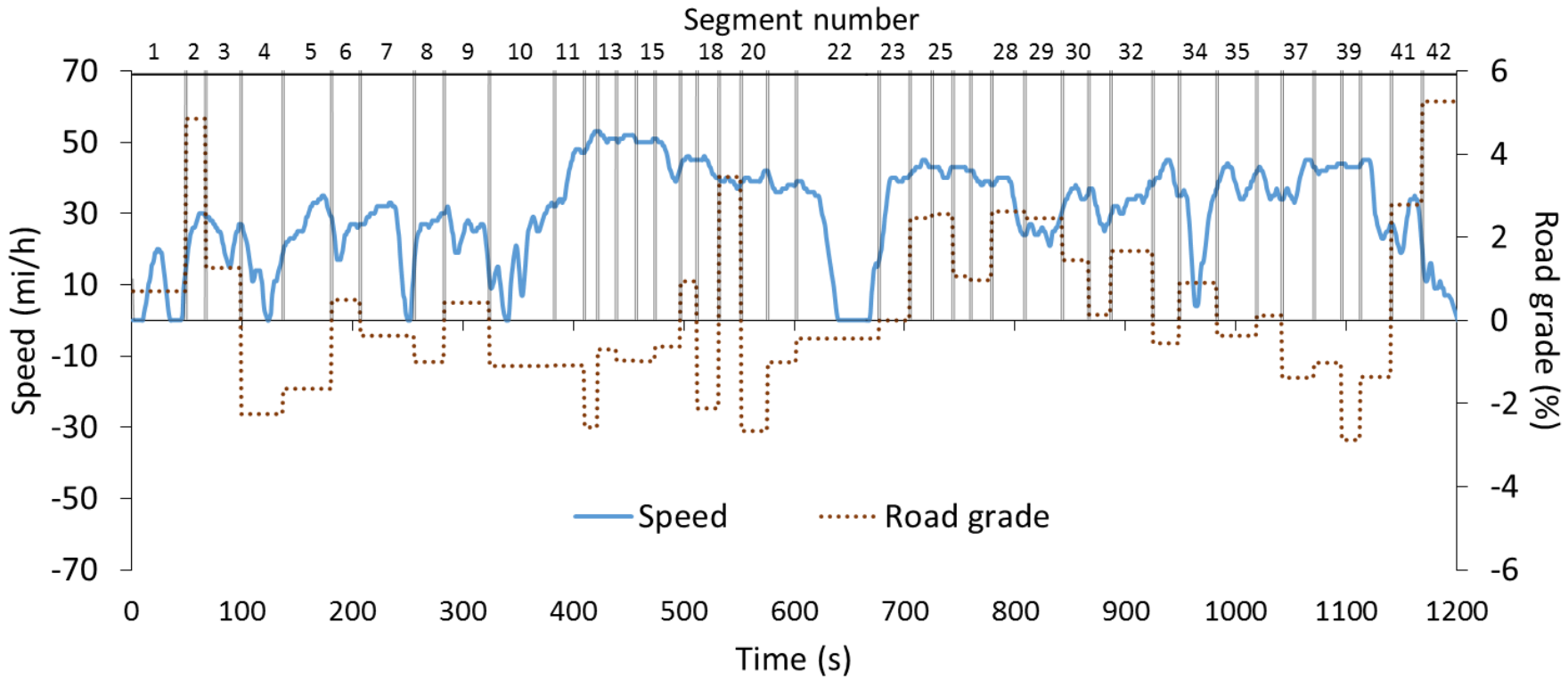


C-in route divided into segments

Methods: segmented trajectories

- Second by second vehicle speed
- Segment average road grade

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



Methods: On-road vehicles emission model

US-EPA MOVES 3

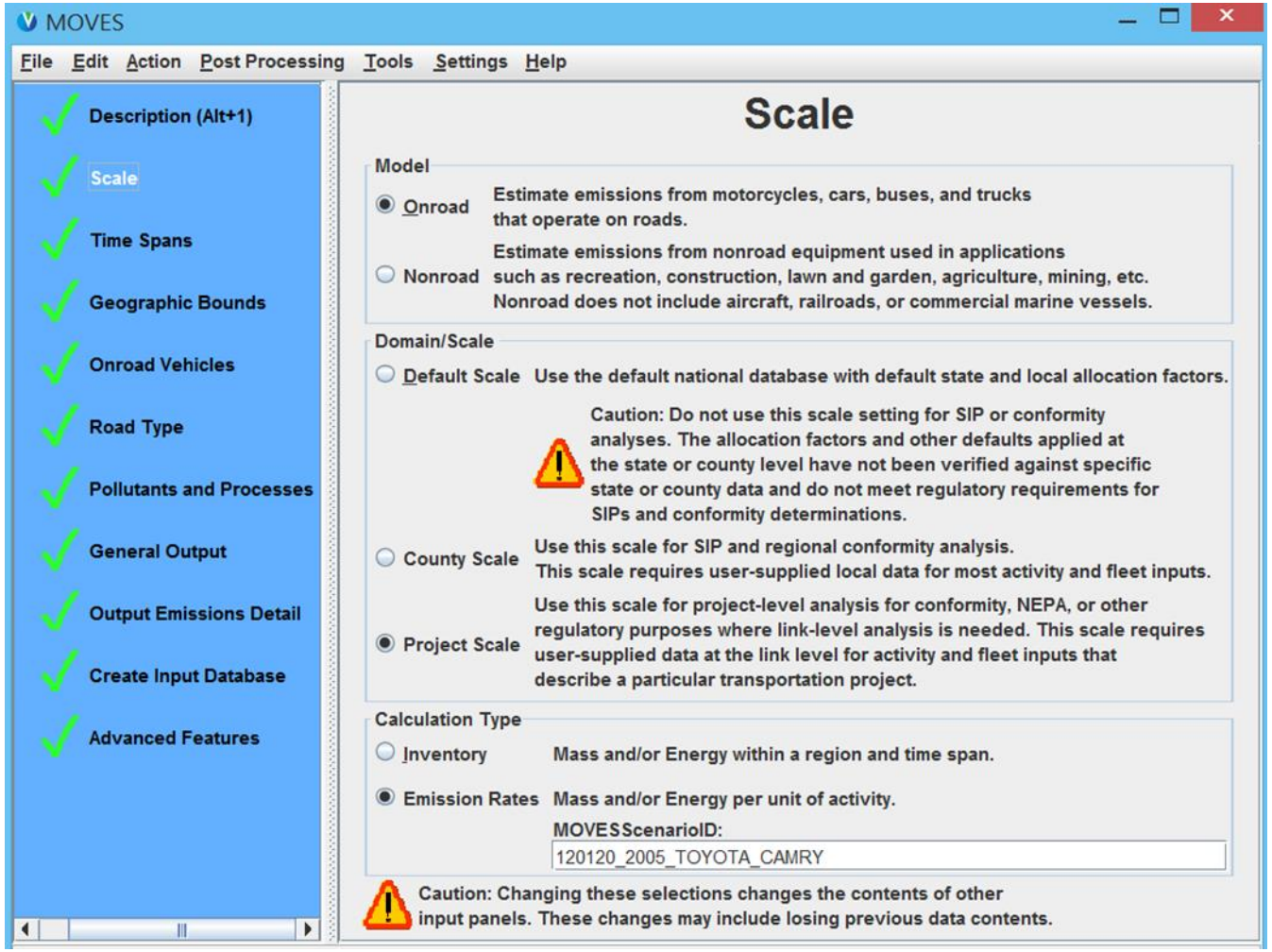
Vehicle type

Vehicle age

Vehicle activity (1Hz speed profiles and RG) by segment

Ambient condition

Fleet average segment based emission rates



Methods: Hotspots definition

Emission **hotspots** are defined as segments within the top 10% (≥ 90th 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 80th to 90th percentile).

