

Clean Air Zones- big models for big questions

Scott Hamilton, PhD
Ricardo, UK



Topics for this talk

- **No legislation** (its almost home time after all)
- Main focus is **large scale air quality modelling**
- How it can be used to model **big policy interventions** (like CAZs!)
- **A case study** I modelled in our **RapidAIR** system for this event- which hopefully shows the benefits of a national scale high resolution model set up consistently for all areas
- “**What is the best we can expect from available or soon to be available technologies?**”
- Some thoughts/explanations on **the findings**

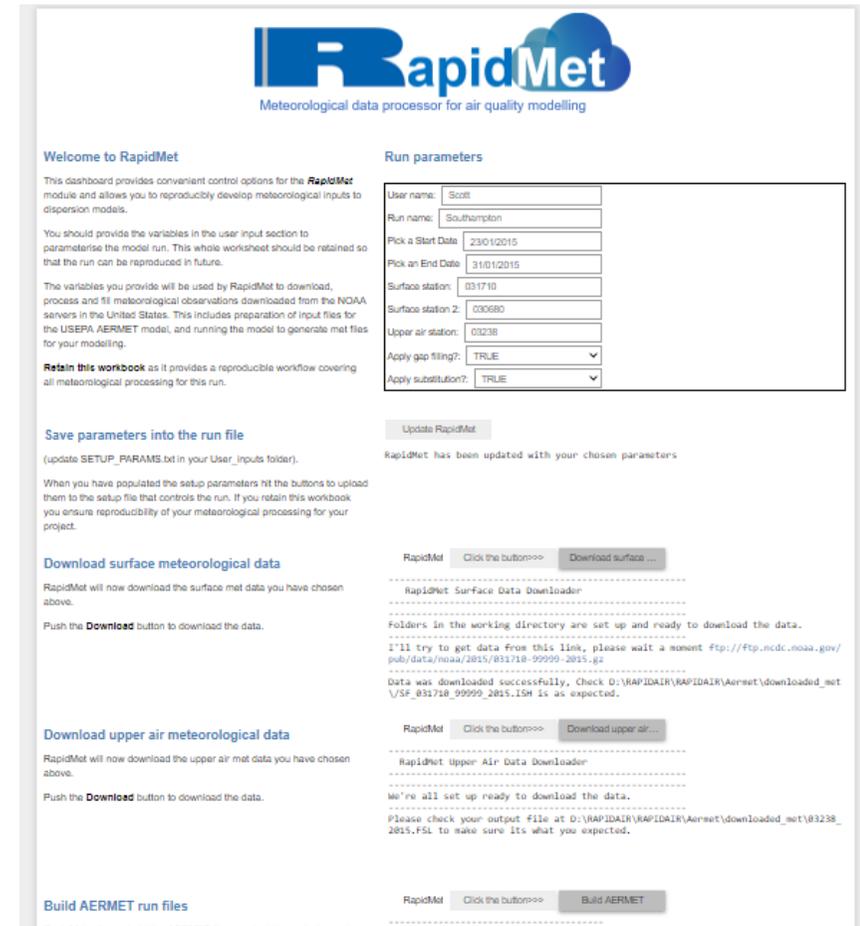
Summary of functionality

What is RapidAir® ?

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

Some neat things it does:

- Traffic emissions model built in (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 unlimited domain size
- 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)



RapidMet
Meteorological data processor for air quality modelling

Welcome to RapidMet

This dashboard provides convenient control options for the **RapidMet** module and allows you to reproducibly develop meteorological inputs to dispersion models.

You should provide the variables in the user input section to parameterise the model run. This whole worksheet should be retained so that the run can be reproduced in future.

The variables you provide will be used by RapidMet to download, process and fill meteorological observations downloaded from the NOAA servers in the United States. This includes preparation of input files for the USEPA AERMET model, and running the model to generate met files for your modelling.

Retain this workbook as it provides a reproducible workflow covering all meteorological processing for this run.

Save parameters into the run file

(update SETUP_PARAMS.txt in your User_inputs folder).

When you have populated the setup parameters hit the buttons to upload them to the setup file that controls the run. If you retain this workbook you ensure reproducibility of your meteorological processing for your project.

Download surface meteorological data

RapidMet will now download the surface met data you have chosen above.

Push the **Download** button to download the data.

Download upper air meteorological data

RapidMet will now download the upper air met data you have chosen above.

Push the **Download** button to download the data.

Build AERMET run files

RapidMet will now build the AERMET files needed to control the run.

Run parameters

User name: Scott
Run name: Southampton
Pick a Start Date: 23/01/2015
Pick an End Date: 31/01/2015
Surface station: 031710
Surface station 2: 030680
Upper air station: 03238
Apply gap filling?: TRUE
Apply substitution?: TRUE

Update RapidMet

RapidMet has been updated with your chosen parameters

RapidMet Click the button >>> Download surface ...

RapidMet Surface Data Downloader

Folders in the working directory are set up and ready to download the data.

I'll try to get data from this link, please wait a moment ftp://ftp.ncdc.noaa.gov/pub/data/noaa/2015/031718-99999-2015.gz

Data was downloaded successfully. Check D:\RAPIDAIR\RAPIDAIR\Aermet\downloaded_met\15F_031718_99999_2015.15M is as expected.

RapidMet Click the button >>> Download upper air ...

RapidMet Upper Air Data Downloader

We're all set up ready to download the data.

Please check your output file at D:\RAPIDAIR\RAPIDAIR\Aermet\downloaded_met\03238_2015.F51 to make sure it's what you expected.

RapidMet Click the button >>> Build AERMET

RapidAir UI- either Windows application or online



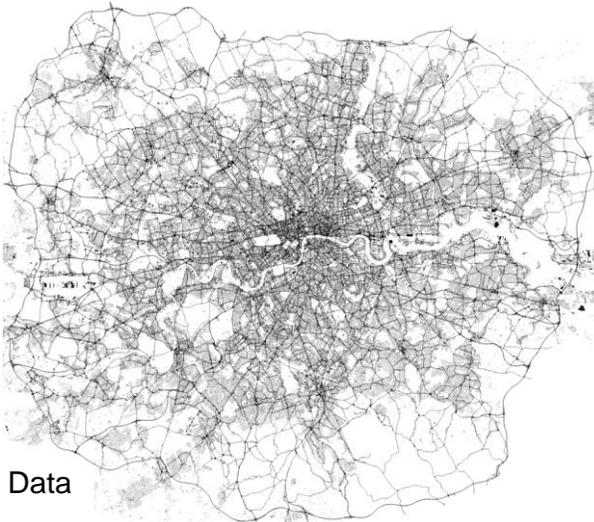
The image displays the RapidAir dispersion modelling system interface, which is a Windows application. The main window features a large satellite map of a region with a network of roads highlighted in red and blue. The text "RapidAIR" is overlaid on the map. The interface includes a menu bar with options: About, Global settings, RapidMet, RapidRoad, Canyon, Utilities, and Maps.

Several configuration windows are open, showing various settings and maps:

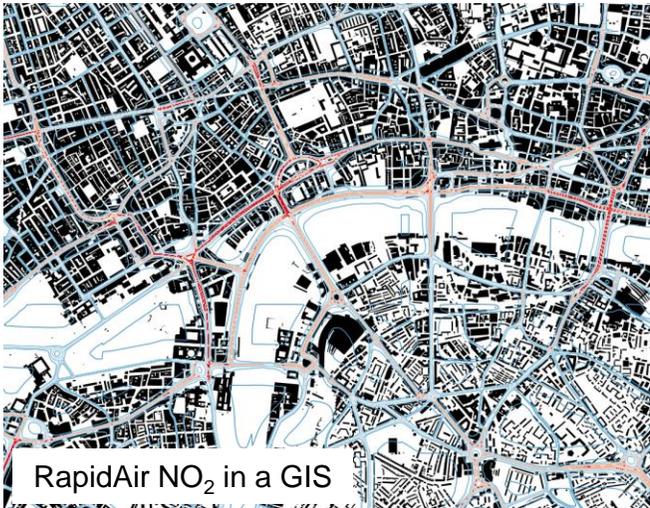
- Gather and process meteorological data:** This window allows users to define surface and upper air meteorology inputs. It includes fields for "Select year of meteorology downloads" (set to 2012), "Surface station 1 code", "Surface station 2 code", and "Surface station 3 code". It also has a "Run AERMET" section with "AERMET start date" and "AERMET end date" (both set to 01/01/2000). There are checkboxes for "Post processing options" such as "n-cloud filling (select)", "Cloud filling (select)", and "Maximum cloud gap size".
- Download UK background map:** This window allows users to download a background map for the year 2015. It includes options to "Select pollutant for background download" (set to NOx), "Clip to RapidROAD grid extent (R), or retain map dimensions (M)", and "Resample background map to same resolution as RapidROAD?". There are sections for "Exclude sources (all pollutants)" and "Exclude sources (PM only)".
- Convert NOx to NO2 (polynomial):** This window allows users to convert NOx to NO2 using a polynomial equation. It includes fields for "Path to NOx raster", "Coefficient (a)", "Coefficient (b)", and "Intercept (c)", and a "Convert NOx to NO2" button.
- Raster math (two rasters):** This window allows users to perform raster math on two rasters. It includes fields for "Path to raster 1", "Path to raster 2", and "Provide path to result file". There is a "Math operation" dropdown menu and a "Perform raster computation" button.
- Extract values at receptors:** This window allows users to extract values at receptors. It includes fields for "Path to receptor points file", "Path to concentrations to be sampled", and "Select pollutant" (set to NOx). There is an "Extract receptor values" button.
- Map of UK surface met stations:** This window shows a map of the UK with numerous blue pins representing surface meteorology stations. A tooltip for a station in Doncaster Sheffield is visible, showing "USAF_code: 034054", "Station_Na: DONCASTER SHEFFIELD", "Elev: 16.8", "Begin: 20050507", and "End: 20170513".
- Map of UK upper air met stations:** This window shows a map of the UK with several red pins representing upper air meteorology stations.

The bottom right corner of the interface features the Ricardo Energy & Environment logo.

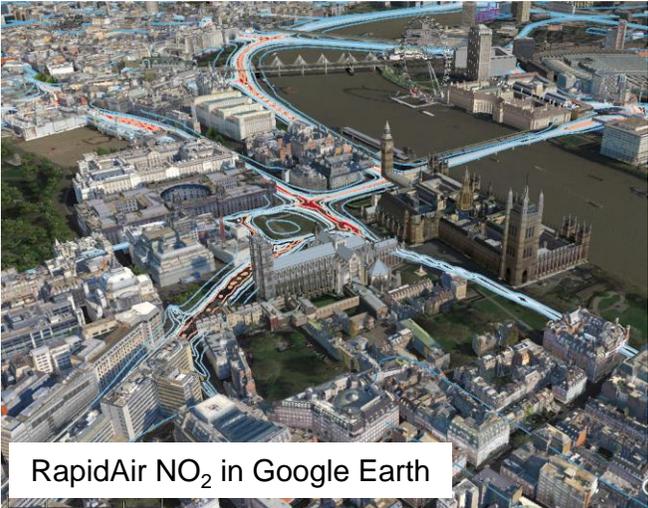
Mostly it's a dispersion model we're using in large urban areas- this is London



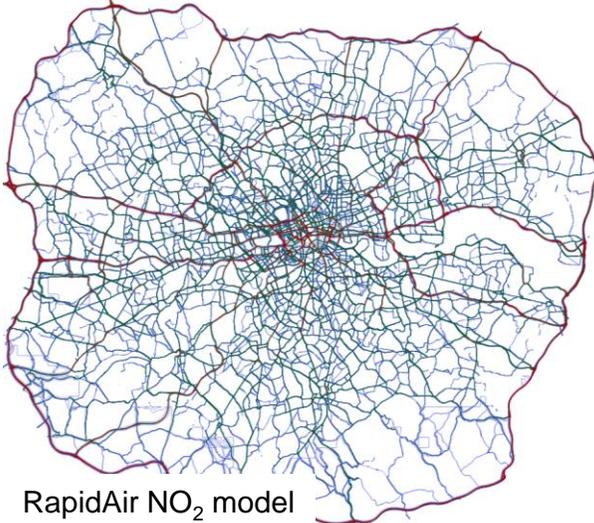
Data



RapidAir NO₂ in a GIS



RapidAir NO₂ in Google Earth



RapidAir NO₂ model



RapidAir NO₂ in a GIS



RapidAir NO₂ in Google Earth

Conferences and papers....



Presented at the 16th Annual CMAS Conference, Chapel Hill, NC, October 23-25, 2017

Development and validation of a rapid urban scale dispersion modelling platform

16th ANNUAL
CMAS
Conference
Oct. 23-25 | Chapel Hill

Scott L. Hamilton*
Ricardo Energy and Environment, UK

Nicola Masey, Iain Beverland
University of Strathclyde, UK

Invited to collaborate with the USEPA in their
UK/US expert dispersion modelling group

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Article

pubs.acs.org/est

ENVIRONMENTAL
Science & Technology

Development, Evaluation, and Comparison of Land Use Regression Modeling Methods to Estimate Residential Exposure to Nitrogen Dioxide in a Cohort Study

Jonathan Gillespie,[†] Iain J. Beverland,^{*†} Scott Hamilton,[‡] and Sandosh Padmanabhan[§]

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Development and evaluation of the RapidAir dispersion model, including the use of geospatial surrogates to represent street canyon effects



Submitted....

