Chemical composition of aerosol particles including UFPs in Saxony

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- Adverse human health effects by exposure to fine particles depending on size and chemical composition
- Observation of the EU limit value of PM_{10} = 50 μgm^{-3}, the Federal Administration Court in Leipzig recently pronounced a judgement confirming the right to clean air for every citizen
- Influence of fine particles on radiative forcing by direct (scattering or absorbing of radiation) or indirect (formation of CCN, thereby influencing cloud droplet size distribution and albedo) processes
- Influence on atmospheric multiphase chemistry:
  reactions in gas and liquid phase, reactions on particle surfaces, uptake and equilibria reactions, radical reactions
  $\Rightarrow$ alteration of existing particles, formation of new particles

Investigation of

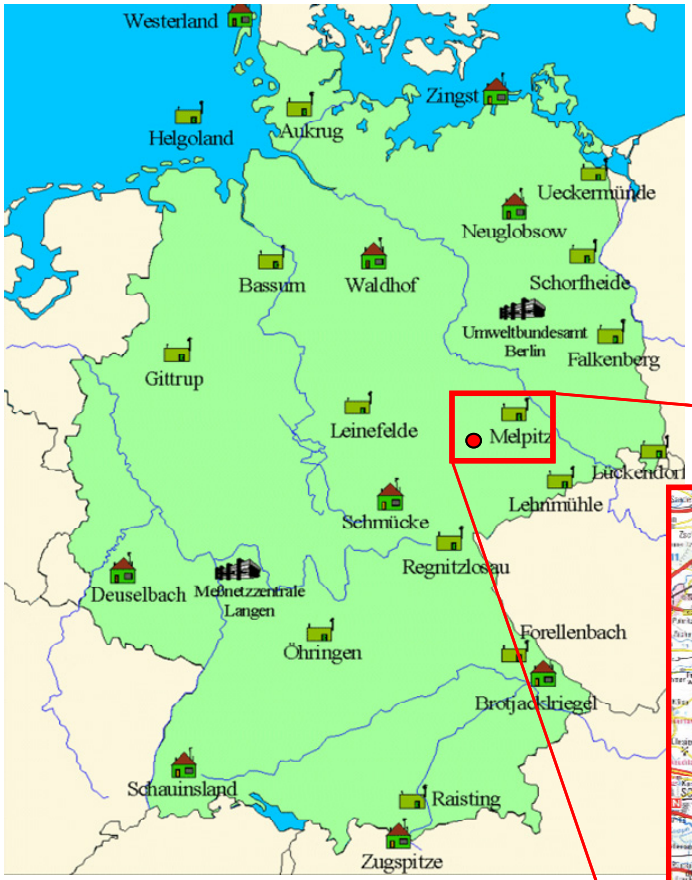
- particle sources
- fractions of different particle sources
- long range transport effects

was performed by combination of

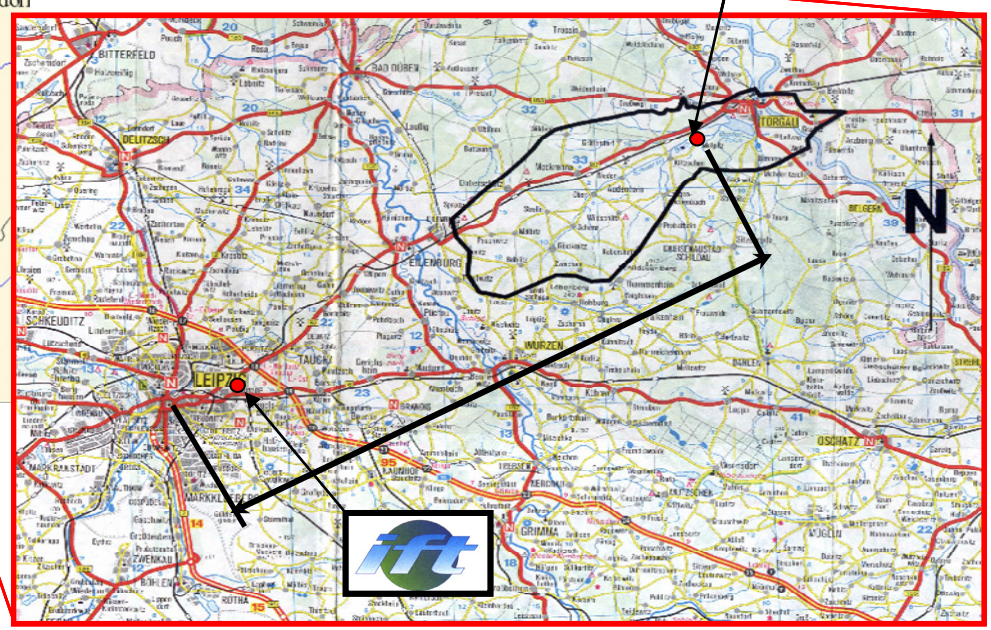
- size-segregated particle sampling using impactors
- sampling during different seasons (mostly summer/winter)
- sampling at different polluted sites in Saxony
- chemical analysis of all particle size ranges
- trajectory analysis (NOAA HYSPLIT) to estimate air mass origin

Projects in Saxony dealing with particle investigation by size-segregated sampling and chemical analysis performed during the last decade (without claim of completeness) were a.o.:

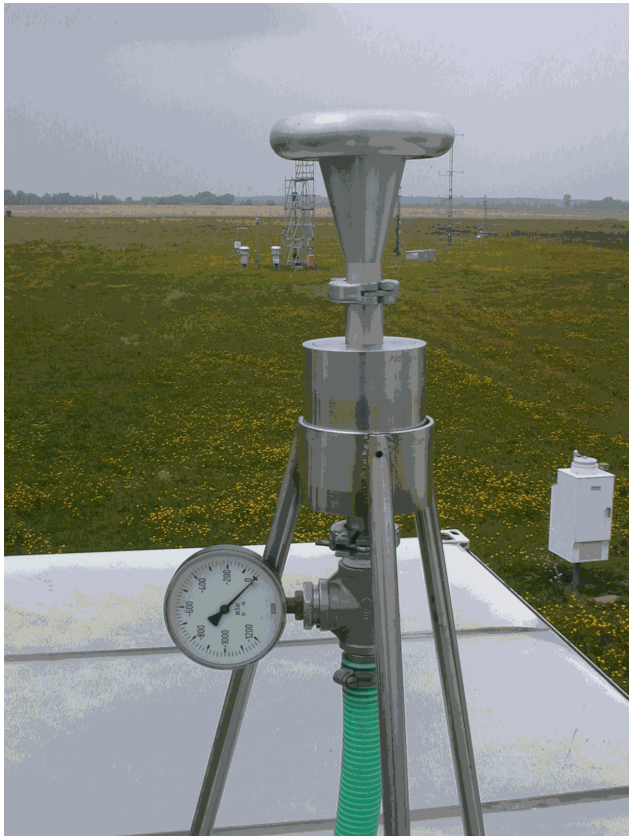
- „MINT“ (autumn 1997) at the research station Melpitz of the IfT
- „Feinstaub“, a source study (1999/2000) at 3 stations in Leipzig and Melpitz - LfUG I
- „Schwebstaub“, a study of size-segregated chemical composition at 2 stations in Dresden (2003/04) - LfUG II
- „Ferneintrag“, a study of long range transport at 5 stations in Saxony (2006/07) - LfUG III
- FAT project „Carbon in nanoparticles“ (2004/05), investigation of particles in a busy street canyon
- „Holzfeuerungen“ (wood burning) starting Oct. 2007 - LfUG IV



Distance:
Leipzig (downtown) to Melpitz
about 50 km
(12°56‘ E, 51°32‘ N,
Altitude 86 m above see level)



UBA network and the IfT research station Melpitz



BERNER impactor

Cuts: 0.05/0.14/0.42/1.2/3.5/10 µm
aerodynamic diameter

Flow: 4.5 m^3h^{-1}

Sampling time: 24 hours

MOUDI/Nano-MOUDI – System

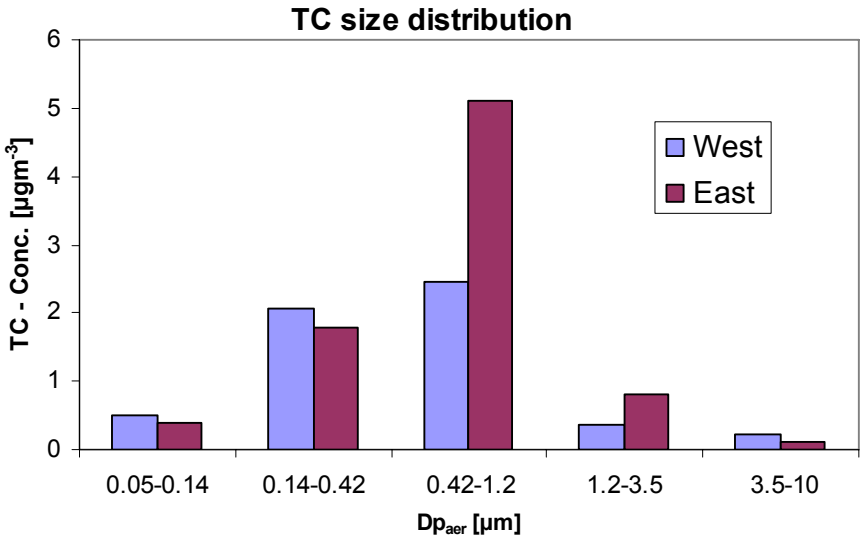
(Micro-Orifice Uniform Deposit Impactor)

