Ricardo
Energy & Environment

Development and validation of a rapid urban scale dispersion modelling platform

Scott Hamilton
Ricardo, UK

Nicola Masey, Iain Beverland
University of Strathclyde, UK

Ricardo team:

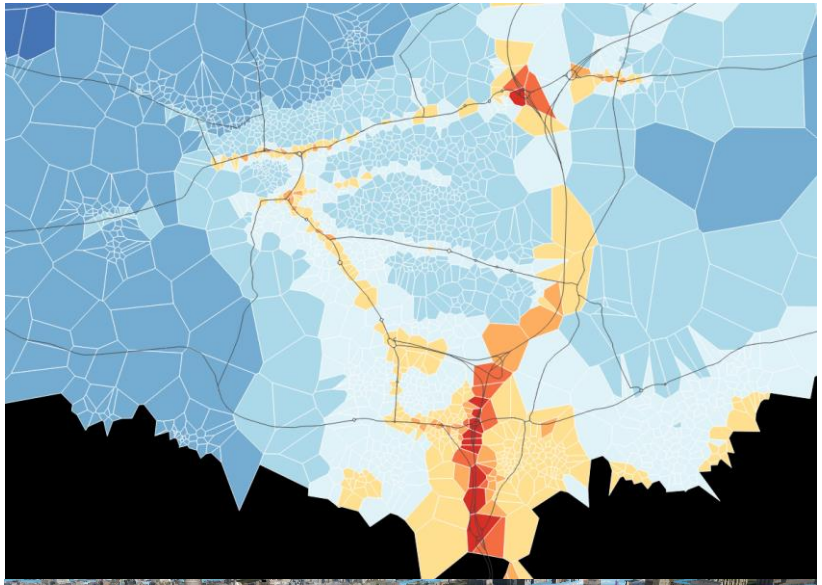
Scott Hamilton,
Andy Lewin
Celine Bouvet

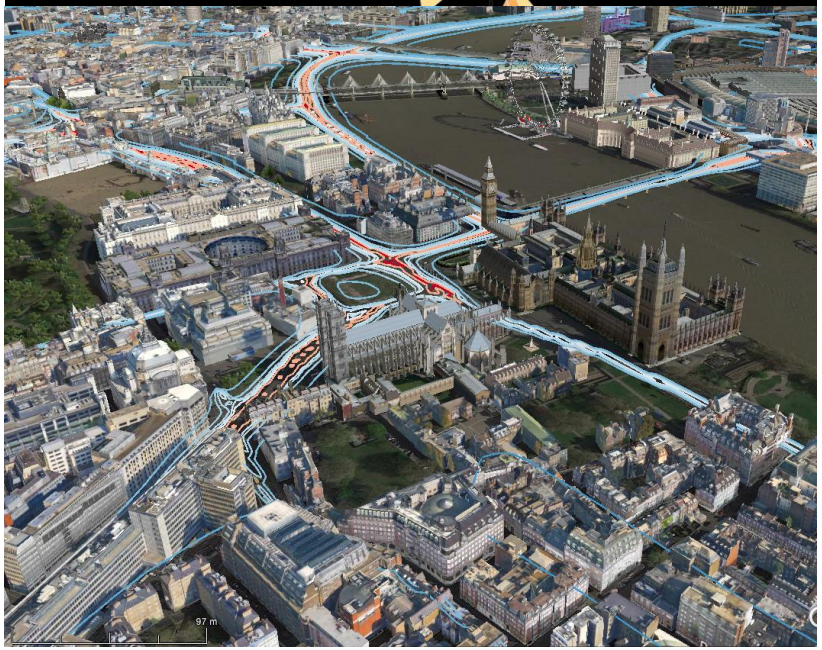

University of Strathclyde team:

Nicola Masey
Iain Beverland


THANKS!

Some **very** important acknowledgements





- USEPA- thankyou for AERMOD, AERMET and MMIF, and educational resources
- CMAS- thankyou for the models, tools and training resources (and CMAS conference!)
- NOAA- thankyou for the excellent meteorological data repository
- UK Met Office- thankyou for the UK met observations and street canyon research/models
- UK DEFRA- thankyou for all the air quality observations, pollution mapping and inventories
- OSGeo project- thankyou for GDAL
- Python developers- thankyou for all the amazing libraries, and for making them open

Too long didn't read (TL;DR)

What is RapidAir?

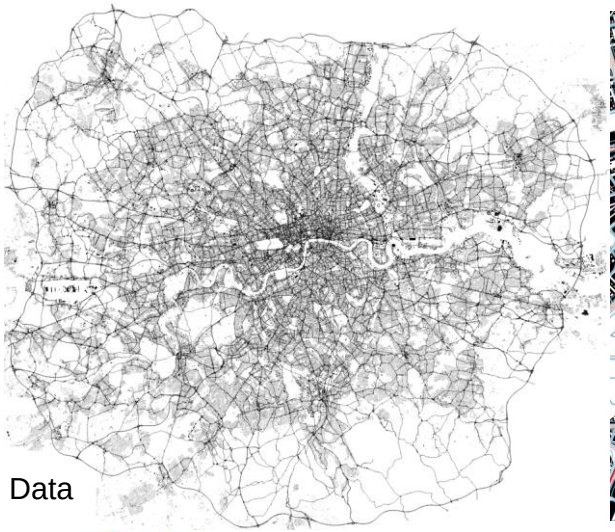
Dispersion model which also eases the workflow for such modelling in cities and regions.

Some neat things it does:

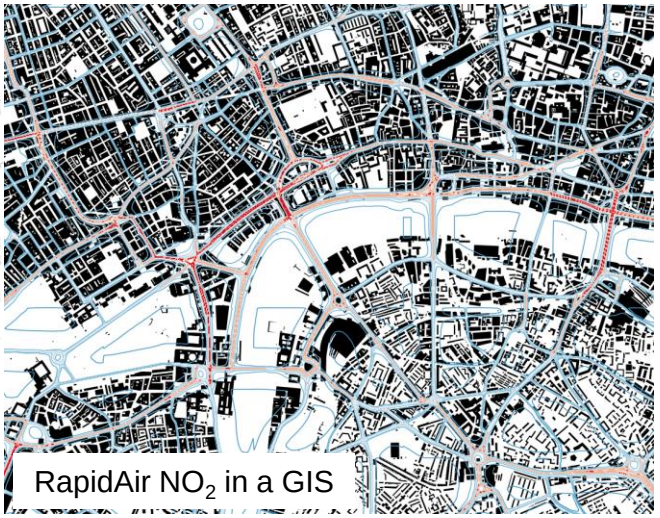
- Traffic emissions (1 million links in 1 minute)
- Road dispersion model including canyons
- Area source model e.g. for large dispersed sources (e.g. domestic)
- Unlimited domain size and resolution (testing with 3 billion locations)
- Domain splitting to account for size, variations in physical parameters
- Met data- met data gathering, filling, substitution, running AERMET
- Automatic handling of background values (in the UK)
- Model validation is automatic with calculation of error metrics (biases, r2, etc)
- Model scaling can be done automatically
- Empirical NOx NO2 chemistry (based on OLS model of background, fNO2, road NOx)
- Interactive plotting (in a web browser dashboard)
- GUI driven option (in a web browser dashboard)

The modeller has no choice but to embed a completely reproducible workflow. We can recreate their results from a single text file. QA is easy!!

