A modelling system for predicting urban $PM_{2.5}$ concentrations. Numerical results and evaluation against the data in Helsinki

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1. Aims
2. The measurements
3. The modelling system
   - Emission modelling
   - Dispersion modelling
   - Backgroud modelling
4. Results and Conclusions
   - spatial concentration distributions
   - comparison with measurements
   - problems & further work

Aims

Development and validation of a modelling system for predicting urban $PM_{2.5}$ concentrations

Measurements

- YTV –monitoring network (continuous)
- EMEP stations (continuous)
- Measurement campaigns

PM MONITORING SITES in HELSINKI METROPOLITAN AREA

Site	Site type	Vehicles /day	Distance from street	Measured average hourly quantities
Töölö	Urban traffic	12 000 - 25 000	5 m	PM_{10}
Vallila	Urban traffic	14 000	14 m	$PM_{2.5}$ & PM_{10}
Leppävaara	Suburban traffic	15 000 - 61 000	25 m	PM_{10}
Kallio	Urban background	8000	80 m	$PM_{2.5}$ & PM_{10} since '99
Luukki	Regional background	4000	800 m	PM_{10}

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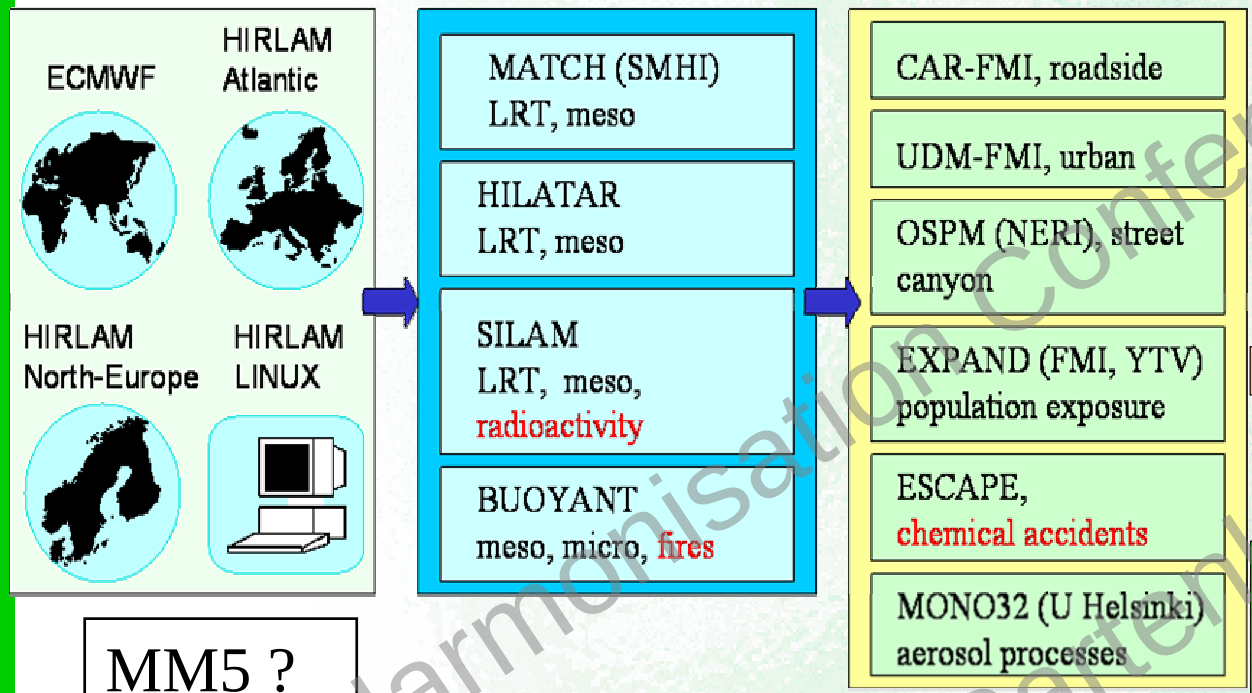

Modelling systems (FMI)

Geographical information

Emission characteristics

Measurements
Meteorology, traffic, pollution

Traffic simulation
Macro-EMME/2 (YTV)
Micro-HUTSIM (TKK)

Emission inventories
VTT, LIISA
Corinair

Weather prediction, met. pre-processing
HIRLAM, MPP-FMI

Dispersion of pollutants
- stationary sources: UDM-FMI
- roadside: CAR-FMI
- street canyon: OSPM (NERI)
- forecasting air quality: API-FMI

Activity Model

Exposure model

Statistical Analysis

GIS
MapInfo

Visualisation

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Model for urban fine particles

$$PM_{2.5}(r,t) = PM_{2.5}^{tr}(r,t) + PM_{2.5}^{st}(r,t) + PM_{2.5}^{bg}(t)$$

$PM_{2.5}(r,t)$

is the total measured concentration at time t, at spatial coordinate r

st : stationary sources
tr : vehicular traffic (exh+non-exh)
bg: background (LRT)

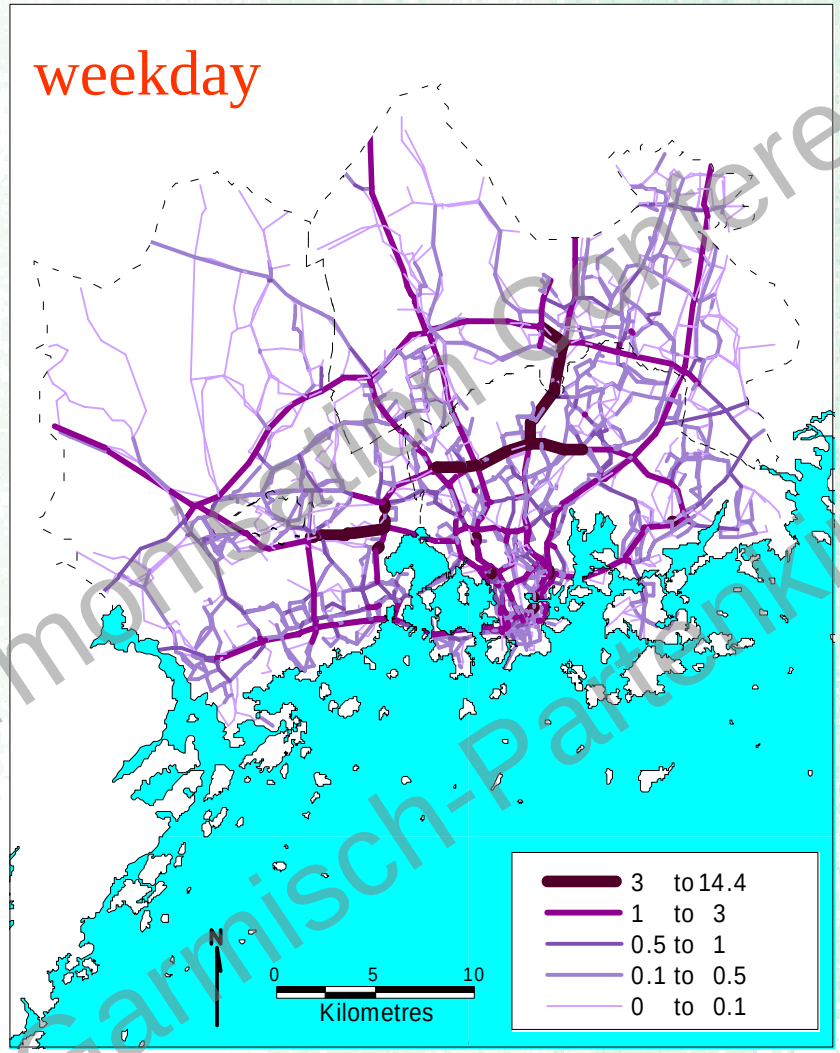
Assumptions:

- Exhaust traffic emissions purely $PM_{2.5}$
- Other traffic related emissions are directly proportional to exhaust emissions
- Regional and long-range transported background purely $PM_{2.5}$
- Ion-sum is a good proxy for LRT

Most important model components

1. Emission model for $PM_{2.5}$
   - ➢ coldstarts taken into account
2. Roadside dispersion model CAR-FMI
3. Statistical model for regional and long-range transported $PM_{2.5}$

Daily averaged $PM_{2.5}$ line source emissions (kg/d/km) in the Helsinki Metropolitan Area in 2002



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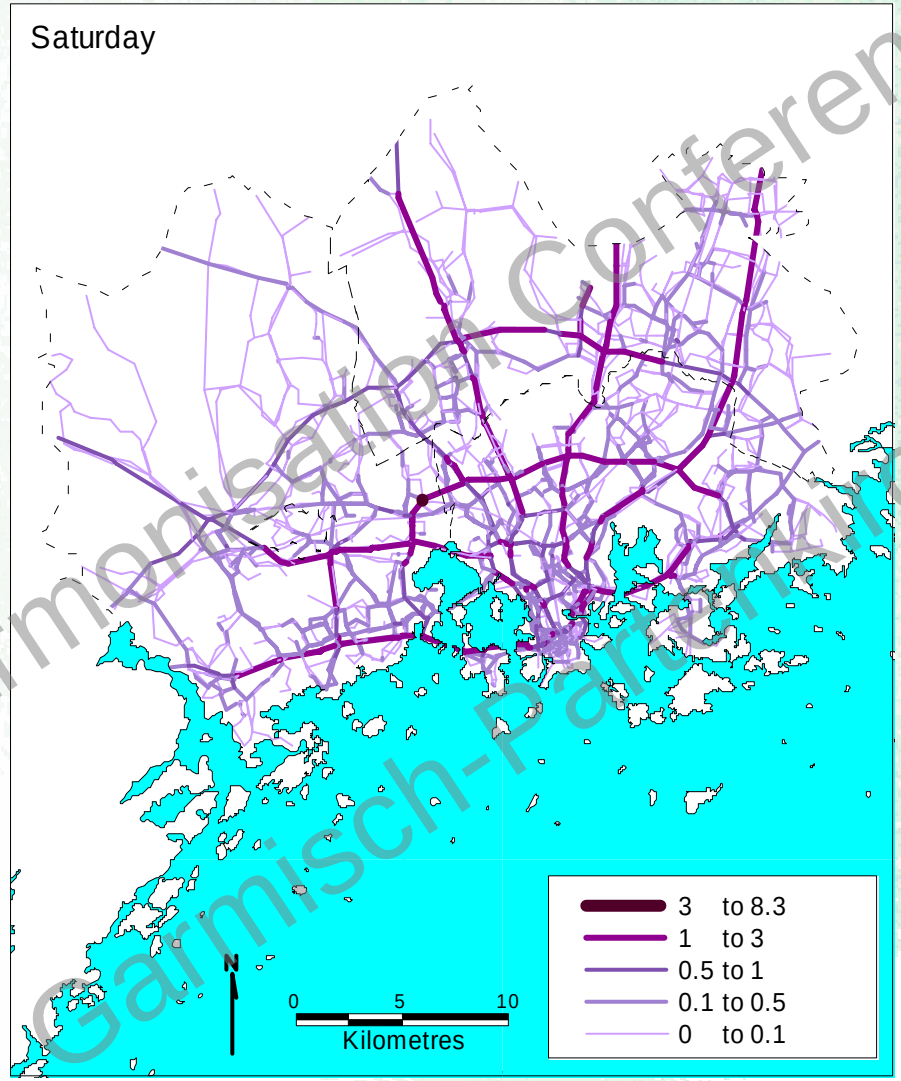

