Real-world assessment of exhaust particles in chase vehicle studies

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Introduction

Although a lot of progress has been made understanding the number/size distributions of particles emitted from internal combustion engines there are still large uncertainties on their measurement, especially if volatile (nucleation mode) particles occur. While it is well understood that diesel particles consist of elemental carbon, organic carbon, sulfuric acid, and some metal ash, there is only very limited information available on the chemical composition of the nucleation mode particles. It has been suggested that the dilution conditions applied in the emission laboratory have a significant influence on the presence of nucleation mode particles. In this paper we report real-world particle size distributions and emission factors measured in the exhaust plume of two diesel and one gasoline passenger cars.

Questions addressed in this presentation include:
What is the real-world particle number/size distribution, which occurs under atmospheric dilution conditions?
What is the effect of the fuel sulfur, oxidation cat and exhaust line temperature?
What are the nanoparticle emissions during acceleration and deceleration events?

Experimental set-up

To address real-world dilution the Ford Mobile Laboratory (FML) was used. This is a "state of the art" laboratory based on a Ford Transit. While carefully following vehicles under controlled conditions, air from their exhaust plume is continuously sampled and analyzed inside the mobile laboratory. The on-road measurements were performed on a high-speed oval of 4 km length per lap. In order to avoid disturbances from other sources no other vehicles were allowed on the test track during the measurements. Sampling was performed through a 6 mm stainless steel inlet in front of the radiator grill.

In a typical experiment the test car was warmed up at 120 km h-1 while the FML was driving in front and sampling background air. The exhaust plume could be sampled when the test car passed the FML. The distance was kept constant at typically 14 m. In order to calculate the dilution factor the NOx concentration was measured and corrected for the background values. It is assumed that the NOx emissions during the constant speed chasing are identical with laboratory values. Typical dilution ratios were in the range of 1000-10000.

Summary & Conclusions

- Sampling setup was confirmed: No dependence on sampling probe extension
- Exhaust plume mixing time and dilution factor had no impact on nucleation particles
- Nucleation particles occurred during atmospheric dilution only at 100 and 120 km h^{-1}, if 360 ppm S fuel and oxidation catalyst were used
- Using 10 ppm S fuel, no nucleation particles were observed
- Formation of nucleation particles is dependent on the condition of exhaust system: currently it is not clear, if this is due to a deposition/release effect
- Nucleation particles were observed during acceleration and deceleration with high sulfur fuel (350 ppm) and oxidation catalyst
- No nucleation particles occurred with low sulfur fuel (40 ppm) and oxidation catalyst
- Particle emission from gasoline car were at background level

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Introduction

- Public debate on the emission of particulates
  - Air quality and health concerns
  - Sources of particulates: Industry, road transport, and natural
- Particle number/size measurement still exhibit large uncertainties, especially due to nucleation particles
- What is the effect of the fuel sulfur, oxidation cat and exhaust line temperature?
- Nanoparticle emissions during acceleration/ deceleration

On-road chasing of exhaust plume

Test vehicle:

1.8 l Diesel
speed, fuel consumption
exhaust temperatures

Ford Mobile Lab:

SMPS, CPC, NOx,
CO, T and RH

Test track:

high speed oval,
4 km/lap

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In-let for on-road sampling

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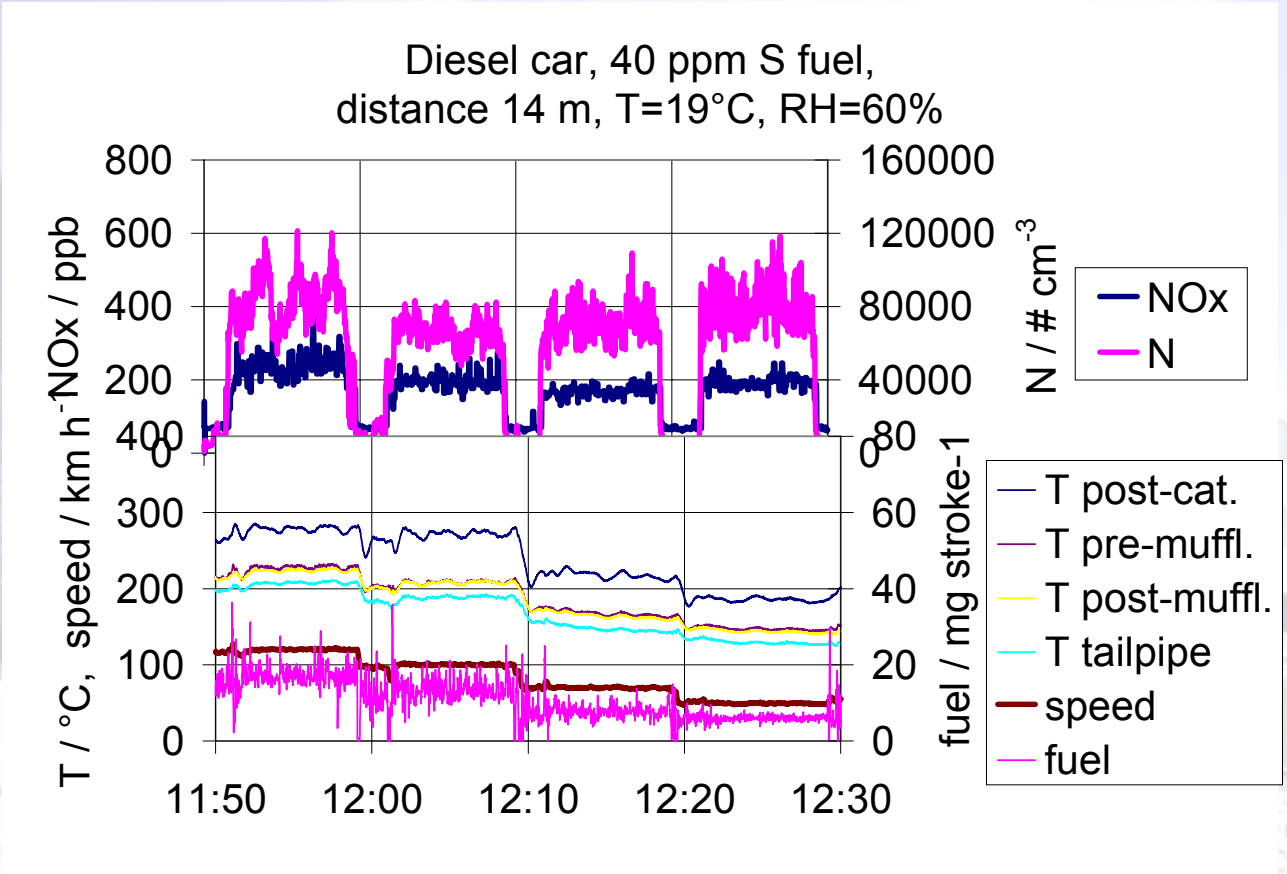
Exhaust chasing of diesel vehicle at different speeds



