Tender for work requested by the Atmospheric Dispersion Modelling Liaison Committee (ADMLC)

Topic for which funding is sought

An investigation of the uncertainties in dispersion patterns and predictions introduced by climate change in regulatory atmospheric dispersion models.

Background and context

Air dispersion models are tools to make decisions. Meteorological (met) input data is paramount in atmospheric air dispersion modelling, as it dictates how pollutants transport, disperse and interact with surfaces and obstacles. Regulatory modelling software such as ADMS or AERMOD require several parameters of hourly sequential meteorological data for a year, although it is recommended that model sensitivity is addressed by considering up to 5 years of historical data to account for interannual variability [1]. Dispersion models typically rely on historical met data to predict concentrations and areas of potential impact downwind of emitters.

In July 2025, the UK Met Office released its annual report ‘State of the UK Climate in 2024’ [2], which provides a summary of UK climate trends and variations based on observations from previous decades. The report emphasises that temperature and rainfall extremes are increasing in frequency and intensity. It highlights that the last three years have been the UK’s warmest on record with increased number of days with temperature anomalies; the most recent decade 2015-2024 warmer than 1961-1990 by 1.24°C. With a continuous record-setting weather conditions, the use of historical met data for air dispersion modelling may become less reliable for predicting future scenarios, especially for long-term projects.

The UK Met Office released the UK Climate Projections (UKCP) [3]; a set of tools and datasets projecting UK climate change in future scenarios (up to 2100), based on the latest developments in climate science. UKCP includes data from high resolution (2.2 km) and coarse resolution (60 km) in a range of formats. Such projections emphasise the likelihood of record-breaking temperatures, rainfalls and extreme events in the upcoming decades.

An ADMLC report published in 2001 [4] explored the suitability of meteorological data for short range dispersion models. The report considered historical datasets from observing stations between the 1950s and the 1990s to assess their relevance and understand the consequences of using historical data in air dispersion models. The study concluded that met datasets have a ‘limited lifetime’ subject to changes in urbanisation, observations and location of the observing station. Recent trends in extreme weather pose the question of whether the same conclusion would apply in the present day. A new study would also account for improvements in the sophistication of air dispersion models, as well as statistical analysis techniques and met data quality and availability. Furthermore, exploring the potential need to account for future met would address the ‘longevity’ of conclusions derived from air dispersion model exercises.

An ADMLC report published in 2011 [5] provided a qualitative review of met conditions that could trigger non-steady state situations. It concluded that steady-state models are acceptable in most near-field situations subject to the characteristics and complexity of the area. Meteorological changes may challenge key assumptions of steady-state models such as each hour is separate and independent of previous hours. With increases in unusual and extreme meteorological events, there is the potential for more dispersion situations to require non-steady state models.

The effect of climate change on air quality was explored in 2010 for two urban sites in the UK [6]. Hourly meteorological data obtained from Hadley Centre climate simulations for the current (i.e. between 1970 and 1990) and future climate (i.e. between 2070 and 2090) showed a higher frequency of heat waves in the projected future climate at both sites. ADMS (version 3) modelling found increases in annual mean NO_x of up to 39% for large point sources (e.g. a large power station with a stack height above 250 m), suggesting that climate change may be important in the regulation of large sources. However, the authors also acknowledge the substantial uncertainties associated with their results.

The need to develop an integrated modelling framework for climate change and air quality to inform policies was investigated in 2017 [7]. Using models based on the UK Met Office's Unified Model, the study developed a 12 km resolution model over the UK nested in lower resolution composition-climate models. They produced air quality forecasts and compared with air quality observations, finding the higher resolution improved simulation of primary pollutants NO_2 and SO_2. The study highlights the importance of using high-resolution emissions data for air quality modelling and the complexities associated with coupling climate and air quality models even from the same model framework.

The role of climate change models and changing meteorology along with emerging requirements for climate change adaptation [8] may put into question whether the use of historical met data in regulatory air dispersion models provides 'future-proof' decision-making. This is especially relevant when regulating long-lived emitters, the air quality impacts of which may change under future meteorological conditions.

Project scope

This project will evaluate the uncertainties introduced by climate change in predictions derived from regulatory atmospheric dispersion models. The project should consider practical options to deal with uncertainties, including the development and testing of protocols to account for future meteorological changes in decision-making.

Research questions

ADMLC is interested in seeking answers to the following questions:

1) What are the limitations and challenges of continuing the use of historical met?
2) What is the potential 'lifetime' of model predictions based on historical met in the light of changing met patterns?
3) What are the challenges, uncertainties, and limitations of using future met?
4) Should future met be considered for regulatory and policy purposes?

Project objectives

1) Evaluation and significance of historical met data

The work must explore the continued relevance and applicability of historical met data for a range of dispersion scenarios and representative locations within the UK. The objective is to set an evidence-based baseline for indicators/met conditions that might represent future met, interrogating the longevity of current practices.

This evaluation must consider changes in urbanisation, noting that land use changes might have more significant impacts on dispersion than meteorological changes alone.

2) Evaluation and significance of available projected met data

The work must explore available met parameters from UK climate projection models to regional scales, without seeking to review all available or upcoming climate models. The objective is to frame those with potential for regulatory use, considering aspects of accessibility, readiness, format, accuracy, complexity and uncertainty.