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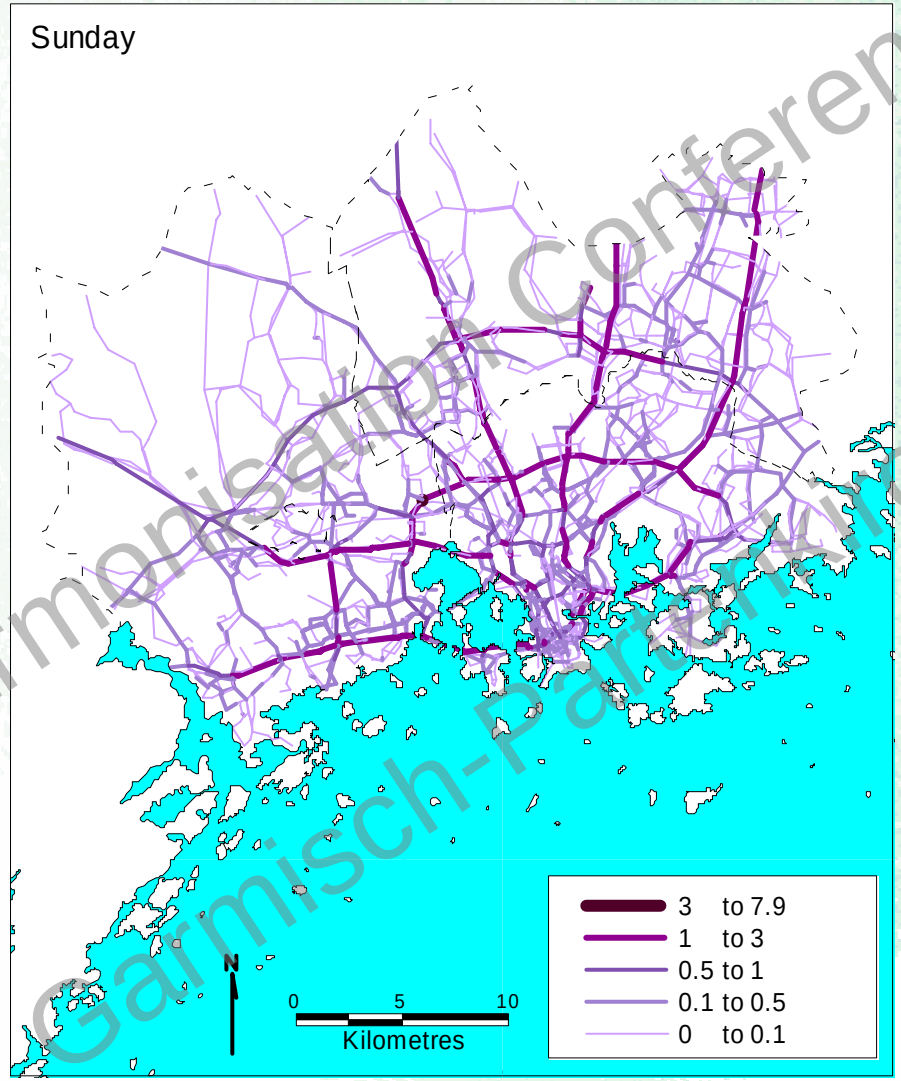

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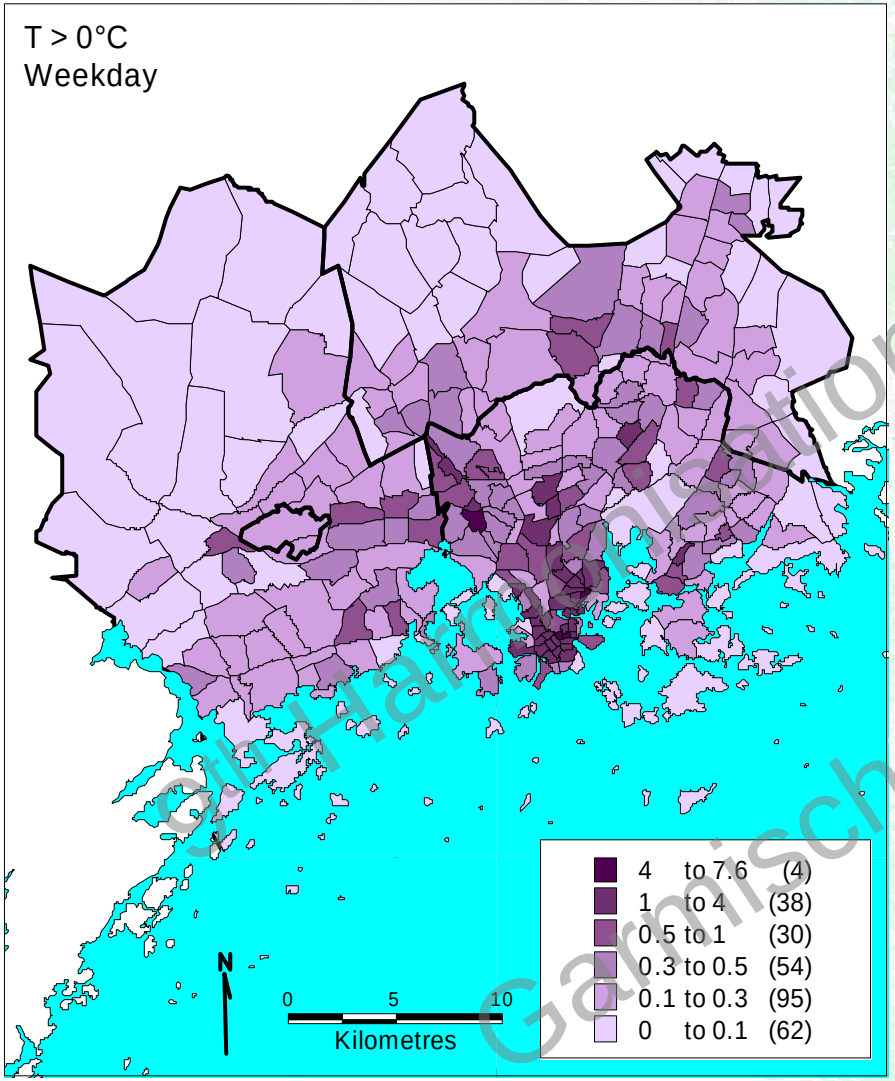
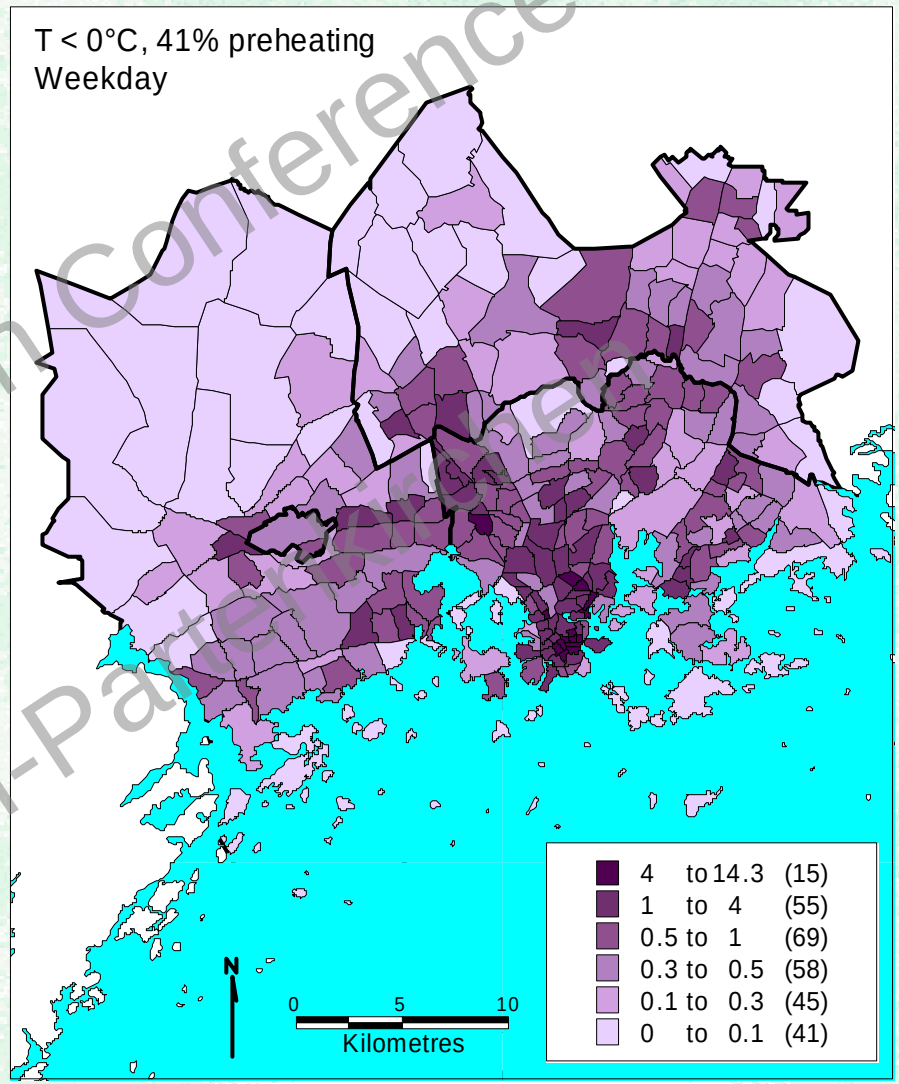
Daily averaged cold start emissions of $PM_{2.5}$ (kg/d/km²) in the Helsinki Metropolitan Area in 2002





