Real-World Evaluation of a Catalyzed GPF on Reduction of PM and Gaseous Emissions from a Light-Duty GDI Vehicle Using PEMS

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Introduction

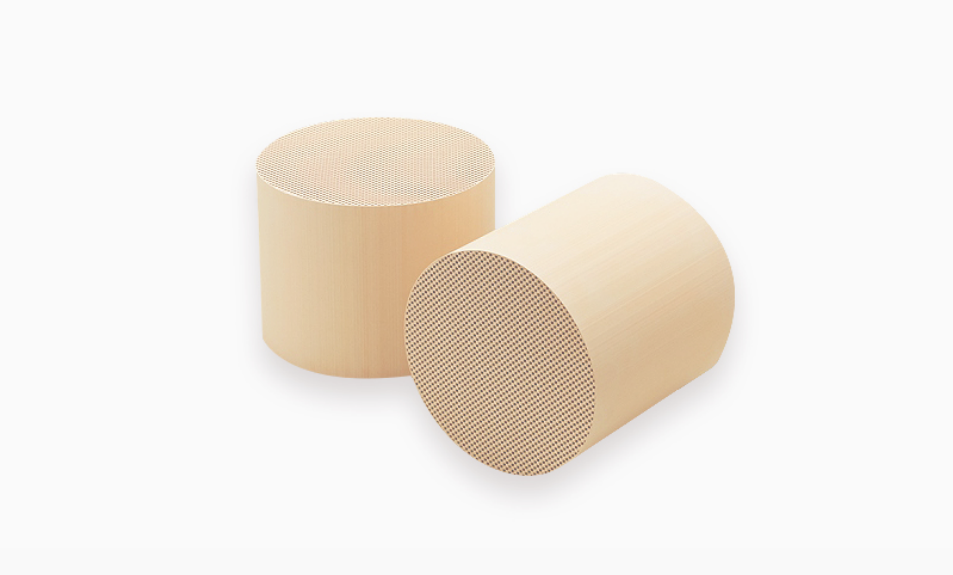
- GDI engines are gaining popularity in the automotive market
  - Better fuel economy and lower CO2 emissions
  - Higher PM and NOx emissions
- Countries are enforcing stricter PM regulations
- Much stricter emissions regulations with the LEDV III standard in US.
- Gasoline Particulate Filters (GPF) are a new promising technology that is shown to reduce PM emissions.

Background

- Dynamometer based measurements of vehicle emissions have been the standard
  - Not necessarily accurate estimate of power demands
- Concern about the actual atmospheric pollution levels of nitrogen oxides (NOx) and particulate matter (PM)
  - Even with stricter regulations
- PEMS are becoming an important regulatory tool, as evidenced by recent developments in the US and EU

Goal

- How does a catalyzed GPF affect real world driving emissions
  - Is it a cheap effective way of meeting new, stricter PM and NOx standards?
- Fuel Economy, CO2 penalty?



Test Approach

- The vehicle was triplicated in downtown Los Angeles, Mt. Baldy, I-10 Highway, and downtown San Diego.
  - Designed to be broadly different in order to differentiate vehicle operating effects on the exhaust emissions
  - Near 3 hours of drive time for each route
- Tested with the original exhaust set-up and with the retrofitted GPF

Catalyzed GPF

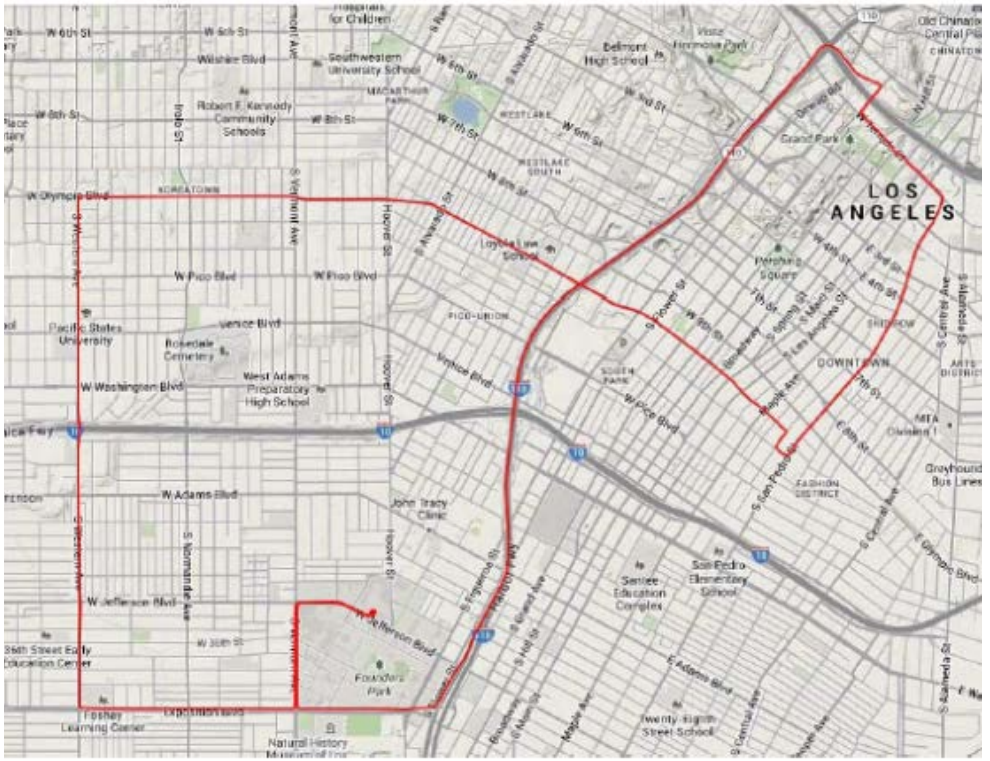
- Retrofitted with a catalyzed GPF installed in place of the underfloor TWC
- TWC washcoat with approximately 1.0 g/L loading of palladium (Pd) and rhodium (Rh)
  - Pd:Rh ratio of 4:1
  - Typical to catalysts with matching certification level
- Cell density of 300 cells per square inch (cpsi)

