Foto: Jörg Sintermann, AWEL

Effects of traffic related abatement policies on Swiss air quality trends

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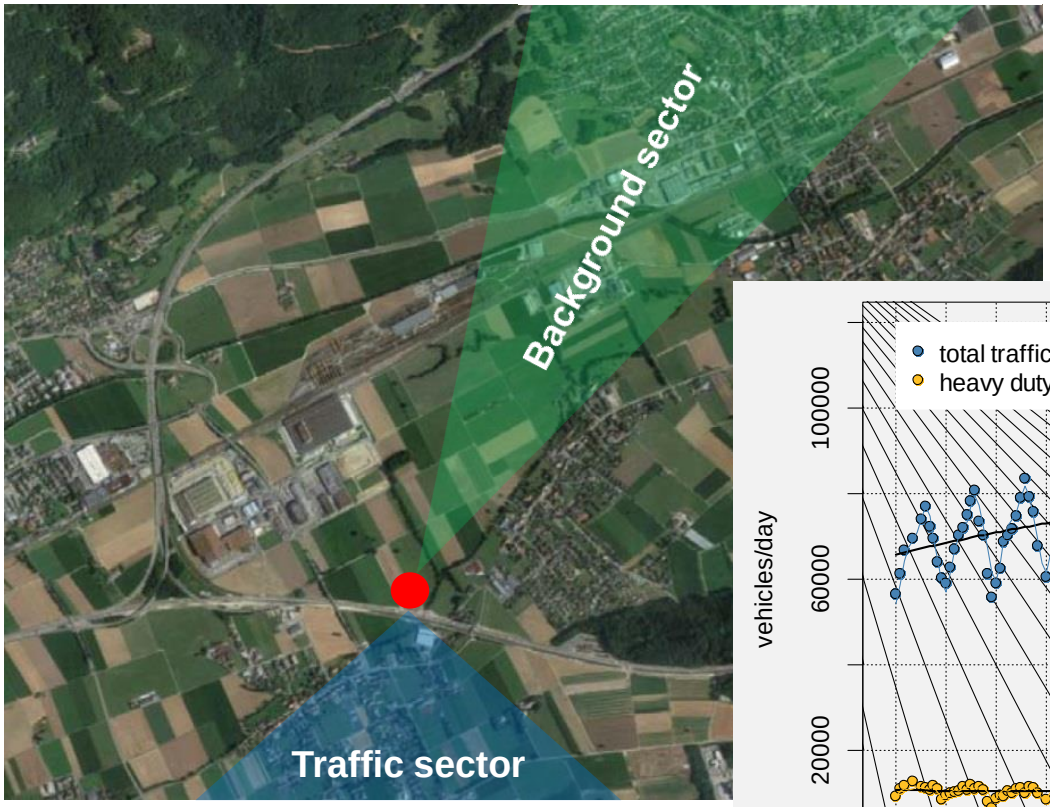
Motivation - Measures implemented in Switzerland to reduce air pollution from traffic (and non-road engines)

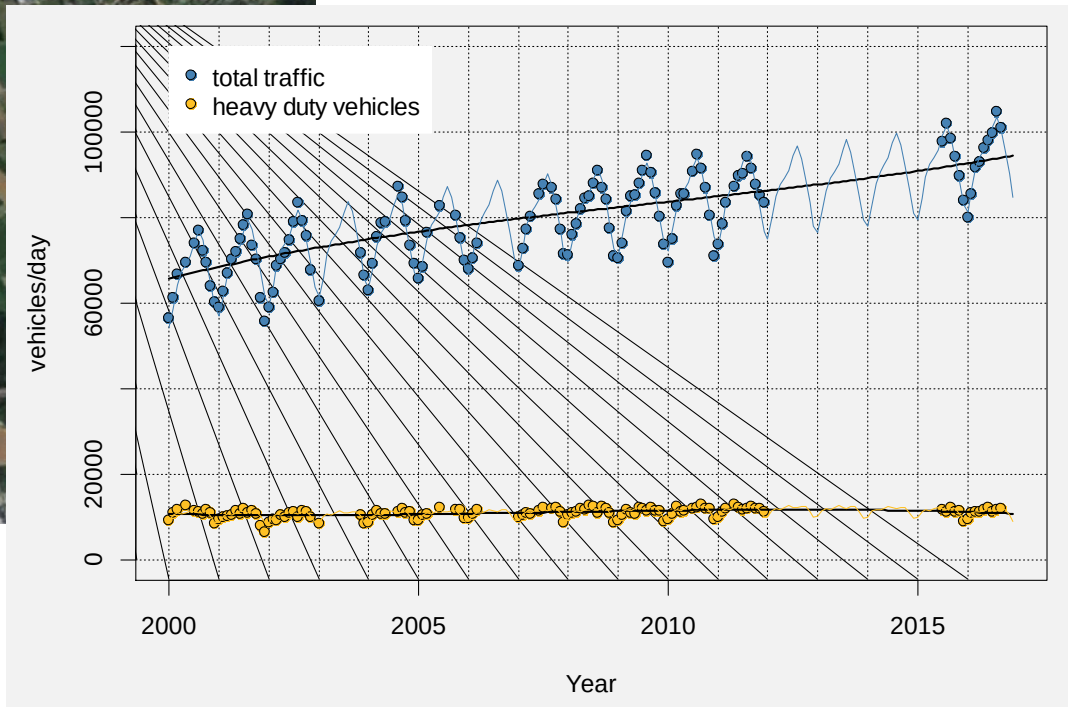
- Implementation of the Euro emission standards (beginning 1995) – for example, Euro 5 (since 2009) and Euro 6 emission standards require that diesel vehicles are equipped with diesel particulate filter (DPF)
- Stepwise reduction of sulfur content in fuels (< 10 mg/kg since 2010)
- Implementation of policies and programs to fit DPF to non-road diesel engines (construction machines, ship engines, cargo trains etc.) – for example, emission limits for particle number concentration (PNC) for construction machines since 2010
- Heavy vehicle charge (LSVA) for kilometers driven on Swiss roads depends on Euro emission standard
- Financial incentives for public transport companies for operating low-emission busses (since 2008, refund of mineral oil tax for busses equipped with DPF)
- …

⇨ **Impact on air quality?**

Rural traffic site Haerkingen



- 20m north of highway A1
- traffic increased from 70’000 vehicles/day in 2000 to 95’000 vehicles/day in 2016



