Integrated Assessment Modelling Developments in the UK: the SNAPS consortium project

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1. **Current version of UKIAM (version 3) as applied to scenarios for UK to 2025 and 2030 and comparisons with GAINS (Helen ApSimon)**

2. **New developments (version 4) for future work and reflecting priorities from review of uncertainties (Tim Oxley)**

Emission projections
National Atmos.
Emission Inventory
partners

Atmospheric Dispersion
European -> street scale
CEH, Met Office, Imperial

SCENARIOS
UKIAM/RAPID

Abatement Options
& Costs. *AMEC,*
Rothamsted (NH3)

Environmental Impacts
Health , ecosystems,
SSSIs, Crops (CEH/Imp.)

Cost v Benefit
Mike Holland

Uncertainties/Robustness
HAZOP, TUBA

Projected Emissions
SO2, NOx, NH3, PM10/PM2.5, *VOCs, Black Carbon*

National Atmospheric Emissions Inventory: *www.naei.defra.gov.uk*

Ricardo-AEA, Aether, AMEC + Rothamsted (agriculture)
Applied to official UK energy scenarios from DECC(eg. UEP45) + DfT data and UK agricultural projections up to 2030
(Or use NAEI EFs with other energy scenarios e.g. for Committee on Climate Change)

**Collaboration -> database new technologies eg CCS, new fuels, vehicles etc**
(NB Ricardo-AEA report "Emission factors for alternative vehicle technologies" Feb 2013)

Road Transport Emissions

???? What will Euro 6/VI emissions achieve?????

GAINS emissions for UK ~90 kt less than NAEI projections

Taken from "New insights from comprehensive on-road measurements of NOx, NO2 and NH3 from vehicle remote sensing in London. David Carslaw & Glyn Rhys-Tyler at Kings College London published in Atmospheric Environment
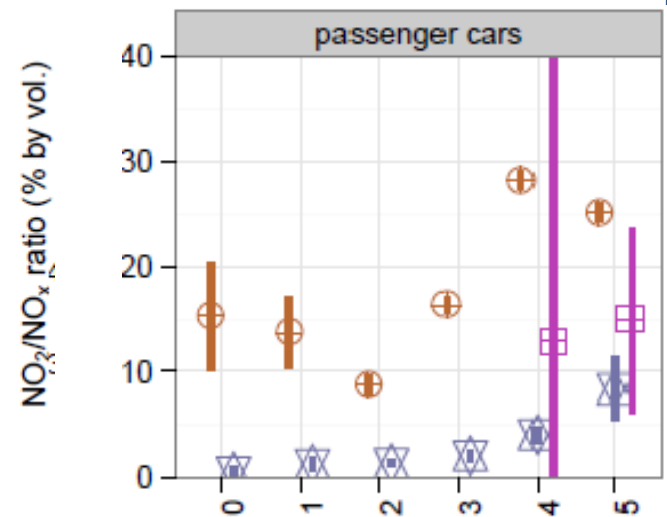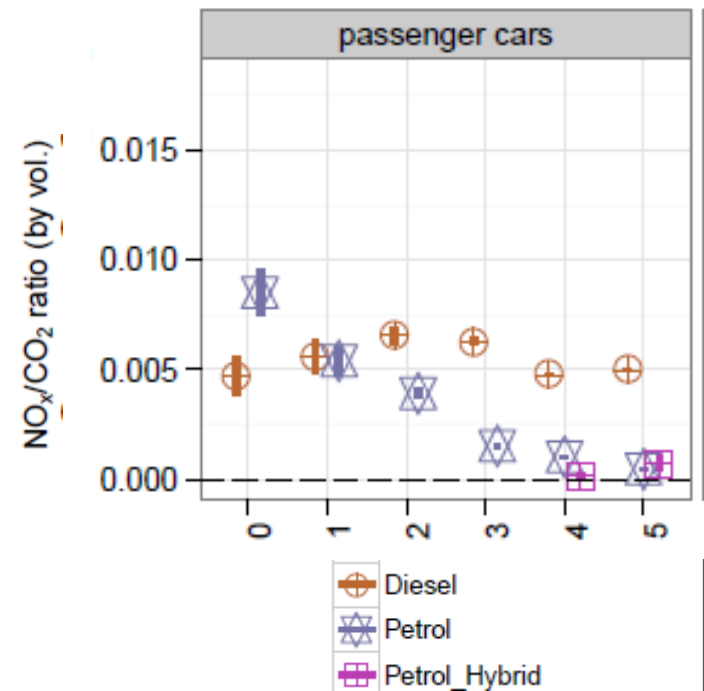
Abatement Measures and Costs

Multi-Pollutant Measures Database, MPMD compiled by AMEC plus agricultural measures by Tom Misselbrook (Rothamsted)

Includes both technical measures and behavioural change-e.g ecodriving, switch coal to nuclear power etc

For each measure effect on SO2,NOx, NH3, PM10/PM2.5, VOCs and on GHG emissions, and corresponding costs

Some measures with negative costs

Used to define UKIAM scenarios (and cost curves for Defra).