Vehicle Parameters

Make and Model	2017 Ford Fusion
Cylinder number	4, Inline
Displacement	1.5 L
Horsepower	181 at 6000 rpm
Torque	185 lb-ft at 4320 rpm
Compression ratio	10.0:1
Fuel Delivery	Direct Injection, Centrally-Mounted
Emissions Standards	USEPA:T3B30, CA: SULEV 30 PZEV

Downtown LA Route

- Starts and ends at USC's main campus
- Urban Driving
  - Low vehicle speed with stop and go operation
- ~16 miles (25 km)
- Average speed of 15.7 mph (25.3 km/h)

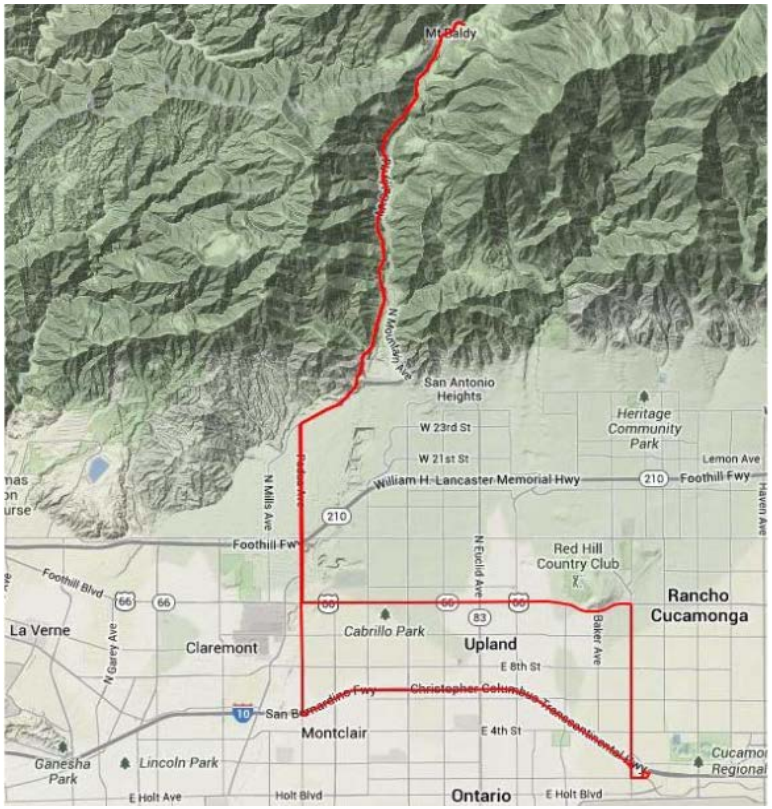


I-10 Highway Route

- Highway driving
  - High speed and stop and go patterns during rush hour
- ~43 miles (70 km) in distance
- Average vehicle speed of 48.3 mi/h (77.8 km/h).

Mt. Baldy Route

- Uphill/downhill driving
  - Steep road grades and medium to higher speeds during operation
- Average Speed of 25.1 mph (40.4 km/hr)
- ~ 44.2 miles (71.1 km)



Downtown San Diego Route

- The route starts and terminates at the harbor at sea level
- Urban Driving
  - Low vehicle speed with stop and go operation and some highway speeds
- Average Speed of

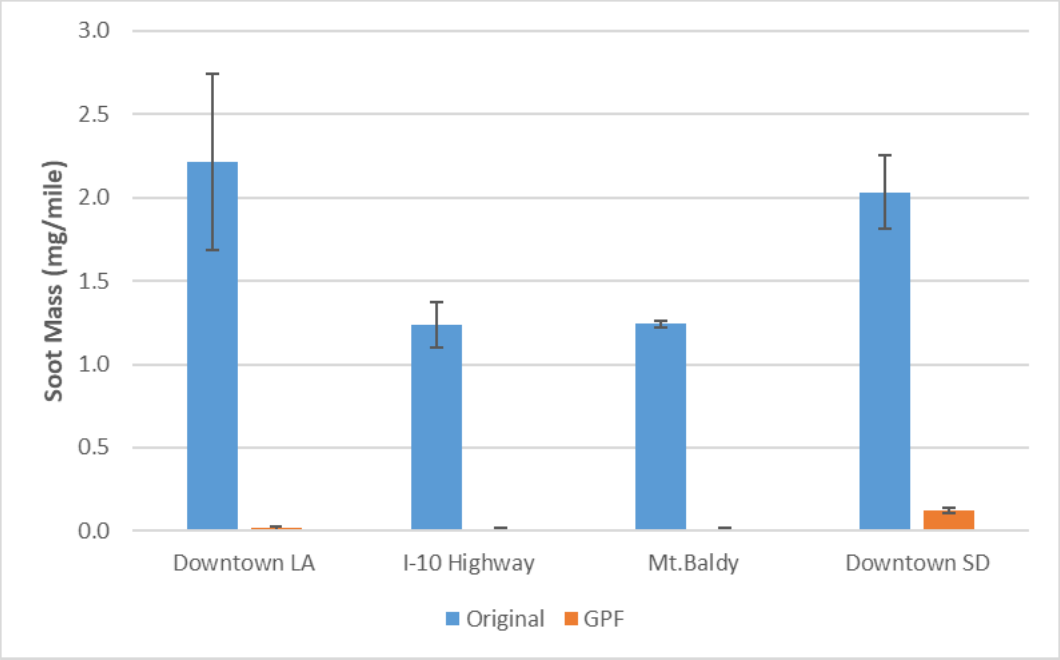
  13.1 mph (21 km/h)
- ~13 miles (21 km)

