

# MAQS-Health

Multi-Model Air Quality System for Health Research

David Carruthers, Principal Investigator, CERC

*Clean Air Champions Round Table*

15 February 2022

**CERC**



UNIVERSITY OF  
BIRMINGHAM

University of  
Hertfordshire **UH**

Lancaster  
University



  
Clean Air  
Programme

# MAQS-Health: Project Concept

University of  
Hertfordshire **UH**



**CERC**

Lancaster  
University



UNIVERSITY OF  
BIRMINGHAM

## Requirement

- “High resolution prediction capability to support personal exposure for health impacts, through national and local model developments” (objective of Work Package 2B within the SPF Clean Air Programme)

## Science

- Development & evaluation of a coupled air quality modelling system spanning national to urban street scales
- Flexible modular system linking advanced widely used regional chemical transport & local models
- Accounts for physical & chemical processes occurring at all relevant spatial and temporal scales
- Includes a verification system for validation of model predictions

## Community

- An open structure facilitating system development and modification by stakeholders
- Available to the UK research community for air quality and health via the SPF Clean Air Framework platform
- Compatibility with associated SPF DUKEMS emissions and DIMEX-UK exposure modelling projects



Met Office

**NPL**  
National Physical Laboratory



Department  
for Environment  
Food & Rural Affairs

**Clean Air  
Programme**

The Clean Air (W1) programme is led by NERC and the Met Office, with Innovate UK, EPSRC, ESRC, MRC, NPL & Defra as delivery partners.

# 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**

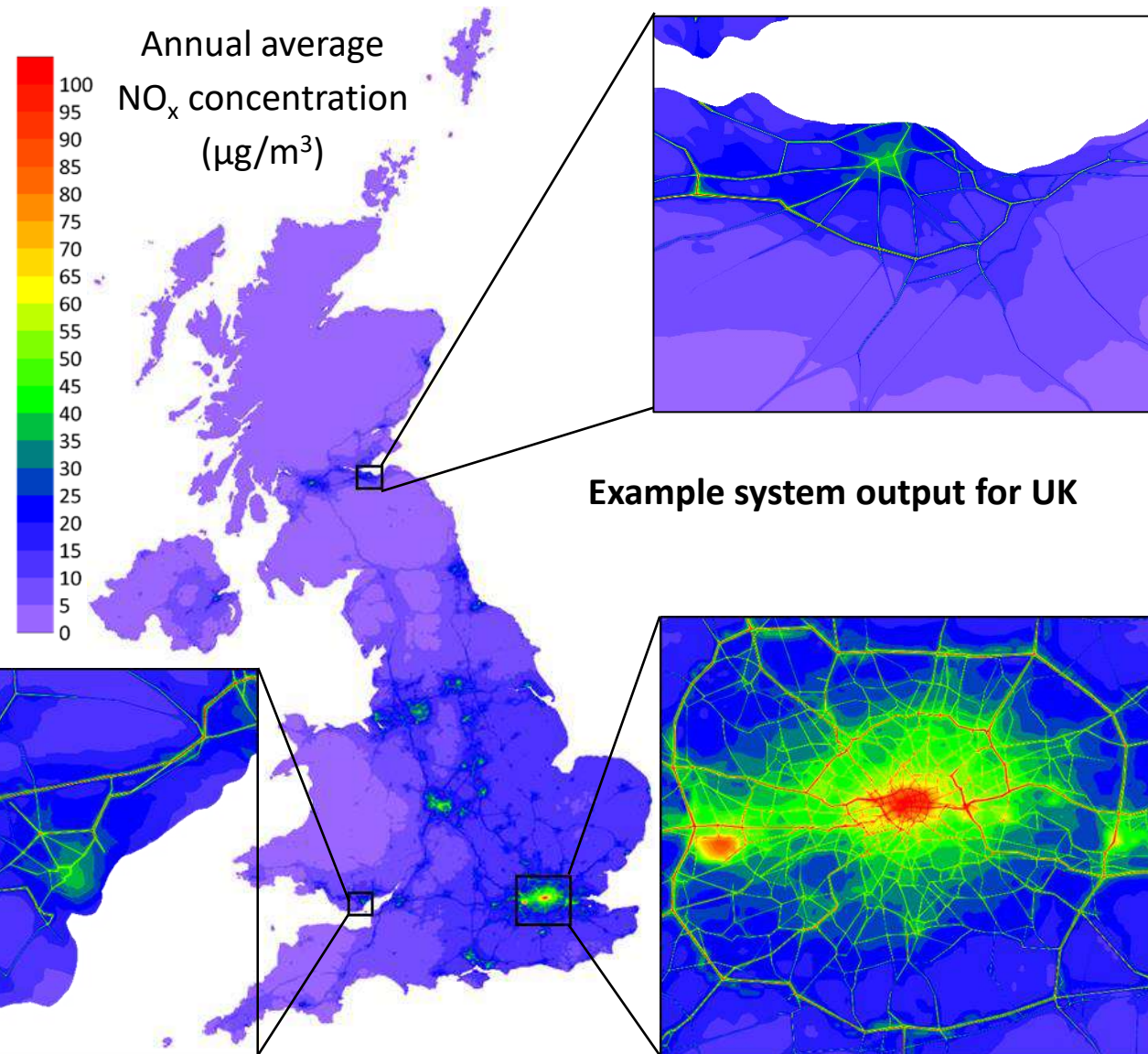
- Regional pollution levels contribute significantly to pollution levels in urban areas
- Eulerian chemical transport models (CTMs) model regional and global pollutant transport and complex atmospheric chemistry
- Range of RM options include: **CMAQ, CAMx, EMEP, WRF-Chem, CHIMERE, UKCA+AQUM\***

