

Atmosphere and Local Environment

Defra's Modelling Review 2010/11

Presentation for APRIL – 06/04/11
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Overview of Presentation

- ▶ Aims and objectives of Defra's Modelling Review.
- ▶ Defra's policy needs and modelled evidence requirements.
- ▶ Closer look at the intercomparison exercise – process, set up and early results.
- ▶ Summary of the Review's progress to date and next steps.

Background to the Review



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- ▶ Value For Money:
 - ▷ 13 air quality models to provide data for a range of policy requirements and annual spend of £1.5 mill on modelling. Need to be sure we're getting VFM.
- ▶ Suitability:
 - ▷ Models must be fit for purpose – screening vs scientific state of the art.
 - ▷ Must understand limitations and review whether models have been stretched beyond their capability.
- ▶ Strategic Direction:
 - ▷ Good practice to undertake strategic reviews ,see SAC report*
 - ▷ Need to ensure that we are well connected internally and that there is no unnecessary duplication in data/effort.
 - ▷ Need to evaluate future requirements or needs not currently met and options available to us.

▶ * http://sac.defra.gov.uk/wp-content/uploads/2010/12/SAC-MOD_10_Final_Report.pdf

Focus: Objectives of the Review



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- ▶ Review Defra's current modelling capacity – models currently used, outputs generated, uses of data.
- ▶ Review extent to which current policy requirements are being met by these outputs.
- ▶ Highlight any gaps in policy requirements, any models being used which are not fit for purpose or any requirements not met by current capacity.
- ▶ Highlight likely future policy requirements and extent to which new tools might need to be developed.
- ▶ Investigate and take forward recommendations on options available – including models which should be invested in and/or developed further.

What Does Defra need Models for?



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Policy Driver/Evidence Need	
Directive Compliance (2008/50/EC, 2004/107/EC)	National scale modelling capacity– base case and projections
	Site specific modelling of hotspots
	Point source modelling
	Urban scale modelling
	Regional scale modelling
	Ozone modelling capacity
Assessment of Policy Options including revision of the Air Quality Strategy	Measures screening testing
Health protection impact assessment	Population exposure
Ecosystems impact assessment	Deposition modelling to estimate and forecast critical loads
	Concentration data
	Screening and detailed modelling capacity
	Ozone flux
Modelling to account for impact of climate change and of climate change measures.	Measures testing, scenario analysis, projections, application and links to urban, regional and national modelling.
Negotiations for new Directives - potentially new metrics required.	Unknown yet. Need to be flexible.

Modelling Review Methodology



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- ▶ Inputs to the Review:
 - ▷ Information on Defra's current arrangements:
 - ▶ models used, outputs generated, links to policy (NERC student input).
 - ▶ Defra's policy drivers and current/future evidence needs.
 - ▷ Data generated from a Model Intercomparison Exercise.
- ▶ The Review is being supported by an independent Steering Group (M Williams, P Monks, D Laxen, R Barrowcliffe).
- ▶ The Group has overseen the collection of evidence, evaluated the available information and are providing recommendations.

Model Intercomparison Exercise



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- ▶ A key data source for the Modelling Review.
- ▶ Aims:
 - ▷ to identify available models and detail on the range and limits of model performance.
 - ▷ To create an ongoing forum for modellers to discuss and evaluate models within a technical community.
- ▶ D. Carslaw has led the data analysis using openair to undertake central data analysis.
- ▶ Open to all – inclusive process, not just Defra contractors. New participants also welcome.
- ▶ Approx. thirty participants – researchers, practitioners and consultants carrying out a coordinated air quality modelling exercise....

Models Involved in the Exercise.....



