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Suitability of ADMS-Urban and MAQS for modelling under the EU Air Quality Directive 2024/2881

Cambridge Environmental Research Consultants (CERC) air quality modelling software is ideally placed to be used under Directive (EU) 2024/2881. This document provides an overview of the Directive's requirements for air quality modelling, shows how CERC's software, ADMS-Urban and MAQS, meets these requirements, and presents case studies showing practical applications of the software.

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Introduction – Importance of modelling

Directive (EU) 2024/2881 is the latest European Union (EU) Ambient Air Quality Directive (AAQD) establishing a comprehensive regulatory framework aimed at eliminating the harmful effects of air pollution on human health and the environment by 2050.

The directive consolidates and replaces Directives 2008/50/EC and 2004/107/EC, introducing stricter air quality standards together with strengthened requirements for planning, monitoring, and enforcement. *Of particular relevance is the significantly enhanced role of modelling applications*. The directive contains 79 references to modelling, compared with 21 and 12 in the two preceding directives, respectively, clearly demonstrating the growing importance attributed to modelling. This importance is further underscored by the publication of the Air quality modelling for air quality policy document, which provides detailed technical guidance to support the implementation of air quality modelling under the new Directive.

Under Directive (EU) 2024/2881, air quality modelling plays a central role across several key applications, including:

- **Air Quality Assessment**: providing information on the spatial distribution and levels of air pollution;
- **Spatial Representativeness**: informing the assessment of spatial representativeness and the design of monitoring networks;
- **Source Apportionment**: assessing the links between emission sources and observed air pollution levels and peaks;
- **Air Quality Planning**: quantifying the impacts of planned or implemented emissions reduction measures; and
- **Forecasting**: delivering short-term projections of air pollution levels.

CERC has extensive expertise in air quality modelling and associated applications. CERC software, which includes the Atmospheric Dispersion Modelling System (ADMS), is world renowned, with hundreds of users in the UK, Europe and globally.

ADMS-Urban is the most comprehensive dispersion model within the ADMS suite. It is suitable for air quality studies of complex urban environments due to its ability to describe in detail the dispersion on a range of scales, from street level to city-wide, while considering the entire range of relevant emission sources. Its sister model, ADMS-Airport, additionally allows for detailed modelling of aircraft emissions.

The Multi-Model Air Quality System (MAQS) is an automated multi-scale air quality modelling system that couples the street scale-resolution ADMS-Urban model to regional model datasets. MAQS combines these regional and local concentrations in such a way as to minimise double-counting of emissions and to ensure that the chemical processes are accounted for at all timescales while remaining computationally efficient and user-friendly.

MAQS directly supports a number of regional meteorological and chemical transport model file formats, specifically:

- **Meteorology**: WRF;
- **Emissions**: CMAQ and WRF-Chem;
- **Concentrations**: CMAQ, CAMx, CHIMERE, EMEP and WRF-Chem.

Meteorology, emissions and concentrations data from other models can be used in conjunction with MAQS, but datasets need to be converted into generic input file formats (2D or 3D). The MAQS User Guide provides further details.

General requirements for air quality modelling under EU AQD 2024/2881

Directive (EU) 2024/2881 places a strong emphasis on the use of modelling applications. Modelling is referenced 79 times across Articles 5, 7, 8, 9, 11 and 15 as well as in Annexes IV, V, VI, VII and X. The Directive introduces more sophisticated monitoring and assessment regimes, which explicitly strengthen the role of modelling to ensure continuity of measurements (in case a fixed monitor needs to be moved from the current location) and improved spatial representativeness for the following pollutants: sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter (PM_{10} and $PM_{2.5}$), benzene, carbon monoxide, arsenic, cadmium, lead, nickel, benzo(a)pyrene and ozone.

In this context, the following terminology should be considered:

- **Assessment thresholds** are pollutant concentration limits that determine the assessment method required for each zone. Depending on whether pollutant concentrations are below or above the threshold, the assessment method may rely on fixed continuous measurements, air quality modelling, indicative measurements, or a combination thereof;
- **Limit Value (LV)** is a legally binding pollutant concentration value, set to protect human health, that must not be breached;
- **Target Value (TV)** is a pollutant concentration value set to avoid long-term harmful effects. It is less strict than an LV, as it is required to be attained only when the necessary measures required to reach it do not incur disproportionate cost.

