MAQS-Health

Multi-Model Air Quality System for Health Research

National annual average streetscale resolution air quality modelling

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30 June 2022

UK annual average modelling

- Introduction to MAQS-Health
- Input data
- Run configuration
- Evaluation results
- Concentration maps
- Assessment of annual average modelling approach
- Acknowledgements

CERC Contributors
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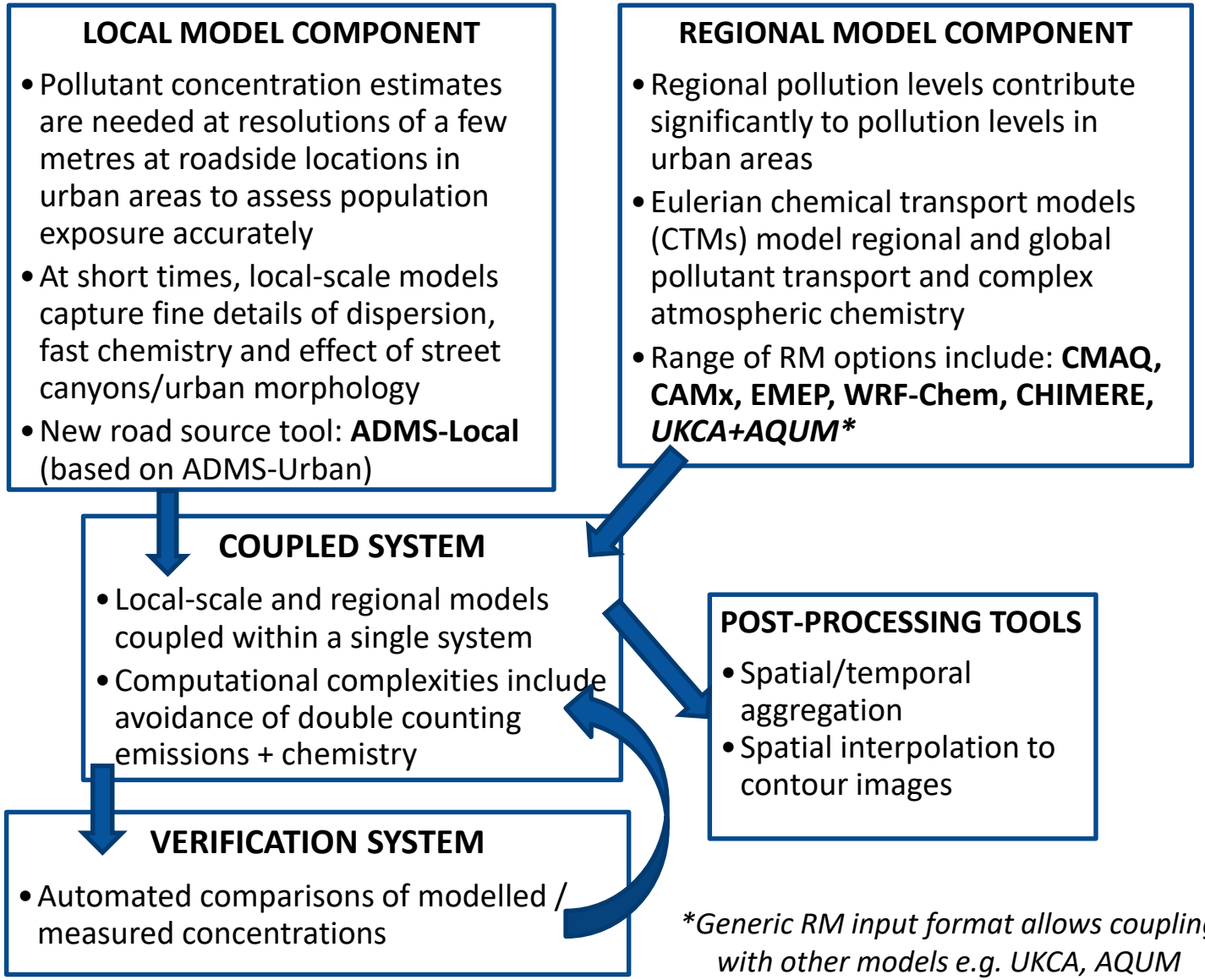
Introduction to MAQS-Health

- MAQS-Health coupled system: developed under UK Government Strategic Priorities Fund (SPF) Clean Air Program, administered by the Met Office (DN424739)
- Learn more about MAQS-Health in Room B this afternoon:
  - Coupled system design and two test configurations - 15:30 Martin Seaton
  - Verification system component - 14:50 Amy Stidworthy
  - A typical hourly modelling configuration - 14:30 Jian Zhong



Aims of MAQS-Health national annual average modelling

Generate fine-resolution annual average concentration maps for full UK inhabited land mass with continuous variation between roadside and background locations

Test annual average modelling approach coupling to PCM Defra background concentrations

uk-air.defra.gov.uk/data/pcm-data

MAQS-Health annual average

Test MAQS-Health coupled system in large domains

(40000+ cells)

Use of virtual machines for flexible computing resources

(Microsoft Azure)