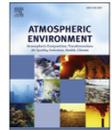


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Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv



Short communication

Influence of wind-speed on short-duration NO₂ measurements using Palmes and Ogawa passive diffusion samplers



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^b School of Chemistry, Joseph Black Building, University of Edinburgh, David Brewster Road, Edinburgh, EH9 3FJ, UK

^c Ricardo Energy and Environment, 18 Blythswood Square, Glasgow, G2 4BG, UK

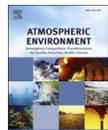


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Short communication

Estimation of spatial patterns of urban air pollution over a 4-week period from repeated 5-min measurements



Jonathan Gillespie^a, Nicola Masey^a, Mathew R. Heal^b, Scott Hamilton^c, Iain J. Beverland^{a,*}

^a Department of Civil and Environmental Engineering, University of Strathclyde, 505F James Weir Building, 75 Montrose Street, Glasgow, G1 1XJ, UK

^b School of Chemistry, University of Edinburgh, David Brewster Road, Edinburgh, EH9 3FJ, UK

^c Ricardo Energy and Environment, Blythswood Square, Glasgow, G2 4BG, UK

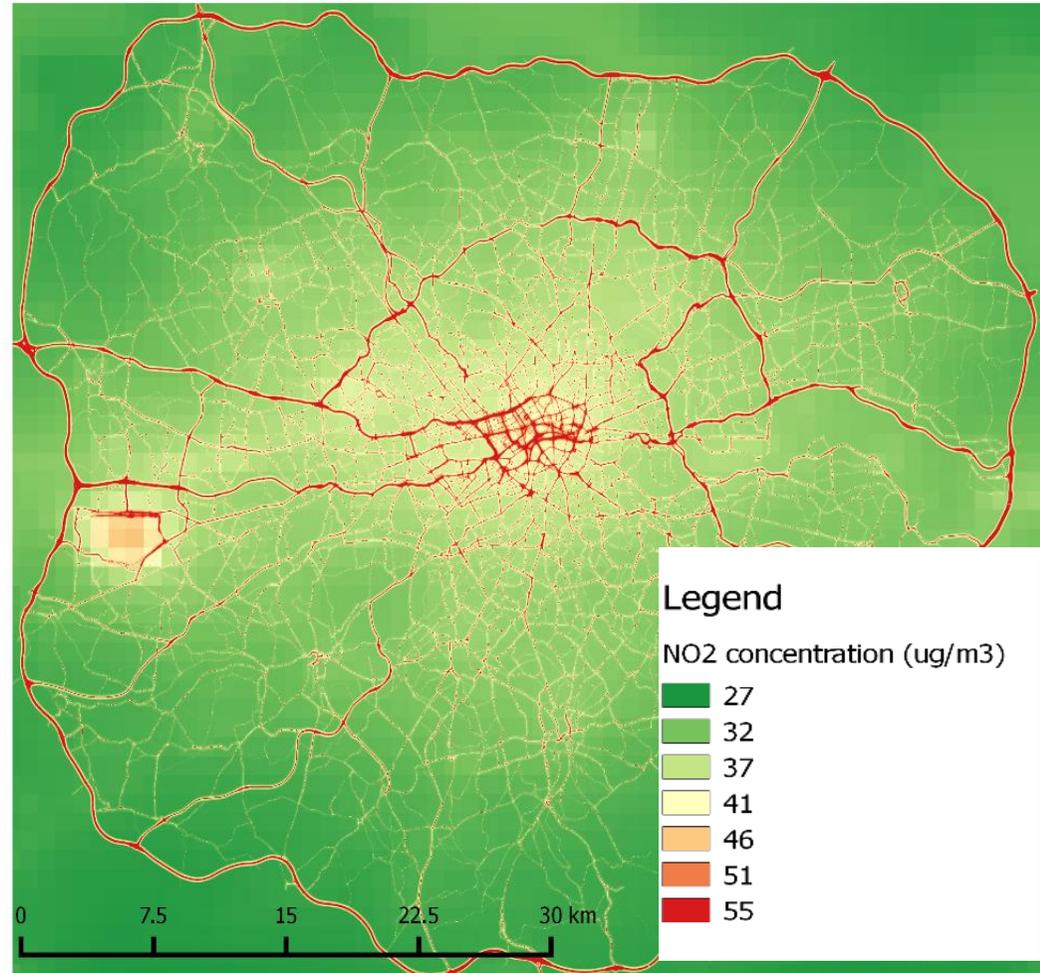
London study (in review)

We modelled concentrations of NO_x and NO₂ 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 NO_x and NO₂ 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 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

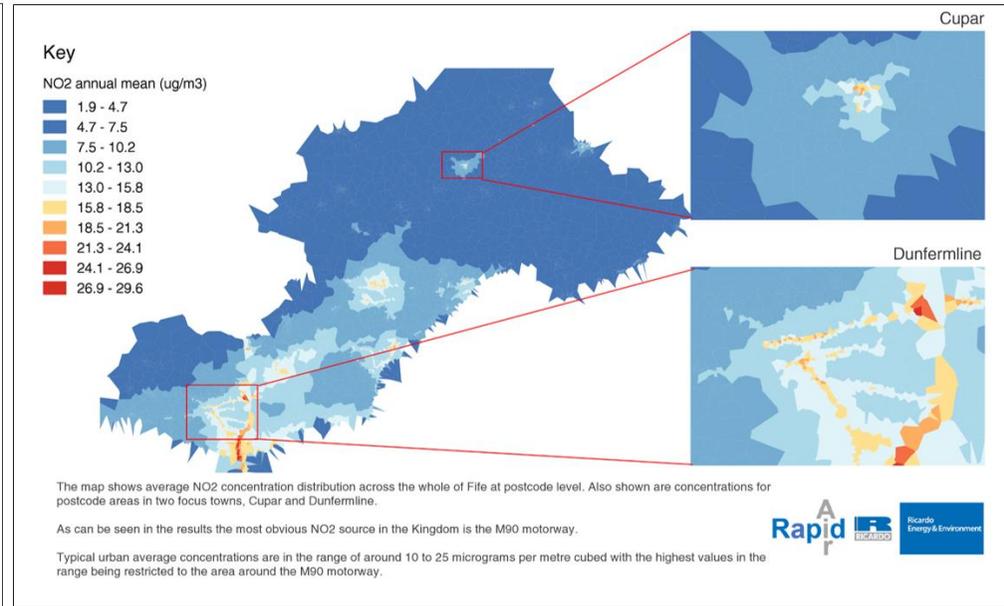
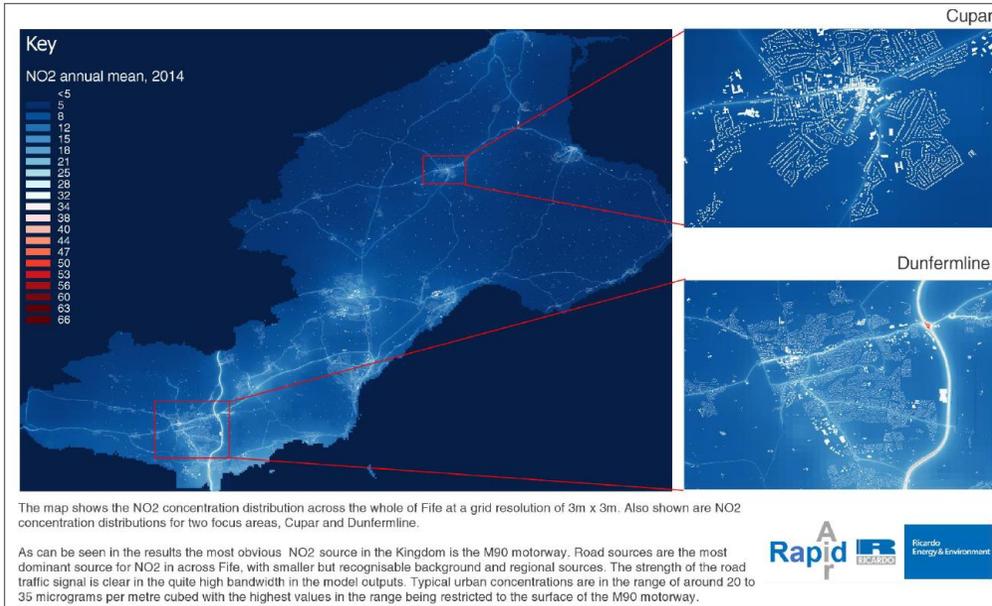
The performance statistics for the surrogates for urban morphology are reasonably close to those from the models which treat canyons discretely.

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

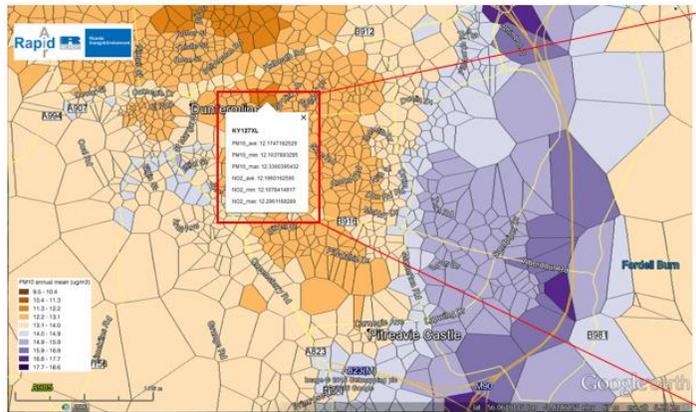
The model results should be compared with measured concentrations and the modeler may choose the best performing street canyon model for their case.

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



PM₁₀ average by postcode



Concentrations for a single postcode

KY127XL	
PM10_ave:	12.1747182529
PM10_min:	12.1037893295
PM10_max:	12.3360395432
NO2_ave:	12.1960162595
NO2_min:	12.1078414917
NO2_max:	12.2961168289

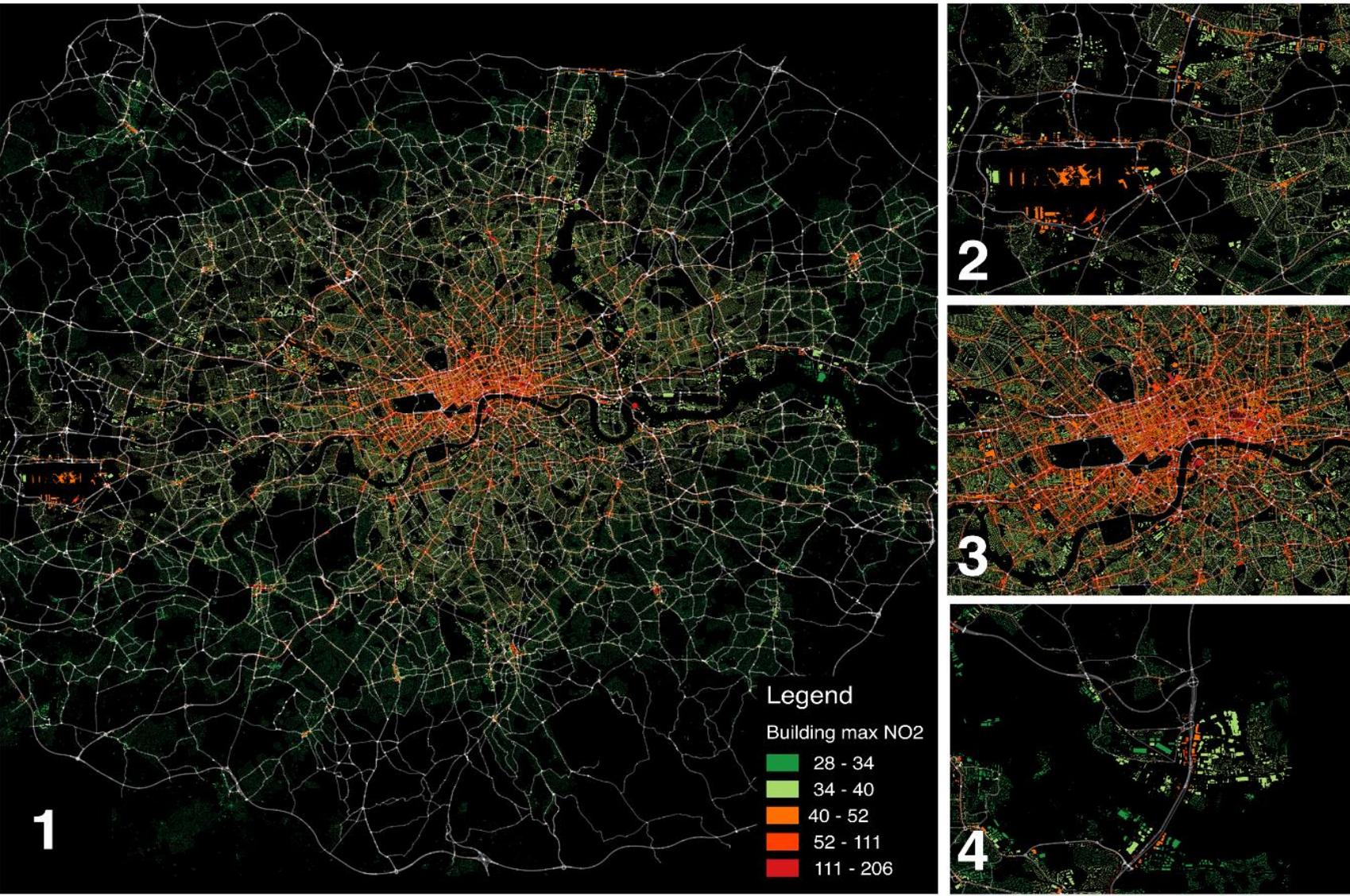
Every postcode in Fife has annual mean modelled concentrations of NO₂ and PM₁₀. Maximum, minimum and mean values within each postcode area are provided.

