

MAQS-Health

Multi-Model Air Quality System for Health Research

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CERC



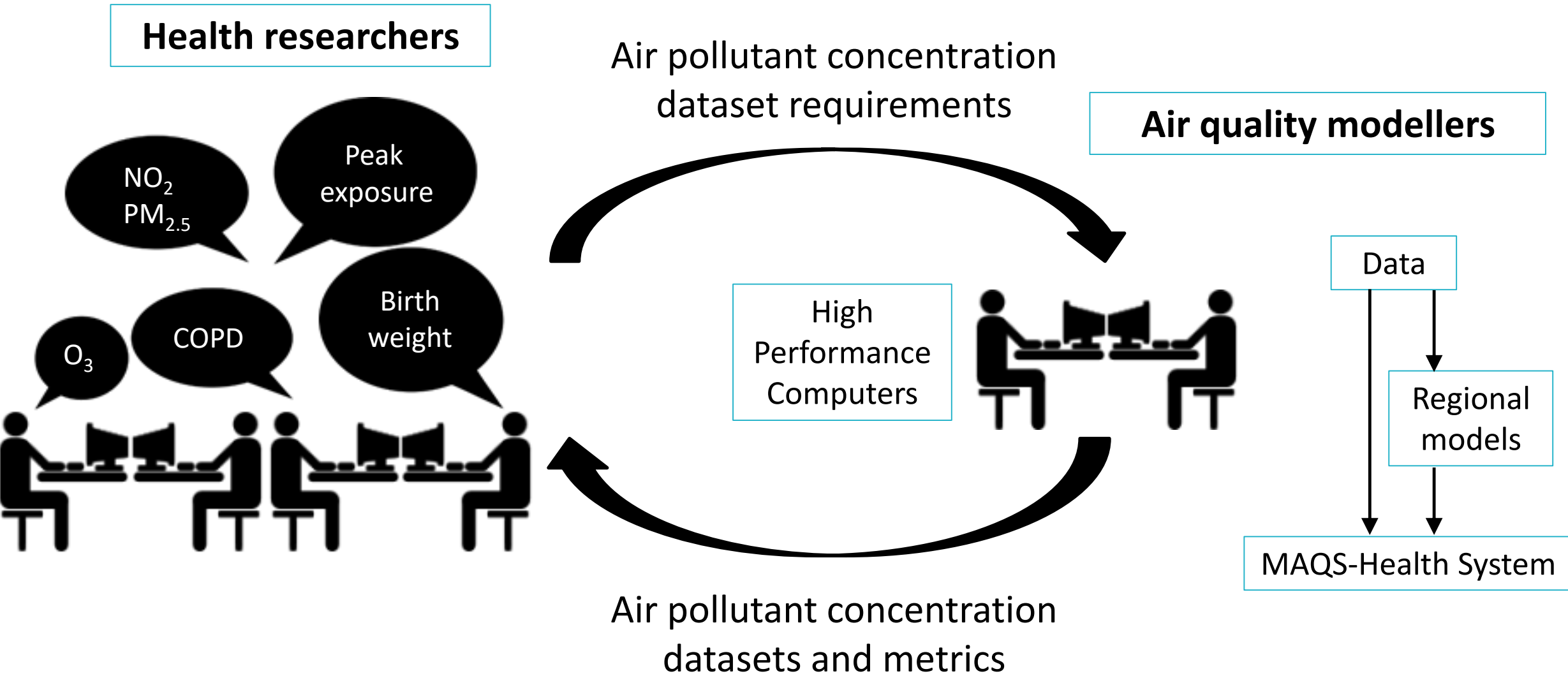
UNIVERSITY OF
BIRMINGHAM

University of
Hertfordshire **UH**

Lancaster
University



MAQS-Health: A modelling system to enable health research



MAQS-Health: System overview

LOCAL MODEL COMPONENT

- Pollutant concentration estimates are needed at resolutions of a few metres at roadside locations in urban areas to assess population exposure accurately
- At short times, local-scale models capture fine details of dispersion, fast chemistry and effect of street canyons/urban morphology
- New road source tool: **ADMS-Local** (based on ADMS-Urban)

REGIONAL MODEL COMPONENT

- Regional pollution levels contribute significantly to pollution levels in urban areas
- Eulerian chemical transport models (CTMs) model regional and global pollutant transport and complex atmospheric chemistry
- Range of RM options include: **CMAQ, CAMx, EMEP, WRF-Chem, CHIMERE, UKCA+AQUM***

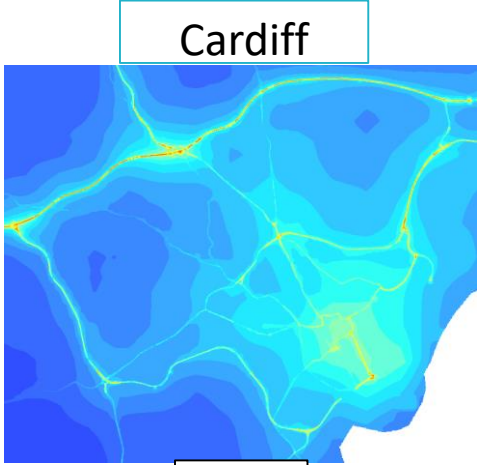
COUPLED SYSTEM

- Local-scale and regional models coupled within a single system
- Computational complexities include avoidance of double counting emissions + chemistry

VERIFICATION SYSTEM

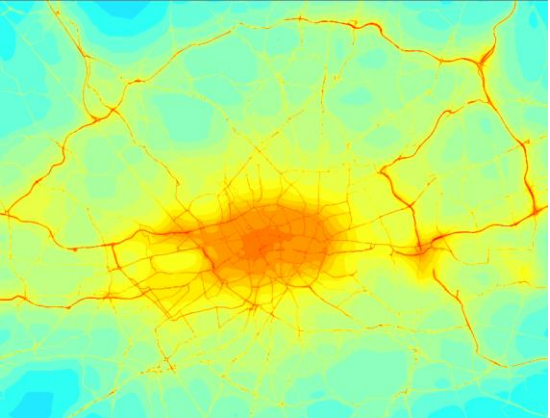
- Automated comparisons of modelled / measured

Example system output for UK



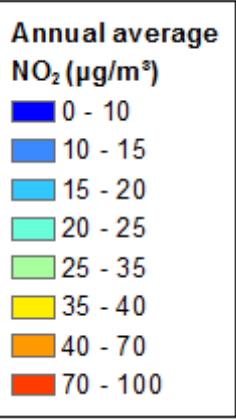
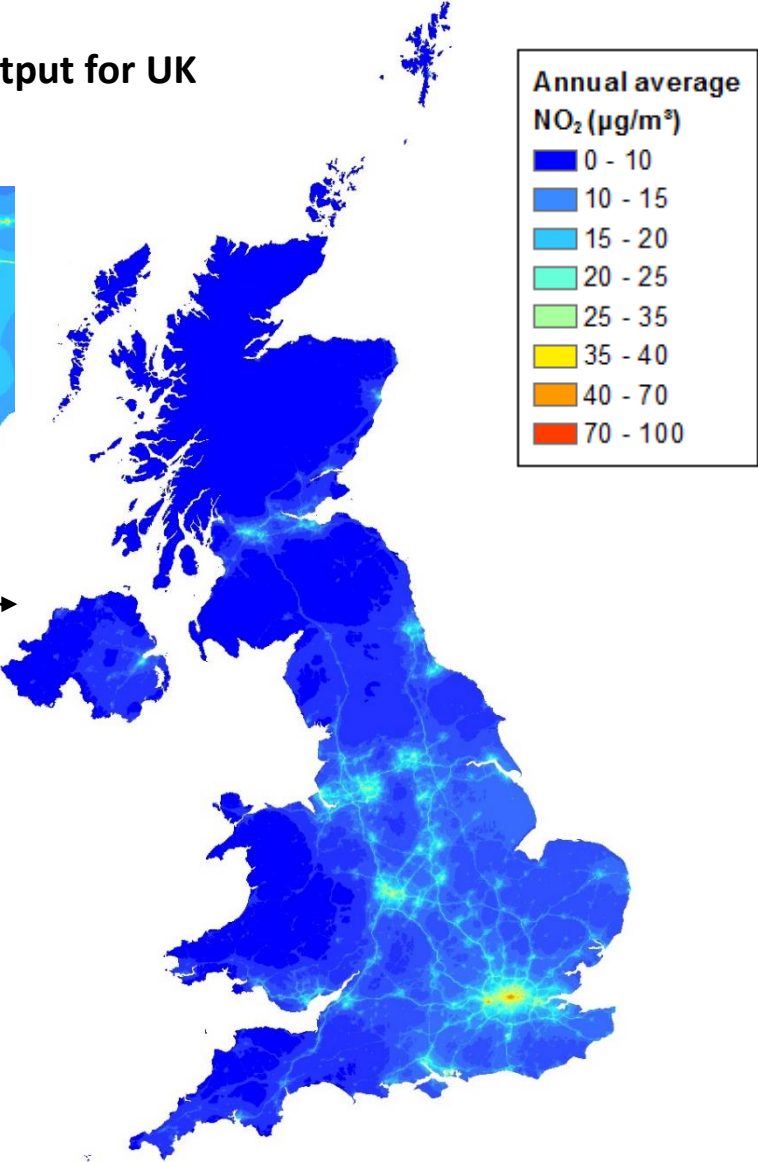
Cardiff

