# The London Hybrid Exposure Model

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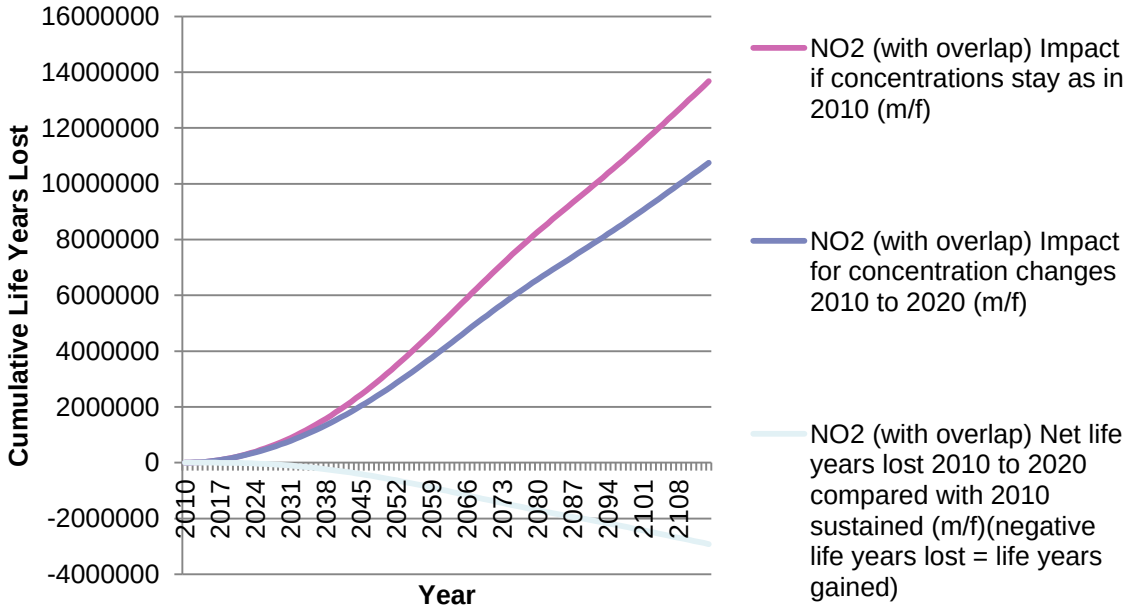
# HIA method for long term exposure to $PM_{2.5}$ and $NO_2$

**Full Impact methodology**

- Use PWAC
- Uses life tables of pop. and death in 2010 by single year age group
- Follow life tables through for a lifetime 105 years to 2114, with new birth cohorts
- Use EPA lag 30% effect first year, 12.5% years 2-5, 20% years 5-20
- Results can be summarised as total Life Years and loss of Life Expectancy from birth
- Impact of future reduction scenarios on Life Years and life-expectancy

## Recent example of scenario testing in London for $NO_2$

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# Background

- Studies using epidemiological methods find health issues linked to air pollution including respiratory problems, cardio-vascular…
- These (static) methods may be assigning pollutant exposure to subjects/populations incorrectly

Possible areas of error

- **Coarse spatial scale** of pollutants (monitoring site, degrees of longitude, city-wide, borough, postcode)
- **Coarse temporal scale**, annual averages
- **Lack of movement** of subjects
- Lack of **microenvironments**

# Aim

To create a **dynamic exposure** model and compare this with ‘static’ exposure methods for $NO_2$ and $PM_{2.5}$

To create a dynamic model we need

- **High quality spatial and temporal** air quality model
- **Detailed information** about where people go and spend their time
- **Microenvironmental** modelling to account for different environments

# Address and Hybrid approaches to exposure assessment

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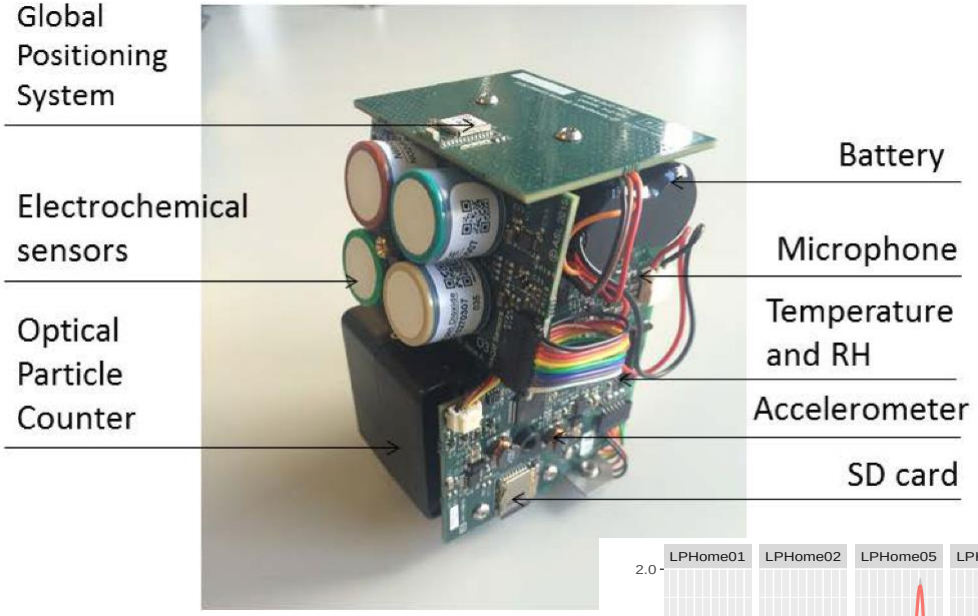
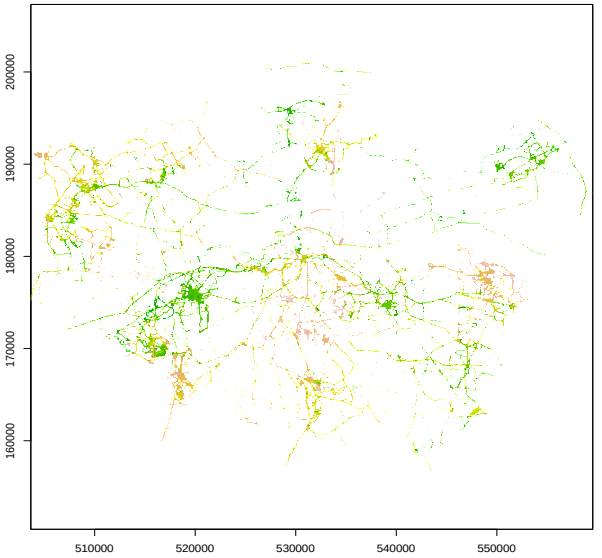
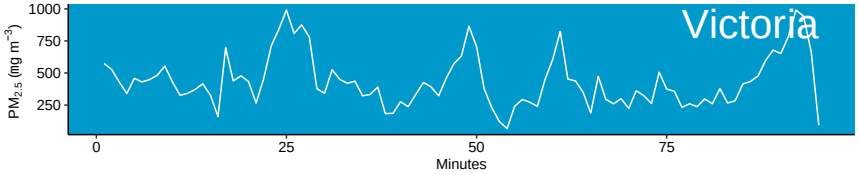
# Exposure monitoring (PAM)

