PAUL SCHERRER INSTITUT PSI

Wir schaffen Wissen – heute für morgen

Gas Phase Composition and Secondary Organic Aerosol Formation from Gasoline Direct Injection Vehicles Investigated in Batch and Flow Reactors:

Do gasoline particle filters (GPFs) help us to clean (secondary) carbonaceous particulate matter?

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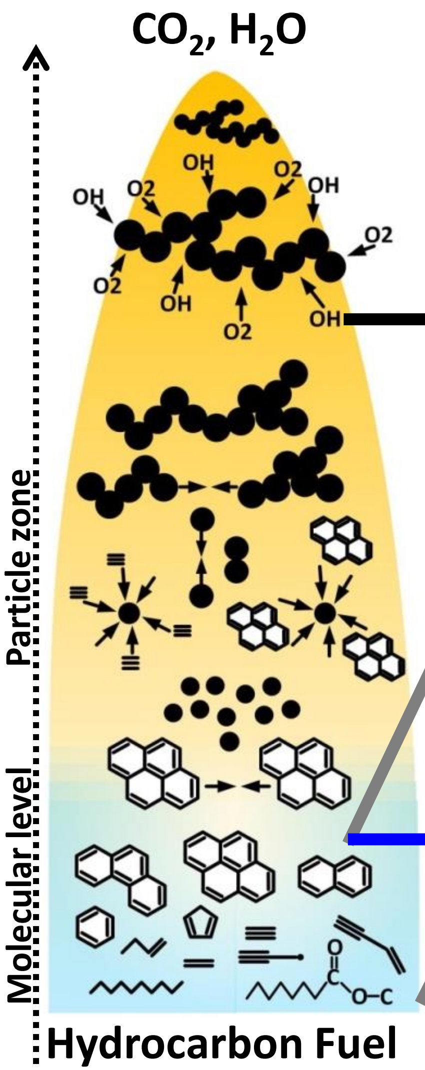
Paul Scherrer Institute, Laboratory of Atmospheric Chemistry, Switzerland

Carbonaceous Emissions



Reference: http://combustion.mie.utoronto.ca/

Black carbon (BC); =refractory PM, **particulate**

Primary organic aerosol (POA);
=non-refractory PM, **particulate** organic compounds

ATMOSPHERIC COOLING & DILUTION

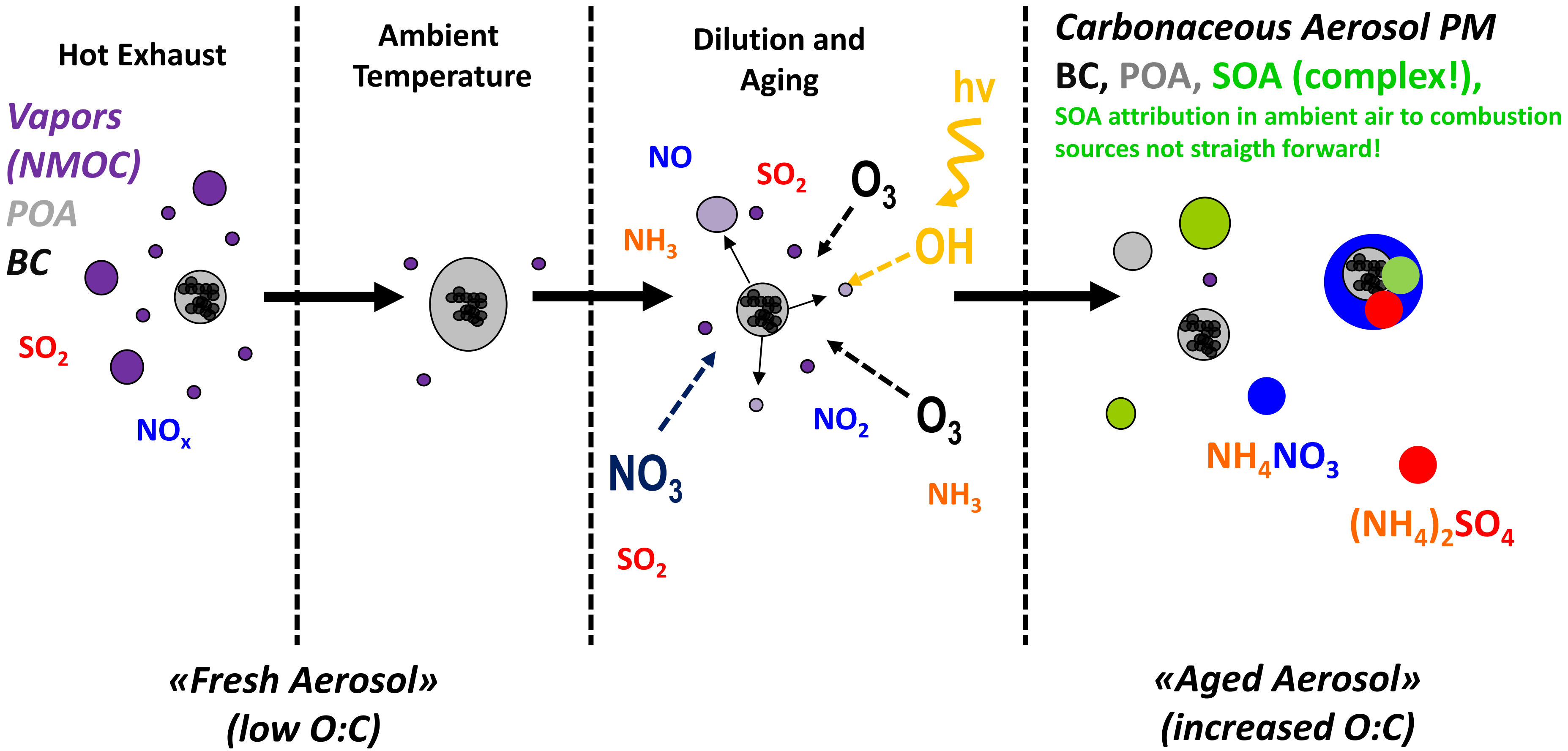
Gasphase non-methane organic compounds (NMOC)

