Cold Temperature Effects on Speciated MSAT Emissions from Three Modern GDI Light-Duty Vehicles

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U. S. EPA Office of Research and Development

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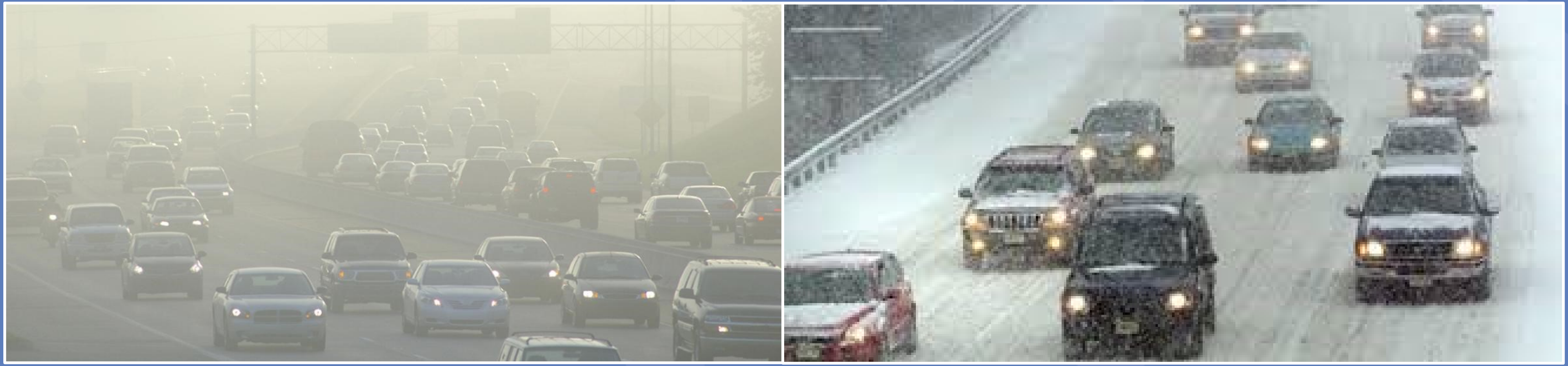
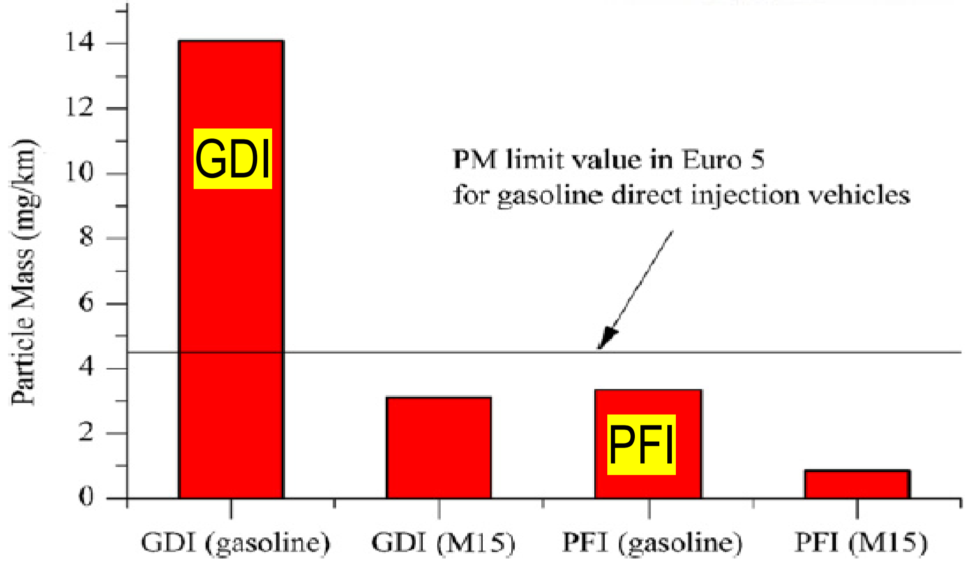


Office of Research and Development
National Risk Management Research Laboratory

Study Background

- Gasoline direct injection (GDI) engines were introduced into the market in 2007 and their market share has rapidly increased to 52% of MY2017 light-duty (LD) vehicles[1]
- Emissions studies of GDI vehicles have mostly focused on particles; few studies have measured speciated mobile source air toxics (MSATs)
- Effect of different GDI technologies and cold temperature on speciated MSATs in LD vehicle emissions are not well known



Liang et al., 2013

[1]https://www.epa.gov/fuel-economy/trends-report

PFI=port fuel injection

United States Environmental Protection Agency

Test Conditions

Objective: To characterize speciated volatile and semivolatile organic emissions from LD GDI vehicle exhaust at warm and cold temperatures

Fuel: E10 gasoline from pump (summer and winter grades)

Temperature: 72 ° F (22 ° C), 20 ° F (-7 ° C)

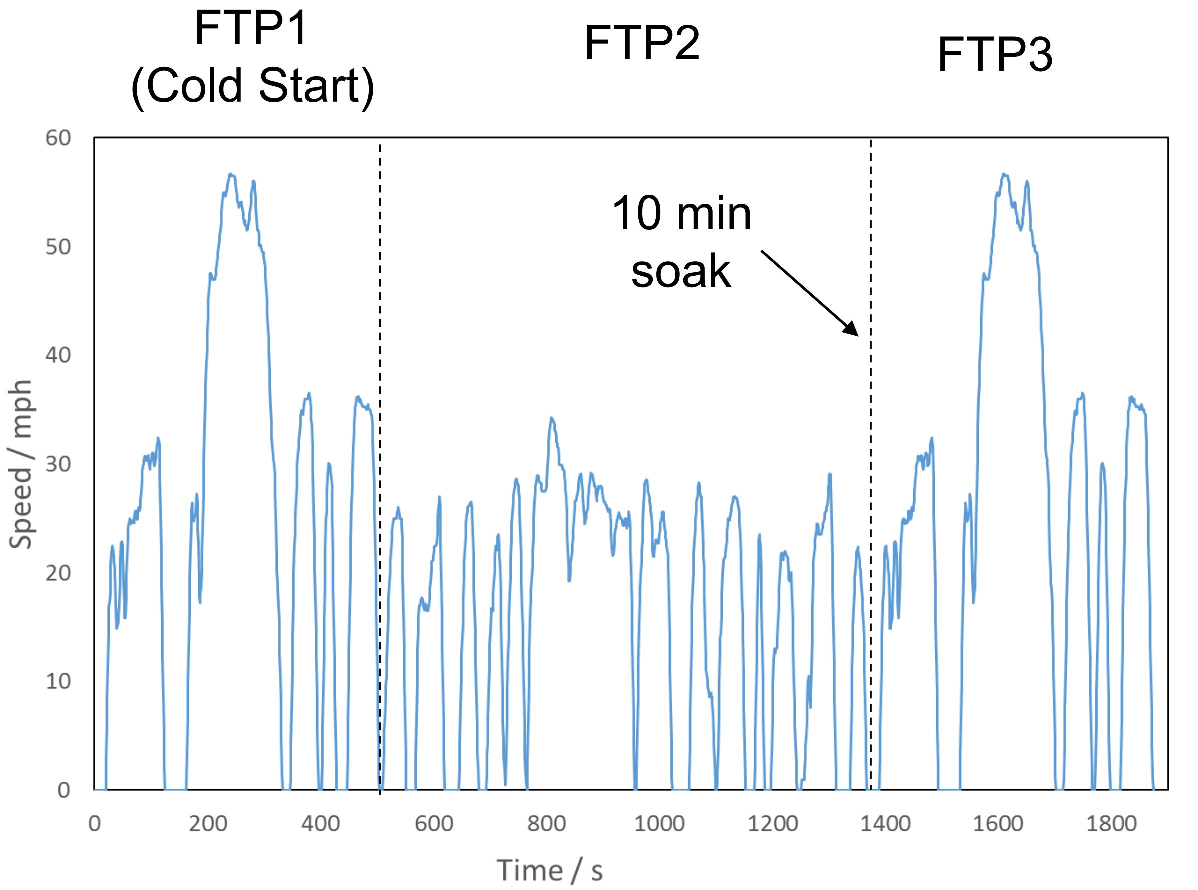
Dynamometer: 48 in. roll, max 12,000 lbs, -30 to 43 ° C

