Linking tailpipe to ambient – primary emissions versus secondary PM formation

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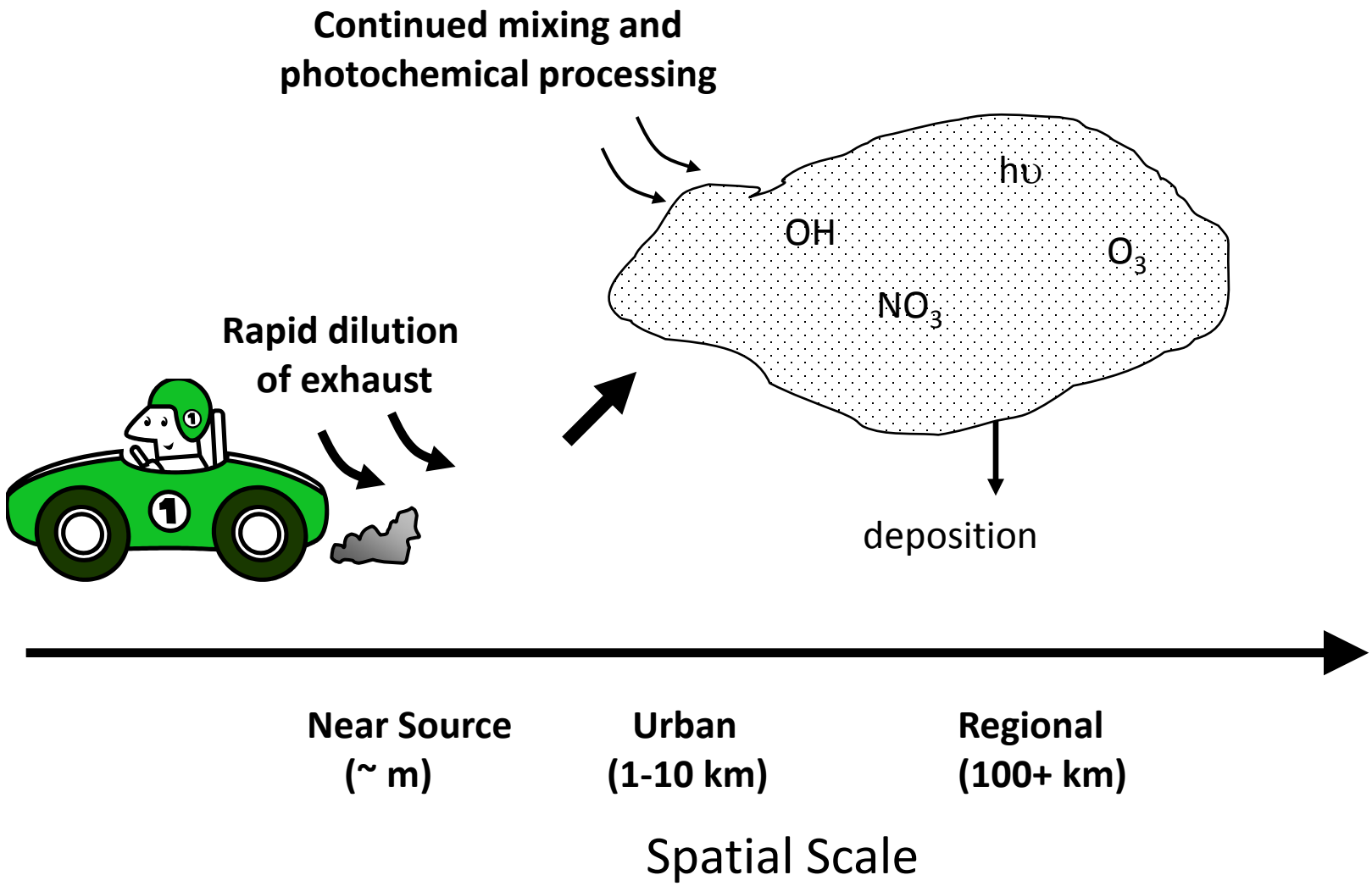
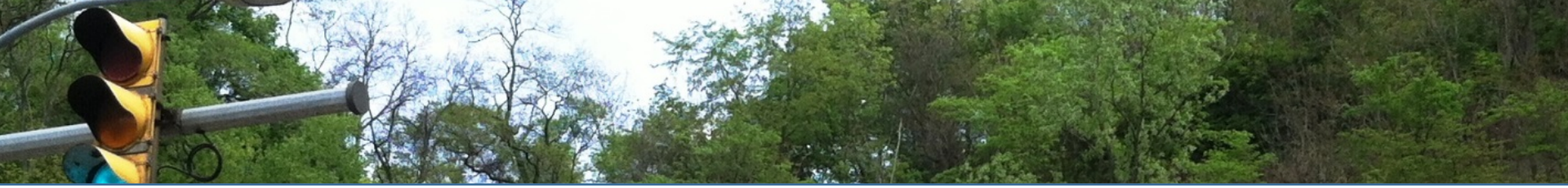
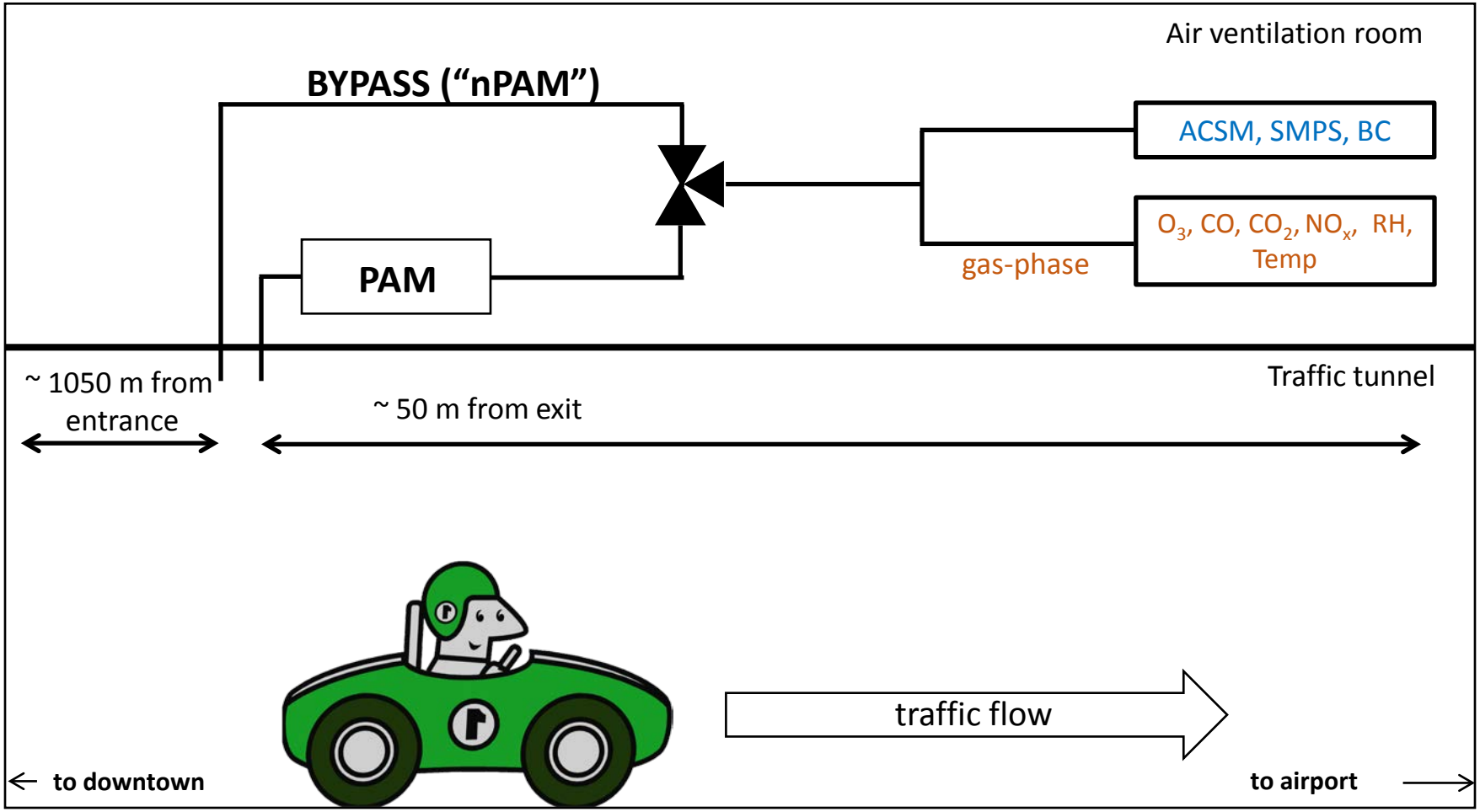
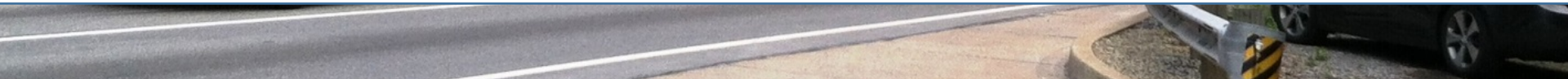
How important is secondary PM production?