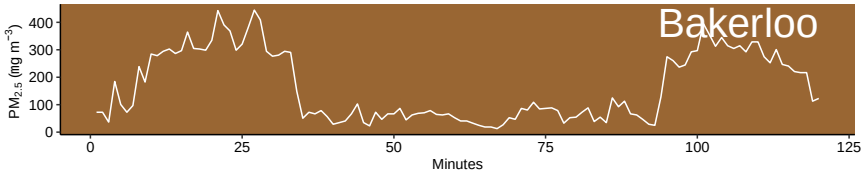


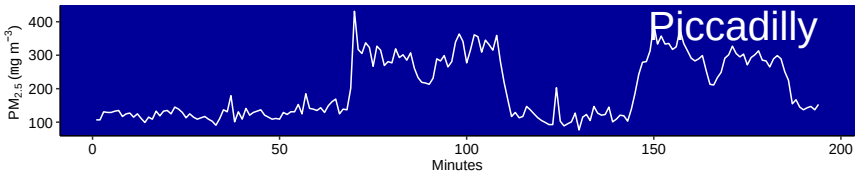



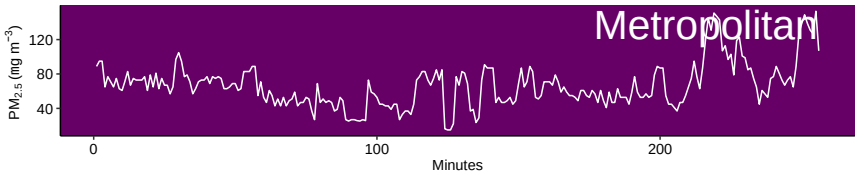

**Derived parameters:**
activity intensity, pollutant dose, sleeping, cooking, smoking (passive or active), socialising, sport, fireplace, candle burning, transport mode, location re-visitation rate (indoor and outdoor)

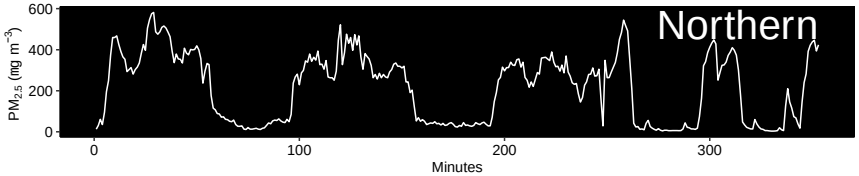
# $PM_{2.5}$ mass on the London Underground

