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science for global insight

Modelling exceedances of air quality limit values

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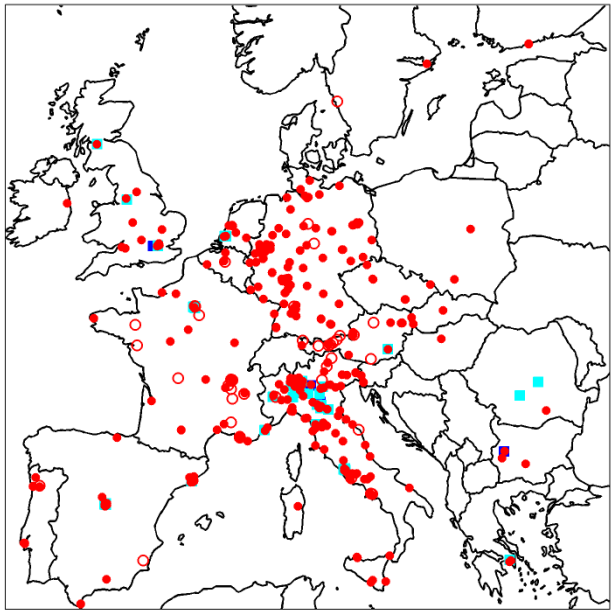
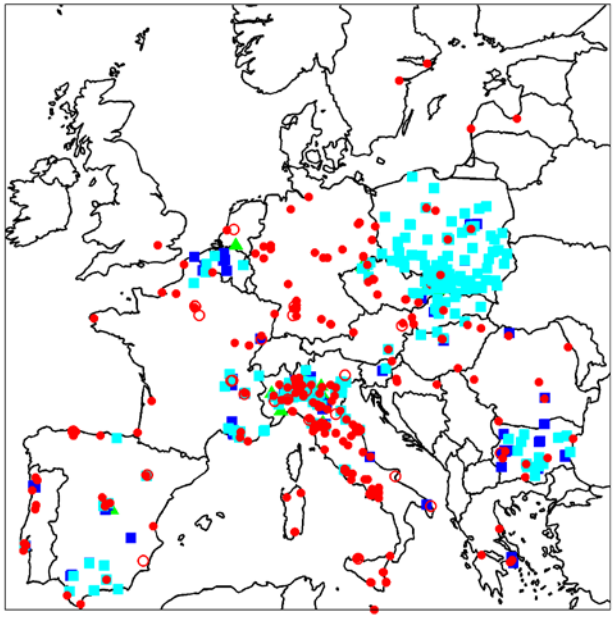
Introduction

- NO_2 & PM_{10} Limit Values still exceeded widely in the EU
- Challenge: estimate compliance under future scenarios
- traffic related pollutants: exceedances at traffic stations

NO_2 stations exceeding LV: 2009



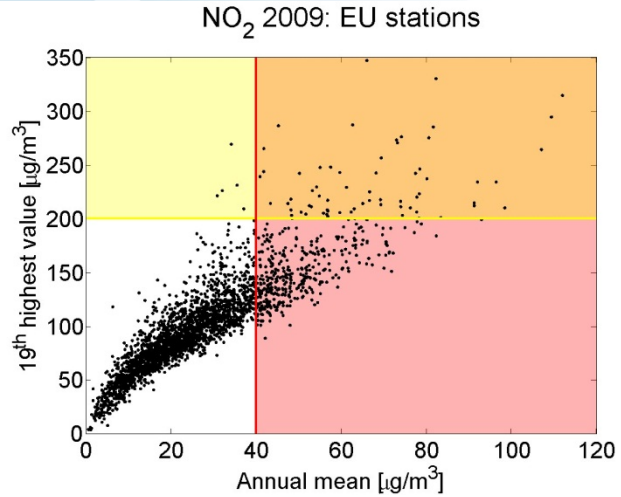
PM_{10} stations exceeding LV: 2009

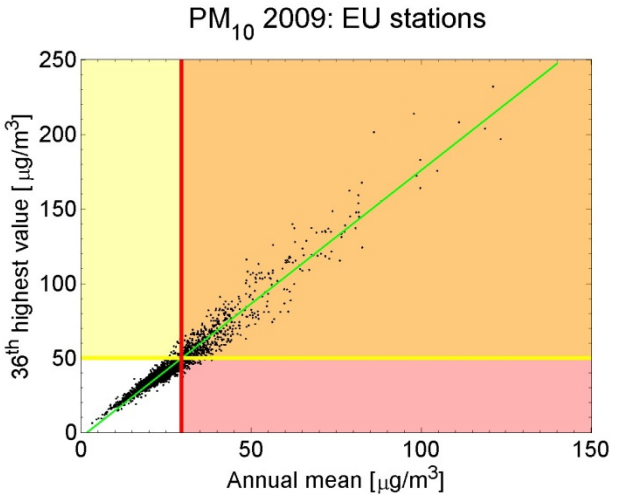


Introduction

- NO_2 & PM_{10} Limit Values still exceeded widely in the EU
- Challenge: estimate compliance under future scenarios
- traffic related pollutants: exceedances at traffic stations
- GAINS model currently assesses impacts at 28km grid, health impacts at 7×7km grid (urban background level)

  $\Rightarrow$ additional methodology needed
- Different LVs: Only annual means modelled in GAINS – focus on more stringent target





Methodology overview

1. Observed NO_2 at roadside station (2009 annual mean)
2. Disaggregate into components
3. Explain components for the past
4. Model components for the future

See also: Kiesewetter et al. (2013), TSAP Report #9, GAINS website

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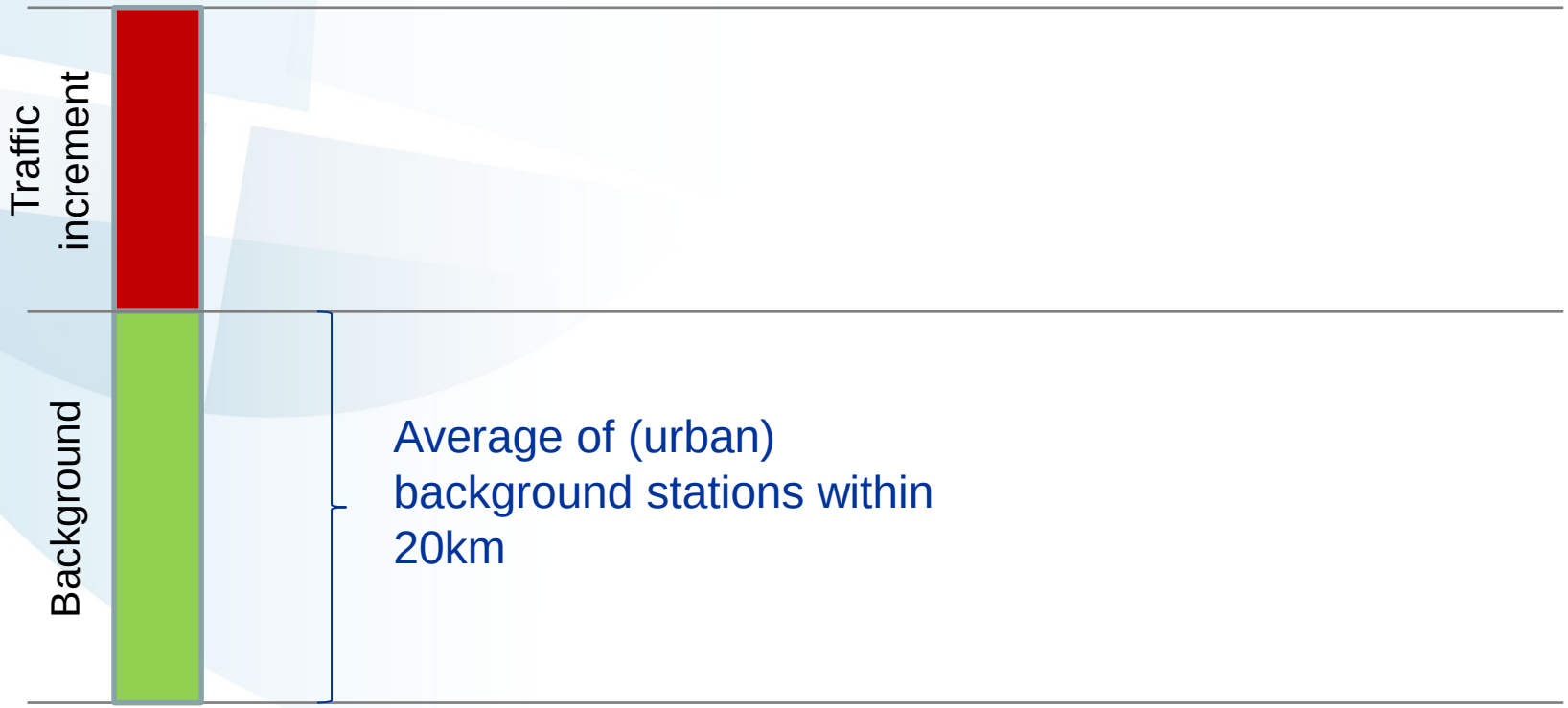

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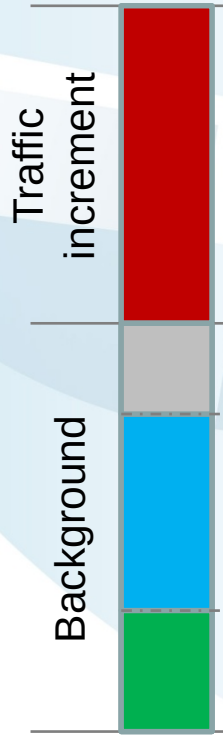

Component	Caused by	Modelled with
Traffic increment	Local traffic emissions	Traffic increment model
Unexplained residual	?	constant
Urban increment	Low-level emissions	CHIMERE model (7x7km)
Regional background	EU28 emissions	EMEP model (28x28km)

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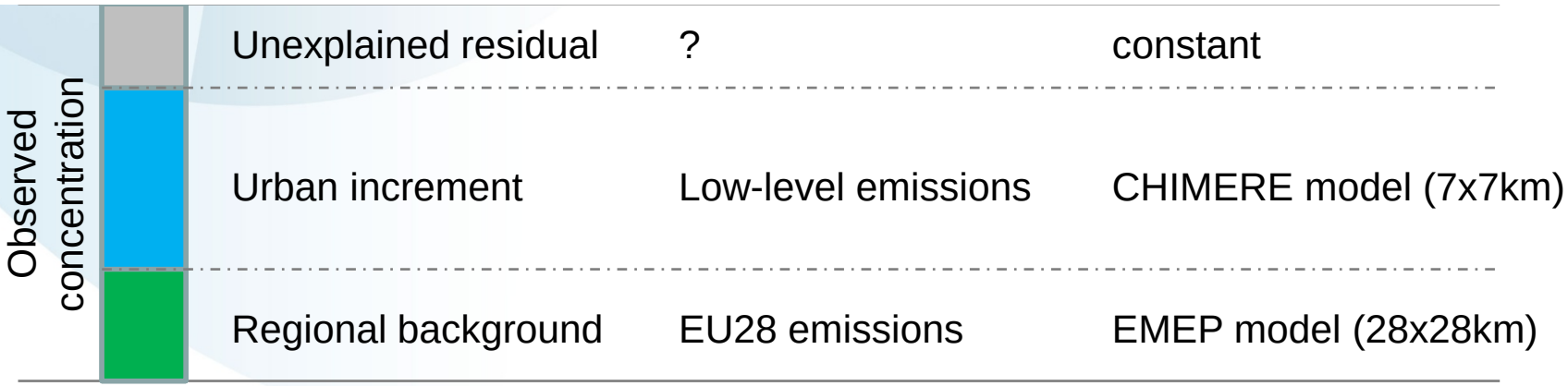

