The EMEP4UK model:
examples of some current applications & developments

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with acknowledgements to many other collaborators and PhD students at …. UoE Schools of Chemistry & GeoSciences, CEH, EMEP MSC-W, CERC, IMK-IFU Karlsruhe, …..

and to funders
…. NERC, CEH, Defra, EMEP, EU-ECLAIRE …..

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THE UNIVERSITY OF EDINBURGH

Outline

- Brief description of the EMEP4UK regional atmospheric chemistry transport model (ACTM)

- Example applications:
  - The recent UK PM episode
  - Mitigation of UK $PM_{2.5}$

- Example ongoing developments:
  - Increasing spatial resolution ($\rightarrow$ for health exposure)
  - Coupling to dynamic emissions

The EMEP4UK ACTM

3D Eulerian framework (Vieno et al., 2010) derived from EMEP MSC-W model (Simpson et al., 2012)

5 km × 5 km British Isles grid nested within EMEP 50 km × 50 km domain

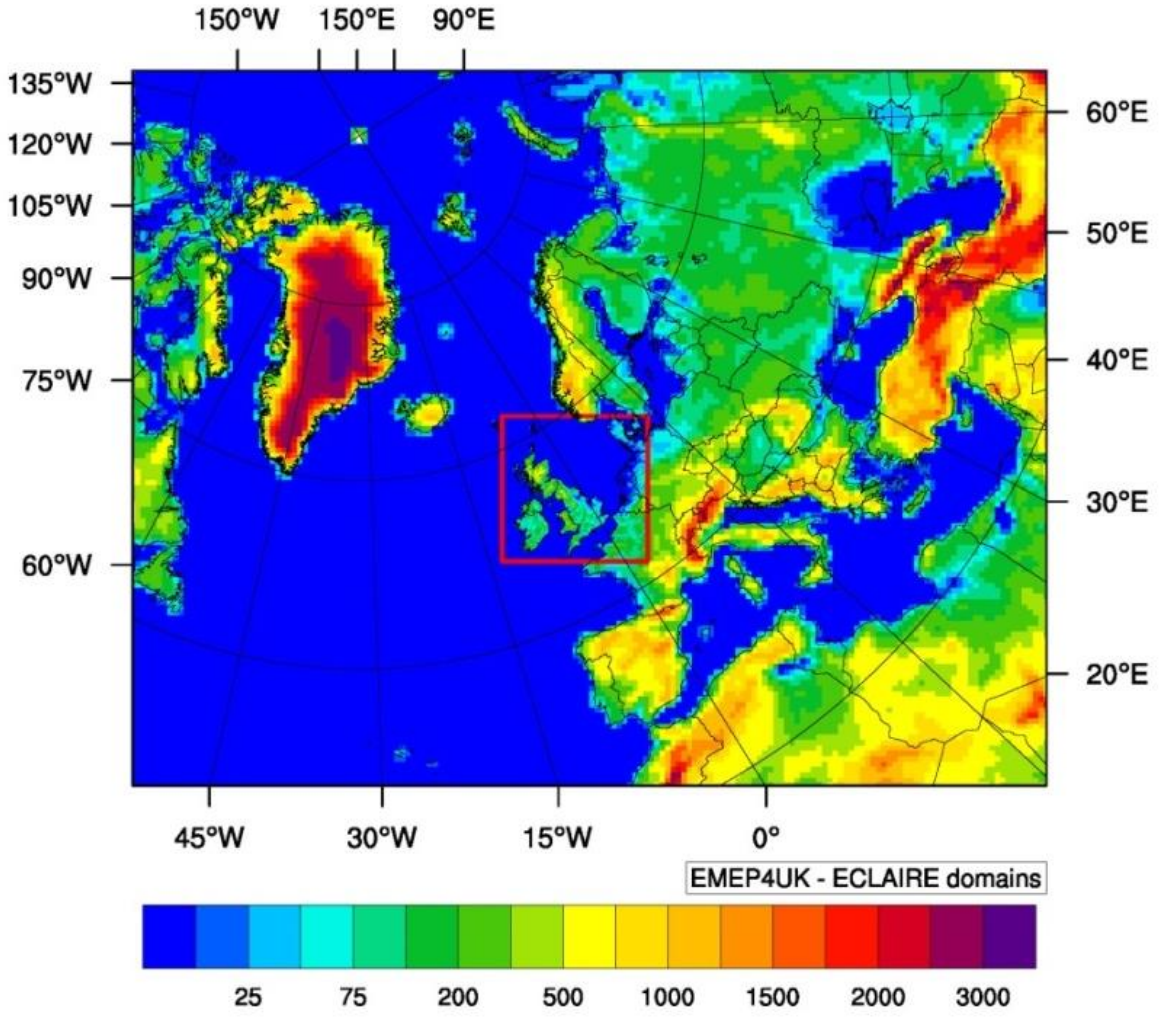
20 vertical layers to ~16 km, surface layer 90 m

Meteorology driver is WRF 3.5 (www.wrf-model.org)

CRIv2 R5 chemical solver (195 species, 569 reactions; Watson et al. 2008)

PM includes SIA, SOA, sea-salt, dust, forest fire…

Dry and wet deposition as for EMEP main model



⇒ Hourly output of concentrations, deposition & met variables

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Rapid simulations of the spring 2014 UK particulate matter air pollution event


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2 April 2014 Last updated at 15:28

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Air pollution: High levels to spread across England

The pollution has caused a thick layer of dust to form on cars and buildings, as Pallab Ghosh reports

People with health problems are being warned to avoid strenuous activity after forecasts that air pollution will reach high levels in parts of England.

Defra issued warnings as high pollution levels were recorded on Tuesday.

The pollution - a mix of local and European emissions and dust from the Sahara - is forecast in parts of south England, the Midlands and East Anglia.

Related Stories

Why are pollution levels so high?

Saharan dust visible on cars

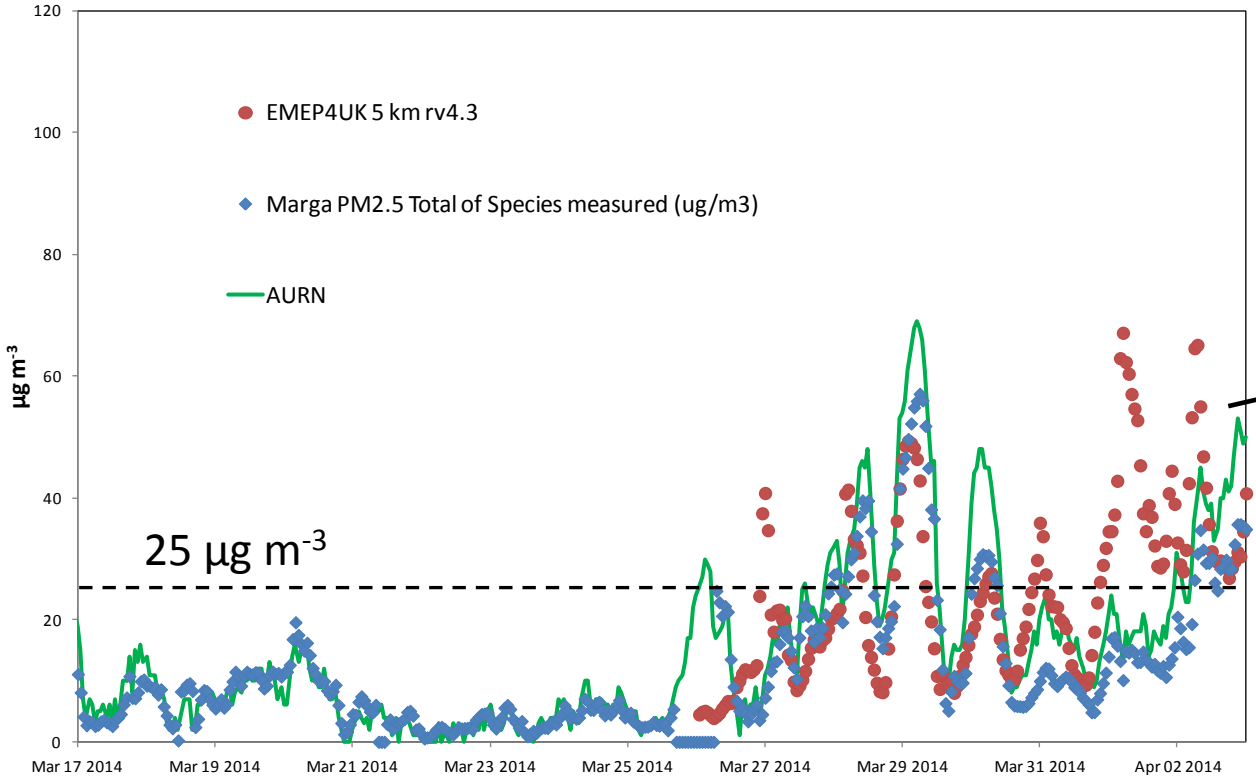
What will pollution do to us?

Used 2010 emissions

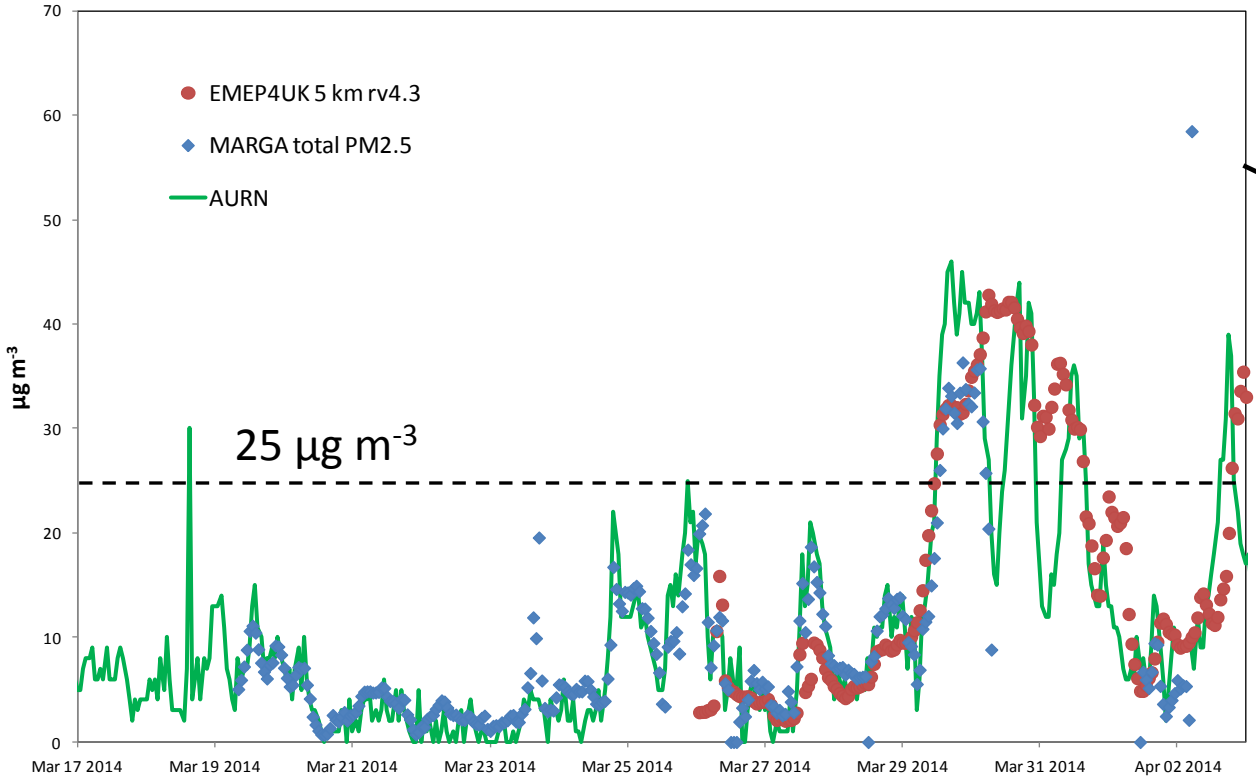
Contributions from UK/non-UK emissions investigated by simple sensitivity expt. with zero anthropogenic UK emissions