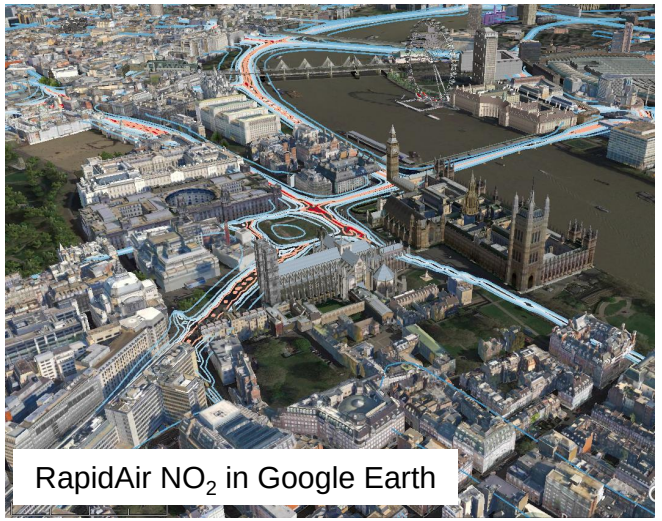
Mostly it's a dispersion model we're using in large urban areas- this is London



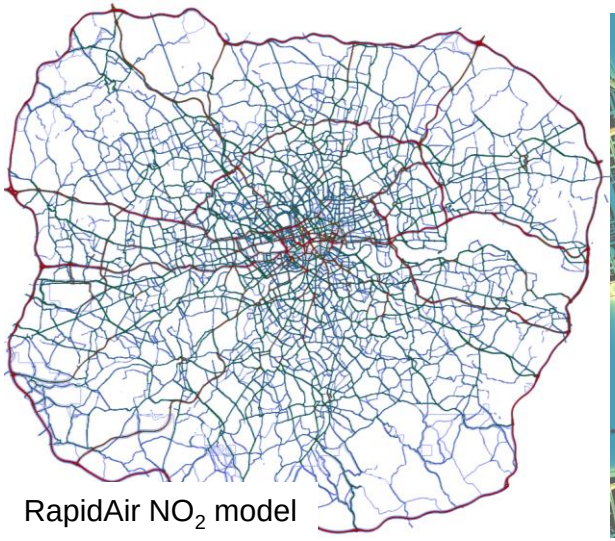
Data



RapidAir NO_2 in a GIS



RapidAir NO_2 in Google Earth



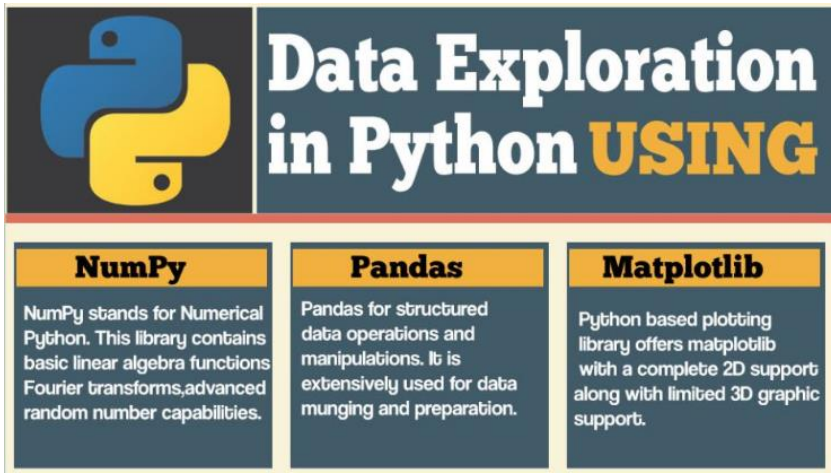
RapidAir NO_2 model

RapidAir NO_2 in a GIS

RapidAir NO_2 in Google Earth

A golden age of scientific computing resources

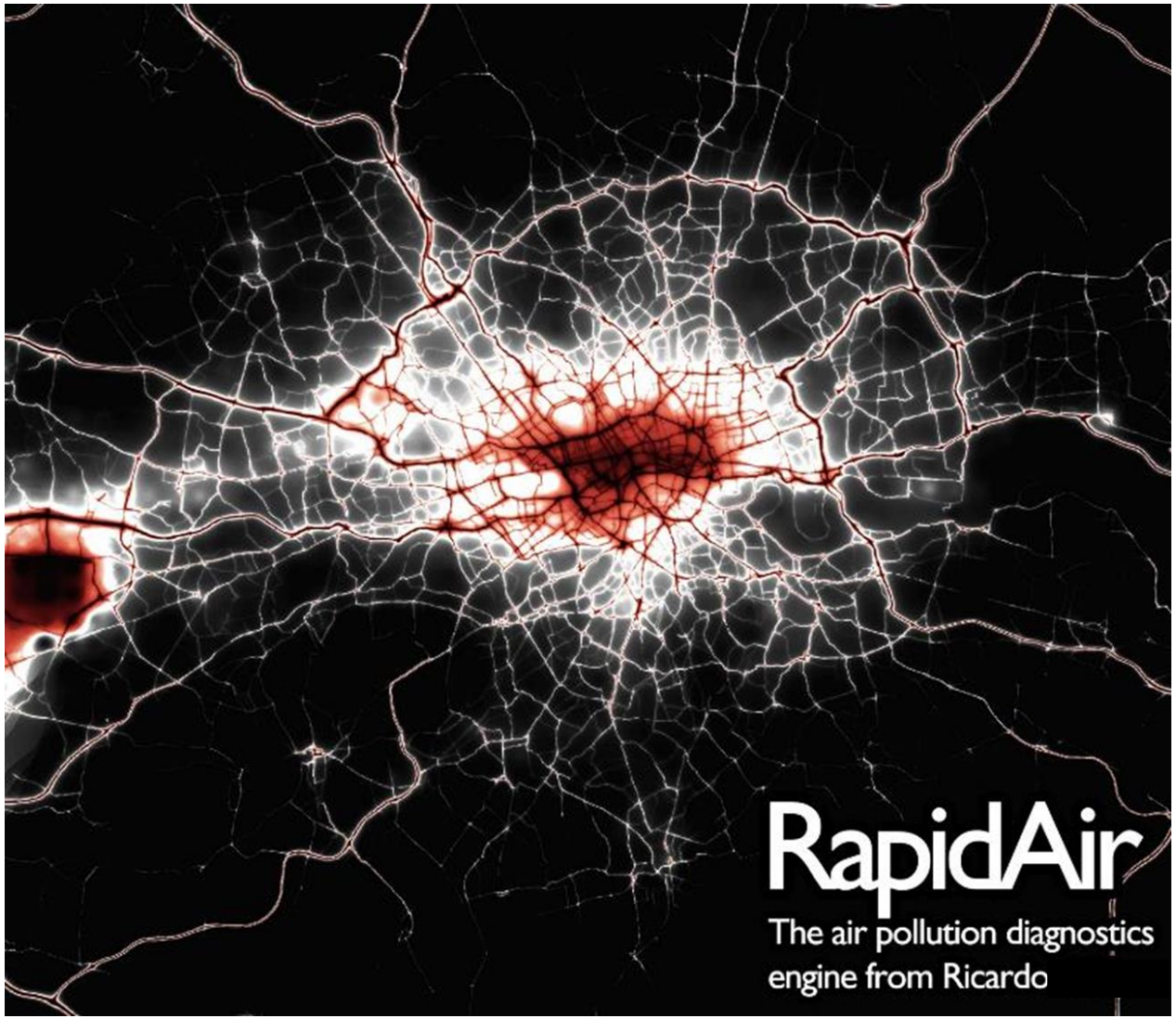
We can now manage “big” environmental data in a manageable and reproducible way using open source technology. This is needed for such large, high resolution models with hundreds of millions of data points.



Python 2.7 is the main glue language performing all of the computation in our model

An example of the power of the methods is the use of python and it’s NumPy and Pandas modules to develop pyCOPERT, a road traffic emissions inventory tool in RapidAir. The model can calculate emissions of NOx, PM10, PM2.5 and CO from >1 million road links in <60 seconds.