**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



\*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.:

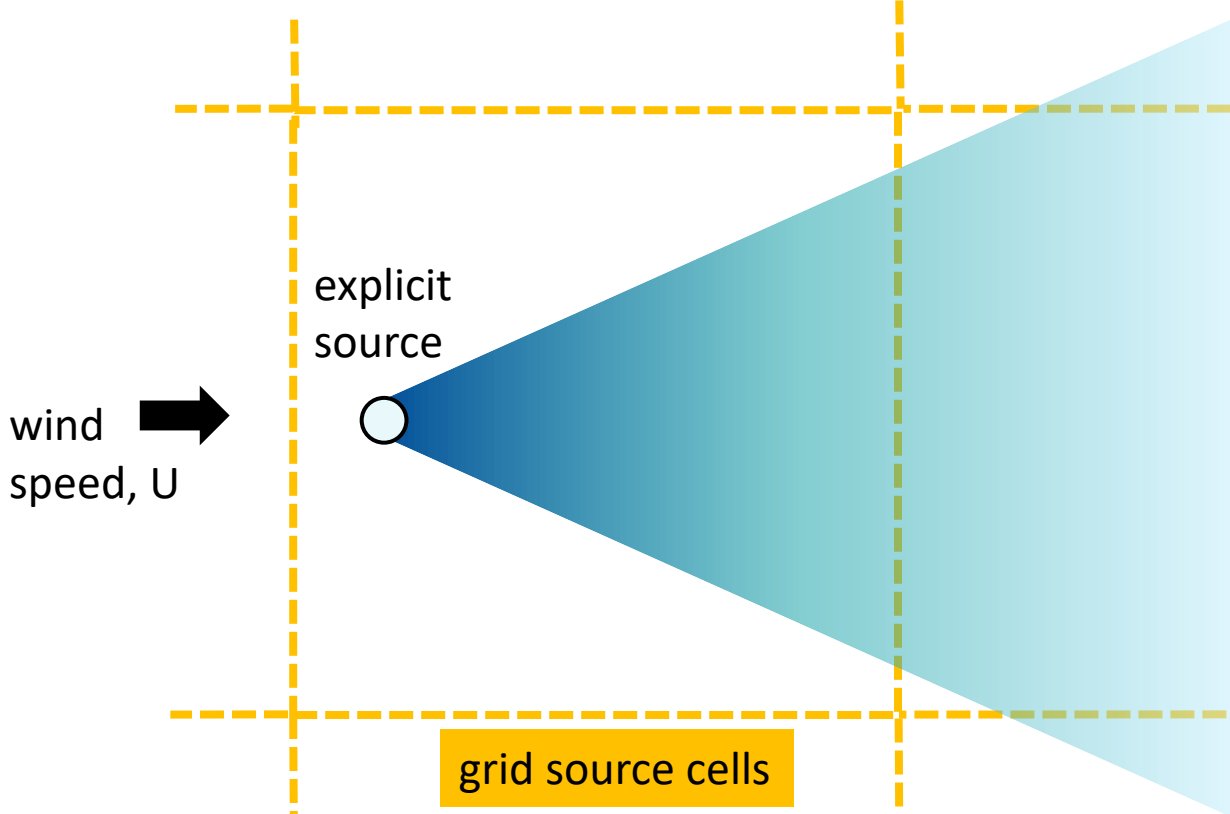
$$\text{Concentration within nested domain} = \text{Regional modelling of emissions} - \text{Gridded locally modelled emissions } (\Delta T) + \text{Explicit locally modelled emissions } (\Delta T)$$

**Assume**

- Plume well mixed in time  $\Delta T$
- Meteorology and emissions are slowly varying on time scale  $\Delta T$

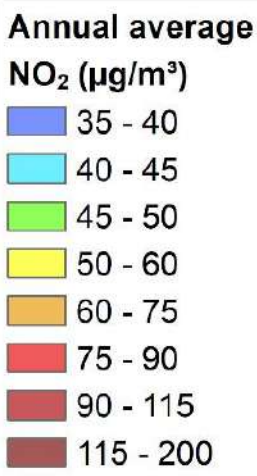
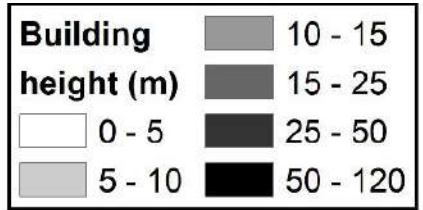
**Use**