14 km



Inner London

27 km



*Generic RM input format allows coupling with other models e.g. UKCA, AQUM

MAQS-Health: Coupled system concept

- Aim:** to couple local model to regional model without double counting emissions i.e.:


$$\text{Concentration within nested domain} = \text{Regional modelling of emissions} - \text{Gridded locally modelled emissions } (\Delta T) + \text{Explicit locally modelled emissions } (\Delta T)$$

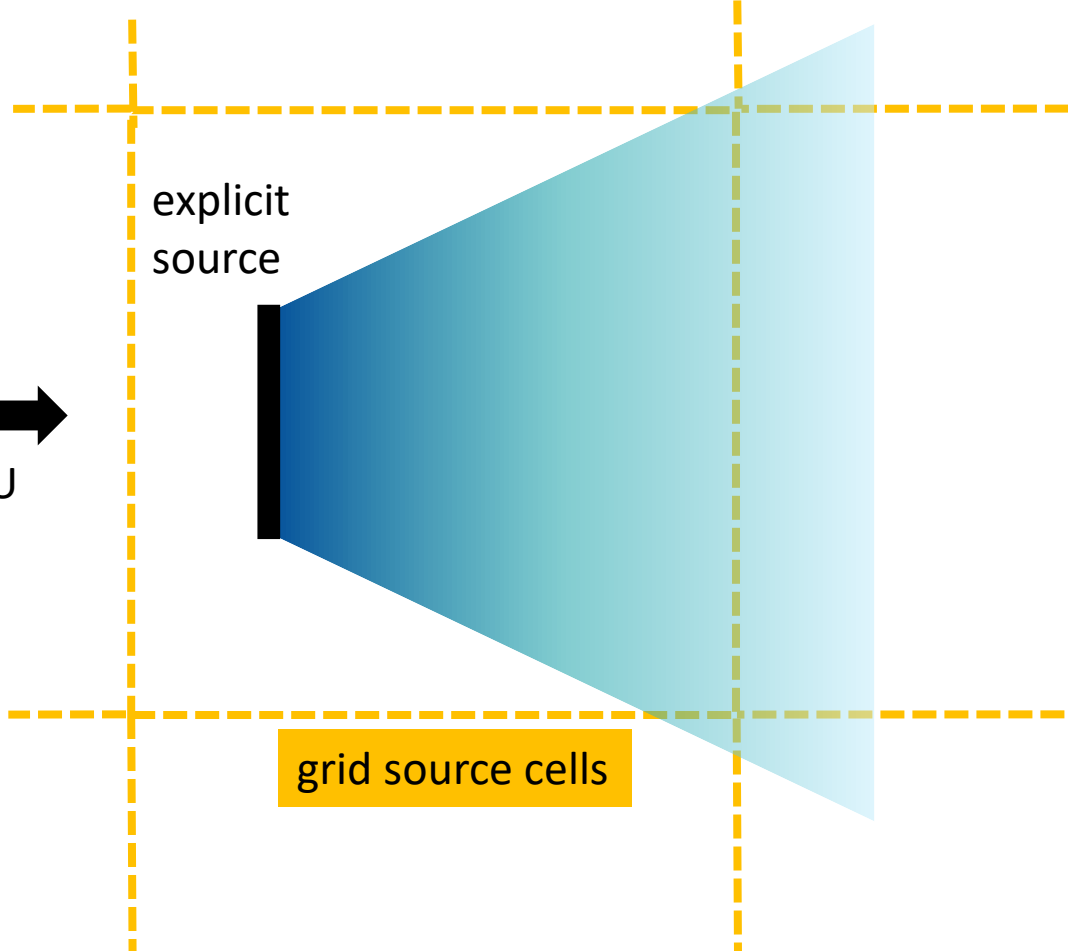
Assume

- Plume well mixed in time ΔT
- Meteorology and emissions are slowly varying on time scale ΔT

Use

- Local model for $t < \Delta T$
- Regional model for larger time and hence larger spatial scales

wind speed, U 

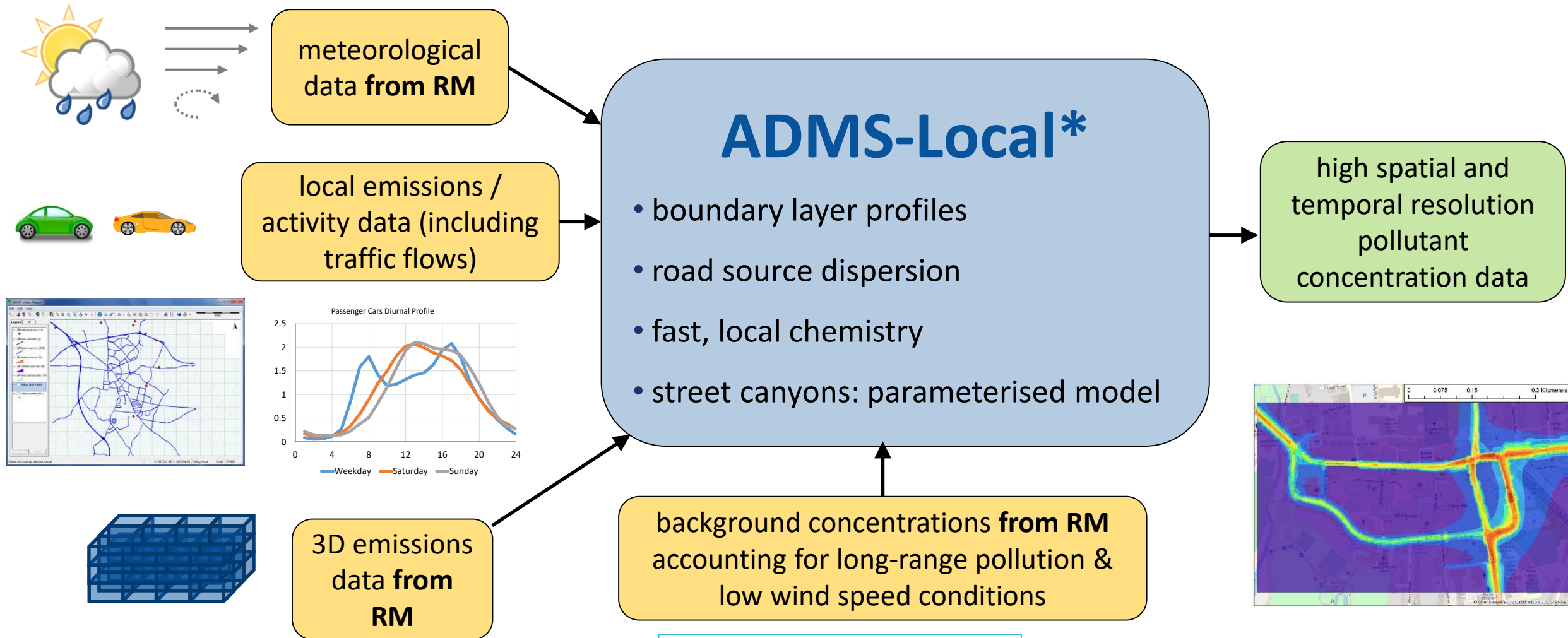


ADMS-Local: Overview

INPUTS

Local model

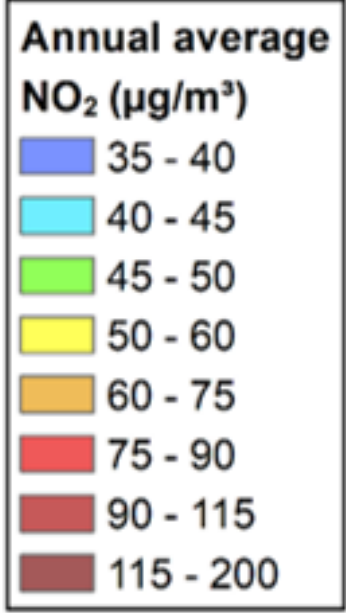
OUTPUTS



*based upon ADMS-Urban

ADMS-Local: Evaluation

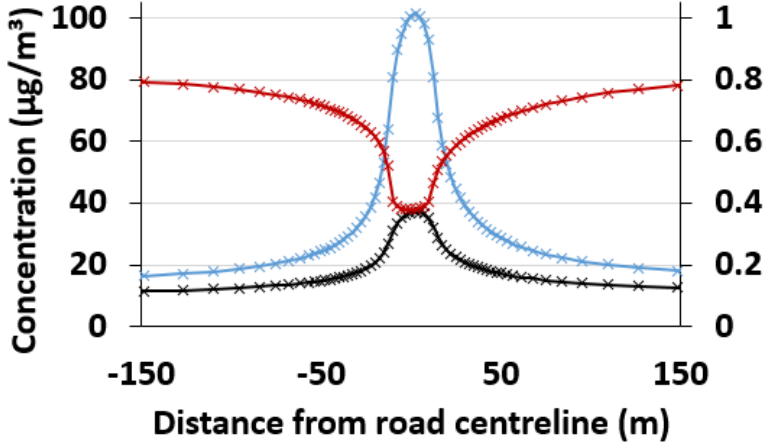
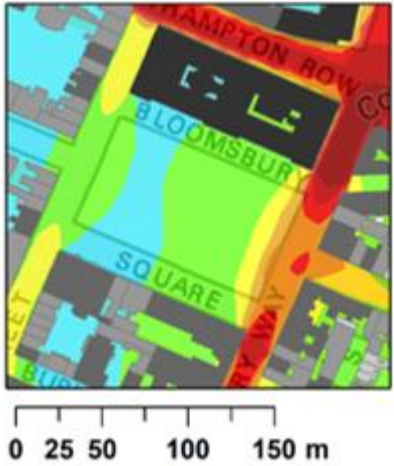
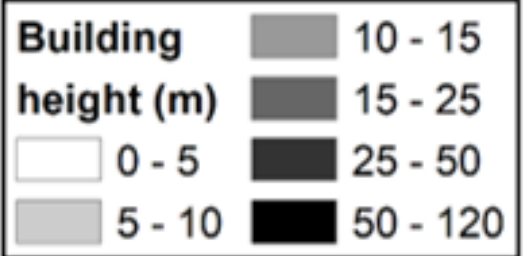
Study	Purpose
Comparison with ADMS-Urban: NO _x , NO ₂	To ensure consistency with ADMS-Urban open roads, including chemistry
SRN real world open road evaluation	To test performance of road source dispersion
TRAPOS: NO _x (Hood et al. 2021)	To test performance of parameterised canyon approach
London 2012: NO _x , NO ₂ , O ₃ , PM _{2.5} , PM ₁₀ (Hood et al. 2018)	To test city-scale modelling of open roads, canyons, volume source modelling, and chemistry