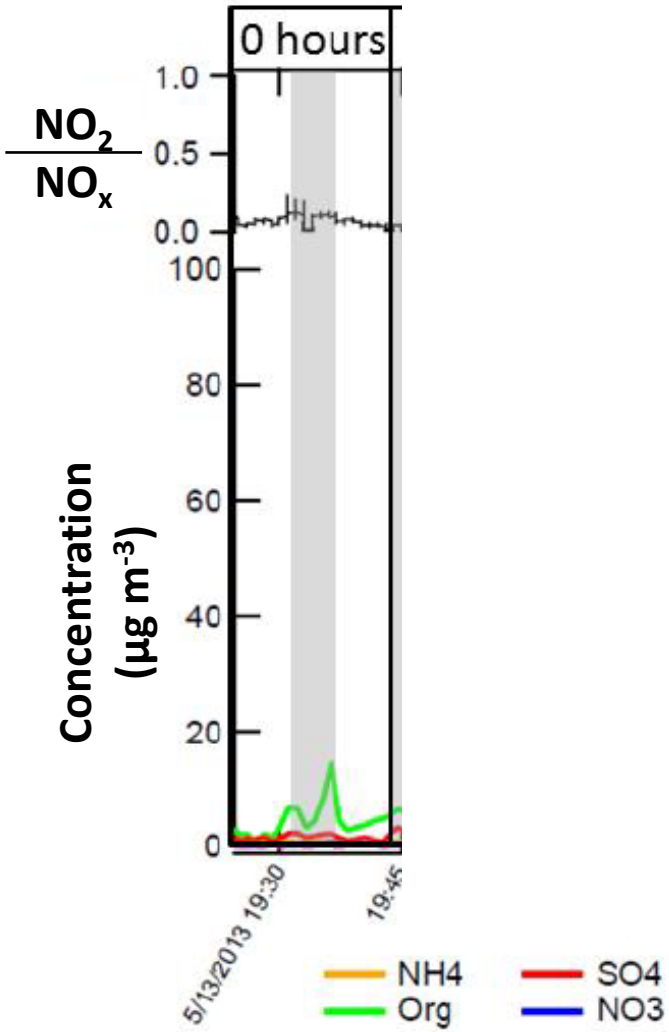
FORT PITT TUNNEL
STAY IN LANE
EAST
376
MILE
69
.0
STAY IN LANE
DO NOT CROSS CENTER




Air ventilation room
BYPASS ("nPAM")
ACSM, SMPS, BC
O_3, CO, CO_2, NO_x, RH, Temp
gas-phase
PAM
Traffic tunnel
~ 1050 m from entrance
~ 50 m from exit
traffic flow
to downtown
to airport



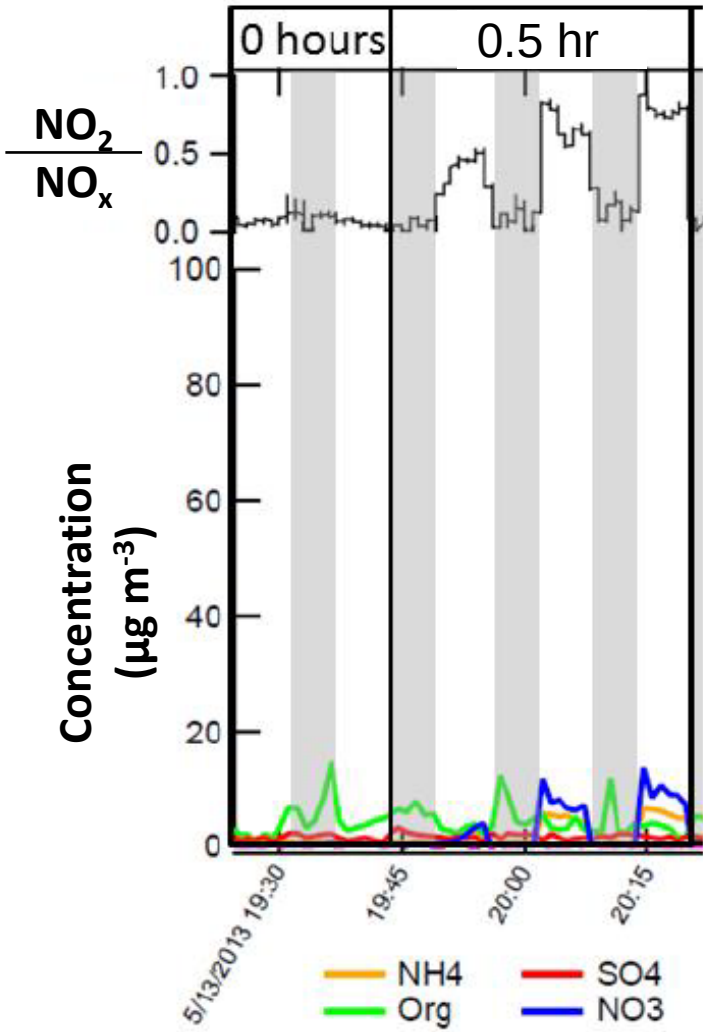
Primary Emissions



(Tkacik et al. EST 2014)

< 30 min oxidation

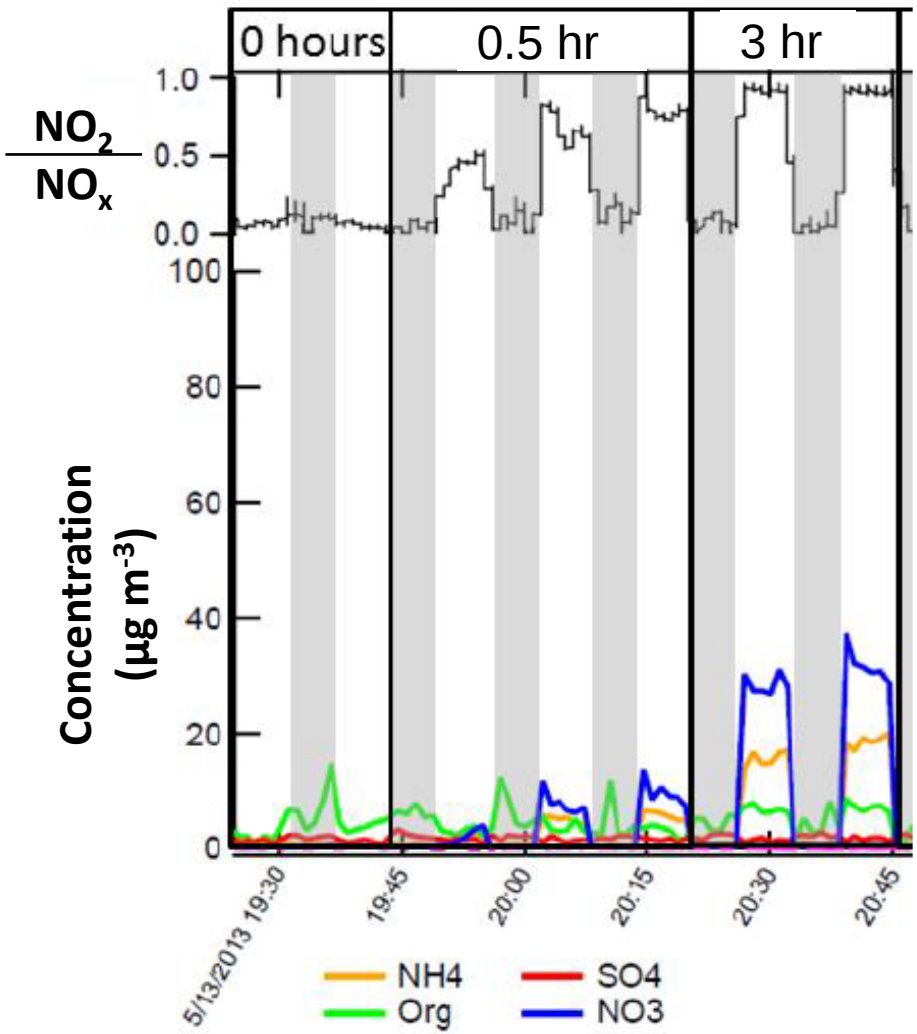
[OH] = 6 x 106 molec/cm³



(Tkacik et al. EST 2014)