Atmospheric Modelling-> source footprints

CEH modelling: FRAME Lagrangian model and EMEP4UK

Met Office: NAME model (particle in cell used for emergencies/episodes)

Imperial College: local scale urban modelling

Draw on other modelling too eg ADMS (CERC), and can use UKIAM as framework to exchange/compare models

NB Model intercomparison exercise and new Air Quality Modelling Steering Group chaired by Martin Williams

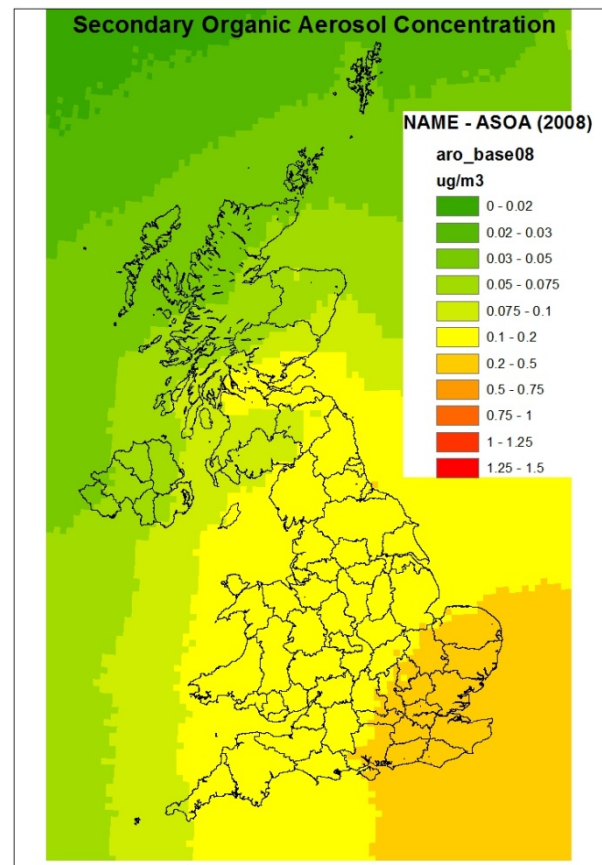# Secondary Organic Aerosol from NAME model
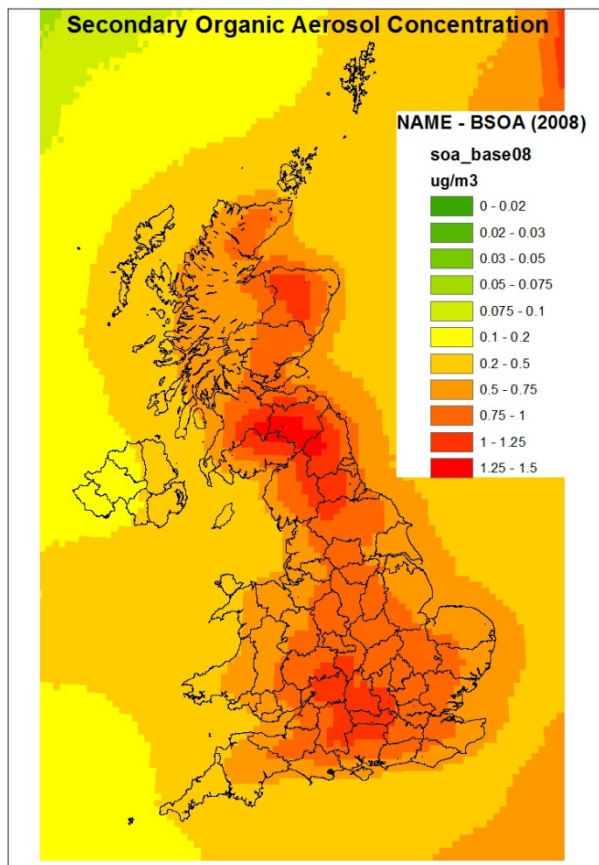
biogenic

New data from
Met Office model:

Biogenic >>
anthropogenic

SOA lot higher
than GAINS/EMEP
-> will compare
with EMEP4UK

? Agricultural
sector

anthropogenic

Redington, A.L. & Derwent, R.G, 2013, Modelling secondary organic aerosol in the United Kingdom, *Atmos. Env*., 64, 349-357