Models transition between canyons and open roads

Contains OS data © Crown Copyright and database right 2021

Models near-road dispersion & chemistry



MAQS-Health: System outputs

Raw outputs from coupled system

MAQS-Health Tools

Processed outputs

MAQS-Health output file

- Two types of system runs:
 1. **Receptor** (quick, executes in hours)
 2. **Contour** (longer, executes in days)
- **Variable grid** output file (netCDF format), to resolve concentration gradients near roads
- **Hourly** or annual concentration data for multiple pollutants: NO_x , NO_2 , O_3 , PM_{10} , $\text{PM}_{2.5}^*$

Spatial subsets e.g. average within a boundary

Temporal subsets e.g. school run, weekday, weekend

MAQS-Health output file

Interpolate between concentrations at output points to generate a regularly spaced concentration grid

Text file or grid file

Generate contour maps from grid file

Beta testing: Modelling groups and domains

Organisation: University of Edinburgh
Domain: Scotland
Cities: Edinburgh, Glasgow, Aberdeen, Dundee
Regional model: EMEP
Group lead: Prof Ruth Doherty

Organisation: Lancaster University
Domain: Northern Ireland
Cities: Belfast
Regional model: WRF-Chem
Group lead: Prof Oliver Wild

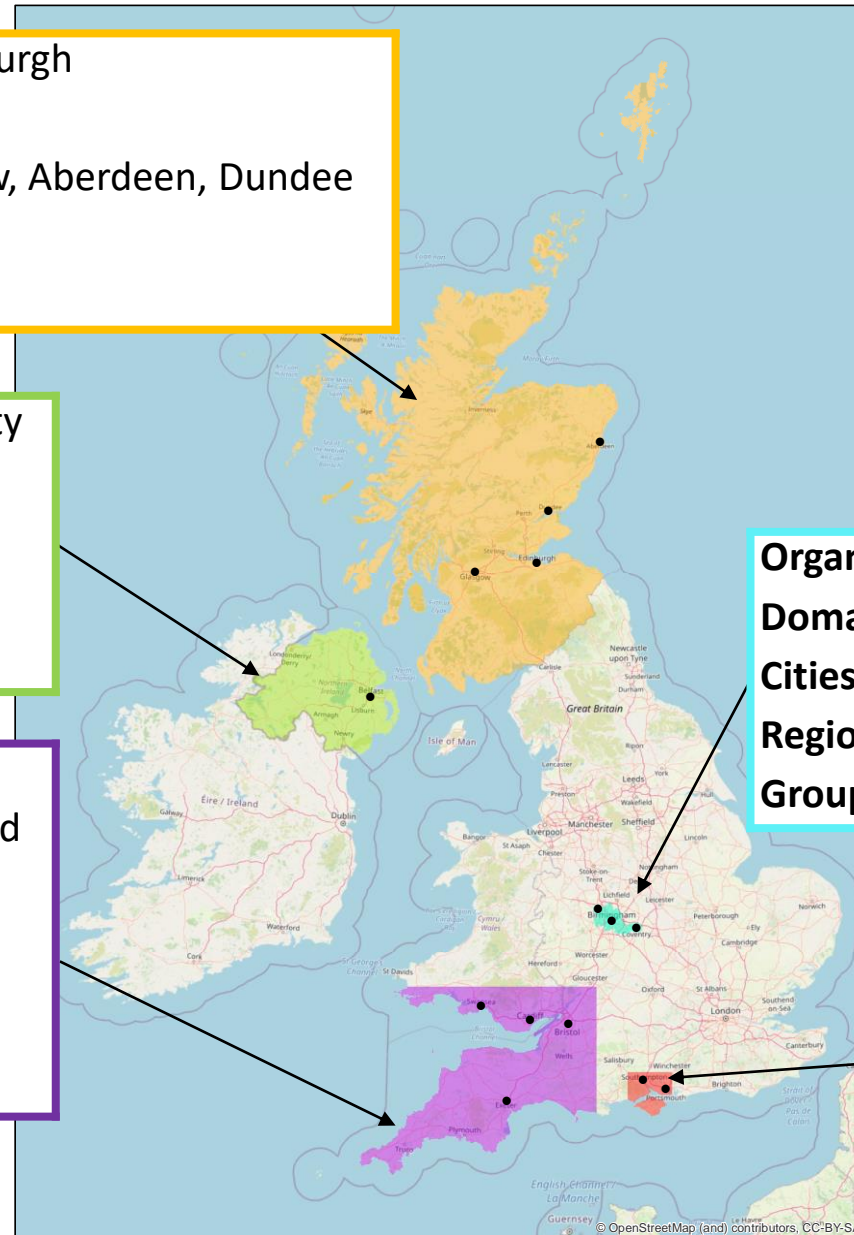
Organisation: Met Office
Domain: South-West England & South Wales
Cities: Exeter, Bristol, Cardiff, Swansea
Regional model: AQUM
Group lead: Dr Rachel McInnes

Organisation: University of Birmingham
Domain: West Midlands
Cities: Birmingham, Wolverhampton, Coventry
Regional model: CMAQ
Group lead: Prof William Bloss

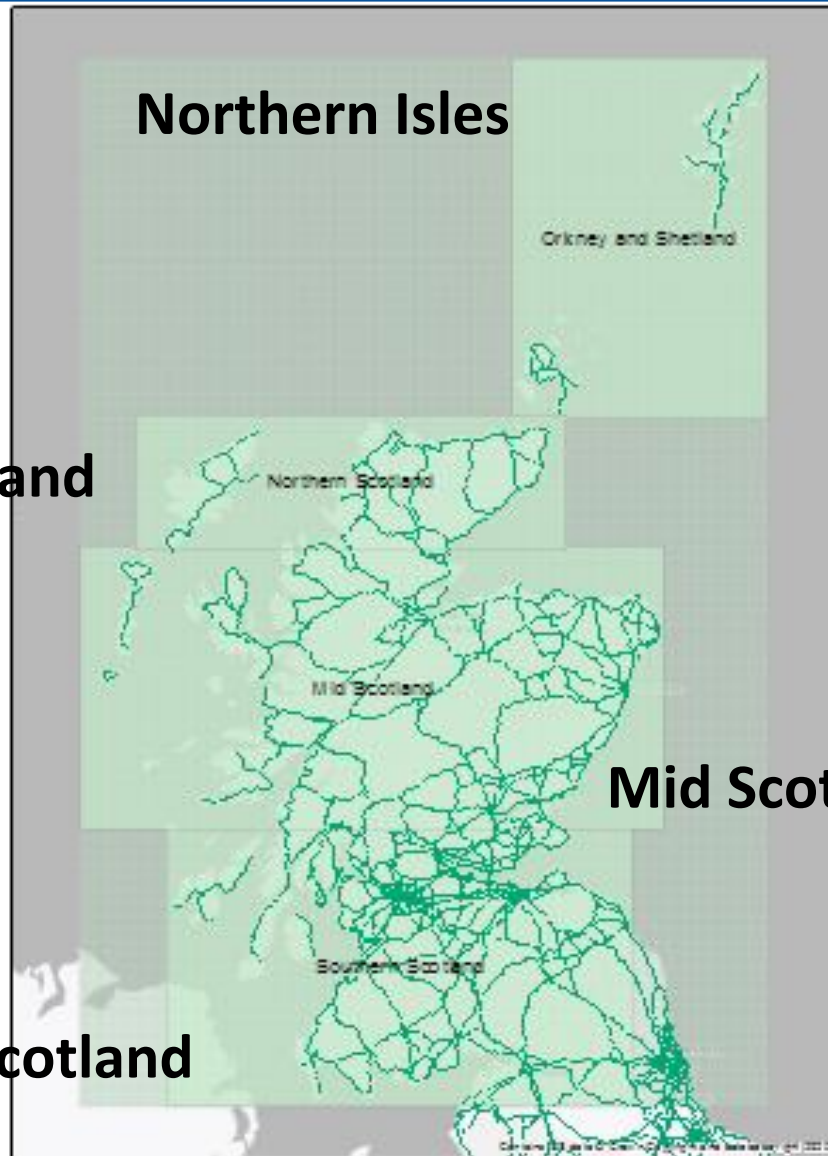
Modelling groups at **CERC**, the **Met Office** and project partners the Universities of **Birmingham**, **Edinburgh**, **Hertfordshire*** and **Lancaster** have beta-tested the system