In contrast to Directives 2008/50/EC and 2004/107/EC, the revised Directive strengthens the role of supplementary assessment methods, such as air quality modelling and indicative measurements, in all zones where pollutant concentrations exceed a relevant LV or TV. From 2028, the use of these supplementary assessment methods, in combination with fixed measurements, will become mandatory in such zones.

Threshold exceedances

In all zones where pollutant assessment thresholds are exceeded, ambient air quality must be assessed using fixed measurements. These may be supplemented by modelling applications to provide additional information on spatial distribution and the spatial representativeness of fixed monitoring sites (Regimes 1a and 1b of **Figure 1**).

In zones where pollutant levels exceed the relevant assessment threshold but remain below the applicable LV, TV, or critical level (corresponding to Regime 1b of **Figure 1**), the number of fixed measurement sites can be reduced by up to 50%. This reduction can be achieved provided that modelling applications and/or indicative measurements are used and that the information obtained is sufficient to adequately assess air quality.

From 2028, modelling applications, or indicative measurement, must also be used in addition to fixed measurements in areas where pollutant levels exceed an LV or TV, corresponding to Regime 1a of **Figure 1**.

In zones classified as below the assessment threshold, modelling applications, indicative measurements, objective estimation or a combination of the listed techniques are sufficient for ambient air quality assessment (Regime 2 of **Figure 1**).

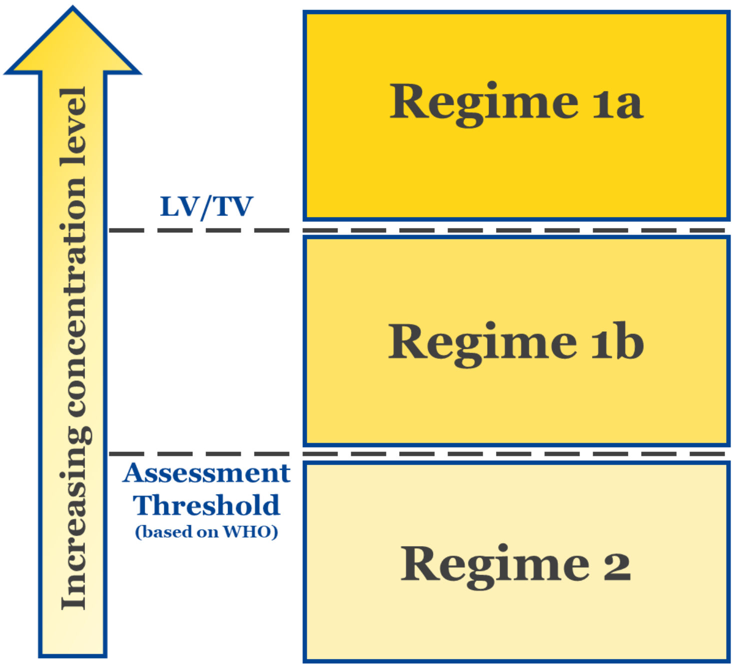

Figure 1 – Diagram summarising the assessment regimes defined in Directive (EU) 2024/2881. Regime 1a applies to zones where the pollutant concentrations exceed the relevant LV or TV, Regime 1b where concentrations remain below these values despite exceeding the assessment threshold and Regime 2 where concentrations are below the assessment threshold. Adapted from Directorate-General for Environment, March 2025.

Spatial representativeness

Modelling applications should be used to provide information on the spatial representativeness of fixed measurements. In this context, modelling must be done at least every five years. Where modelling identifies an exceedance of an LV or TV in areas not covered by fixed measurements (or their spatial representativeness), the directive requires installation of at least one additional fixed or indicative measurement site at the air pollution hotspot(s) identified by the modelling.

Air quality roadmaps and plans

Where pollutant levels exceed any LV or TV in a particular zone, the Directive requires the development of air quality roadmaps and plans. Modelling can be used to understand the reasons for exceedances, for example by undertaking source apportionment, and to provide evidence for the likely impact of air quality control measures.

- **Roadmaps**: For the period from 1 January 2026 to 31 December 2029, where pollutant levels in a zone exceed any LV or TV to be attained by 1 January 2030, air quality roadmaps for the relevant pollutant must be developed. The roadmap must define measures to ensure compliance by the applicable attainment deadline.

- **Air quality plans**: Where pollutant levels exceed any LV or TV, air quality plans need to set out appropriate measures to achieve compliance. The exceedance period must be kept as short as possible.