Khan et al., 2020

Methods: Model hotspot prediction analysis

- Confusion matrix: summary of prediction results per pollutant:

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

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:

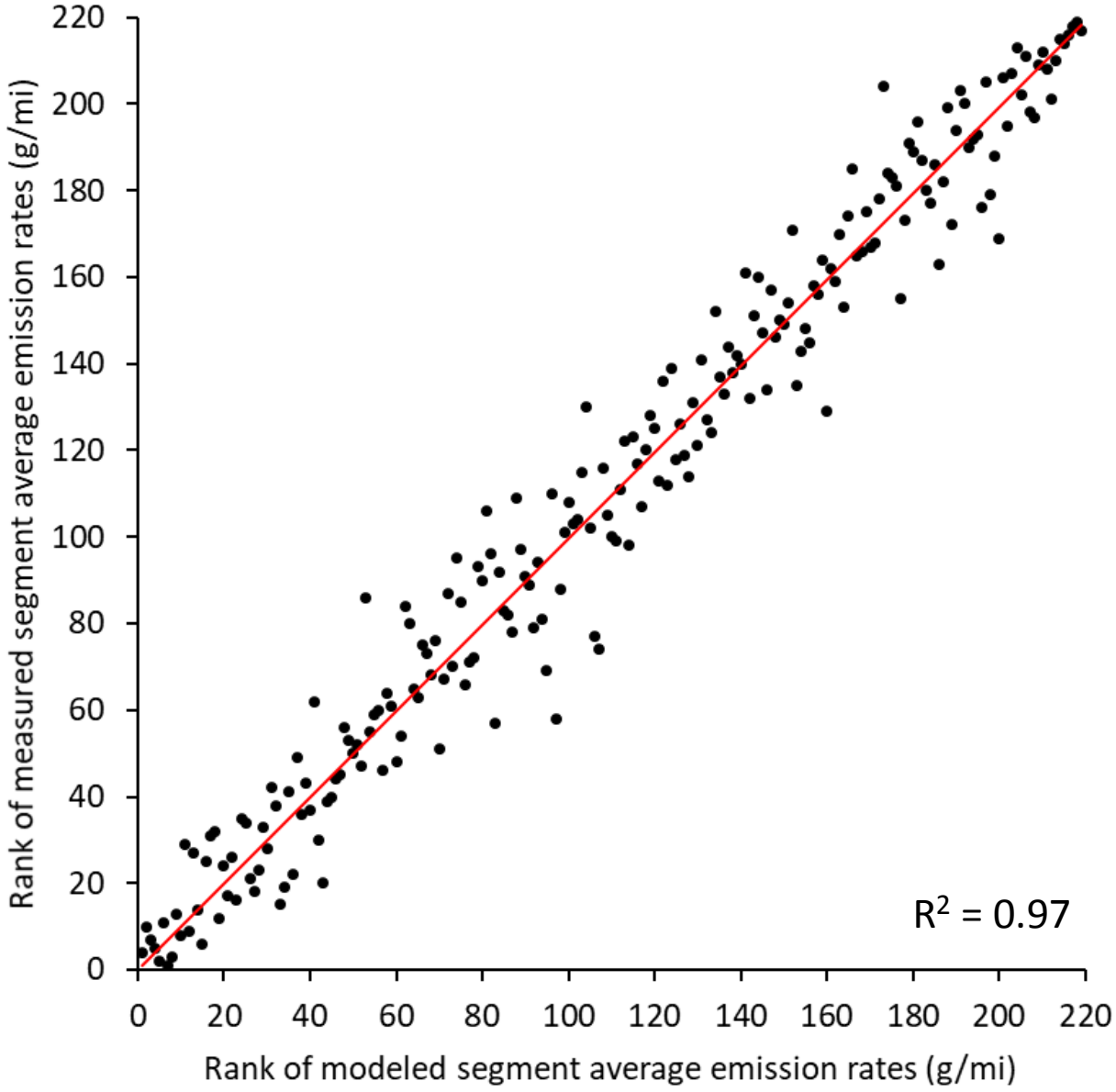
$$\text{P}\ (\%) = \left(\frac{\text{TP}}{\underbrace{\text{TP}+\text{FP}}_{\text{Model positives}}}\right) \times 100$$

