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

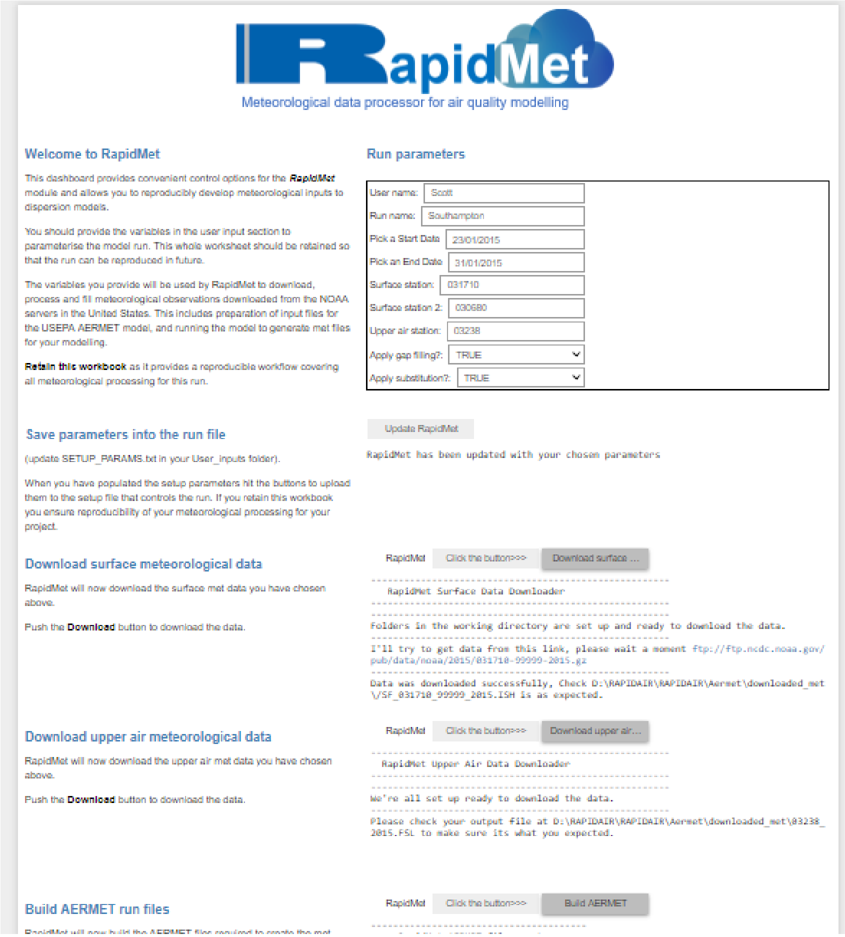
Summary of functionality

What is RapidAir® ?

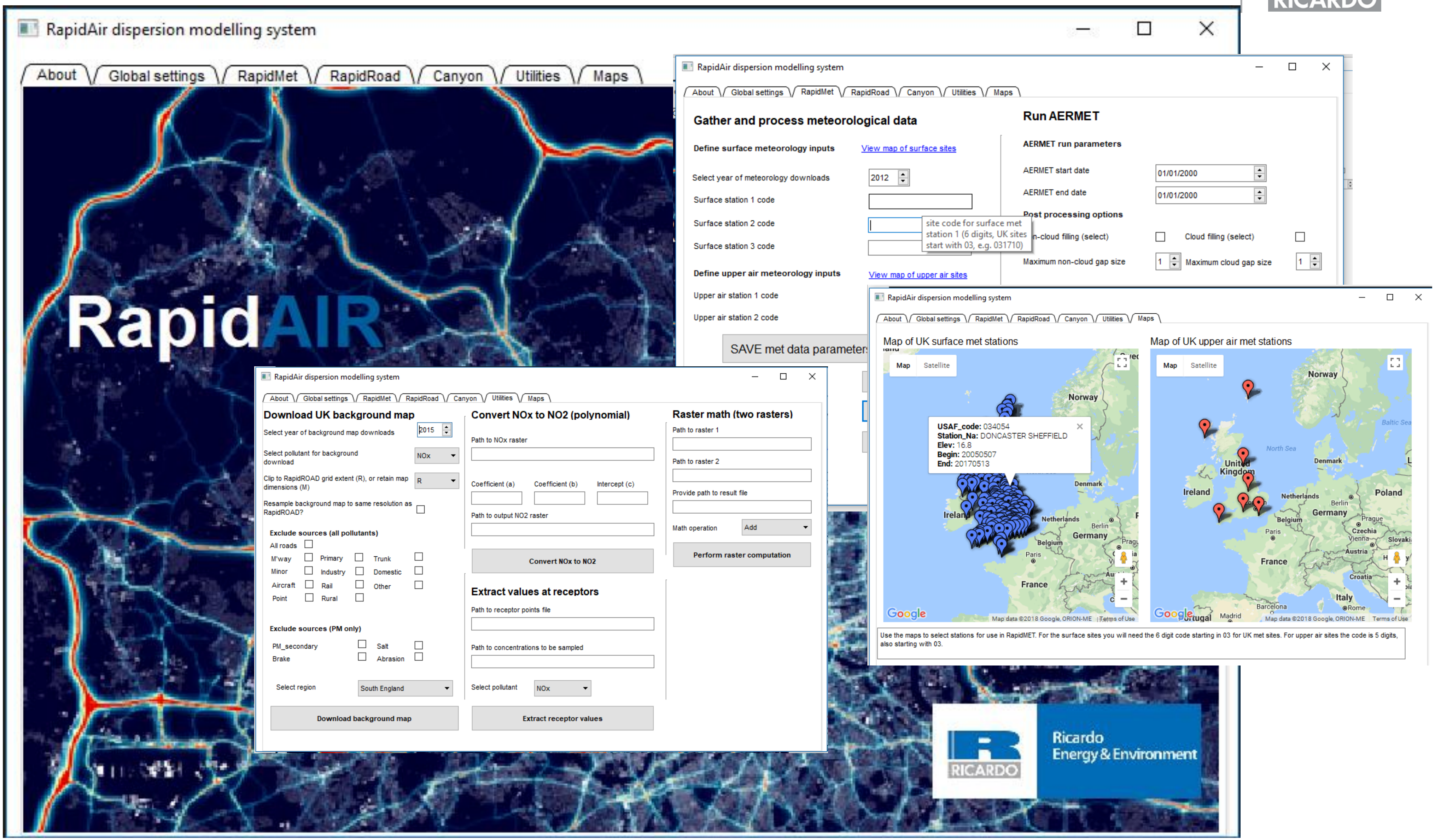
Dispersion model which also eases the workflow for such modelling in cities and regions.

Some neat things it does:

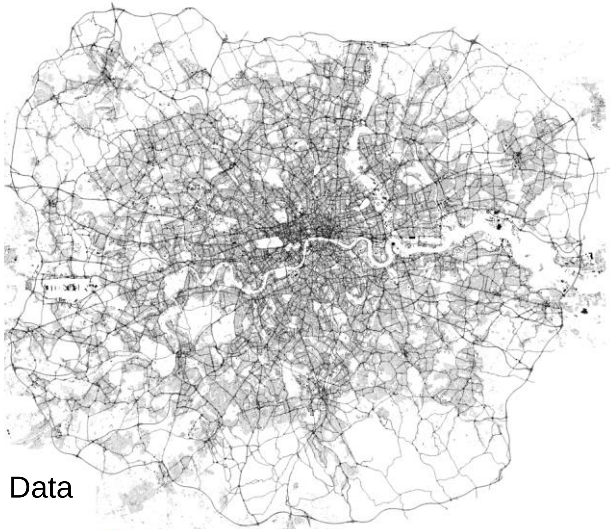
- Traffic emissions model built in (1 million links in 1 minute)
- Road dispersion model including canyons
- Area source model e.g. for large dispersed sources (e.g. domestic)
- Unlimited domain size and resolution (testing with 3 billion locations)
- Domain splitting unlimited domain size
- Met data- 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)



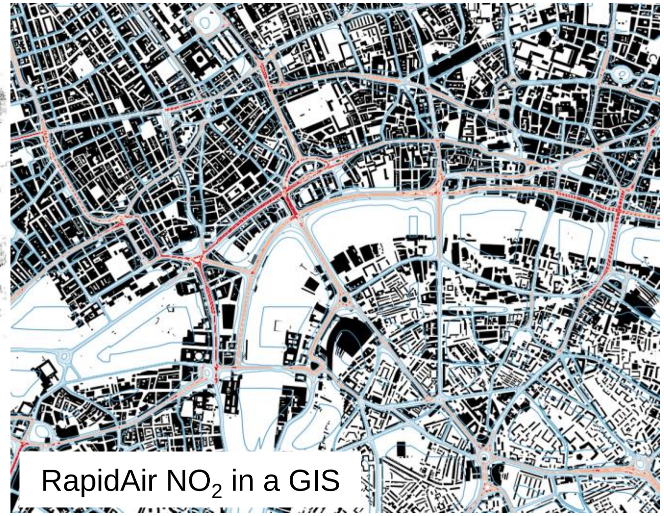
RapidAir UI- either Windows application or online



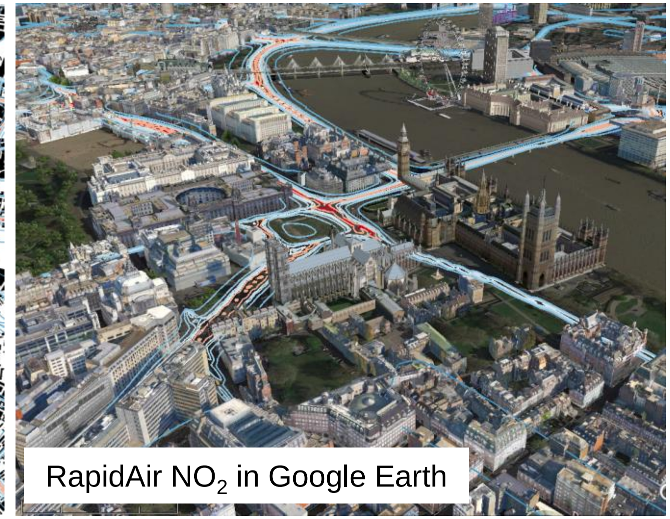
Mostly it's a dispersion model we're using in large urban areas- this is London



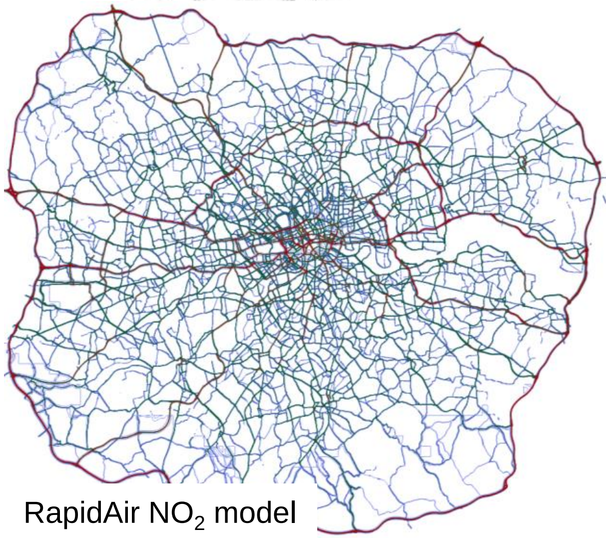
Data



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

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

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

Submitted….

