Centre for Environment and Health

Comprehensive Analysis of Annual 2005/2008 Simulation of WRF/CMAQ over Southeast of England

The 13th International Conference on Harmonization within Atmospheric Dispersion Modelling for Regulatory Purposes

IBM Forum Paris, France

1 - 4 June 2010

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Environmental Research Group and Lung Biology

Outline

1. CMAQ modelling system
2. Model domain, physics and chemistry setting
3. Model evaluation framework
4. Results and discussion
5. Summary and future work

CMAQ modelling system at the ERG

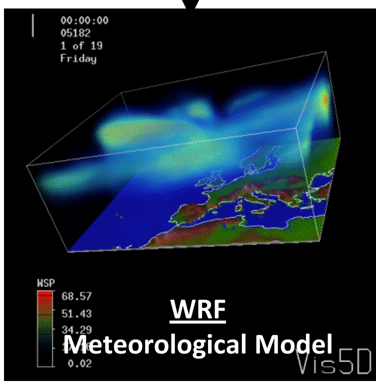
Medical Research Council

Health Protection Agency

Centre for Environment and Health

NCEP GFS

STOCHEM



MCIP
Meteorology-Chemistry Interface Processor

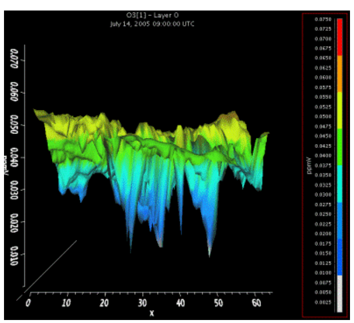
SMOKE/ ERG Emission Processor

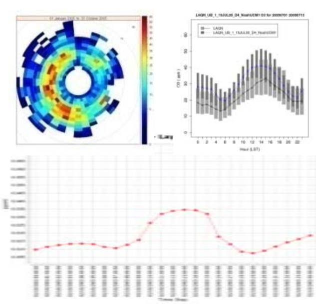
CMAQ Chemical Transport Model (CCTM)

- **Governing Equations**
- **Transport Algorithms**
- **Gas Phase Chemistry**
- **Cloud Chemistry & Dynamism**
- **Aerosol Chemistry & Dynamism**
- **Plume-in Grid Treatment**

ICON & BCON
Initial Concentrations and Boundary Conditions Processors

JPROC
Photolysis Processor





AMET / OpenAir
Analysis and visualisation tools

Applications

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Emissions processor for CMAQ

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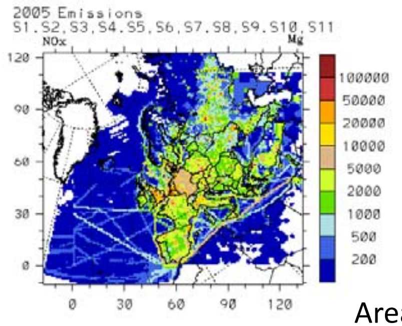
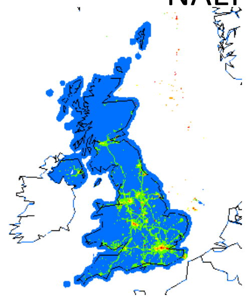
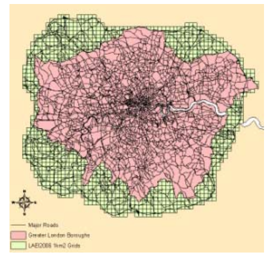
EMEP: 50x50 km^2