Environmental Protection

Ecosystems: acidification and eutrophication
CEH ->Critical load mapping broken down by habitat;
all natural ecosystem areas and for SSSIs

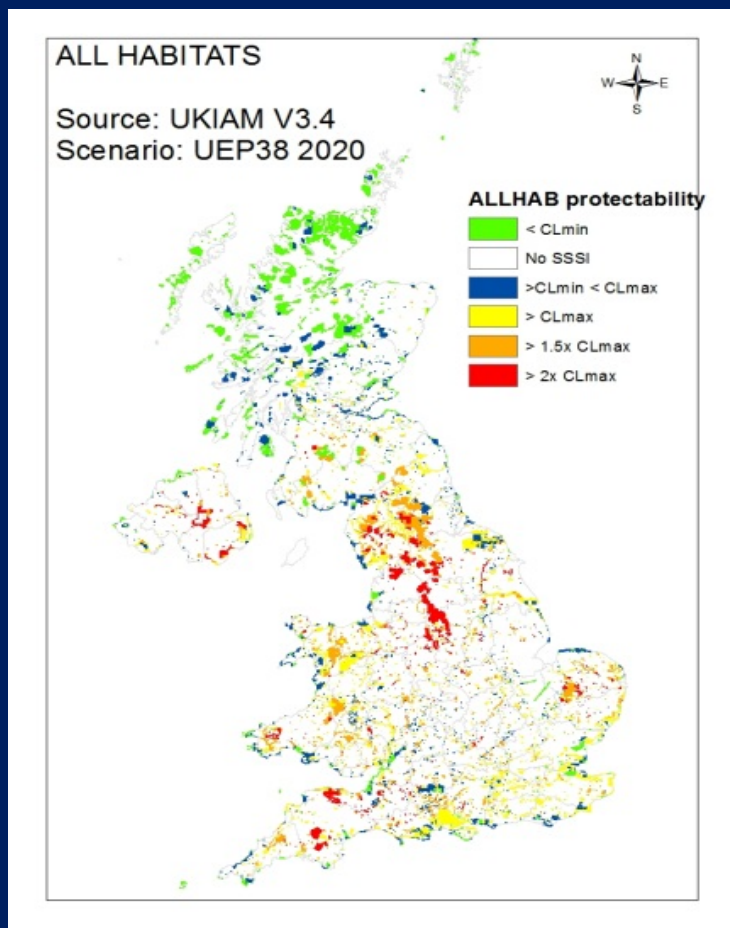*(Ozone damage to crops forests : Gina Mills at CEH ->*
in progress)

Human health:
**population weighted mean exposure PM2.5, NO2**

Exceedance of limit values for NO2 and PM10

Protection of ecosystems and biodiversity

GAINS gives much more optimistic view for eutrophication than UK modelling at 5x5 km grid scale (which compares well with CBED empirical mapping for UK). NB MIE gave very diverse results between UK models.

ALL HABITATS

Source: UKIAM V3.4
Scenario: UEP38 2020

ALLHAB protectability
- < CLmin
- No SSSI
- >CLmin < CLmax
- > CLmax
- > 1.5x CLmax
- > 2x CLmax

UKIAM alternative focus on SSSIs: Exceedance of critical loads for excess nitrogen (also available for individual habitats)

ALL HABITATS - Number of habitats exceeding protectabiilty bands (2020)
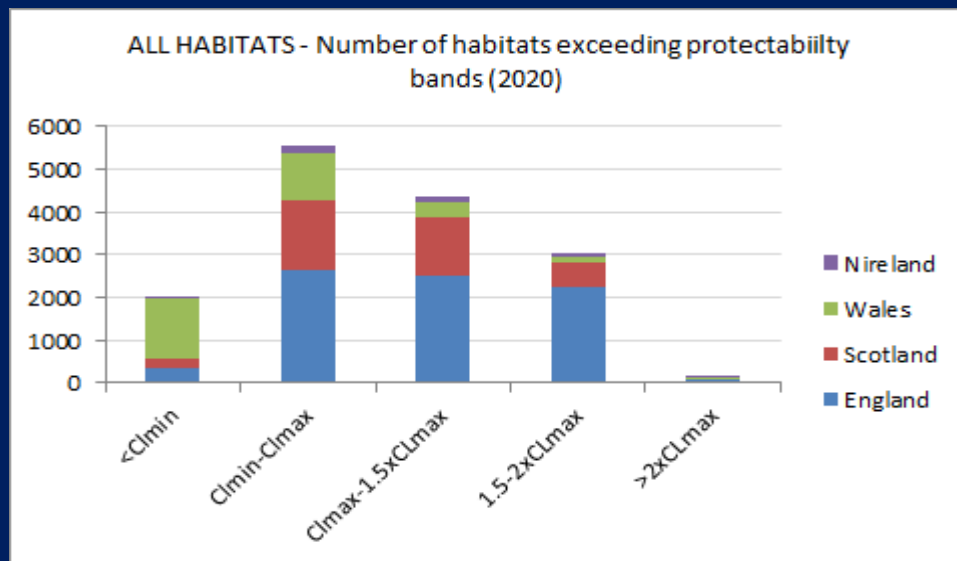
Cost Benefit Analysis
Working with Mike Holland