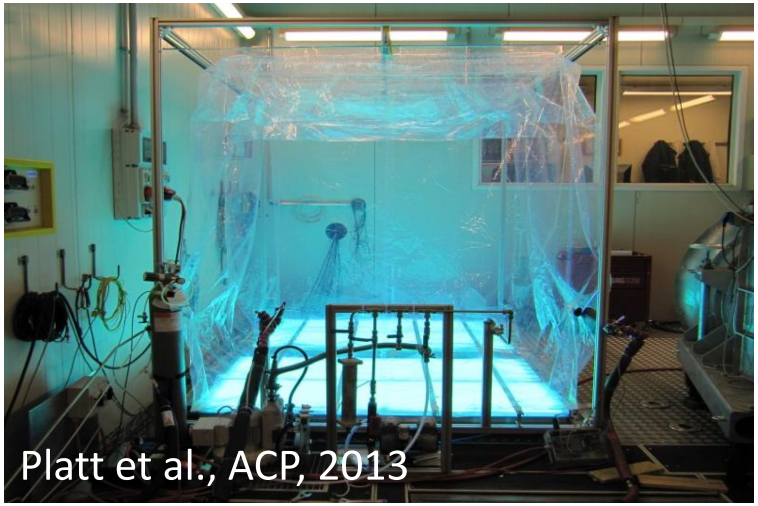
unburned fuel

ATMOSPHERIC OXIDATION (O_3, OH, NO_3)

Secondary organic aerosol (SOA)
=non-refractory PM, secondary organic **particulate** organic compounds

SOA formation

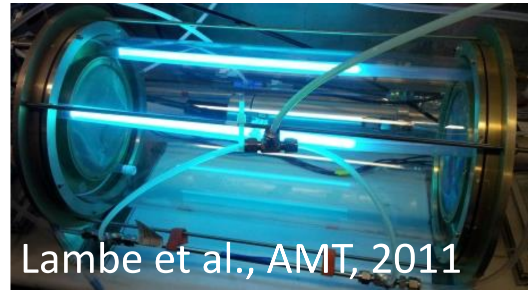




PSI Mobile Smog Chamber (SC), V = 10 m^3

UVA lamps, I_{max} at $\lambda = 350 - 400$ nm

picture taken when installed at JRC Ispra, (2013)



Oxidation Flow Reactor (OFR)
V = 0.015 m^3

UVC lamps,
λ = 185 nm and 254 nm
«OFR185»

