COLD TEMPERATURE EFFECTS ON SPECIATED VOC EMISSIONS FROM MODERN GDI LIGHT-DUTY VEHICLES: Preliminary Results

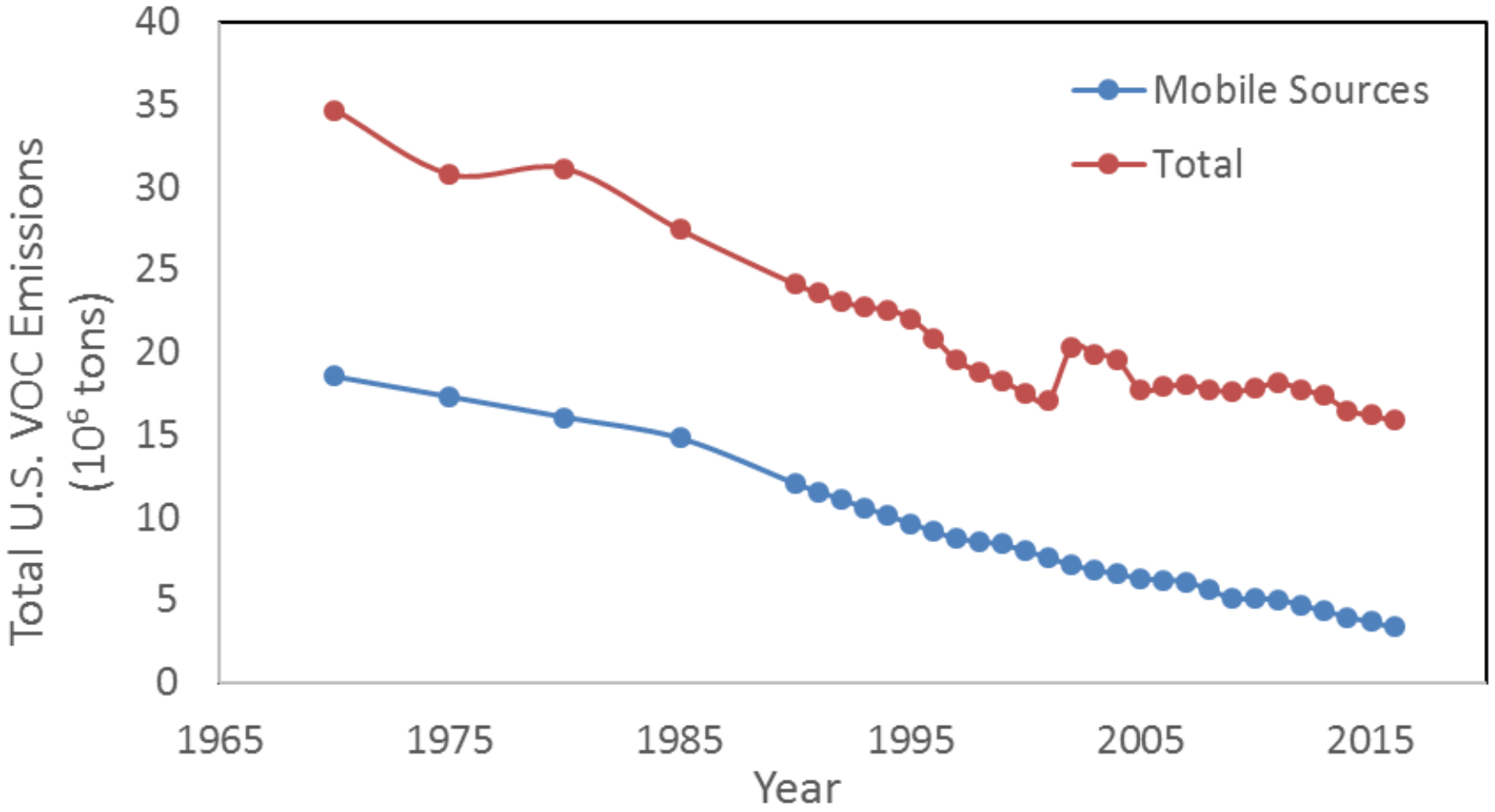
Ingrid George, Michael Hays, Richard Snow, James Faircloth, Thomas Long and Richard Baldauf

Office of Research and Development,

U. S. Environmental Protection Agency

Emissions Inventory Conference
Baltimore, MD
Aug. 18, 2017

Mobile Source VOC Emissions



VOC emissions have been steadily decreasing

Transportation sector contributes ~20% of all (non-biogenic) U.S. VOC emissions in 2016

Detailed speciated VOC emissions data is needed to accurately predict the air quality impacts of mobile sources

https://www.epa.gov/air-emissions-inventories/air-pollutant-emissions-trends-data

ORD's Vehicle Emissions Research

Overall objective: to characterize speciated gas- and particle-phase emissions in vehicle exhaust with focus on high priority data gaps in emissions inventories/models

- Biofuels: ethanol/gasoline blends, biodiesel/diesel blends
- Ambient temperatures: "winter" effect (-7 C vs 22 C)
- Modern engine and emission control technologies: diesel emission control aftertreatments, GDI technologies
- Driving conditions: trailer towing

Recent Studies: Ethanol/LD gasoline vehicle study, Biodiesel HDV study, GDI gasoline study (current)