Instruments

- AVL Move 493 Gas PEMs
  - NDIR for CO/CO2
  - UV for NO/NO2
  - FID for THC
- AVL MSS 483
  - Photoacoustic measurement
- UCR Filter Box and pump
  - Teflon Filter
  - Gravimetric Analysis
- Semtech 2.5” EFM

Soot Mass Reduced Over 90%

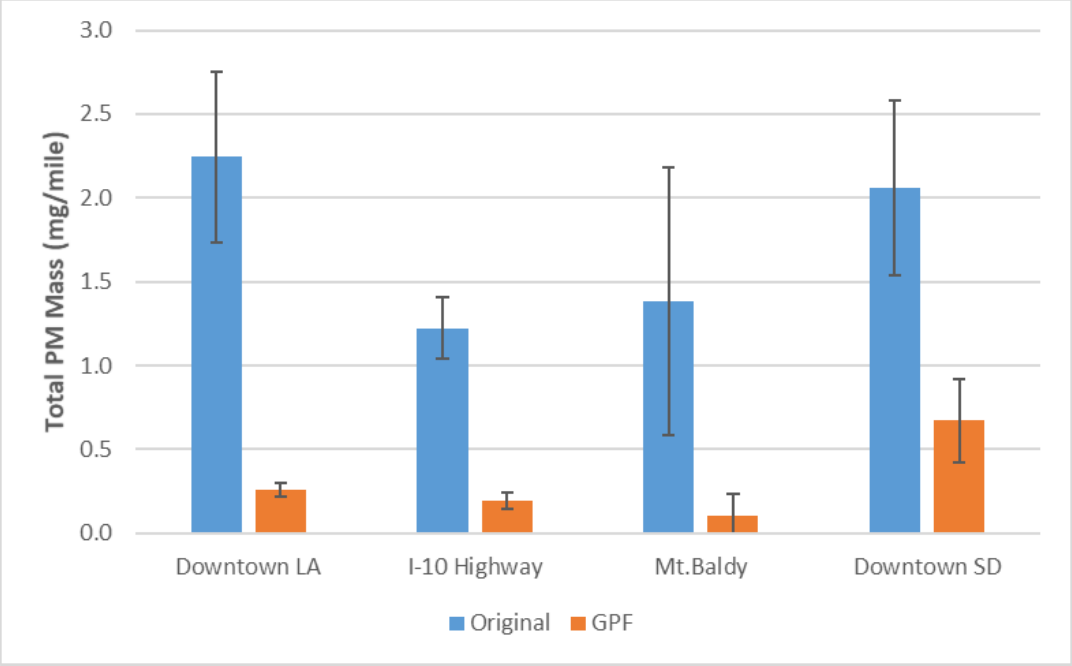
- Significant reduction in soot mass when using a catalyzed GPF



Soot Mass	LA	I-10 Highway	Mt. Baldy	SD
% Difference	-99.30	-99.13	-99.19	-93.90

PM Mass Reduced over 65%

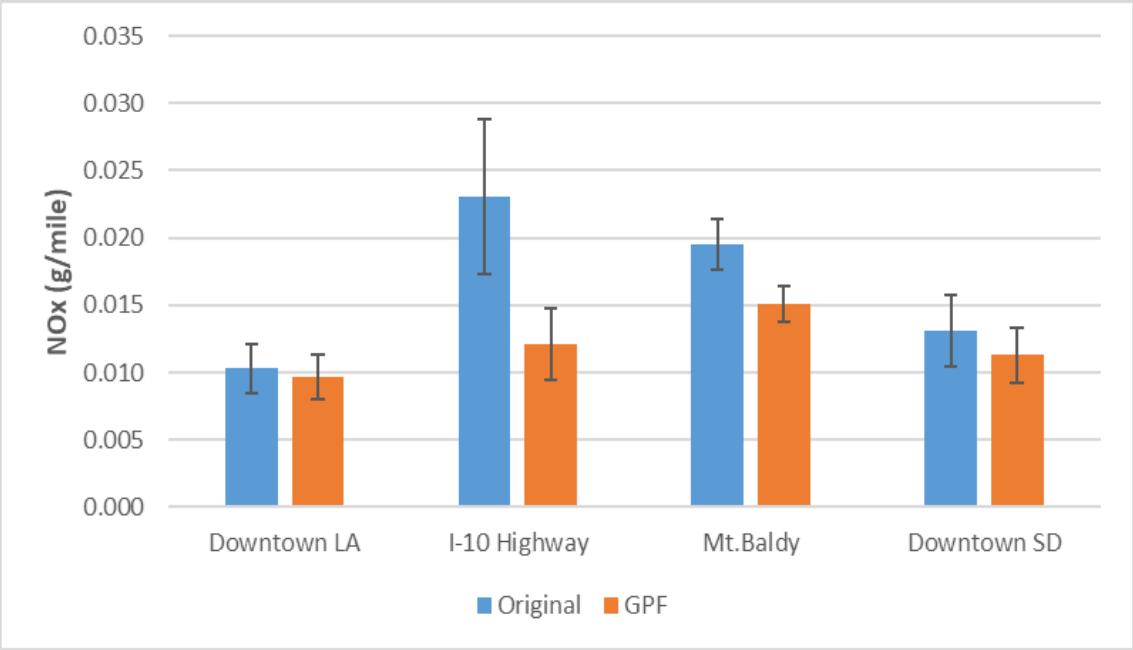
- Substantial decrease in PM mass
- All routes showed PM well below 1mg/mi