The information to be included in air quality plans and air quality roadmaps are detailed in the Annex VIII of the Directive (EU) 2024/2881.

ADMS-Urban is fit-for-purpose

Under Directive (EU) 2024/2881 Member States can choose appropriate model(s) to use for modelling applications, provided they are fit-for-purpose. The Air quality modelling for air quality policy document does not formulate any legal provisions, rather it outlines current good practices in the European modelling community and the ambition level for air quality modelling in Europe for applications in relation to air quality policy. **Here, we review this information in the context of ADMS-Urban in order to assess this model's suitability for use in modelling applications as part of the latest Directive.**

Tables 1 and **2** summarise the compatibility of ADMS-Urban model features and modelling approaches, respectively, with the revised Directive (EU) 2024/2881 based on the Air quality modelling for air quality policy document. The tables contain, for each model capability item, the associated category, which is either 'recommendation' or 'good practice'. ADMS-Urban compatibility is classified using a traffic light system; green items represent directly compatible capabilities and orange items are those for which the model is compatible provided some pre- and/or post-processing of data is performed. The associated reference to the Air quality modelling for air quality policy document is given.

The information presented in **Tables 1** and **2** demonstrates that ADMS-Urban, alongside associated tools such as CERC's Model Evaluation Toolkit, are in line with the majority of recommendations and good practice guidance.

Table 1 – Summary of the compatibility of ADMS-Urban model features with current good-practice standards and recommendations within the European air quality modelling community. The references refer to the Air quality modelling for air quality policy document.

Category	Type	Model Capability	Model Compatible?	Reference
Fitness-for-purpose	Recommendation	The model is specifically designed to meet the requirements of particular planning application	**YES**	1.5, 5.4.1
Appropriate spatial and temporal resolution	Recommendation	The model has the appropriate spatial and temporal resolution	**YES**	1.4.1, 1.4.2, 5.4.1
	Recommendation	The model is capable of reproducing long-term and short-term indicators	**YES**	1.4.1, 3.3
	Recommendation	The model is capable of addressing hotspots, such as street canyons, and broader exceedances.	**YES**	5.4.1
Quality of Emissions Inputs and Scenario Design	Recommendation	The model can be provided with emission data that are spatially gridded, vertically distributed, and temporally resolved	**YES**	1.4.3
	Recommendation	The model can utilise detailed source data and emissions factors for mitigation impacts	**YES**	1.4.3, 5.2.4
	Recommendation	The model can produce a baseline (business-as-usual) scenario	**YES**	5.2.4
Meteorological Data Considerations	Recommendation	The model utilises meteorological data covering the modelled period and consider inter-annual variability	**YES**	1.4.4, 5.3.3
	Recommendation	The model utilises WMO-standard data	**YES with data pre-processing**	1.4.4
	Good Practice	The model is capable of assessing representativeness if using single-year meteorological data	**YES**	5.3.3

Table 1 – Summary of the compatibility of ADMS-Urban model features with current good-practice standards and recommendations within the European air quality modelling community. The references refer to the Air quality modelling for air quality policy document. *(continued)*.

Category	Type	Model		Reference
		Capability	Compatible?	
Boundary Conditions and Background Contributions	Recommendation	The model can make use of boundary conditions that reflect future trends, integrating regional policies	**YES with data pre-processing**	1.4.5, 5.3.2
	Recommendation	The model can use harmonised EU-wide data (e.g. CAMS, EMEP) for background trends	**YES with data pre-processing**	5.3.2
	Recommendation	The model utilises robust chains to integrate projections and avoid double-counting	**YES**	1.4.7, 5.3.2
Source Apportionment Integration	Recommendation	Source apportionment (SA) should assess the impact of mitigation measures	**YES**	4.1, 5.2.2
	Recommendation	For planning, methods providing "potential impacts" (concentration changes from emission changes) are suitable. Linearity of reactive compounds must be checked	**YES**	4.2.1, 4.3.1

Table 2 – Summary of the compatibility of ADMS-Urban modelling approach with current good-practice standards and recommendations within the European air quality modelling community. The references refer to the Air quality modelling for air quality policy document.

