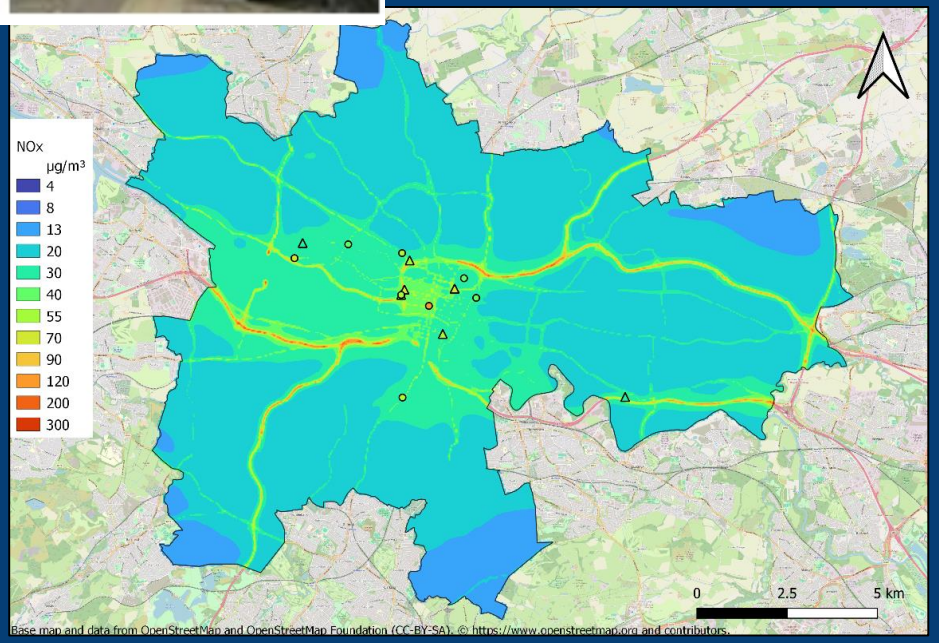


Application of inverse air quality modelling techniques to a sensor network in Glasgow

Amy Stidworthy, Andrea Di Antonio, David Carruthers, George McCosh, Rod Jones, Lekan Popoola (University of Cambridge), Jim Mills (Scotswolds), Ilaria Thibault (Vodafone)

AQE Show, 9-10 October 2024

Cambridge Environmental Research Consultants

CERC

- SME based in Cambridge
- Experts in air quality since 1985
- Managing Director is Dr David Carruthers, previous member of AQEG
- Around 20 technical staff with science / maths / engineering backgrounds

Activities

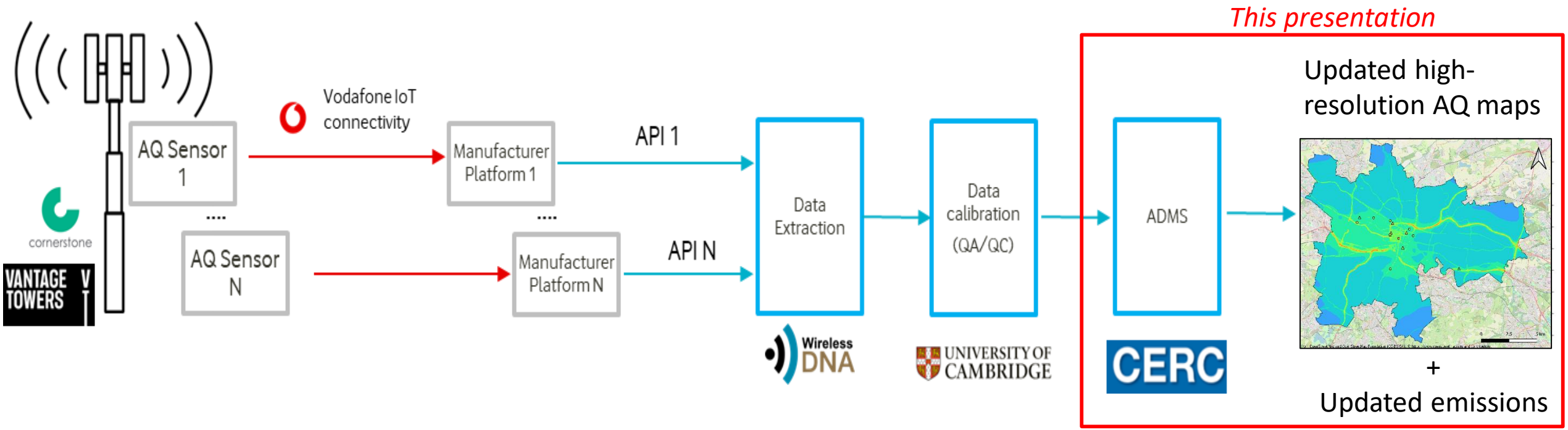
- ADMS model development
- ADMS model licensing, support and training
- Air quality consultancy (EIA, AQM, Permitting)
- Research projects
- Air quality forecasting (London, Manchester, York, Riga (Latvia) and Klang (Malaysia))

Clients

- Academic institutions
- Local authorities
- National government and agencies (e.g. Defra, Met Office, EA, ADMLC)
- Commercial air quality consultancies
- Industry operators
- NGOs

Background

In the ‘Network as a Sensor’ project, CERC developed a system that automatically assimilates sensor concentration data with CERC’s ADMS-Urban dispersion model to deliver 10 metre resolution, calibrated, pollution maps for Glasgow City Centre, and updated emissions based on measurements



Thibault I, Jones R, Mills J, Popoola O and Stidworthy A, 2023: The suitability of a mobile communications network to deliver high-resolution air quality measurements. Envirotech Online, September 2023.

ADMS-Urban: CERC's Atmospheric Dispersion Modelling System

meteorological data

emissions / activity data (including traffic flows)

source data

background concentrations

time-varying emission profiles

ADMS-Urban

- dispersion
- met. pre-processor
- regional model link
- chemistry
- deposition
- street canyons
- urban canopy
- tunnels
- elevated roads
- buildings
- complex terrain

high resolution pollution maps

annual averages, exceedences, percentiles, hourly means

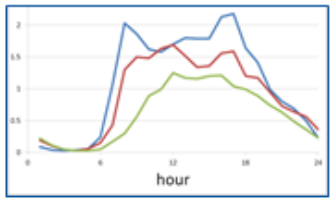
comparison with monitoring data

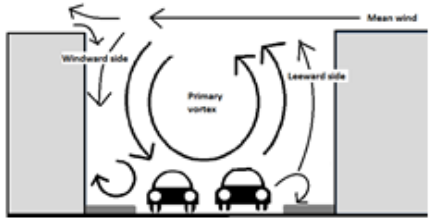
comparison with air quality standards

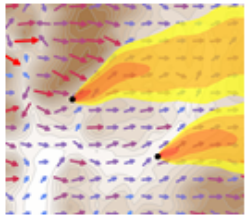
source apportionment, footprints

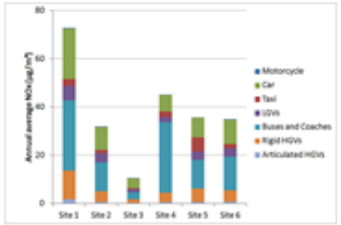
future scenarios

traffic management



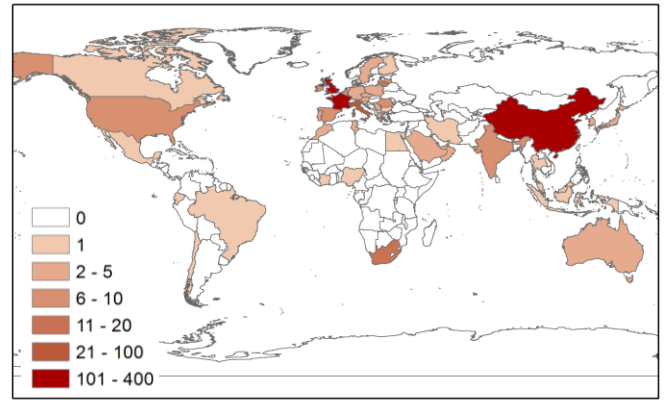






Hundreds of ADMS licences worldwide

Organisations using ADMS per country



Widely used by…

- Companies
- Regulatory bodies
- Local government
- National government
- Research organisations

Provided with…

- Professional Helpdesk Service
- Training (online available)
- Detailed user documentation