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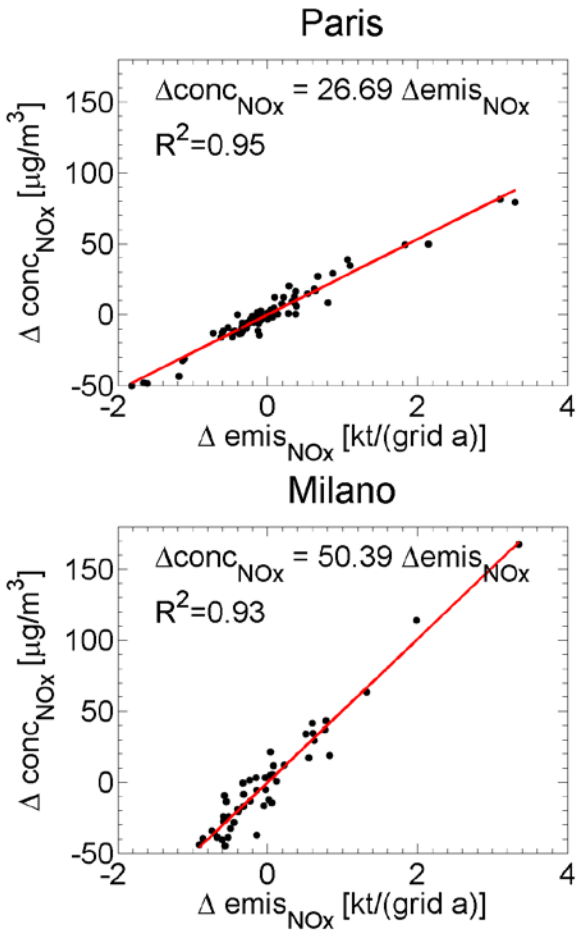
Modelling the background

- "28km" linear transfer coefficients from EMEP model
- "7km" CHIMERE run: subgrid structure caused by low-level (domestic, transport) emissions



Concept:
Linear relation between emission and concentration increment

$\Delta conc = \xi \cdot \Delta emis$

for NO_x, $PM_{2.5}$, PM_{coarse}

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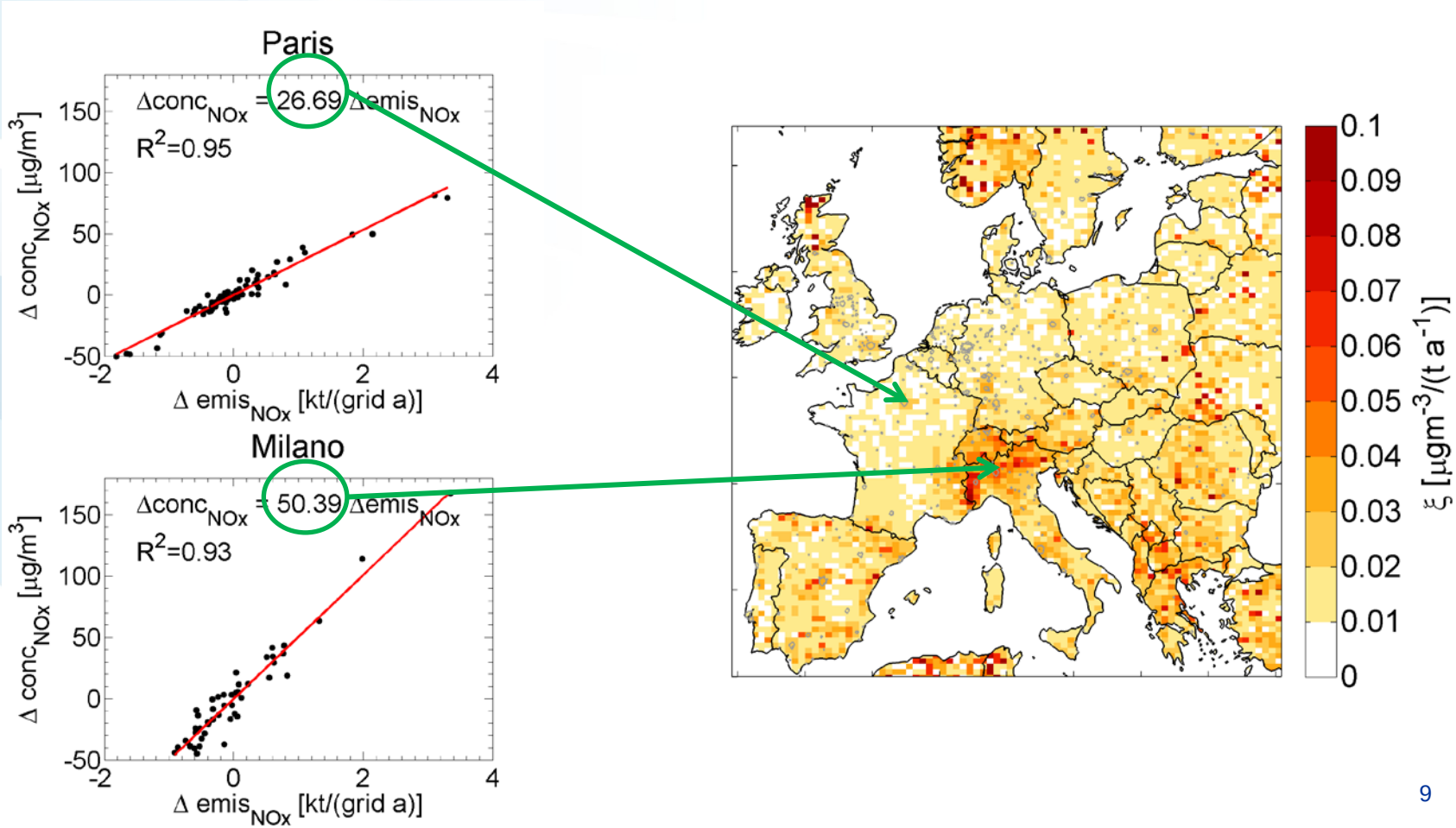

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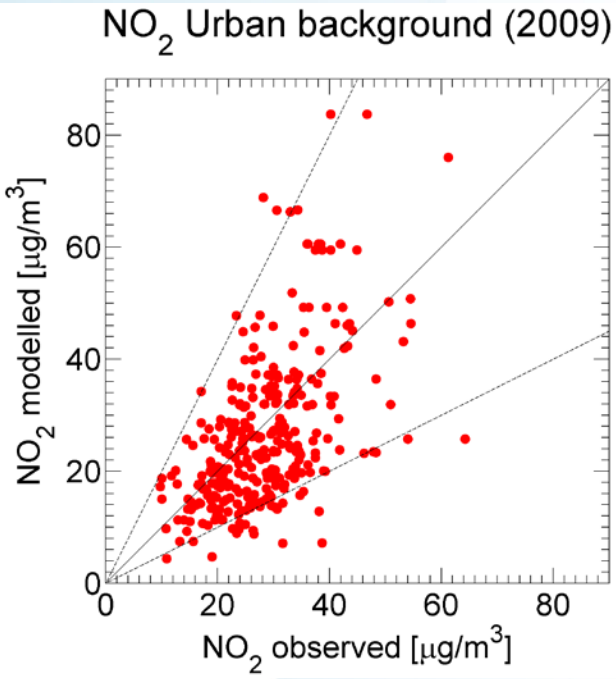
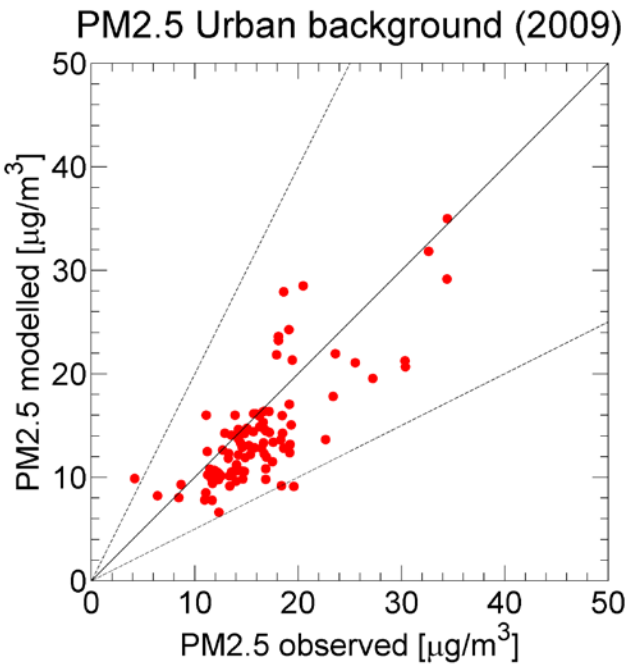
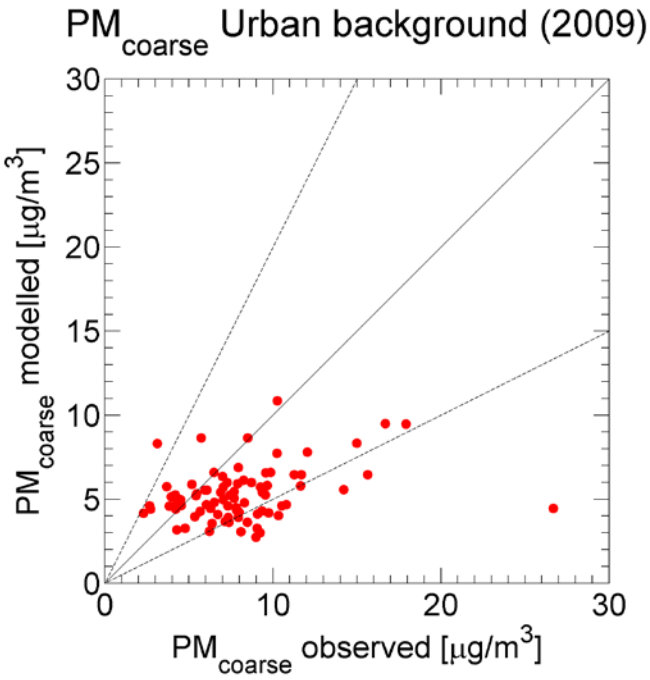
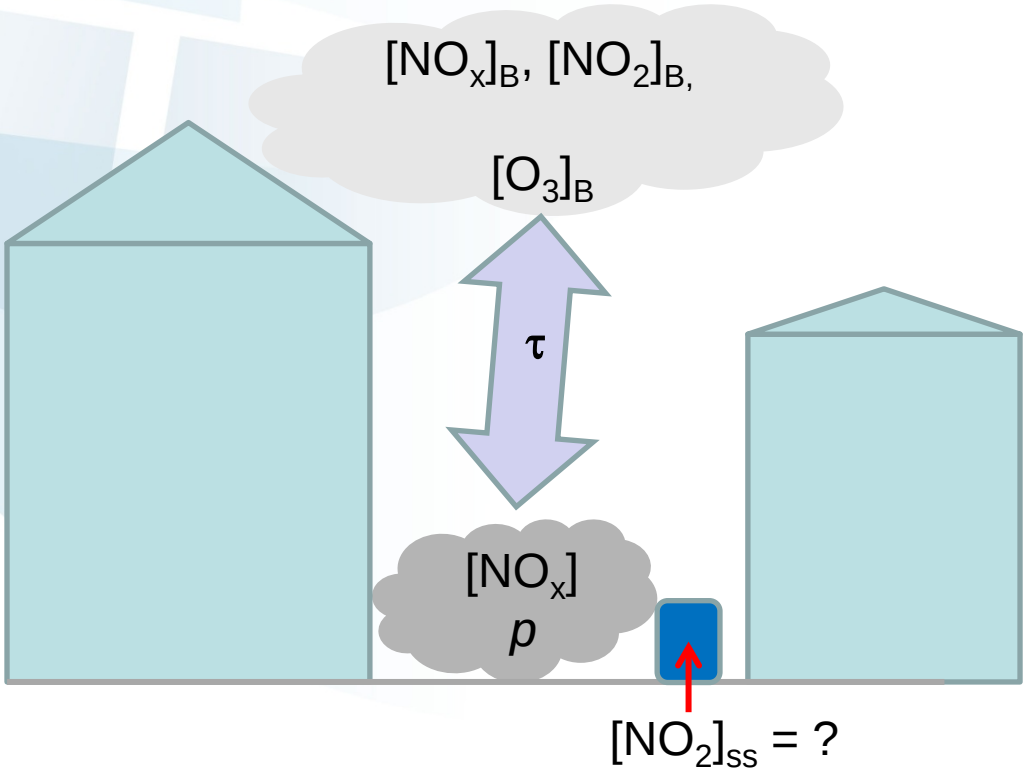