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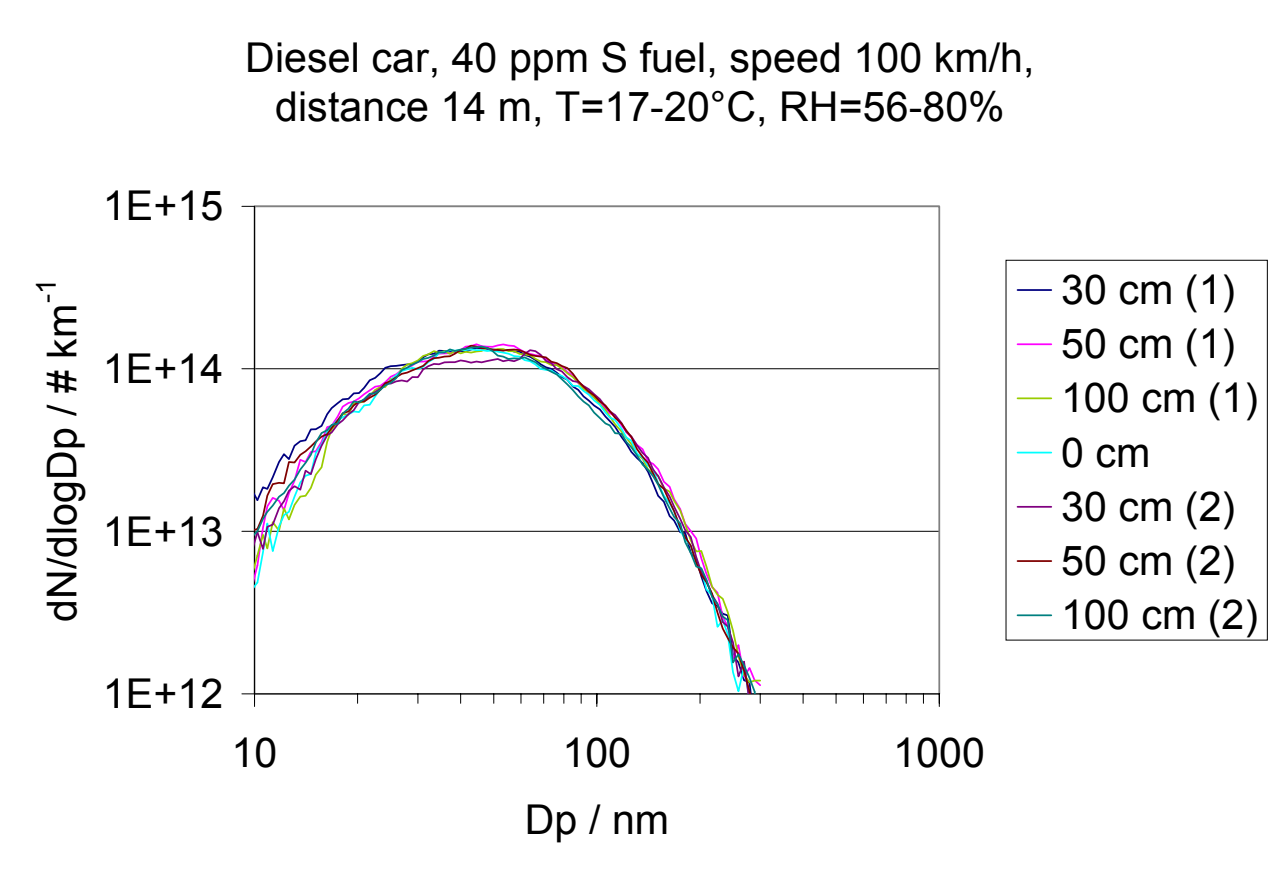
Extension of sampling probe (1)