⇨ data filtering (wind direction, wind speed, daytime)

⇨ calculation of *roadside increments*

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Rural traffic site Haerkingen

calculated trends of roadside increments for **2005 - 2016**

Strong downward trends!
⇒ Success of abatement policies

Pollutant	Unit	Trend
Δ NO_x	ppb·m^{-3}·$year^{-1}$	-2.47 [-3.18, -1.72]
	% $year^{-1}$	-2.9 [-3.7, -2.0]
Δ NO_2	ppb·m^{-3}·$year^{-1}$	0.16 [-0.12, 0.38]
	% $year^{-1}$	0.8 [-0.6, 1.9]
Δ CO	ppb·m^{-3}·$year^{-1}$	-10.93 [-14.64, -7.64]
	% $year^{-1}$	-7.3 [-9.8, -5.1]
Δ CO_2*	ppm·m^{-3}·$year^{-1}$	0.19 [-0.81, 0.97]
	% $year^{-1}$	0.5 [-2.2, 2.6]
Δ PM_{10}	µg·m^{-3}·$year^{-1}$	-0.19 [-0.35, 0.09]
	% $year^{-1}$	-6.3 [-11.3, 3.0]
Δ PNC	number cm^{-3}·$year^{-1}$	-3172 [-4913, -1903]
	% $year^{-1}$	-7.3 [-11.3, -4.4]
Δ EBC**	µg·m^{-3}·$year^{-1}$	-0.24 [-0.29, -0.22]
	% $year^{-1}$	-11.6 [-13.5, 10.4]

* Trend for 2008-2016
** Trend for 2007-2016

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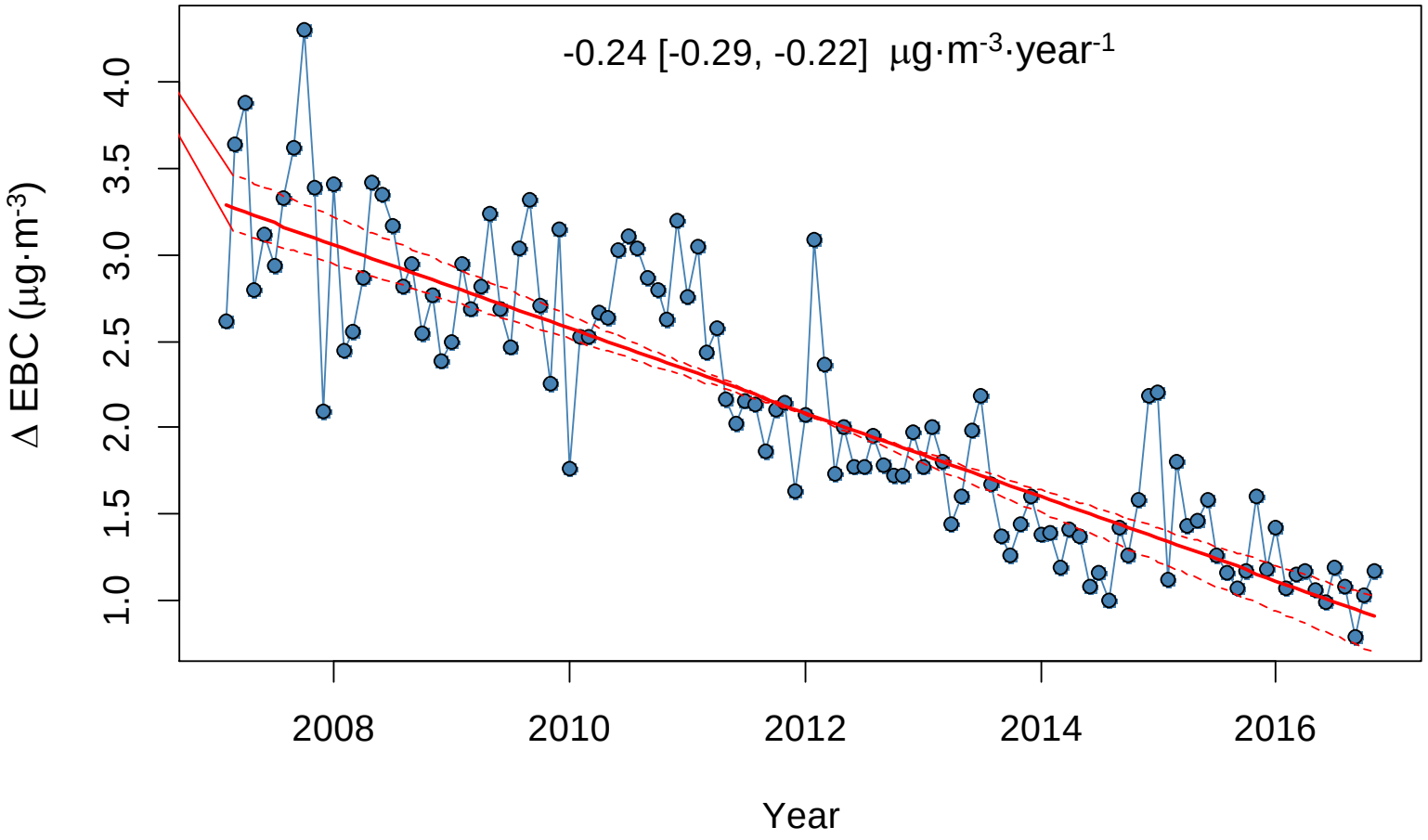
calculated trend of equivalent black carbon (EBC) roadside increment