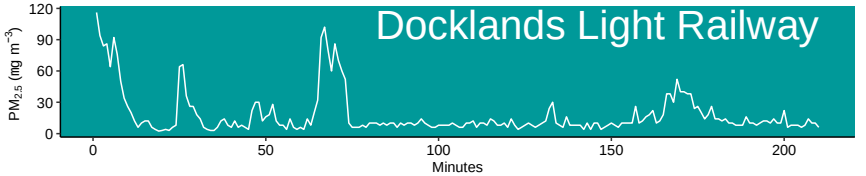


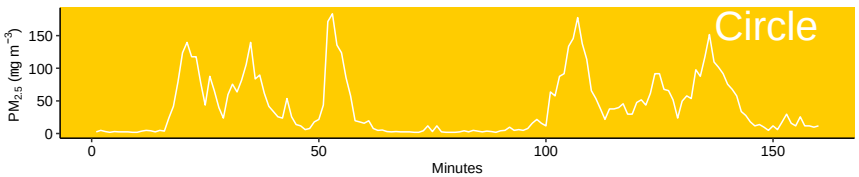



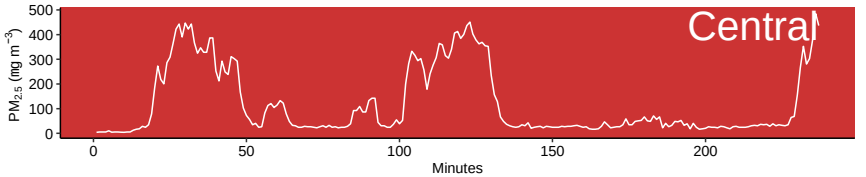



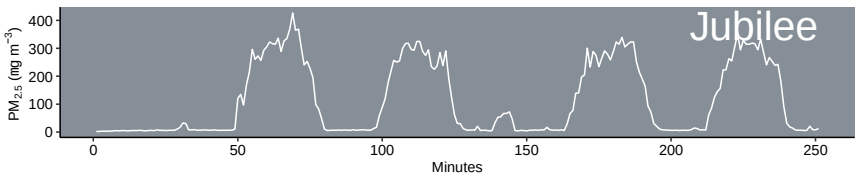



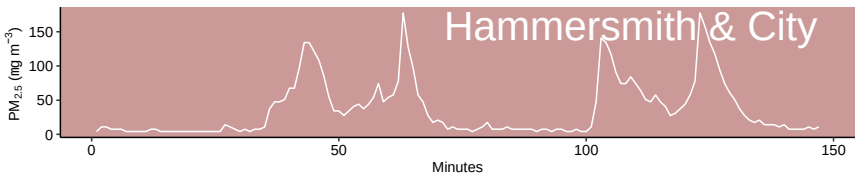



