Introduction and Initial Field Data of a Novel, Portable Nanoparticle Sizing Instrument

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The measurement of nanoparticles has received increasing attention during the last years. Sources of nanoparticles are manifold and include almost all kind of combustion processes. In addition, engineered nanoparticles and particles from industrial process emissions need to be characterized. However, nanoparticles are also present in ambient air as well as in indoor environments (e.g. from cooking, laser printer emissions, candles, or environmental tobacco smoke). A key parameter for the characterization of particles is their size distribution and number. Recent health studies indicate an important role of particle number and surface in contrast to particle mass, which is often used due to the availability of measurement techniques and long-term data series (e.g. PM10). Particle mass also still is legislated in a variety of current legislations. The newest EURO classifications for vehicles are the first that include a particle number standard.

We are introducing a novel, portable nanoparticle sizing instrument, the NanoScan SMPS. It has been designed for multiple applications such as mobile studies, in-vehicle measurements, industrial process emissions, tunnel studies, and workplaces. Its measurement technique is based on the electrical mobility sizing of a Scanning Mobility Particle Sizer (SMPS), using a Radial Differential Mobility Analyzer (R-DMA). The size classified particles are individually counted by an integrated, isopropanol-based Condensation Particle Counter (CPC). Number size distributions in the range from 10 to 420 nm can be obtained in 13 channels. Its size range can be extended to coarse particles with an additional instrument, the Optical Particle Sizer (OPS). The device is portable, easy to use and without any hazardous substances (no butanol, no radioactivity). In addition to the scanning mode (SMPS) there is also the possibility to observe one specific particle size with 1 sec resolution (single mode).

We present measurements from different sources and locations, including test aerosols in the laboratory, work place aerosol and in-vehicle measurements. The novel NanoScan SMPS compares well with established methods and size measurements such as the research-grade SMPS. Figure 1 shows this comparison for laboratory generated polydisperse test aerosols sodium chloride (NaCl) and emery oil. The 13 size bins of the NanoScan SMPS (bars) agree very well with the SMPS (curve) that has a higher resolution. The NanoScan SMPS is also capable to measure monodisperse aerosol distribution and both instruments were compared with monodisperse silver particles. The accuracy of the NanoScan SMPS for monodisperse particles depends somewhat on size, because the diameter bins are not even distributed. The resolution is higher for smaller particles and there is also the strength of the unipolar charging (higher charging efficiency for particles < 30 nm compared to bipolar charging).

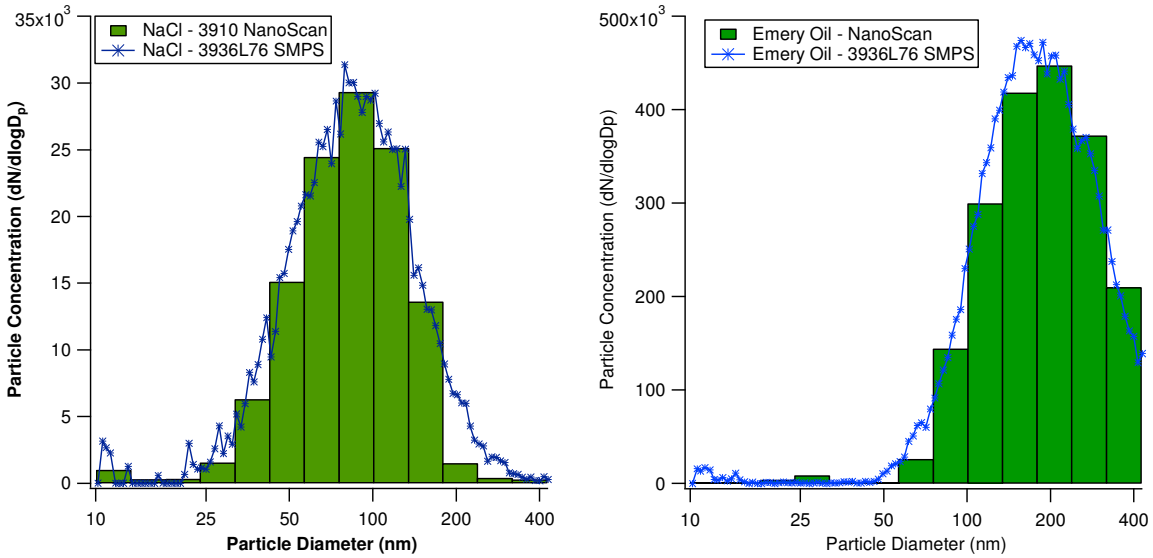

Figure 1: Comparison of laboratory generated test aerosols with NanoScan and a version of the research-grade SMPS. The left panel shows the comparison for sodium chloride (NaCl), the right panel for emery oil.

The comparison of NanoScan SMPS and Fast Mobility Particle Sizer (FMPS), which has a higher time and size resolution but the same way of unipolar charging is in good agreement. Similar size distributions and total particle concentrations of a work place aerosol that originates from metal inert gas soldering are presented.

An in-vehicle study with the NanoScan SMPS measuring cabin air of a car while driving in Germany gives just one example of a spatial and temporal measurement. The drive was mainly on the highway A1 but included also city and rural roads from Cologne main station to a small town North of Bremen in total about 380 km. Figure 2 shows the total concentration and the geometric mean diameter that are direct provided by the instruments based on the measured particle number size distributions. The measured particle concentrations show the exposure of the driver which is health relevant considering the high fraction of nanoparticles (< 100 nm) but they correlate also with the ambient aerosol. This can help to get a spatial measurement profile and pinpoint source regions. The total particle concentration levels range from 10^3 to 10^6 particles per cm^3 and due to the size distribution it is possible to characterize the aerosol further and identify specific regions e.g. a construction side.

During all measurements the portable NanoScan SMPS demonstrated its reliability and easy handling to provide valuable information about size and concentration of nanoparticles in a wide field of applications.

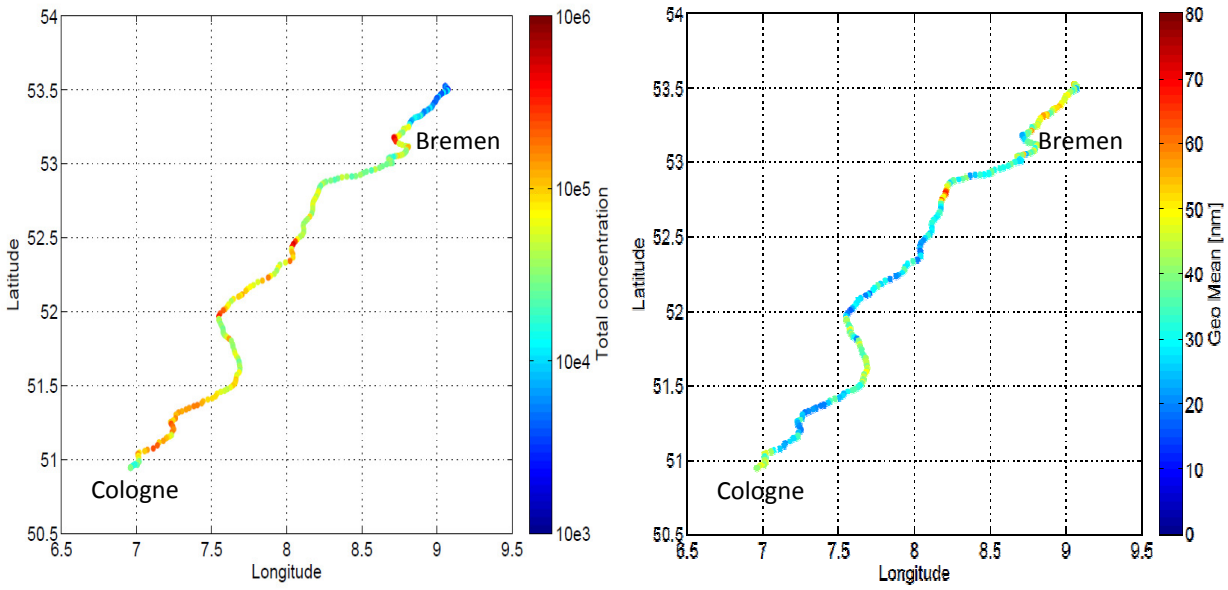

Figure 2: Temporal and spatial in-vehicle measurement of cabin air in a car while driving 380 km in Germany. On the left the total particle concentration and on the right the geometric mean diameter that results from the individual particle size distribution is displayed in color bars, respectively.

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Zürich June 26th 2012

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Common Nanoparticle Sources

Industrial Process Emissions

May be harmful to workers and impossible to detect with standard monitoring instruments.

Vehicle Exhaust

Particulate emissions from vehicles are primarily in the nanoparticle size range.

Biomass Burning

The environmental implications of nanoparticle manufacturing are still largely unknown.

Emissions from Office Equipment

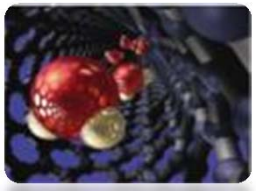
Some types of office equipment are known to generate large quantities of nanoparticles.

Candle and Incense Smoke

The indoor air quality effect from candles and incense is frequently overlooked.

Engineered Nanoparticles

Engineered nanoparticles are the building blocks of some of the most innovative products.



Tobacco Smoke

Tobacco smoke and other indoor combustion sources are a known health hazard.

Stack Emissions

The environmental implications of nanoparticle manufacturing are still largely unknown.

Cooking Fumes

Can be dominant source of nanoparticles in indoor air in certain parts of the world.

Chemical Reactions

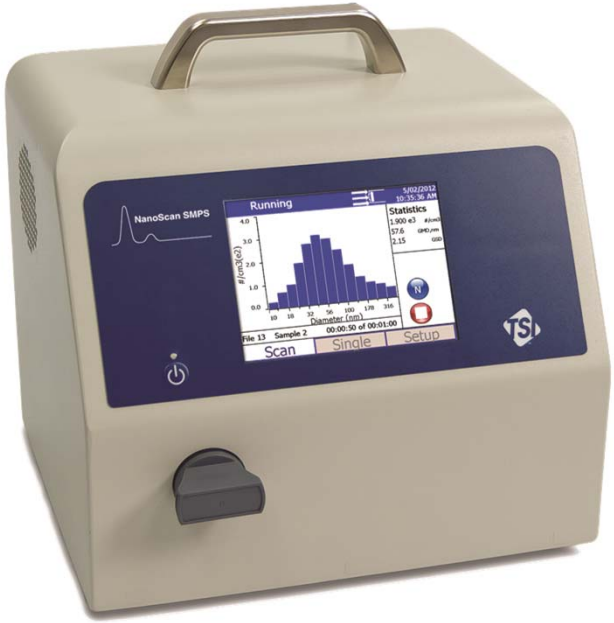
In the atmosphere and reactions from cleaning solvents or other household chemicals.