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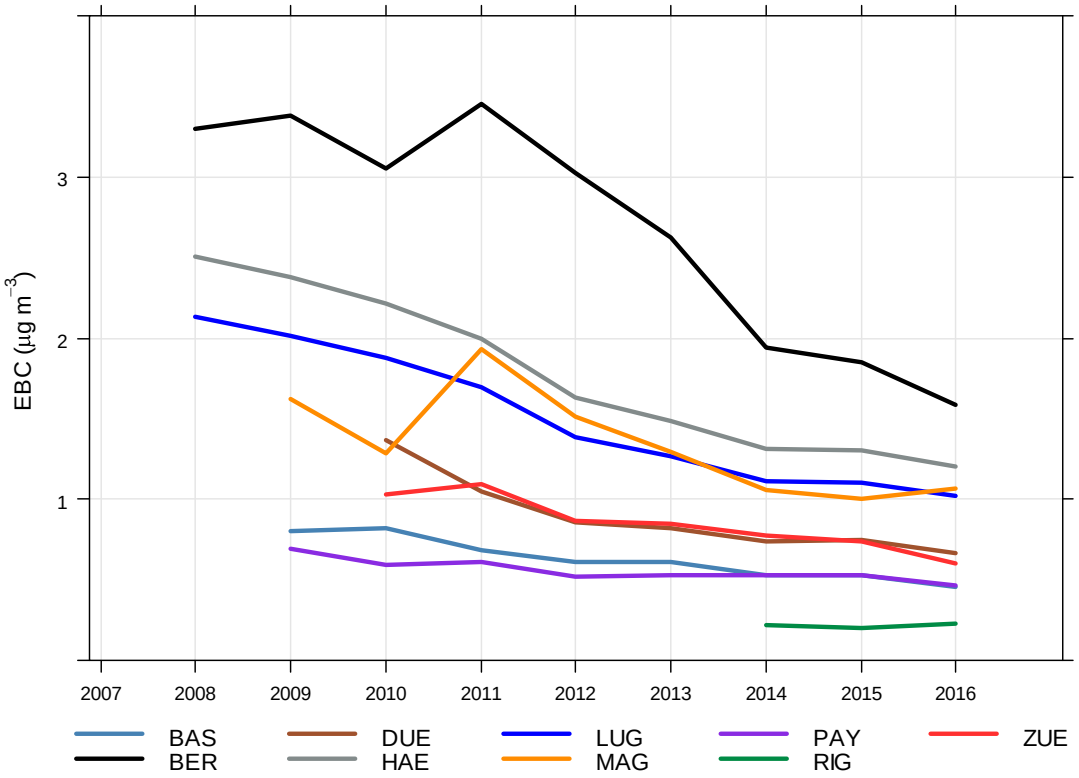
Trend of equivalent black carbon (EBC) in Switzerland



Station	Site type	Trend EBC ($\mu g \cdot m^{-3} \cdot y^{-1}$)
BER	Urban, Traffic	-0.20 (-0.28, -0.12)
HAE	Rural, Traffic	-0.19 (-0.21, -0.17)
ZUE	Urban	-0.08 (-0.10, -0.06)
LUG	Urban	-0.17 (-0.19, -0.16)
DUE	Suburban	-0.07 (-0.09, -0.05)
BAS	Suburban	-0.03 (-0.04, -0.02)
MAG	Rural	-0.08 (-0.15,-0.05)
PAY	Rural	-0.03 (-0.05,-0.02)
RIG	Rural >1000 m asl	-0.01 (-0.03, 0.01)[a]

[a] *based on data from 3½ years*

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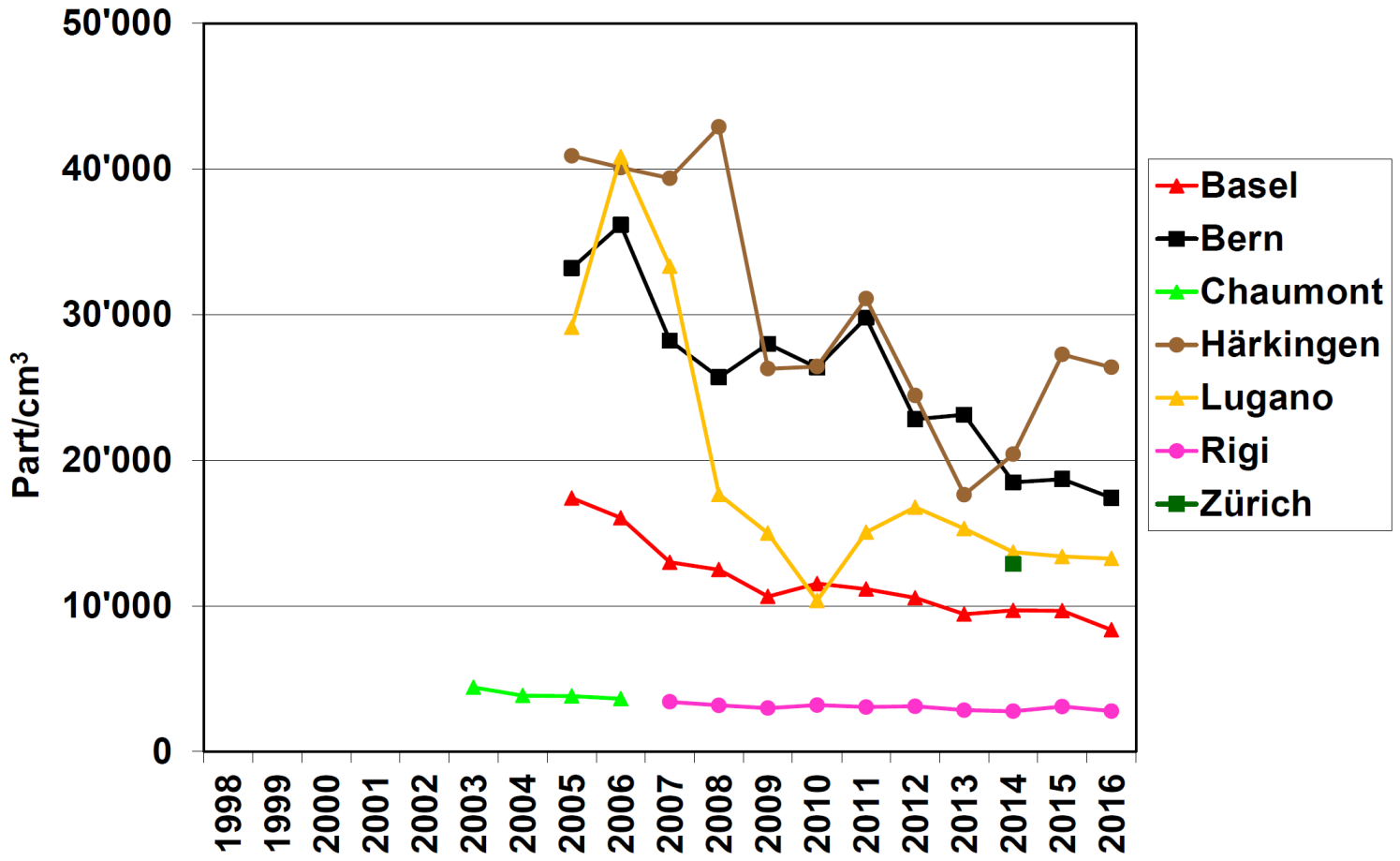
Trend of particle number concentration (PNC) in Switzerland