ORD's Vehicle Emissions Facilities

Light-duty Dynamometer:
48 in. roll
Capacity: 12,000 lbs
Temp: -30 to 43 ° C

Heavy-duty Dynamometer:
72 in. roll
Capacity: 30,000 lbs
Temp: 22 ° C

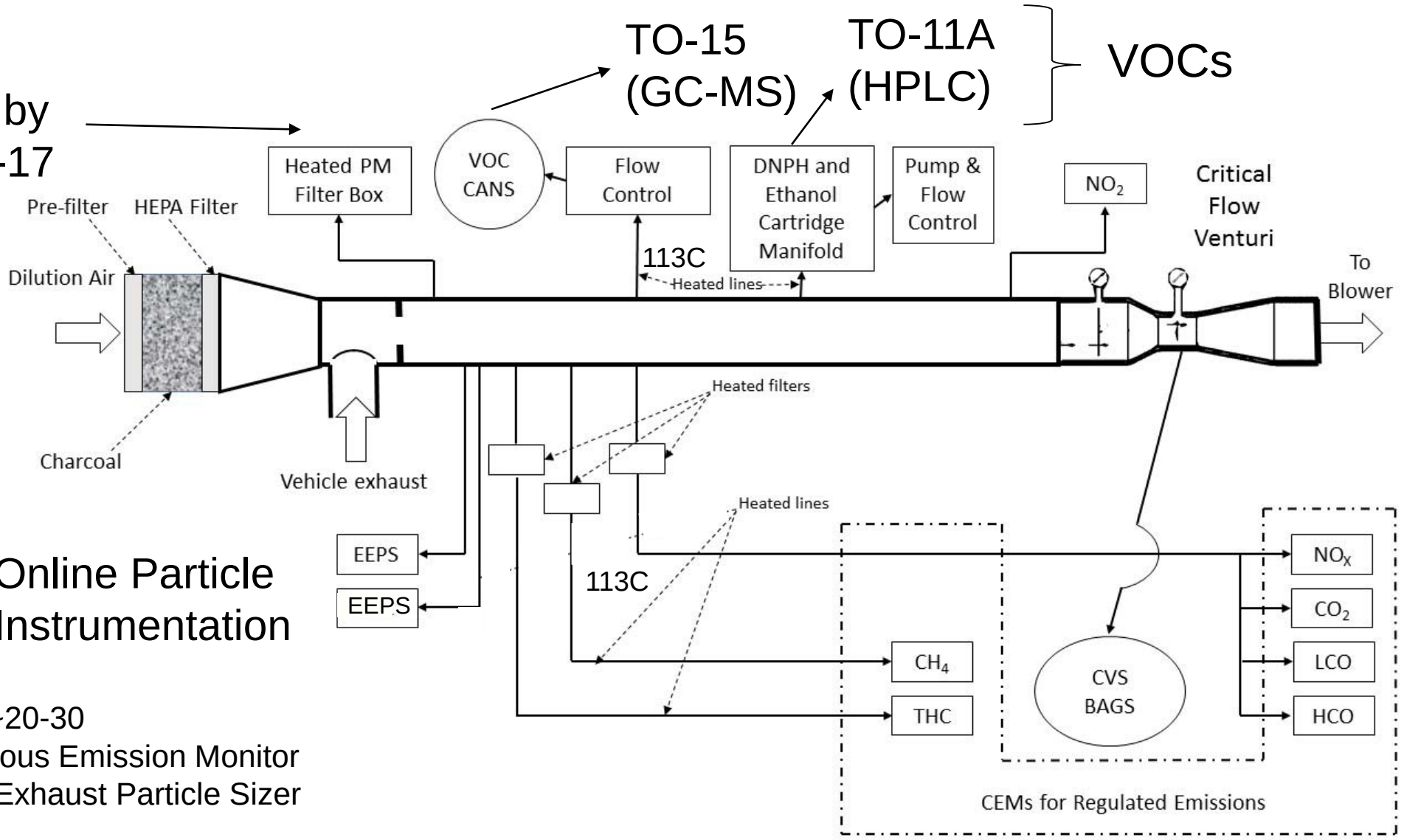
Dilution Tunnel and Sampling

Speciated SVOCs/PM by TO-13A/TO-17 (GC/MS)

TO-15 (GC-MS)

TO-11A (HPLC)

VOCs

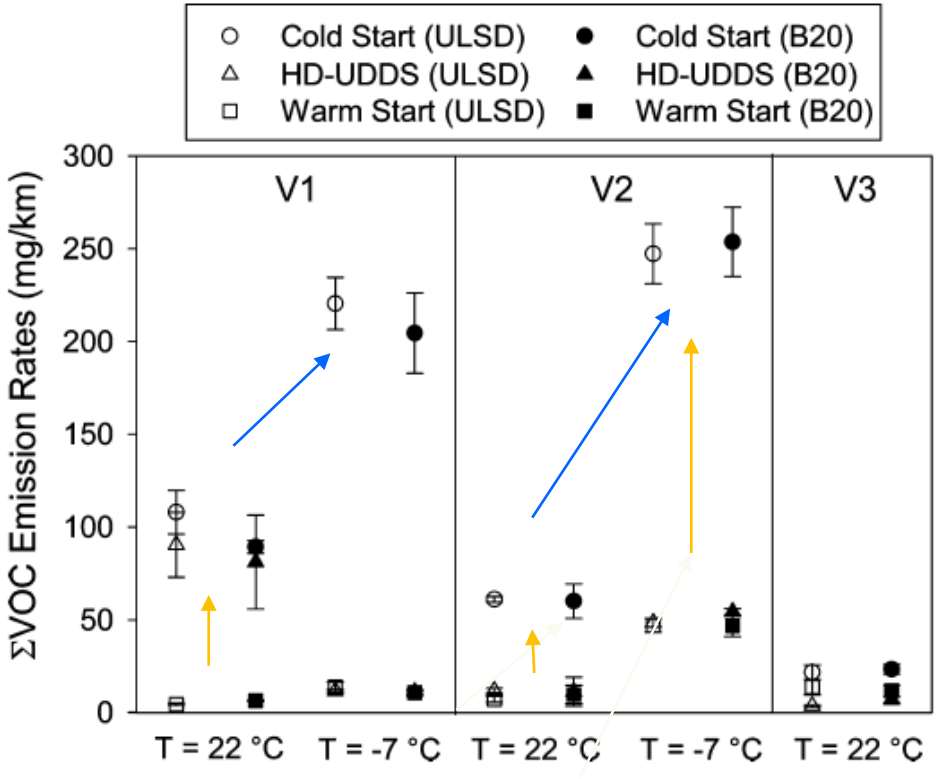


Online Particle Instrumentation

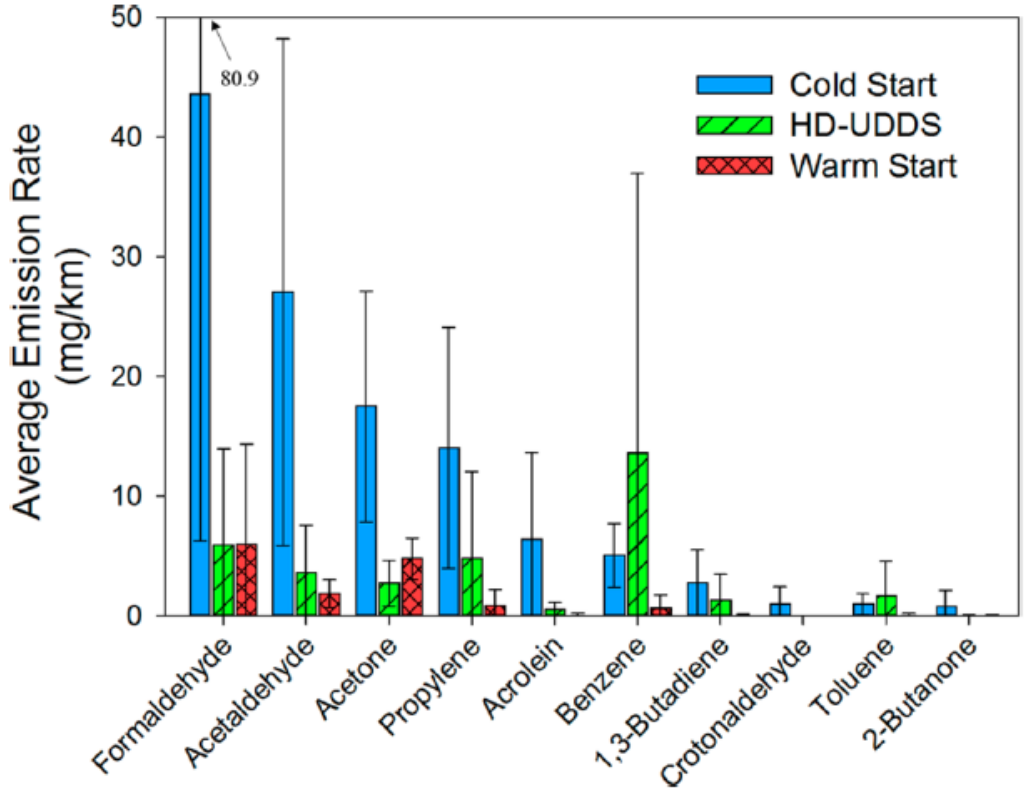
CEMs

Dilution factor ~20-30
CEM = Continuous Emission Monitor
EEPS=Engine Exhaust Particle Sizer