Organisation: CERC
Domain: United Kingdom
Regional model: Defra background maps

Organisation: University of Hertfordshire
Domain: Portsmouth and Southampton
Cities: Portsmouth, Southampton
Regional model: CMAQ
Group lead: Prof Ranjeet Sokhi
*** Testing ongoing**



System evaluation: Scotland



• Scotland

- Shipra Jain & Ruth Doherty, University of Edinburgh
- Time period: 2018
- Domain size: 182,654 km²
- Regional model dataset (meteorology and 'background' pollutant concentrations):
 - WRF, EMEP4UK (from UKCEH)
 - 1 km resolution
- Local model data inputs:
 - Road emissions from DUKEMS Major Roads DataBase*
 - Street canyon properties derived Ordnance Survey MasterMap 3D buildings

*supplied only for use in evaluating MAQS-Health

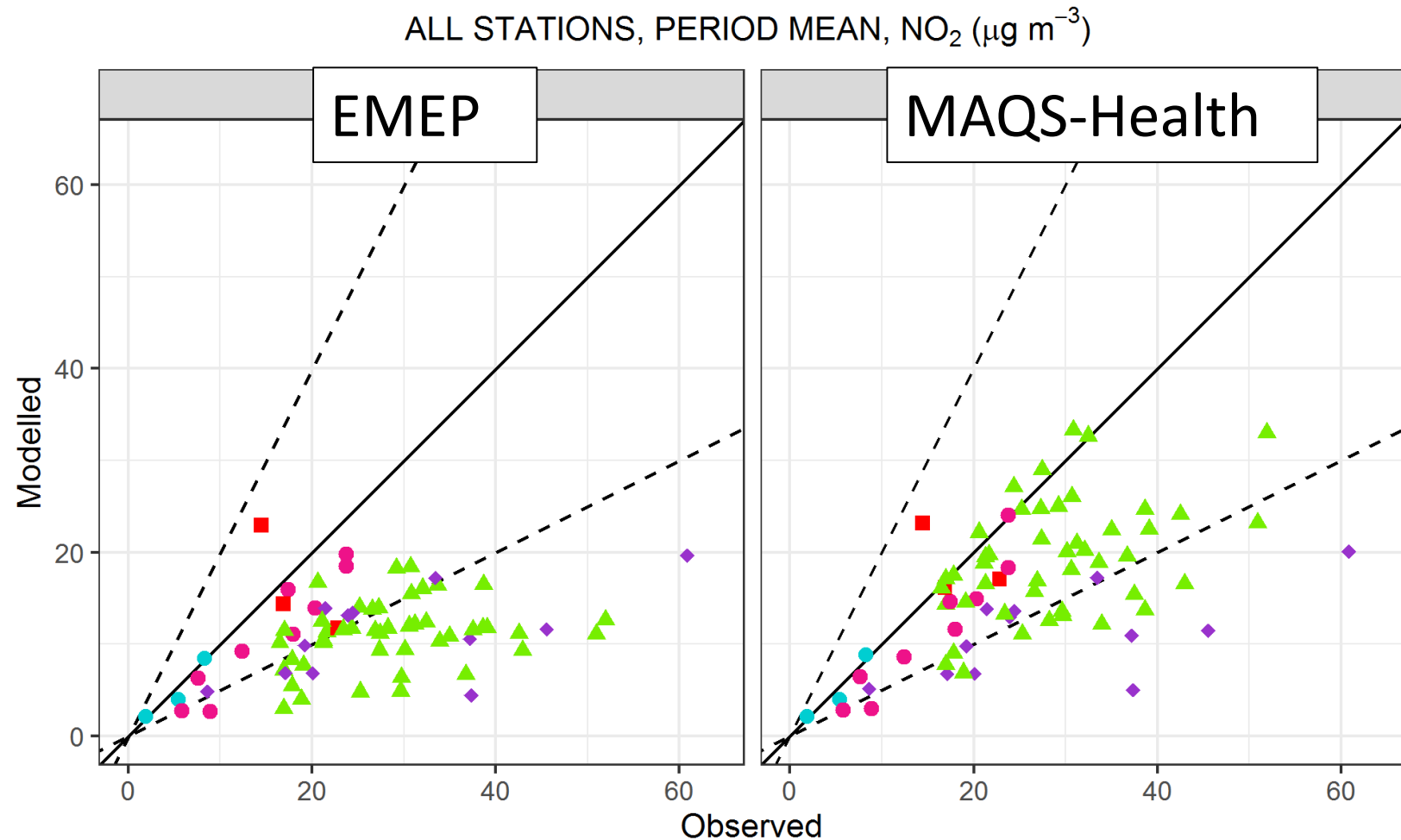
Northern Scotland

Mid Scotland

Southern Scotland

System evaluation results: Scotland

- Rural background locations unchanged by coupled system
- Urban background locations show small increase
- Roadside locations show a larger increase provided that nearest road to monitor is modelled



Station Types: ■ industrial ● rural bg ▲ traffic ◆ traffic noroad ● urban bg

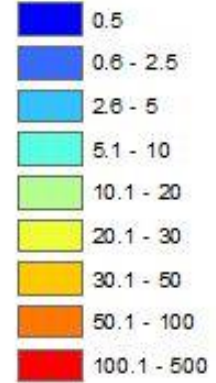
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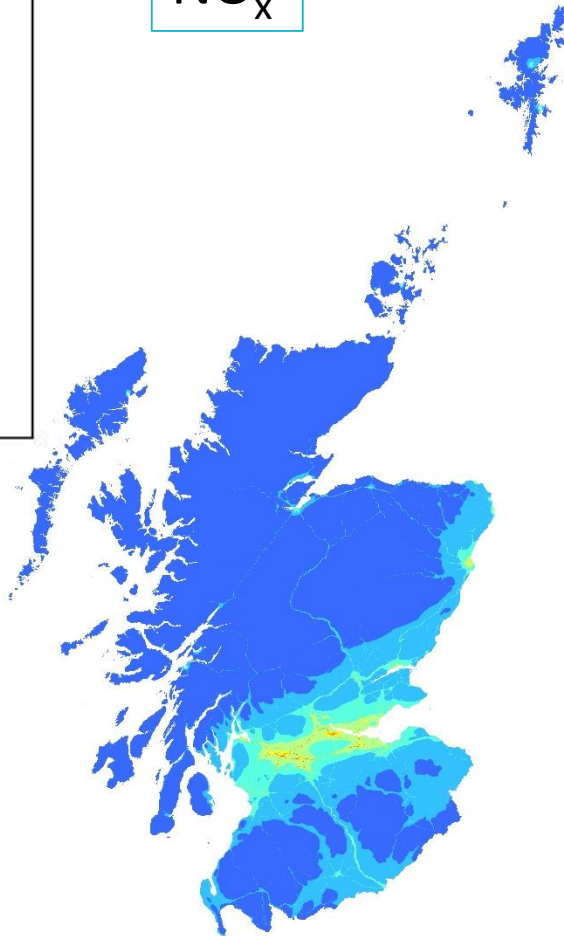
System evaluation results: Scotland