Contents lists available at ScienceDirect
Atmospheric Environment
journal homepage: www.elsevier.com/locate/atmosenv

Short communication

Influence of wind-speed on short-duration NO_2 measurements using Palmes and Ogawa passive diffusion samplers

Nicola Masey [a], Jonathan Gillespie [a], Mathew R. Heal [b], Scott Hamilton [c], Iain J. Beverland [a,*]

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

Environmental Science & Technology
Article
pubs.acs.org/est

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[§]

[†] Department of Civil and Environmental Engineering, University of Strathclyde, James Weir Building, 75 Montrose Street, Glasgow, G1 1XJ, U.K.
[‡] Ricardo Energy and Environment, 18 Blythswood Square, Glasgow G2 4BG, U.K.
[§] University of Glasgow, Institute of Cardiovascular and Medical Sciences, British Heart Foundation Glasgow Cardiovascular Research Centre, 126 University Place, Glasgow G12 8TA

Contents lists available at ScienceDirect
Atmospheric Environment
journal homepage: www.elsevier.com/locate/atmosenv

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

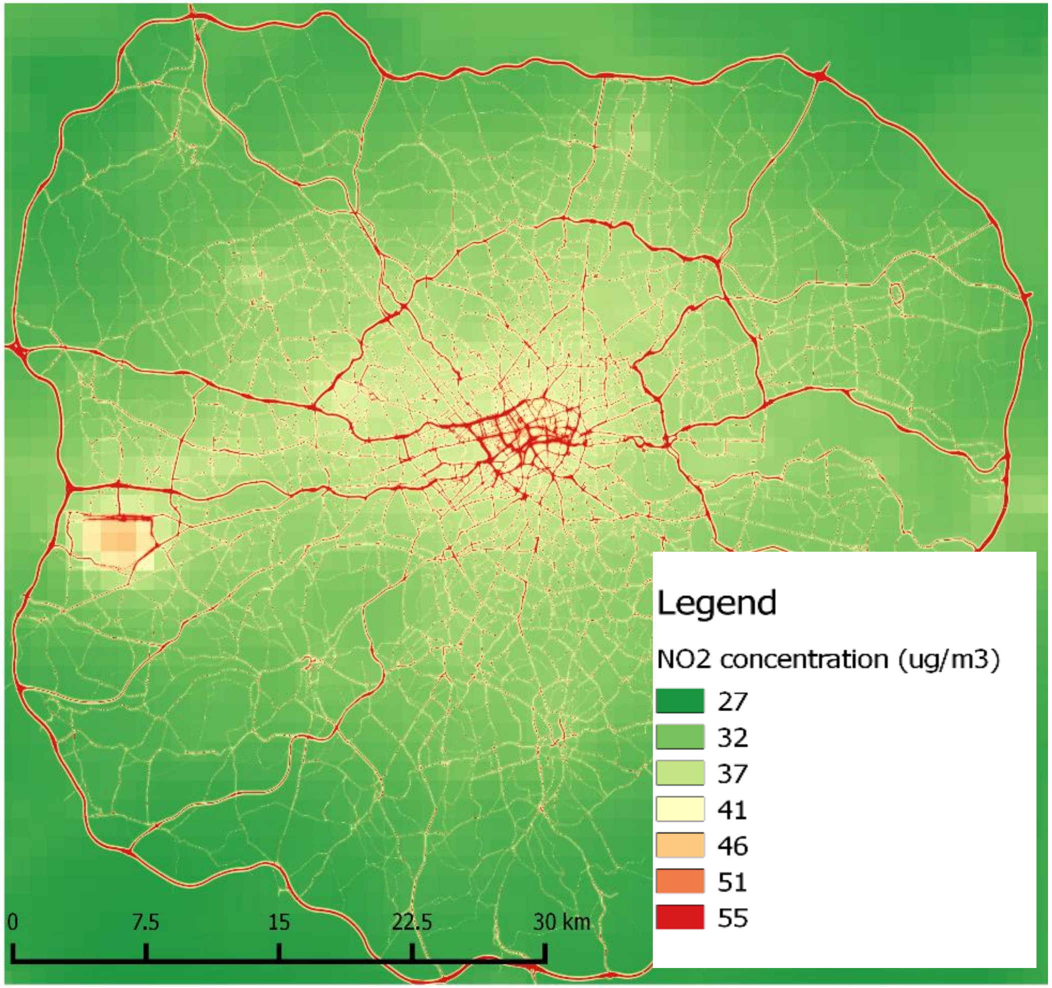
London study (in review)

We modelled concentrations of 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 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

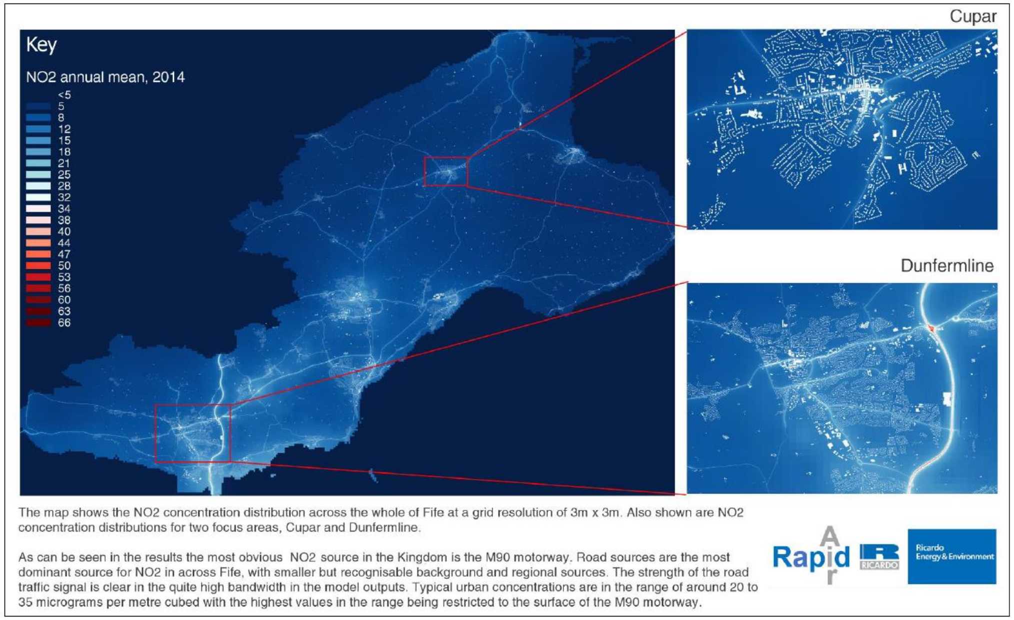
The performance statistics for the surrogates for urban morphology are reasonably close to those from the models which treat canyons discretely.

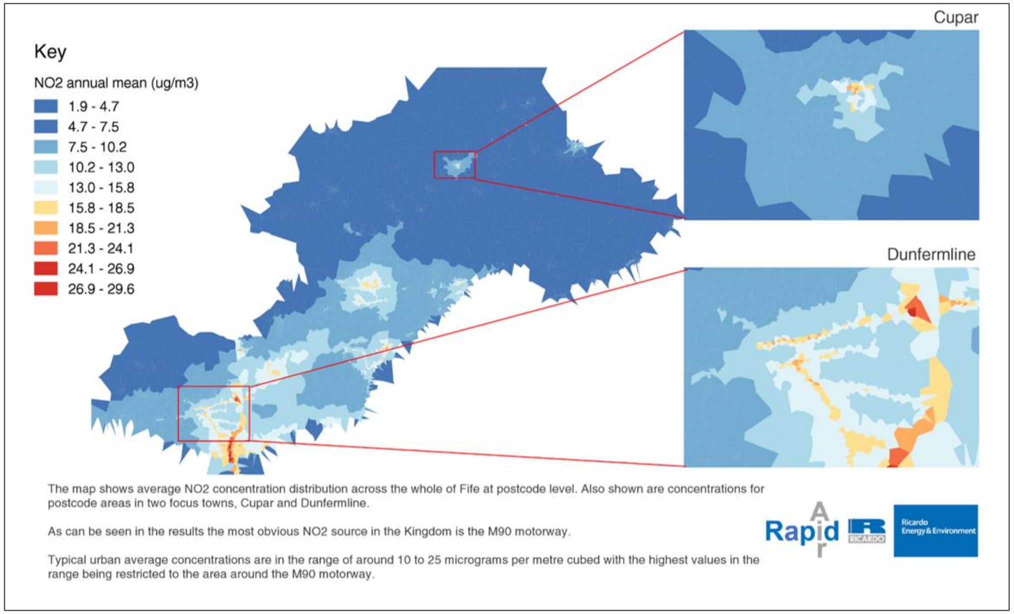
For NO2 compliance assessment RapidAir could be used with either the STREET or AEOLIUS model options switched on as they perform well.

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

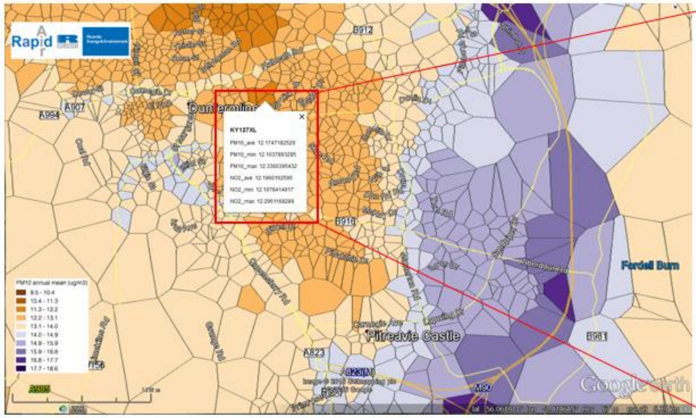
The surrogate canyon models could be used as screening tools and perhaps to spatially delineate locations where the street canyon models should be invoked.