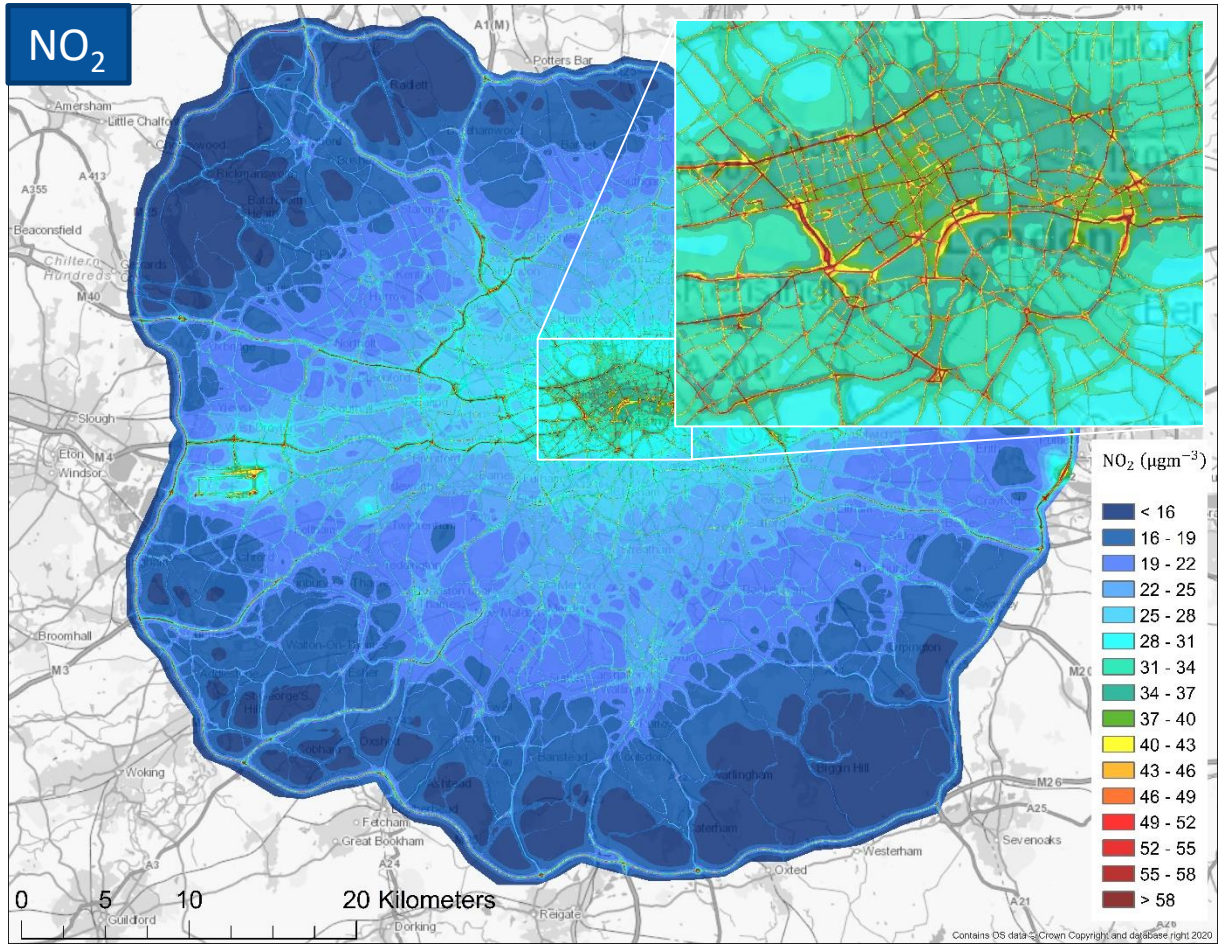
CERC

www.cerc.co.uk/ADMS-Urban

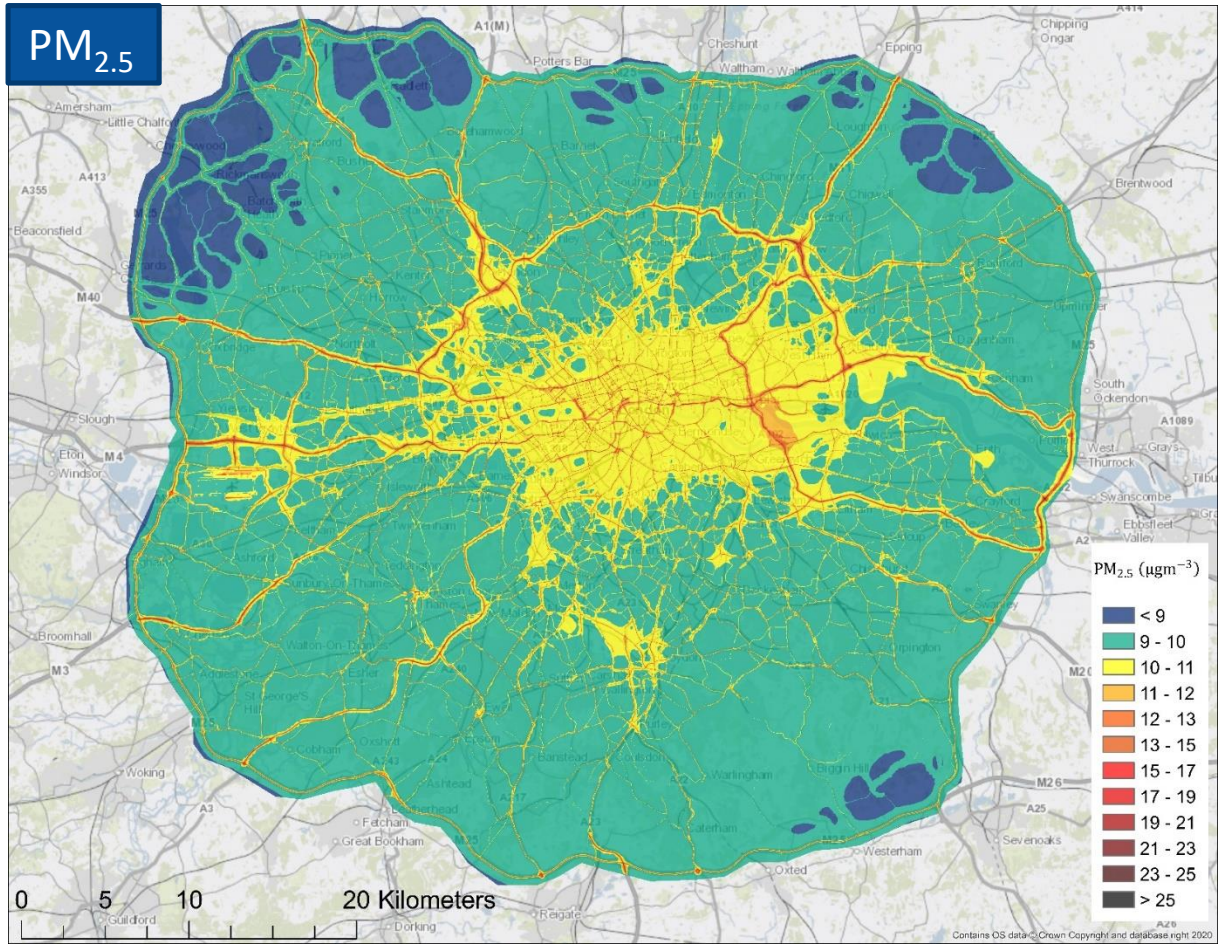
AQE Show, 9-10 October 2024

Example ADMS-Urban pollution maps

Modelled air pollution in London in 2019 with a resolution of 10 metres



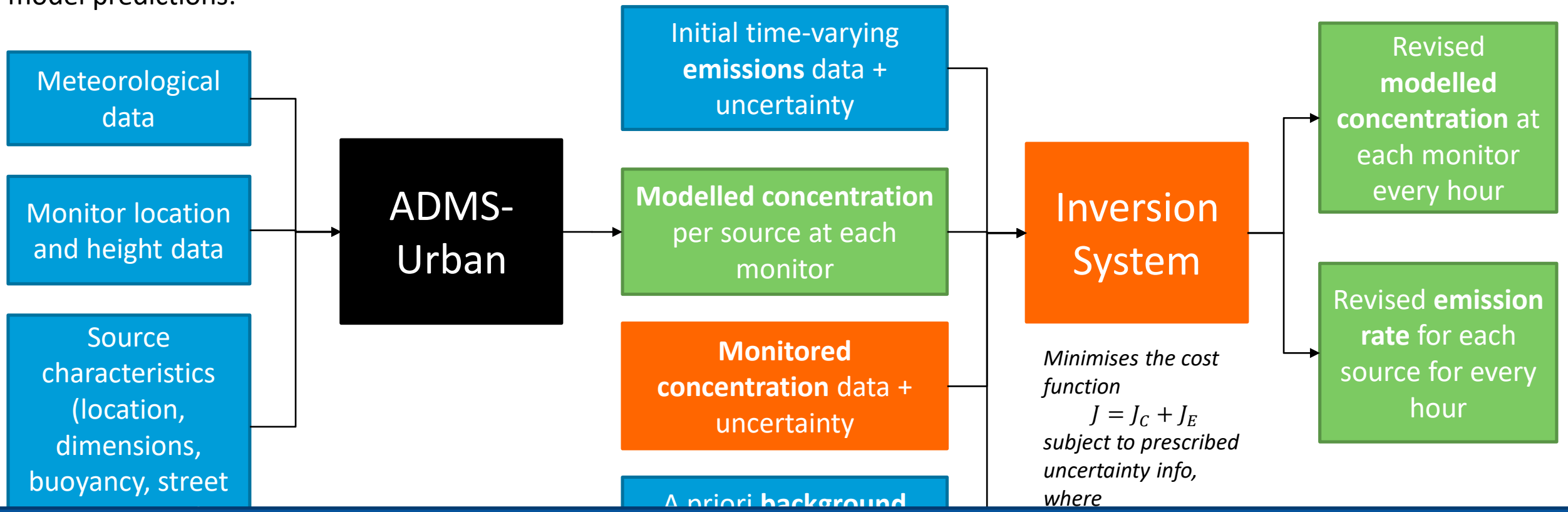
Area coloured yellow, orange and red exceeds UK annual objective of 40 µg/m³ for NO_2



Area coloured yellow, orange and red exceeds WHO guideline of 10 µg/m³ for $PM_{2.5}$

CERC Inversion System: Overview

The inversion scheme uses monitoring data from a network of monitors/sensors to adjust emissions to reduce error in the model predictions:

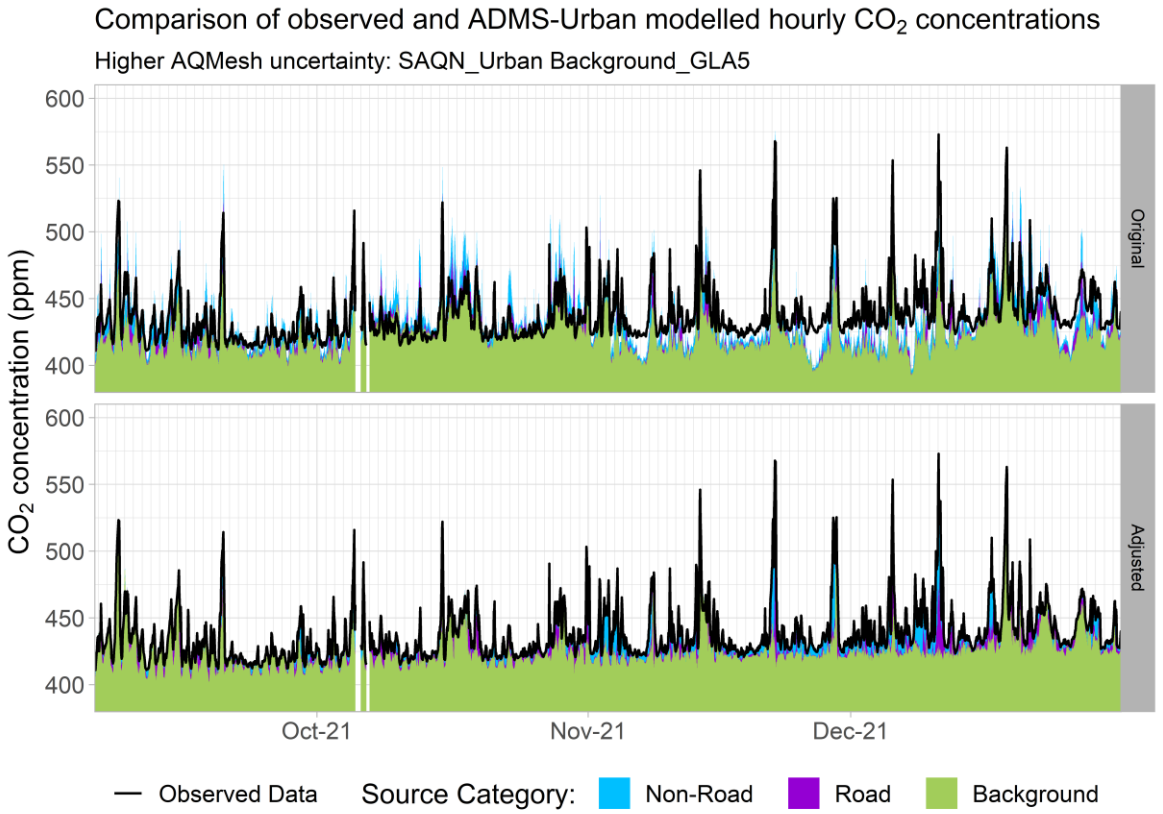


+ Time covariance:

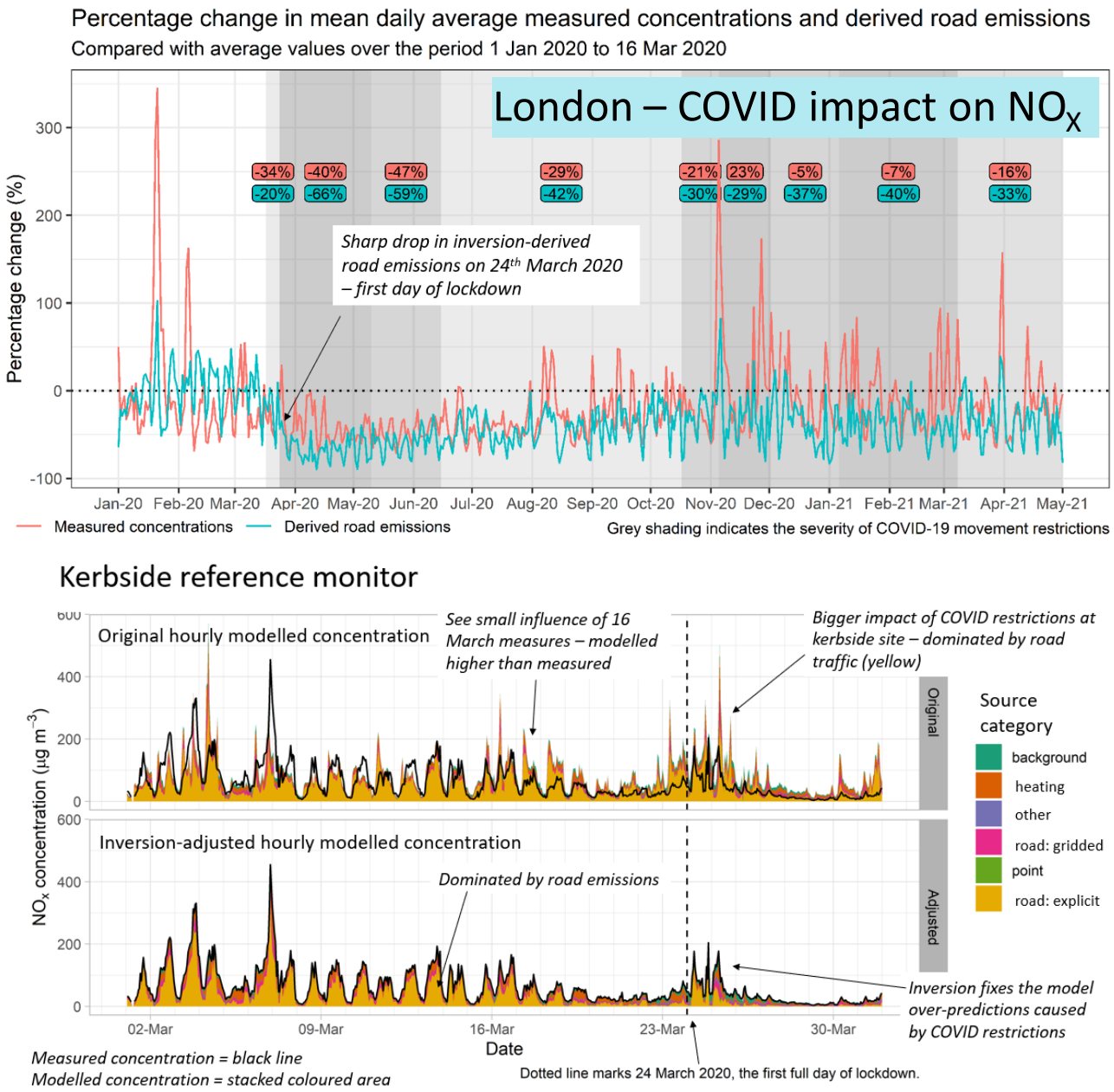
- Hours on the *same weekday* and at the *same time of day* over a *3-week period* are treated as co-varying
- Means that for each calculation hour, modelled concentrations and measurements from 3 hours are included: the calculation hour, 1 week before and 2 weeks before.
- System allows for 'break dates' and 'unusual dates': events that disrupt the covariance, such as bank holidays

Example inversion results from other projects

Glasgow CO_2 (previous project – presented at AQE 2022)



… Plus recent research projects for the Environment Agency using this technique to estimate methane emissions