PM Mass	LA	I-10 Highway	Mt. Baldy	SD
% Difference	-88.55	-84.15	-92.27	-67.32

NOx Reduction

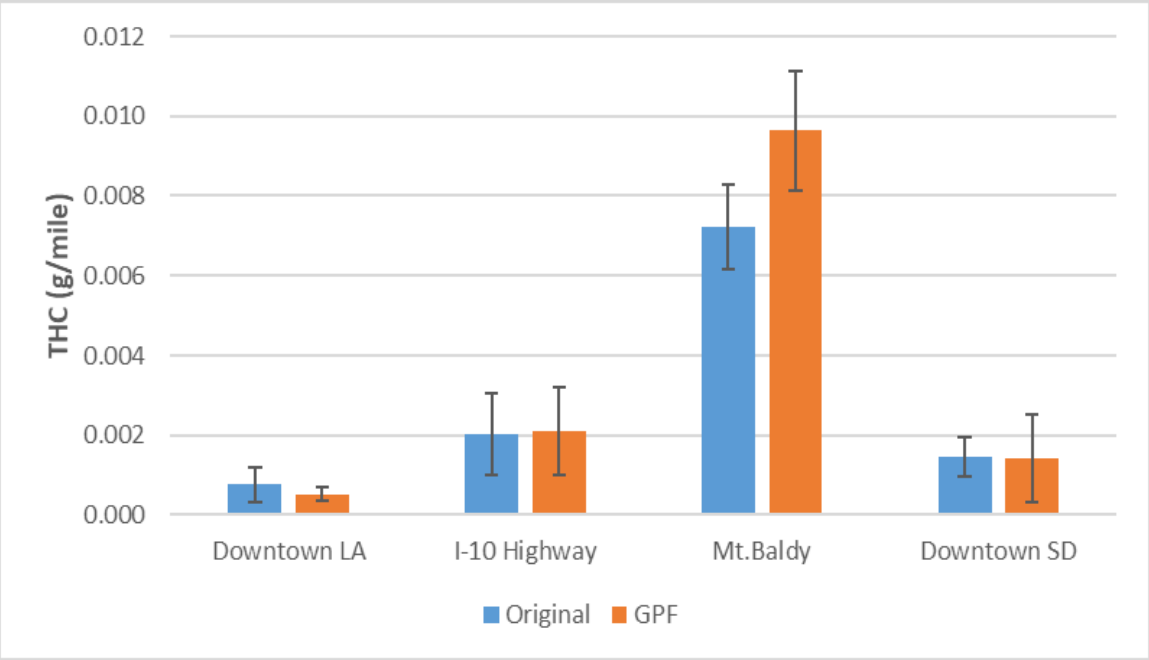
- Decreasing trend in NOx emissions
- Significant reductions for highway and mountain



NOx	LA	I-10 Highway	Mt. Baldy	SD
% Difference	-6.18	-47.41	-22.60	-14.12

No Change in THC

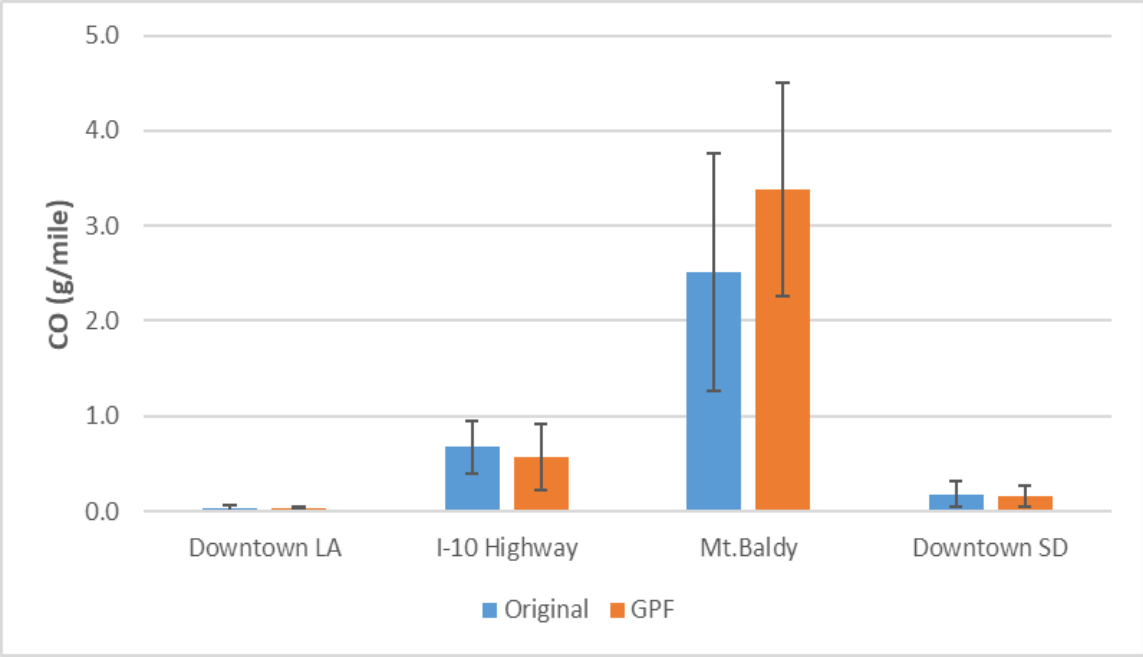
- No statistically significant changes in THC