UK Projects- example





PM_{10} average by postcode



Concentrations for a single postcode

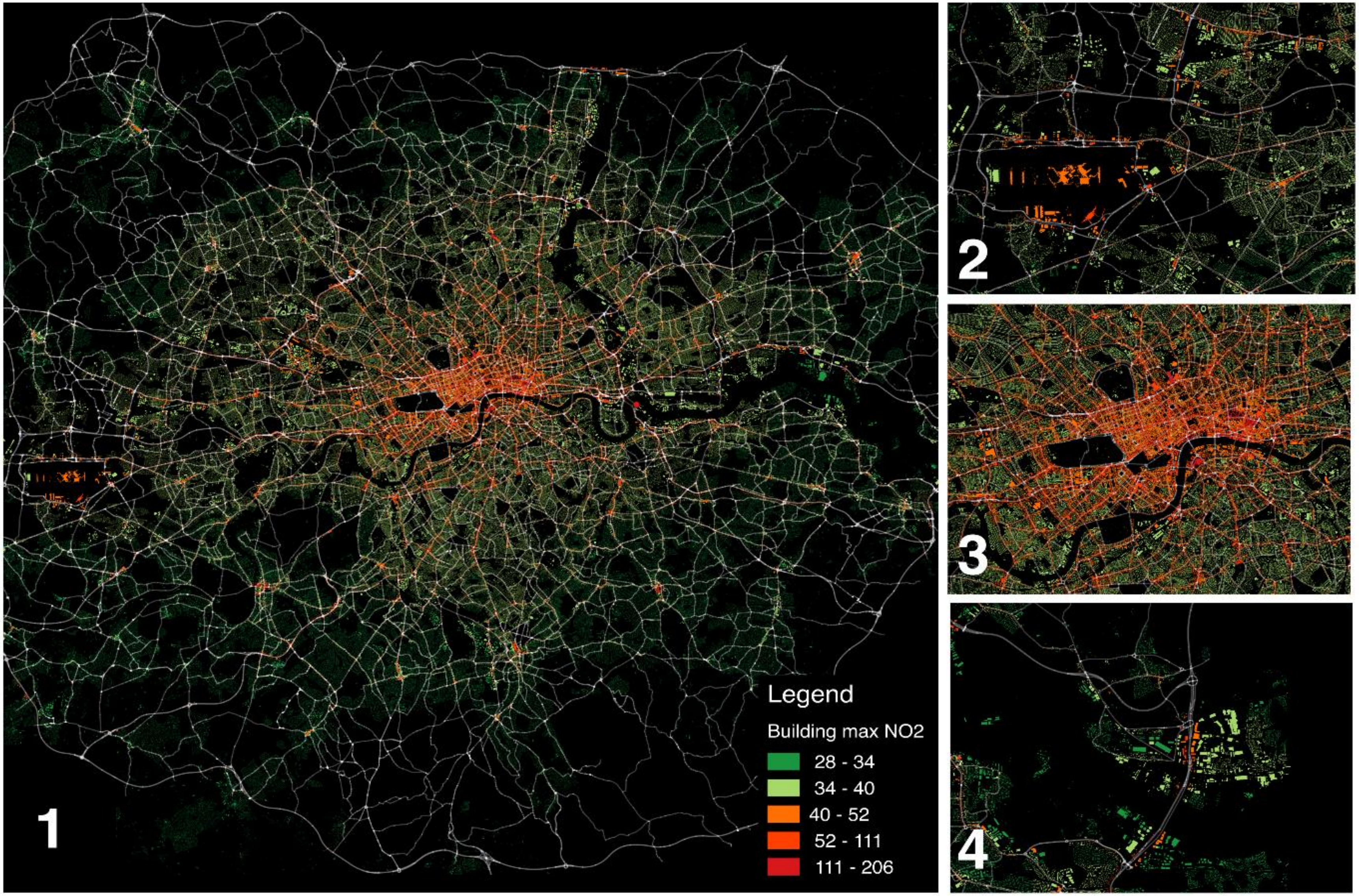
Every postcode in Fife has annual mean modelled concentrations of NO_2 and PM_{10}. Maximum, minimum and mean values within each postcode area are provided.

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

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.

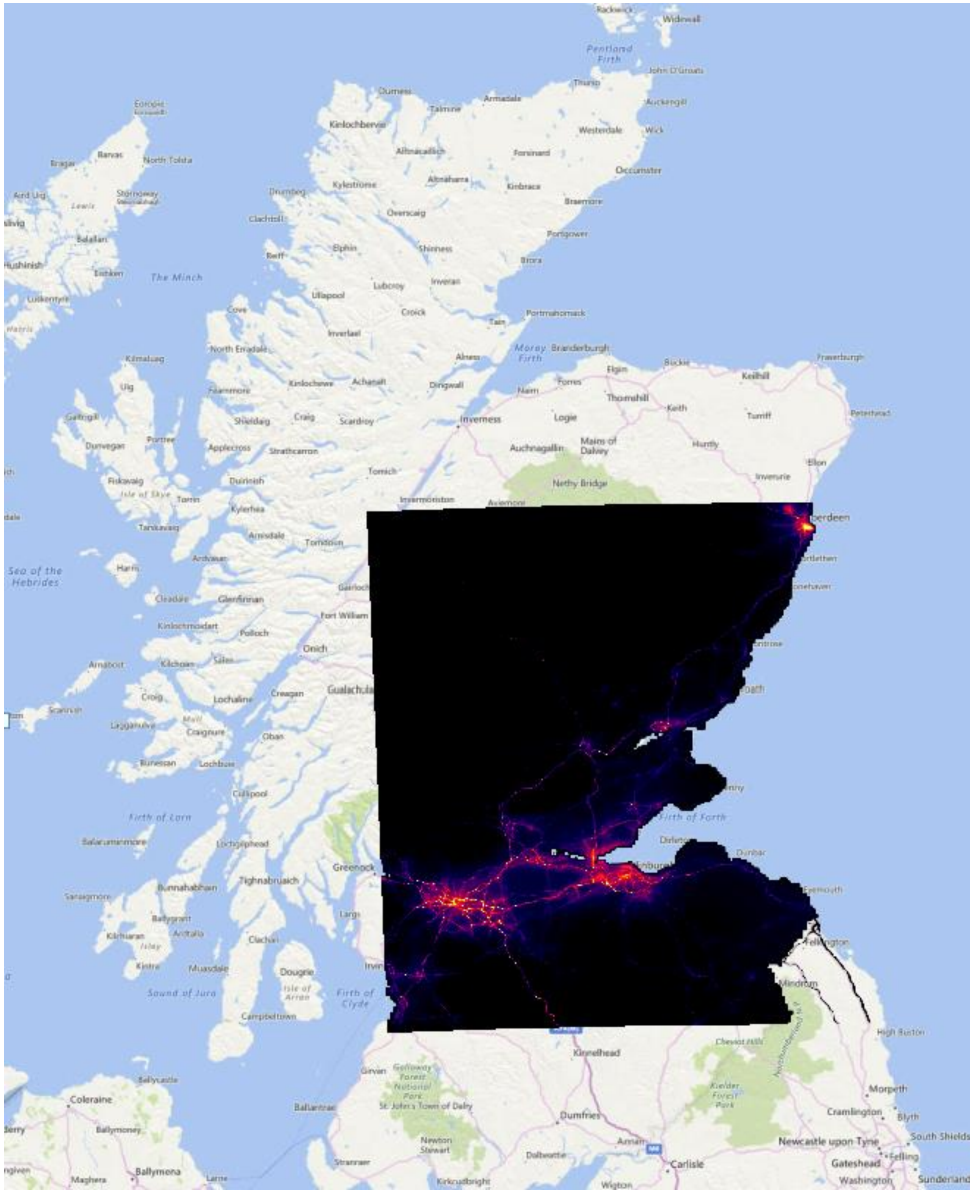
- Test case 1 involves setting all light and heavy vehicles to engine technologies which are either best currently available, or best that will soon be available (e.g. Euro 6 D)

- 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
total_NOx_gkms	
Mean	**0.067**
Standard Error	0.000
Median	0.047
Mode	0.015
Standard Deviation	0.071
Sample Variance	0.005
Kurtosis	15.687
Skewness	3.296
Range	0.903
Minimum	0.000
Maximum	**0.904**
Sum	**9383.301**
Count	140929.000

BAT plus no diesel	Column1
total_NOx_gkms	
Mean	**0.015**
Standard Error	0.000
Median	0.012
Mode	0.003
Standard Deviation	0.015
Sample Variance	0.000
Kurtosis	14.069
Skewness	3.052
Range	0.166
Minimum	0.000
Maximum	**0.166**
Sum	**2128.661**
Count	140929.000