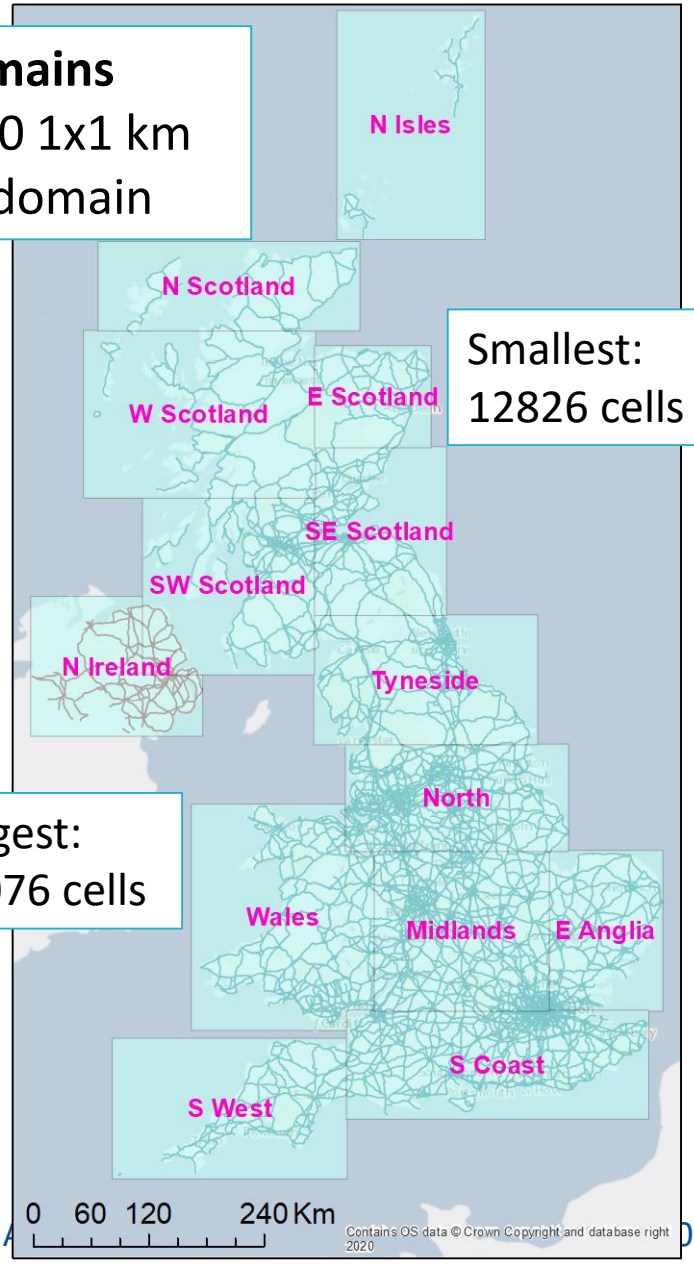
Input data

- **Gridded concentrations**
  - Defra / PCM background maps for NO_X, NO_2, PM_{10} and $PM_{2.5}$
  - 1 km resolution, annual average concentrations only
  - Calibrated with background measurements
  - Widely used for local air quality modelling, freely available for multiple years
- **Explicit road emissions**
  - GB: DUKEMS (Ricardo) major road emissions for 2018 (Ordnance Survey Open Roads network)
  - Edinburgh: high resolution city centre NO_X and NO_2 road emissions (SEPA)
  - NI: top-down calculations from gridded NAEI road emissions on to Open Street Map road geometry
- **Other data**
  - Hourly, 1 km resolution Weather Forecasting and Research (WRF) provided via UK-SCAPE (UKCEH)
  - Monthly average diurnal profile O_3: processed from hourly measured urban background data (Nottingham AURN)
  - Approximate street canyon parameters derived from Local Climate Zone data ('**generic** parameters'), with road carriageway and canyon widths corrected in the vicinity of monitors ('**site-specific** parameters')
  - Site properties including urban canopy parameters also derived from Local Climate Zone data

Run configuration

- Annual average calculations only
- Output NO_X, NO_2, PM_{10} and $PM_{2.5}$
- Run on 2 Microsoft Azure cloud virtual machines, using Linux OS, 44 cores plus 1 TB data disk each
- 2 receptor domains: GB and NI, different road emissions datasets
- 14 contour domains to cover full UK inhabited land mass: Scilly Isles to Shetland, minimising overlaps and empty (offshore) cells
- System output locations
  - 200 m resolution regular grid
  - Automatic calculation points along road sources
  - Additional automatic interpolated points along road sources

Map of domains
Average ~30000 1x1 km cells in each domain



Smallest: 12826 cells

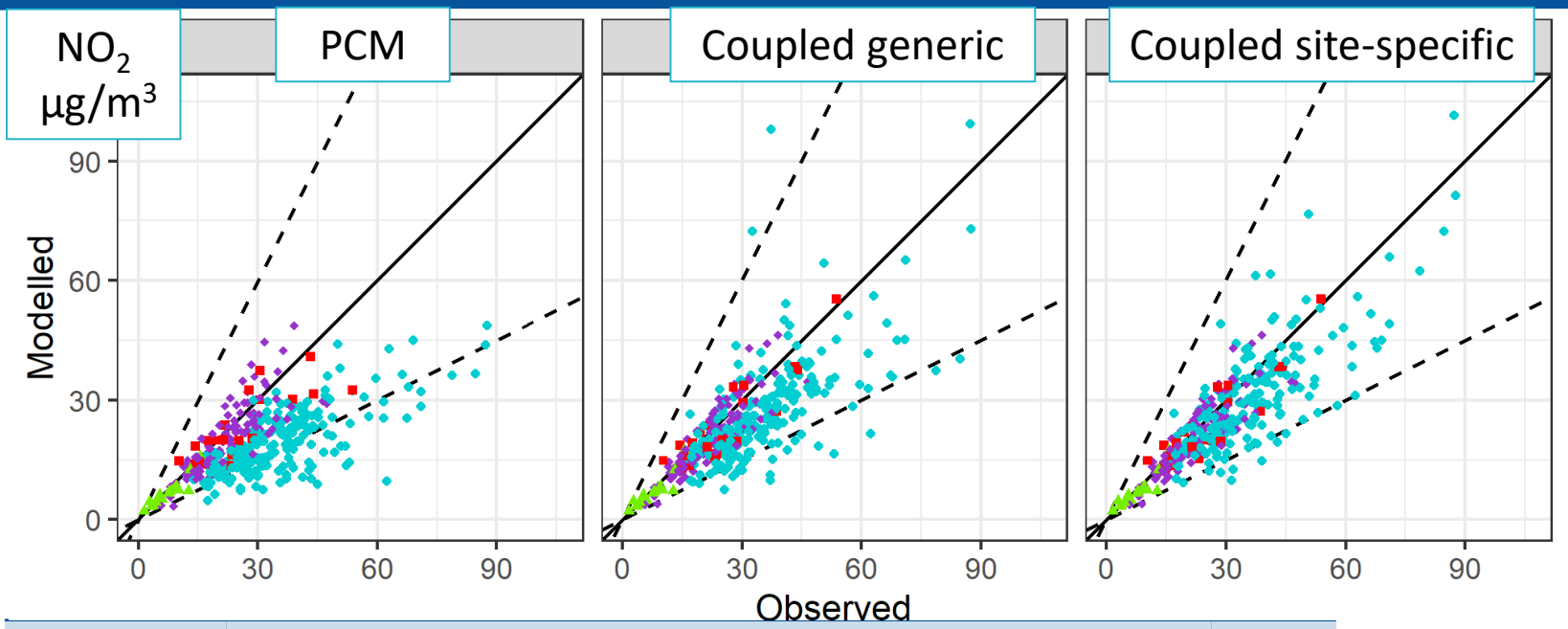
Largest: 45076 cells

Dependence of output point locations on road sources leads to non-linear relationship between number of cells and run time