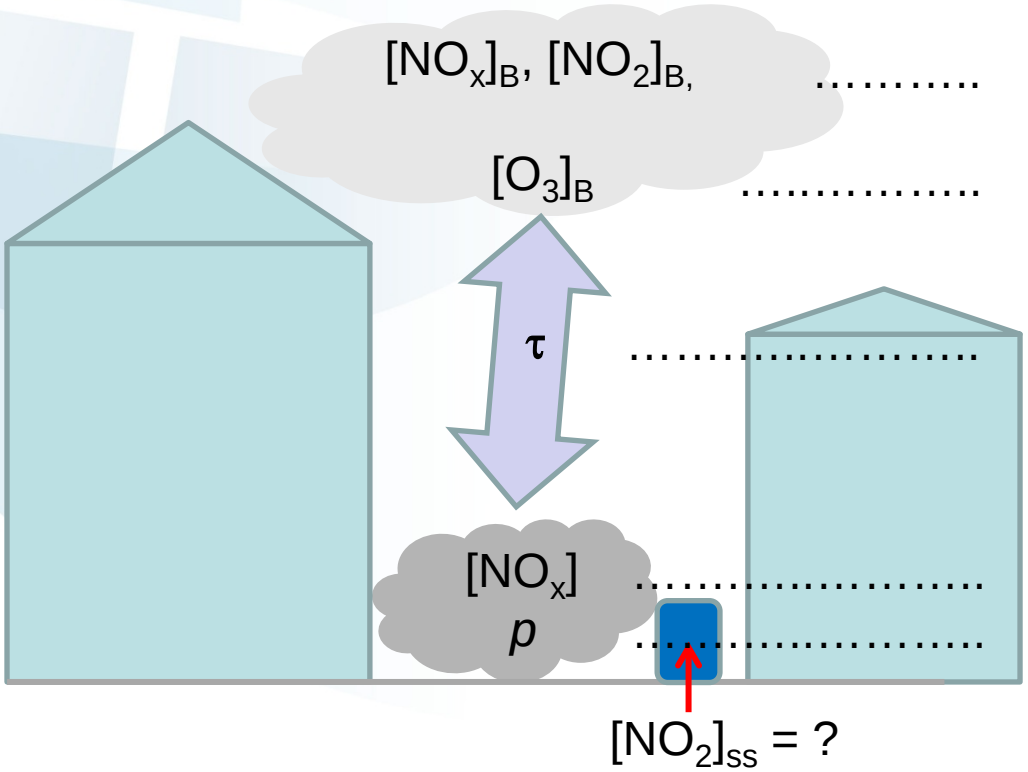
NO_2 traffic increment

- Box model calculating steady state NO_2, considering
  - Dispersion of NO_2 emissions in the street canyon
  - Oxidation of NO emissions by O_3
  - Mixing with urban background
  - NO_2 photolysis



NO_2 traffic increment

- Required inputs:
  - Background NO_2, NO_x, O_3
  - Roadside NO_x = NO + NO_2
  - Share of NO_2 in NO_x traffic emissions: *p*
  - Residence time of air in street canyon τ



- Taken from:

EMEP transfer coefficients + CHIMERE downscaling

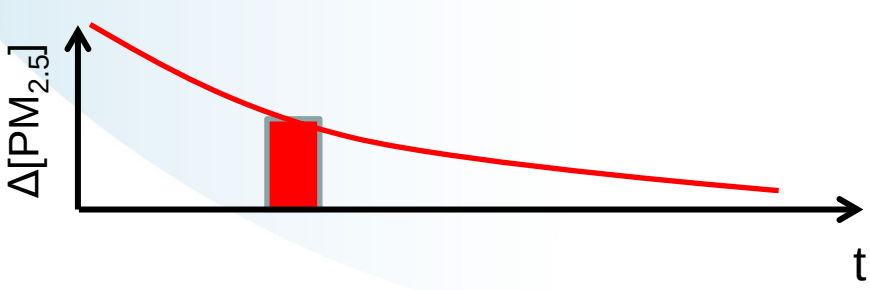
past observations (const.)

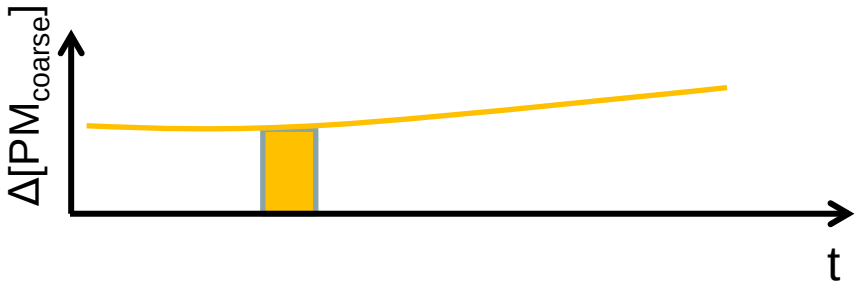
Estimated from past observations (using weekly pattern)

$[NO_x]_B + \Delta[NO_x] \sim emis_{NOx}$ from GAINS

PM_{10} traffic increment

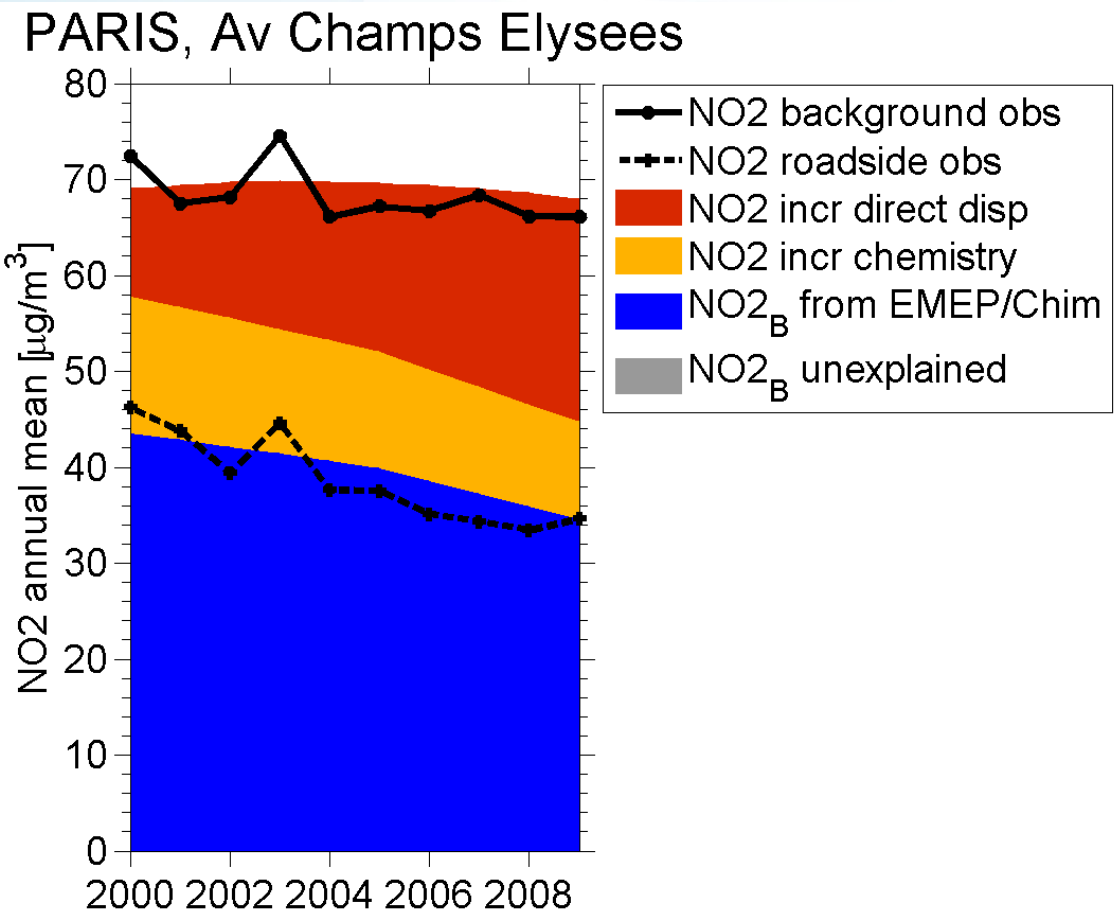
- $\Delta[PM_{10}] = \Delta[PM_{2.5}] + \Delta[PM_{coarse}]$
- Disaggregation of traffic increment is hardly measured
- Assumptions:
  - $PM_{2.5}$ disperses like inert gas (NO_x)
  - PM_{coarse} subject to sedimentation and resuspension
- Methodology:
  - Estimate $\Delta[PM_{2.5}]$ for 2009: $\Delta[\mathrm{PM}_{2.5}] = \frac{emis_{PM\,2.5}}{emis_{NOx}} \Delta[\mathrm{NO}_x]$
  - Diagnose $\Delta[PM_{coarse}]$ as residual
  - Scale each component with respective emission trend