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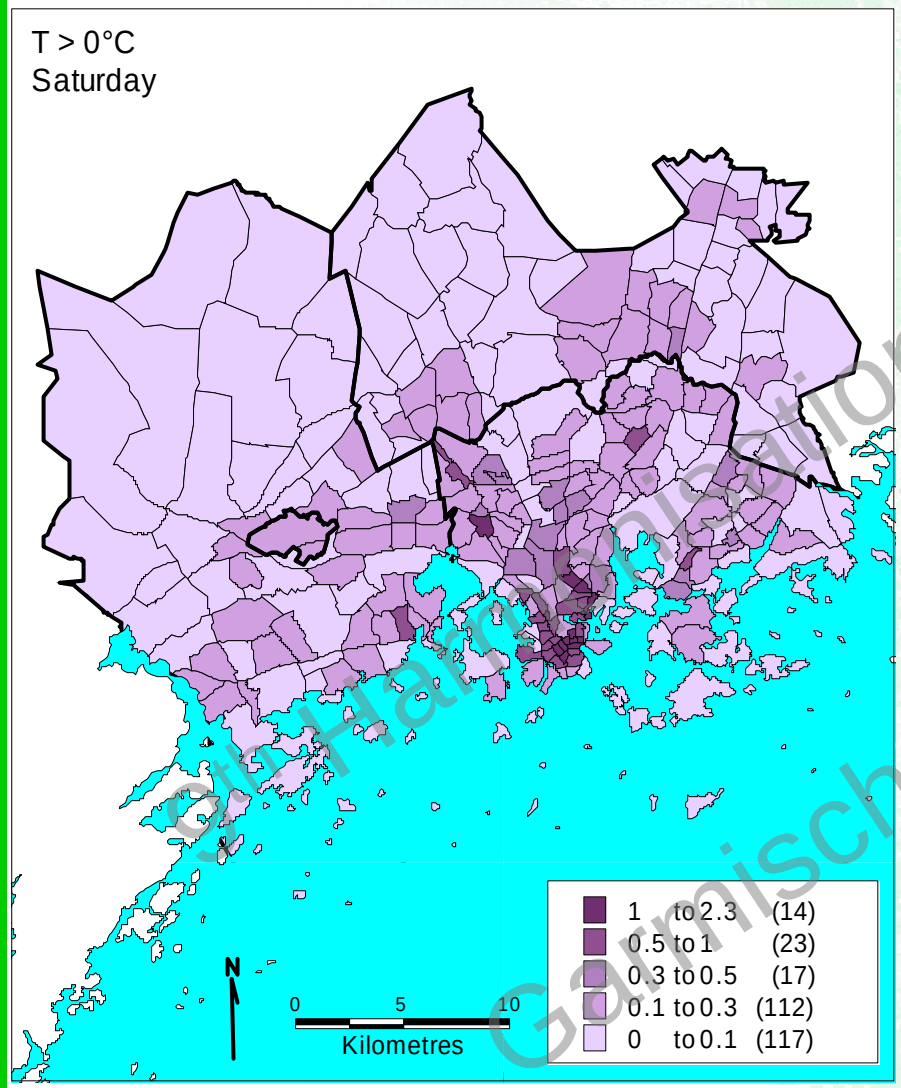

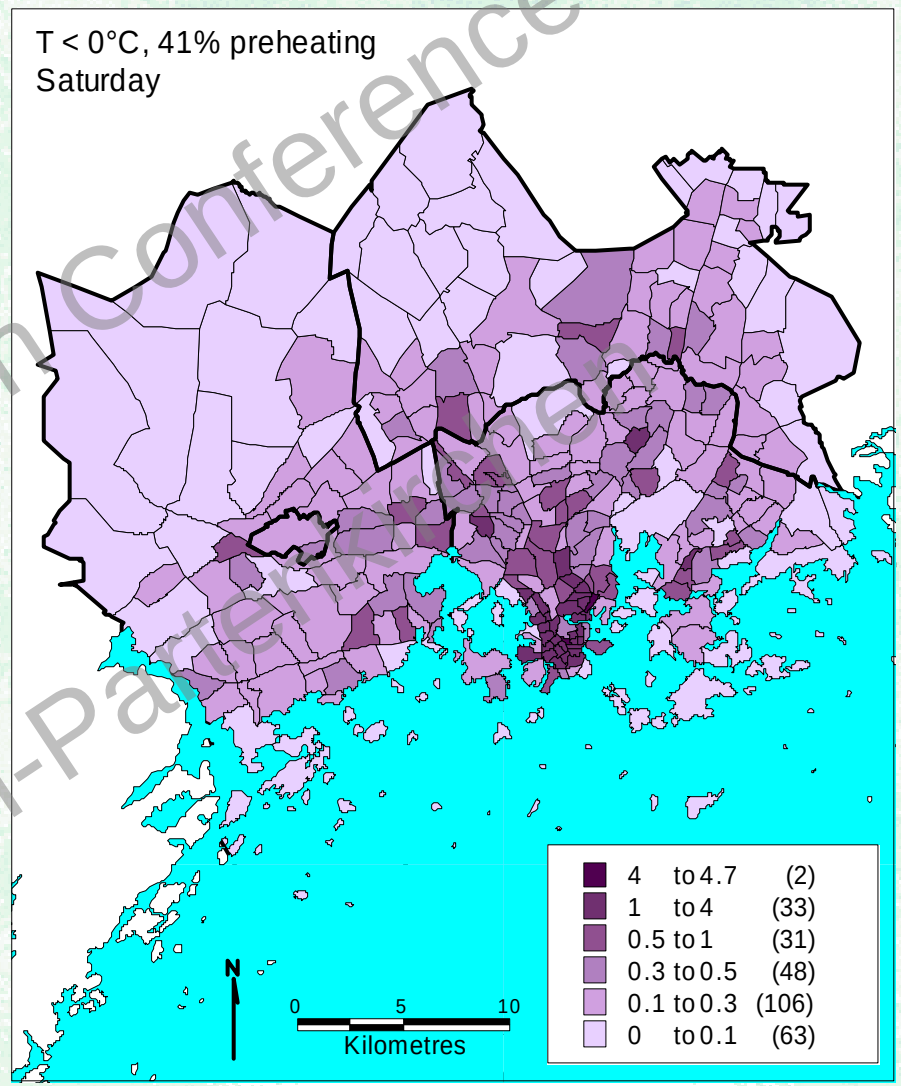

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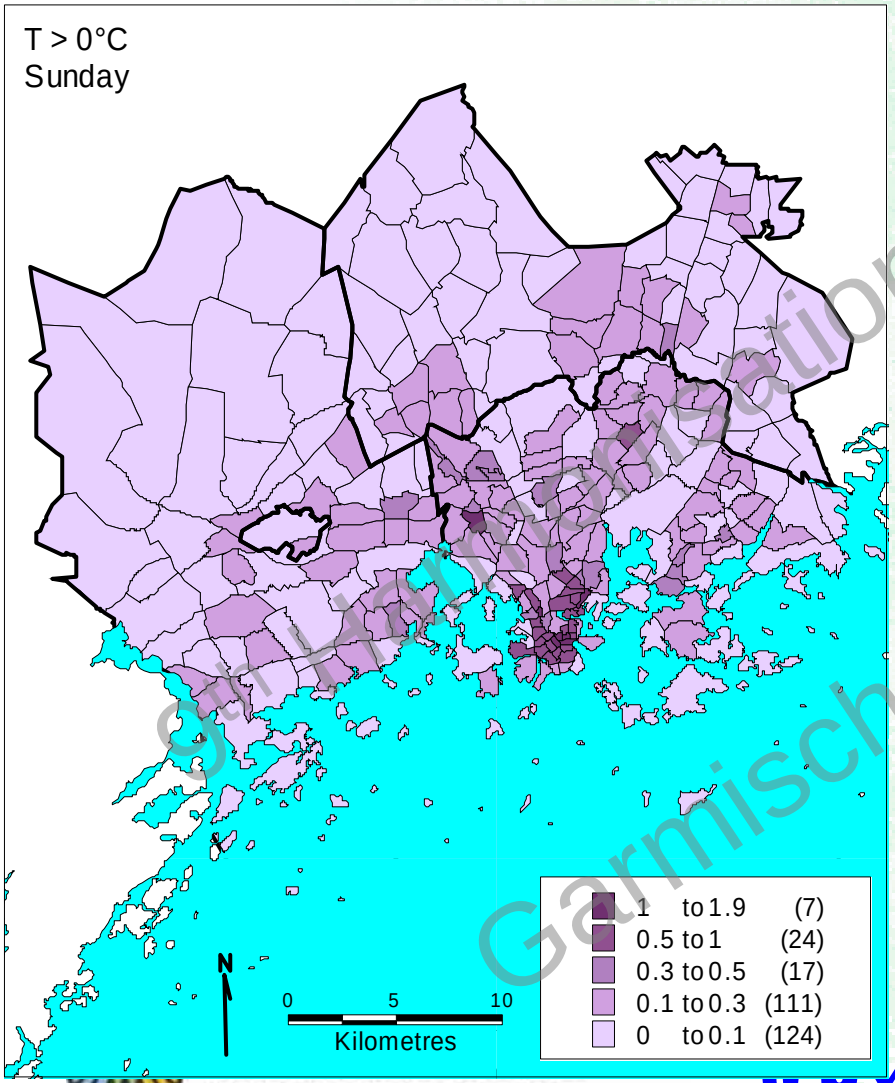

