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A street network box model to assess emission reduction policies at the neighbourhood scale

Helen Pearce, William Bloss, Xiaoming Cai, and Zhaoya Gong
University of Birmingham, Geography, Earth and Environmental Sciences, Birmingham, United Kingdom of Great Britain – England, Scotland, Wales (hip335@student.bham.ac.uk)

A street network box model has been designed to assess how connected road links interact and influence nitrogen dioxide (NO_2) concentrations at the neighbourhood scale. The overall aim of developing this model is to investigate both theoretical and applied questions, including how social policy and neighbourhood-level action can improve air quality in cities.

The computationally lightweight model presented here relies on component boxes connected at intersections and along road links to mix pollutant concentrations throughout the network. It is therefore similar in architecture and theory to the operational French network model, SIRANE. Mass is conserved so that the sum of vehicle emissions and pollutants advected into each box are equal to the sum of turbulent exchanges at the top of the box with overlying urban canopy background air and pollutants advected out of each box. Fast NO_x-O_3 reactions are fully integrated and simulated at every time step (1 second), which will enable high temporal resolution traffic emissions to be integrated in the future. The model, implemented in R, enables mixing between two boxes (simple road link), three boxes ('t-junction'), and four boxes (cross roads), with the capability to automatically determine the direction of mixing based on the overlying wind direction. The network in turn consists of multiple boxes and connections, all of which can be oriented in any direction with respect to the wind direction.

Low traffic neighbourhoods (LTNs) have become a popular tool for UK urban planners to attempt to reduce population exposure to NO_2 and particulate matter, and encourage active travel. Inspired by Dutch city designs and Barcelona's 'superblocks', LTNs typically take the form of blocking vehicle access to minor residential roads, while keeping them open for residents and active transport users. The model described above has been applied to an area of approximately 1 km^2 in the Kings Heath area of Birmingham (UK) where an LTN has been proposed. The network consists of 29 boxes and each box represents a road link, including major road links surrounding the residential area. Background concentrations for NO, NO_2 and O_3 were obtained from a nearby AURN site maintained by Defra. Meteorological conditions were measured at Birmingham City airport and a mean wind speed for each 10-degree wind direction sector was determined. One model was run for each wind direction and corresponding speed, enabling the relative contribution of local emissions and transported pollutants for each box to be assessed. Subsequently, the frequency of occurrence was used to weight each model's outputs to produce a

simulated annual average concentration map.

Initial results are promising; when compared to the output from traditional air quality modelling software, the spatial distribution of NO_2 concentrations are in agreement. The impact of pollutant redistribution throughout the network under prevailing wind conditions and the potential impact of a LTN on NO_2 concentrations inside and outside the designated area will also be presented.