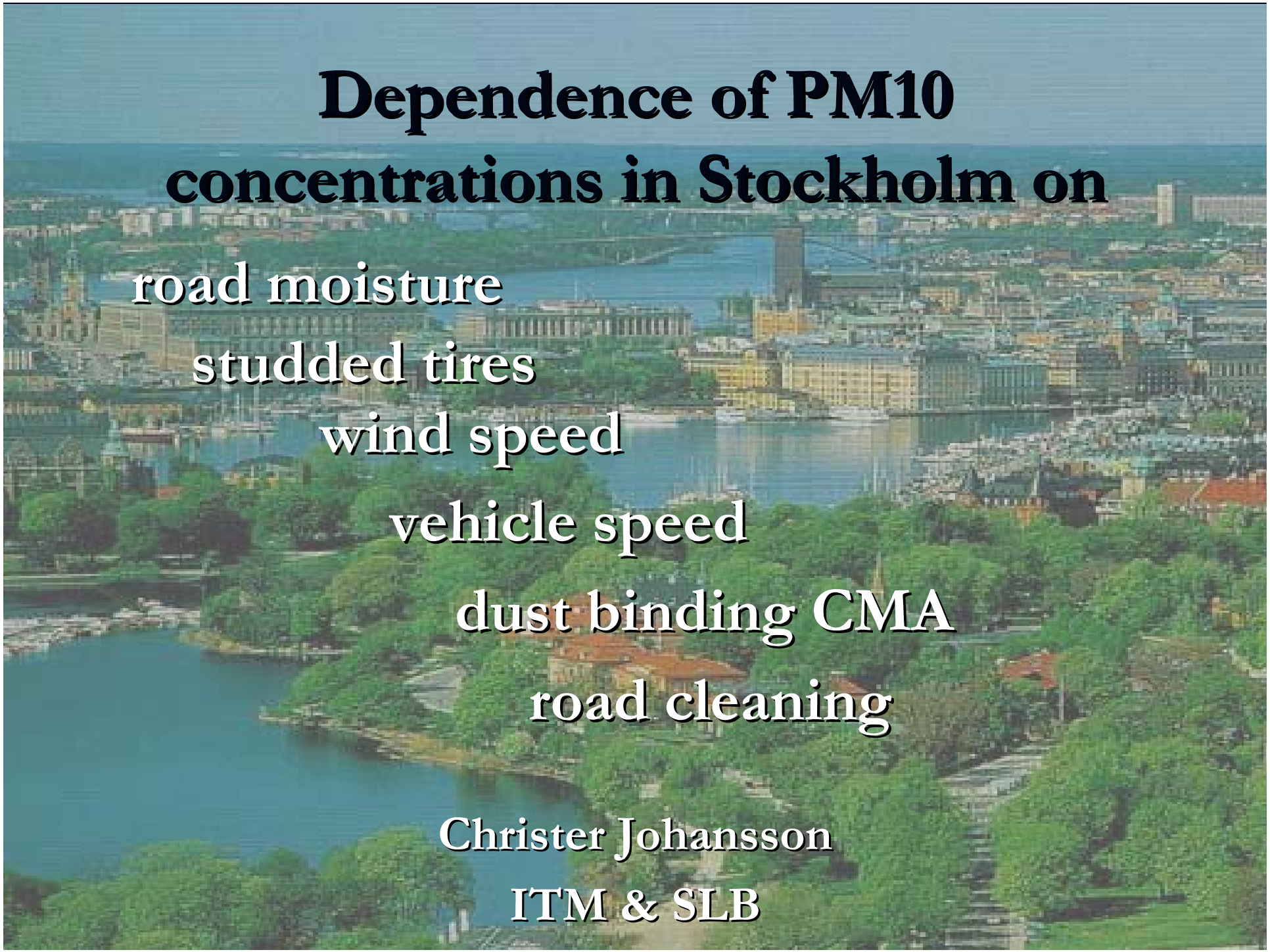
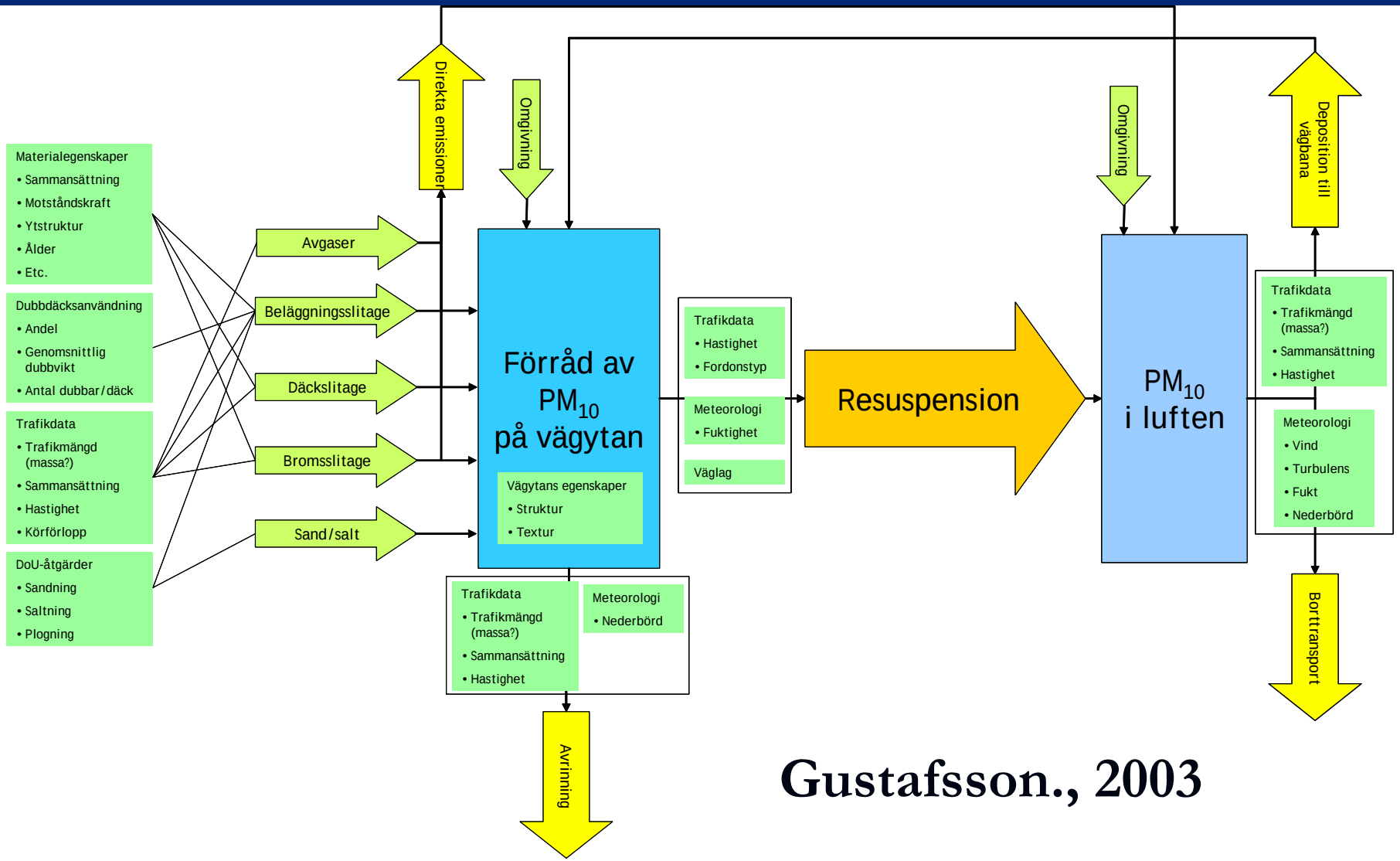
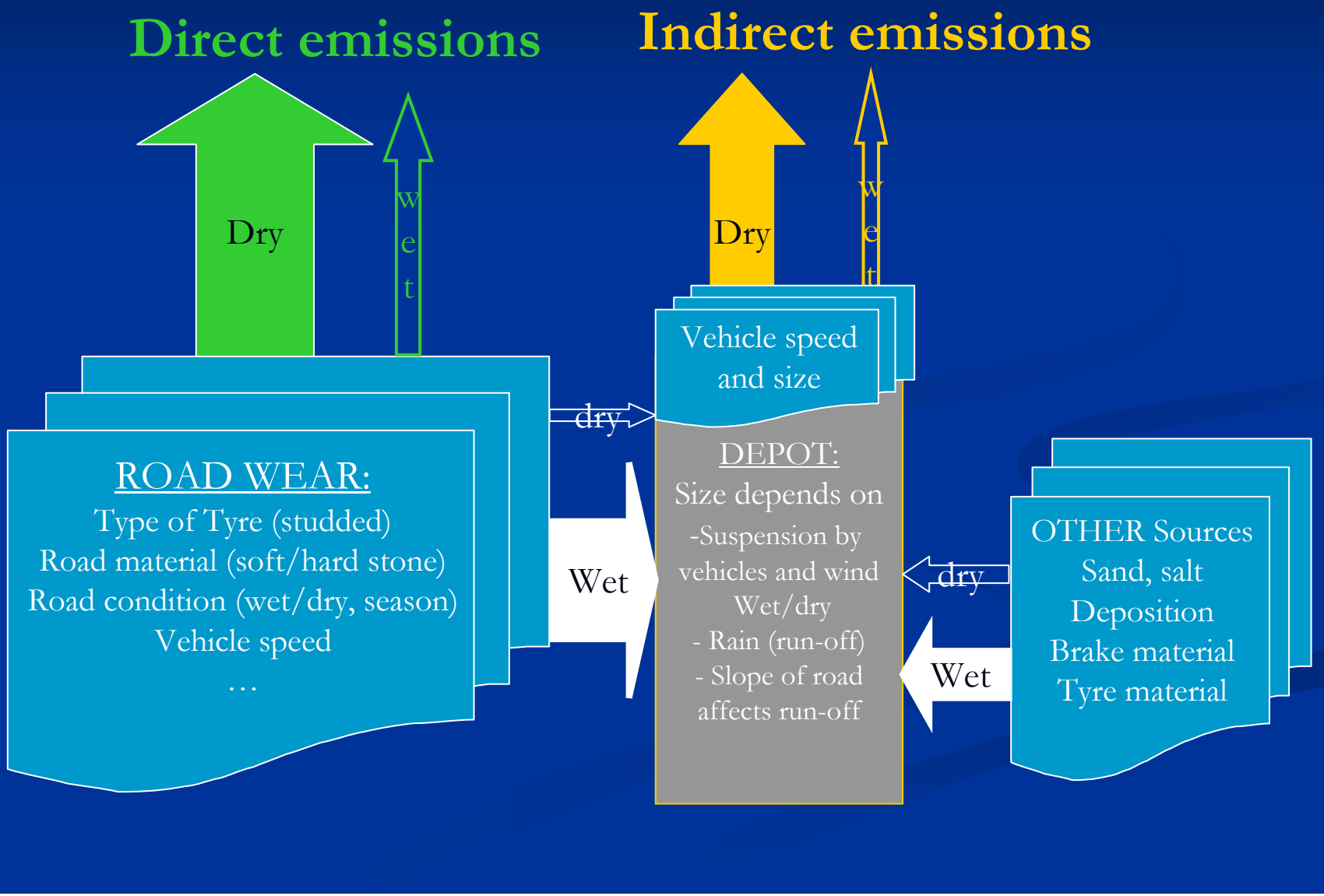

Dependence of PM10 concentrations in Stockholm on
road moisture
studded tires
wind speed
vehicle speed
dust binding CMA
road cleaning
Christer Johansson
ITM & SLB

Summary (in swedish)

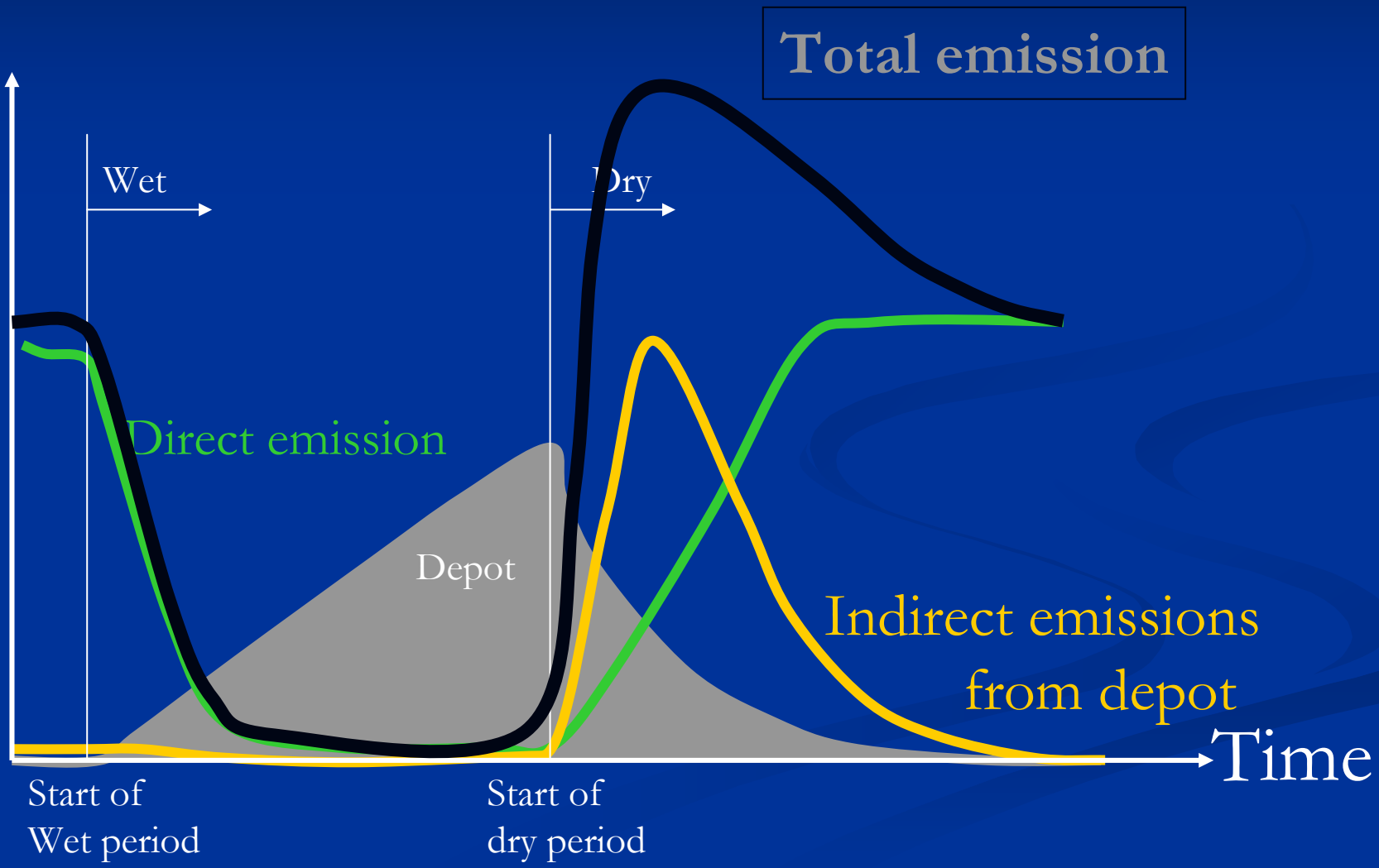


Gustafsson., 2003

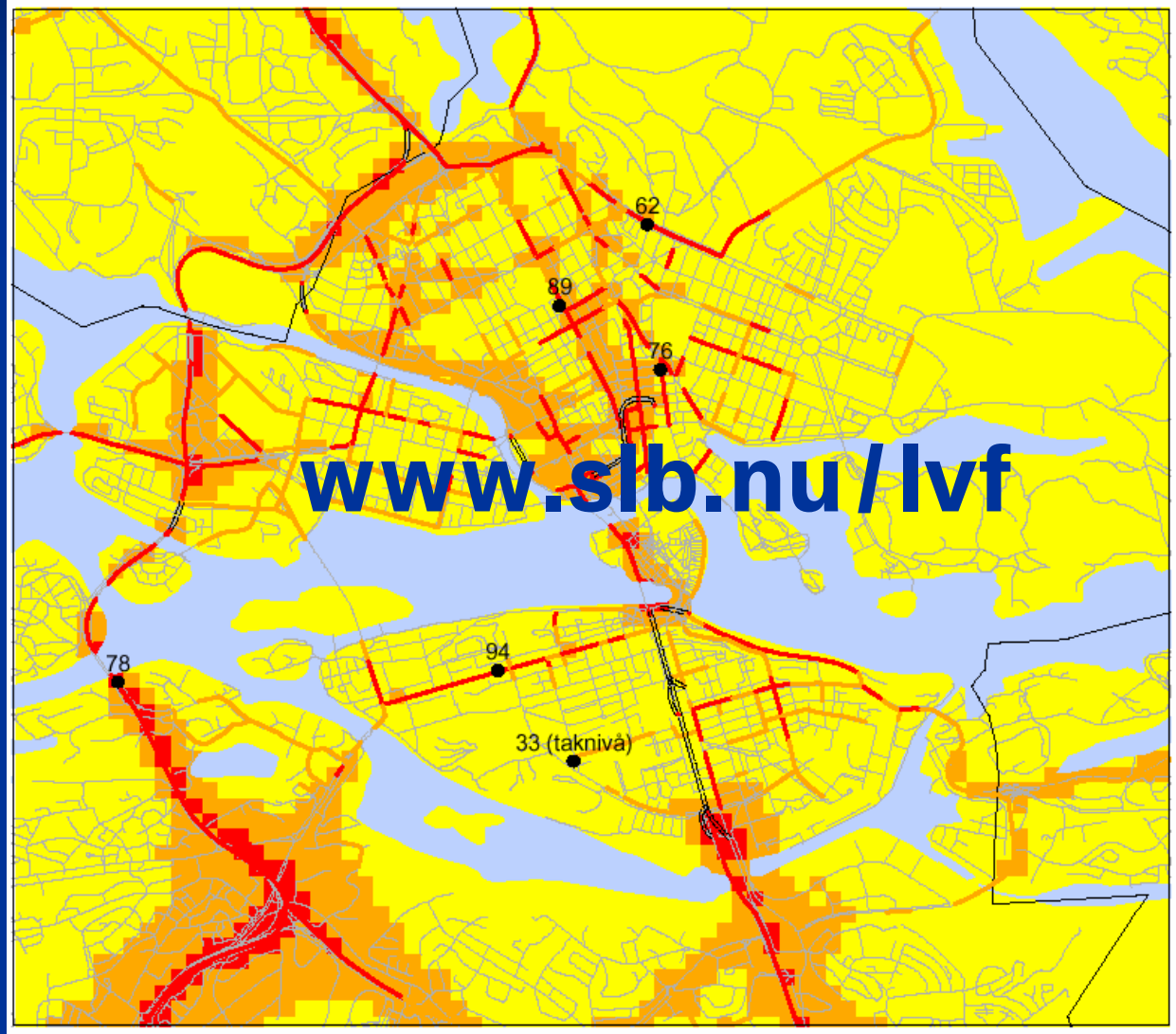
Conceptual model of non-exhaust PM emissions from roads



Conceptual model: Dynamic behaviour



PM10 in Stockholm exceeds directive on many roads



Miljökvalitetsnormer för inandningsbara partiklar, PM10 (<10 µm)

Från 2001 gäller nya svenska miljökvalitetsnormer för inandningsbara partiklar, PM10. Normerna omfattar dygnsmedelvärden och årsmedelvärde och skall klaras från och med 2005.