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

What if Scotland was a CAZ?



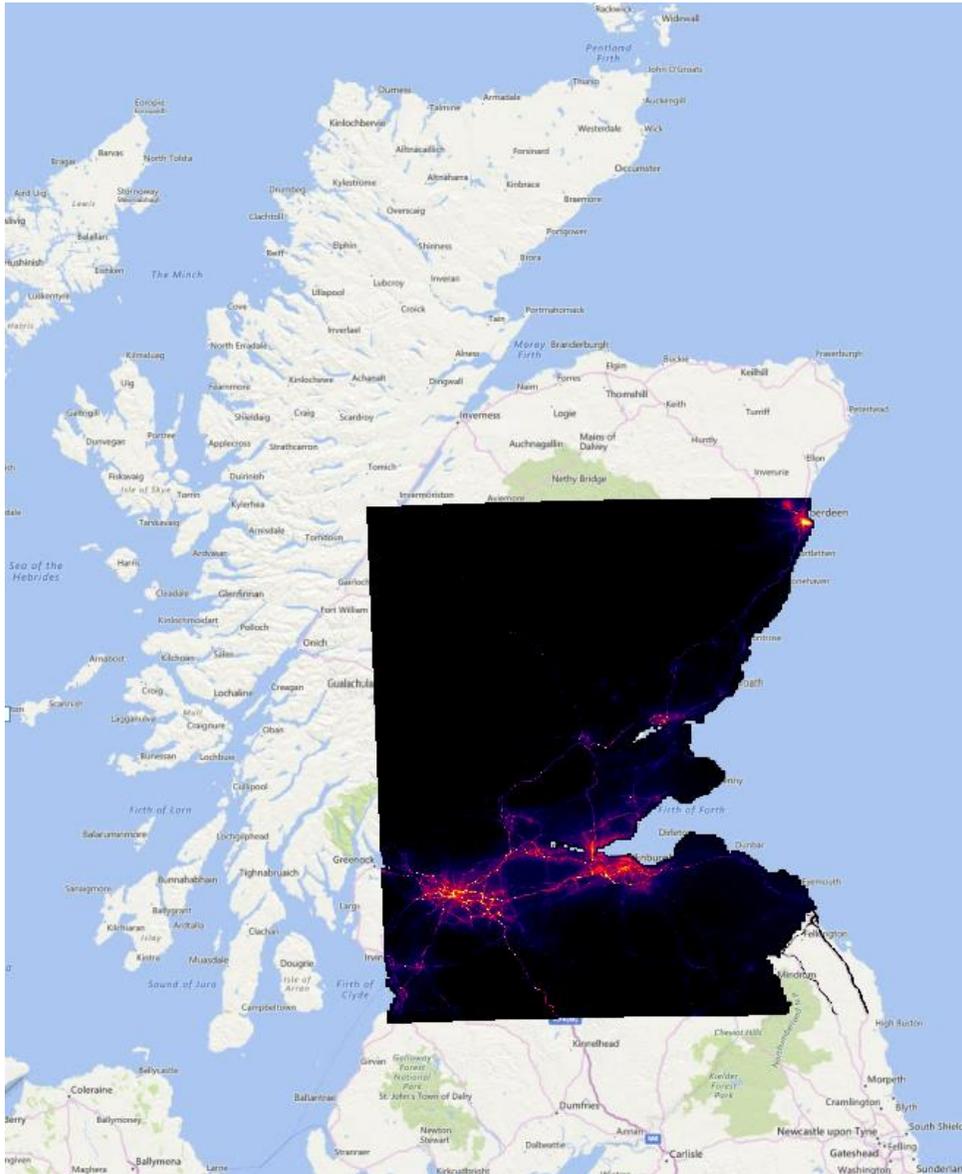
- New air quality modelling techniques allow us to very quickly look at very large areas of the country in a single model run. For the purposes of today I modelled a high level “what if” scenario for most of Scotland which is designed to stimulate discussion around what engine technology improvement can deliver in the next decade or so
- The case I’m going to show you is not concerned with detailed CAZ schemes or boundaries, but simply asks the question, what’s the best we can expect from currently available, or soon to be available technologies?
- Baseline is the 2016 fleet mix from the DfT, including fuel use split, technology mix, vehicle weight categories, Scotland specific information where applicable.
- Test case 1 involves setting all light and heavy vehicles to engine technologies which are either best currently available, or best that will soon be available (e.g. Euro 6 D)
- Test case 2 asks what we could expect from a radical reduction in diesel vehicles in the light fleet (to zero!)

Some important clarifications...



- The modelling in this talk took **less than two days** and was done especially for this talk.
- It is **based on openly available data** so a lot of effort was avoided
- This is mainly **to show what can be done with modern dispersion modelling methods** to get fast answers to wide ranging policy measures
- A key benefit is **complete consistency** between towns and cities as they are in the same model run (its also really fast)

What if Scotland had a single very large CAZ?



Model domain

- 400 million discrete points
- 10m resolution
- Stretches from South Ayrshire in the south west to Aberdeen in the north East
- Modelled in our **RapidAIR** suite specially for this event-run time ~150 sec
- Emissions modelled in our **RapidEMS** module (140,000 links in the UK wide model, run time a few seconds)

Emission modelling- NOx

All emissions were modelled in our RapidEMS system, which uses the COPERT V coefficients in a computationally efficient manner. We can calculate emissions on 1 million road links in 1 minute.

There are 140,000 road links in the model (though most of these are in the rest of the UK)

Base case	Column1	BAT plus no diesel	Column1
<i>total_NOx_gkms</i>		<i>total_NOx_gkms</i>	
Mean	0.067	Mean	0.015
Standard Error	0.000	Standard Error	0.000
Median	0.047	Median	0.012
Mode	0.015	Mode	0.003
Standard Deviation	0.071	Standard Deviation	0.015
Sample Variance	0.005	Sample Variance	0.000
Kurtosis	15.687	Kurtosis	14.069
Skewness	3.296	Skewness	3.052
Range	0.903	Range	0.166
Minimum	0.000	Minimum	0.000
Maximum	0.904	Maximum	0.166
Sum	9383.301	Sum	2128.661
Count	140929.000	Count	140929.000

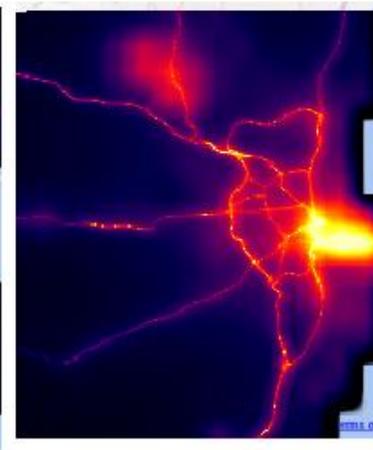
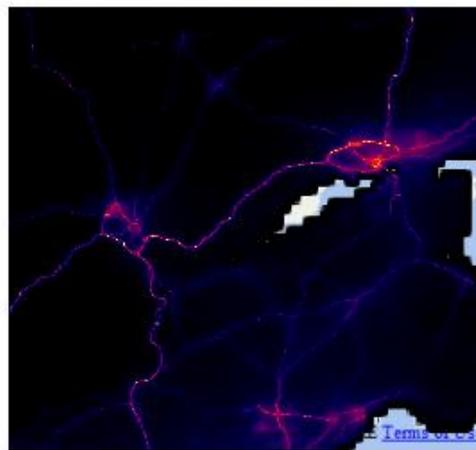
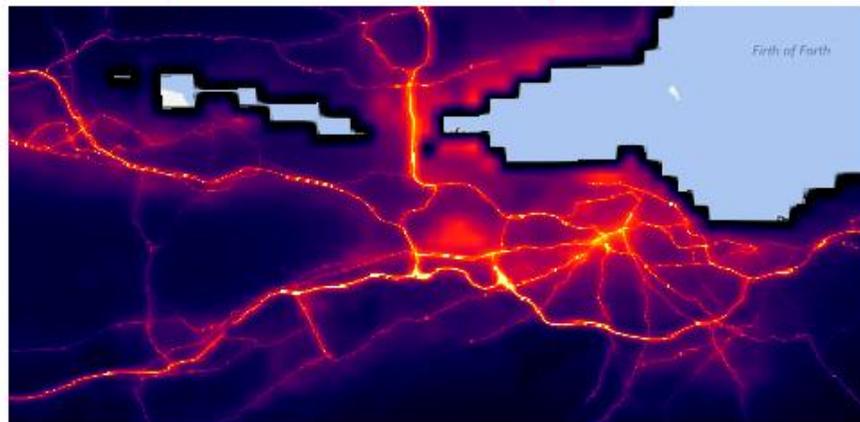
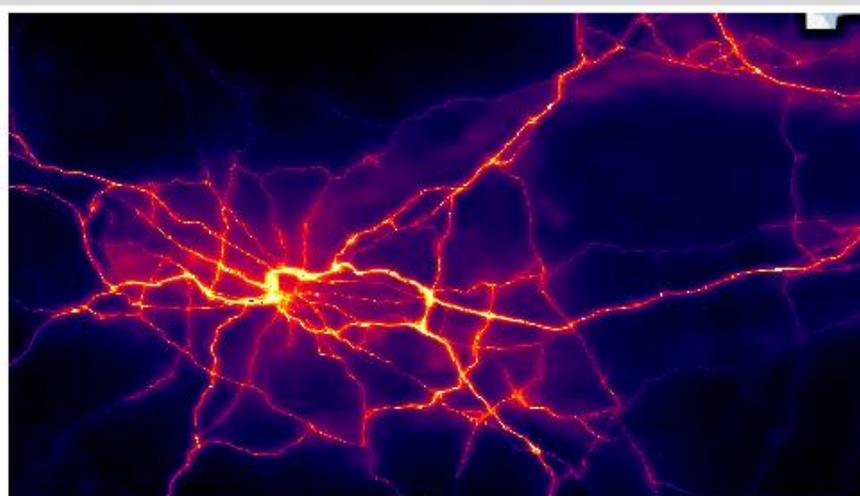
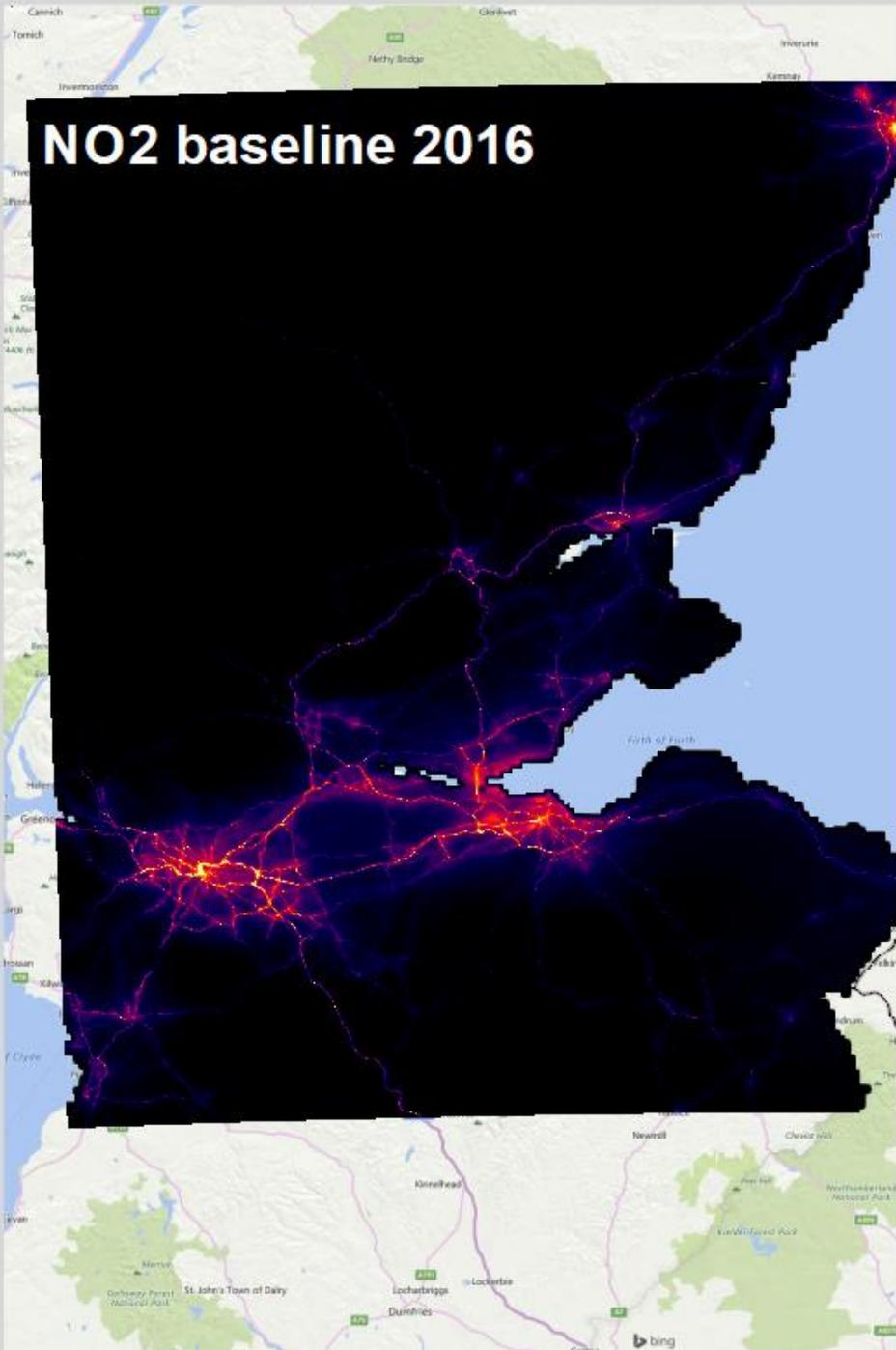
Emission modelling- PM10

All emissions were modelled in our RapidEMS system, which uses the COPERT V coefficients in a computationally efficient manner. We can calculate emissions on 1 million road links in 1 minute.