Station results and statistical treatment

- Results for ~2000 stations, among them ~350 exceeding
- Individual station results difficult to interpret: station specific characteristics (fleet etc) not considered



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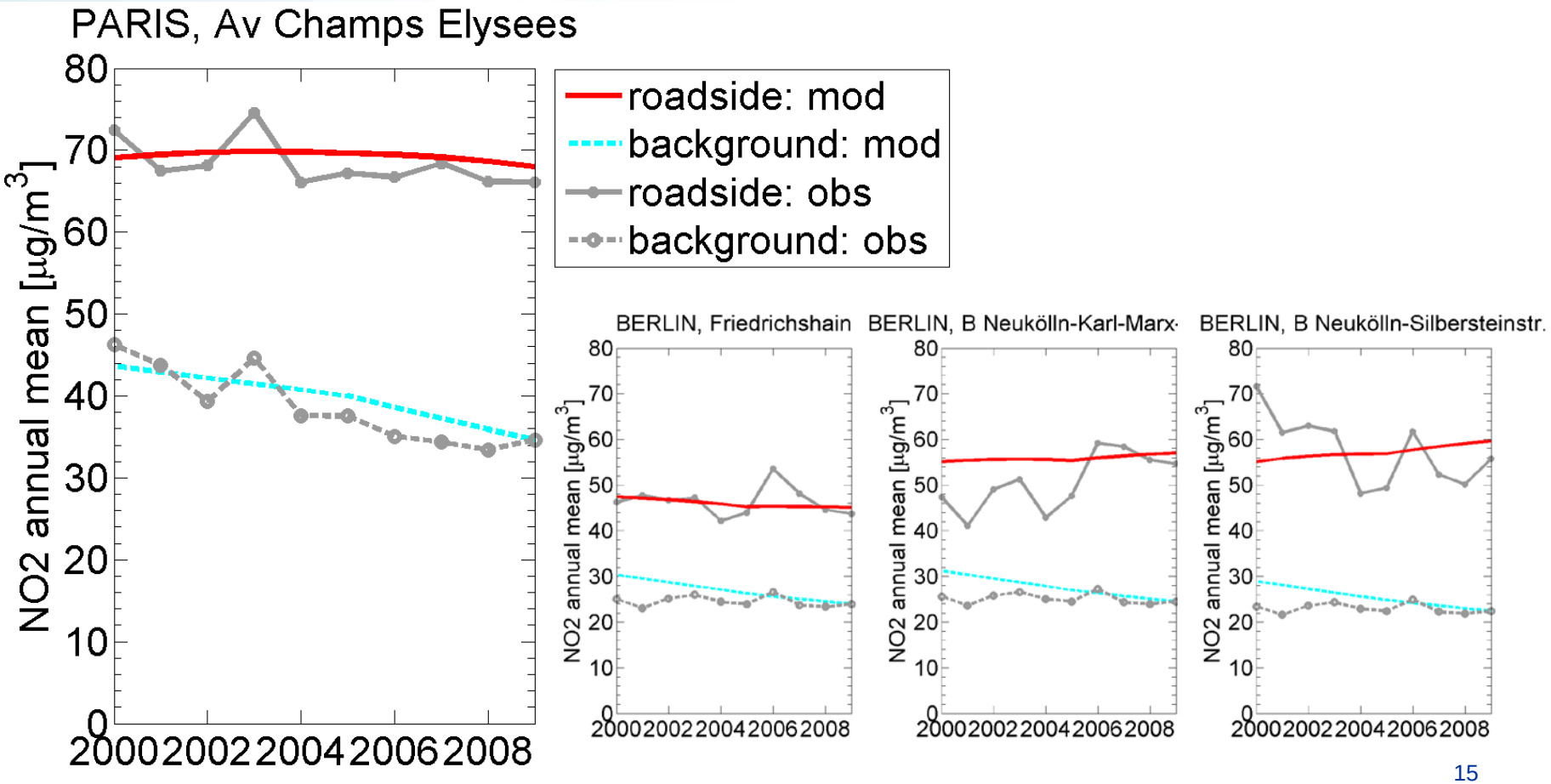

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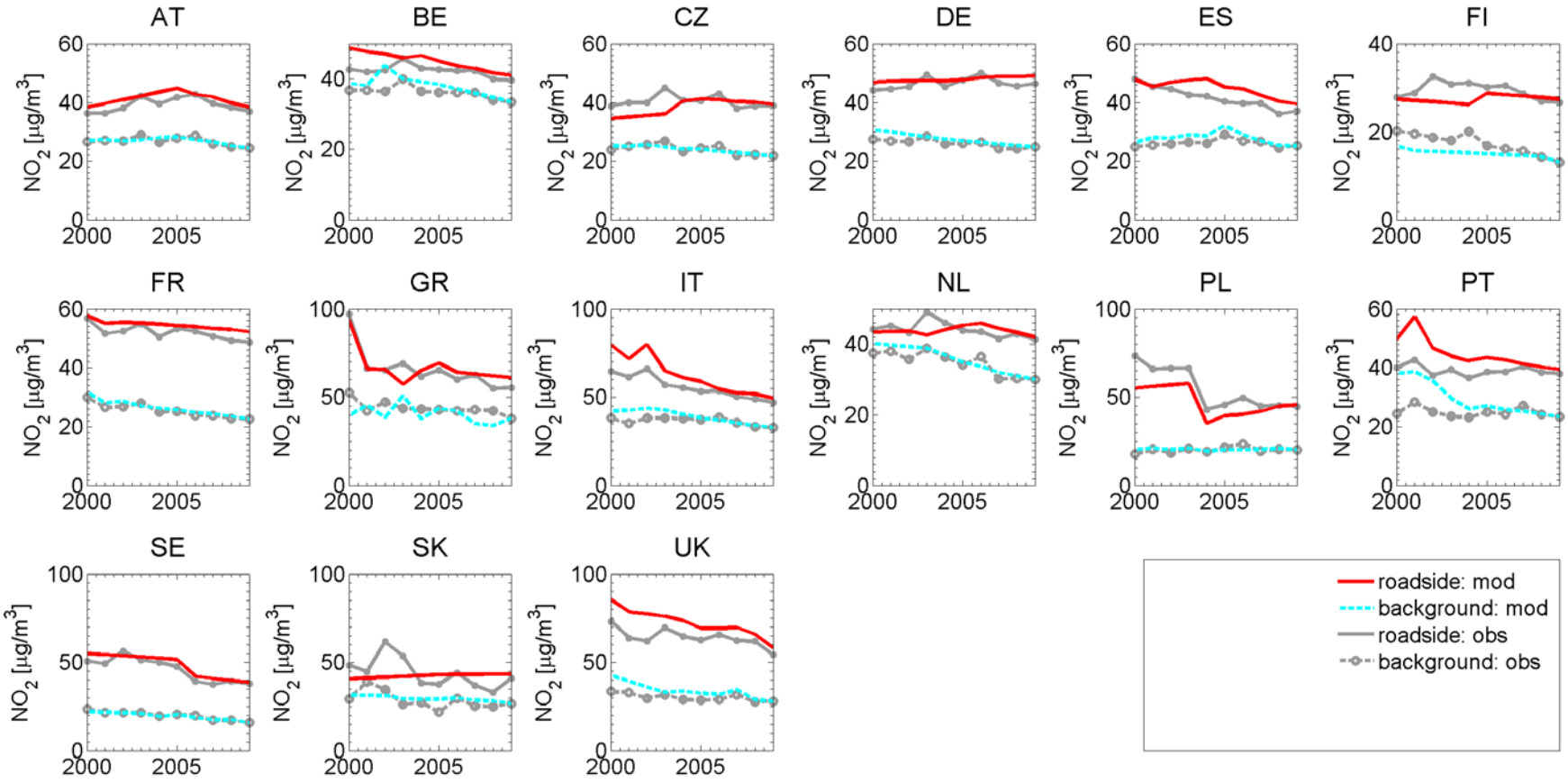
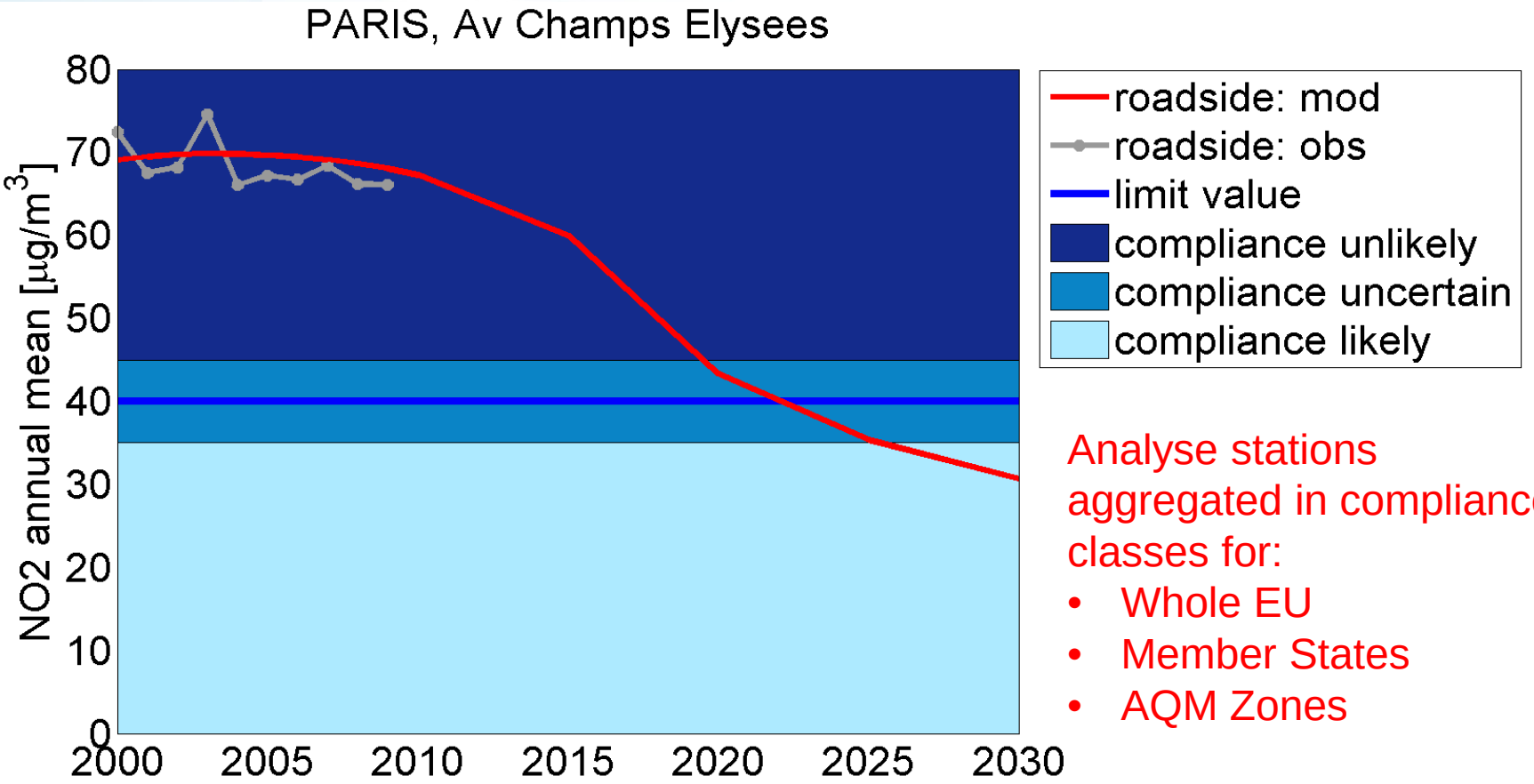


Dealing with uncertainty: aggregation

- Results for ~2000 stations, among them ~350 exceeding
- How far can station related results go?