CERC

Glasgow Vodafone Network as a Sensor measurement network

Greenfield

Streetworks

PoC 1 Test Site

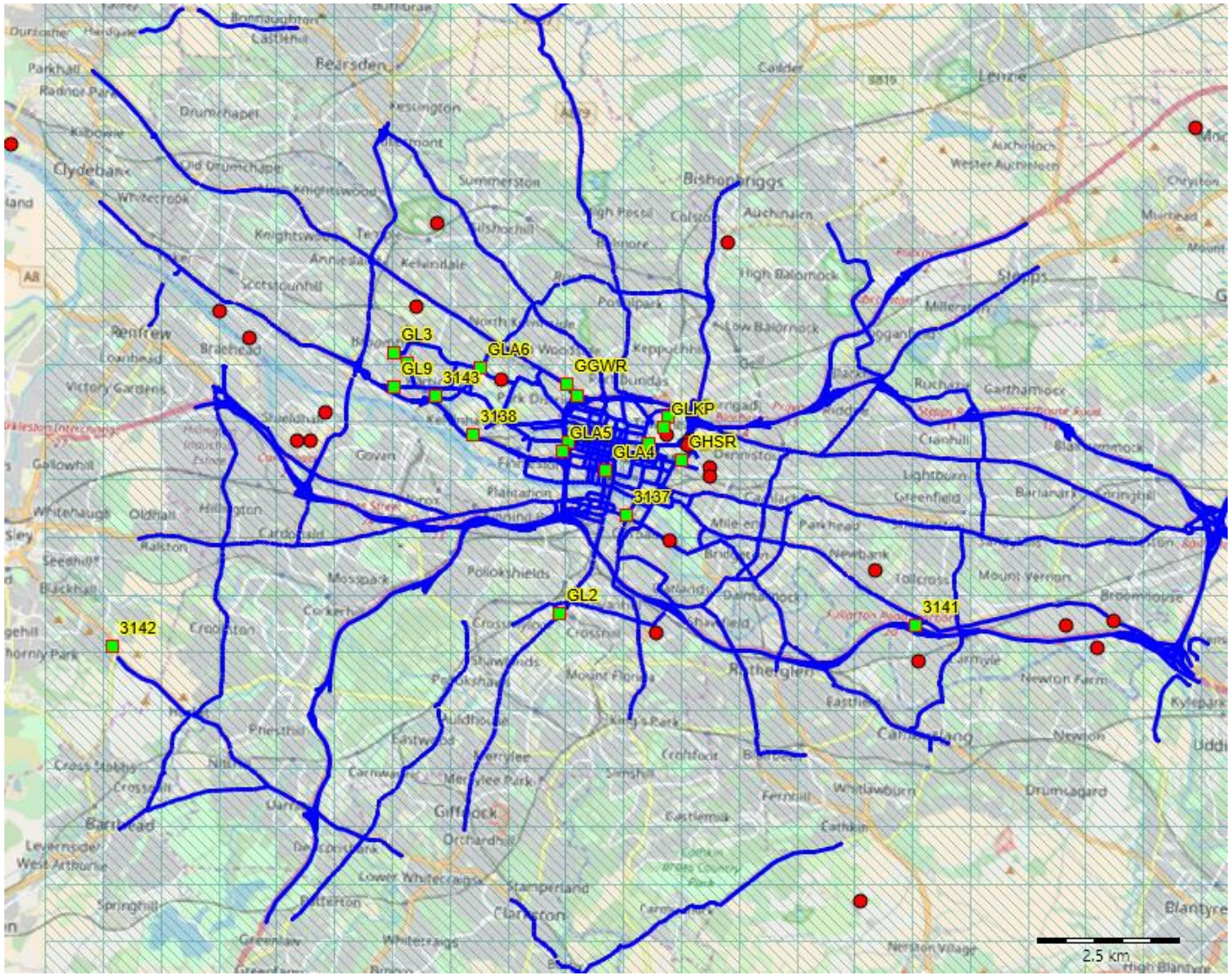
Reference Sites

Network of 16 sensors across 11 sites

9 existing council-operated reference sites

CERC

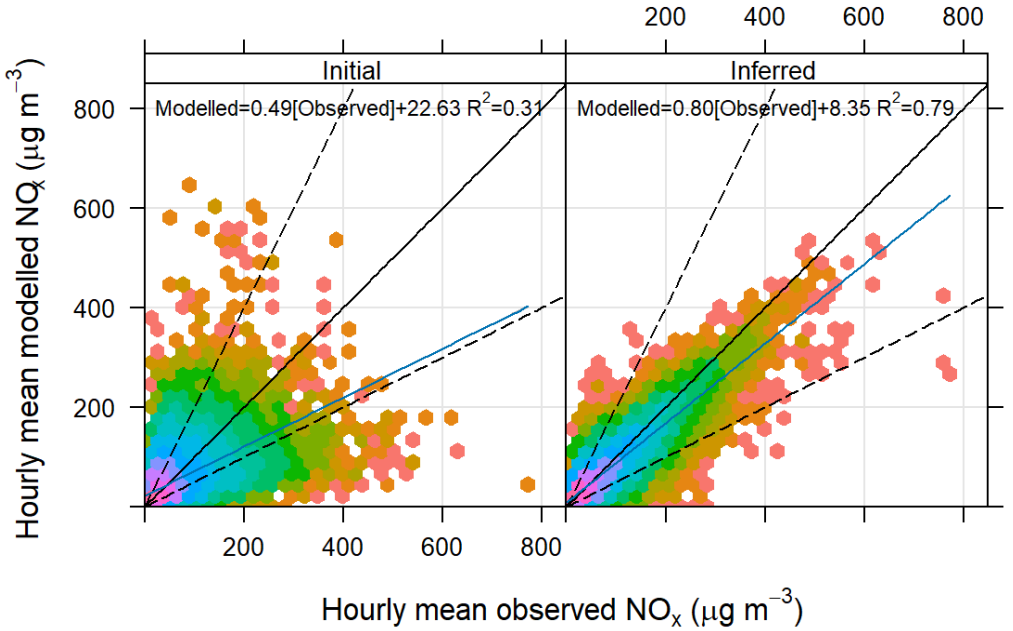
ADMS-Urban modelling for Glasgow

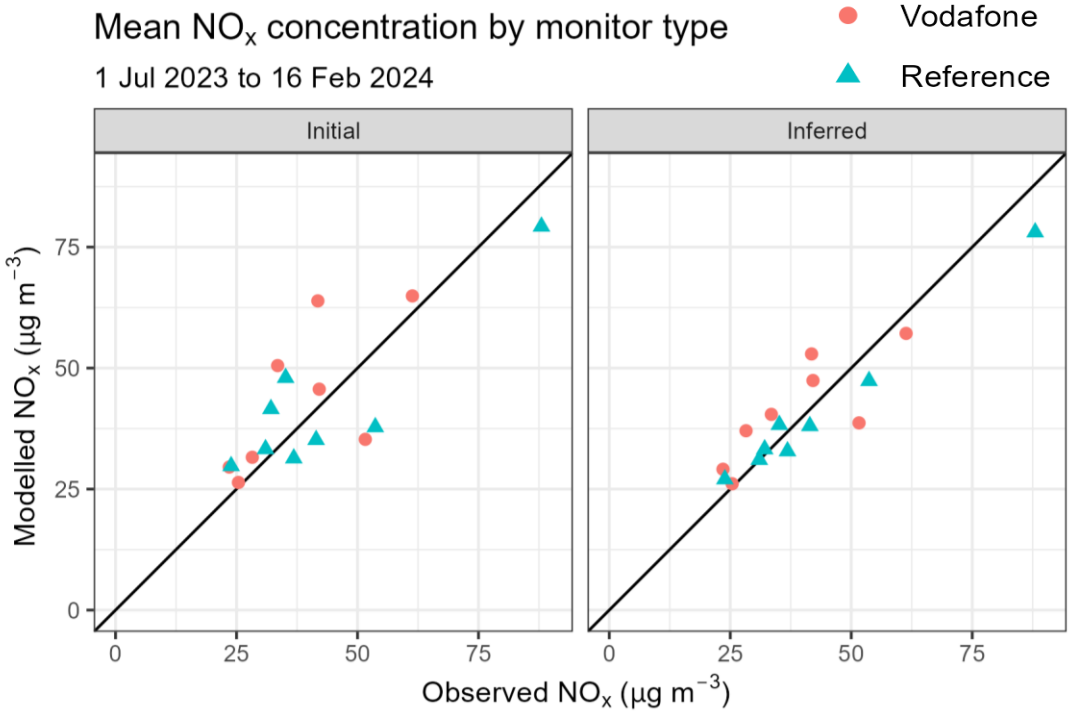


- Modelled using CERC's ADMS-Urban
- 2948 road sources (blue lines)
- 48 point sources (red dots)
- 494 1km x 1km grid sources (hatched squares)
- 26 monitoring sites (reference and Vodafone sensors) (green squares)
- Emissions from NAEI for 2021, with real-world adjustments applied to NOx and PM, traffic flows from 2017/2019
- Street canyons
- Time varying road traffic emissions profiles
- Meteorology from the Glasgow Bishopton met site
- Background PM from Auchencorth Moss; NO_2, NO_x and O_3 from Bush Estate; CO2 from baseline sensor data