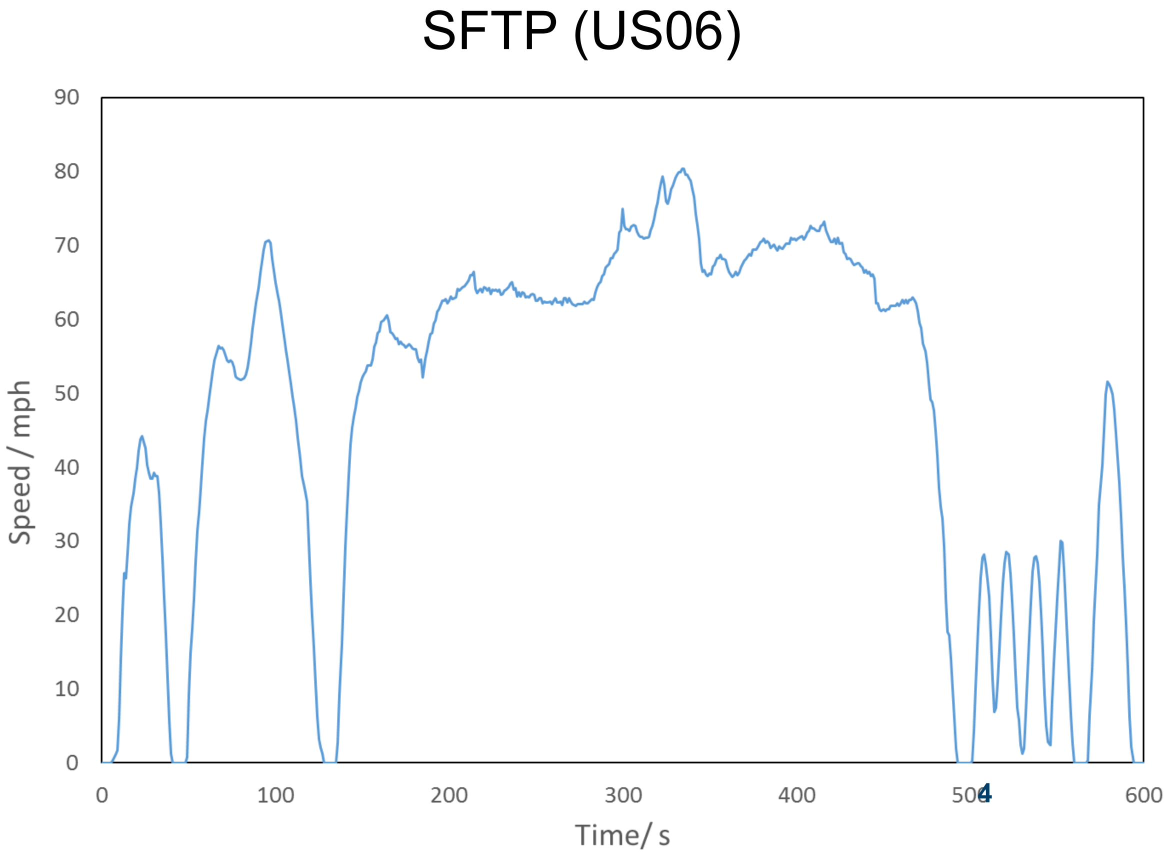
GDI Vehicles (Tier 2 Bin 5, MY 2014-2015):

- V1) ODO=12,700 miles, 2.4 liter, naturally aspirated, wall-guided
- V2) ODO=10,500 miles, 1.5 liter, spray-guided, turbocharged
- V3) ODO=9,200 miles, 1.8 liter, wall and air guided, turbocharged

Driving Cycle

Vehicles were tested over cold start EPA Federal Test Procedure (FTP) to simulate city driving followed by part of the supplementary FTP (US06) to simulate aggressive driving.





Dilution Tunnel and Sampling

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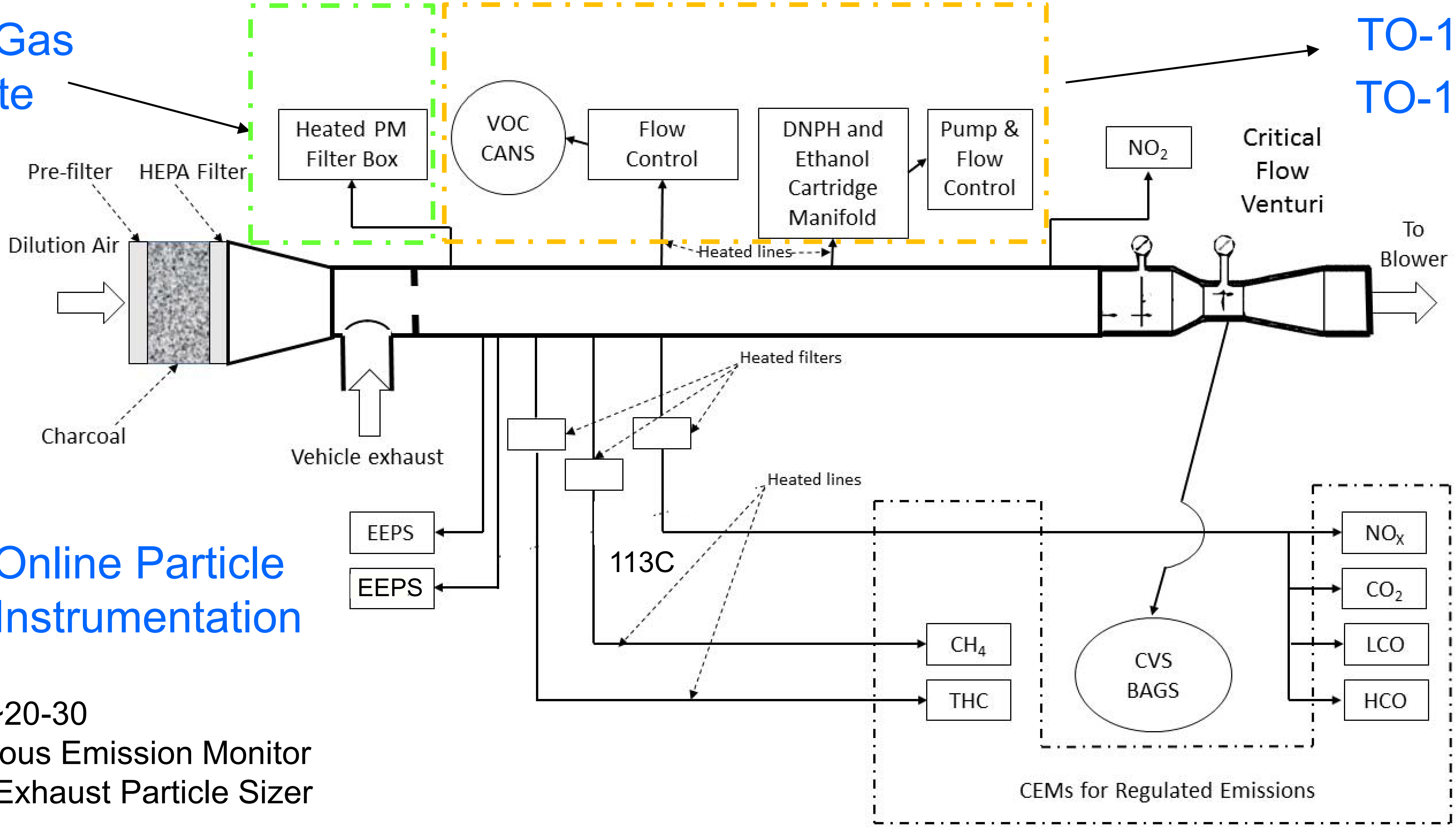
Speciated Gas & Particulate SVOCs (GC/MS)