Category	Type	Model		Reference
		Capability	Compatible?	
Quality of Emissions Inputs and Scenario Design	Good Practice	The model can produce Maximum Feasible Reduction[1] scenarios to identify highest achievable reductions	YES with emissions data processing	5.2.4
	Good Practice	The model can use Emission Reductions for Attainment[2] scenarios for compliance projections	YES with emissions data processing	5.2.4
	Recommendation	If needed, sensitivity tests for best/worst-case scenarios, related to uncertainties in efficiency of emission abatement technology, implementation effectiveness, adoption, exemptions, and enforcements of measures can be performed	YES with additional data processing	5.2.4, 5.4.2
Model Validation and Bias Adjustment for Future Scenarios	Recommendation	The model must be validated and fulfil the Modelling Quality Objective (MQO) for the reference situation	YES with data post-processing	1.5, 3.3, 3.4, 5.4.2
	Recommendation	For future scenarios, the model can be adjusted for bias observed in the reference case, applying methods (e.g. absolute or relative differences) based on understanding the bias's cause	YES with data post-processing	1.4.6, 5.3.5, 5.4.2
	Recommendation	If data fusion or assimilation is used, the model can use independent observations for validation	YES with data post-processing	1.4.6, 3.4.4

[1] Defined in the Air quality modelling for air quality policy as "An emission scenario that reflects what is achievable within a specific time period and includes all known technically feasible measures, irrespective of their cost, as well as structural or behavioural changes, that are realistically achievable".
[2] The Air quality modelling for air quality policy describes this scenario as a simpler case where exceedances are due to just one major and local source, where it can be useful to first estimate the emission reductions required to achieve compliance. From here, measures must be found that can attain this emission reduction. Once the required emission reductions are determined, an air quality calculation still needs to be made to confirm whether compliance is attainable.

Table 2 – Summary of the compatibility of ADMS-Urban modelling approach with current good-practice standards and recommendations within the European air quality modelling community. The references refer to the [Air quality modelling for air quality policy document.]() *(continued)*.

Category	Type	Model		Reference
		Capability	**Compatible?**	
Dynamic Sensitivity and Evaluation	Recommendation	Evaluate the model's sensitivity to emissions changes, especially for non-linear chemistry	**YES with emissions data processing**	5.4.3
	Good Practice	Reproduce historical trends to validate model and emissions	**YES**	5.4.3
	Good Practice	Use tools like DELTA for dynamic sensitivity evaluation	**YES**	3.4.5, 5.4.3
Comprehensive Spatial Coverage	Recommendation	Projections should cover the entire zone, using Exceedance Situation Indicators	**YES**	5.3.1
Accounting for Natural Sources and Winter-sanding/Salting	Recommendation	The model is capable of subtracting the contributions from natural sources and winter-sanding/salting from exceedances if appropriately quantified and reasonable measures to lower concentrations are demonstrated	**YES with data pre- and post-processing**	3.7, 5.3.4
Quality Assurance/Quality Control (QA/QC) and Documentation	Recommendation	A rigorous QA/QC process is essential, involving thorough checks of all input data, model implementation, and output	**YES**	1.5, 5.4.2
	Recommendation	The modelling system and its validation must be well documented	**YES**	1.5
	Recommendation	Information on methodology, assumptions, projection data, and, where possible, uncertainty margins and sensitivity scenarios must be described in air quality plans and roadmaps	**YES with analysis reporting**	5.1.2, 5.4.2

ADMS-Urban showcases

ADMS-Urban is applied to a wide range of air quality management, forecasting and policy development studies in cities worldwide. A small selection of ADMS-Urban case studies are described below.

WM-Air project

The West Midlands Air Quality Improvement Programme (WM-Air) was an initiative funded by the UK's NERC which considered the relationship between improvements in air quality and the associated health, environmental and economic benefits. The project involved street-scale air quality modelling using ADMS-Urban to assess pollutant concentrations relating to a base year in addition to a range of emissions scenarios. The study covered the entire West Midlands Combined Authority region, including many highly-populated urban areas such as Birmingham, Wolverhampton, Coventry, Walsall and Sandwell. The study provided evidence to inform policy. Baseline and scenario air quality modelling results have been published (Zhong et al., 2021, Zhong et al., 2024).