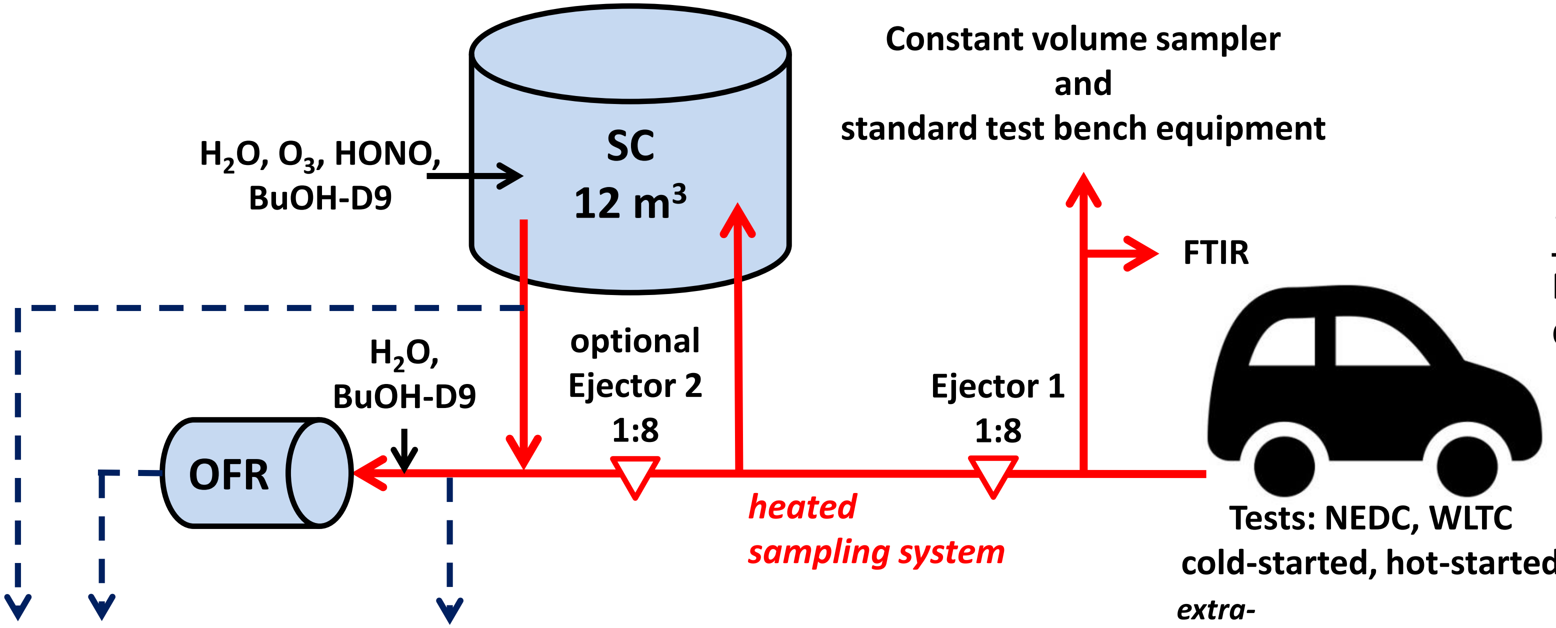
<u>Vehicle testing:</u>

Gasoline Light Duty (Euro 4/5), including GDI, with 2 prototype GPFs

GDI1: Opel Insignia (Euro 5b+), standard and w/GPF
GDI2: Opel Zafira Tourer (Euro 5b+), standard
GDI3: VW Golf Plus (Euro 4), standard

GDI4: Volvo V60 (Euro 5a, but «looks-like» Euro 6) standard and w/GPF and w/catGPF

Vehicle installed in Biel, in 2014



Testbench:

FH Biel, CH

Gasomep Project

Particles: Aerosol MS (HR-TOF-AMS)

NMOCs: Proton-transfer-reaction MS (HR-PTR-TOF-MS)

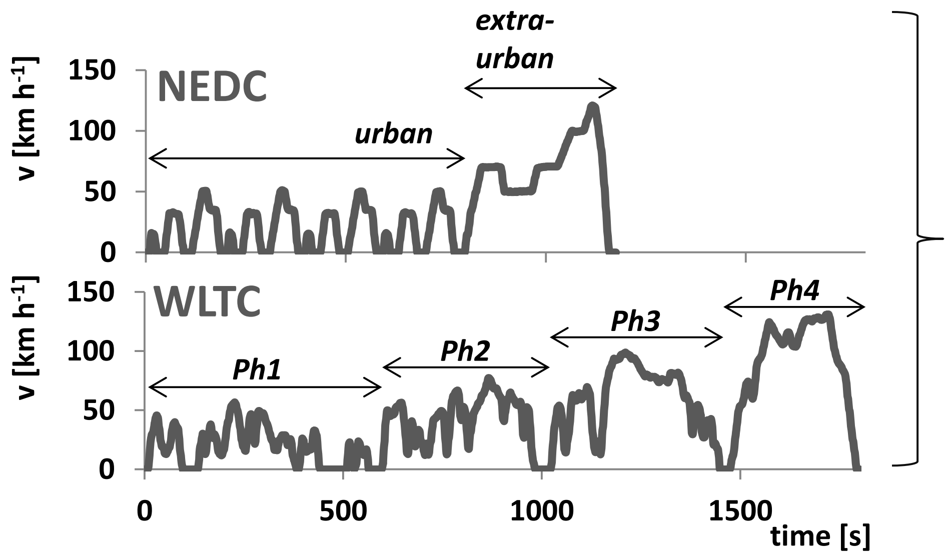
Supporting Instrumentation:

CO_2, CO, CH_4,

NMHC (FID), THC (FID), CH_4 (FID)

