PAUL SCHERRER INSTITUT

Wir schaffen Wissen – heute für morgen

Emissions from HFO combustion in a ship research engine and associated secondary organic aerosol formation potential

Imad El Haddad – Paul Scherrer Institut

Zurich, 30 June 2015

Ship emissions overview

⇒ **Maritime transport globally important:**
>200 Mio Tons of fuel per year

(21% of the total global fuel consumption)

⇒ **Substantial contribution anthropogenic PM:**
coastal regions up to 50%, but little is known

⇒ **No stringent regulations:**

→ **Heavy fuel oil (HFO):**

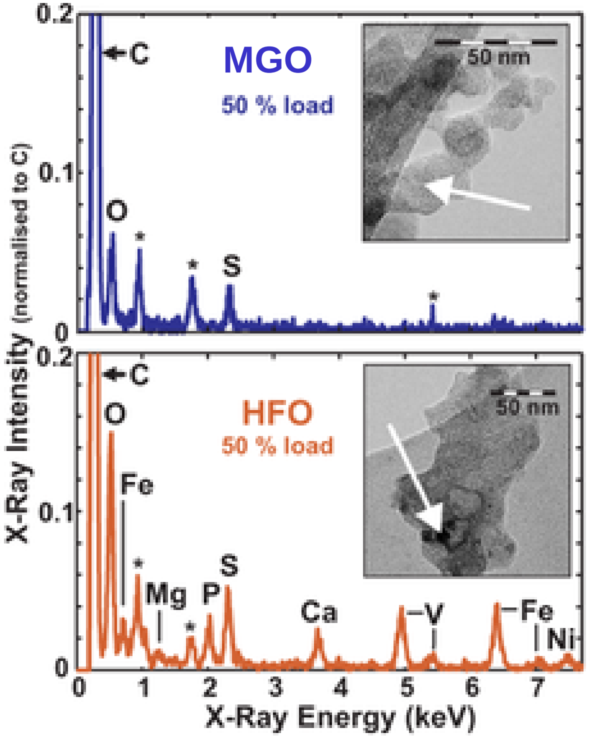
used mainly on open ocean (170 Mio. Tons)
high sulfur content (limit 3.5%)

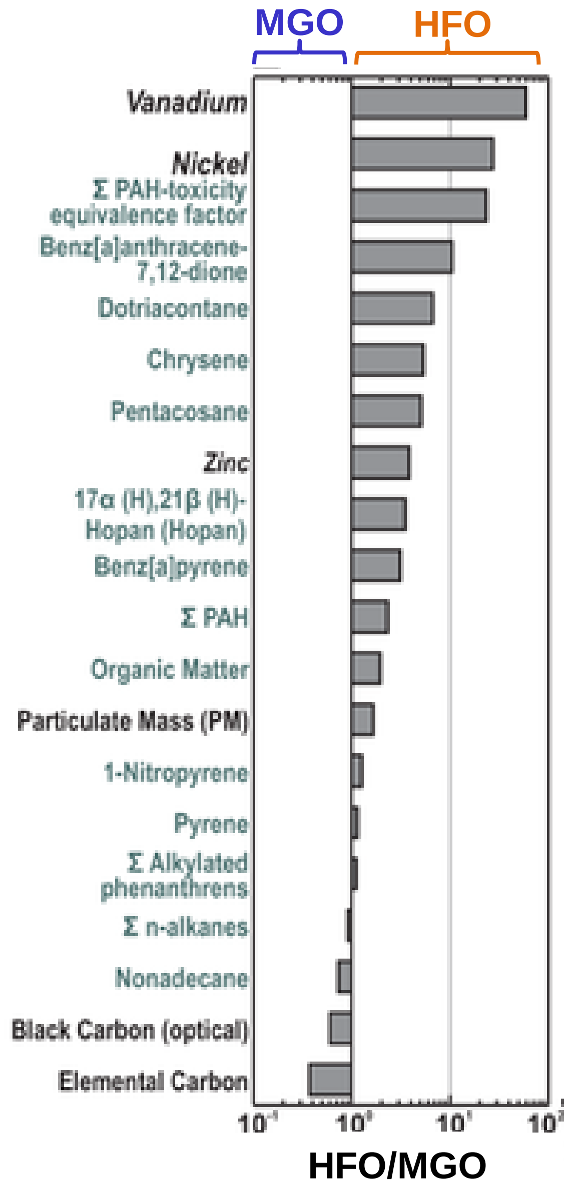
→ **Marine gas oil (MGO):**

used in controlled areas/harbors (43 Mio. Tons)
less viscous low sulfur content (limit 1%)