Motivation for developing the model

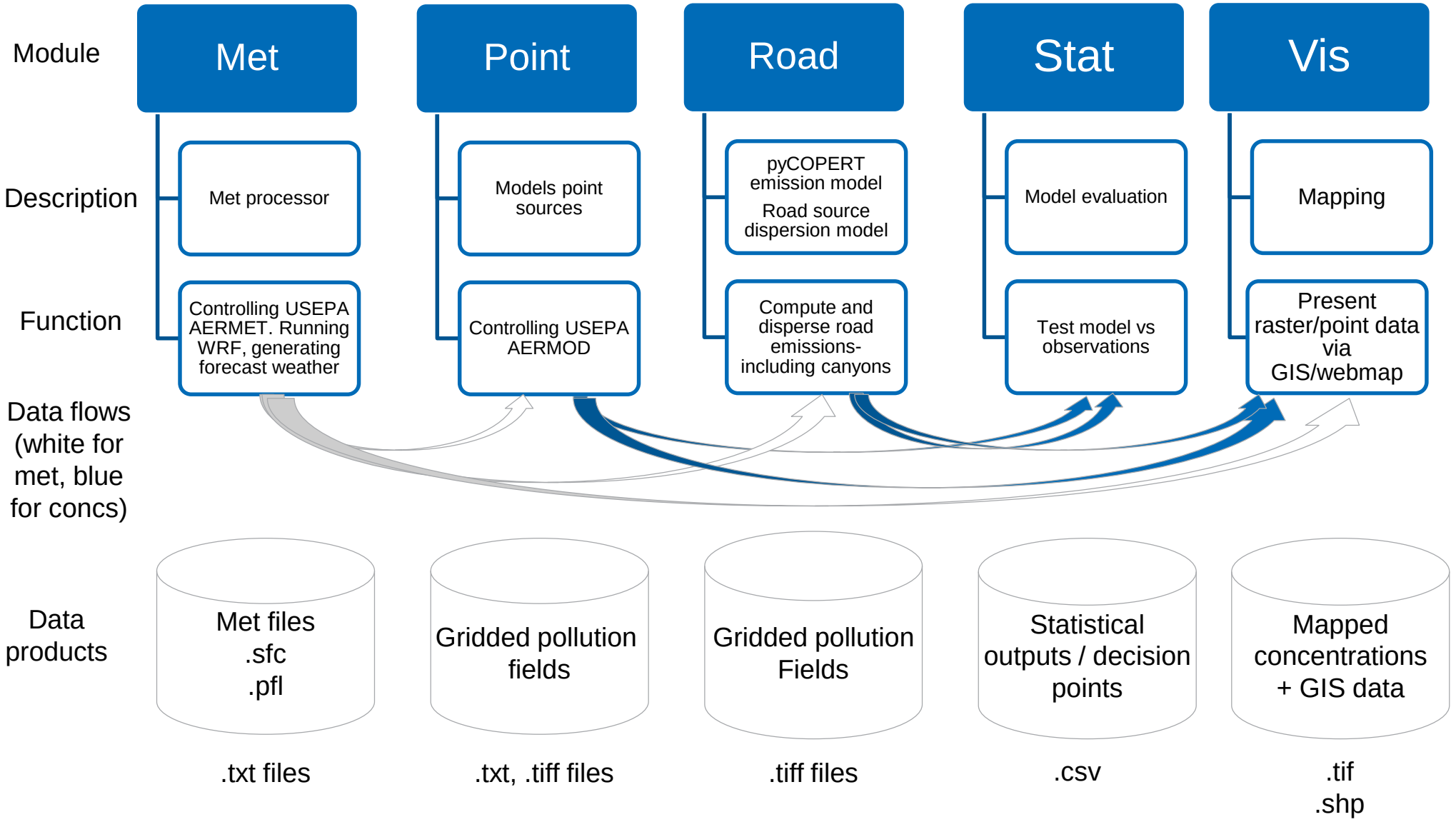


- We needed a cost effective but robust emissions and dispersion model for our consulting projects
- We wanted a platform we could integrate into a ‘software as a service’ offering in future
- So we set to work….
- We wrote a **lot** of code….

More background

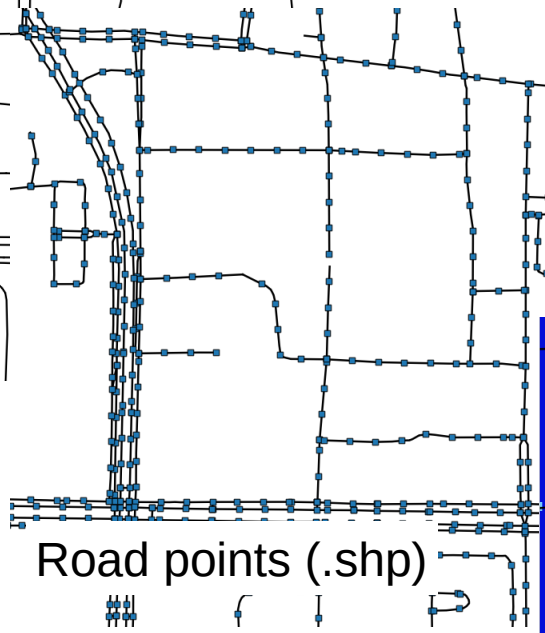
- So far we've used the system in the UK, Middle East, China with much more to come.
- The system utilises the USEPA AERMET and AERMOD modelling suites for both stationary and non-stationary sources at the city scale
- The road traffic module follows guidance laid out by the USEPA in their Hotspot Conformity series
- We have coupled this to the latest emission convolution modelling methods to create lightning fast dispersion modelling functionality for road transport emissions
- Model performance is judged based on the usual metrics such as Root Mean Square Error, Mean Bias, Index of Agreement and Coefficient of Efficiency- we take model performance very seriously
- We believe that sophisticated models must be supported by compelling data visualisations to encourage engagement by decision makers and the public, so we spend a lot of time thinking about this… more later…

Our custom python modules

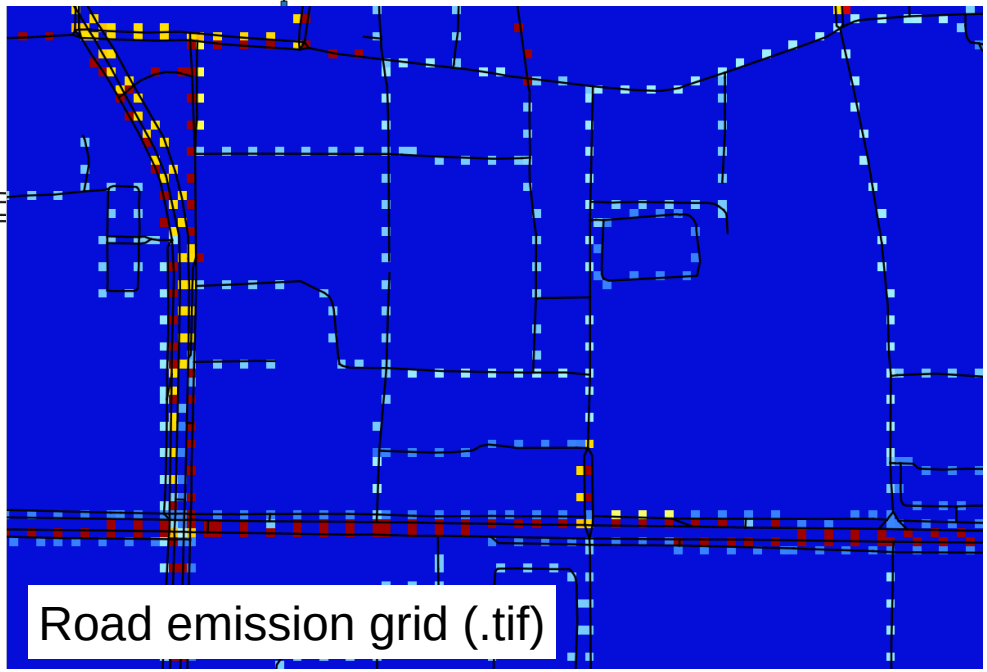


Representative workflow- emissions

Road polylines (.shp)