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



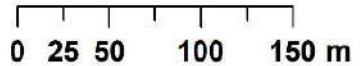
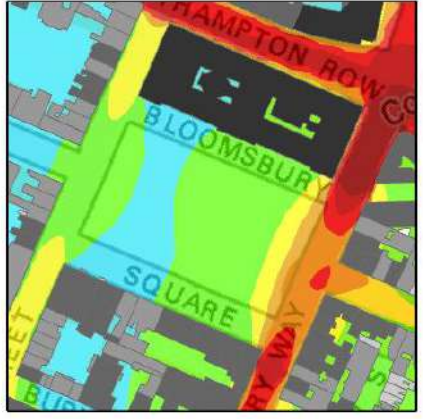
# ADMS-Local: Evaluation

Models transition between canyons and open roads

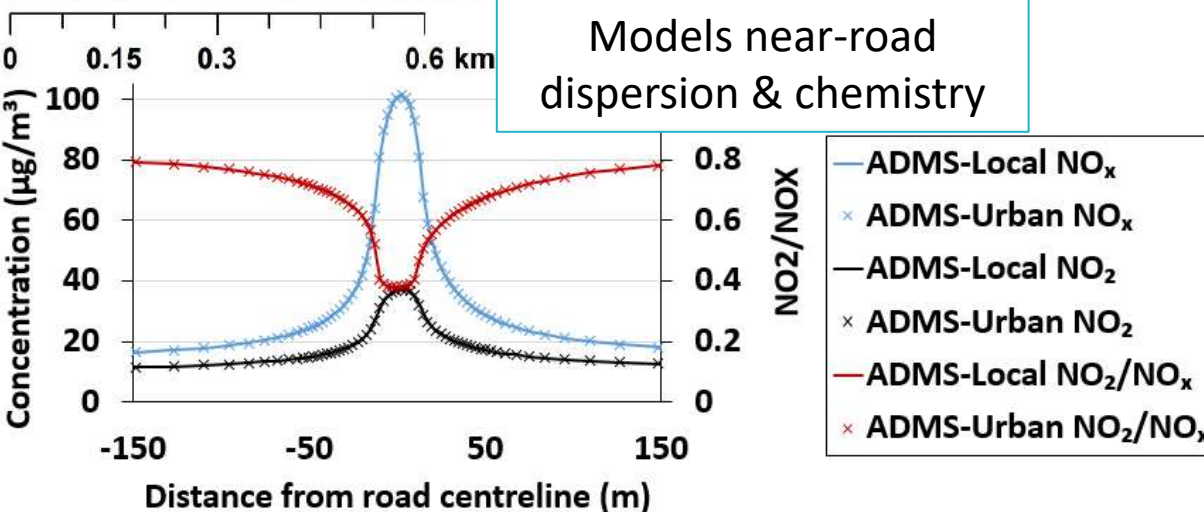


- ADMS-Local model formulation consistent with ADMS-Urban for open road source dispersion
- Simplified approach to modelling street canyons: parameterised canyon method, derived from multiple runs of ADMS-Urban Advanced Canyon module