NanoScan SMPS

→ Characterization of Nanoparticles: Number and Size

Novel, portable instrument: NanoScan SMPS

- Accurate and reliable characterization of size and number of airborne nanoparticles
  - Particle size distributions from 10 to 420 nm in 13 channels
  - Concentration range ≤1 000 000 particles/cm^3
- Rapid (60 sec) size scans
- Lightweight, portable, and affordable
  - Battery operated or extended use
  - On-board data storage capacity



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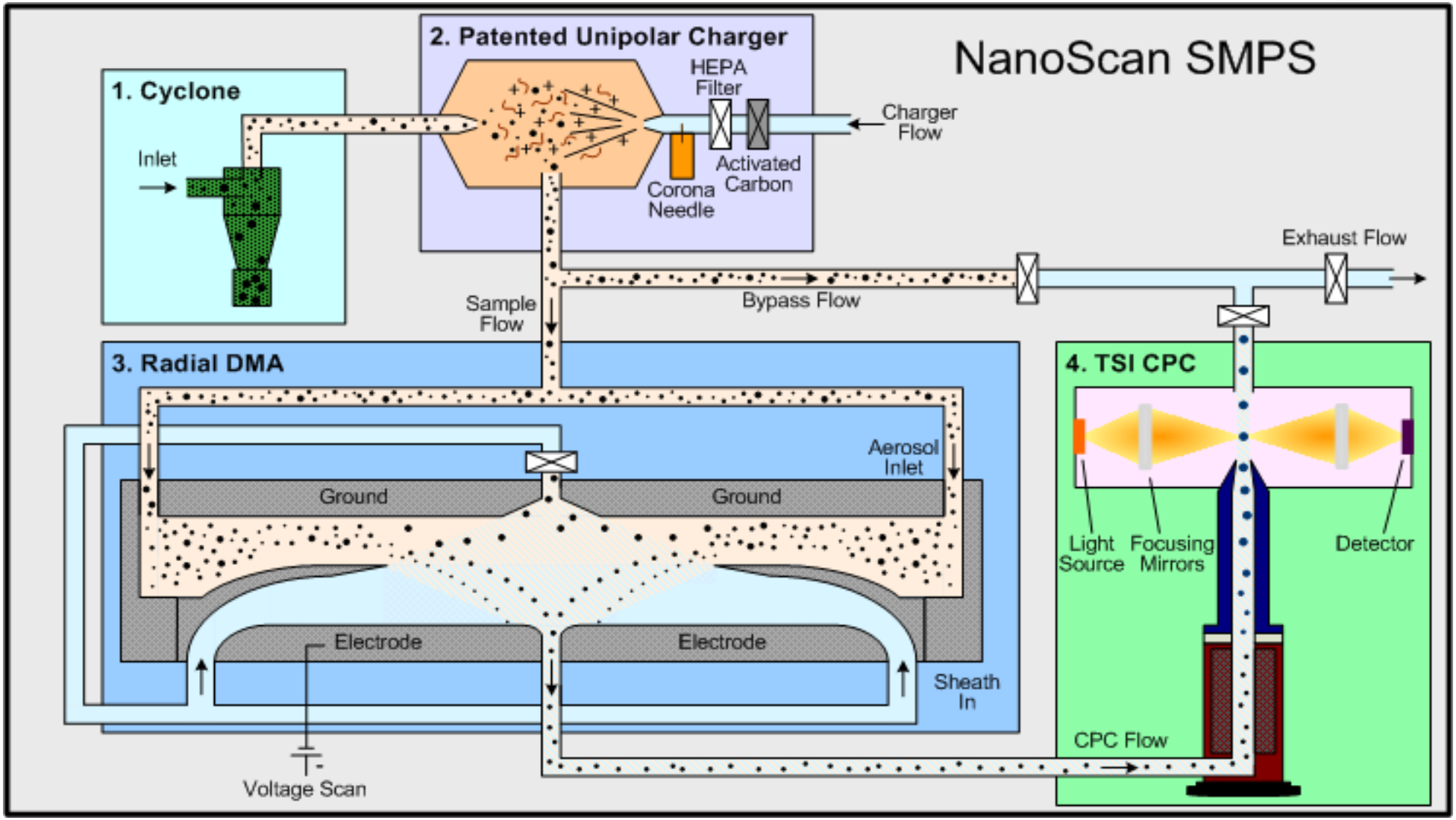
Instrument Specifications

Feature	Description
Size Range	10 - 420 nm
Size Channels	13 Channels (fixed)
Concentration Range	≤ 1 000 000 particles/cm^3
Modes of Operation	• Scanning (PSD & # conc.) • Single Size (# conc. @ fixed size)
Measurement Time	• Scanning: 60 seconds (fixed) • Single Size: 1 second (fixed)
Flow Rates	• Inlet: 0.80 LPM • Sample: 0.25 LPM
Instrument Run Time	• 6-12 hrs. w/o A/C power or external reservoir • 3-8 days with A/C power & external reservoir
Data Storage	• On-board (8 – 10 days continuous operation) • USB Storage Drive Option

NanoScan SMPS Schematic



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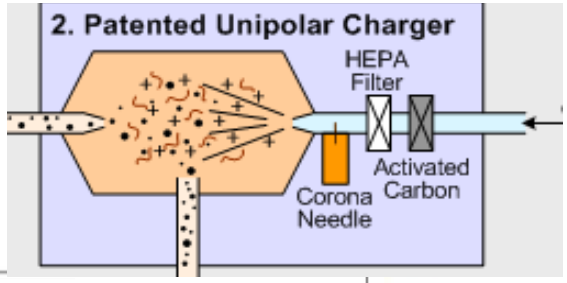
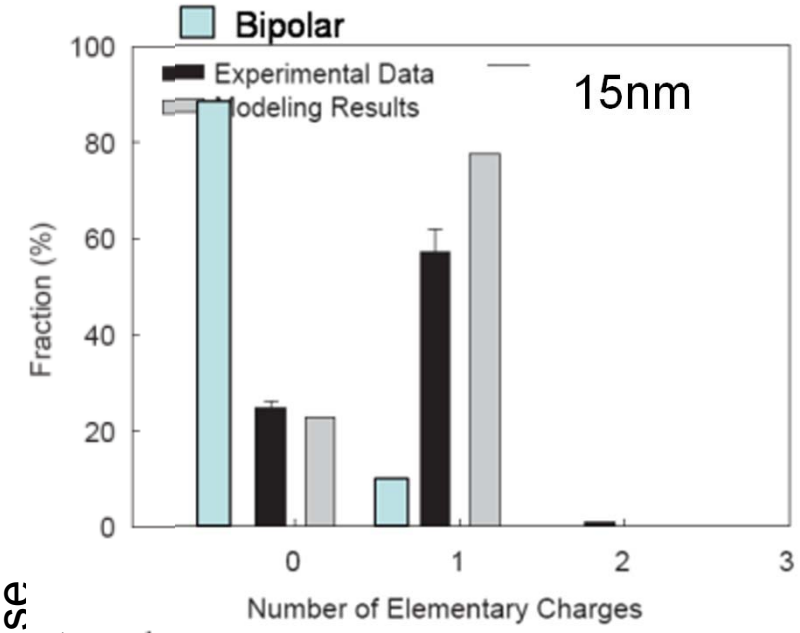
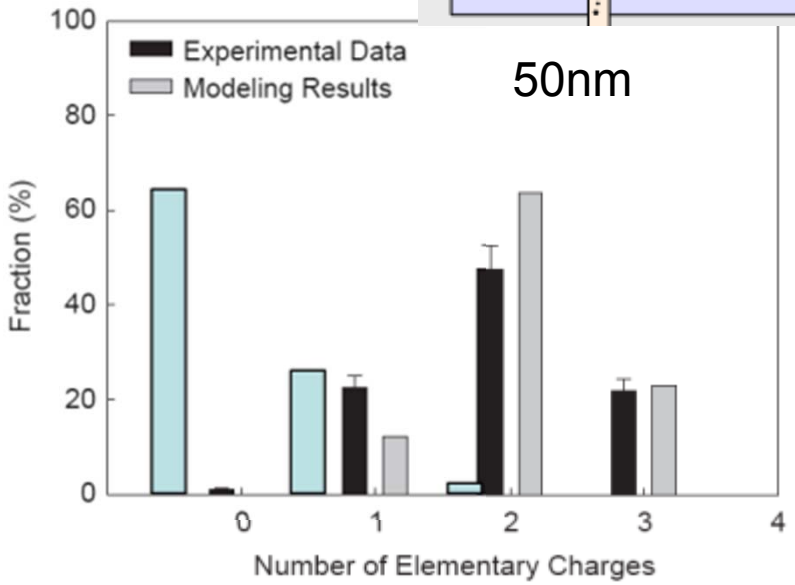
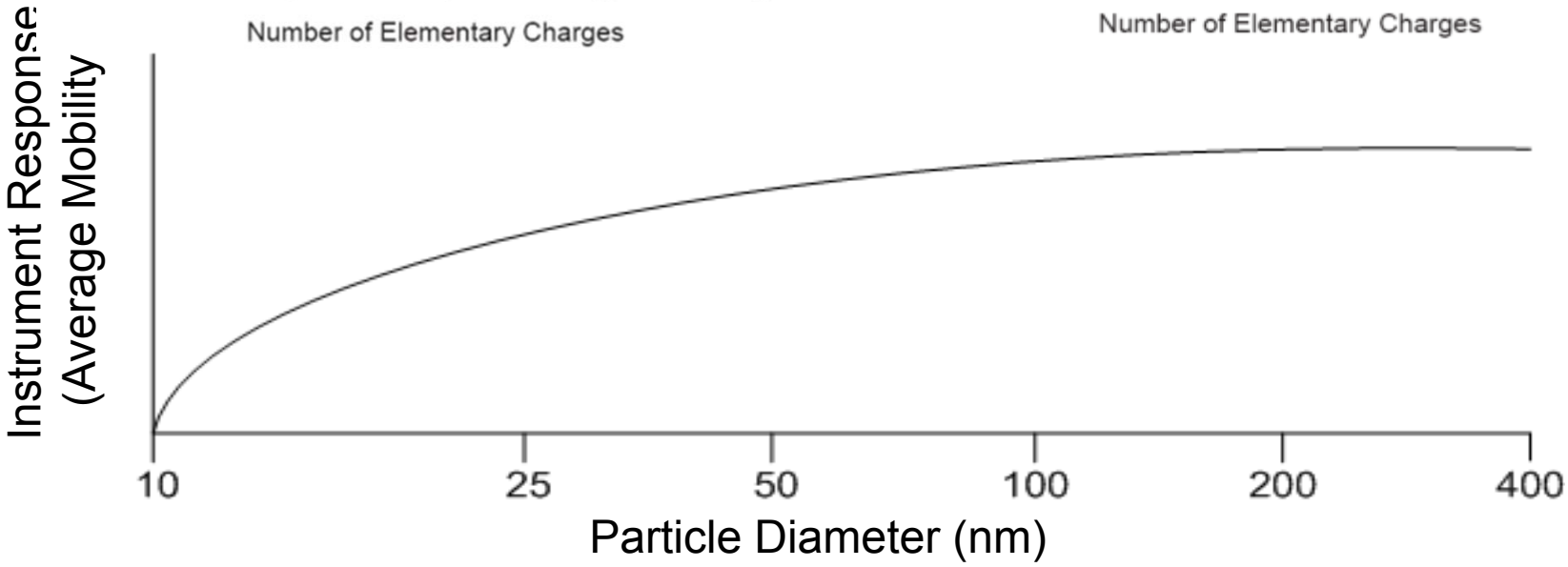
Unipolar Charger