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Strong downward trends!
⇒ Success of abatement policies

No significant trend

* Trend for 2008-2016
** Trend for 2007-2016

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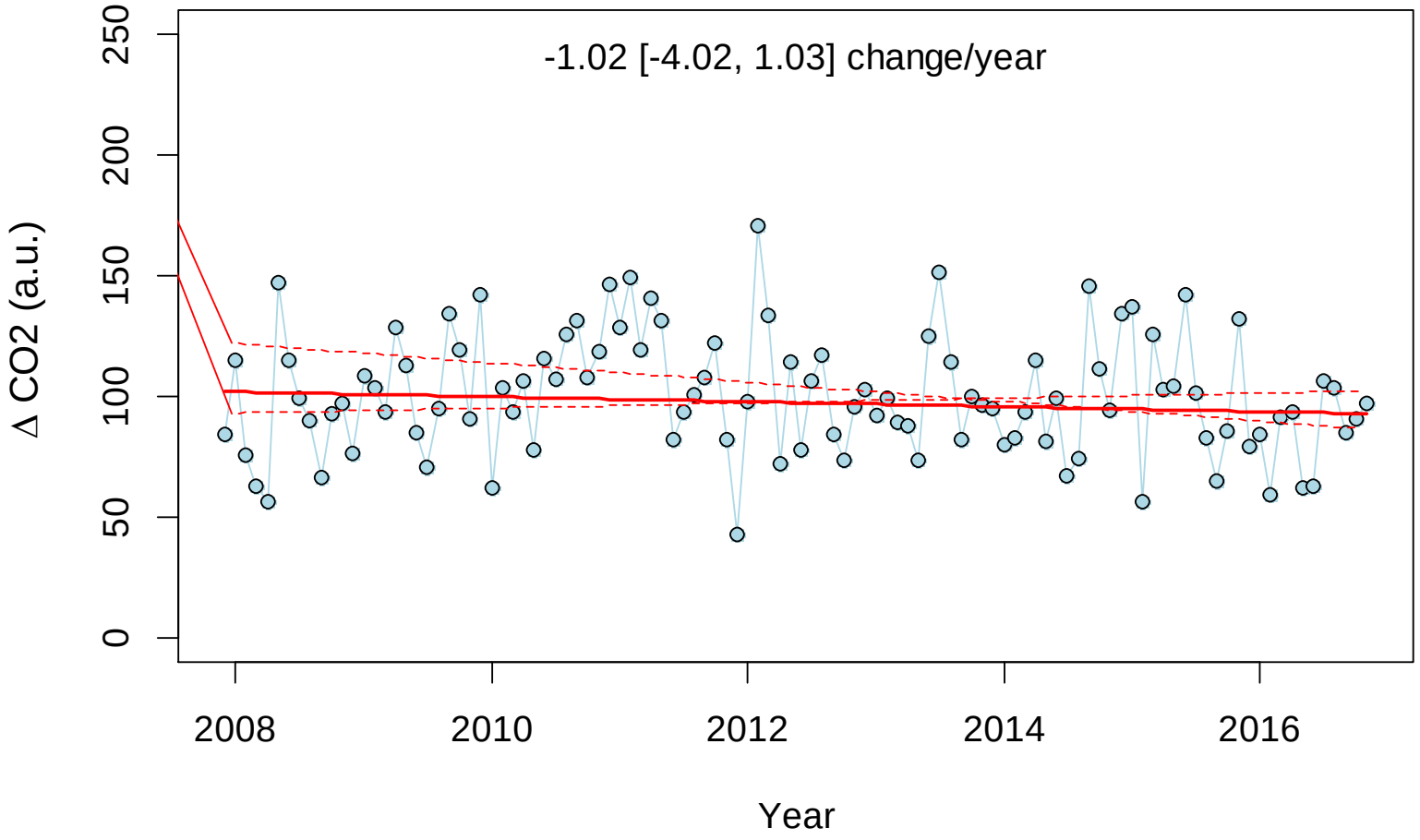
calculated trend of CO_2 roadside increment (normalized to traffic activity)



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Strong downward trends!
⇒ Success of abatement policies

Downward trend of NO_x
No significant trend of NO_2!