Contains OS data © Crown Copyright and database right 2021



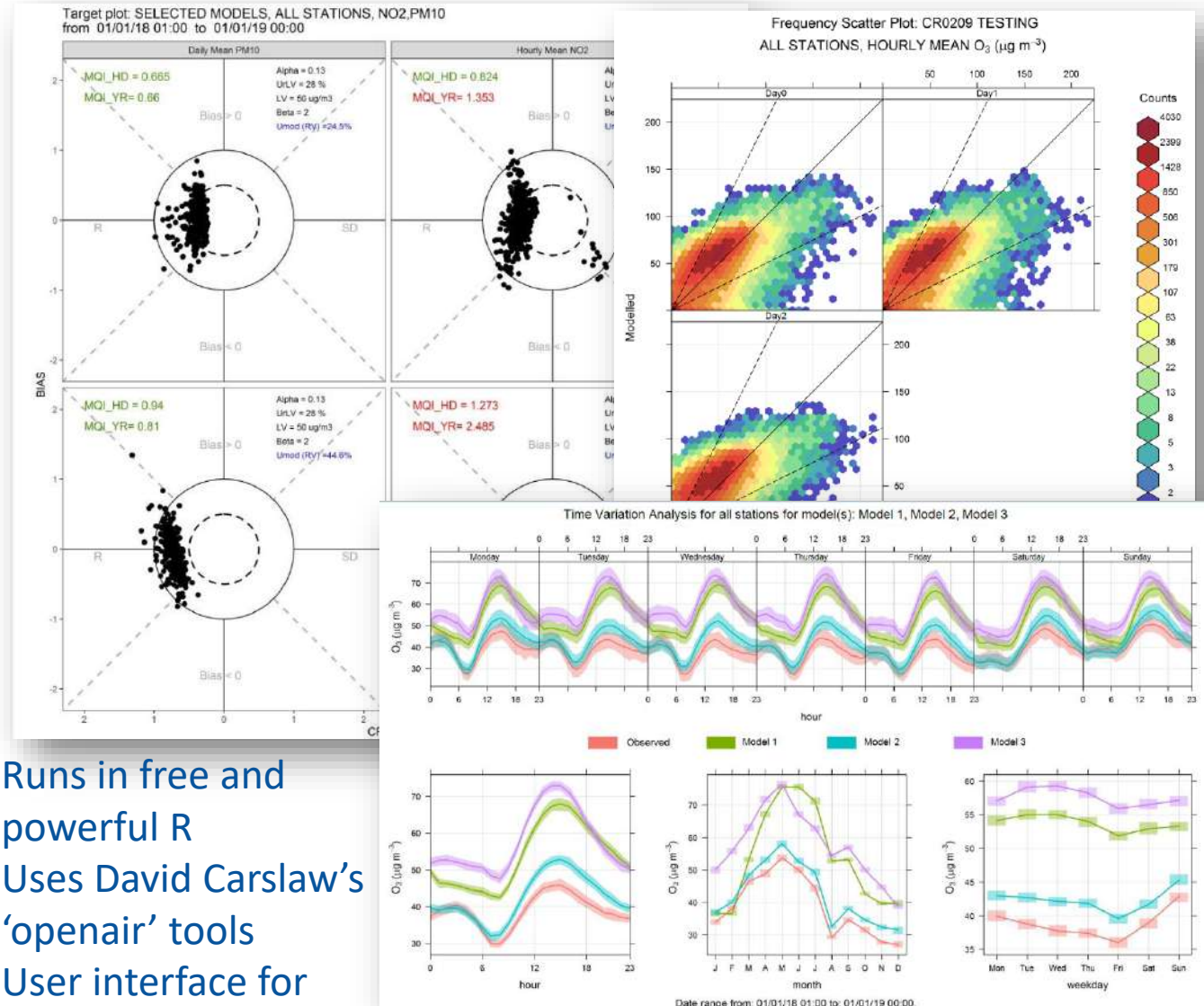
Models near-road dispersion & chemistry



Study	Purpose
Comparison with ADMS-Urban: NO <sub>x</sub> , NO <sub>2</sub>	To ensure consistency with ADMS-Urban open roads, including chemistry
TRAPOS: NO <sub>x</sub> (Hood et al. 2021)	To test performance of parameterised canyon approach
London 2012: NO <sub>x</sub> , NO <sub>2</sub> , O <sub>3</sub> , PM <sub>2.5</sub> , PM <sub>10</sub> (Hood et al. 2018)	To test city-scale modelling of open roads, canyons, volume source modelling, and chemistry

# MAQS-Health Verification System (VS)

- Provides validation of concentration outputs of both the regional model and the coupled system against in situ observed data
- The VS has been designed to:
  - provide an automated, standardised method of comparing MAQS-Health coupled system output with in situ observed data
  - be compatible with all MAQS-Health coupled system supported modelled data formats
  - provide easy access to online measured data
  - enable easy model inter-comparison
  - output a wide range of statistics and publication-ready graphs
- Used for defra Model Inter-comparison Exercise (MIE)



- ❖ Runs in free and powerful R
- ❖ Uses David Carslaw's 'openair' tools
- ❖ User interface for Windows users

# 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

*Caveat: Domains have not yet been finalised*

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

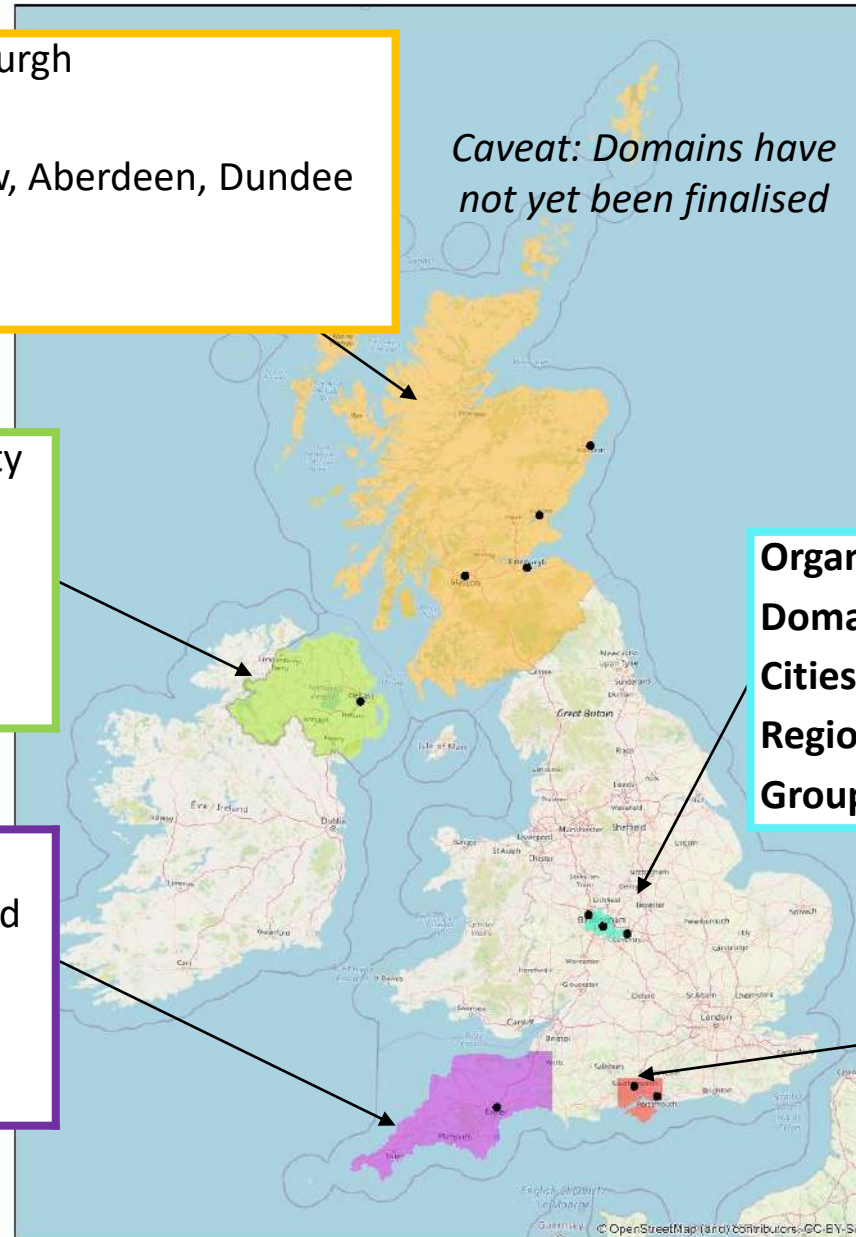
**Organisation:** University of Birmingham  
**Domain:** West Midlands  
**Cities:** Birmingham, Wolverhampton, Coventry  
**Regional model:** CMAQ  
**Group lead:** Prof William Bloss