För PM10 blir dygnsvärdet svårast att klara. Medelvärdet under det 36:e värsta dygnet får inte vara högre än 50 µg/m3.

Kartan visar beräknad PM10-halt för 36:e värsta dygnet 2002 enligt följande färgskala:

Tunnel (100-500 µg/m3)

>50 µg/m3

39 - 50 µg/m3

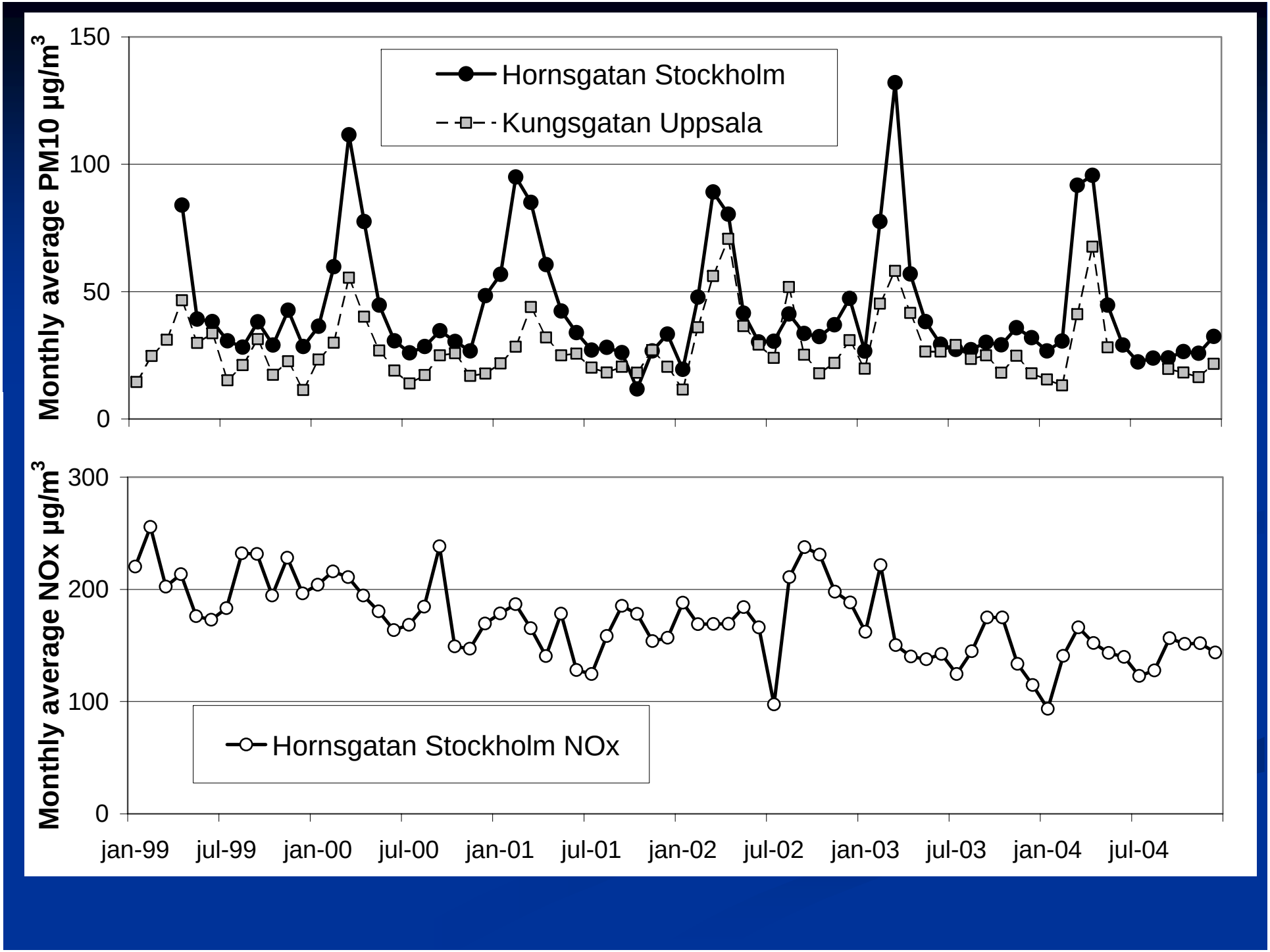
27 - 39 µg/m3

< 27 µg/m3

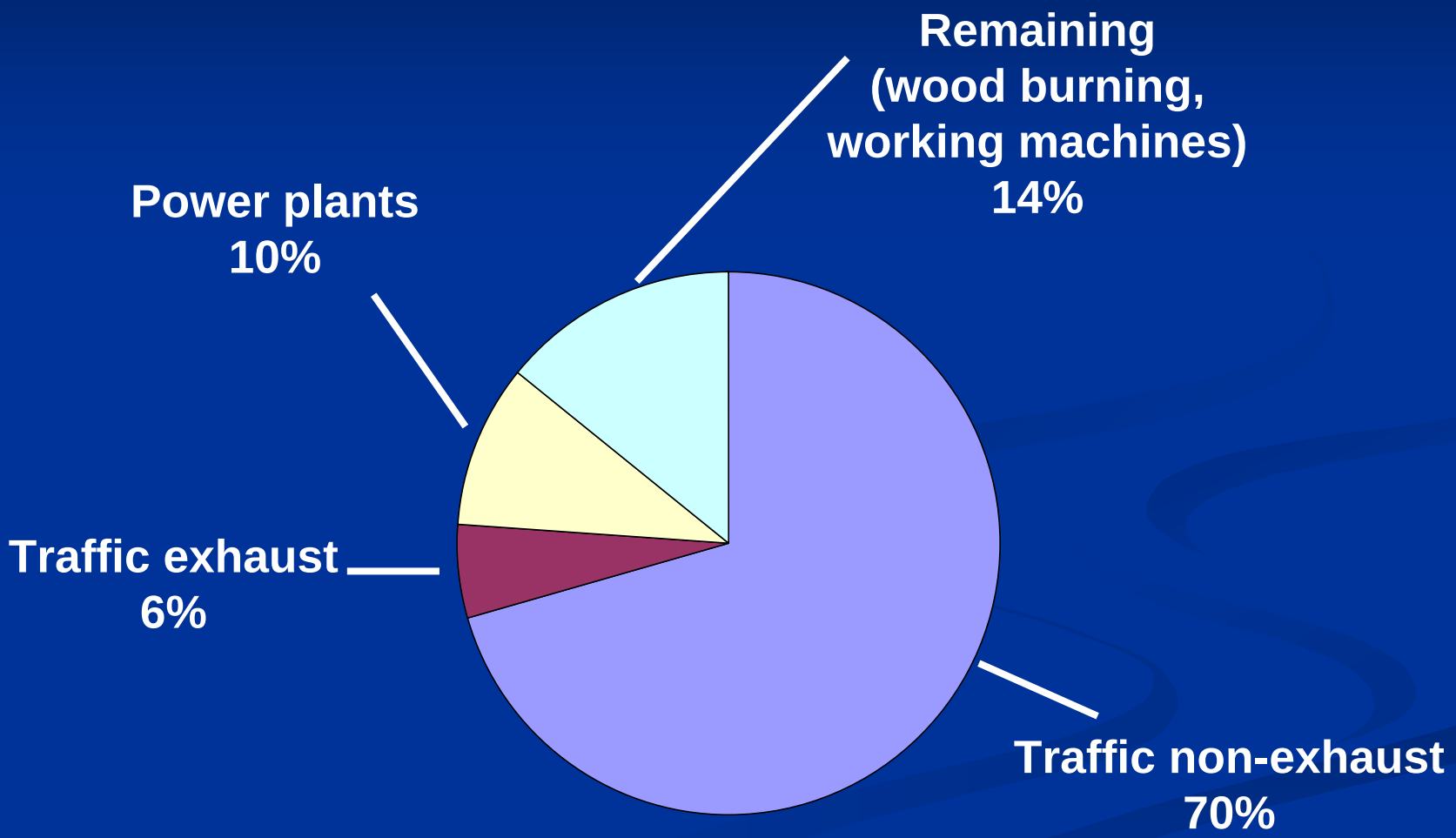
Halterna har beräknats två meter över marknivå. Om markerad gatusträcka har slutet gaturum har halterna beräknats två meter över gångbana (innerstadsbebyggelse). Vid övrig bebyggelse avser färgmarkeringen beräknade halter 10 till 20 meter från vägen.

Uppmätta PM10-halter för 2002 har markerats med siffervärden.

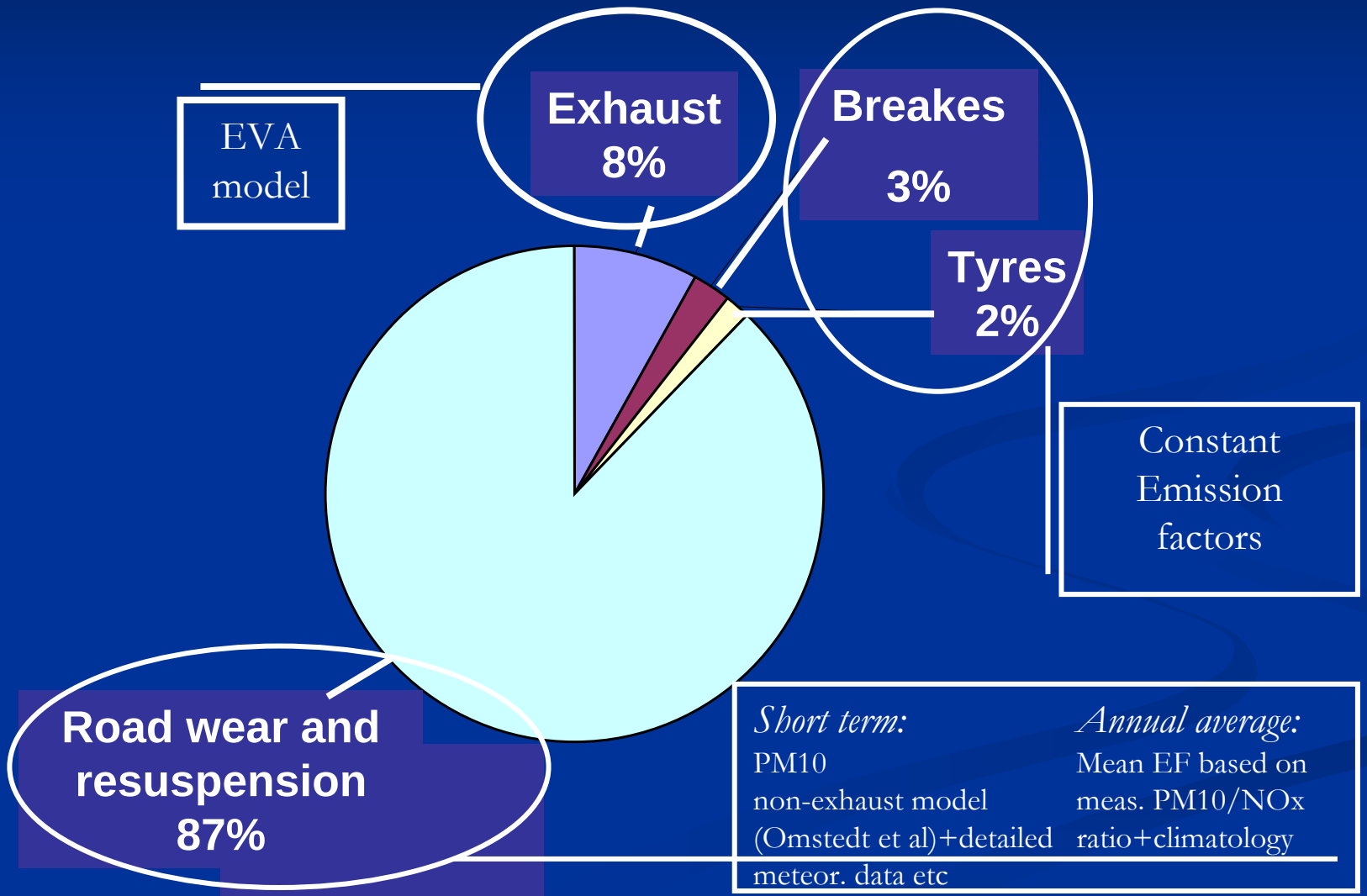
Varför, vad ska vi göra?


Monthly average PM10 µg/m3
150
100
50
0
Hornsgatan Stockholm
Kungsgatan Uppsala
Monthly average NOx µg/m3
300
200
100
0
Hornsgatan Stockholm NOx
jan-99
jul-99
jan-00
jul-00
jan-01
jul-01
jan-02
jul-02
jan-03
jul-03
jan-04
jul-04