Three hours of Oxidation

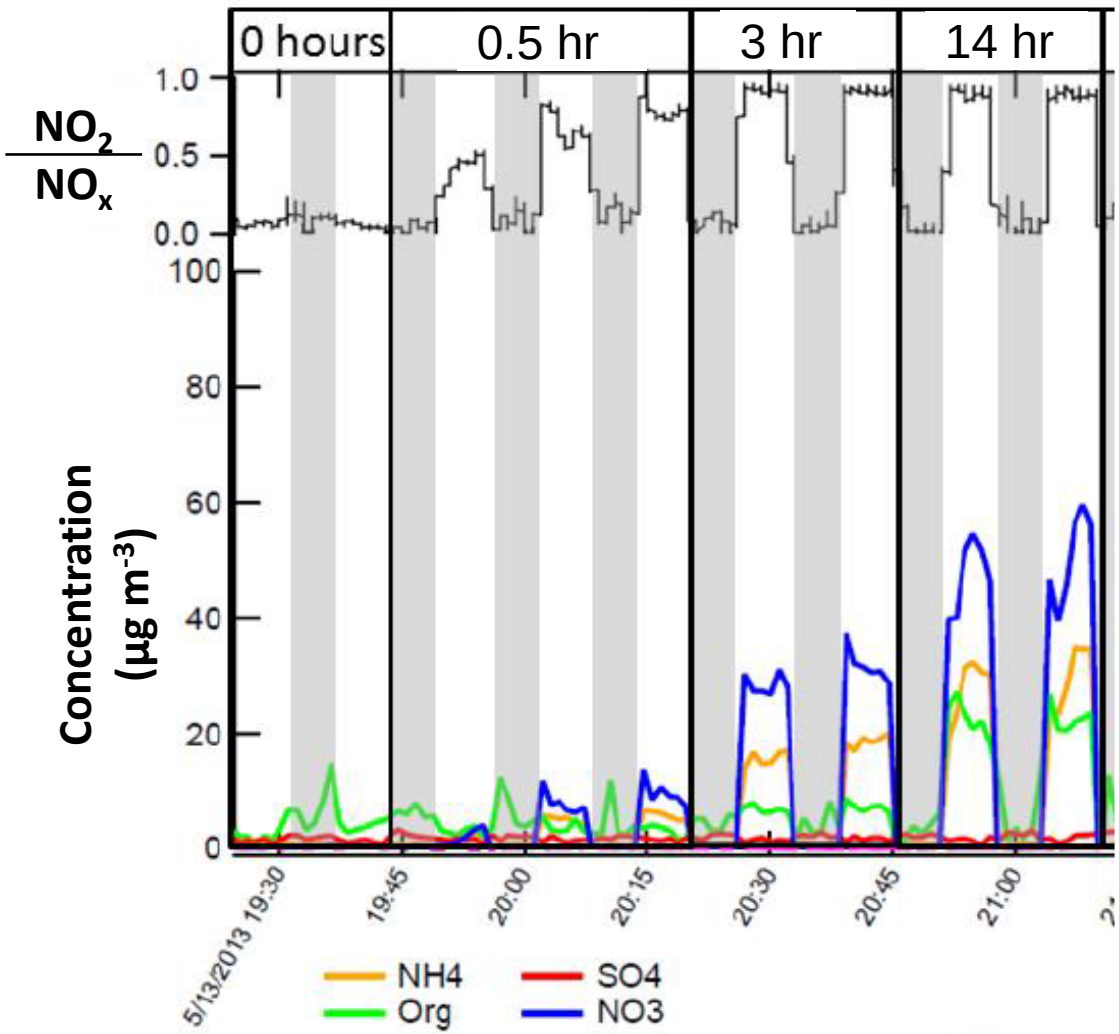
[OH] = 6 x 106 molec/cm³



(Tkacik et al. EST 2014)

Fourteen Hours of Oxidation

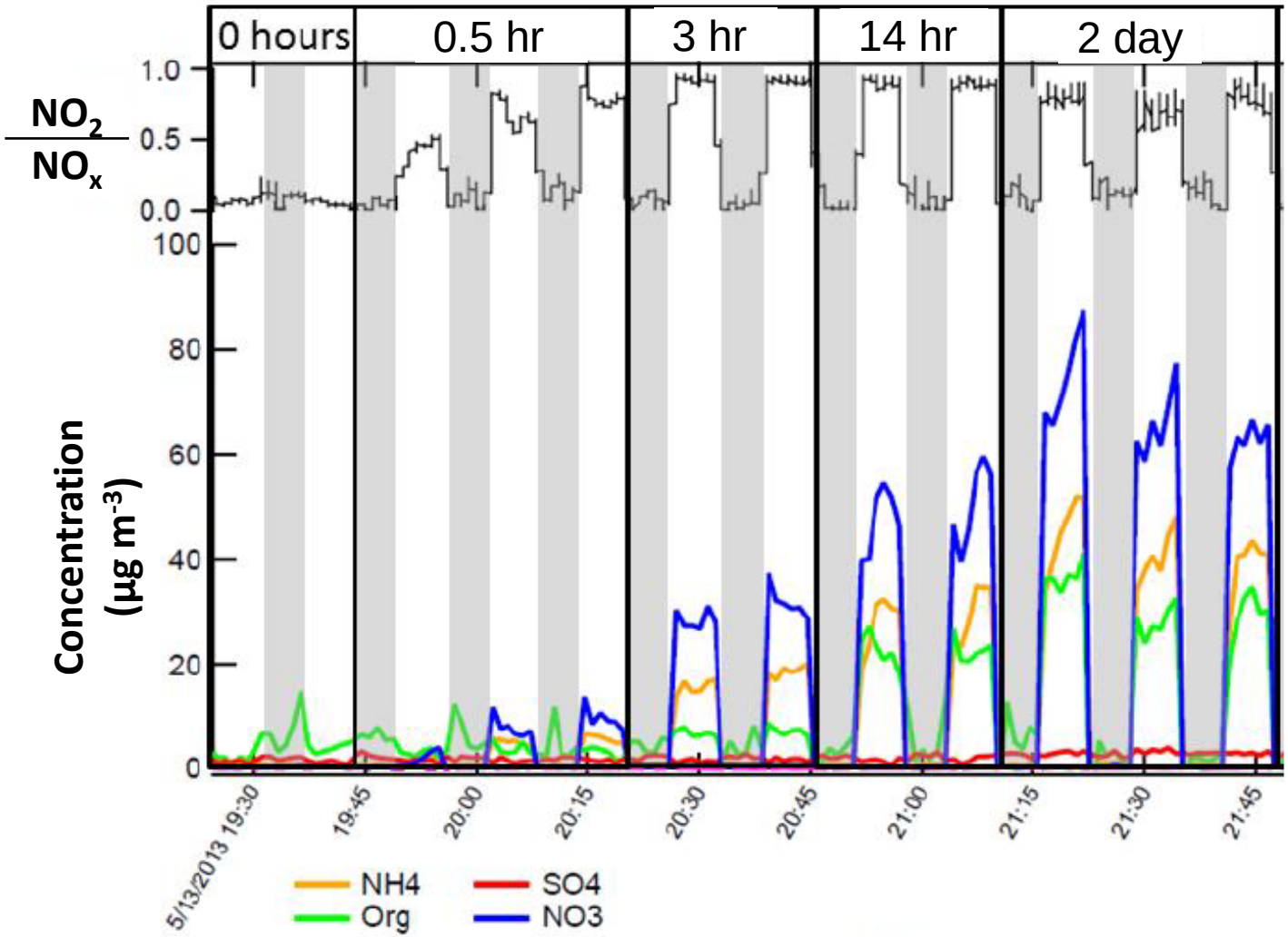
[OH] = 6 x 106 molec/cm³



(Tkacik et al. EST 2014)