Biodiesel HD Vehicle Study Highlights



Cold Start/Cold Temp effects significantly increase emissions



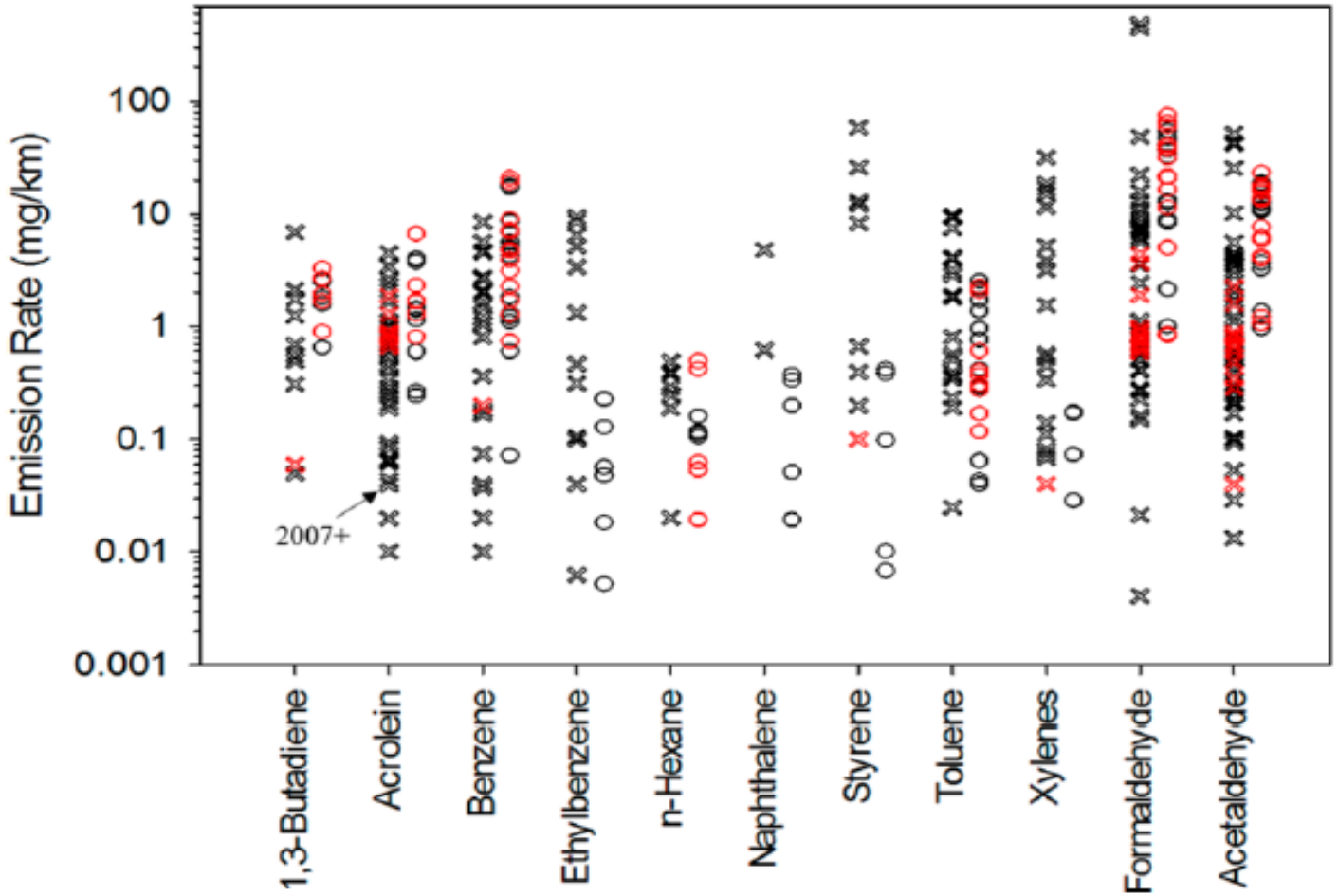
Carbonyls represent most of cold start VOC emissions

Test Conditions: Three LHDD trucks (MY2011), T= -7, 22 C, Fuels: B0, soy B20
Driving Cycle: MHDTLO, HD-UDDS Ref: George et al. 2014

Biodiesel HD Vehicle Study Highlights

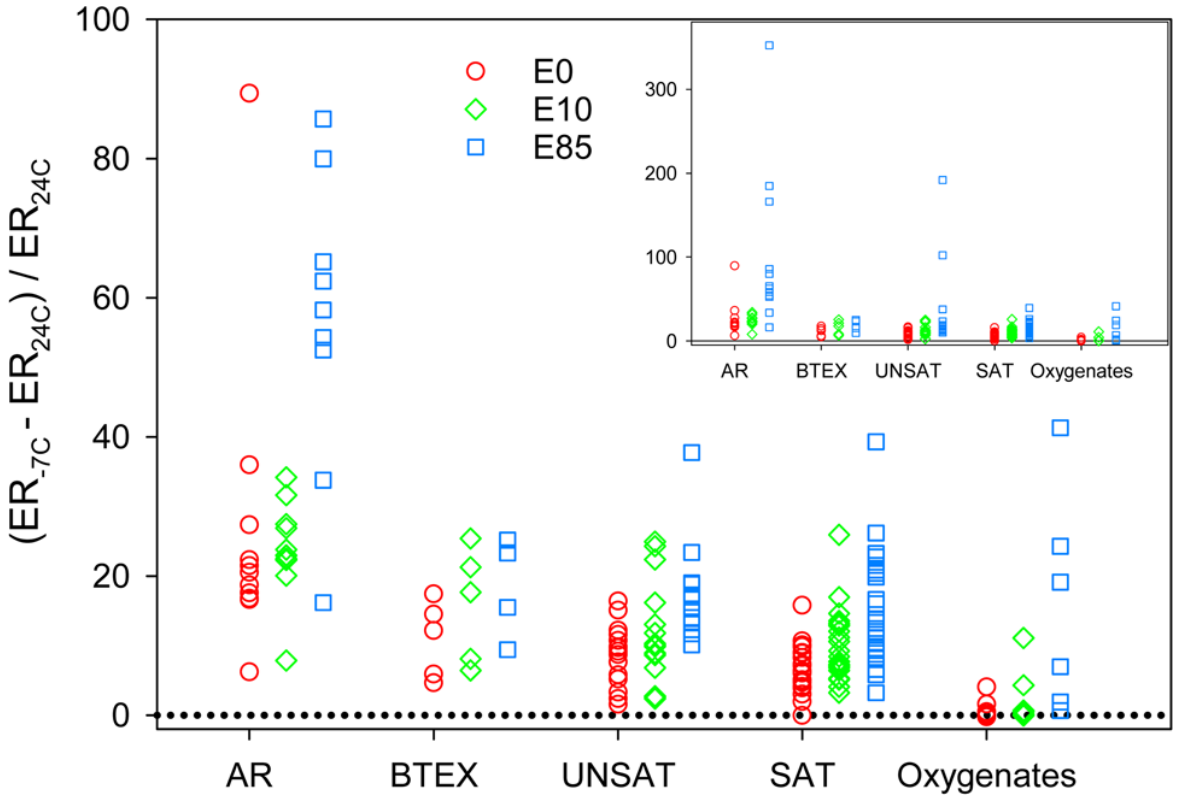
United States Environmental Protection Agency