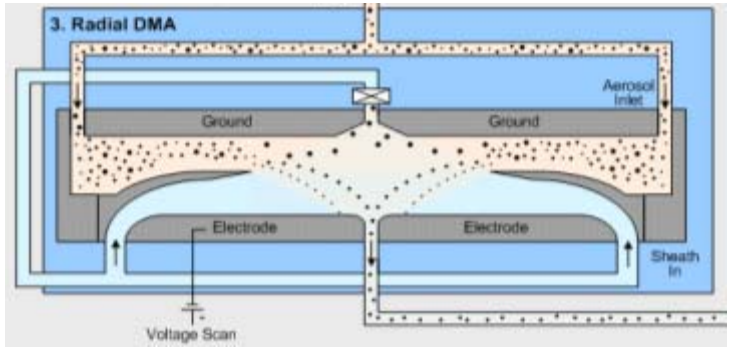


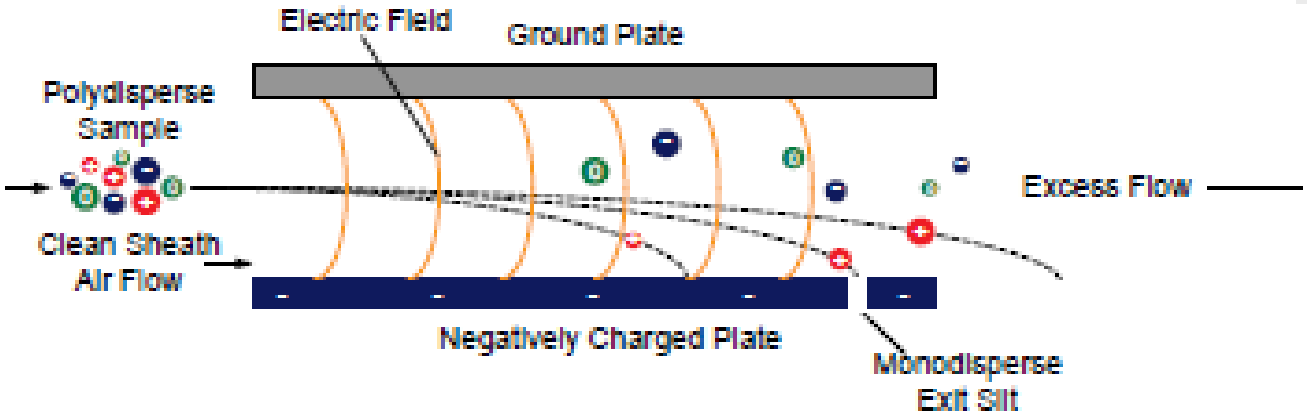


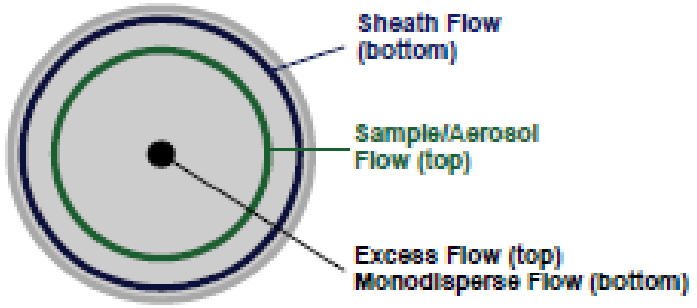


Chaolong Qi, Da-Ren Chen,*David Y.H.* , "Experimental study of a new corona-based unipolar aerosol charger," Journal of Aerosol Science 38(2007) 775-792.

Radial DMA







View on RDMA from the top

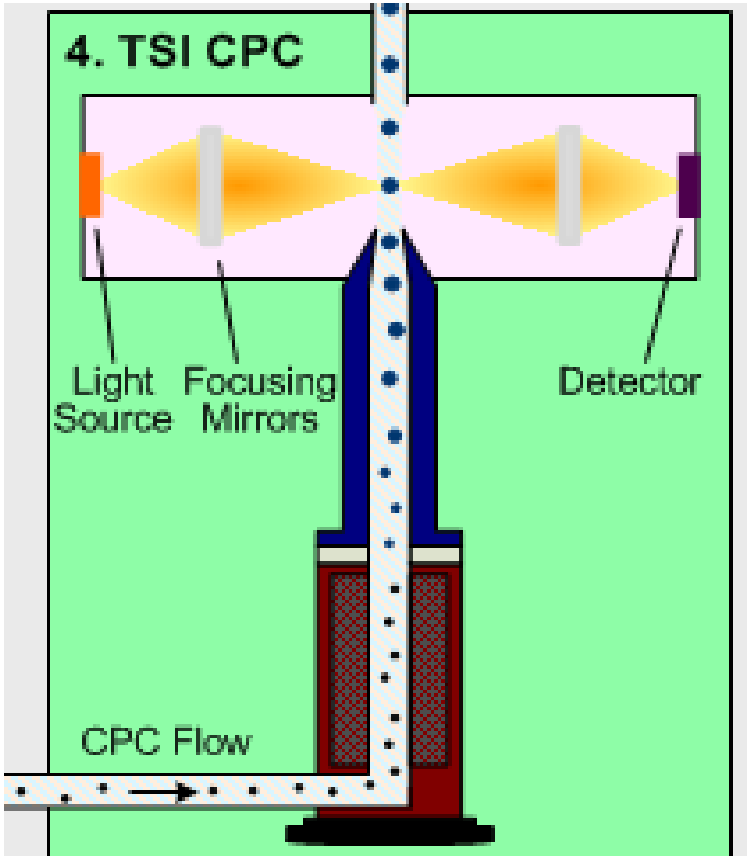
- Compact way to build a Differential Mobility Analyzer (DMA)
- Transfer function identical to cylindrical DMA but electric field parameter takes on new form specific to radial geometry
- Sheath to aerosol ratio fixed for each design
- Resolution limited at some point due to non-ideal gas flow and electric field edge effects

Zhang S.H., Akutsu Y., Russell L.M., Flagan R.C., Seinfeld J.H.: Radial Differential Analyzer, Aerosol Science and Technology, 2007

Particle Counting

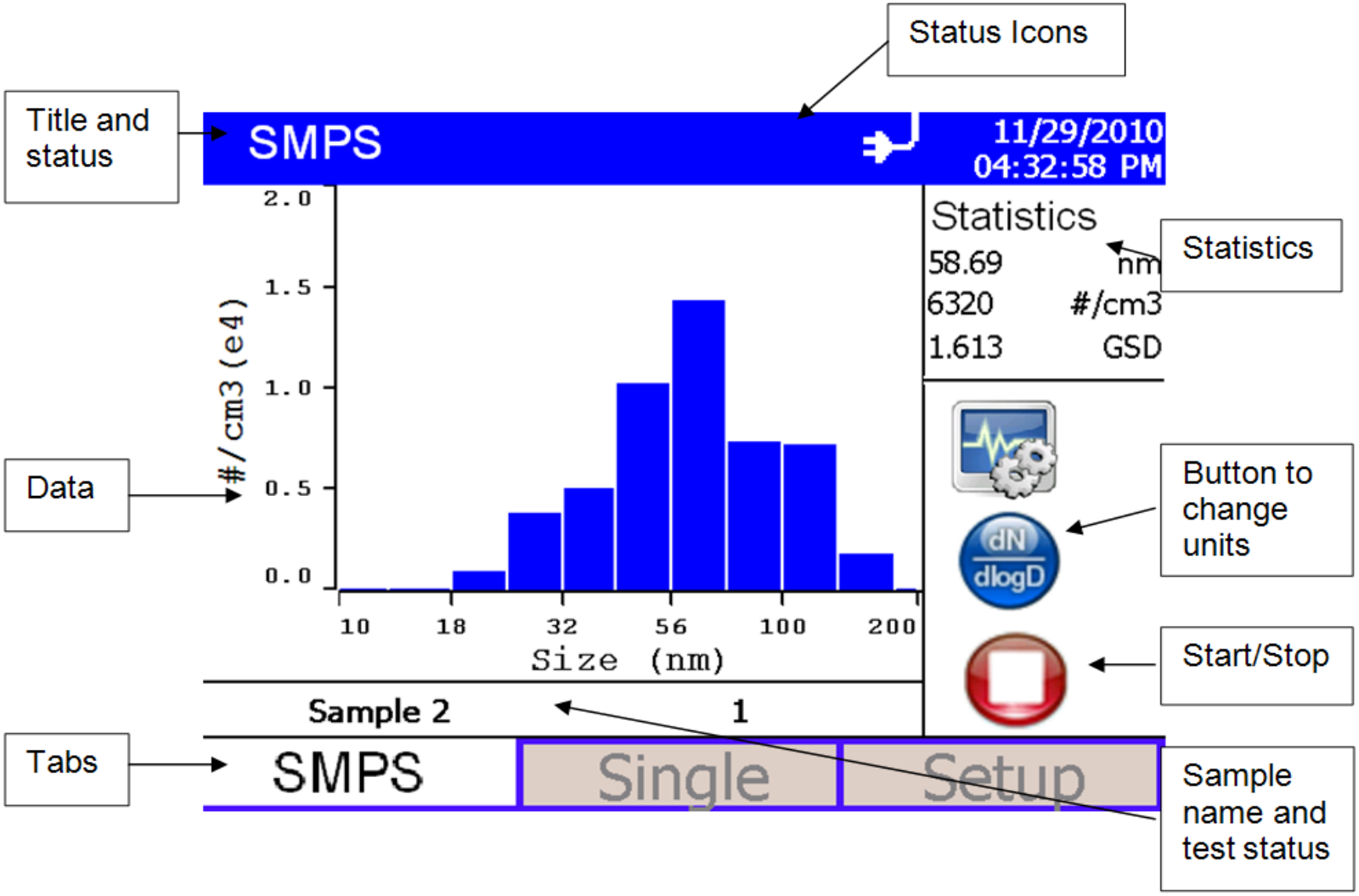
Condensation Particle Counter

- Based on CPC 3007
- Working fluid isopropanol
- Particle concentration up to 1 000 000 particles/cm^3