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Name of Model	Full Model Name	Organisation
ADMS-Urban	Atmospheric Dispersion Modelling Software	CERC
ADMS-Queue	Queue- treats vehicle queuing	
BRUTAL	Background Road and Urban Transport model of Air quality Limit values	Imperial College London
CMAQ	Community Multi-Scale Air Quality Model	University of Hertfordshire
		AEA
		JEP (E-ON & RWE npower)
		King's College London
EMEP4UK	European Monitoring and Evaluation Programme UK Model	University of Edinburgh
EMEP MSC-W	European Monitoring and Evaluation Programme MSC-W Model	Norwegian Meteorological Inst.
ERG-Toolkit	Environmental Research Group-London Air Pollution Toolkit	King's College London
FRAME	Fine Resolution Atmospheric Multi-pollutant Exchange	CEH-Edinburgh
HARM	Hull Acid Rain Model	University of Nottingham
NAME	Numerical Atmospheric-dispersion Modelling Environment	The Met Office
OSRM	Ozone Source Receptor Model	AEA
PCM	Pollution Climate Mapping Model	AEA
PTM	Photochemical Trajectory Model	RdScientific
AQUM	Air Quality in the Unified Model	The Met Office
UKIAM	UK Integrated Assessment Model	Imperial College London

Intercomparison Methodology



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- ▶ Unique in Europe in terms of scope and methodology.
- ▶ Aims to use pre-existing data where possible eg from other intercomparisons (CREMO) or Defra's existing evidence base.
- ▶ 3 groups – Urban, Regional (Ozone) and Deposition.
- ▶ Split into phases which build in complexity.
- ▶ Limited harmonisation of inputs to reduce resource requirements.
- ▶ Statistical analysis based on Defra's Model Intercomparison Protocol*. All data processed centrally into an automated report template using openair.
- ▶ Very quick turnaround– less than 6 weeks for modellers to produce outputs. Analysis undertaken centrally in 3 weeks using openair.

*http://uk-air.defra.gov.uk/reports/cat05/1006241607_100608_MIP_Final_Version.pdf

Focus on Urban Group

- ▶ Participants: AEA – Pollution Climate Model, CERC – ADMS and ADMS-QUEUE, King’s College London – ERG Toolkit and CMAQ with nested urban model and Imperial College London – UKIAM/BRUTAL.
- ▶ Modellers required to complete a questionnaire summarising their model’s capability and details of parameters/options selected for this exercise.
- ▶ Focus on London, 118 monitoring stations, 2009, NO_x, NO₂, PM₁₀, PM_{2.5}, Ozone.
- ▶ Met data – defined by the groups- options varied from measured data RAF Waddington to modelled Weather Research and Forecasting (WRF) data
- ▶ Model calibration allowed, but must be noted.
- ▶ Only the OS grid refs of monitoring stations provided. Very limited harmonisation.

Data Analysis

- ▶ Completed by D. Carslaw using openair, all code and methods available so anyone can reproduce results. Outputs are stats and graphics in an automated report containing all the codes.
- ▶ Ensures harmonisation of calculation process and transparency of the analysis.
- ▶ Very time and resource efficient. Allowed for last minute changes to data – report takes minutes to re-run.
- ▶ Can do detailed analyses of spatial and temporal behaviour of models-very sensitive diagnostics.
- ▶ Allows us to update results in future. Reports will be published on UK-AIR shortly.

Statistics used in evaluation

► **FAC2** $0.5 \leq \frac{M_i}{O_i} \leq 2.0$

$$MB = \frac{1}{n} \sum_{i=1}^N M_i - O_i$$

$$MGE = \frac{1}{n} \sum_{i=1}^N |M_i - O_i|$$

$$NMB = \frac{\sum_{i=1}^n M_i - O_i}{\sum_{i=1}^n O_i}$$

$$NMGE = \frac{\sum_{i=1}^n |M_i - O_i|}{\sum_{i=1}^n O_i}$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^n (M_i - O_i)^2}{n}}$$

$$r = \frac{1}{(n-1)} \sum_{i=1}^n \left(\frac{M_i - \bar{M}}{\sigma_M} \right) \left(\frac{O_i - \bar{O}}{\sigma_O} \right)$$