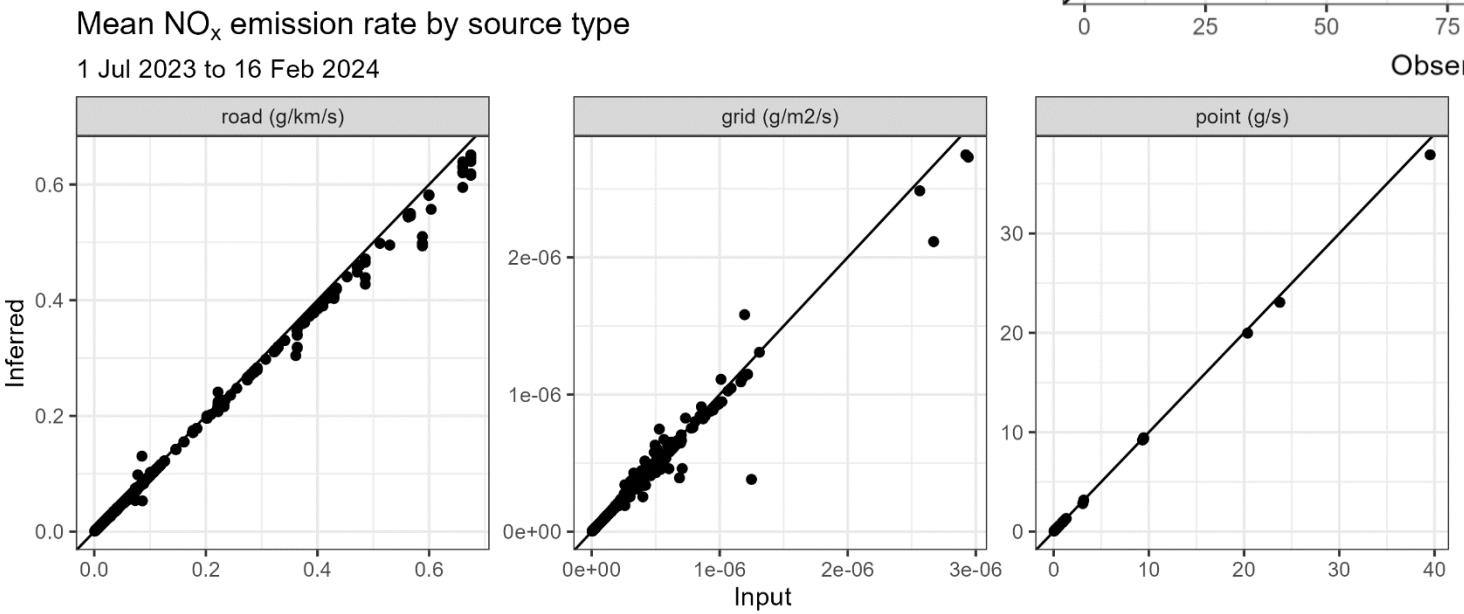
Inversion results: NO_x

Concentrations at monitoring sites

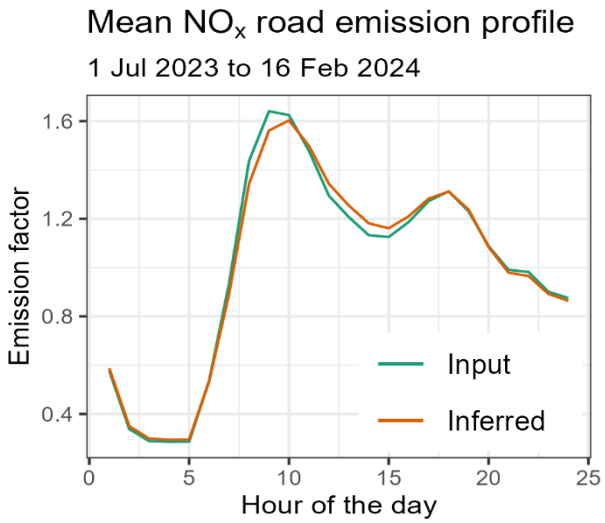




Average emission rate changes by source type



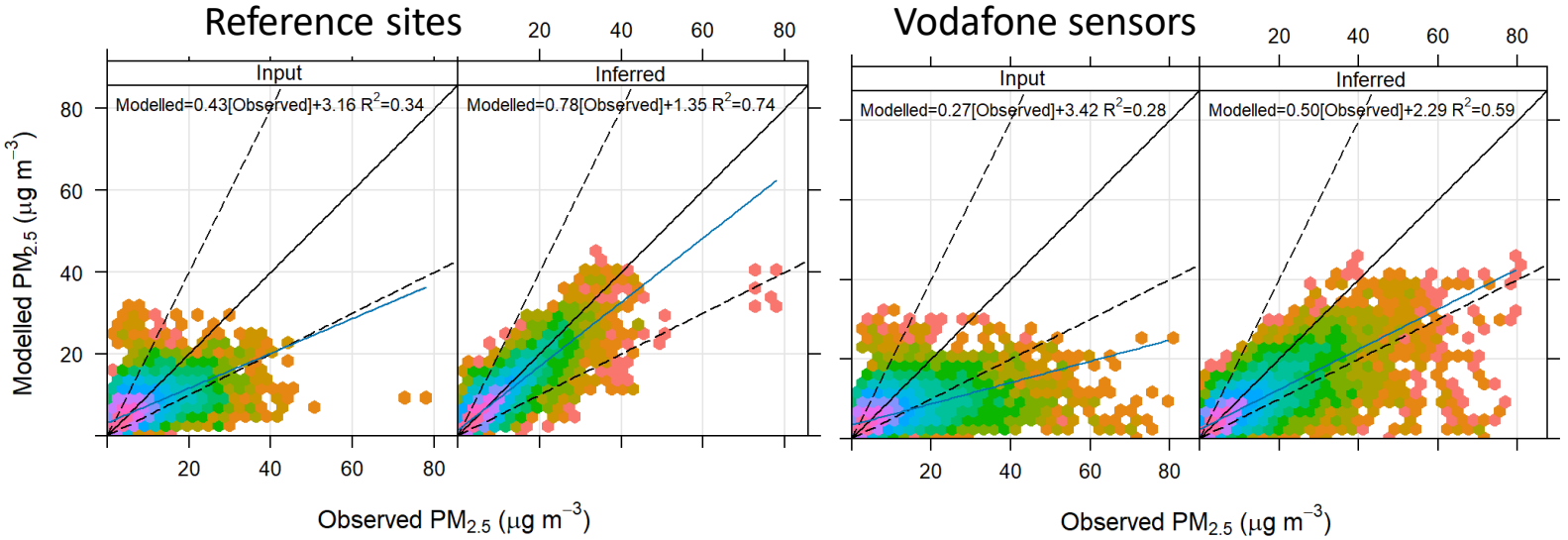
Average changes:
Roads -3.0%
Grids -2.1%
Points -0.6%