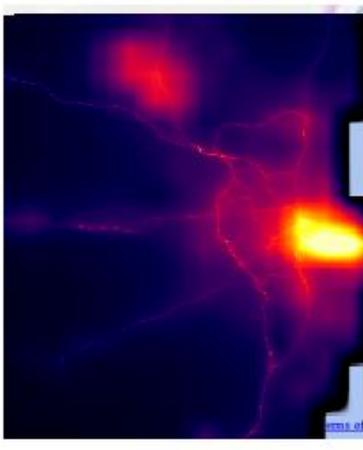
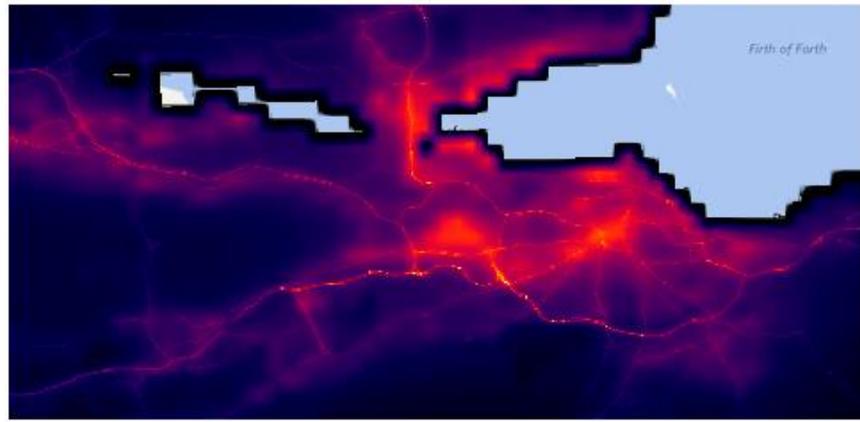
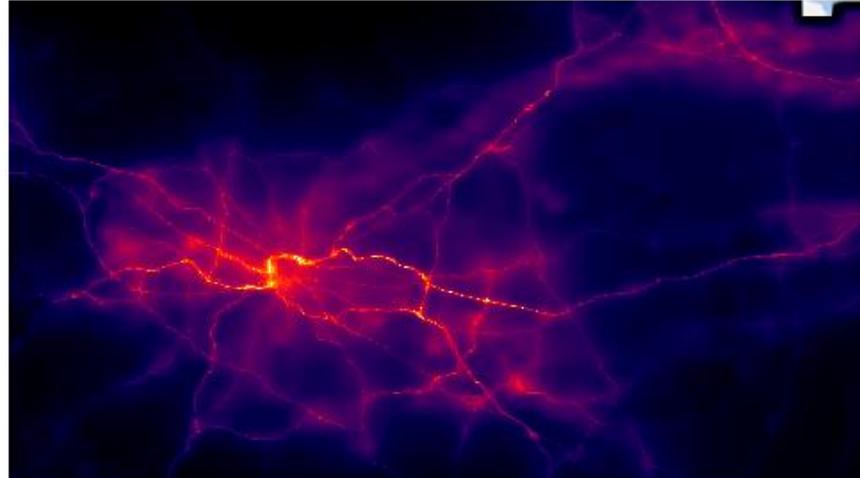
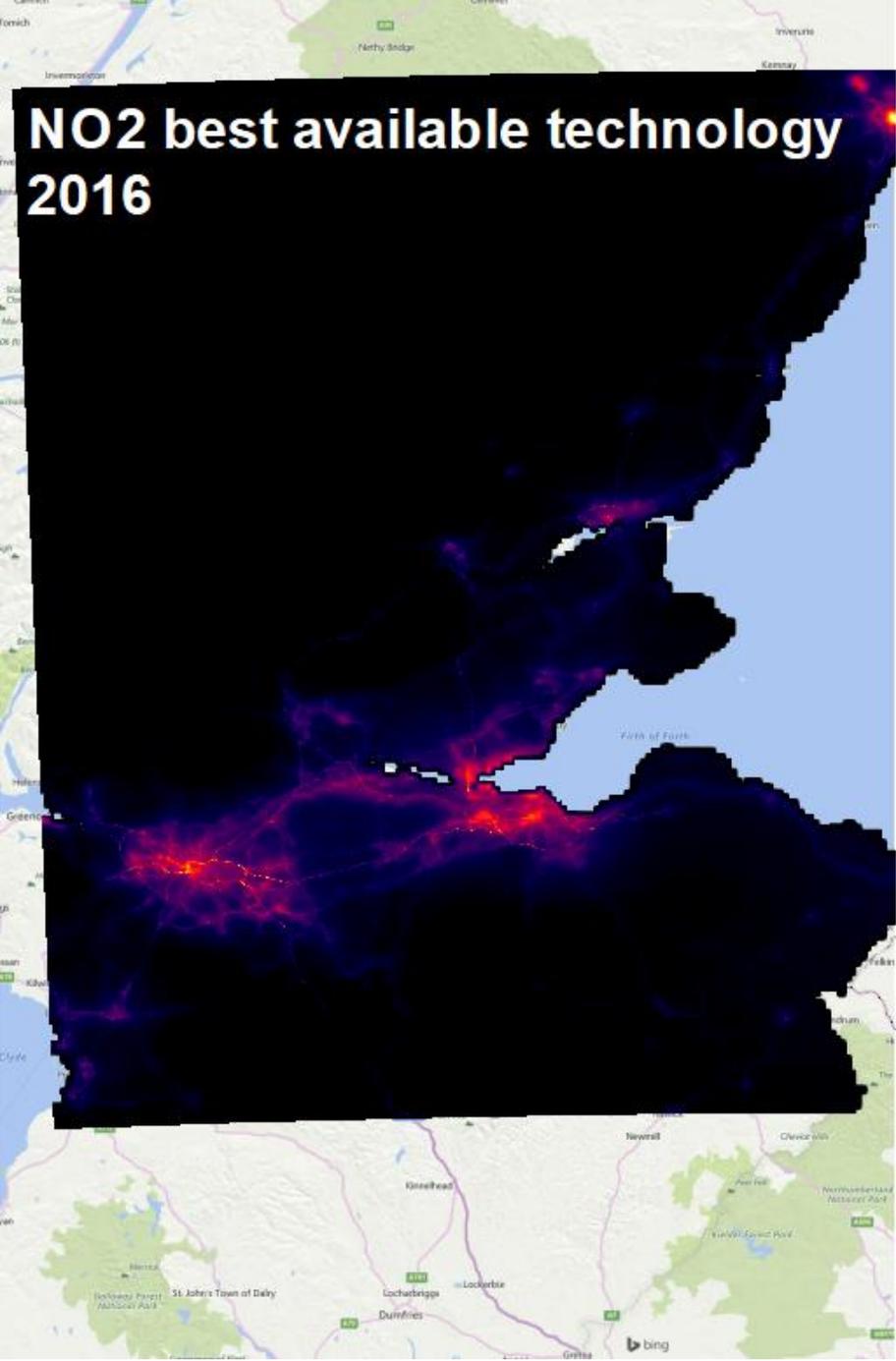
There are 140,000 road links in the model (though most of these are in the rest of the UK)

Base case	Column1	BAT plus no diesel	Column1
<i>total_PM10_gkms</i>		<i>total_PM10_gkms</i>	
Mean	0.007	Mean	0.007
Standard Error	0.000	Standard Error	0.000
Median	0.006	Median	0.005
Mode	0.002	Mode	0.002
Standard Deviation	0.007	Standard Deviation	0.006
Sample Variance	0.000	Sample Variance	0.000
Kurtosis	14.687	Kurtosis	14.250
Skewness	3.206	Skewness	3.138
Range	0.074	Range	0.065
Minimum	0.000	Minimum	0.000
Maximum	0.074	Maximum	0.065
Sum	1056.233	Sum	949.775
Count	140929.000	Count	140929.000

NO2 baseline 2016

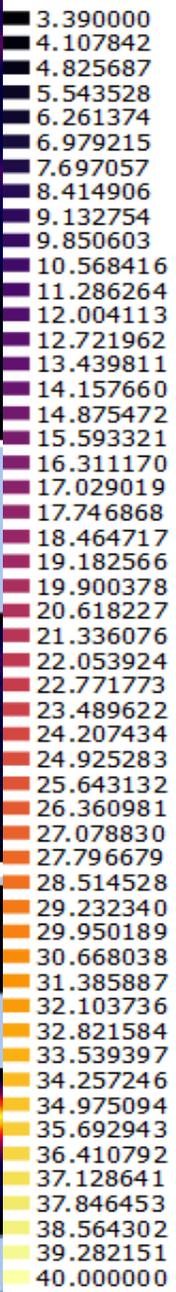
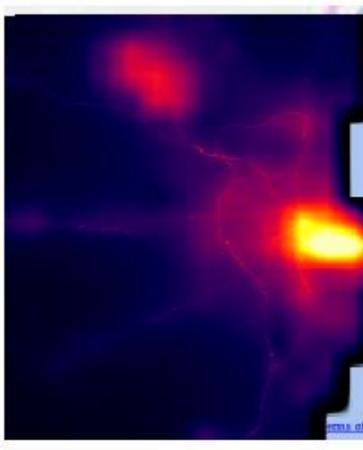
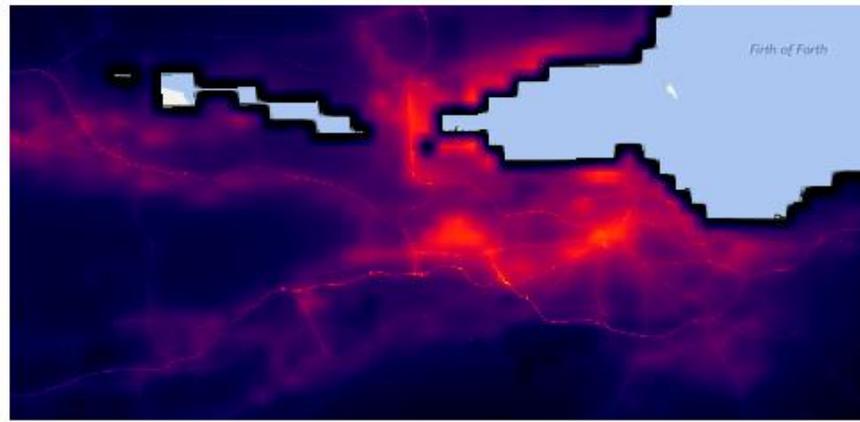
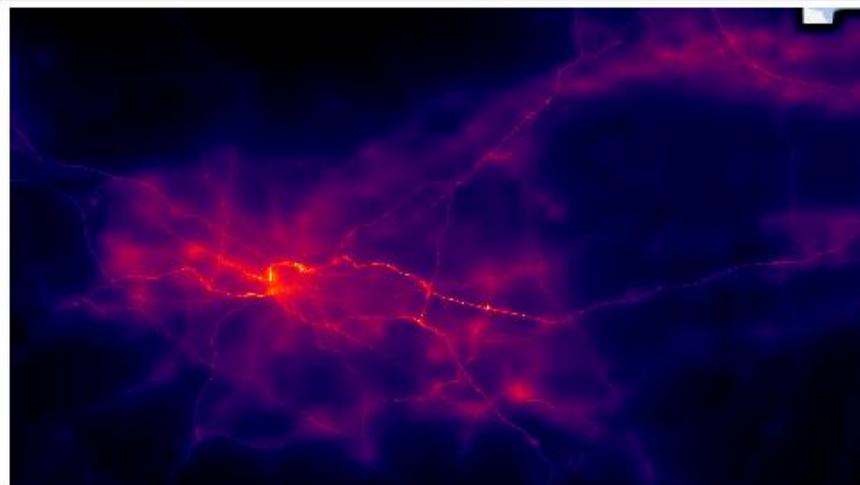
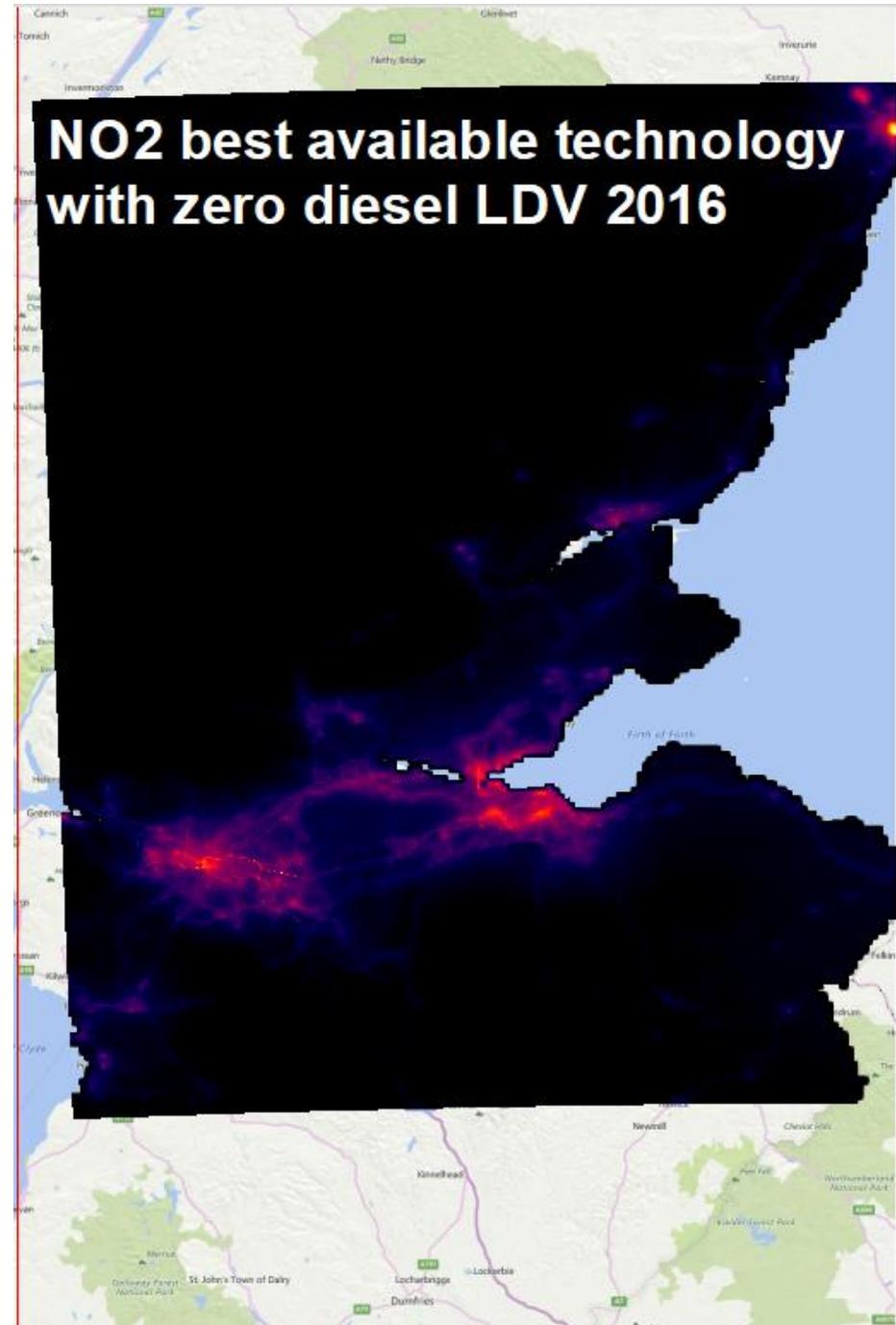