Workshop in Feb 2014 to compare Defra UK government "Green Book" guidance on valuing air quality impacts *(see www.gov.uk/air-quality-economic-analysis)* with Mike Hollands approach as used with GAINS

Linking UKIAM output to benefits analysis at a national level by Mike Holland

Preliminary applications to CBA for UK scenarios (PM2.5 dominant health impact ; extending to other effects)

Damage costs NO₂
(tentative investigation)

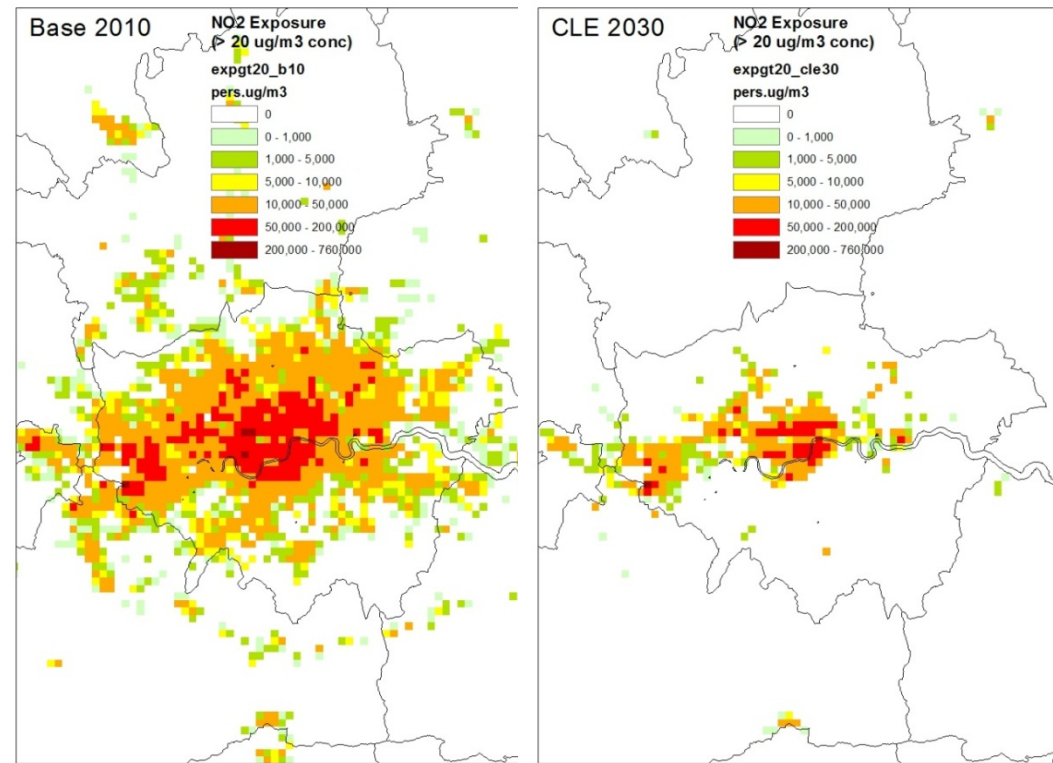**HRAPIE functions for effects often specified for NO₂ >20 μg/m3**

-> Set indicator as exposure exceeding threshold of 20?