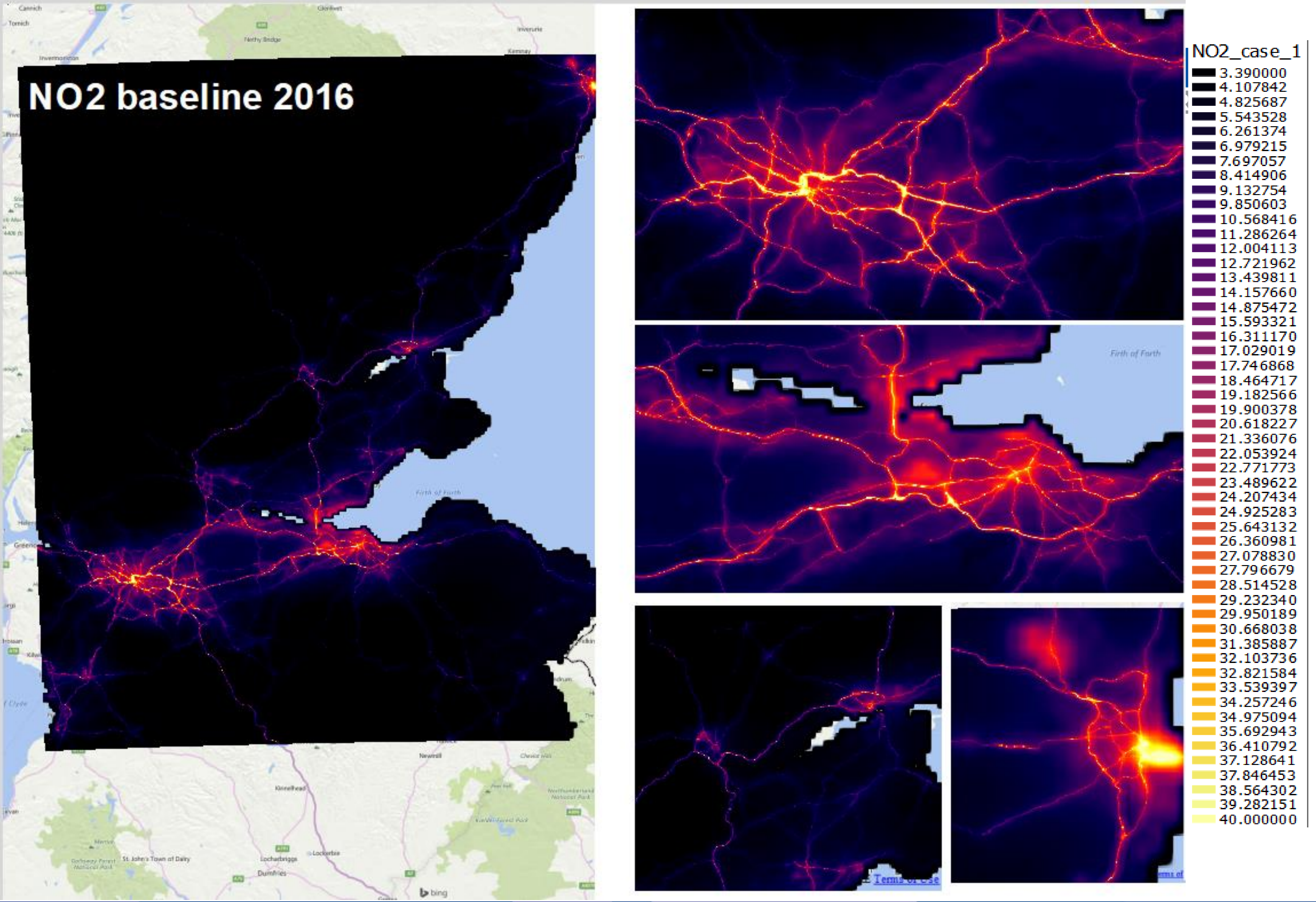
Emission modelling- PM10

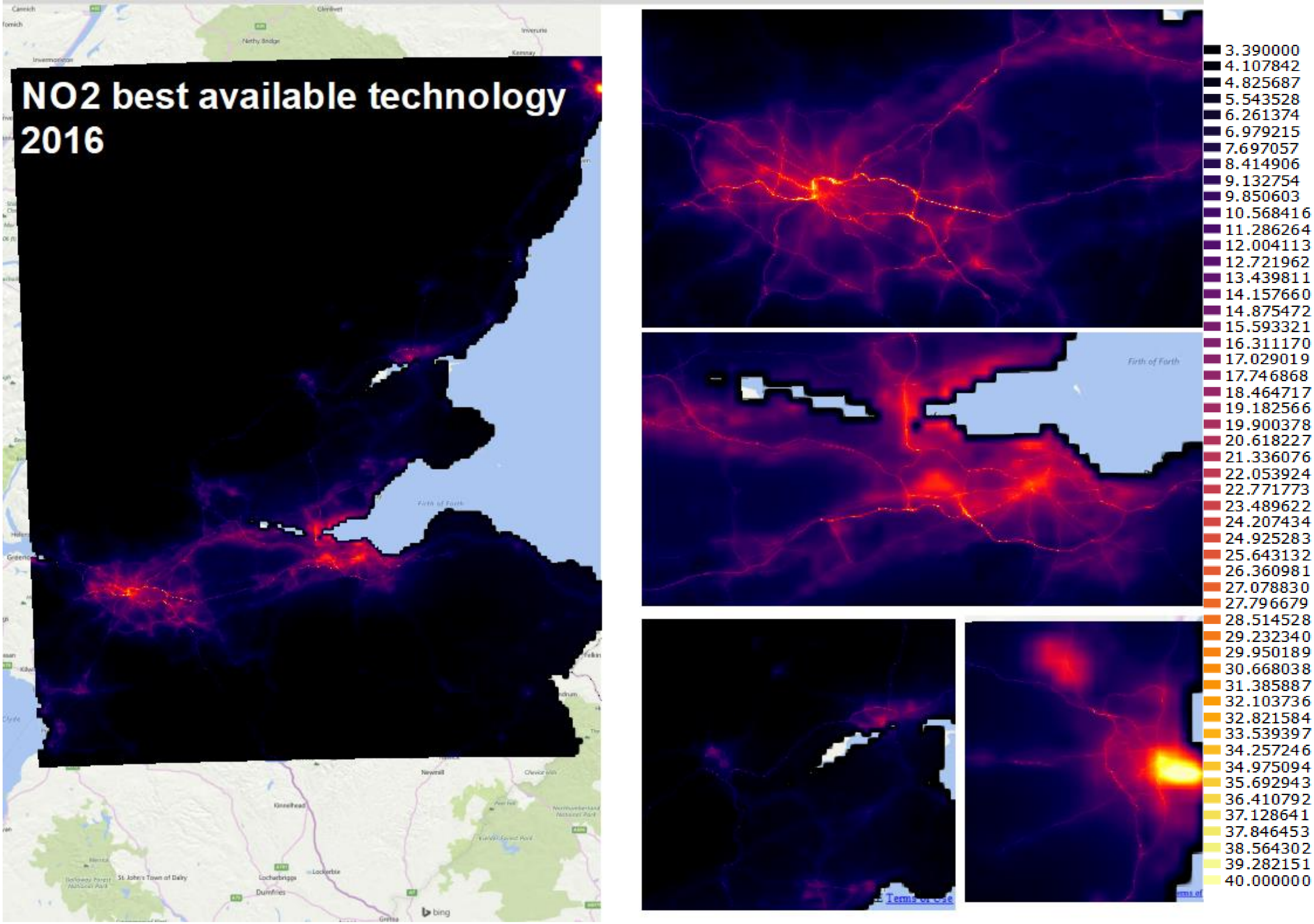
All emissions were modelled in our RapidEMS system, which uses the COPERT V coefficients in a computationally efficient manner. We can calculate emissions on 1 million road links in 1 minute.

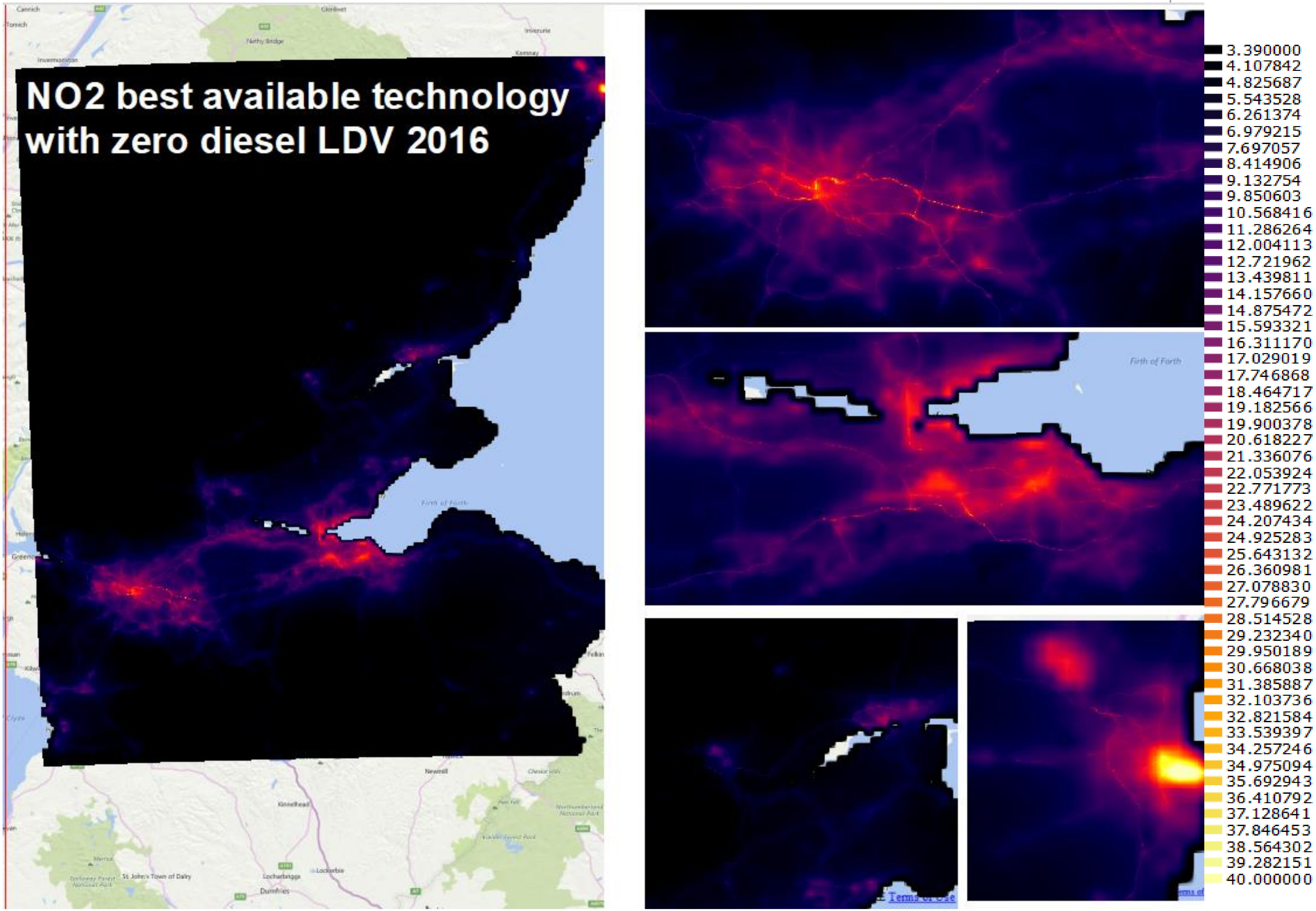
There are 140,000 road links in the model (though most of these are in the rest of the UK)

Base case	Column1
total_PM10_gkms	
Mean	**0.007**
Standard Error	0.000
Median	0.006
Mode	0.002
Standard Deviation	0.007
Sample Variance	0.000
Kurtosis	14.687
Skewness	3.206
Range	0.074
Minimum	0.000
Maximum	**0.074**
Sum	**1056.233**
Count	140929.000

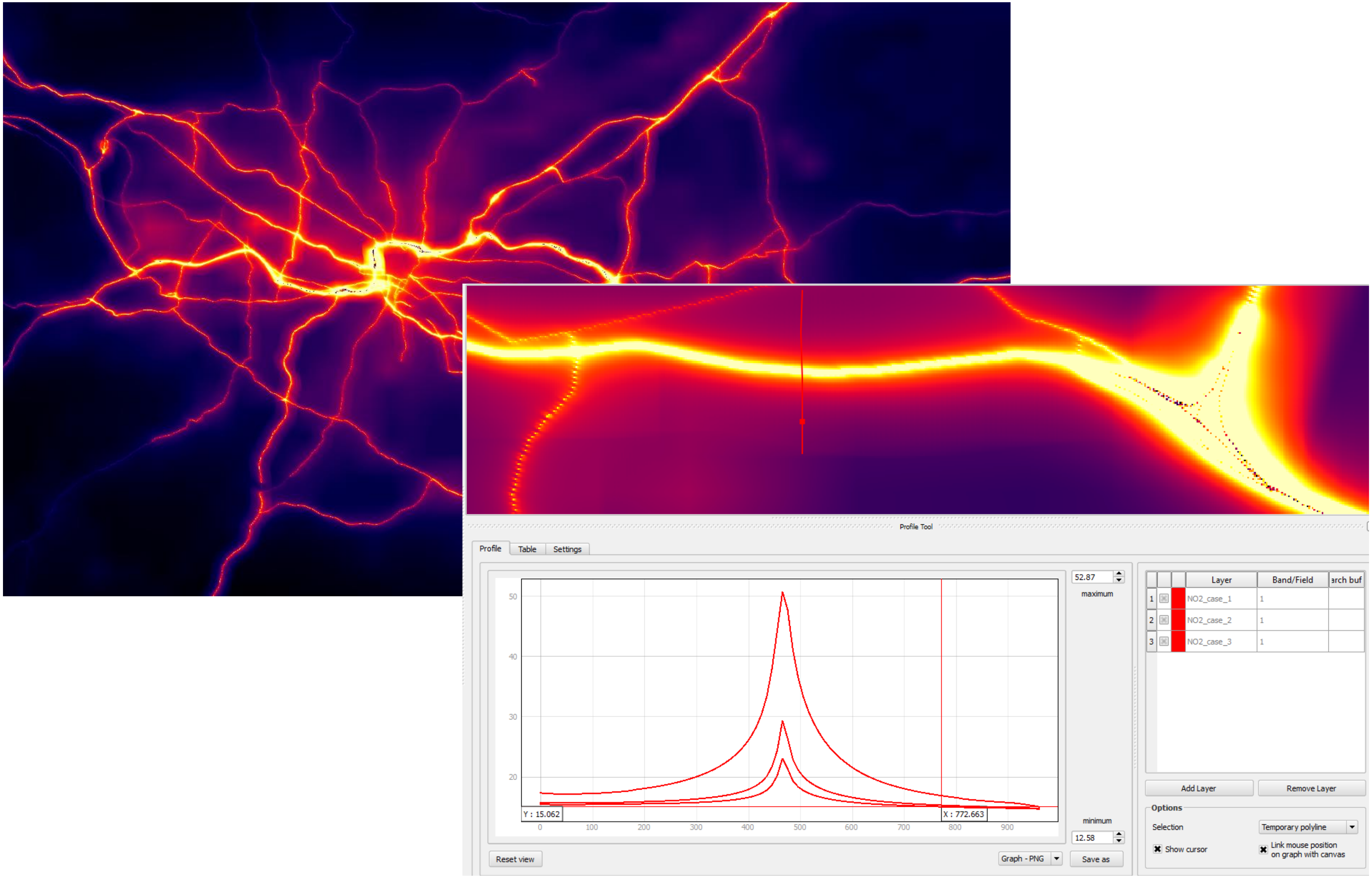
BAT plus no diesel	Column1
total_PM10_gkms	
Mean	**0.007**
Standard Error	0.000
Median	0.005
Mode	0.002
Standard Deviation	0.006
Sample Variance	0.000
Kurtosis	14.250
Skewness	3.138
Range	0.065
Minimum	0.000
Maximum	**0.065**
Sum	**949.775**
Count	140929.000