=> No influence of sampling probe extension on soot mode particles

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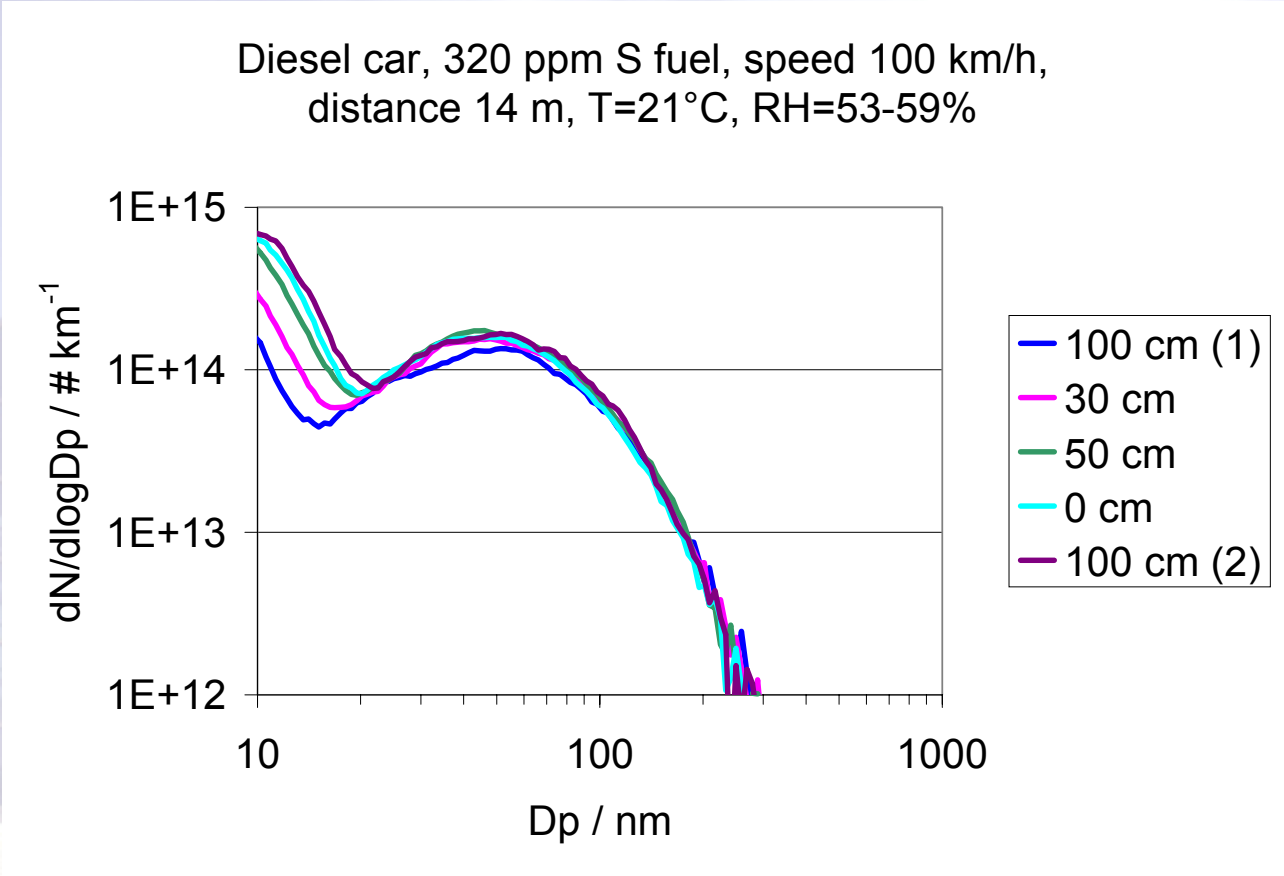
Extension of sampling probe (2)



