Urban dispersion modelling of nanoparticles in the West Midlands, UK

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INTRODUCTION

Nanoparticles are tiny and respirable particles (Zhong et al., 2020). Because of their small sizes, nanoparticles can penetrate cells and tissue, accumulate in lungs, and cause health effects. Nanoparticles may possess a larger potential for adverse health effects than larger particles (e.g. $PM_{2.5}$ and PM_{10}). Particle number concentration (PNC) is the most common measure for nanoparticles. Nanoparticles often dominate the total ambient PNC in urban environments. There is a strong need to quantify the PNC in the ambient air through measurements and modelling.

This study aims to simulate the dispersion of PNC in the West Midlands (WM), UK and to provide street scale resolution maps of PNC for potential epidemiological studies.

METHODOLOGY

This work used the local scale ADMS-Urban model, which is an advanced quasi-Gaussian plume dispersion modelling system. This model implements a physics-based approach to represent the characteristics of the atmospheric boundary layer. It can represent a variety of source types (Fig. 1) occurring in urban environments and requires a range of input data (e.g. emissions, meteorological and background data). The baseline modelling year in this study is 2019, which is the last normal year before Covid 19. Particle number was used as a passive scalar, with no inclusion of aerosol microphysics. In order to account for the street canyon effect for traffic sources and urban canopy effect on atmospheric turbulence, advanced canyon and urban canopy parameters were used and derived based on the building data and road network shapefiles using ArcGIS tools.

The modelling case was run on the University of Birmingham's BlueBEAR HPC using a task farming option in the ADMS-Urban model (Zhong et al., 2021). The overall elapsed time for a typical annual contour simulation was about 22 hours.