VOC Analysis

TO-15 (GC-MS)

TO-11A (HPLC)

Online Particle Instrumentation

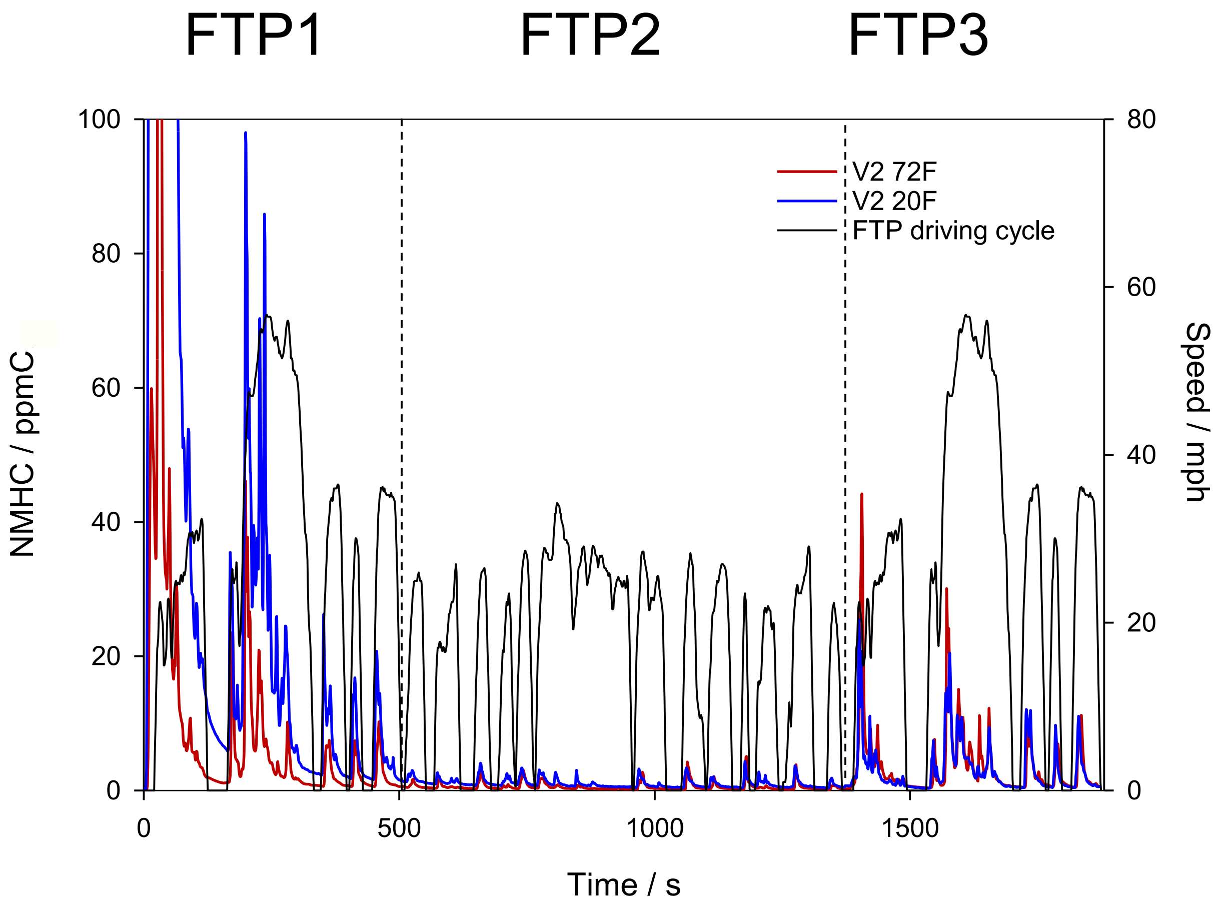
CEMs

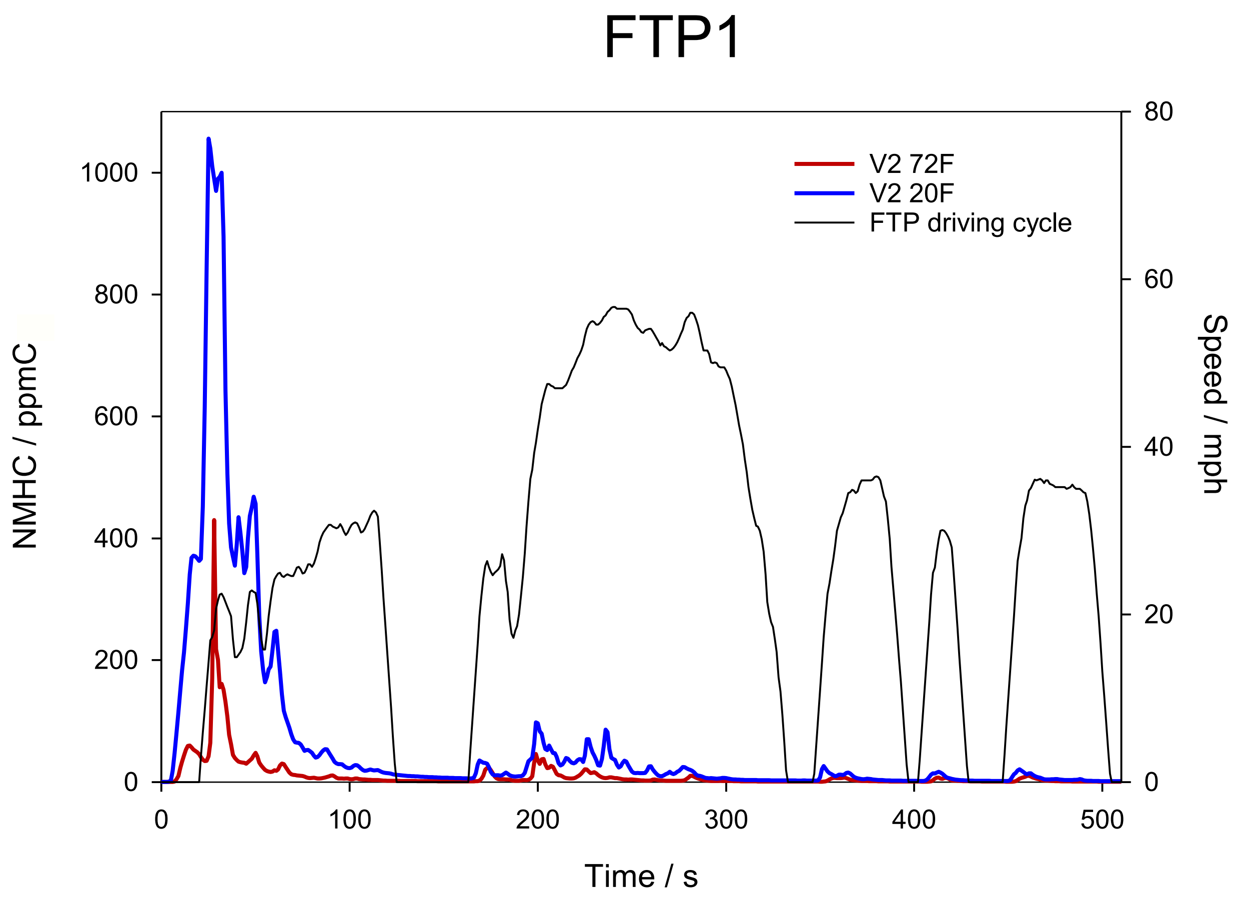
Dilution factor ~20-30

CEM = Continuous Emission Monitor

EEPS=Engine Exhaust Particle Sizer