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

Results: Measured vs. modeled ranked emission rates per segment

CO_2

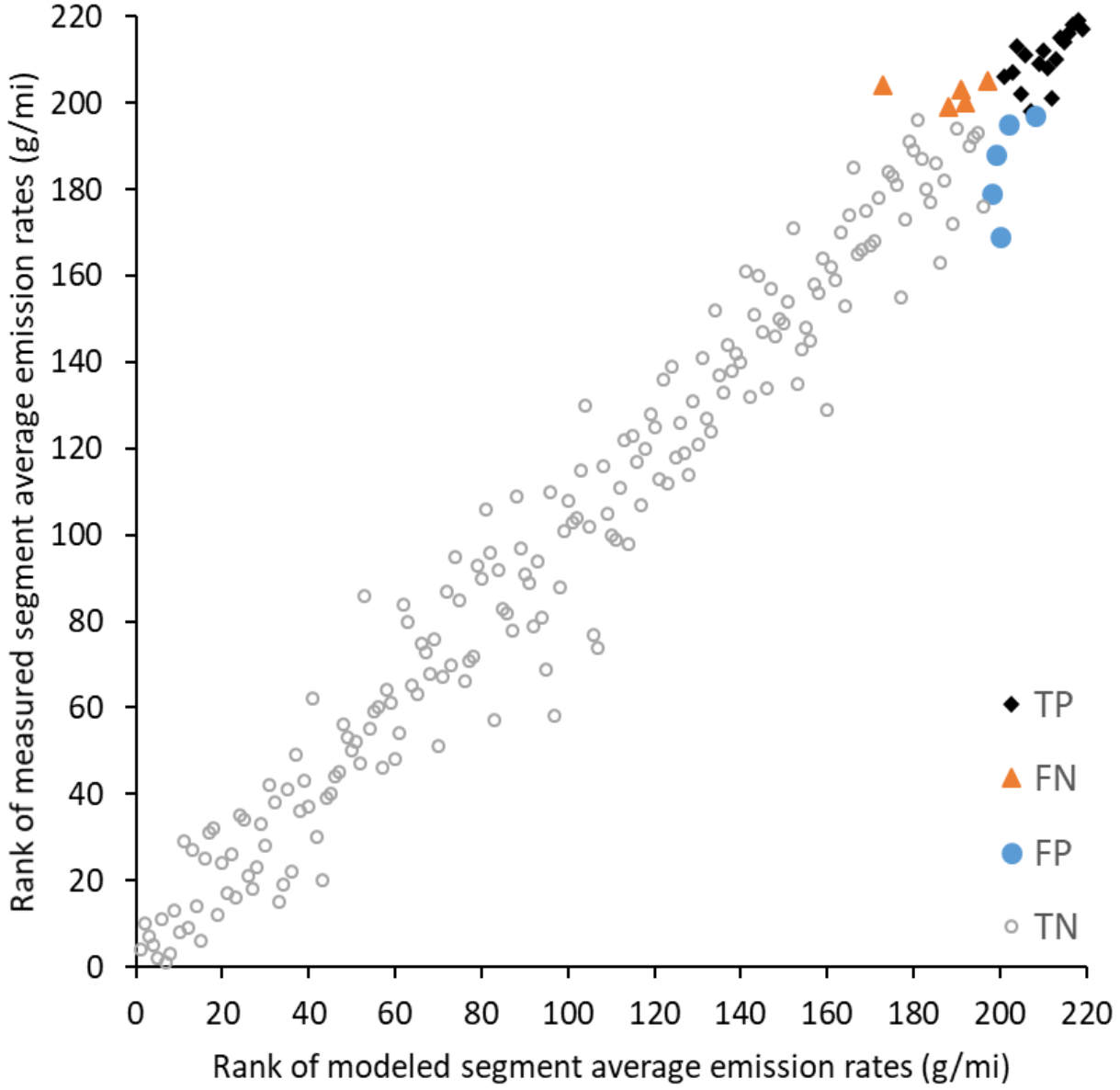
- Fleet average results based on 232 vehicles data
- Outbound routes
- 219 segments (points)