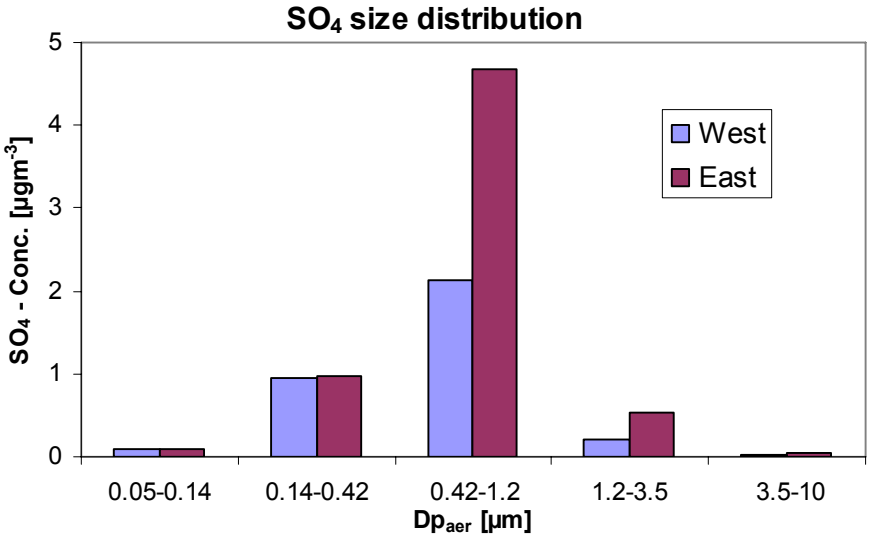
MOUDI: size range Dp_{aer}= 0.056–18 µm/flow: 1.8 m^3h^{-1}

Nano-MOUDI: Dp_{aer}= 0.010–0.056 µm/flow: 0.6 m^3h^{-1}

Sampling time: (24) 48 – 96 hours

Sampling instruments

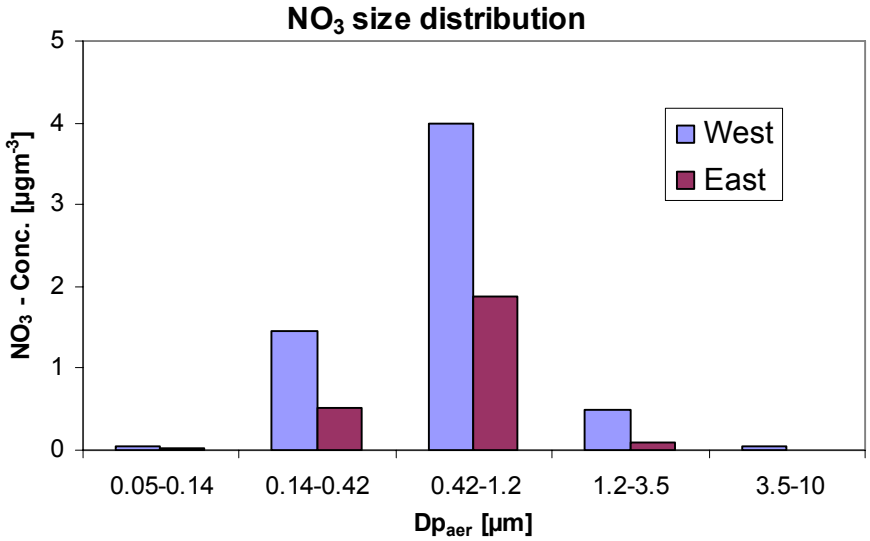




TC: significant W/E-differences on size ranges
Dp_{aer}= 0.42-1.2 and 1.2-3.5 µm, trend E >W

SO_4: significant W/E-difference on size range
Dp_{aer}= 0.42-1.2 µm, trend E >W

NO_3: significant W/E-differences on size ranges
Dp_{aer}= 0.14-0.42, 0.42-1.2, and 1.2-3.5 µm, trend W > E



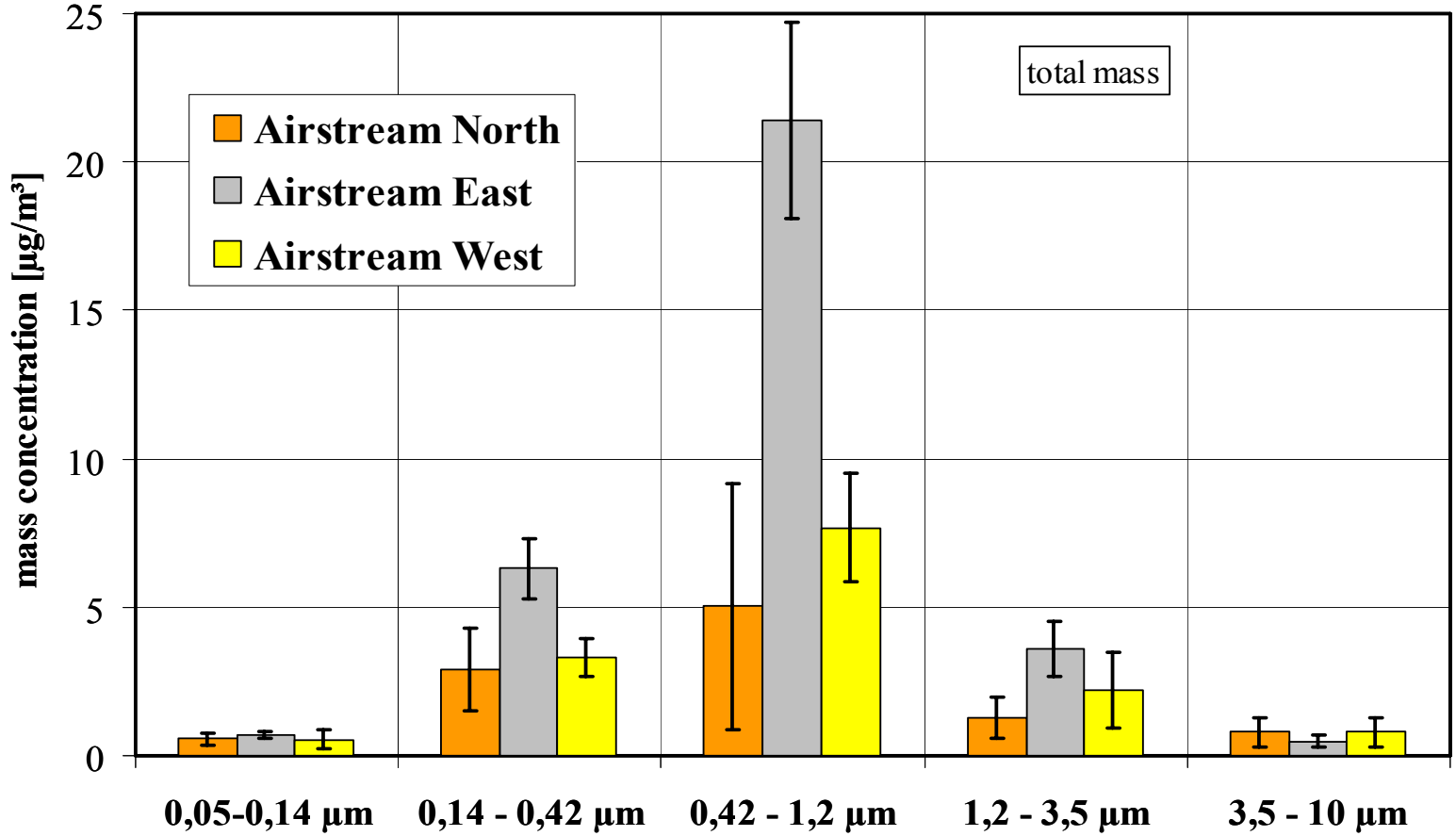
Significance was confirmed by Student‘s t-test (5% error probability)

Some MINT 97 results (west/east – contrast)