Evaluation: Overview

- Comparison of annual average modelled concentration with annual average measurements at near-road and background automatic monitoring sites, using MAQS-Health verification system
- Note PCM concentrations are from 1 km gridded data at all site types
  - Valid comparison for rural and urban background sites
  - Included for roadside sites as an indicator of background contribution in coupled system
  - Not representative of PCM near-road concentrations (separate dataset)
- Evaluation of NO_2 and PM_{10} for GB only presented. $PM_{2.5}$ not shown as roadside increment smaller than PM_{10} and fewer measurements available.
- Additional uncertainty in Northern Ireland: explicit road emissions calculated differently

Evaluation: NO_2



Station Types:

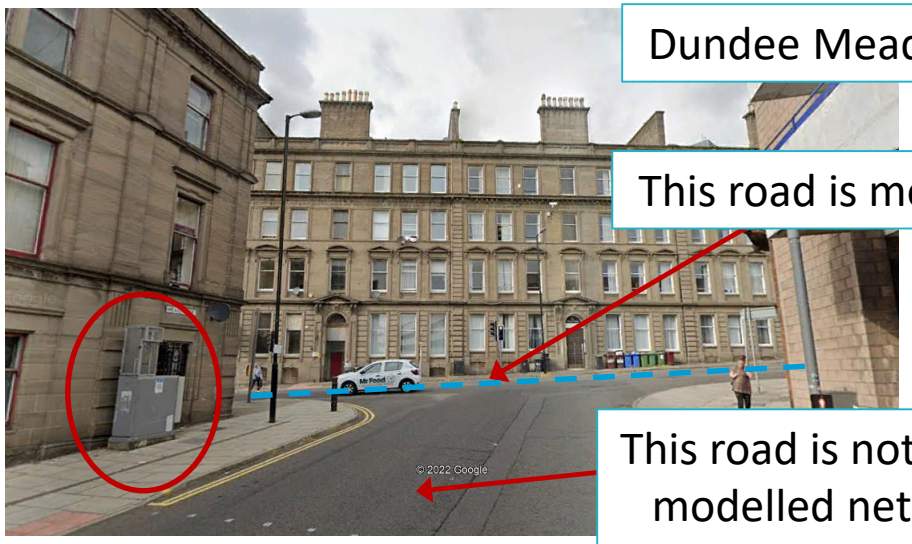
- industrial
- roadside
- rural background
- urban background

Site type	Model	Obs mean	Mod mean	Fb	NMSE	NMSD	R	Fac2
	Ideal			*0.00*	*0.00*	*0.00*	*1.00*	*1.00*
Rural	PCM	7.7	7.0	-0.09	0.05	-0.14	0.93	1.00
	Coupled generic	7.7	7.1	-0.08	0.05	-0.09	0.92	1.00
	Coupled site-specific	7.7	7.1	-0.08	0.05	-0.09	0.92	1.00
Urban background	PCM	22.6	21.0	-0.07	0.06	0.03	0.82	0.99
	Coupled generic	22.6	21.2	-0.06	0.04	0.03	0.88	0.99
	Coupled site-specific	22.6	21.2	-0.06	0.04	0.03	0.88	0.99
Roadside	PCM	35.5	19.1	-0.60	0.53	-0.41	0.73	0.62
	Coupled generic	35.5	27.1	-0.27	0.20	-0.02	0.66	0.88
	Coupled site-specific	35.5	29.9	-0.17	0.10	-0.02	0.78	0.95

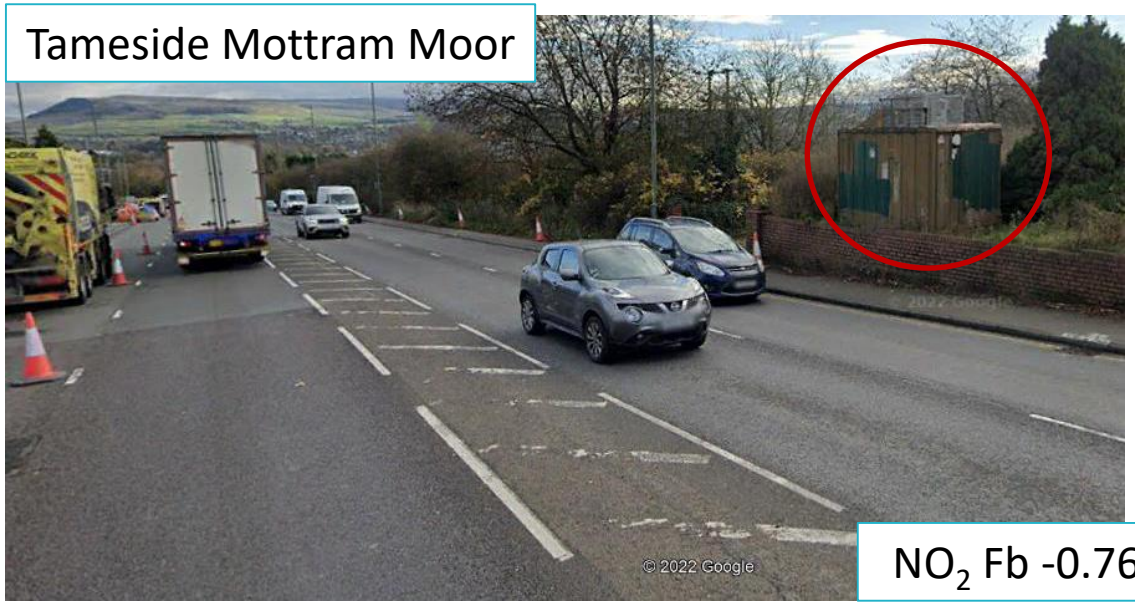
- Clear increment of NO_2 concentrations at near-road sites with the coupled model
- Some underprediction of roadside concentrations (~17%)
- Improvement in model performance with site-specific road and canyon geometry parameters
- Improved correlation at urban background sites with coupled system