Annual Average

$\text{NO}_x \mu\text{g}/\text{m}^3$

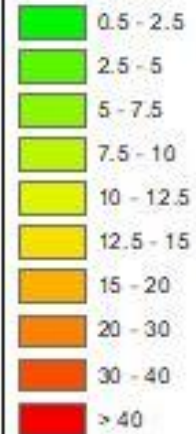


NO_x

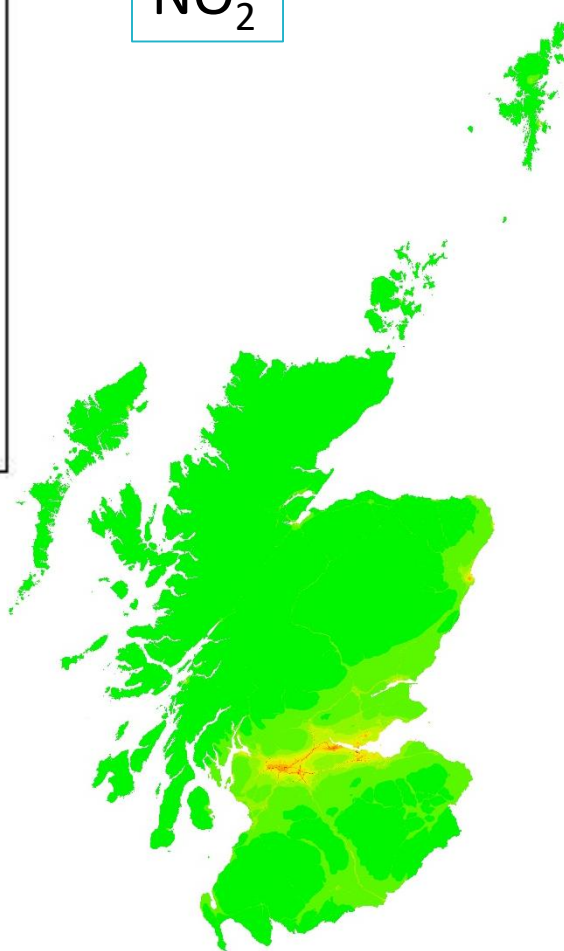


Annual Average

$\text{NO}_2 \mu\text{g}/\text{m}^3$

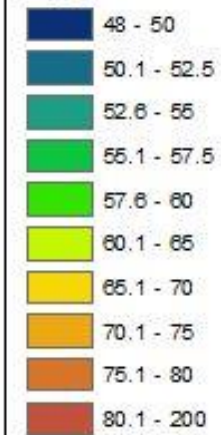


NO_2

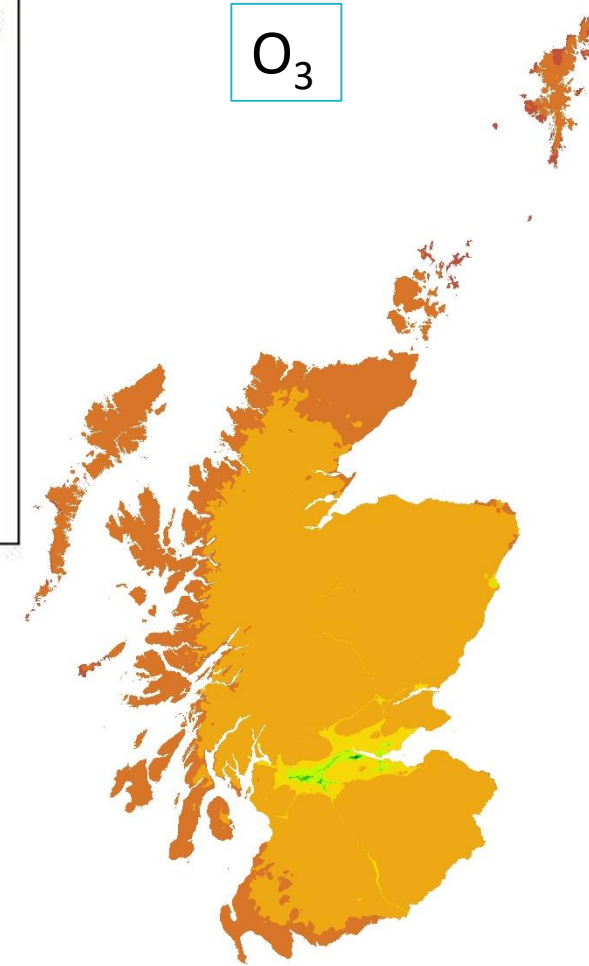


Annual Average

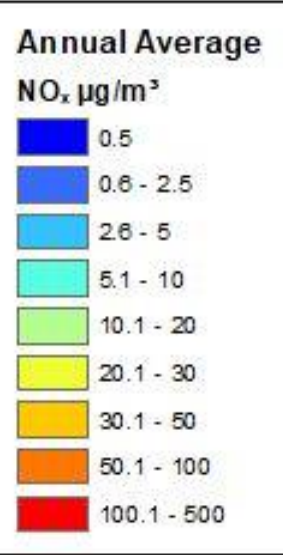
$\text{O}_3 \mu\text{g}/\text{m}^3$



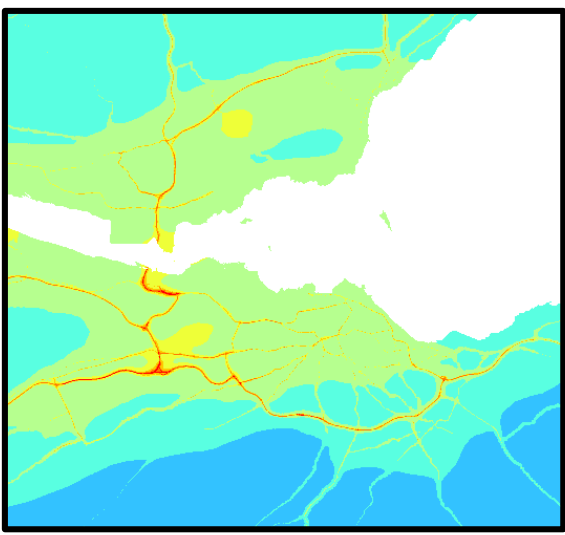
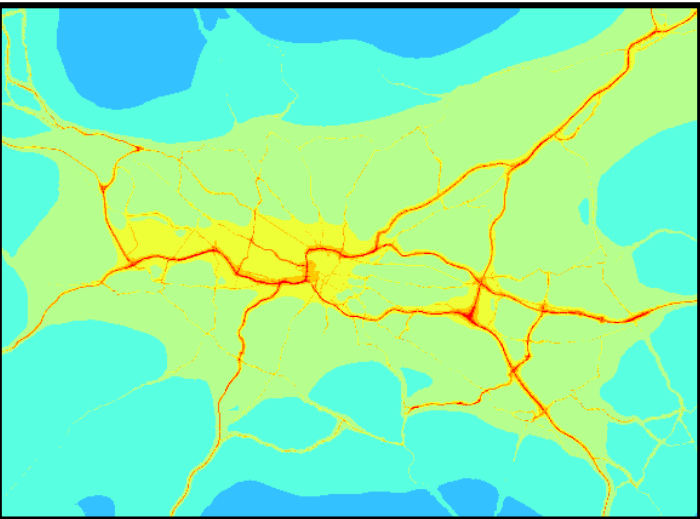
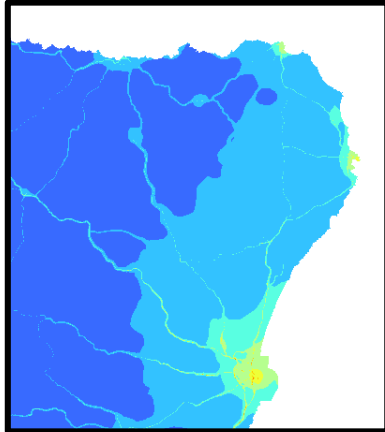
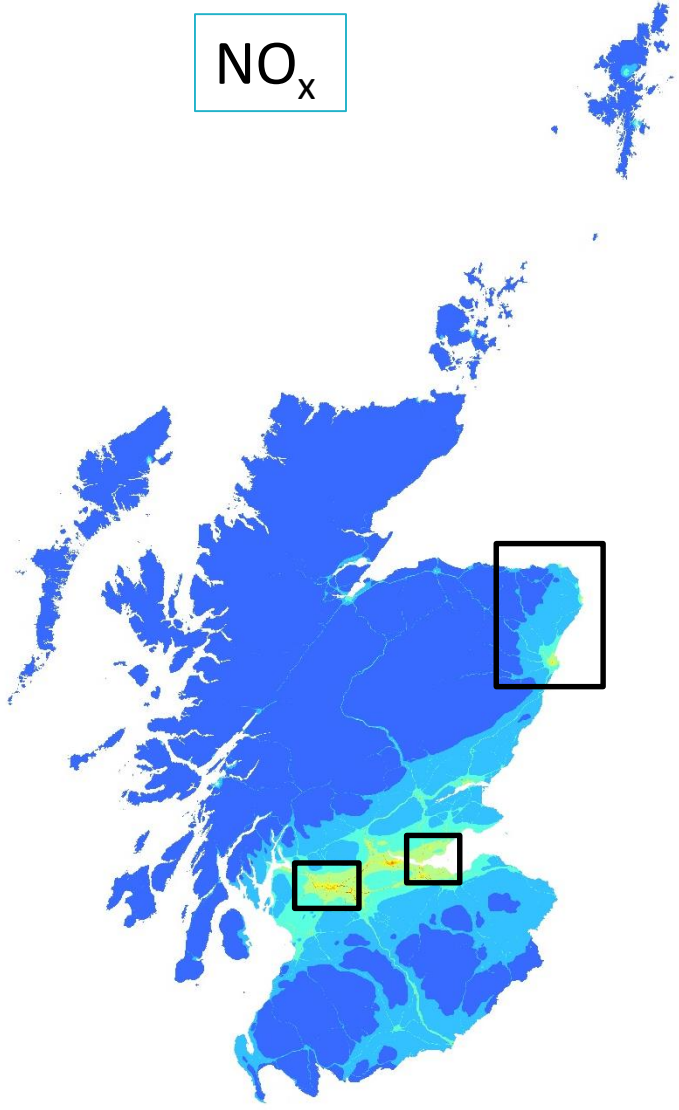
O_3



System evaluation results: Scotland



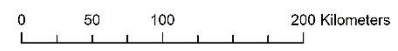
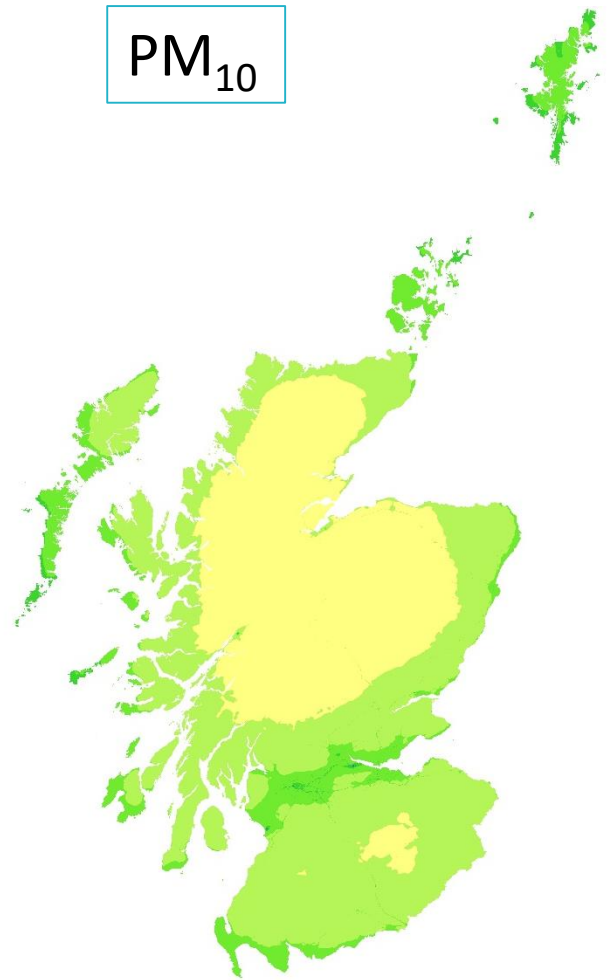
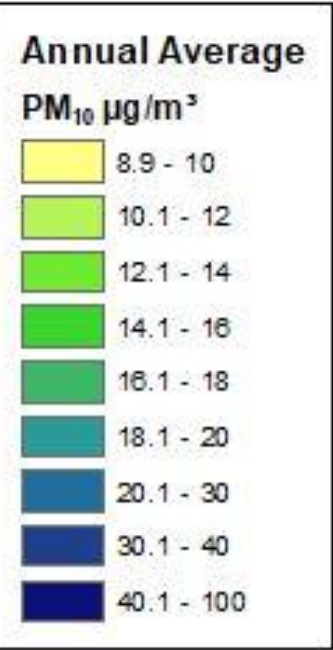
NO_x