THC	LA	I-10 Highway	Mt. Baldy	SD
% Difference	-31.17	3.48	33.77	-2.36

No Change in CO

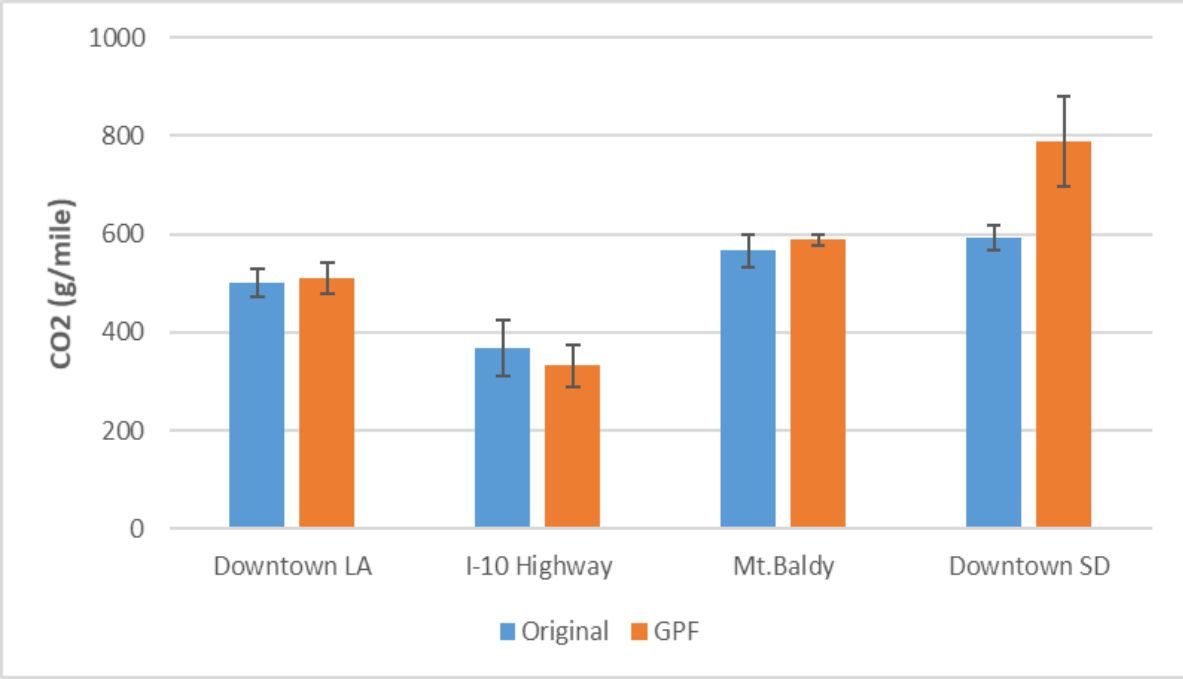
- No statistically significant difference for any of the routes
- Similar trend to THC emissions



CO	LA	I-10 Highway	Mt. Baldy	SD
% Difference	24.52	-15.21	35.13	-13.02

CO2 Penalty

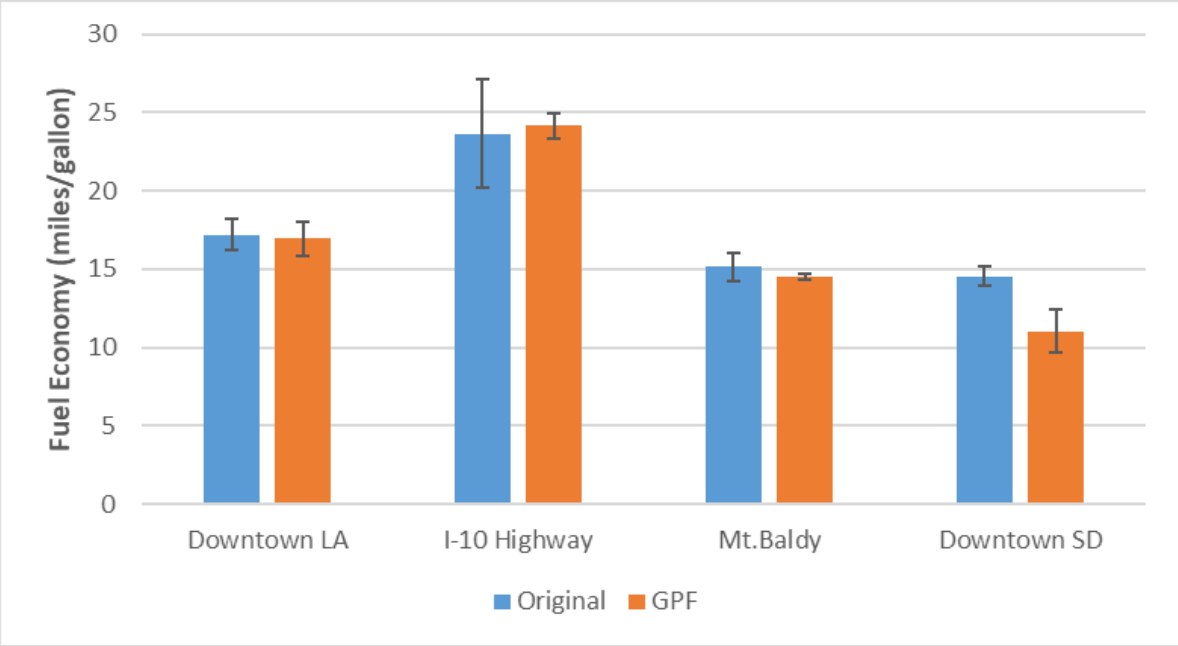
- Small statistically significant penalty on CO2 emissions for SD route