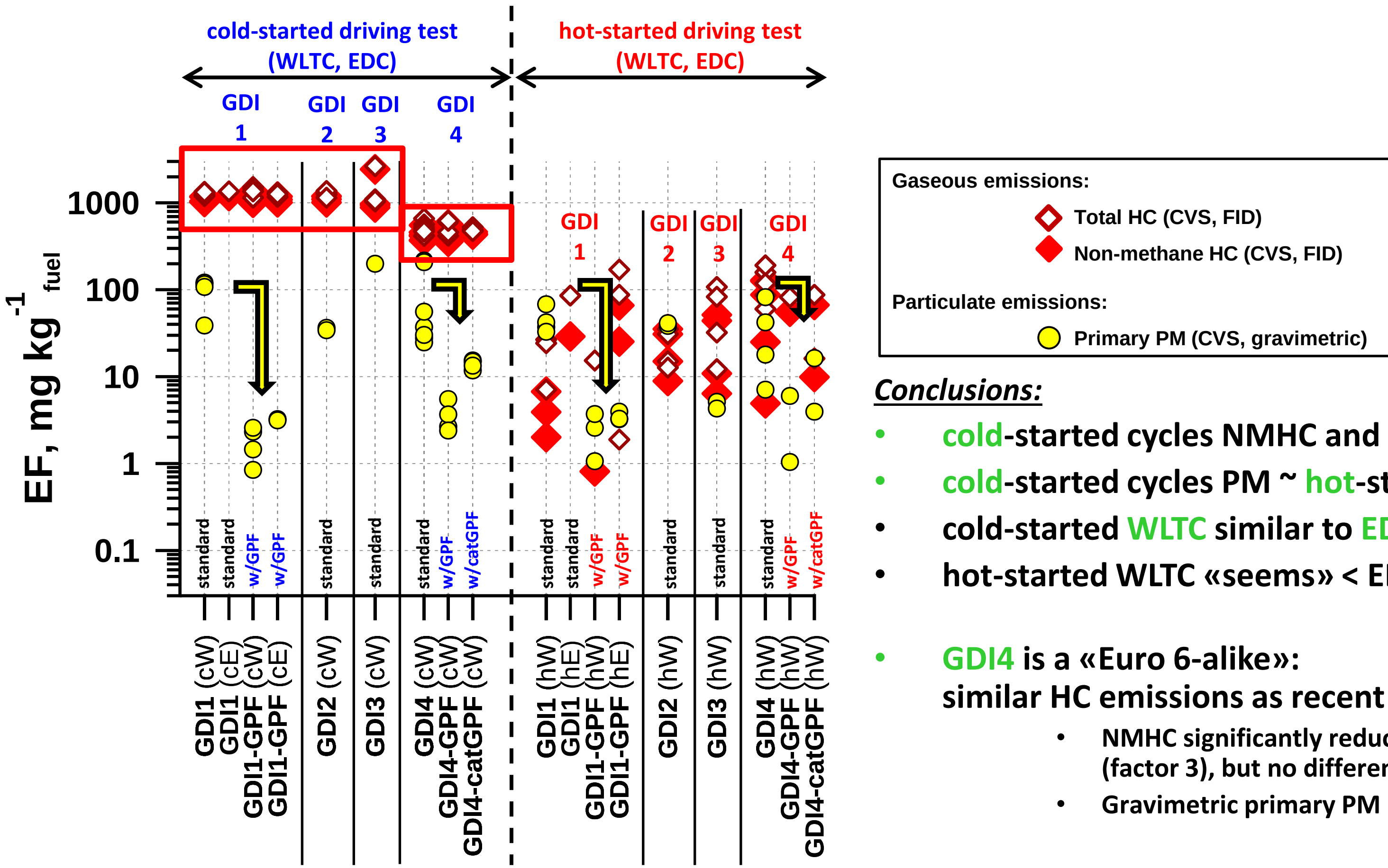
NO_x, O_3, RH, T,

SMPS, CPC, Aethalometers



RESULTS

GDI emissions: cold vs hot, standard vs GPF



Conclusions:

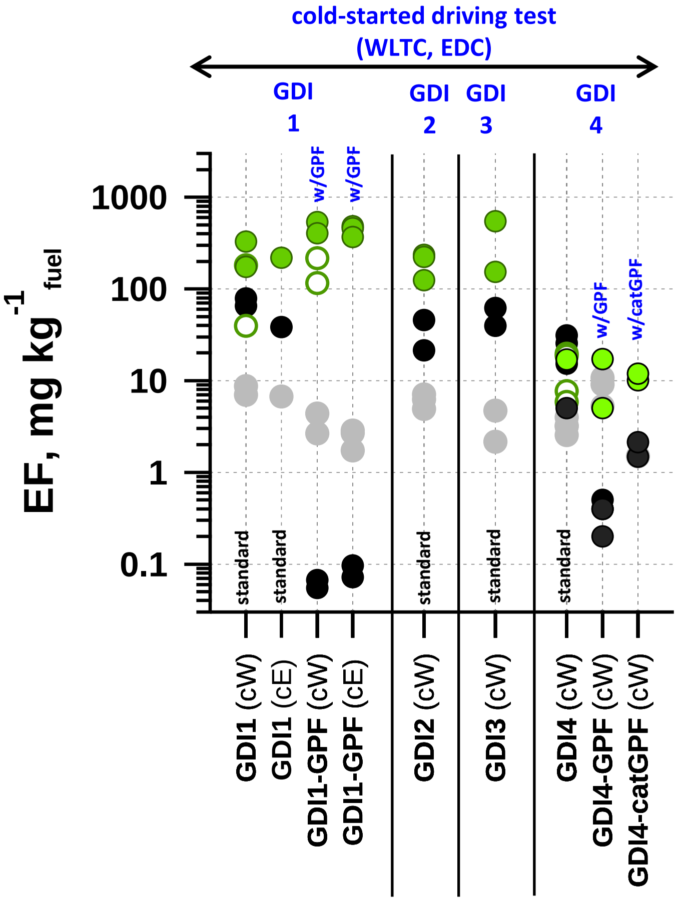
- cold-started cycles NMHC and THC > hot-started
- cold-started cycles PM ~ hot-started
- cold-started WLTC similar to EDC (NMHC, PM)
- hot-started WLTC «seems» < EDC for 1 vehicle (NMHC)

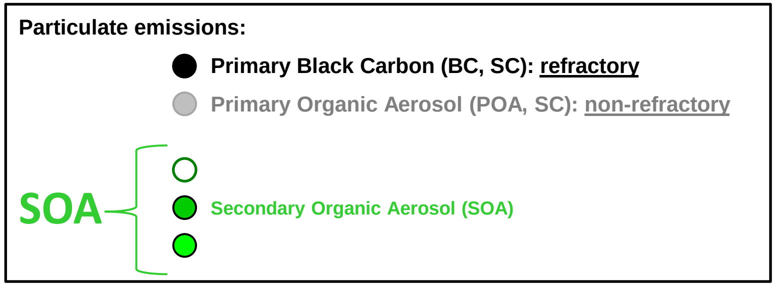
- GDI4 is a «Euro 6-alike»:
  similar HC emissions as recent Euro 6 results:
  - NMHC significantly reduced during cold-started cycles (factor 3), but no difference during hot-started cycles.
  - Gravimetric primary PM not reduced!

