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SANTA MARTA, 2023-03-24

ASSESSMENT OF CONCENTRATIONS, POPULATION EXPOSURE AND RELATED HEALTH EFFECTS

METHODS AND EXAMPLES OF NATIONAL ASSESSMENTS

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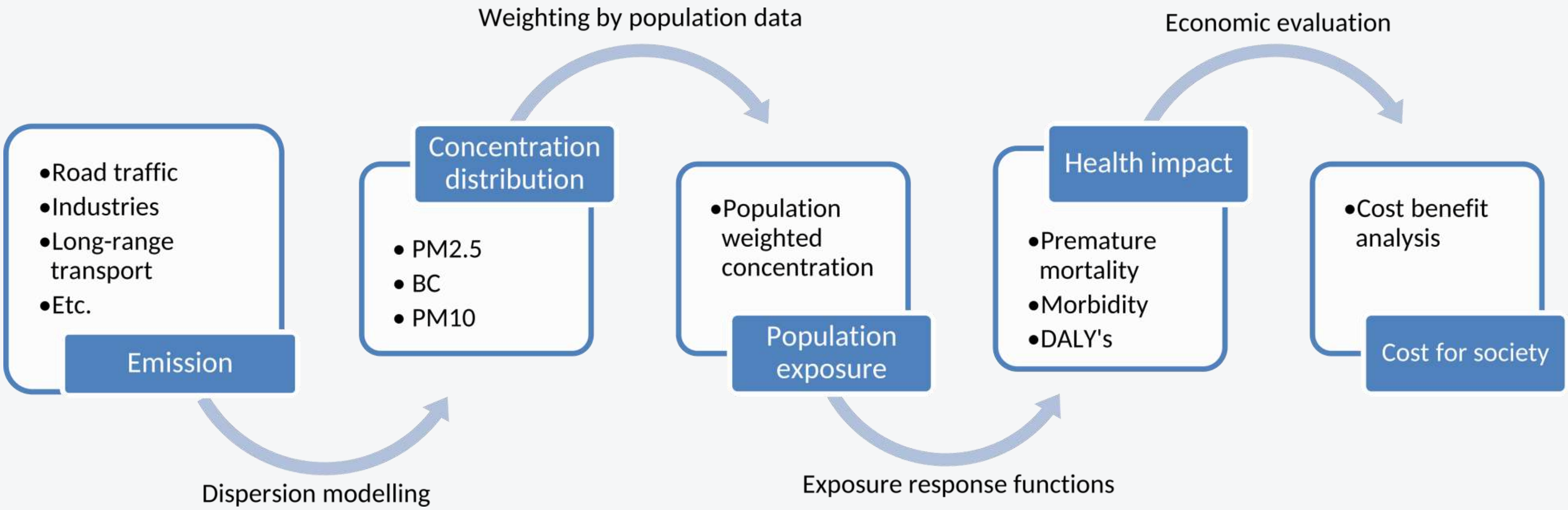
Scope

- Recap of state-of-the-art health impact assessment for PM
- Difference between associations of PM and premature death for near-source and long-range exposure
- Aim
- Dispersion modelling strategy
- CLAIR air quality modelling system
- Emissions inventories
- Results
- Take-home message

The impact pathway



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Assessment of premature mortality due to PM exposure – state-of-the-art

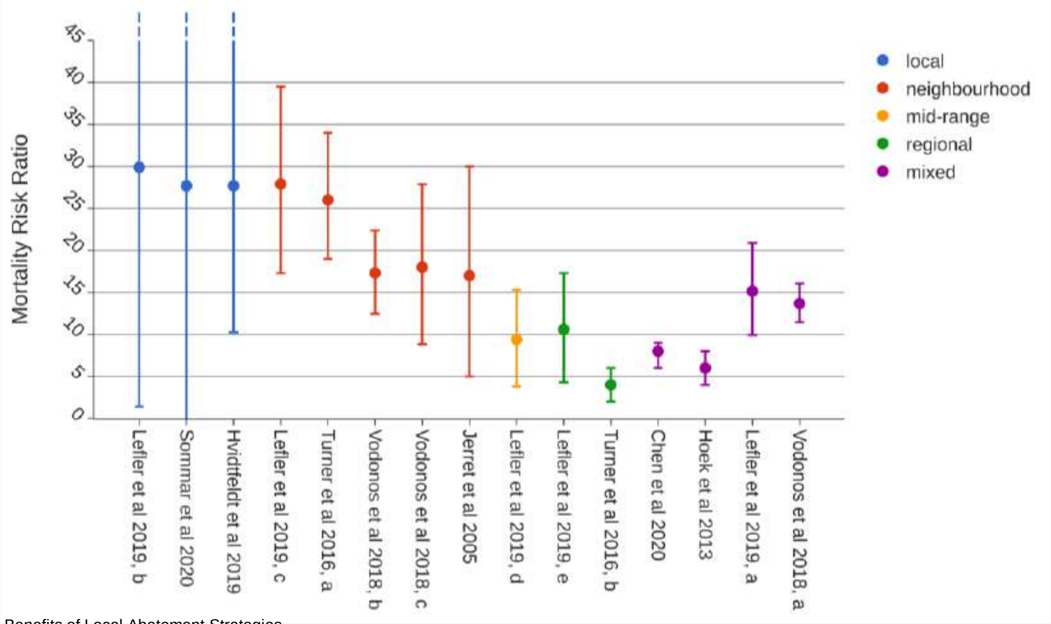
- Health impact assessments mainly **focus on particles**, particularly $PM_{2.5}$
- Health effects of PM seen at levels **well below current standard**(1)
- **Linear exposure-response relationships reasonable** for PM and all-cause mortality(1)
- It is expected that the **relative toxicity** for PM of different sizes and of different chemical composition **differs.** However, due to insufficient evidence, they are often **treated as equally hazardous** to health in HIA (2)
- **Insufficient evidence** in real-world studies to ascertain if **non-exhaust-PM** has adverse effects (3) (but considered in HIA as part of $PM_{2.5}$ and PM_{10})
- Exposure-response functions seem to be **steeper at lower concentrations**

(1) WHO 2013, REVIHAAP Project
(2) COMEAP (2022) Statement on the differential toxicity of particulate matter according to source or constituents
(3) COMEAP (2020) Statement on the evidence for health effects associated with exposure to non-exhaust particulate matter from road transport.’