CO2	LA	I-10 Highway	Mt. Baldy	SD
% Difference	1.46	-10.01	3.91	33.29

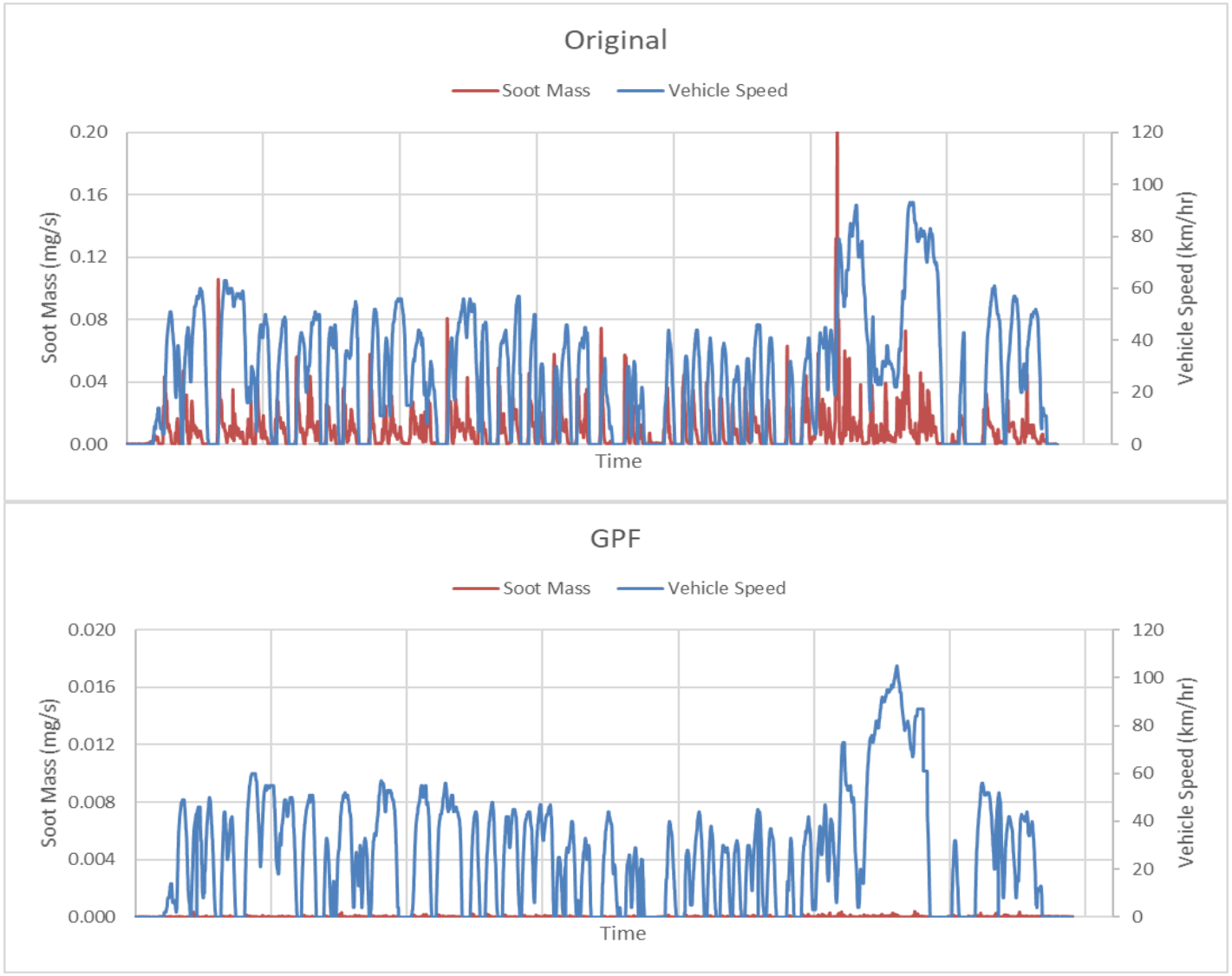
Fuel Economy Penalty

- Small penalty for SD route
- Calculated using a carbon balance

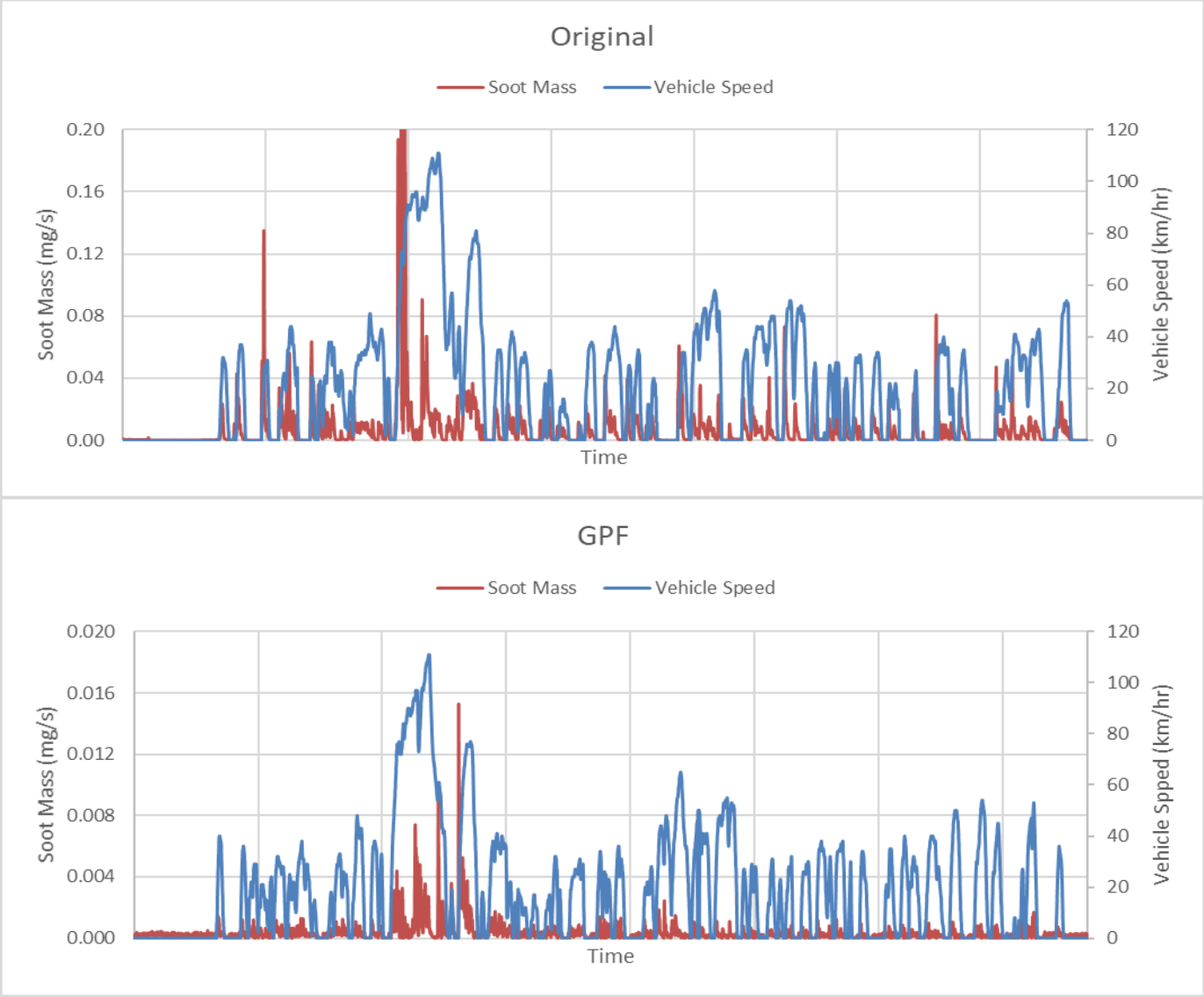


Fuel Economy	LA	I-10 Highway	Mt. Baldy	SD
% Difference	-1.40	2.27	-4.18	-24.32

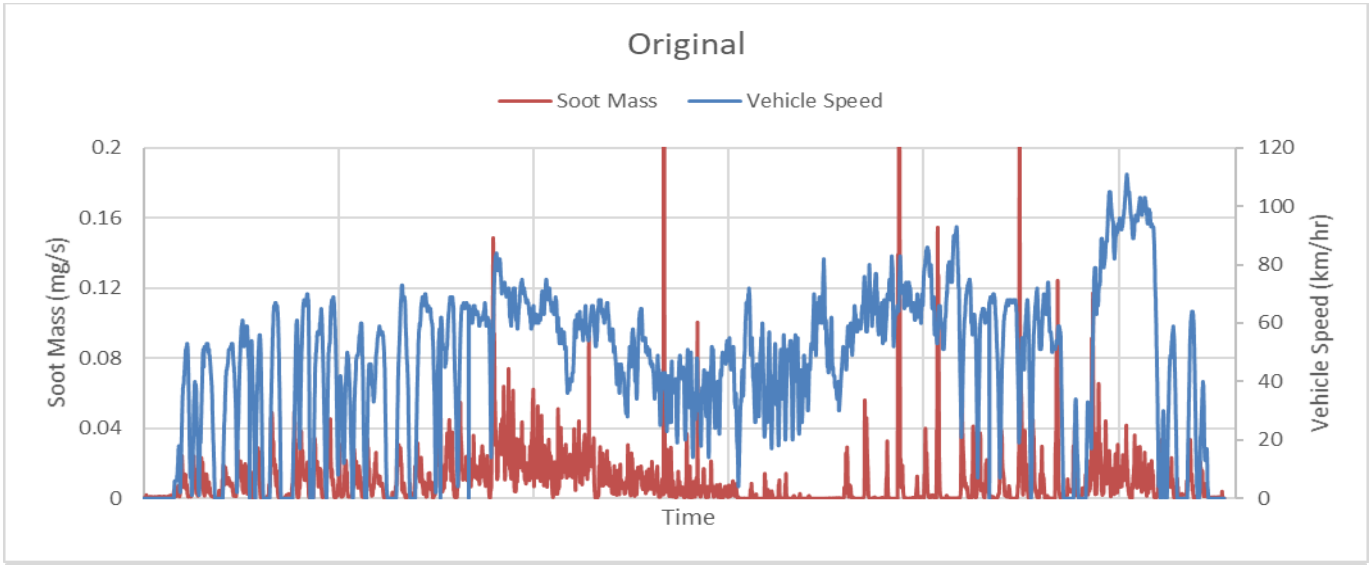
Los Angeles Real Time Soot