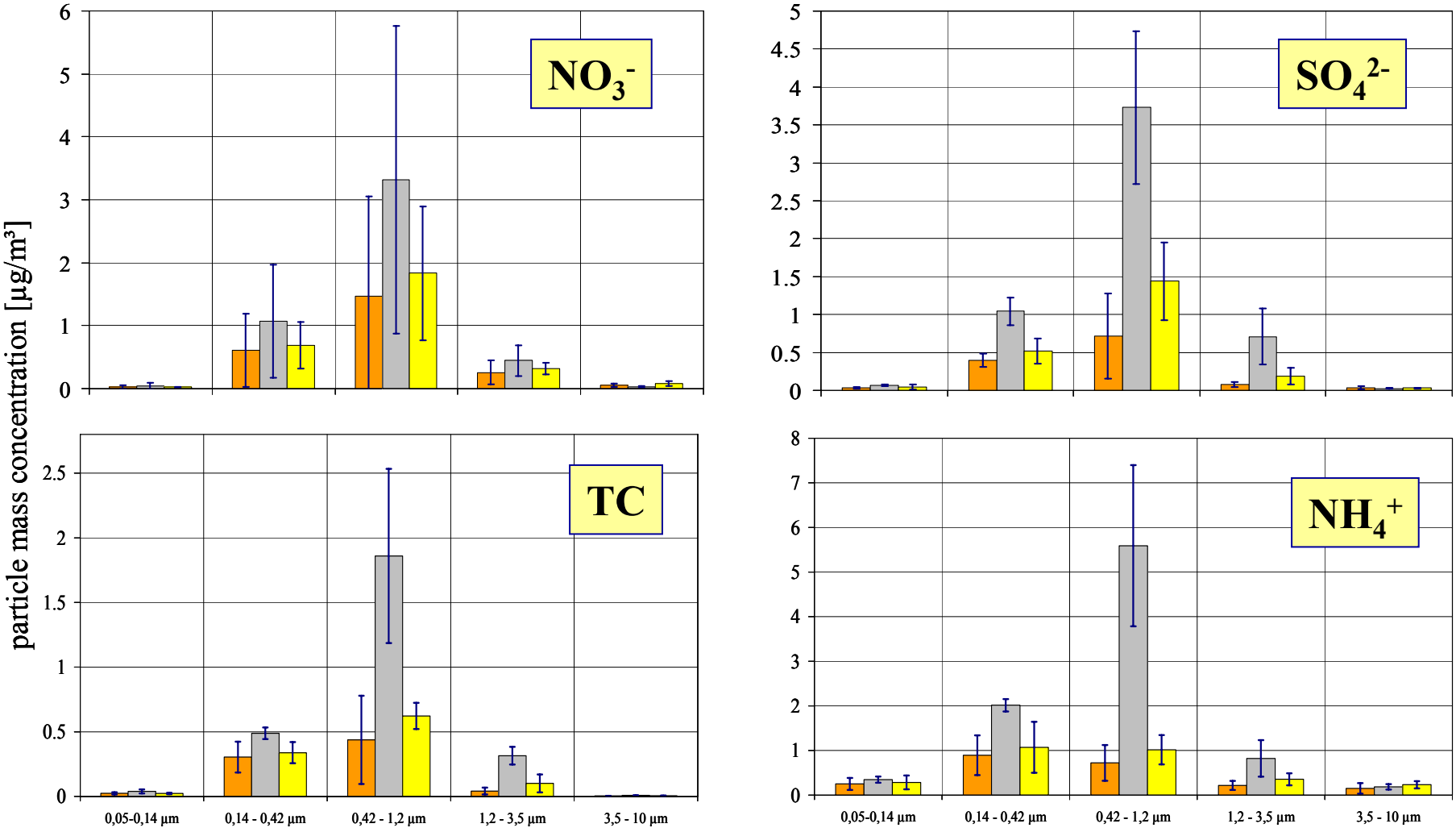
Air stream North: **northern Atlantic** 2003: 10-27, 10-30 and 11-03

Air stream West: **Atlantic and Western Europe** 2003: 11-17, 11-20 and 11-24

Air stream East: **continental, Eastern Europe** 2003: 11-08, 11-09 and 11-13

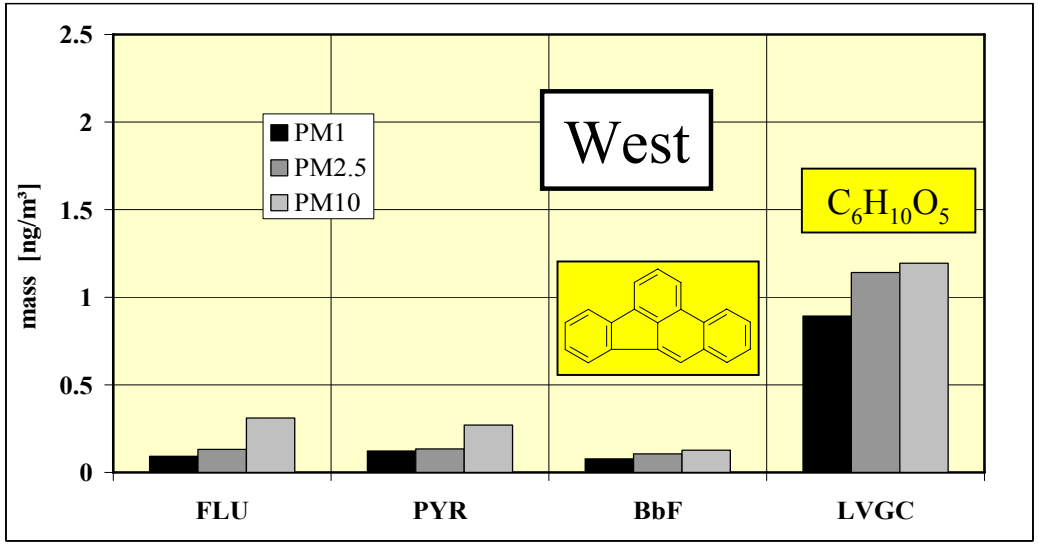


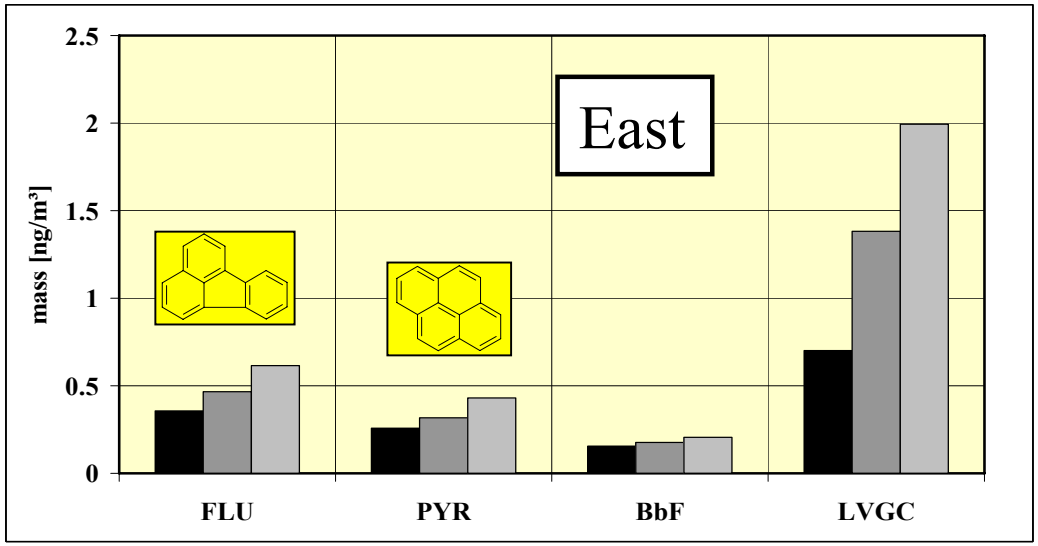
Size segregated particle mass in 2003 Melpitz episodes



Air stream: North, West, and East

Main ions and TC in 2003 Melpitz episodes





GC-MS
(for Levoglucosan derivated with Trimethylsilylammoniumhydroxide)