**Organisation:** Met Office  
**Domain:** South-West England  
**Cities:** Exeter  
**Regional model:** AQUM  
**Group lead:** Dr Rachel McInnes

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

Modelling groups at the **Met Office** and project partners the Universities of **Birmingham**, **Edinburgh**, **Hertfordshire** and **Lancaster** are **beta testing** the system

Thanks to DUKEMS for providing a major road emissions dataset



# System Evaluation Results



UNIVERSITY OF  
BIRMINGHAM



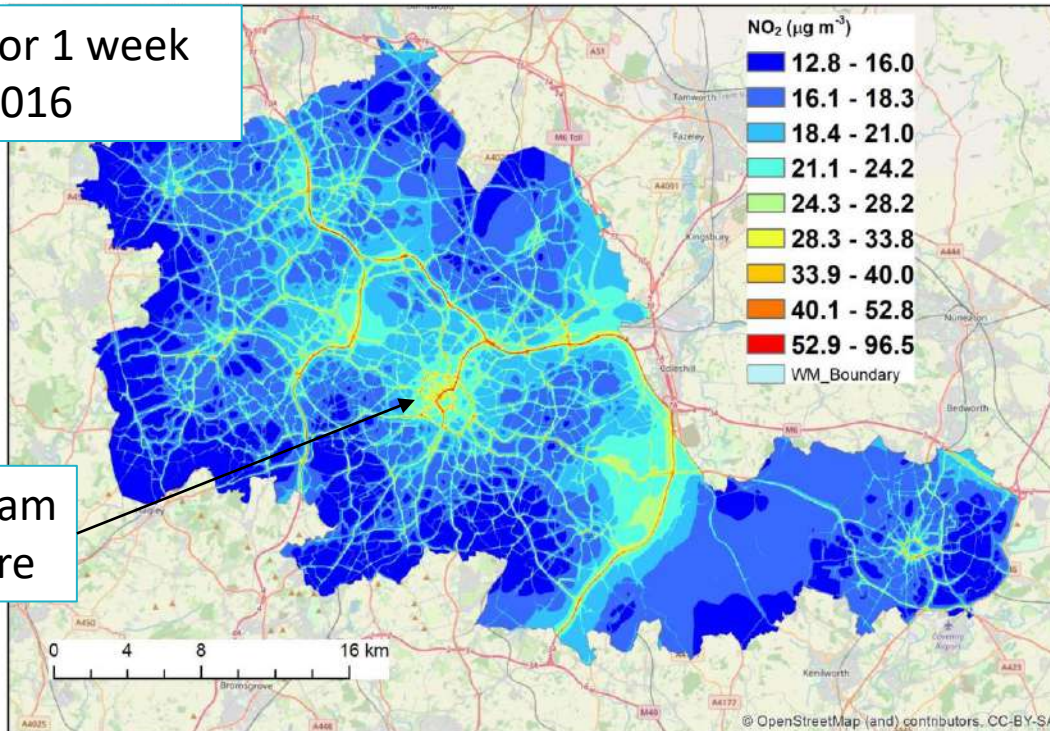
## West Midlands

- Small domain (55 km by 35 km)
- Local model inputs available from WM-Air project, so system used for supplementary investigations
- Evaluation and pollution mapping runs complete