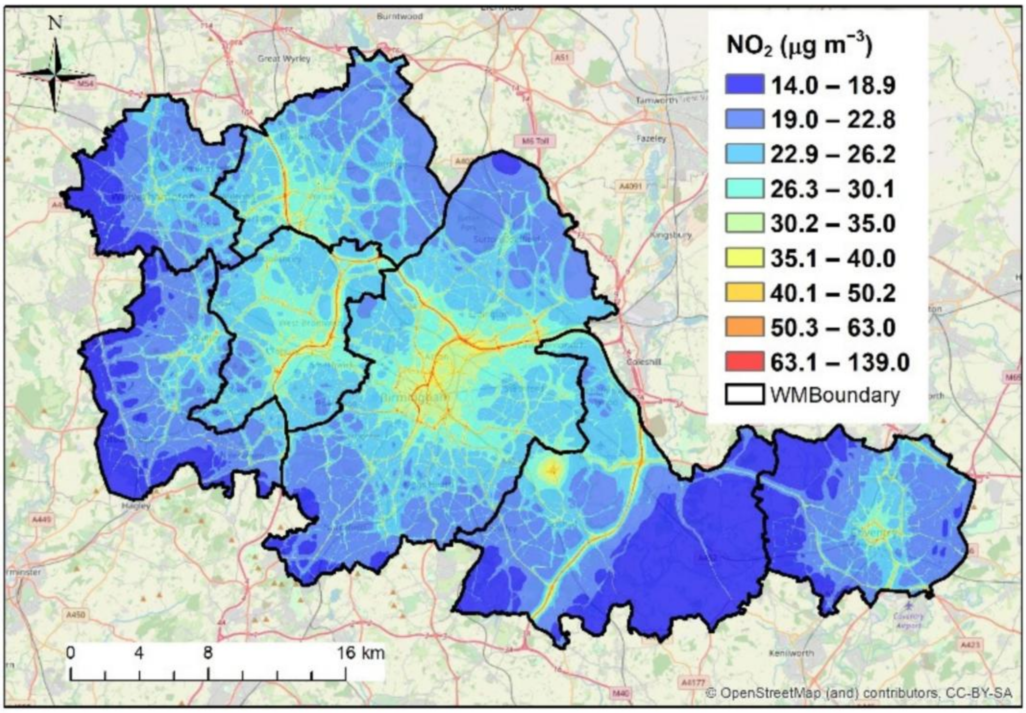

Figure 2 – Annual average NO_2 concentrations at 10 m resolution modelled with ADMS-Urban in the UK West Midlands for 2016. Areas exceeding the air quality standard limit of 40 μgm^{-3} are shown in orange and red. From Zhong et al. (2021).

City of London

CERC was commissioned by the City of London Corporation to undertake air quality modelling across the City of London in order to assess compliance with air quality standards. The modelling has been carried out annually since 2018 to monitor the progress towards the aim of 90% compliance with the NO_2 air quality objective. The plots below show the annual NO_2 concentration values for 2018 and 2024 in the City of London.