National NO_2 modelling – but local effects are important

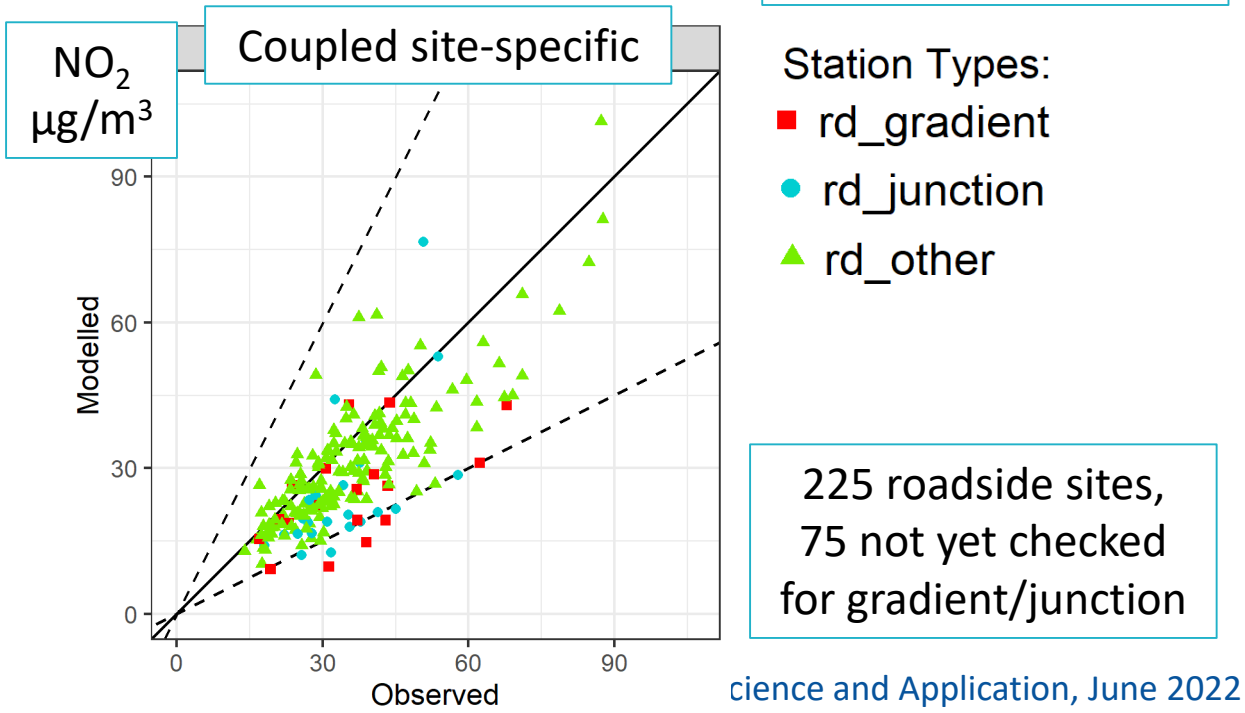
- Low resolution road network
  - Some roadside sites are located at junctions where not all significant roads are modelled
  - A few smaller access roads are assigned excessive emissions from the associated major road
  - Road elevation data not readily available
- Explicit road emissions are based on average traffic speeds per road type
  - No gradient or local traffic congestion effects



Tameside Mottram Moor



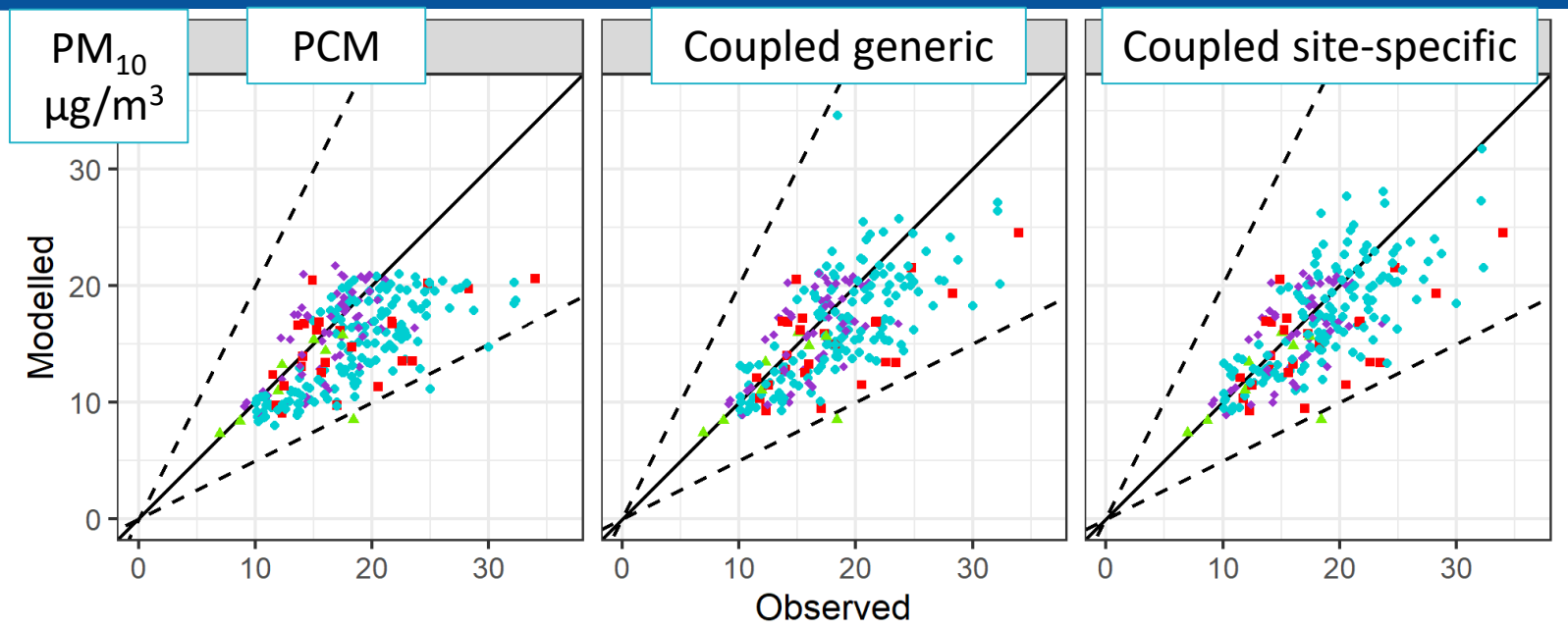
NO_2 Fb -0.76



225 roadside sites, 75 not yet checked for gradient/junction

cience and Application, June 2022

Evaluation: PM_{10}



Station Types:

■ industrial ● roadside

▲ rural background ◆ urban background

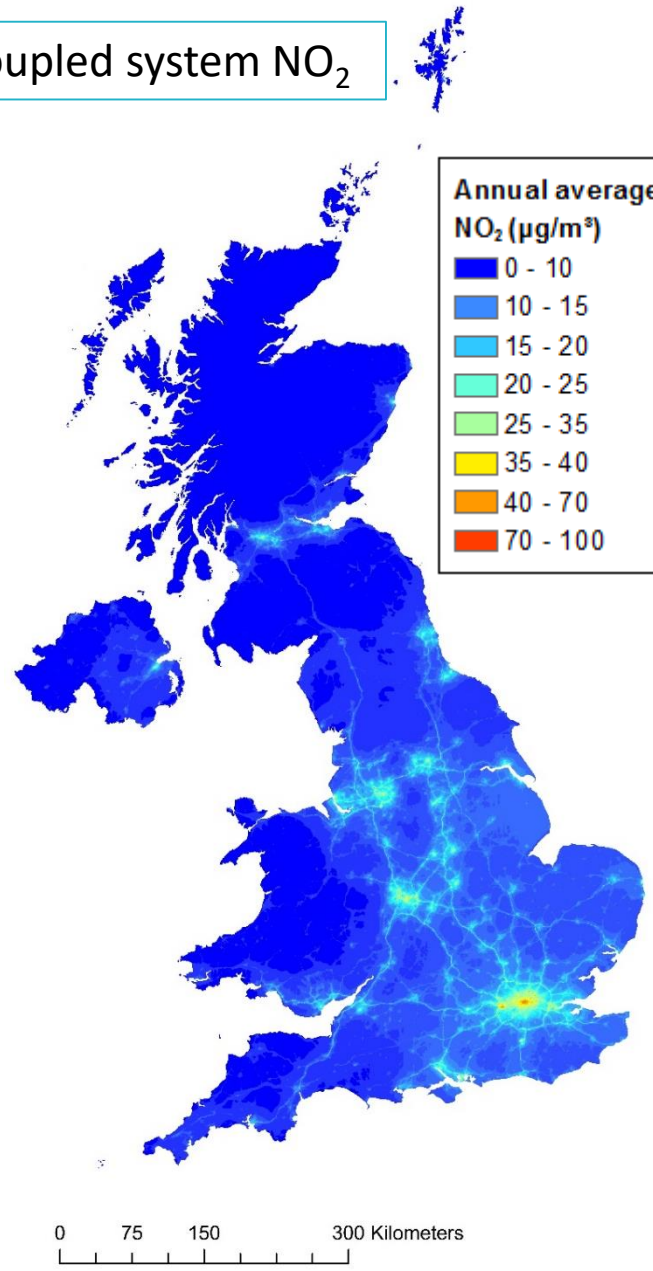
Site type	Model	Obs mean	Mod mean	Fb	NMSE	NMSD	R	Fac2
	Ideal			*0.00*	*0.00*	*0.00*	*1.00*	*1.00*
Rural	PCM	13.3	11.8	-0.13	0.08	-0.13	0.58	0.88
	Coupled generic	13.3	11.9	-0.12	0.08	-0.11	0.57	0.88
	Coupled site-specific	13.3	11.9	-0.12	0.08	-0.11	0.57	0.88
Urban background	PCM	16.2	15.9	-0.02	0.03	0.13	0.63	1.00
	Coupled generic	16.2	16.0	-0.01	0.03	0.12	0.66	1.00
	Coupled site-specific	16.2	16.0	-0.01	0.03	0.12	0.66	1.00
Roadside	PCM	18.7	14.8	-0.24	0.10	-0.22	0.72	0.99
	Coupled generic	18.7	16.5	-0.12	0.06	-0.07	0.71	1.00
	Coupled site-specific	18.7	17.3	-0.08	0.04	-0.08	0.74	1.00

- Small increment of PM_{10} concentrations at near-road sites with the coupled model
- Slight underprediction of roadside concentrations (8%)
- Small improvement in model performance with site-specific road and canyon geometry parameters
- Bigger roadside increment in PM_{10} than $PM_{2.5}$

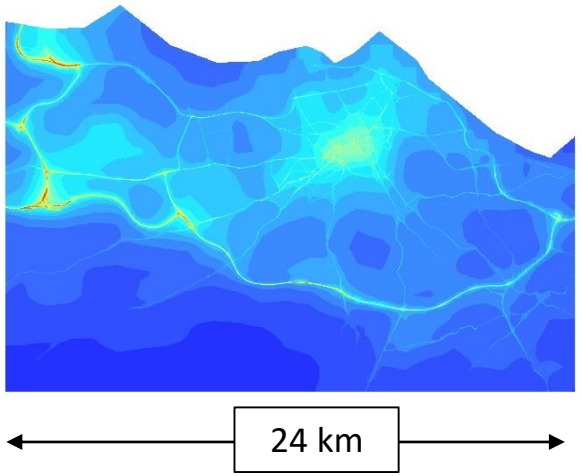
Concentration maps: NO_2

- Average run time for each domain around 12 hours (4.5 to 19 hours)
- Image processing using R, ADMS Grid Interpolator, GDAL and ArcGIS
- Image resolution 20 m
- Preliminary results

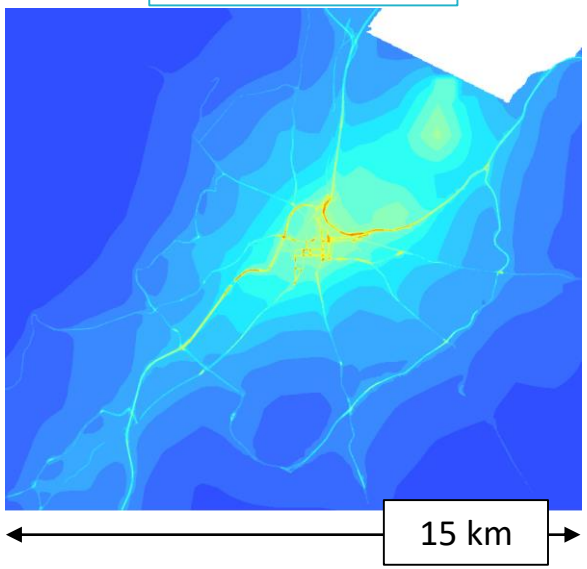
Coupled system NO_2



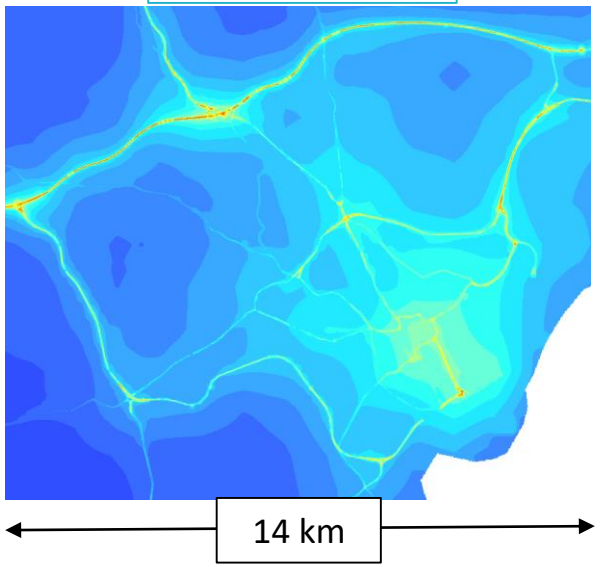
Edinburgh (with SEPA roads)