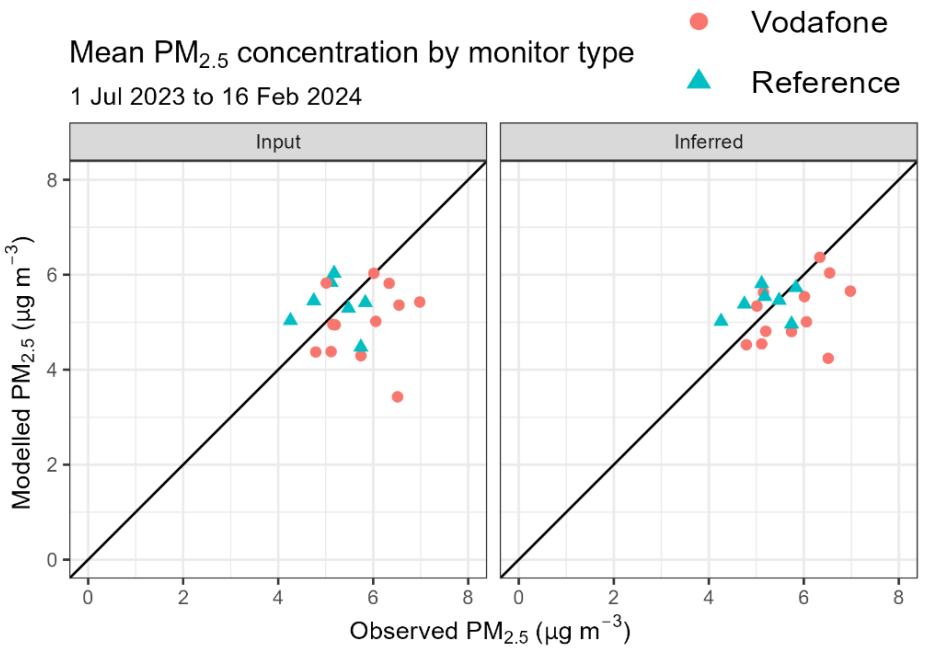


CERC

Inversion results: $PM_{2.5}$

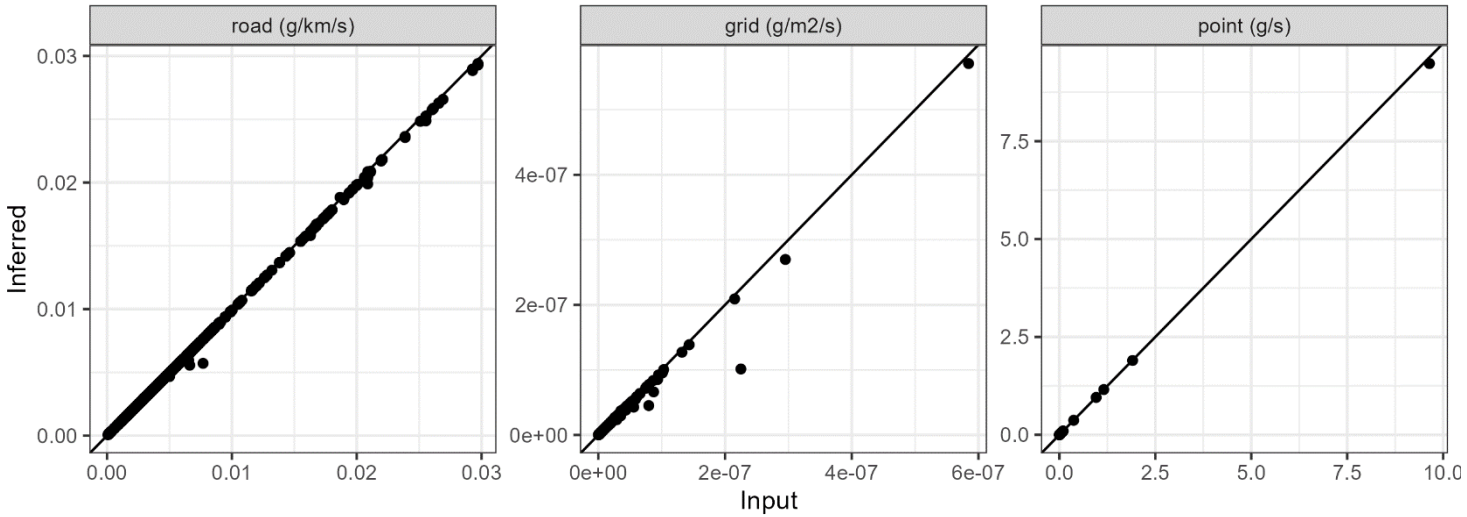
Concentrations at monitoring sites





Mean $PM_{2.5}$ emission rate by source type

1 Jul 2023 to 16 Feb 2024



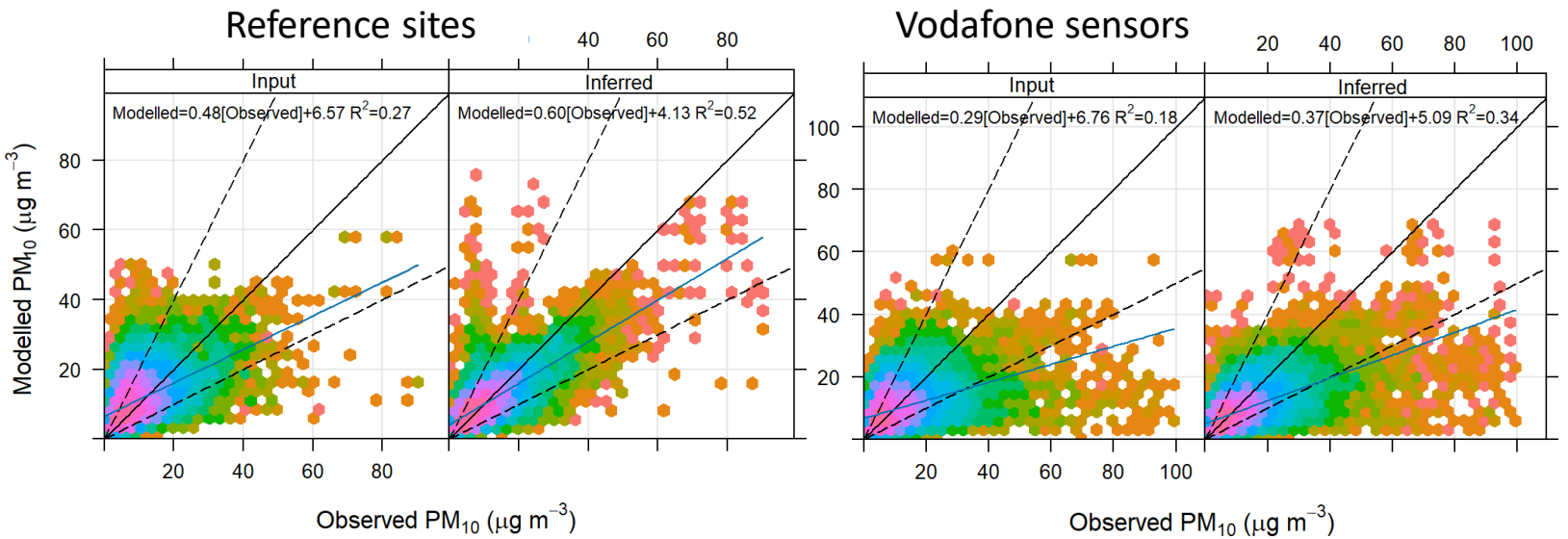
Average emission rate changes by source type

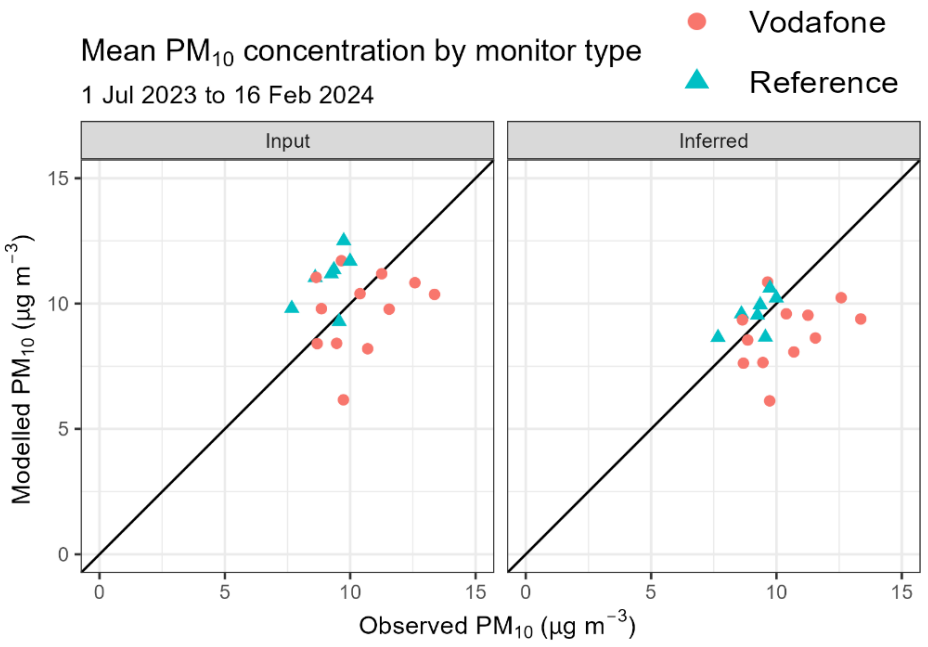
Average changes:
Roads -1.0%
Grids -3.1%
Points -0.1%

CERC

Inversion results: PM_{10}

Concentrations at monitoring sites

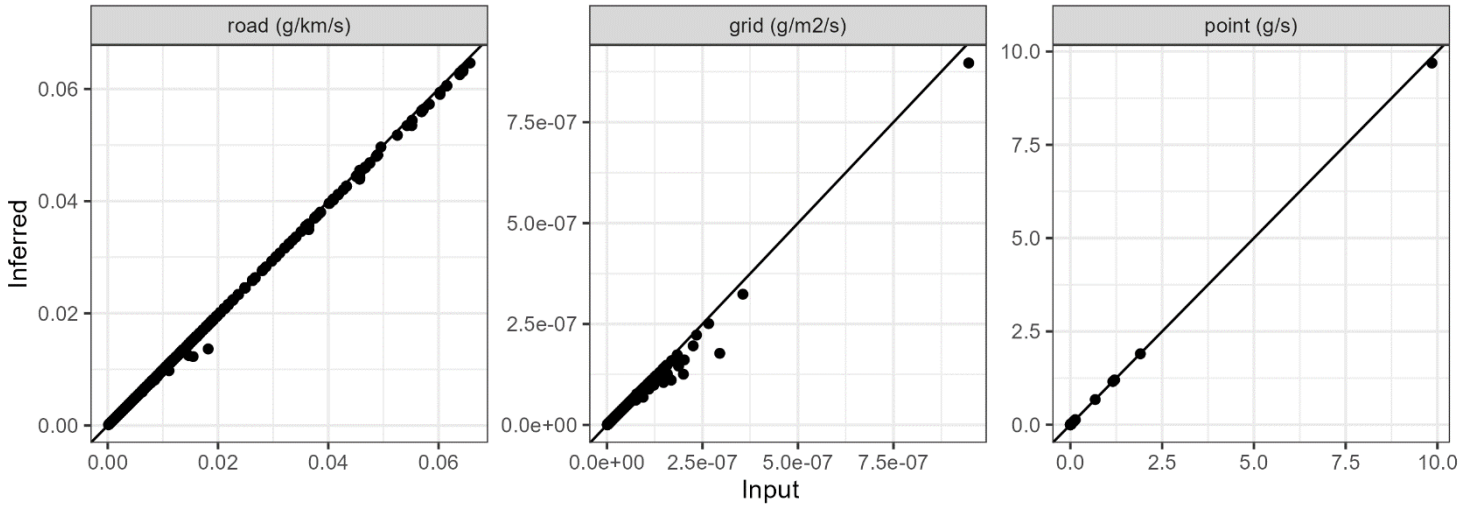




Mean PM_{10} emission rate by source type

1 Jul 2023 to 16 Feb 2024

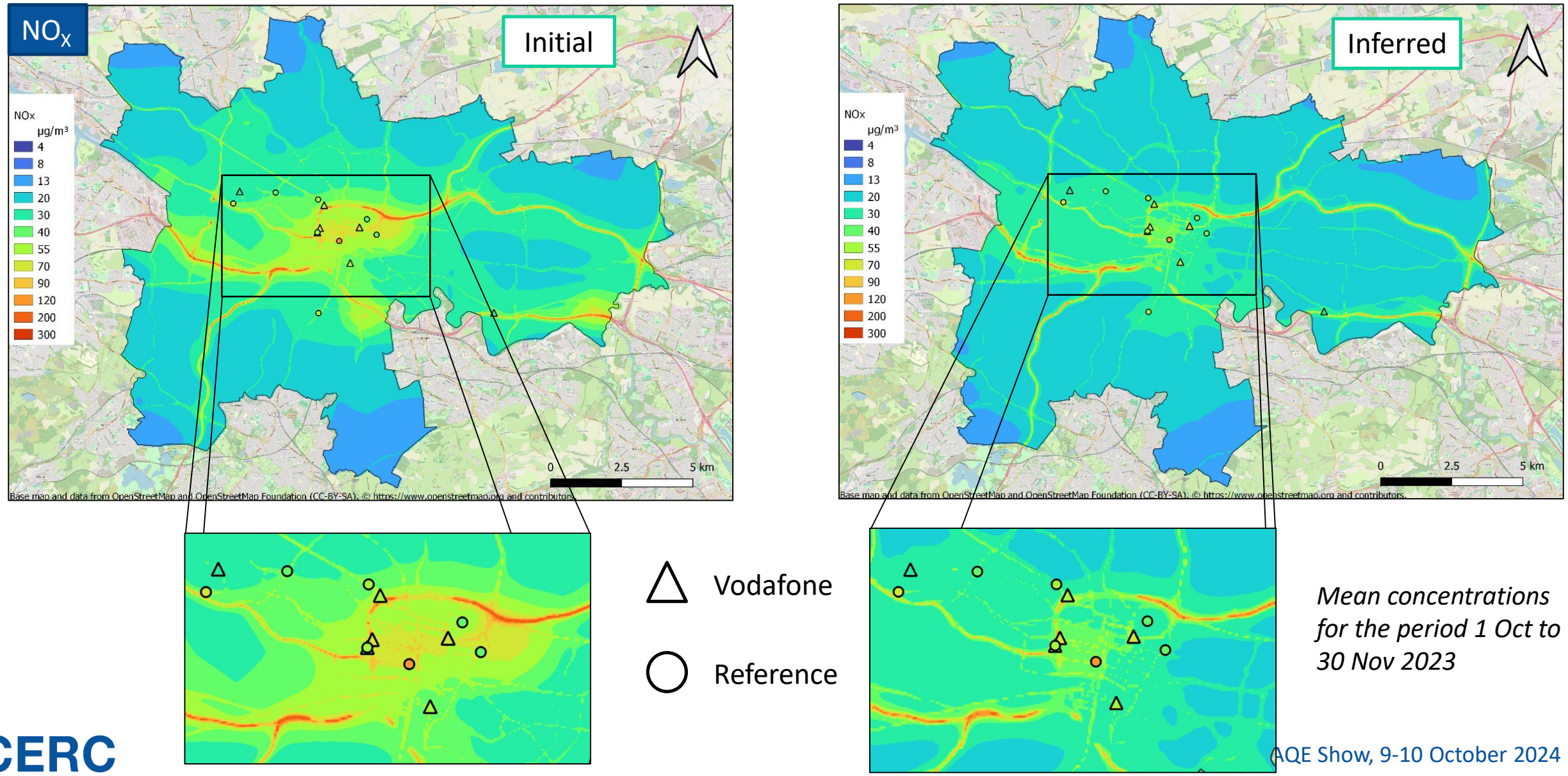
Average emission rate changes by source type