No significant trend

* Trend for 2008-2016
** Trend for 2007-2016

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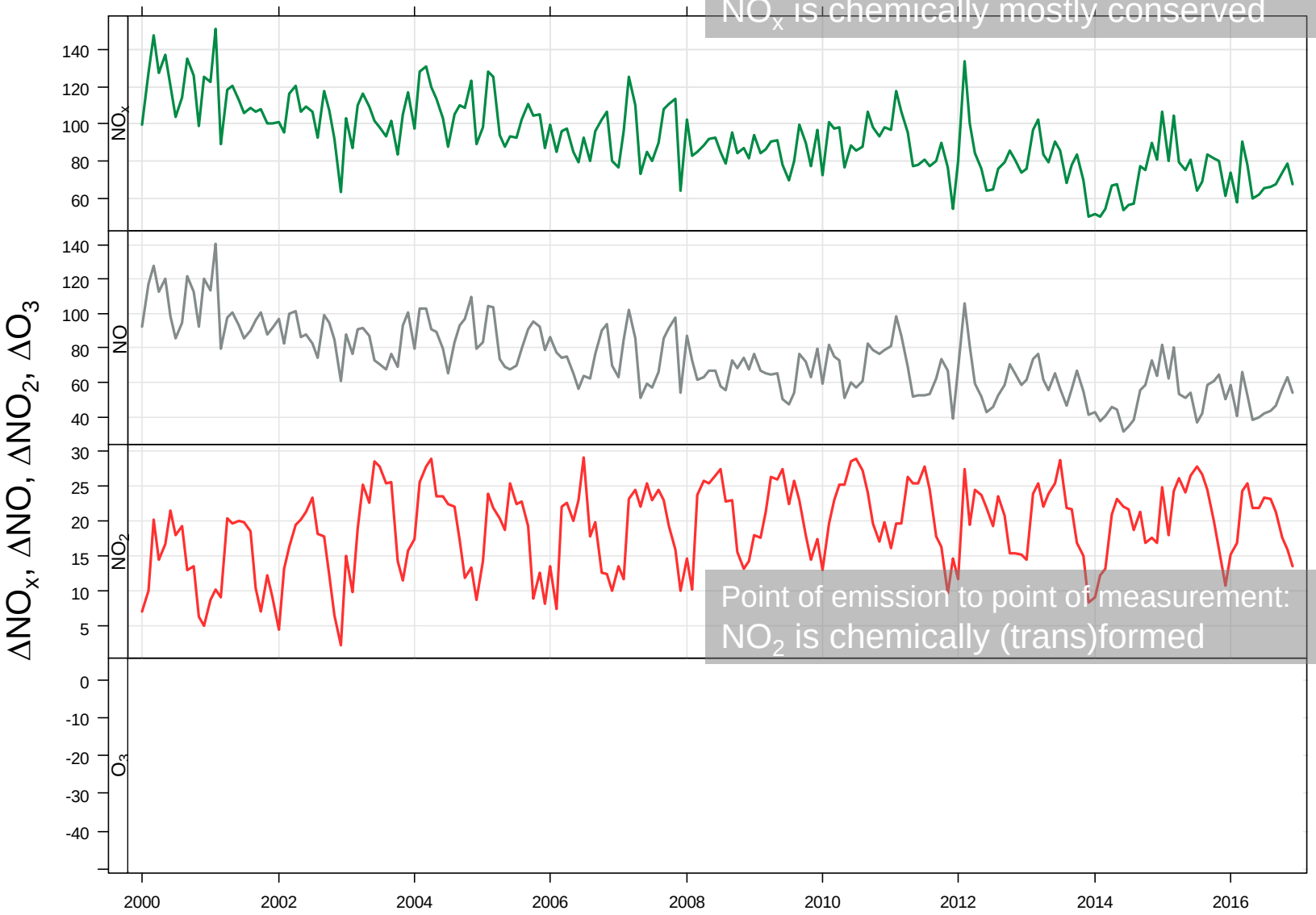
Rural traffic site Haerkingen – time series of road side increments

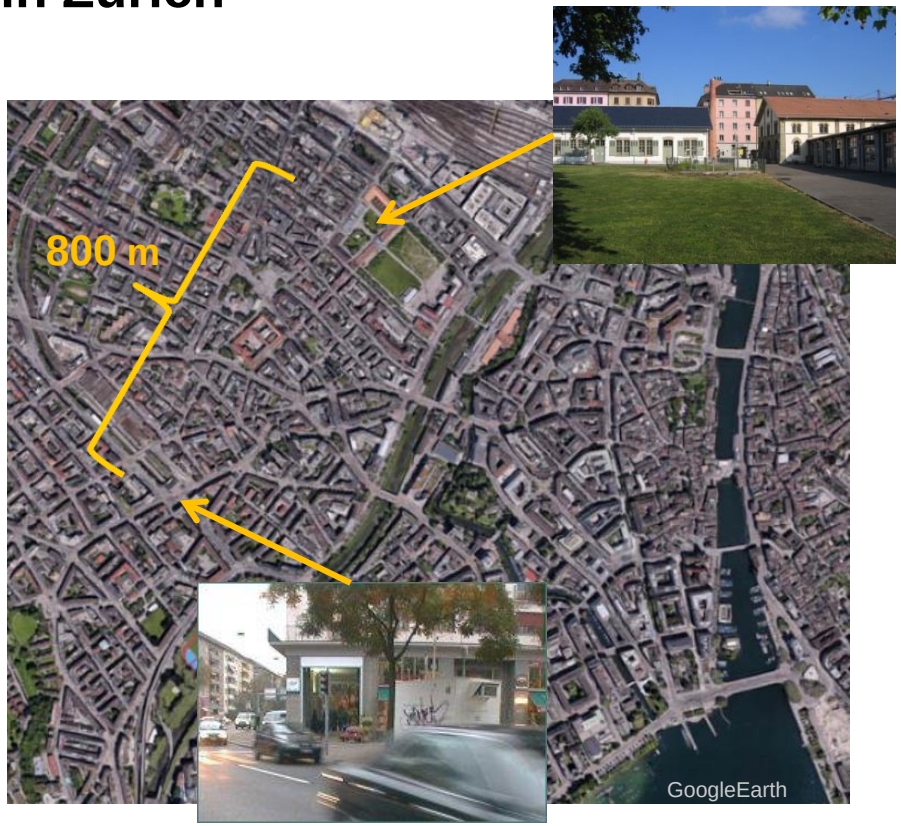
Trend of ΔNO_2?

Point of emission to point of measurement:
NO_x is chemically mostly conserved



Point of emission to point of measurement:
NO_2 is chemically (trans)formed

Trend of ΔNO_2 (roadsite increment) in Zurich



urban background
(Zürich Zeughaushof)

$$NO_{2\,t} = NO_{2\,b} + \Delta NO_2$$

traffic site
(Zürich Schimmelstrasse)

roadside increment

$$\Delta NO_2 = (O_{3\,b} - O_{3\,t}) + \alpha \cdot (NO_{x\,t} - NO_{x\,b}) + \beta$$