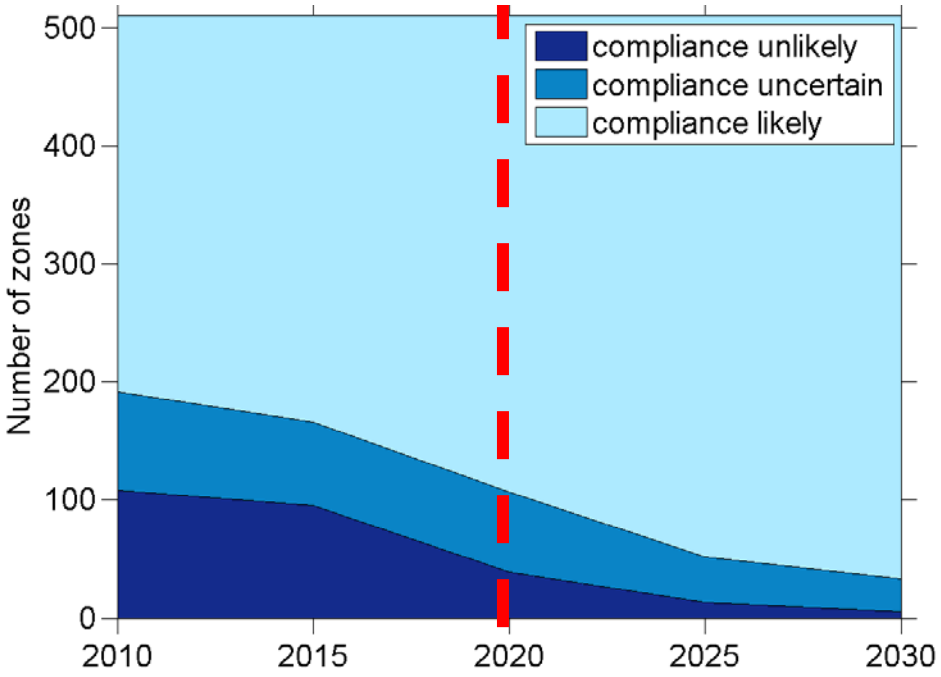


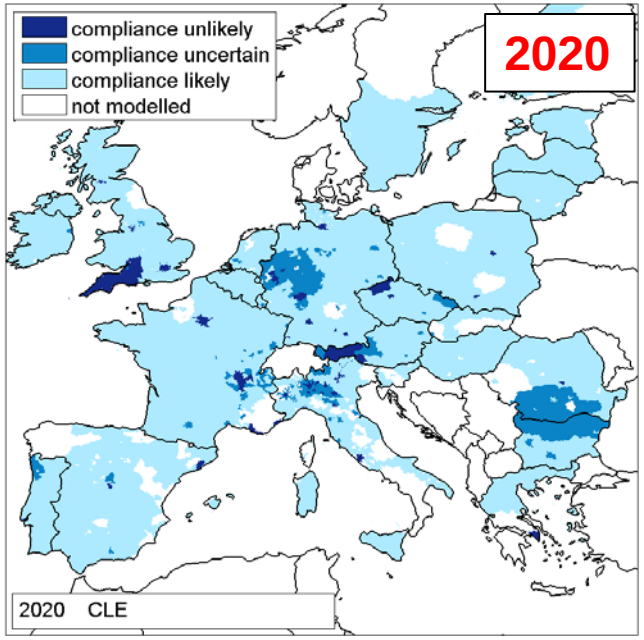
Analyse stations aggregated in compliance classes for:

- Whole EU
- Member States
- AQM Zones

Results I. NO_2 baseline

Current Legislation





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- Only few zones in non-compliance by 2025/30
- Scope for local measures: faster / further improvement

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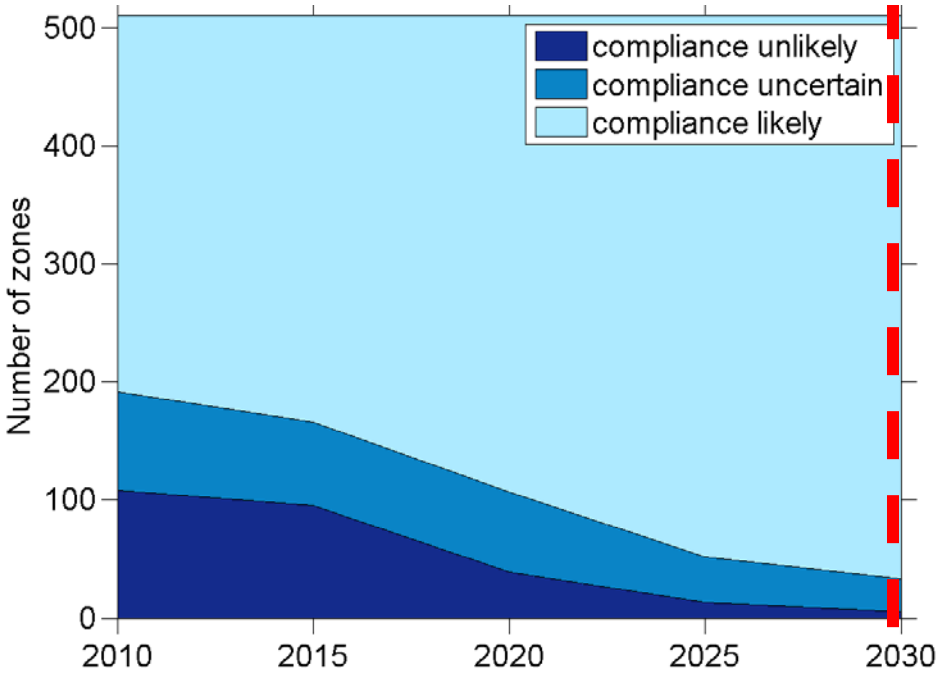

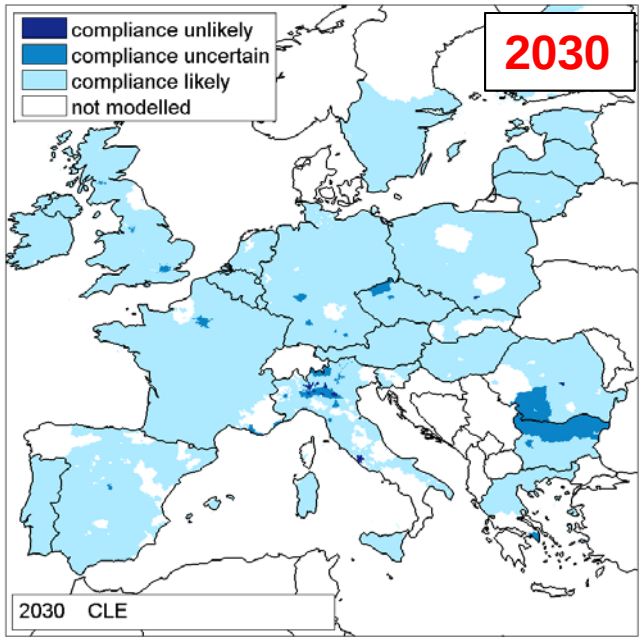

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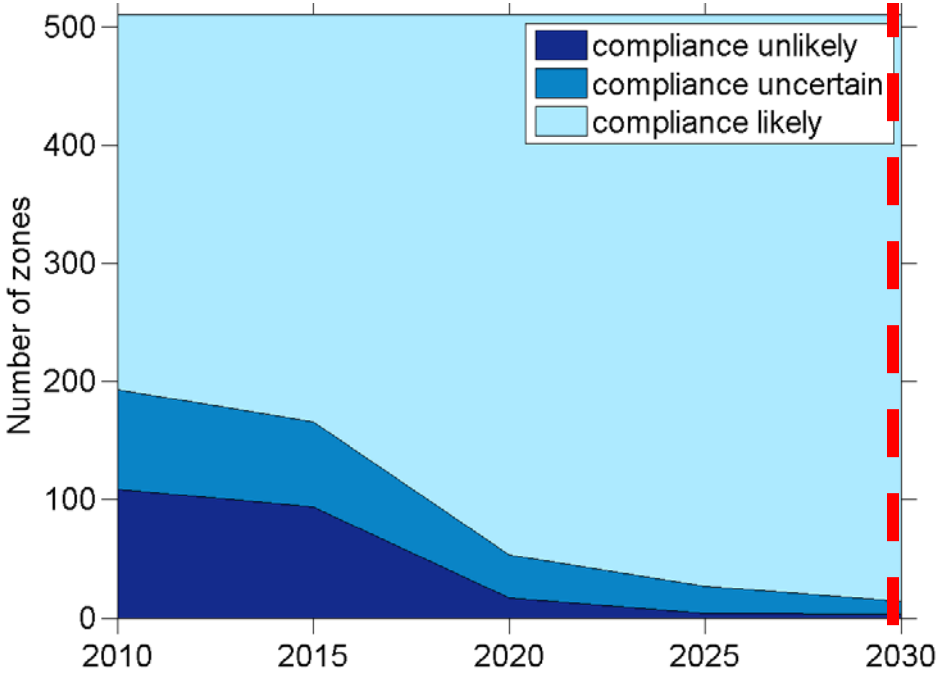