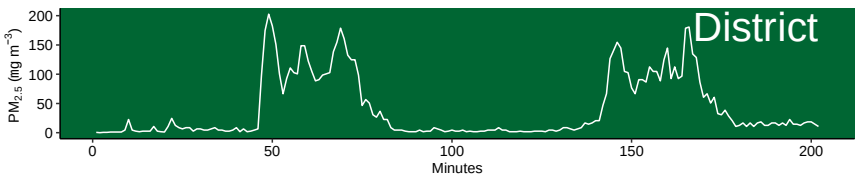

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# Personal exposure

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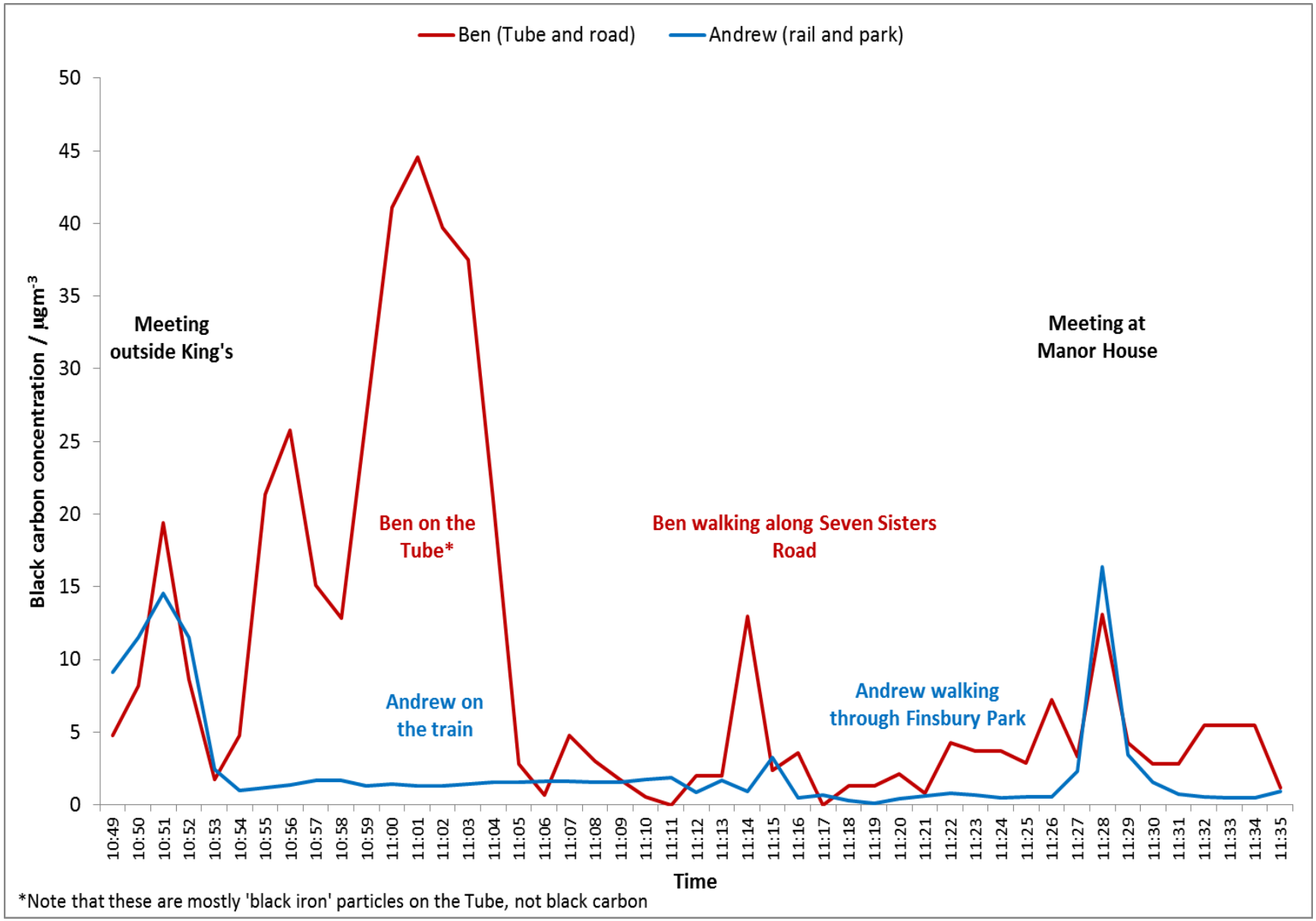
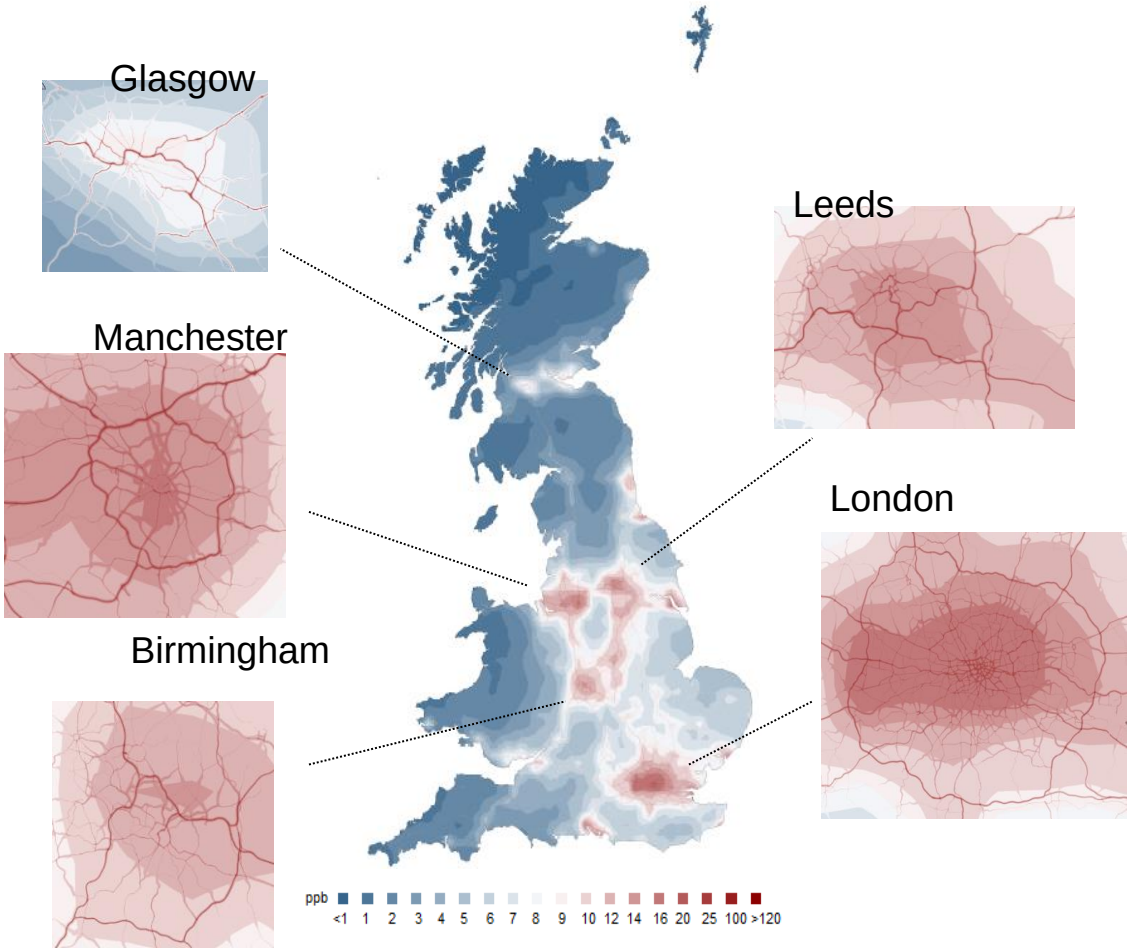