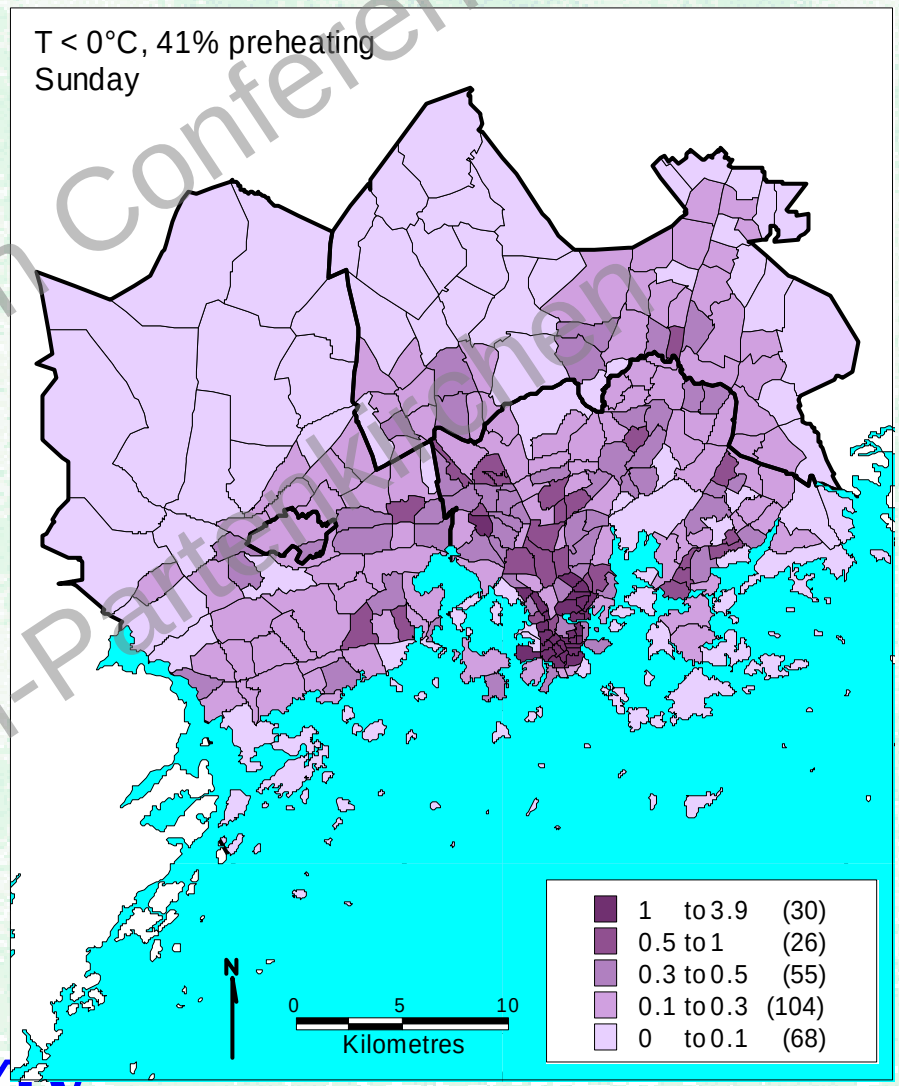

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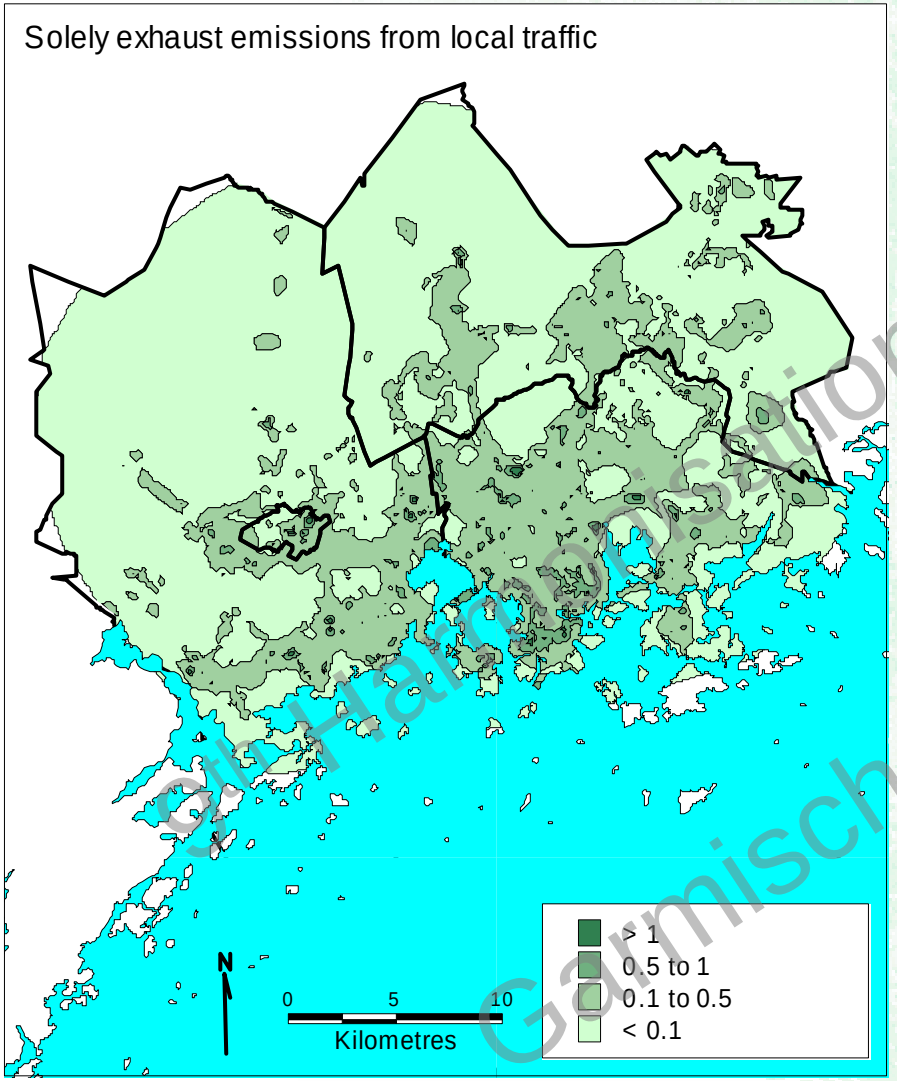
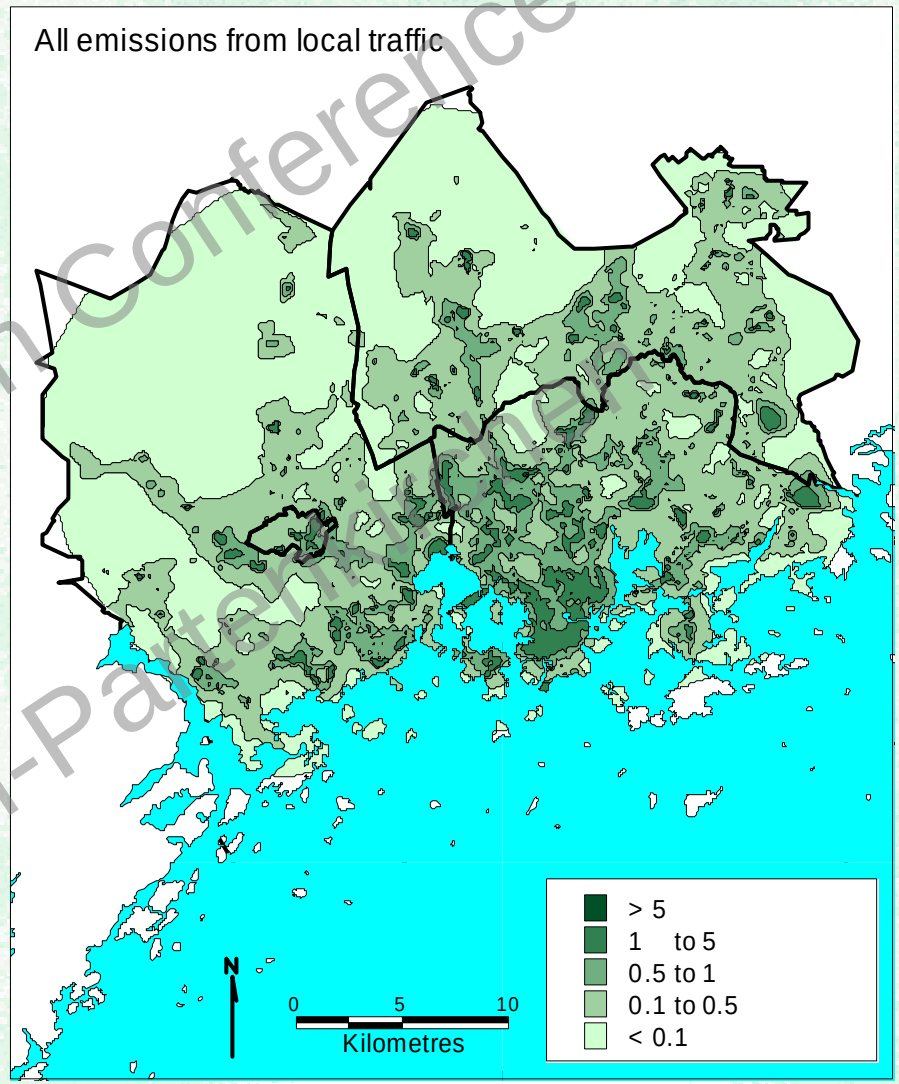
Annual average $PM_{2.5}$ concentrations ($\mu g/m^3$) in the Helsinki Metropolitan Area in 2002





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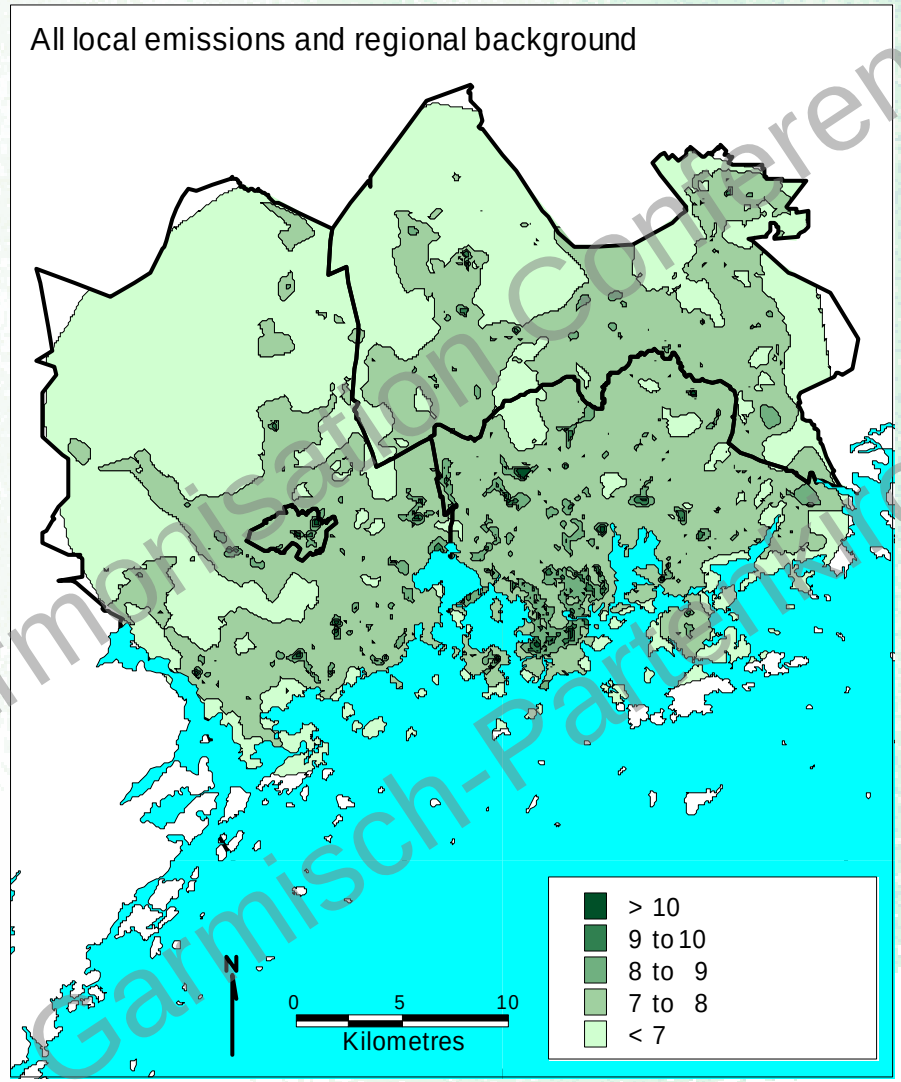