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

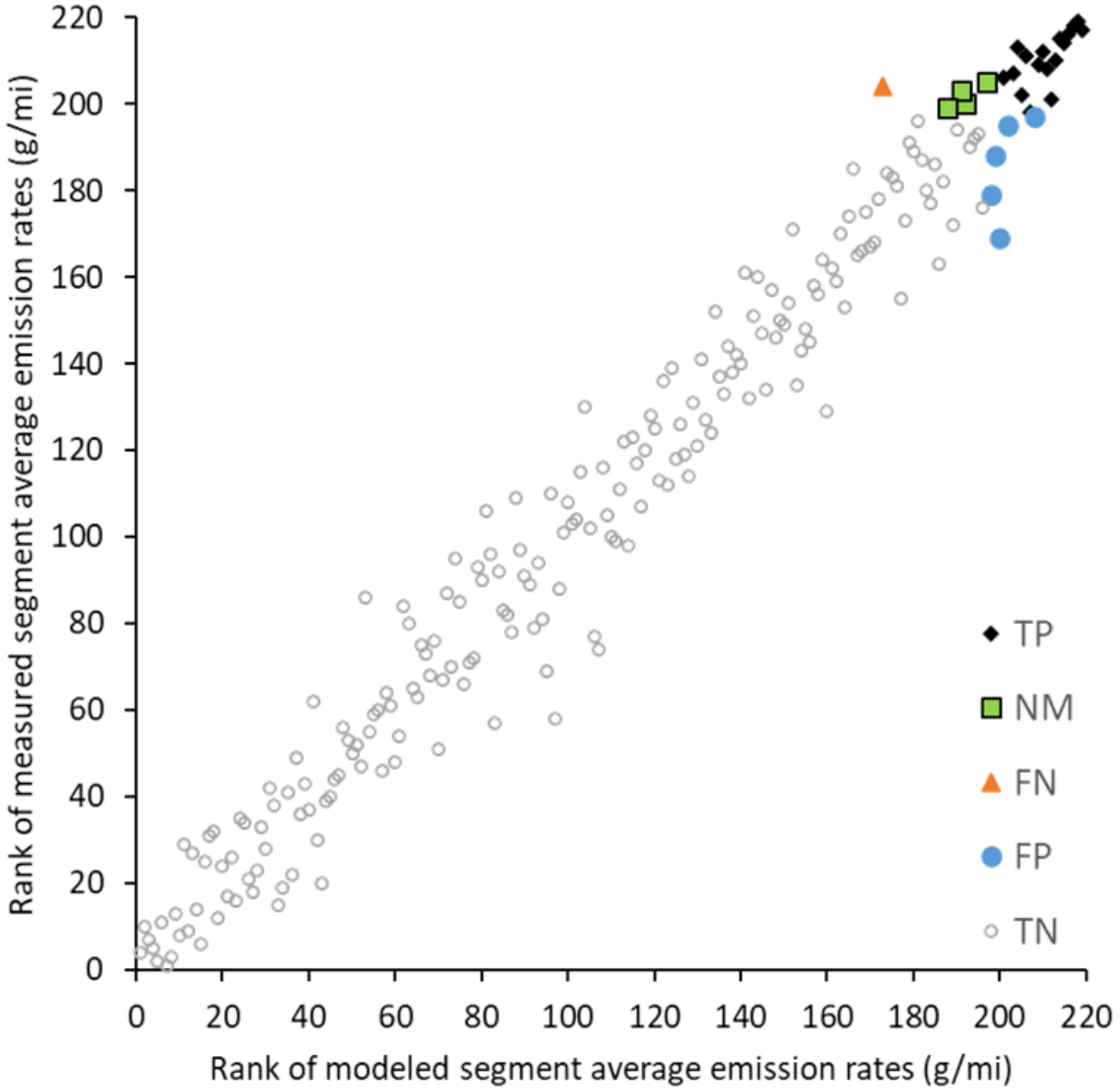
CO_2

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