Associations between $PM_{2.5}$ and premature mortality

- Growing evidence of differences between associations based on within-city concentration gradients vs. between-city concentration gradients
- Number of premature deaths due to PM in cities is probably underestimated in many studies.
- We need to further reduce air pollution in our cities!

Percent increase in mortality per 10 µg/m^3 increase in $PM_{2.5}$
Comparison of associations based on exposure at different scales



Segersson et al. 2021, Near-source Risk Functions For Particulate Matter Are Critical When Assessing the Health Benefits of Local Abatement Strategies.

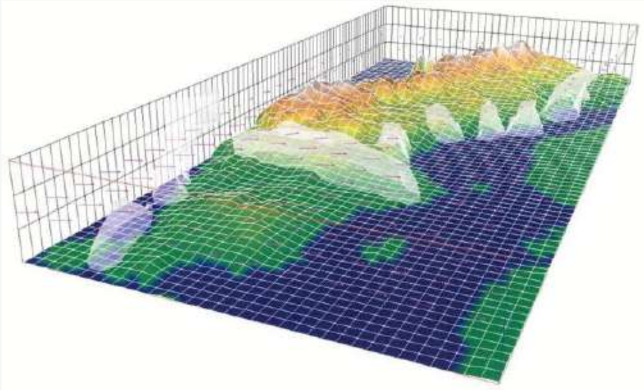
Overall aim

- Estimate source-specific population exposure to ambient NO_2, PM_{10} and $PM_{2.5}$ at ~100x100 m^2 resolution, from 1990-2019, for entire Sweden
- Separate estimates of near-source and long-range exposure
- Fusion of measurements and model results to minimize systematic bias
- Automated methodology that can be repeated on a yearly basis

(1) Frohn, L et al. Evaluation of high-resolution atmospheric chemistry-transport exposure modelling for the continental Nordic countries based on the UBM model. *Atmos Env* (submitted)
(2) Staffoggia et al. A random forest approach to estimate daily particulate matter, nitrogen oxide and ozone at a fine spatial resolution in Sweden. *Atmosphere.* 2020.

Scale closure using 3 models

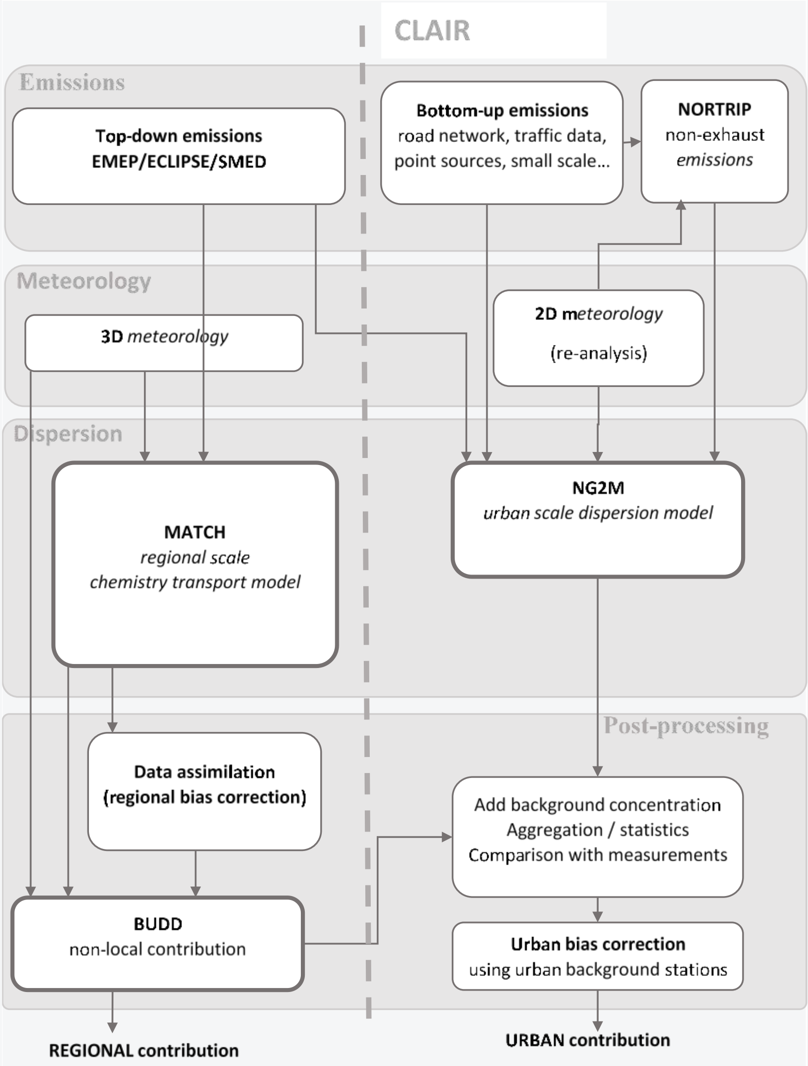
1. **MATCH**, Multi-scale Atmospheric Transport and Chemistry model
2. **BUDD**: a semi-lagrangean post-processing scheme for estimation of the non-local contribution
3. **NG2M**: a gaussian model, part of the CLAIR air quality modelling system.