⇒ Increase of nucleation particles with time

⇒ No influence of sampling probe extension on nucleation particles

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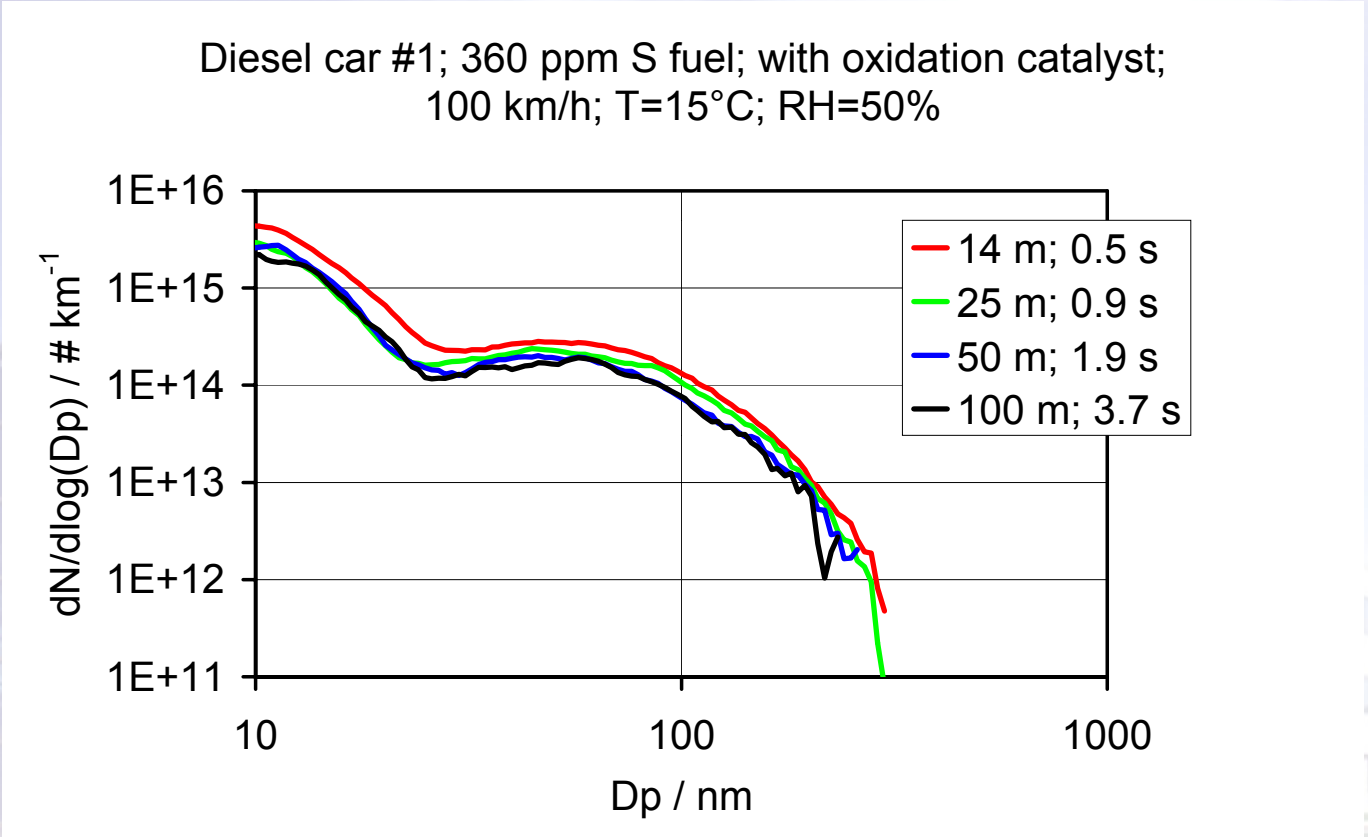
Variation of chasing distance



=> Chasing distance increases D_f from 1000 to 9000

=> No impact on nucleation mode particles

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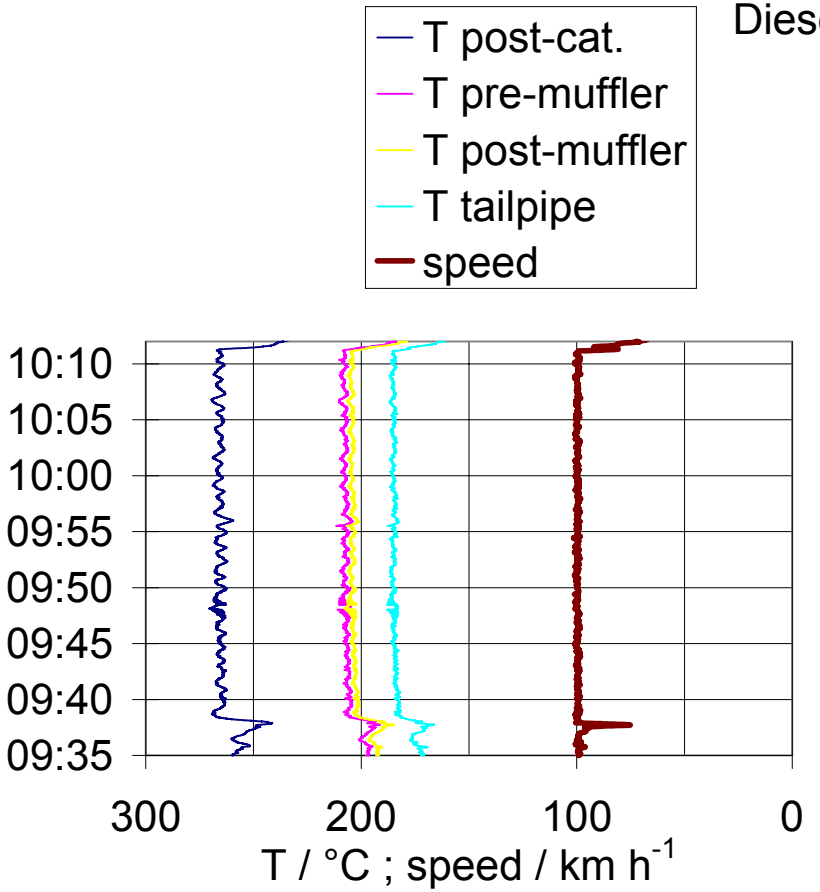
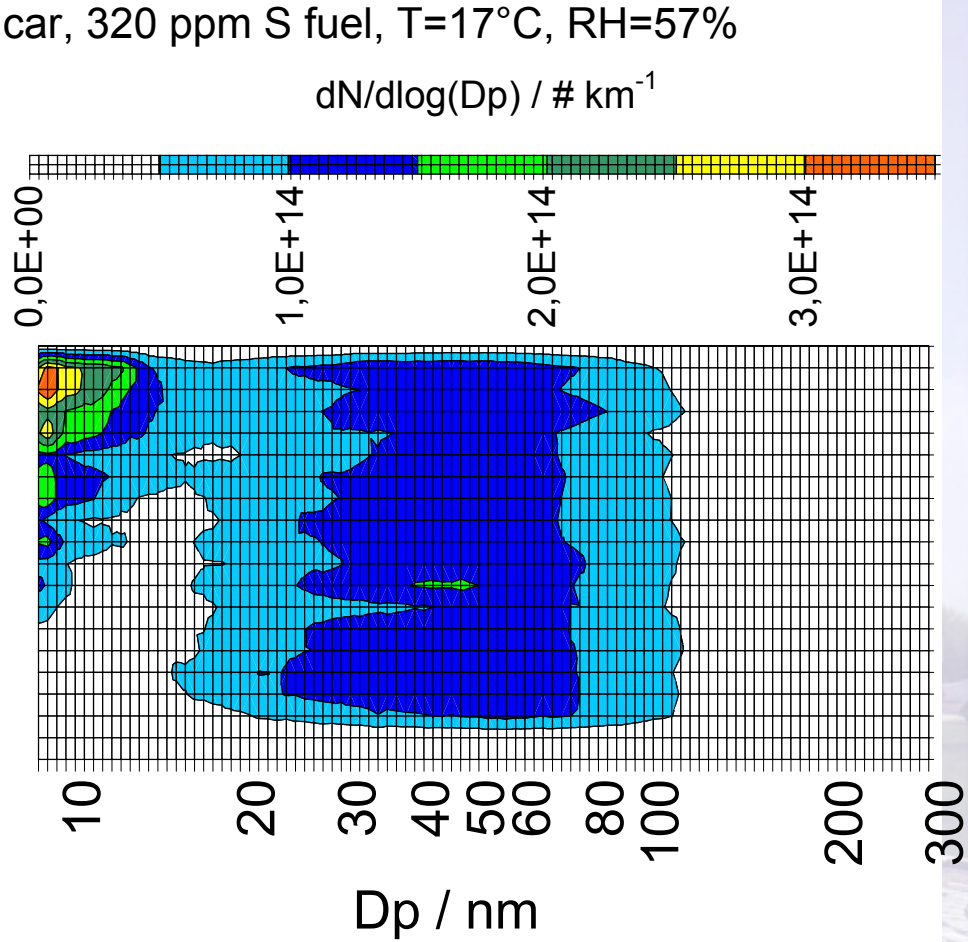
Time evolution of nucleation mode particles