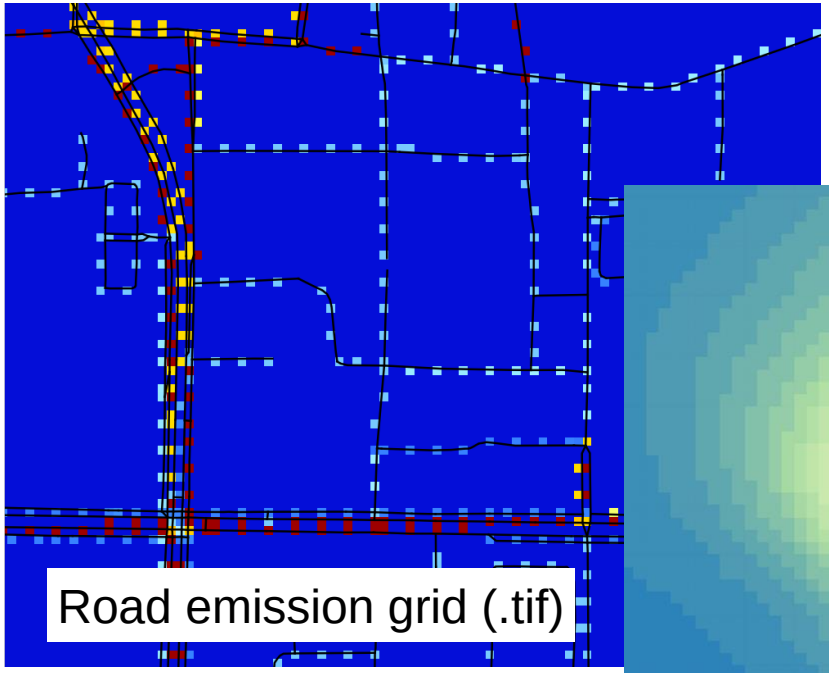


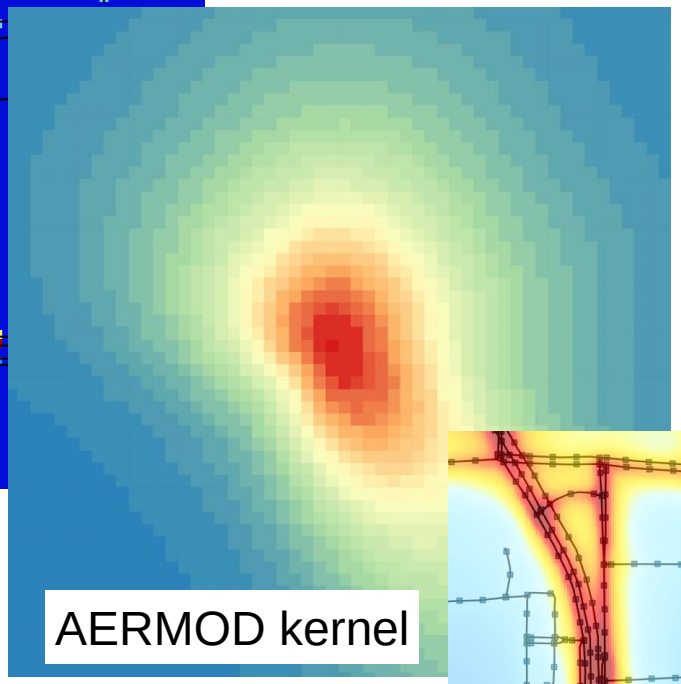
Road points (.shp)



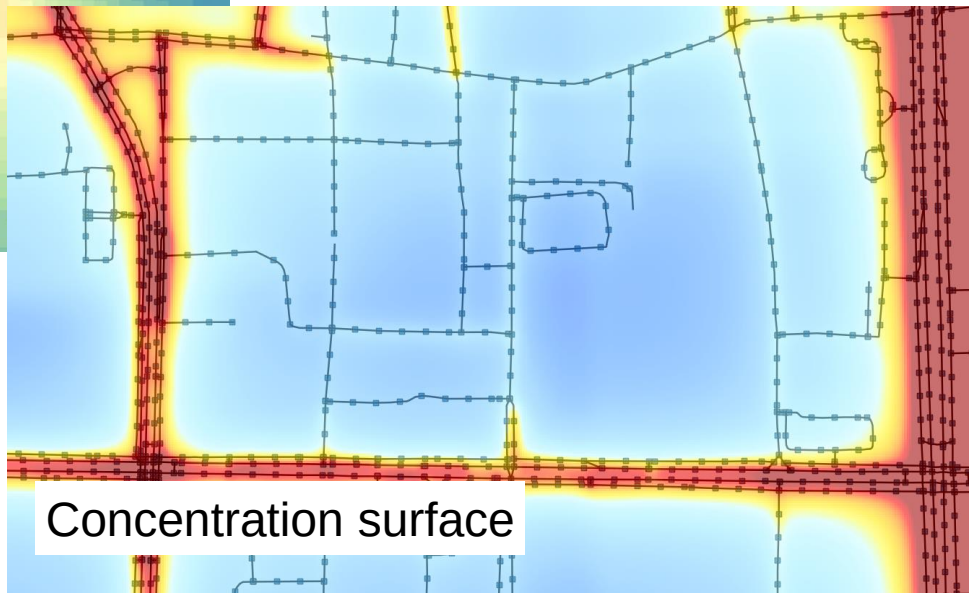
Road emission grid (.tif)

Representative workflow- concentrations





Not to scale



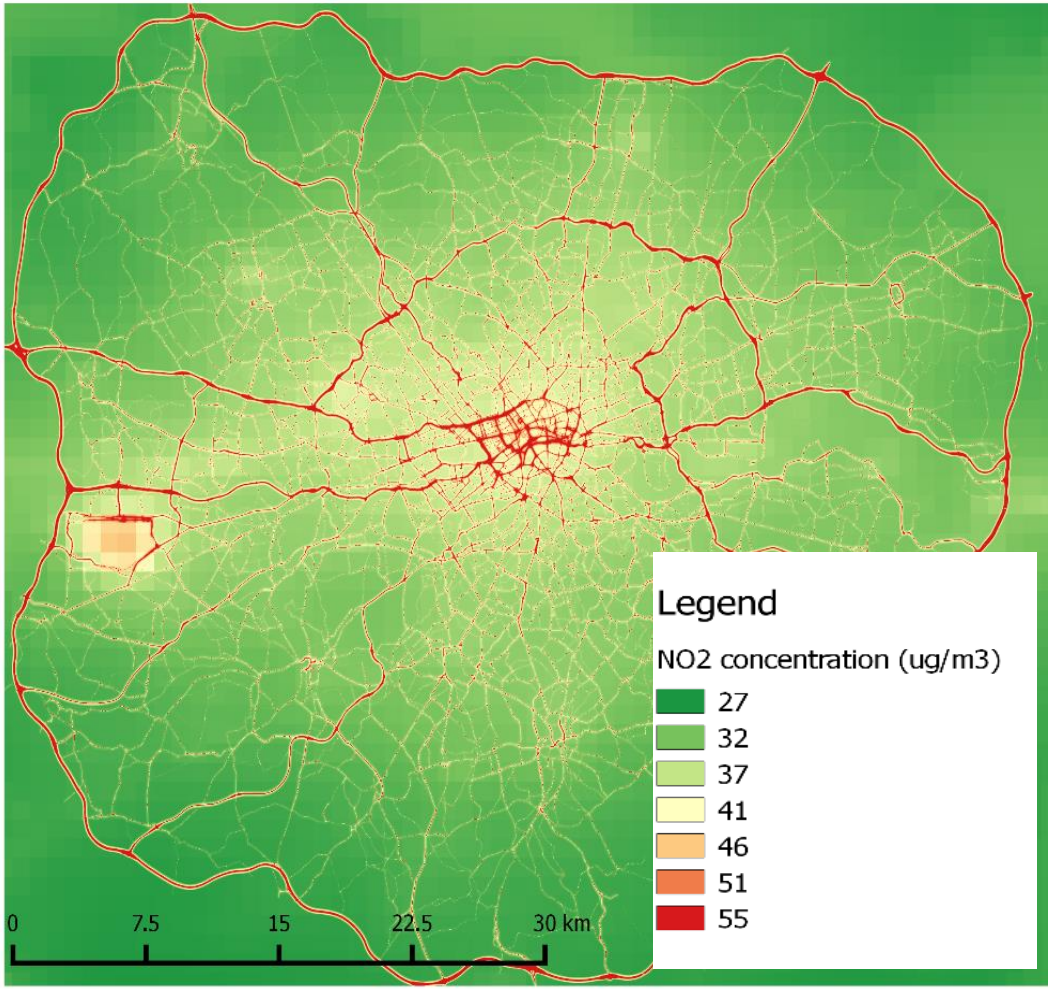
London study

We modelled concentrations of NOx and NO_2 in Greater London.