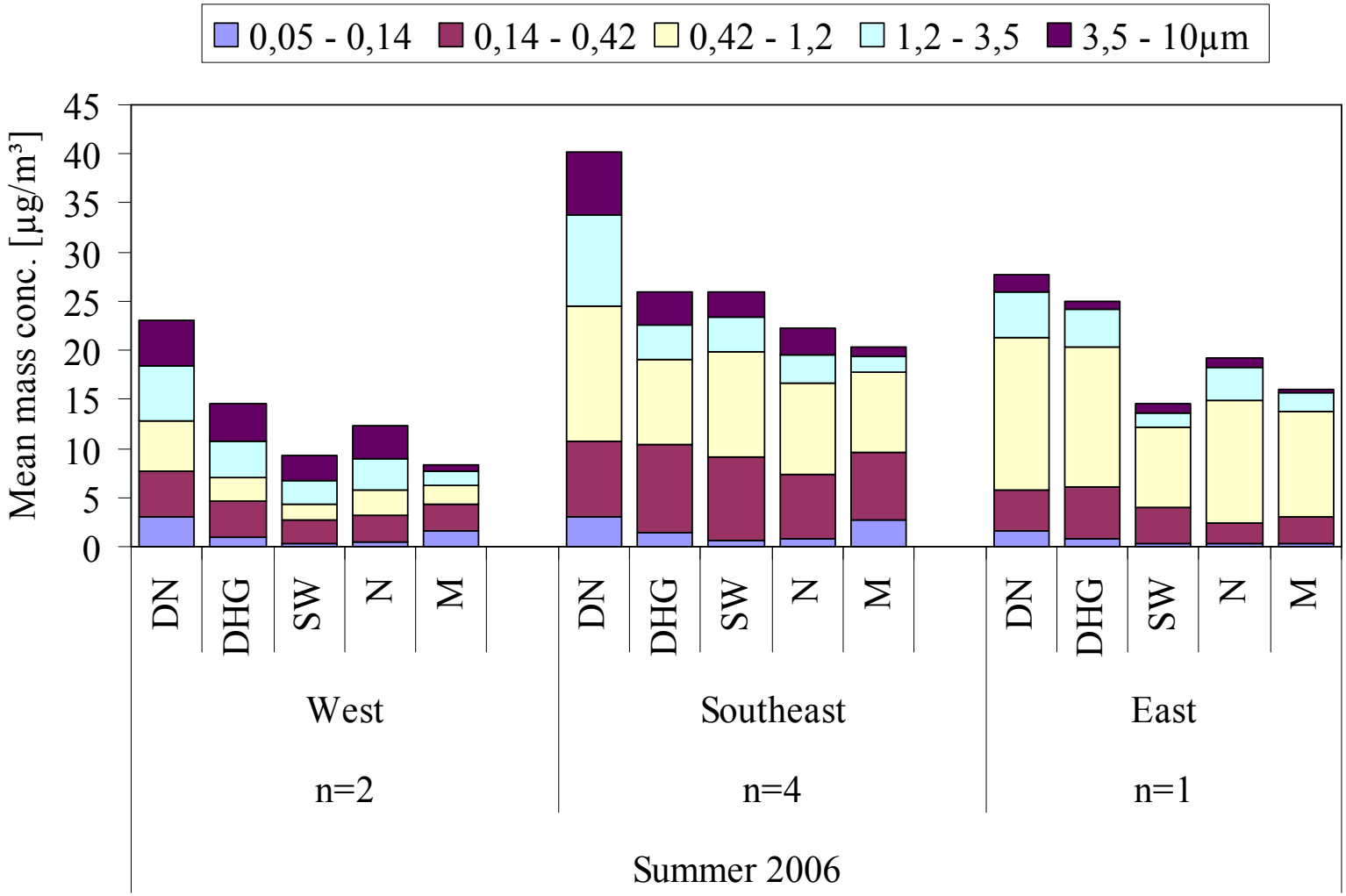
2004-03-15

2004-03-12

Melpitz

FLU -	Fluoranthene	combustion
PYR -	Pyrene	combustion
BbF -	Benzo(b)-fluoranthene	gasoline marker
LVGC	Levoglucosan	biomass burning

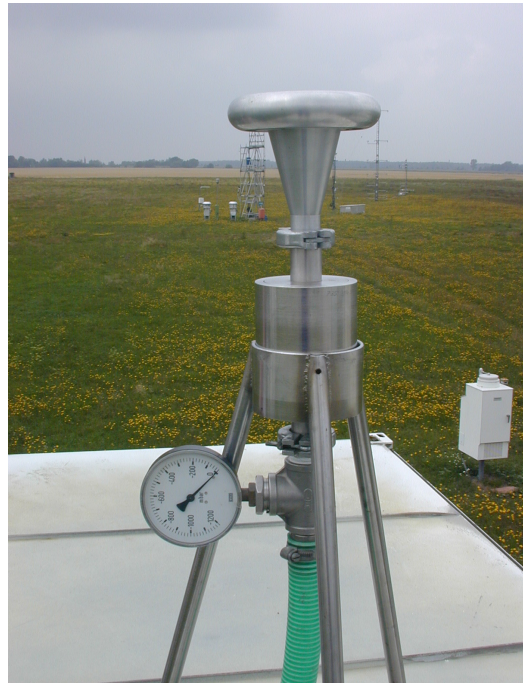
Selected organic species according to air mass origin



Particle mass distribution in summer 2006 (Melpitz)

Traffic influenced urban site Leipzig

Urban background site on the IfT roof (4 km NE)



Regional background research site Melpitz (50 km NE)

LfUG I measurement sites

Source apportionment from particle measurement data using a set of basic assumptions and logical deductions:

1) Traffic density is assumed to be nearly constant throughout the year
2) Particulate carbon in the size range Dp_{aer}= 0.05-0.14 µm originate entirely from traffic emissions with a characteristic OC/EC ratio
3) Higher size ranges include for EC aged traffic emissions and domestic heating emissions in winter (for OC the same), as well as aged traffic emissions in summer and for OC aged traffic emissions together with biogenic emissions
4) Diesel engine vehicles emit 90% of the particles originating from traffic in Saxony
5) Mixing Layer Height (MLH) is assumed to be in summer twice as high than in winter, for winter/summer comparison MLH is formally adapted by doubling summer concentrations

Considering these assumptions calculation can be performed using following equations:

(1) EC(traffic) = EC(summer)

(2) EC(diesel) = EC(traffic) · 0.9

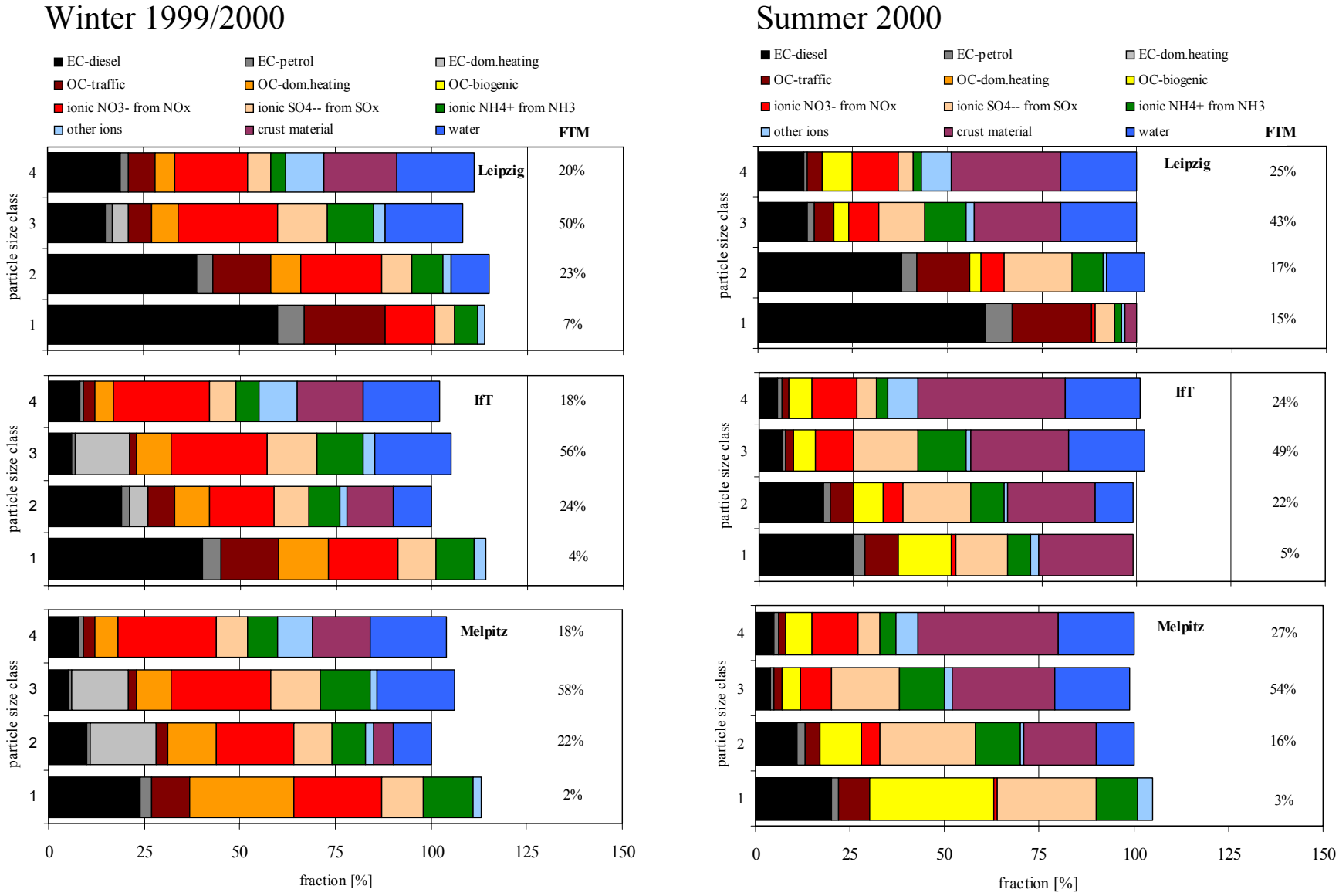
(3) EC(petrol) = EC(traffic) · 0.1

(4) OC(traffic) = EC(traffic) · OC/EC(traffic)