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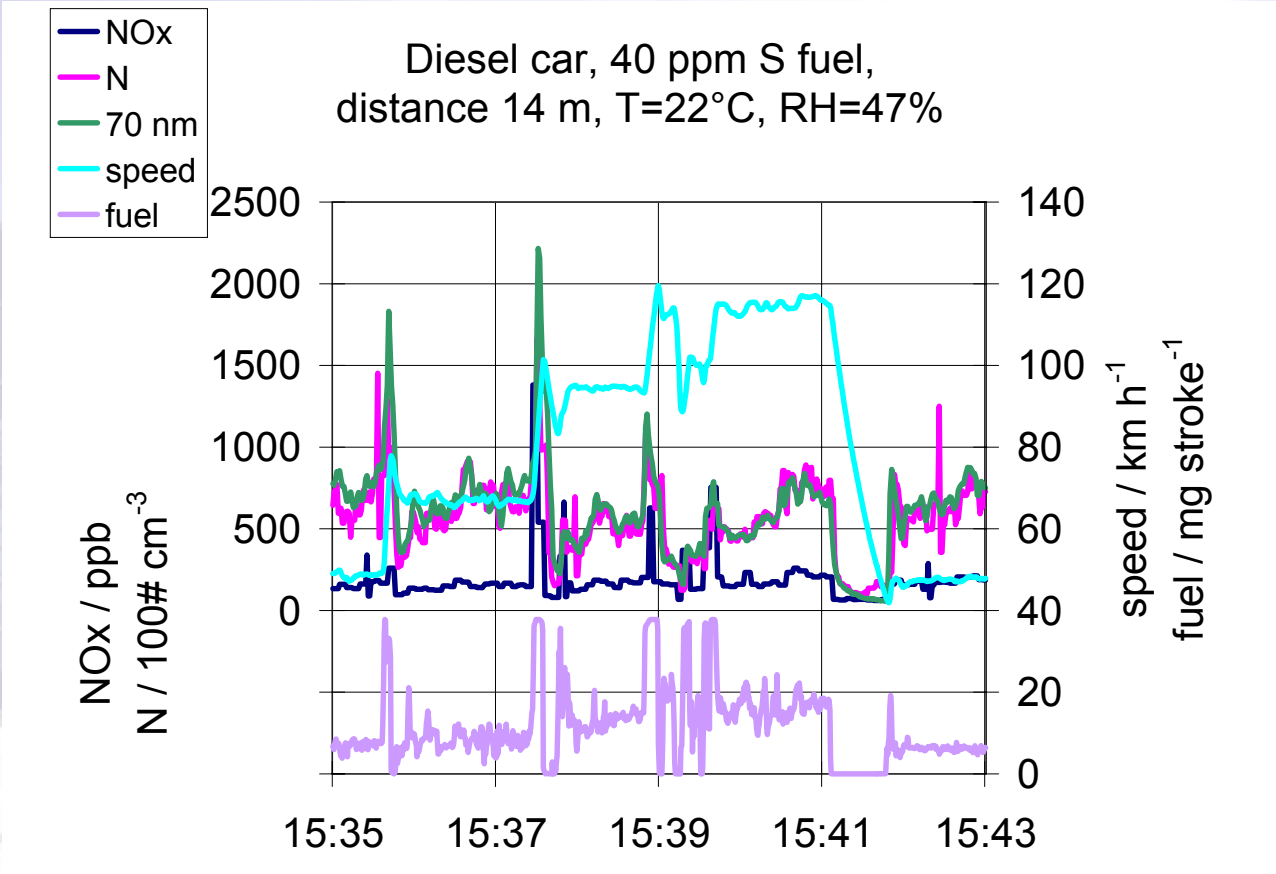
Particle emission during acceleration/ deceleration (40 ppm S)