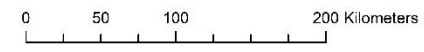
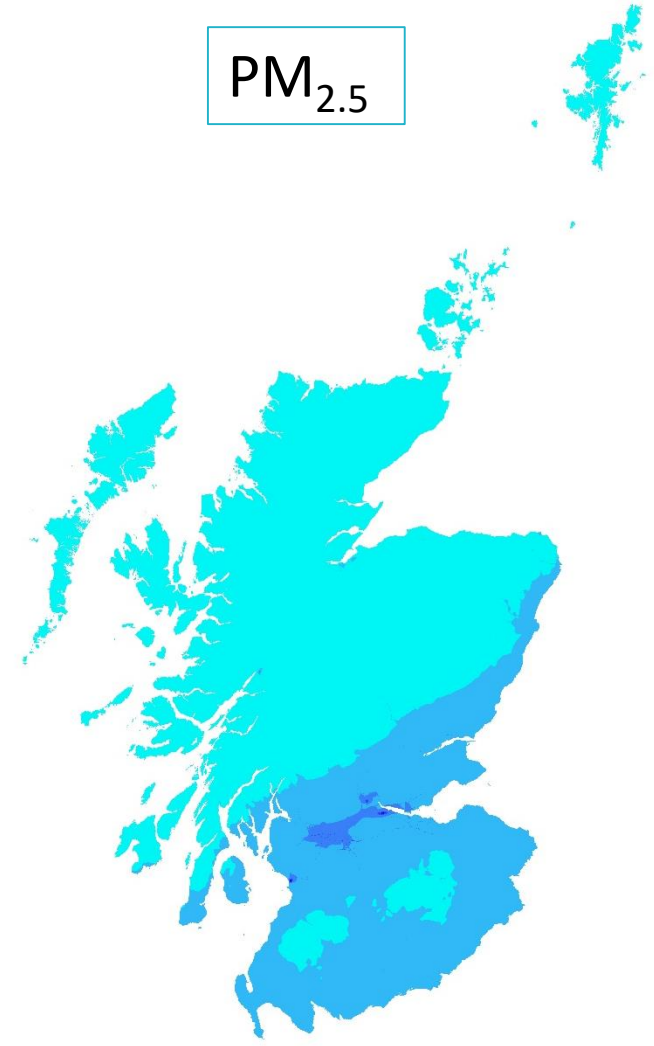
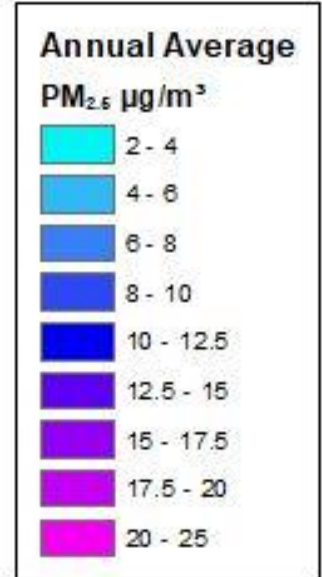
System Evaluation Results: Scotland



PM₁₀



PM_{2.5}



System evaluation: Northern Ireland

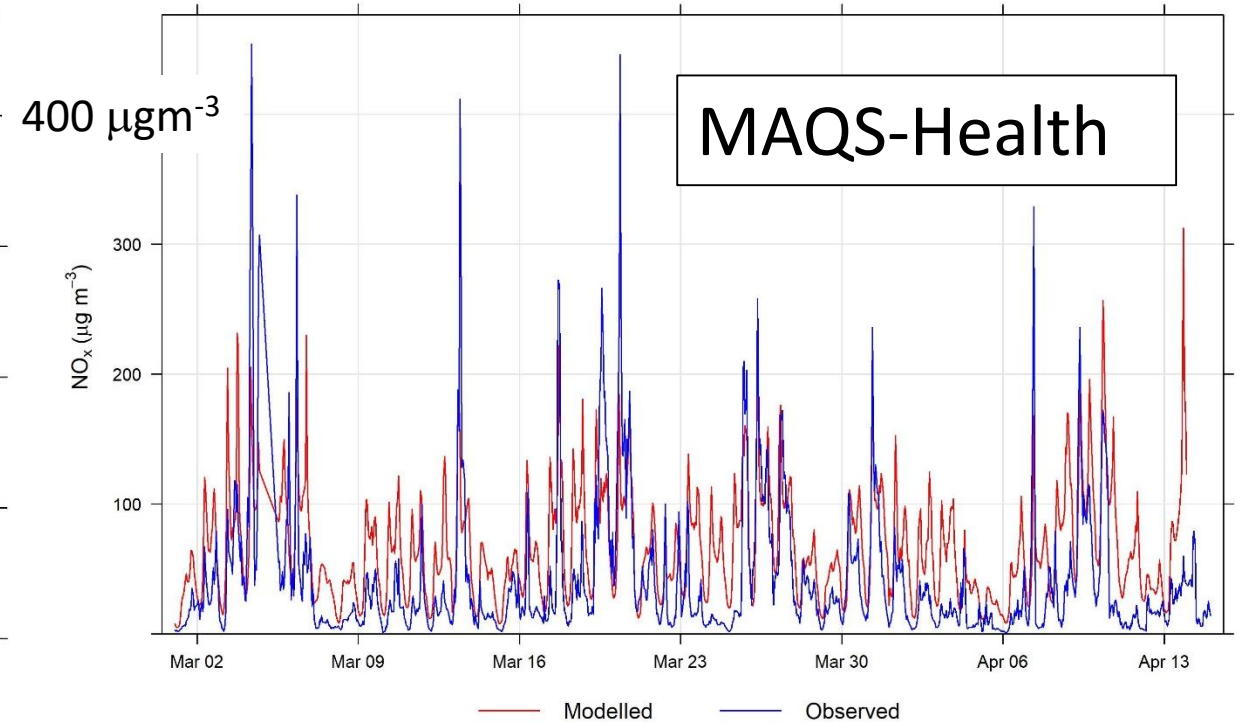
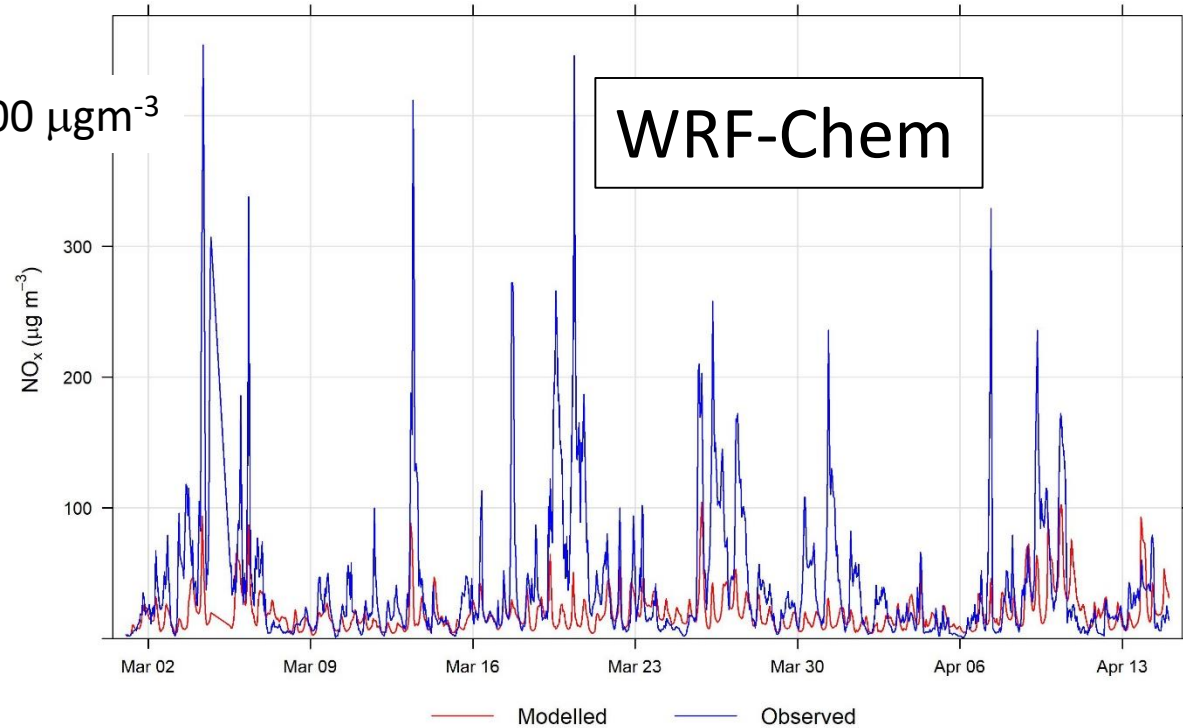