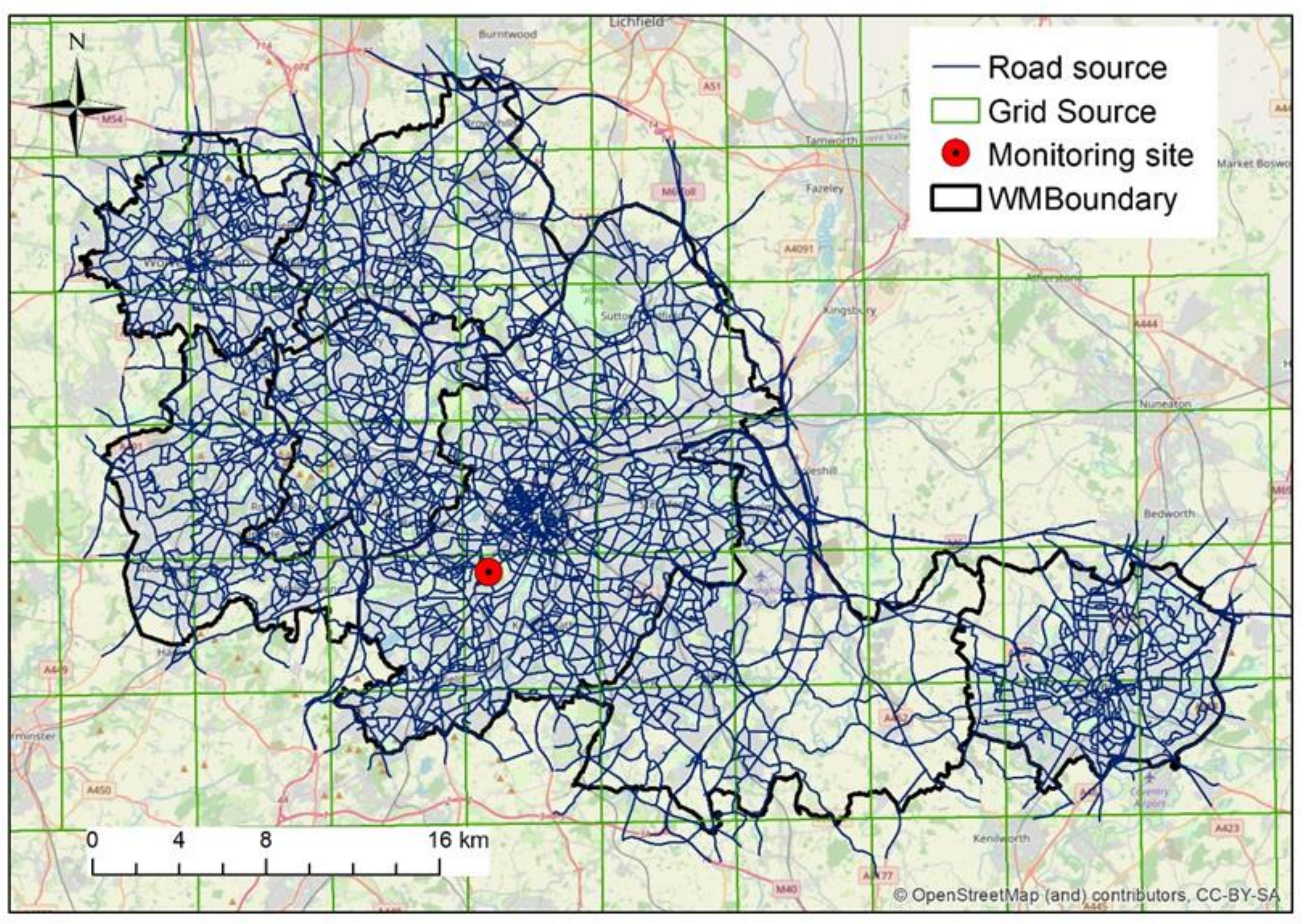

Fig. 1 Emission sources implemented in the ADMS-Urban model over the West Midlands. Gridded emissions of particle numbers were supplied by TNO. The monitoring site at the Birmingham Air Quality Supersite (BAQS) is also indicated.

LITERATURE CITED

ZHONG, J., NIKOLOVA, I., CAI, X., MACKENZIE, A. R., ALAM, M. S., XU, R., SINGH, A. & HARRISON, R. M. 2020. Neighbourhood-scale dispersion of traffic-induced ultrafine particles in central London: WRF large eddy simulations. Environ. Pollut., 266, 115223.

ZHONG, J., HOOD, C., JOHNSON, K., STOCKER, J., HANDLEY, J., WOLSTENCROFT, M., MAZZEO, A., CAI, X. & BLOSS, W. J. 2021. Using Task Farming to Optimise a Street-Scale Resolution Air Quality Model of the West Midlands (UK). Atmosphere, 12, 983.

RESULTS AND DISCUSSION

▪Model evaluation

Model evaluation was conducted by comparing the modelled and measured data at the Birmingham Air Quality Supersite (BAQS). Overall, the model performed well with slight underestimation and 71% of modelled data is within a factor of 2 of measured data (Fig. 2).