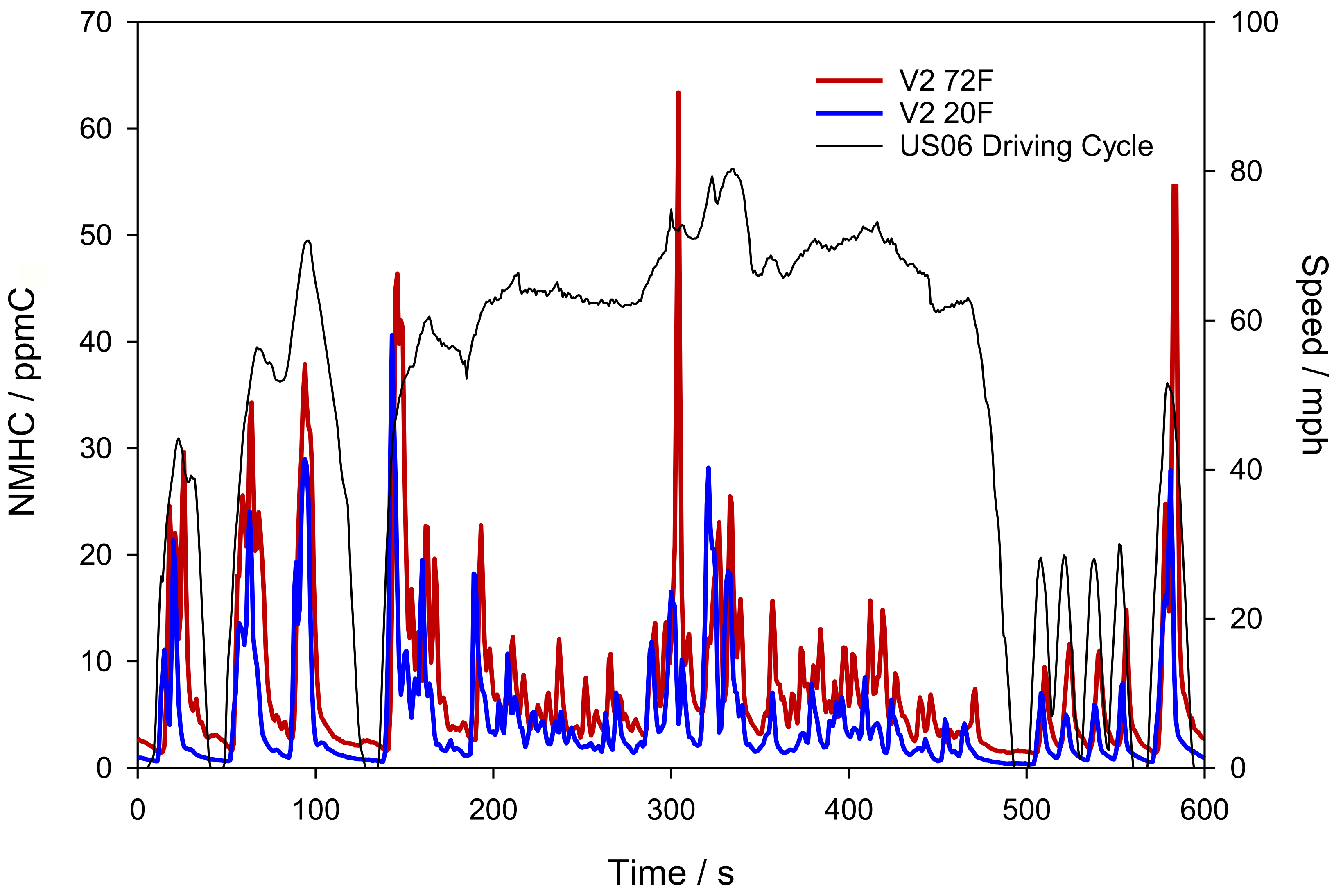
NMHC Traces - FTP





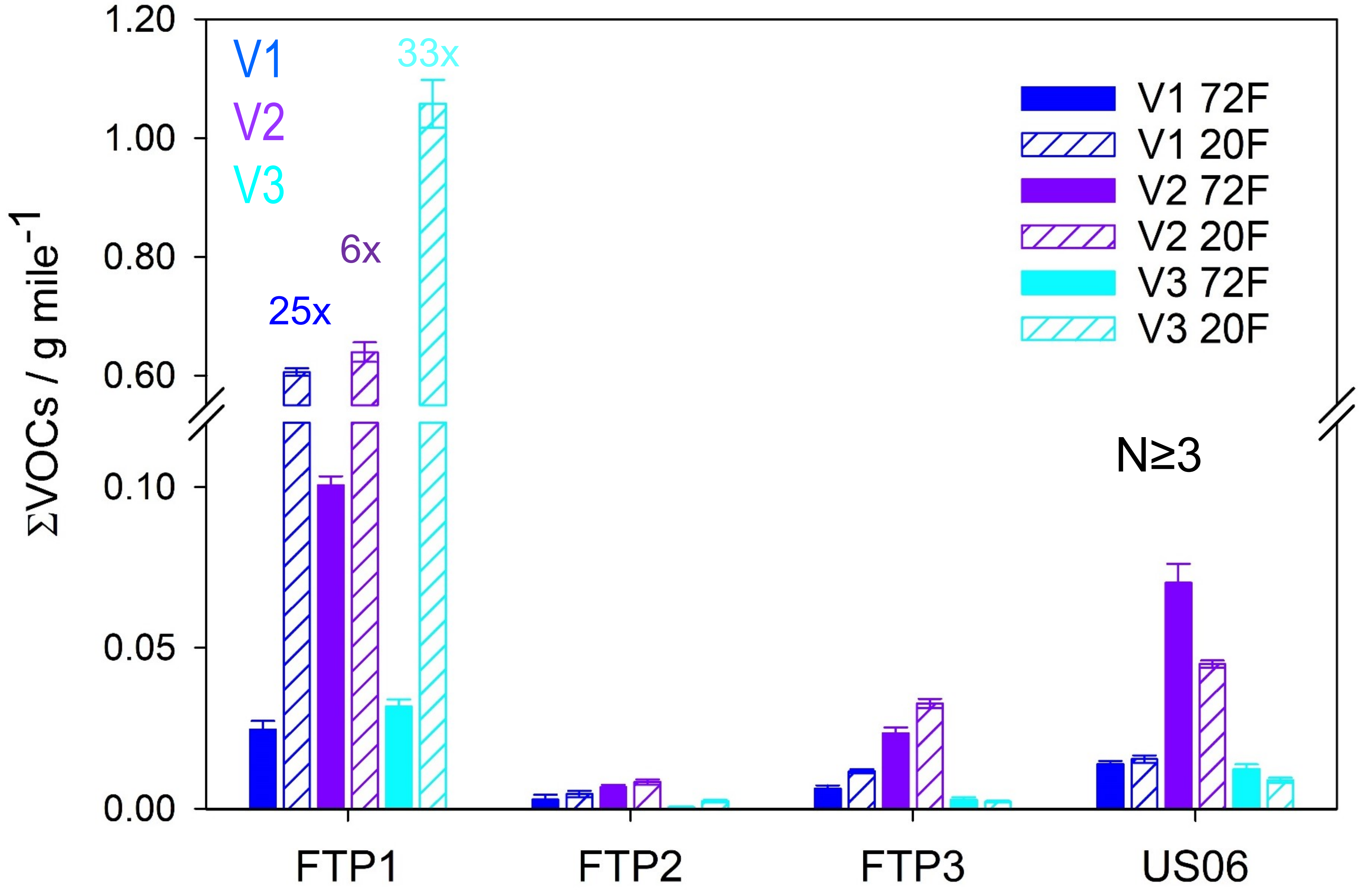
NMHC=non-methane hydrocarbon

NMHC Traces – US06



US06 characterized by multiple spikes in NHMC emissions coinciding with heavy accelerations during the driving cycle