# CMAQ-Urban Capabilities

- USEPA community model, constantly updated with **best science**
- Fine temporal and spatial grid resolution (down to 20m hourly) – **to best represent observations, epi study and HIA**
- Used in 2050 NIHR project – **to study air quality impact of climate change policy**
- Applicable anywhere in the world – **used worldwide in China, India, USA…**
- Multi-scale/level with nesting capability – **City to National to Continental scale**
- Predict future AQ – **used for policy development**
- Tackle long range transport issue – **study foot print of large point source**
- Multi-pollutant model – **allows more policy issues to be tackled**
- Suitable for source apportionment – **nesting Europe, UK, London**
- Cost and CPU runtimes – **Not a problem! Predict multi years for epi study**

# Outdoor air quality (CMAQ-urban*)




Weather Research and Forecasting (WRF) meteorological model, the USEPA's CMAQ model and ADMS-roads

Six road categories are included in the calculation

Model outputs: Hourly/Daily/Annual – nitrogen oxides ($NO_x$), nitrogen dioxide ($NO_2$), ozone ($O_3$), particle matter (PM) components by source type ($PM_{10/2.5}$)

Computing facilities…..lots of them

Emissions inventories

UK National Atmospheric Emissions Inventory (NAEI)
King's Great Britain road traffic emissions
European Monitoring and Evaluation Programme (EMEP, http://www.ceip.at/)
European Pollutant Release and Transfer Register (EPRTR)
Biogenic Emission Inventory System (BEIS v3.14) VOC and soil NO
Eclipse - IIASA

Boundary conditions: Met. and air quality

CMAQ-urban ref - Beevers SD , Kitwiroon N, Williams ML, Carslaw DC. 2012. One way coupling of CMAQ and a road source dispersion model for fine scale air pollution predictions. Atmospheric Environment 59, pp 47-58

*CMAQ-urban is the Community Multi-scale Air Quality (CMAQ) + Atmospheric Dispersion Modelling System (ADMS) roads model

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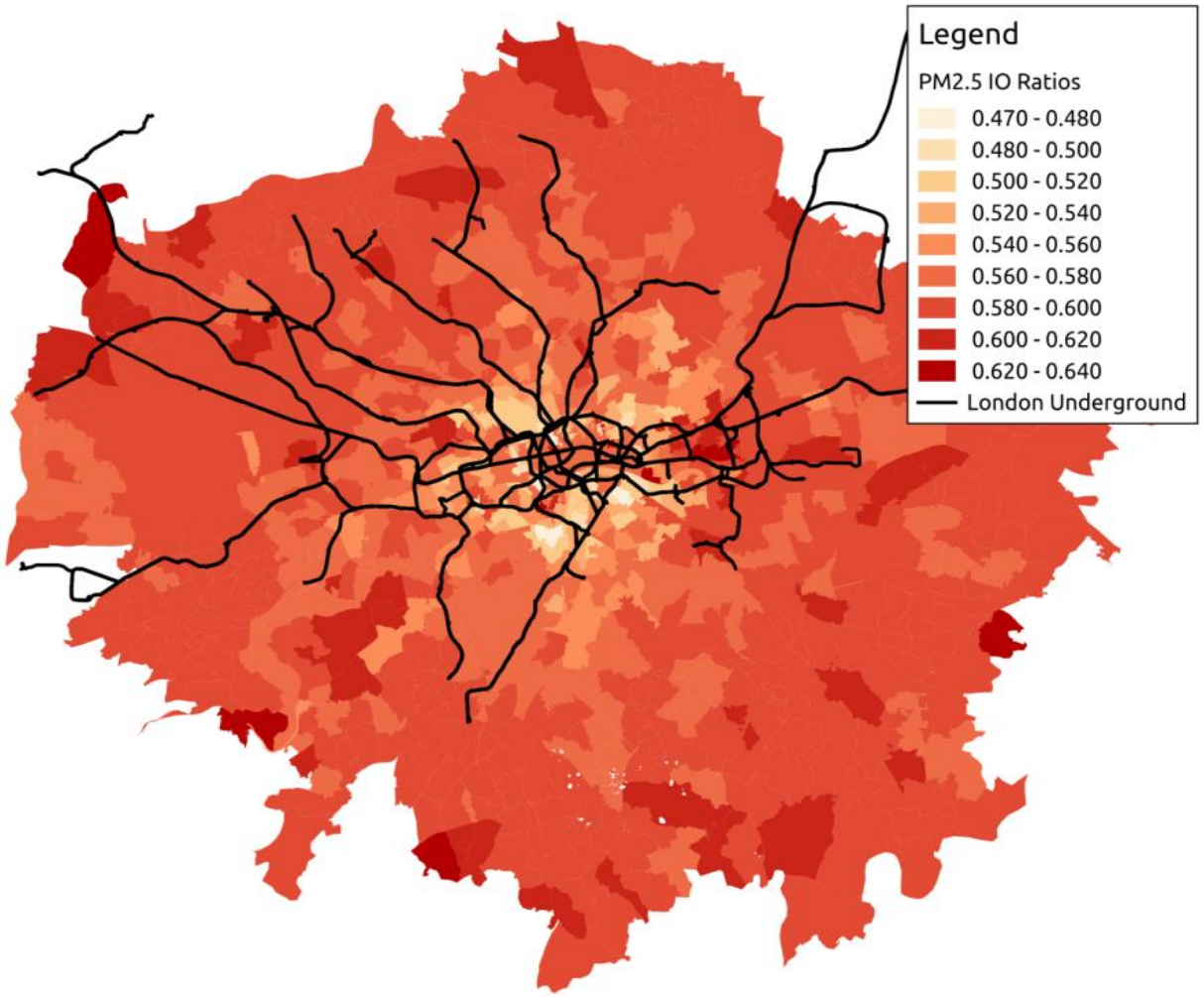
# Methods – Micro environmental

When people are indoors, we use indoor/outdoor ratios to calculate their exposure to outdoors pollutants, indoors.