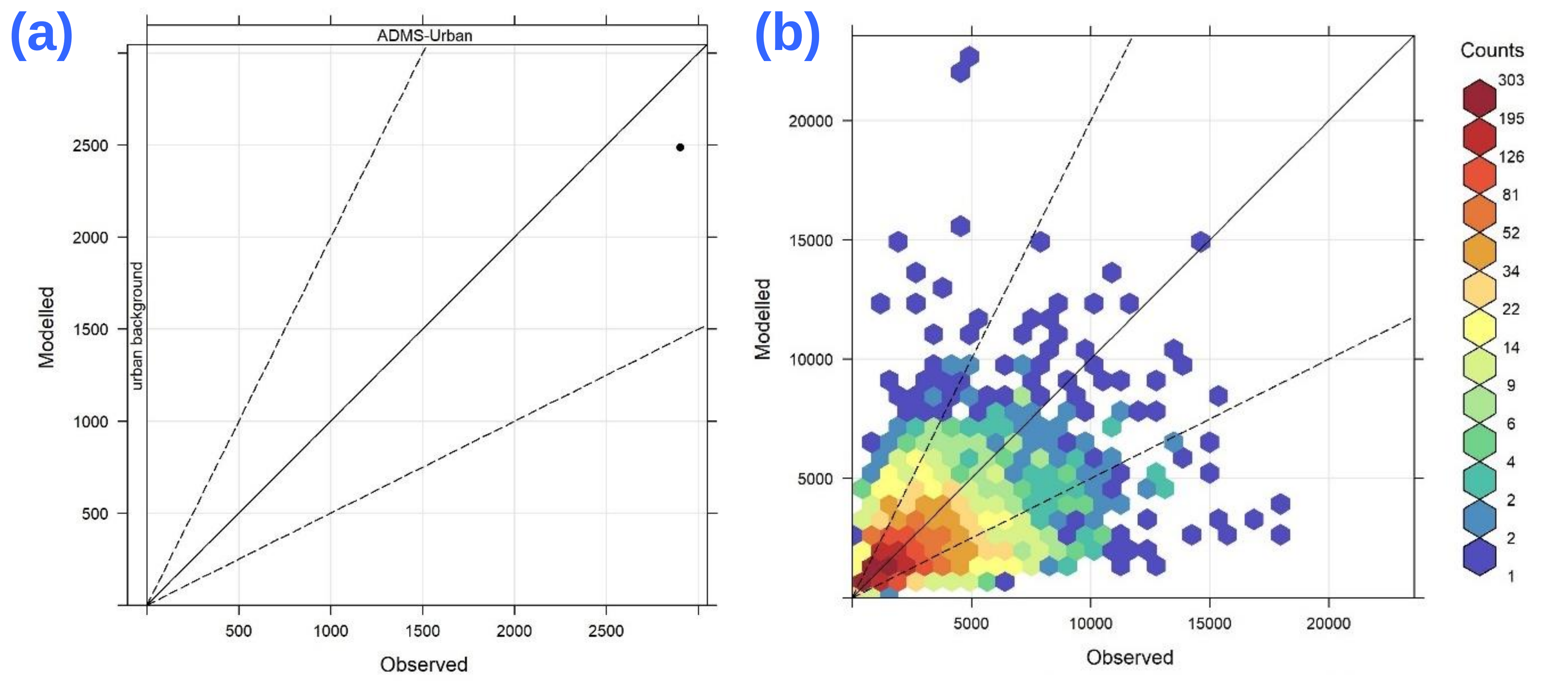

Fig. 2 (a) Annual averages comparison and (b) frequency scatter plots between the model and observation at BAQS for PNC between 10 and 100 nm (PNC_{10_100}, unit in # cm-3) for the 2019 baseline case.

▪PNC mapping

There were clear patterns of the influence of traffic emissions on the distributions of PNC with higher levels near major roads in the city centre and motorways (Fig. 3a). The spatial averaging at population related polygon layers results in smoothing of the highest and lowest concentrations with narrower ranges of PNCs (Fig. 3b).

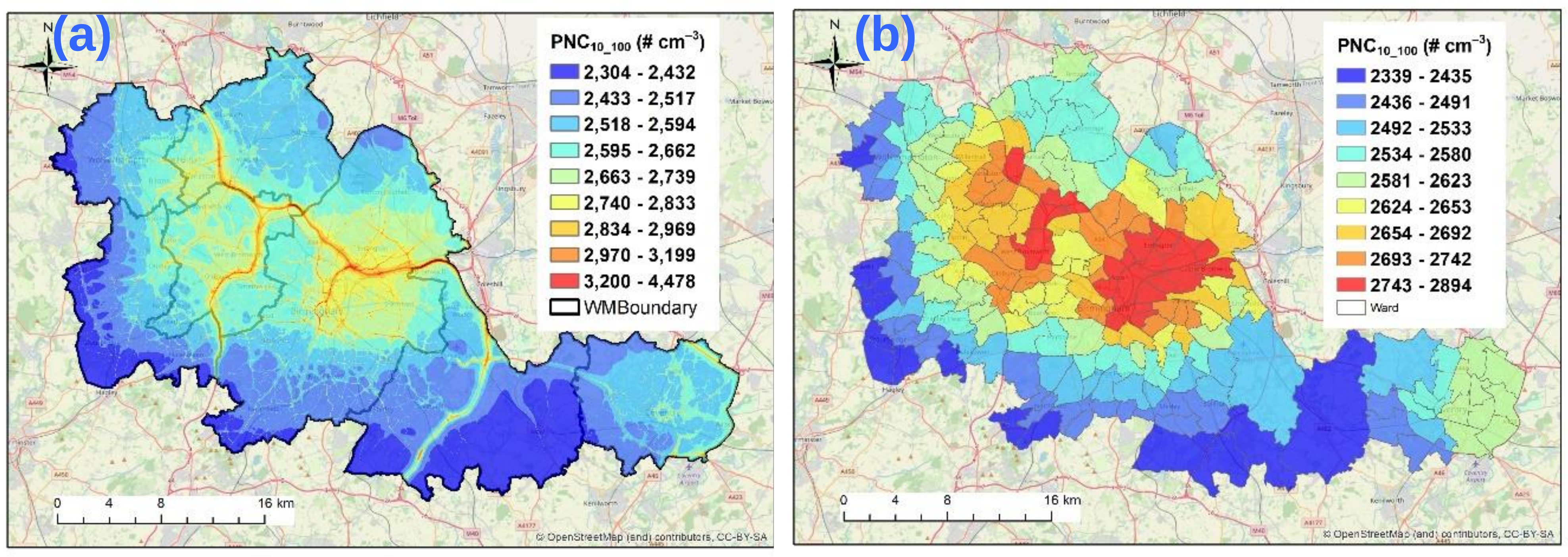

Fig. 3 Annual PNC maps for PNC_{10_100} at 10 m × 10 m resolution (a) and at the electoral ward level (b) for the 2019 baseline case.