- GPF and catGPF:
  - No influence on NMHC and THC emission factors
  - Significant reduction in particulate matter!

=> How about secondary organic aerosol (SOA)?

GDI emissions: cold vs hot, standard vs GPF



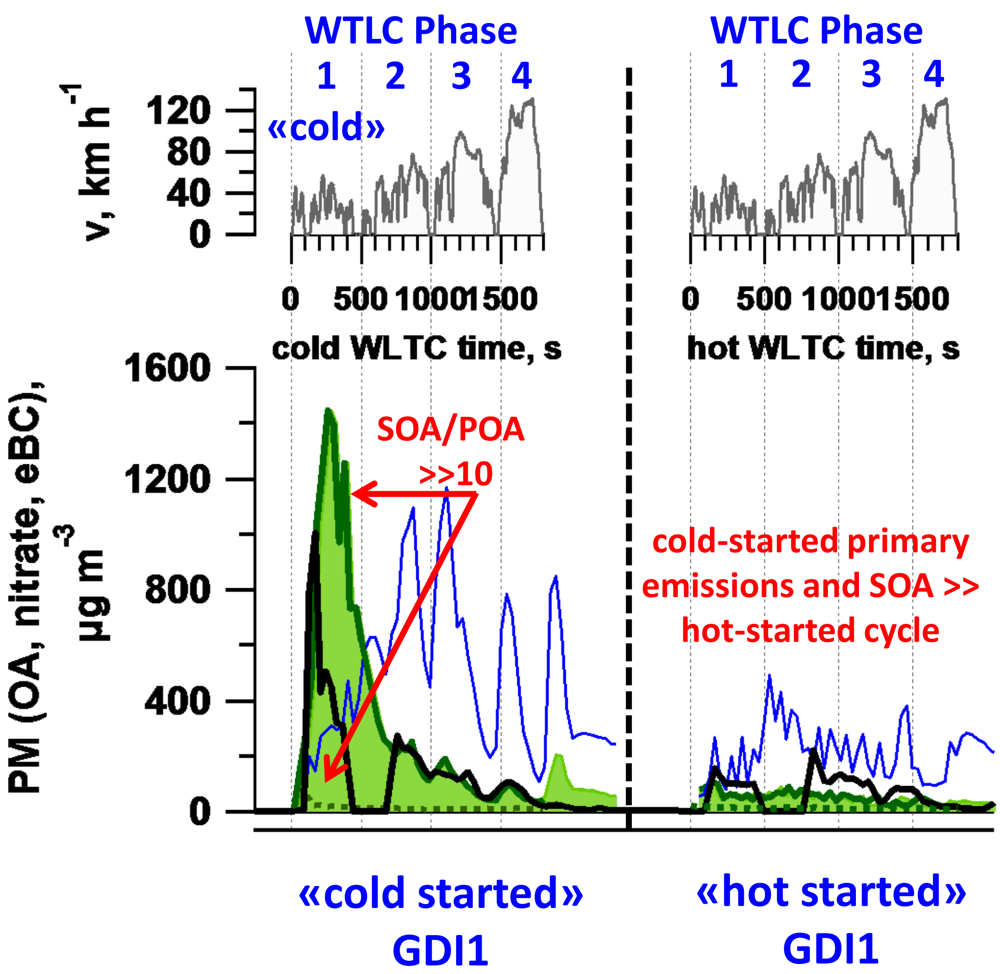


Conclusions:

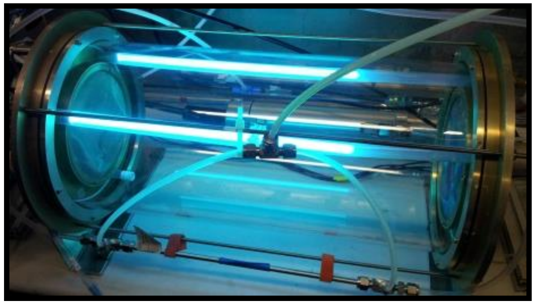
- **Refractory PM (Black Carbon) >> Non-refractory primary POA** (primary PM dominated by Black Carbon (also «Elemental Carbon»).
- **GDI4 («Euro 6»-alike):**
  - no reduction in BC or POA compared to GDI1-3
  - SOA reduced in analogy to reduced NMHC emissions!
- **GPF and catGPF:**
  - Significant reduction in refractory PM (Black carbon)!
  - No reduction in POA (gaseous when passing GPF)
  - No influence on SOA (gaseous precursor pass by the GPF)

=> Which driving/engine condition is causing the SOA formation?