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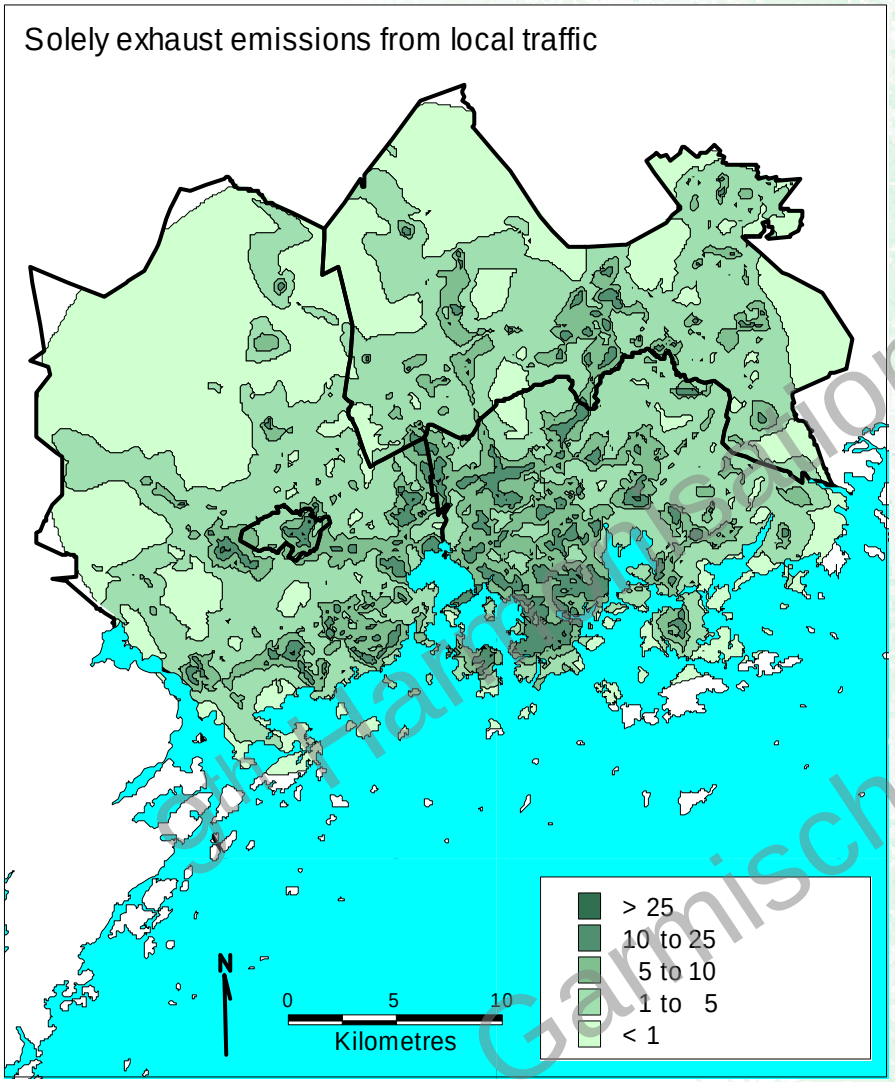
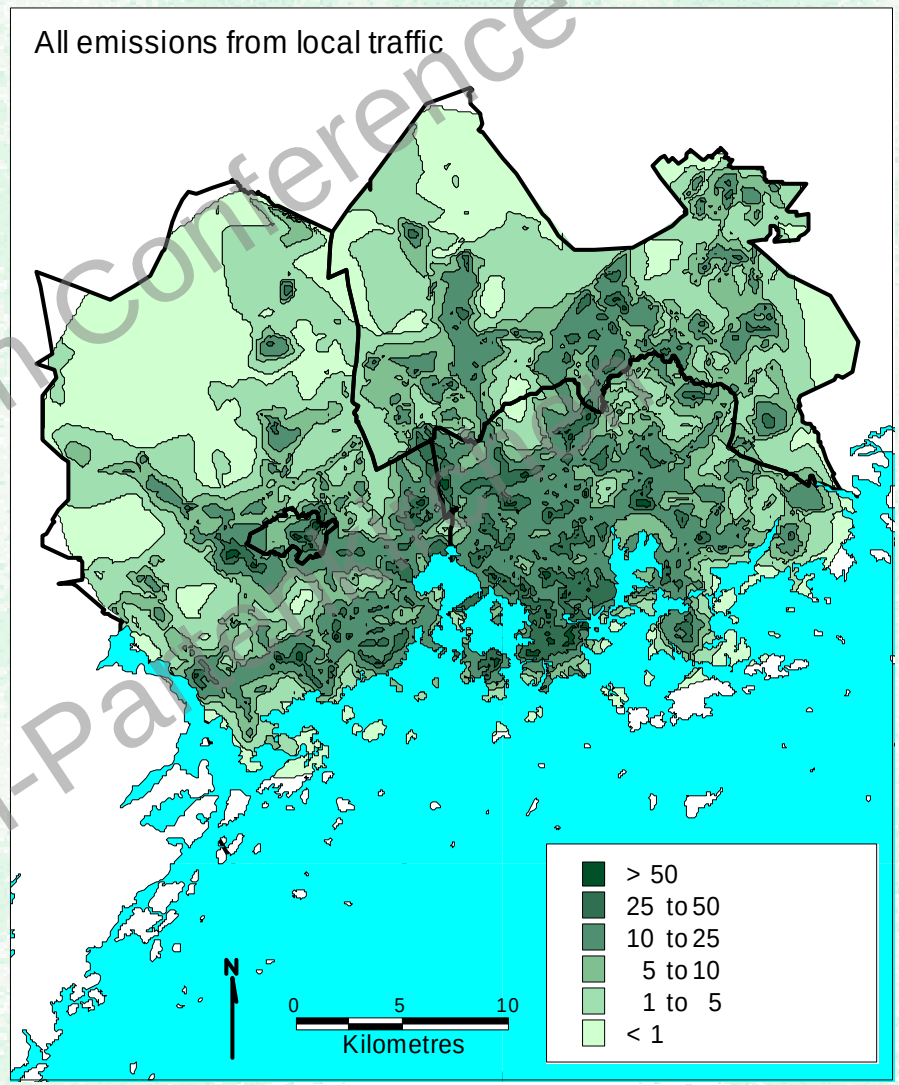
Maximum hourly $PM_{2.5}$ concentrations ($\mu g/m^3$) in the Helsinki Metropolitan Area in 2002





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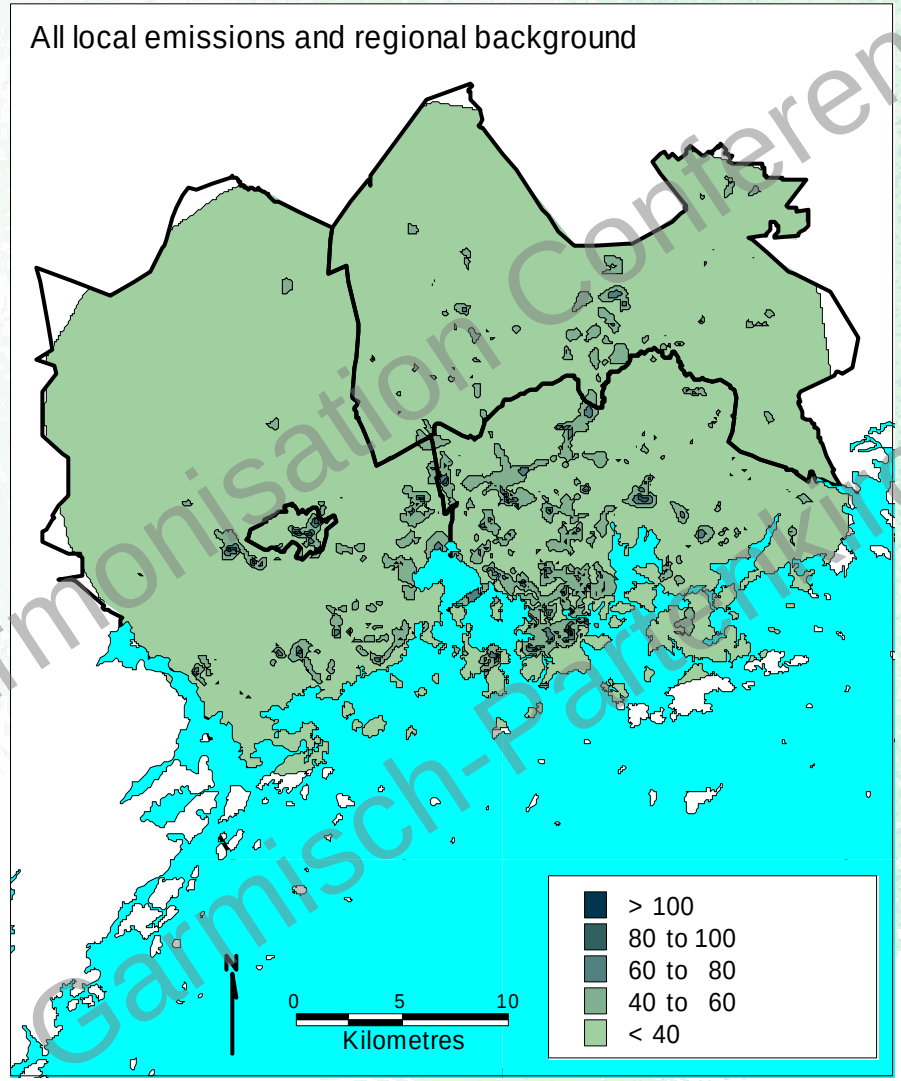
Maximum hourly $PM_{2.5}$ concentrations (µg/m³) in the Helsinki Metropolitan Area in 2002