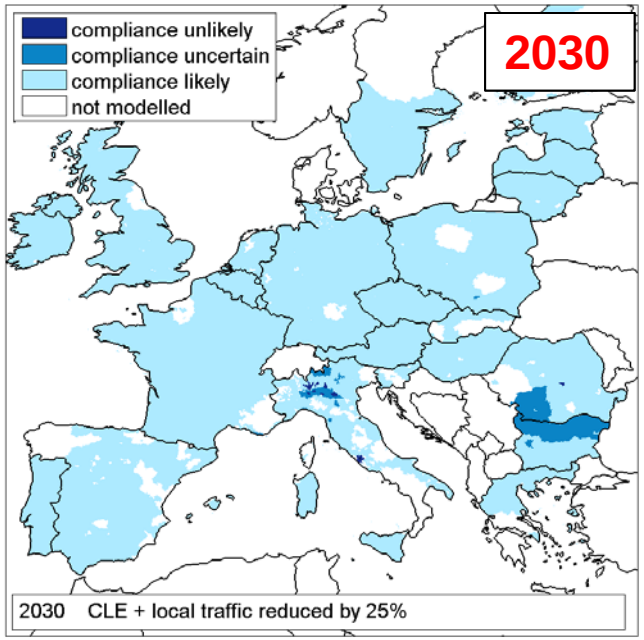

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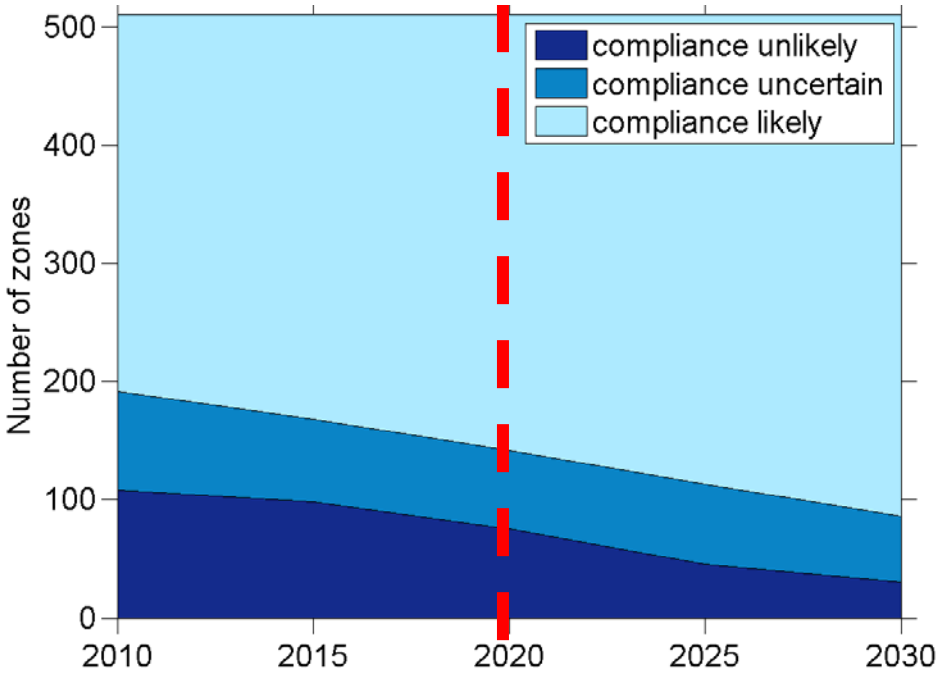
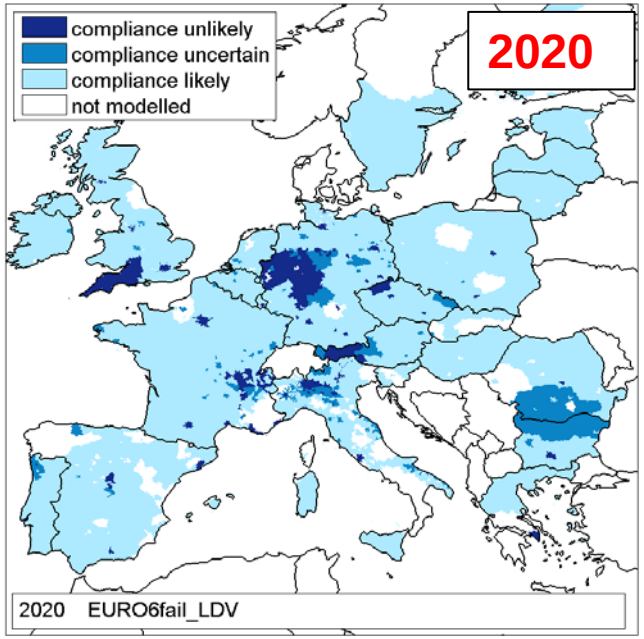
Results II. NO_2: What if EURO6 fails?

EURO6 failure





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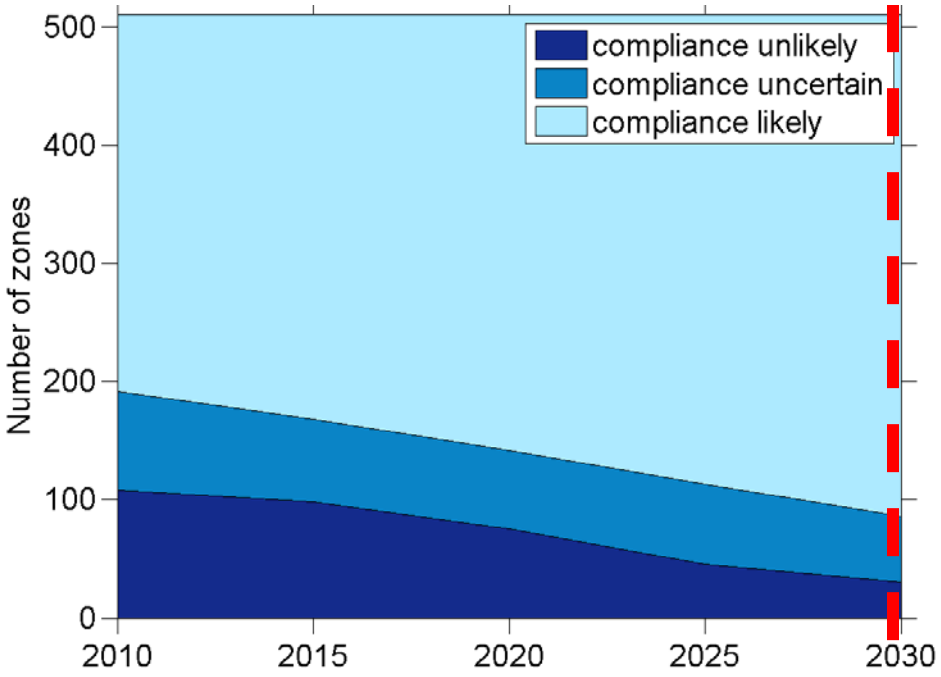

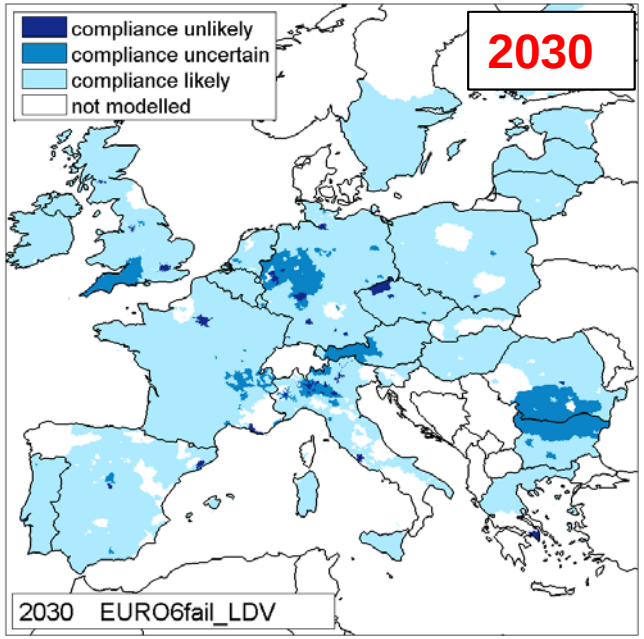

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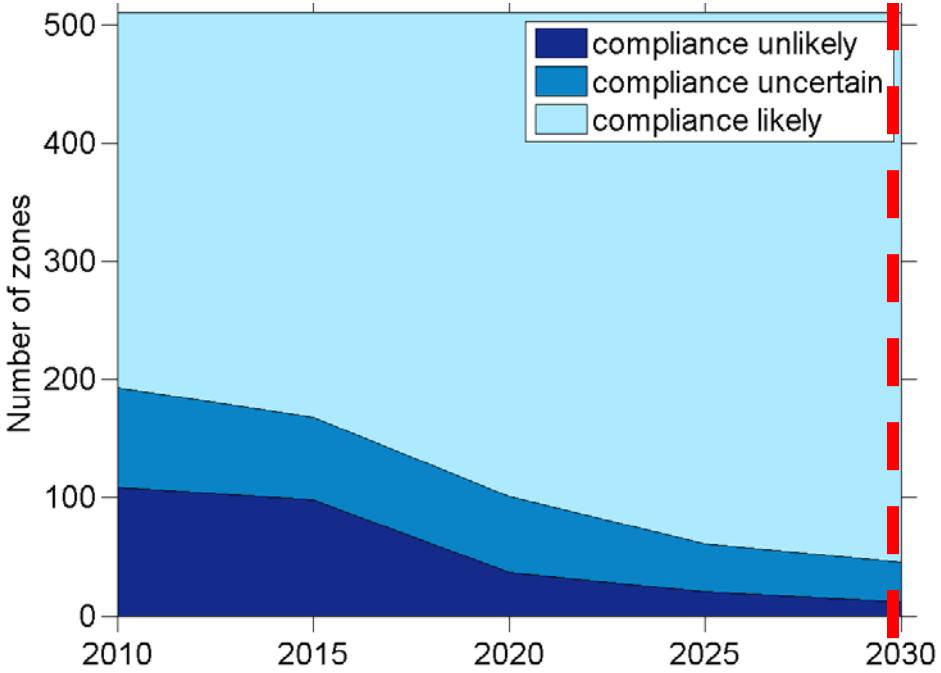
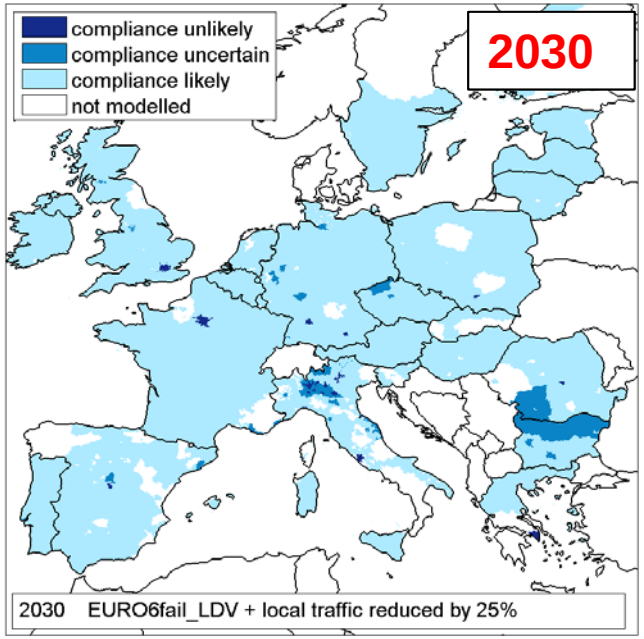
EURO6 failure + local traffic reduced by 25%