=> Ratio of N(tot)/N(70nm) is constant

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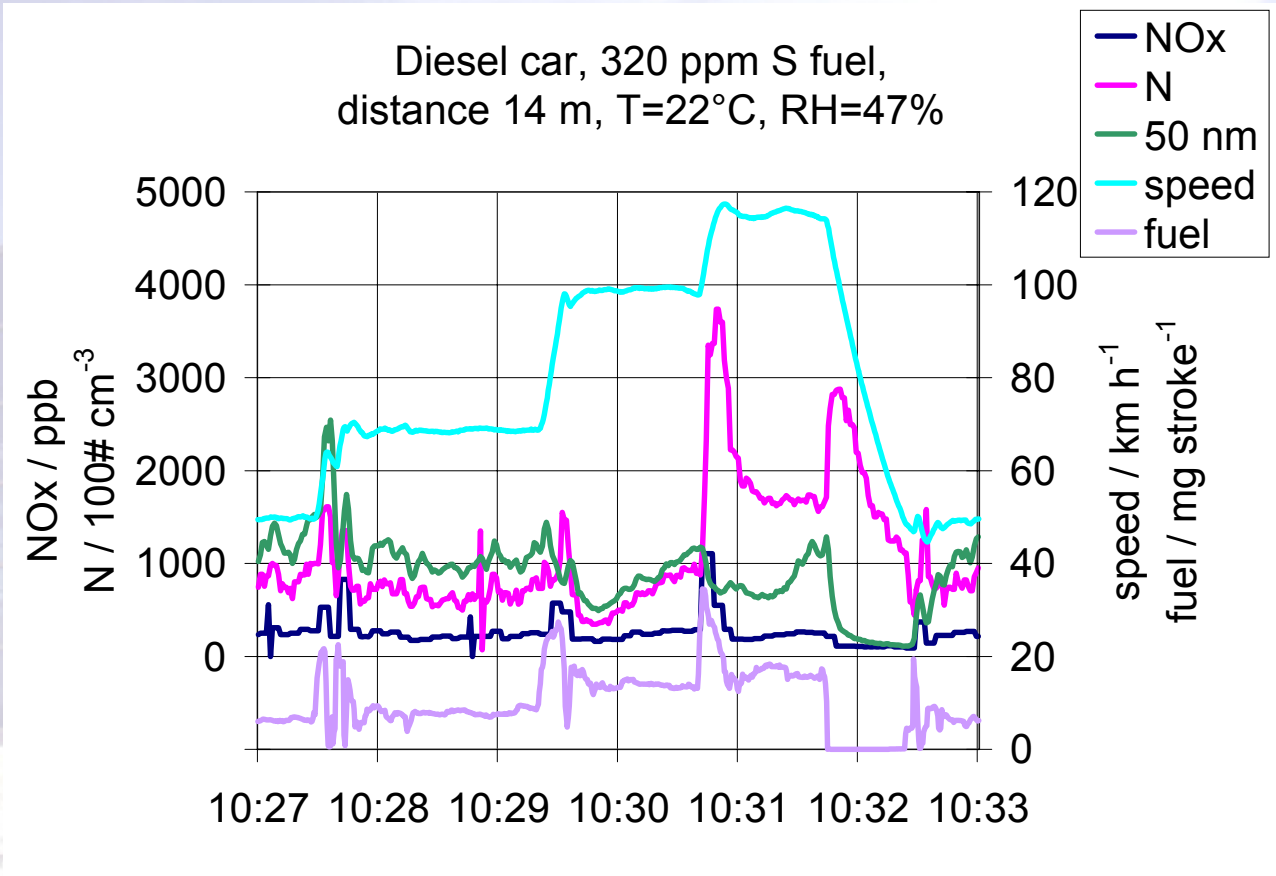
Particle emission during acceleration/ deceleration (320 ppm S)



=> Increased ratio of N(tot)/N(70nm) during accel./decel.