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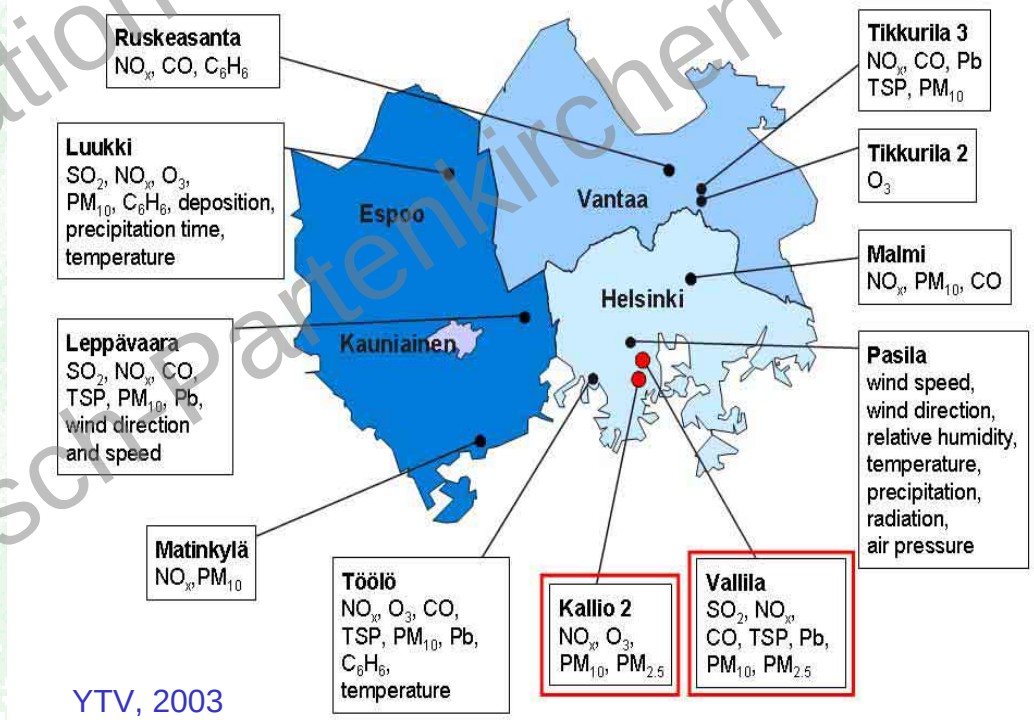
Predicted vs. observed daily mean $PM_{2.5}$ concentrations in Helsinki in 2002

- Computations by mainframe version of CAR-FMI line source model
- Observations from YTV monitoring stations at Vallila and Kallio



YTV, 2003

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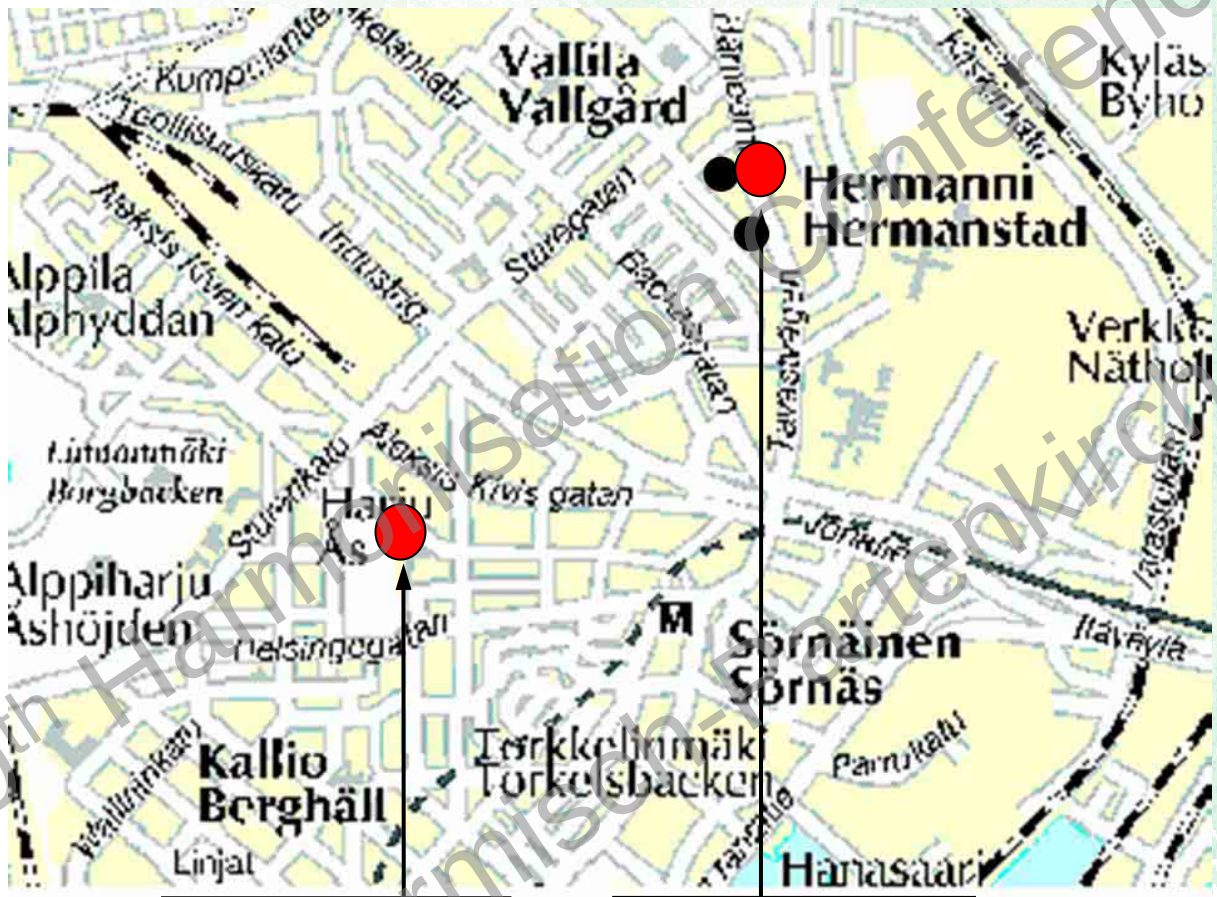
Location of YTV monitoring stations



200 m

N

YTV, 2002

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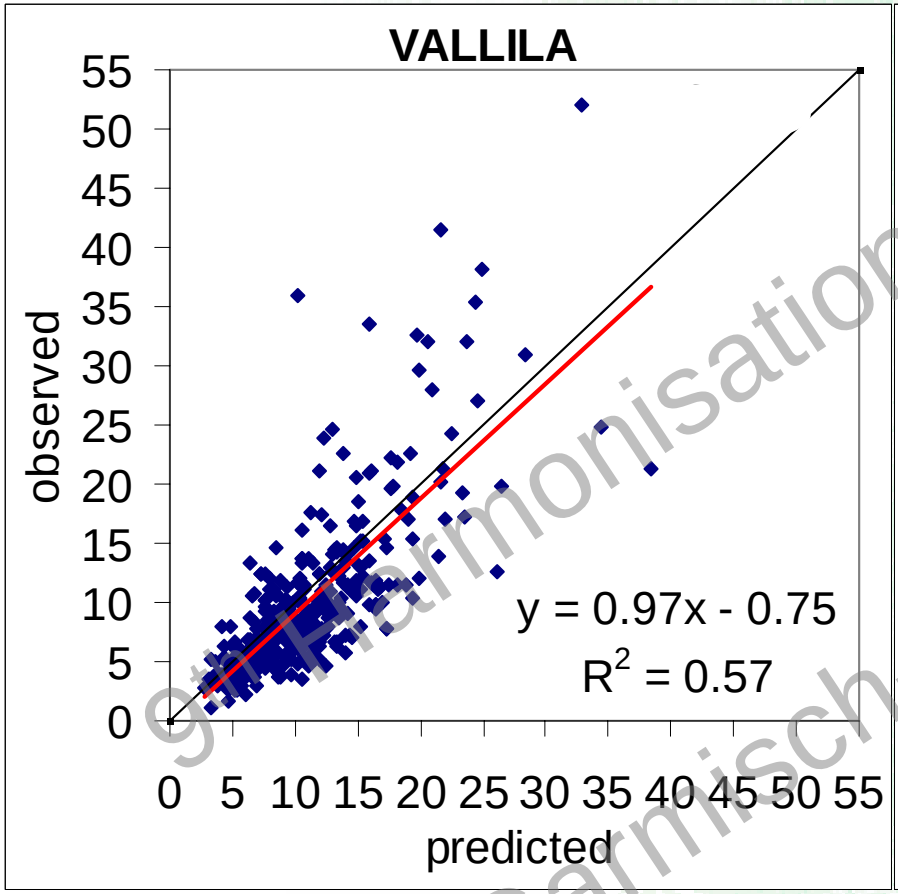
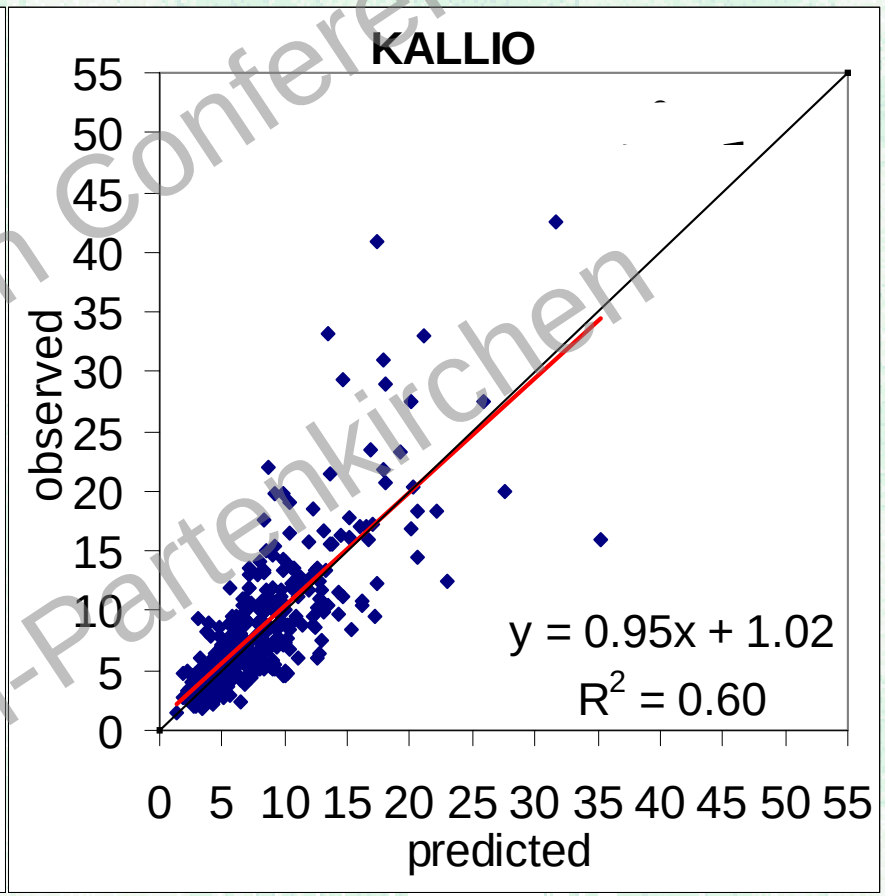
Predicted vs. observed daily mean $PM_{2.5}$ concentrations –scatter plot & IA