(5) EC(dom. heating) = EC(winter) – EC(summer)

(6) OC(dom. heating) = OC(winter) – OC(traffic)

(7) OC(biogenic) = OC(summer) – OC(traffic)



Fine particle study (LfUG I): source attribution

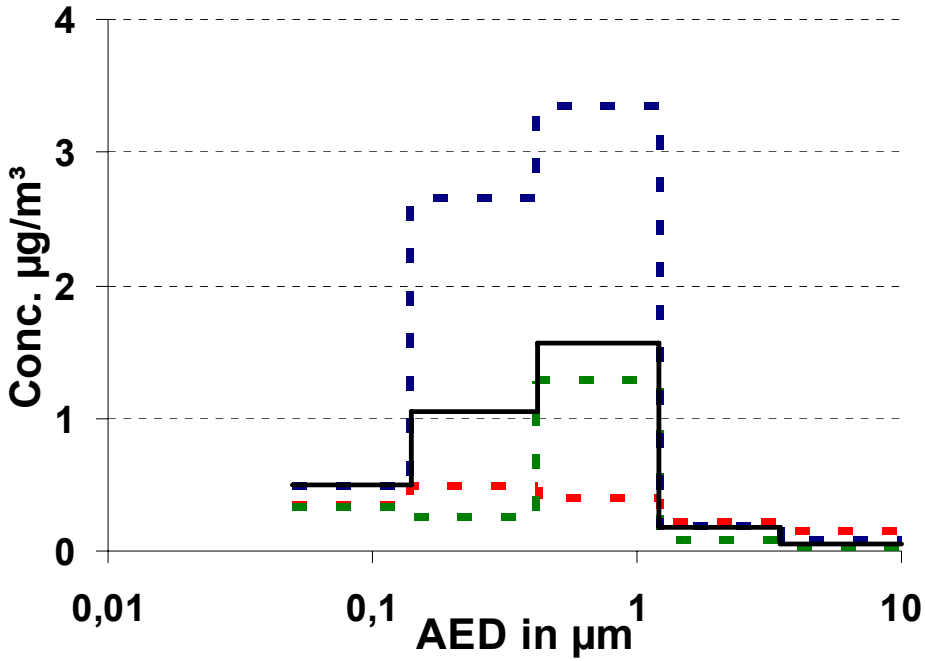
Dresden – Nord (DN)
Urban traffic site
Traffic density: 55000 vehicles/day

Urban background site
Traffic density < 5000 veh./day

Particle sampling: PM_{10}, $PM_{2.5}$
Size-segregated: BERNER, MOUDI

Winter and summer sampling

LfUG II measurement sites in Dresden



BERNER impactor
5 stage sampling

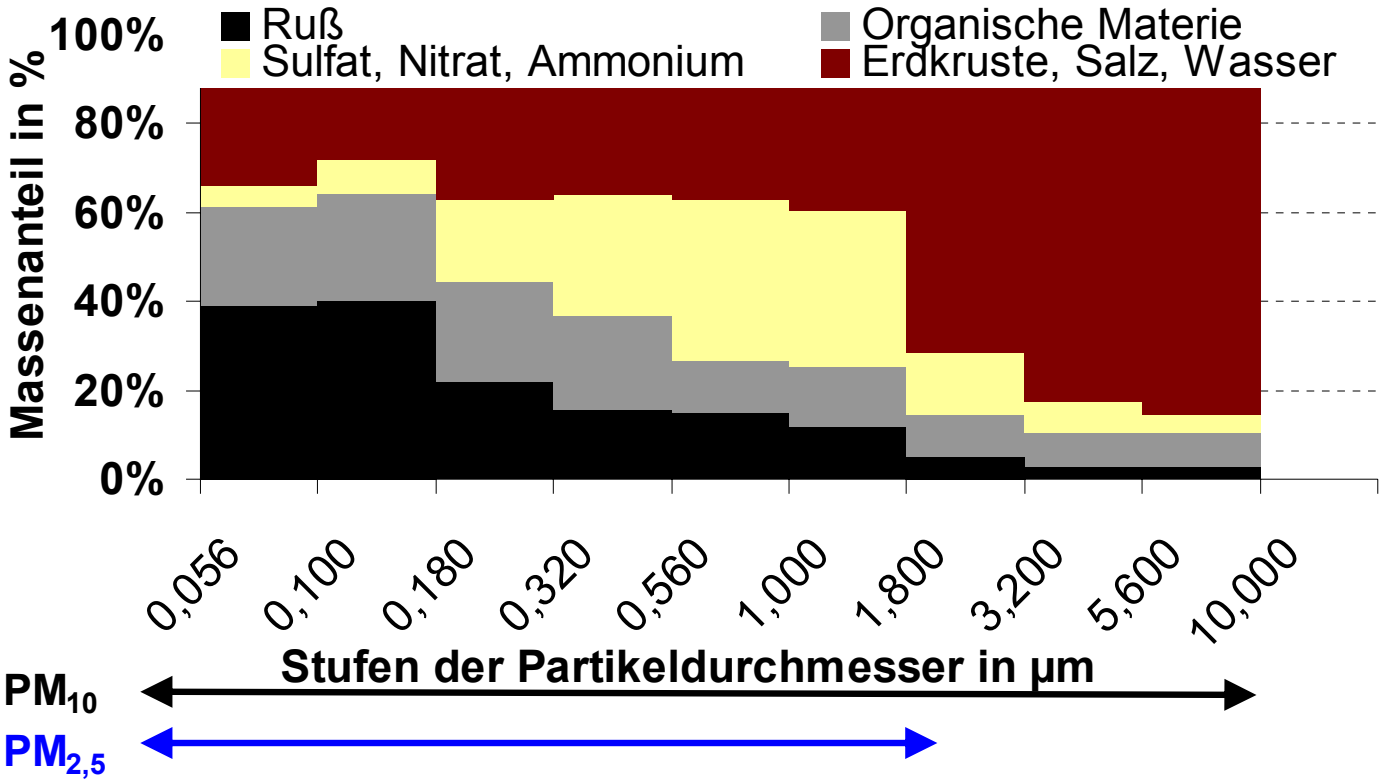
Average line: n = 8 / 6°C

Weekday before heating period
n = 2 / 12°C

Weekday during heating period
n = 2 / 2°C
domestic heating emissions

Saturday + New Year
during heating period (n = 2 / 2°C)
less vehicles on the road: a half of passenger cars
a quarter of trucks