NO2 baseline 2016
Firth of Forth
Firth of Forth
NO2_case_1
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
34.975094
35.692943
36.410792
37.128641
37.846453
38.564302
39.282151
40.000000
Terms of Use
bing

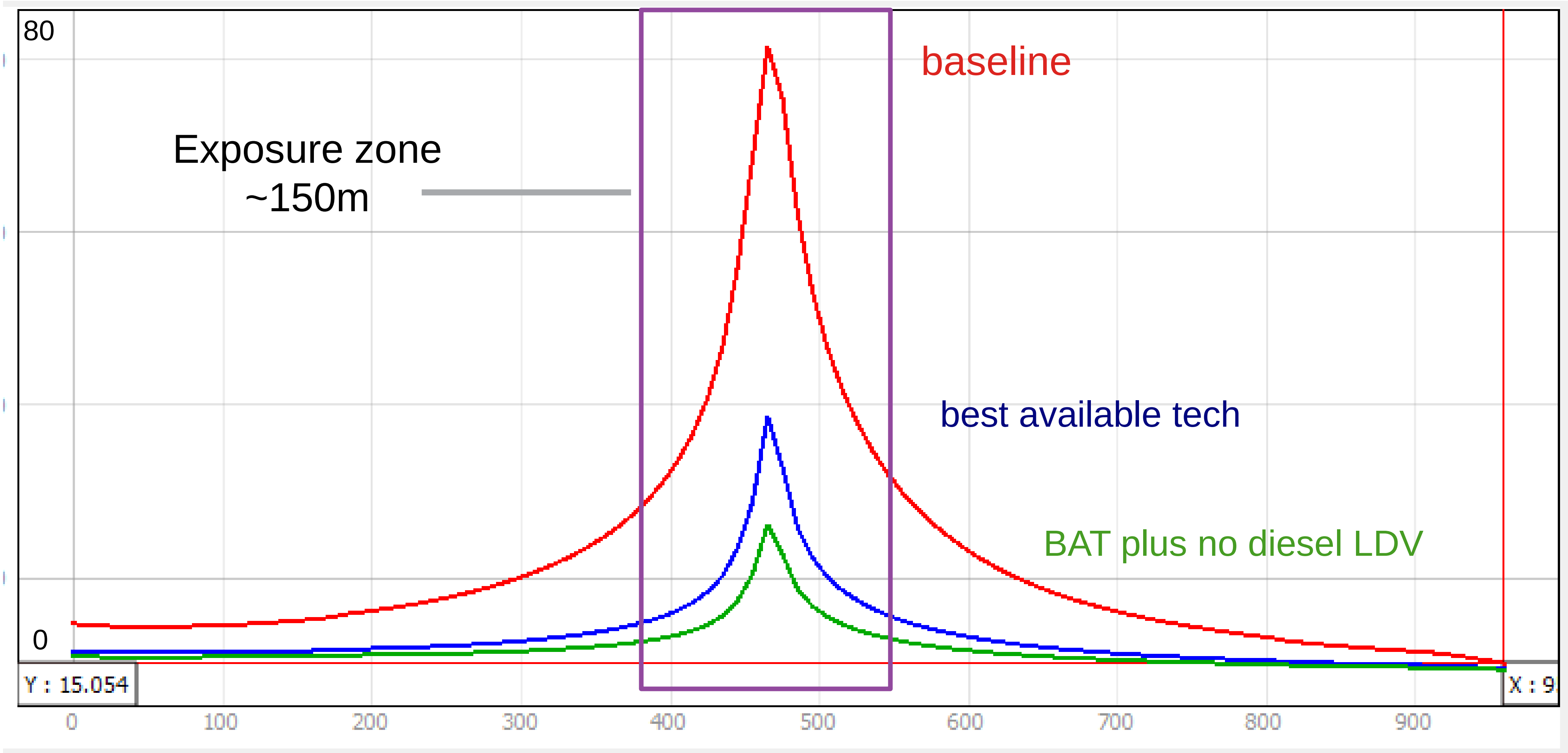

NO2 best available technology
2016
Firth of Forth
Firth of Forth
3.390000
4.107842
4.825687
5.543528
6.261374
6.979215
7.697057
8.414906
9.132754
9.850603
10.568416
11.286264
12.004113
12.721962
13.439811
14.157660
14.875472
15.593321
16.311170
17.029019
17.746868
18.464717
19.182566
19.900378
20.618227
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
34.975094
35.692943
36.410792
37.128641
37.846453
38.564302
39.282151
40.000000


NO2 best available technology with zero diesel LDV 2016
Firth of Forth
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
34.975094
35.692943
36.410792
37.128641
37.846453
38.564302
39.282151
40.000000

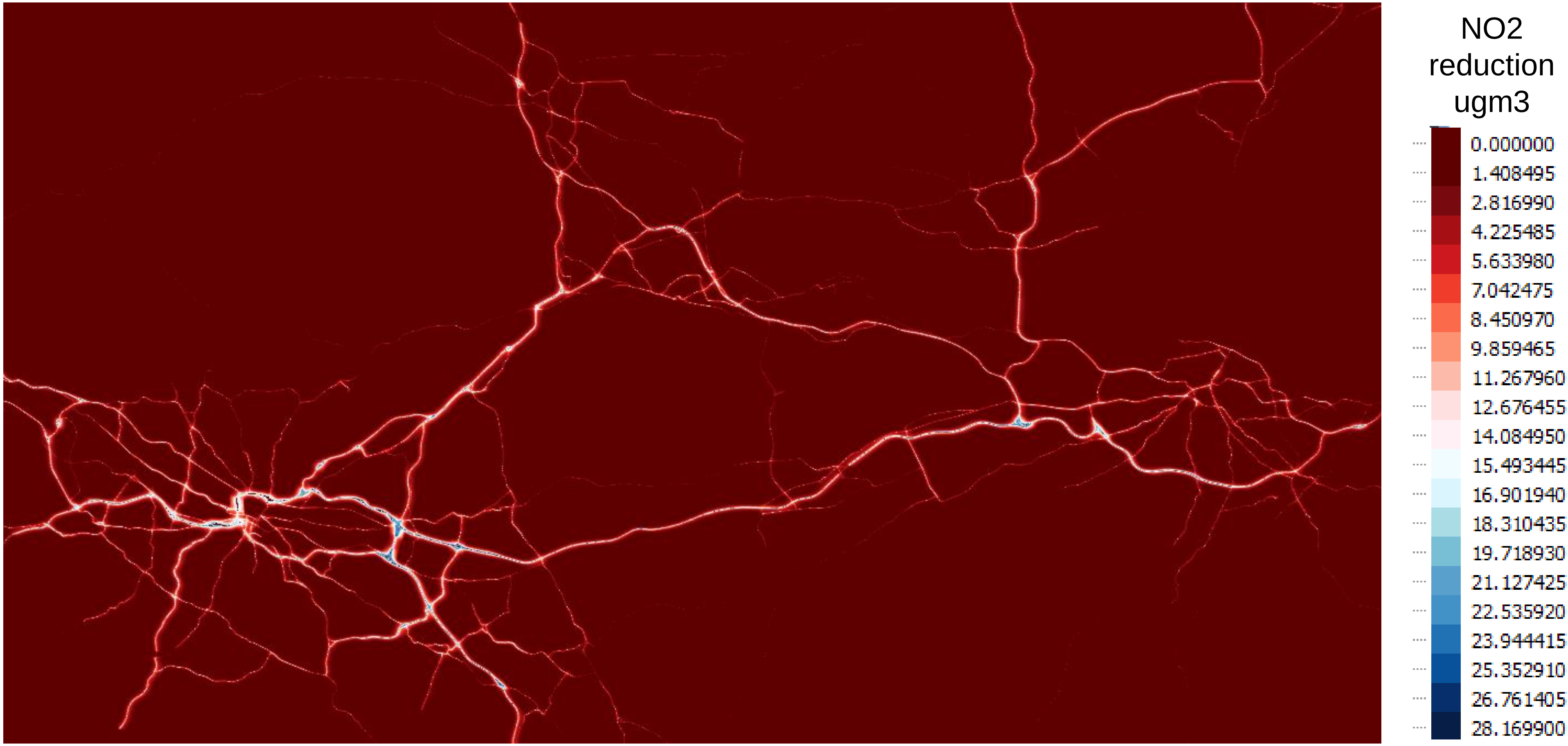
Results at roadside- concentrations in a transect for a typical motorway