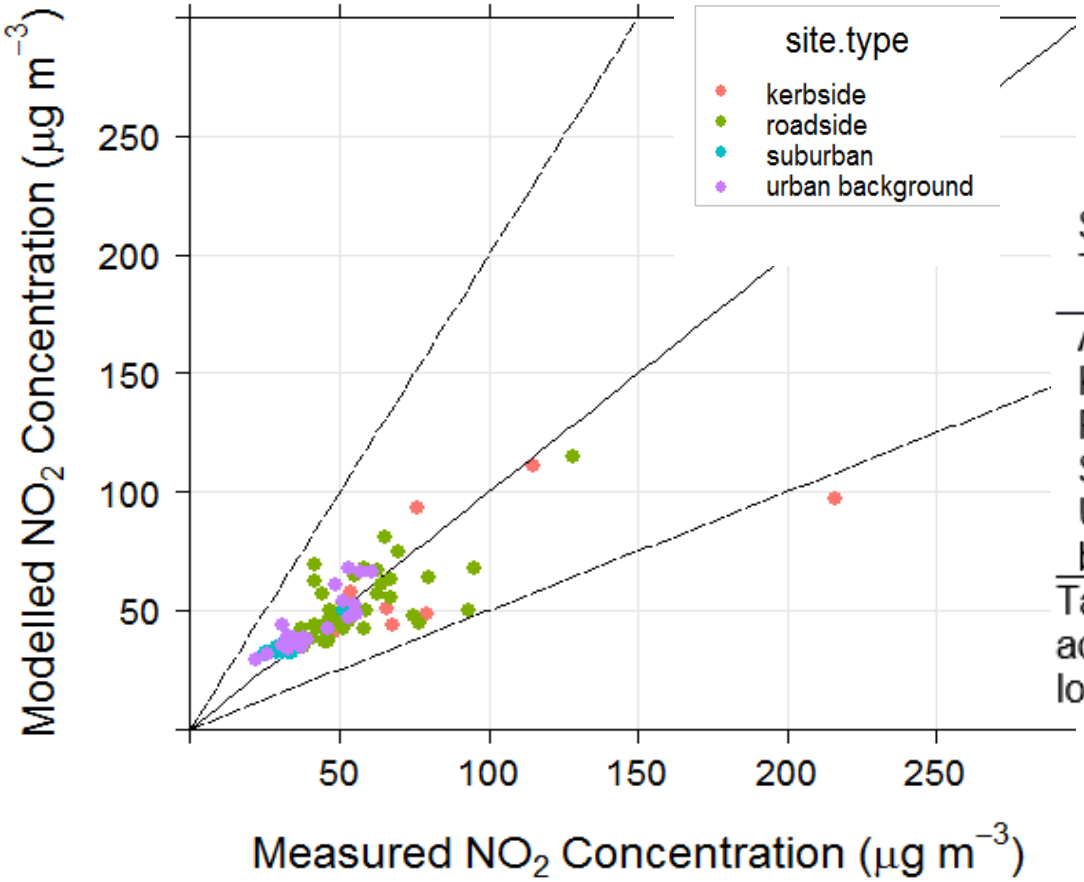
This was the study area used in a previous Department for Environment, Food and Rural Affairs (DEFRA) Urban Model Evaluation exercise, which evaluated several existing models (Carslaw, 2011).

We modelled annual average NOx and NO_2 concentrations for 2008; the same year used by the DEFRA study to enable statistical comparison between RapidAir and the models assessed in the DEFRA comparison.

We evaluated the model at 86 continuous monitoring locations from the London Air Quality Network (LAQN) monitoring network.



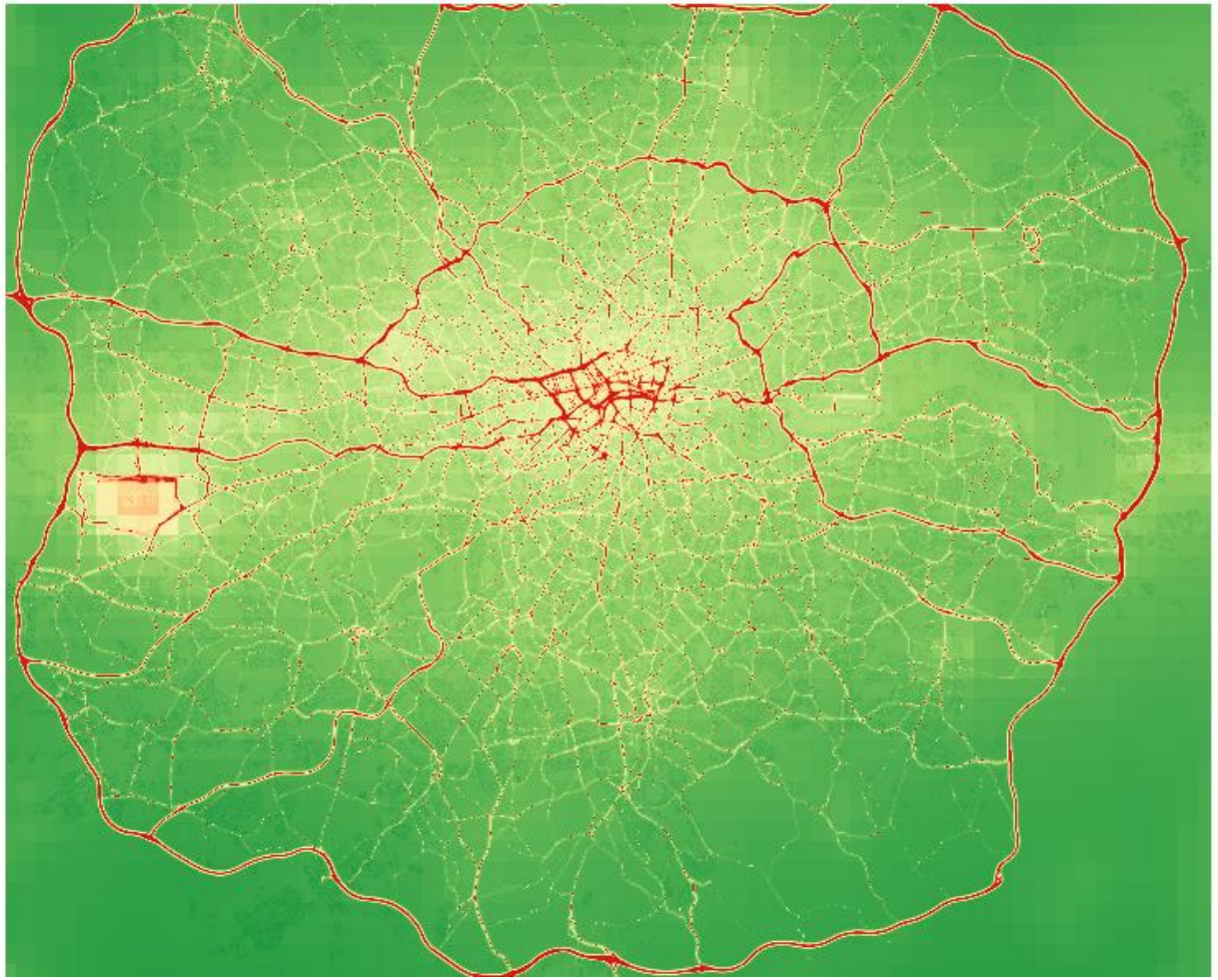
London study (no canyon treatment)