Ship emissions overview

Oeder et al., PlosOne 2015



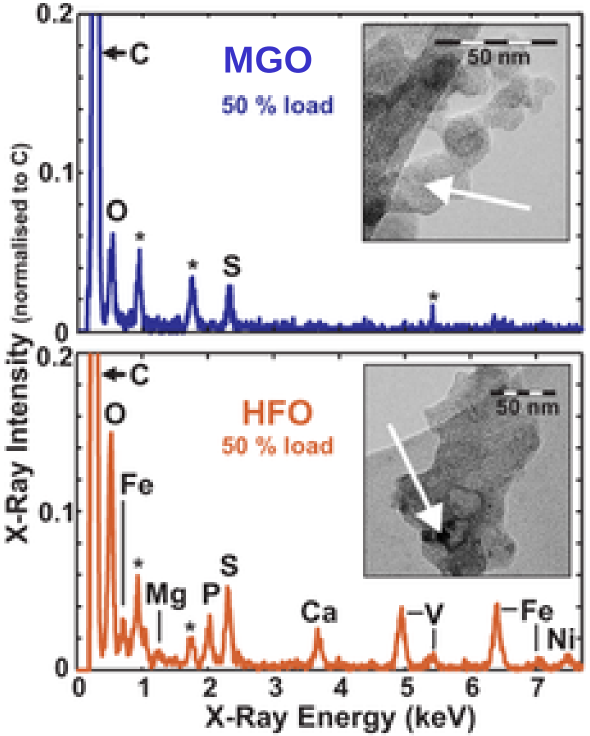


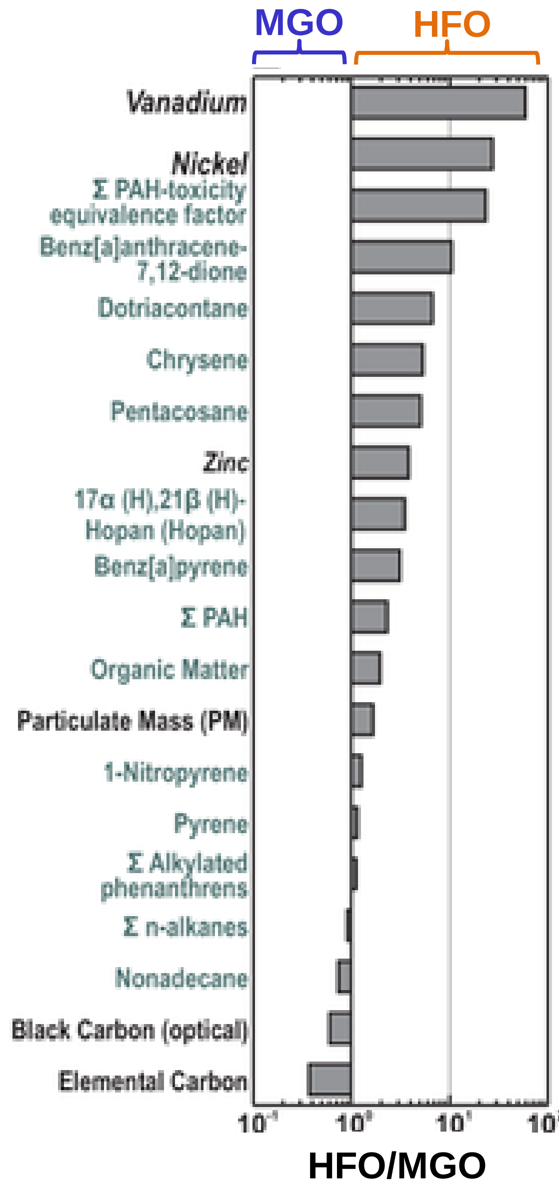
HFO emissions: heavy metals and PAHs

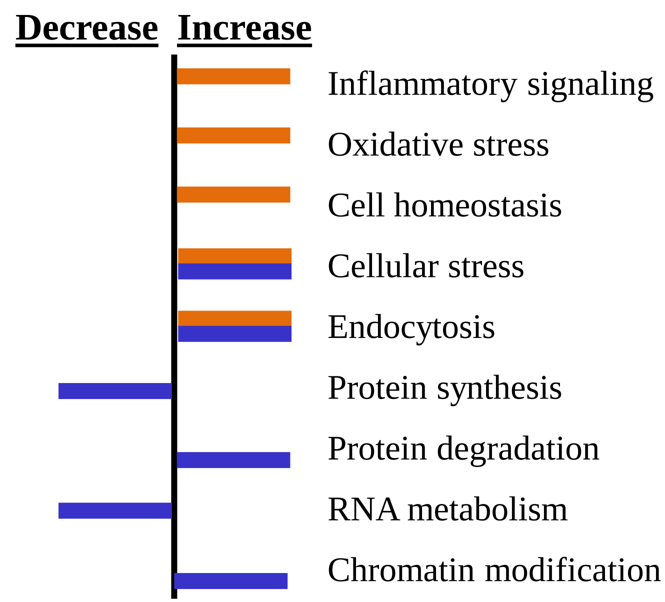
MGO emissions: elemental carbon (soot)

Ship emissions overview

Oeder et al., PlosOne 2015







HFO emissions: heavy metals and PAHs

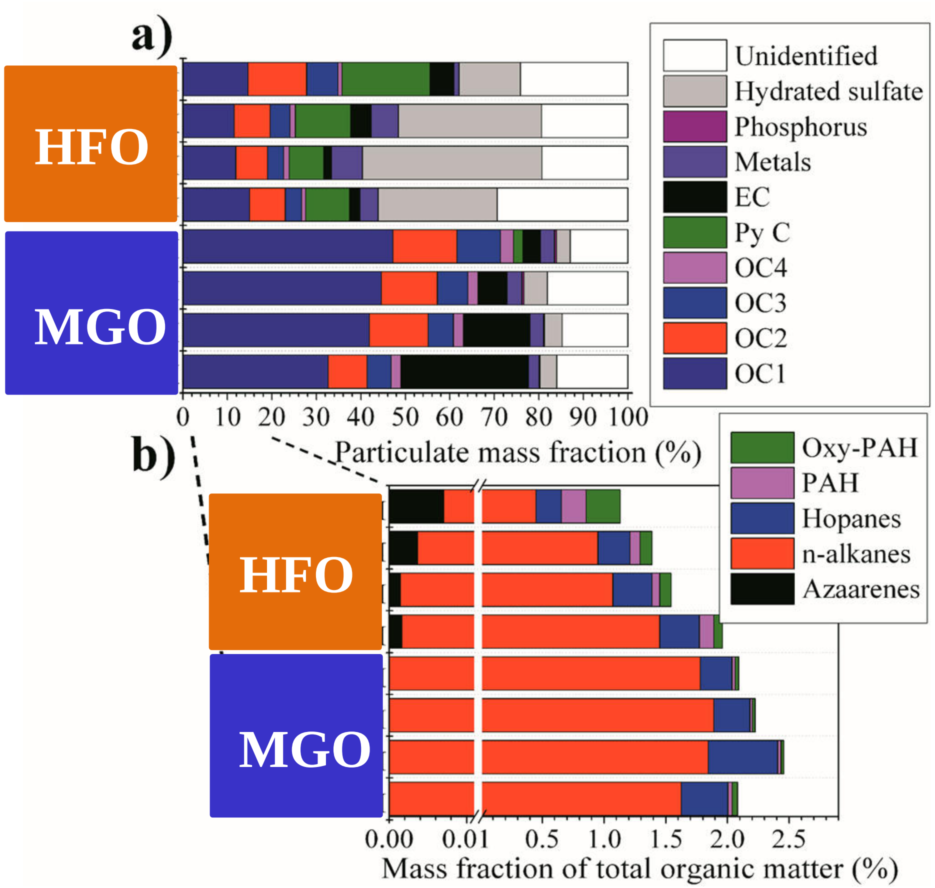
MGO emissions: elemental carbon (soot)

HFO emissions: induce oxidative stress and inflammatory reactions

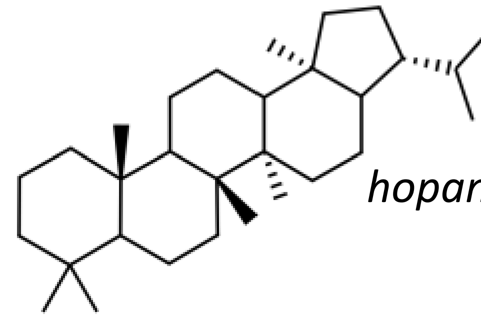
MGO emissions: genotoxic; affect protein synthesis and mitosis

Ship emissions overview

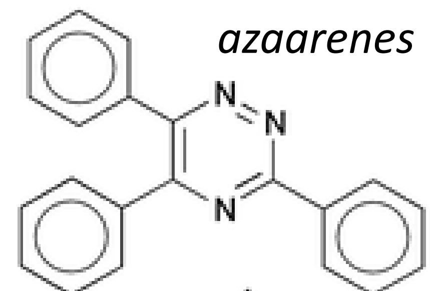
Sippula et al., EST, 2014



hopanes



azaarenes



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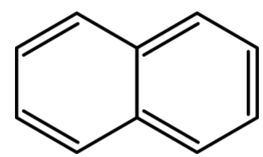
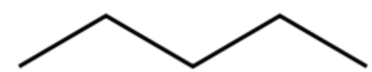
PAHs