Total PM emissions in Stockholm



Road traffic emissions in Stockholm

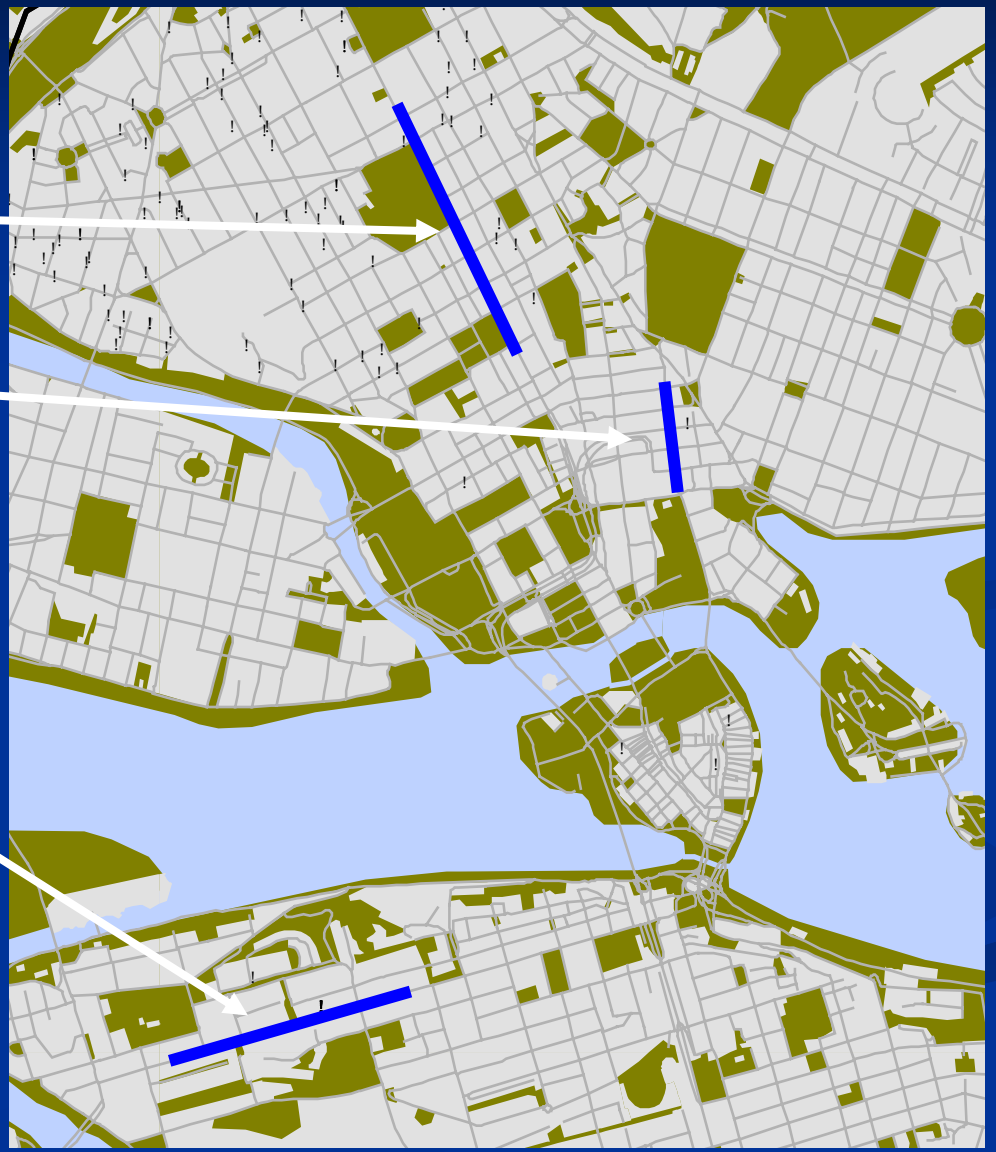


Measuring sites in Stockholm

Sveavägen
- 30 000 vehicles/day
- 4 lanes
- 30 m wide
- started 2002

Norrlandsgatan
- 10 000 vehicles/day
- 2 lanes
- 15 m wide
- started 2002

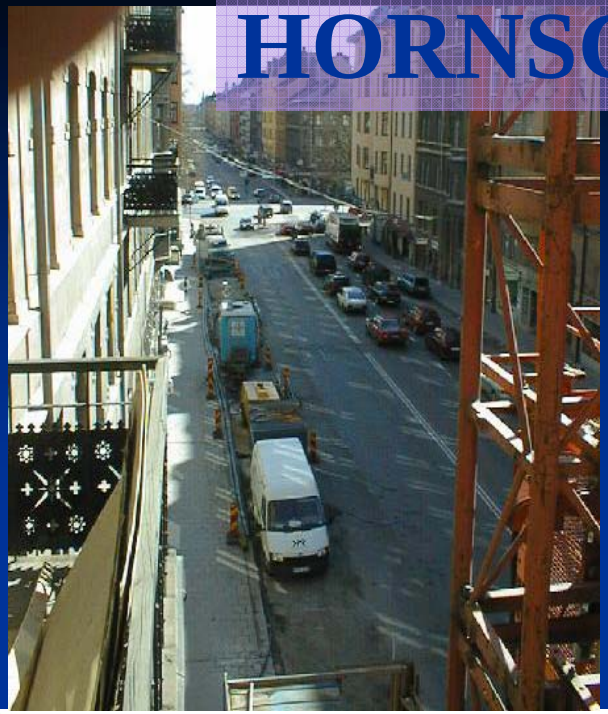
Hornsgatan
- 40 000 vehicles/day
- 4 lanes
- 24 m wide
- started 1999



HORNSGATAN

Total PM10 &PM2.5 emission factor

40 000 veh/day



Norrlandsgatan

PM10, NOx
Temperature, rel hum
Road moisture
Web-camera, traffic

Sveavägen

PM10, PM2.5
Metals (fine, coarse)
NOx, CO

Kristensson et al., 2003

Road tunnel study 1998/99

30-40 000 Veh/day

PM10, PM2.5, NOx
Traffic number +speed
Particle size distribution
Ventilation rate

Road moisture

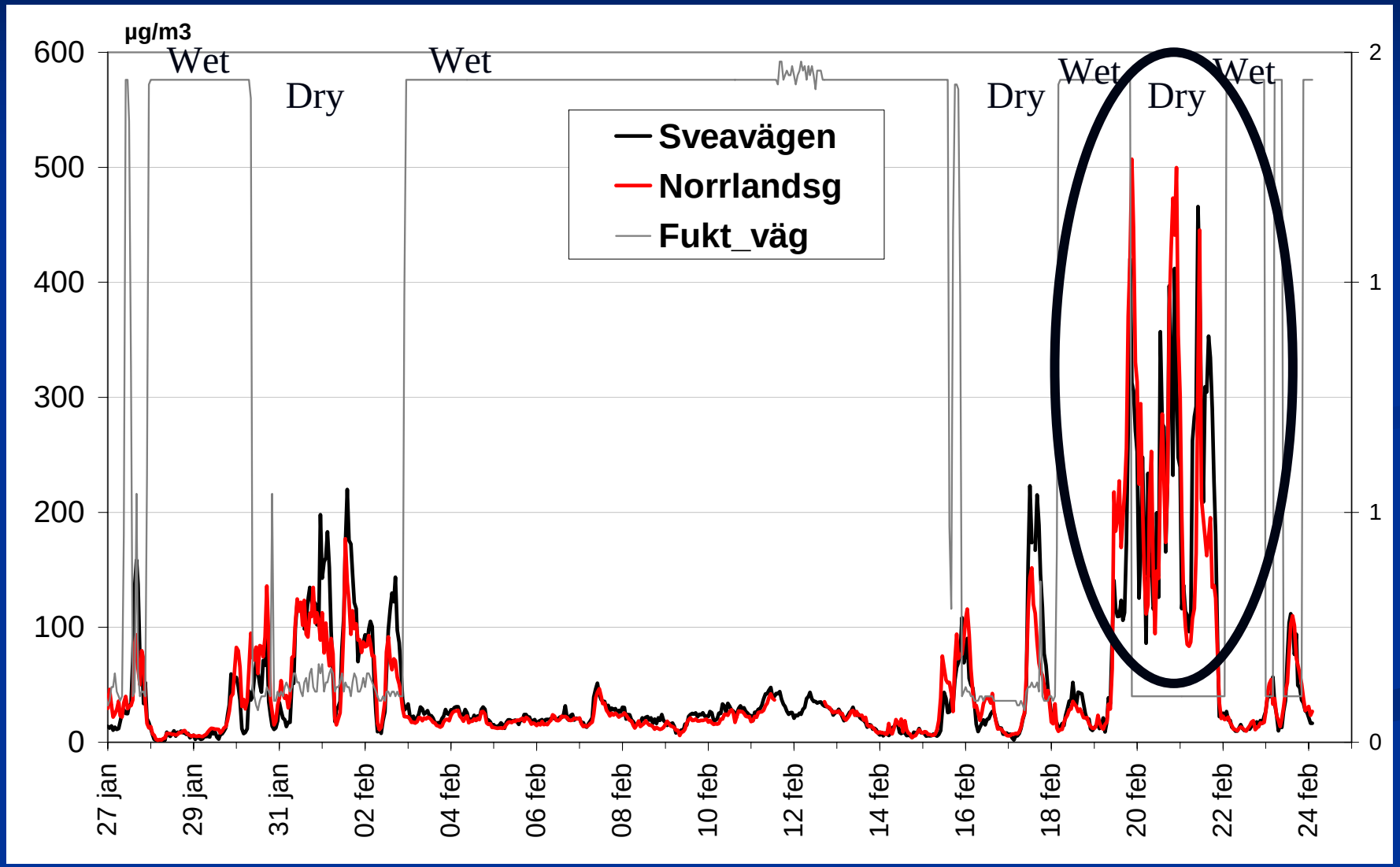
Affects

-hourly and daily variations of emissions

- road wear

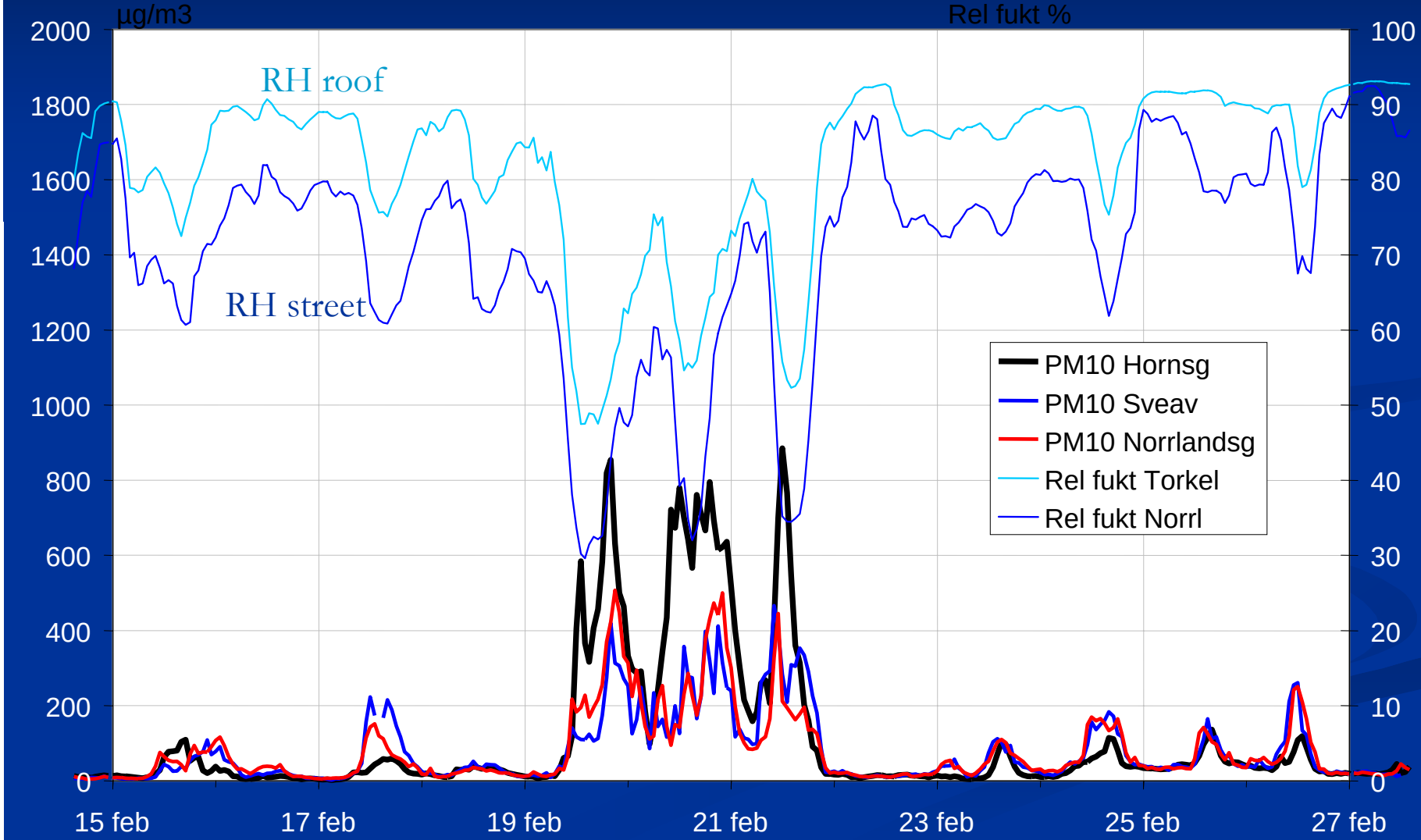
- size of the depot

PM10 & road moisture



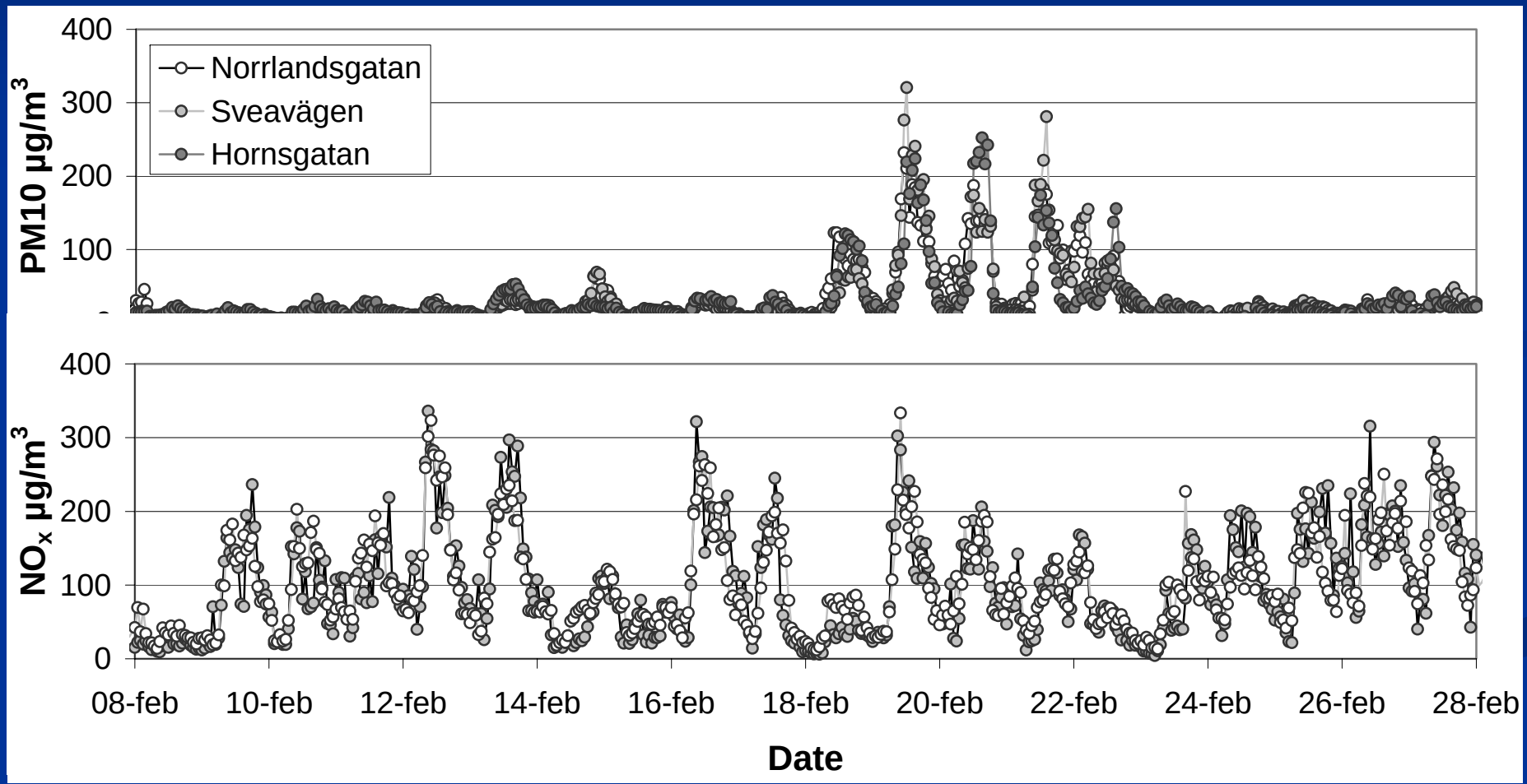
Johansson et al., 2004

Very low relative humidity to dry for salt to absorb humidity, preceeded by wet period