EMEP4UK vs. observations – hourly $PM_{2.5}$

Harwell $PM_{2.5}$

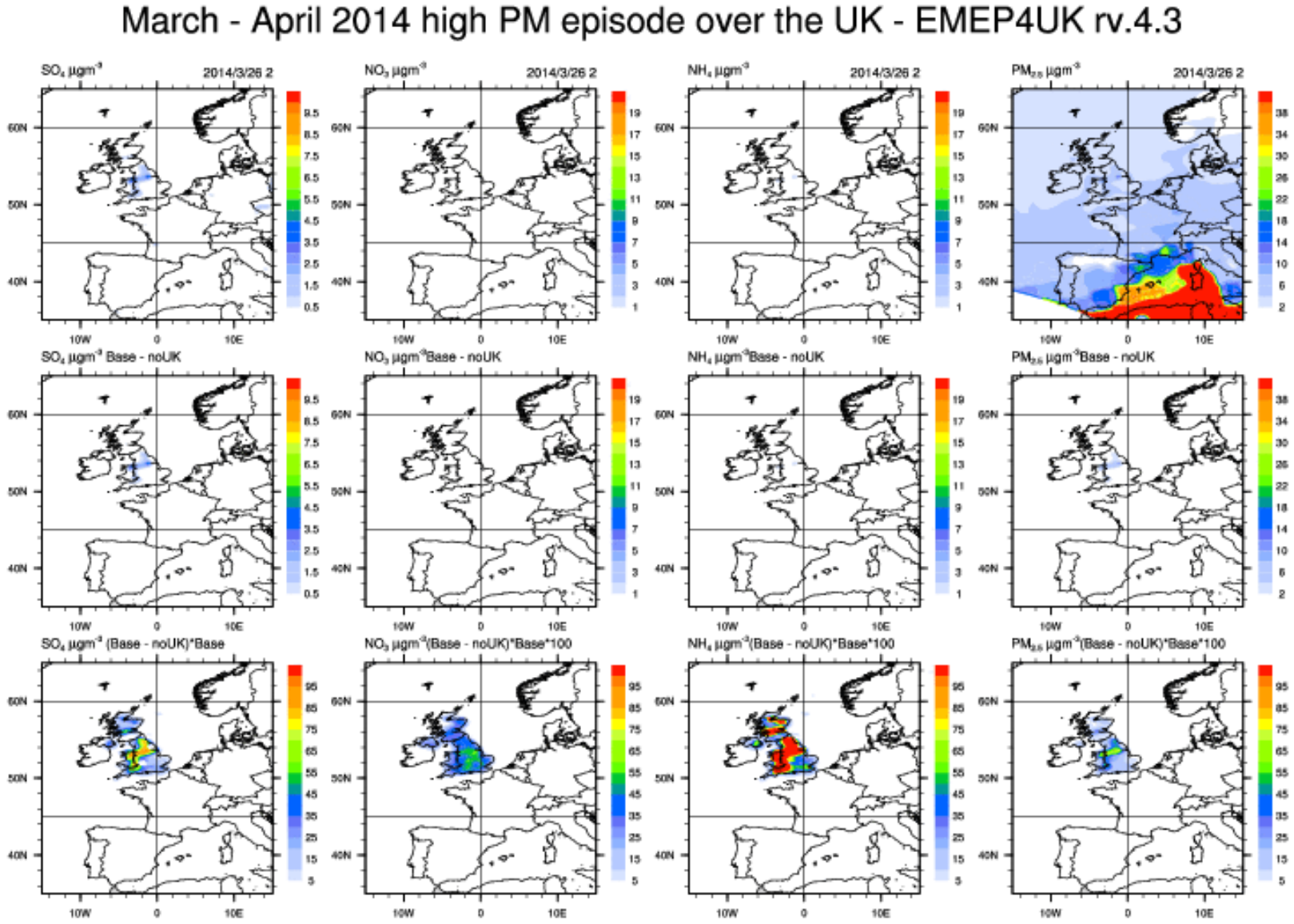


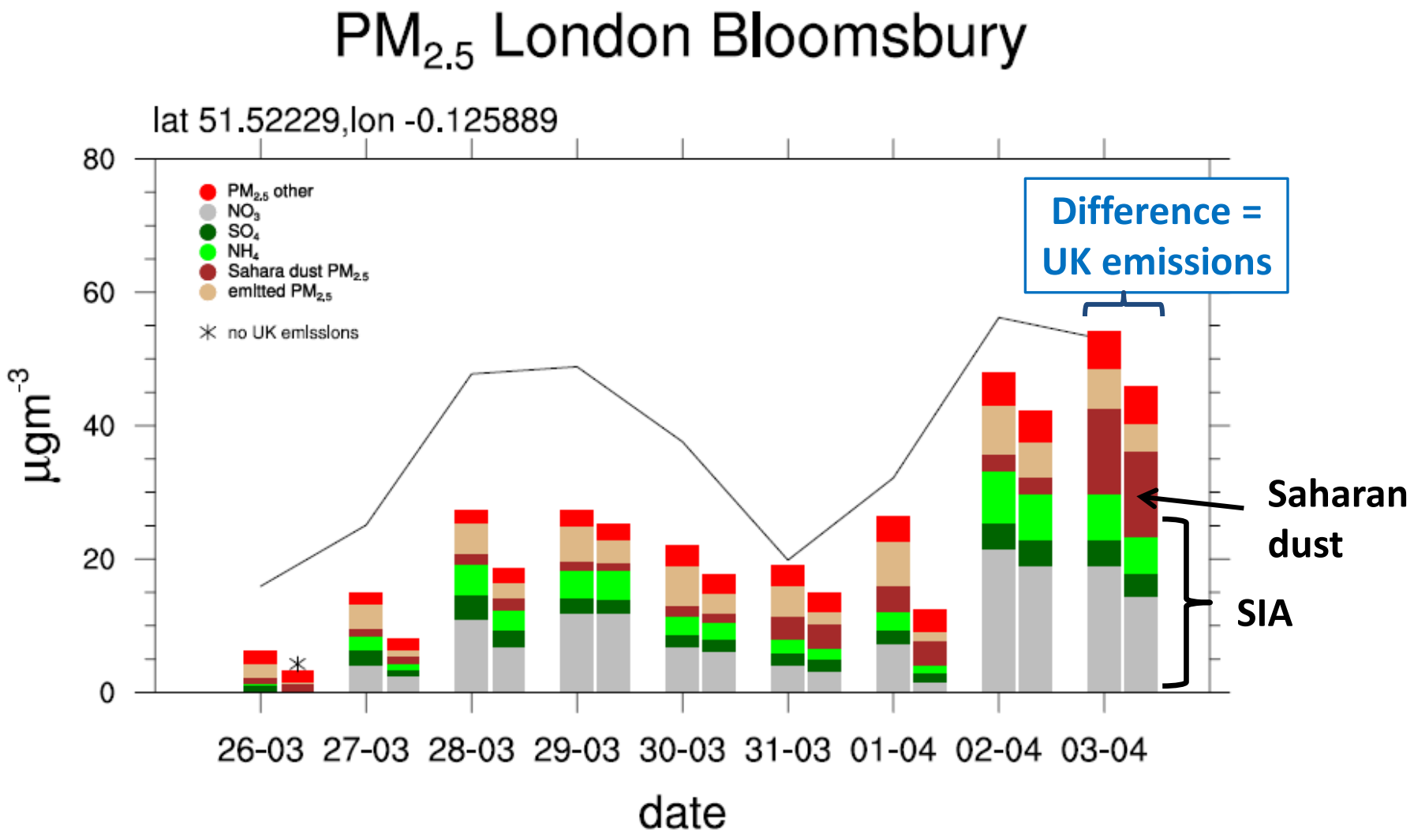
EMEP4UK vs. observations – hourly $PM_{2.5}$

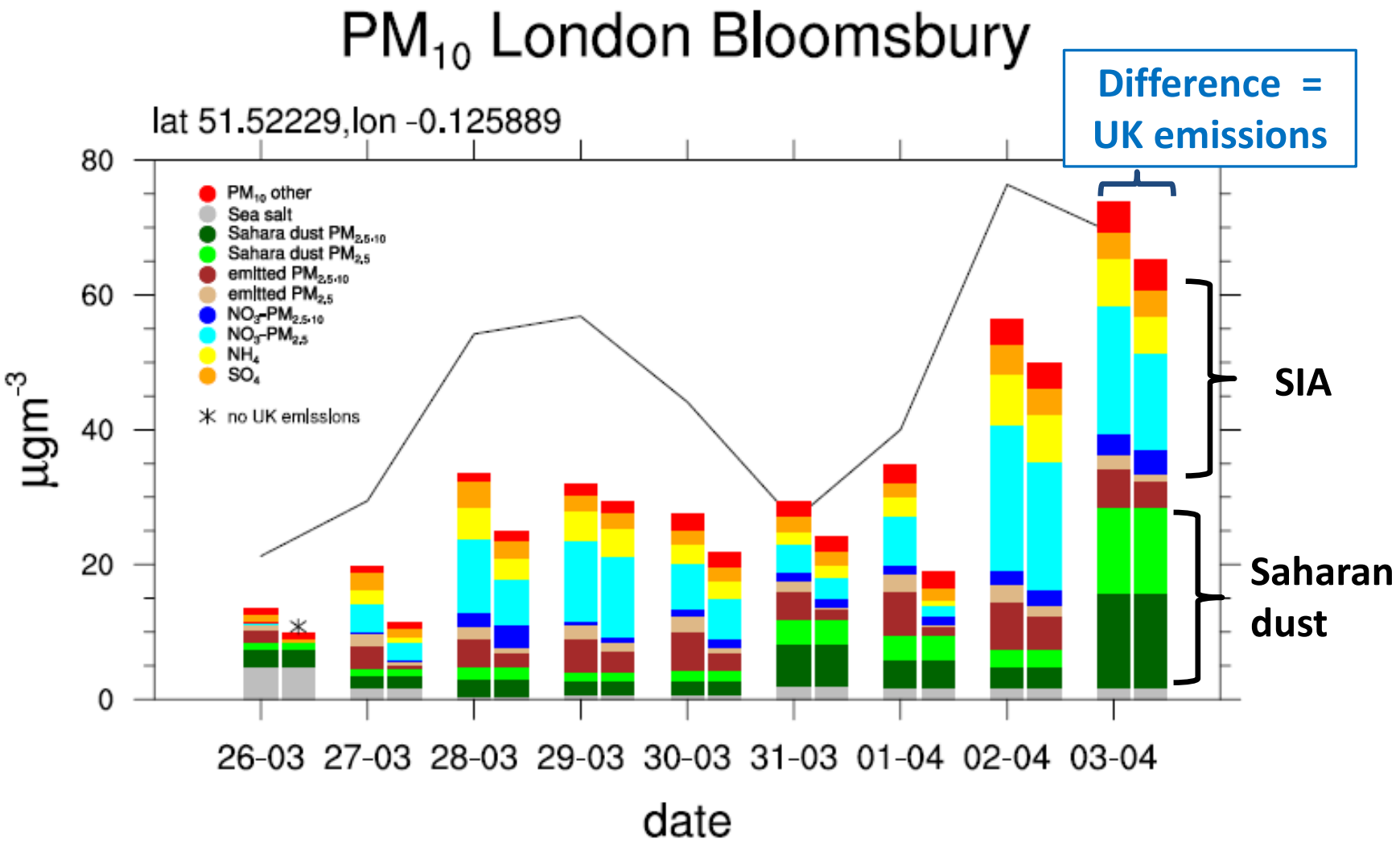


Auchencorth $PM_{2.5}$

Hourly means, 26th Mar – 3rd Apr




PM2.5 London Bloomsbury
lat 51.52229,lon -0.125889
PM2.5 other
NO3
SO4
NH4
Sahara dust PM2.5
emitted PM2.5
no UK emissions
Difference = UK emissions
Saharan dust
SIA
µgm-3
0
20
40
60
80
26-03
27-03
28-03
29-03
30-03
31-03
01-04
02-04
03-04
date