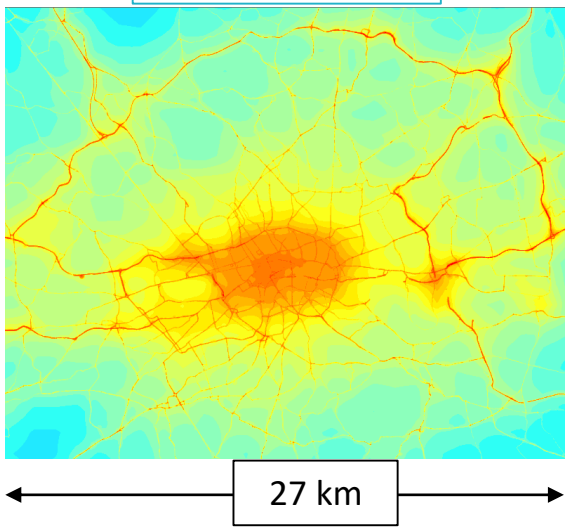
Belfast



Cardiff



Inner London



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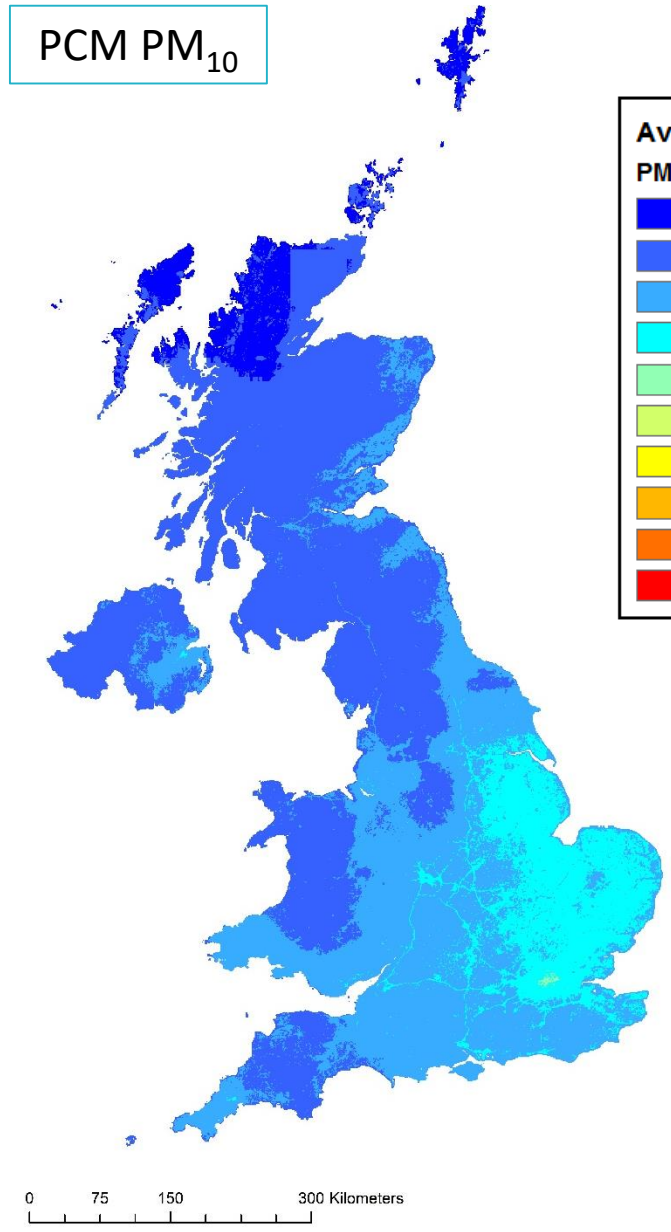
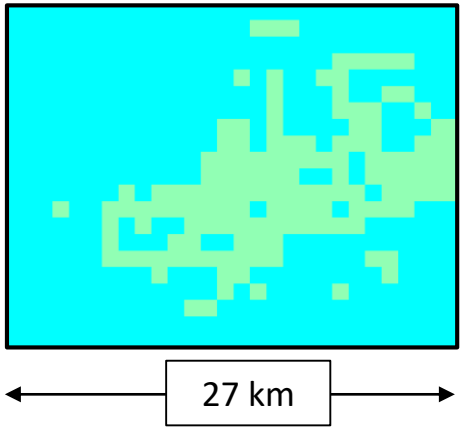
Concentration maps: PM_{10}