NO2 best available technology 2016

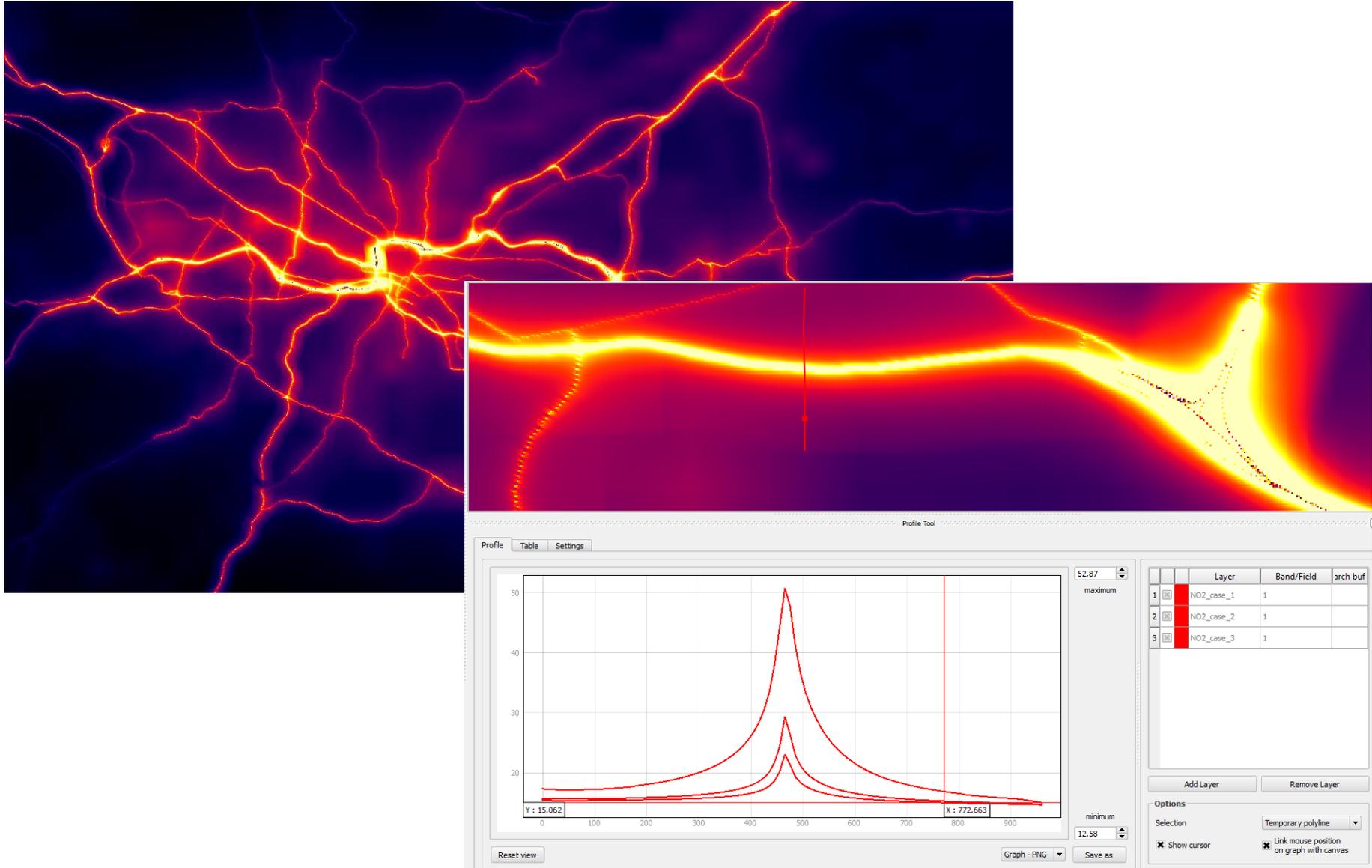


- 3.390000
- 4.107842
- 4.825687
- 5.543528
- 6.261374
- 6.979215
- 7.697057
- 8.414906
- 9.132754
- 9.850603
- 10.568416
- 11.286264
- 12.004113
- 12.721962
- 13.439811
- 14.157660
- 14.875472
- 15.593321
- 16.311170
- 17.029019
- 17.746868
- 18.464717
- 19.182566
- 19.900378
- 20.618227
- 21.336076
- 22.053924
- 22.771773
- 23.489622
- 24.207434
- 24.925283
- 25.643132
- 26.360981
- 27.078830
- 27.796679
- 28.514528
- 29.232340
- 29.950189
- 30.668038
- 31.385887
- 32.103736
- 32.821584
- 33.539397
- 34.257246
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- 37.128641
- 37.846453
- 38.564302
- 39.282151
- 40.000000

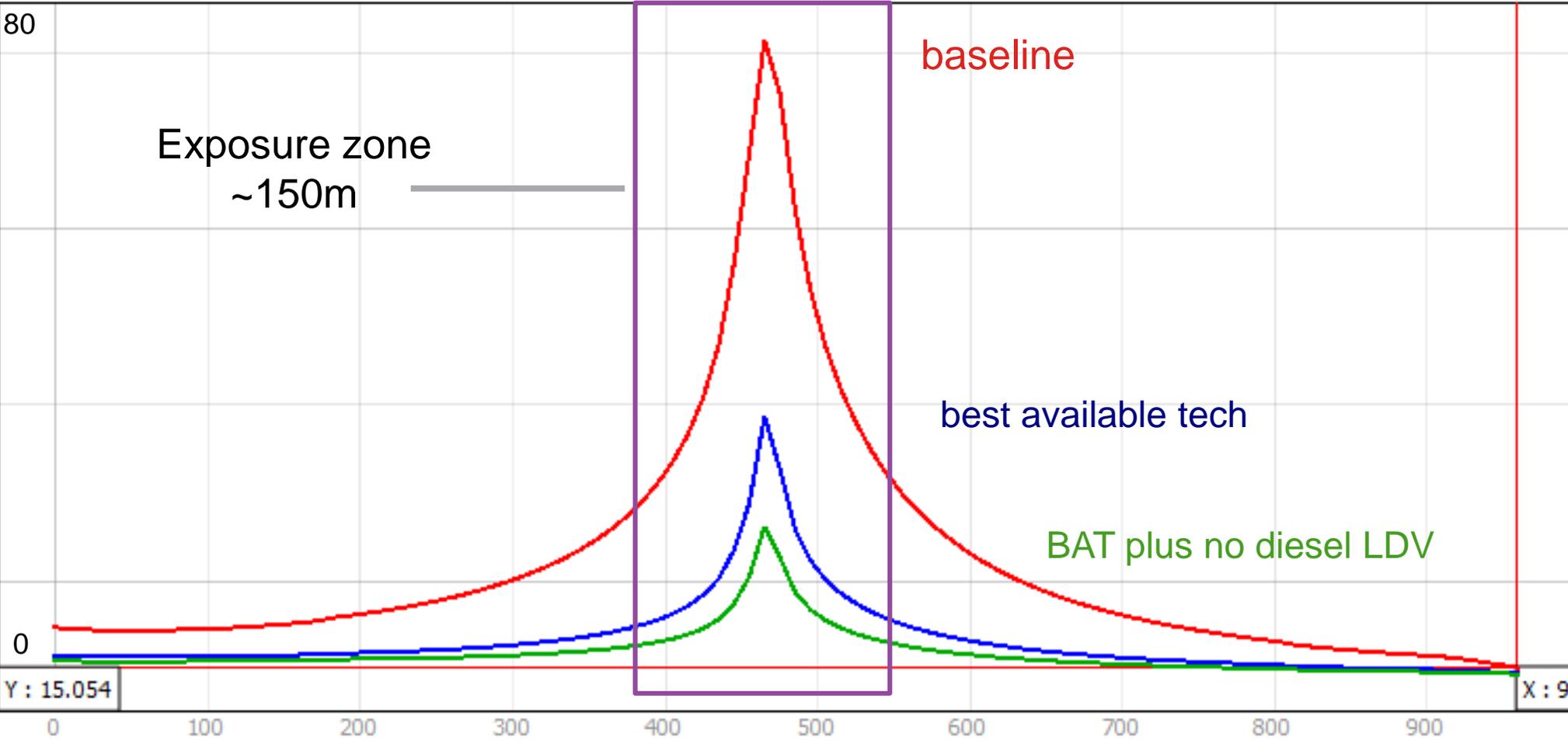
NO2 best available technology with zero diesel LDV 2016