PM10 London Bloomsbury
lat 51.52229,lon -0.125889
Difference = UK emissions
PM10 other
Sea salt
Sahara dust PM2.5-10
Sahara dust PM2.5
emitted PM2.5-10
emitted PM2.5
NO3-PM2.5-10
NO3-PM2.5
NH4
SO4
no UK emissions
SIA
Saharan dust
µgm-3
0
20
40
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01-04
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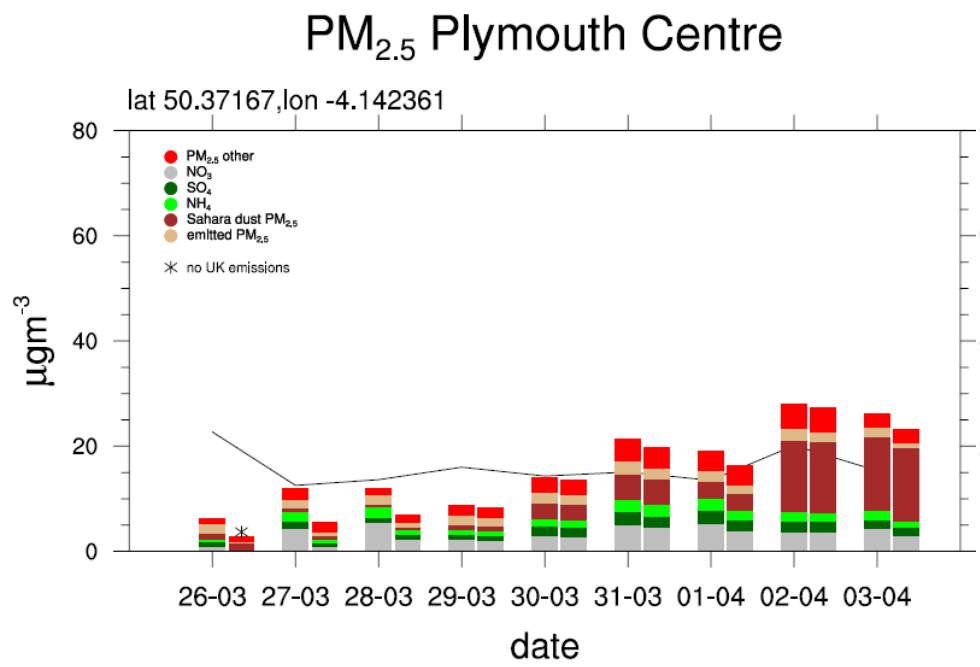
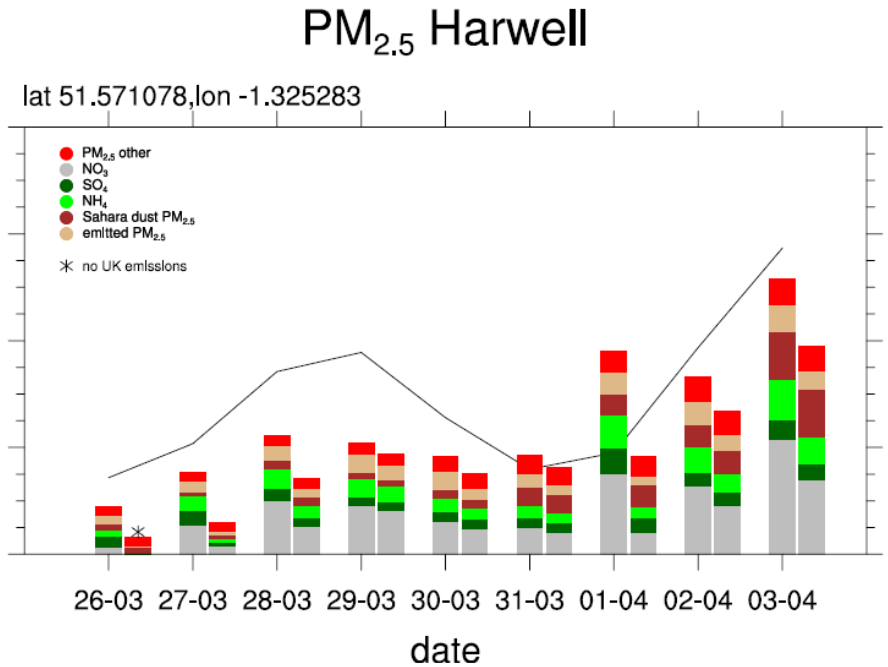
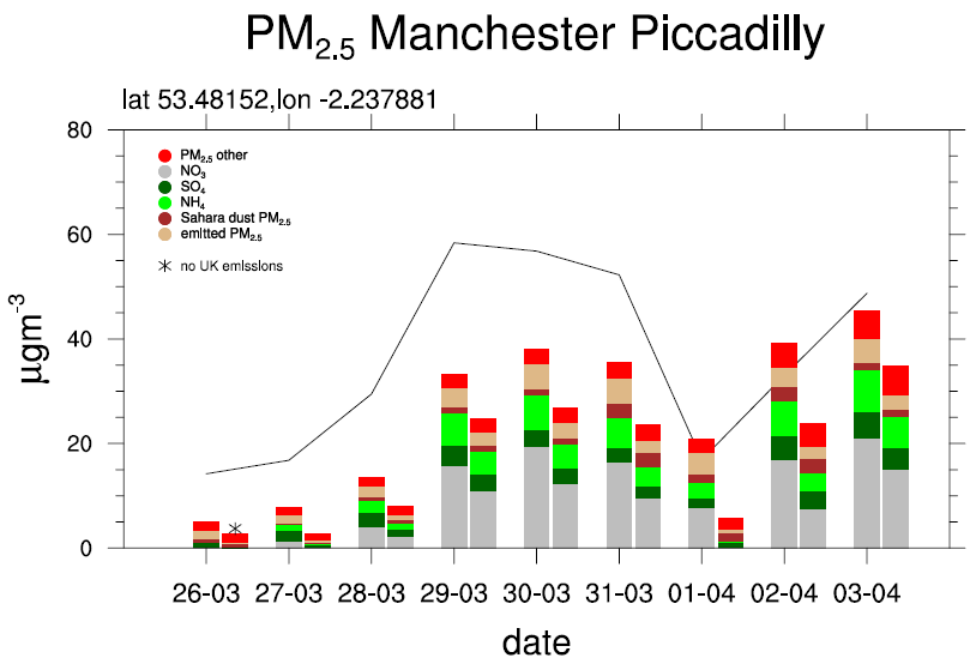
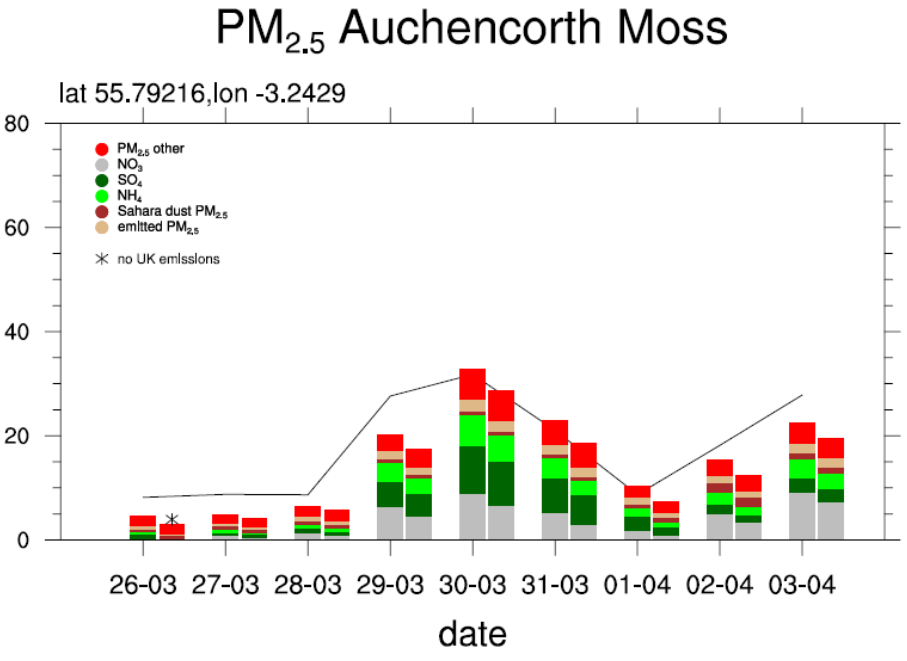
03-04
date


PM2.5 Plymouth Centre
lat 50.37167,lon -4.142361
PM2.5 other
NO3
SO4
NH4
Sahara dust PM2.5
emitted PM2.5
no UK emissions
μgm-3
0
20
40
60
80
26-03 27-03 28-03 29-03 30-03 31-03 01-04 02-04 03-04
date


PM2.5 Harwell
lat 51.571078,lon -1.325283
PM2.5 other
NO3
SO4
NH4
Sahara dust PM2.5
emitted PM2.5
no UK emissions
0
20
40
60
80
26-03 27-03 28-03 29-03 30-03 31-03 01-04 02-04 03-04
date


PM2.5 Manchester Piccadilly
lat 53.48152,lon -2.237881
PM2.5 other
NO3
SO4
NH4
Sahara dust PM2.5
emitted PM2.5
no UK emissions
μgm-3
0
20
40
60
80
26-03 27-03 28-03 29-03 30-03 31-03 01-04 02-04 03-04
date


PM2.5 Auchencorth Moss
lat 55.79216,lon -3.2429
PM2.5 other
NO3
SO4
NH4
Sahara dust PM2.5
emitted PM2.5
no UK emissions
0
20
40
60
80
26-03 27-03 28-03 29-03 30-03 31-03 01-04 02-04 03-04
date

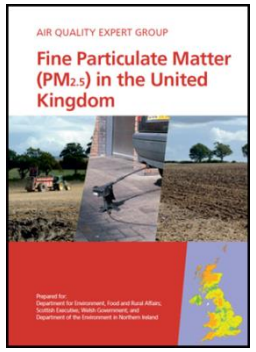
- The EMEP4UK model does a reasonable job of simulating the magnitude and timing of the development of the episode for $PM_{2.5}$ (& PM_{10}) across the UK

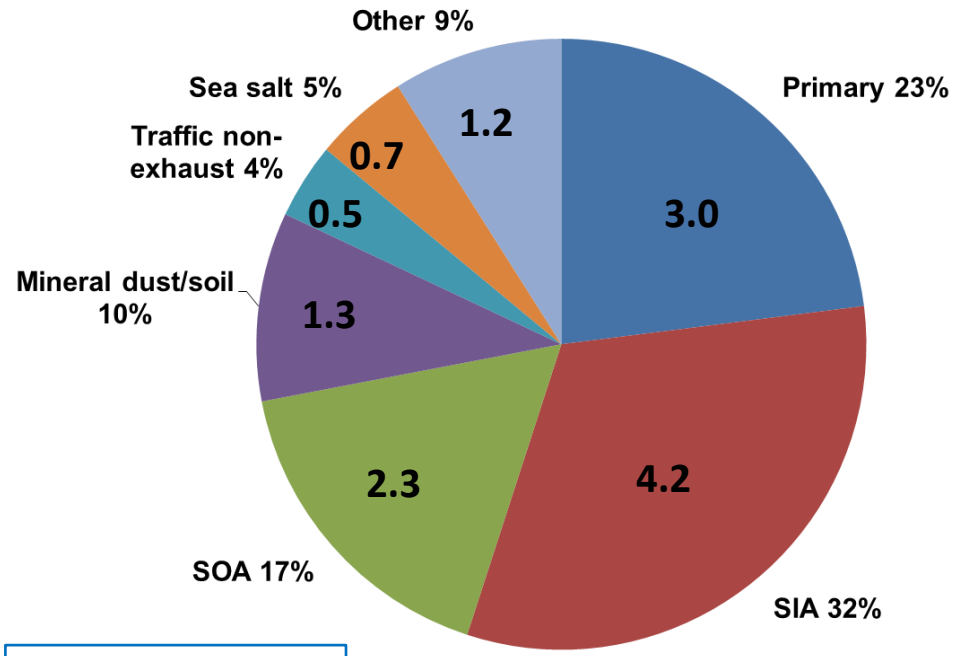
- Substantial $PM_{2.5}$ from non-UK emissions during the episode

- Nitrate is a major component of $PM_{2.5}$ throughout this period; Saharan dust arrives later

Modelling support for Air Quality Expert Group report "Mitigation of $PM_{2.5}$"

(Follow-up to AQEG's $PM_{2.5}$ report)