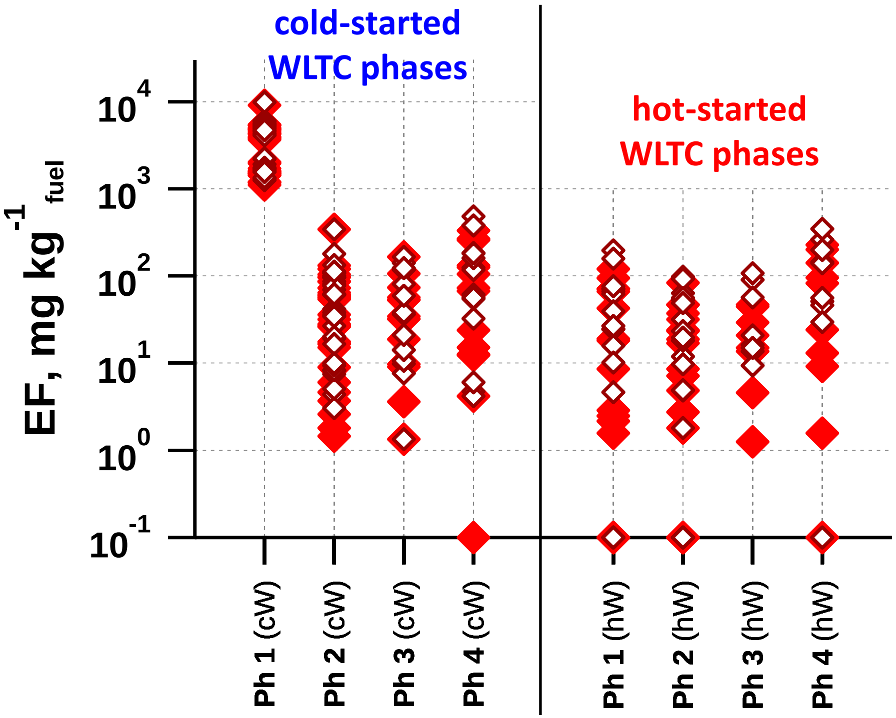
Time-resolved SOA as function of WLTC



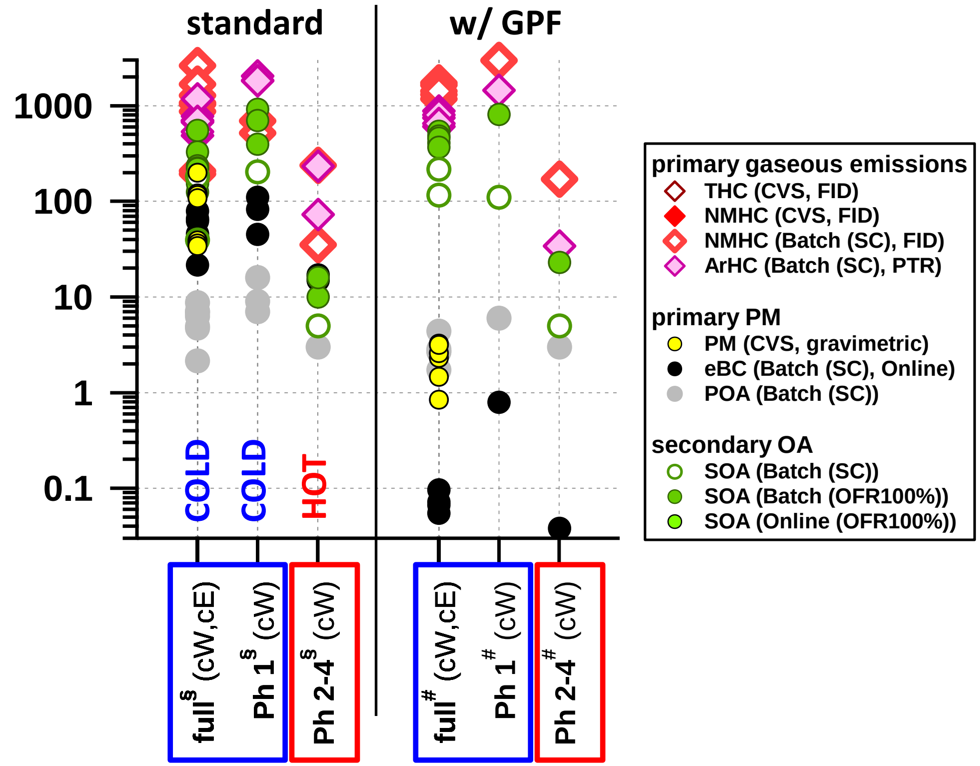
OFR



GDI emissions as function of test cycle phase (i.e. driving behavior and engine condition)



cold-started (cW) vs hot-started (hW) WLTC (GDI1-4)