More sensitive indicator than total exposure Focuses on urban populations Implies lower damage costs/ benefits

Population weighted exposure to NO₂ > 20μg/m₃

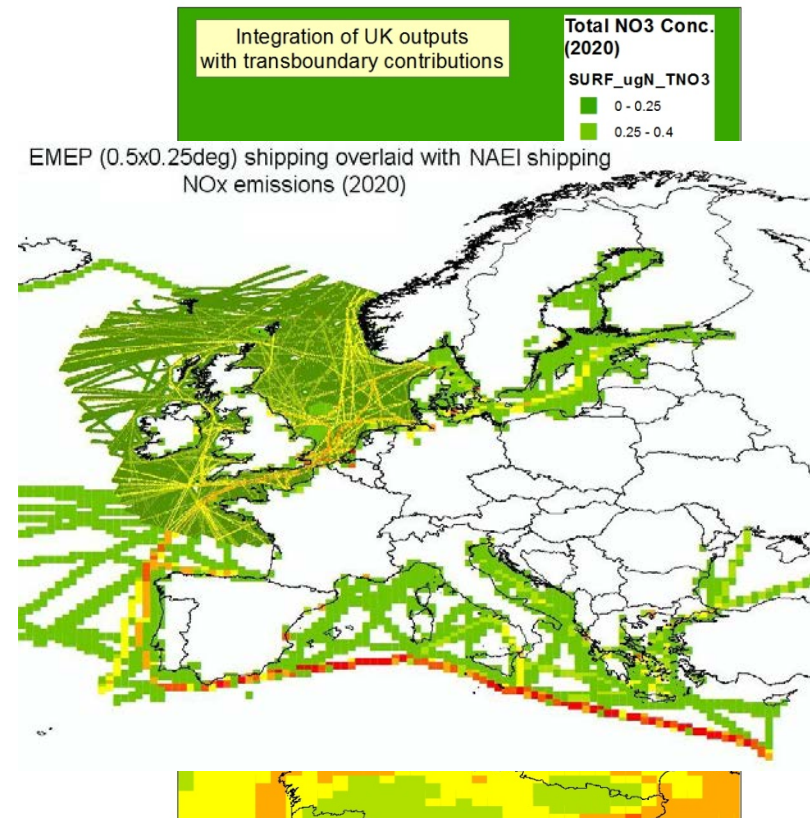| Population Weighted Mean Concentration (μg/m³)				
	Total NO₂		NO2 > 20μg/m³	
Scenario	London	National	London	National
2010 Baseline	24.45	14.70	4.75	1.09
CLE2030	17.32	9.49	1.04	0.23

UK Integrated Assessment Model
Ongoing Upgrades
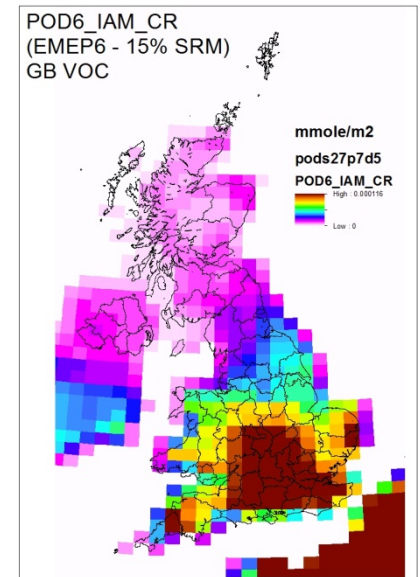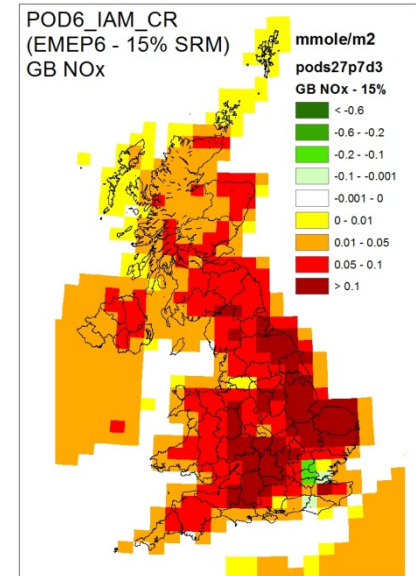
- *Transboundary contributions*
- *Ozone*
- *Road Transport*

Transboundary Contributions

- New EMEP data (0.5˚x0.25˚) incorporated into ASAM model to remain comparable with GAINS
  - Many thanks to IIASA (Chris Heyes) and EMEP-W (Michael Schulz) for permission to use the new dataset in ASAM model
- EMEP/NAEI shipping emissions combined for FRAME modelling of UK boundary conditions
  - Sensitivity study planned for EMEP/EMEP4UK and FRAME/FRAME-Europe representations of shipping
- Utilisation of POD data for addressing damage to crops and ecosystem in UK
  - To be superseded by EMEP4UK representations within SNAPS contract

Integration of UK outputs with transboundary contributions

Total NO3 Conc. (2020)

SURF_ugN_TNO3
- 0 - 0.25
- 0.25 - 0.4

EMEP (0.5x0.25deg) shipping overlaid with NAEI shipping NOx emissions (2020)