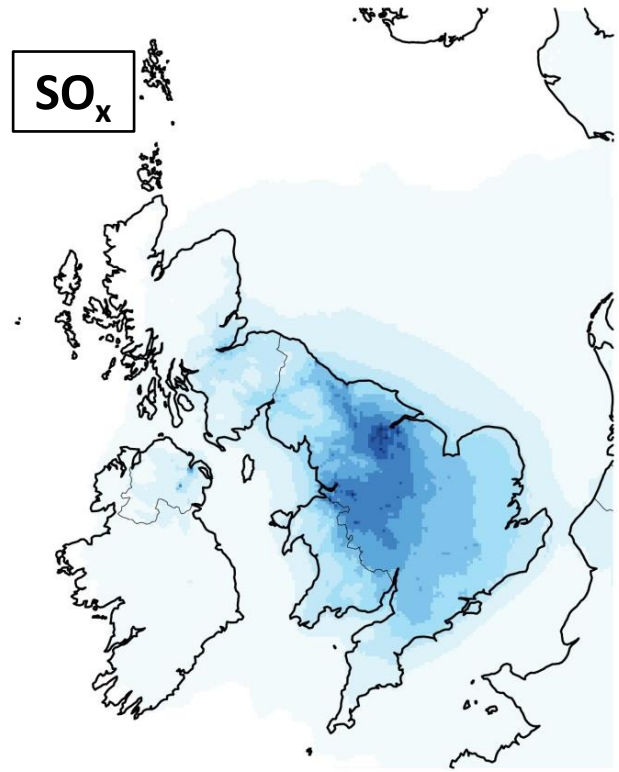


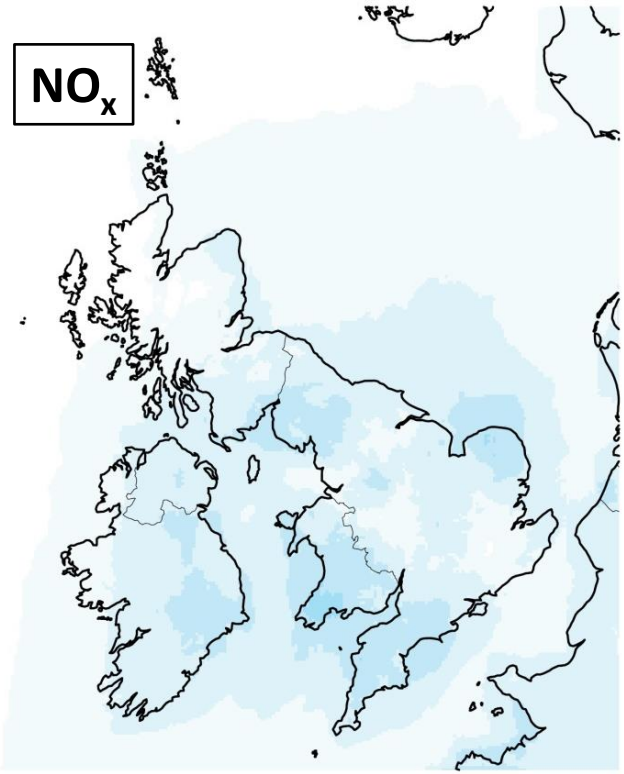
UK AEI 13 µg m^{-3} (PCM model)

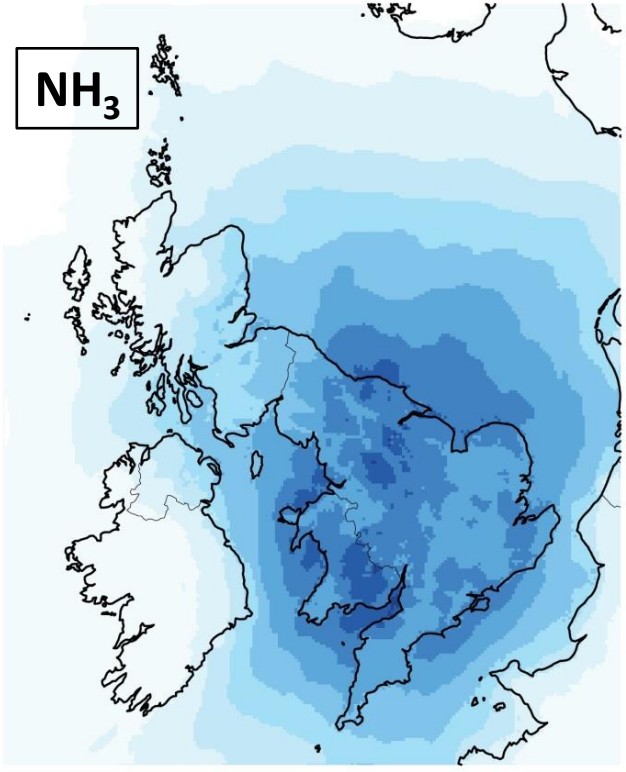
- To quantify how much of the $PM_{2.5}$ in the UK is controllable, at least in principle, by the UK
- Identify what component emissions reductions are most effective in reducing total $PM_{2.5}$

⇒ EMEP4UK sensitivity experiments where UK anthropogenic emissions of NH_3, NO_x, SO_2 and primary $PM_{2.5}$ each reduced by 30%

Reductions in $PM_{2.5}$ (µg m^{-3}) for 30% reductions in UK SO_x, NO_x or NH_3 emissions







70% SO_x emis - Base

-0.45 -0.3 -0.15 0 0.15 0.3 0.45

70% NO_x emis - Base

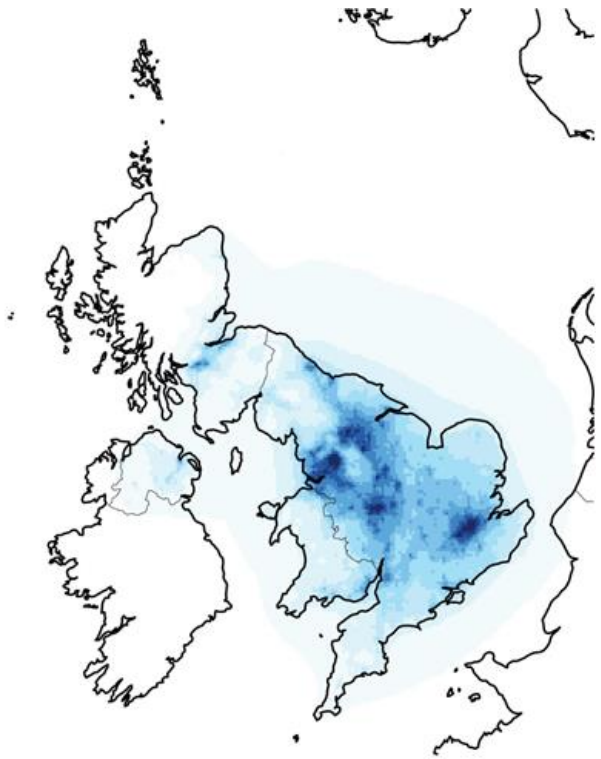
-0.45 -0.3 -0.15 0 0.15 0.3 0.45

70% NH_3 emis - Base

-0.45 -0.3 -0.15 0 0.15 0.3 0.45

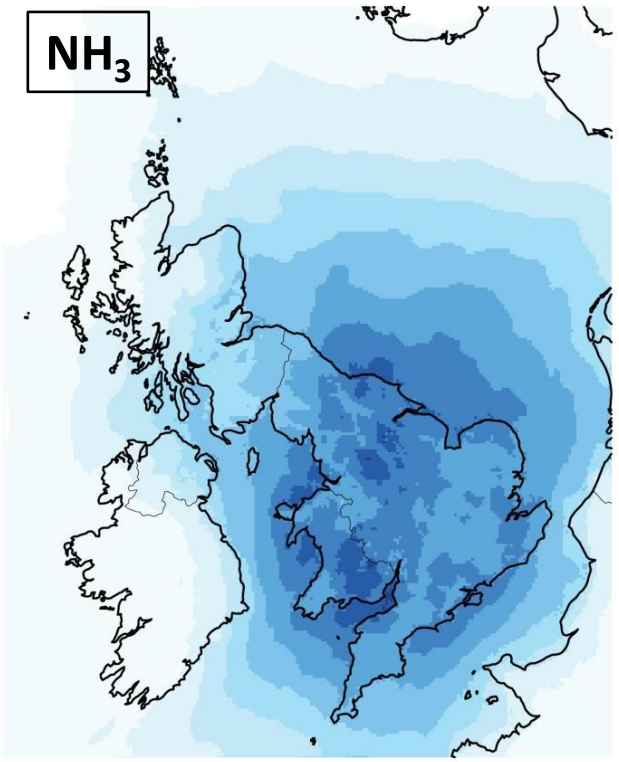
Only small reductions in UK $PM_{2.5}$ from 30% reductions in UK emissions

…and for 30% reductions in UK primary $PM_{2.5}$



70% PPM_{25} emis - Base

-0.45 -0.3 -0.15 0 0.15 0.3 0.45



70% NH_3 emis - Base

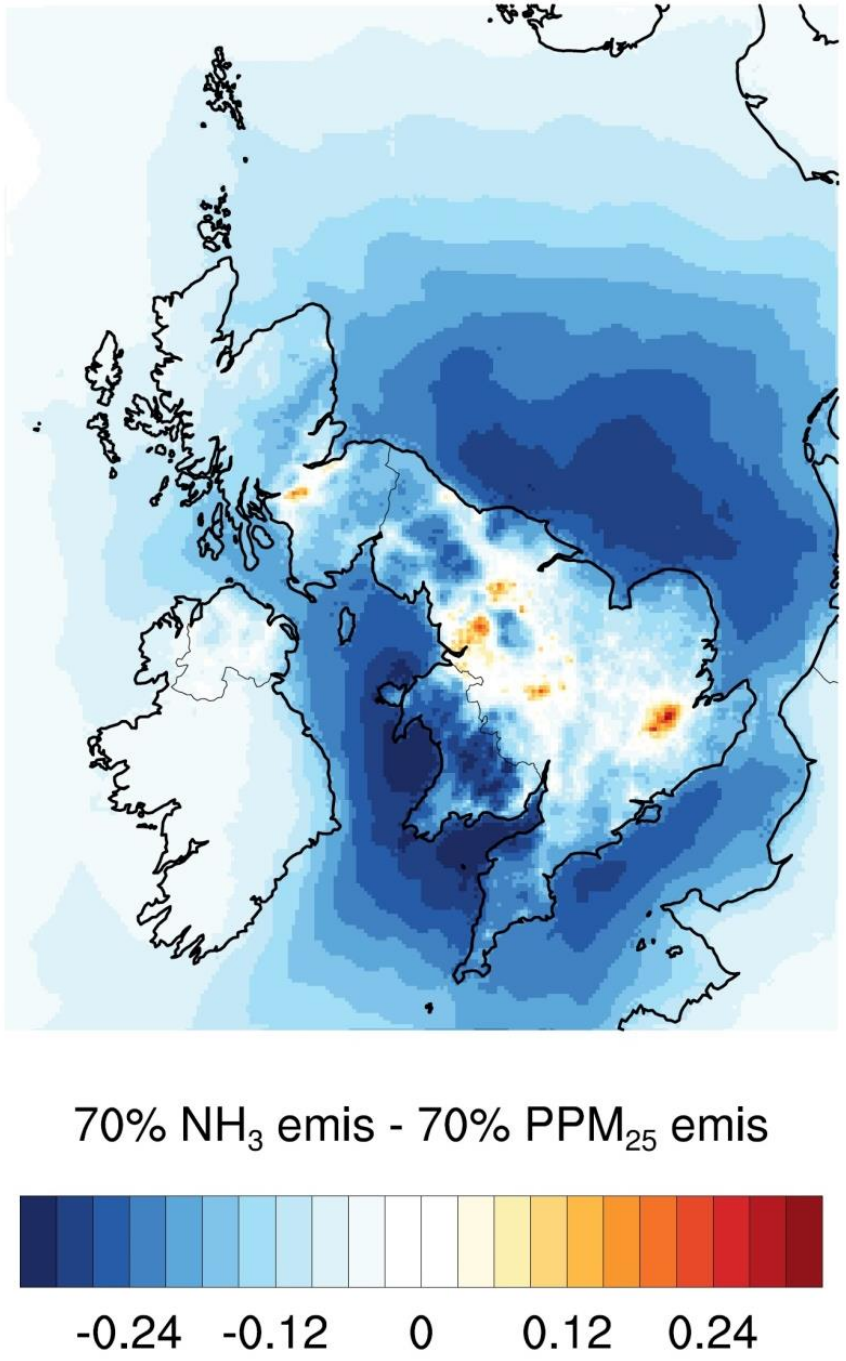
-0.45 -0.3 -0.15 0 0.15 0.3 0.45

Different spatial patterns from reductions in UK emissions of primary $PM_{2.5}$ and NH_3

The difference in effect on $PM_{2.5}$ of 30% reductions in UK NH_3 or primary $PM_{2.5}$

Blue = 30% NH_3 reductions more effective at mitigating $PM_{2.5}$ than 30% primary $PM_{2.5}$ reductions

Orange = 30% primary $PM_{2.5}$ reductions more effective at mitigating $PM_{2.5}$ than 30% NH_3 reductions



Estimates of impact of 30% UK emissions reductions on the UK $PM_{2.5}$ Average Exposure Indicator of ~13 µg m^{-3}