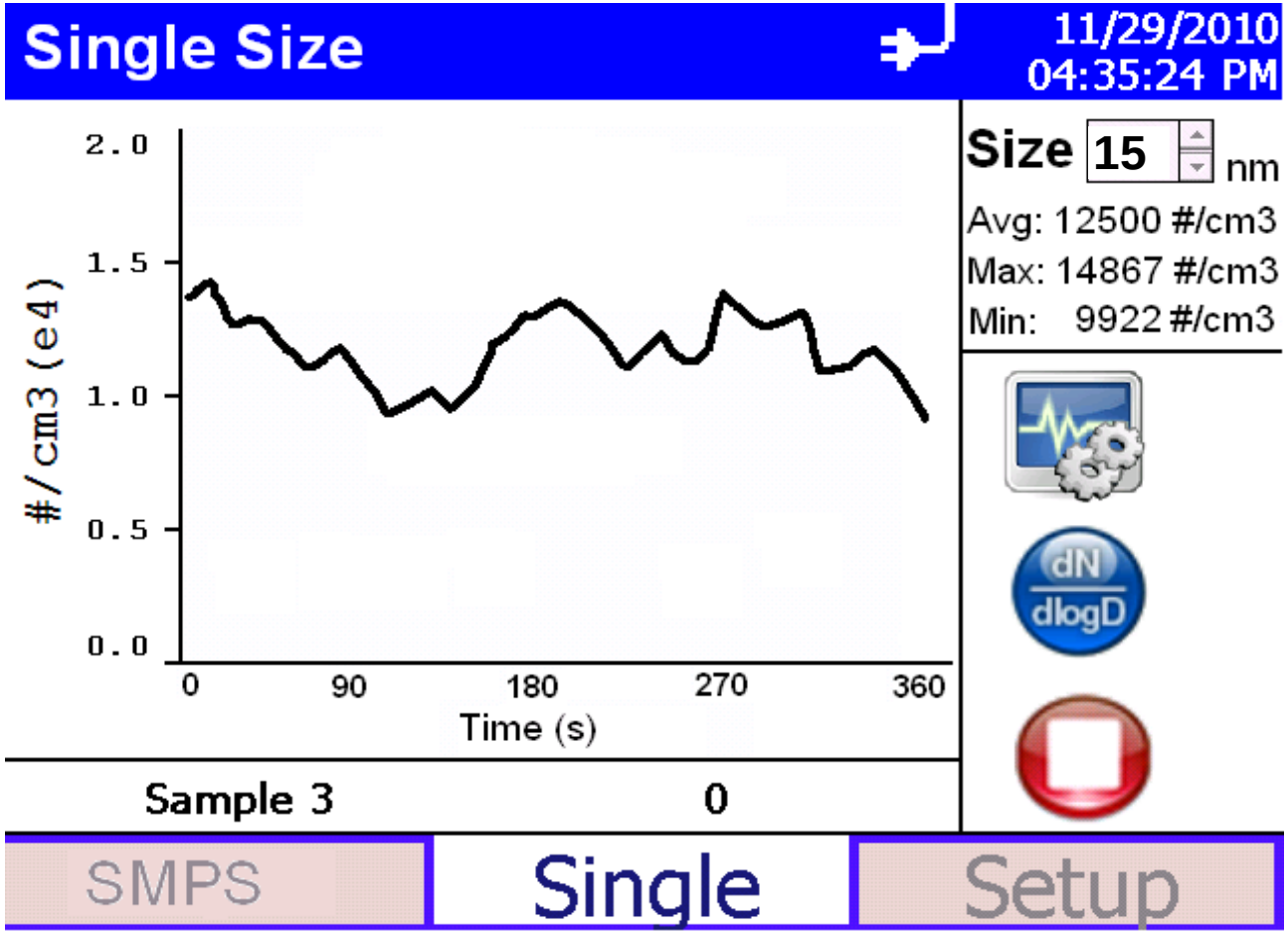
Instrument Interface (1)

SMPS Scanning mode



Instrument Interface (2)

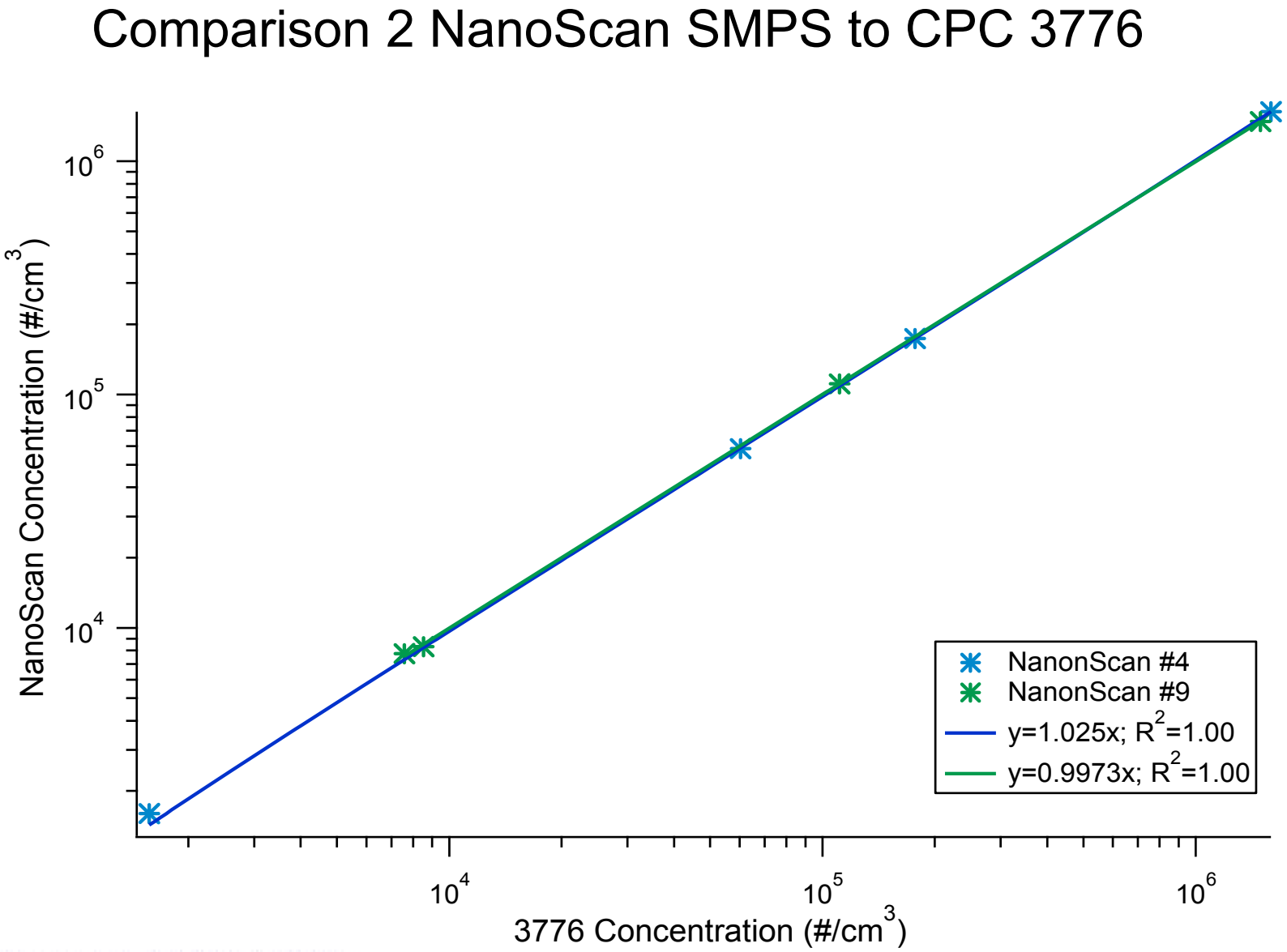
Single Particle Monitoring



Instrument Validation Test

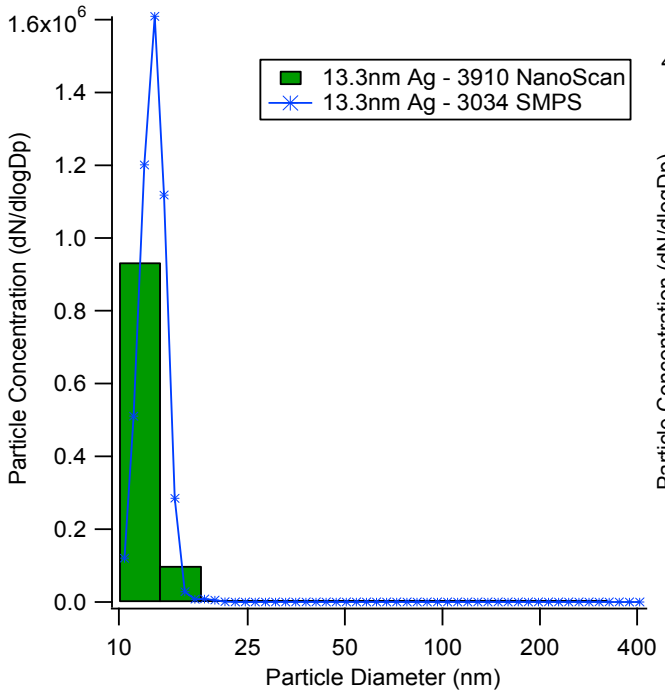
- NanoScan SMPS was thoroughly characterized
- Parameters that were determined include
  - Particle concentration linearity
  - Particle size accuracy
  - Intercomparison with other particle sizers
  - Temperature & humidity testing
  - Flow stability

Concentration Linearity

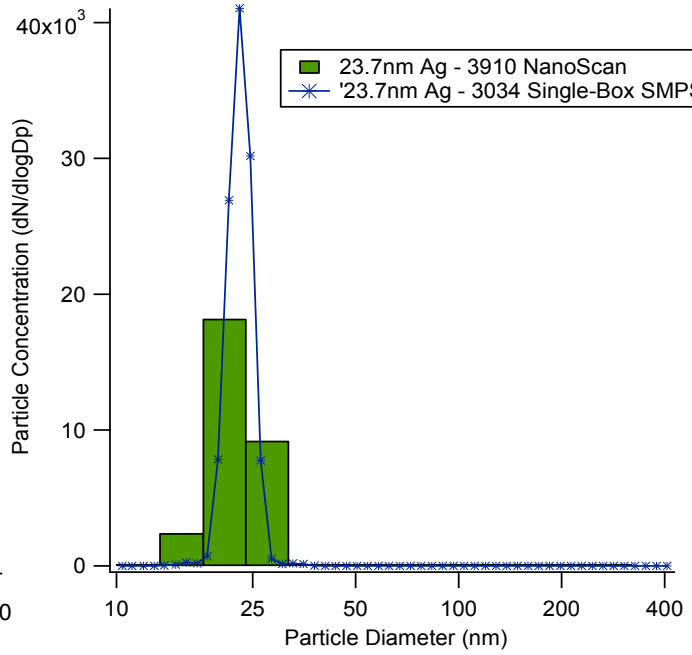


Particle Size Accuracy

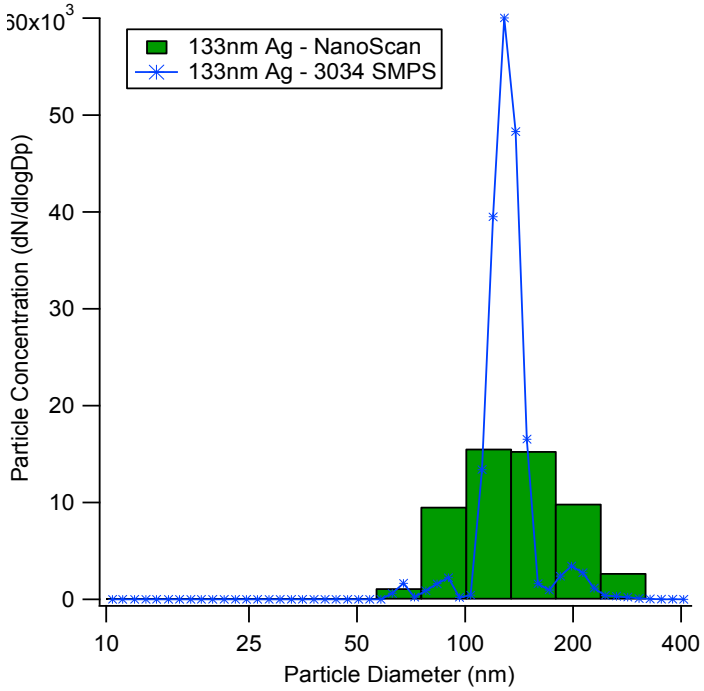
Comparison of NanoScan SMPS to SMPS 3034 for silver nanoparticles