NO2 cross road profile of concentrations- M74 in Glasgow



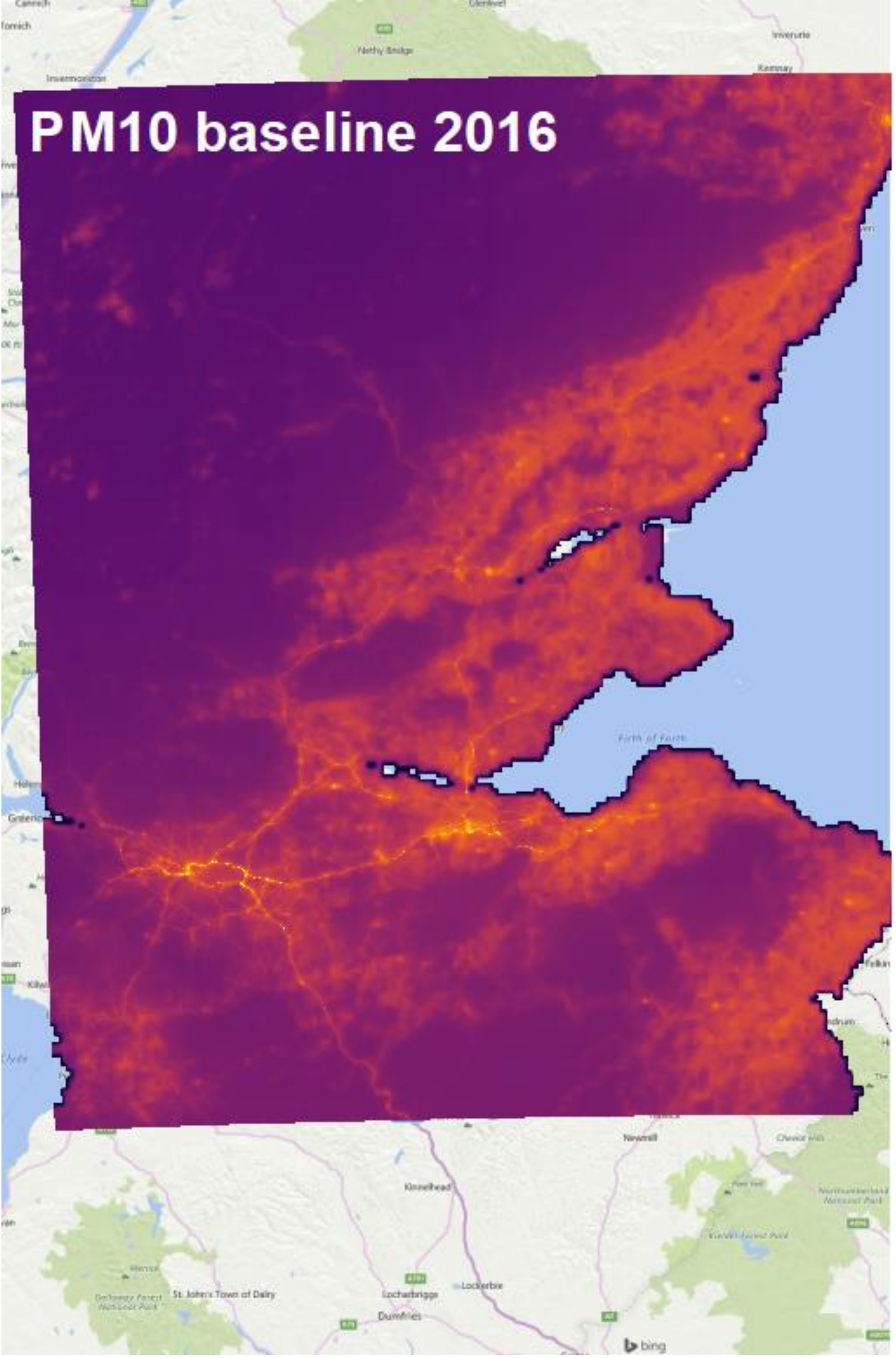
NO2 difference plot- central belt (base minus BAT)

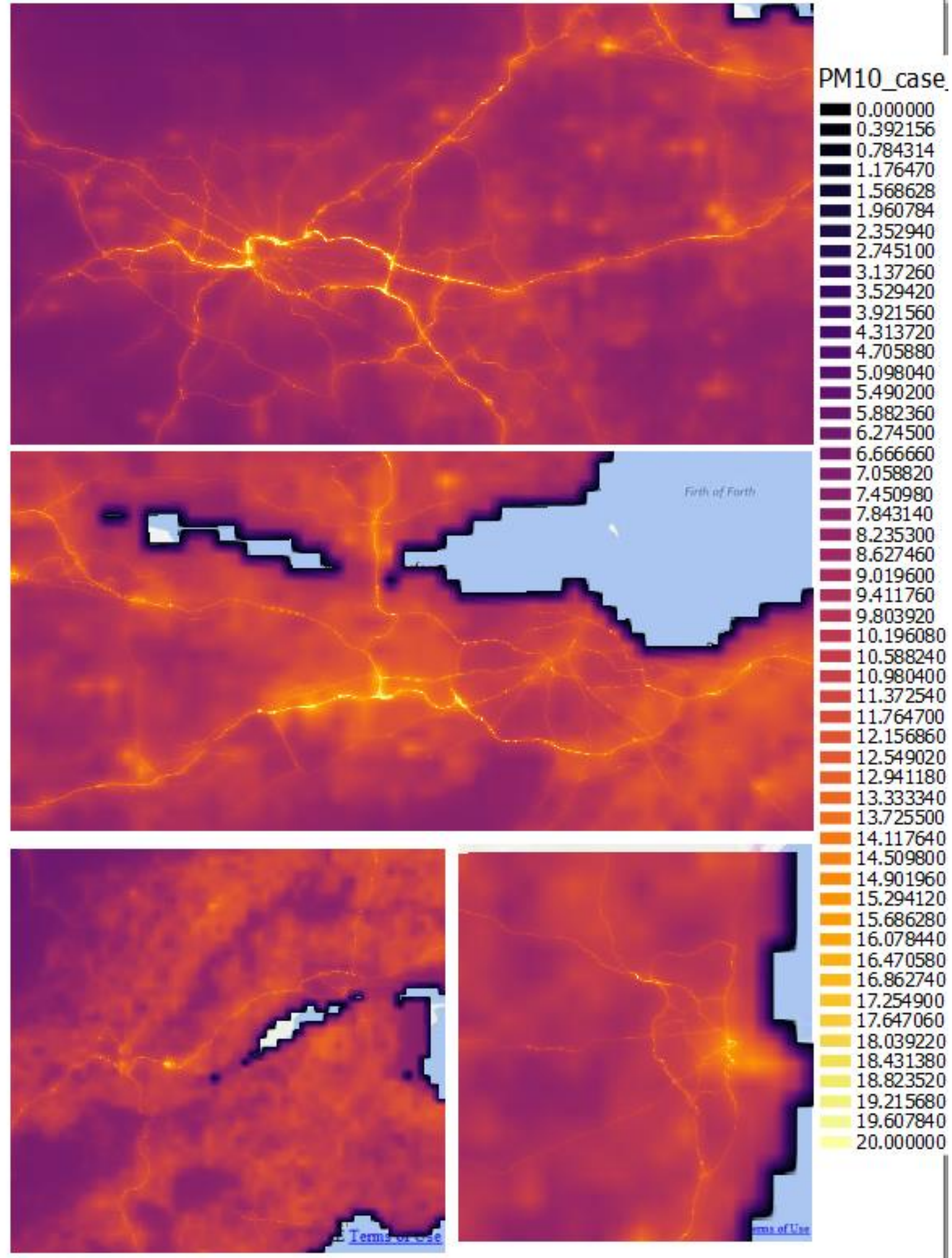


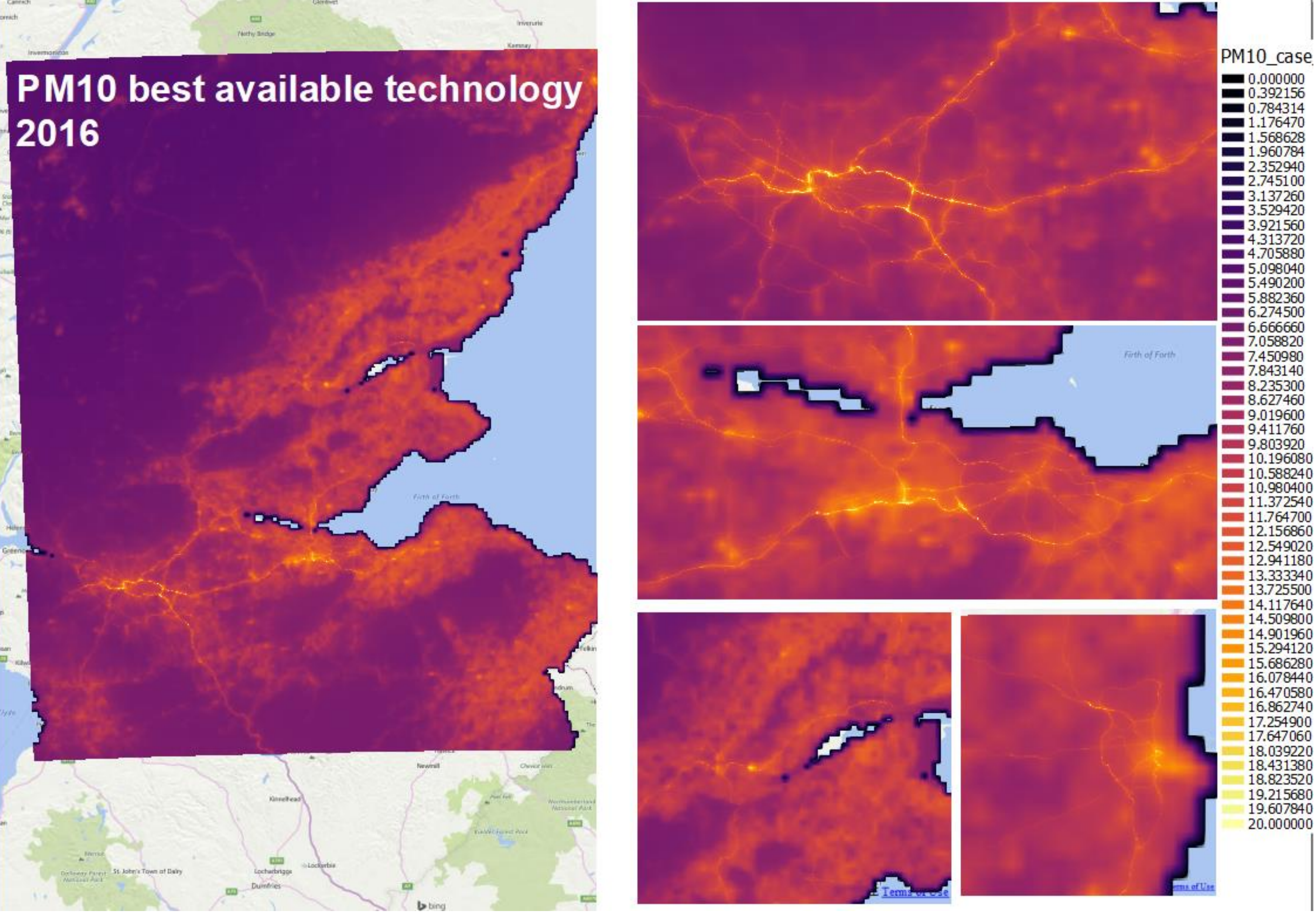
Very highest concentrations are attenuated by up to 28 ugm3, more typically roadside concentrations reduced by about 5 to 10 ugm3.