MATCH
Multi-scale Atmospheric Transport and CHemistry

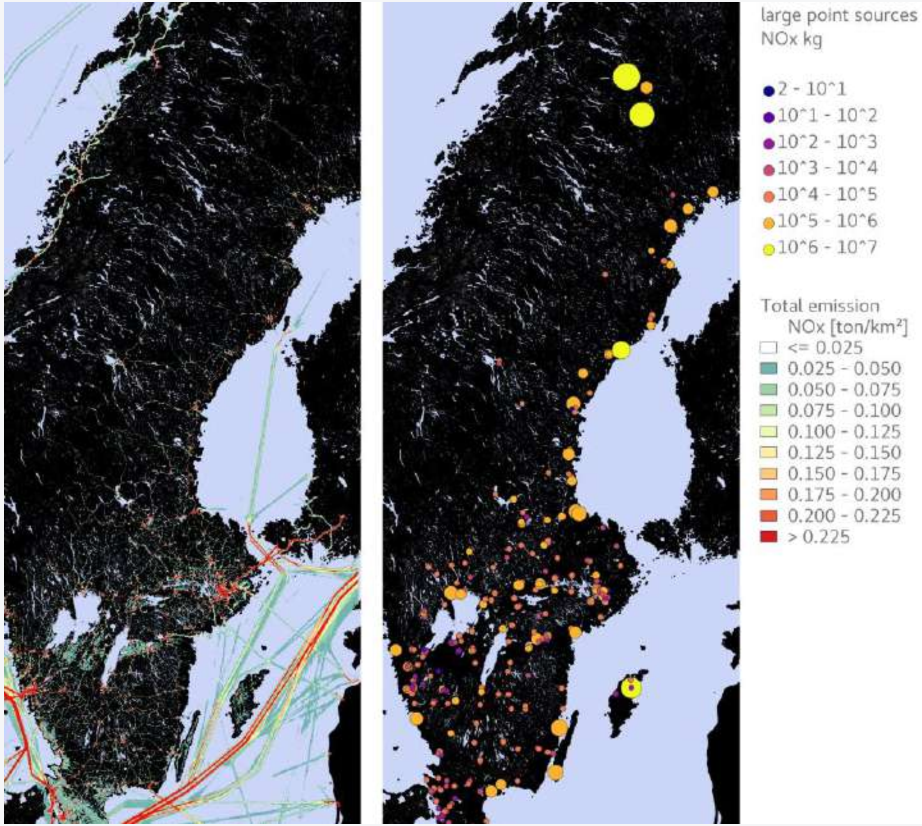
CLAIR Air quality modelling system

- Developed since 2015
- Taylored for urban air quality and climate studies
- Integrates emission inventories, dispersion-modelling and post-processing
- Employs Postgresql and netCDF
- Automated modelling chains



Emissions

- Top-down, gridded, emissions for regional scale modelling from Nordic WelfAir project[1]
- Bottom-up emission inventories for the local scale modelling every ~5 years



1. https://projects.au.dk/nordicwelfair/

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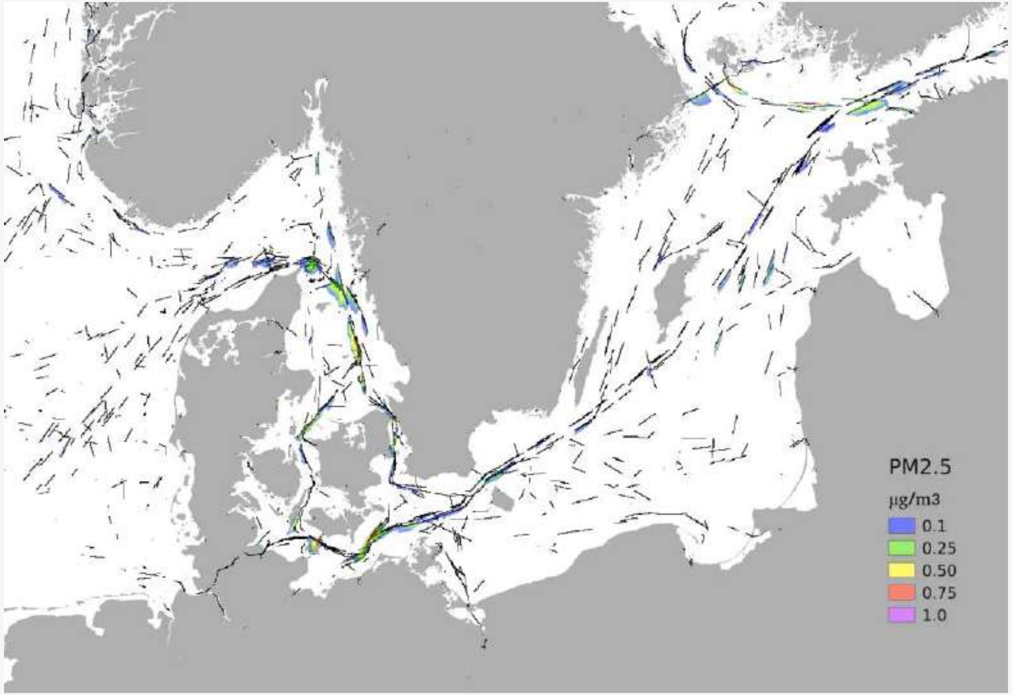
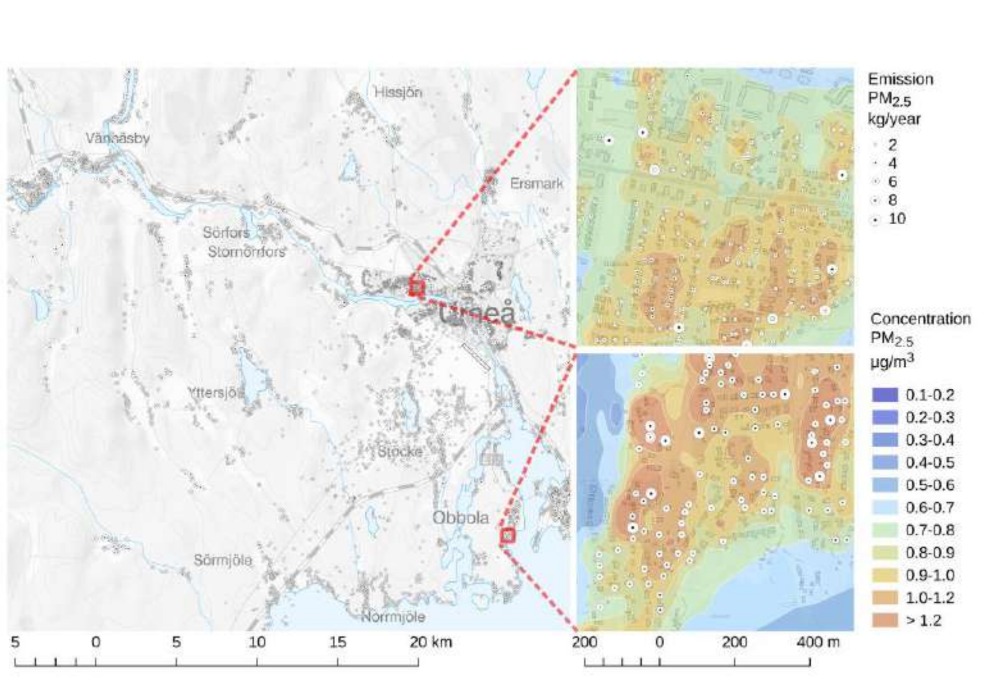
Shipping emissions using data from AIS-transponders