13.3 nm



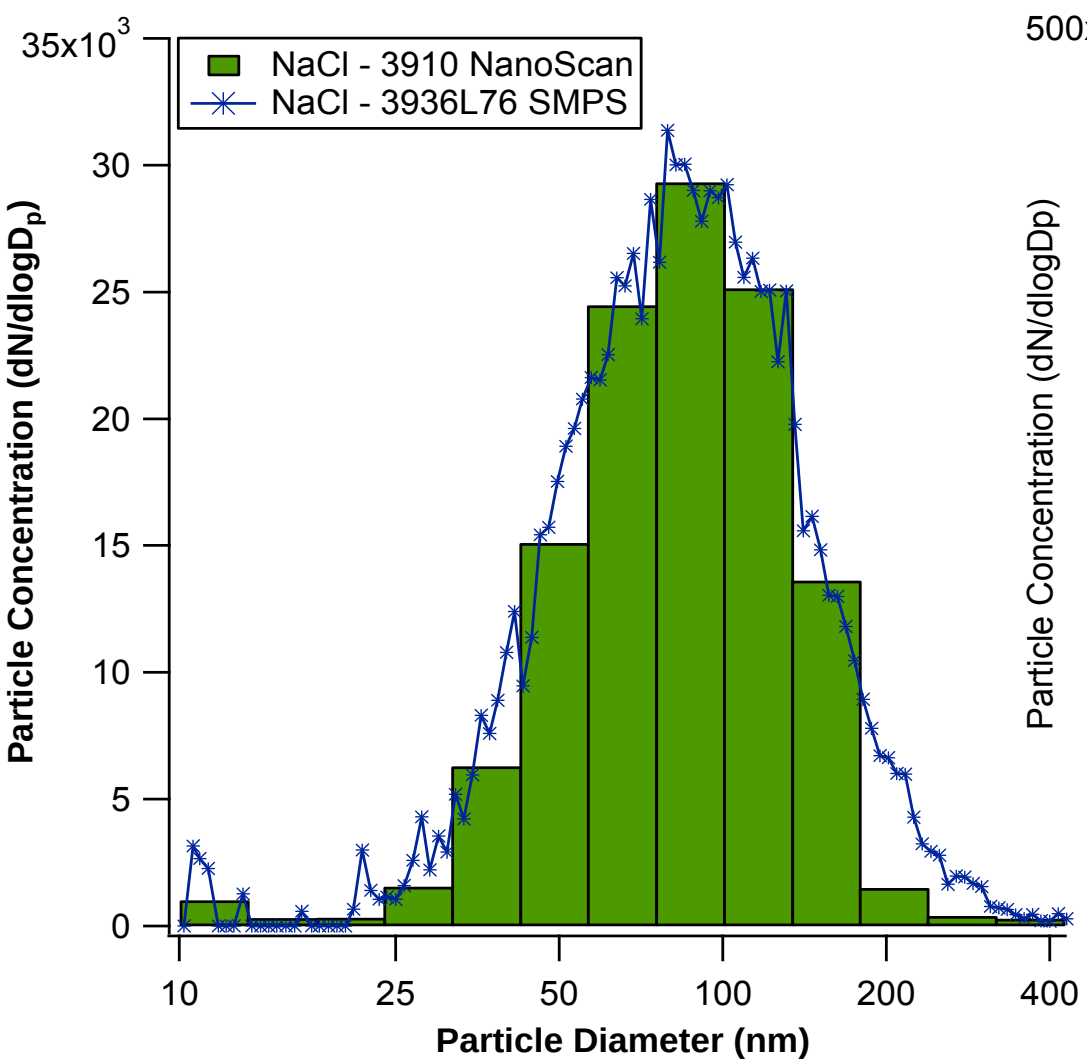
23.7 nm

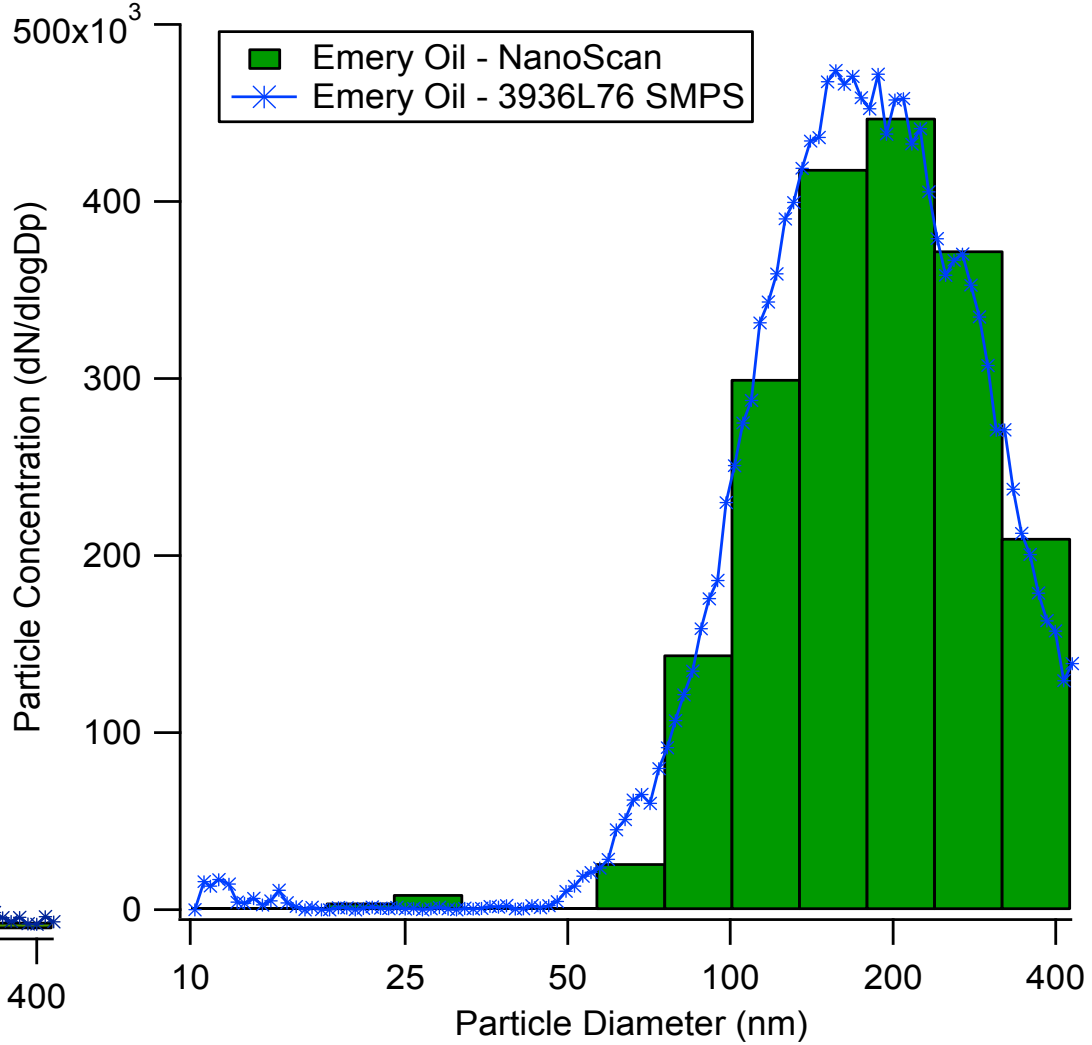


133 nm

SMPS Comparison Data

Comparison of NanoScan SMPS to SMPS 3936L76





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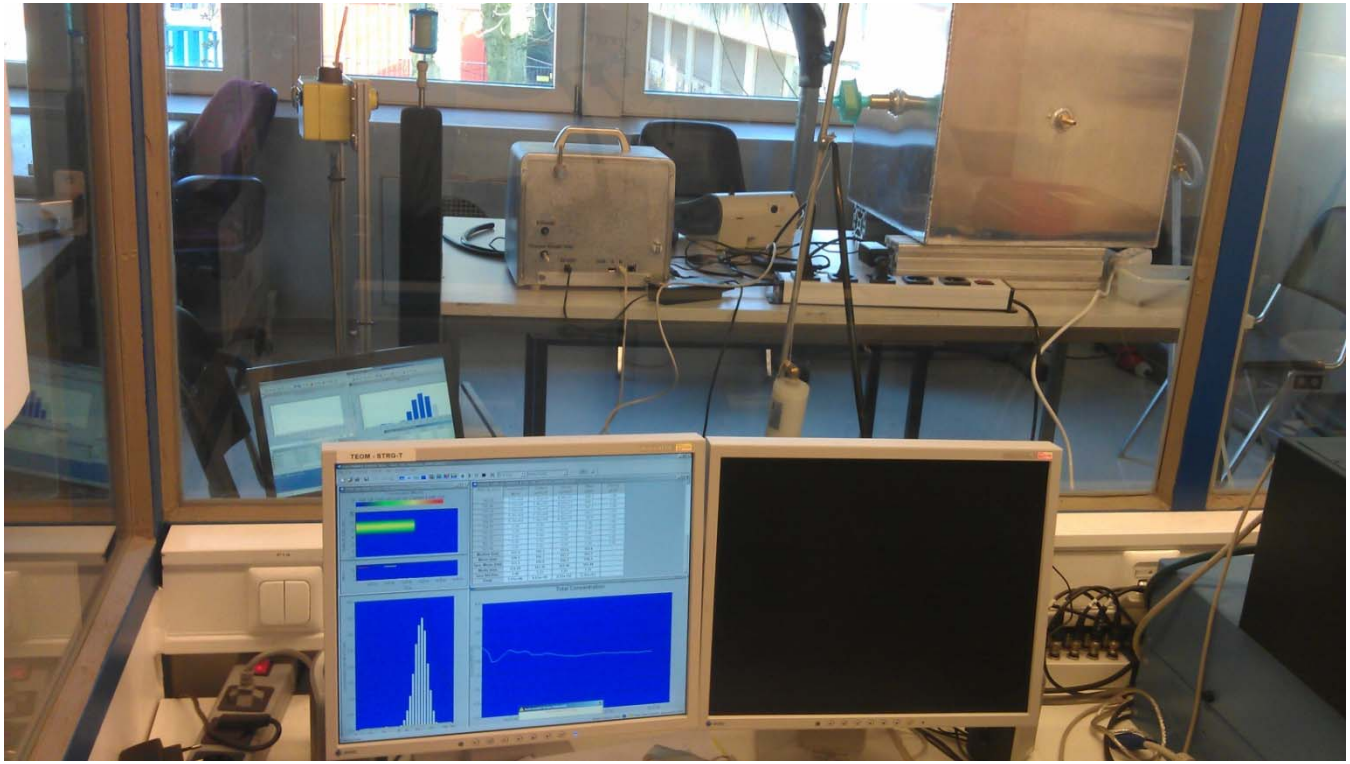
FMPS Intercomparison Data