Average changes:
Roads -1.4%
Grids -5.8%
Points -0.1%

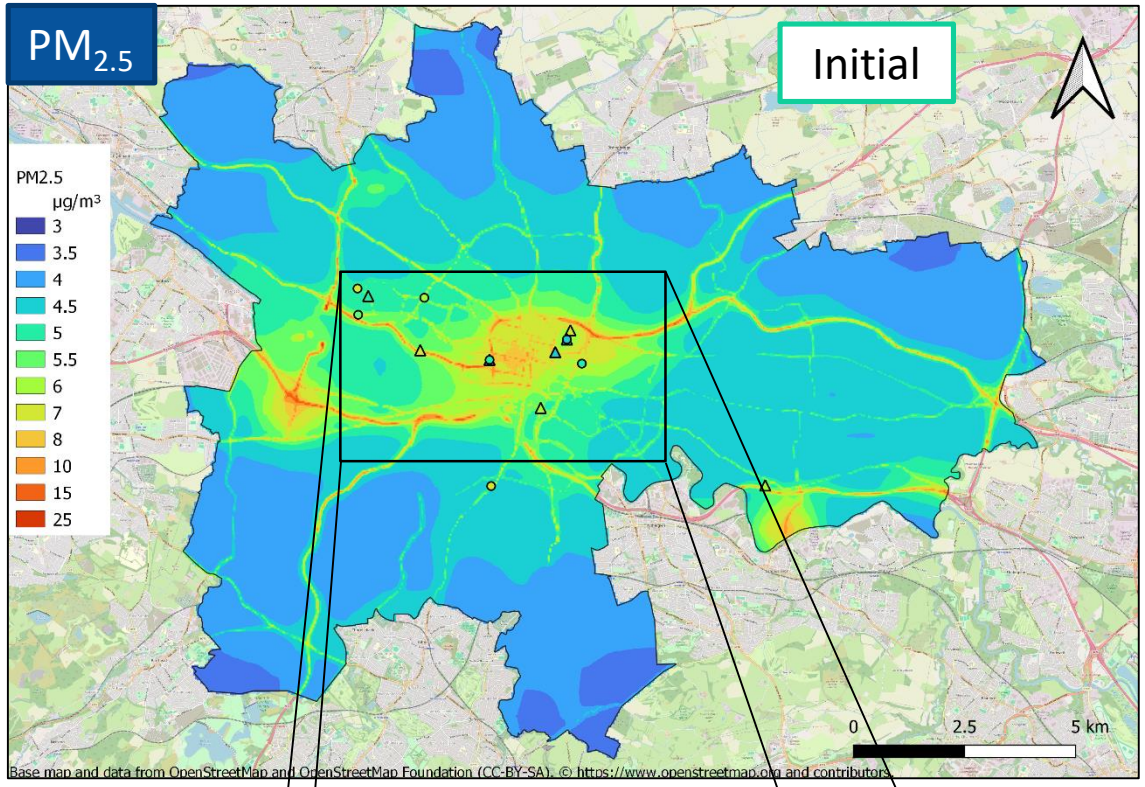
CERC

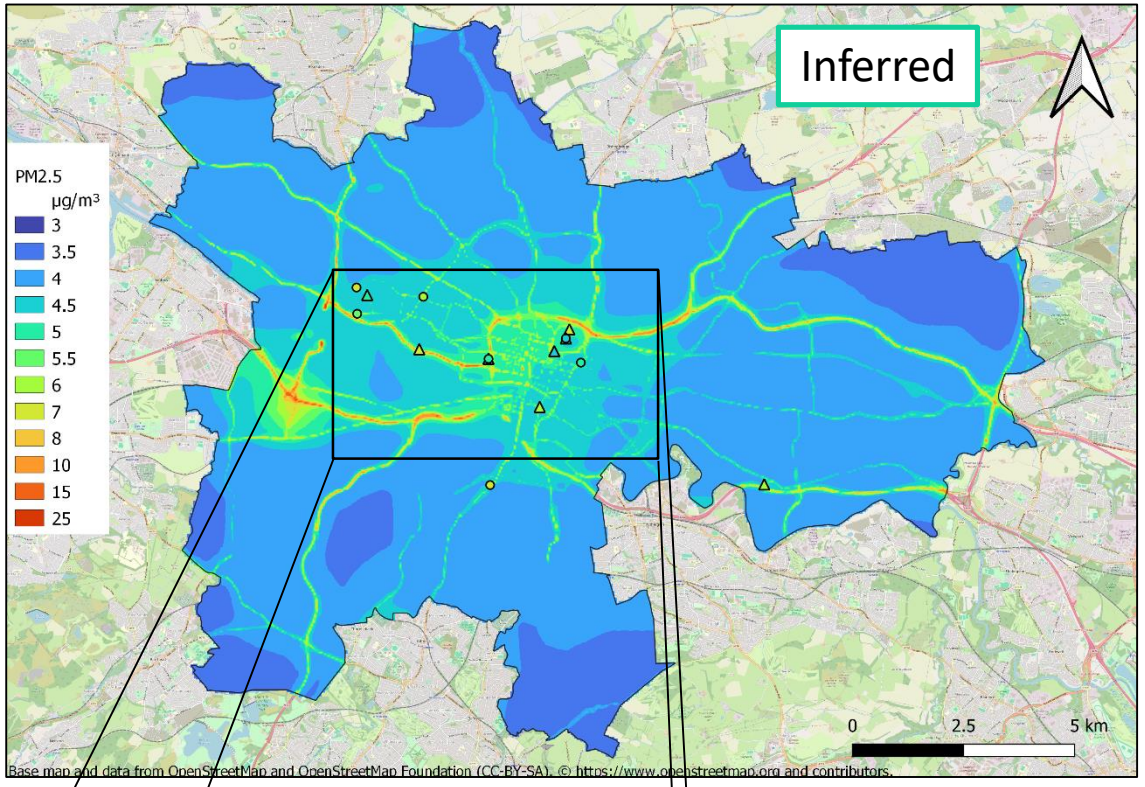
Inferred maps combine model and measurements: NO_X

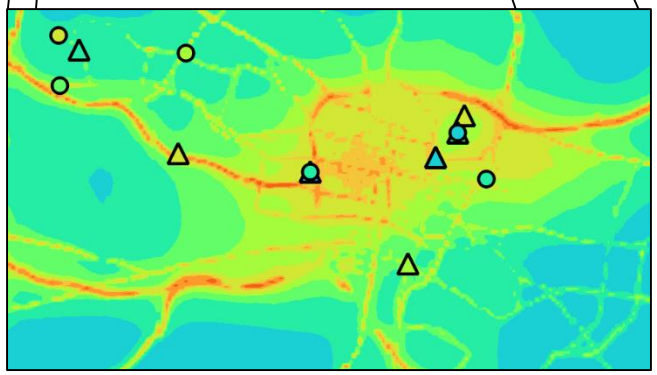


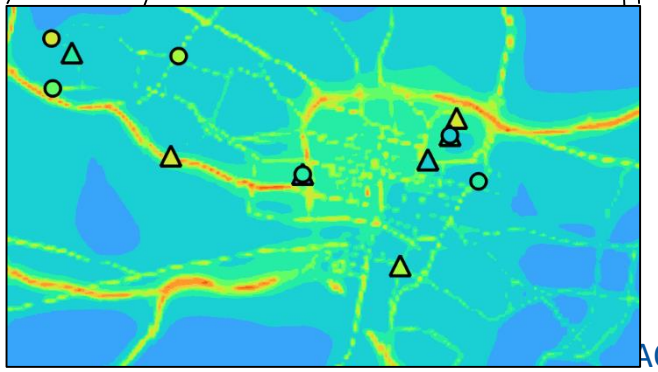
Mean concentrations for the period 1 Oct to 30 Nov 2023