Results at roadside- concentrations in a transect for a typical motorway



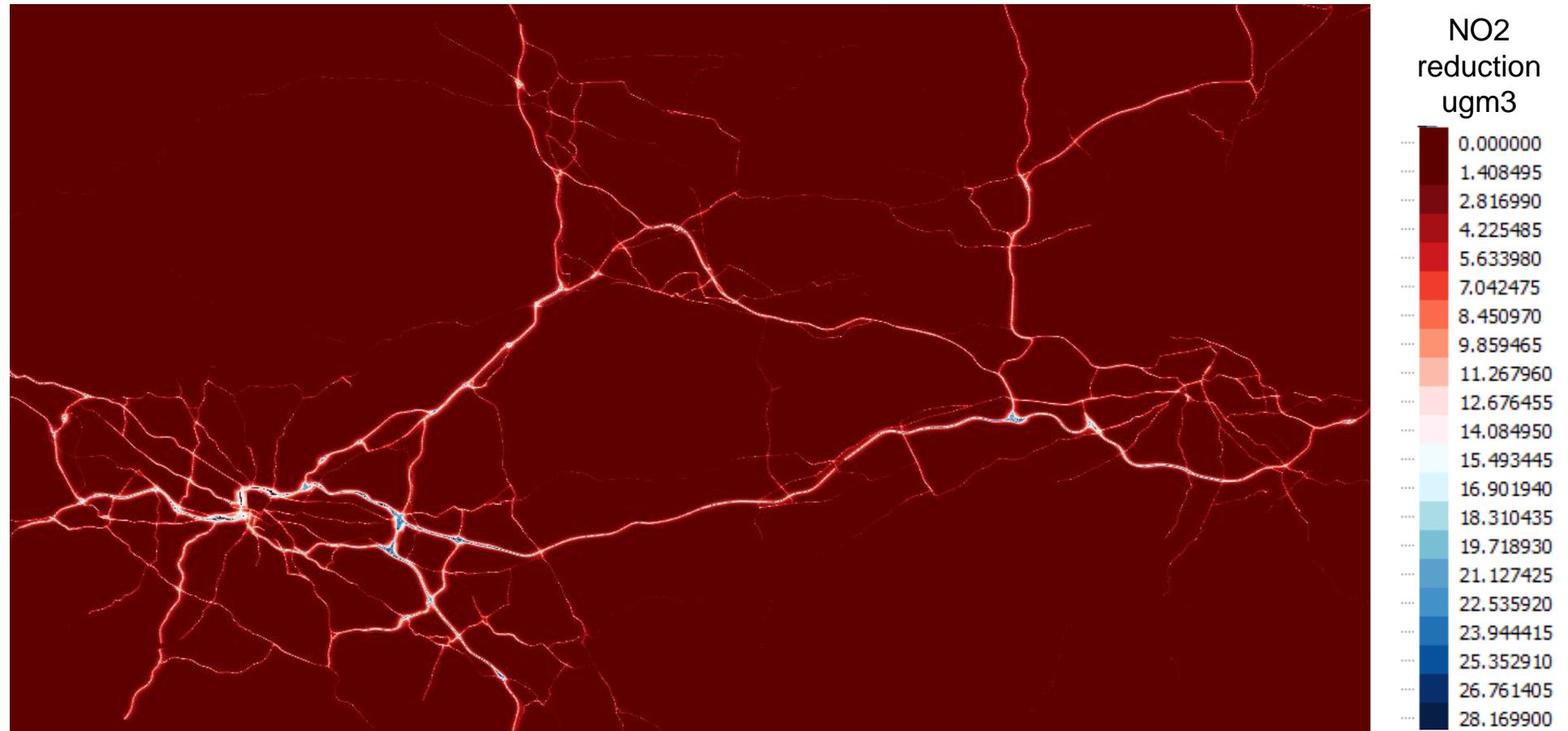
NO2 cross road profile of concentrations- M74 in Glasgow



Y : 15.054

X : 9

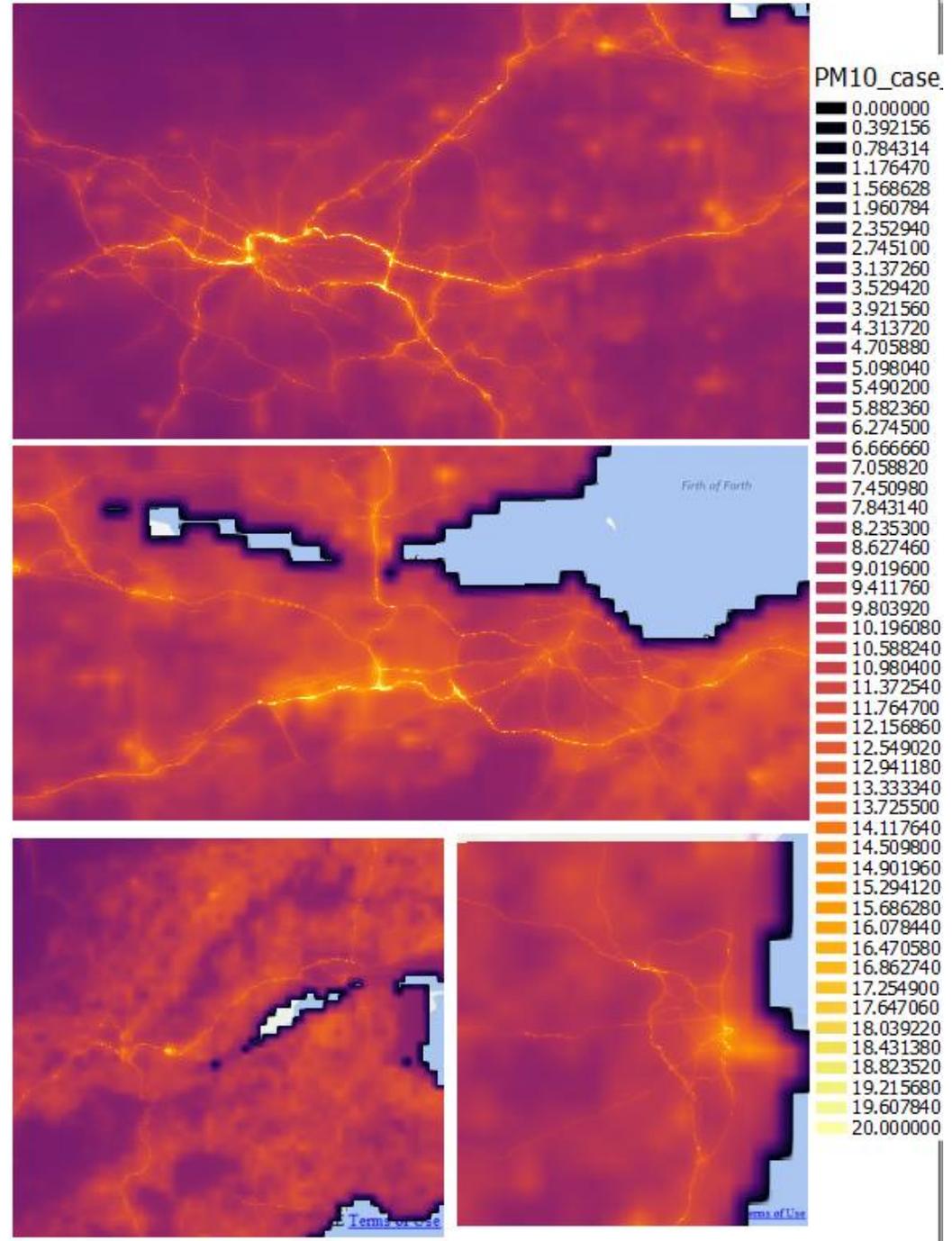
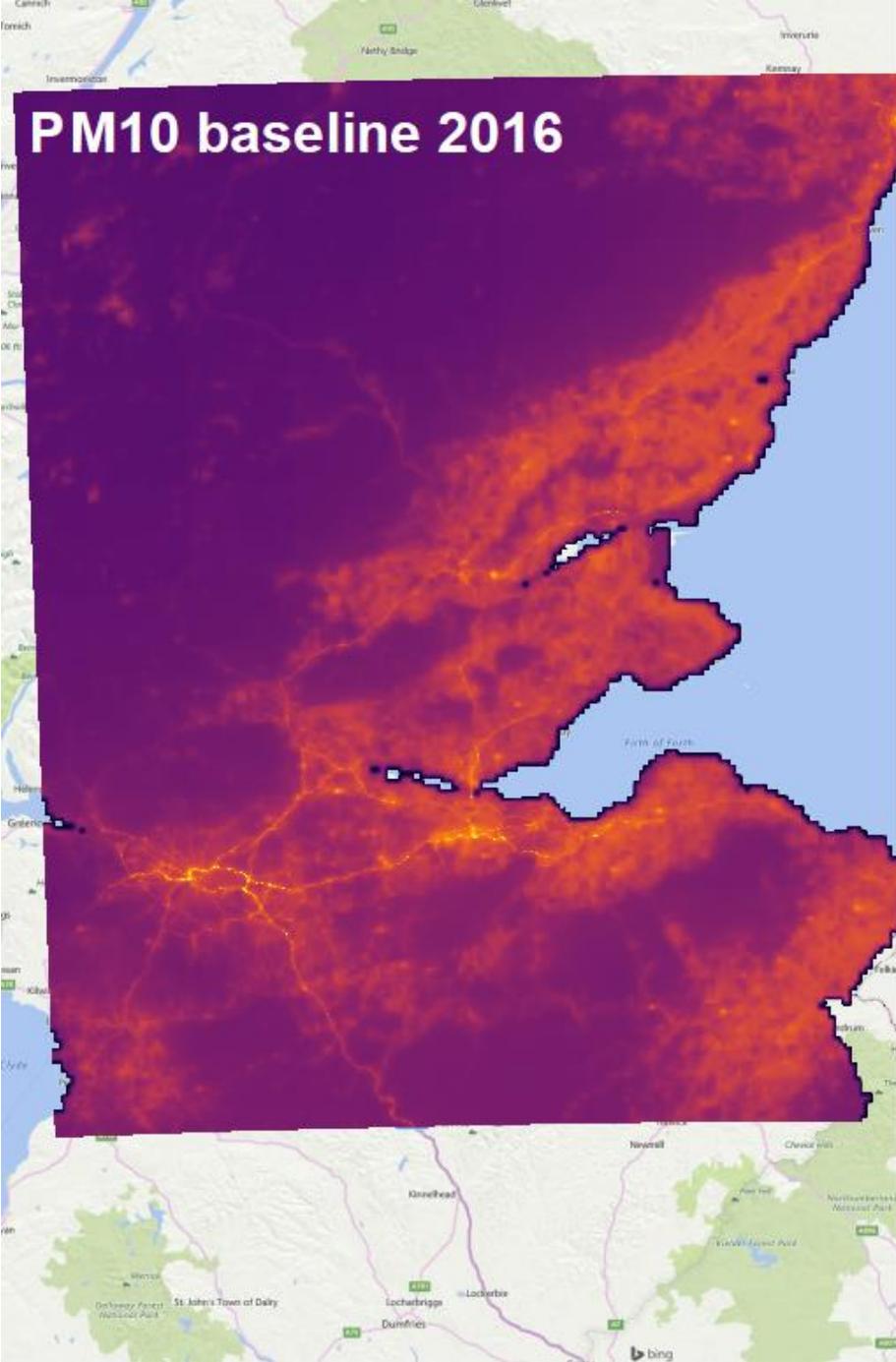
NO2 difference plot- central belt (base minus BAT)