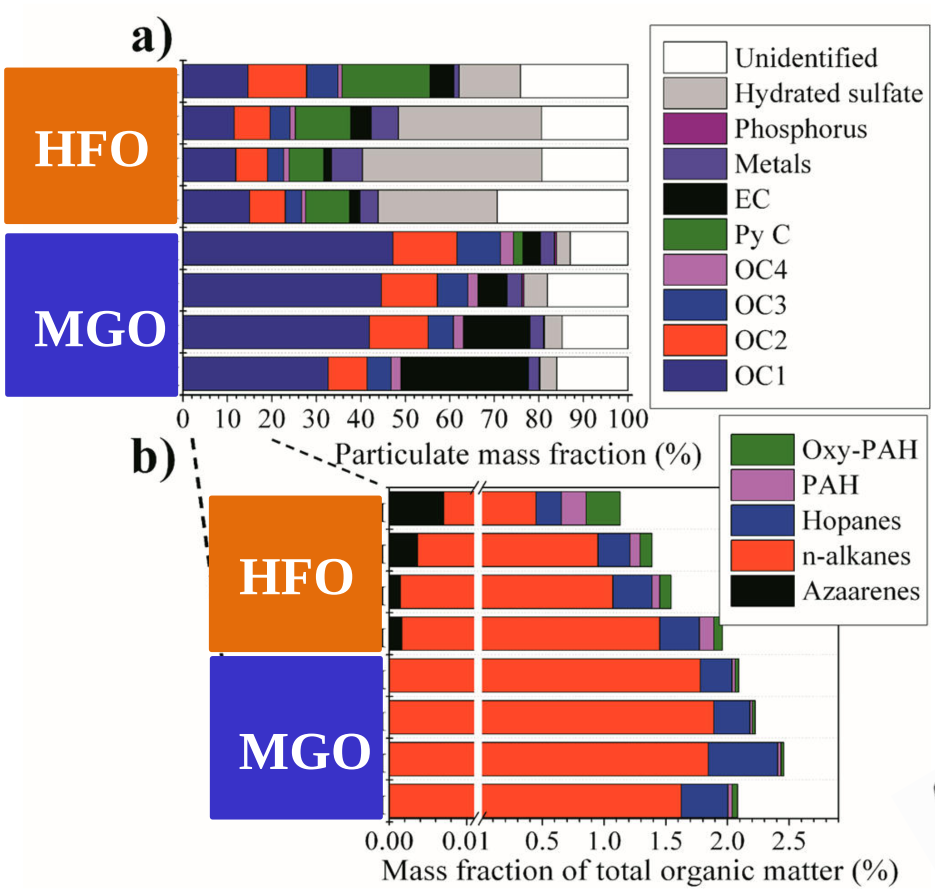
alkanes

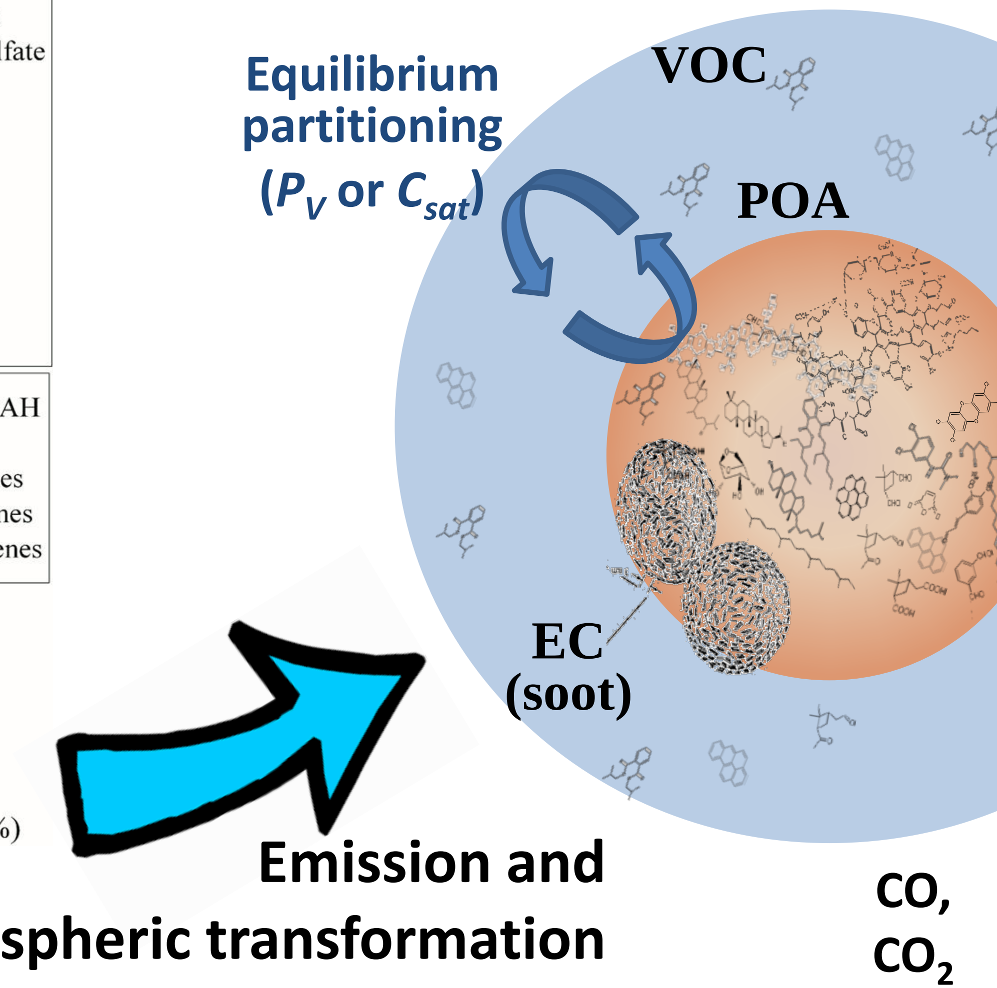


Only a minor fraction of the organic aerosol emissions is identified…

Ship emissions overview

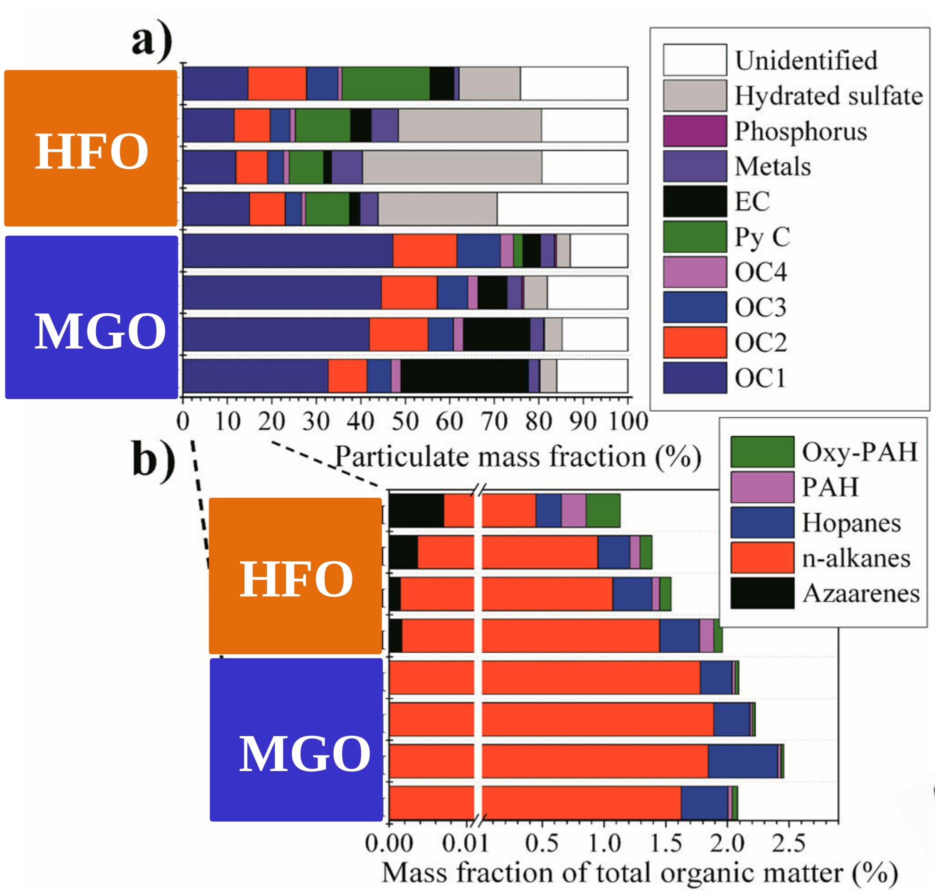
Sippula et al., EST, 2014

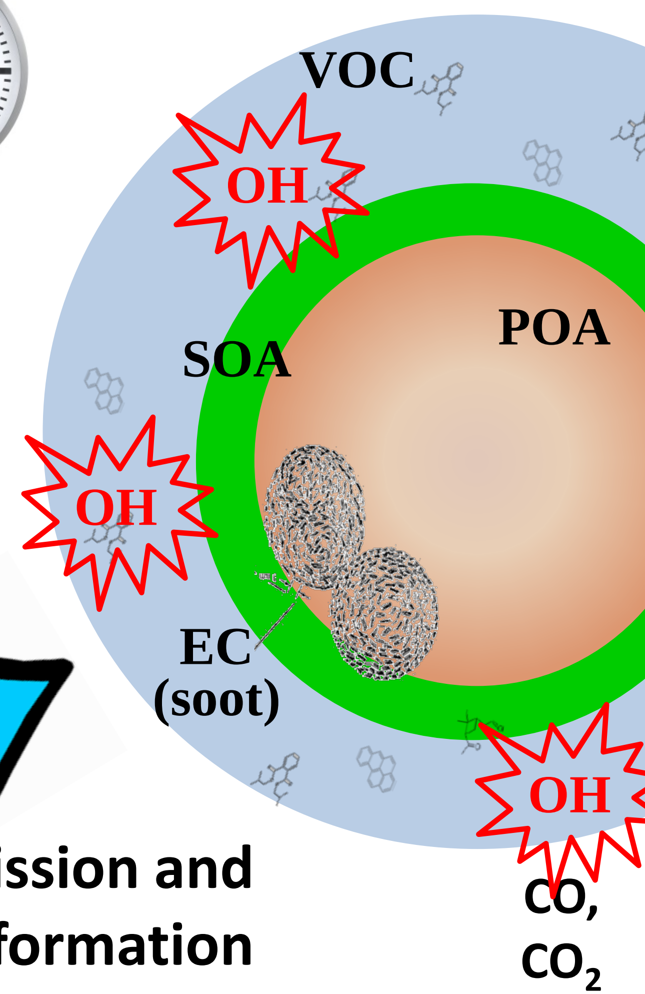




Ship emissions overview