Inferred maps combine model and measurements: $PM_{2.5}$







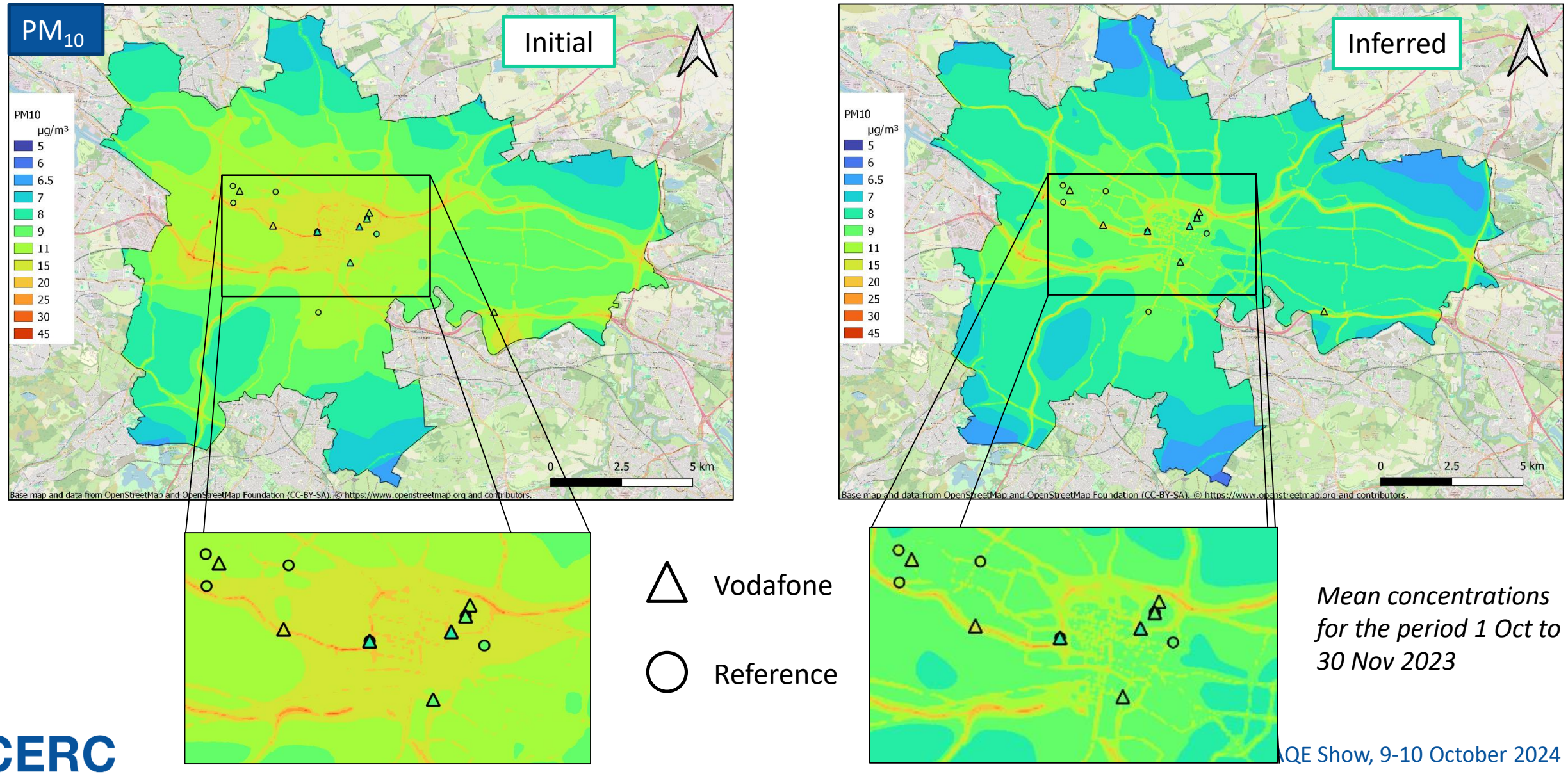


△ Vodafone

○ Reference

Mean concentrations for the period 1 Oct to 30 Nov 2023

Inferred maps combine model and measurements: PM_{10}



Mean concentrations for the period 1 Oct to 30 Nov 2023

Summary

- Sensor measurements from the Vodafone network and reference monitors have been combined with the ADMS-Urban model using advanced inversion techniques
- The system extracts maximum information from low cost sensors while accounting for higher measurement uncertainties compared with reference monitors
- The updated emissions inventories were fed back into ADMS-Urban to produce updated high resolution AQ maps
- Results for Glasgow suggest that NO_X, PM_{10} and $PM_{2.5}$ road emissions were around 2 - 5% lower, on average, during the 2023/4 study period than the input emissions inventory, which used NAEI 2021 and road traffic flows from 2017/19. This is likely partly due to the low emissions zone introduced in Glasgow city centre on 1 June 2023.

Next steps…

- Greenhouse gases project with Cambridge University:
  - Developing the inversion system from an internal research tool into a practical tool for modellers (AQ and GHG)
  - Application of the tool to CO_2 emissions from a farm in Cambridgeshire, using sensor measurements
  - CH_4: Investigative study into the trade-offs between monitoring network density and monitor accuracy: how many sensors is enough to quantify emissions accurately?

Thank you for listening

Amy.stidworthy@cerc.co.uk

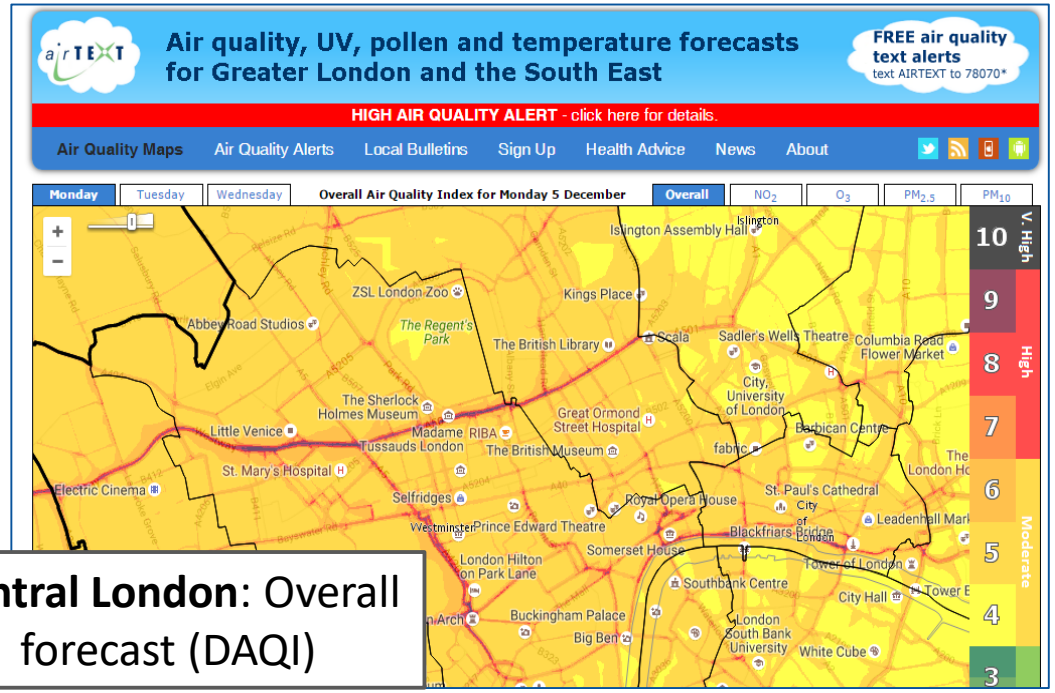
Inverse Modelling Approach for Glasgow

- Road emissions uncertainty: 50%; Road emissions covariance = 5%
- Grid emissions uncertainty: 100%; Grid emissions covariance = 10%
- Point emissions uncertainty: 50%; Point emissions covariance = 0%
- Background uncertainty: 2 $\mu g\ m^{-3}$
- Measurement uncertainty:
  - NO_X: Reference = 8 $\mu g\ m^{-3}$; Vodafone = 24 $\mu g\ m^{-3}$
  - $PM_{2.5}$: Reference = 2 $\mu g\ m^{-3}$; Vodafone = 4 $\mu g\ m^{-3}$
  - PM_{10}: Reference = 4 $\mu g\ m^{-3}$; Vodafone = 8 $\mu g\ m^{-3}$

Local AQ forecasting and alert services using ADMS-Urban

London airTEXT (since 2007)

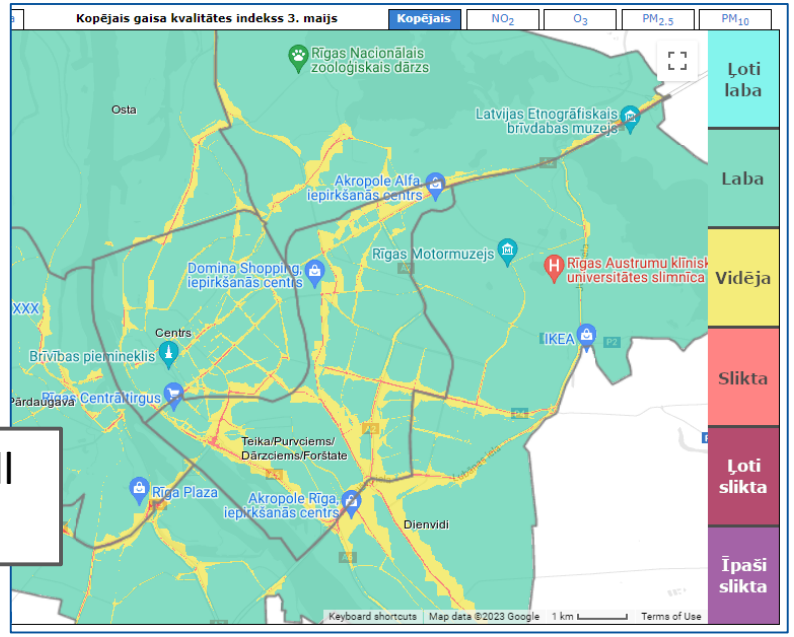
- www.airtext.info
- Stakeholders include Greater London Authority
- 2023-2024 project for Southwark and Lambeth councils to update airTEXT and develop 3 apps for the general public, schools and healthcare settings. Working with digital and community research agencies. Funded by Defra AQ grant.



Central London: Overall forecast (DAQI)

Riga airTEXT (since 2018)

- www.rigaairtext.lv
- CAMS "Use Case"
- Stakeholder is Riga City Council



Central Riga: Overall forecast (EUAQI)

Clean Air for Greater Manchester (since 2019)

- www.cleanairgm.com
- Stakeholder is Transport for Greater Manchester

Greater Manchester: $PM_{2.5}$ forecast (DAQI)

+ New in 2024: York!

- airqualityalerts.york.gov.uk
- Stakeholder is City of York Council