Component	EMEP4UK data	From other data	
Primary $PM_{2.5}$	0.4	up to 0.8	if 1:1 proportionality
NH_3	0.34	0.16-0.22 0.1-0.34	Nemitz et al. EMEP S-R
SO_2	0.28	0.14-0.20 0.12-0.35	Nemitz et al. EMEP S-R
NO_x	0.10	0.10-0.15 0.03-0.07	Nemitz et al. EMEP S-R
VOC	0.08	-	
Total	**~1.2 µg m^{-3}**	**~ 1 – 1.7 µg m^{-3}**	

Only ~10% reduction in AEI

Targeting primary $PM_{2.5}$ is most effective (but NH_3 and SO_2 also important)

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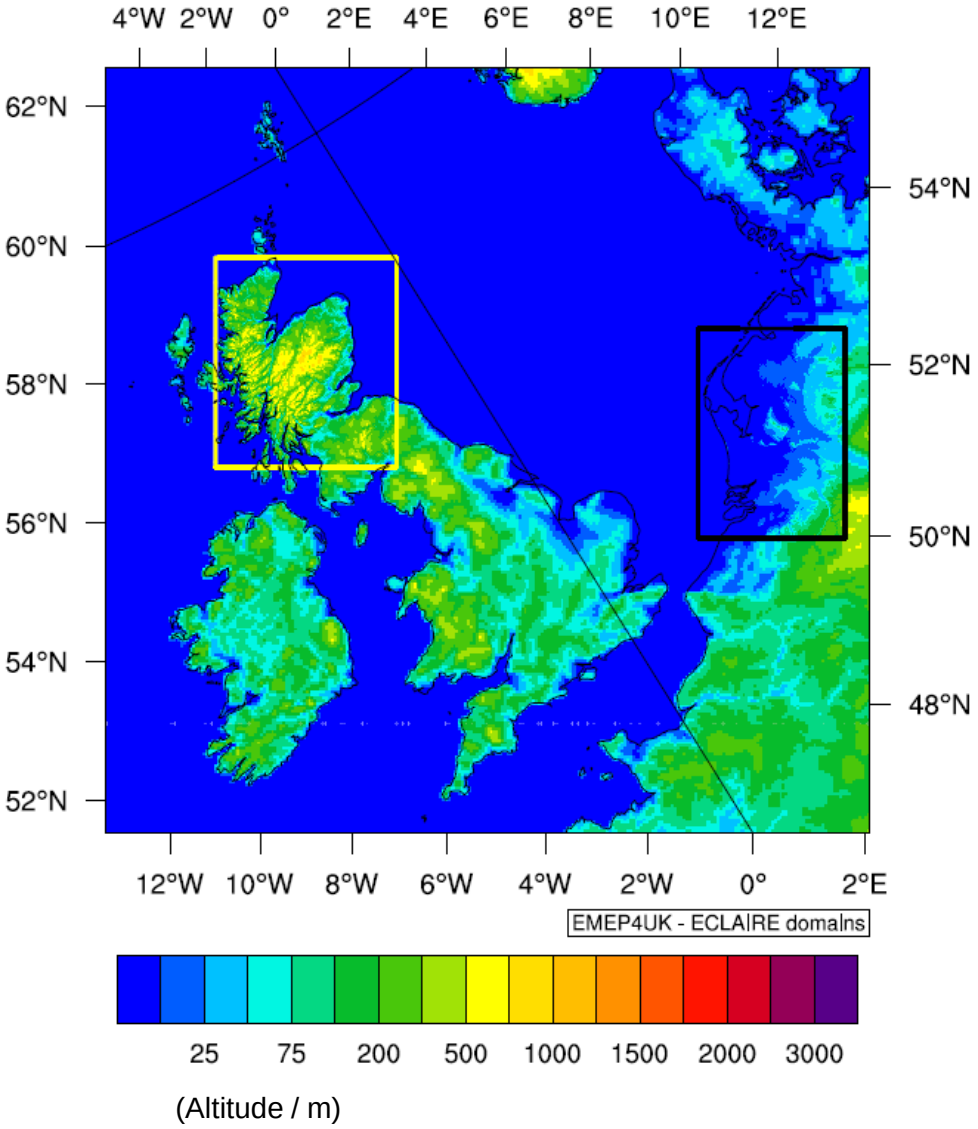
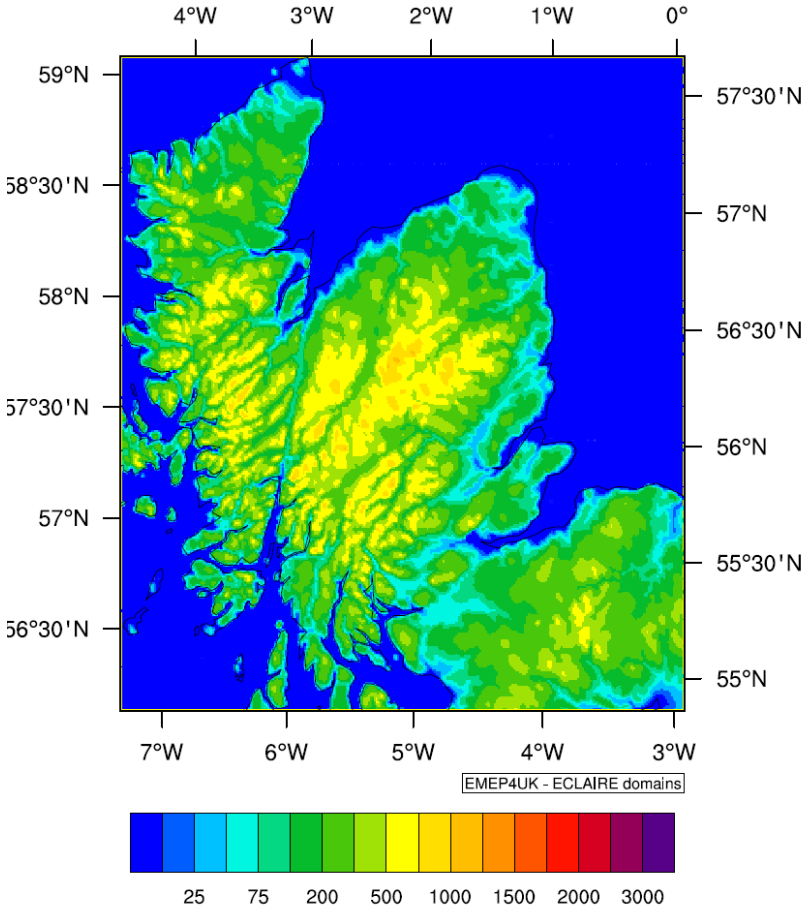
Increasing EMEP4UK rv4.3 horizontal resolution