Two Days of Oxidation

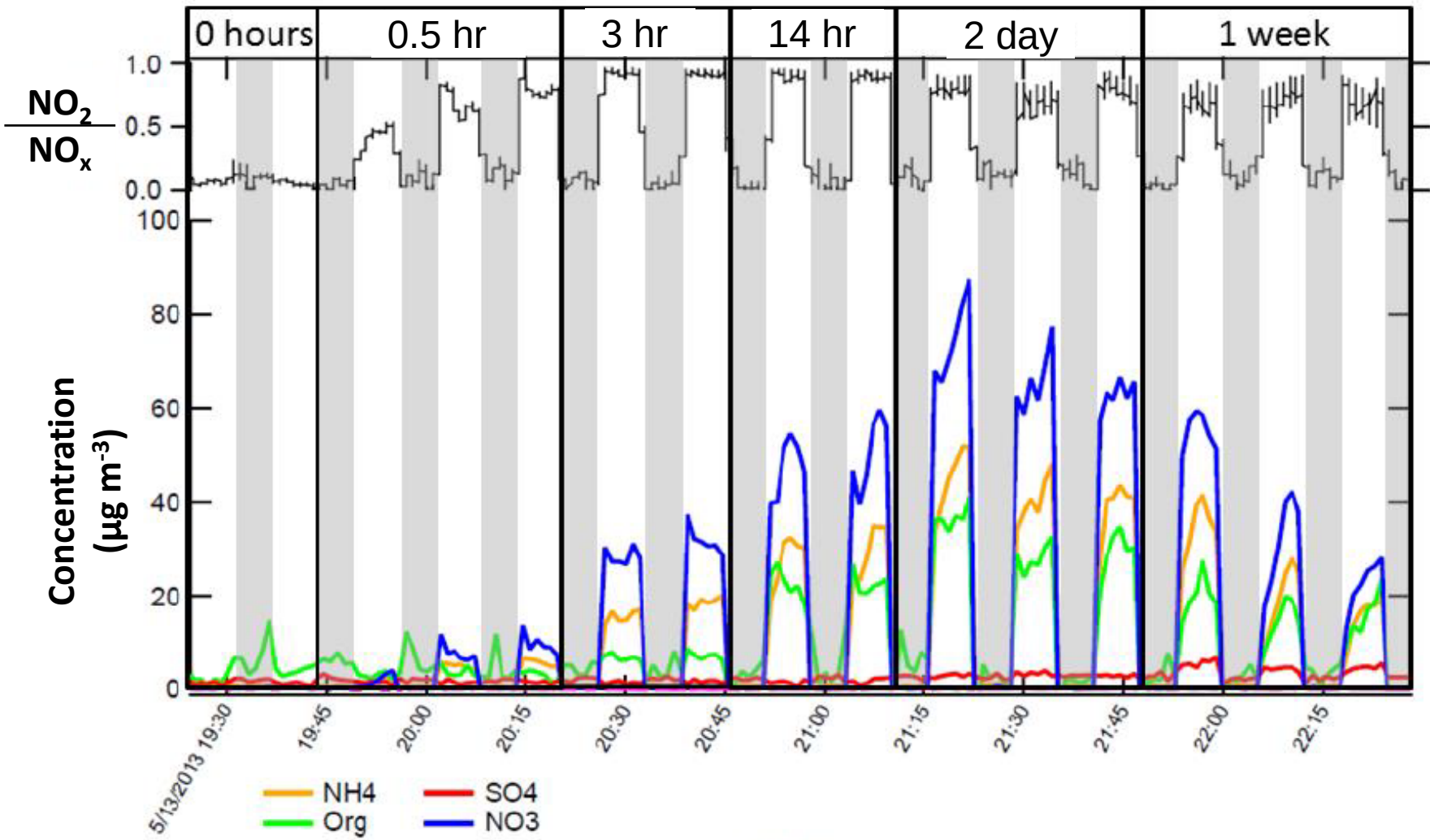
[OH] = 6 x 106 molec/cm³



(Tkacik et al. EST 2014)

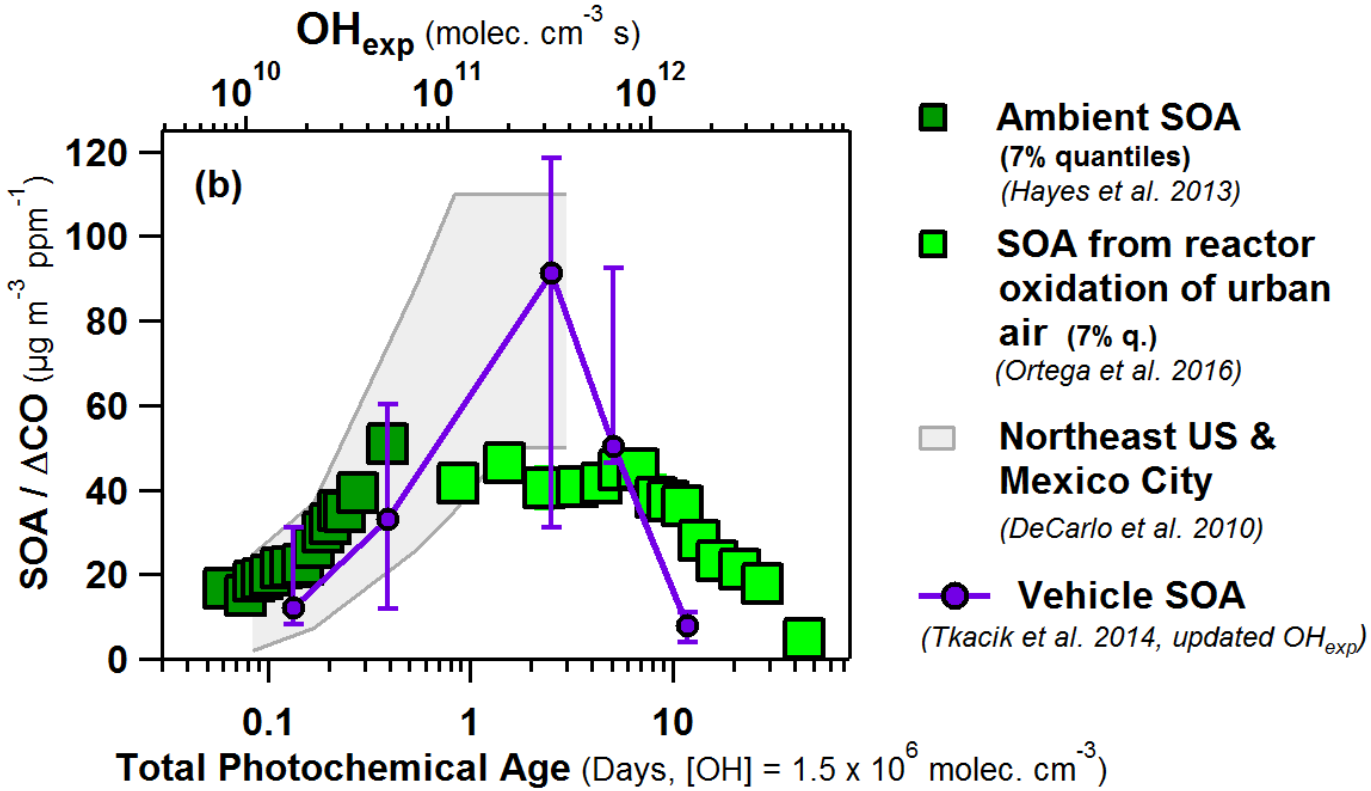
Secondary PM >> Primary Emissions

[OH] = 6 x 106 molec/cm³



(Tkacik et al. EST 2014)

Secondary organic aerosol production in tunnel consistent with ambient data

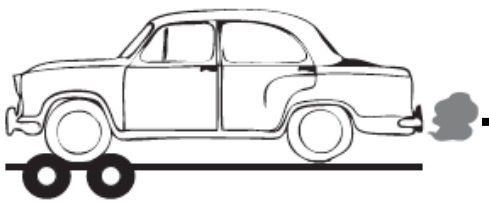


(Ortega et al. ACP 2016)