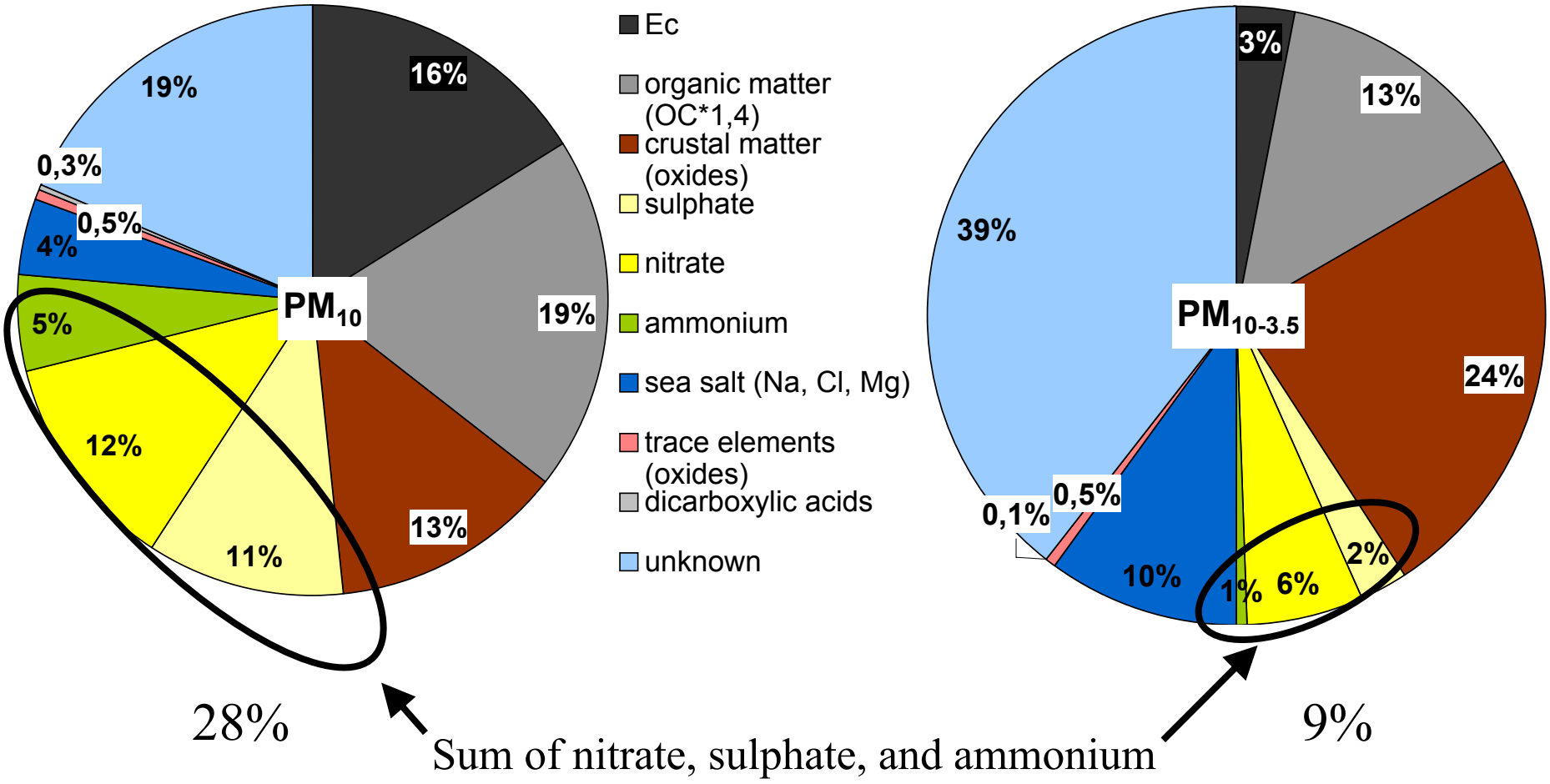
EC before and during heating period



Soot fraction decreases with growing particle diameter, ultrafine particles consists to about 60% of carbonaceous material

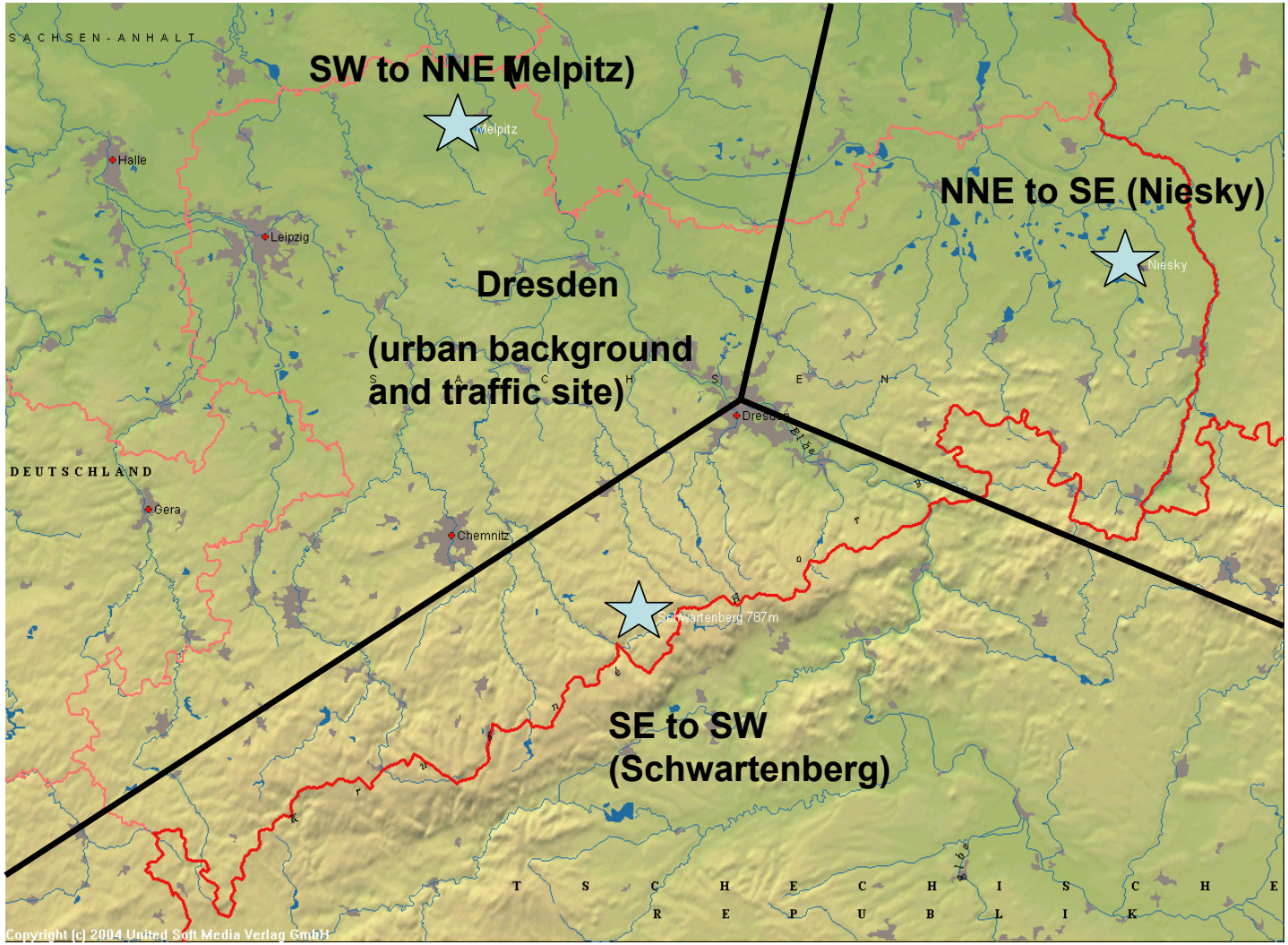
Coarse particles mainly consists of crustal material, sea salt or thawing salt

Distribution of particle main components (MOUDI)



Chemical composition of PM_{10} and the coarse fraction at the kerbside station in Dresden-Nord

Sector arrangement for long range transport events



SLUG III measurement sites in Saxony

Determination of air mass origin by meteorological analysis and 96 hours backward trajectories (NOAA HYSPLIT)

Source apportionment of particle components was performed following the **Lenschow approach:**

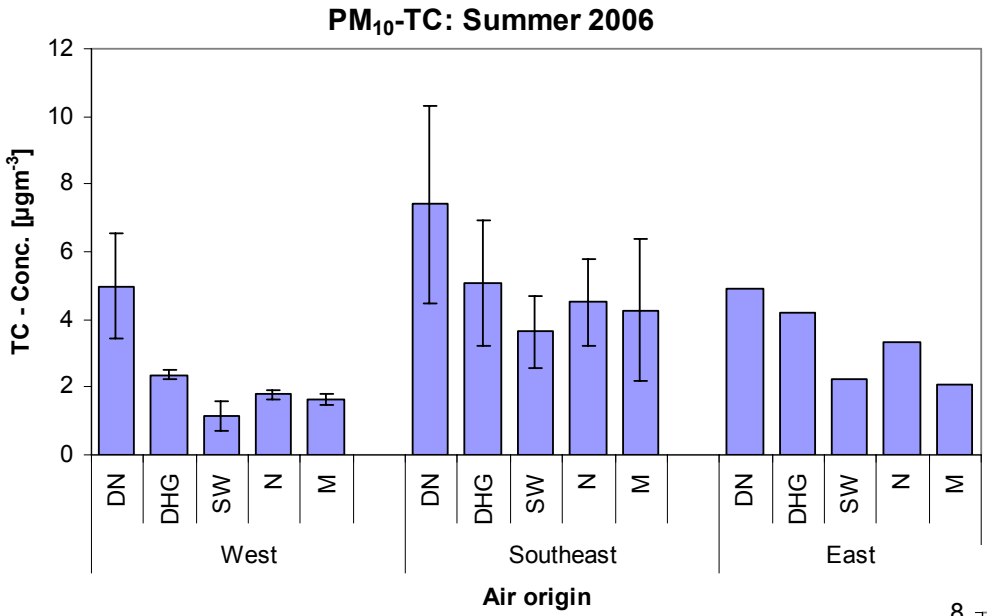
Local traffic = Urban traffic site – Urban backgroud site