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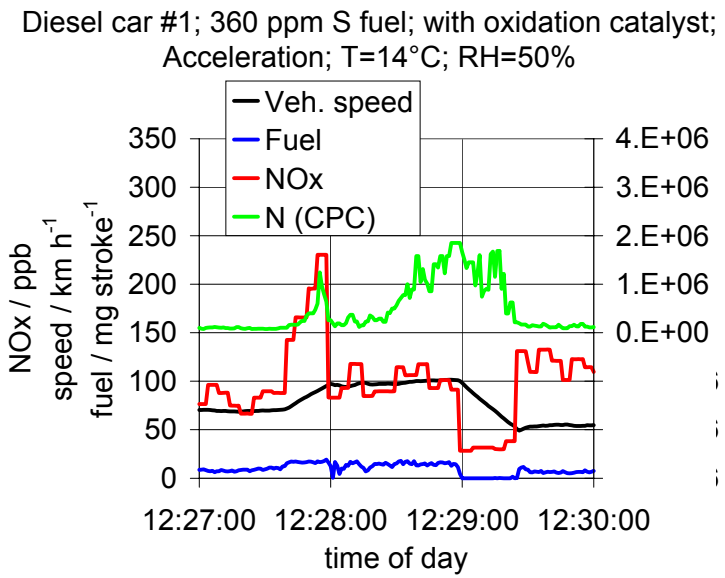
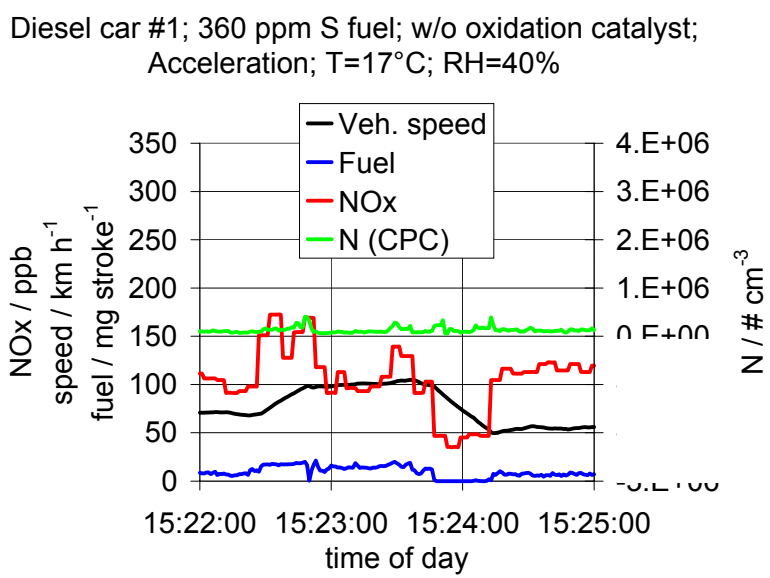
Acceleration/deceleration 360 ppm S; w & w/o oxicat.





=> Large PM number is only present if high S fuel and oxi. catalyst

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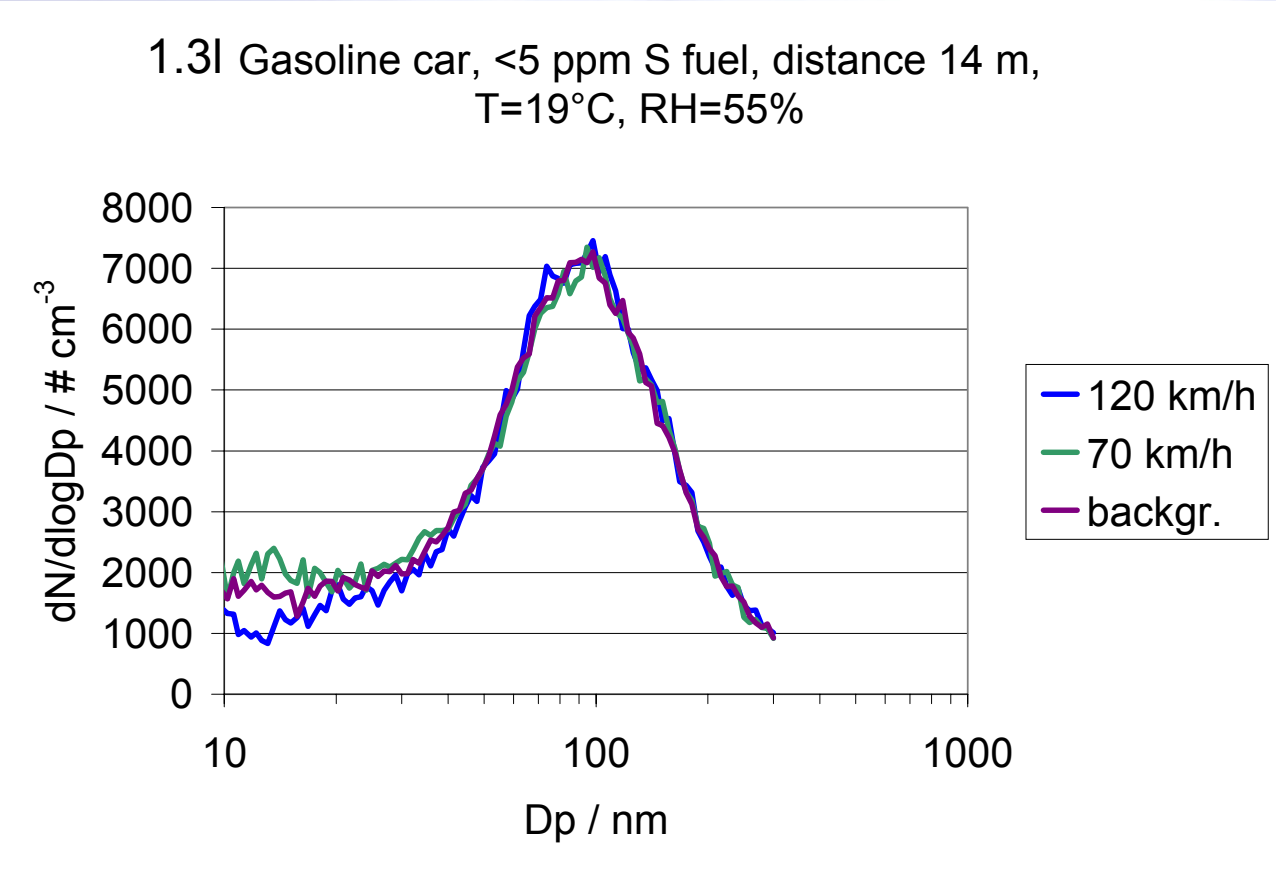
Exhaust chasing of gasoline car