NO2 results- explained

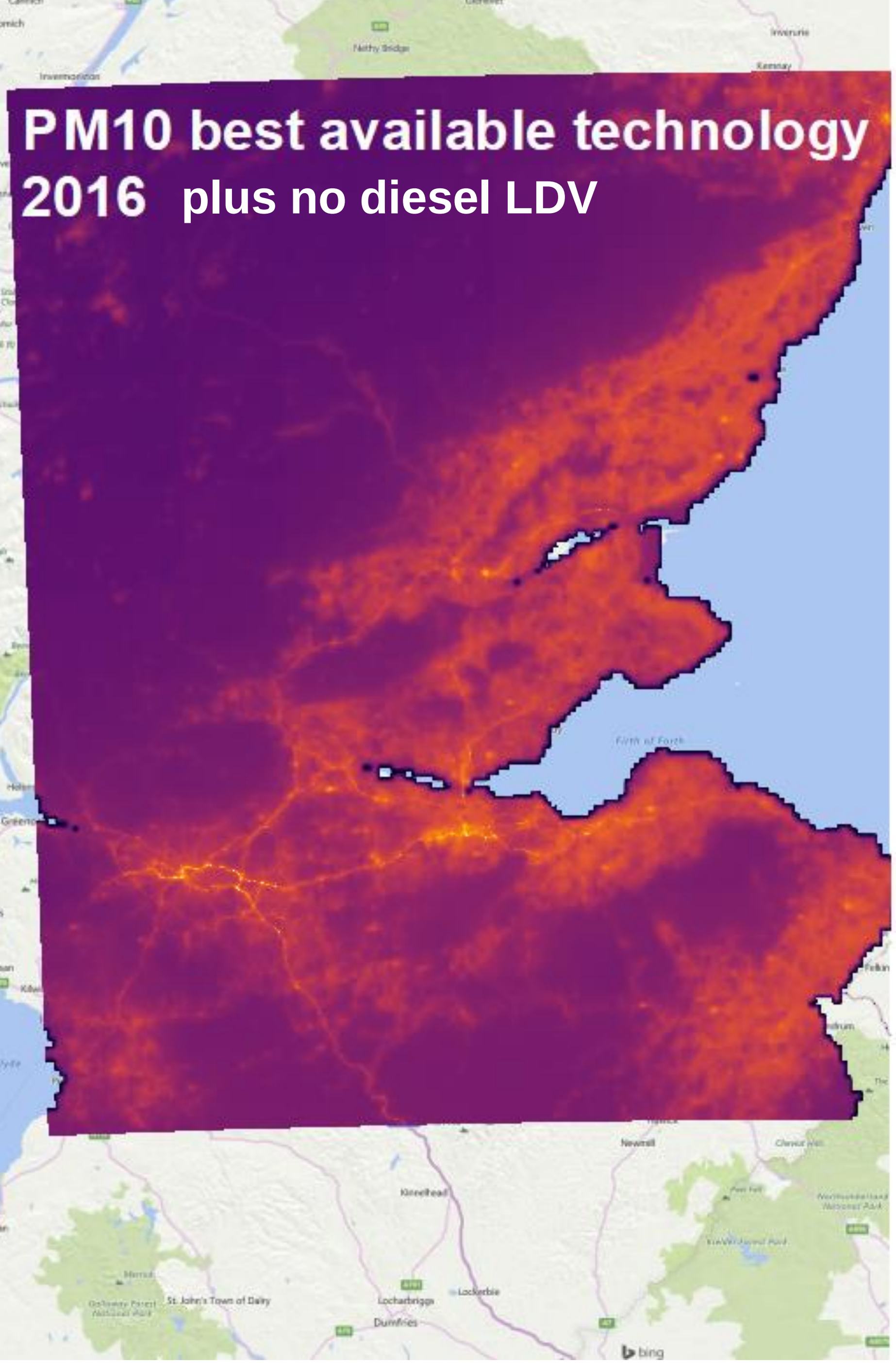
- New iterations of Euro 6 are expected to deliver very substantial reductions in NOx and hence NO2
- Traffic is usually the dominant source so reductions in emissions in this sector are very apparent in overall concentrations
- Hence if the new Euro standards deliver, significant reductions in NO2 should 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

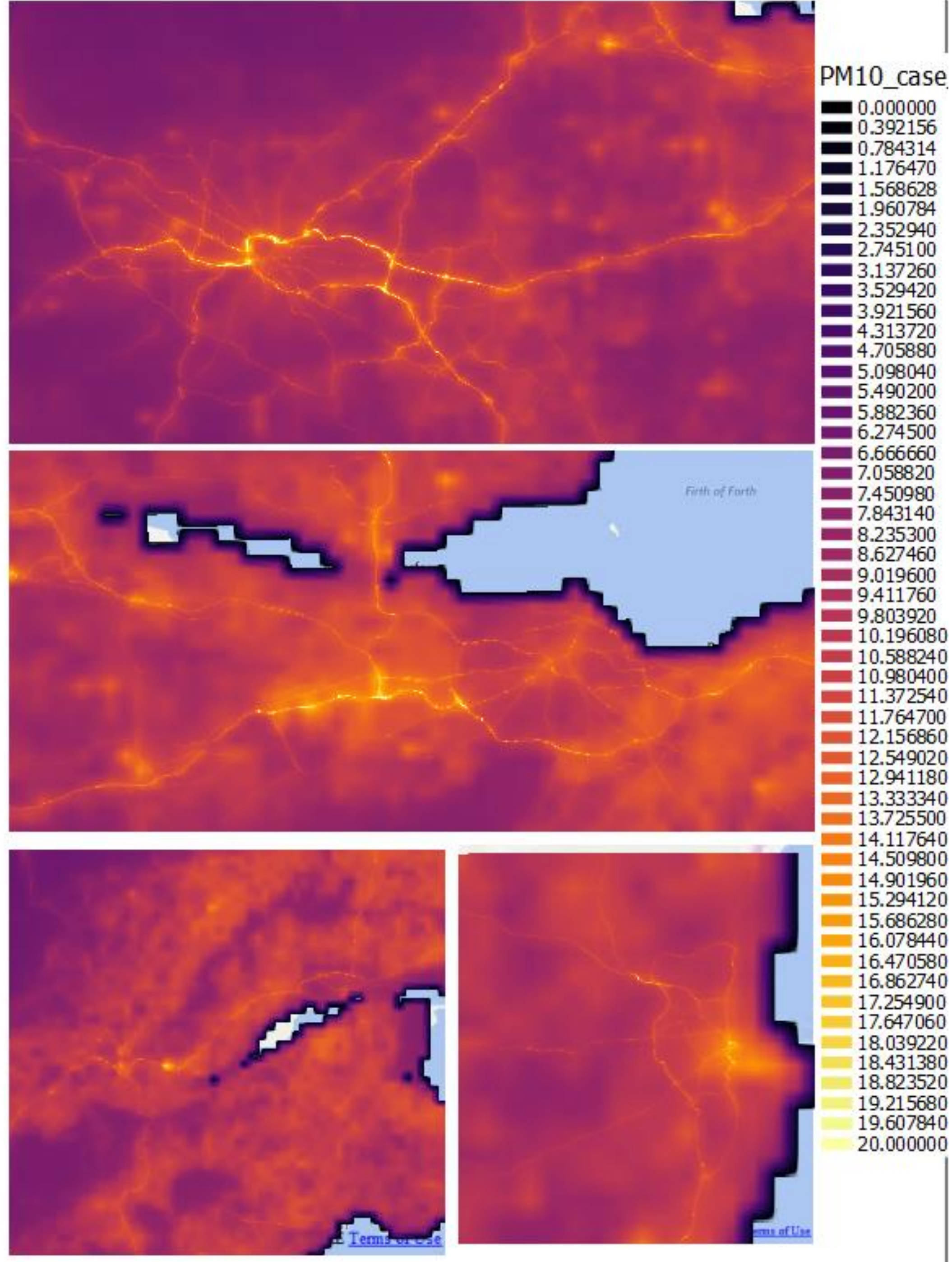

PM10 baseline 2016
Firth of Forth


Firth of Forth
PM10_case_
0.000000
0.392156
0.784314
1.176470
1.568628
1.960784
2.352940
2.745100
3.137260
3.529420
3.921560
4.313720
4.705880
5.098040
5.490200
5.882360
6.274500
6.666660
7.058820
7.450980
7.843140
8.235300
8.627460
9.019600
9.411760
9.803920
10.196080
10.588240
10.980400
11.372540
11.764700
12.156860
12.549020
12.941180
13.333340
13.725500
14.117640
14.509800
14.901960
15.294120
15.686280
16.078440
16.470580
16.862740
17.254900
17.647060
18.039220
18.431380
18.823520
19.215680
19.607840
20.000000

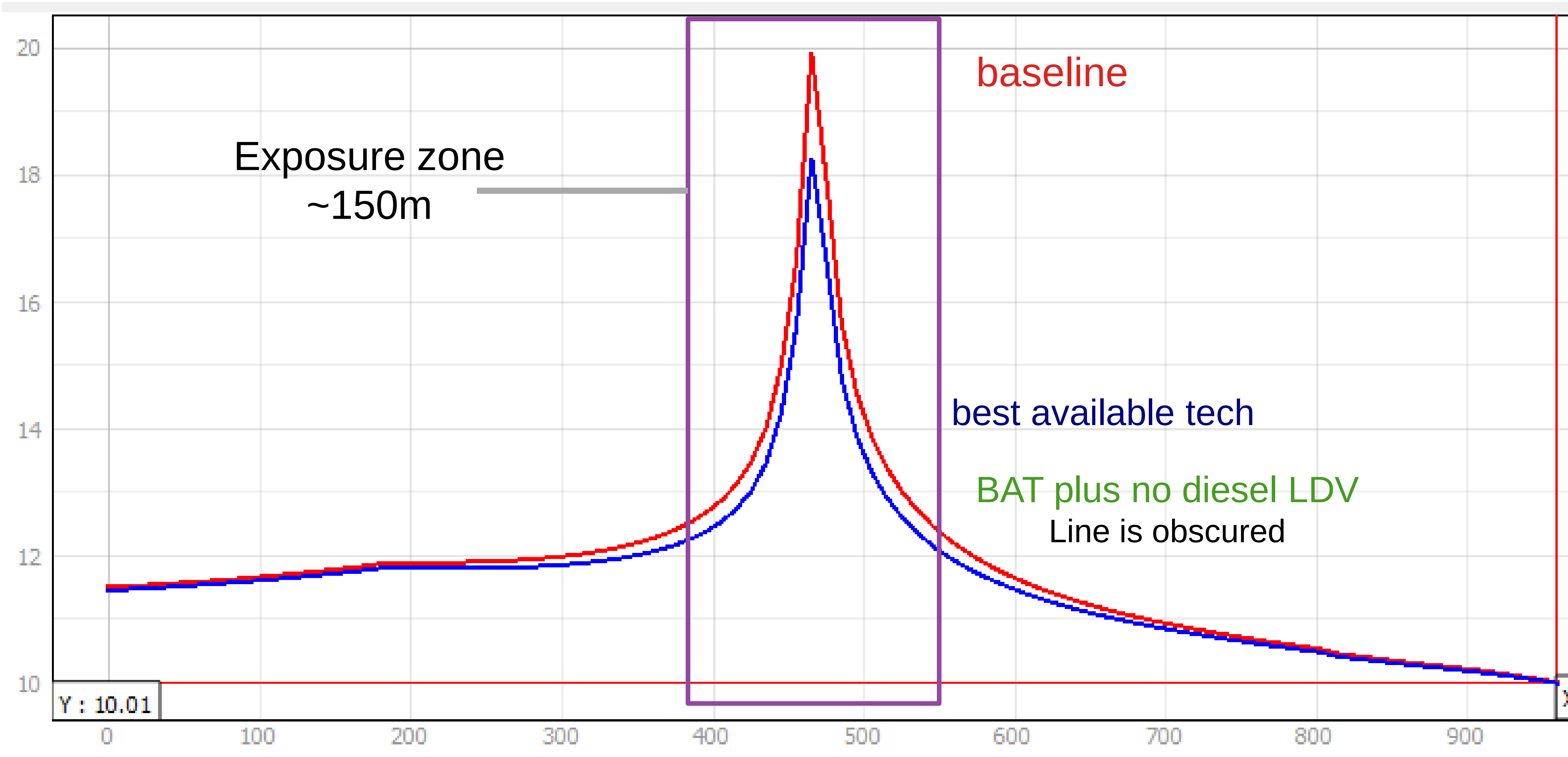

PM10 best available technology
2016
Firth of Forth
Firth of Forth
PM10_case
0.000000
0.392156
0.784314
1.176470
1.568628
1.960784
2.352940
2.745100
3.137260
3.529420
3.921560
4.313720
4.705880
5.098040
5.490200
5.882360
6.274500
6.666660
7.058820
7.450980
7.843140
8.235300
8.627460
9.019600
9.411760
9.803920
10.196080
10.588240
10.980400
11.372540
11.764700
12.156860
12.549020
12.941180
13.333340
13.725500
14.117640
14.509800
14.901960
15.294120
15.686280
16.078440
16.470580
16.862740
17.254900
17.647060
18.039220
18.431380
18.823520
19.215680
19.607840
20.000000