MSAT ERs in literature

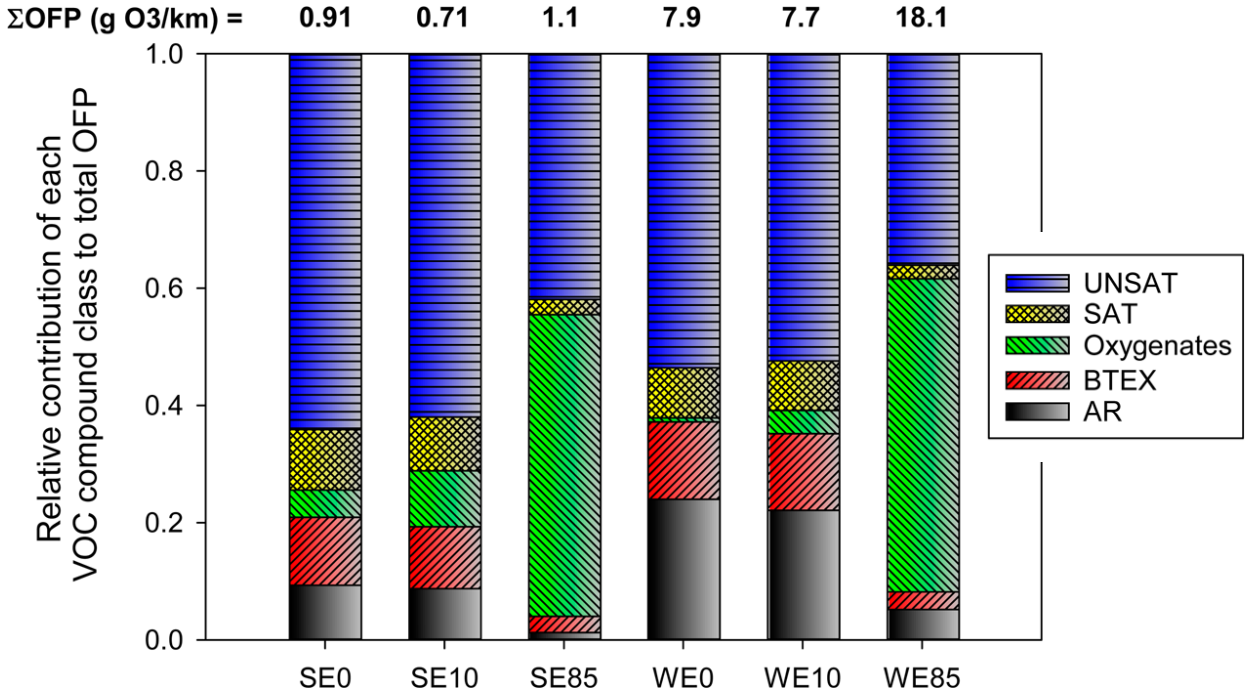


One previous study reported major mobile source air toxics (MSATs) VOC emissions from modern HD diesel vehicle

Ethanol LD Vehicle Study Highlights



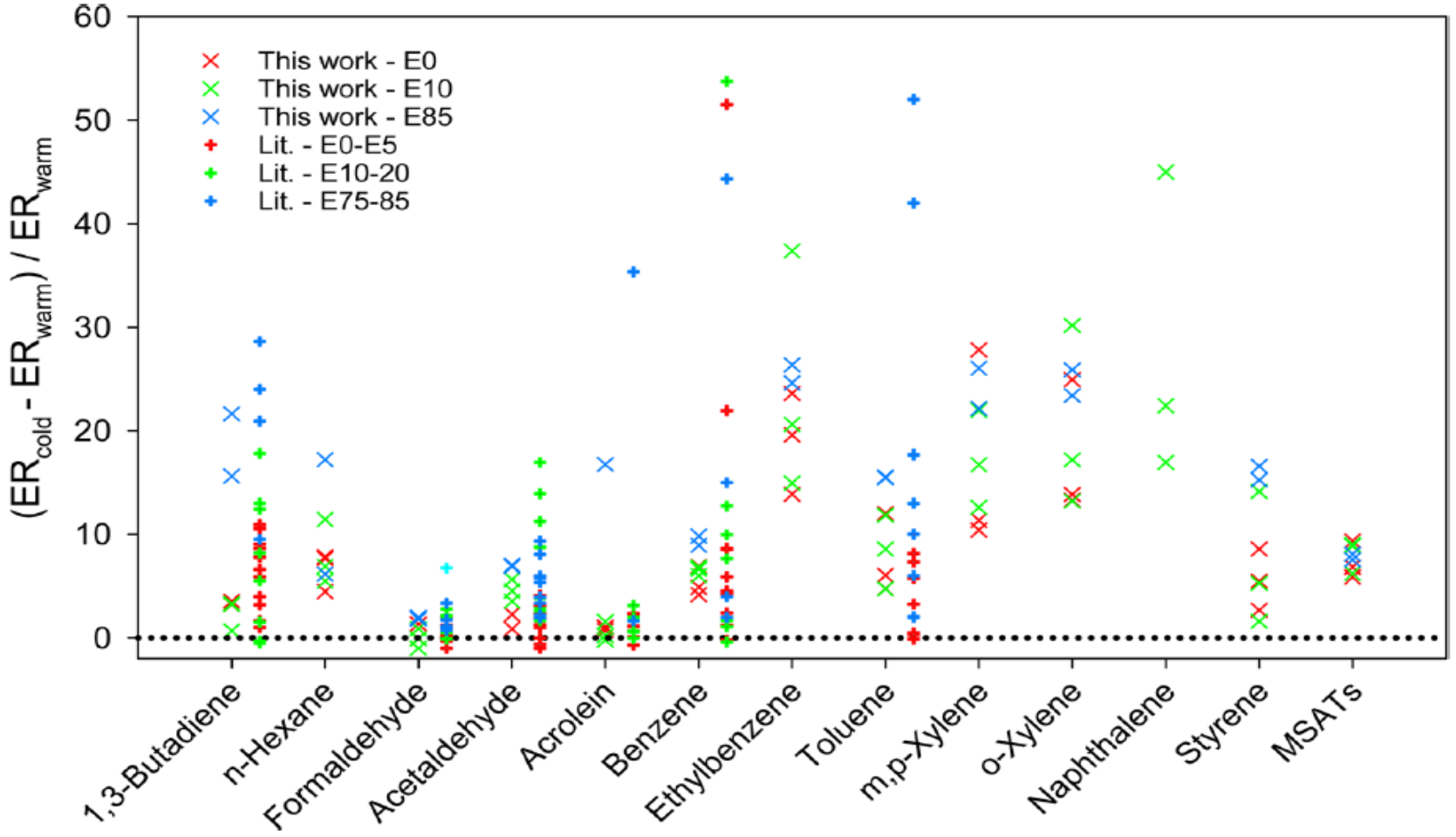
Cold temp VOC emissions enhancements vary with compound class and fuel



VOCs contribute to ozone formation potentials variably by fuel

Test Conditions: Three LD gasoline vehicles (MY2008), T= -7, 24 C, Fuels: E0,E10,E85, Driving Cycle: LA92. Ref.: George et al. 2015.