Provided by colleagues at UCL, hourly ratios by postcode

# Hybrid exposure model

http://www.londonair.org.uk/research/Modelling-Air/custom/index.html

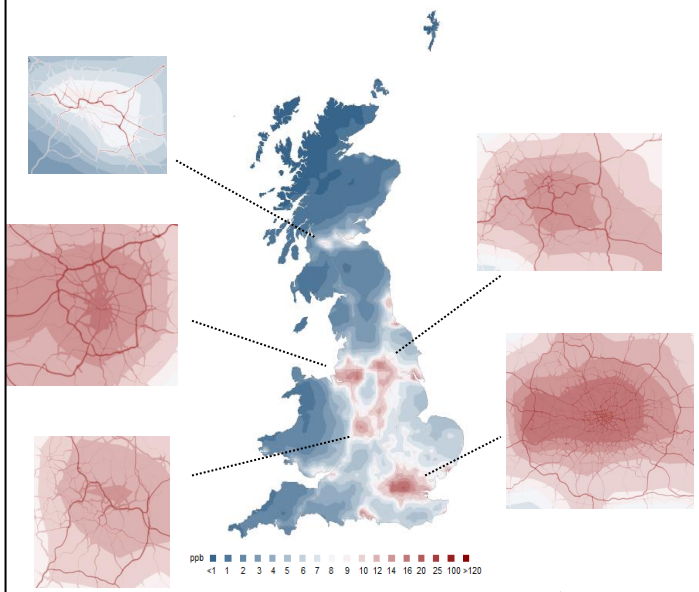
**In-vehicle air quality**

Micro-environmental modelling: in-vehicle (bus, car, train, tube), cycle, walk, indoors (I/O exchange - J Taylor (UCL))

$$\frac{dC_{in}}{dt} = \lambda_{win}(C_{out} - C_{in}) - n\lambda_{HVAC}C_{in} - V_g\left(\frac{A}{V}\right)C_{in} + \frac{Q}{V}$$

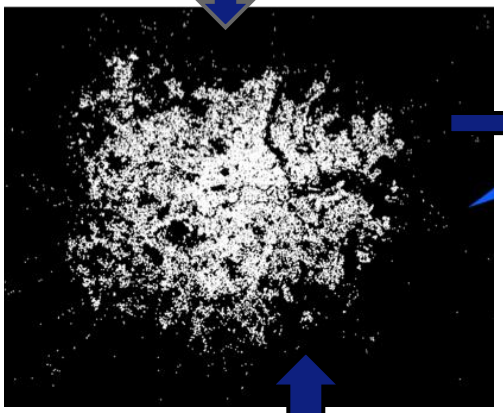
**Outdoor air quality**

CMAQ-urban air quality model (outdoor concentrations)

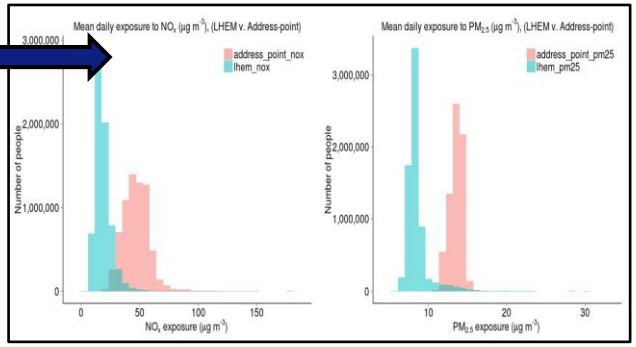



London Travel Demand Survey: Trips by transport mode: Age, gender and socio-economic status

**Travelling**

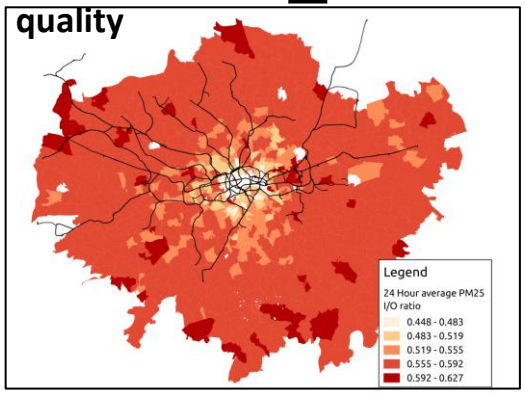


**Personal exposure**




The average LHEM exposure is estimated to be 37% lower for $PM_{2.5}$ and 61% lower for $NO_x$ ($NO+NO_2$), than at the residential address

**Indoor air quality**




Smith et al., 2016. The London Hybrid Exposure Model (LHEM): Improving human exposure estimates to $NO_2$ and $PM_{2.5}$ in an urban setting. ES&T

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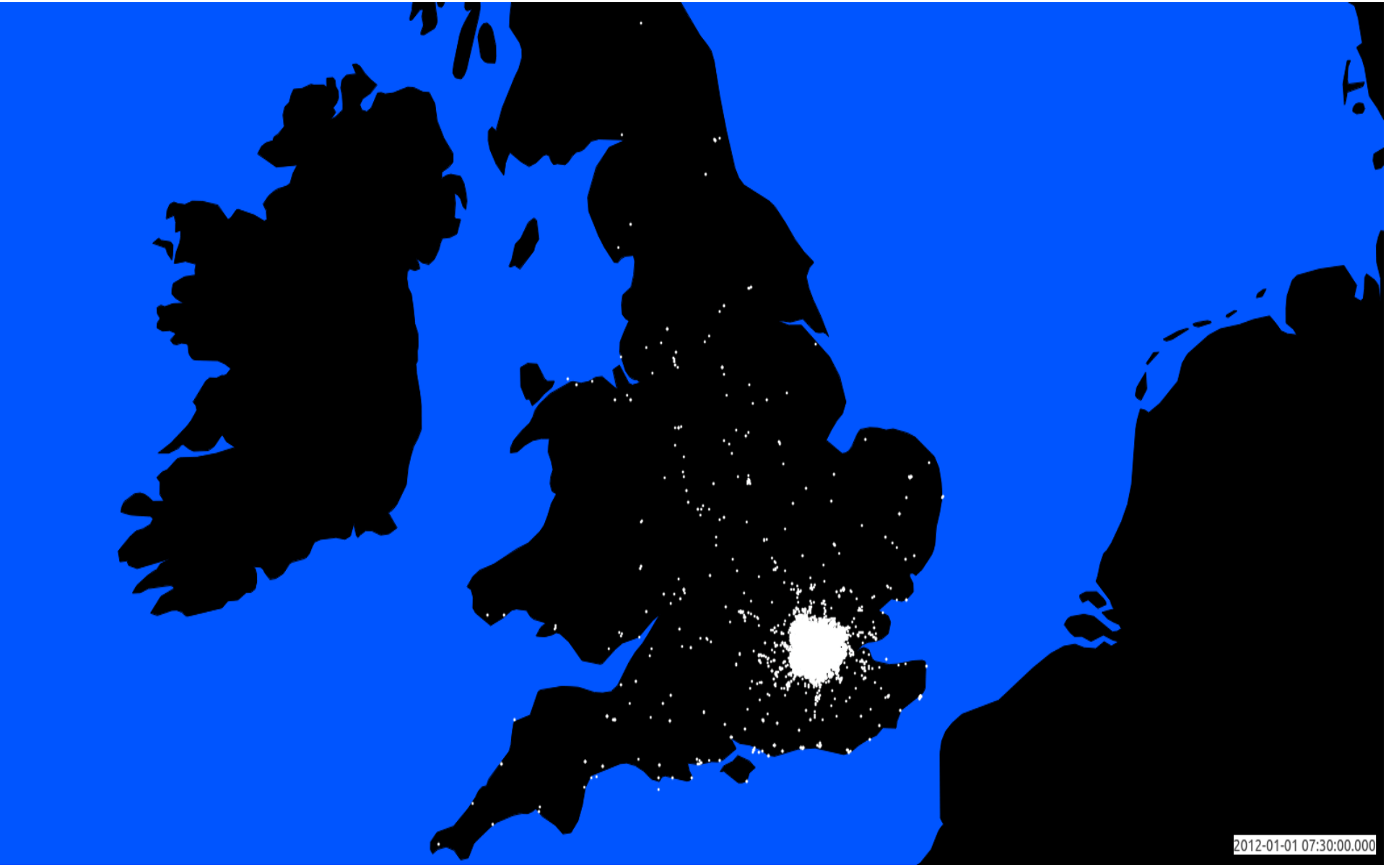
# London journey’s