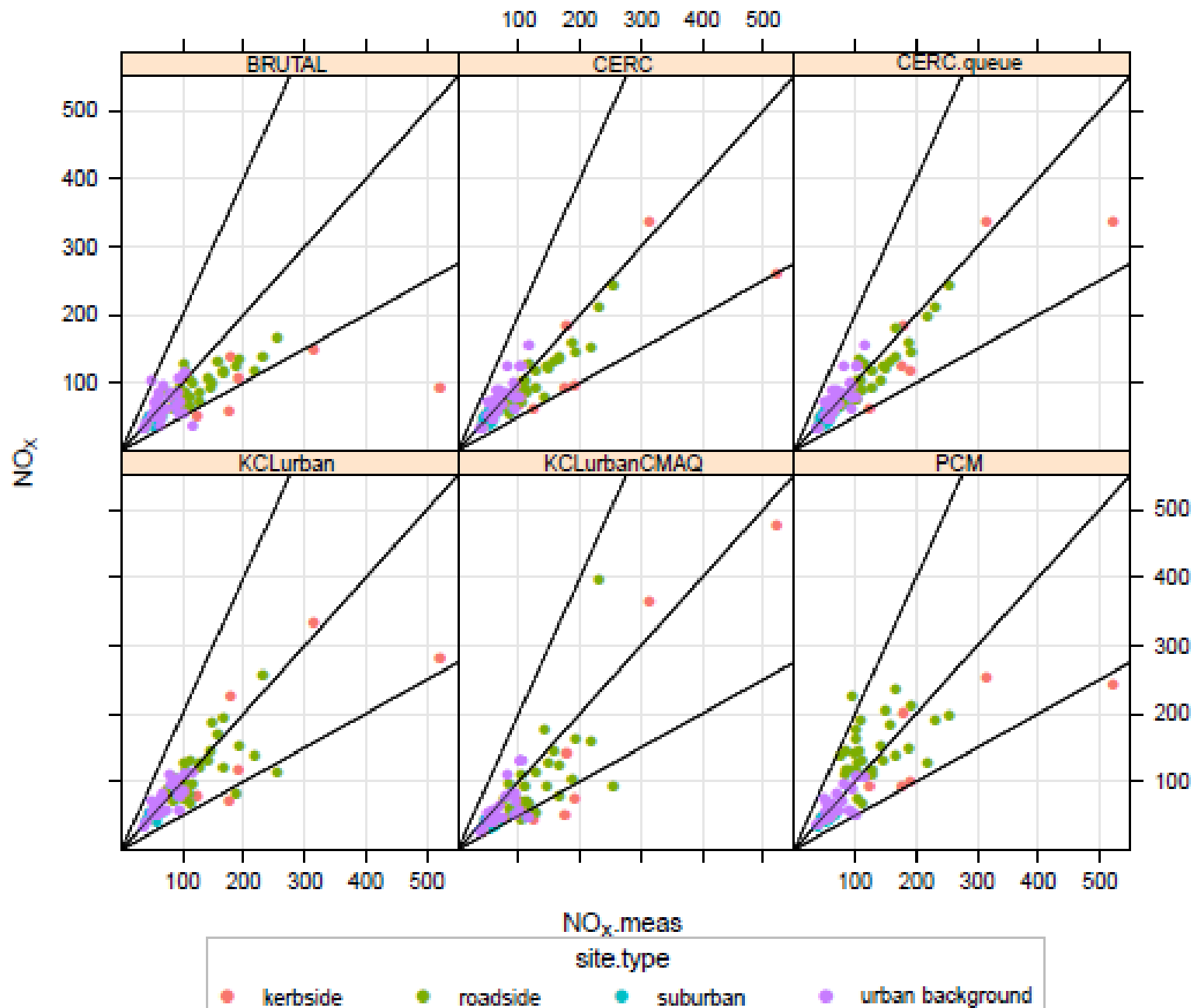


Figure 1: Scatter plot of measured versus predicted annual mean NO_x concentrations.