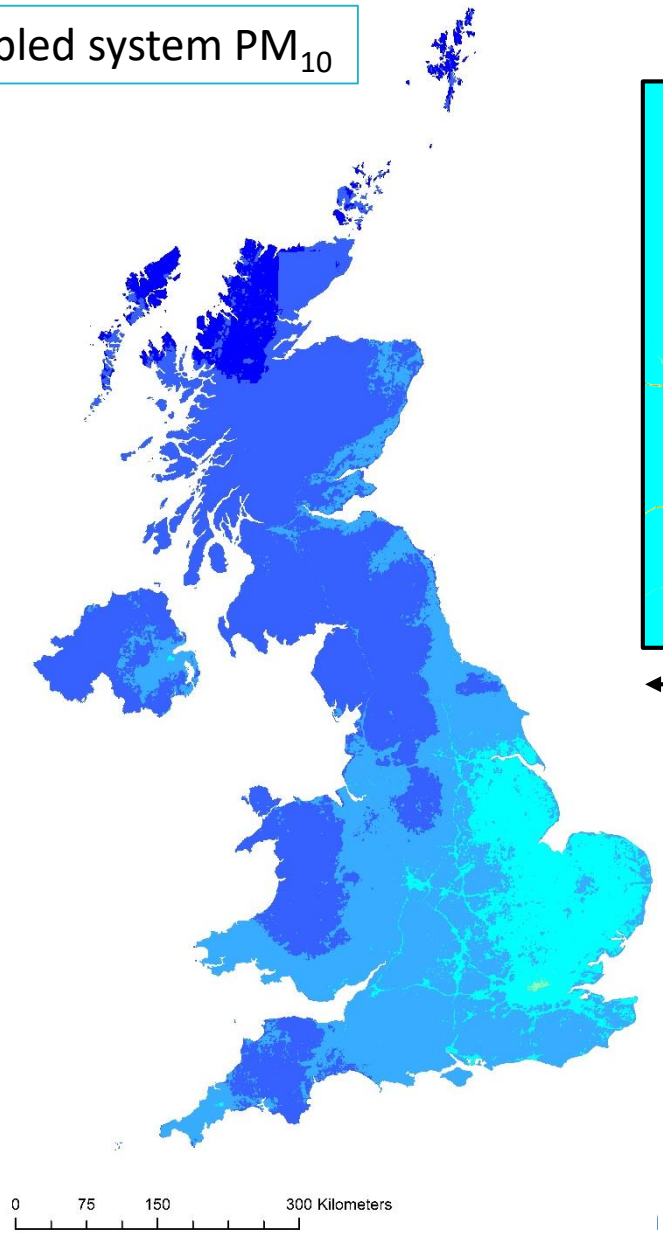
PCM PM_{10}



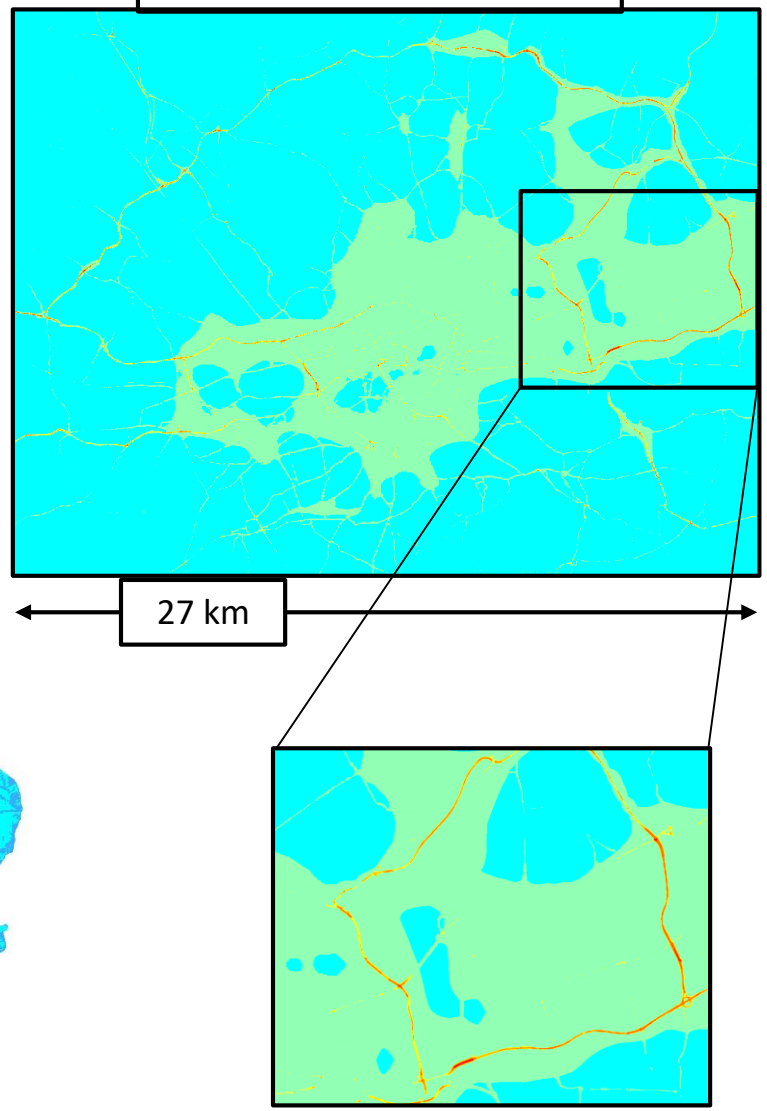
PCM Inner London



Coupled system PM_{10}



Coupled Inner London

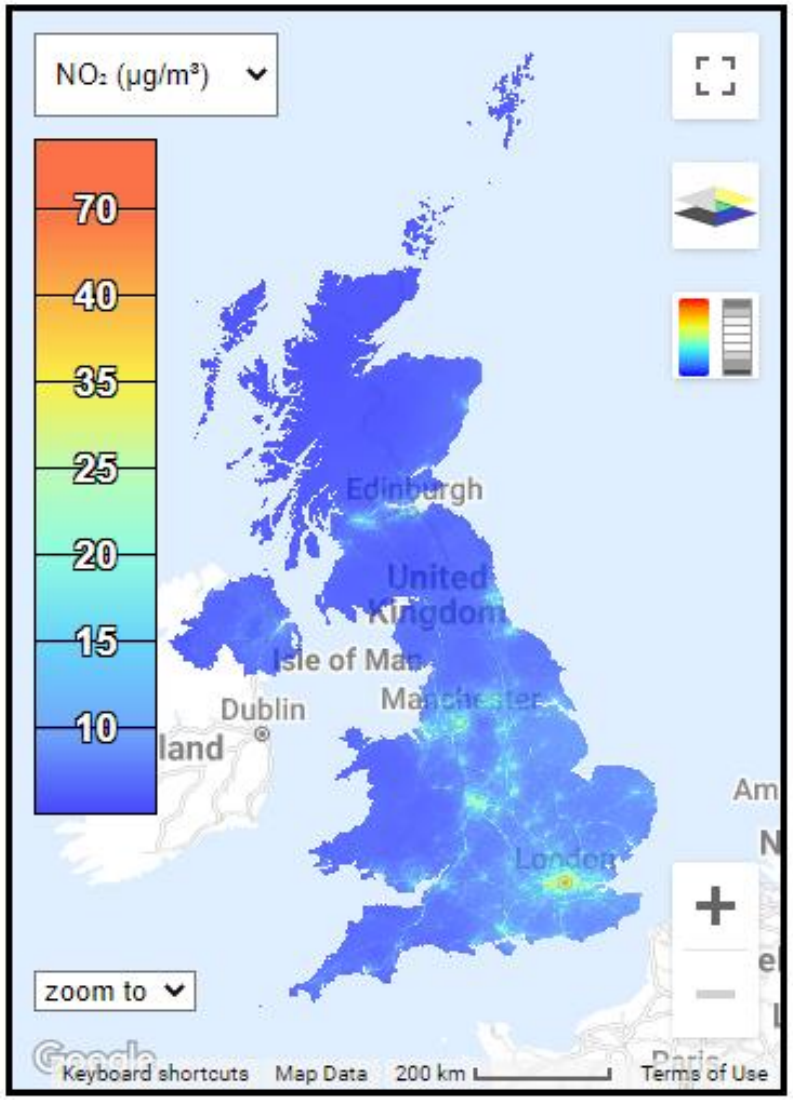


Assessment of annual average modelling approach

- Advantages
  - Regional concentrations freely available for multiple years
  - Fast run times
  - Small output file size
  - Calibrated regional concentrations give good agreement at background receptors
- Disadvantages
  - Only annual average concentrations, no temporal variation or episodes
  - No control of regional model concentrations or emissions, no scenarios
  - Assumptions required for background O_3 concentrations for simplified local chemistry
  - Meteorological data used in local modelling unrelated to those used for regional concentrations

Acknowledgements

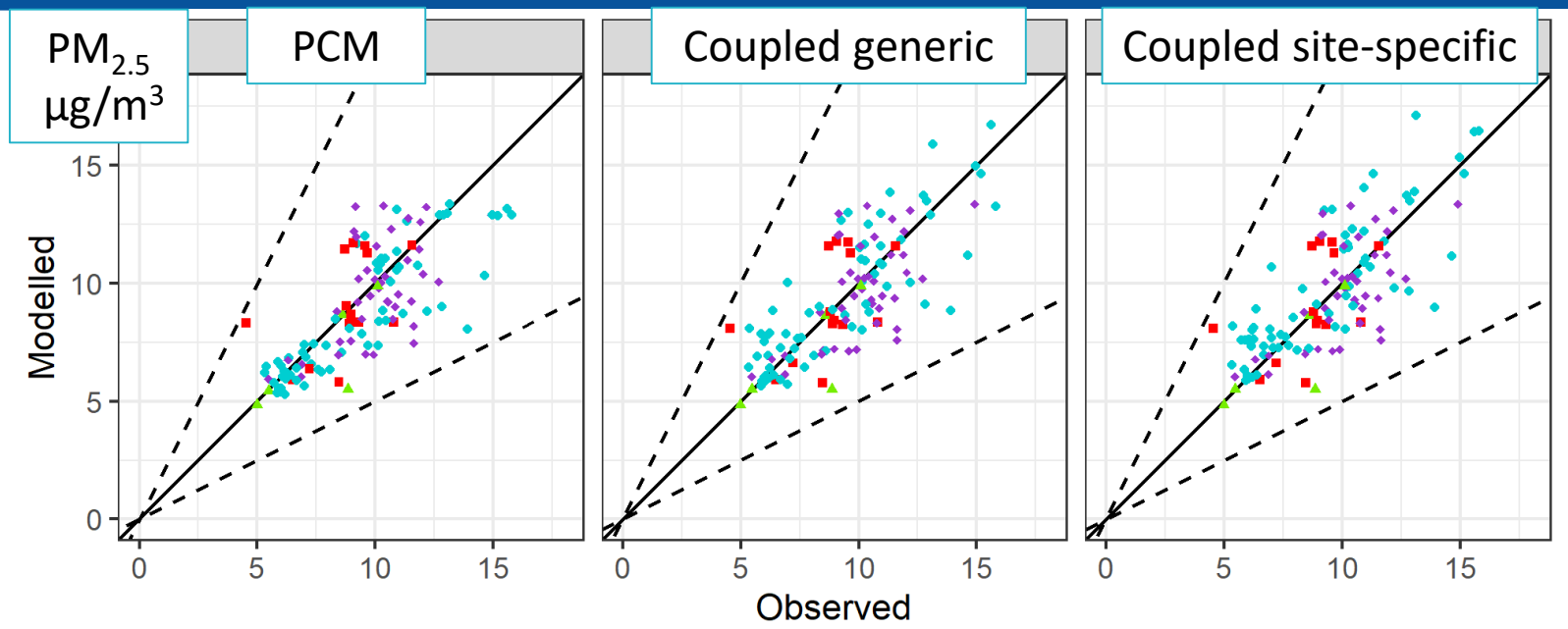
- Defra/Ricardo: PCM annual background maps
- UKCEH: hourly WRF data (UK-SCAPE)
- DUKEMS/Ricardo: GB Major road annual average emissions and time-variation
- Demuzere et al. 2019 LCZ data for canyon and urban canopy parameters
- SEPA Edinburgh NO_X and NO_2 road emissions built for the Cleaner Air for Scotland National Modelling Framework (Contains public sector information licenced under the Open Government Licence v.3.0. Copyright SEPA 2021)