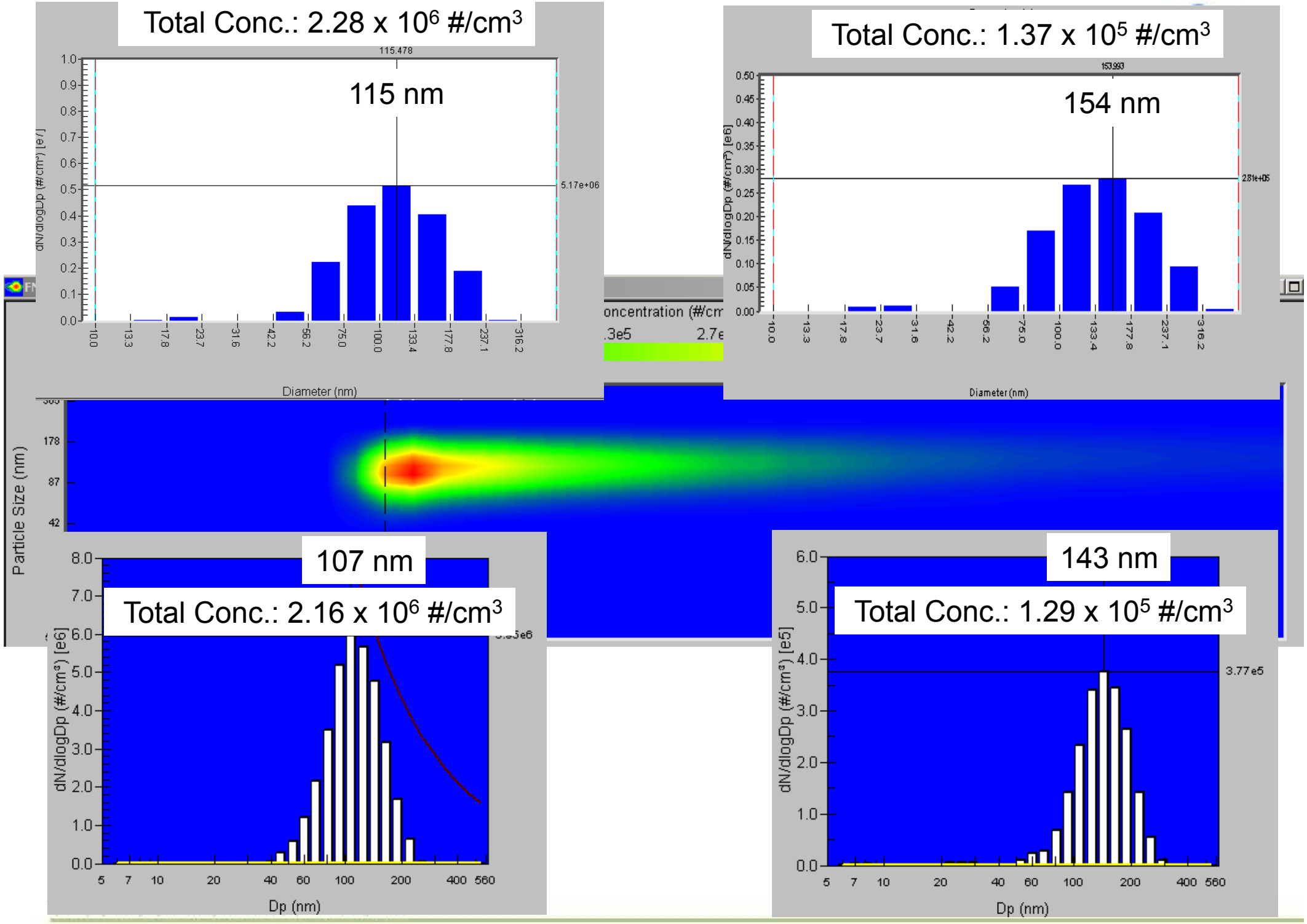
Work place emissions, example: MIG* Soldering



Comparison NanoScan SMPS with Fast Mobility Particle Sizer (FMPS)

*MIG = metal inert gas

Measurements done at Exposition Laboratory
Institute and Out-patient Clinic of Occupational Medicine
RWTH Aachen - University Hospital Aachen
Dr. Peter Brand



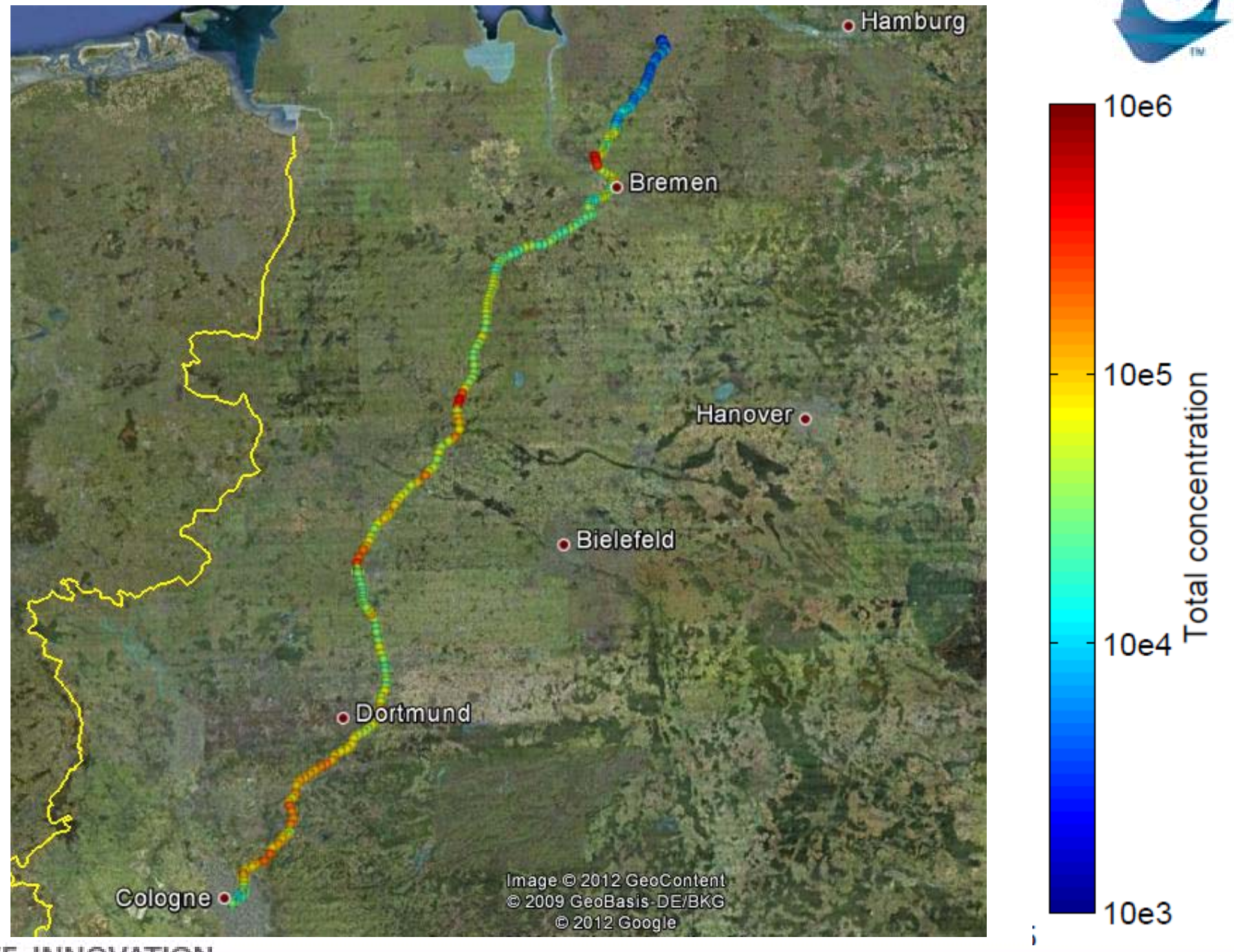
Application:
Mobil Measurements

Sampling indoor air in cabin of a car

- NanoScan SMPS
- GPS tracker

- 380 km drive i
  Germany

Particle Total Concentration



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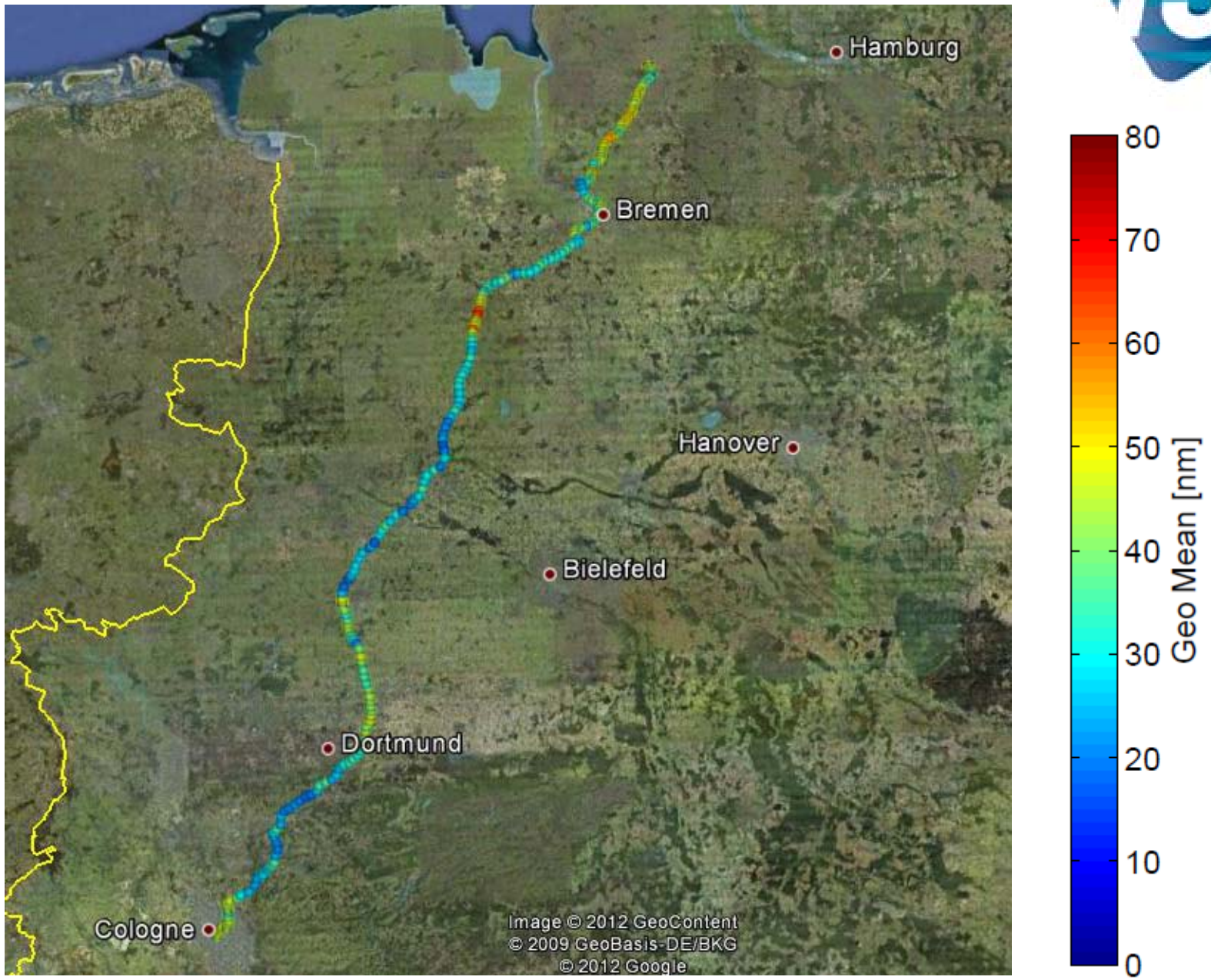
Geometric Mean Diameter