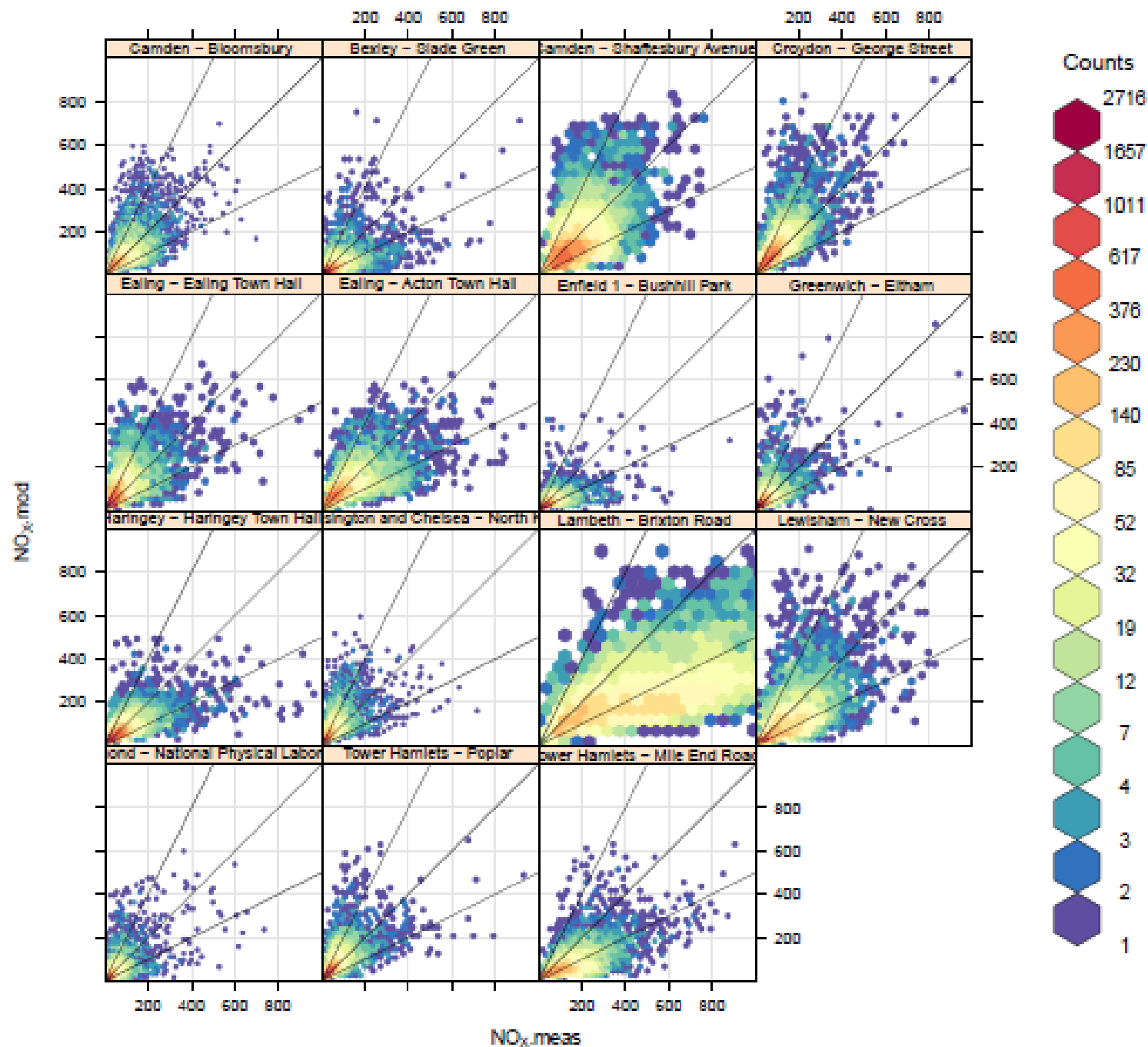
Initial observations from Urban Group



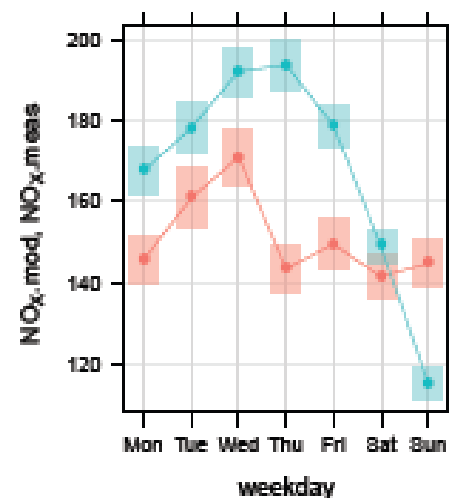
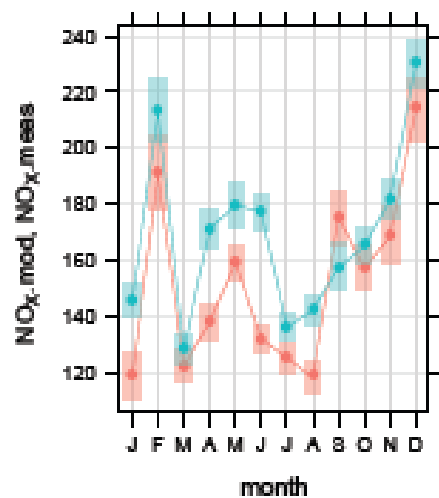