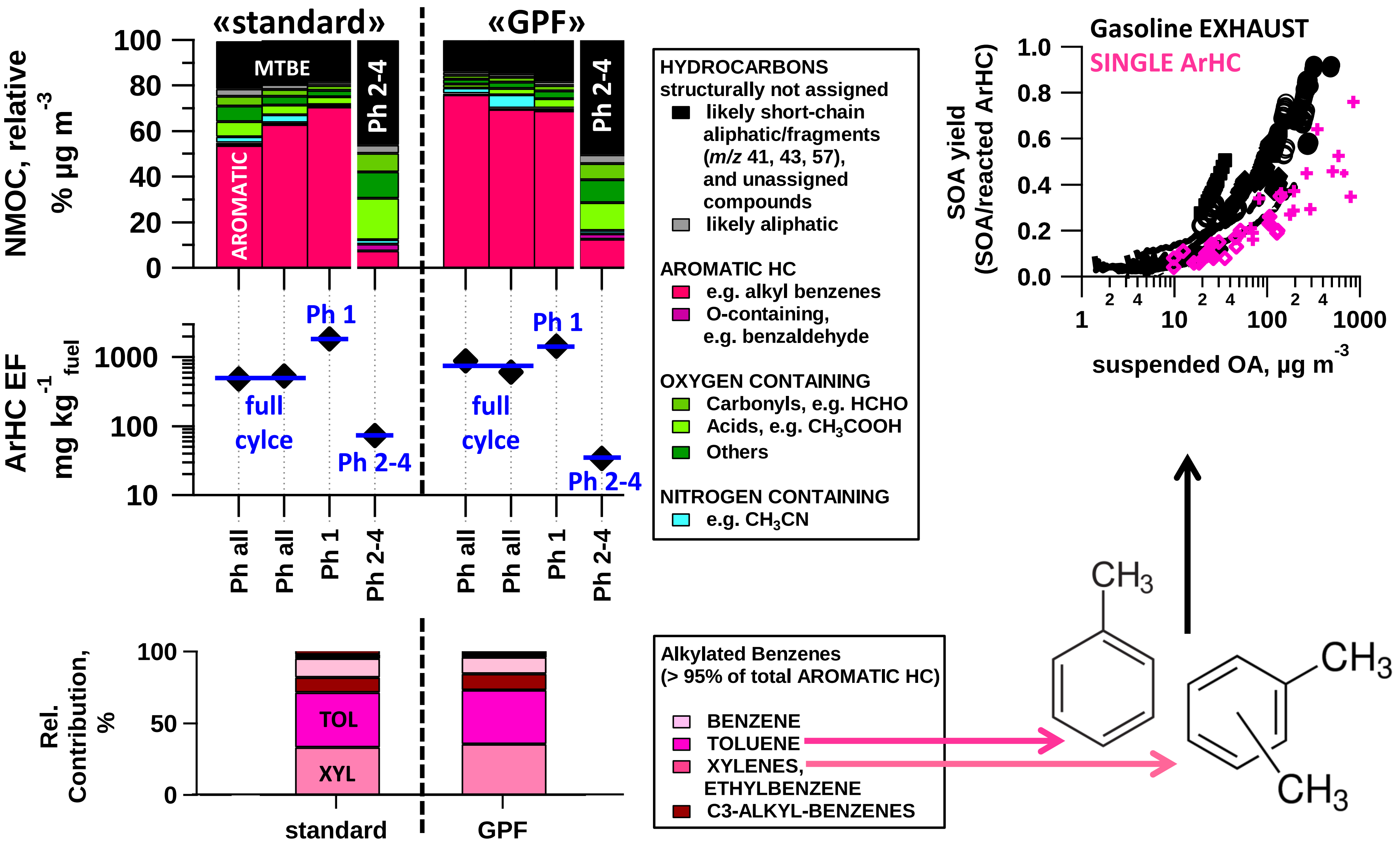


§GDI1-3 standard vs #GDI1 w/GPF cold-started WLTC (cW) and EDC (cE)

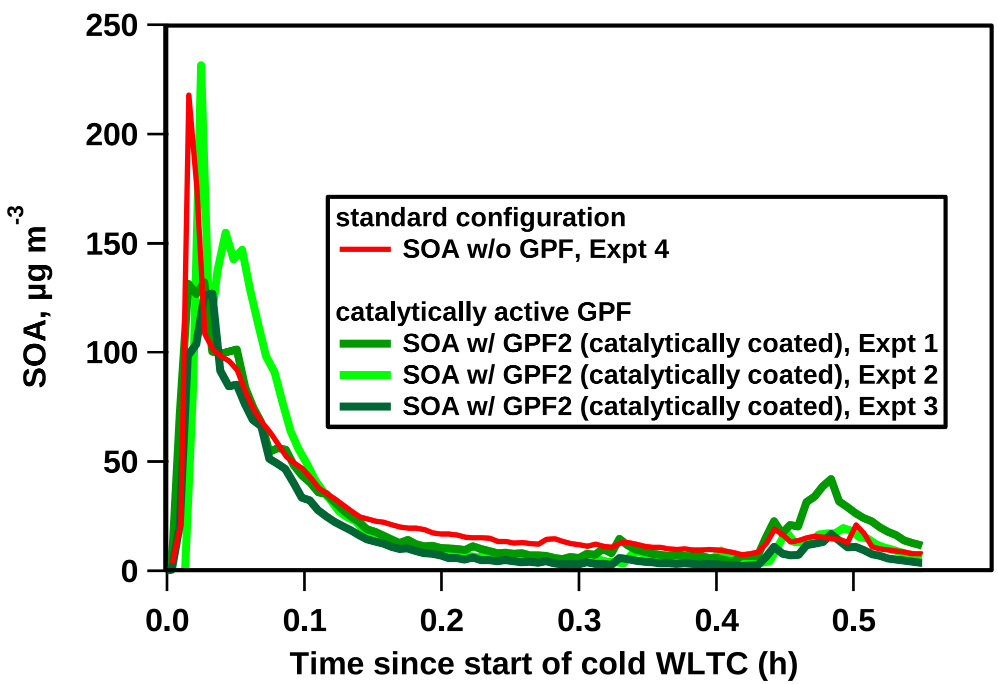
Cold-started emissions (especially engine start-up) dominate the total emissions over the driving cycle!