# London journey's


The Open Route Service API (www.openrouteservice.org) was used to simulate walking trips (shortest-path), Project OSRM API (www.project-osrm.org) to simulate car trips (quickest-path), Google Directions (https://developers.google.com/maps/documentation/directions/) to simulate cycling (quickest-path), and the TfL Journey Planner (journeyplanner.tfl.gov.uk) to simulate public transport trips (overground train, the London underground, the Docklands Light Railway and bus).

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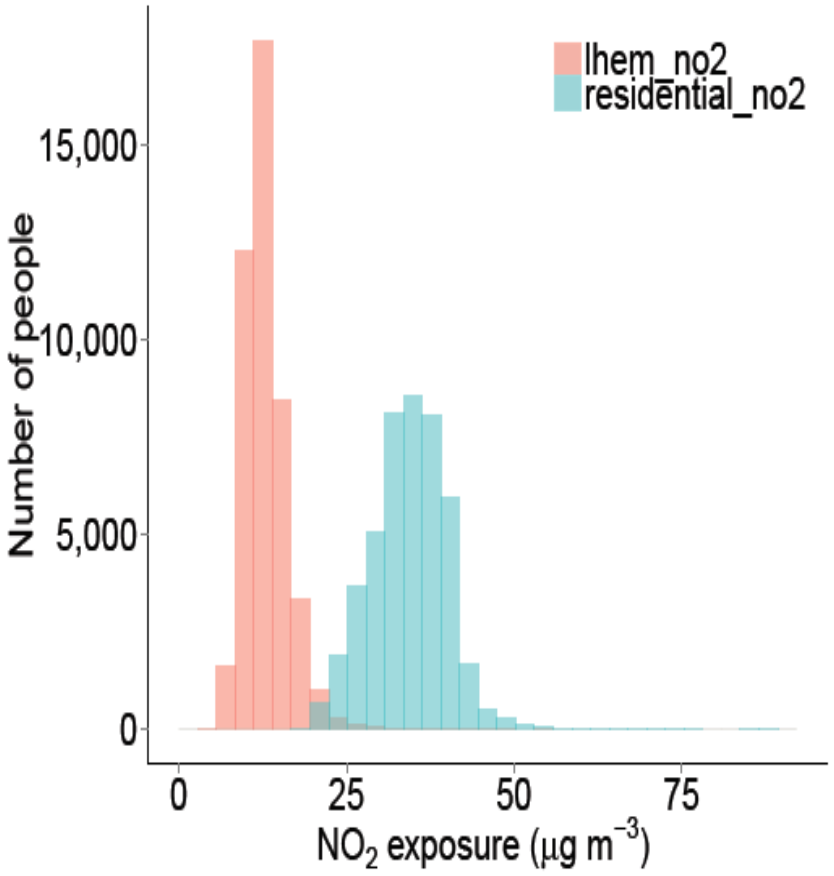
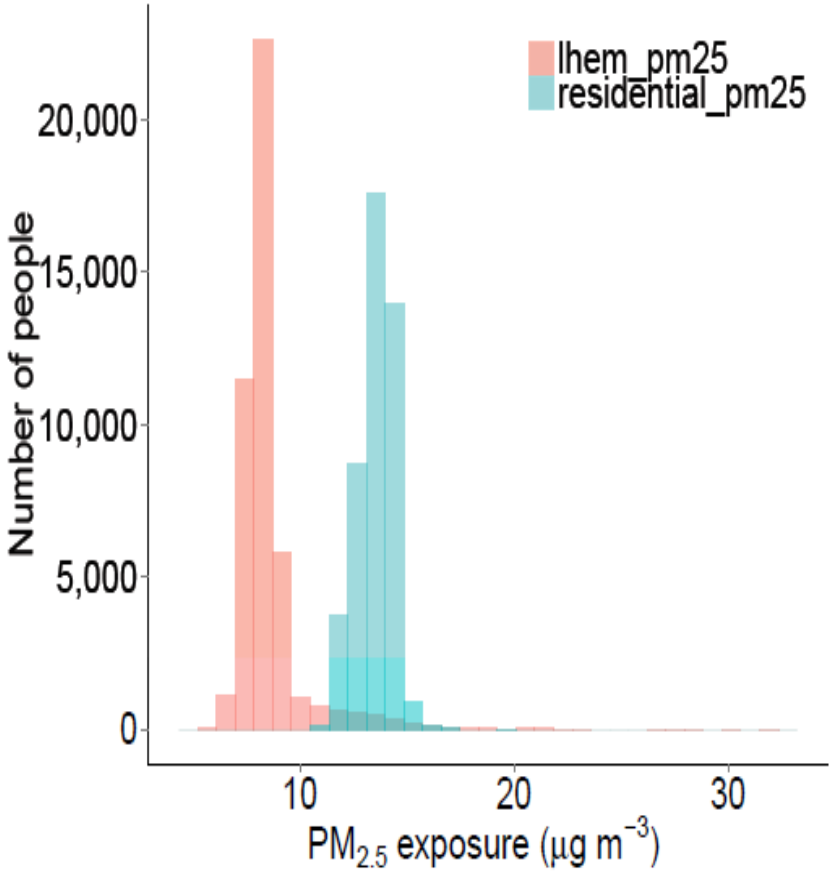
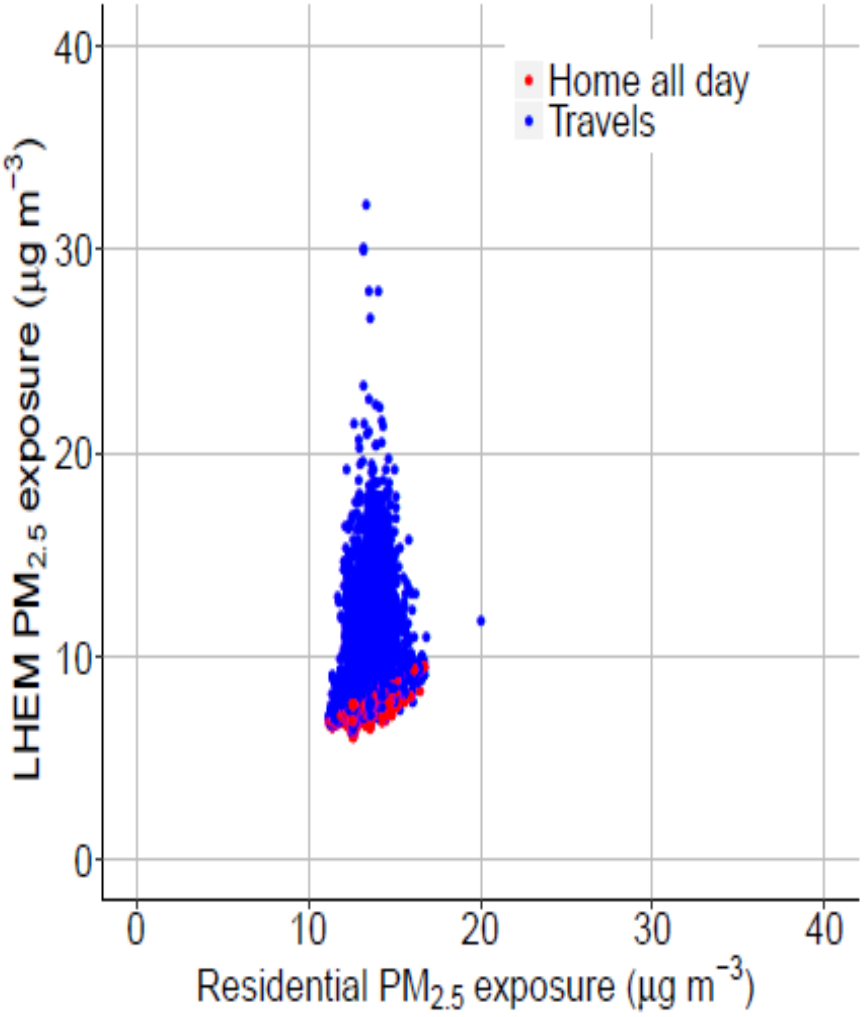
# Results – Residential v. dynamic