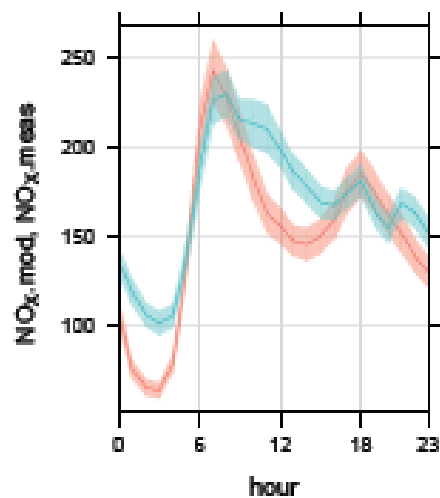
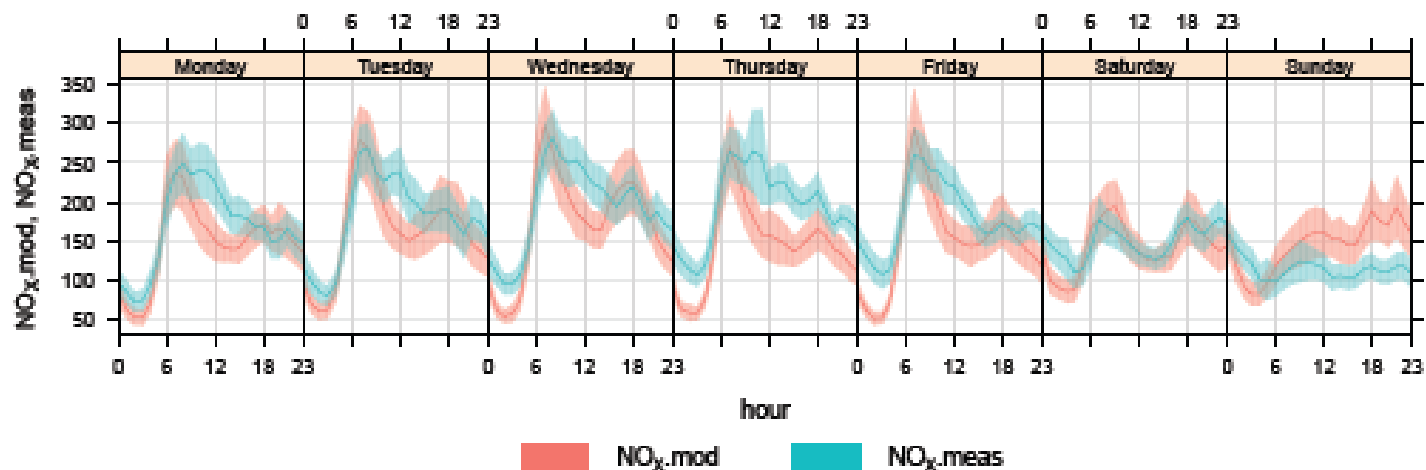
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Table 1: Summary model evaluation statistics for annual mean NO_x.