- **Northern Ireland**

- Fred Otu-Larbi & Oliver Wild , Lancaster University
- Time period: March 2020
- Domain size: 23,490 km²
- Regional model dataset (meteorology and 'background' pollutant concentrations):
 - WRF-Chem regional chemical transport model
 - 3 km resolution
- Local model data inputs:
 - Top-down approach used to derive road source emissions from National Atmospheric Emissions Inventory data <https://naei.beis.gov.uk/> and Open Street Map road geometry
 - Street canyon properties derived from Local Climate Zone data <http://www.wudapt.org/lcz/>

System evaluation results: Northern Ireland

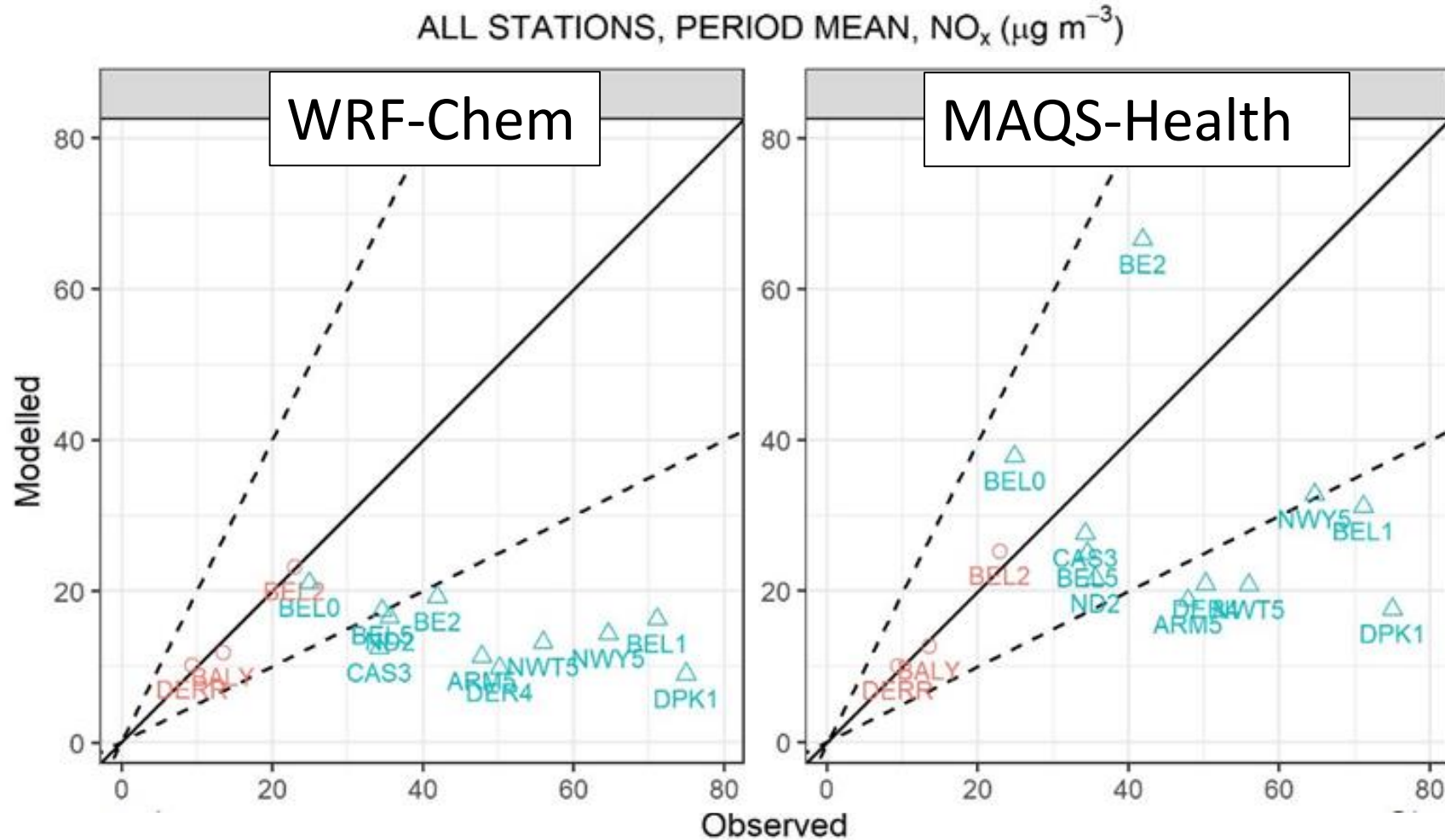
MAQS-Health coupled system improves estimates of NO_x at Belfast Westlink Roden Street



Modelled

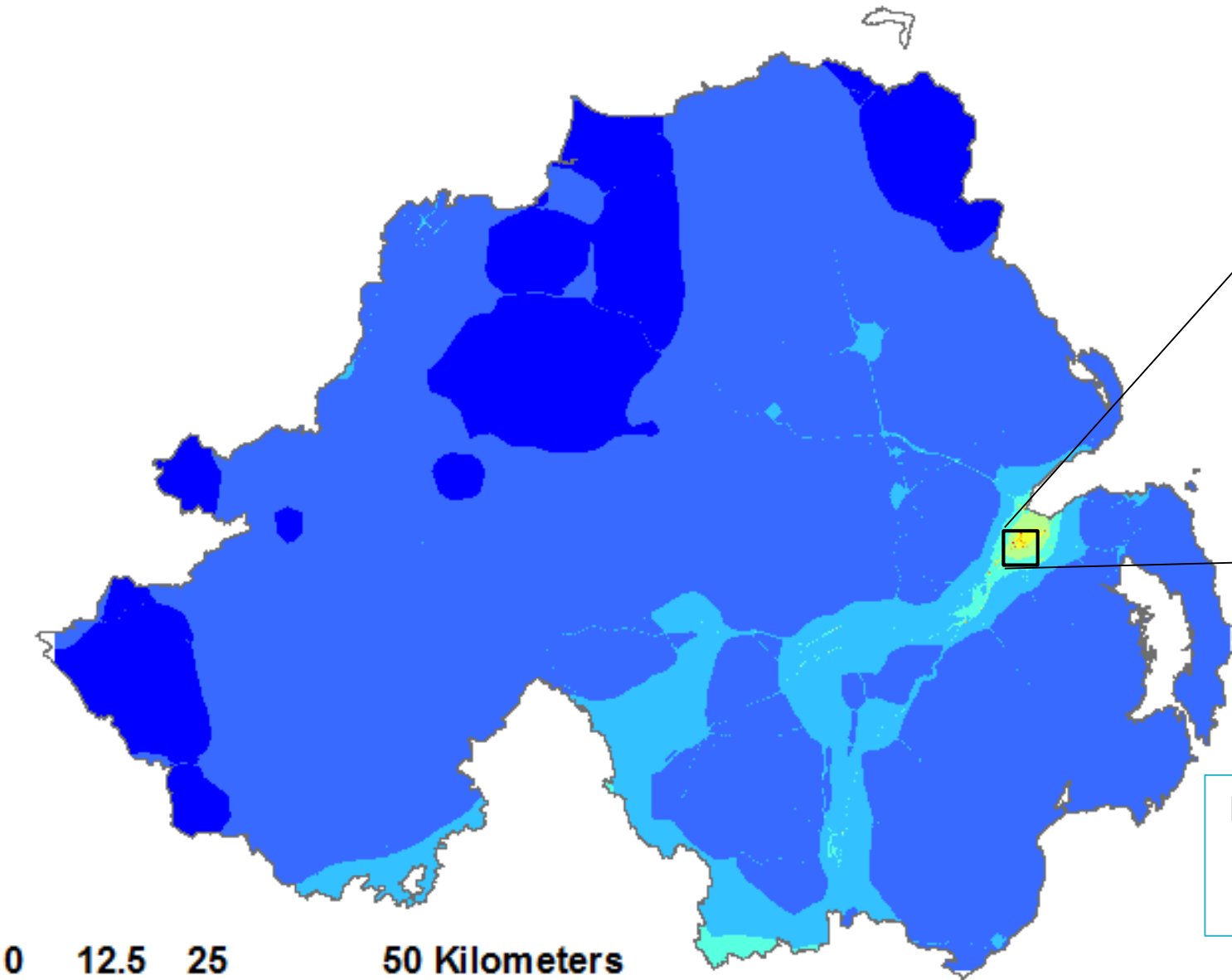
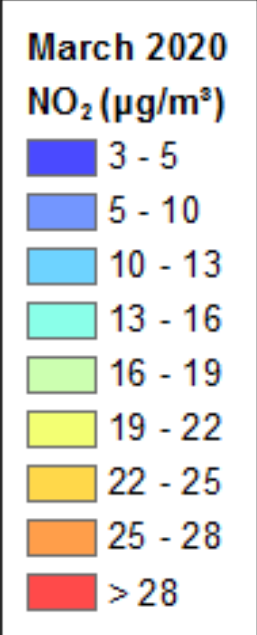
Observed