Urban background = Urban background site – Rural background site

Regional background = Rural background site

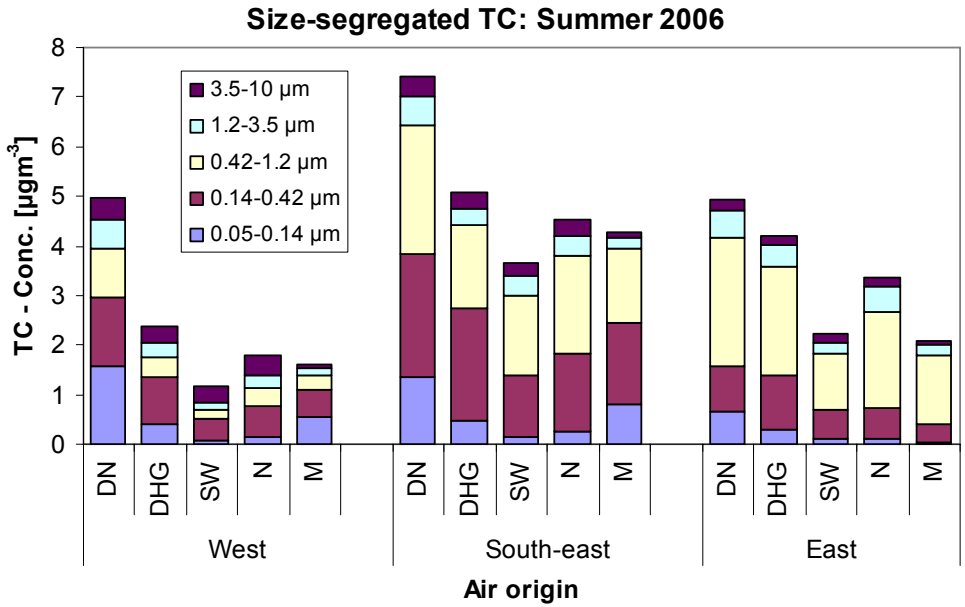
Urban traffic site:	Dresden - North	DN
Urban background site:	Dresden - Herzogingarten	DHG
Rural backgroud sites:	Melpitz (sector SW to NNE)	M
	Niesky (sector NNE to SE)	N
	Schwartenberg (sector SE to SW)	SW

Estimating of particle fractions by Lenschow approach



Highest TC at DN site (traffic) at all air origin directions

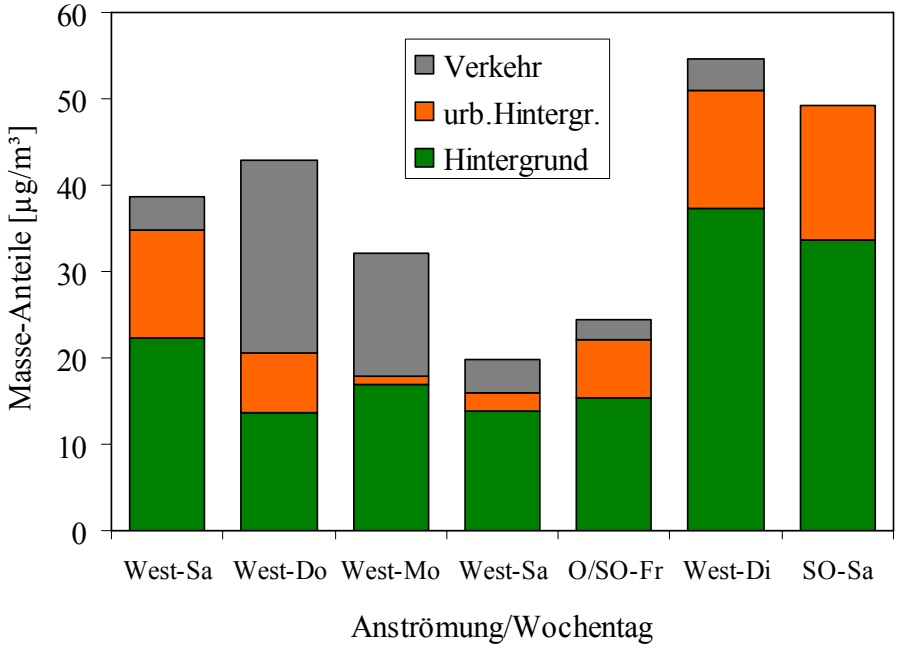
During SE and E air origin TC higher than at W direction at all sites

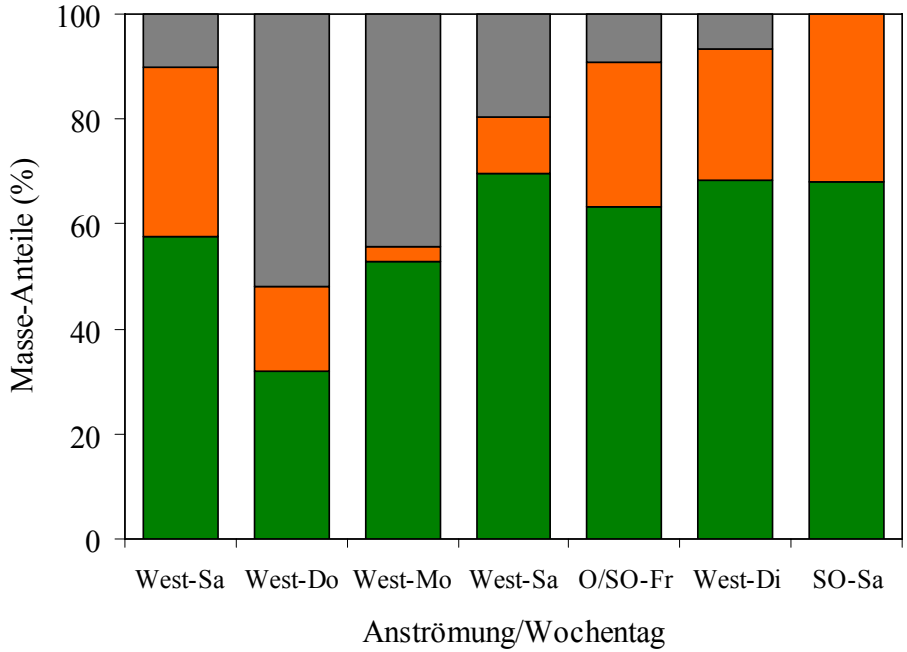


Size-segregation shows:
Highest fraction of UFP at DN site (fresh traffic emissions), esp. during air origin from west

Highest fractions of 0.14-1.2 µm particles showing residence time in air > 1 week (long range transport) during SE and E air origin

TC concentrations depending on air origin



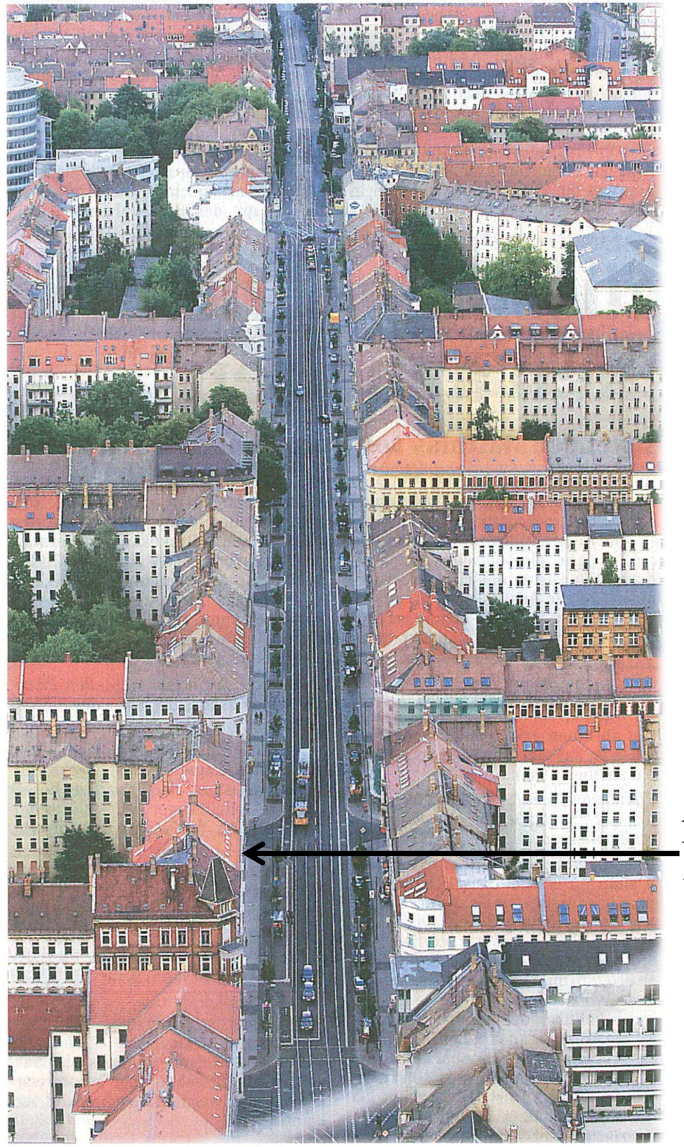


Maximum local traffic fraction of PM_{10} was found at west air origin on workdays (up to 50%)

Regional backgroud fraction can rise up to 60% independent of air origin and weekday

Lenschow approach to PM_{10} mass for DN site

Sampling site in the Eisenbahnstraße, situated in the section between the crossroad with the H.-Liebmann-Straße (in the foreground) and the crossroad with the Torgauer Straße (in the background)