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Imperial College London

Phytotoxic Ozone Dose
(POD)

- Use EMEP representation until EMEP4UK data (5km resolution) becomes available

- POD6 to be used to assess crop damage (initially wheat, but can be extended to oilseed rape)
  - NO_X emission reductions have significantly greater impact on POD6 than reductions in VOC emissions

- POD1 can be used to assess impacts on beech and birch

- Model parameterisations to be based upon ICP Vegetation Modelling & Mapping Manual

- Crop damage estimates to provide input to Cost-Benefit Analysis (Mike Holland)

POD6_IAM_CR
(EMEP6 - 15% SRM)
GB NOx

mmole/m2
pods27p7d3
GB NOx - 15%

| < -0.6 |
| -0.6 - -0.2 |
| -0.2 - -0.1 |
| -0.1 - -0.001 |
| -0.001 - 0 |
| 0 - 0.01 |
| 0.01 - 0.05 |
| 0.05 - 0.1 |
| > 0.1 |

POD6_IAM_CR
(EMEP6 - 15% SRM)
GB VOC

mmole/m2
pods27p7d5
POD6_IAM_CR

High : 0.000116
Low : 0

UKIAM Development
(Version 4)

- Transboundary influences captured by ASAM model (previous slides)

- New source-receptor relationships for UK sources being generated by FRAME model

- Additional emission sources to accommodate both VOC emissions and new technologies such as anaerobic digestion (NH_3)

- Black Carbon now included based upon source-specific percentages of BC contributing to $PM_{2.5}$

- Significant improvement of treatment of road transport and urban air quality (BRUTAL model)

- Version 4 due for completion in July 2014

Oxley *et al.*, 2013, Modelling future impacts of air pollution using the multi-scale UK Integrated Assessment Model, *Environment International*, 61, 17-35

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Road Transport & Urban Air Quality

- **BRUTAL model performed acceptably during the Defra Model Inter-comparison Exercise (MIE)**
  - Aggregated fleet composition and road speeds
  - 1x1km resolution
  - Unable to capture roadside hotspots (eg. large volumes of buses in Putney, Brixton Hill, Oxford Street etc.)
  - NO_2 sensitivities to diesel mix, and assumptions about Euro technologies and primary NO_2 emissions

- **Model updated to latest NAEI speed-dependent emission factors**
  - Includes revised Euro assumptions and projected Euro7 efficiencies

- **Traffic flows, fleet composition and road speeds updated to recent LAEI representations**
  - Fleet composition and road speeds change from cell to cell, and on different road types *within* cell