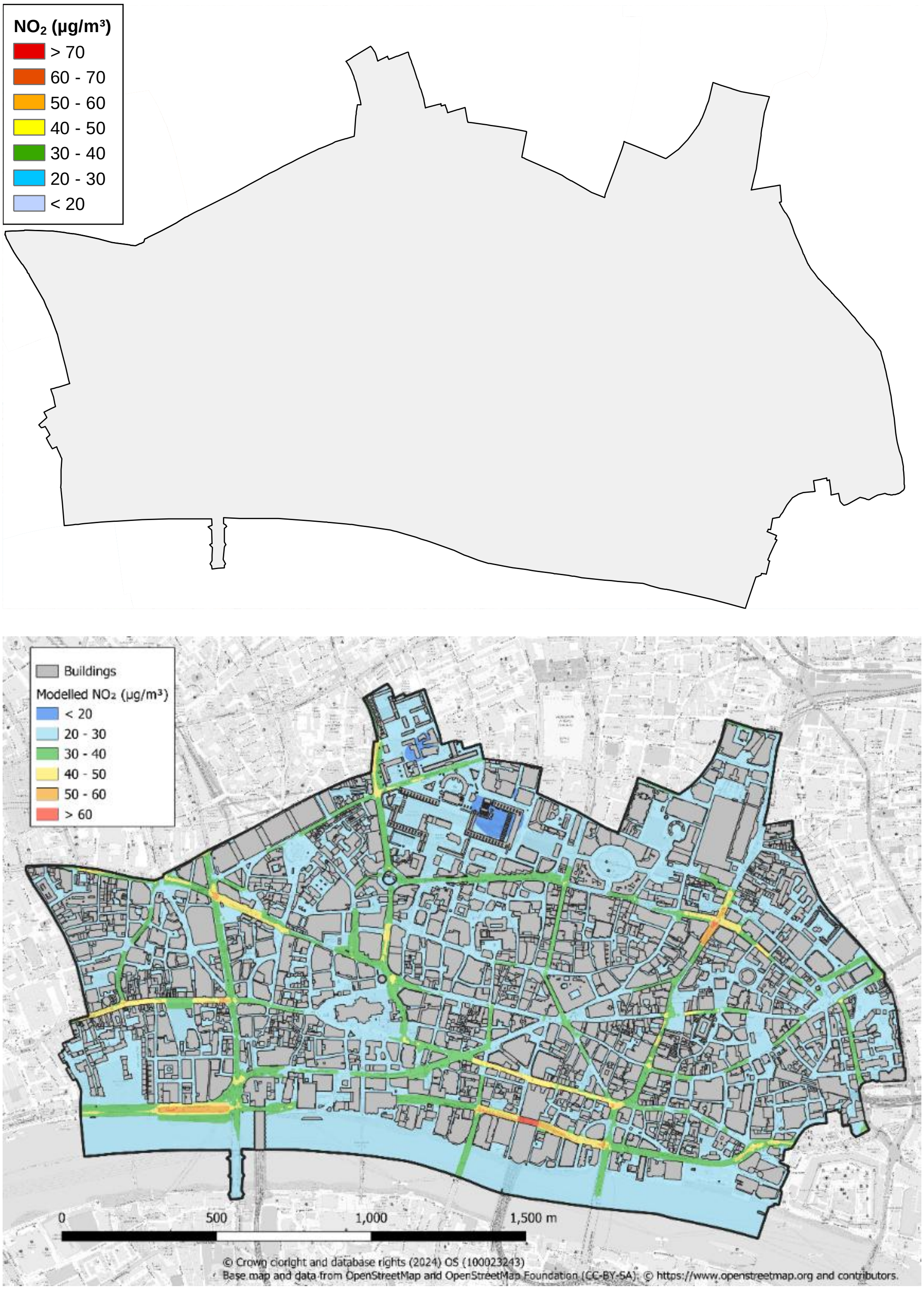

Figure 3 – Annual average NO$_2$ concentrations modelled with ADMS-Urban in the City of London for 2018 (top panel) and 2024 (bottom panel).

Oxford

CERC used ADMS-Urban to assess emissions mitigation scenarios from Net Zero policies calculating impacts of pollutants on health outcomes, mortality and associated healthcare costs across Oxfordshire, for Oxfordshire County Council.