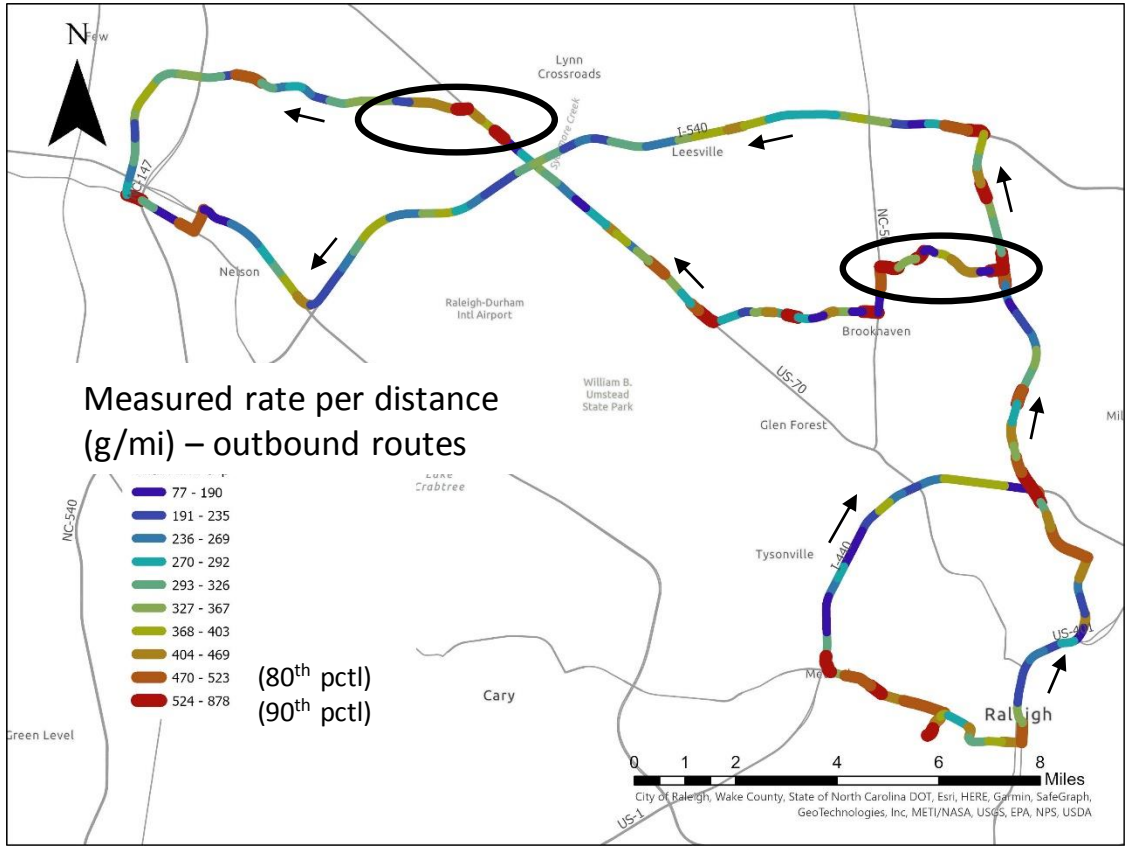
Results: Measured vs. modeled ranked emission rates per segment – Identification of hotspots and near misses CO_2