locally formed secondary NO_2

primary NO_2 from local traffic

residual

α: NO_2/NO_x emission ratio

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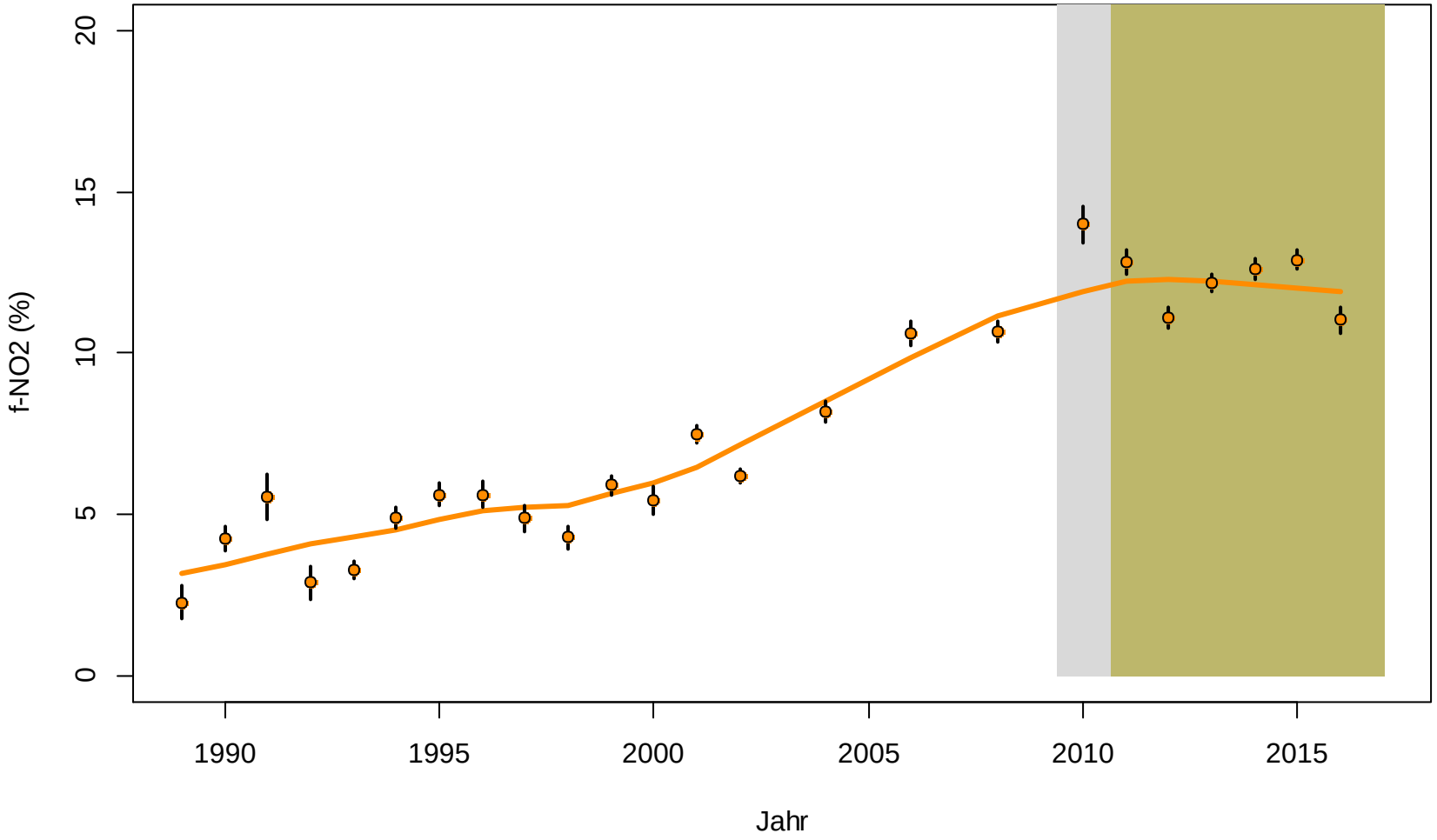
Trend of NO_2/NO_x emission ratio in Zurich



see also Carslaw et al. Faraday. Disc. (2016) for trend in London (UK)

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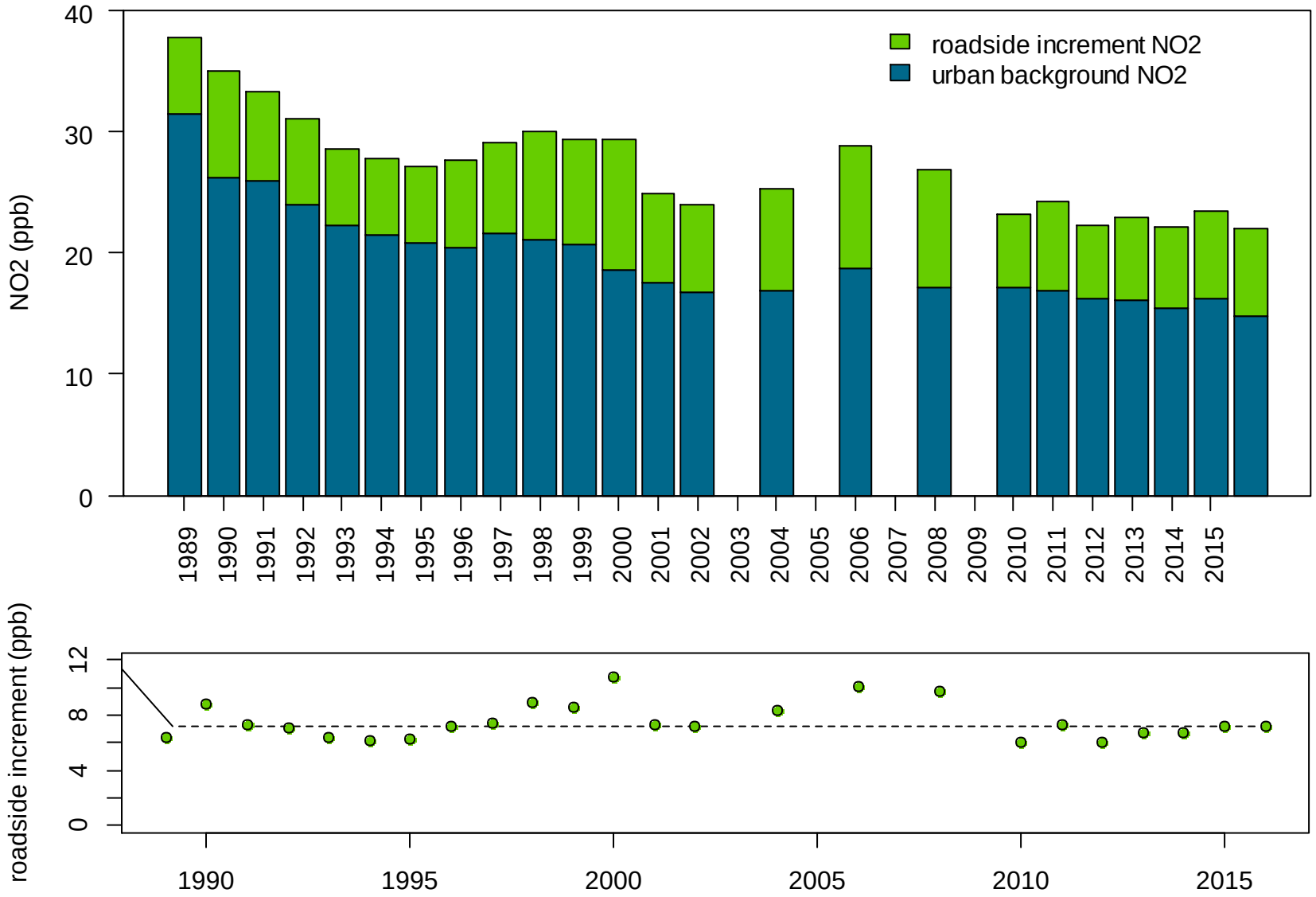
Trend of background NO_2 and roadsite increment (Δ NO_2) at ZH-Schimmelstrasse