Sippula et al., EST, 2014



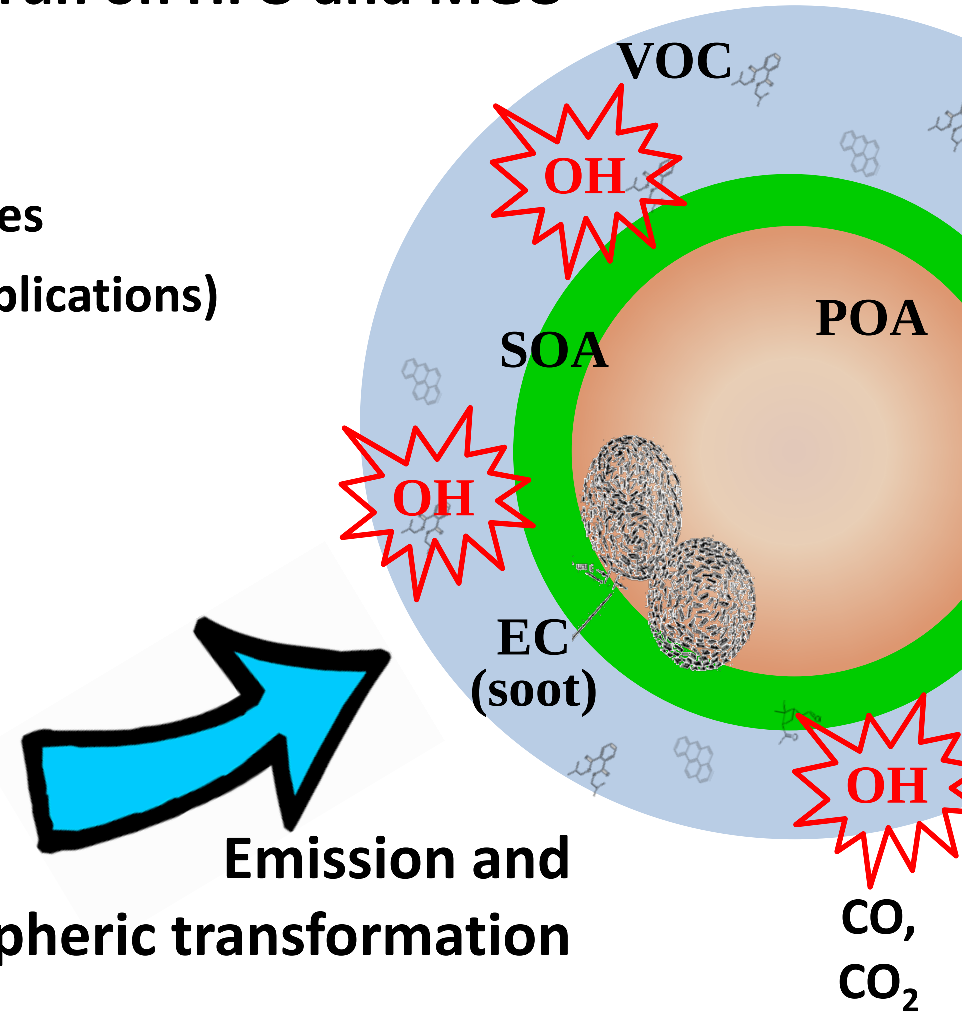


Emission and atmospheric transformation

Objectives

Study emissions from ship engines run on HFO and MGO

- ⇒ **Volatility and partitioning**
- ⇒ **Reaction rates and atmospheric lifetimes**
- ⇒ **SOA potential (possibly with health implications)**