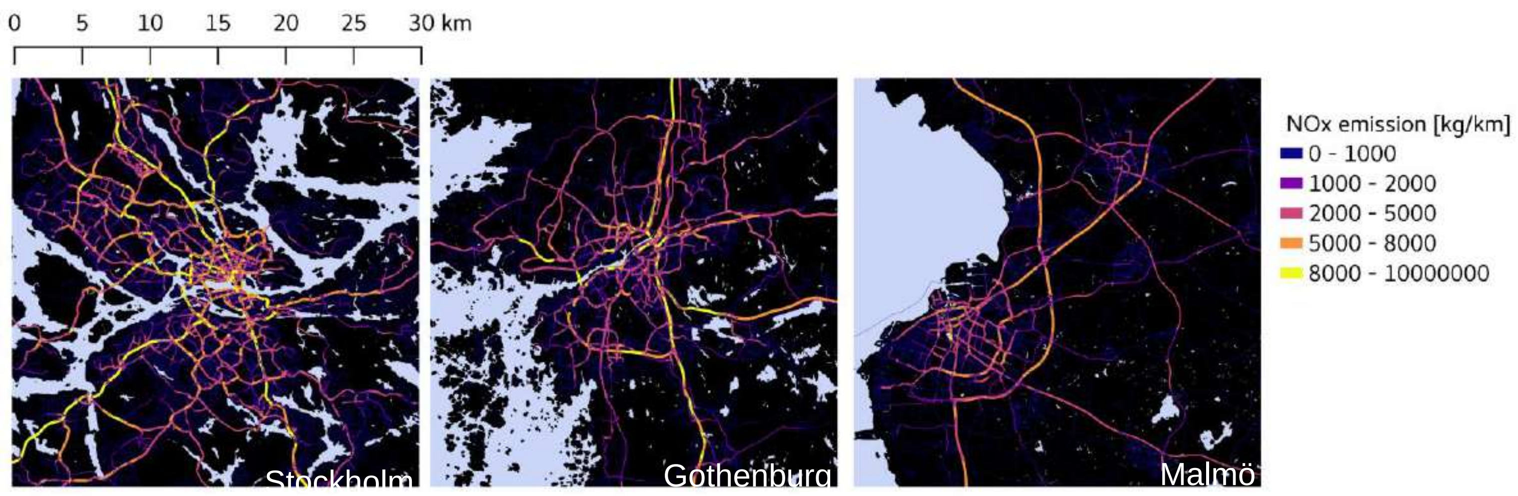
Residential wood combustion

- Available regional registers of stoves and boilers from chimney sweepers
- Generalization of across areas without detailed information
- Statistics from surveys wood consumption and types of appliances etc.



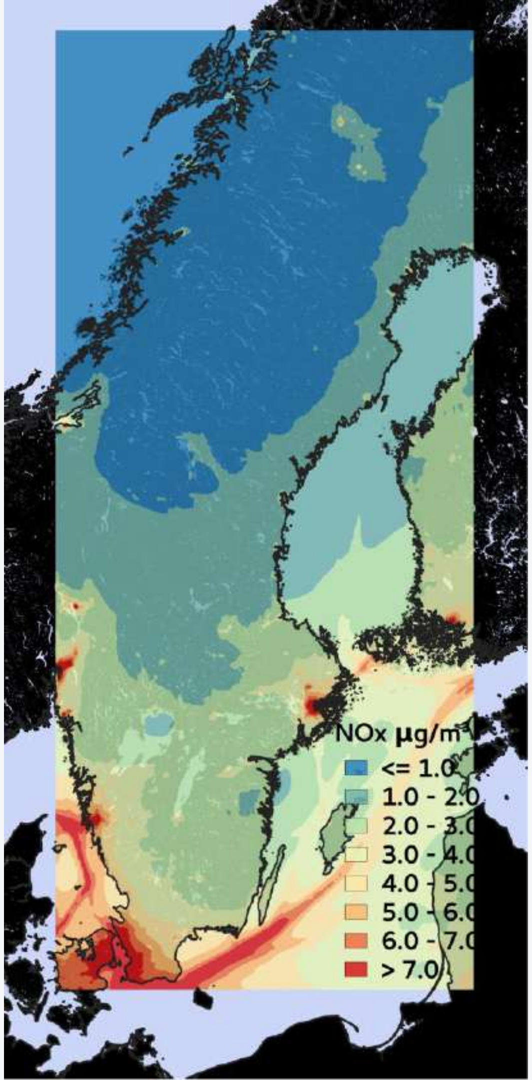
Road traffic

- Fleet composition based on statistics
- Traffic flow and share of heavy vehicles from measurements and modelling by Swedish road administration
- Emission factors from HBEFA (https://www.hbefa.net/e/index.html)