Total Speciated VOC Emissions

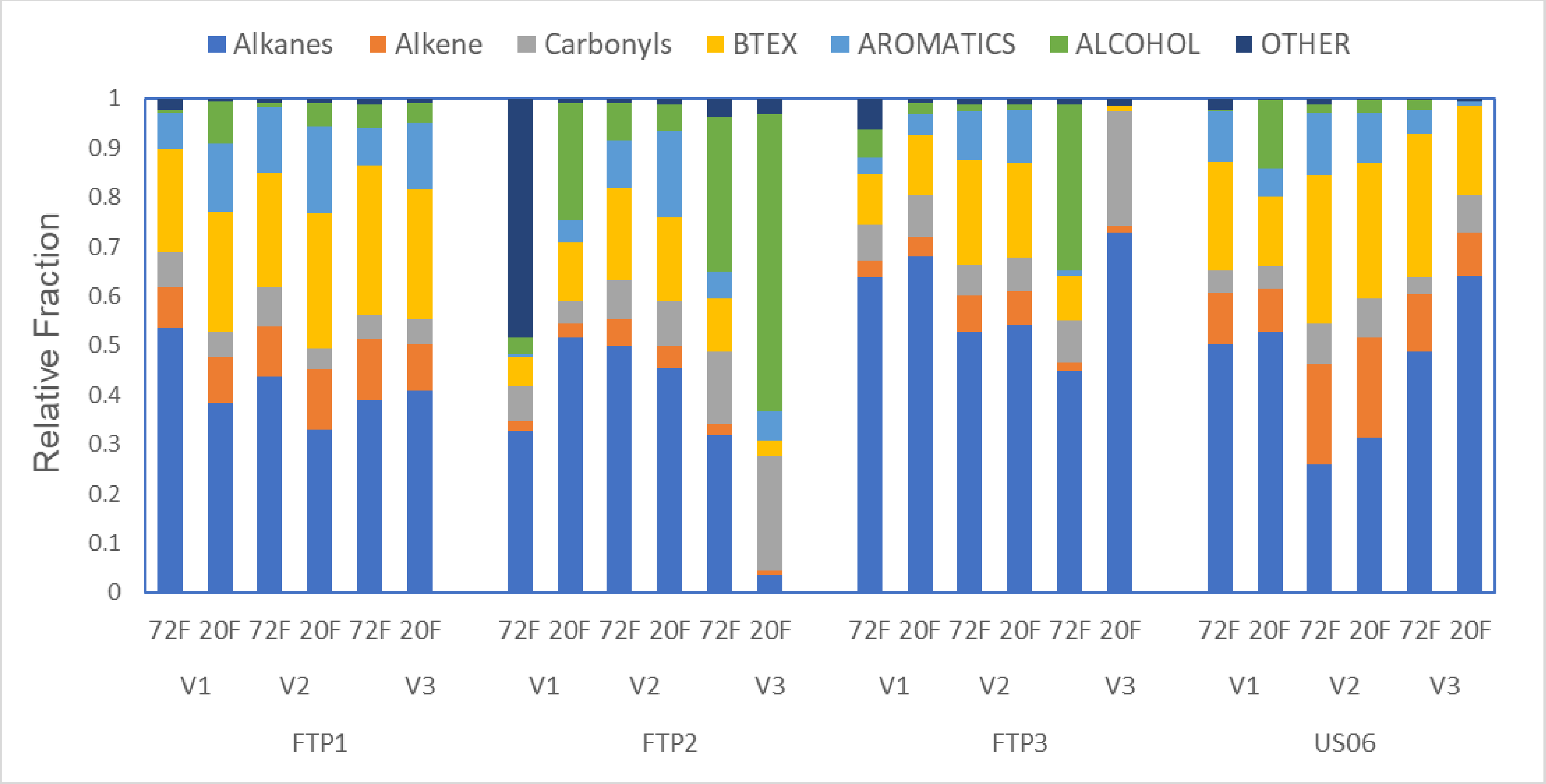


Cold temp effect was most prominent during cold start and varied by vehicle

Cold start emissions were substantially higher (4-500x) than warm start

V2 emissions were in mostly higher than V1, V3

VOC Composition by Condition



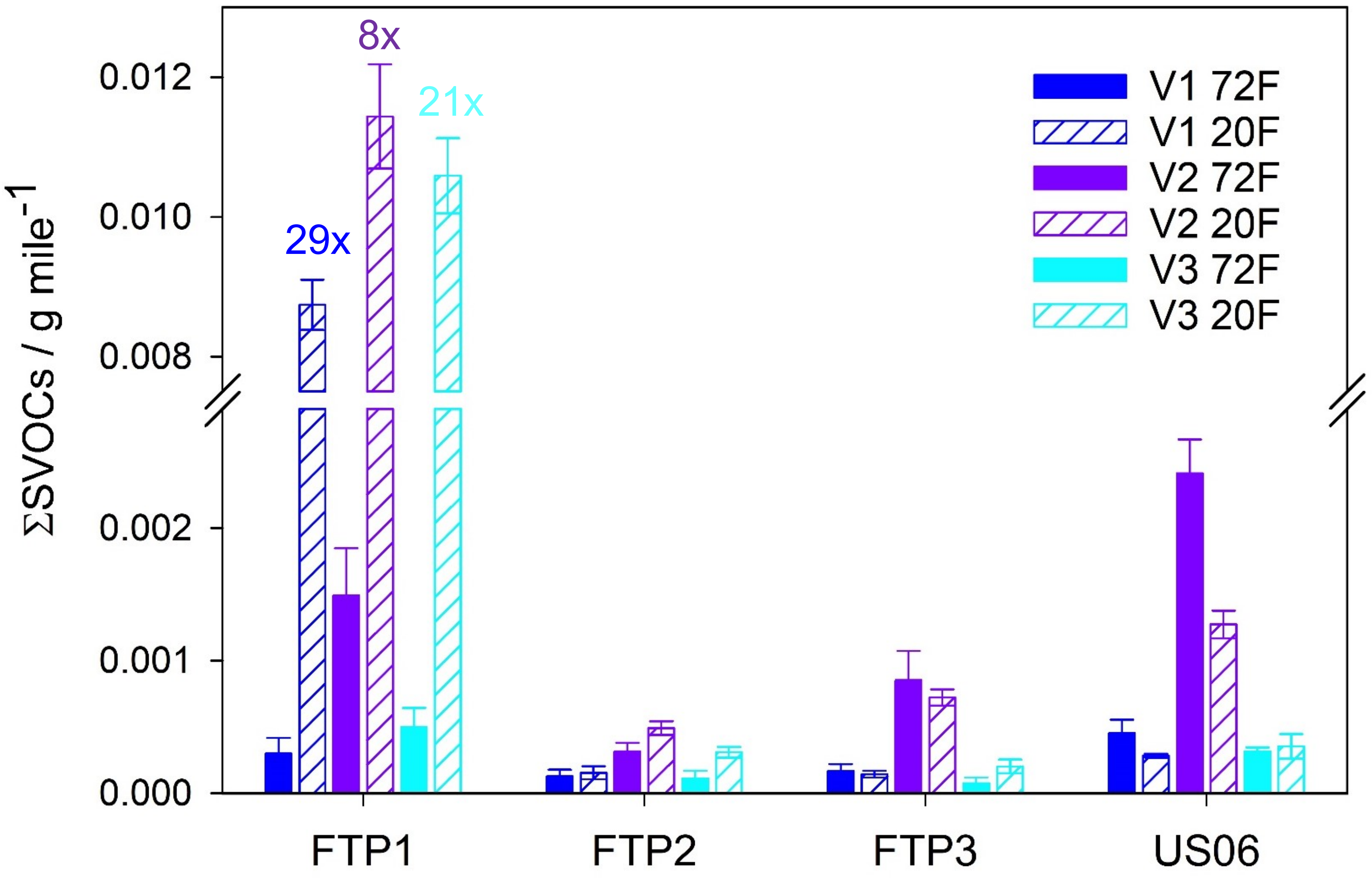
FTP1: Cold temp increases aromatic fraction