PM10 best available technology 2016 plus no diesel LDV

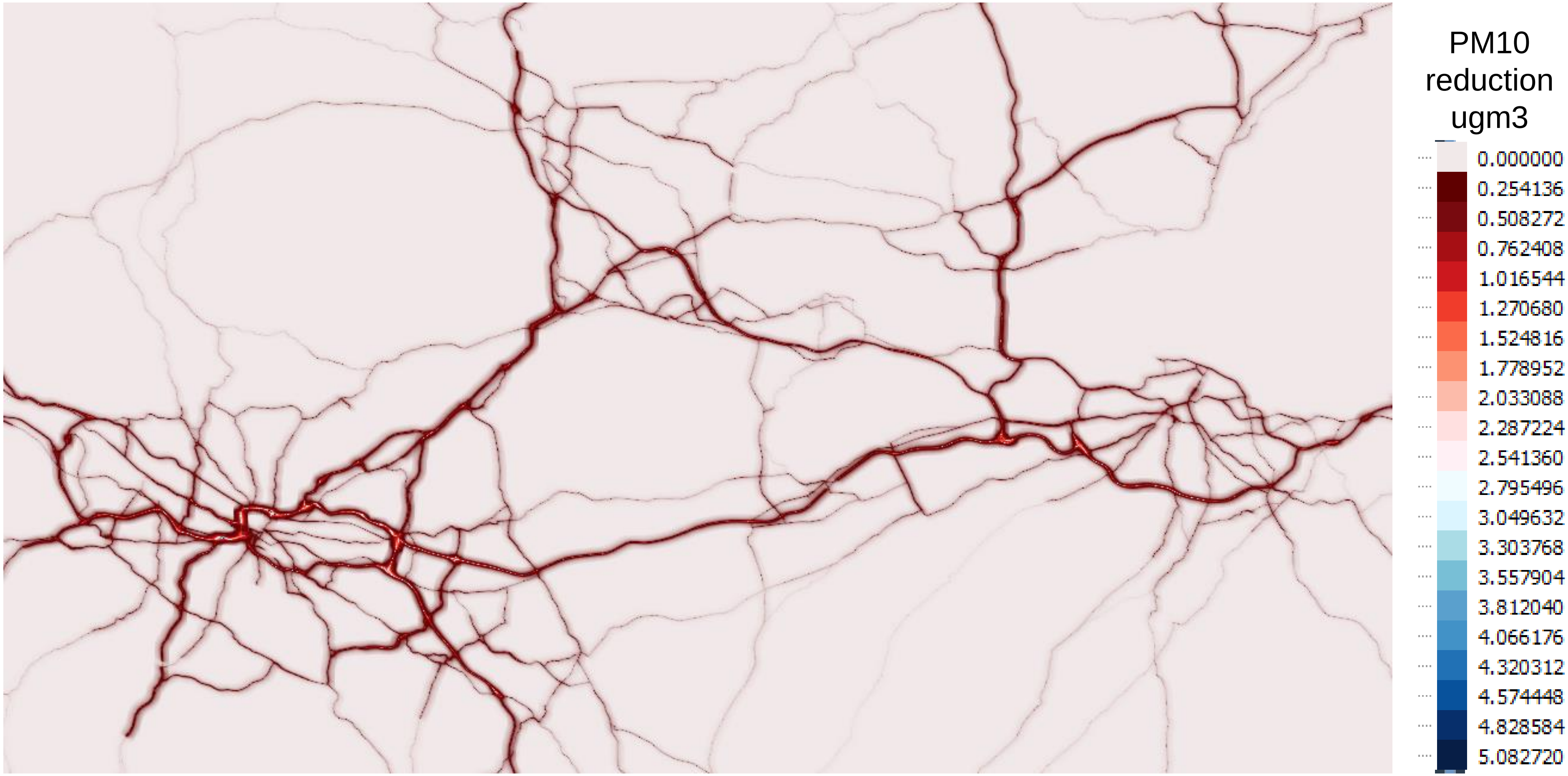




PM10 cross road profile of concentrations- M74 in Glasgow



PM10 difference plot- central belt (base minus BAT)



Very highest concentrations are attenuated by up to 5 ugm3, more typically roadside concentrations reduced by about 0.5 to 1 ugm3.

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

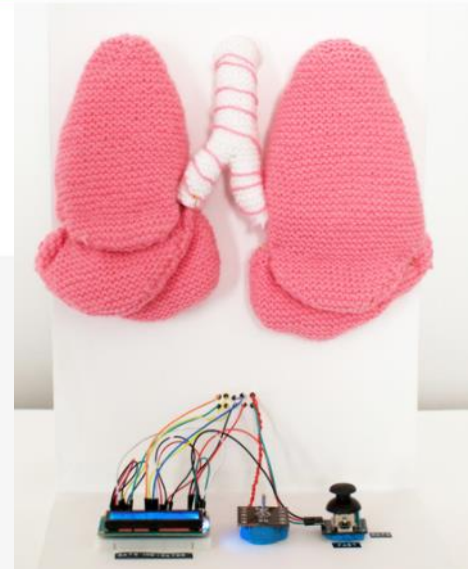
KANTAR
Information is Beautiful
Awards

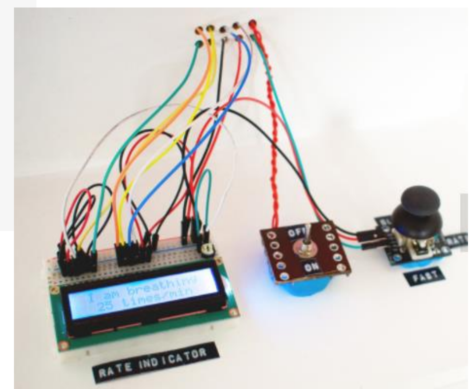
About News Awards Showcase

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





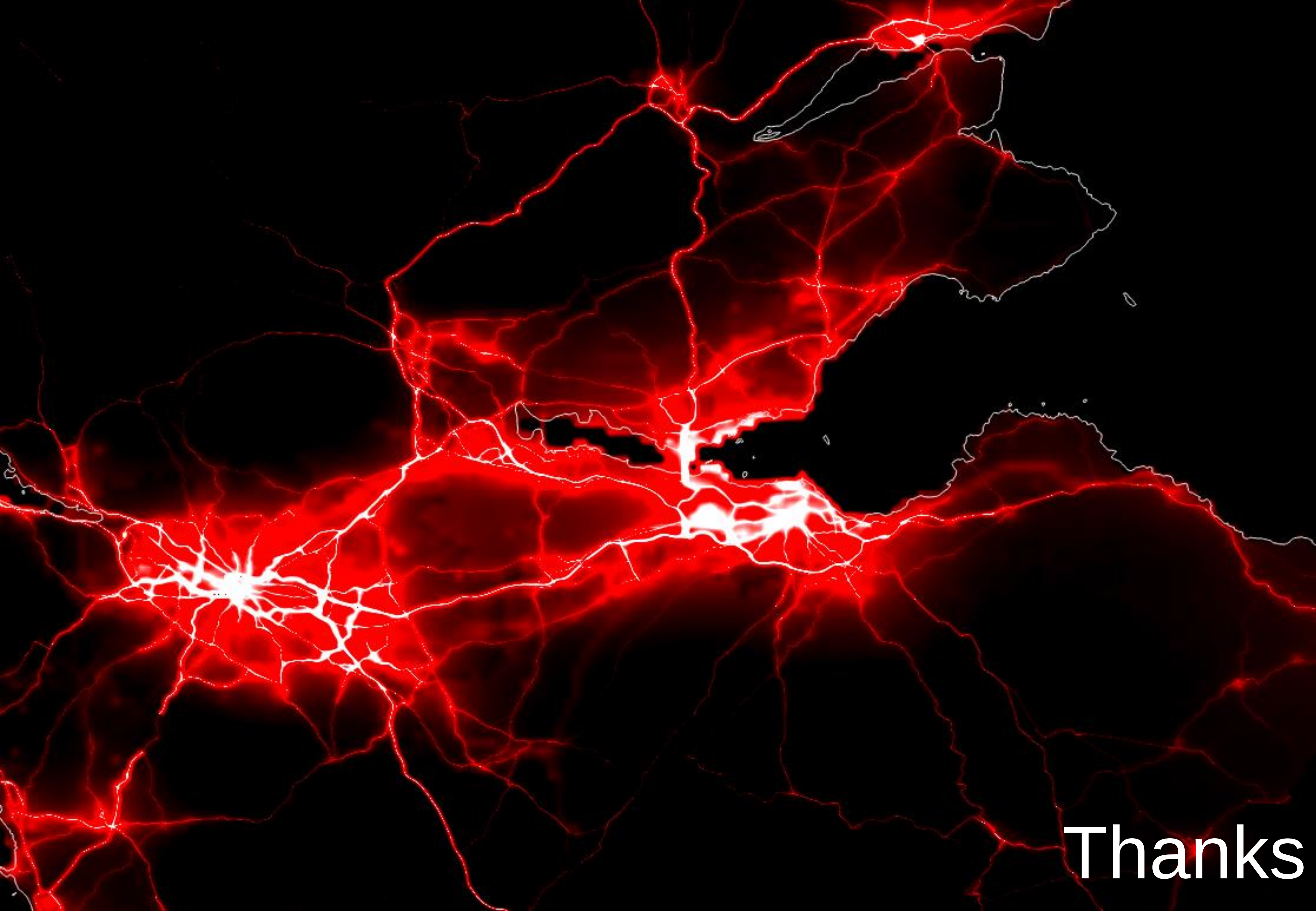
Results from a Ricardo collaboration with Trudi Hannah at Glasgow School of Art.

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 NOx from better vehicles has the potential to deliver quite large reductions in NO_2 in our towns and cities. This is mainly because road traffic NOx is still the dominant source driving high concentrations
  - Going beyond BAT and removing diesel vehicles delivers additional gains but these are more marginal for NOx
  - The same vehicle improvements reduce PM_{10} as well but by a smaller amount
  - The reduction in PM_{10} 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 PM_{10} 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 PM_{10} in Scotland.


Thanks

RICARDO

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