Ethanol LD Vehicle Study Highlights



No previous cold temp emissions data for several major MSAT VOCs

GDI Study - Motivation

- Gasoline direct injection (GDI) engines were introduced into the market in 2007 and their market share has rapidly increased to 46% of MY2015 LD cars/trucks[1]
- Emissions studies of GDI vehicles have mostly focused on PM/PN; few studies have measured MSATs/speciated VOCs
- The effect of different GDI technologies and ambient temperature on LD vehicle emissions are not well known

<u>Objective</u>: To characterize speciated volatile organic emissions from three LD GDI vehicle exhaust at warm and cold temps (20 and 72 ° F)

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

GDI Study - Test Conditions

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

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

Vehicles: Three GDI gasoline vehicles (V1, V2, V3)

Driving Cycles: FTP, SFTP (US06)

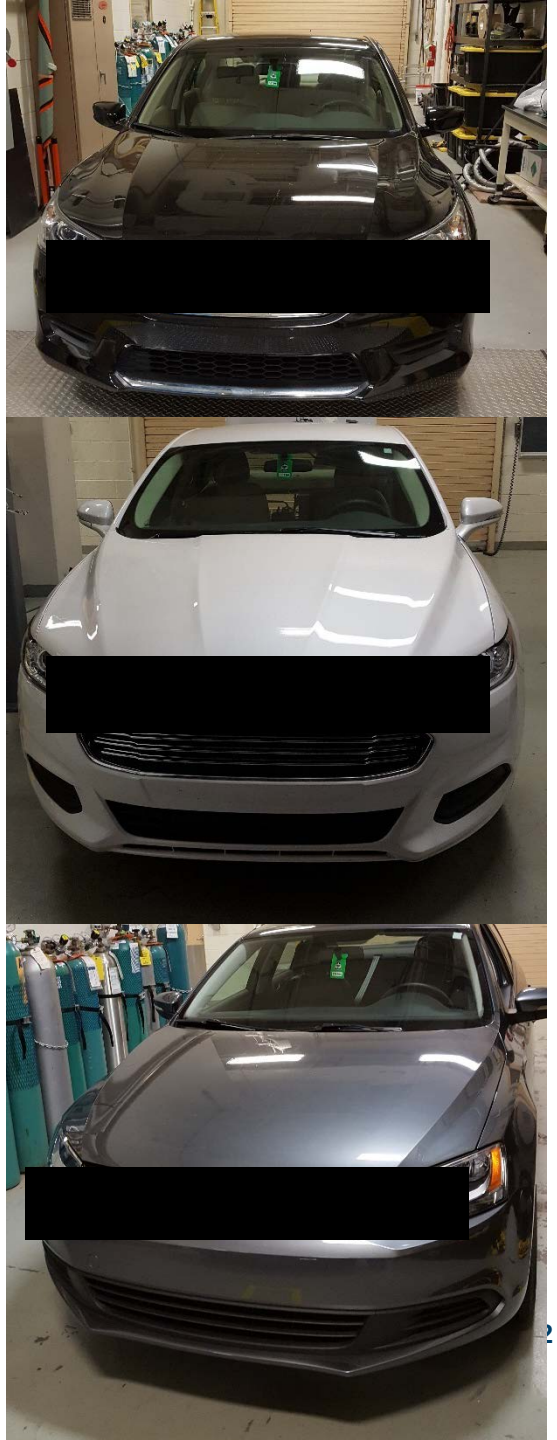
Dynamometer: Light-duty dyno (48 in. roll)

Test Vehicles:

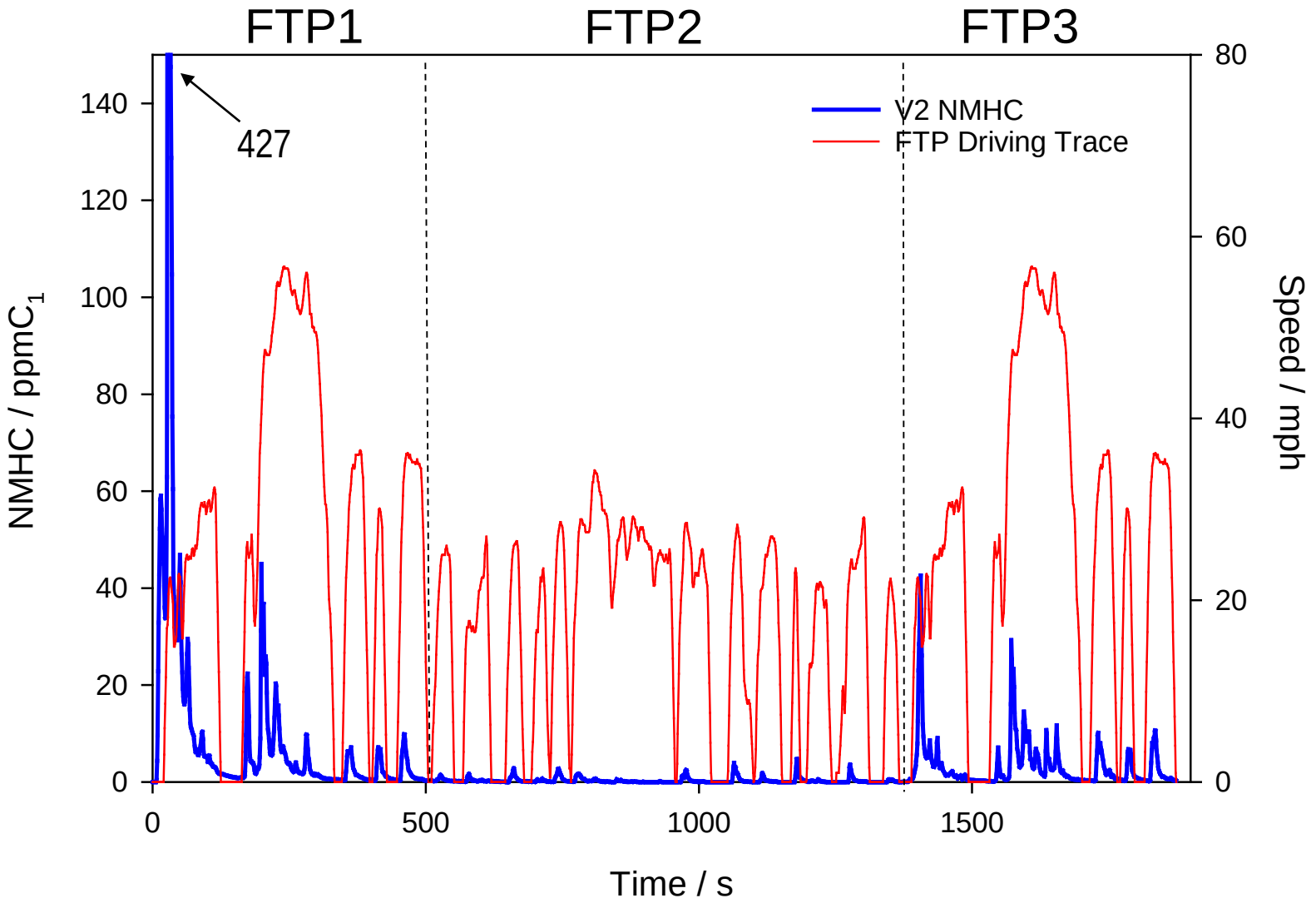
V1) MY 2014 (Tier 2, Bin 5)
ODO=12,700 miles, 2.4 liter,
Naturally aspirated, wall-guided GDI engine