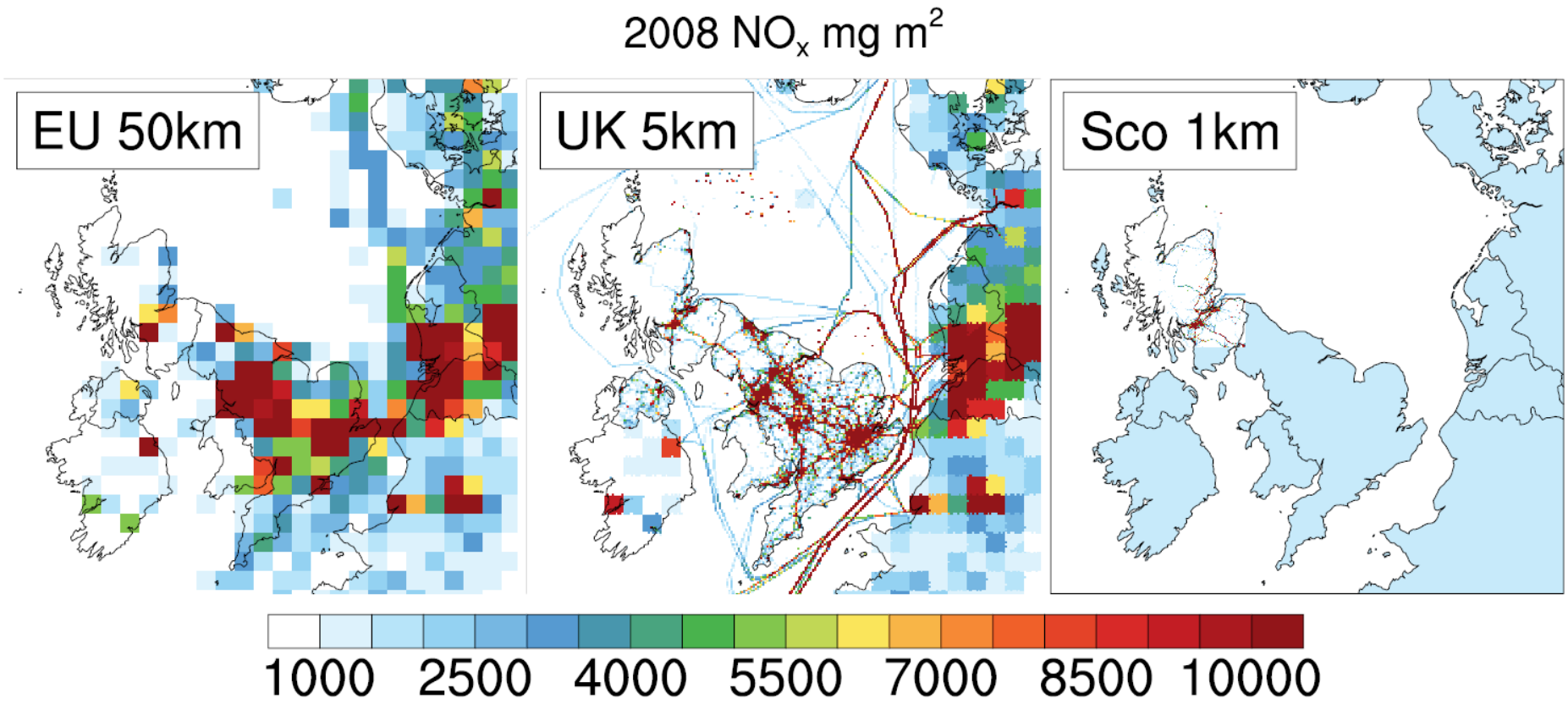


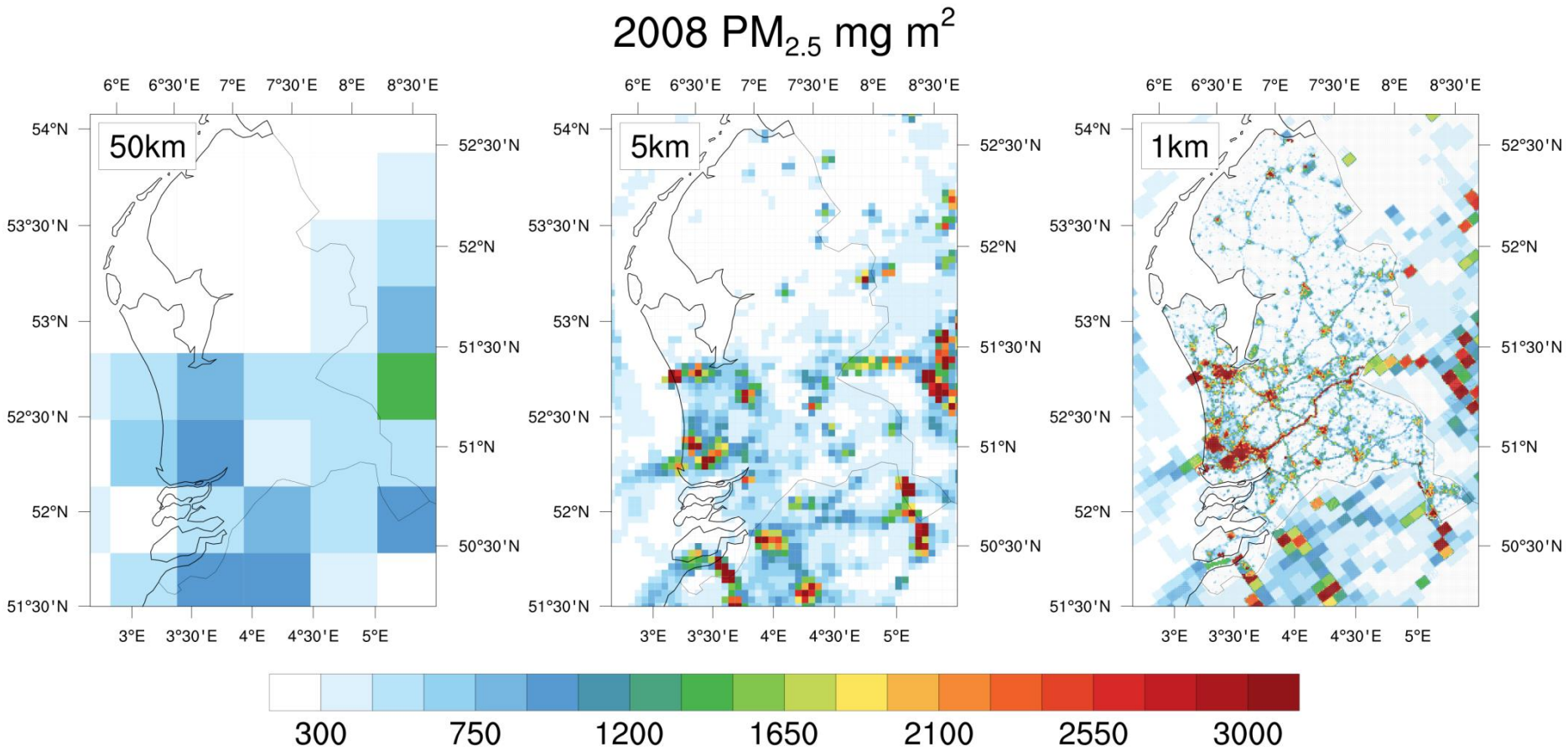


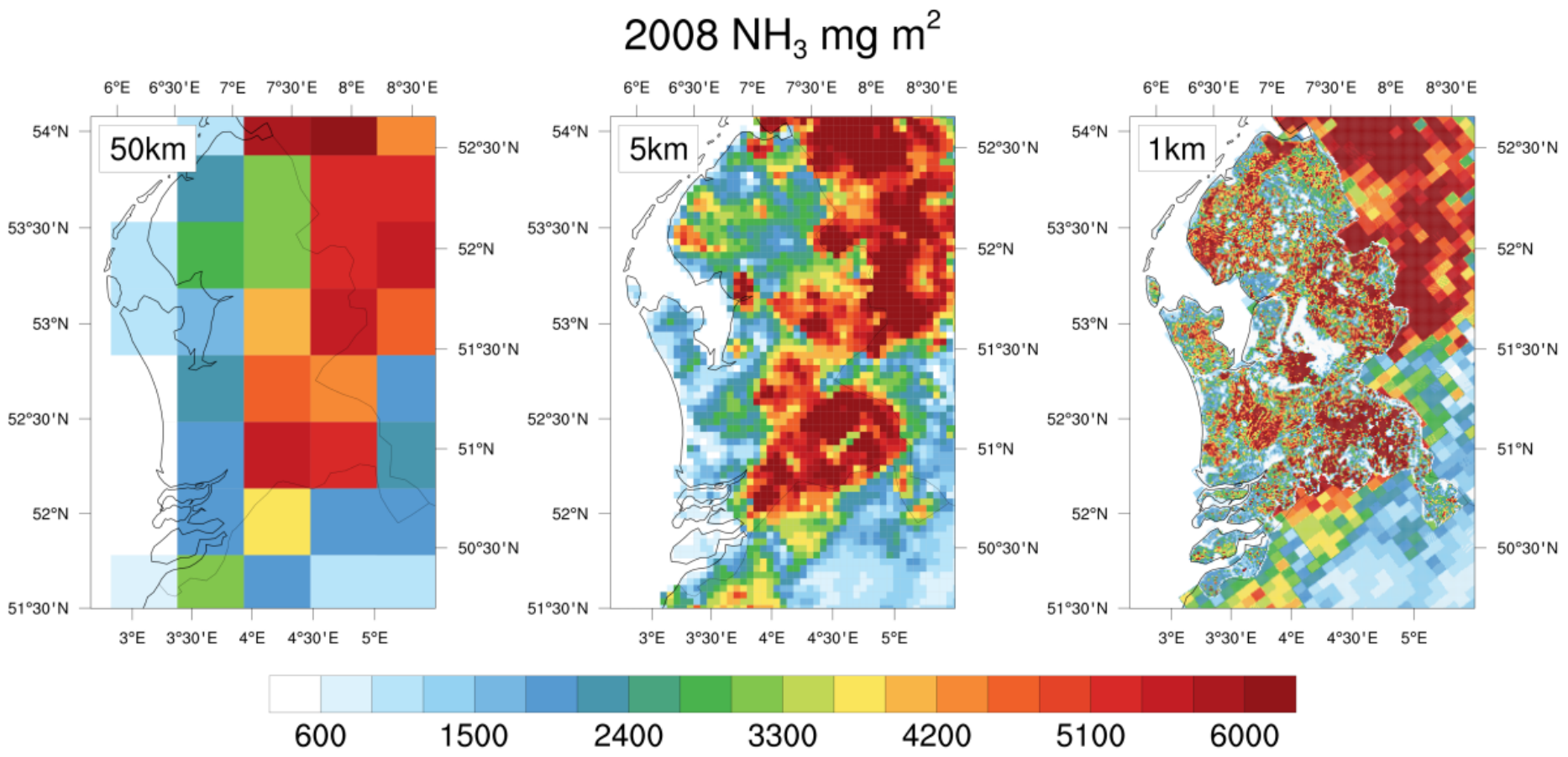
1 km spatial resolution

Visualisation of emissions at different scales

NO_x annual emissions

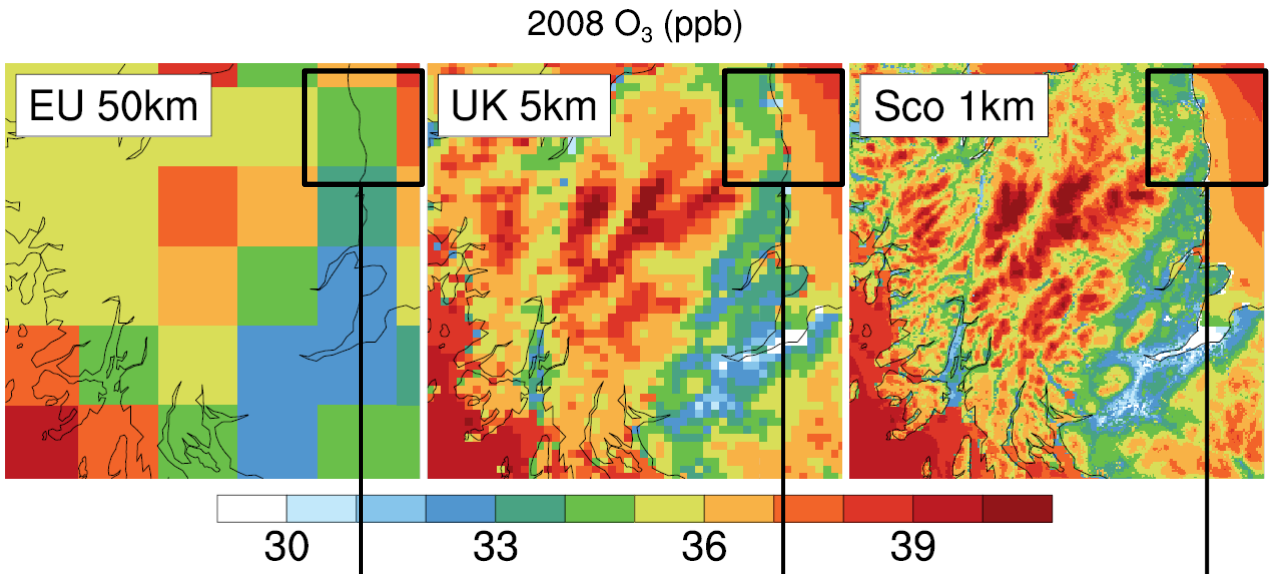



2008 PM2.5 mg m2
50km
5km
1km
6°E
6°30'E
7°E
7°30'E
8°E
8°30'E
54°N
53°30'N
53°N
52°30'N
52°N
51°30'N
51°N
50°30'N
3°E
3°30'E
4°E
4°30'E
5°E
300
750
1200
1650
2100
2550
3000


2008 NH3 mg m2
50km
5km
1km
6°E
6°30'E
7°E
7°30'E
8°E
8°30'E
54°N
53°30'N
53°N
52°30'N
52°N
51°30'N
51°N
50°30'N
3°E
3°30'E
4°E
4°30'E
5°E
600
1500
2400
3300
4200
5100
6000

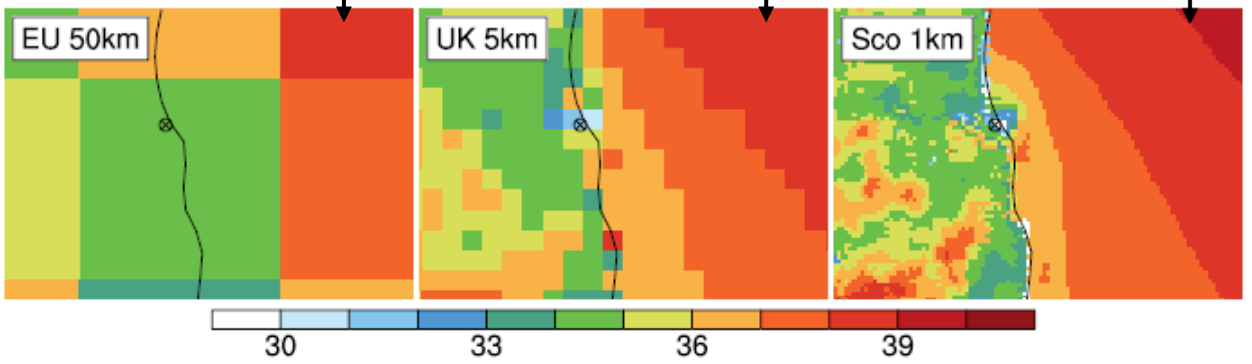
Effect of model resolution on simulated exposure