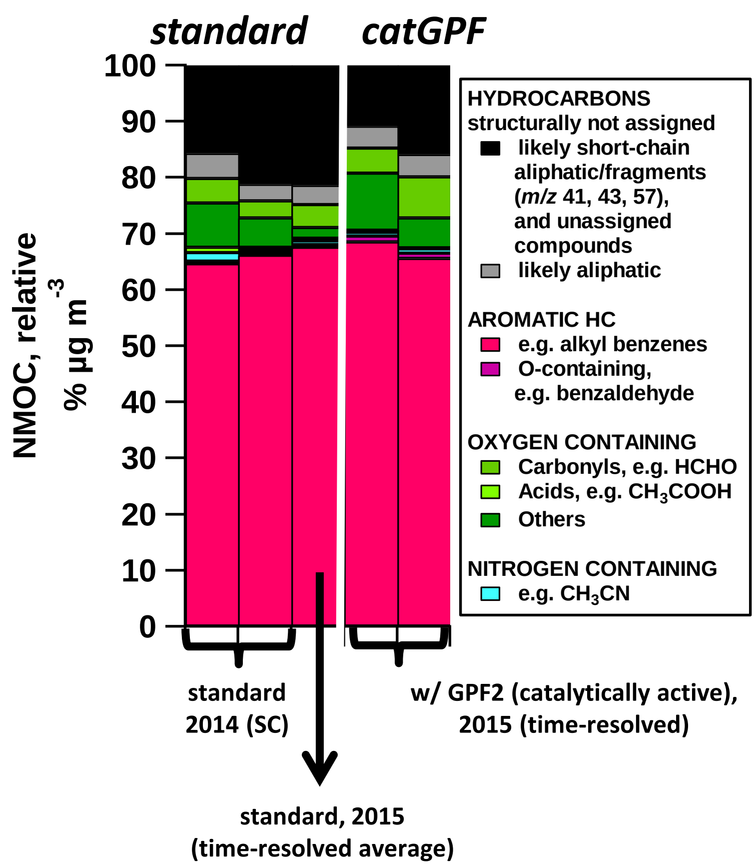
=> Are aromatic hydrocarbons important precursors for SOA under those conditions?

Cold-start and GPF influence on NMOC



Catalytically coated GPF does not influence NMOCs and SOA either.





Conclusions

- DOC/DPF: very effective for BC, POA
- Modern diesel SOA is low (precursors are removed by after-treatment system)
- GDI technology moves LDV exhaust towards higher BC emissions;
  SOA a big contributor too
- GPFs can significantly reduce BC and hence total PM emissions (high BC/POA)
- (Retrofitted) GPF (catalytically coated or uncoated) does not influence the NMOC fraction, SOA precursors and SOA
  - most SOA precursors are emitted when after-treatment system is cold
  - only few aromatic compounds appear dominant
- Cold-start effect remains an issue also with (cat)GPF!
  - Lower light-off temperatures for catalytic converters, hydrocarbon traps for extremely volatile material (monocyclic aromatics), or aromatic-free fuel are needed in addition to GPFs.
  - Speciated NMOC fraction needs attention in regulatory testing!
  - Euro6 might already solve parts of the NMHC issue, but more work is needed!

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Thank you!

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Confederaziun svizra

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Ufficio federale dell'ambiente UFAM
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References:

Pieber et al., (in preparation), 2017
Platt et al., (accpeted), 2017

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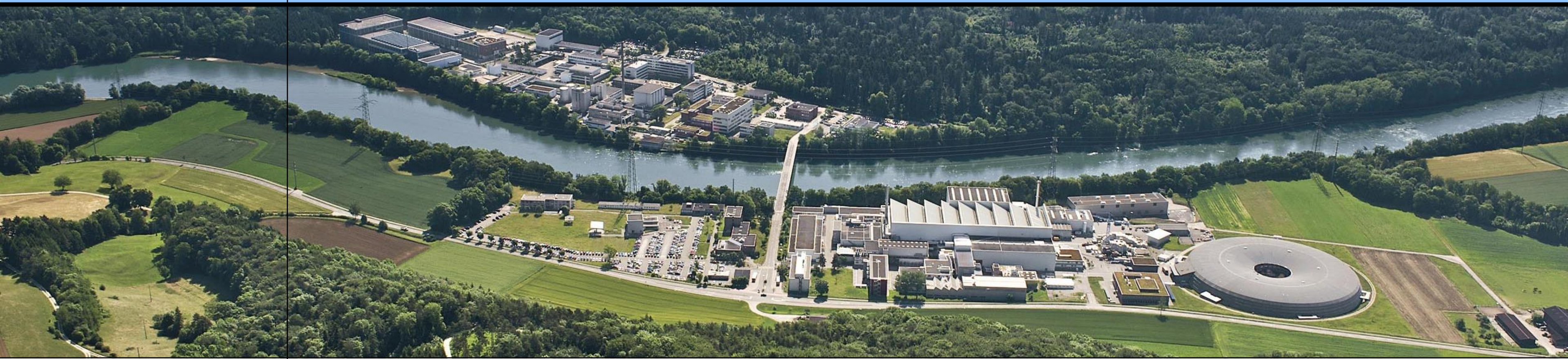

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QUESTIONS?

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