https://cerc.co.uk/environmental-research/urban-air-quality.html#MAQS-Health

Thank you

Evaluation: $PM_{2.5}$



Station Types:

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- roadside
- rural background
- urban background

Site type	Model	Obs mean	Mod mean	Fb	NMSE	NMSD	R	Fac2
	Ideal			*0.00*	*0.00*	*0.00*	*1.00*	*1.00*
Rural	PCM	7.6	6.9	-0.10	0.04	0.00	0.79	1.00
	Coupled generic	7.6	6.9	-0.10	0.04	-0.01	0.78	1.00
	Coupled site-specific	7.6	6.9	-0.10	0.04	-0.01	0.78	1.00
Urban background	PCM	10.1	9.7	-0.04	0.03	0.20	0.59	1.00
	Coupled generic	10.1	9.7	-0.04	0.03	0.18	0.60	1.00
	Coupled site-specific	10.1	9.7	-0.04	0.03	0.18	0.60	1.00
Roadside	PCM	9.2	8.6	-0.07	0.03	-0.11	0.85	1.00
	Coupled generic	9.2	9.4	0.02	0.03	-0.03	0.84	1.00
	Coupled site-specific	9.2	9.8	0.06	0.03	0.00	0.83	1.00

- Small increment of $PM_{2.5}$ concentrations at near-road sites with the coupled model
- Average measured $PM_{2.5}$ at roadside lower than urban background – uneven distribution of monitors around UK
- Some overprediction of roadside concentrations
- Unclear change in model performance with site-specific road and canyon geometry parameters