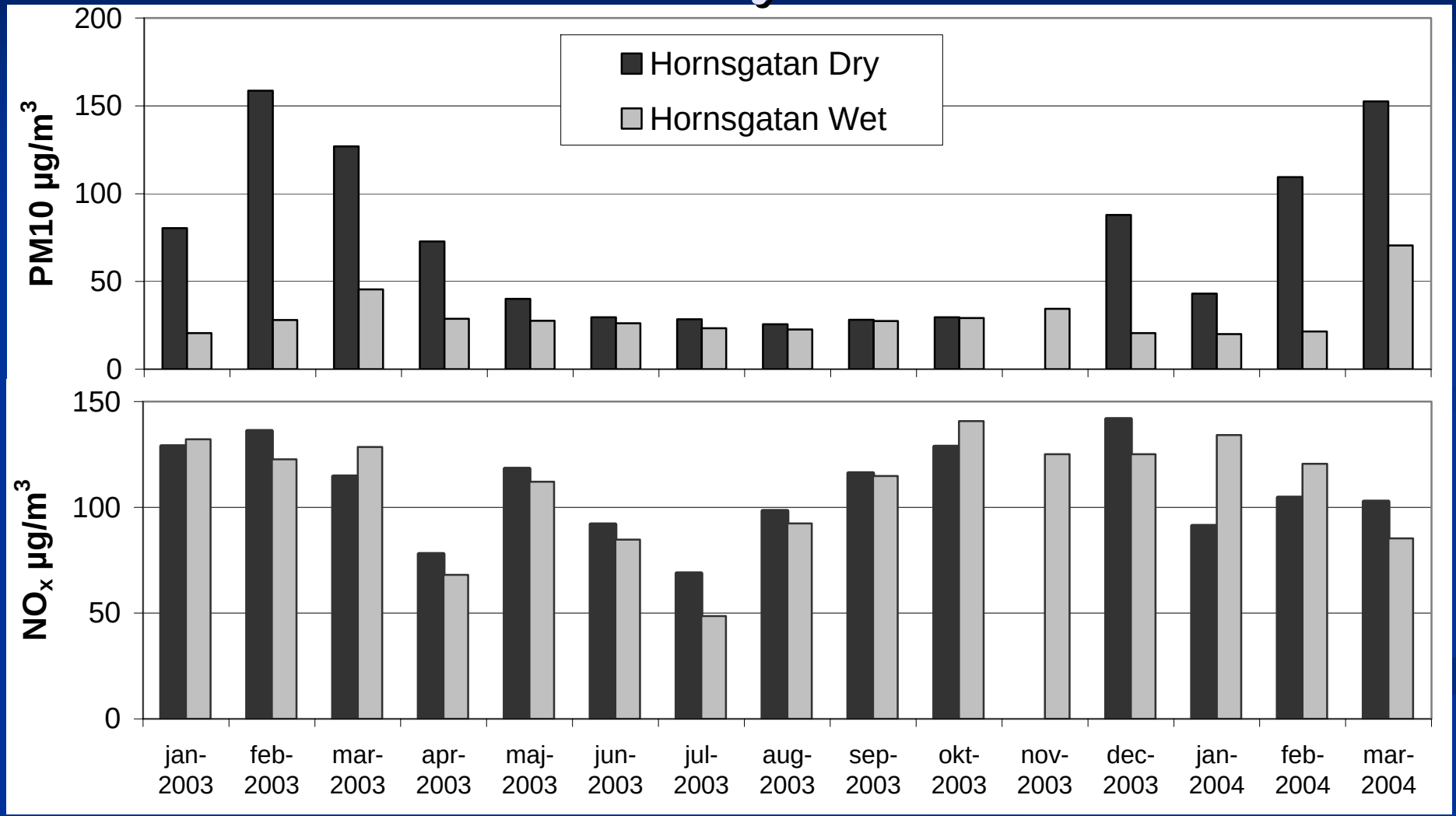


Johansson et al., 2004

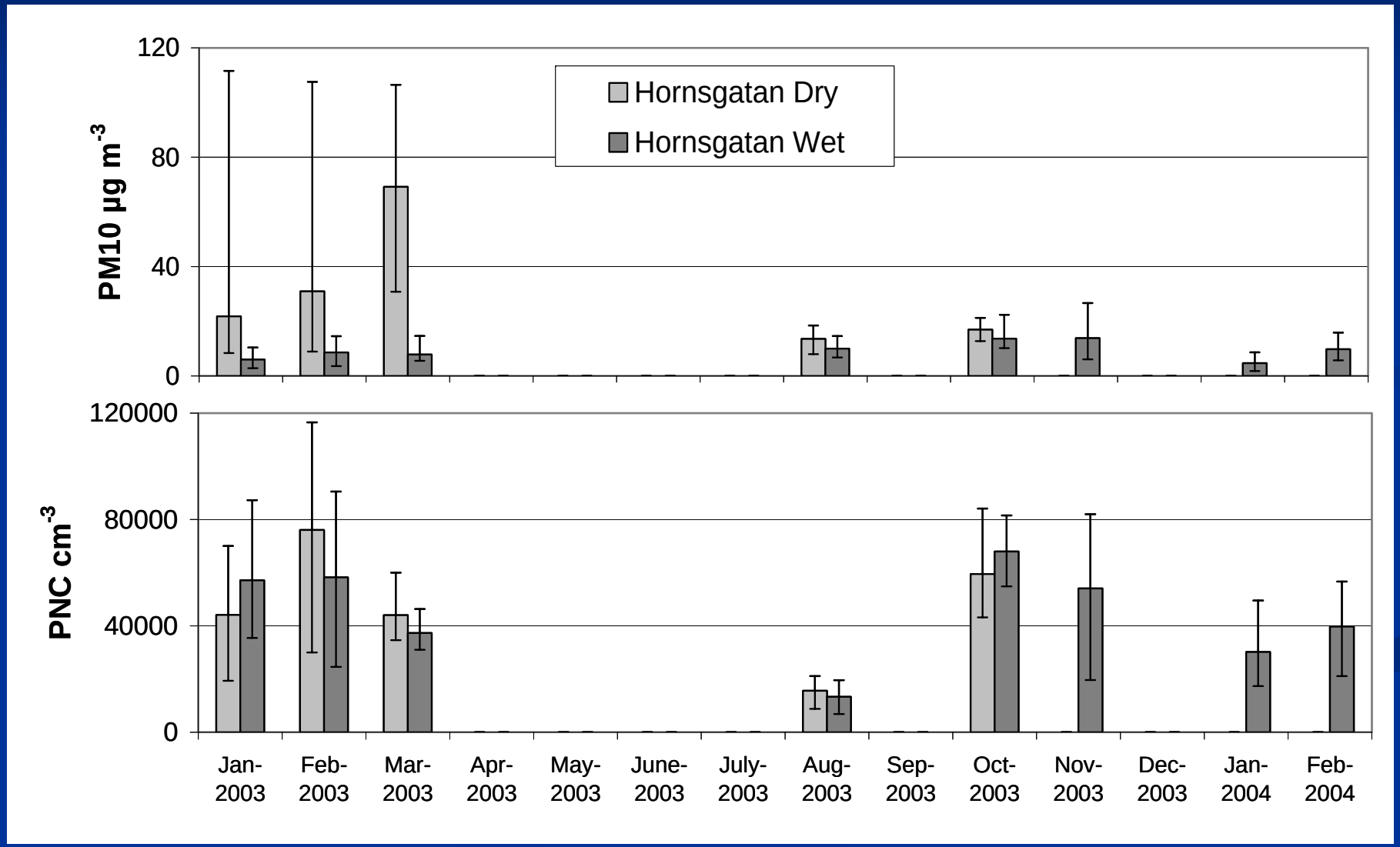
Road moisture PM10 & NOx



Road moisture PM10 and NOx Monthly means



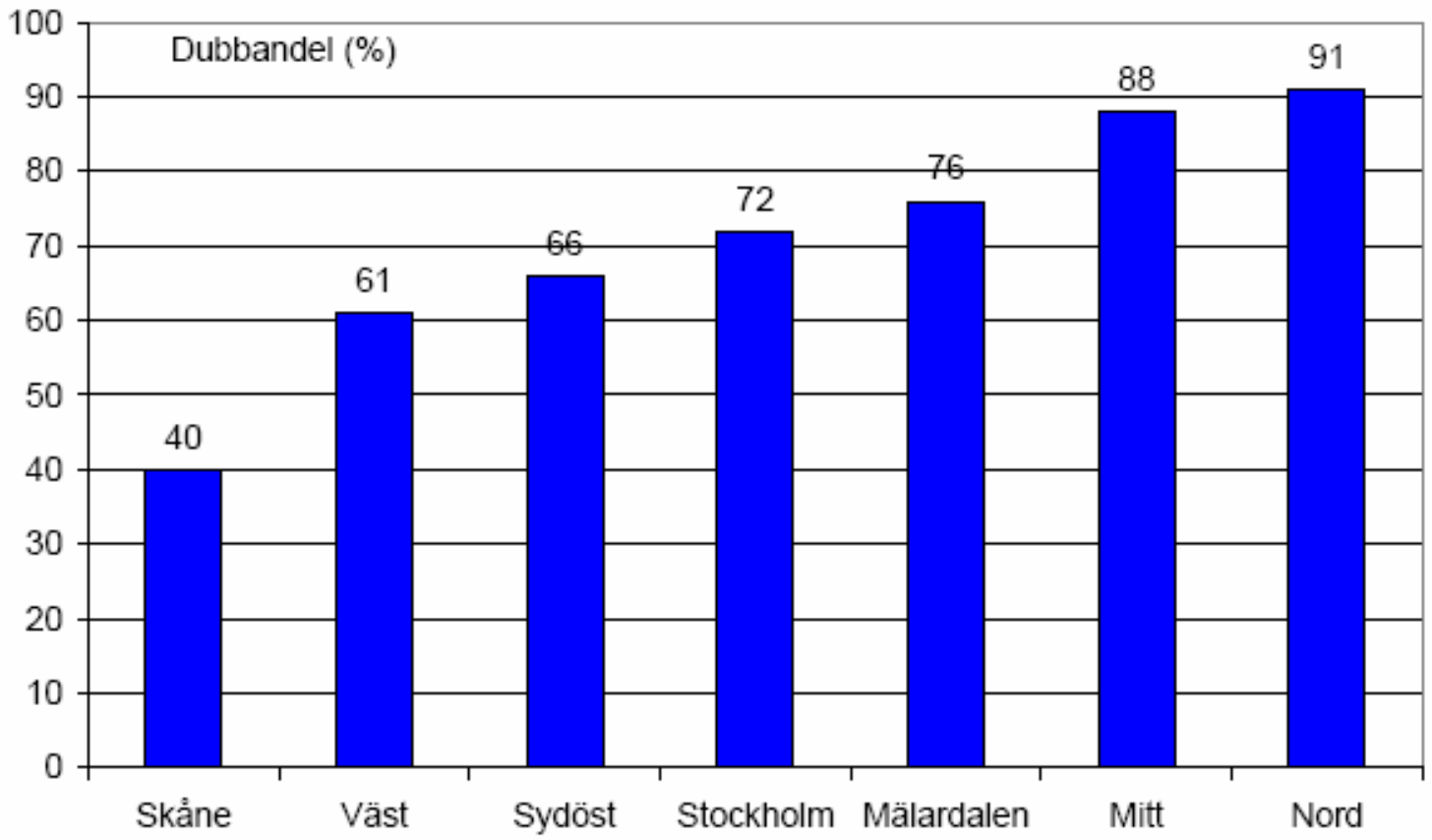
Road moisture & number conc.



Studded tyres

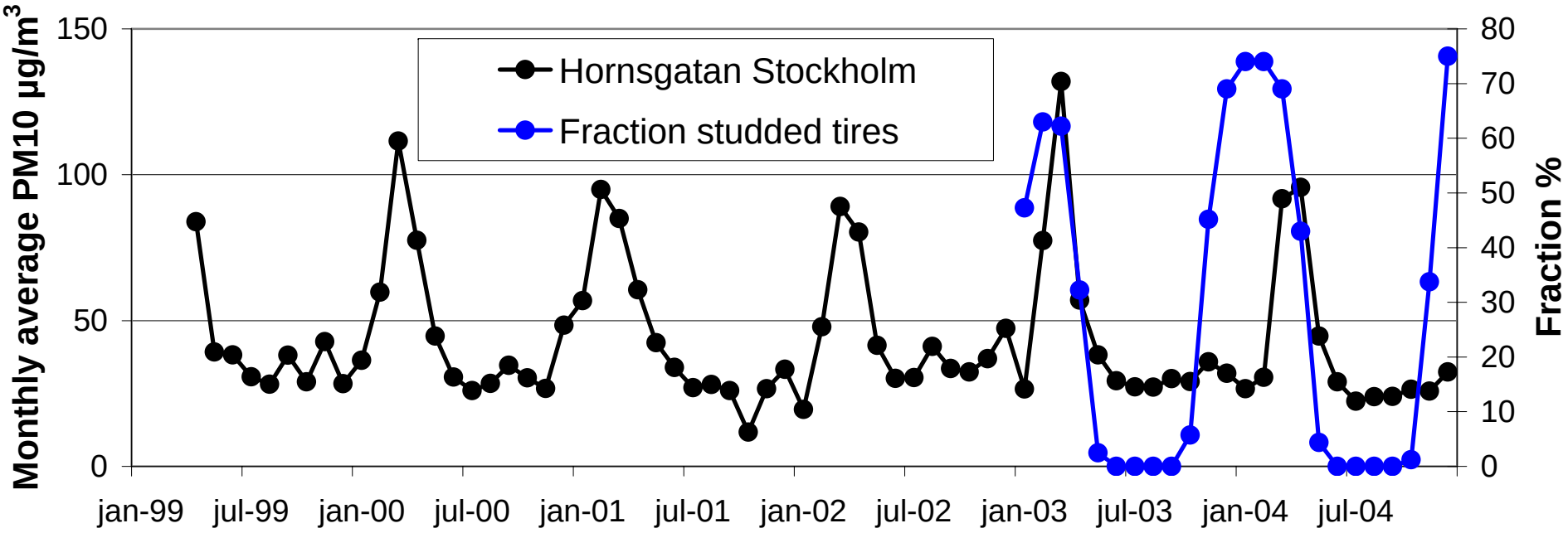
- Single most important factor for the generally high PM10 levels in Stockholm region
- Increases road wear drastically (both wet and dry)

Use of studded tyres in Sweden



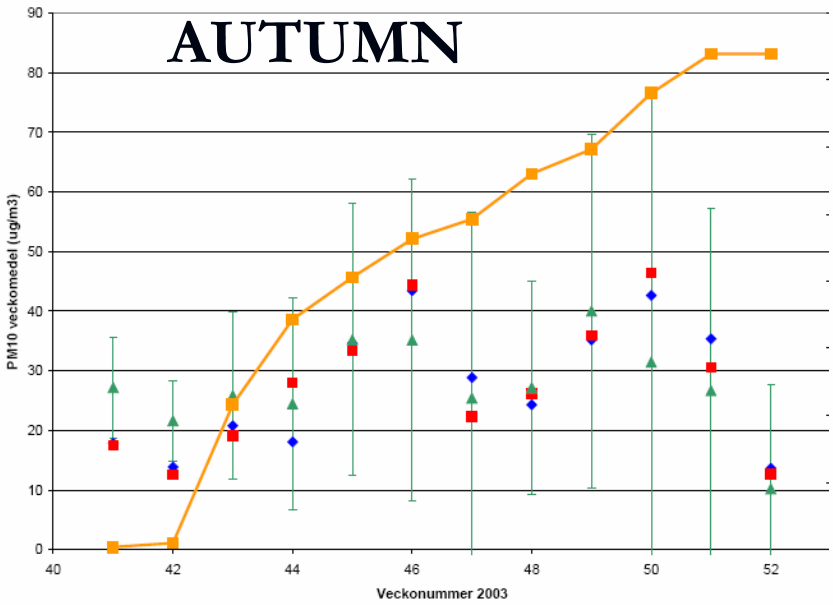
Figur 13. Andel av personbilarna i olika delar av Sverige som hade dubbdäck i februari 2002. Källa Däckbranschens informationsråd, Pontus Grönvall, Slottsgatan 8, Varberg.

Monthly average PM10 levels

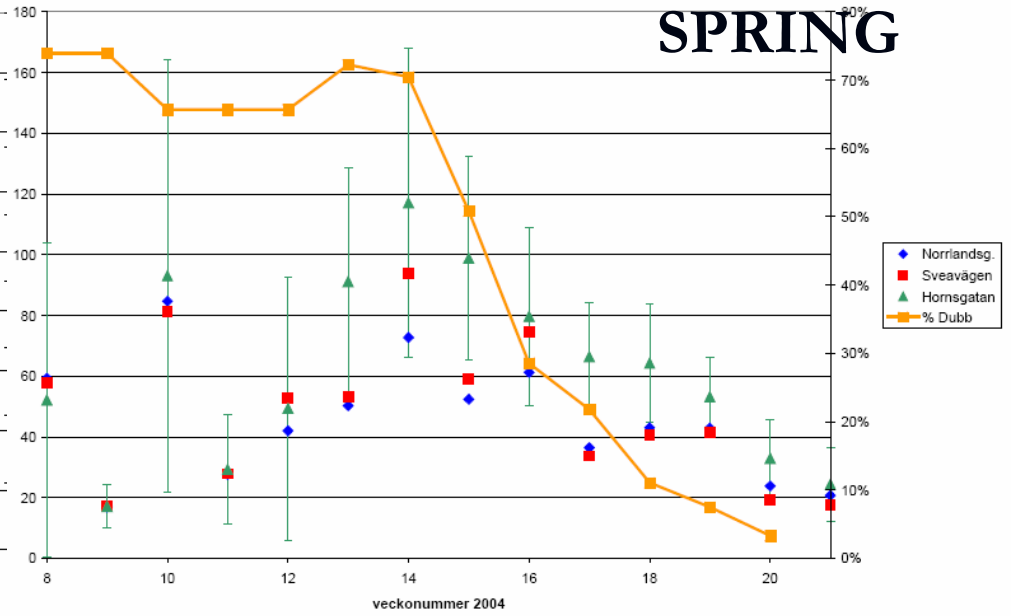


- Winter tyres must be used from Dec 1 until March 31 i Sweden
- Above 70 % during Dec-Feb

PM10 and share of studded tyres



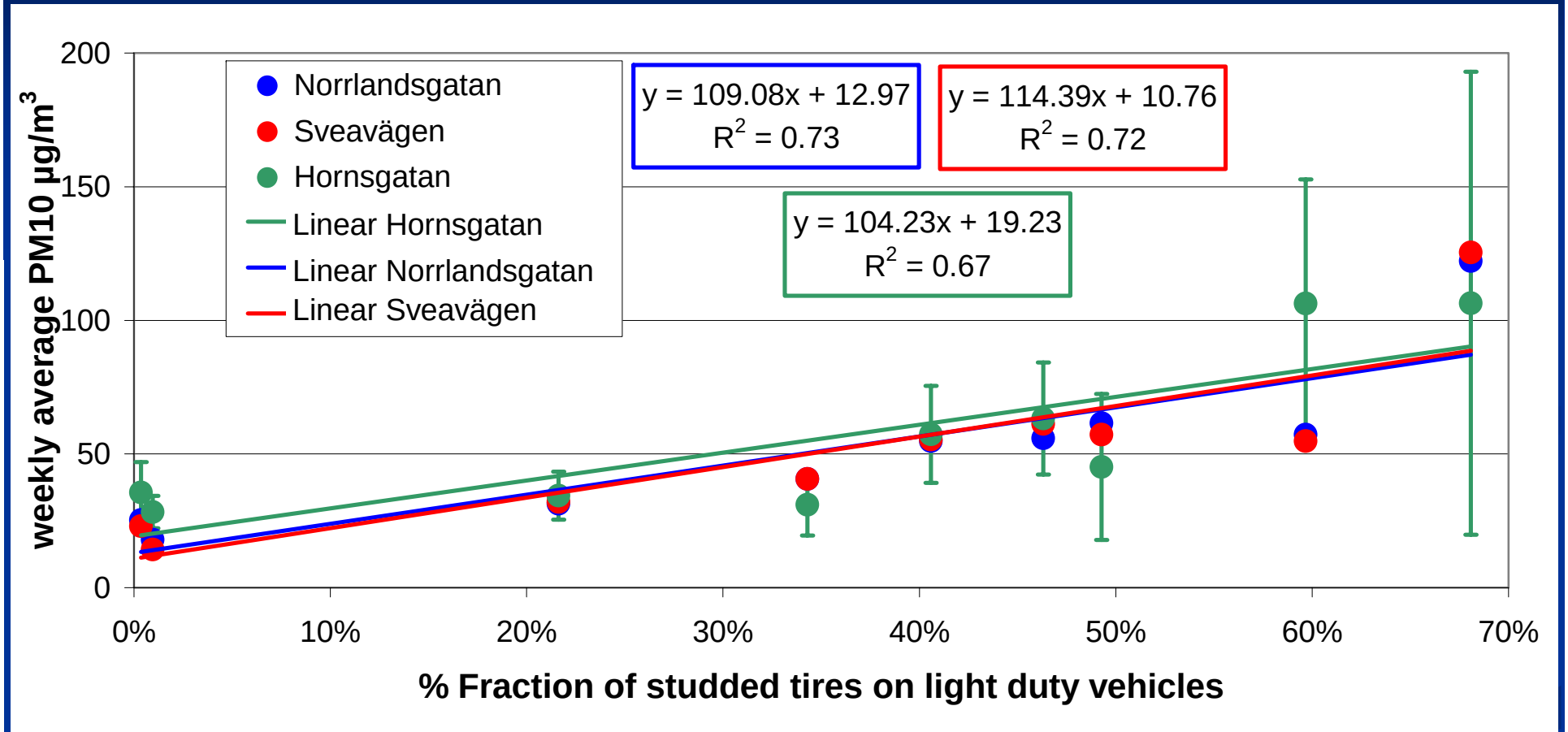
Figur 14. Veckomedelvärden för PM10 på tre innerstads gator i St
procentandel dubbdäck under hösten 2003. De vertikala linjerna
standardavvikelsen för Hornsgatan.



ur 15. Veckomedel för PM10 på tre innerstads gator i Stockholm samt
centandel dubbdäck under våren 2004. De vertikala linjerna motsvarar
ndardavvikelsen för Hornsgatan.