VALLILA: R^2 = 0.57, IA = 0.84

KALLIO: R^2 = 0.60, IA = 0.86

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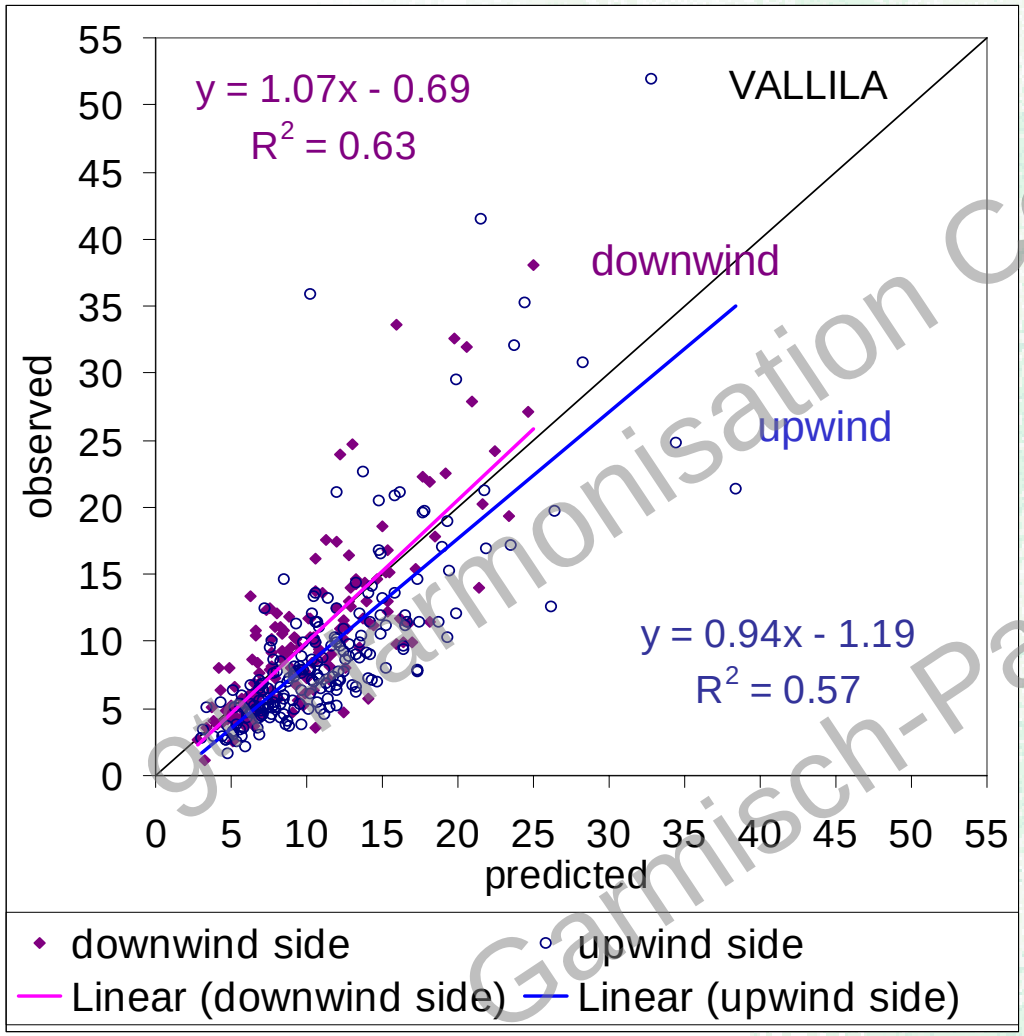
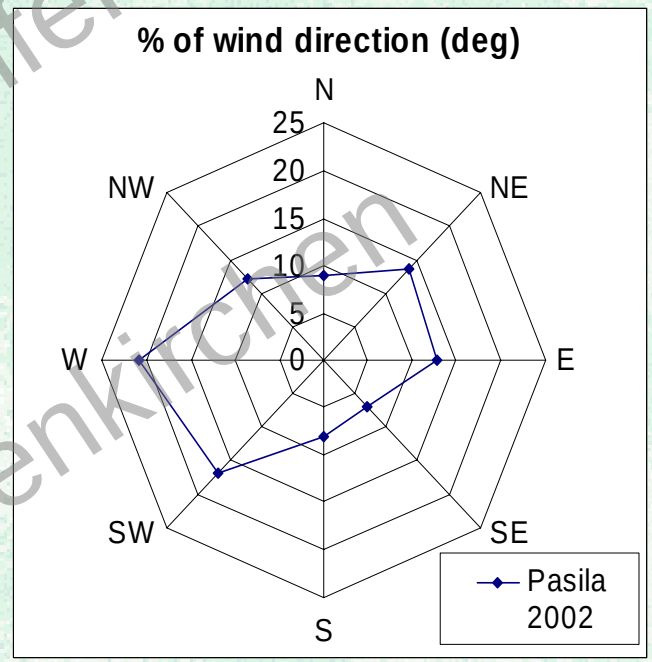
Predicted vs. observed daily mean $PM_{2.5}$ concentration in **Vallila** – scatter plot in terms of wind direction





downwind < 180 deg
upwind > 180 deg

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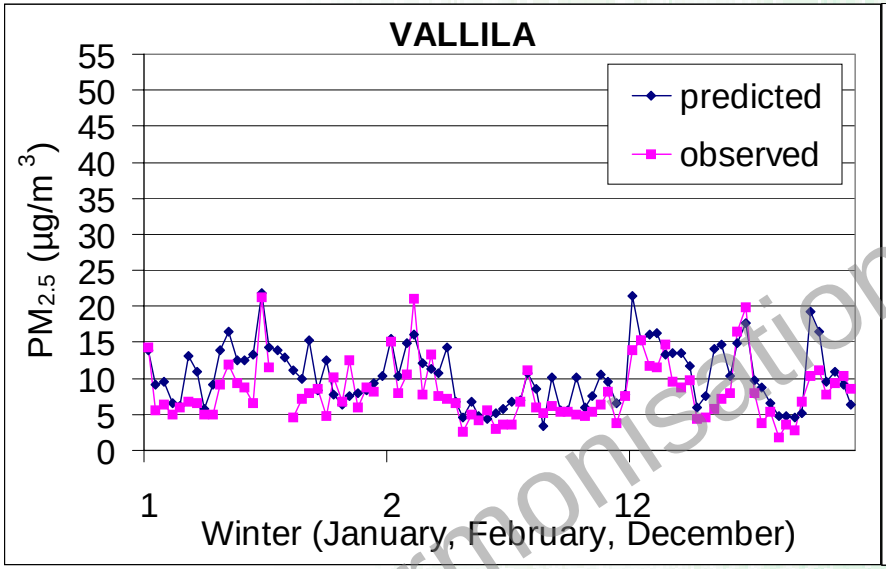
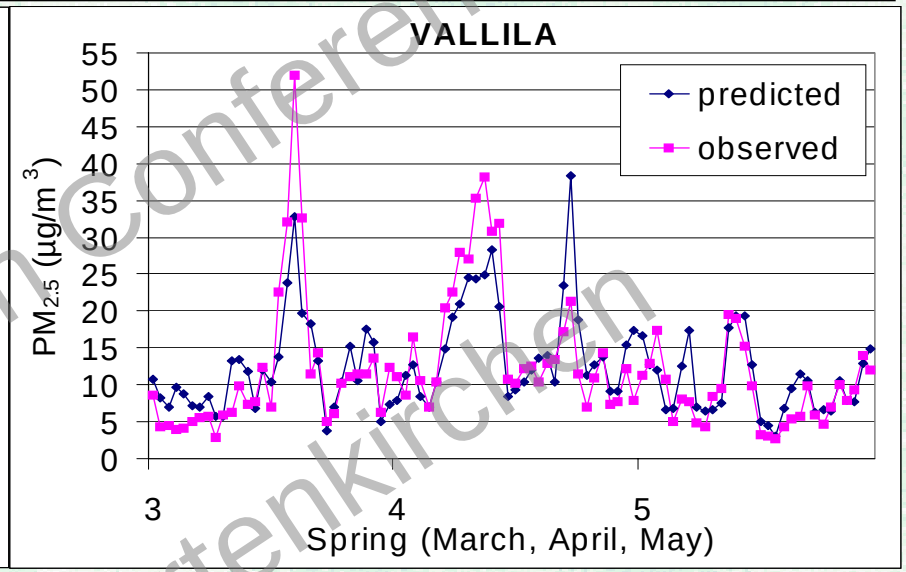
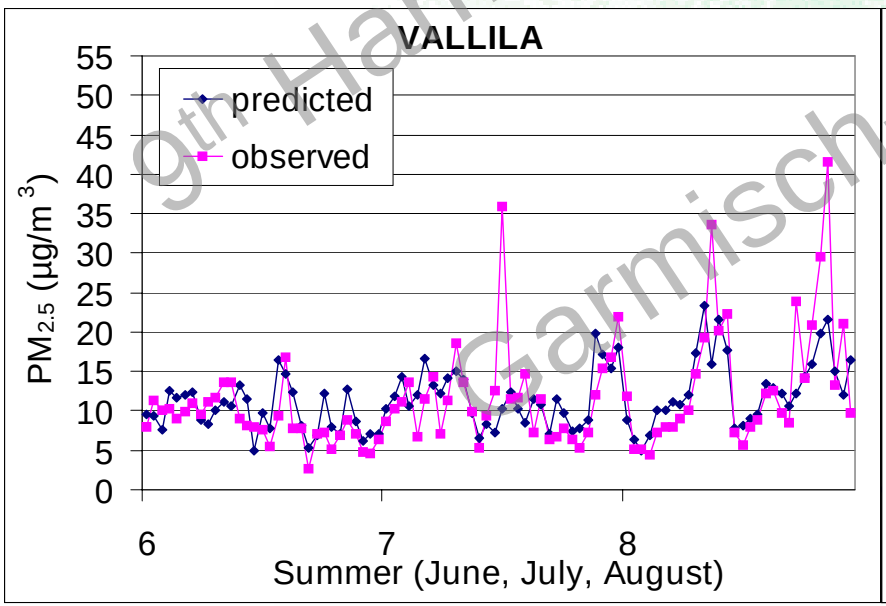
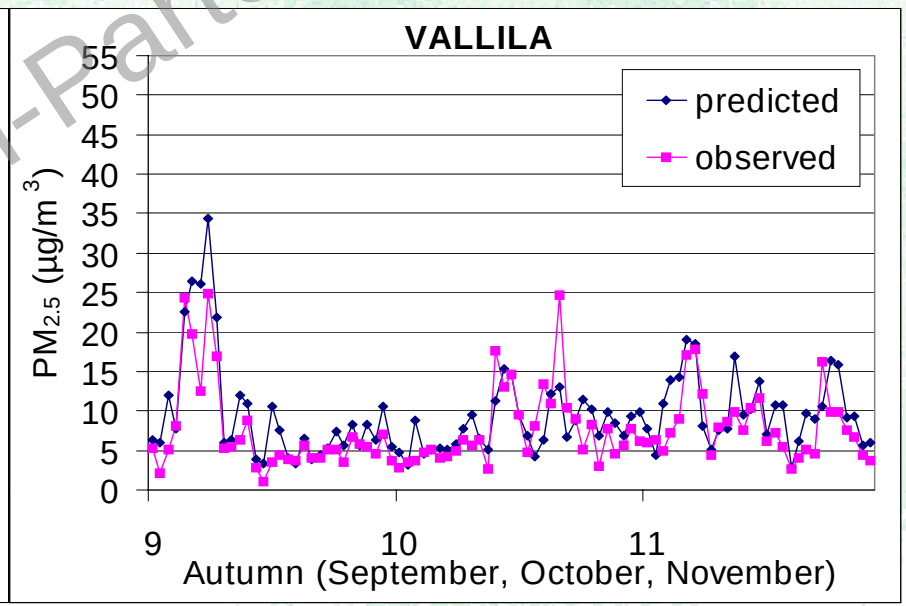
Predicted and observed daily mean $PM_{2.5}$ concentrations in **Vallila** –seasonal variation

