Modelling high-resolution NO_2 concentrations over the United Kingdom using RapidAIR

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Introduction

In order to investigate the health effects associated with exposure to air pollution, air quality models can be used to estimate an individuals exposure. Regional models allow concentrations to be predicted over a large area and consequently allow many individuals exposure to be allocated for health studies. In addition they can be used for forecasting applications to inform at-risk individuals when elevated pollution levels may occur.

A limitation in current regional models is the resolution which can be modelled. For example, in the UK the regional model is produced at 1 km resolution. This means that the fine-scale variations in air quality concentrations are lost and as a result individuals may be misallocated exposure or there may be missed high pollution forecast events.

The aims of the work are:

- Develop the RapidAIR model to allow regional modelling at high spatial resolution.
- Generate highly spatially resolved NO_2 concentrations for the UK for a 2018 base year.
- Demonstrate the applicability of the RapidAIR model to test a hypothetical national-scale mitigation measure to reduce road traffic emissions.

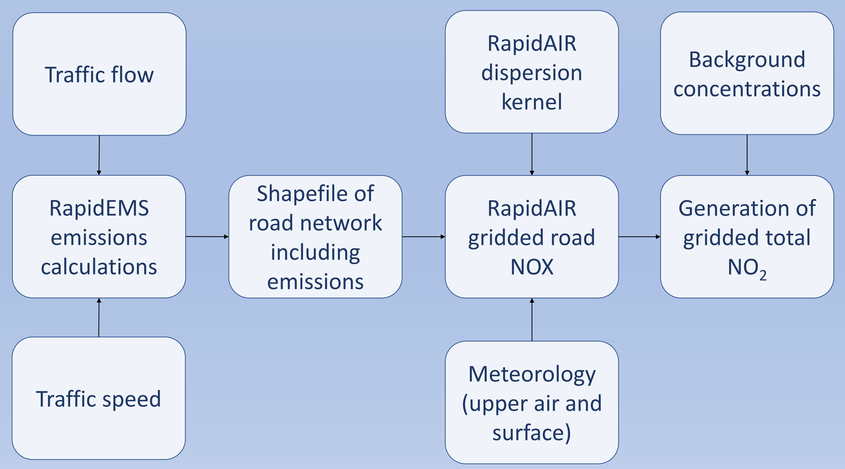

Figure 1: RapidAIR modelling process

Methods

Input data
Traffic flows and speeds on the major road links in the UK were available from the UK National Atmospheric Emissions Inventory as a shapefile. A custom python script was written to manipulate the traffic data into the required format for the emissions processor.

Emissions processing
Emissions were calculated for each road link using Ricardo's RapidEMS model. RapidEMS uses COPERT 5 emissions factors. This resulted in emissions calculations for ~142,000 road link (calculated in under 5 minutes) – these were used as input to RapidAIR.

RapidAIR
RapidAIR is a python-based model used extensively in the UK and internationally to model high-resolution (< 5 m) city-scale concentrations (Masey et al., 2018; Yang et al., 2019). The modelling process is shown in Figure 1.
Using a standard laptop with 16 Gb RAM, 50 m road-NOx concentrations have been produced for the UK-wide domain (676 x 99 km) using RapidAIR. Mapped concentrations from background sources, such as industry or domestic combustion, were available from the UK Government.

Two models are presented in this paper –2018 base year, and a hypothetical scenario assuming all vehicles in the UK in 2018 were of Euro 6 emissions standard.

2018 Baseline Results

The RapidAIR model has been adapted to allow generation of high resolution (50 m) NO_2 concentrations for the whole of the UK. The regional model concentrations show higher NO_2 concentrations in the main cities in the UK (Figure 2a). A comparison of the modelled NO_2 concentrations with measured NO_2 concentrations at the UK Automatic Urban and Rural Network monitoring locations shows the model predictions are within a factor of 2 of the measurements in 91 % of locations (FAC2 = 0.91, n=52).

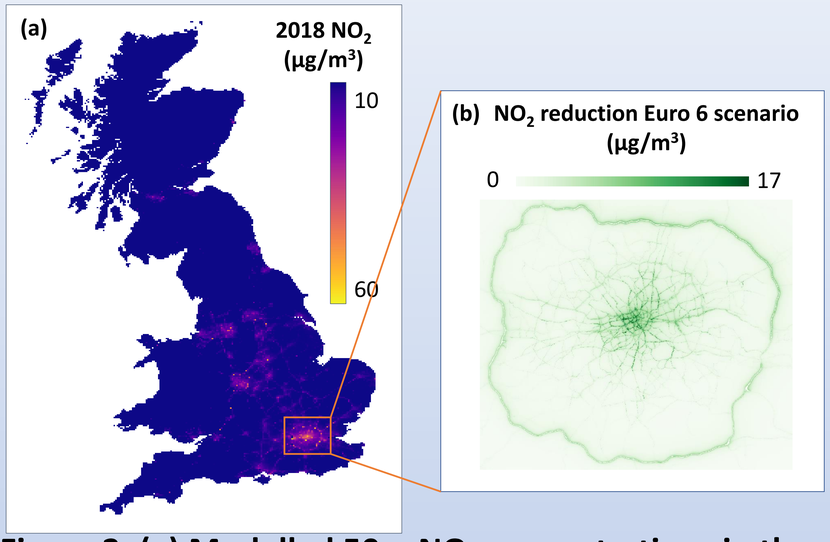

Figure 2: (a) Modelled 50m NO_2 concentrations in the UK (2018 baseline); (b) Base – Euro 6 NO_2 in London

Scenario results

The Euro 6 vehicle scenario shows significant reductions in NO_2 concentrations (Figure 2b) – e.g. concentrations sampled at the UK monitoring network show a 7 % reduction in NO_2 concentrations on average as a result of the Euro 6 scenario.

Conclusions and next steps

We have shown that RapidAIR can be used to model regional NO_2 concentrations in the UK at 50 m resolution, and shown its ability to test the impact of large-scale mitigation measures.

While 50 m resolution concentrations is an improvement on traditional regional models, we are further developing the RapidAIR model to increase the resolution, e.g. by automatically splitting the domain into smaller, more computationally manageable areas.

We used a single meteorology station and surface roughness value as input to the RapidAIR model. In reality, there will be intra-region variations in these. Further work will develop the use of varying meteorological data and roughness values

Masey, Nicola, Scott Hamilton, and Iain J. Beverland. "Development and evaluation of the RapidAir® dispersion model, including the use of geospatial surrogates to represent street canyon effects." *Environmental modelling & software* 108 (2018): 253-263.
Yang, Daoyuan, et al. "High-resolution mapping of vehicle emissions of atmospheric pollutants based on large-scale, real-world traffic datasets." *Atmospheric Chemistry and Physics* 19.13 (2019): 8831-8843.