Johansson et al., 2004

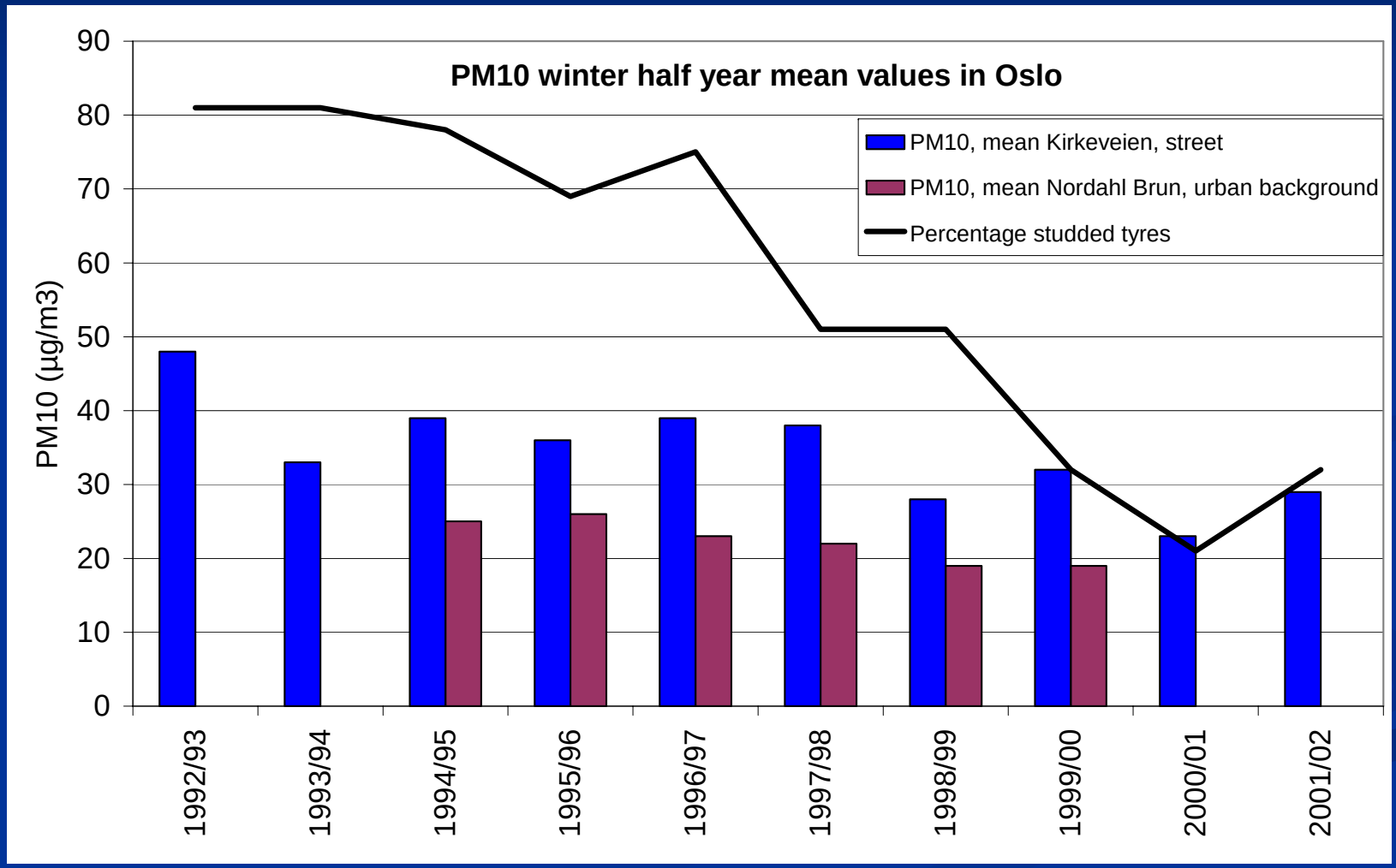
PM10 and studded tires Oct -Dec 2003



~10µg/m^3 increase in the weekly PM10 levels for a 10 % increase in the fraction of studded tires

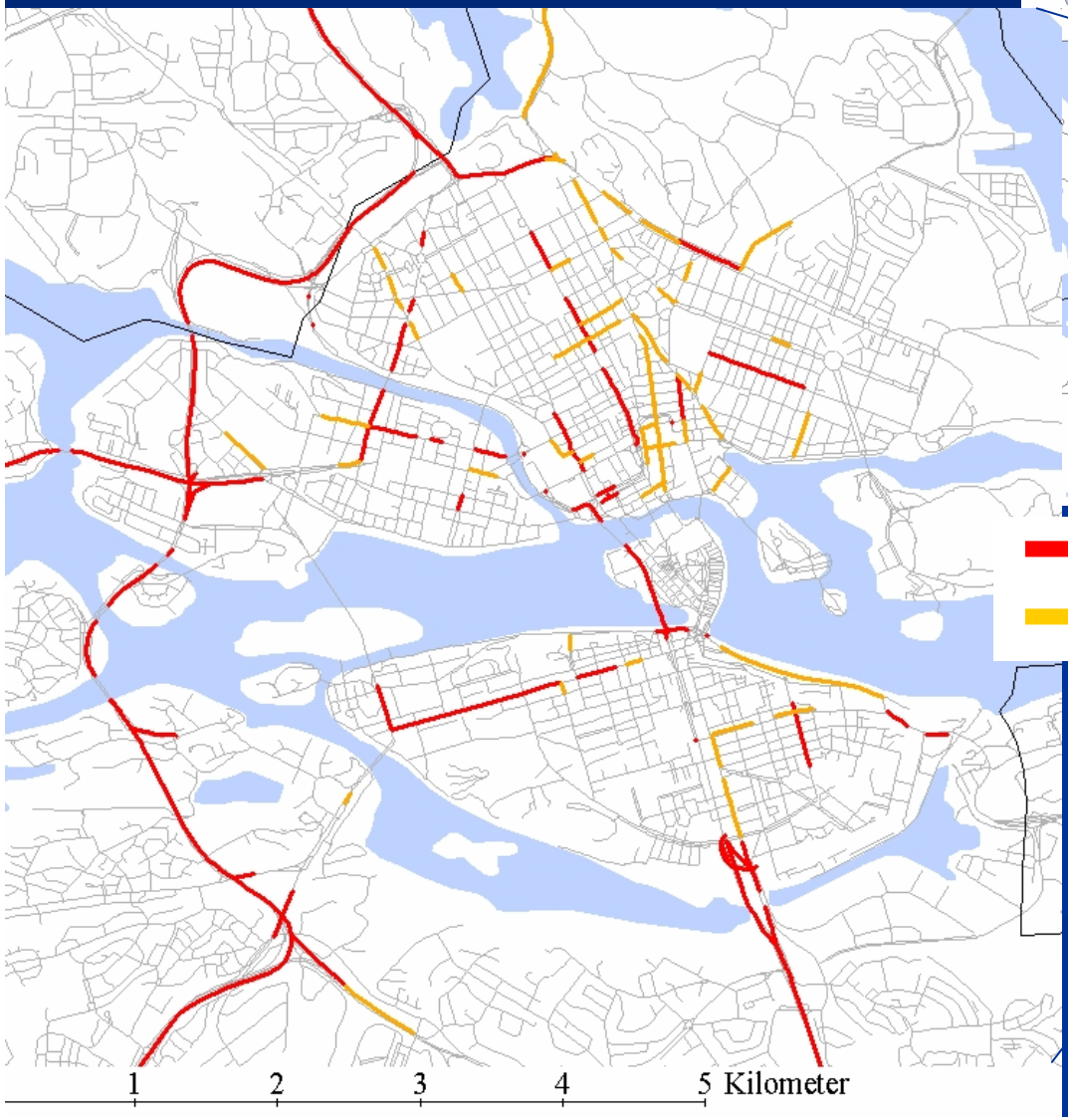
Johansson et al., 2004

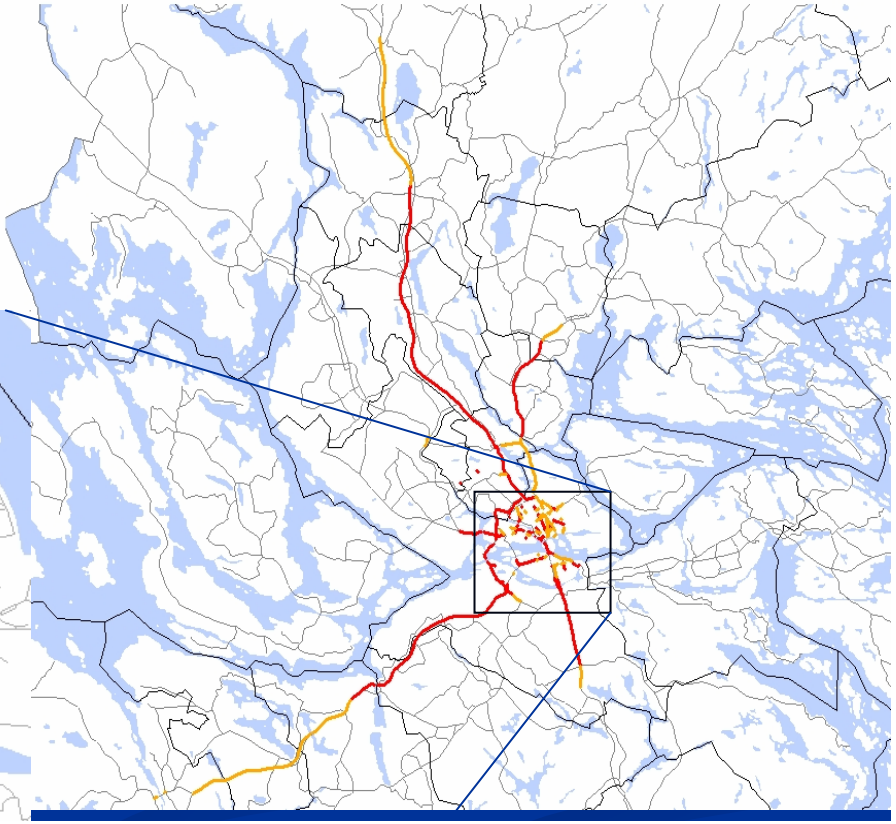
PM10 & studded tyres in Oslo



Steinar Larssen, NILU

Rough estimate of effect of reducing studded to 35 %





>50µg/m³ for the 36th day

Former red street

Vehicle speed

Higher speed may increase

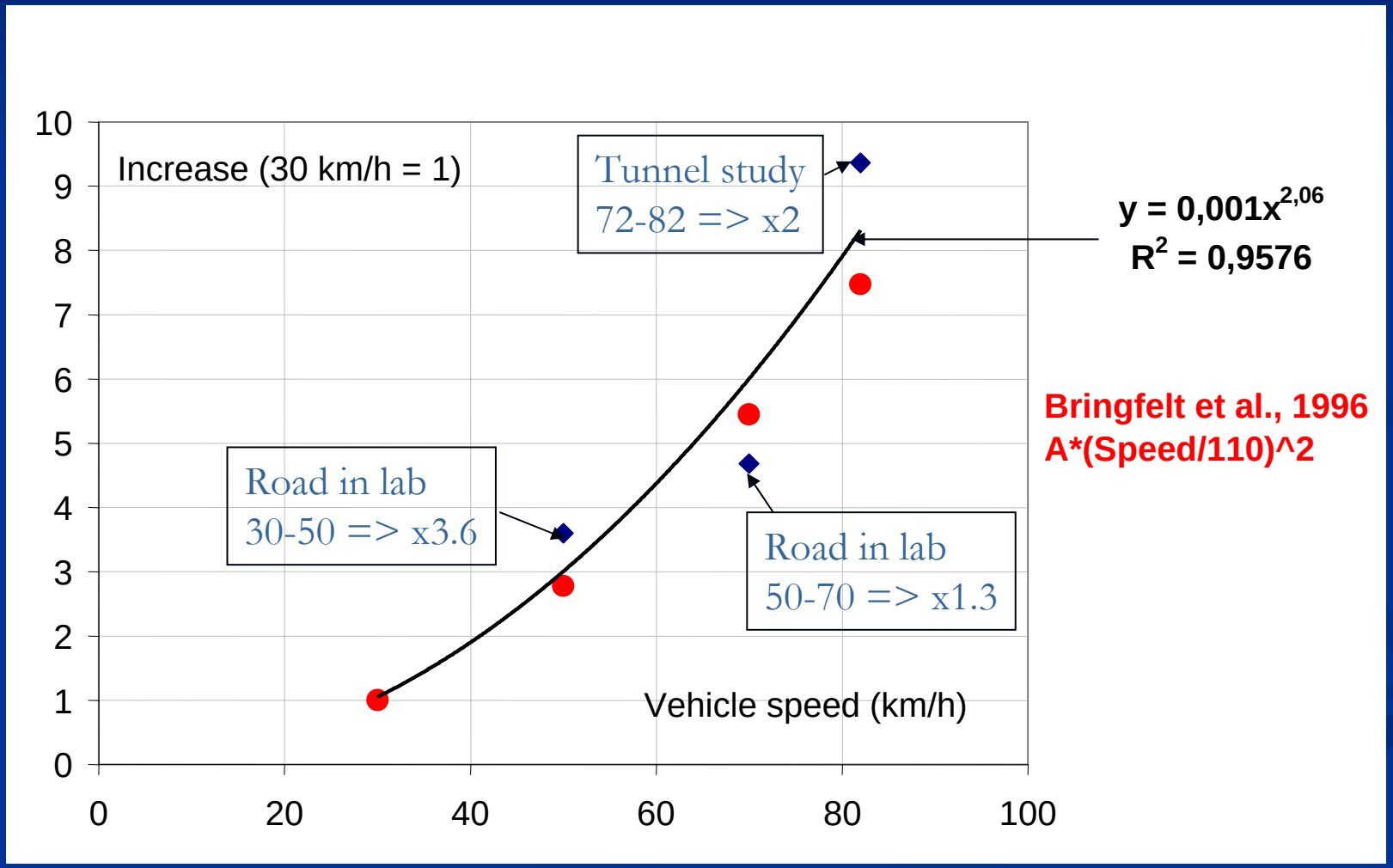
- Road wear (especially if studded tyres)
- Suspension of PM, but it depletes the depot
- Ventilation (dilution)
- Rate of evaporation from roads

Effect of vehicle speed

Type of measurement	Share studded tyre	Change in speed Km/h	Road condition	Change in PM10	Reference
Lab. road test facility	100%	30 to 50	Dry, no sand, quartsite	Increase by factor 3.6	Gustafsson et al., 2005
Lab. road test facility	100%	50 to 70	Dry, no sand, quartsite	Increase by factor 1.3	Gustafsson et al., 2005
Road tunnel Stockholm	Ca 70%	72 to 82	Dry mainly, no sand Quartsite	Increase by factor 2	Johansson et al., 2001; Kristensson et al., 2004
Main road ambient Oslo	24%	77 to 67	Variabel	Decrease with 35%	Hagen et al., 2005

Lower speed gives less PM2.5!