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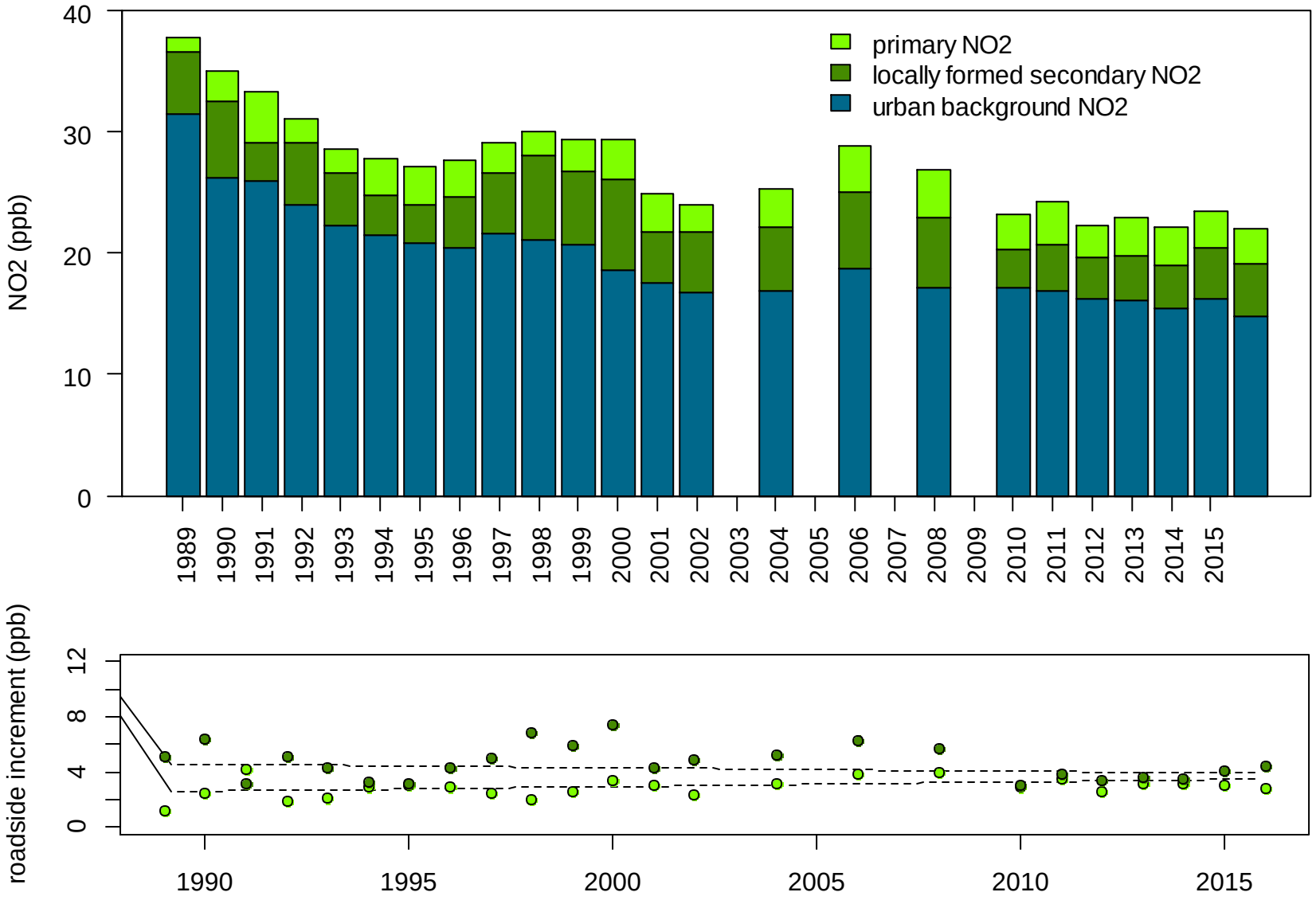
Trend of background NO_2, local secondary & primary NO_2 at ZH-Schimmelstrasse



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Conclusions

- Policies for the abatement of air pollution from traffic as implemented in Switzerland have been successful
  - Remarkable downward trend of black carbon (due to DPF)
  - Clear downward trends of other air pollutants (e.g. PNC and NO_x)

- However, NO_2 roadside increment shows no improvement. Three reasons:
  1. Real world NO_x emissions of diesel vehicles are larger than the EURO emission limits
  2. NO_2/NO_x emission ratio from diesel vehicles was increasing until recently
  3. Locally formed secondary NO_2 (reaction of NO with O_3) remained constant although NO has been declining

  $\Rightarrow$ For reducing NO_2 roadside increment, further reduction of NO_x emissions needed

- Average traffic fleet on Swiss highway (A1, Haerkingen site) shows no change in CO_2-emissions per vehicle for 2008-2016 period
- Similar work for London (UK) by Font and Fuller *Environ. Pollution* (2016)

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Foto: Jörg Sintermann, AWEL

Thank you!