Carslaw, D.C., 2011, Defra urban model evaluation analysis - Phase 1, Environmental Research Group, King's College London, 15th April 2011, http://uk-air.defra.gov.uk/library/
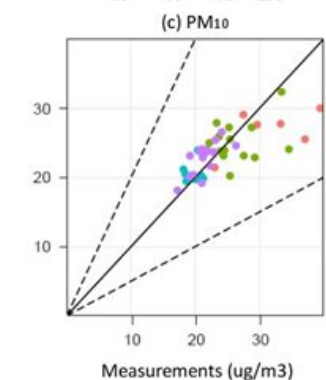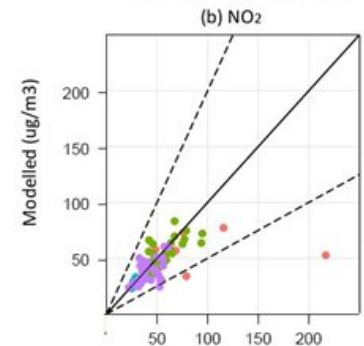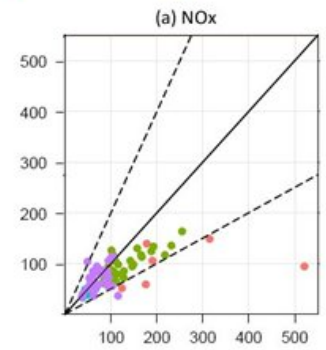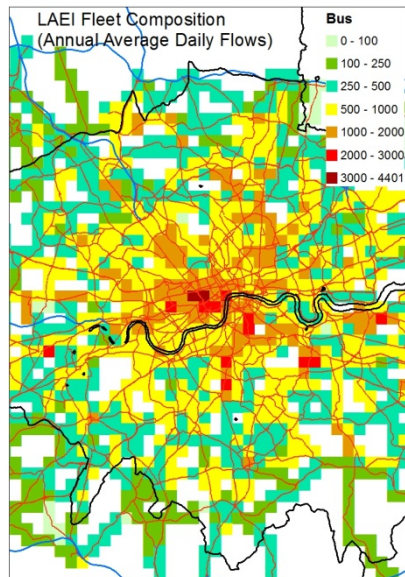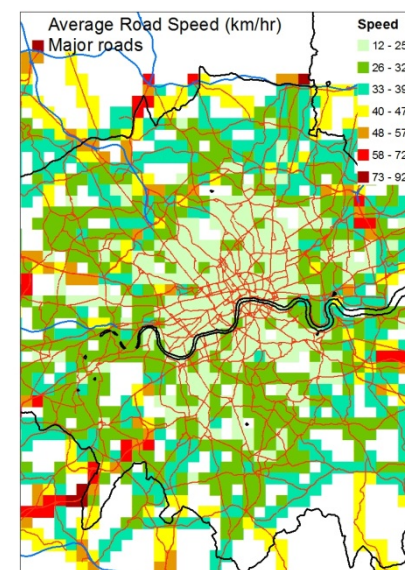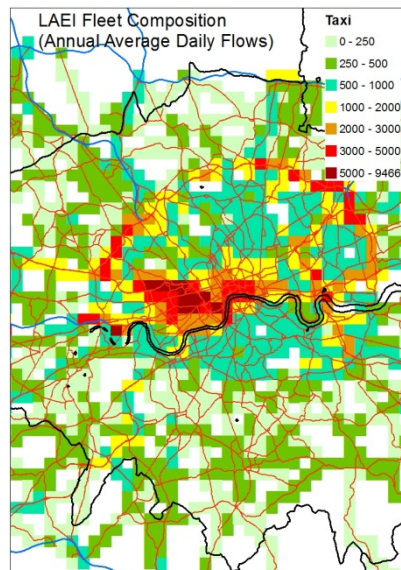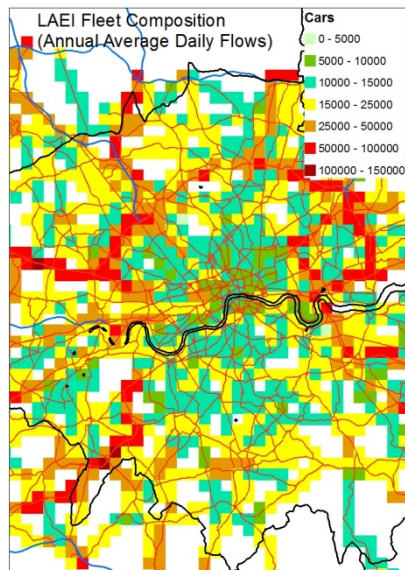
Definition of Roads
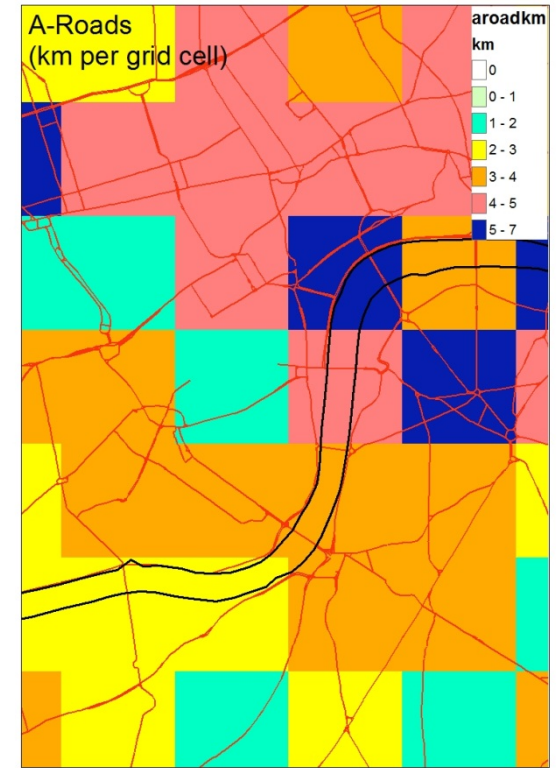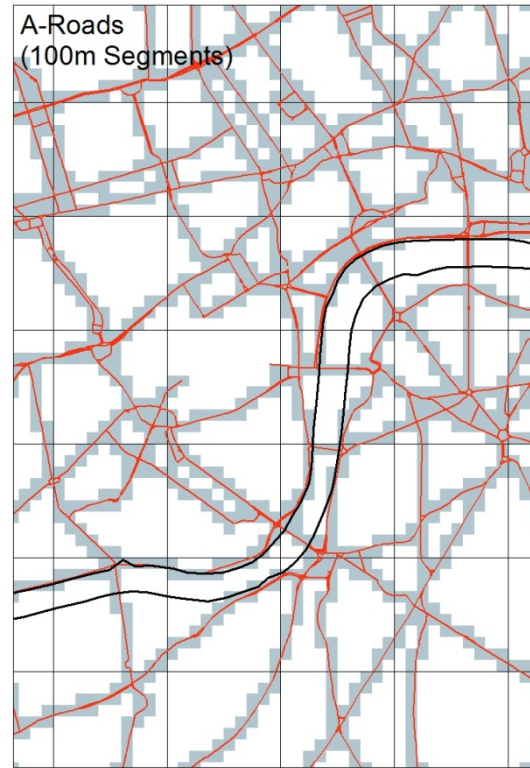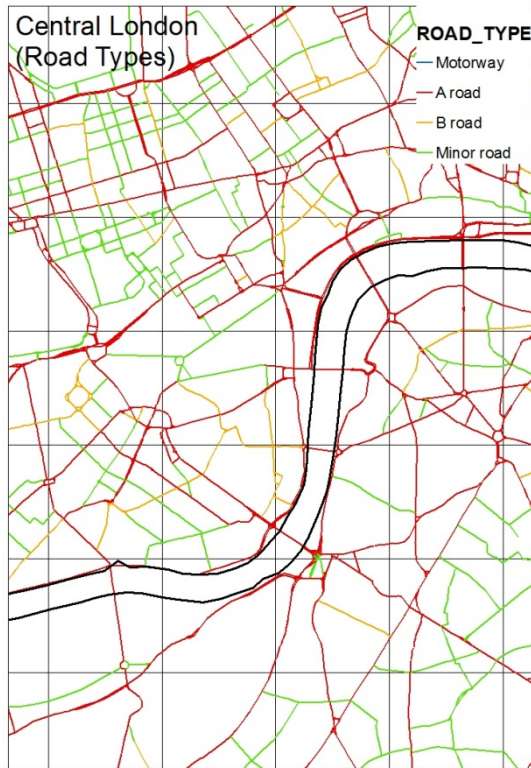
- Different road types handled separately
- Assume 100m of road in each 'segment'
- Accumulate total road length of each road type for each 1x1km grid cell
- Repeated for road speed and vehicle mix to calculate average for grid cell