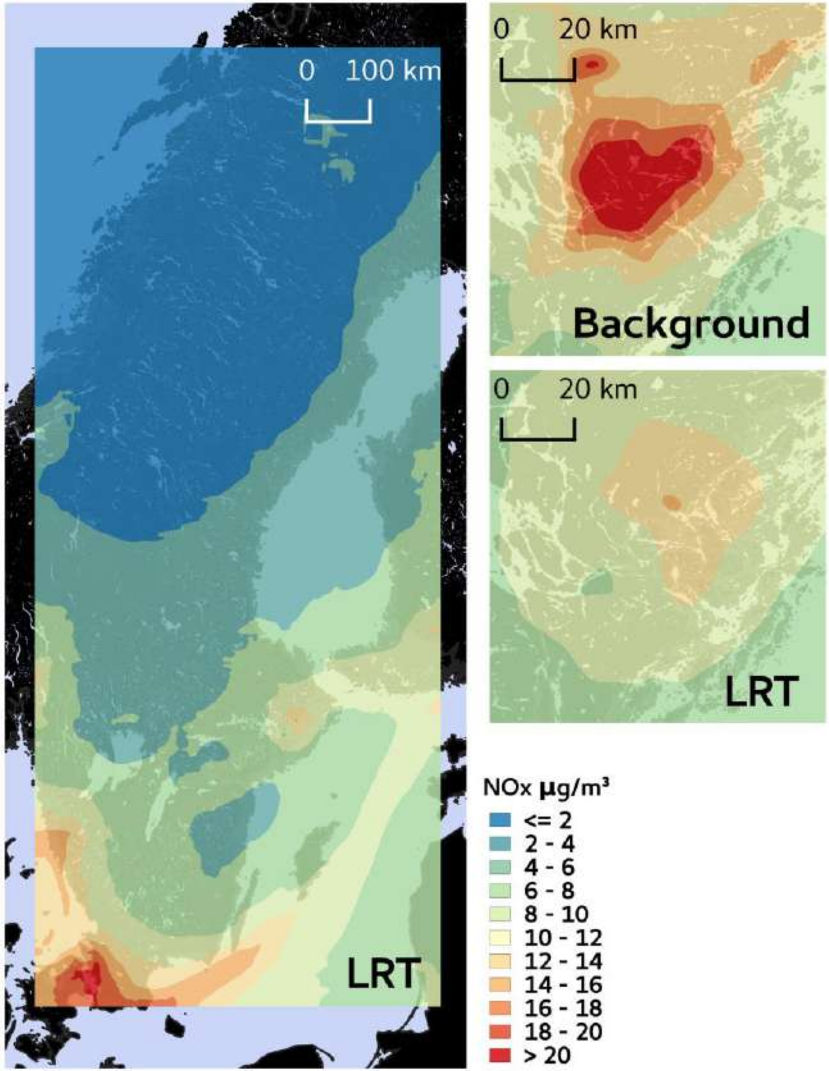
Regional background

- The MATCH (Multi-scale Atmospheric Transport and Chemistry) model
- Includes photo-chemistry, nitrogen and sulphur chemistry, aerosol dynamics (optional) and dry and wet deposition
- Bias correction
  - Estimate difference between measured and modelled daily average concentration at all regional background stations
  - Interpolate correction from daily to hourly
  - Grid the hourly bias-correction using Kriging



Long-range transport

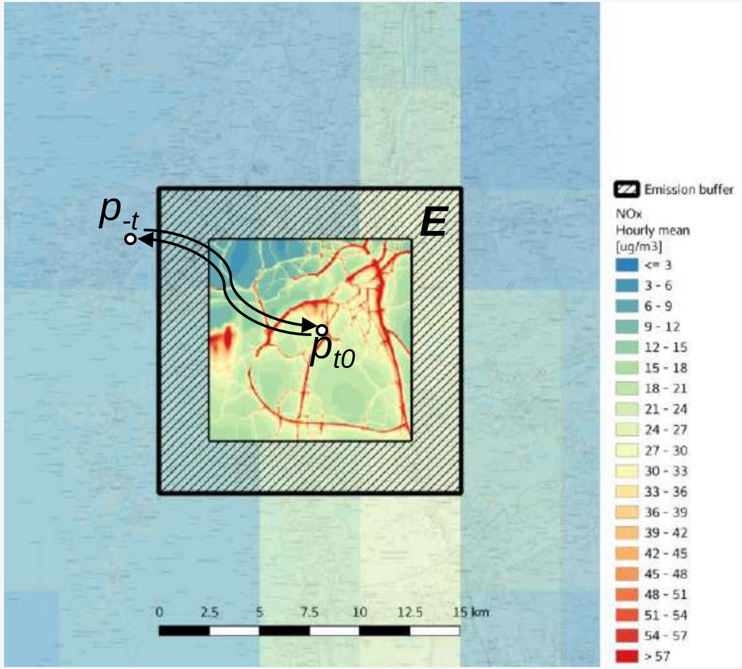
- Background calculated with MATCH includes contribution from local sources
- BUDD (Back-trace Upwind Diffuse Downwind), removes contribution from sources within a rolling window corresponding to a buffered local scale modelling domain



BUDD
- Backtrace Upwind Diffuse Downwind

Using 2 levels of hourly concentration and meteorological data at 5x5 km^2 resolution. For each grid cell at ground level:

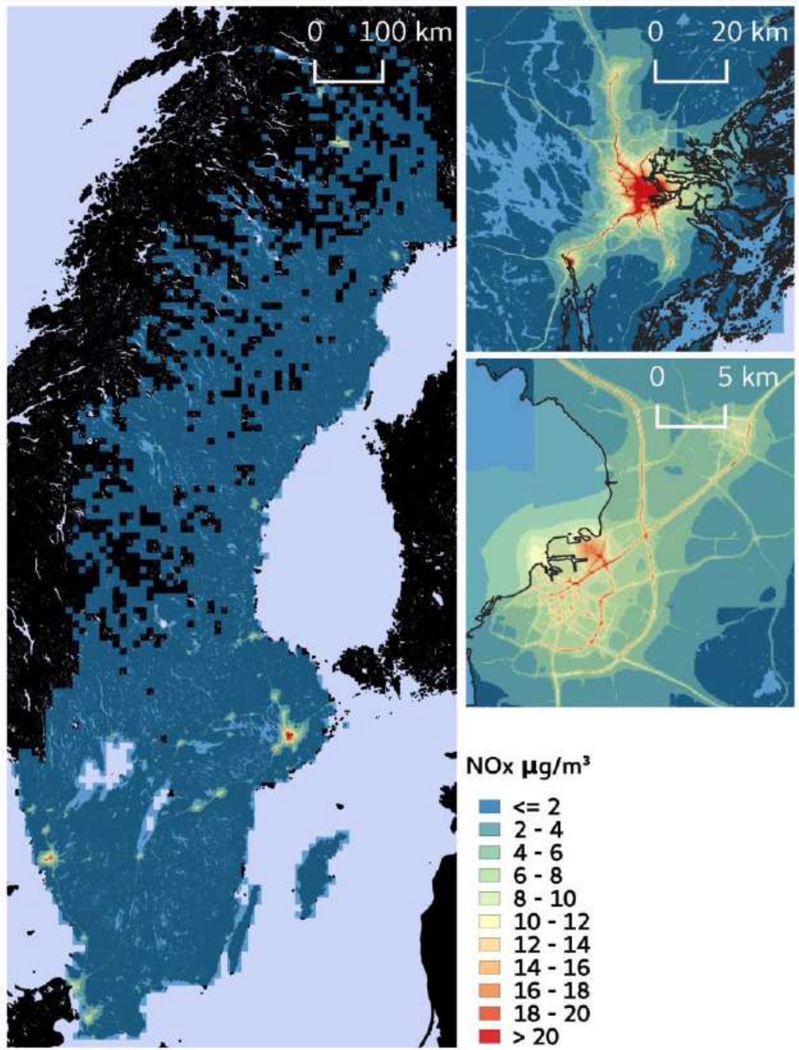
1. Back-trace air parcel upwind along trajectory for time ***-t***, until reaching outer edge of emission buffer ***E***.
2. At point p_{-t}, interpolate concentration in vertical column up to mixing height z_i.
3. Calculate diffusivity profile from ground to mixing height, depending on wind speed and atmospheric stability
4. Solve diffusion equation for vertical profile during transport time from p_{-t} to p_{t0}