Many thanks to

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- Umwelt- und Gesundheitsschutz Zürich (UGZ) for data from Zurich Schimmelstrasse

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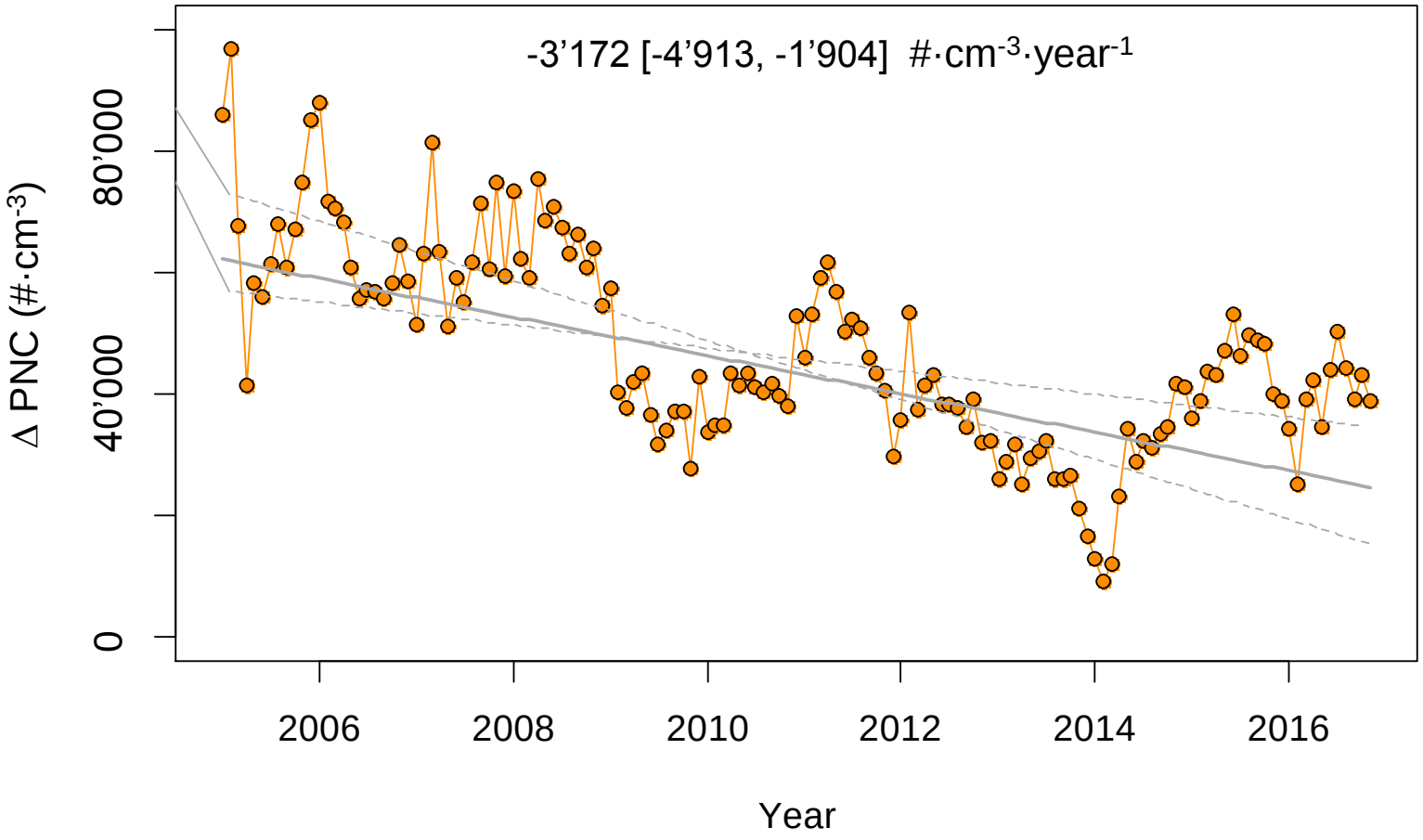
trend of roadside increment of the number concentration of particles > 5 nm (PNC)



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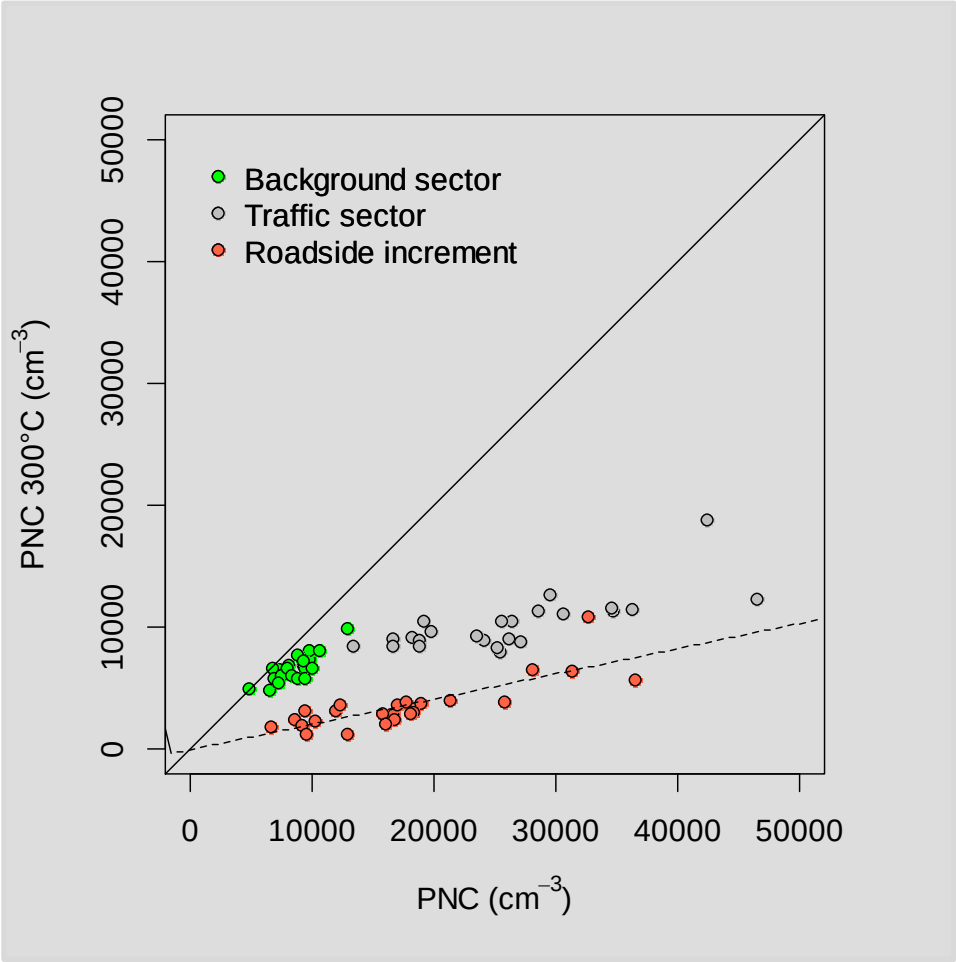
Number concentration of refractory particles (up to 300°C) vs. total particles



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