Fleet Composition & Road Speed (London)
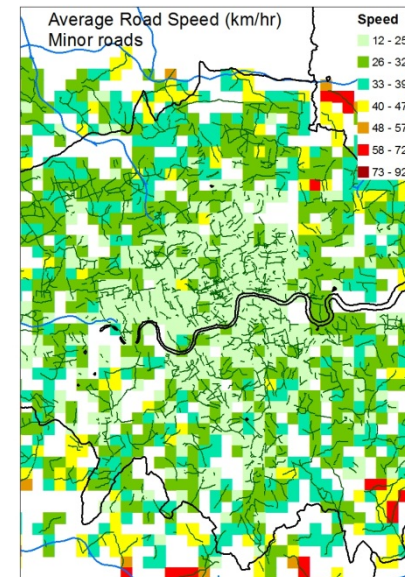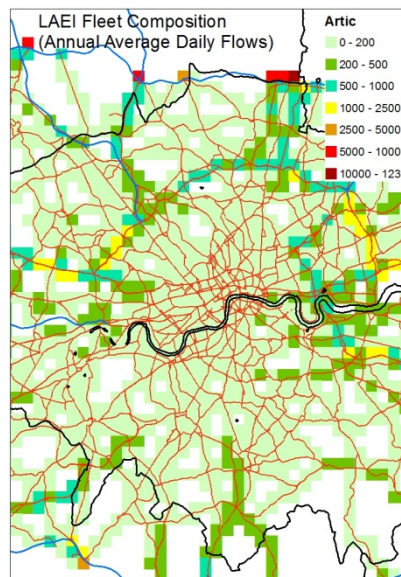
Uncertainty Analysis

- HAZOP study carried out to identify areas of uncertainty
  - Emissions, atmospheric dispersion, AQ monitoring, …
  - Traffic fleet composition, Euro technology assumptions, fNO_2, …
- Utilisation of *openair* software
  - http://www.openair-project.org/
  - Developed in 'R' by King's College (David Carslaw)
  - Central to analyses in Defra Model Inter-comparison Exercise
- Software to be used to
  - Validate model against current measurements
    - Increased confidence in model results
  - Evaluate uncertainties in future scenarios
    - Use projected baseline instead of measurements
- PhD Student (Rosalind O'Driscoll)