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

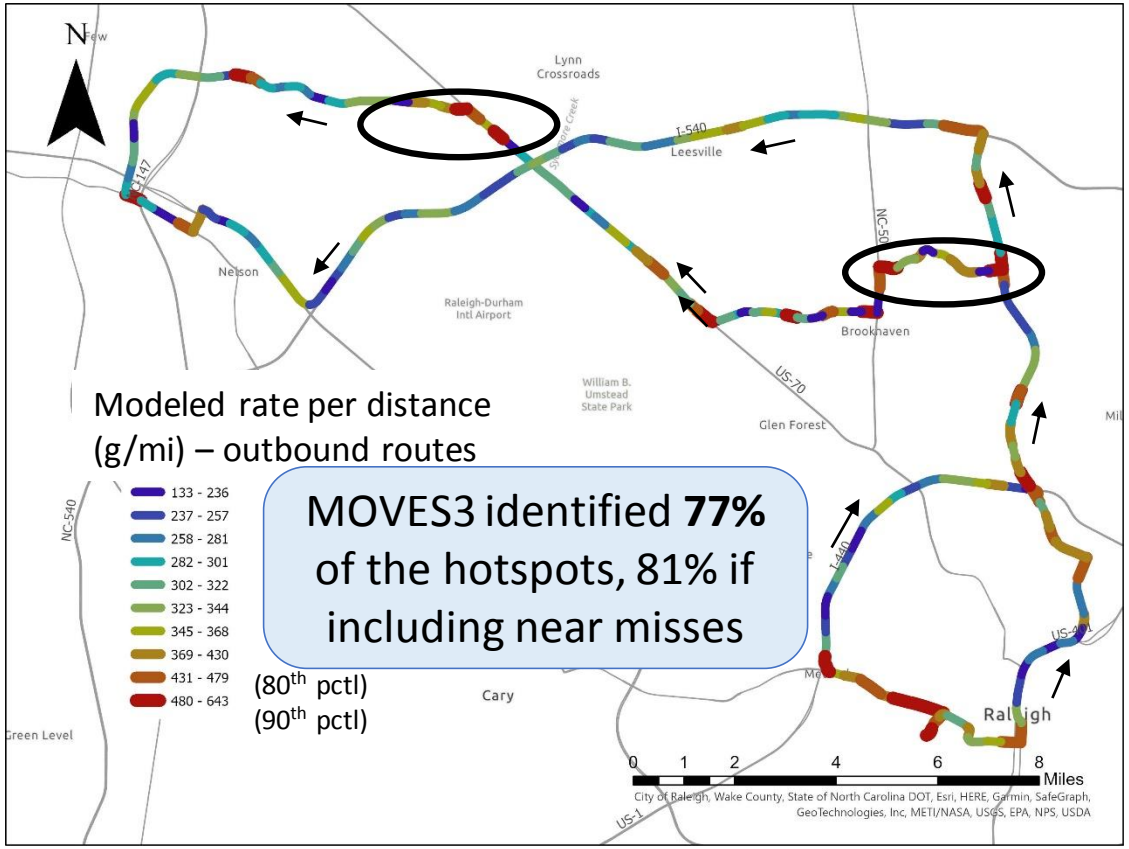


Results: MOVES3 modeled and measured emission rates per segments – average for 232 vehicles – CO_2