System evaluation results: Northern Ireland

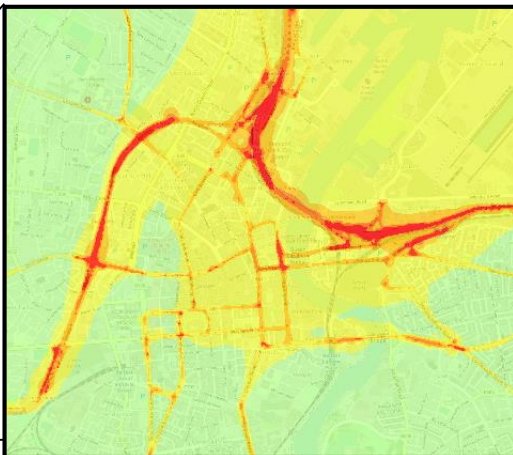


Rural sites very similar, urban sites greatly improved (but still low at some locations)

System evaluation results: Northern Ireland



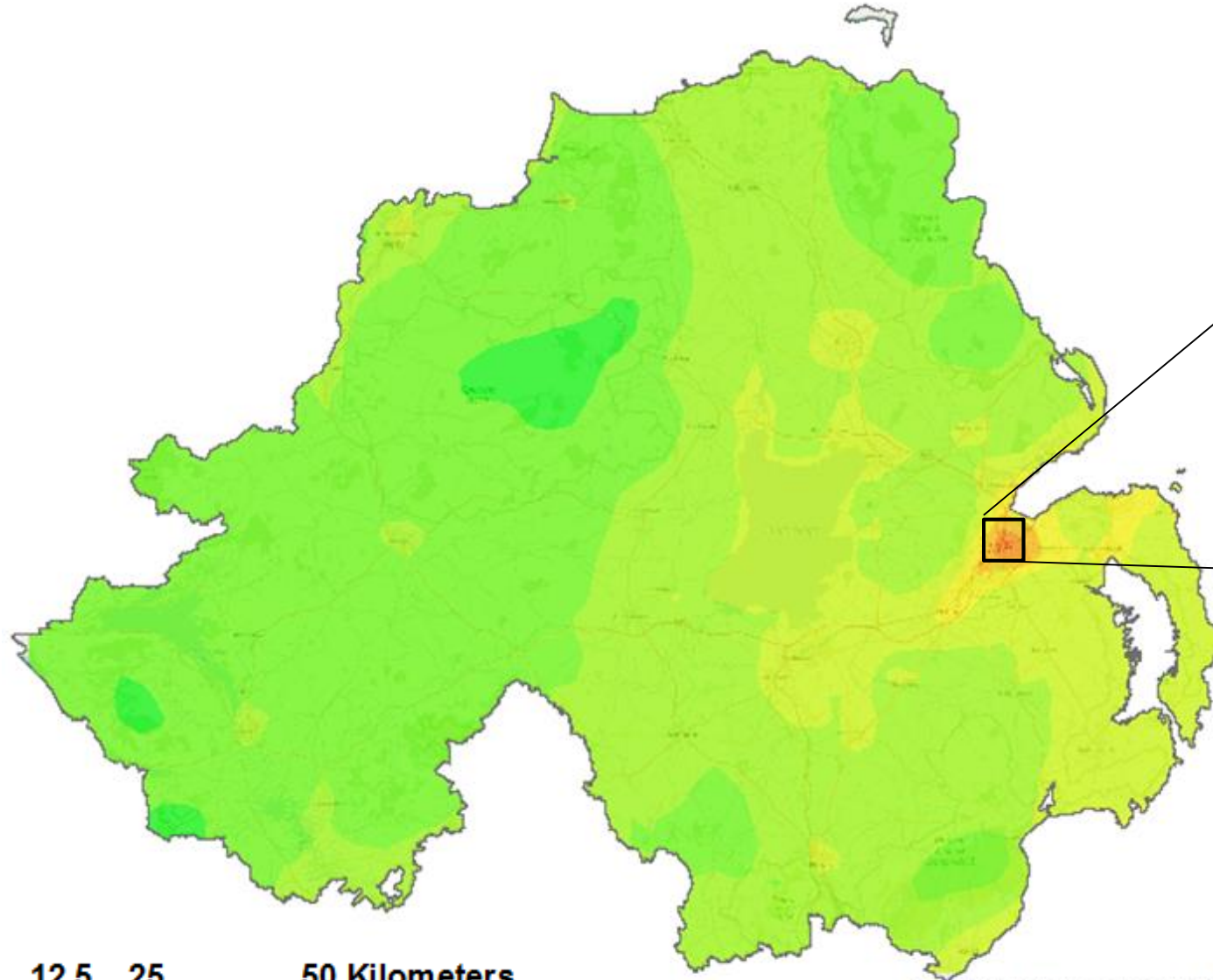
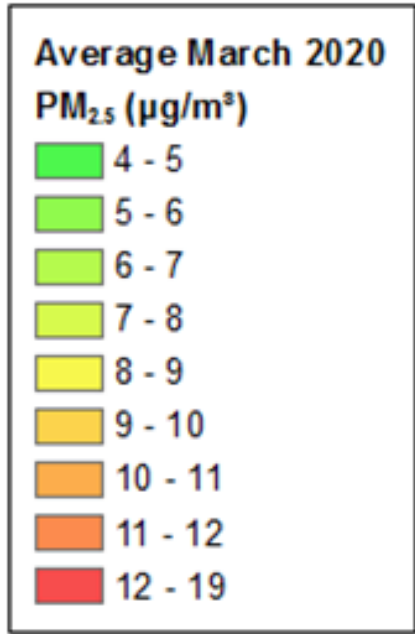
← 3km →



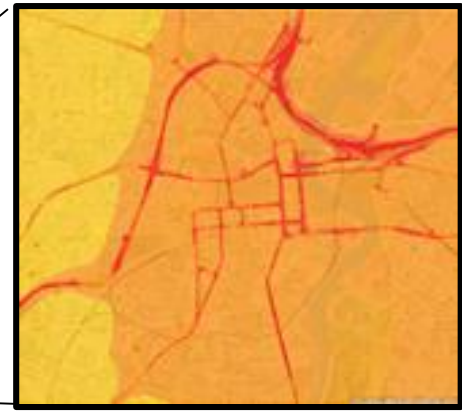
Belfast

NO₂ concentrations (µg/m³) generated by MAQS-Health

System evaluation results: Northern Ireland



← 3km →



Belfast

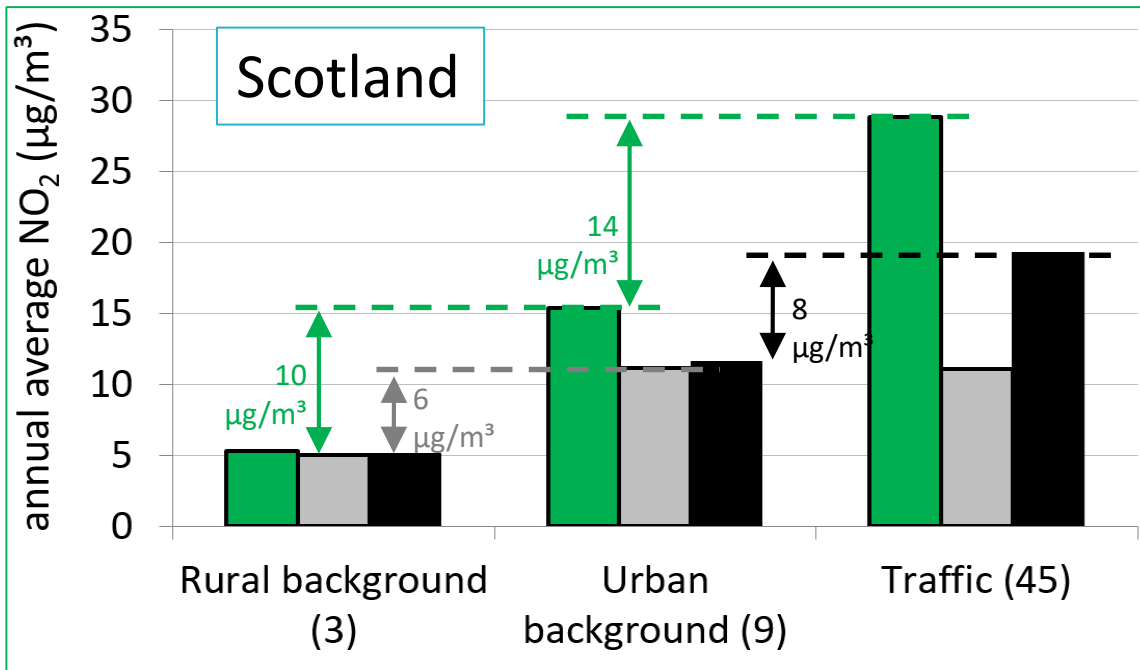
PM_{2.5} concentrations
(µg/m³) generated by
MAQS-Health

0 12.5 25 50 Kilometers

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Summary

Regional, urban and traffic pollutant concentration increments can be modelled and evaluated using MAQS-Health



- Measured
- Regional model (EMEP)
- MAQS-Health

Work supported by the UK Government's Strategic Priorities Fund (SPF) Clean Air Program, administered by the Met Office (DN424739)

- MAQS-Health is an efficient system for generating concentration output for multiple pollutants at high spatial and temporal resolution for use in health research
- MAQS-Health links to a wide range of regional concentration models (hourly and annual), as well as having generic input file options, and incorporates a comprehensive evaluation tool*
- MAQS-Health has been beta tested through multiple applications in the UK and is now available for use (maqs-health@cerc.co.uk)
- Other system applications include assessment of regional and local AQ policies

*Presentation by Amy Stidworthy on 'Toolkit for evaluating regional and local air quality models with observations'