site.type	group	n	FAC2	MB	MGE	NMB	NMGE	RMSE	r
kerbside	BRUTAL	7.00	0.43	-129.15	129.96	-0.56	0.57	184.49	0.21
kerbside	CERC	7.00	0.71	-73.70	80.76	-0.32	0.35	113.55	0.77
kerbside	CERC.queue	7.00	0.86	-53.63	60.69	-0.23	0.26	82.04	0.89
kerbside	KCLurban	7.00	0.86	-60.23	79.39	-0.26	0.35	106.88	0.75
kerbside	KCLurbanCMAQ	7.00	0.57	-57.86	72.36	-0.25	0.32	79.85	0.95
kerbside	PCM	7.00	0.86	-74.53	81.72	-0.32	0.36	119.02	0.77
roadside	BRUTAL	30.00	1.00	-35.26	38.33	-0.27	0.29	46.10	0.79
roadside	CERC	30.00	1.00	-22.78	23.64	-0.17	0.18	27.94	0.94
roadside	CERC.queue	30.00	1.00	-14.29	18.89	-0.11	0.14	21.77	0.93
roadside	KCLurban	30.00	0.93	-14.35	28.00	-0.11	0.21	41.47	0.61
roadside	KCLurbanCMAQ	30.00	0.87	-31.89	46.58	-0.24	0.35	59.96	0.63
roadside	PCM	30.00	0.97	16.20	41.68	0.12	0.32	50.06	0.42
suburban	BRUTAL	11.00	1.00	-7.48	8.73	-0.15	0.17	9.87	0.62
suburban	CERC	11.00	1.00	-4.51	8.23	-0.09	0.16	9.20	0.45
suburban	CERC.queue	11.00	1.00	-4.51	8.23	-0.09	0.16	9.20	0.45
suburban	KCLurban	11.00	1.00	-4.26	7.09	-0.08	0.14	8.18	0.52
suburban	KCLurbanCMAQ	11.00	1.00	-15.37	15.37	-0.30	0.30	17.23	0.36
suburban	PCM	11.00	1.00	-6.14	7.56	-0.12	0.15	9.17	0.59
urban background	BRUTAL	29.00	0.93	-2.71	18.15	-0.04	0.25	25.35	0.33
urban background	CERC	29.00	1.00	5.62	14.64	0.08	0.21	18.14	0.79
urban background	CERC.queue	29.00	1.00	5.62	14.64	0.08	0.21	18.14	0.79
urban background	KCLurban	29.00	1.00	1.43	10.66	0.02	0.15	13.70	0.80
urban background	KCLurbanCMAQ	29.00	0.97	-11.02	17.21	-0.15	0.24	22.91	0.66
urban background	PCM	29.00	0.97	-4.67	12.13	-0.07	0.17	17.73	0.65



Temporal variations in NO_x at the Shaftesbury Avenue site using the ADMS model



- ▶ Directive text is ambiguous, guidance given by FAIRMODE:

$$RDE = \frac{|O_{LV} - M_{LV}|}{LV}$$

- ▶ 90th percentile of these values should be <30% for annual mean NO₂ and 50% for annual PM₁₀.