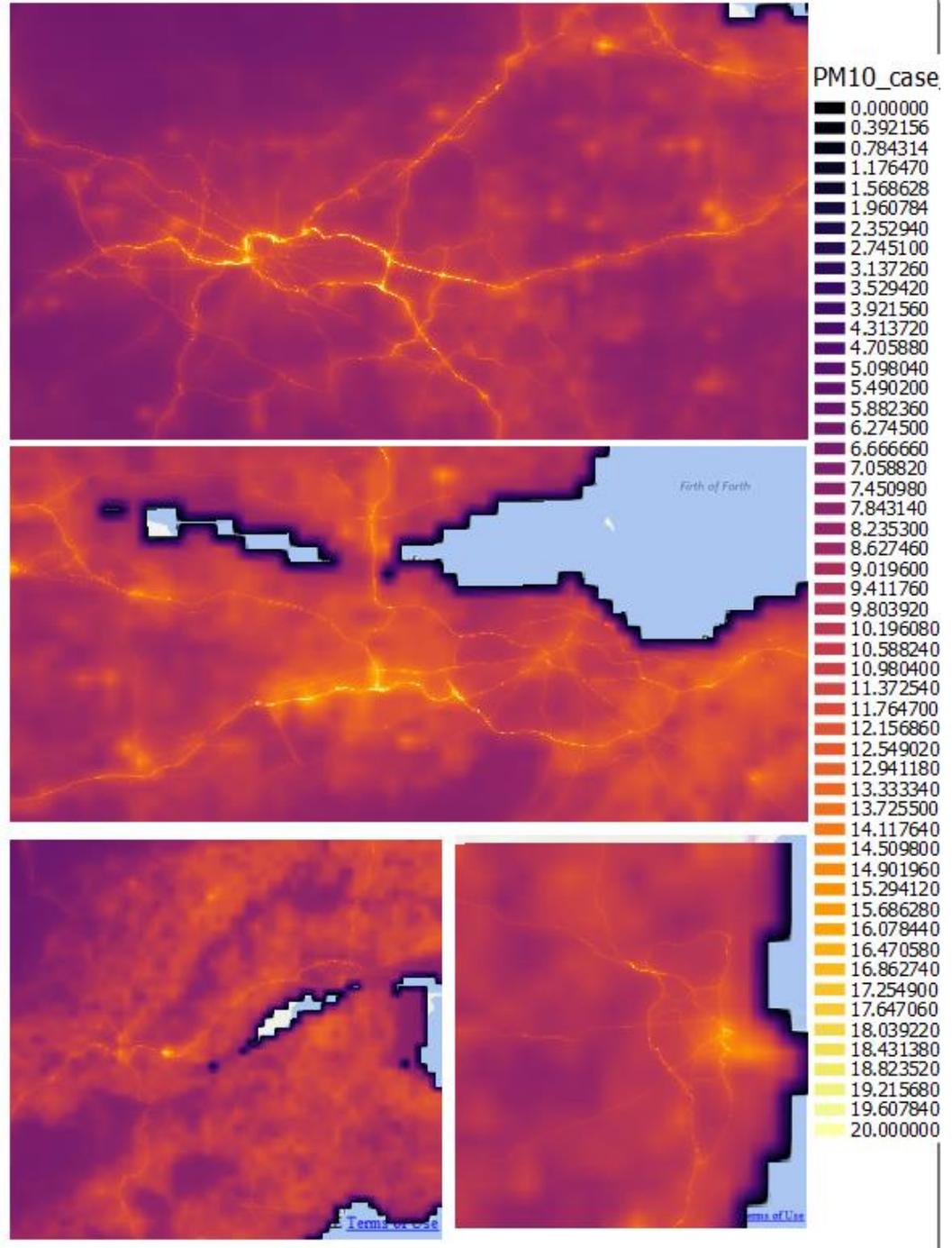
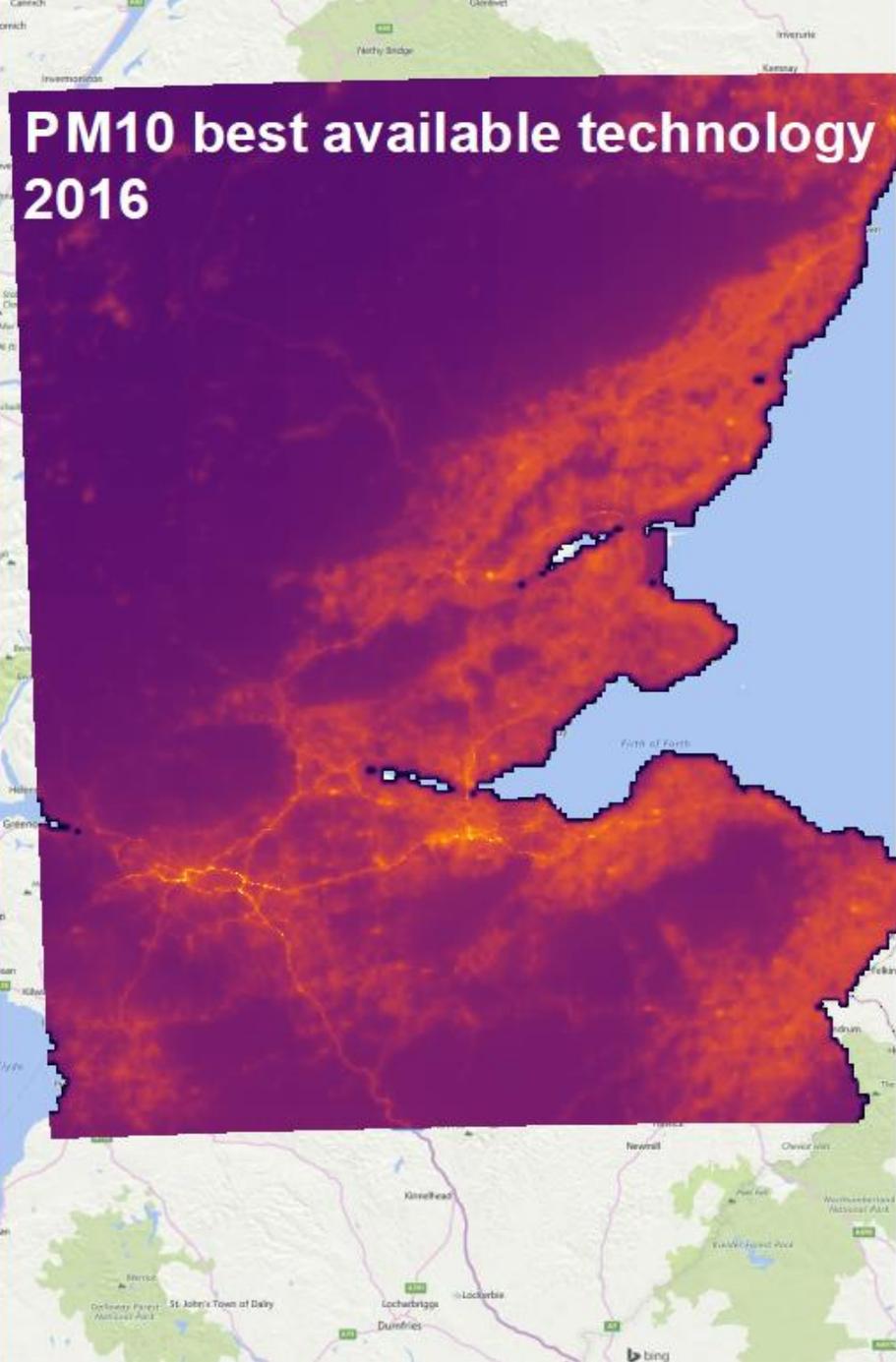


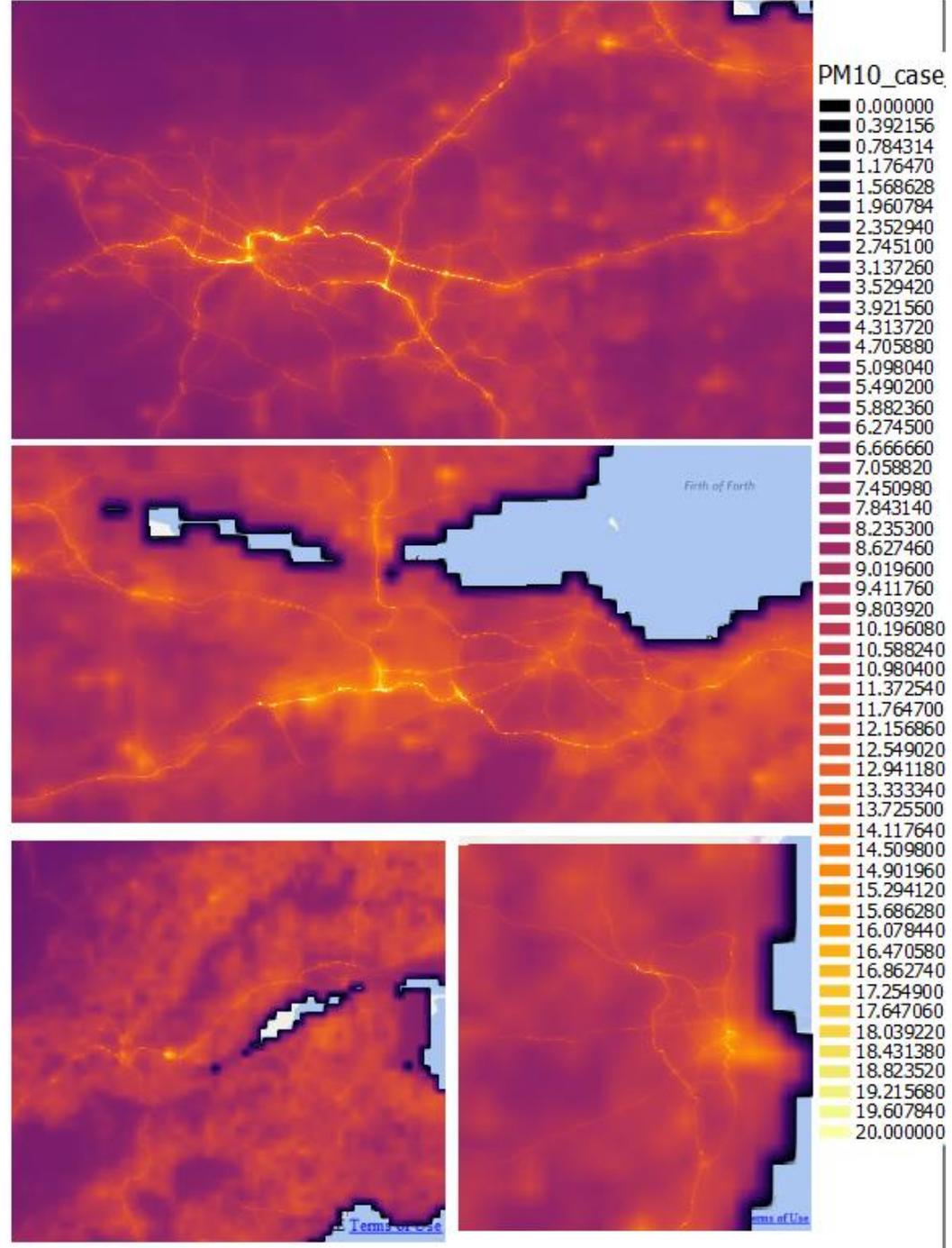
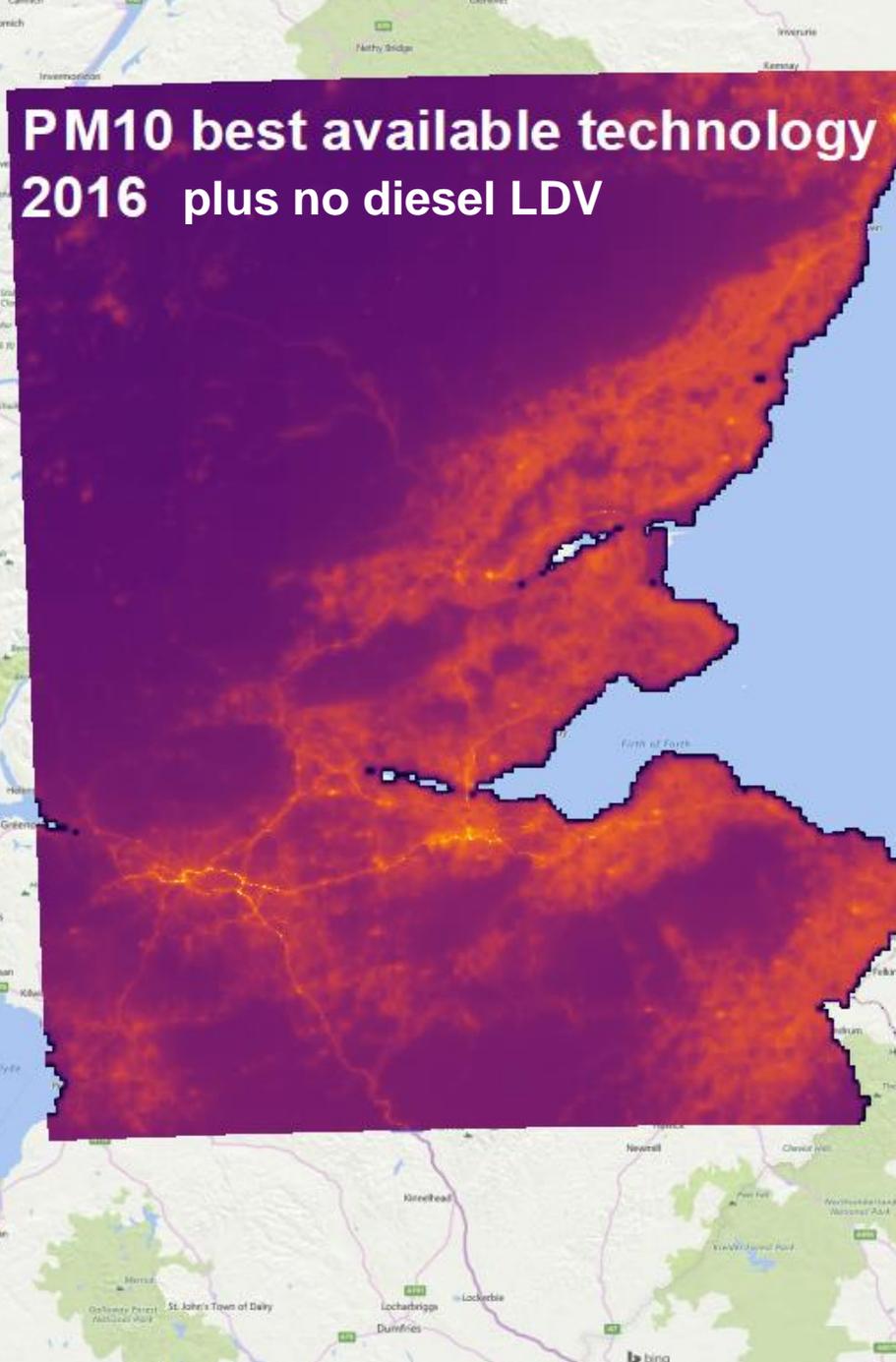
Very highest concentrations are attenuated by up to 28 ug/m³, more typically roadside concentrations reduced by about 5 to 10 ug/m³.