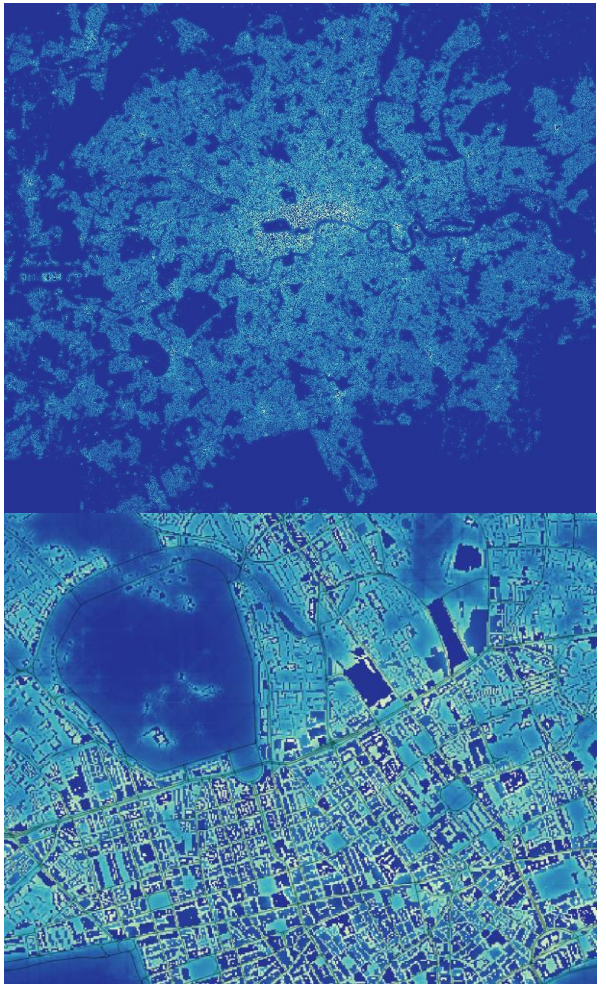
Station Type	n	FAC2	NMB	RMSE (µg/m³)	r
All	86	0.99	-0.05	17.1	0.8
Kerbside	8	0.88	-0.25	45.1	0.7
Roadside	40	1.00	-0.07	13.9	0.7
Suburban	13	1.00	0.08	4.0	0.9
Urban background	25	1.00	0.06	6.0	0.9

Table 1: NO_2 kernel model evaluation statistics (after adjustment for systematic bias) for LAQN receptor locations categorized by site type.

Geospatial surrogates example for street canyon treatment

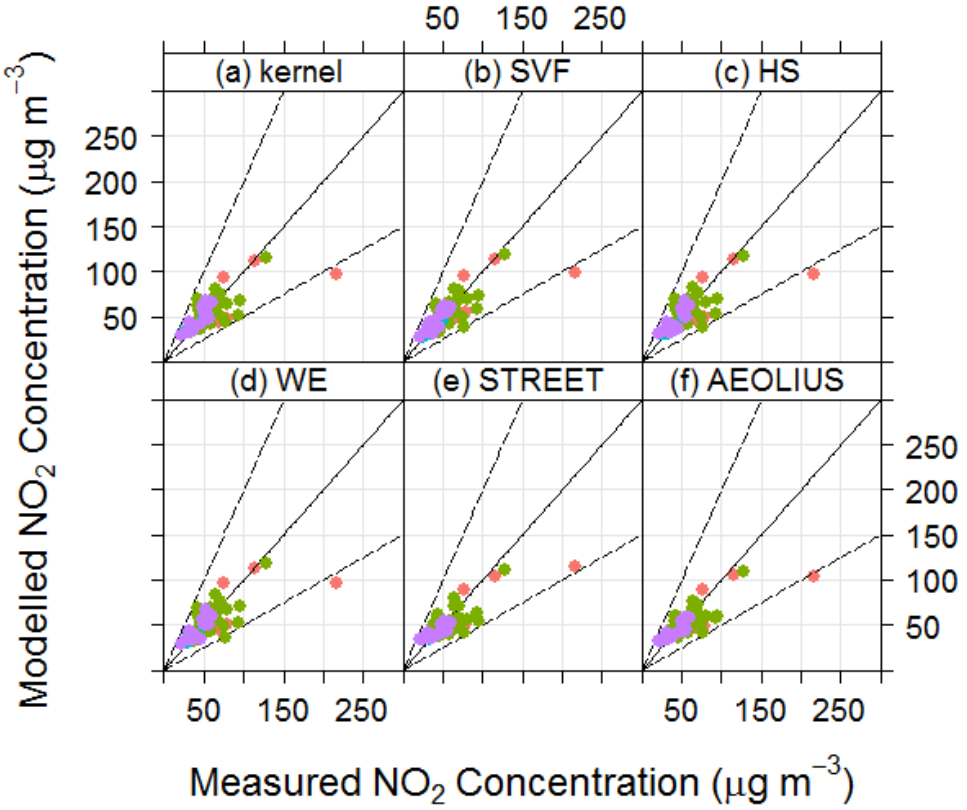


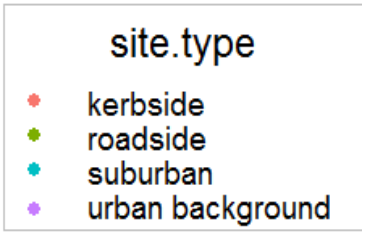
Map of RapidAir predicted NOx concentrations after correction for SVF



SVF image (range 0 – 1)

London study (with canyon treatment)





Model	n	FAC2	NMB	RMSE (µg/m³)	r
Kernel	86	0.99	-0.05	17.1	0.8
SVF	86	0.99	-0.06	16.3	0.8
WE	86	0.98	-0.05	17.0	0.8
HS	86	0.99	-0.06	17.0	0.8
STREET	86	1.00	-0.09	15.9	0.9
AEOLIUS	86	0.99	-0.08	16.4	0.8

Table 4: Summary model evaluation statistics for annual mean NO2 at receptor locations. Statistics are given for the bias corrected Kernel only model, the kernel model after correction using the surrogates for street canyons and then bias corrected, and using the street canyon models with bias correction.

NO_2 estimated by RapidAir kernel model *vs.* observed concentrations (NO_2) (n = 86): (a) uncorrected concentrations from the base-kernel model; and the kernel model after correction using the surrogates for street canyons: (b) sky view factor (SVF), (c) hill shading (HS), (d) wind effect (WE), (e) STREET canyon model and (f) AEOLIUS canyon model.

London study conclusions

The performance was very similar to those computed for other dispersion modelling systems in their DEFRA inter comparison exercise. https://uk-air.defra.gov.uk/library/reports?report_id=777

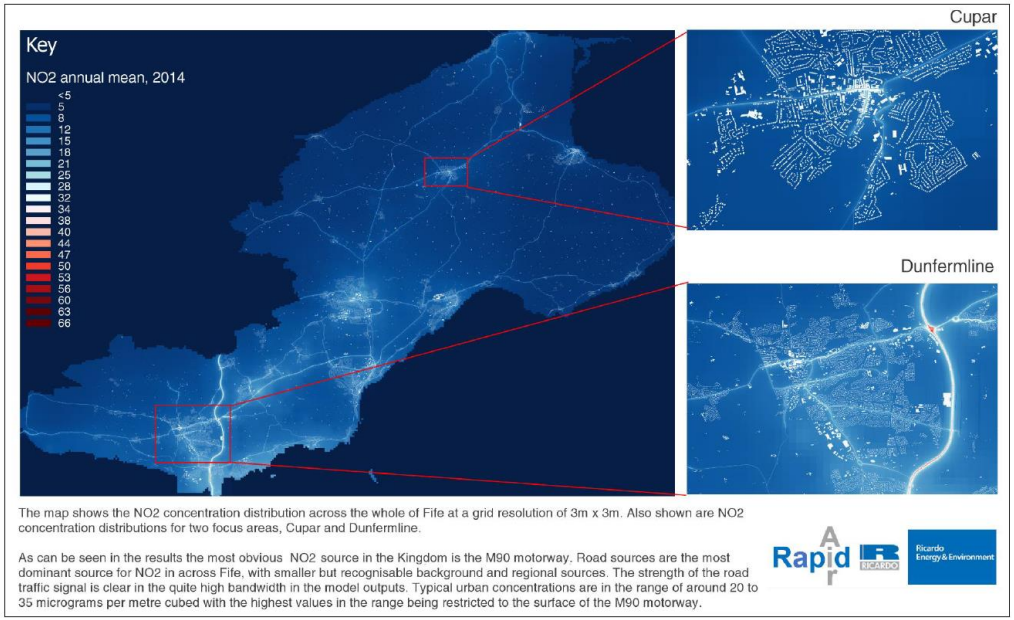
The performance statistics for the surrogates for urban morphology are reasonably close to those from the models which treat canyons discretely.