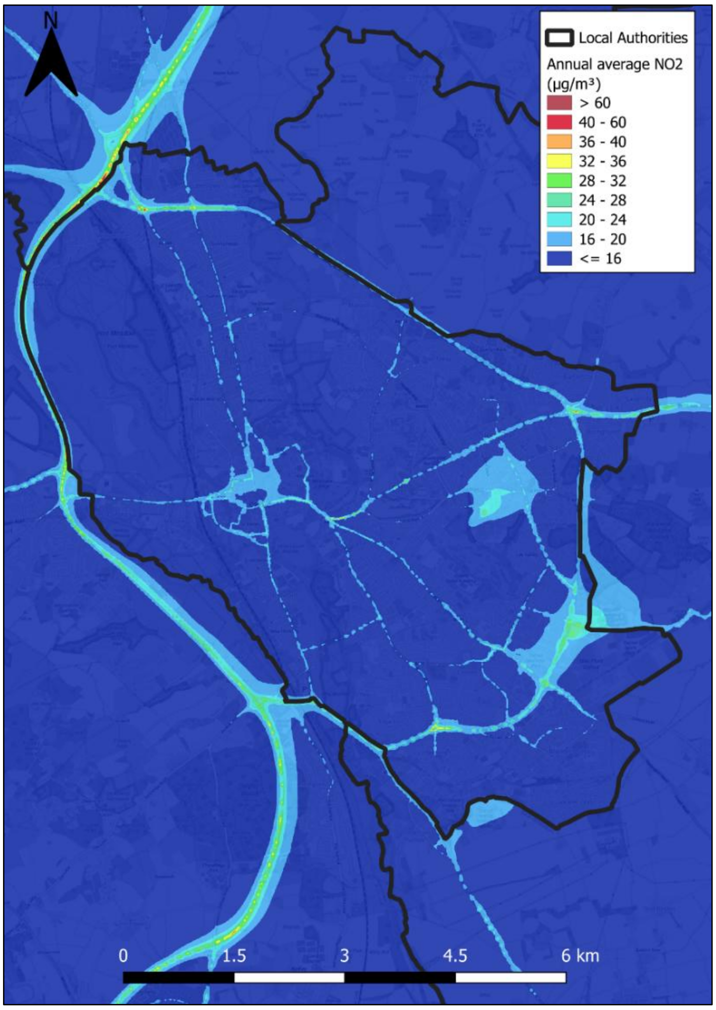

Figure 4 – Annual average NO_2 concentrations modelled with ADMS-Urban in Oxfordshire for 2023.

Dublin

The Irish EPA commissioned CERC to assess street-scale compliance with Irish Air Quality Standards Regulations (AQSR) thresholds for the city of Dublin.

AIRPRO-Beijing

The AIR pollution PROcesses in Beijing (AIRPRO) was a scientific research project funded by the UK's NERC. It investigated street-scale variation of pollutant concentration values using measurements from the Atmospheric Pollution and Human Health in a Chinese Megacity (APHH-China) winter measurement campaign. The results were published in Biggart et al. (2020).

Coupled modelling using MAQS

Gridded regional-scale models provide an adequate representation of pollutant dispersion over large spatial domains, where concentration gradients are relatively low as a result of atmospheric mixing and transport processes (i.e. at longer times after release from the source). These models are particularly effective when long-range transport and detailed atmospheric chemistry are appropriately represented. In contrast, under conditions characterised by steep concentration gradients (i.e. shortly after pollutant release), high-resolution dispersion models are required to accurately capture the spatial variability of pollutant concentrations, as well as the rapid chemical processes that occur, for instance, at roadside locations. These models can be integrated within a single framework, although the coupling process is complex and requires careful treatment of emissions and chemistry across multiple spatial and temporal scales. CERC's Multi-Model Air Quality System (MAQS) addresses this challenge by coupling the street-scale ADMS-Urban model with regional-scale models. The system avoids double counting of emissions while ensuring that chemical transformations are consistently represented across all scales. The modelling framework is described in Hood et al. (2018), which forms the basis of the MAQS methodology and is summarised by the equation presented below:

Concentration within nested domain	=	Regional modelling of emissions	-	Gridded locally modelled emissions (ΔT)	+	Explicit locally modelled emissions (ΔT)

The regional model calculations are performed offline, meaning that the nesting procedure is applied independently to each regional model grid cell rather than being carried out dynamically during the simulation. The local-scale model runs require meteorological fields and background pollutant concentrations derived from the regional model. Although the mixing time ΔT is theoretically dependent on factors such as grid resolution and meteorological conditions, a fixed value in the range of 1 to 2 hours is typically adopted in practical applications. To ensure consistency and accuracy of the coupled modelling system, it is essential that both the regional and local models use consistent emission values. Further details of MAQS can be found in the following resources:

- MAQS description
- MAQS User Guide, including the Technical Summary (Section 8)

Figure 5 shows example pollution maps from EMEP4UK and MAQS for an example application: modelling of Ireland for the Irish Environmental Protection Agency (EPA).