NAEI and LAEI: 1x1km^2





Area and mobile sources

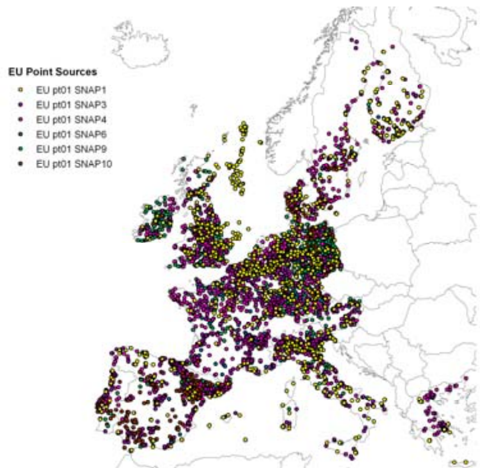
Met Driver

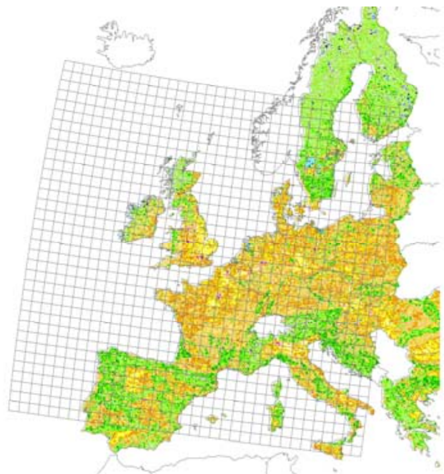
ERG Emissions Processor and SMOKE

Temporal and speciation profiles

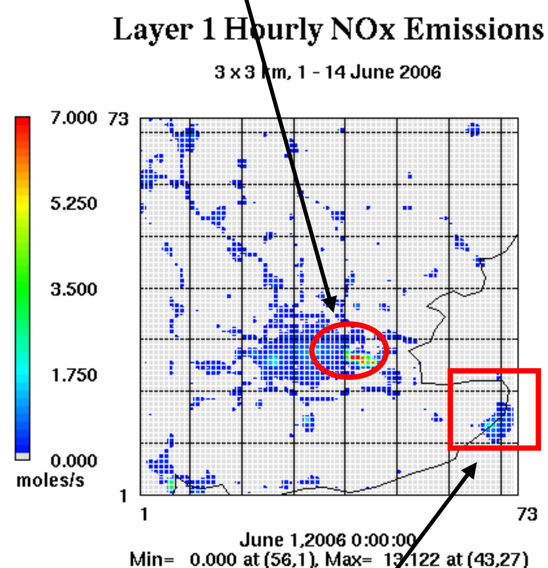
EPER/Point sources

CLC2000/Biogenic sources





Power station – Innogy, Cement non-decarbonising



Dover

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WRF/CMAQ model setup

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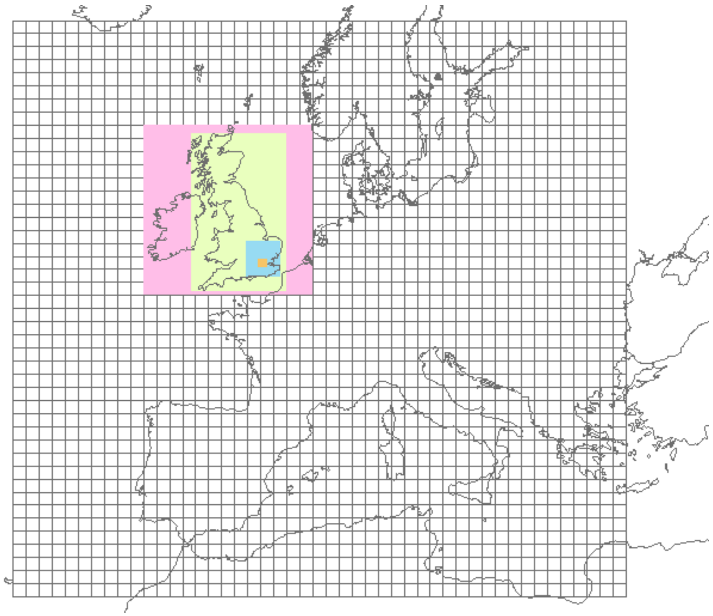

CMAQ Domain Setting:
- Dom1: 81km grid spacing, 47 x 44 cells
- Dom2: 27km grid spacing, 39x39 cells
- Dom3: 9km grid spacing, 66x108 cells
- Dom4: 3km grid spacing, 72x72 cells
- Dom5: 1km grid spacing, 61x51 cells

Vertical Domain:
- 23 Layers with 7 layers under 800 m above ground

Model Version: WRF V3.0.1 and CMAQ 4.6

WRF Initial and boundary conditions: GFS model (1x1 deg)

CMAQ Initial and boundary conditions: STOCHEM

Radiation Scheme: RRTM scheme

Microphysics: Kain-Fritsch (new Eta) scheme

PBL Scheme: YSU scheme

Surface Scheme: Monin-Obukhov scheme

Land Surface Scheme: Noah scheme

Chemical scheme: CB-05 with aqueous and aerosols chemistry

Emissions: EMEP, NAEI, LAEI, EPER

Study period: 2005 (CMAQ and MET) and 2008 (MET)