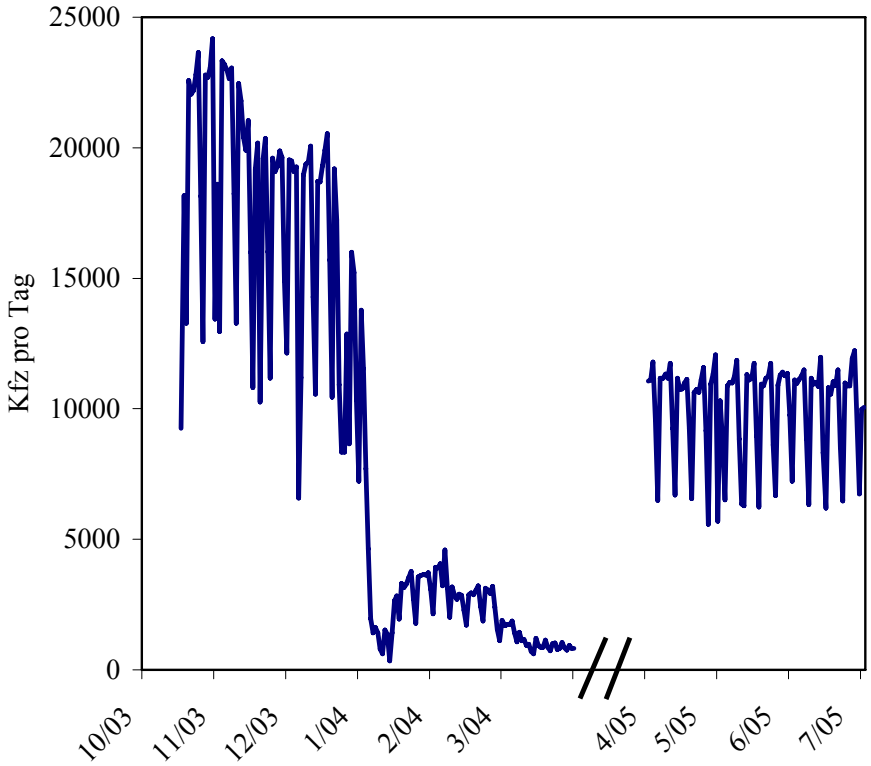


FAT: Forschungs-vereinigung Automobiltechnik e.V.

Site E
measurement inlet
7m above ground

Distance to the IfT and to the city site (near main station) both about 2 km

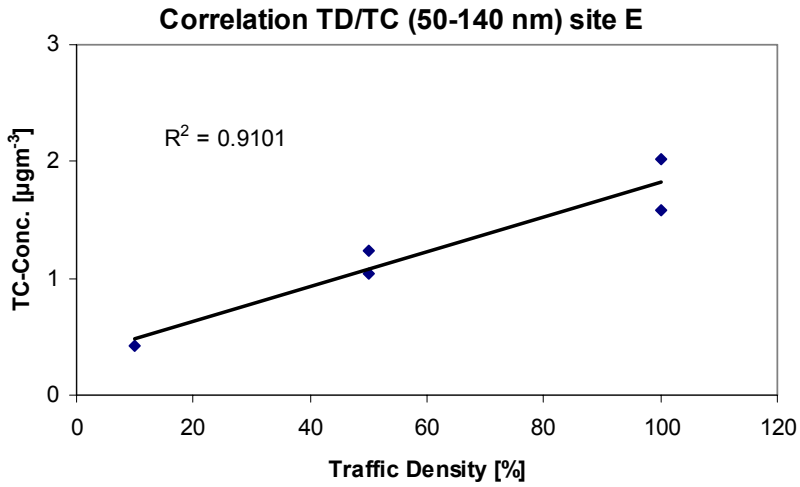
FAT measurement site: street canyon in Leipzig



Traffic density (20000 vehicles/day = 100%) was changing because of reconstruction of the street:

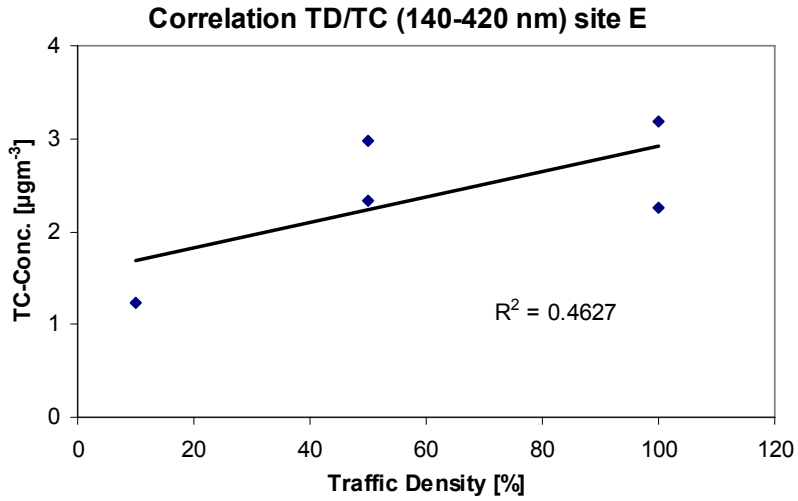
Summer 2003	100%	Winter 2003	100%
Winter 2004	10%		
Winter 2005	50%	Sommer 2005	50%

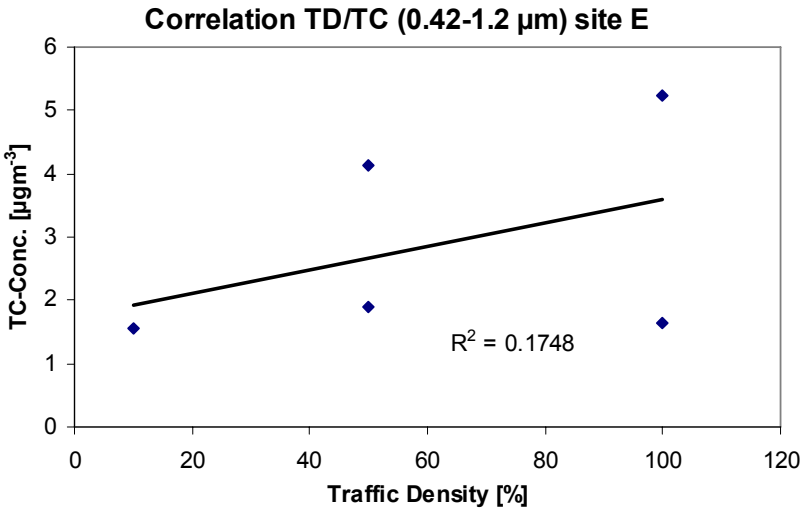
Traffic density during FAT project



Good correlation in the UFP range

Weak correlation in the FP range I





No correlation in the FP range II

TD / TC correlation depending on particle size range

	Aerodynamic particle diameter [nm] 50-140	140-420	420-1200
Concentration [µgm^{-3}]		R^2	
PM	0.78	0.23	0.17
TC	0.91	0.46	0.18
Fraction of local traffic [µgm^{-3}]			
LT-PM	0.76	0.45	0.43
LT-TC	0.89	0.52	0.02
LT-∑alk [ngm^{-3}]	0.99	0.87	0.46

$R^2 \cdot 100\%$ yields the percentage of measurement values explicable by the linear approach

Local traffic is the dominating source in the UFP size range, affect on Fine Particles in the 140-420 nm size range, but has only negligible Influence on Fine Particles in the size ranges beyond.

Comparison of regression parameters

- West / East air pollution differences still exist
- Long-range transport of particles occurs depending on meteorological situation (esp. 0.42-1.2 µm particles)
- EU PM_{10} limit value of 50 $\mu g m^{-3}$ may be (nearly) achieved in such air masses before entering city areas
- Simultaneous size-segregated sampling at three sites makes possible the apportionment of particle components to the fractions local traffic, urban background and regional background for every size range.
- PM_{10} mass distribution shows in average only about 5% and 10-15% of the total mass in the range of 0.05 to 0.14 µm and 0.14 to 0.42 µm, resp. Traffic emission causes the most of the particle number concentration (esp. in the UFP range) but only a minor fraction of the total particle mass.

Conclusions and outlook I

- Steps to observe the PM_{10} limit value have to consider the fine particle range of 0.42 to 1.2 µm (50-60% of total mass) and the coarse mode particles beyond (resuspension).
- Steps to a real improvement of exposition situations relevant to human health should not be focussed to the observation of the mass limit value alone, but should consider also the fine and ultafine particles existing in high number concentrations (without influencing strongly the mass limit value) and the composition of such particles including health hazardous components.
- Investigation of particles emitted by individual wood burning heating systems and their effects on air quality in Saxony are the next steps in this way.

Conclusions and outlock II

LfUG I, III, and IV projects (were) are financial supported by Sächsisches Landesamt für Umwelt und Geologie, Dresden

LfUG II was a special project of the Landesamt für Umwelt und Geologie Dresden in collaboration with the Leibniz - Institute of Tropospheric Research, Leipzig

The collaboration with the Umweltbetriebsgesellschaft (UGB) Dresden is greatly acknowledged.

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Thank you for your attention!

Acknowledgements