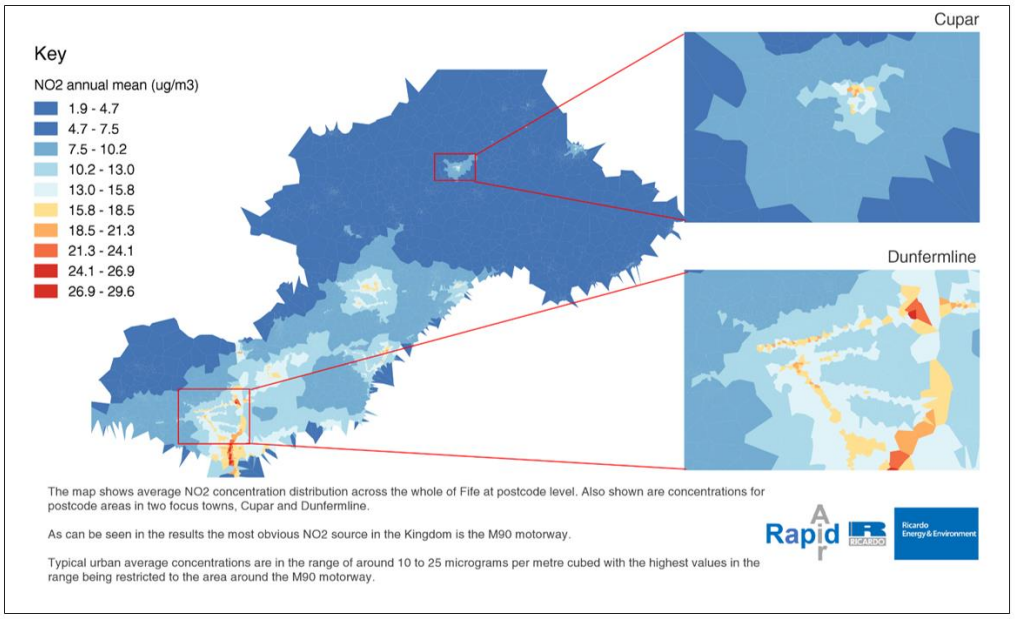
For NO2 compliance assessment RapidAir could be used with either the STREET or AEOLIUS model options switched on as they perform well.

The model results should be compared with measured concentrations and the modeler may choose the best performing street canyon model for their case.

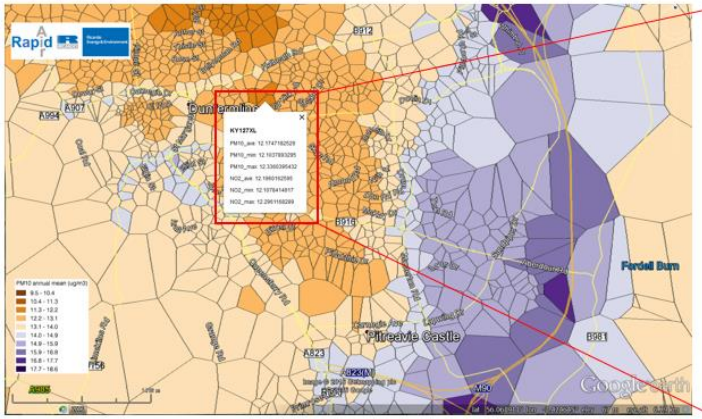
The surrogate canyon models could be used as screening tools and perhaps to spatially delineate locations where the street canyon models should be invoked.

UK Projects- example





PM_{10} average by postcode



Concentrations for a single postcode

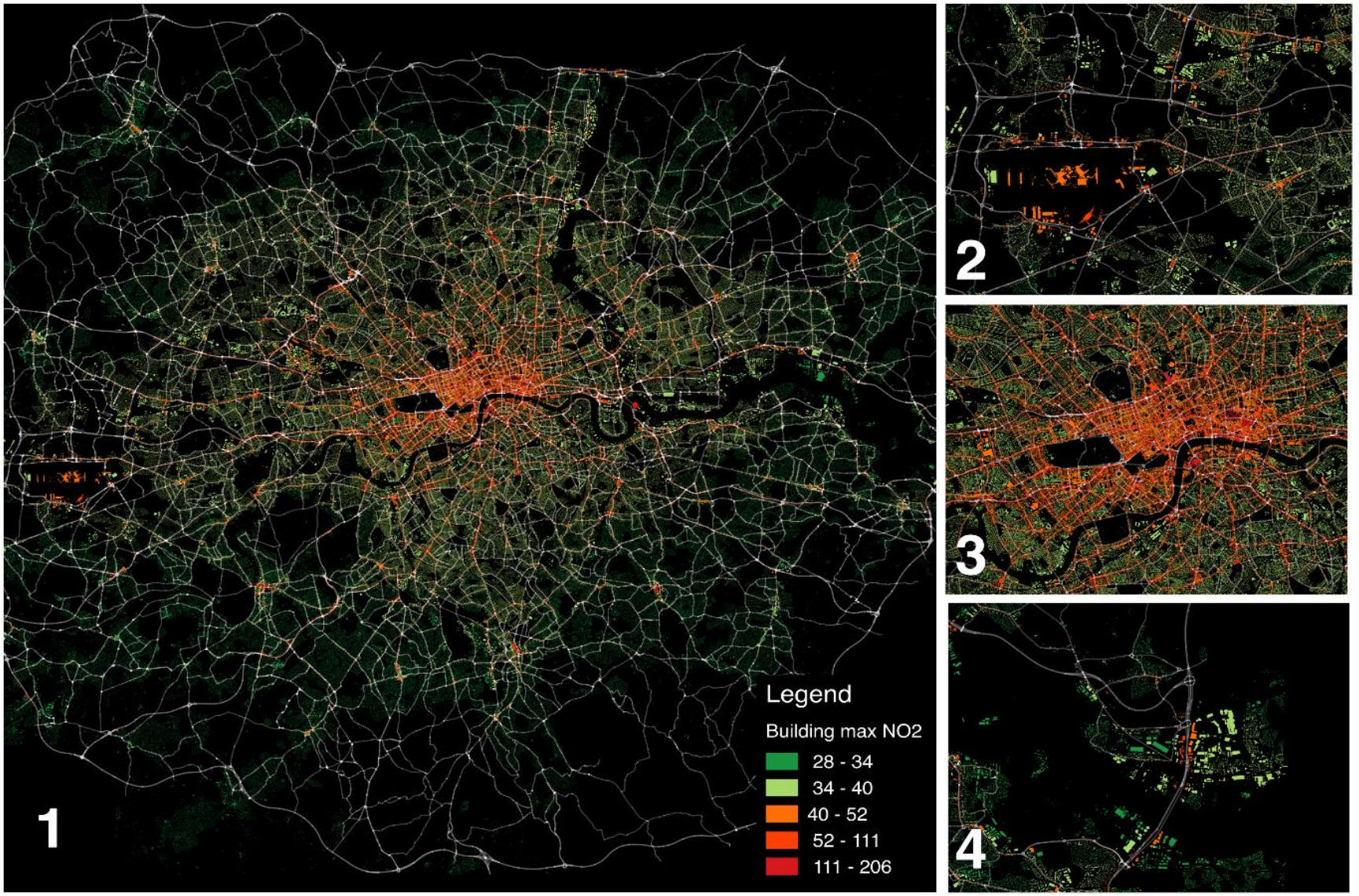
Every postcode in Fife has annual mean modelled concentrations of NO_2 and PM_{10}. Maximum, minimum and mean values within each postcode area are provided.