NO₂ results- explained

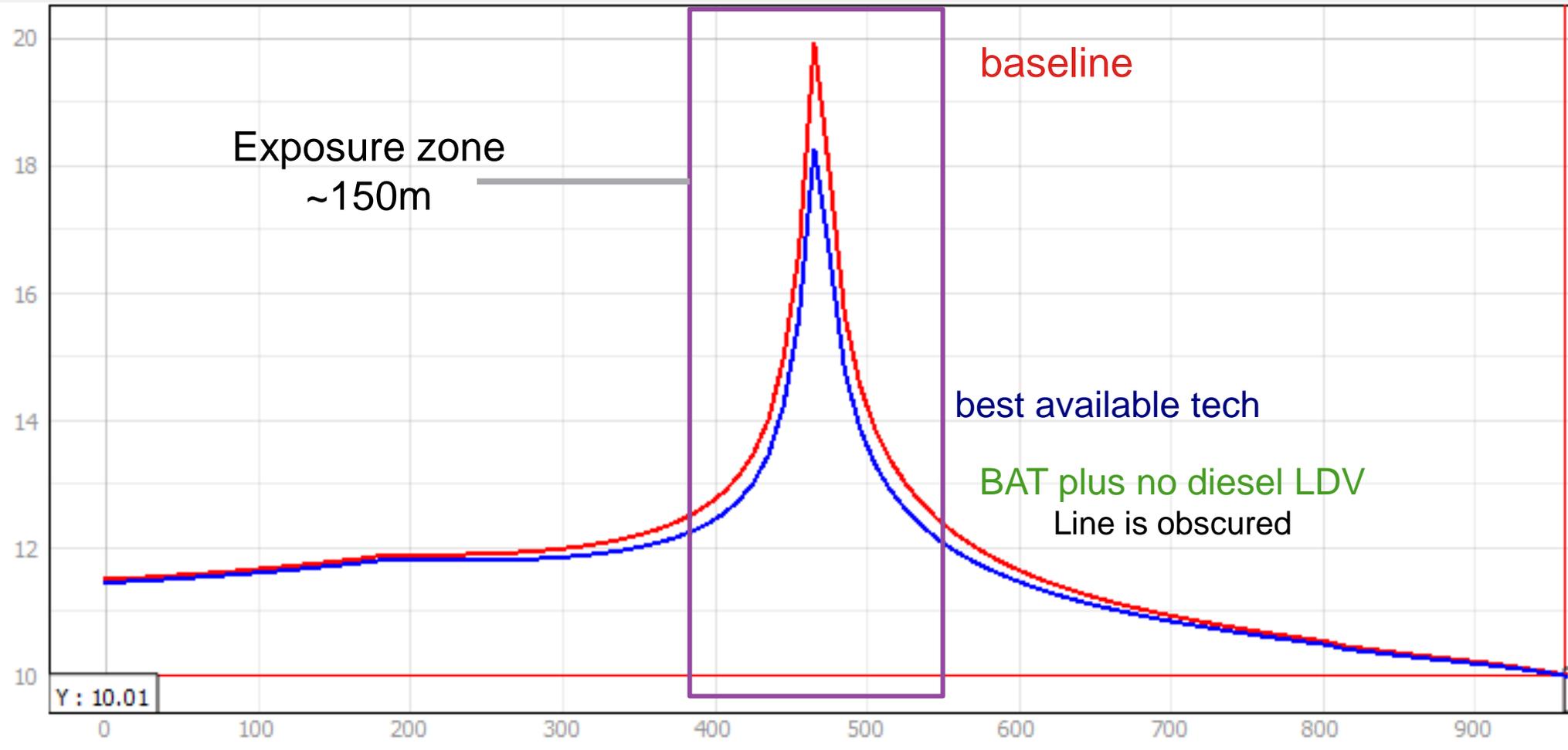
- New iterations of Euro 6 are expected to deliver very substantial reductions in NO_x and hence NO₂
- Traffic is usually the dominant source so reductions in emissions in this sector are very apparent in overall concentrations
- Hence if the new Euro standards deliver, significant reductions in NO₂ should follow
- Going beyond BAT towards removing diesel completely from the LDV fleet delivers more benefits, but these are quite marginal compared with “factored in” improvements that should follow Euro 6 improvements





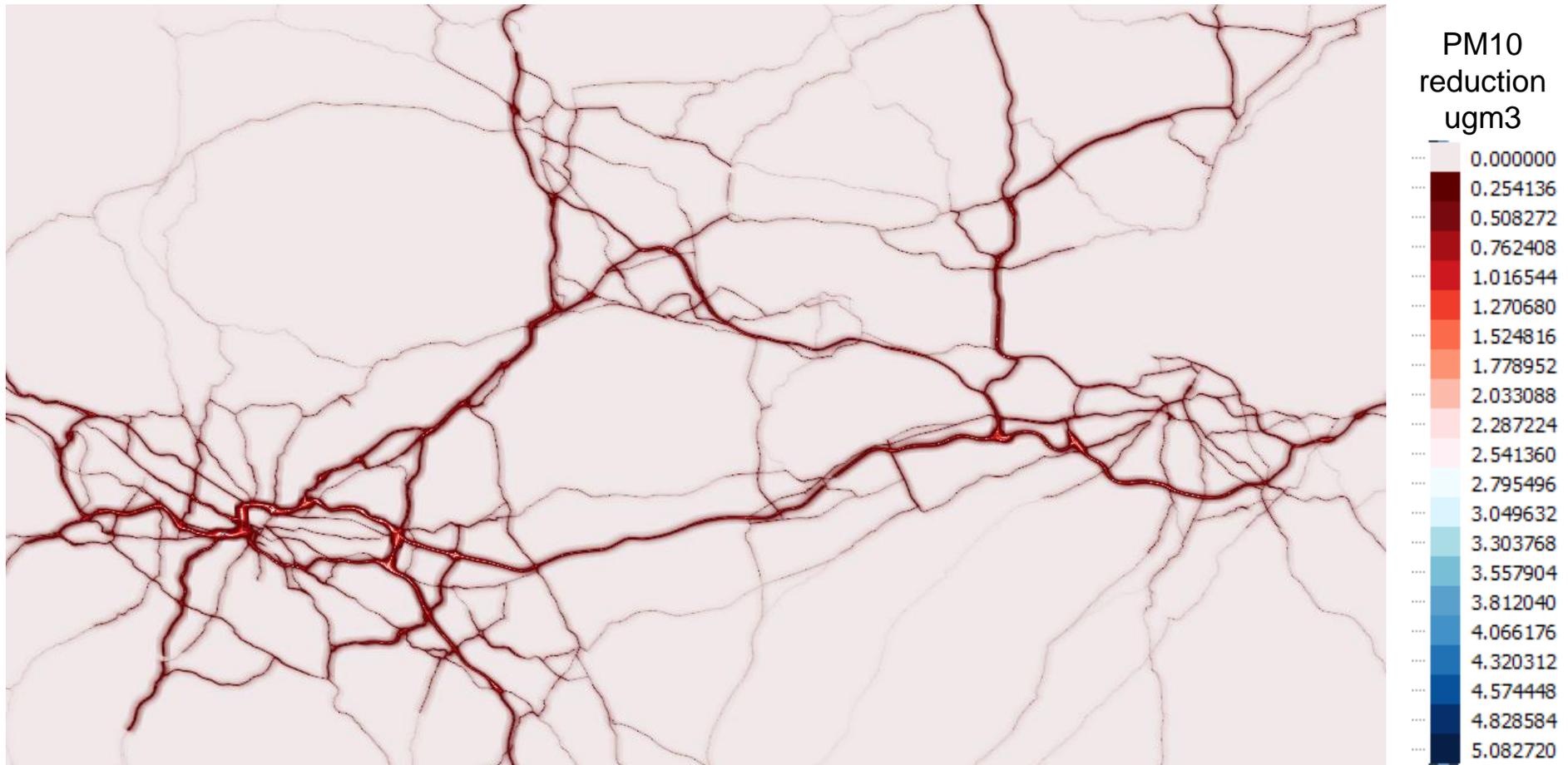


PM10 cross road profile of concentrations- M74 in Glasgow



Y : 10.01

PM10 difference plot- central belt (base minus BAT)



Very highest concentrations are attenuated by up to 5 $\mu\text{g}/\text{m}^3$, more typically roadside concentrations reduced by about 0.5 to 1 $\mu\text{g}/\text{m}^3$.

PM10 results- explained

- New emission standards will not deliver significant reductions in exhaust emissions compared with existing vehicles
- The biggest road traffic component in future years will be tyre, brake and road wear particles. I don't foresee a step change in the prevalence of these technologies. Electric cars still need roads, tyres and brakes after all.
- Traffic is usually not as dominant a source so reductions in emissions in this sector are not as apparent in overall concentrations.
- Hence even for ambitious CAZ schemes we might not expect to see much change in PM10 concentrations- though we would expect some benefit
- Going beyond BAT towards removing diesel completely from the LDV fleet does not change PM10 concentrations at all- diesel emissions from a significantly more petroleum based fleet are much the same as before

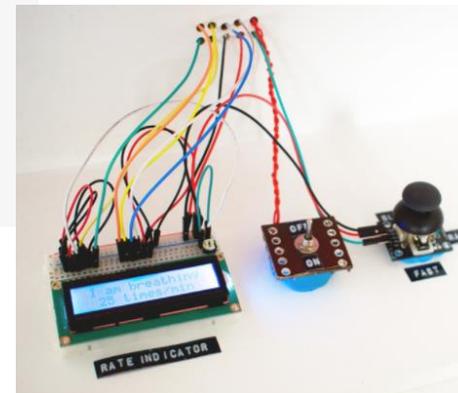


3D Visualisation of Air Pollution in Glasgow

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.

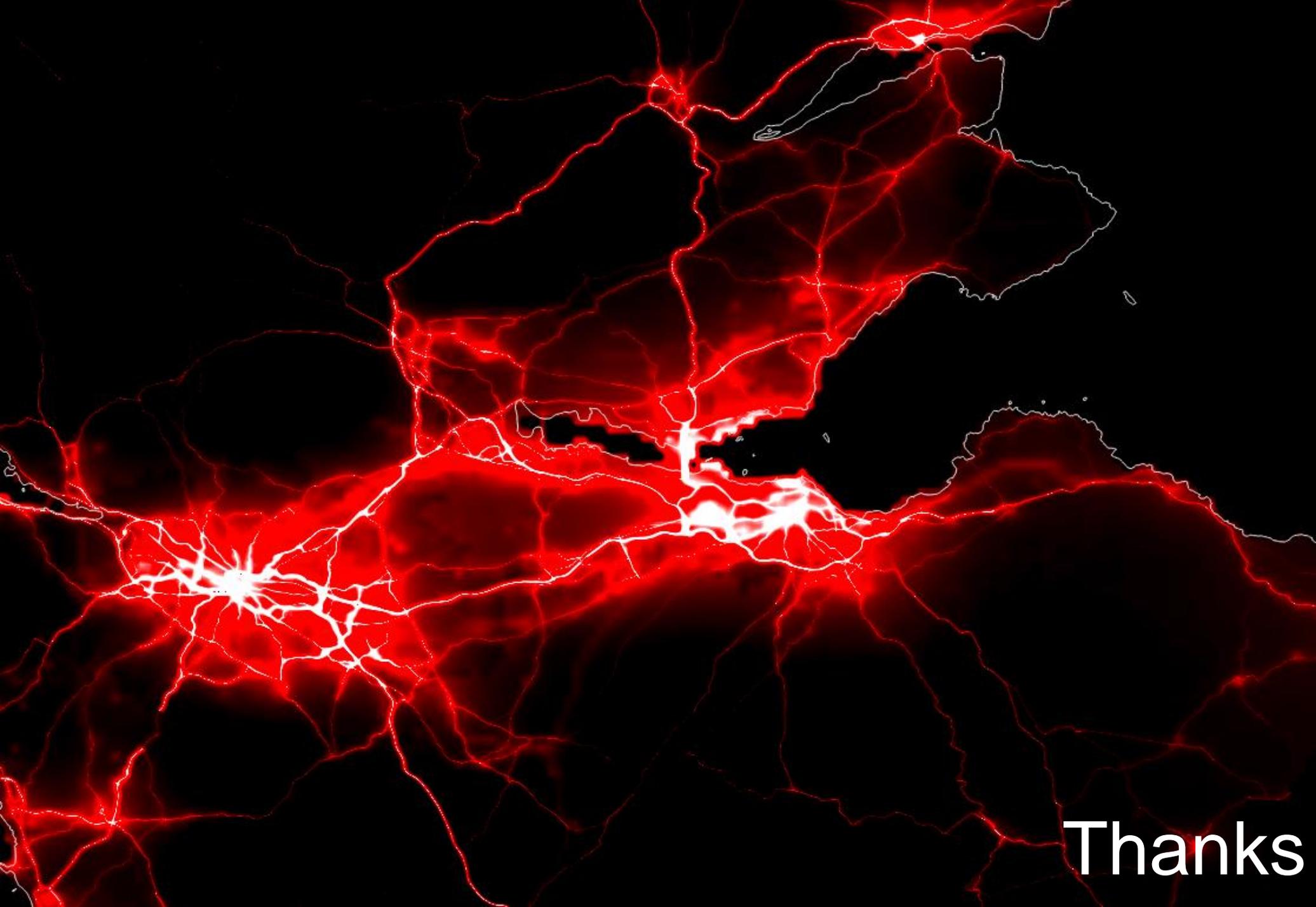


<https://www.informationisbeautifulawards.com/showcase/1614-3d-visualisation-of-air-pollution-in-glasgow>
<http://www.trudihannah.com/#/pollutionvisualisation/>

To conclude



- New modelling methods allow policy that affects large areas to be modelled in a holistic and consistent manner. Its also very time efficient, both in computation and man hours.
- The case study prepared for this event suggests the following:
 - Plausible improvements in NO_x from better vehicles has the potential to deliver quite large reductions in NO₂ in our towns and cities. This is mainly because road traffic NO_x is still the dominant source driving high concentrations
 - Going beyond BAT and removing diesel vehicles delivers additional gains but these are more marginal for NO_x
 - The same vehicle improvements reduce PM₁₀ as well but by a smaller amount
 - The reduction in PM₁₀ is still significant given the health benefits
 - As exhaust emission reduce the non-exhaust component becomes dominant. It is possible therefore that Scotland could still see PM₁₀ concentrations over the 18ugm³ threshold, with the emissions arising from brake, tyre and road particles.
 - Even with electrification, if material science and automotive design can't reduce these uncontrolled releases we may still have a domestic compliance issue for PM₁₀ in Scotland.



Thanks

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