FTP3: Alkanes become more dominant

US06: VOC composition varies by vehicle

EPA United States Environmental Protection Agency

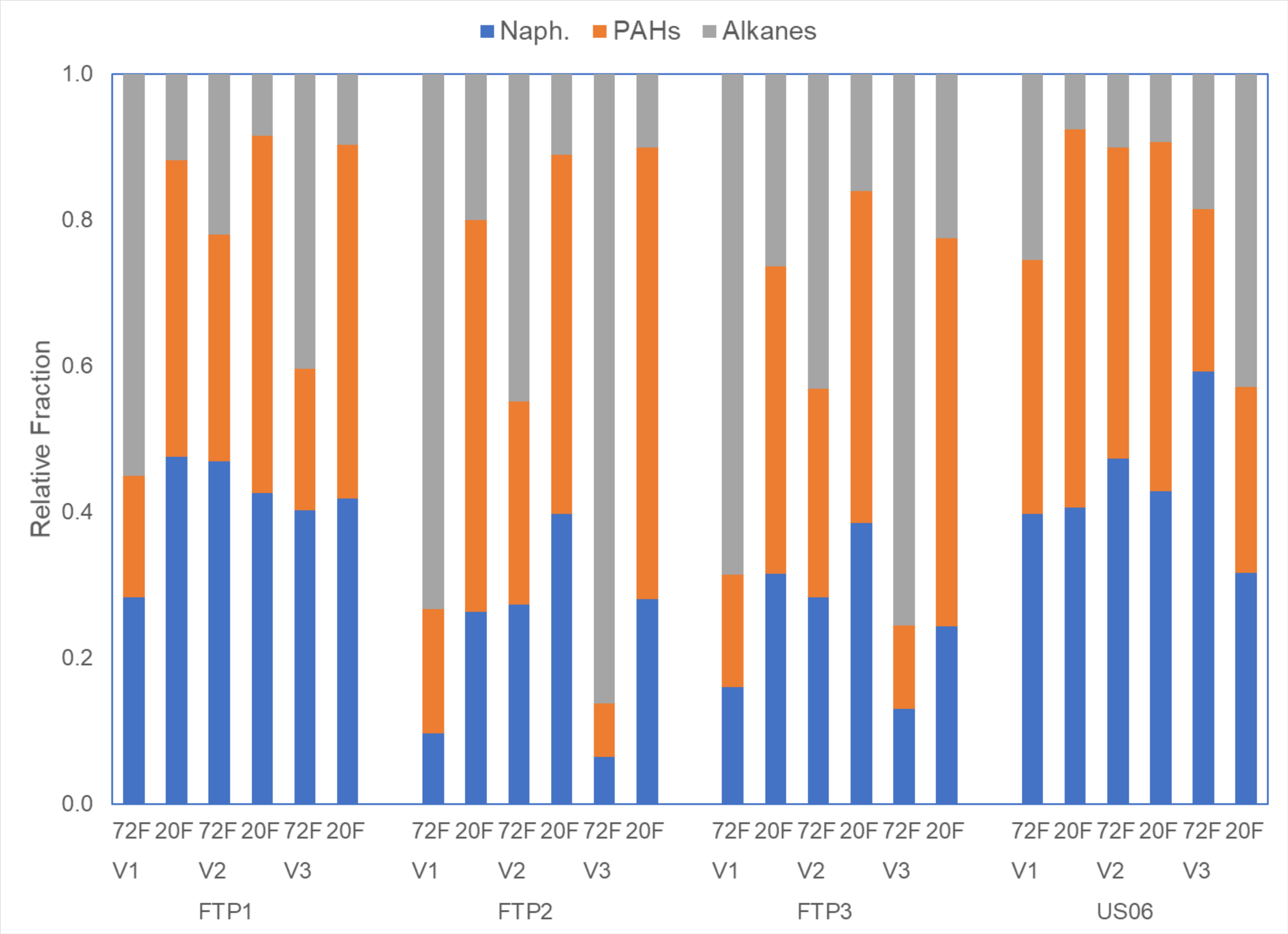
Total Gas-phase SVOC Emissions



Similar trends observed as with VOCs

V2 emissions were in all cases higher than V1, V3 under similar conditions

Gas SVOC Composition by Condition

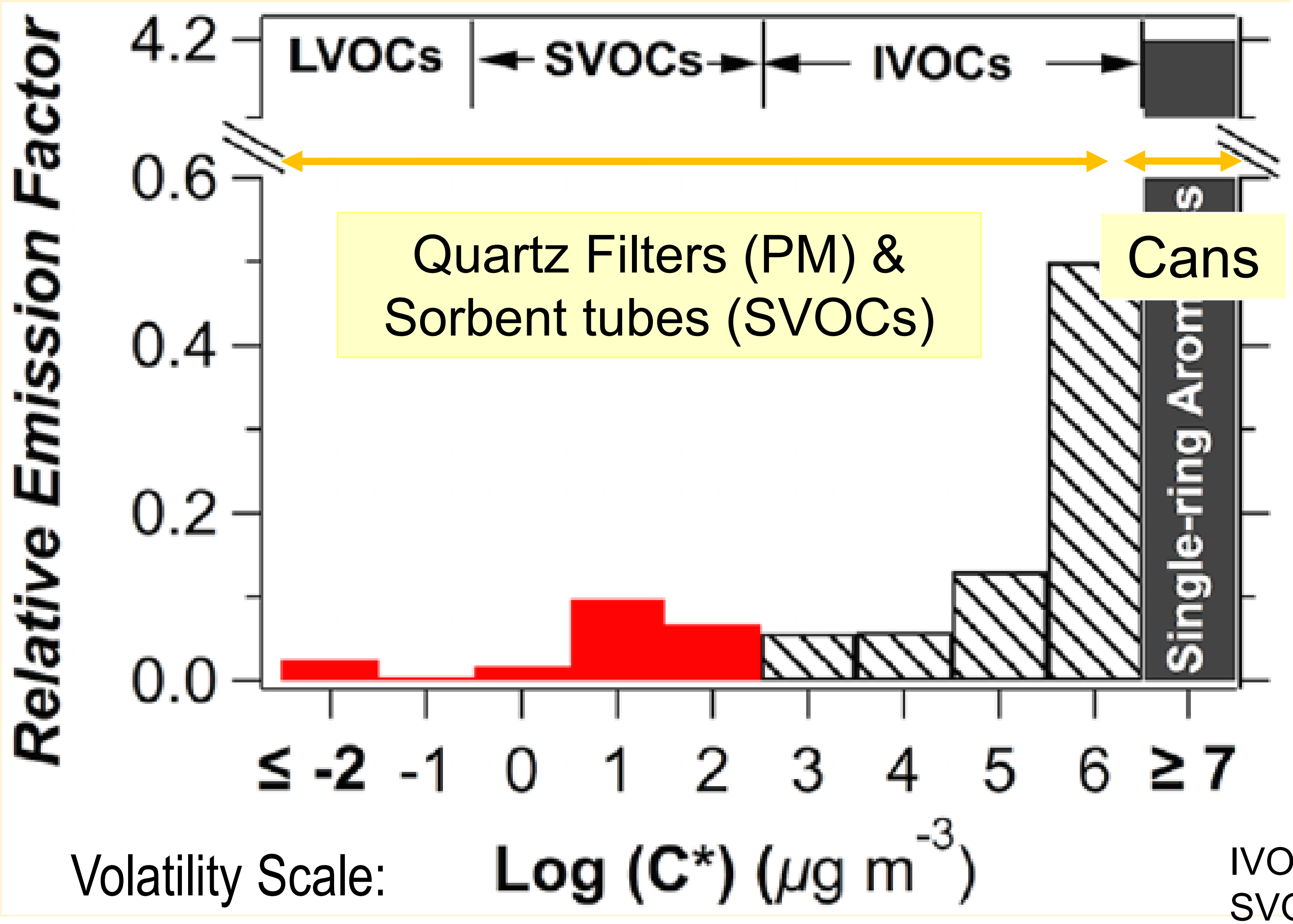


Gas SVOCs mostly consisted of 2-ring PAHs

FTP1 & FTP3: PAH fraction increased with cold temp

US06 consisted mostly of PAHs

Next Steps



Zhao et al., 2016

- Develop volatility based emission rates
- IVOC method intercomparison (TO-15 vs. TO-17)
- Literature comparison

IVOCs=intermediate volatility organic compounds
SVOCs=semivolatile organic compounds
LVOCs=low volatility organic compounds
PM=particulate matter