The work must demonstrate practical and reasonable criteria for shortlisting models, projections and years to address the research questions - such as e.g. the lifetime of an emitting source, decarbonisation milestone years or other key policies. It is recommended that such criteria are peer-reviewed by ADMLC members.

3) Development and demonstration

The project must aim to develop and demonstrate protocols for using historical and/or future met data in regulatory air dispersion models - considering the significance and magnitude of a varying met, extreme conditions, uncertainty and 'lifetime'.

The development must consider the significance of predominant, and extreme met conditions conducive to varying dispersion scenarios and plume behaviour identified in potential projections/historical met.

The work must provide practical case studies and carrying out sensitivity analyses and comparisons for several key scenarios e.g. a typical elevated point source emission, coastal vs. inland location, rural vs. urban, 'tall' vs. 'short' stack, etc. It is recommended that the testing plan is developed in consultation with ADMLC members.

The work must include a systematic comparison of predicted annual and hourly concentrations using historical met data and a proposed protocol and/or projected met data to demonstrate the differences.

4) Discussion and recommendations

Recommendations must be developed to address the pros and cons of the continued use of historical met data as opposed to adopting methods to account for future met changes in regulatory atmospheric dispersion modelling, with a discussion on the uncertainties associated with each.

The work must be transparent and reproducible, including a discussion based on the project research questions. Consultations with ADMLC members before drawing of final conclusions and providing recommendations is strongly recommended.

Project stages

Stage 1: Literature review and analysis

This stage must establish a sound baseline from existing studies and knowledge with a literature review. This stage must also review available historical, and forecast met data in the context of accounting for future met in regulatory air dispersion models.

This stage must address the project objectives number 1) and 2). After completing this stage, it is recommended that ADMLC members are consulted and briefed with the key findings.

Stage 2: Development and demonstration

This stage must aim at developing systematic protocols on using historic and predicted future met data for regulatory dispersion modelling, demonstrating significance through practical case(s) studies, elaborating on the following:
- How it is fit for purpose and based on sound science.
- How it represents improvements compared with existing methods.
- How it can be used by regulators and practitioners for decision-making.
- Uncertainty evaluation of model predictions and input met data.

This stage must address the project objective number 3). It is recommended that the testing plan is peer-reviewed by stakeholders and the ADMLC members are consulted and briefed with the main findings after completing this stage.

Stage 3: Uncertainty, conclusions and recommendations

This stage must discuss project findings, evidencing the limitations of the study and how the current knowledge has been improved by:
- Identifying knowledge gaps and uncertainties.
- Engaging with stakeholders and collecting feedback from stakeholders.
- Providing recommendations for further work.
- Providing recommendations for regulators and model users.

The study should contrast the limitations and advantages of using historic and predicted meteorological inputs for regulatory dispersion modelling, identifying knowledge gaps and uncertainties. This stage addresses the research questions and project objective number 4). Consultation with ADMLC members before the final conclusions and recommendations is recommended.

Stage 4: Reporting and dissemination

This stage must focus on the final project deliverables, which may become publicly available on the ADMLC website:
- Presentation(s) in suitable forums for the purposes of dissemination and/or feedback collation.
- A summary brief of the project and key findings in a suitable language for technical and non-technical audiences.
- An ADMLC format report.
- Optional: Tools, scripts, spreadsheets or others in open-source philosophy will be positively viewed e.g. for advancing on the field, for retrieving projected met data, etc.

References

[1]. Guidance Environmental permitting: air dispersion modelling reports. Available at Environmental permitting: air dispersion modelling reports - GOV.UK [Accessed in August 2025].

[2]. Kendon, M., Doherty, A., Hollis, D., Carlisle, E., Packman, S., Jevrejeva, S., Matthews, A., Williams, J., Garforth, J., Sparks, T. (2025). State of the UK Climate in 2024. International Journal of Climatology, 45(S1). Available at https://doi.org/10.1002/joc.70010 [Accessed in August 2025].

[3]. UK Climate Projections (UKCP). Available at UK Climate Projections (UKCP) - Met Office [Accessed in August 2025].

[4]. Options for the most appropriate meteorological data for use in short range dispersion modelling and methods for undertaking uncertainty analysis. J. Smith. Annual Report 2000/2001. Atmospheric Dispersion Modelling Liaison Committee. Available at: https://admlc.com/wp-content/uploads/2014/05/2002_nrpbw3.pdf [Accessed in August 2025].

[5]. Reviewing Issues Associated with Modelling Atmospheric Dispersion in Changing Meteorological Conditions Source Term Estimation and Event Reconstruction: A Survey. (2011). ADMLC-R6 Atmospheric Dispersion Modelling Liaison Committee Report. Available at: https://admlc.com/wp-content/uploads/2014/05/admlc-r6.pdf [Accessed in August 2025].

[6]. Athanassiadou, M., et al. An assessment of the impact of climate change on air quality at two UK sites. Atmospheric Environment, 2010. 44(15): p. 1877-1886. Available at 10.1016/j.atmosenv.2010.02.024 [Accessed in August 2025].

[7]. Neal, L.S., et al. A description and evaluation of an air quality model nested within global and regional composition-climate models using MetUM. Geosci. Model Dev., 2017. 10(11): p. 3941-3962. Available at gmd-10-3941-2017.pdf [Accessed in August 2025].

[8]. Guidance Climate change: risk assessment and adaptation planning in your management system. Available at Climate change: risk assessment and adaptation planning in your management system - GOV.UK [Accessed in August 2025].