O_3

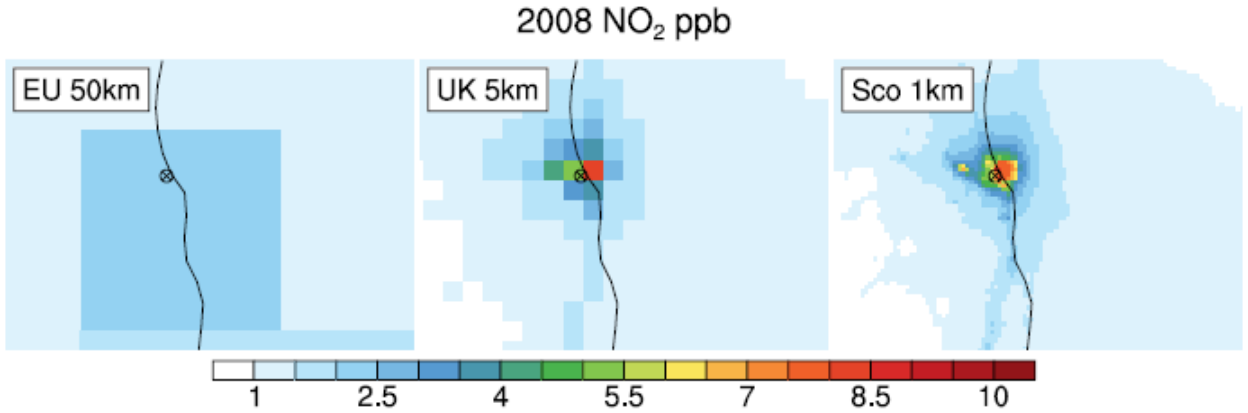


Area around Aberdeen as an example

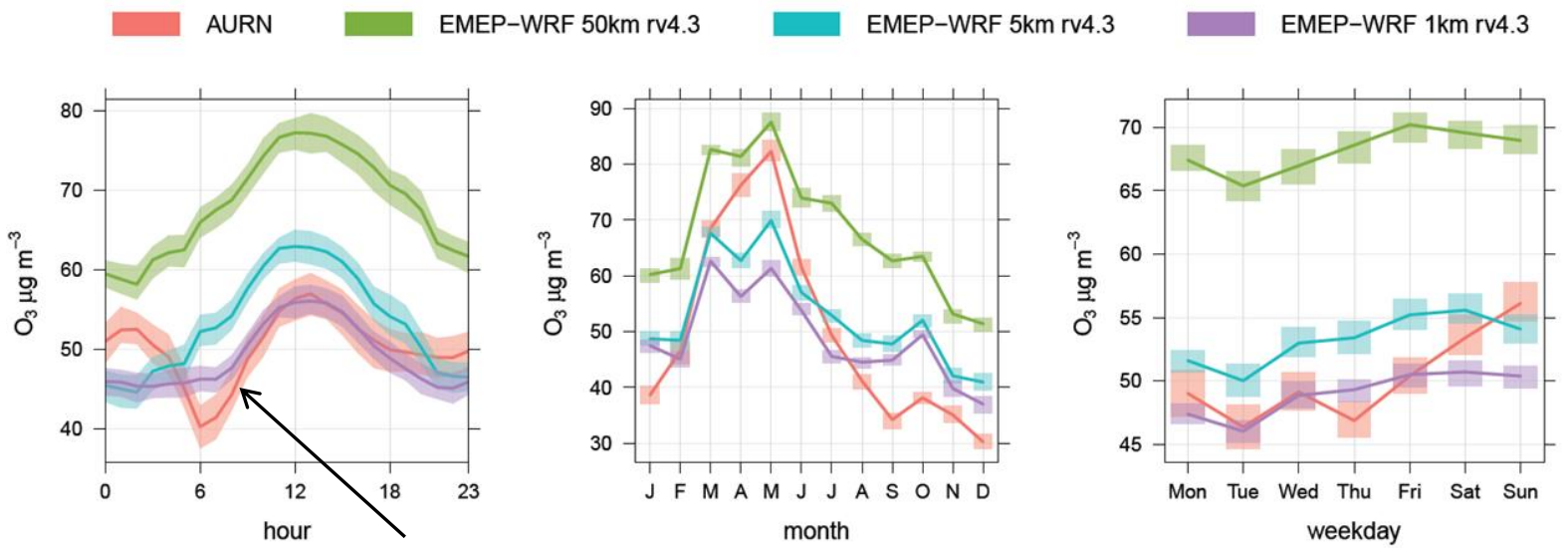
O_3



NO_2



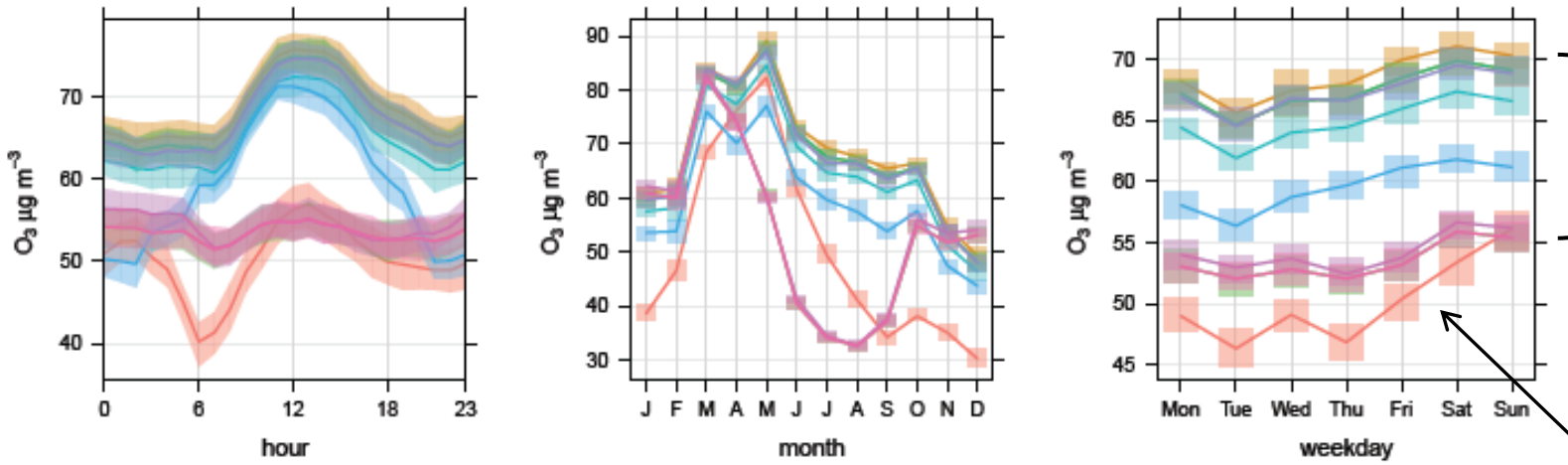
Effect of model resolution on mod-obs comparison



Aberdeen URBAN

red line: UK automatic monitoring network

Notable spatial range in urban O_3 (± 1 km grid cell)



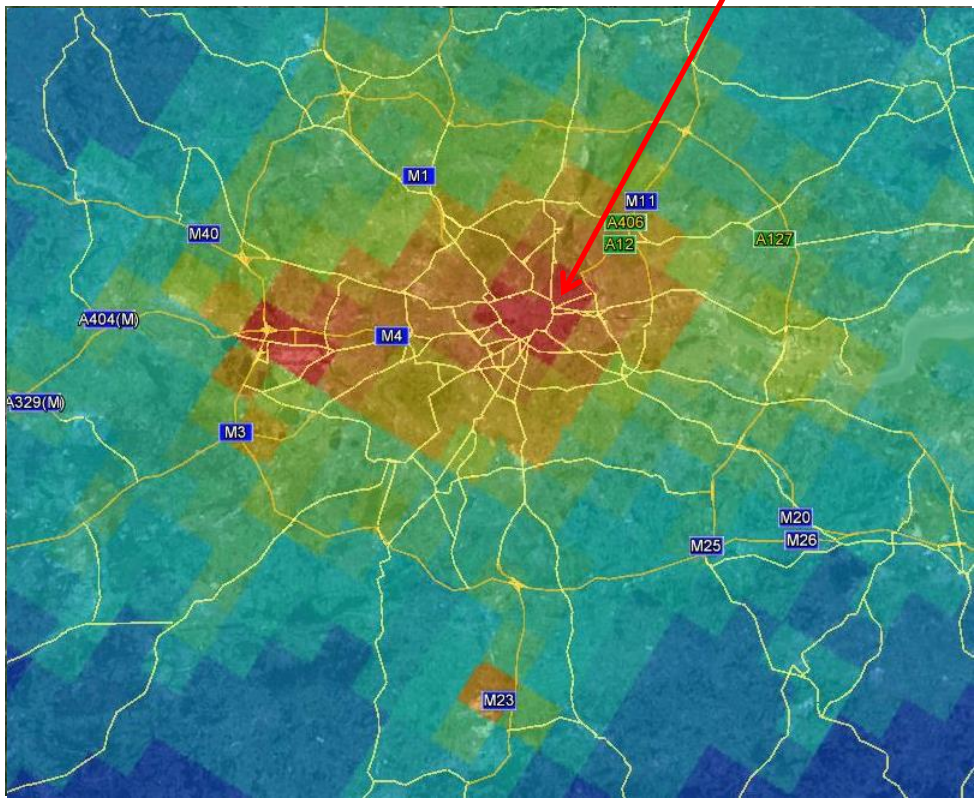
±1 grid cell variation is 15-20 µg m^{-3}

red line: UK automatic monitoring network

The need for yet higher spatial resolution

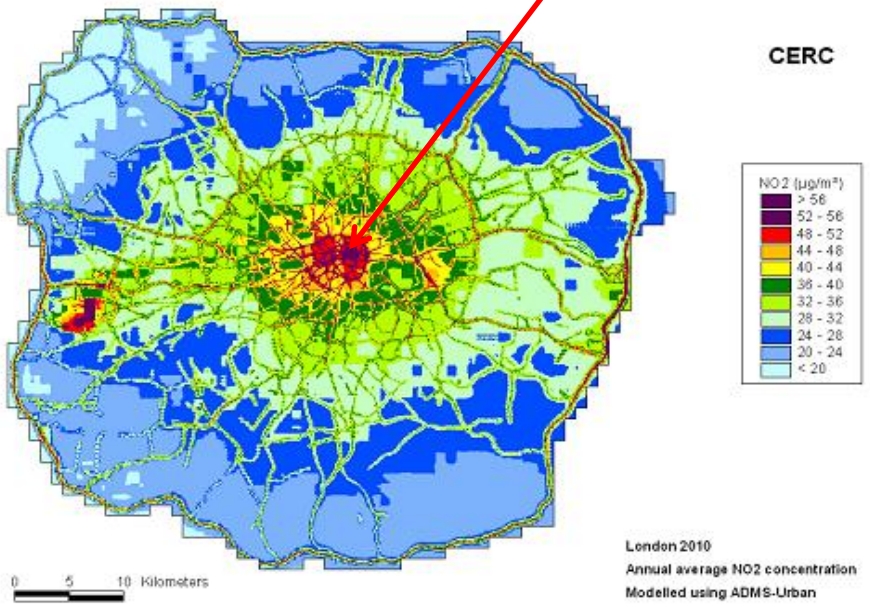
2010 annual average surface concentration of NO_2