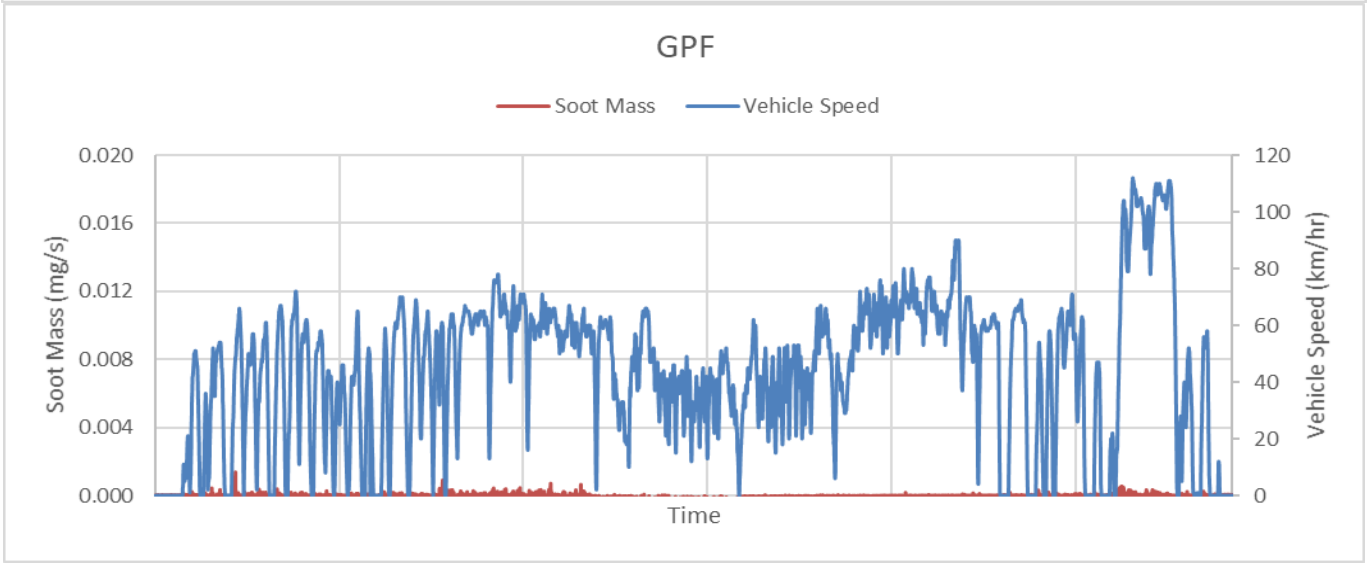


San Diego Real Time Soot

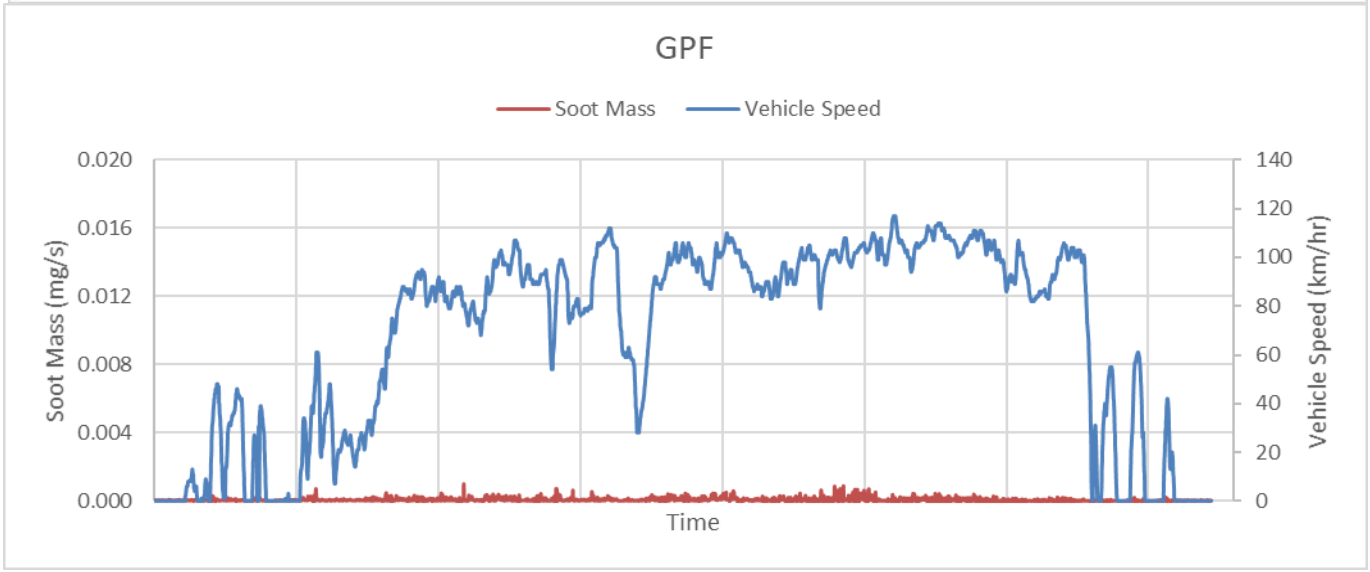


Mt. Baldy Real Time Soot





Highway Real Time Soot



Summary

- Very useful in decreasing PM and soot in any driving condition.
- Decreasing trend in NOx emissions
- Concern of an increased pressure drop effecting fuel economy and CO2 can be mitigated
- Feasible to apply catalyzed GPF to meet the most stringent US emission regulations

Future Work

- Characterize the differences in the San Diego route
  - Humidity, ambient weather and conditions
  - Tougher driving cycle
  - Near the port
  - Outliers
- Differentiate between driving conditions during routes
- PN emissions

Acknowledgements

- Manufacturers of Emissions Controls Association (MECA)
- Air Quality Management District (AQMD)