Apart from annual PNC mapping, the short-term analysis of concentration distribution (percentiles) can be used to assess exceedances. For 24-hour (daily) and 1-hour mean concentrations, the 99^{th} and 99.8^{th} percentiles are normally adopted. The exceedances were observed mostly in the areas close to motorways and major roads directing to motorways (Fig. 4).

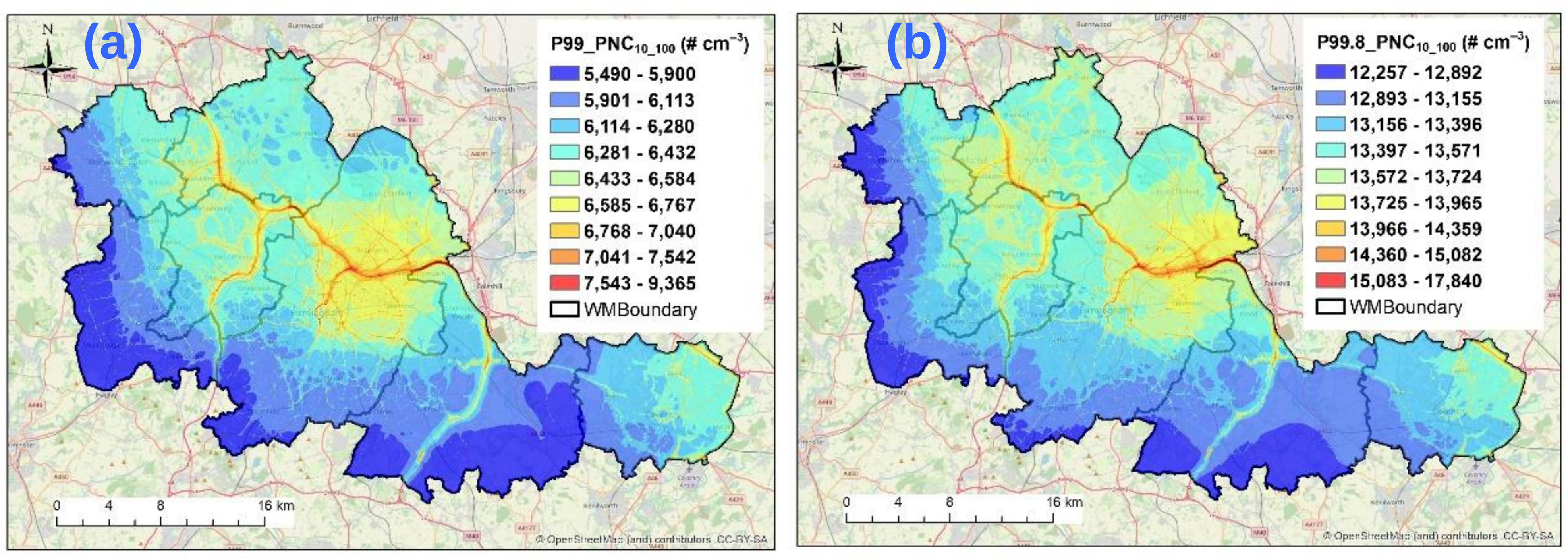

Fig. 4 (a) The 99^{th} percentile PNC maps for 24-hour (daily) mean and (b) 99.8^{th} percentile PNC maps for 1 h mean for PNC_{10_100} at 10 m × 10 m resolution for the 2019 baseline case.

CONCLUSION

▪Model evaluation shows that the model generally performed well although there was a slight underestimation for PNC.

▪PNC maps at a variety of spatial (e.g. street scale and ward level) and temporal resolutions (i.e. annual, 24-hour, and 1-hour) can be generated.

▪PNC mapping could be linked to local population and health data for potential epidemiological studies.

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