~30 µg m^{-3}



EMEP4UK model 5 km × 5 km

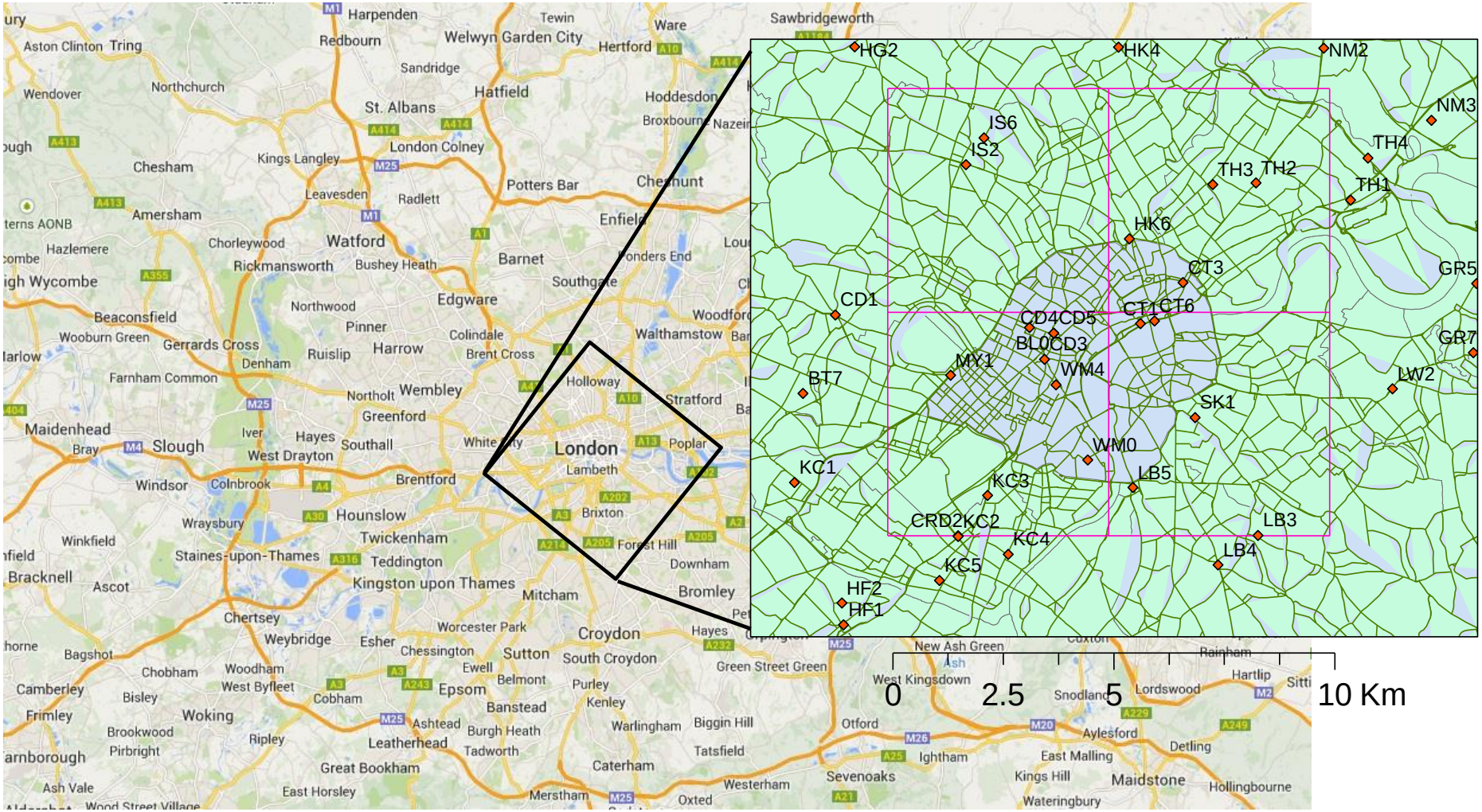
> 50 µg m^{-3}



ADMS-Urban model

CERC

Nesting ADMS-Urban within EMEP4UK – proof of concept in central London

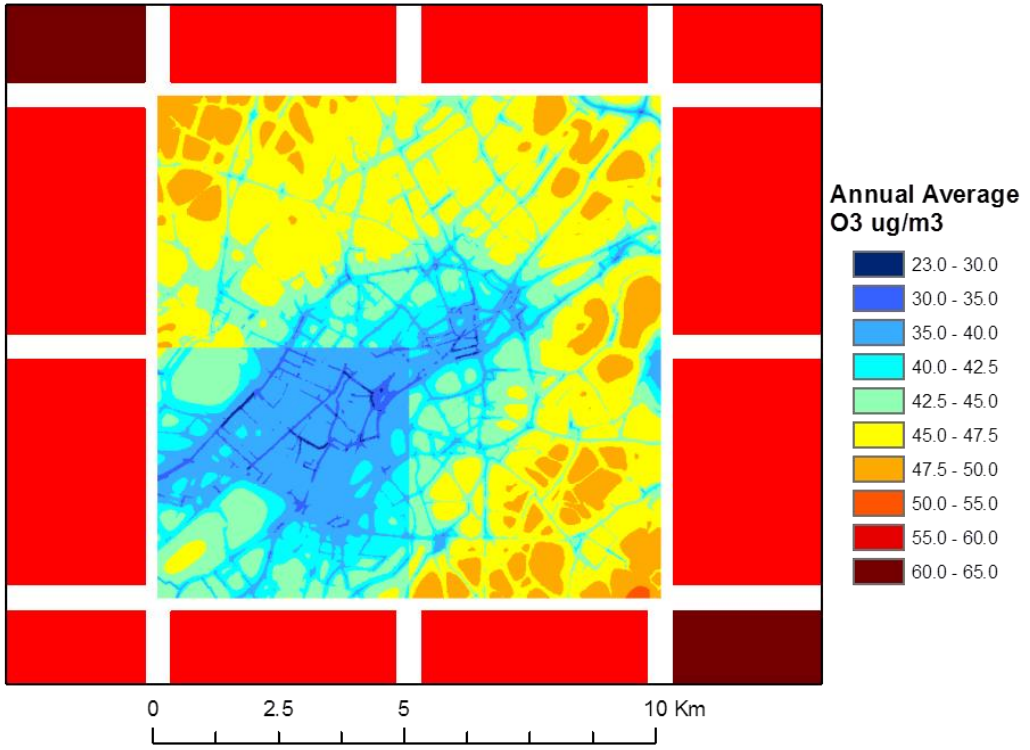


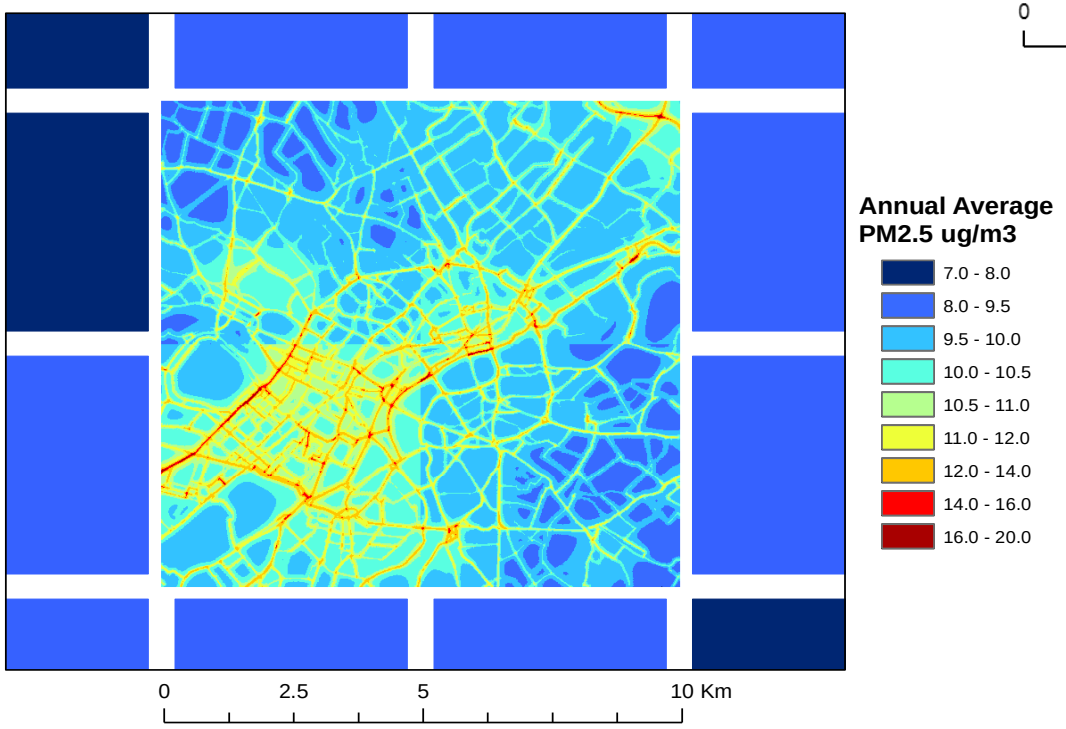
O_3 →

annual averages

(Corrected for double-counting of emissions)

$PM_{2.5}$ ↓



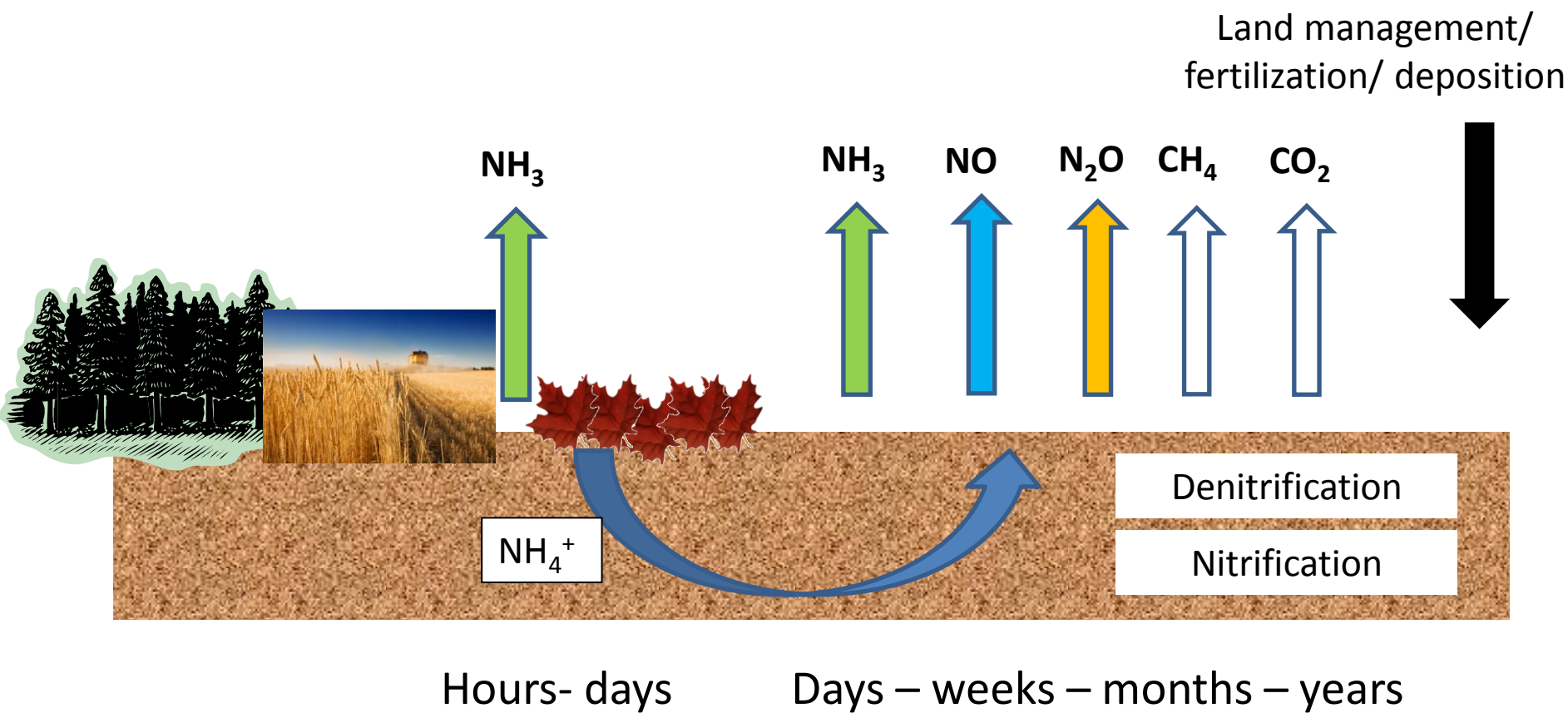


Annual average maps are for illustration only

- the motivation is in being able to derive time series of highly-spatially-resolved pollutant fields without constraint of measurements for BCs

Coupling to dynamic emissions models

Vegetation & litter decay as an example



Hours- days

Days – weeks – months – years

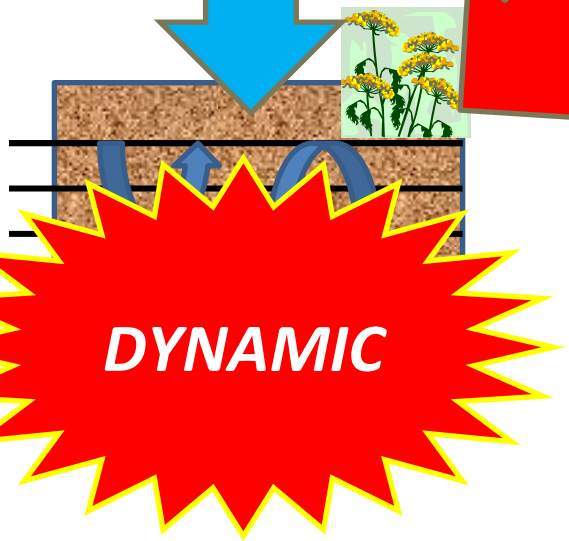
Ecosystem Model

Landscape-DNDC
(denitrification decomposition)

multi-laye mplexity
- *crop*
- *soil t cycling*
- *land management practices*
- *….*

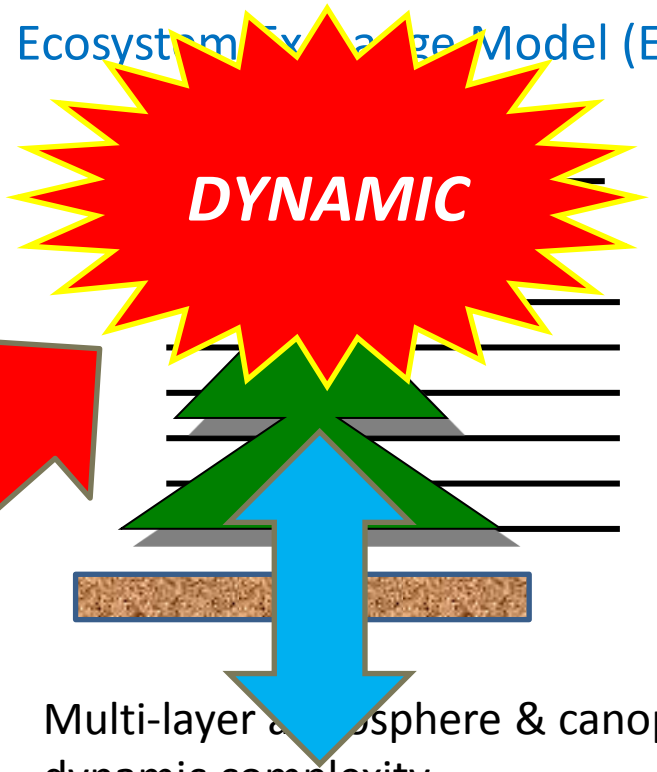
bu
… atmospheric licity

Static



Surface Atmosphere Exchange Model

Ecosyst m Ex a ge Model (ESX)



Multi-layer a osphere & canopy dynamic complexity
- *ics*
- *y*
- *…*

Static

… emissions simplicity

THANK YOU

… and a reiteration of acknowledgements to many colleagues and funders