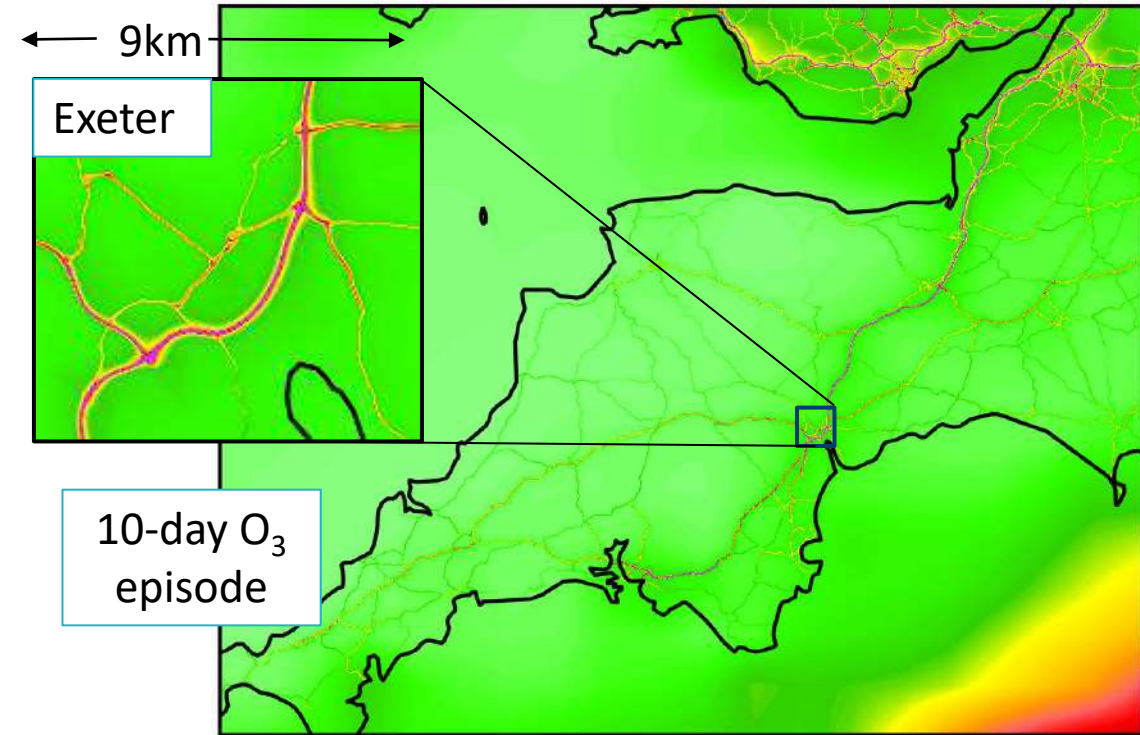
## Southwest England & south Wales

- Large domain (270 km by 220 km)
- Forecasting system: focus on episodes
- Evaluation & pollution mapping runs ongoing