V2) MY 2015 (Tier 2, Bin 5)
ODO=10,500 miles, 1.5 liter,
Spray-guided, turbocharged GDI engine

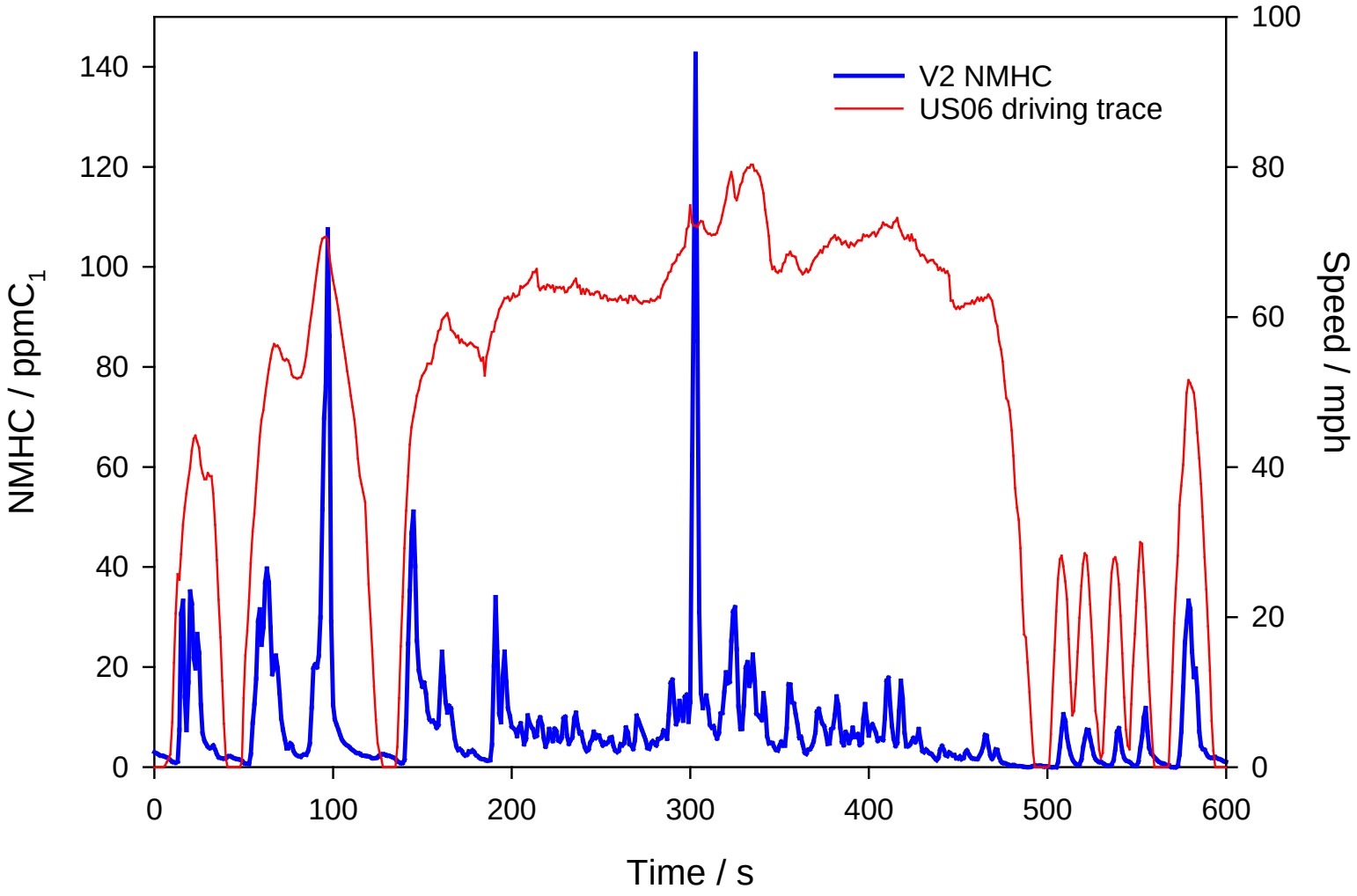
V3) MY 2014 (Tier 2, Bin 5)
ODO=9,200 miles, 1.8 liter
Wall and air guided, turbocharged GDI engine