These values will be useful to health professionals who use postcode level metrics in their analyses.

Ricardo recently developed a RapidAir model for Fife Council. The project was funded by the Scottish Government air quality grants scheme.

The model has a resolution of 3m (>300million prediction points) and covers the whole Kingdom. Data products include common GIS formats, Google Earth layers, interactive report including OpenAir.

UK example, concentrations in building footprints



NO2 annual mean concentrations in building footprints, 2008

Partnership with University of Strathclyde

Development and evaluation of portable passive and real-time measurement systems, and dispersion models, to estimate exposure to traffic-related air pollutants

Nicola Masey

A Thesis presented for the Degree of Doctor of Philosophy

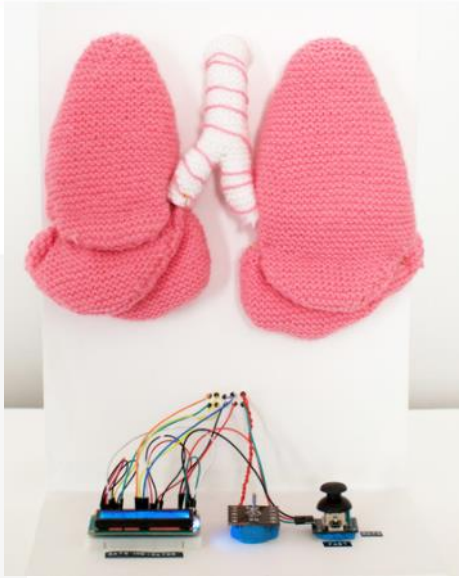
Department of Civil and Environmental Engineering
University of Strathclyde
2017

Nicola now works with me in the modelling group at Ricardo.

KANTAR Information is Beautiful Awards

About News Awards Showcase

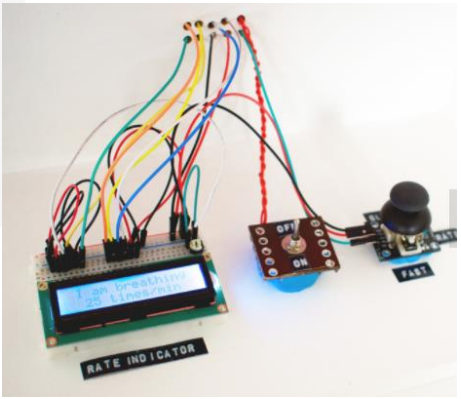
RICARDO



3D Visualisation of Air Pollution in Glasgow

by Trudi Hannah

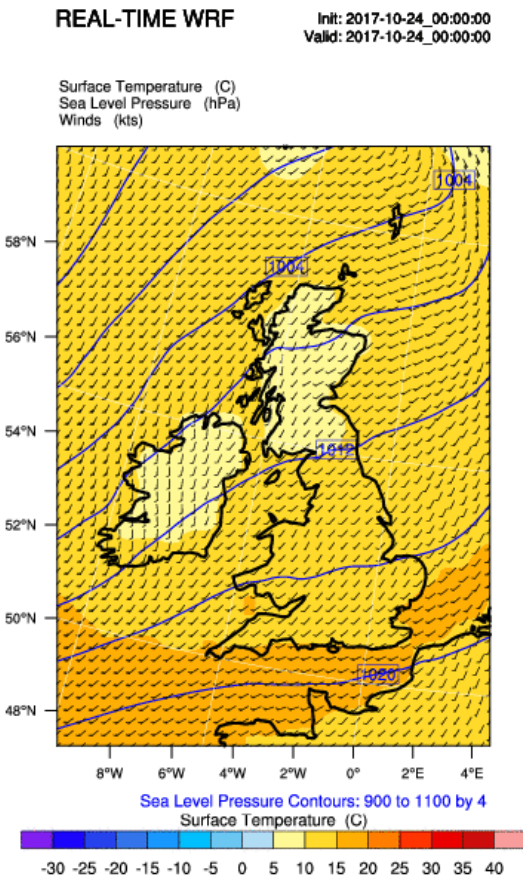
A geophysical investigation of environmental data and exploring new ways to communicate this complex data to the public. The issue of air pollution from road traffic is especially topical at the moment. Emissions from road traffic have long been known to have toxic effects on humans



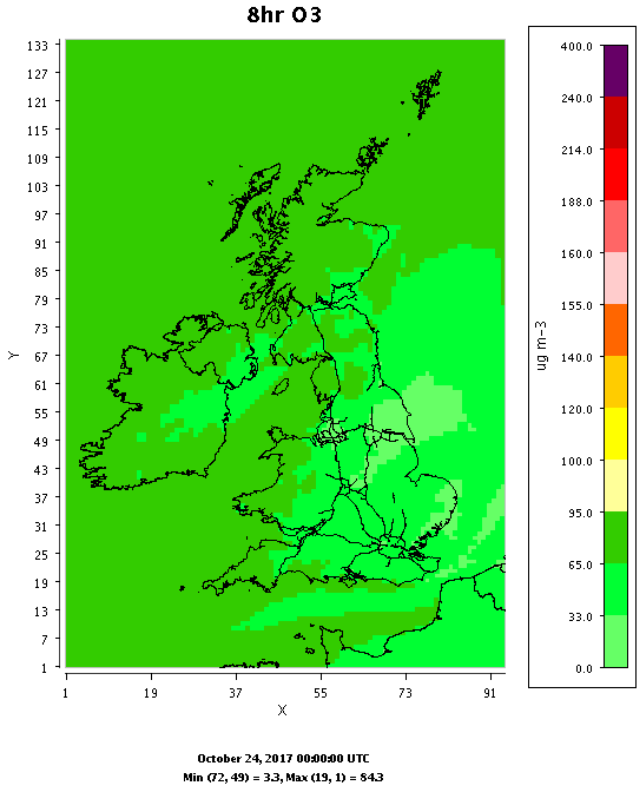
Results from a Ricardo collaboration with Trudi Hannah at Glasgow School of Art.

https://www.informationisbeautifulawards.com/showcase/1614-3d-visualisation-of-air-pollution-in-glasgow
http://www.trudihannah.com/#/pollutionvisualisation/

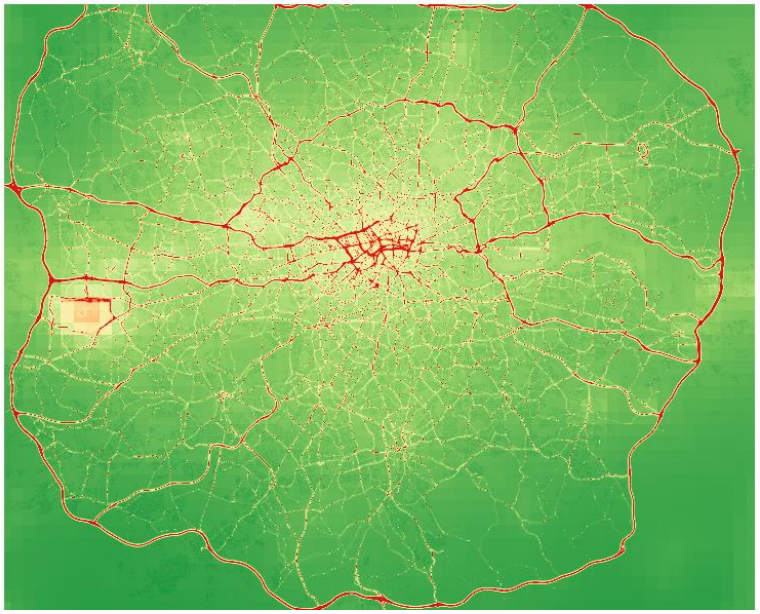
Next steps- integration with operational WRF/CMAQ



WRF



CMAQ



RapidAir at finer temporal resolution using predicted meteorology

We're pretty close to having this going with some validation results but I couldn't get it done in time for the conference.

Thanks!

Scott Hamilton, PhD
Ricardo Energy and Environment
Scott.Hamilton@ricardo.com