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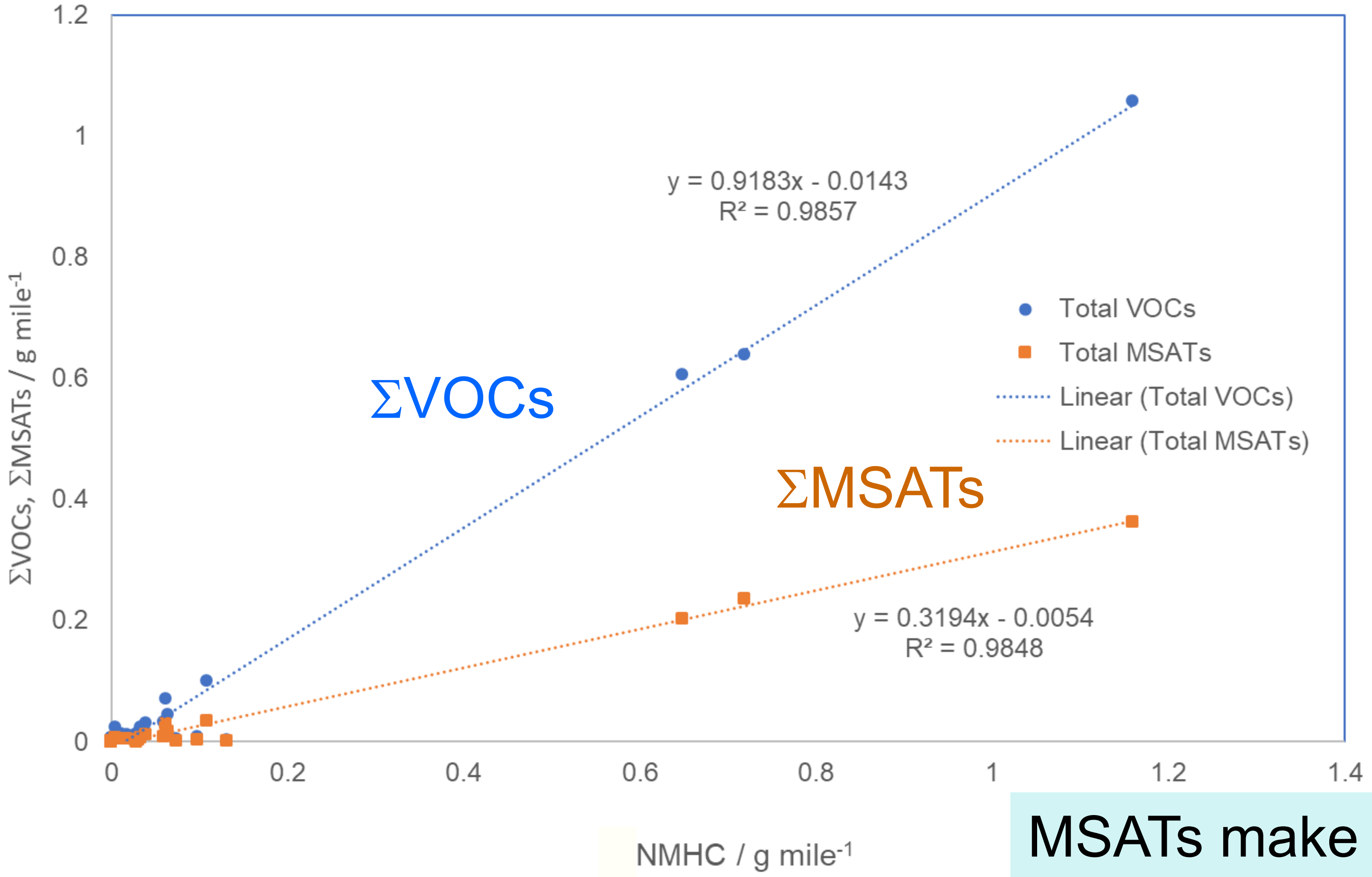
Summary

- Speciated VOC and SVOC emissions were measured for 3 GDI LD vehicles at two temperatures
- Cold temperature substantially increased VOC/ SVOC emissions in FTP1 that varied by vehicle
- VOC composition was dominated by alkanes and BTEX and varied by condition and vehicle; SVOCs were dominated by light PAHs
- We are developing volatility based emission profiles to be used in air quality models