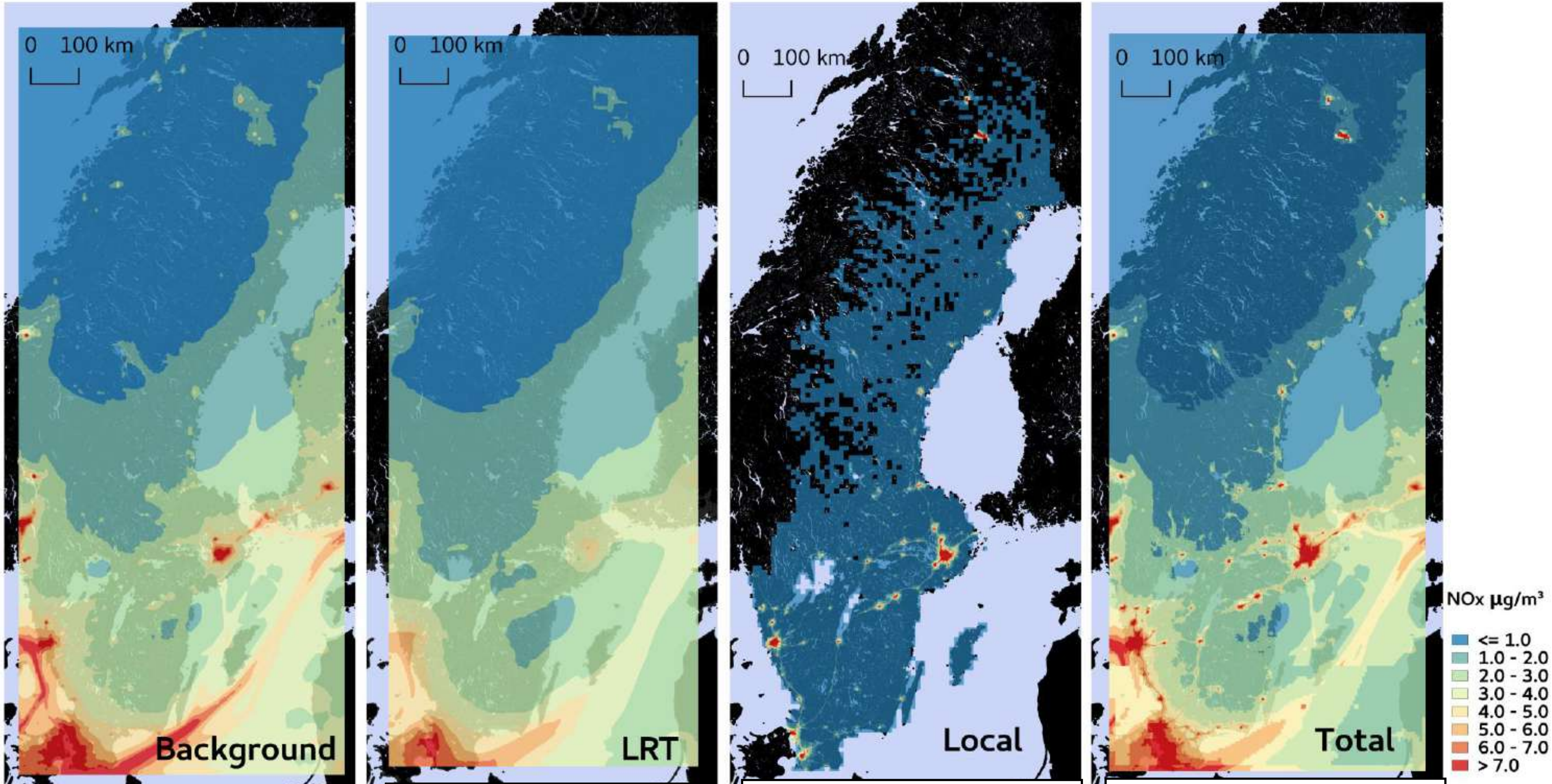


Local contribution

- Gaussian models within CLAIR[1] for point, area and road sources, valid within 20-30 km from source
- National domain divided into tiles (local domains)
- sources also included within a buffer of 15 km
- Local contribution = sum of contribution from road traffic, shipping, industry, residential heating, other sources

1. CLAIR, air quality modelling system used as basis for the national air quality modelling system SIMAIR





Bias-corrected concentration from MATCH CTM model at 5x5 km^2 resolution

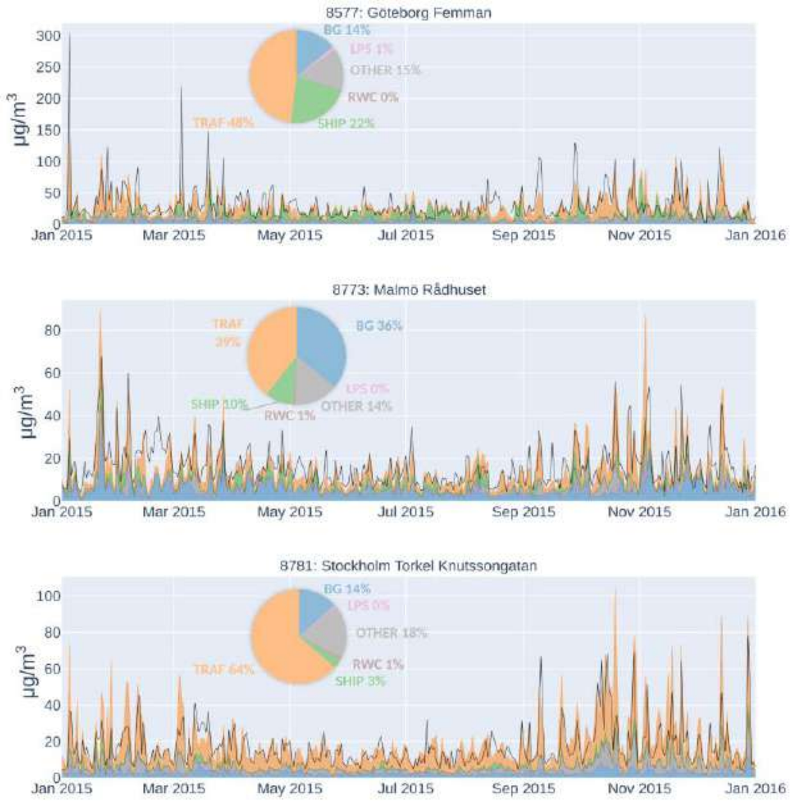
Local contribution at 5x5 km^2 resolution removed from background

Hourly local contribution from CLAIR at 100x100m^2

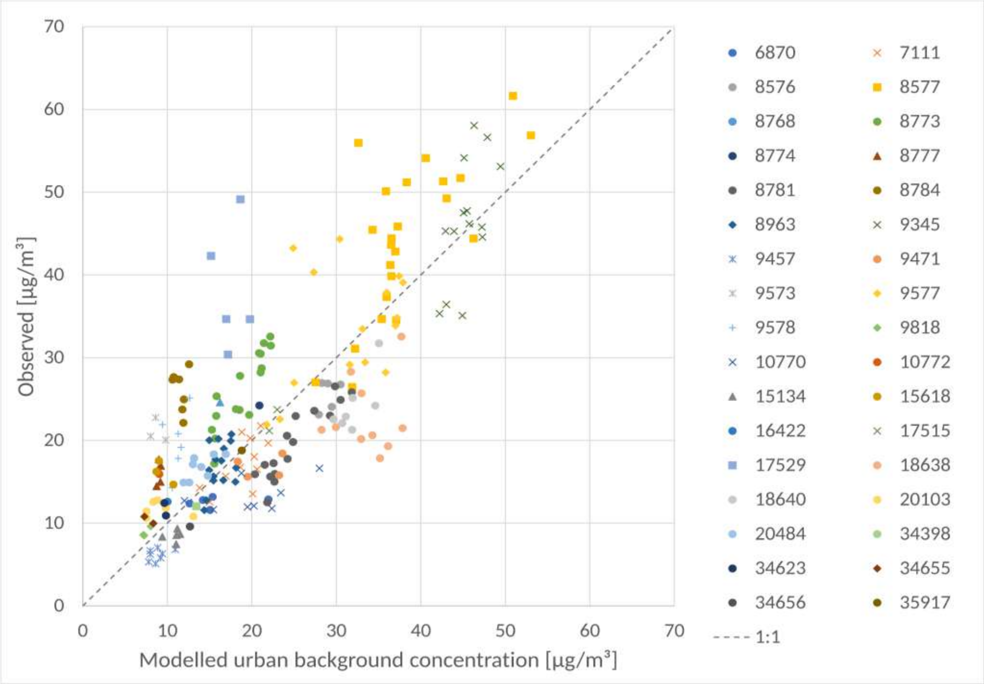
Yearly avg of total NOx during 2015 at 100x100m^2