Non-linear dependence of emission on speed



$y = 0{,}001x^{2{,}06}$

$R^2 = 0{,}9576$

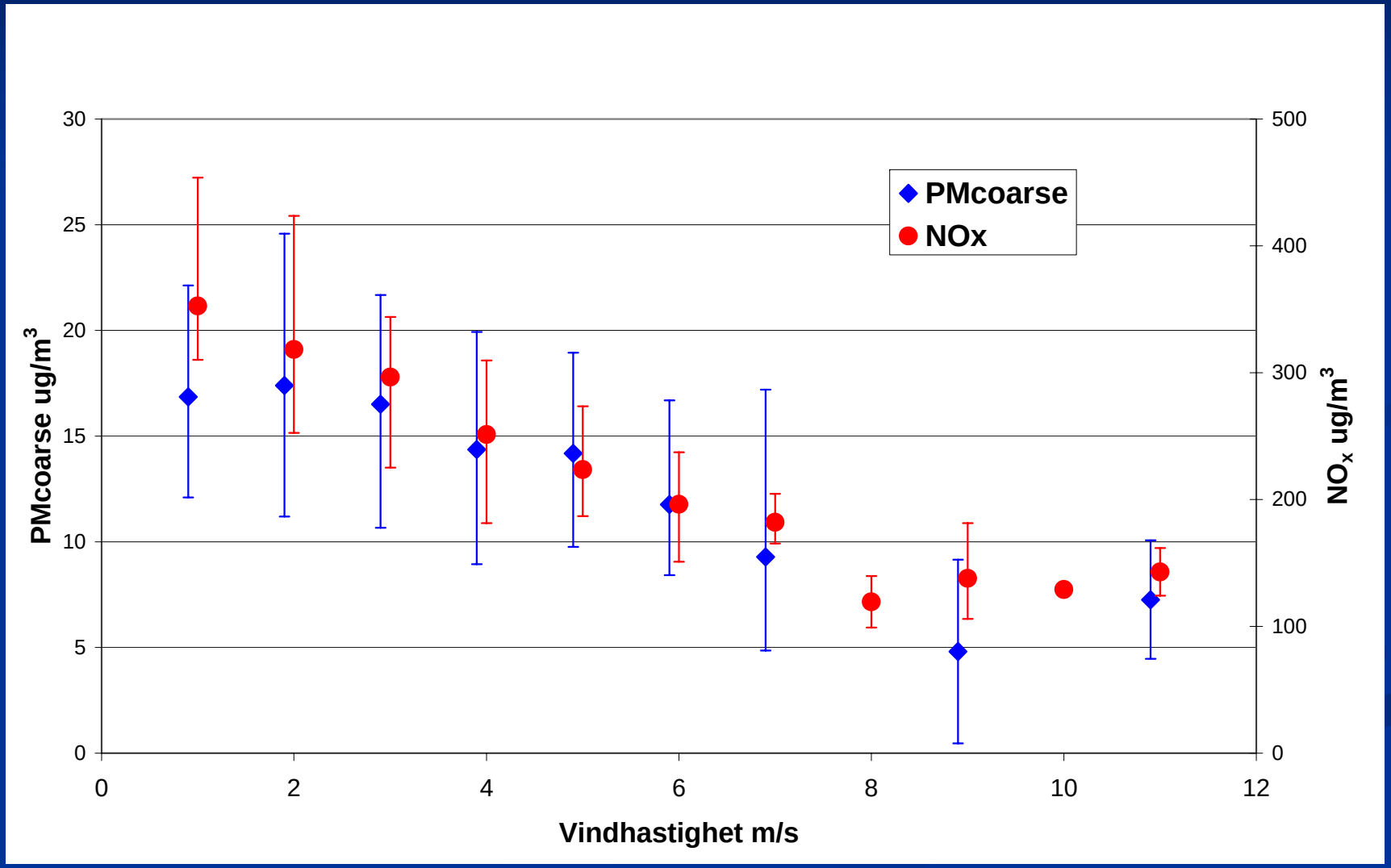
Bringfelt et al., 1996
A*(Speed/110)^2

Wind speed

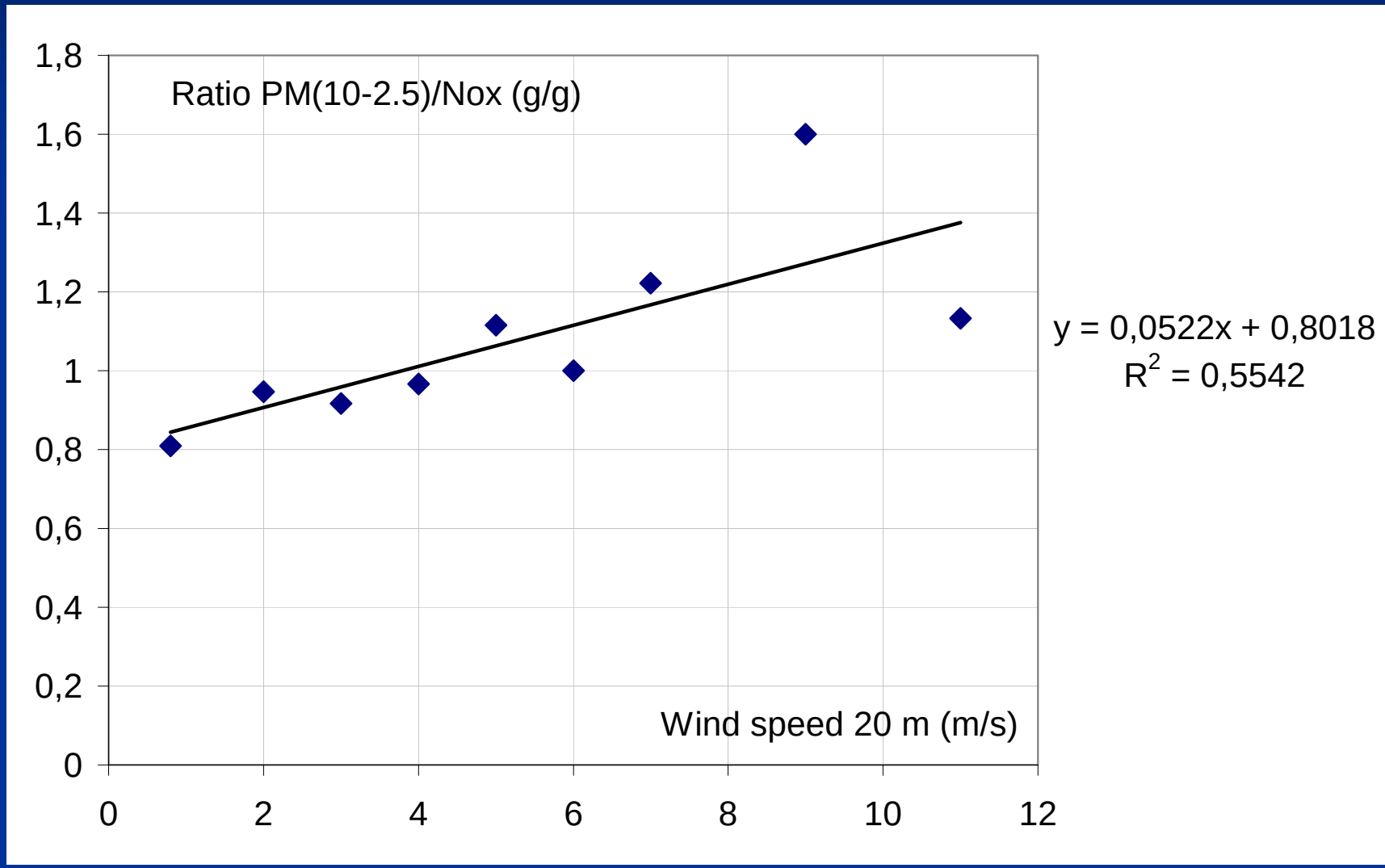
- Increases ventilation/dilution
- May increase suspension of PM
- Increases rate of evaporation
- Increases deposition of PM

PM coarse (PM10-2.5) Hornsgatan,

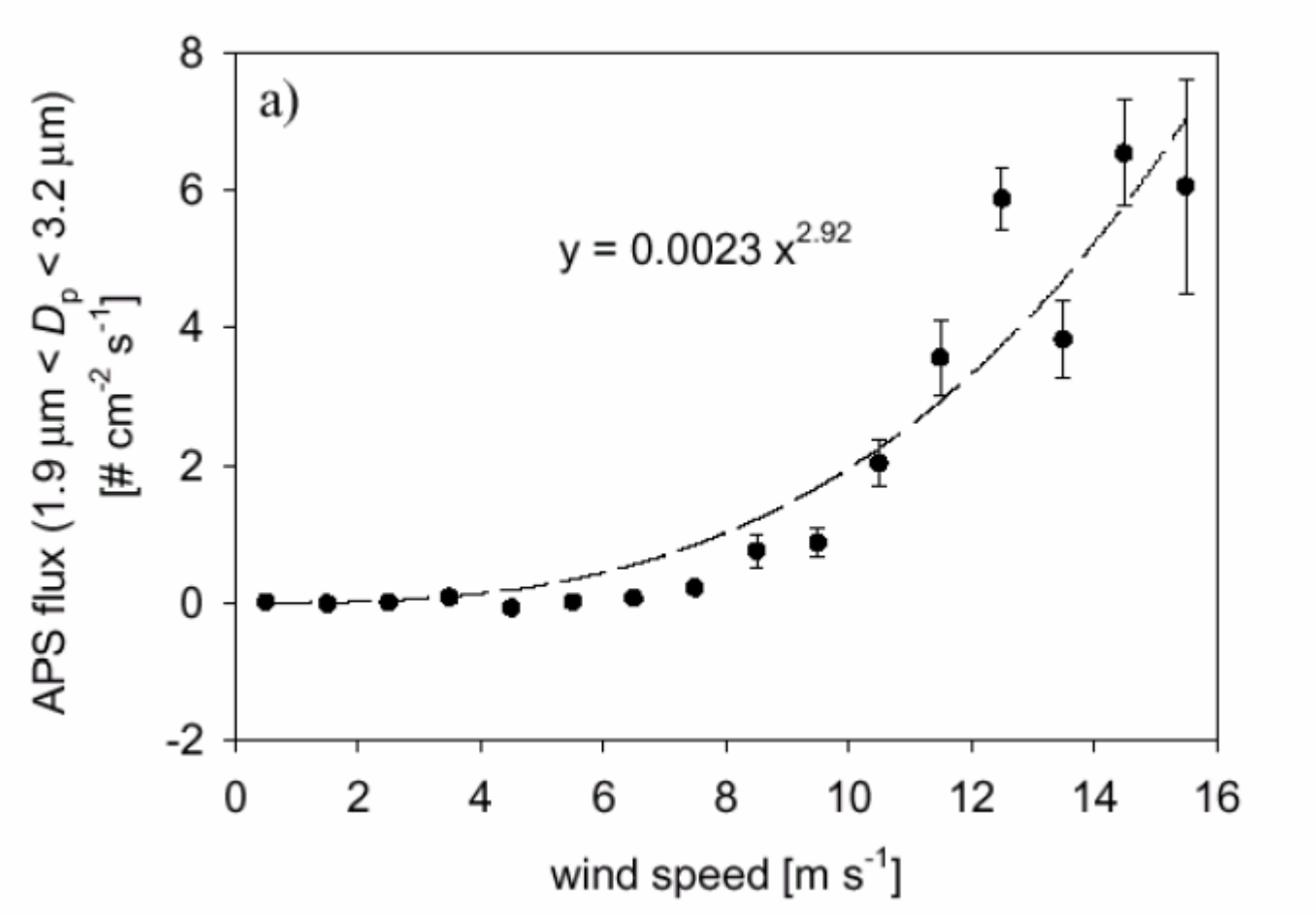
only dry roads



Coarse/NOx vs. wind speed for dry conditions (Hornsgatan)



Flux of 2-3 um PM
Nemitz et al., 2000



Measures to reduce PM10 levels

- Congestion charging

- Less use of studded tyres
- Application of dust binding material

- Intense sweeping of the road surface
- Intense washing of the road surface

CMA

Calcium magnesium Acetate

- Binds road dust, keeps road moist
- Reduces PM10 emissions and levels during dry conditions
- Increases road wear?
- More environmentally friendly, less corrosive compared to NaCl, $CaCl_2$, $MgCl_2$

Washing of verge of high-way

- Reduces suspension of accumulated PM

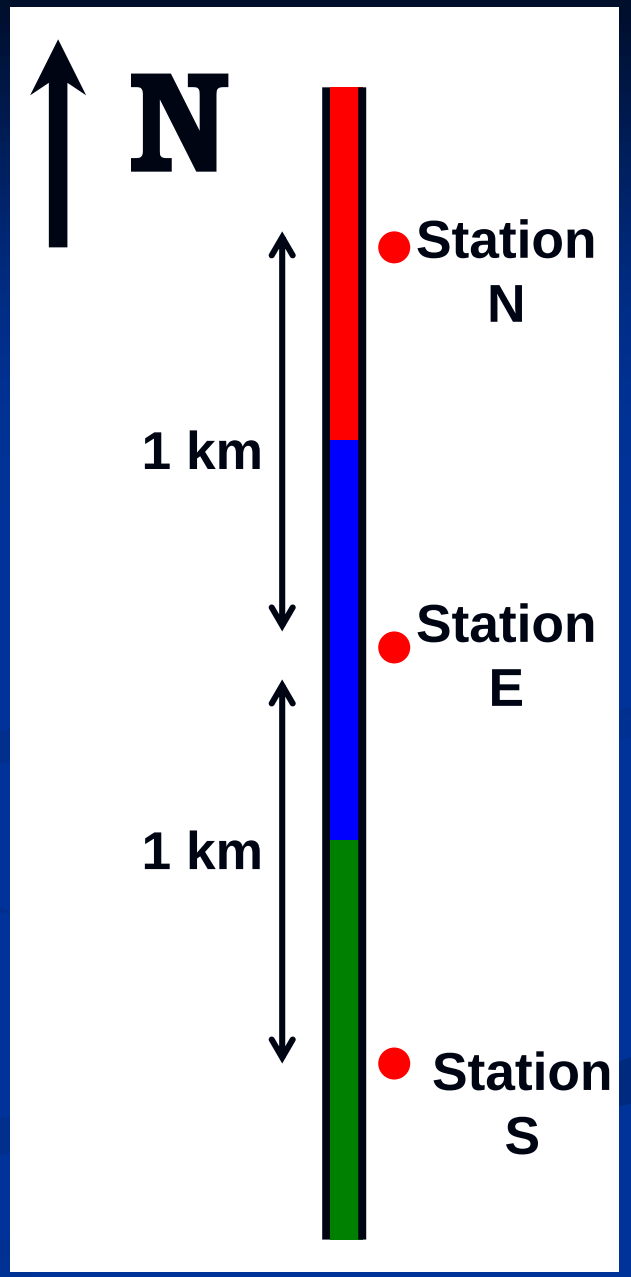
CMA as dust binding material

- CMA (Calcium Magnesium Acetat, Ice-away), 25% water solution, 40 g/m^2
- 3/4 of the carriageway at the Highway
- 21 occasions 2004, 9 occasions 2005

Measuring site along a highway north of Stockholm, 2004

- 4 lane
- No exists
- 60 000 vehicles/day
- No major sources in the surroundings

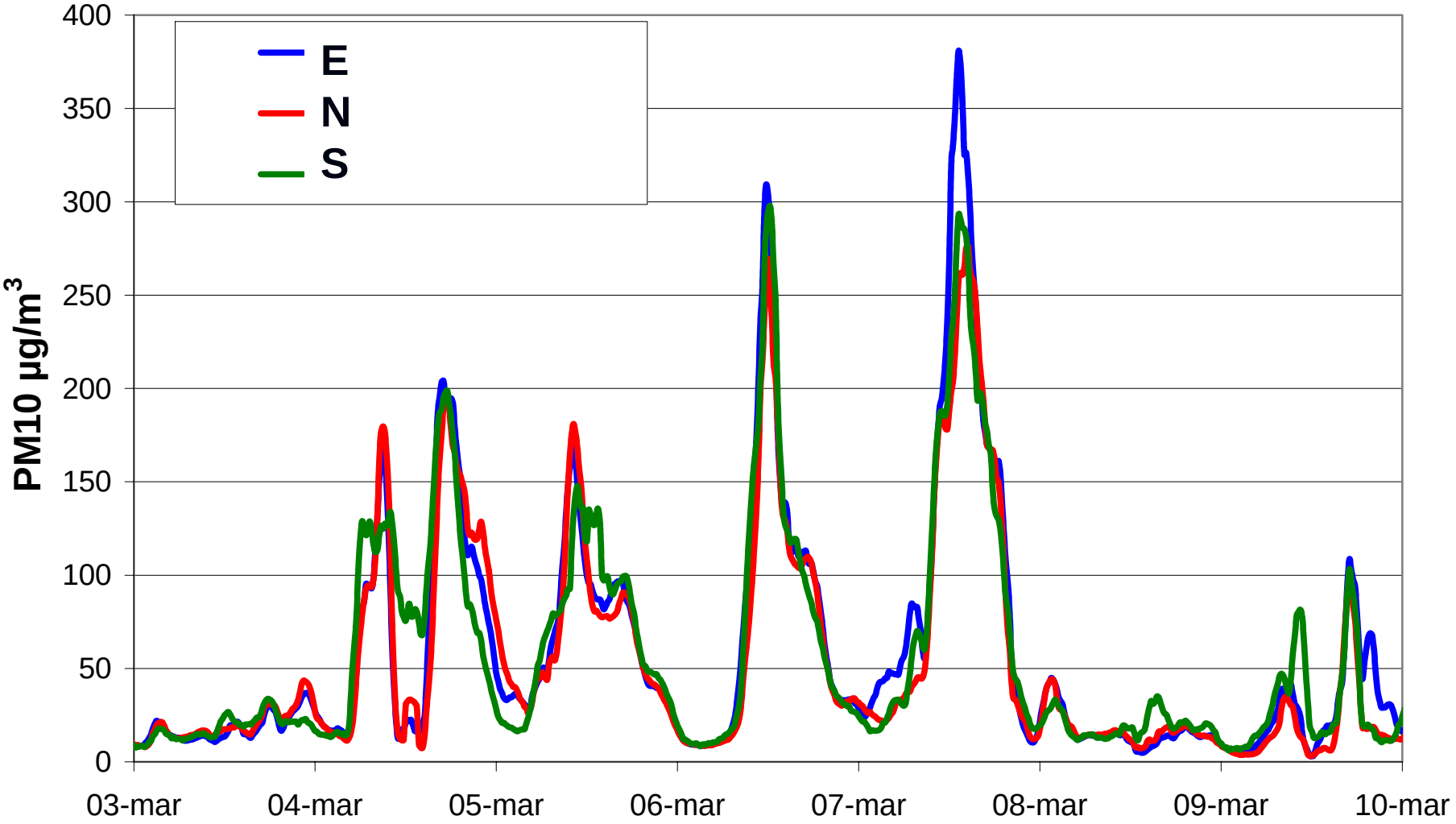
- Stretch **S**: untreated
- Stretch **E**: washed
- Stretch **N**: CMA treated