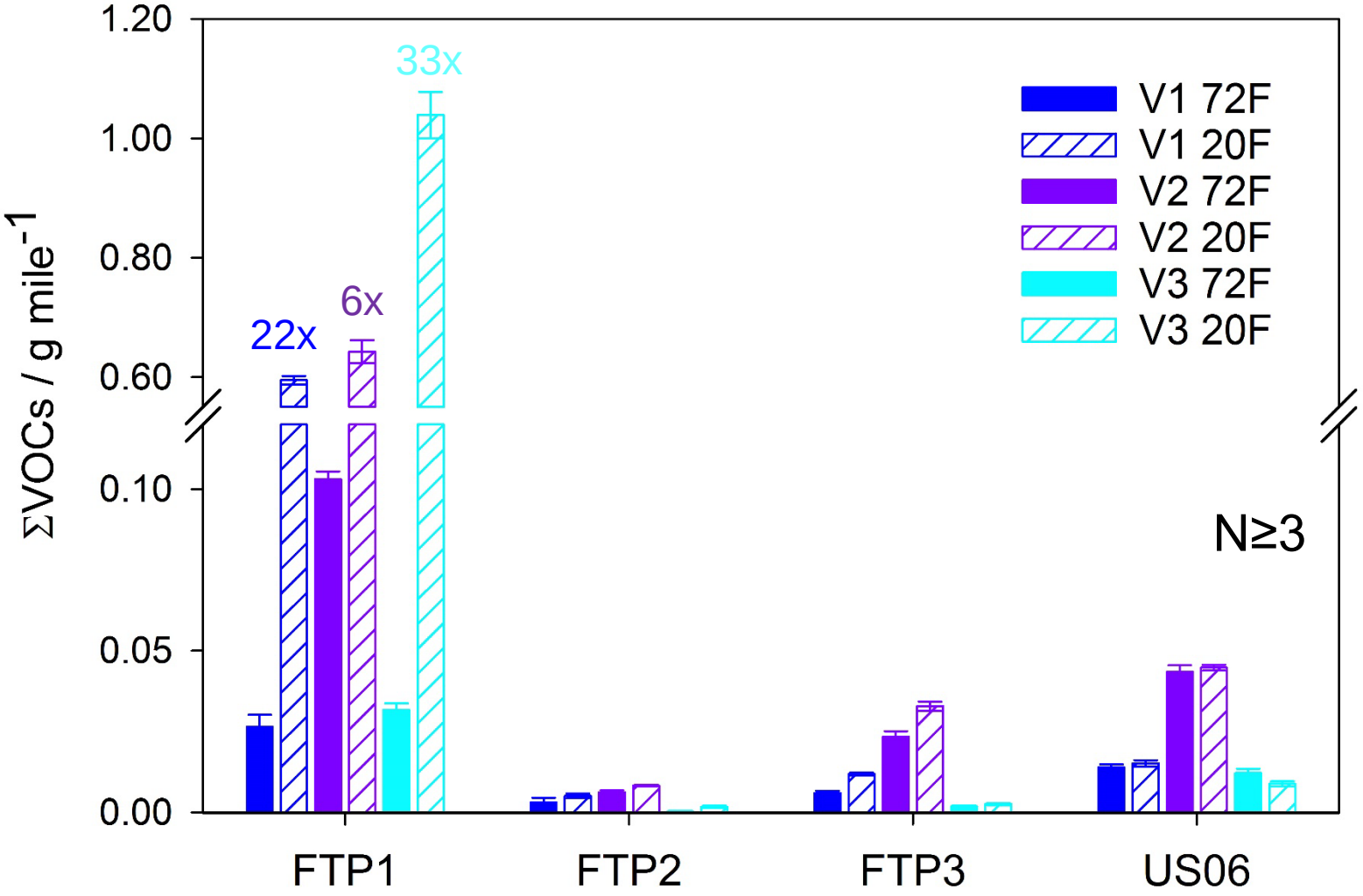
NMHC Traces - FTP



NMHC Traces – US06



Total VOC Emissions

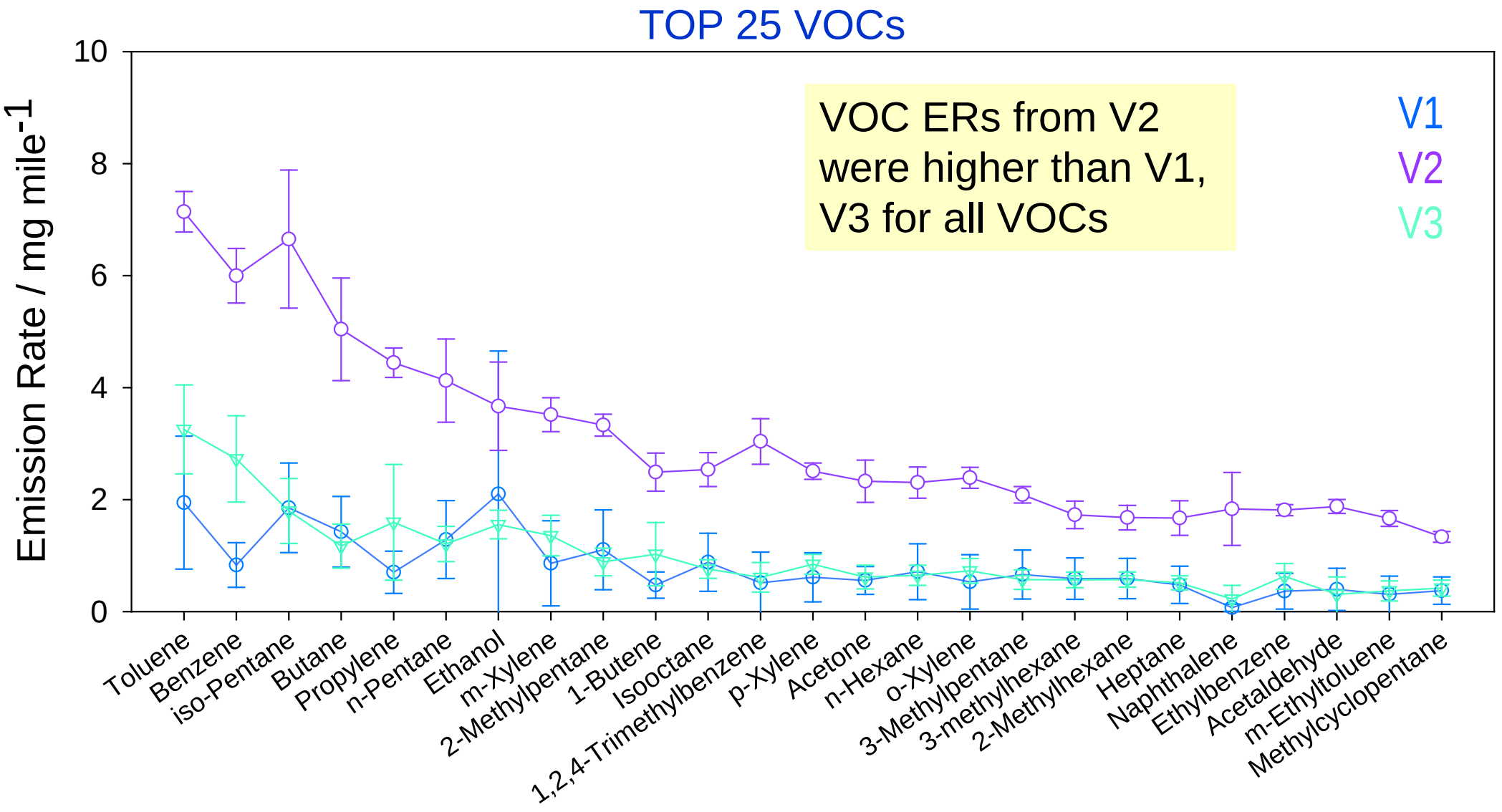


Cold start emissions were substantially higher (4-400x) than warm start (intensified at 20F)