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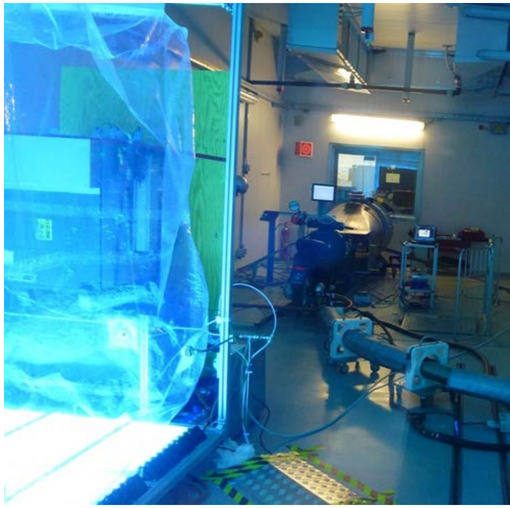
Emission measurements at PSI

LABOR FÜR ATMOSPHÄREN-CHEMIE

Mobile chamber



Cool chamber (down to -20°C)

PAM (fast aging)

Platt et al., 2013; Bruns et al., 2014

Biomass burning

Bruns et al., 2014

Cooking

El Haddad et al., in prep;
Klein et al., in prep

Road vehicles

Platt et al., 2013, 2014; Zardini et al., 2014

Aircraft engines

Biogenic emissions

Ship engines

Project overview: WOOSHI

Pieber et al., in prep

PAUL SCHERRER INSTITUT
PSI

LABOR FÜR ATMOSPHÄREN-CHEMIE

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UNIVERSITY OF CAMBRIDGE

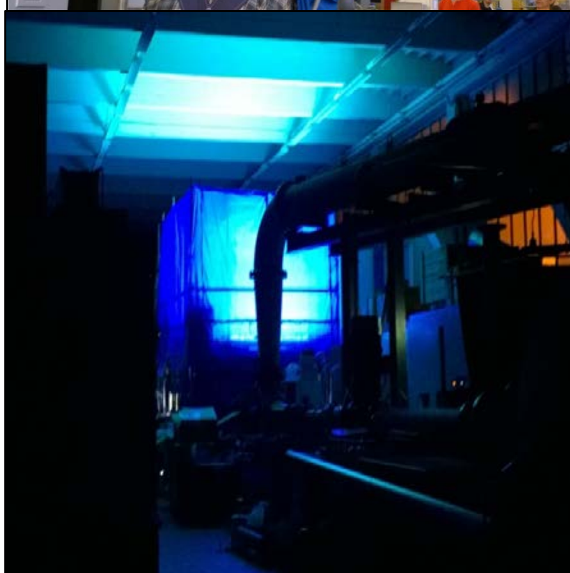
QUT

Queensland University of Technology

Carnegie Mellon University

universität innsbruck

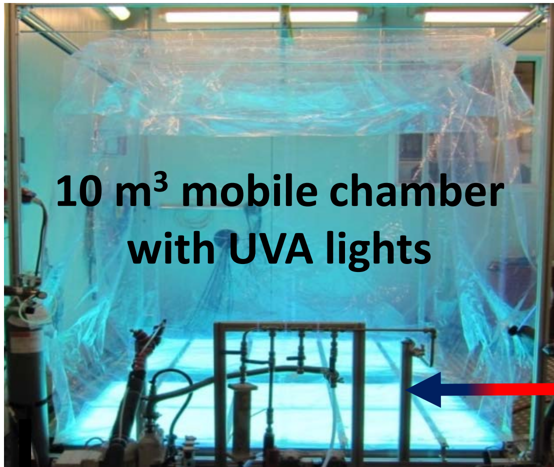
Experimental setup 1/2

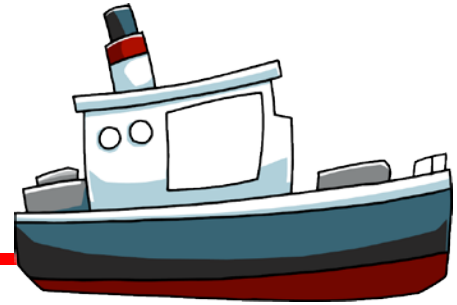


- 4-stroke single cylinder research engine
- can simulate operation of different modern engines
- operated with HFO and MGO
- operated at cruising conditions (50%)

Setup at the University of Rostock

Experimental setup 2/2





Ship engine

Dilution

Online instruments

Ejector Dilutor
(1:10) 150°C

Online gas-phase instruments
(CO2, CO, CH4, NOX, SO2, PTR-ToF-MS/VOC)

Online aerosol-phase instruments
(AMS, CHARON-PTR-ToF-MS/VOC, SMPS-APM, Aethalometer, SP2)