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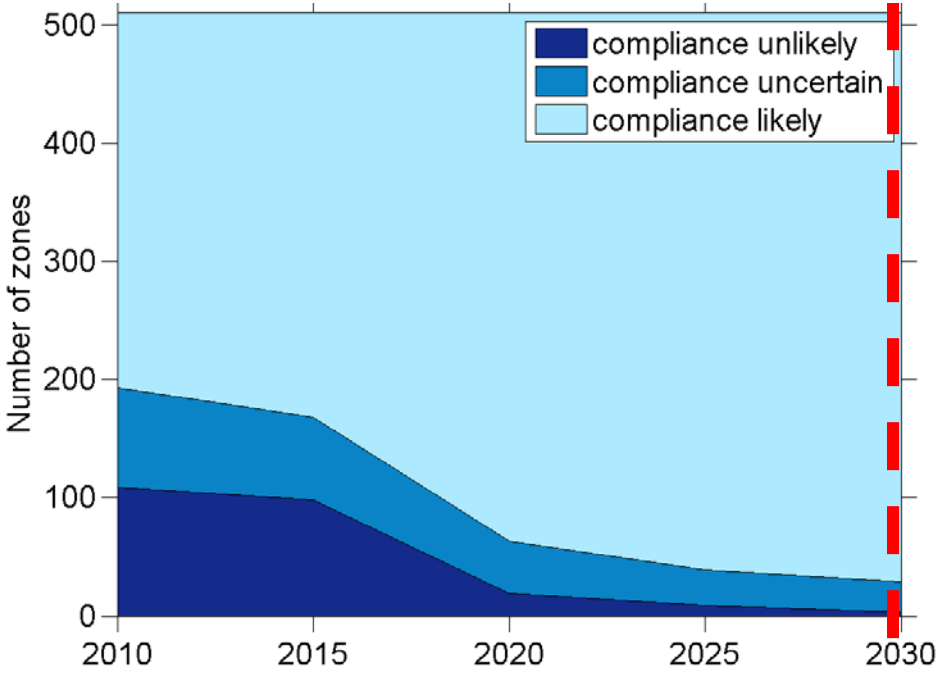

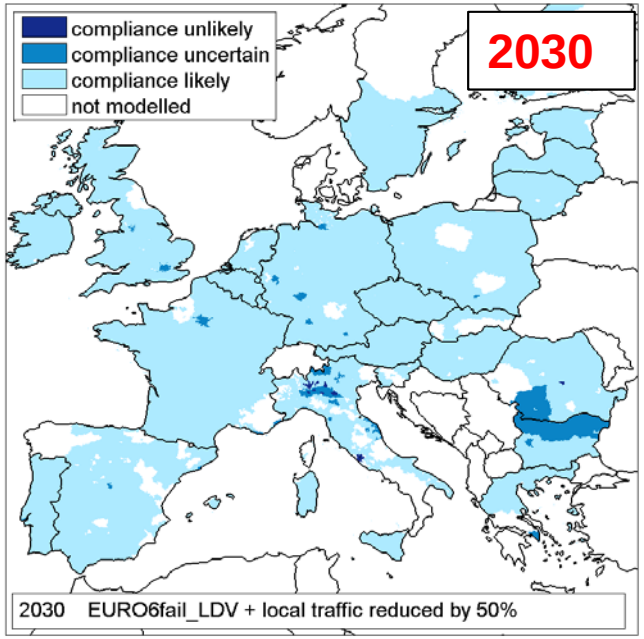

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Results III. PM_{10}

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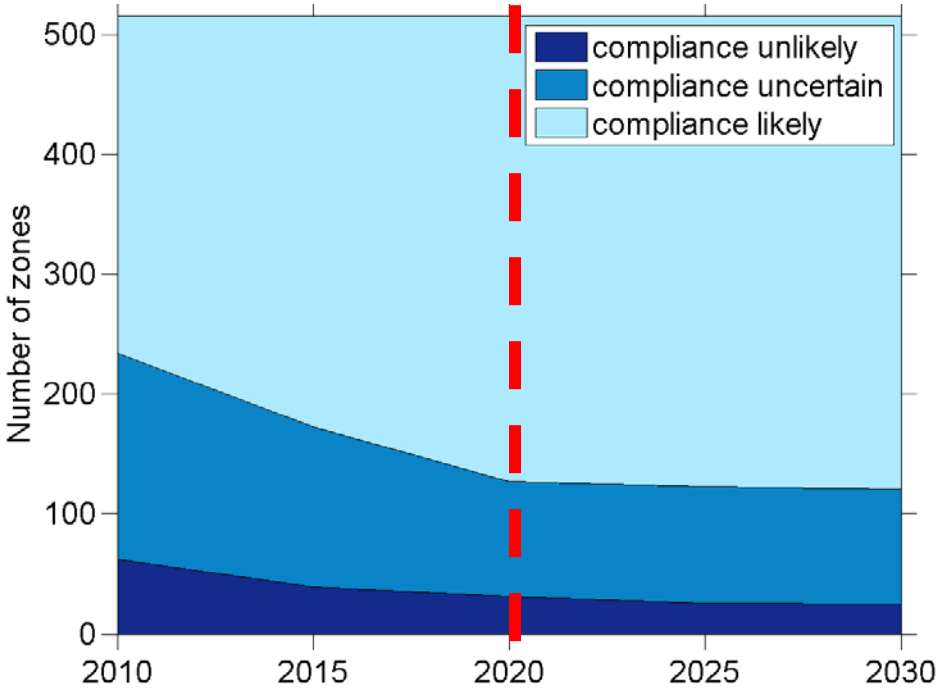

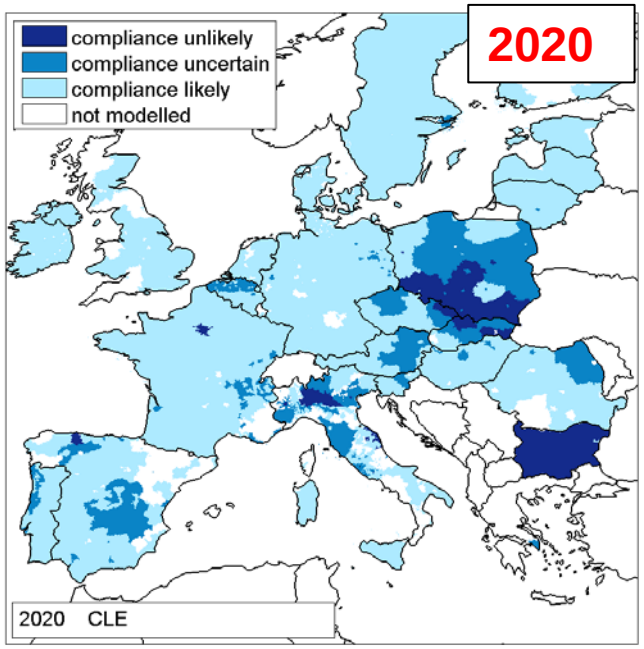

- Current legislation: still non-compliance in 2030
- Can technology solve the issue? Helps in old EU Member States
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- Shift to clean domestic heating would help in Eastern Europe

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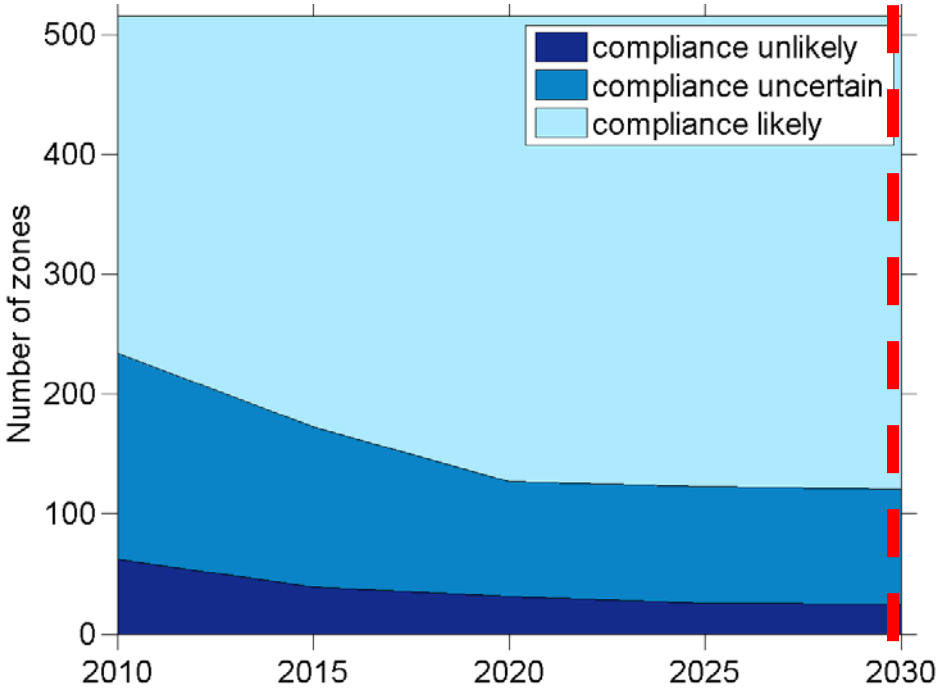