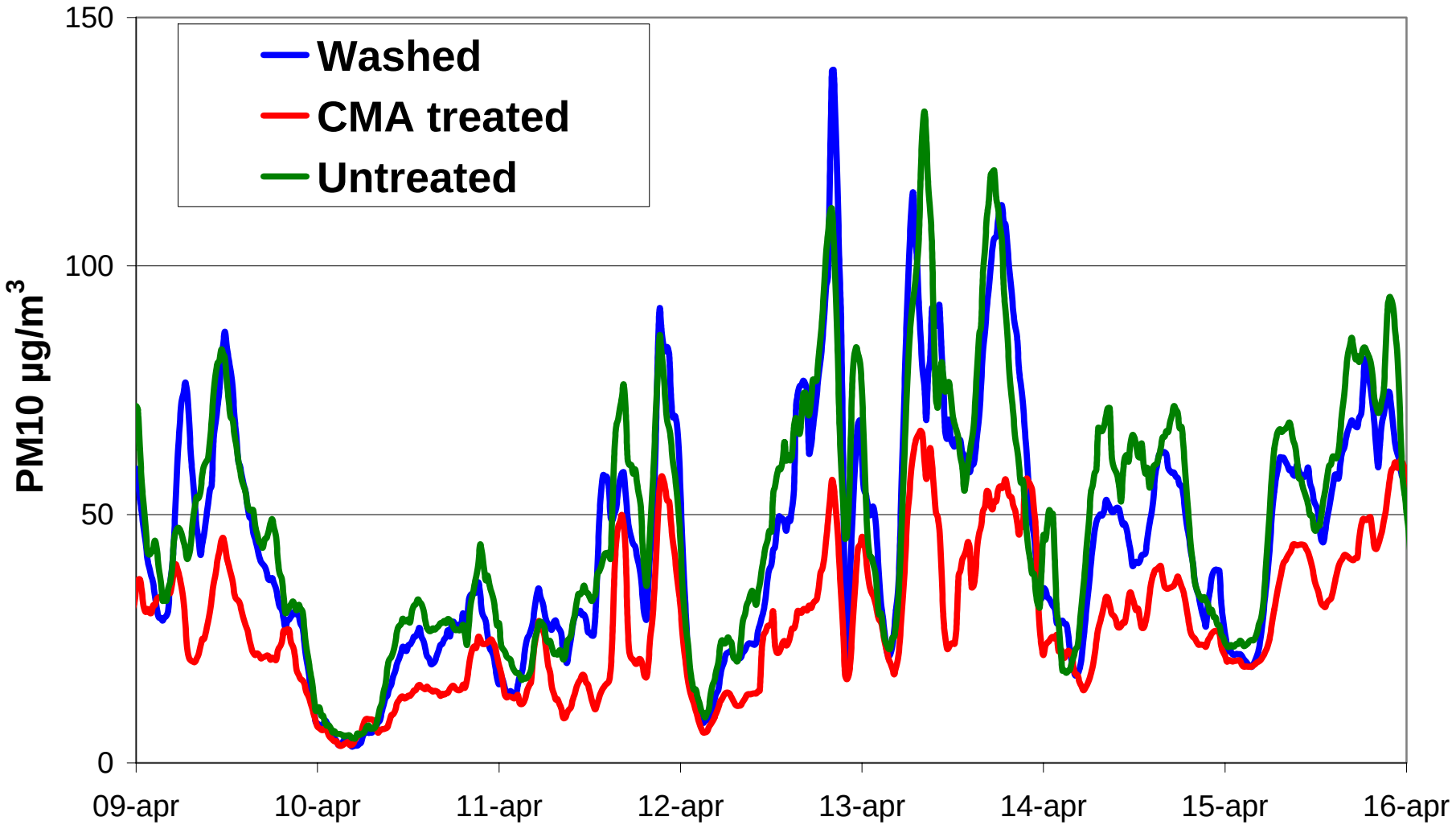
Measuring stations along the highway

CMA on the highway

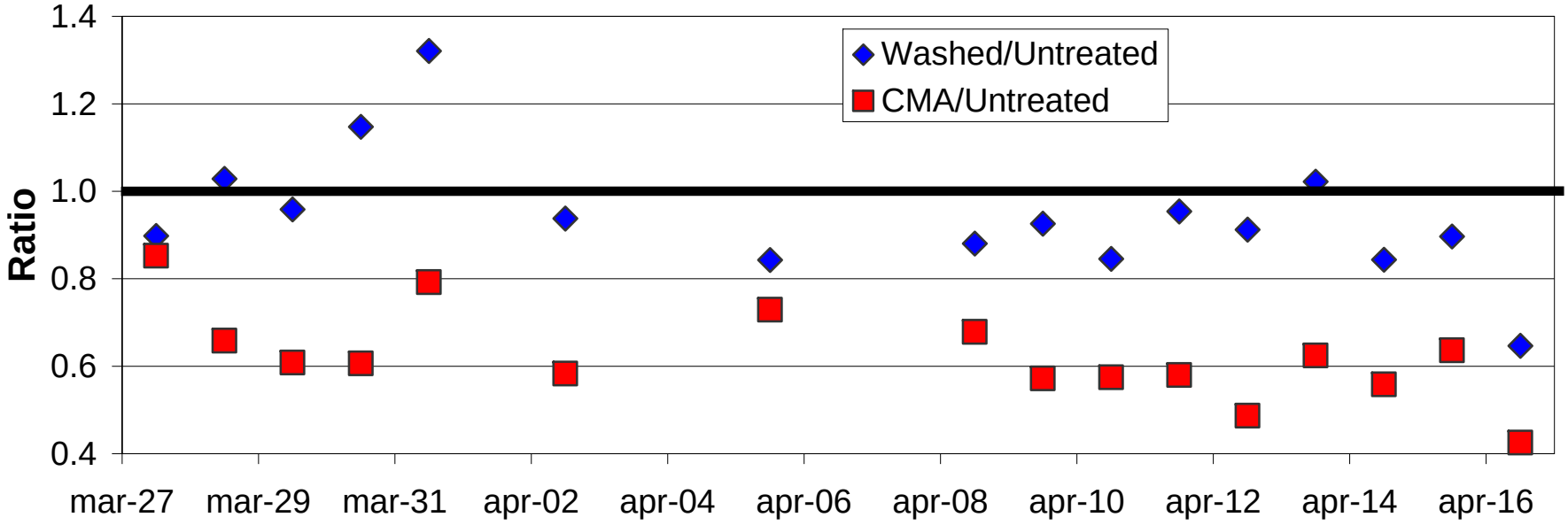
Highway without treatment



Highway after treatment



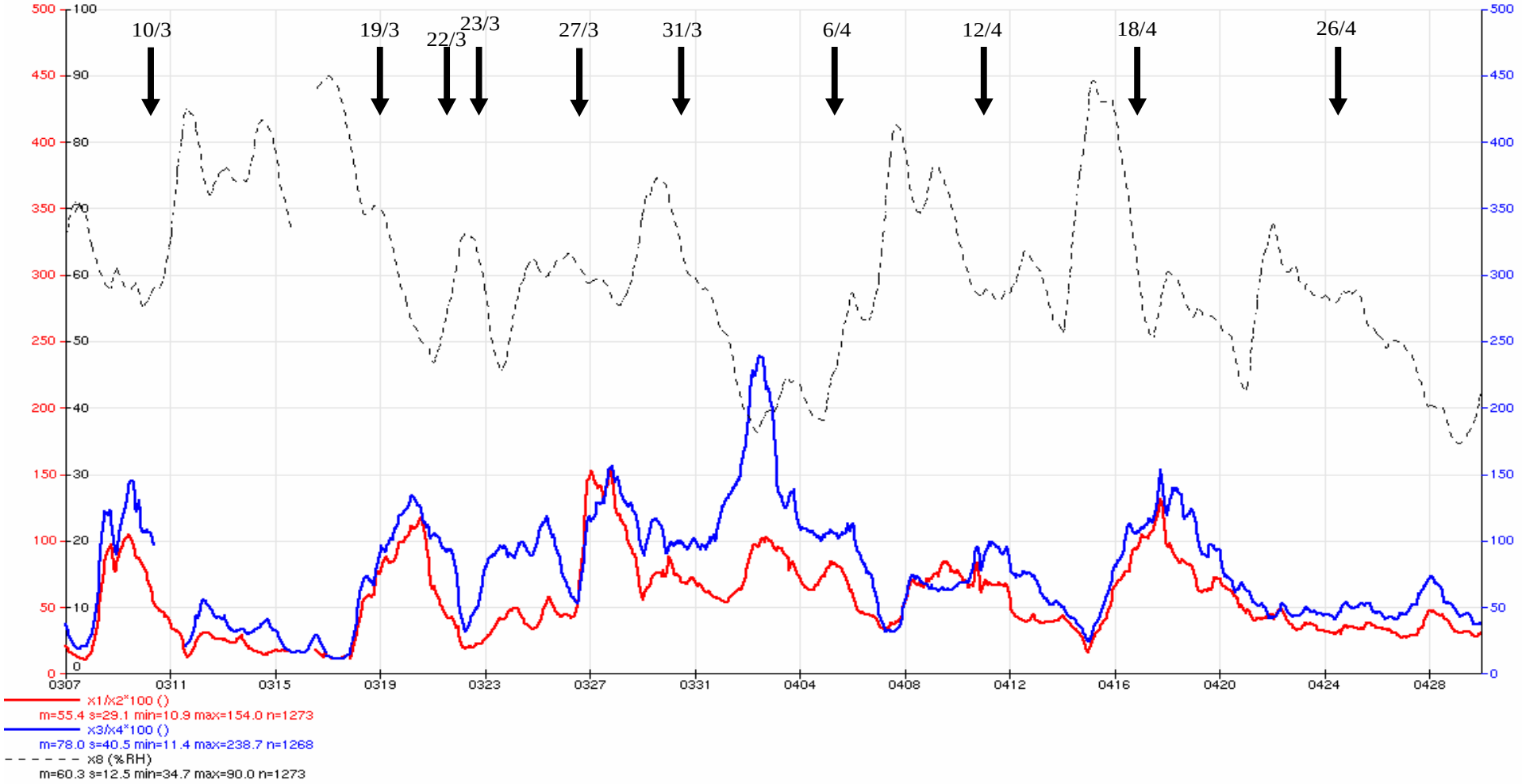
Washing and CMA treatment



- **Average daily reduction**
  - 6 % with high pressure washing
  - 35 % with CMA application

- **Days >50µg/m^3** (of 21)
  - **Untreated: 12**
  - **Washed: 10**
  - **CMA treated: 3**

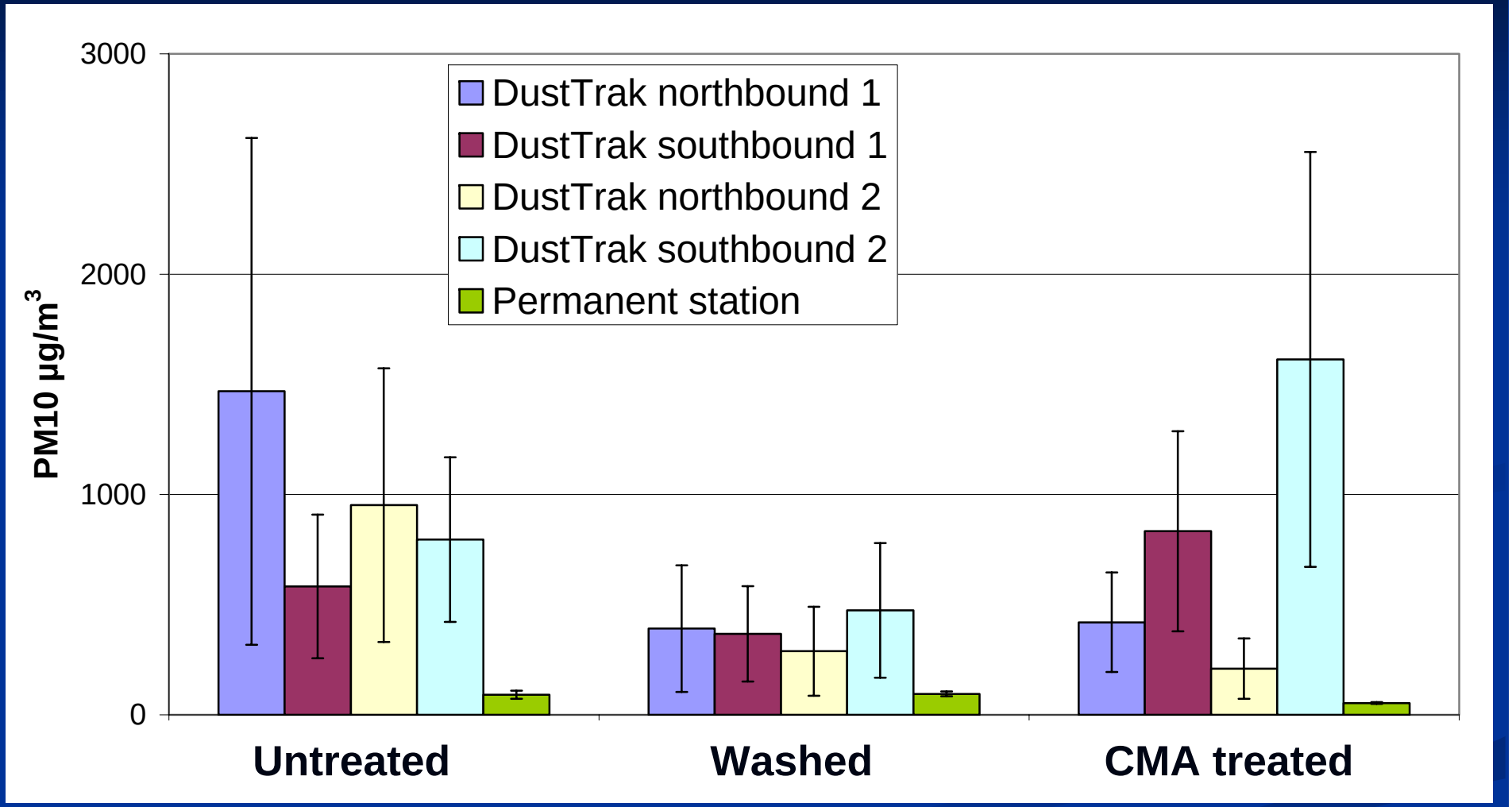
CMA in Stockholm city



Resuspension of dust from the verge

- Measurements with portable DustTrak along the highway
- Two cars
  - Both driving in the verge with 20-30m distance
  - Measurements in the second car
- Comparing with the 3 permanent stations

Resuspension of road dust



Assessment of measures

- A reduction of **10 %** in the fraction of studded tires caused a decrease of around **10 μg/m^3** as weekly average
- Application of CMA caused an average daily reduction of **35 %** on the PM10 levels along the highway
- Resuspension of dust material from the verge has only small influence on the PM10 levels next to the road
- High pressure washing caused an average daily reduction by **6 %** of the PM10 levels along the highway
- No observed effect by intense sweeping

Most effective measures

- Long term effect!
  - Reduce the fraction of studded tires to 40 % (today 75-80%)
- Short term effect!
  - Application of CMA