Model evaluation

Source-specific contribution at urban background monitoring stations

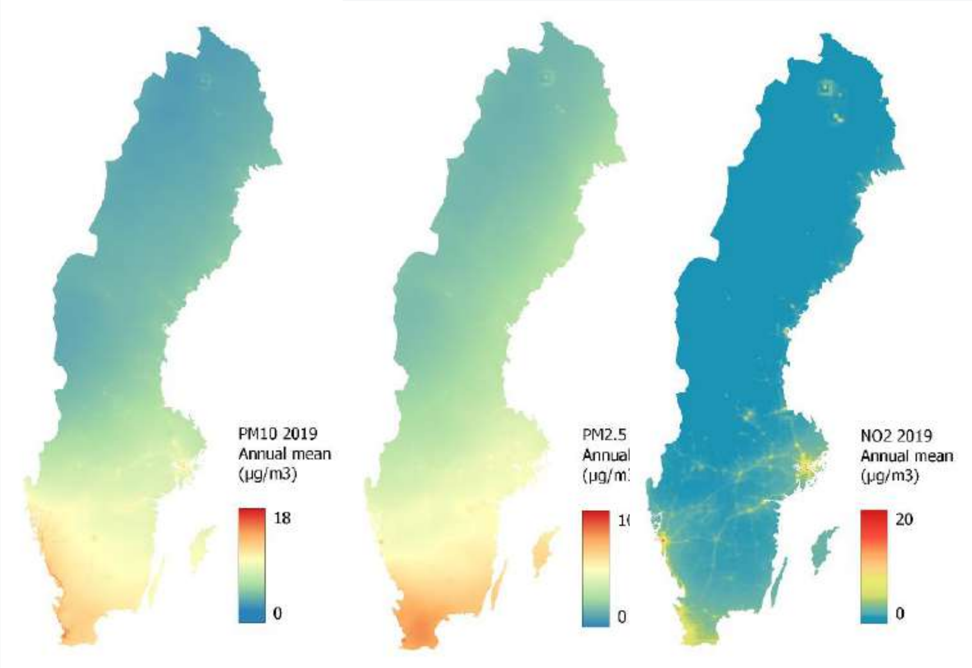


Measured vs model at urban background monitoring stations, daily mean NOx concentration



PM, NO2 and O3

- PM handled in a similar way, but with additional emission modelling for non-exhaust traffic emissions
- Urban NO_2 and O_3 calculated assuming photochemical steady-state, limited by turbulent mixing[1]



1. https://www2.dmu.dk/AtmosphericEnvironment/Docs/NO2scheme.pdf

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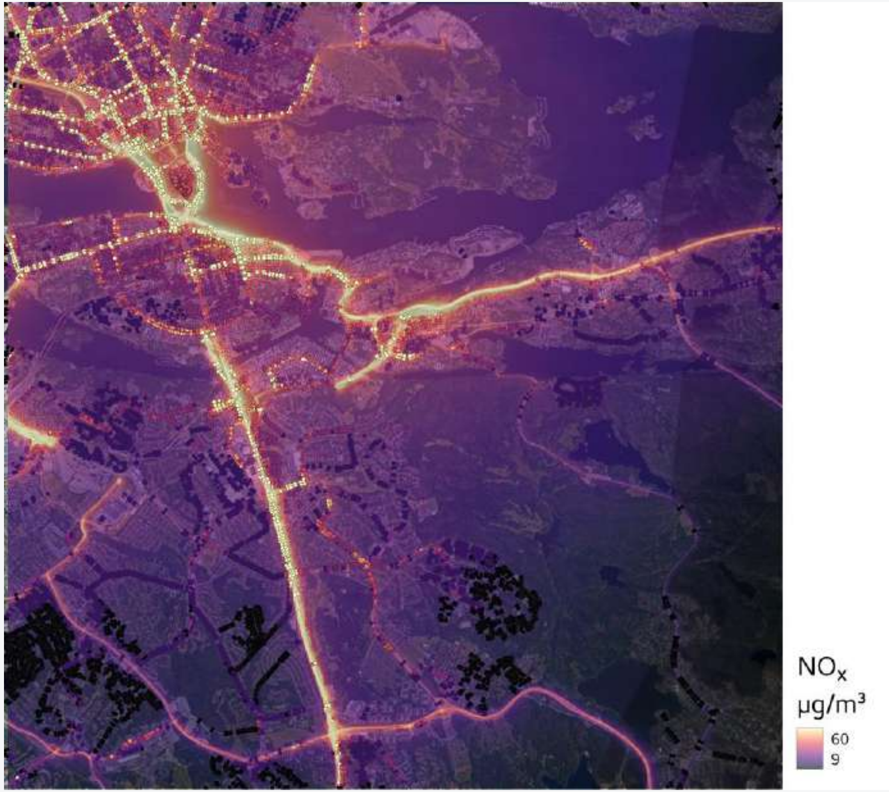
Premature mortality, Sweden 2019

Type of exposure	Estimate	95% LCL	95% UCL
Regional background PM2.5	3296	*2408*	*3566*
Urban small-scale residential heating PM2.5	433	*318*	*457*
Urban shipping PM2.5	80	*59*	*85*
Urban traffic exhaust PM2.5	79	*58*	*84*
Urban traffic non-exhaust PM2.5	122	*89*	*128*
Other urban sources PM2.5	254	*187*	*268*
Urban sources NO2	428	*213*	*841*
Total (urban sources)	4692 (1396)		

Street-canyon increment

- Estimate elevated concentration for all street-canyons
- Street-canyons with > 1k vehicles per day included
- One-way coupling of street-canyon model OSPM
- Including bias-correction at both regional and urban scale



Take-home message

- Number of premature deaths due to locally emitted PM probably underestimated in many studies – **raises more concern to reduce PM emissions in our cities**
- Calculating **near-source and long-range exposure separately** allows us to apply different relative risks when assessing health impacts
- There are methods that allow **almost seamless combination of regional scale chemistry transport models and local scale models –** allowing large scale mapping of air quality with high spatial resolution

Thank you