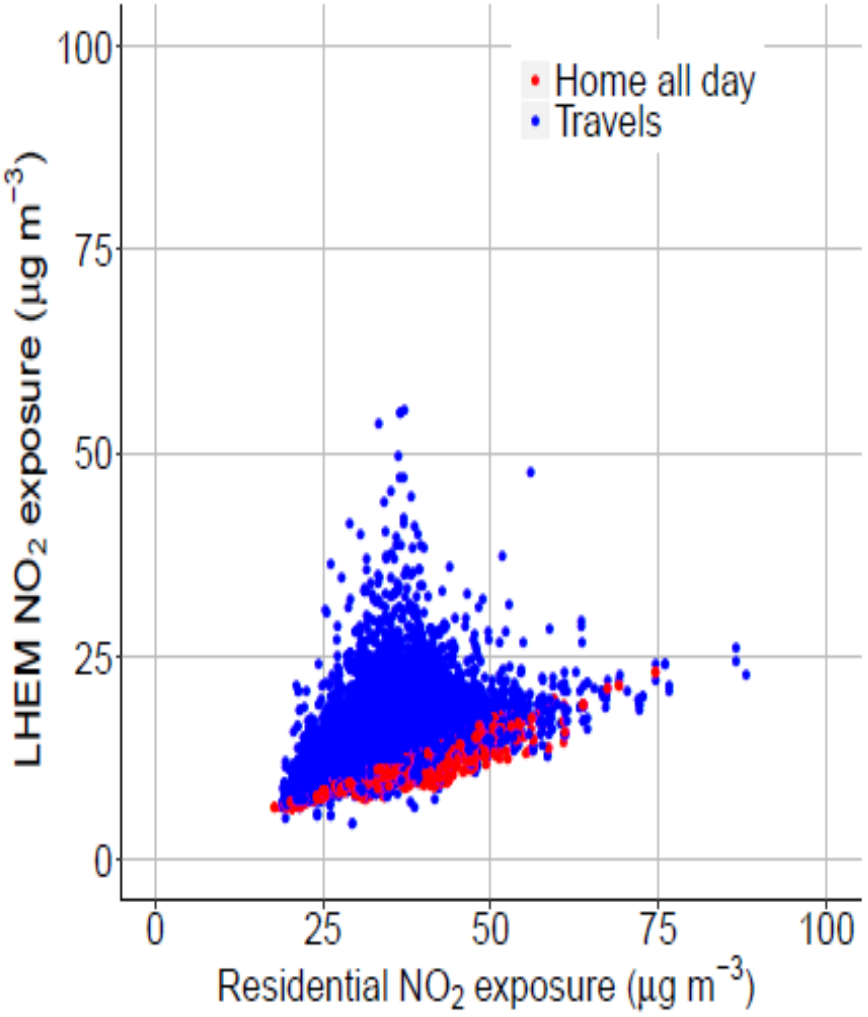



24 hours mean exposure

# Results – Residential v. dynamic



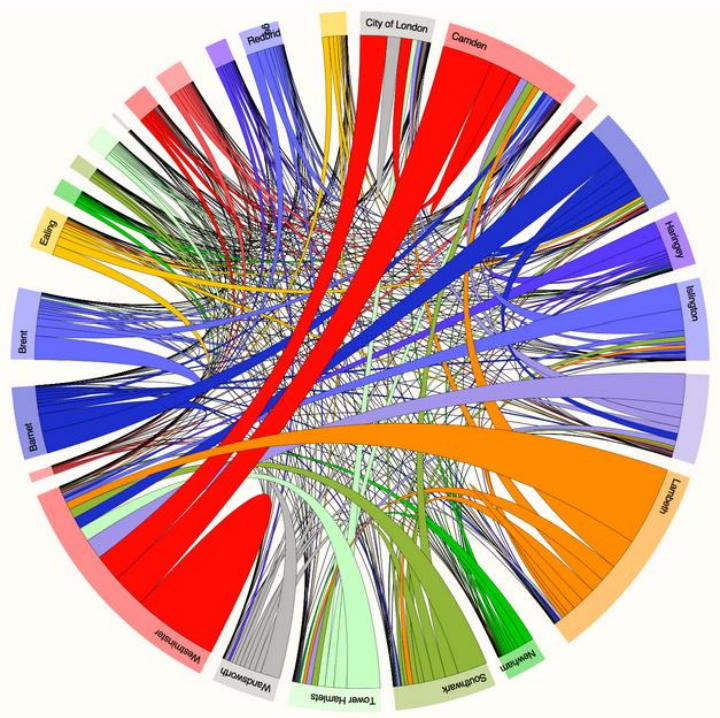
# Conclusions



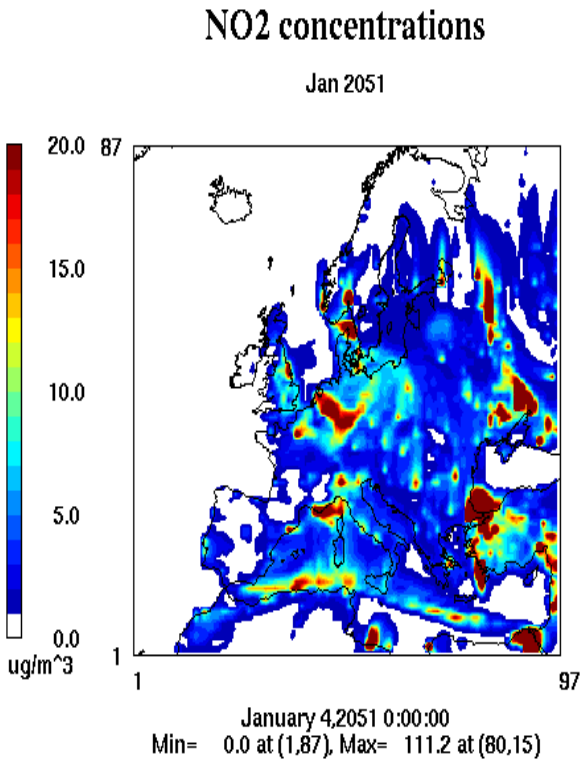
- **Traditional exposure** estimates are **over/under-estimating exposure**
- **Active** traveller exposure vs **inactive** traveller (tubes, cars…)
- **Correlation between pollutants** very different with dynamic model vs static model
- Next step is to incorporate indoor sources emissions, refine microenvironment and validate the model using real data

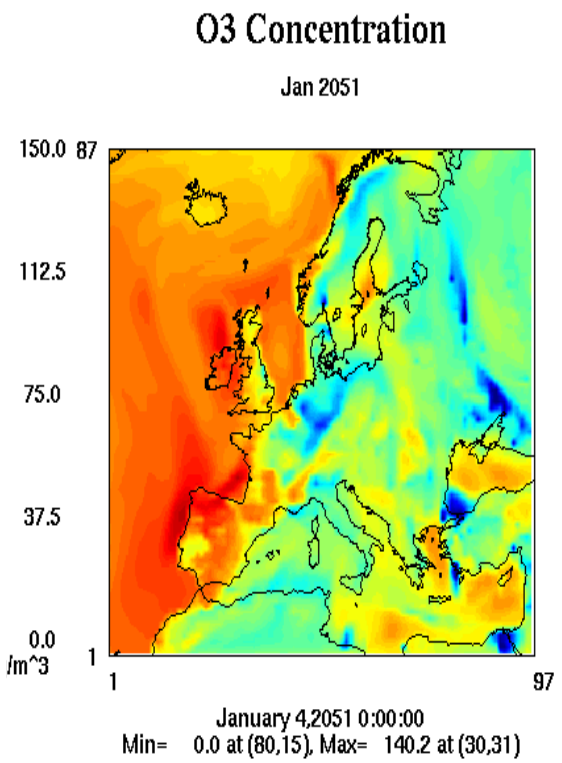
**Expanding** our Hybrid model **to other countries, cities**

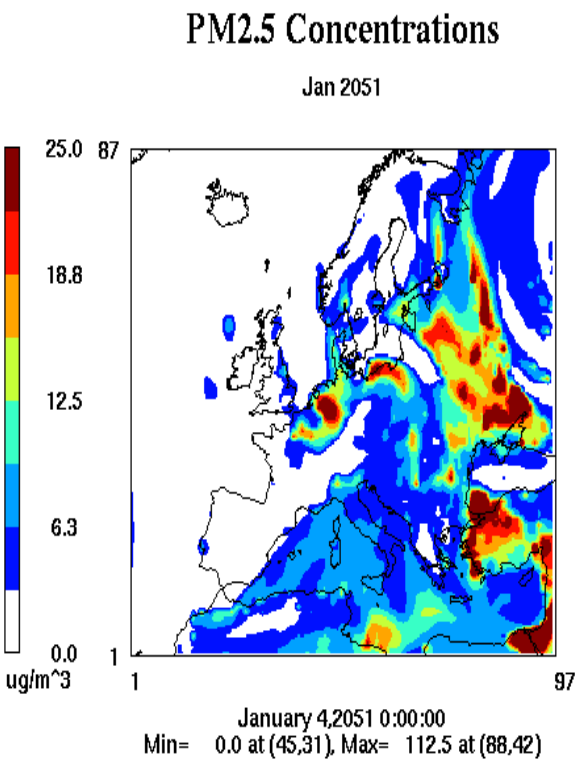
- CMAQ already modelling **Europe** at 15 km resolution (refine urban modelling using road transport emissions)
- Hybrid model method to be updated using people's movement via **survey**, electronic device such as oyster cards or **mobile phone** data



# $NO_2$ $O_3$, and $PM_{2.5}$ in 2051



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# Thanks for your attention…

Thanks to colleagues in the ERG modelling group:
Nutthida Kitwiroon, Sean Beevers, Andrew Beddows, James Smith, Gregor Stewart and Jonathon Taylor (UCL)

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