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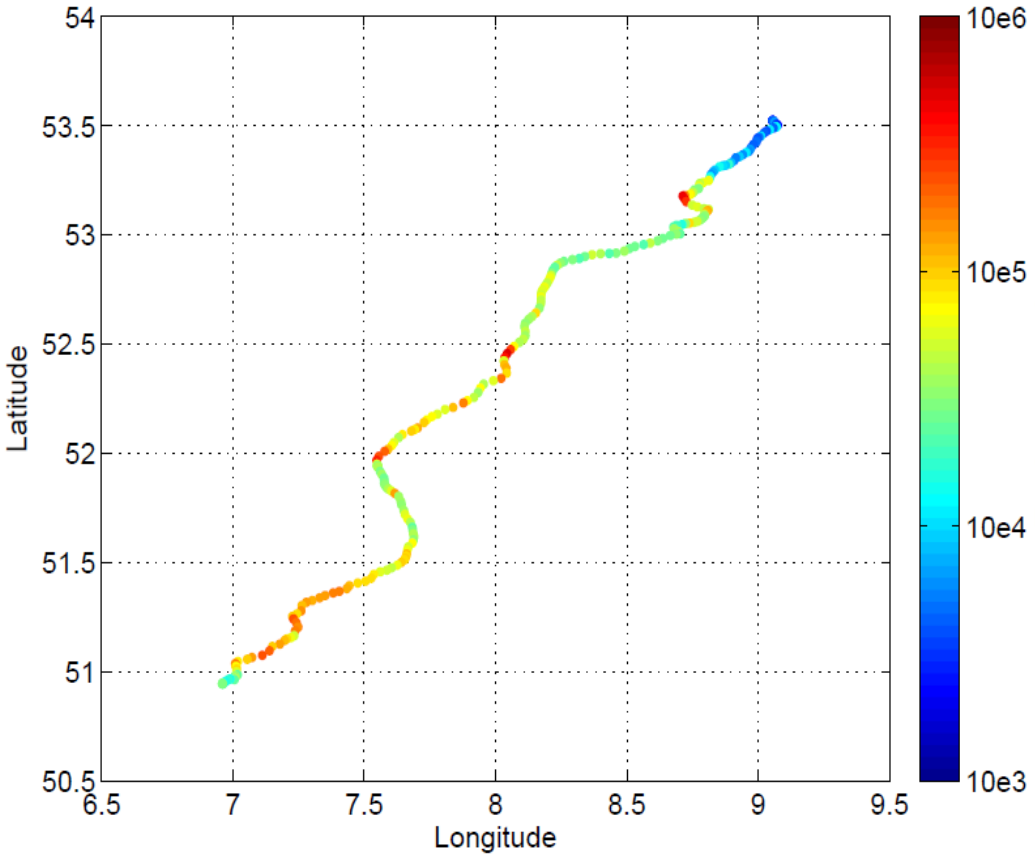
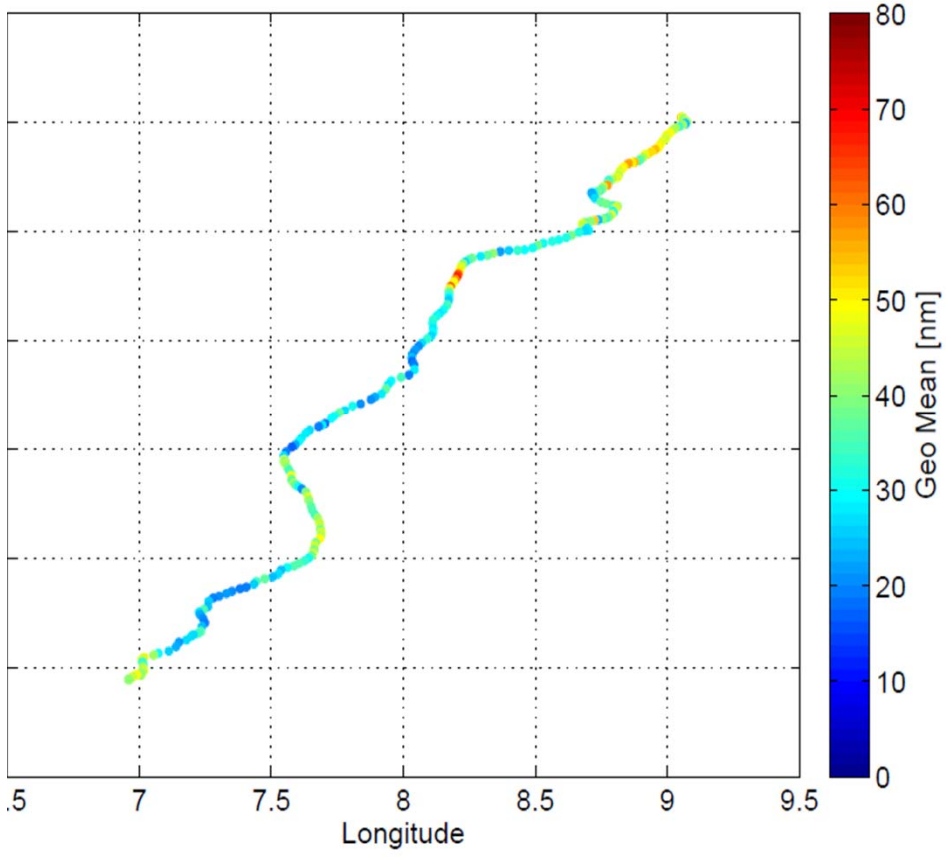
Size Distribution (1)

Total particle concentration



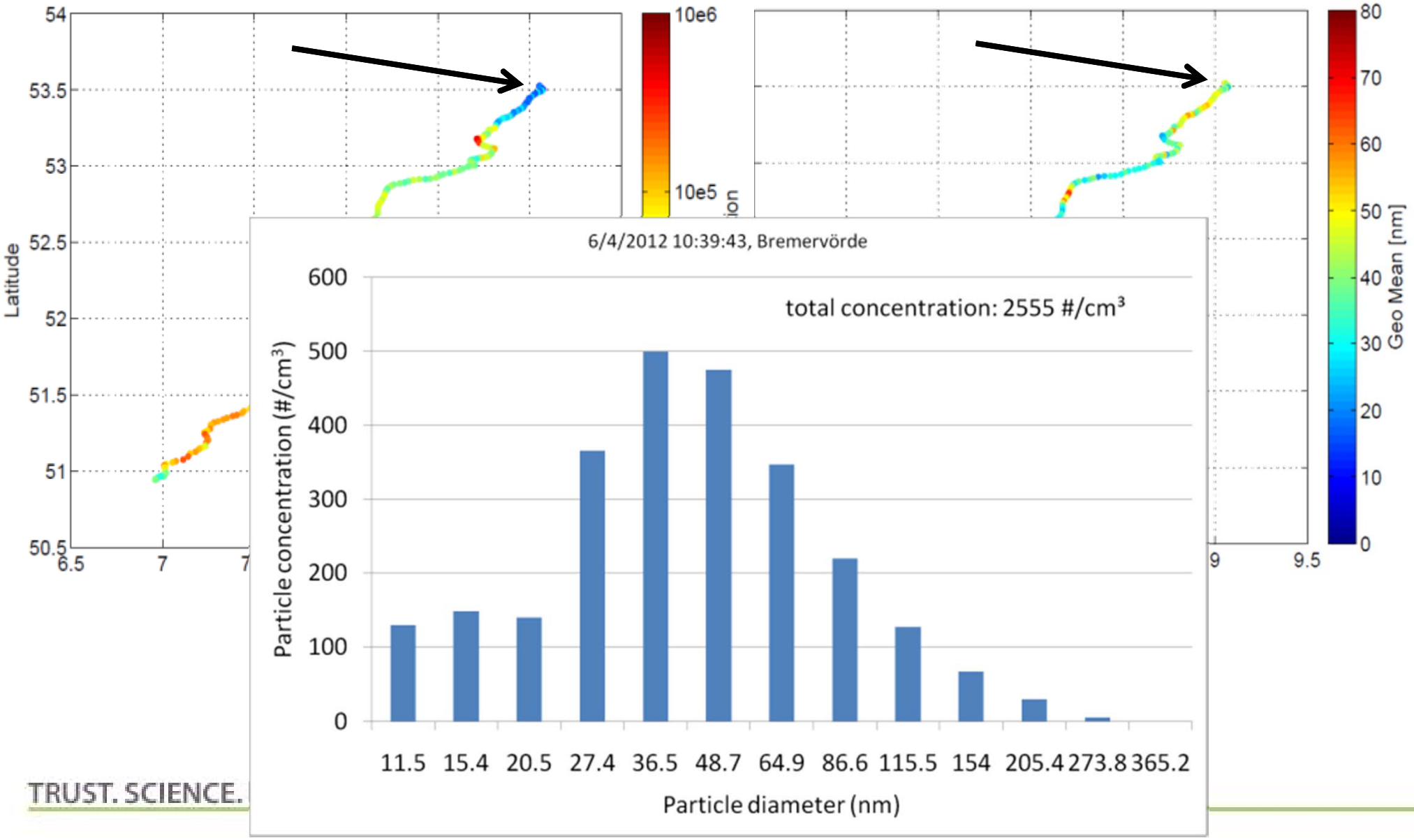
Geometric mean diameter



Size Distribution (1)

Total particle concentration

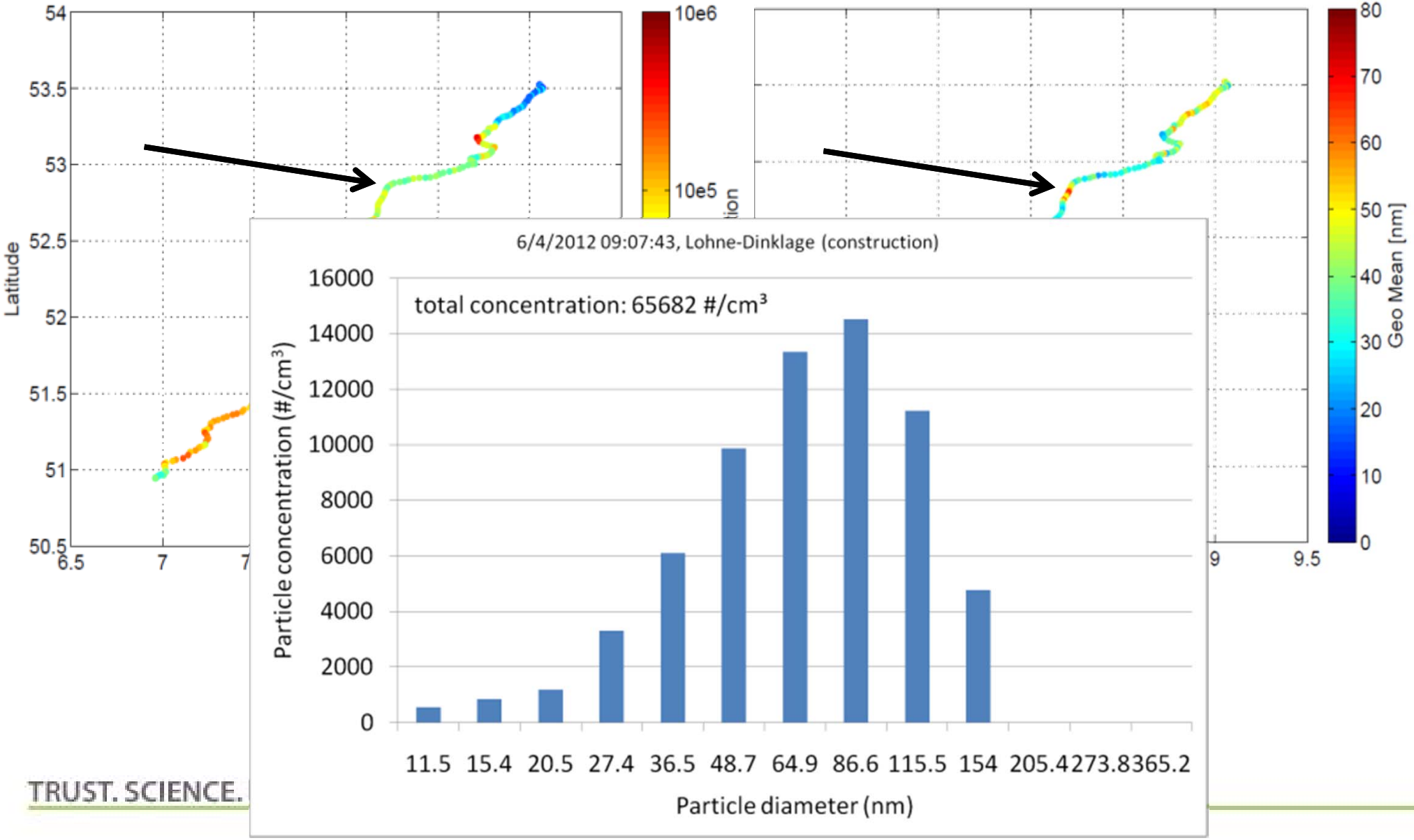
Geometric mean diameter



Size Distribution (2)