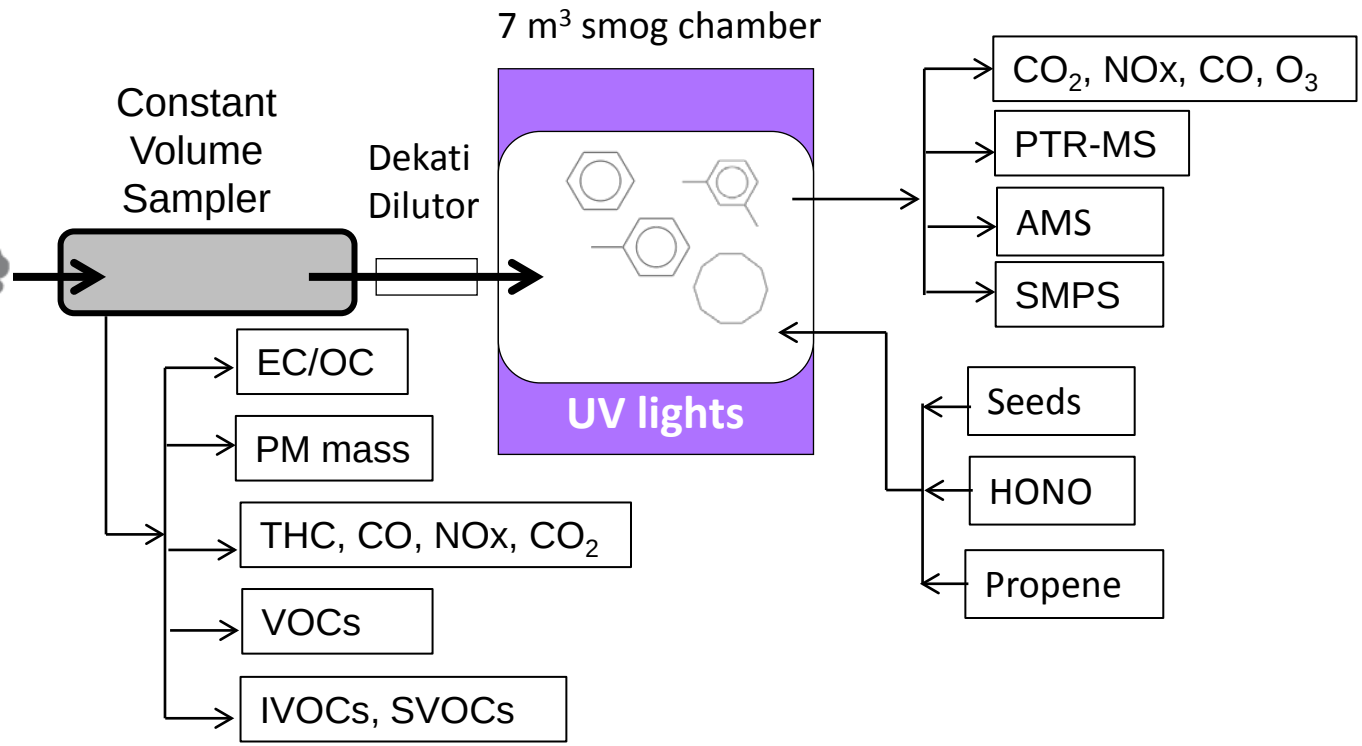
What are effects of technology and fuel on secondary organic aerosol formation?

Experimental Setup

Characterizing SOA formation and Primary Emissions



Test cycle:
Cold-start unified cycle

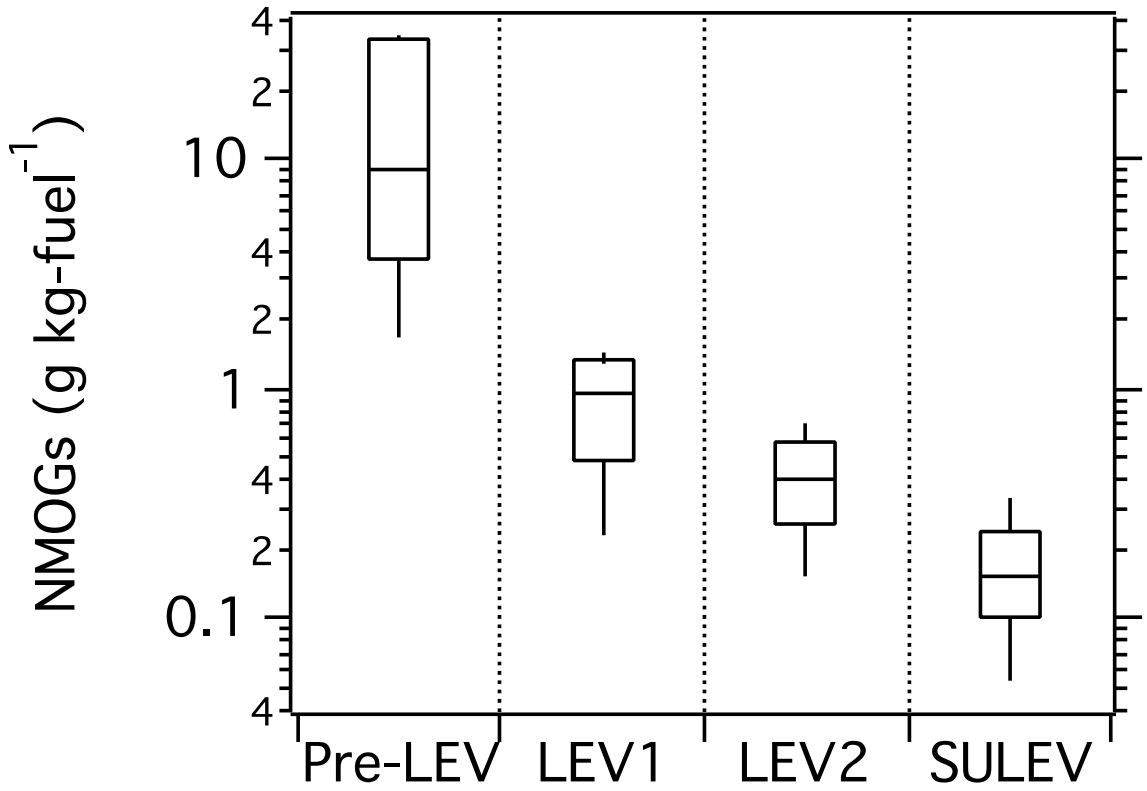


Test fleet:

- **82 LDGVs**
- **1988-2014**
- **19 GDI, 73 PFI**
- **SOA exp. w/ 25 veh**

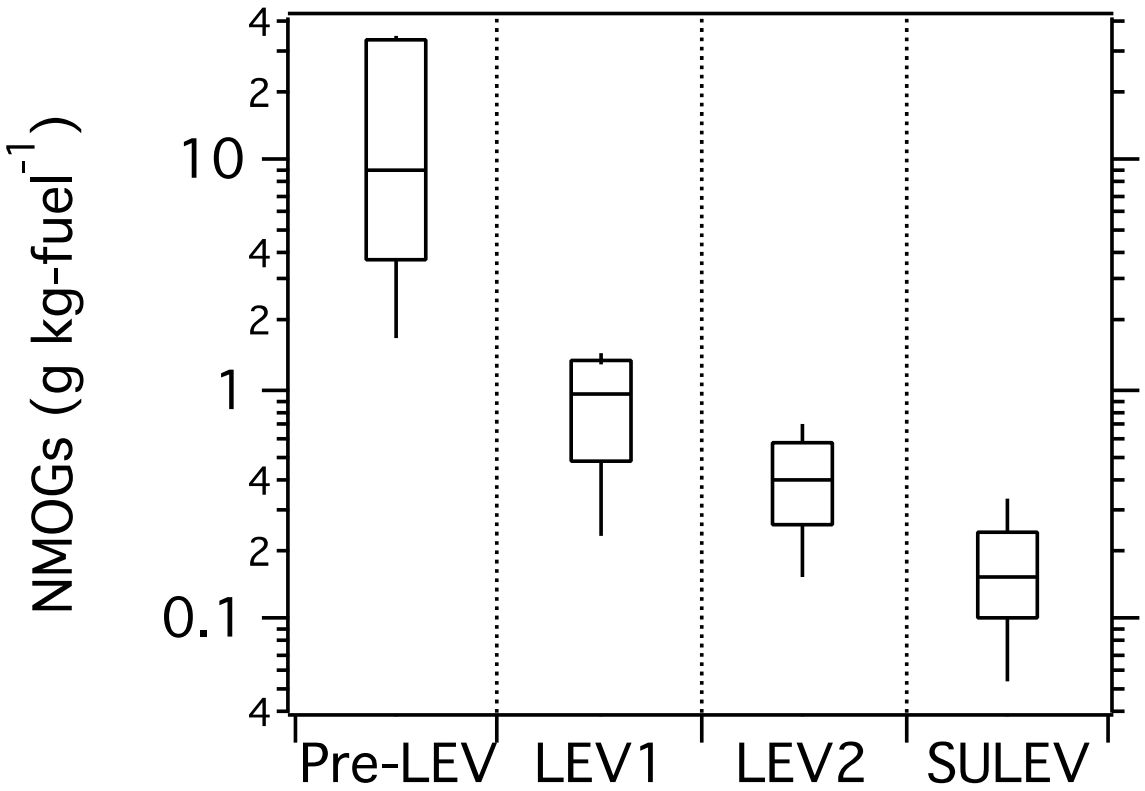
May et al., 2014 AE; Gordon et al., 2014 ACP; Presto et al., 2014 ACP; Zhao et al., 2014; 2015; 2016 EST;