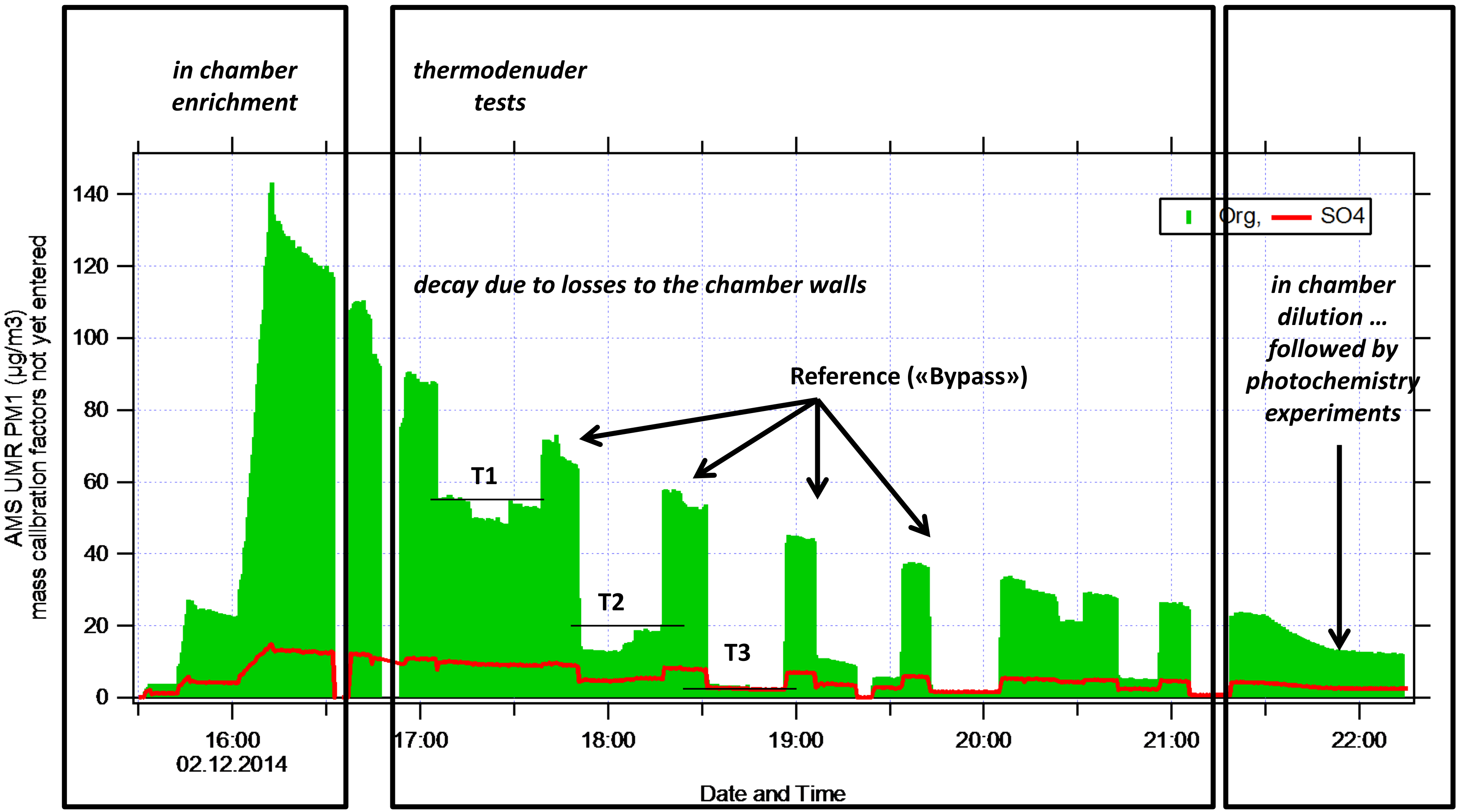
Thermodenuder

Offline samples
(Filters, sorption tubes)