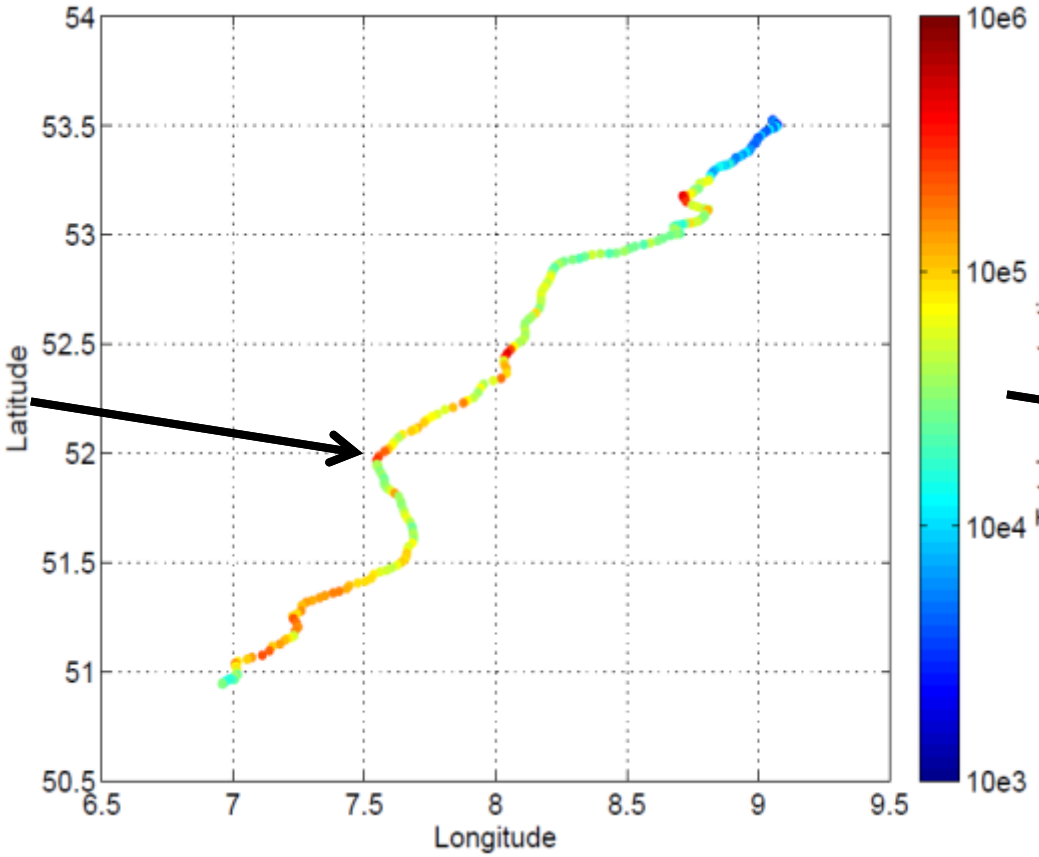
Total particle concentration

Geometric mean diameter

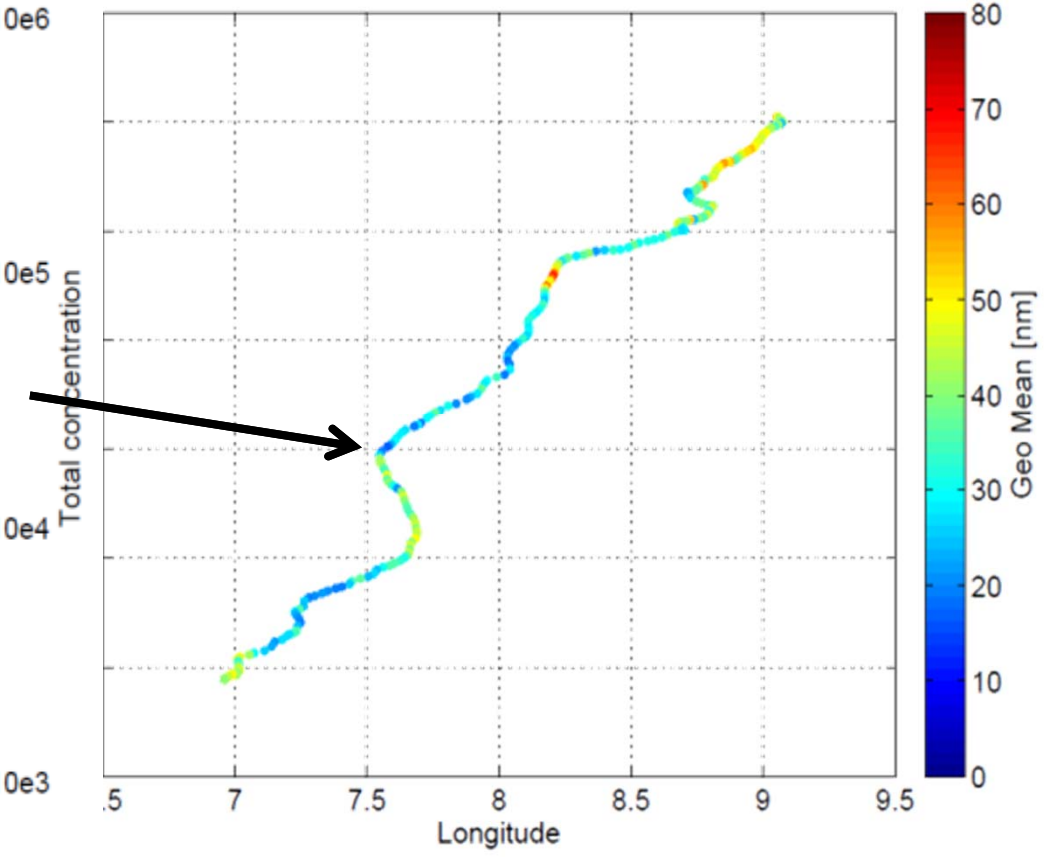


Size Distribution (3)

Total particle concentration



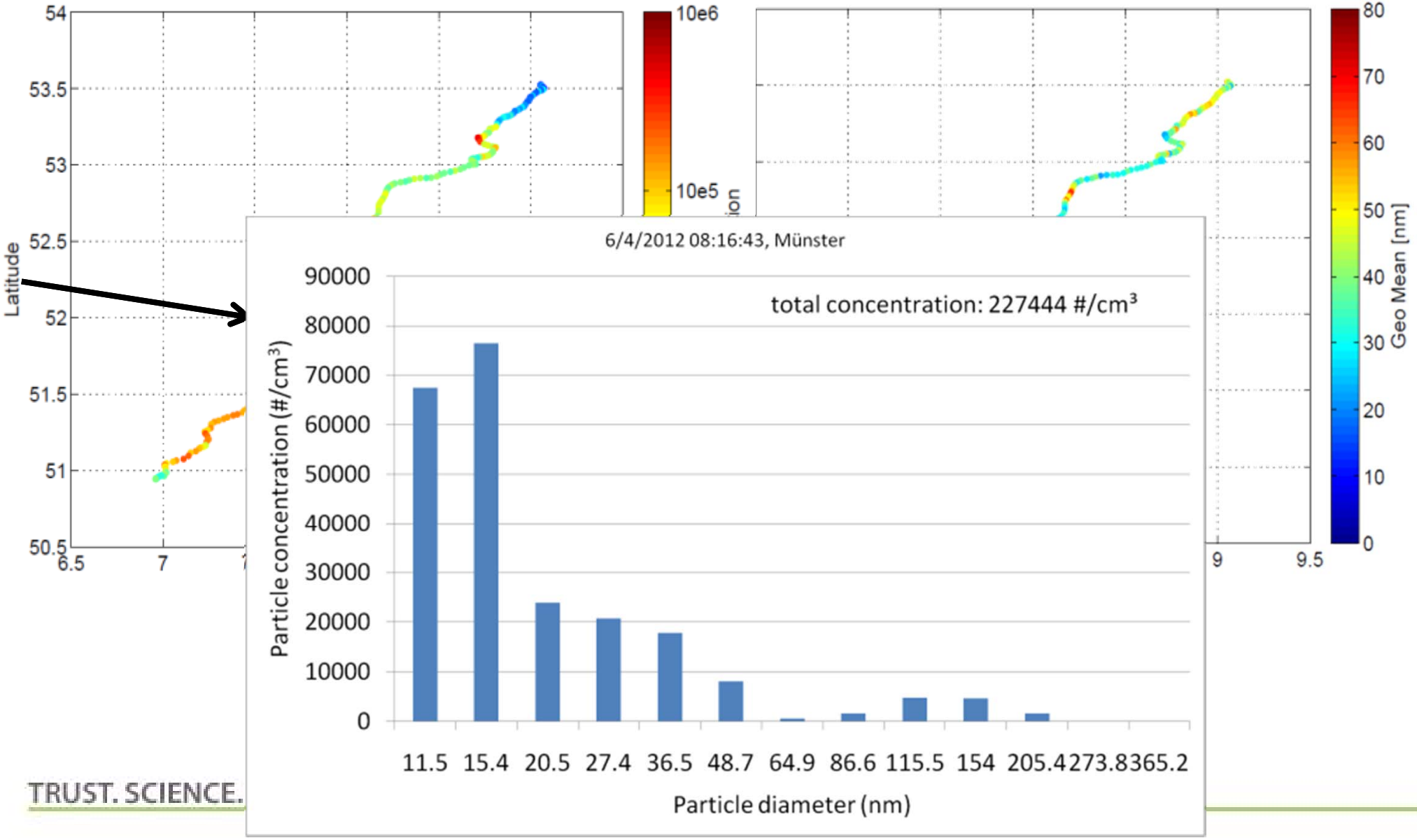
Geometric mean diameter



Size Distribution (3)

Total particle concentration

Geometric mean diameter



Summary

New instrument for real-time nanoparticle measurements
- Range from 10 to 420 nm in 1 min (13 channels)

- Good agreement with established techniques
  - Demonstrated by comparison with component SMPS & FMPS

- Opens up many portable applications, thus allows moving measurements out of the lab
  - On-road and field studies
  - Work place surveys
  - Point source identification

- More data from more sites
  - Temporal and spatial measurements

- Provides investigators with new opportunities
  - Nanoparticle emission/exposure measurements

Thank You For Your Attention!

Any Questions?

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  - Demonstrated by comparison with component SMPS & FMPS
- Opens up many portable applications, thus allows moving measurements out of the lab
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