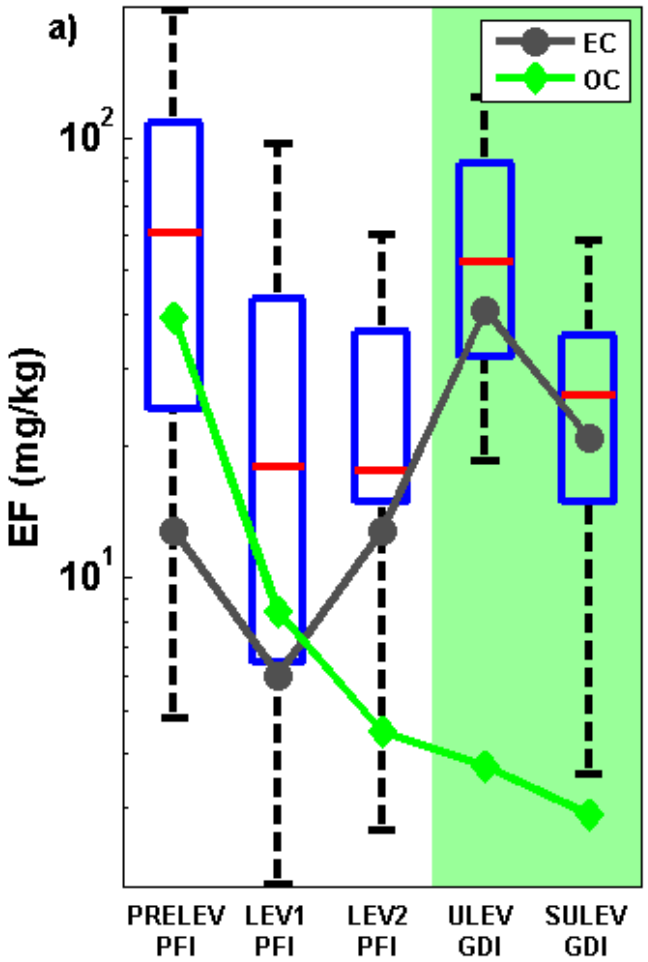
Lower NMHC Emissions from Newer Gasoline Vehicles



(May et al. AE 2014; Salibas et al. in prep)