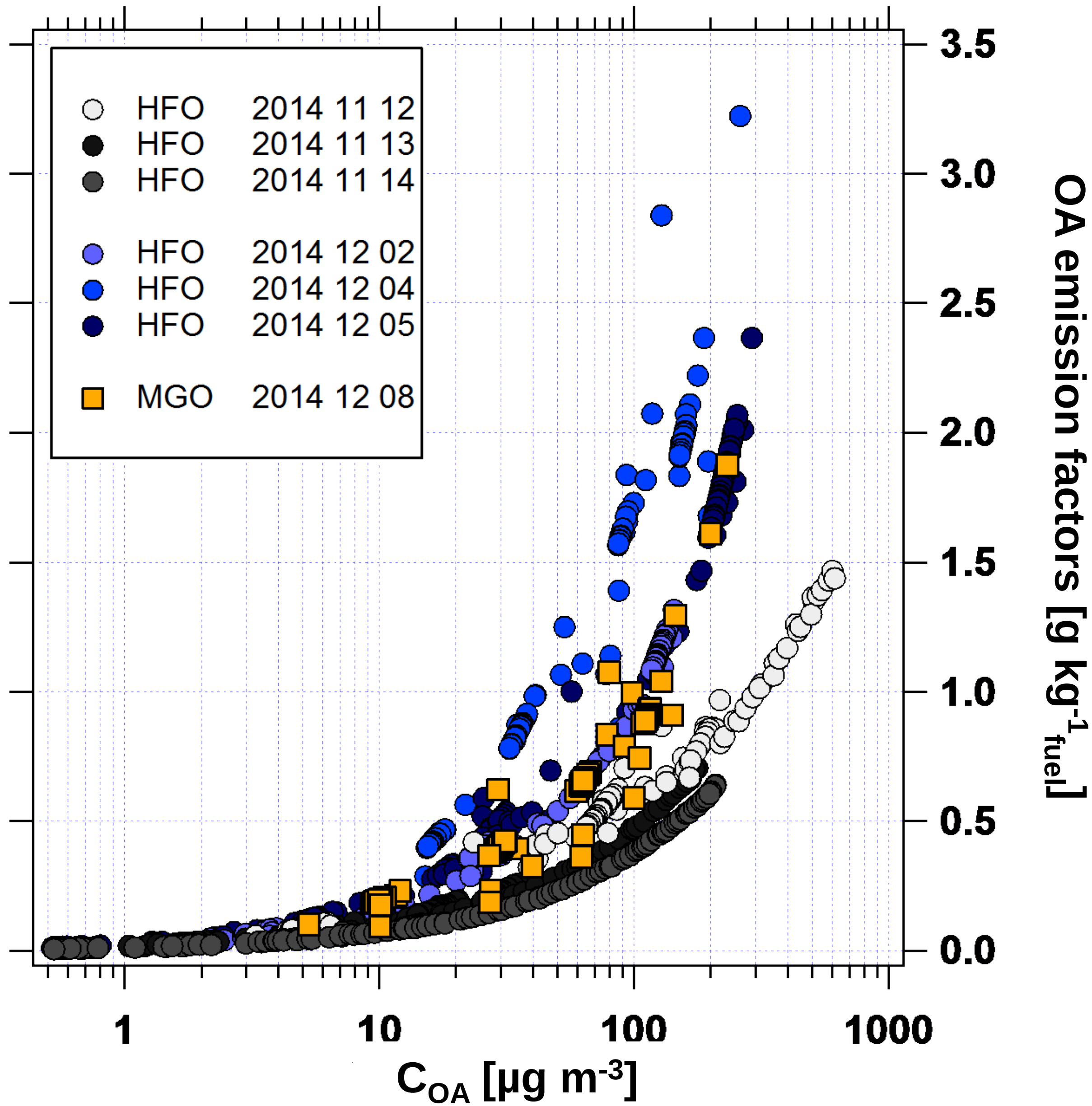
Volatility examination

(1) Dillution
(2) Heat
(3) Chemical composition

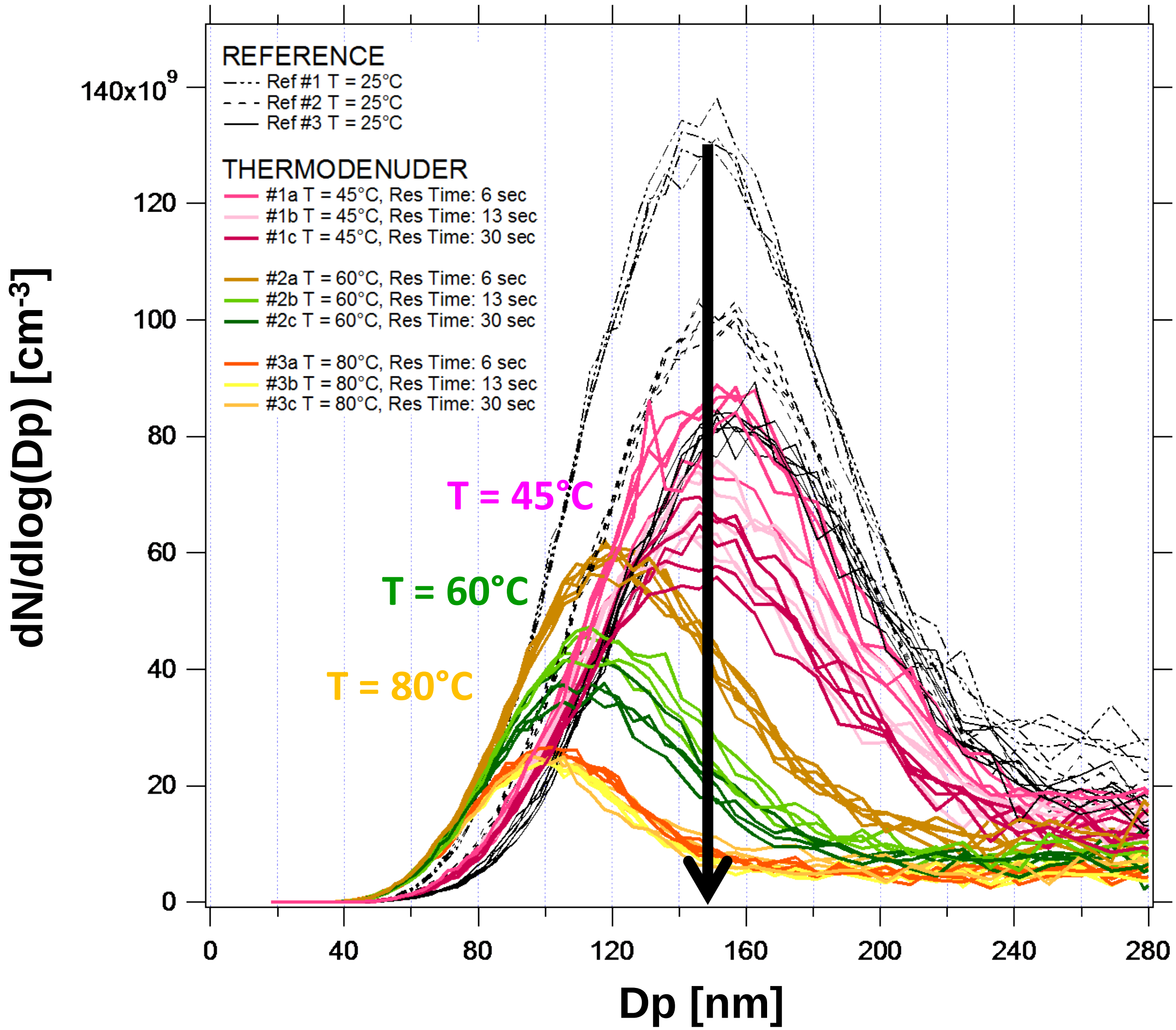
Example


in chamber enrichment
thermodenuder tests
decay due to losses to the chamber walls
in chamber dilution … followed by photochemistry experiments
Reference («Bypass»)
T1
T2
T3
Org, SO4
AMS UMR PM1 (µg/m3)
mass calibration factors not yet entered
140
120
100
80
60
40
20
0
16:00
02.12.2014
17:00
18:00
19:00
20:00
21:00
22:00
Date and Time