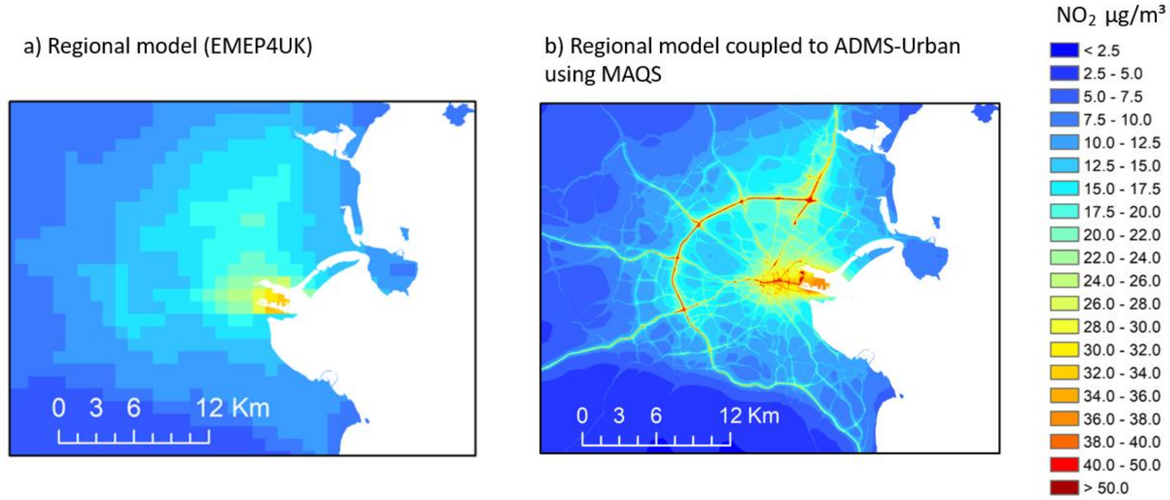

Figure 5 – Map of modelled 2019 NO_2 concentrations over the Dublin area using a) EMEP4UK and b) MAQS, in a CERC/UKCEH collaborative project for the Irish EPA. From regional-to-local scale air quality modelling of the Republic of Ireland.

The figure shows the Dublin area, highlighting the smooth transition between the regional and local modelled concentrations. Previous MAQS applications are described below.

MAQS showcases

A good example of MAQS application in the context of Directive (EU) 2024/2881 is the study involving the generation of street-scale (20 m resolution) pollution maps for Ireland, which is an EU Member State. CERC was commissioned by the Irish EPA to provide air quality modelling of the entire country for the years 2018 and 2019. Although the study was undertaken prior to the introduction of Directive (EU) 2024/2881 and was designed to support compliance with the previous AAQDs, it nevertheless provides an excellent demonstration of the type of integrated modelling approach that can be used to meet the assessment requirements of the new Directive. The MAQS coupled system was used to integrate regional-scale hourly pollutant concentration predictions from EMEP chemical transport model, using meteorological data generated by the WRF mesoscale meteorological model, with local-scale dispersion modelling using ADMS-Urban. The UK Centre for Ecology & Hydrology (UKCEH) performed the WRF and EMEP simulations over Ireland at a horizontal resolution of 1 km, providing the meteorological and background air quality fields required by the coupled modelling framework.

Model outputs were extensively evaluated against measurement data for both 2018 and 2019, including use of FAIRMODE model assessment tools, which have been developed to support model evaluation in the context of the AAQD. High resolution pollution maps corresponding to both short- and long-term AAQD metrics were generated for the whole country. Full details are reported here.

MAQS is appropriate for use in base year historical modelling, scenario assessment and forecasting applications. Other selected case studies are summarised below, with further information available online.

Hong Kong (PRAISE-HK)

This project involved the development and deployment of a real-time, regional-to-local scale air quality forecasting system for Hong Kong. The PRAISE-HK system uses MAQS, with ADMS-Urban coupled to WRF-CMAQ, to provide information on personal exposure at street-level via the PRAISE-HK app. The project is led by the Hong Kong University of Science and Technology, and further details are here.

London, UK (CureAir)

This scientific research project was funded by the UK's Natural Environment Research Council (NERC) and aimed to investigate regional and local effects on urban air quality for current and future climates. MAQS (then known as the 'Regional Model Link', RML) was used to couple a WRF-EMEP model configuration to the ADMS-Urban model, for London. Base year results were published in Hood et al. (2018), while future climate scenario modelling results are reported in Doherty et al. (2026). Further project details are here.

Malaysia and Vietnam (DHAQ-SEA)

This project was a feasibility study to develop a high-resolution air quality forecasting system for regions within the Association of Southeast Asian Nations (ASEAN). The system applied MAQS for 200 km by 200 km domains in Malaysia and Vietnam, with ADMS-Urban coupled to CAMS forecast archive datasets. A comprehensive report describes how the forecasting system could be developed. More details on the project can be found here.

Guandong, China

This project involved air quality modelling using MAQS. MAQS coupled the WRF/CMAQ regional models with ADMS-Urban for Guangdong. Results were published in Zhang et al. (2022), while more details on the project can be found here.

Punjab, Pakistan

This project, led by a group of academics from MIT, LSE and Sciences Po, studied the impacts of transport improvements on air quality in the Punjab region of Pakistan. The project uses MAQS, with ADMS-Urban coupled with ECMWF/CAMS, to determine baseline air quality modelling. More details on the project can be found here.