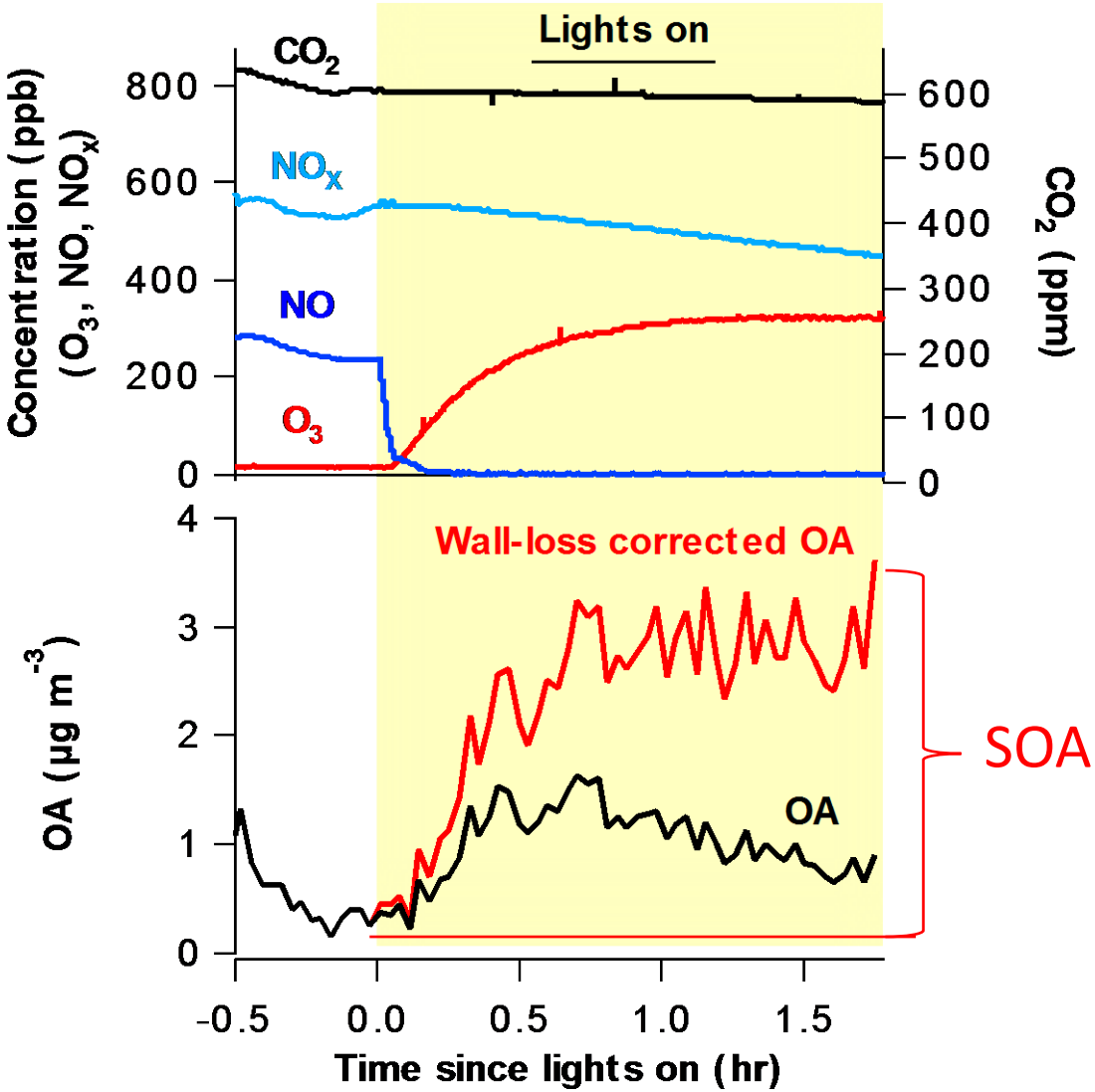
Story Mixed on Primary PM





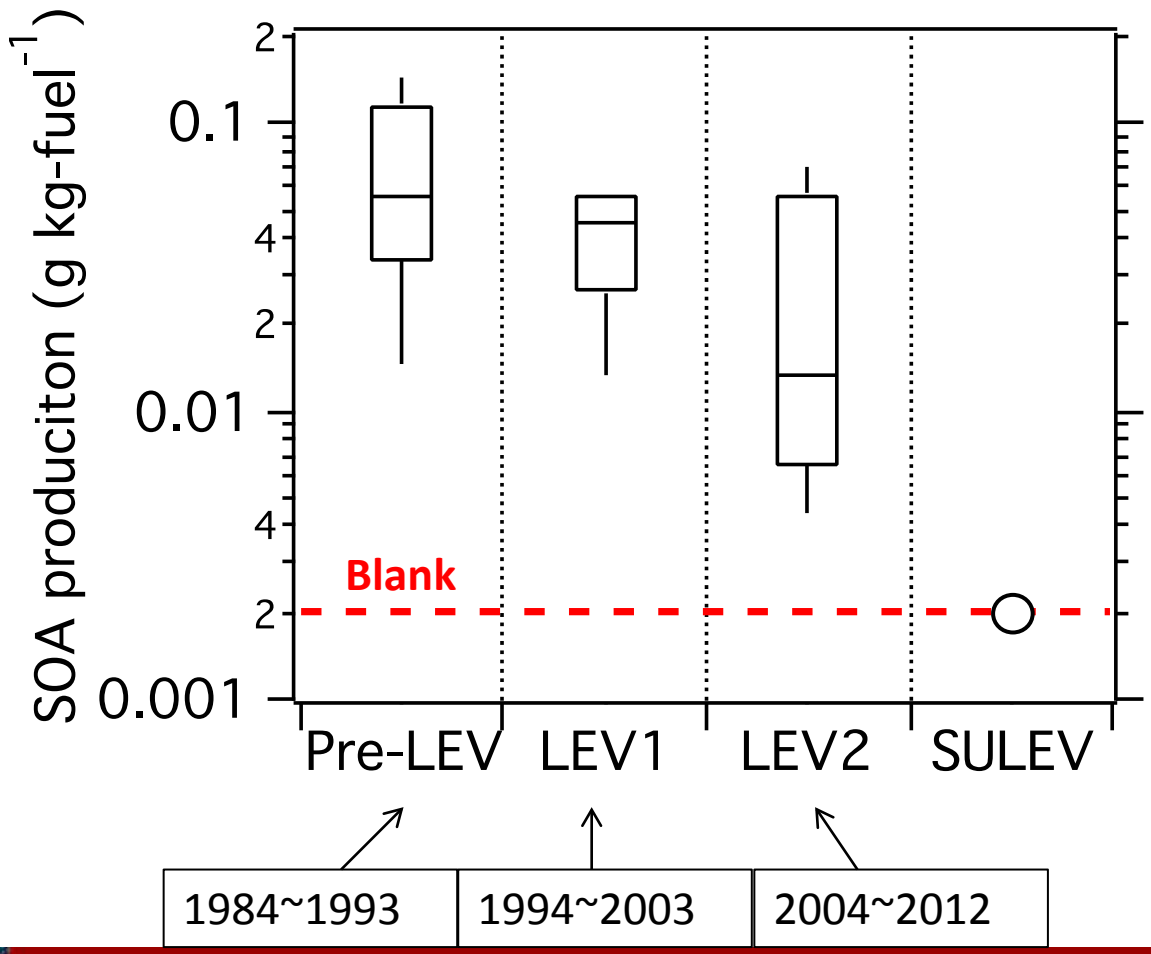
(May et al. AE 2014; Salibas et al. in prep)

Evolution of Gases and Organic Aerosol



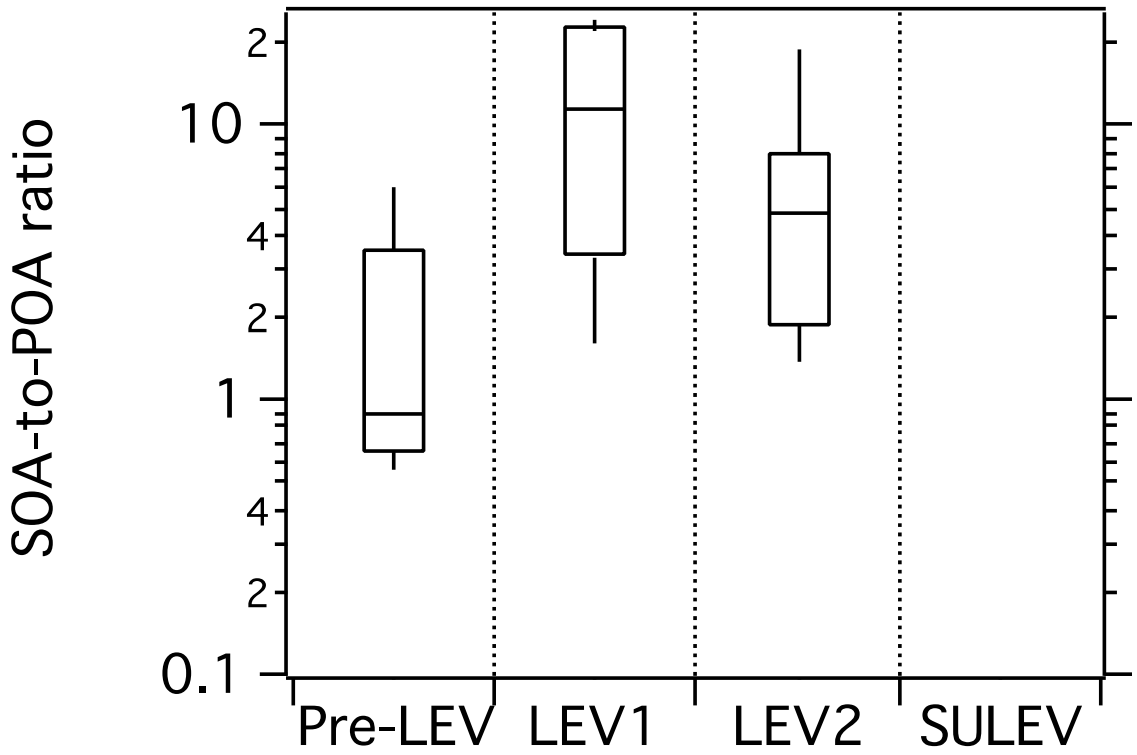
(Gordon et al. ACP 2014)

Lower SOA Formation for Newer Gasoline Vehicles



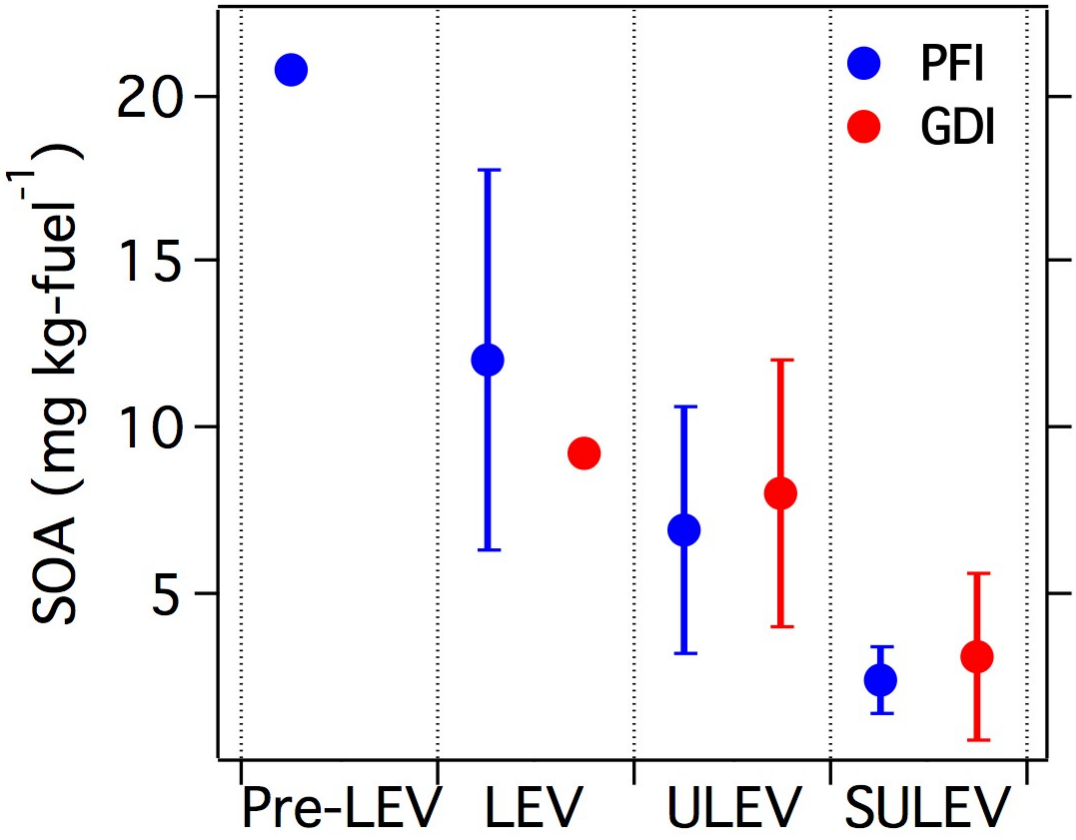
(Gordon et al. ACP 2014; Zhao et al. in prep)