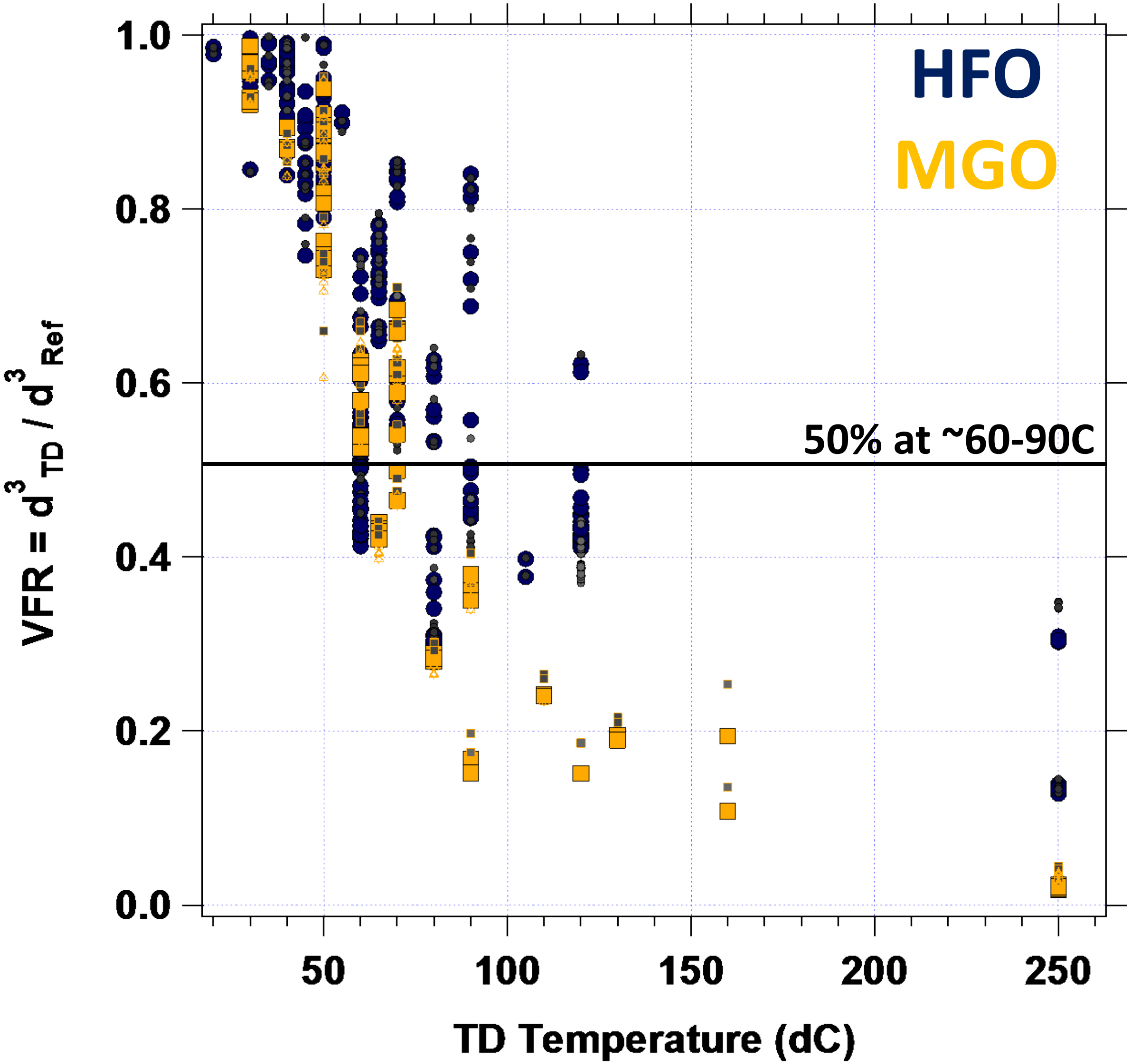
Response to dilution



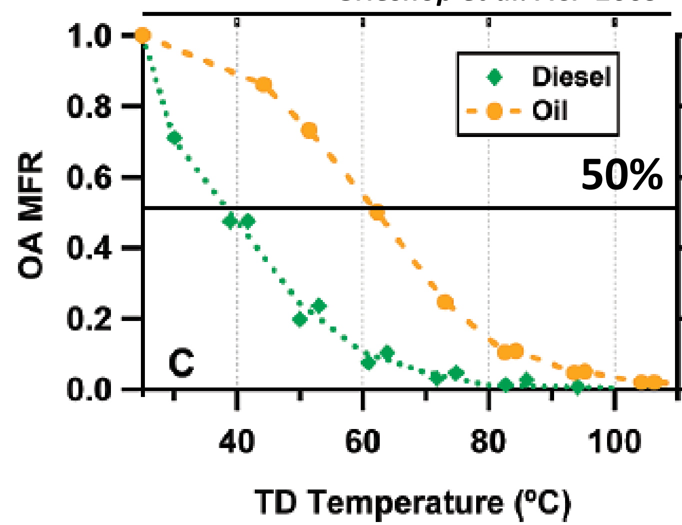
Response to heat



Response to heat



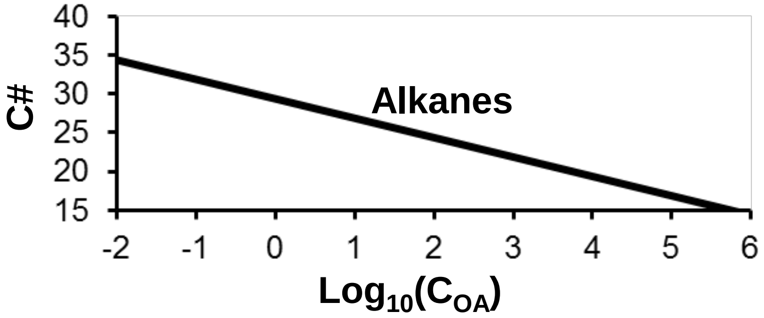
Grieshop et al. ACP 2009

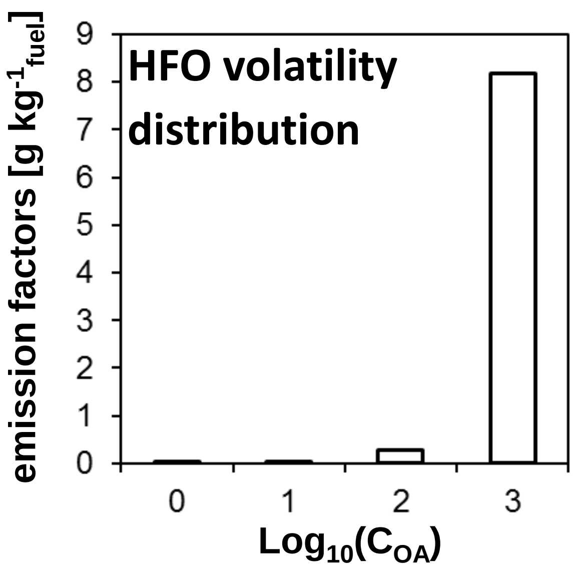


⇒ **Similar behavior as lub-oil**

⇒ **HFO less volatile than MGO**

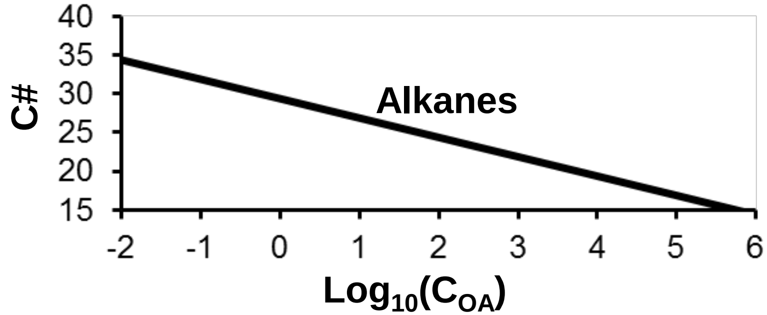
Estimated volatility and half-times

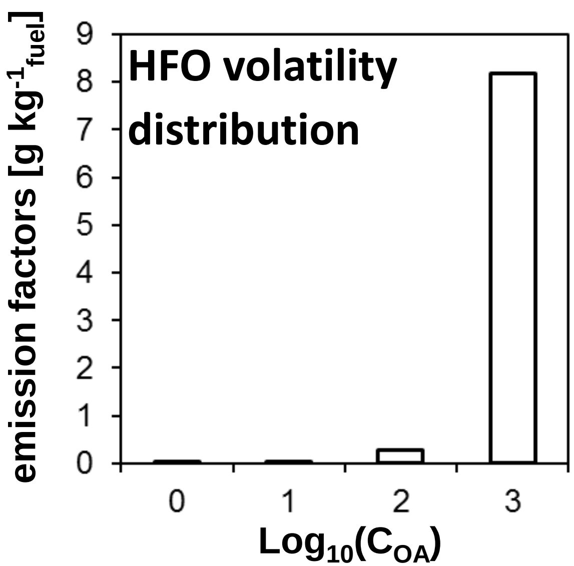


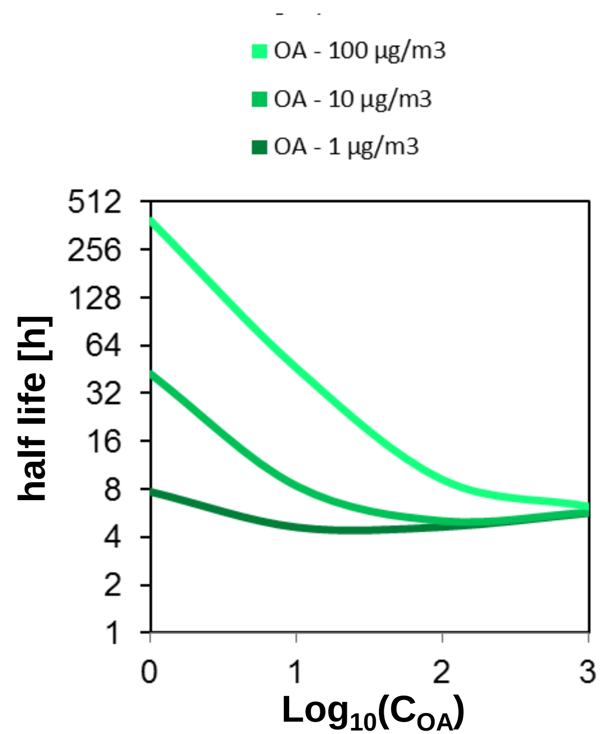


$\Rightarrow$ **Most of the compounds are estimated to be semi-volatile (consistent with C_{20}-C_{25} alkanes)**

Estimated volatility and half-times







⇒ **Most of the compounds are estimated to be semi-volatile (consistent with C_{20}-C_{25} alkanes)**

⇒ **At atmospherically relevant concentrations (1-10 µg/m³), half-lifes shorter than 1 day**