=> No soot of nucleation mode particles detected

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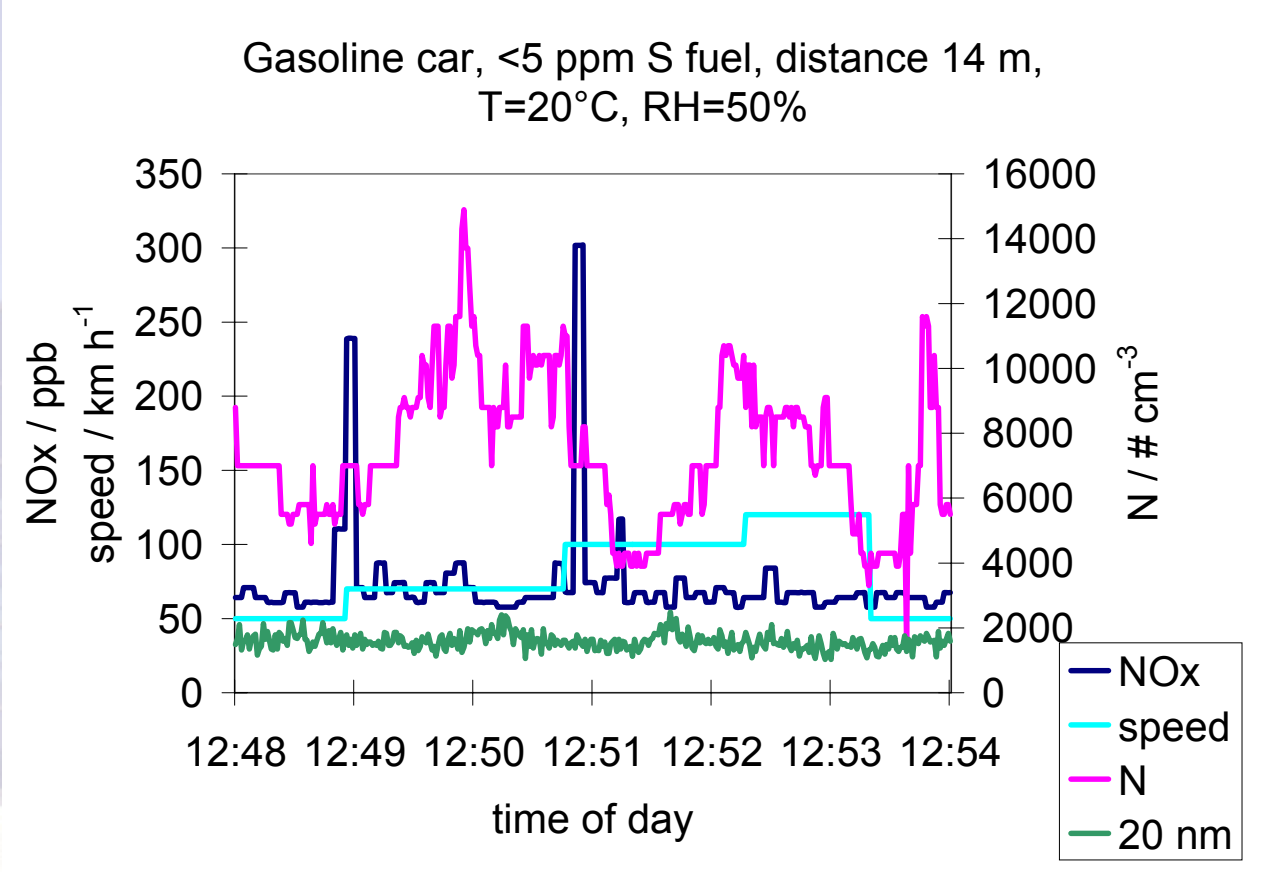
Transient conditions: 1.3l gasol. car



=> NO_x signal detected; particles at background level

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Summary (1)

- Sampling setup confirmed: No dependence on sampling probe extension
- No dependence of nucleation particles on plume mixing time and dilution factor
- Formation of nucleation particles is dependent on condition of exhaust system: deposition/release effect?

Summary (2)

- Nucleation particles observed during acceleration and deceleration with high sulfur fuel (350 ppm) and oxi. catalyst
- No nucleation particles with low sulfur fuel (40 ppm) and oxi. catalyst
- Particle emission from gasoline car are at background level

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