Contour for 1 week  
January 2016

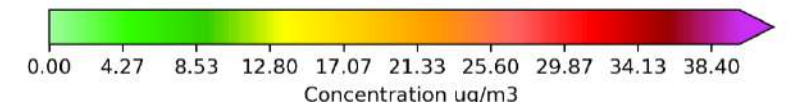


Birmingham  
City Centre



10-day O<sub>3</sub>  
episode

NO<sub>2</sub> concentrations (µg/m<sup>3</sup>)  
generated by MAQS-Health



Clean Air Champions Round Table, 15 February 2022

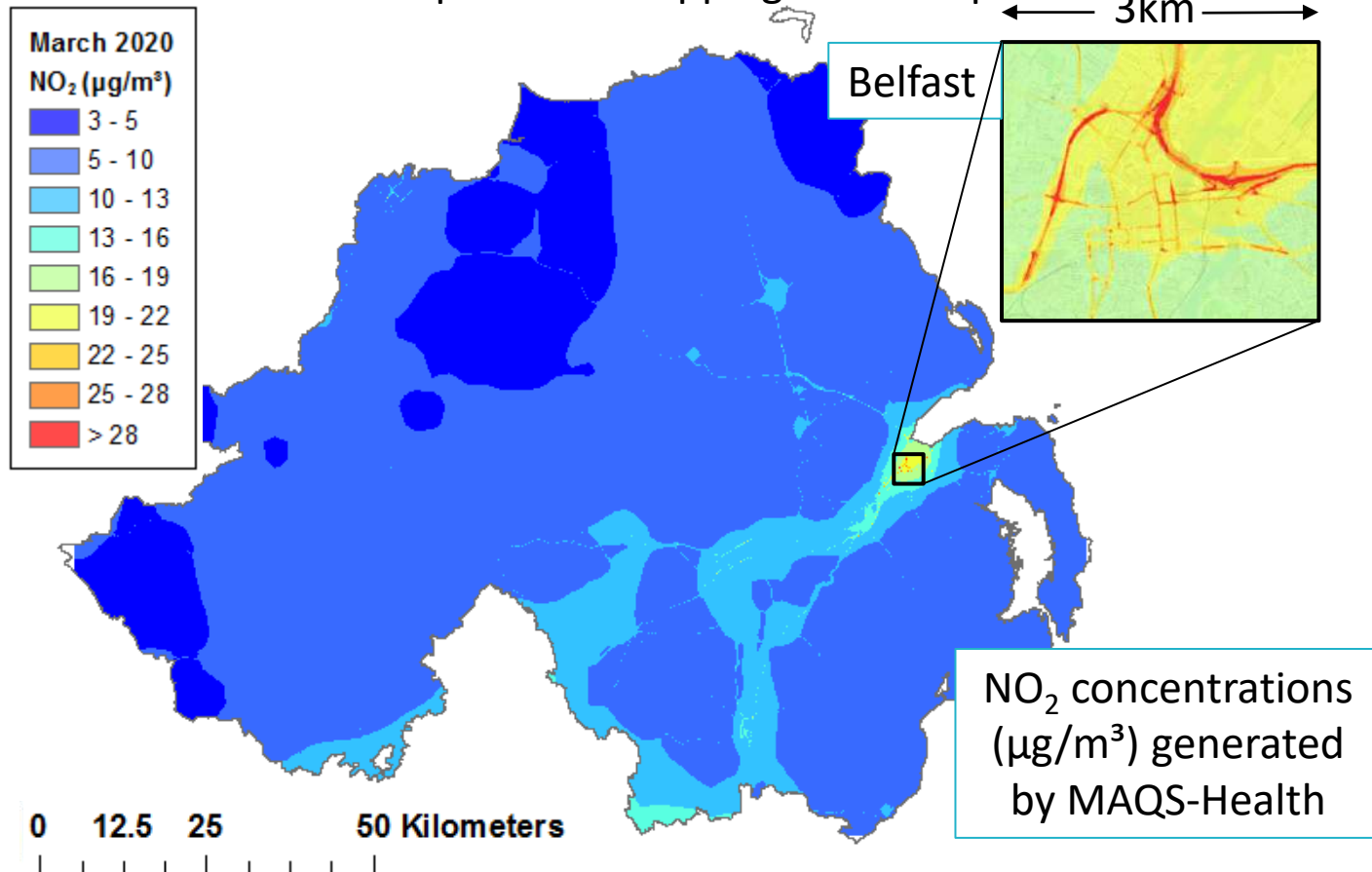


# System Evaluation Results



## • Northern Ireland

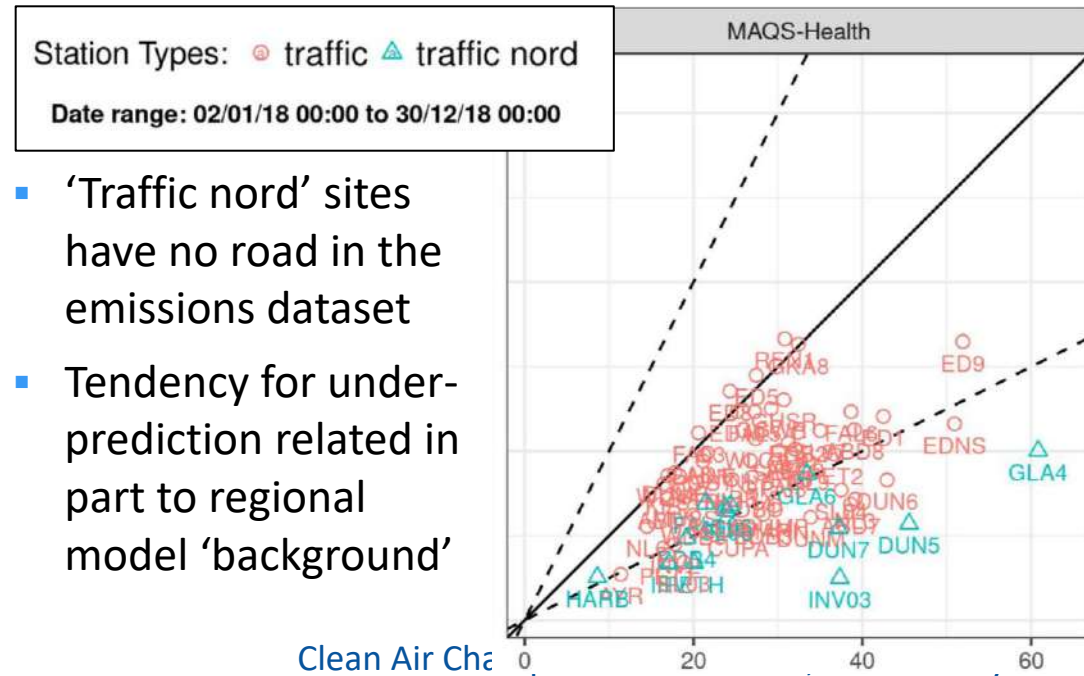
- Moderate domain (175 km by 135km)
- Local emissions and building morphology data unavailable
- Evaluation and pollution mapping runs complete



## • Scotland

- Large domain (380 km by 530 km)
- 3D building data and DUKEMS & SEPA road emissions
- Evaluation complete
- Pollution mapping runs ongoing

Statistical Scatter Plot: MAQS-HEALTH VS  
TRAFFIC, TRAFFIC NORD, PERIOD MEAN, NO<sub>2</sub> (µg m<sup>-3</sup>)