Measured hotspots

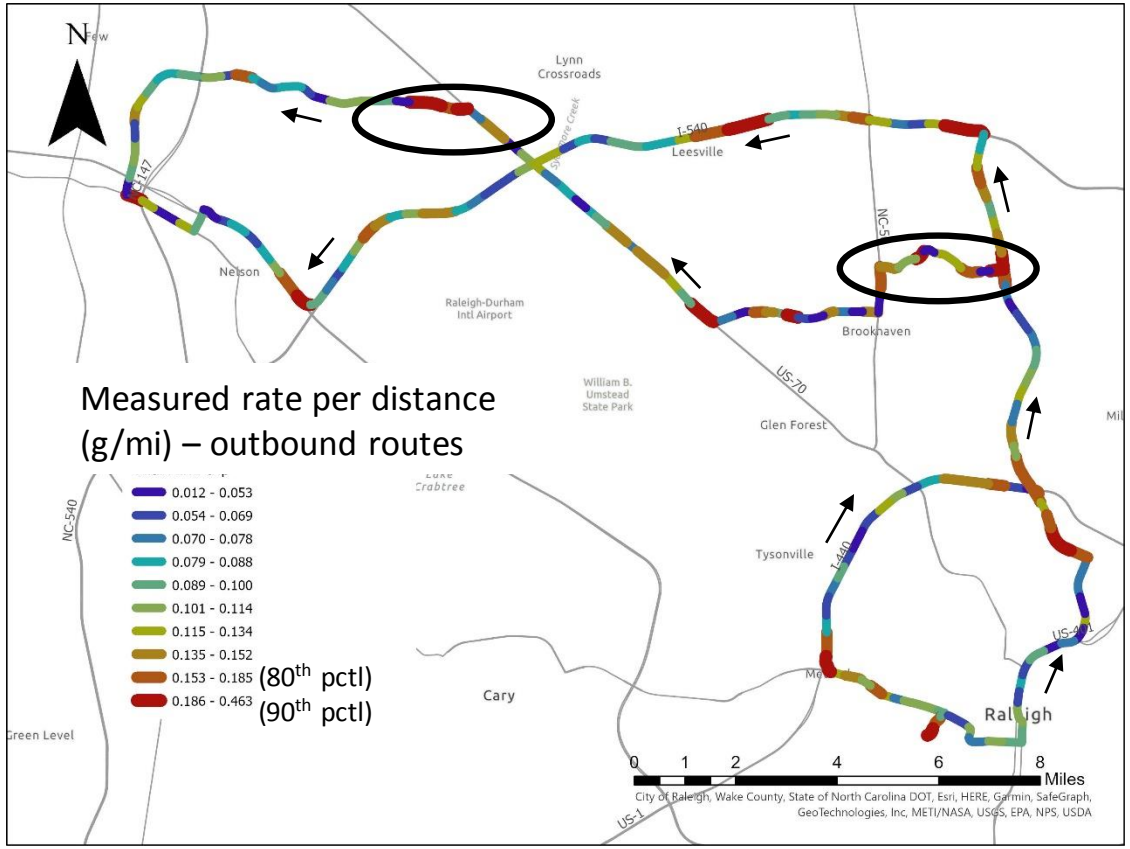


Model predicted hotspots

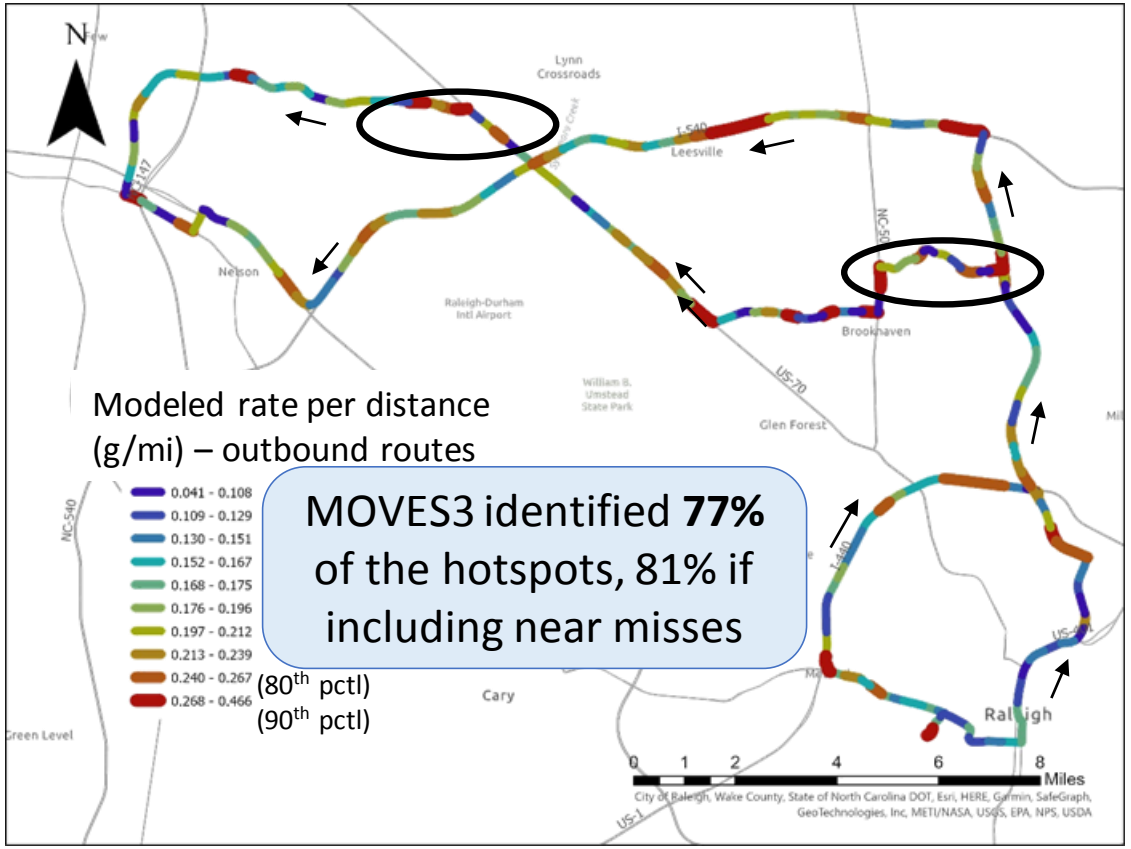


Results: MOVES3 modeled and measured emission rates per segments – average for 232 vehicles – NO_X

Measured hotspots



Model predicted hotspots



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

Accuracy and precision per pollutant

	CO_2	NO_X	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_2	NO_X	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_2 and NO_X, 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.

Thank you!

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