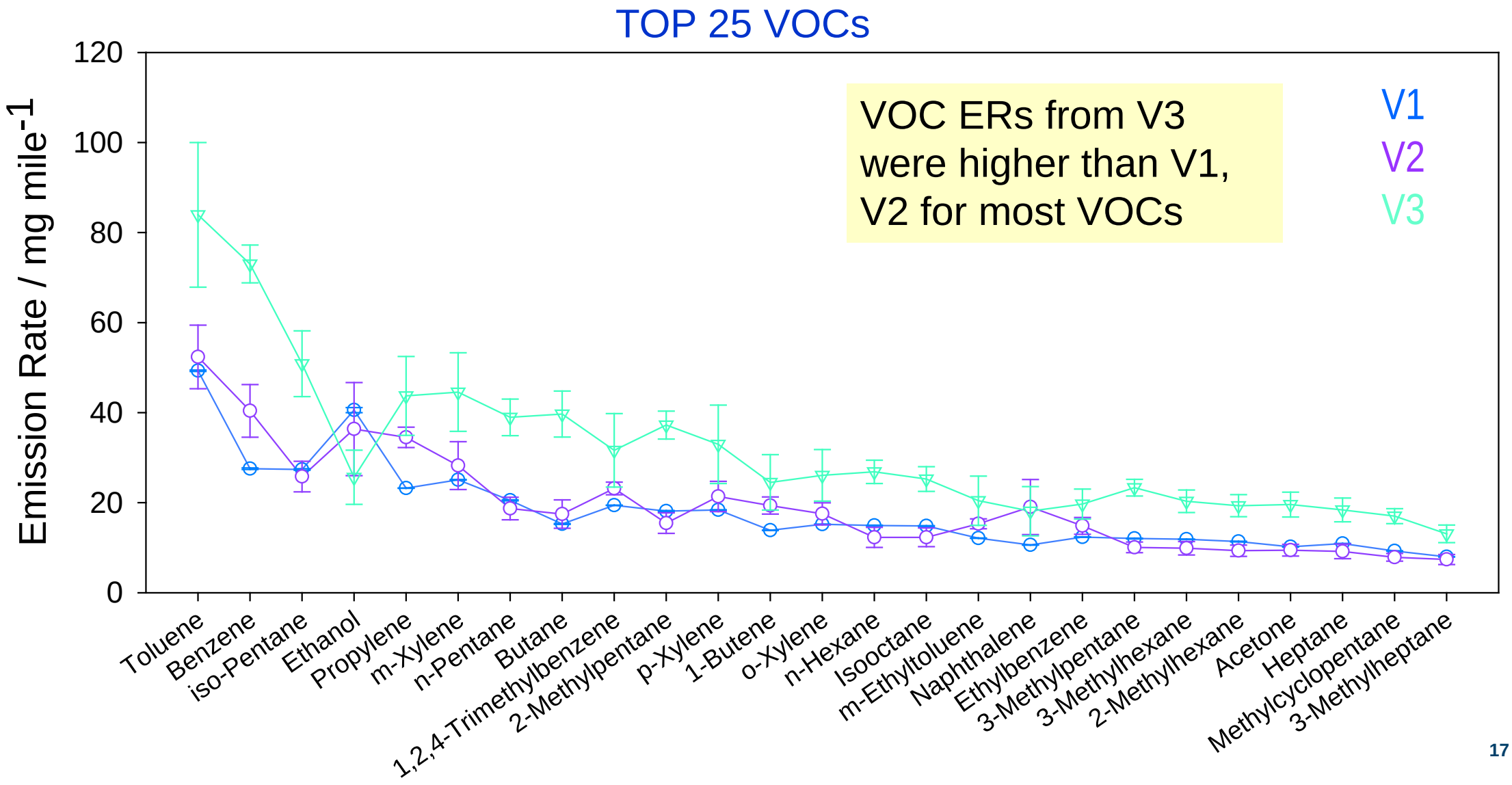
Cold temp. effect was most prominent during cold start and varied by vehicle

V2 emissions were mostly higher than V1, V3

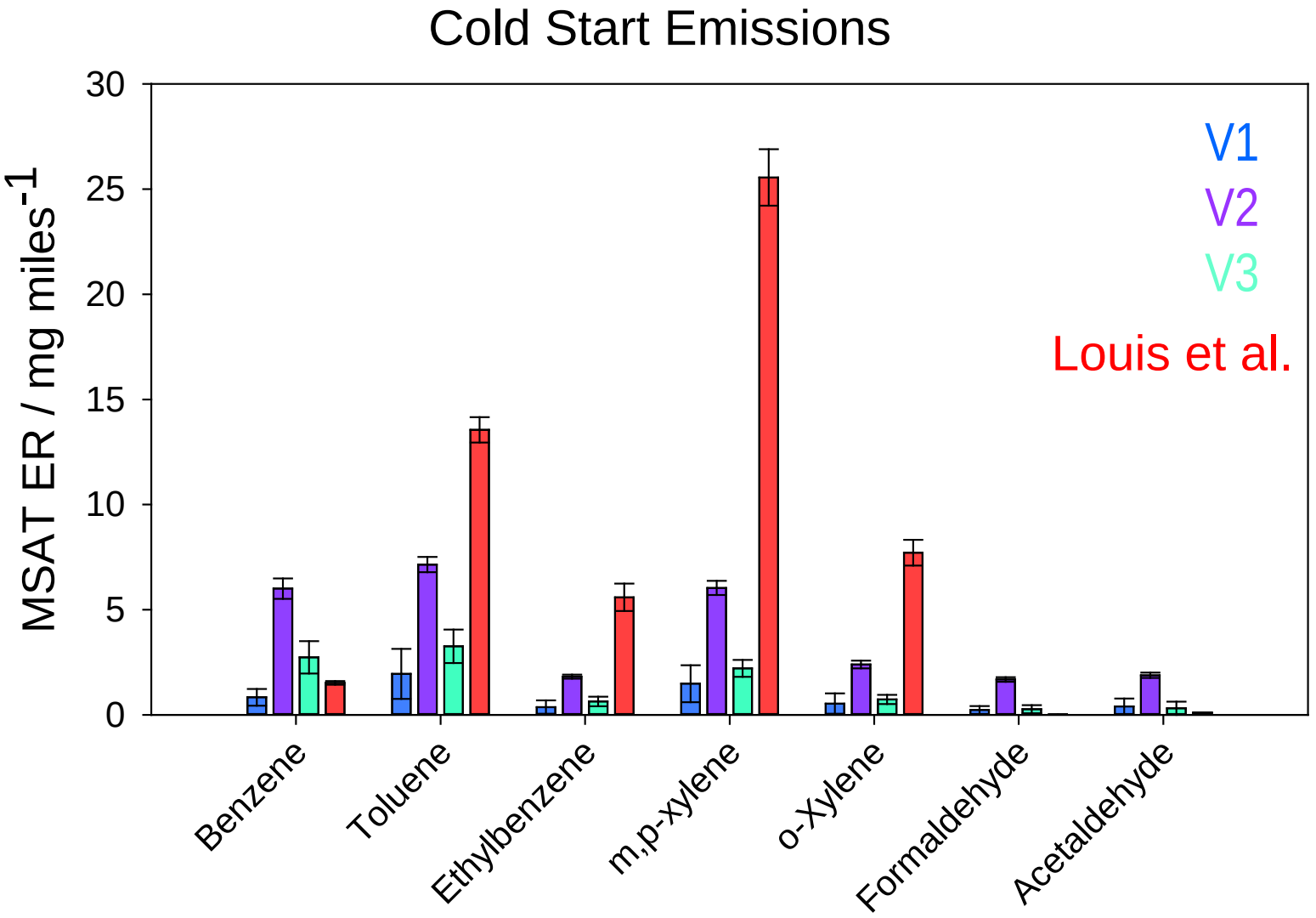
VOC Profiles: Cold start FTP1 (72F)



VOC Profiles: Cold start FTP1 (20F)



Literature comparison



Louis et al. 2016:
Euro 5, Artemis urban CS

Conclusions

- Cold start and cold temp. effects have the most dramatic impact on VOC emissions of conditions studied
- Fuel effects are more subtle for ethanol and biodiesel blends
- Cold temperature enhancements can vary by fuel, vehicle and VOC compound
- Speciated VOC emissions data for modern LD & HD vehicles remains sparse; this work has started to fill some of the data gaps


Questions?