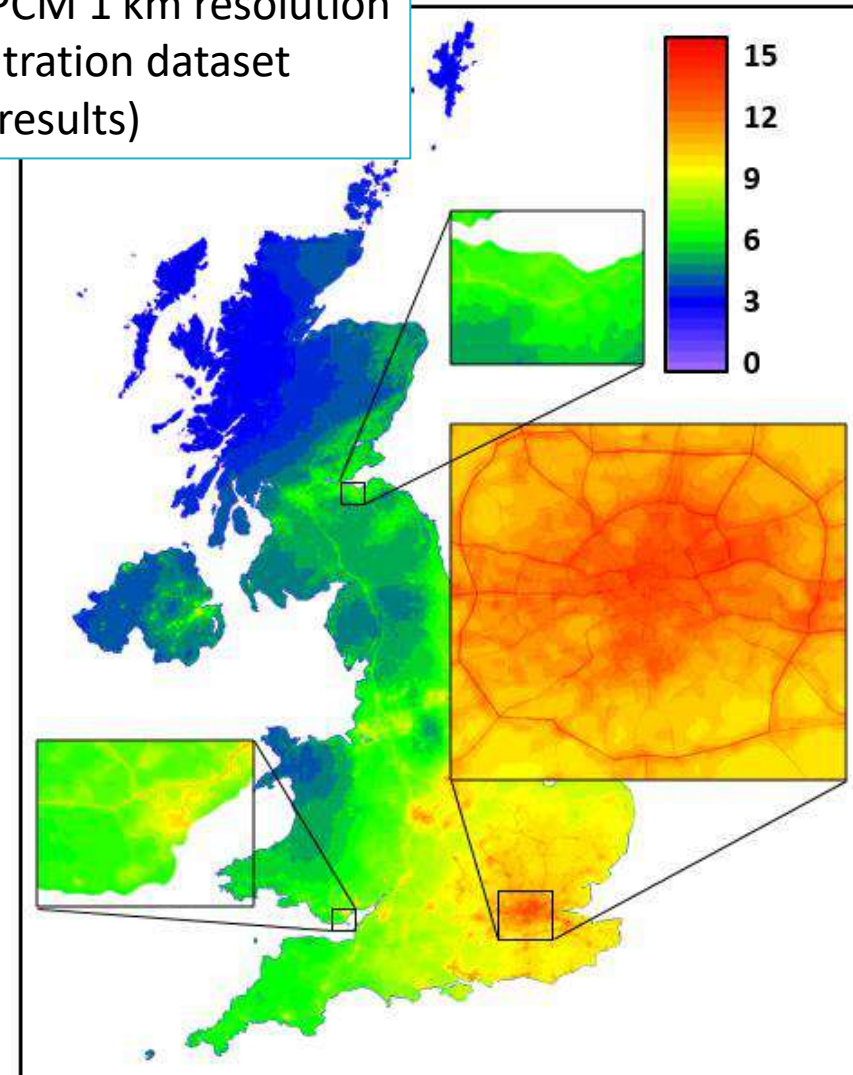
- 'Traffic nord' sites have no road in the emissions dataset
- Tendency for under-prediction related in part to regional model 'background'

# National Model Application using defra (PCM) background maps

## • National modelling

- National MAQS-Health applications require national modelled meteorological and concentration datasets
- Linking to Defra / PCM background maps ensures consistency with measured background concentrations
- DUKEMS (Ricardo) major road emissions for 2018 (Ordnance Survey Open Roads network)
- Hourly, 1 km resolution Weather Forecasting and Research (WRF) provided by DUKEMS (UKCEH)
- Hourly ADMS-Local calculations require estimates of  $O_3$  concentrations for near-road  $NO_x$  chemistry (monthly average diurnal profiles)
- Approximate street canyon parameters derived from Local Climate Zone data, with road carriageway and canyon widths corrected in the vicinity of monitors
- Runs and evaluation ongoing

Annual average  $PM_{2.5}$ : MAQS-Health application using Defra / PCM 1 km resolution 'background' concentration dataset (preliminary results)



# Legacy

- System used for national and regional air quality health impact studies and broader air quality research
- Maintain and develop links with DUKEMS (emissions) and DIMEX-UK (exposure)
- Develop applications linking with indoor air quality (WAVE 2)
- **Issues**
  - Data:
    - Major road traffic emissions not openly available (data provided for current project by DUKEMS for 2018)
    - Major road traffic network sparse so many hotspots not identified
    - 3D building data for calculation of street canyon parameters not openly available (*OSGB data provided for MAQS-Health through Digimap licence for academic partners, and through Met Office for commercial partners*)
    - Sub-source sector data not available through NAEI, so difficult to model release characteristics of certain sectors
    - Proportion of NOX emissions emitted as primary NO2 not provided as part of the NAEI NOX emissions dataset; no accounting for real-world NOx
  - Developments likely needed for compatibility with future updates to regional and meteorological models
  - Support likely needed for new users to adopt the system, or for existing users who update their HPC systems

LOCAL

REGIONAL

Thank you