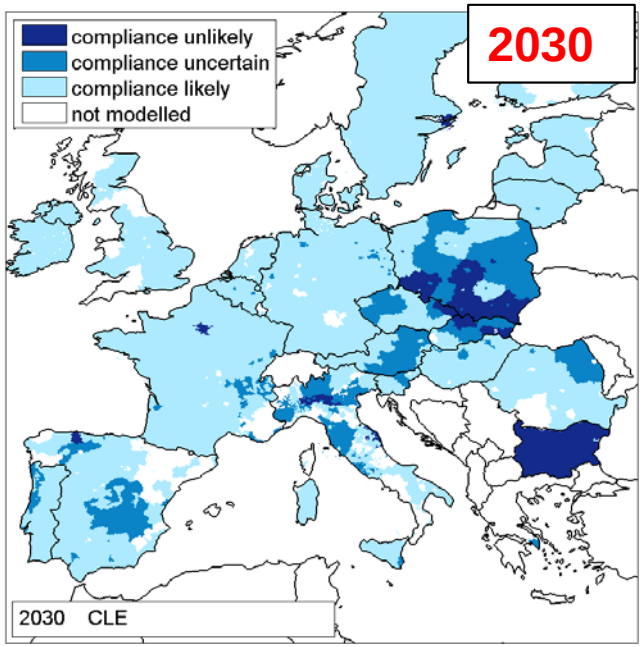

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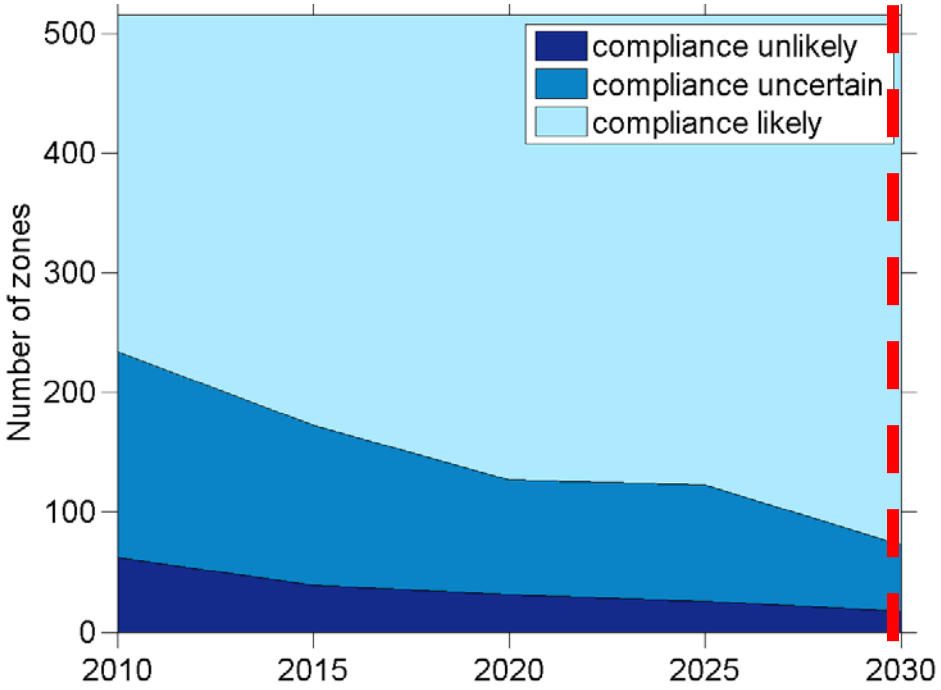
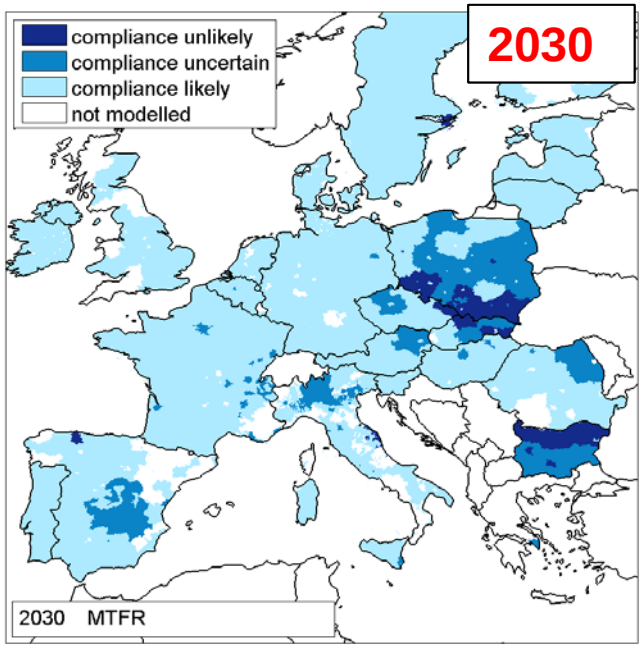
Results III. PM_{10}

Maximum technically feasible reductions in 2030





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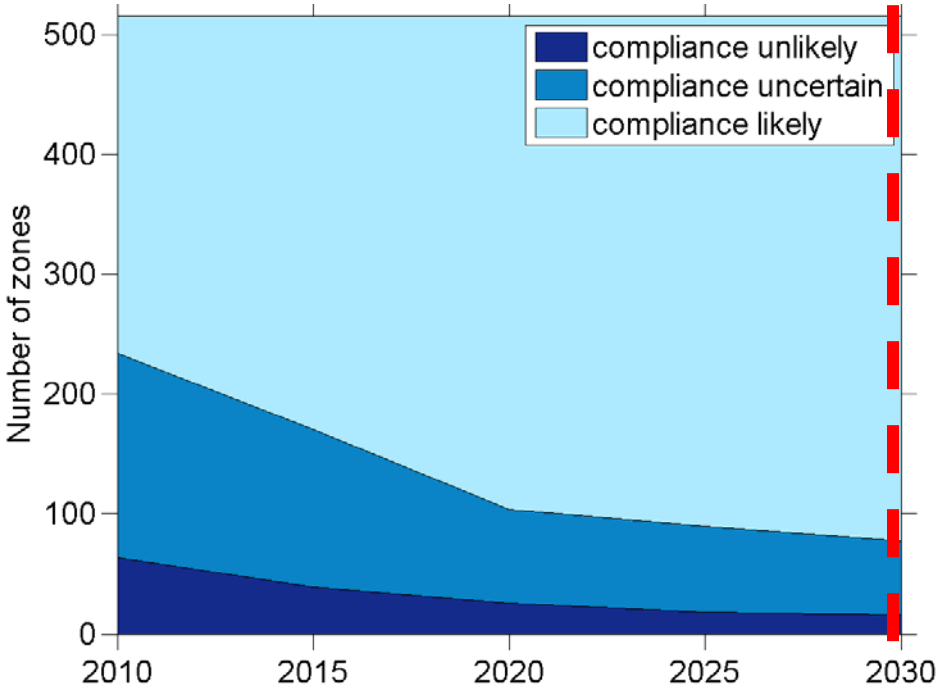
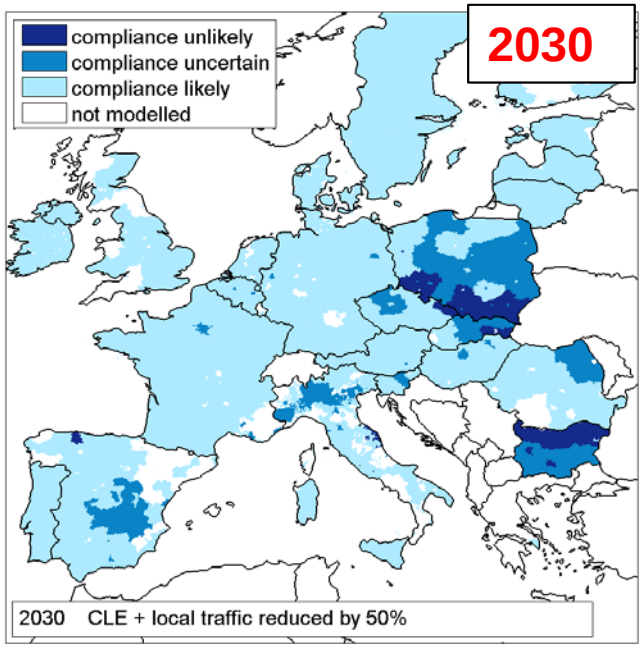
Current Legislation + Reducing local traffic by 50%





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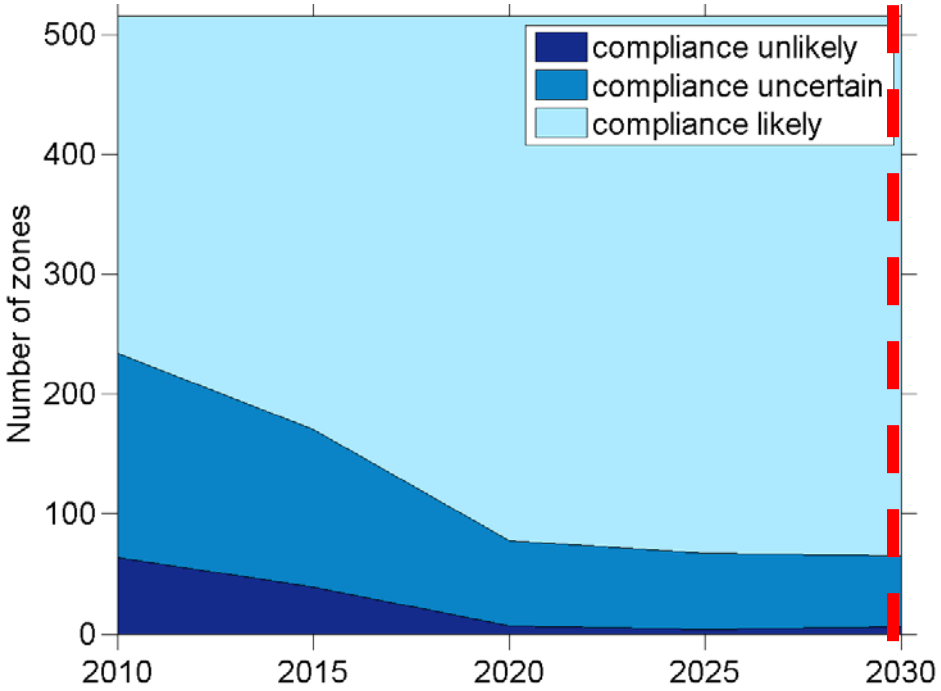
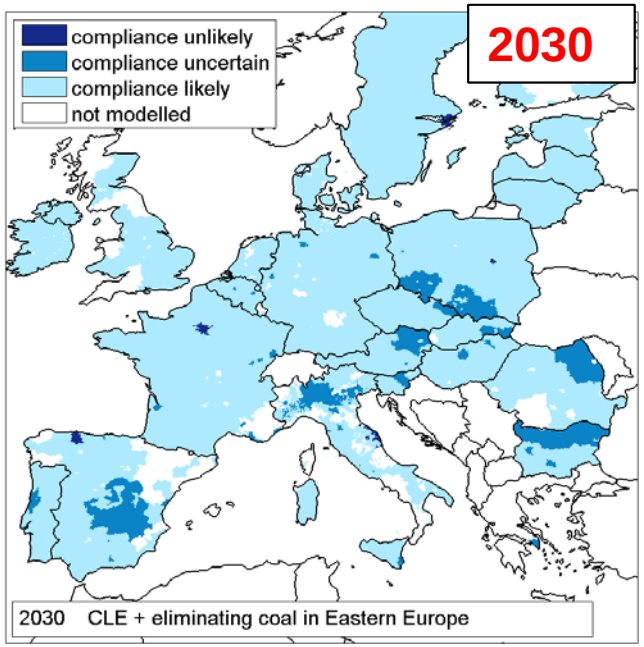
Results III. PM_{10}

Current Legislation + eliminating domestic coal heating in Eastern Europe





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Conclusions

- We have developed a methodology to model compliance with AQ limit values station by station
- Approach: explain past observations (EMEP/CHIMERE/box model) – model different components for the future
- Statistical treatment to make best use of results
- Scenario analysis for NO_2:
  - Large improvements expected already under current legislation
  - Dependent on EURO6 performance
- Scenario analysis for PM_{10}:
  - Improvements, but still likely non-compliance (mainly Eastern Europe)
  - Domestic coal heating in Eastern Europe will remain an issue

Additional Slides

NO_2/NO_x model: Setup

- At street level, only fast chemistry is relevant: NO – NO_2 – O_3 chemistry

$$NO + O_3 \xrightarrow{k} NO_2 + O_2$$

$$NO_2 + h\nu \xrightarrow{J} NO + O$$

$$O + O_2 + M \rightarrow O_3 + M$$

- Rates of change in a system coupled to background (mixing time τ):

$$\frac{d[NO_2]}{dt} = k[NO][O_3] - J[NO_2] + \frac{[NO_2]_V}{\tau} + \frac{[NO_2]_B - [NO_2]}{\tau}$$

$$\frac{d[NO]}{dt} = -k[NO][O_3] + J[NO_2] + \frac{[NO]_V}{\tau} + \frac{[NO]_B - [NO]}{\tau}$$

$$\frac{d[O_3]}{dt} = -k[NO][O_3] + J[NO_2] + \frac{[O_3] - [O_3]_B}{\tau}$$

- Equilibrium is attained within minutes ⇒ calculate steady-state solution (d/dt [ ]= 0)

cf: Duering et al., Meteorol. Z. 20, 67-73 (2011)