Directive RDE for annual NO₂

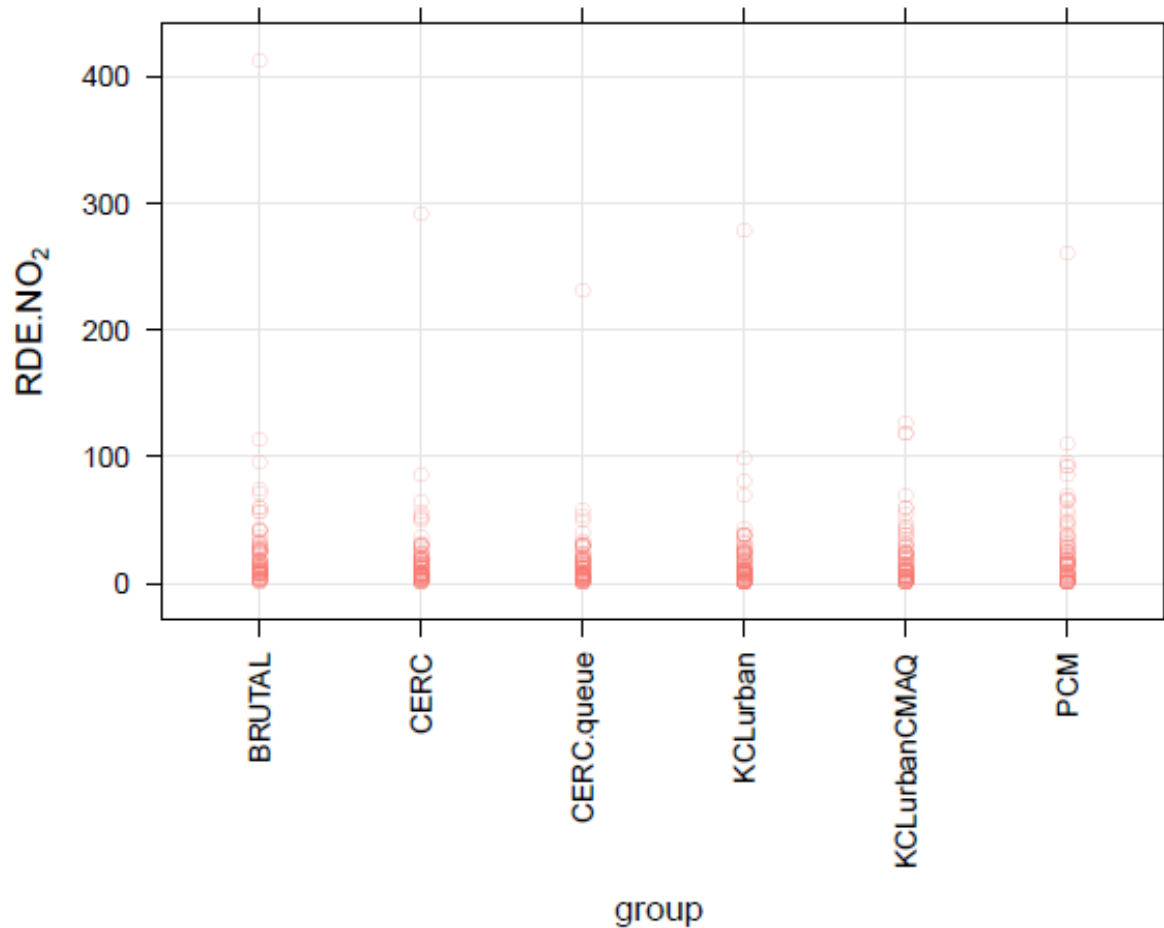


Figure 11: The RDE for annual mean NO₂ concentrations by group.

Phase 2 – Urban Group

- ▶ To date focused on Operational Evaluation, now shift to Dynamic Evaluation:
- ▶ Next phase for the urban scale:
 - ▷ Responses to emissions changes in different sectors (realistic future scenarios?)
 - ▷ Ozone to be evaluated further.
 - ▷ Areas/road lengths in exceedence of EU LVs.
 - ▷ Source apportionment.
 - ▷ Urban and Rural PM_x.

Summary of next steps



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- ▶ Steering Group report and recommendations to Defra being finalised in April. Will be published on UK-AIR.
- ▶ Review the recommendations for the short, medium and long term and produce a strategy for Defra's future modelling capability.
- ▶ Take account of other aspects of uncertainty eg input data, emissions and meteorology which are not covered by this review.
- ▶ Implement any short term changes within current evidence base.
- ▶ Determine processes and pathways to implement medium and long term recommendations.
- ▶ Ensure that Phase 2 of the intercomparison proceeds and that the forum and communication channels we have established for dialogue between modellers continues.

Acknowledgements



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- The participants in the Intercomparison Exercise

CERC

Imperial College London

University of Hertfordshire

AEA

JEP

King's College London

University of York

Norwegian Meteorological Inst.

CEH

University of Nottingham

The Met Office

RdScientific

The Environment Agency

NCAS

University of Birmingham

- NERC and Andrew Smith (Oxford University) for the student placement
- David Carslaw for his contribution with openair.

For more information....



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- ▶ Modelling Review- Emily.connolly@defra.gsi.gov.uk
- ▶ Model Intercomparison Exercise – Samantha.lawrence@defra.gsi.gov.uk
- ▶ Model Intercomparison Protocol: http://uk-air.defra.gov.uk/reports/cat05/1006241607_100608_MIP_Final_Version.pdf
- ▶ Defra Science Advisory Council report on Modelling: http://sac.defra.gov.uk/wp-content/uploads/2010/12/SAC-MOD_10_Final_Report.pdf
- ▶ openair <http://www.openair-project.org/>
- ▶ UK-AIR links (where we will publish info on the Review shortly):
 - ▷ <http://uk-air.defra.gov.uk/research/air-quality-modelling>
 - ▷ <http://uk-air.defra.gov.uk/data/modelling-data>