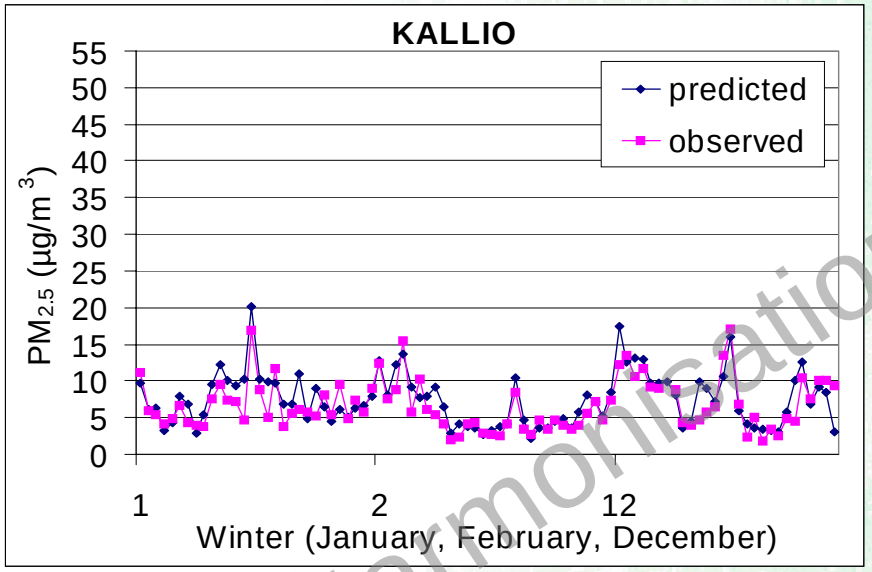


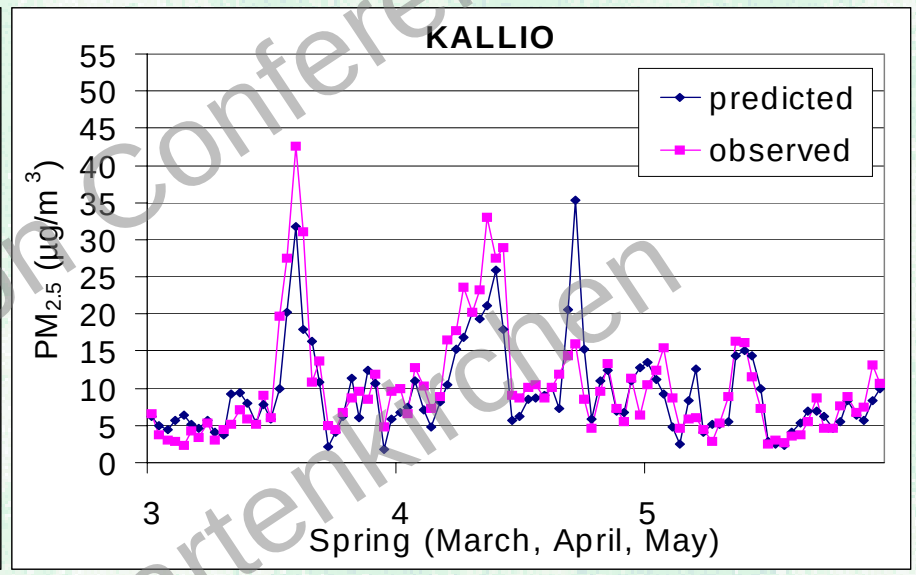


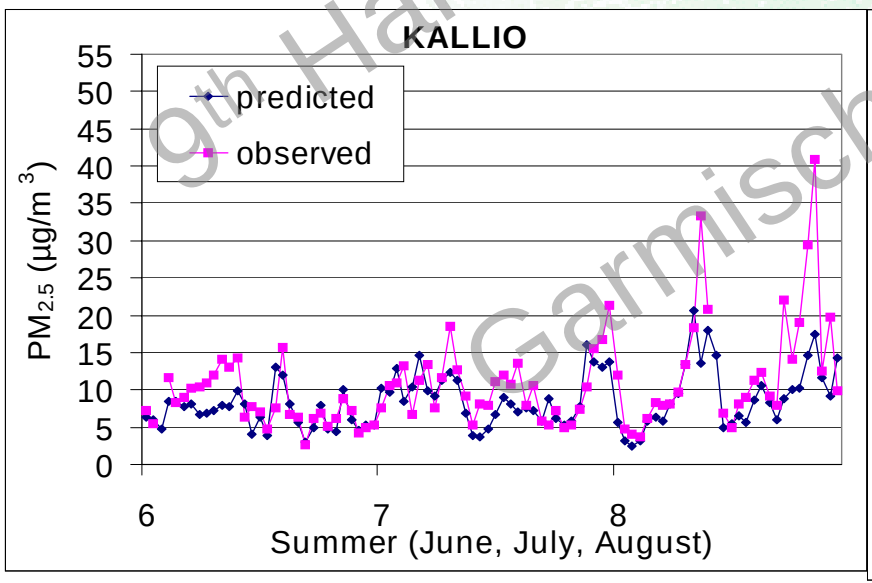


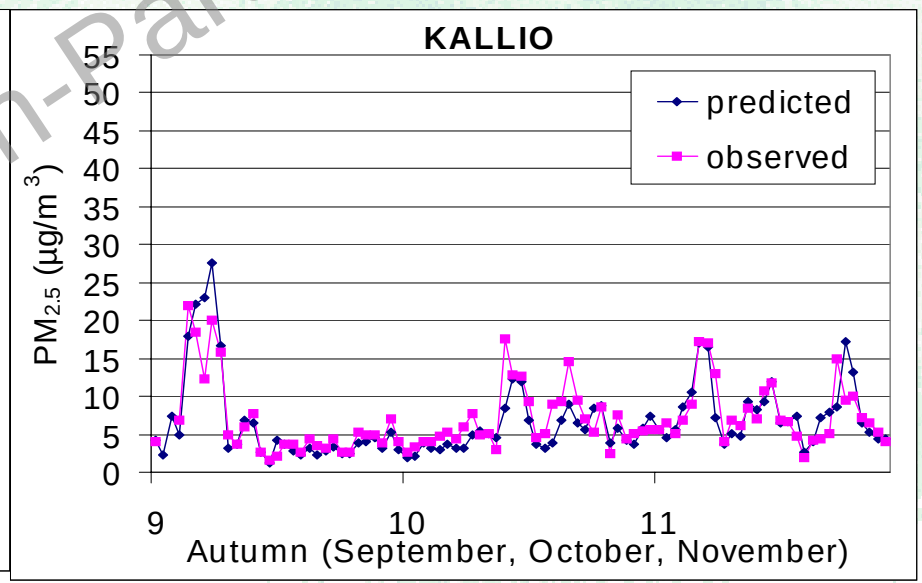


Predicted and observed daily mean $PM_{2.5}$ concentrations in **Kallio** –seasonal variation









Conclusions

- **Modelling system has been developed for urban $PM_{2.5}$**
  - **Applicable also for other European cities (emission coefficients country-specific)**
  - **Includes also the evaluation of regional background $PM_{2.5}$**
- **Spatial concentration distributions of $PM_{2.5}$**
  - **The influence of traffic and LRT on total concentrations**
  - **The annual average, maximum hourly and guideline concentrations**
- **Evaluation of the model performance against the results of the urban monitoring network**
  - **Good statistical agreement of the predicted and measured daily concentrations**

Challenges for future research

- PM emission modelling – especially non-combustion and cold start emissions, and suspension (studied in SAPPHIRE, OSCAR)
- The contribution of LRT is important – Direct regional $PM_{2.5}$ measurements would be welcome; continental scale PM modelling
- Modelling of the aerosol processes, including size distributions and chemical composition (studied in SAPPHIRE)

References

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This is the end …

CREDITS

Academy of Finland

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