Questions?

(Bonus) VOC Comparisons with NMHC

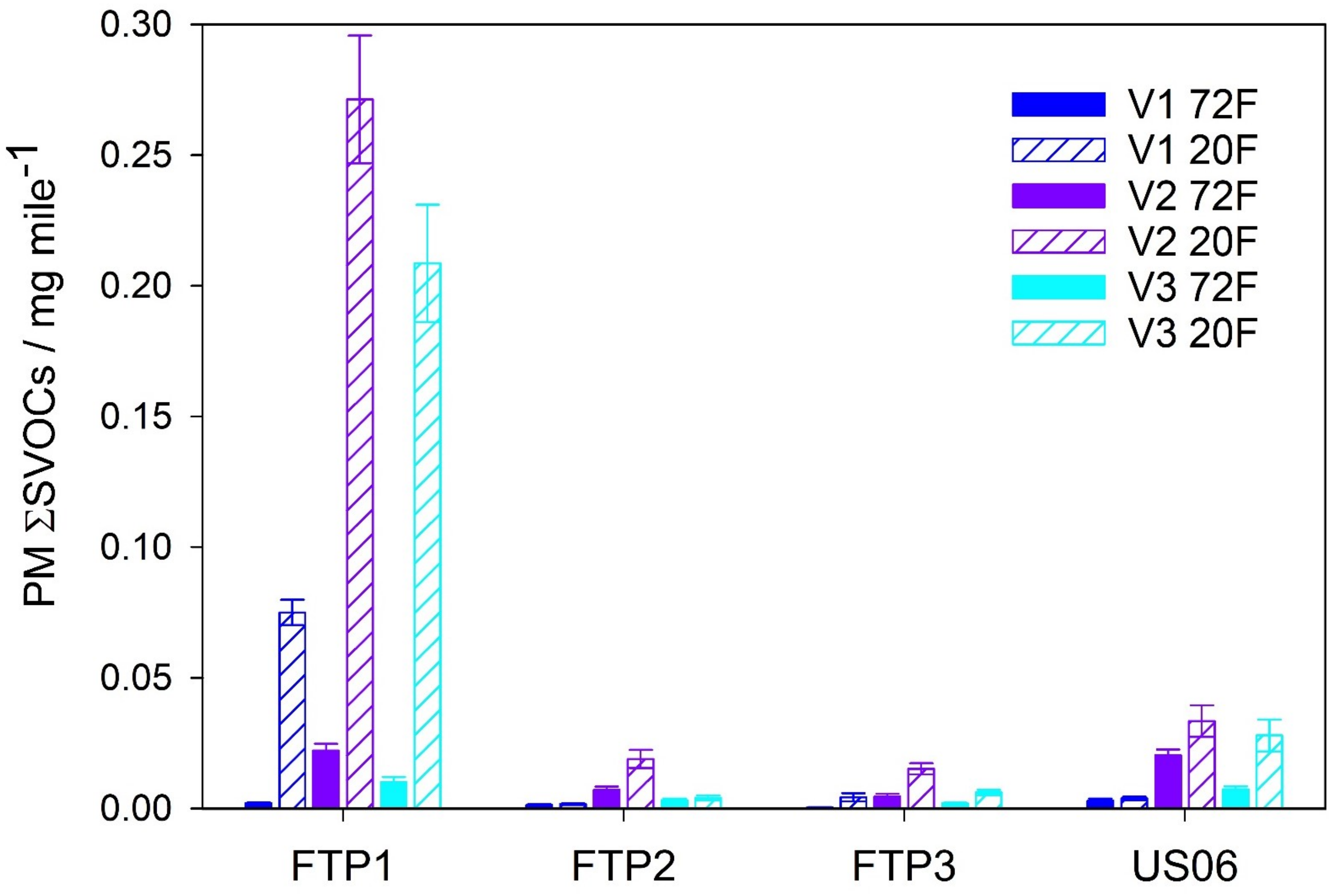


MSATs make up ~1/3 of NMHC

MSAT Correlations

Compound	R^2
1,3-butadiene	0.71
n-Hexane	0.97
Benzene	0.96
Toluene	0.98
Ethylbenzene	0.98
Xylenes	0.99
Styrene	0.79
Naphthalene	0.92
Formaldehyde	0.56
Acetaldehyde	0.90
Acrolein	0.67

(Bonus) Total Particle Phase SVOC Emissions



(Bonus) Particulate SVOC Composition by Condition