SOA production exceed primary PM emissions



(Gordon et al. ACP 2014; Zhao et al. in prep)

Similar SOA for GDI and PFI



(Zhao et al. in prep)

Fuel Effects: Normal gasoline vs. alkylate fuel

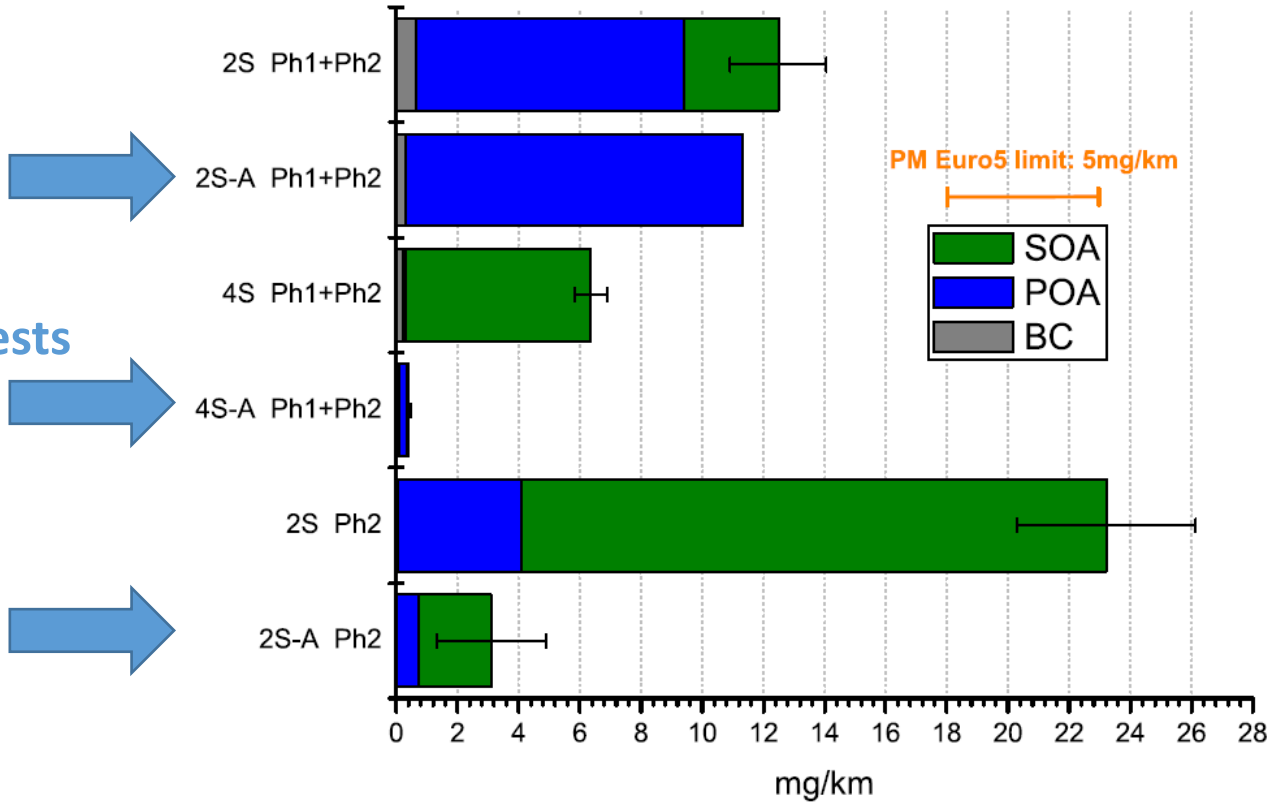
Table 2
Fuel properties from certified ISO/ISO-EN/ASTM analysis. The uncertainty is on the last significant digit.

Property/Compound	Standard fuel	Alkylate fuel	Unit
Aromatics	29.6	<0.4	%vol
Alkenes	4.2	0.1	%vol
Alkanes	61.3	>99.6	%vol
Oxygenates	4.9	<0.1	%vol
Benzene	0.2	<0.01	%vol
H-content	13.16	15.5	%wt
C-content	85.95	84.5	%wt
O-content	0.9	<0.1	%wt
Density (15°C)	759.2	692.4	kg/m^3

(Zardini et al. AE 2014)

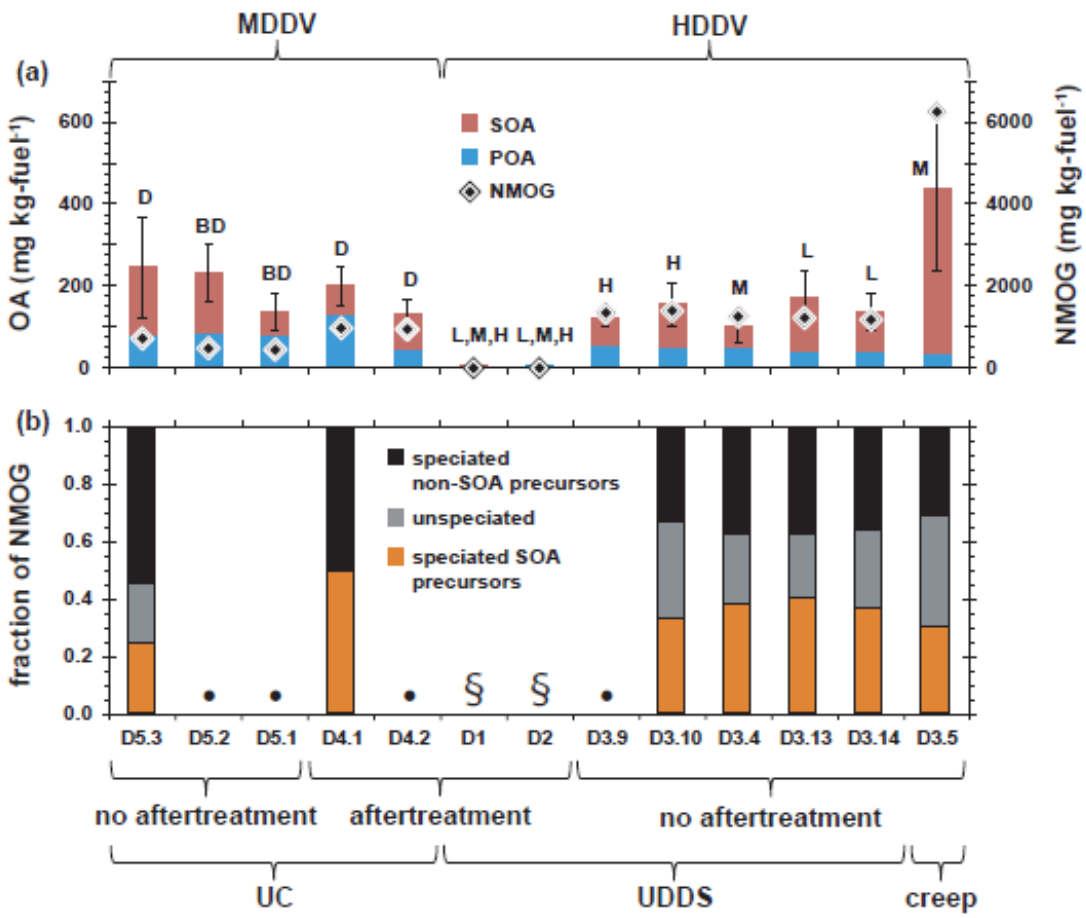
Substantially less SOA production for alkylate fuel

Alkylate Tests



(Zardini et al. AE 2014)

Diesel: SOA formation does not depend on aromatic content



(Gordon et al. ACP 2014; Jathar et al. EST 2013)

Conclusions

- **Human exposure:**
  - Secondary PM >> primary PM emissions from LDGV

<u>Important to control PM precursor emissions</u>

- **Technology & SOA formation:**
  - Newer vehicles emit fewer precursors (Biggest Effect)
  - GDI and PFI vehicles have similar SOA formation
  - Fuel composition
    - Gasoline engines – depends on aromatics
    - Diesel engines – no clear fuel composition effects