Ongoing PM10 projects

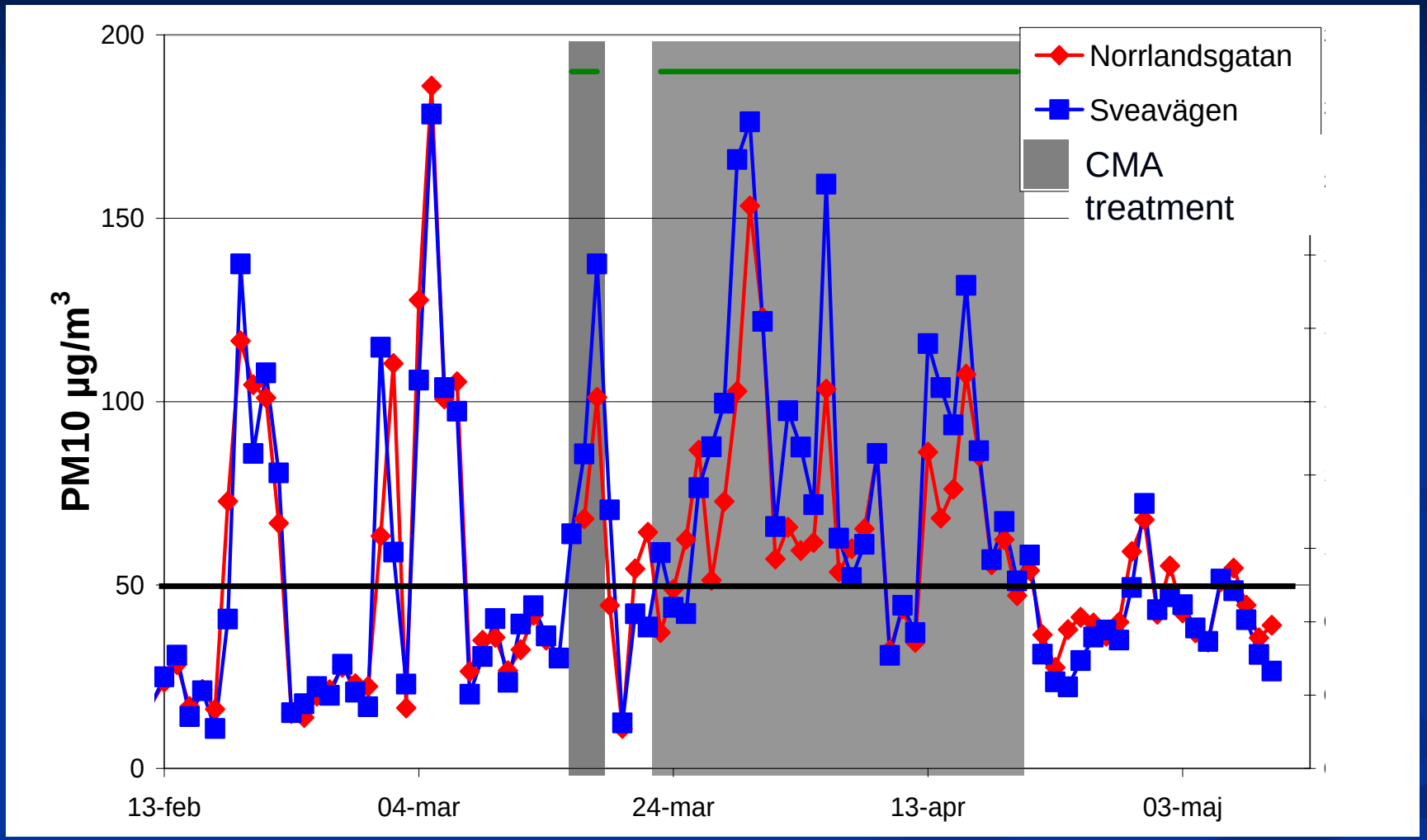
- Mobile PM10 emissions (road wear)
- $MgCl_2$ as dustbinding material on the highway
- More extensive use of CMA in Stockholm 2006
- Brake & Tyre & other sources of PM
  - Nanoparticles from tyres
  - Source receptor modelling based on metals + PAH
- Validation of PM10 non-exhaust emissions model

The End

Future test?

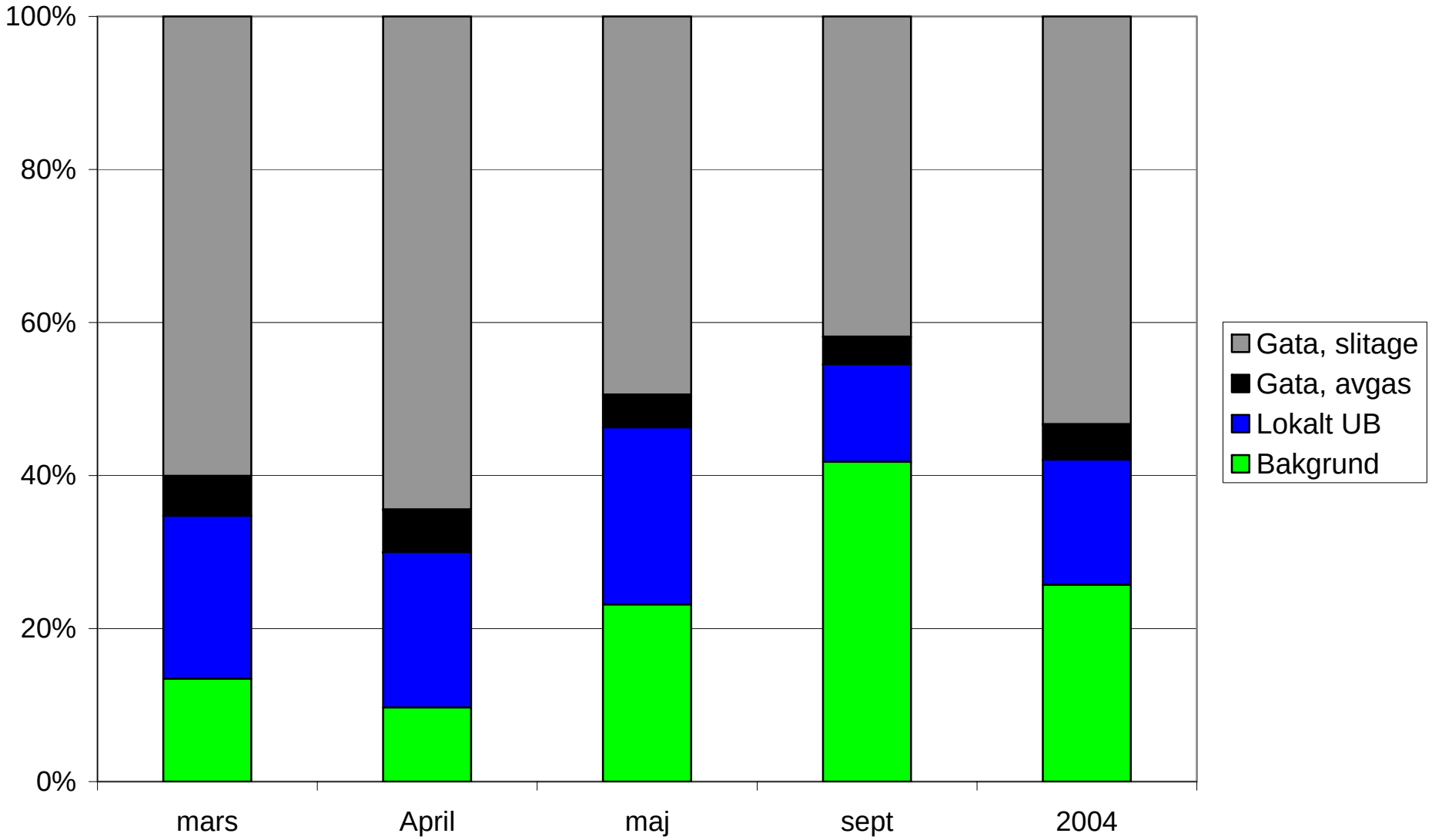
- Reduced sanding
- Different sanding material
- Different pavement
- Reduced speed

CMA application at Norrlandsgatan

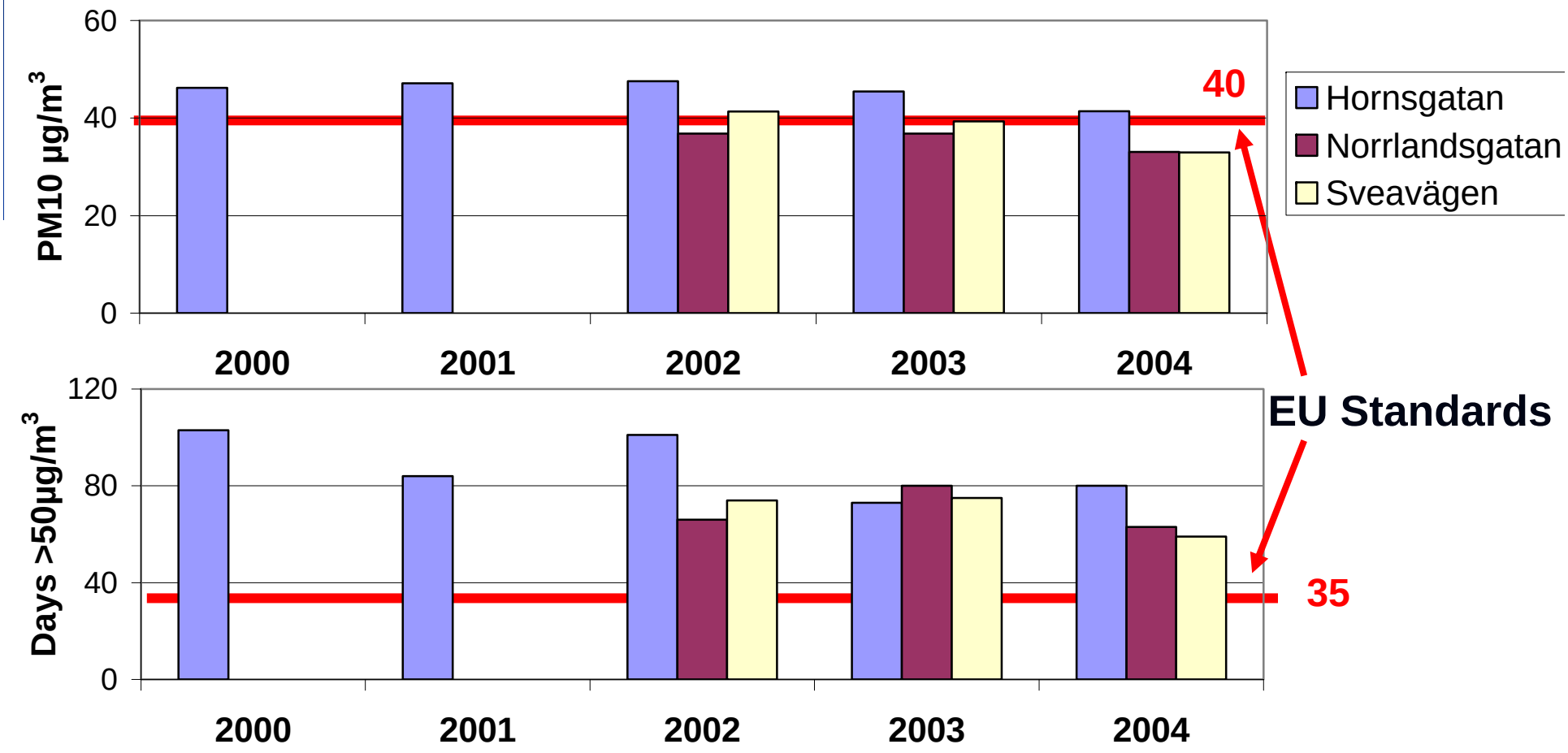


Average reduction in the daily PM10 averages of 10-20 %

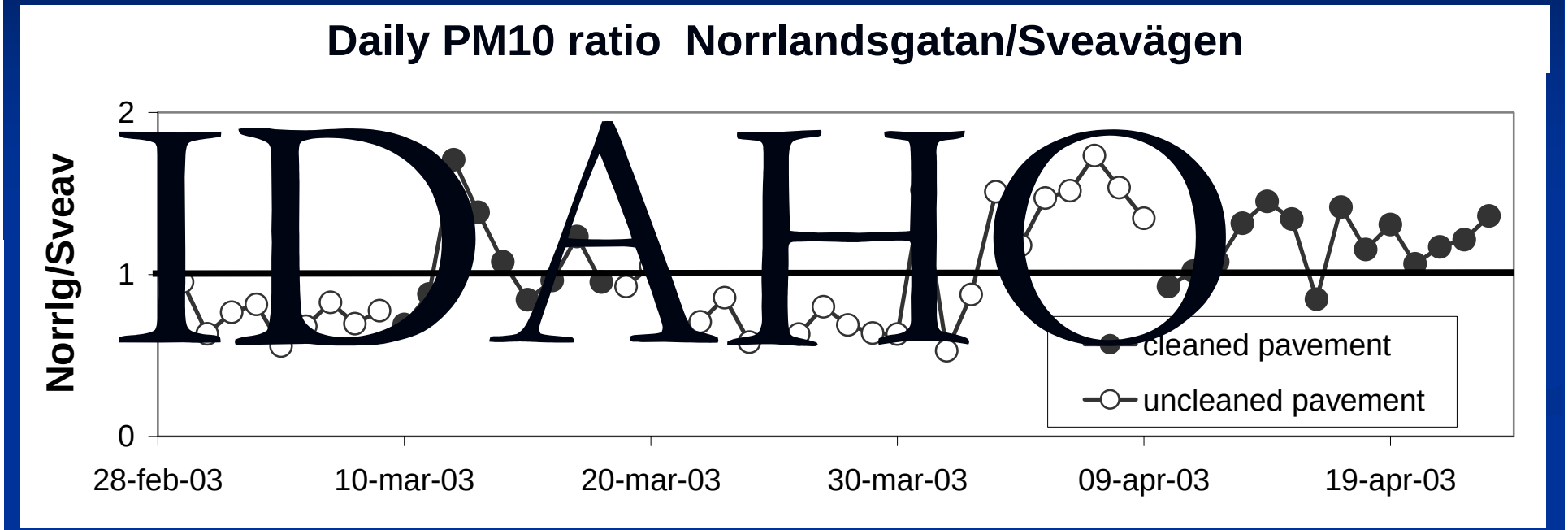
Bidrag till PM10 på Hornsgatan (2004)



Annual average PM10 levels



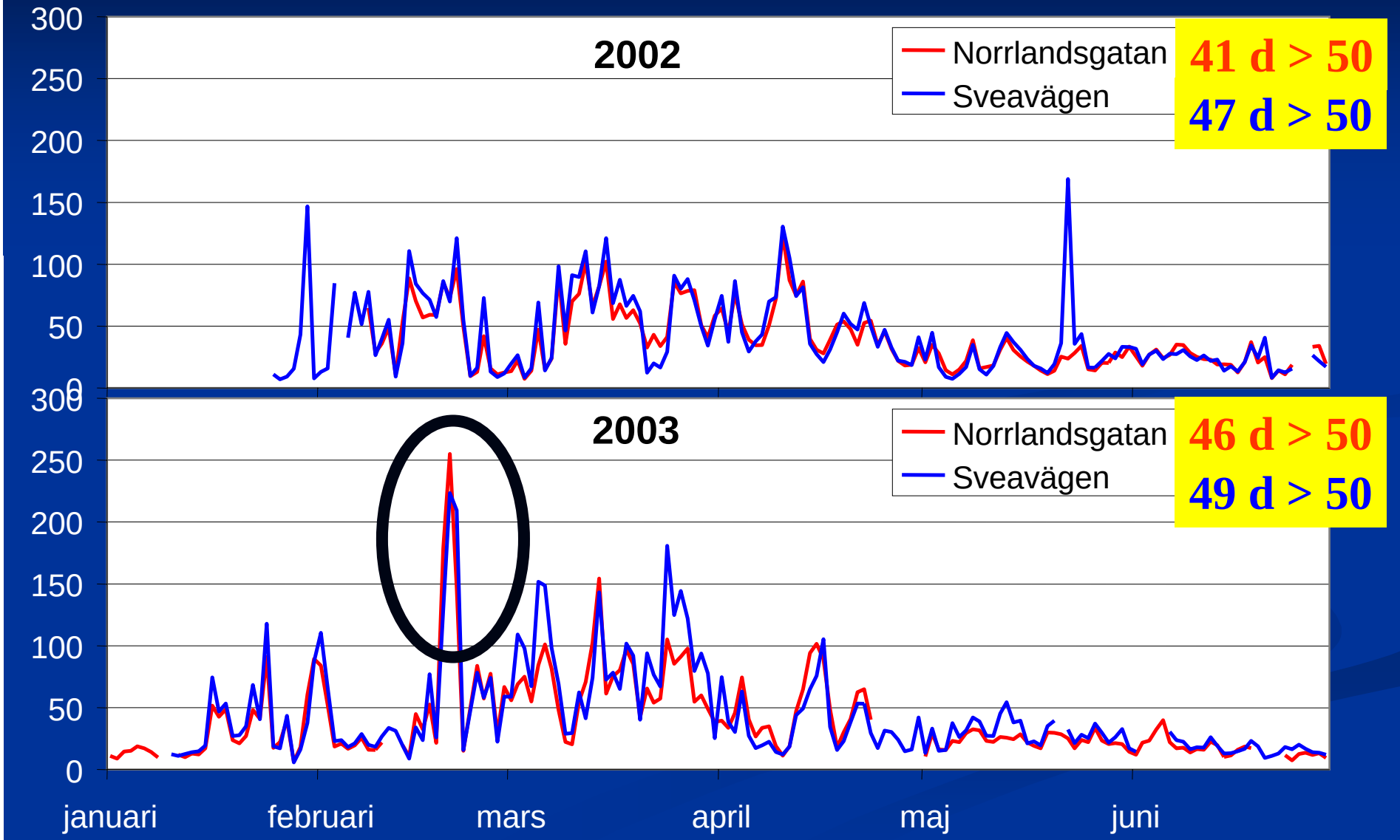
Intense sweeping at Norrlandsgatan spring 2003



	Mar-Apr 2002	Mar-Apr 2003
Norrlandsgatan	41 days > 50µg/m^3	46 days > 50µg/m^3
Sveavägen	47 days > 50µg/m^3	49 days > 50µg/m^3

No statistical significant reduction in the PM10 levels

Frequent sweeping



“Emma” Mobile PM monitoring

Centre (traffic)
Forsdala (wood burning)
Södermalm (wood burning)

Particle size resolved measurements
(UCPC + CPC + DMA + OPC)
+Sot