2005 is a year with no extreme weather condition
2008 is a wetter year

WRF/CMAQ evaluation framework

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Health Protection Agency
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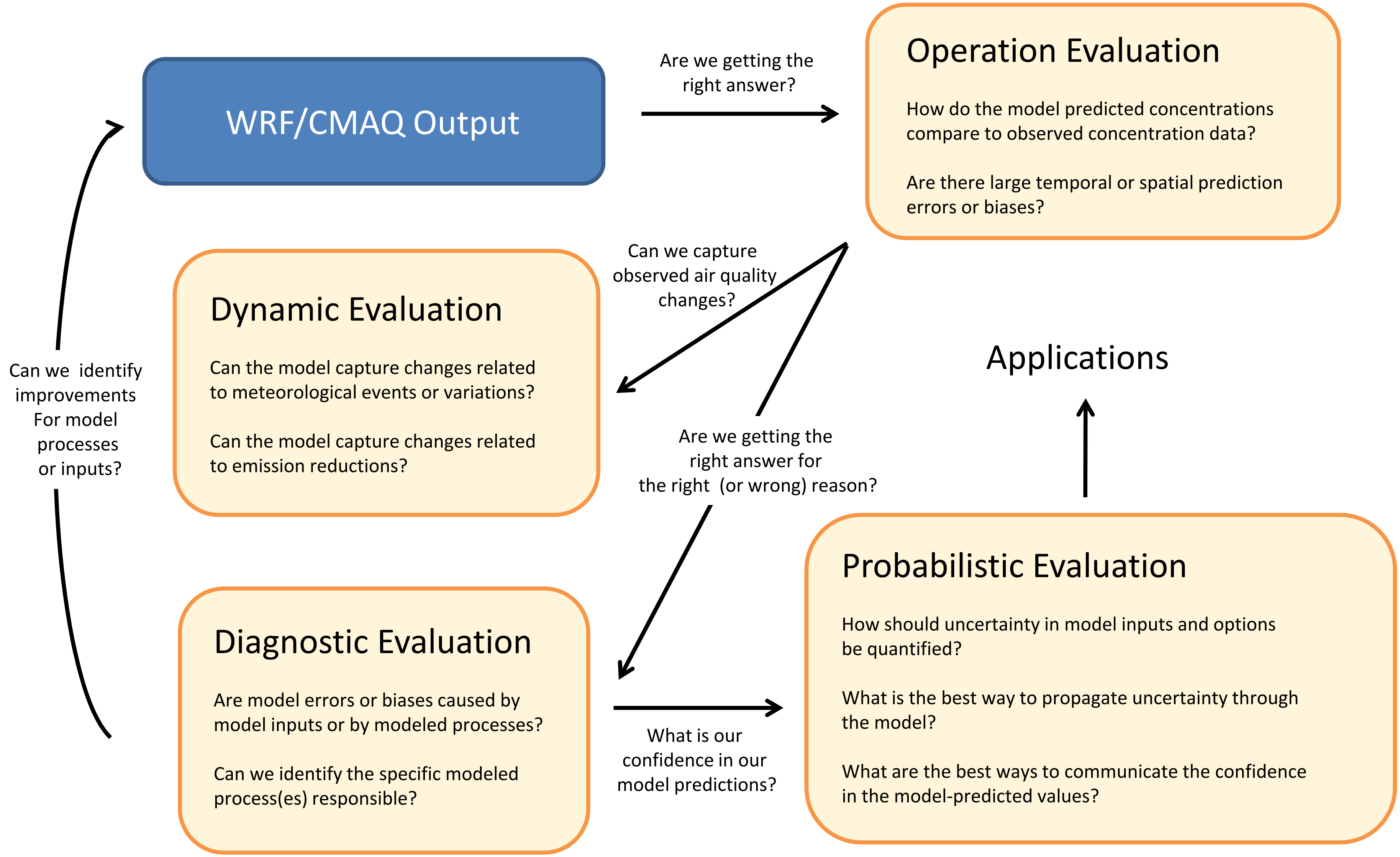

Source: ST RAO (USEPA)

AMET and Openair: Model Evaluation Tools

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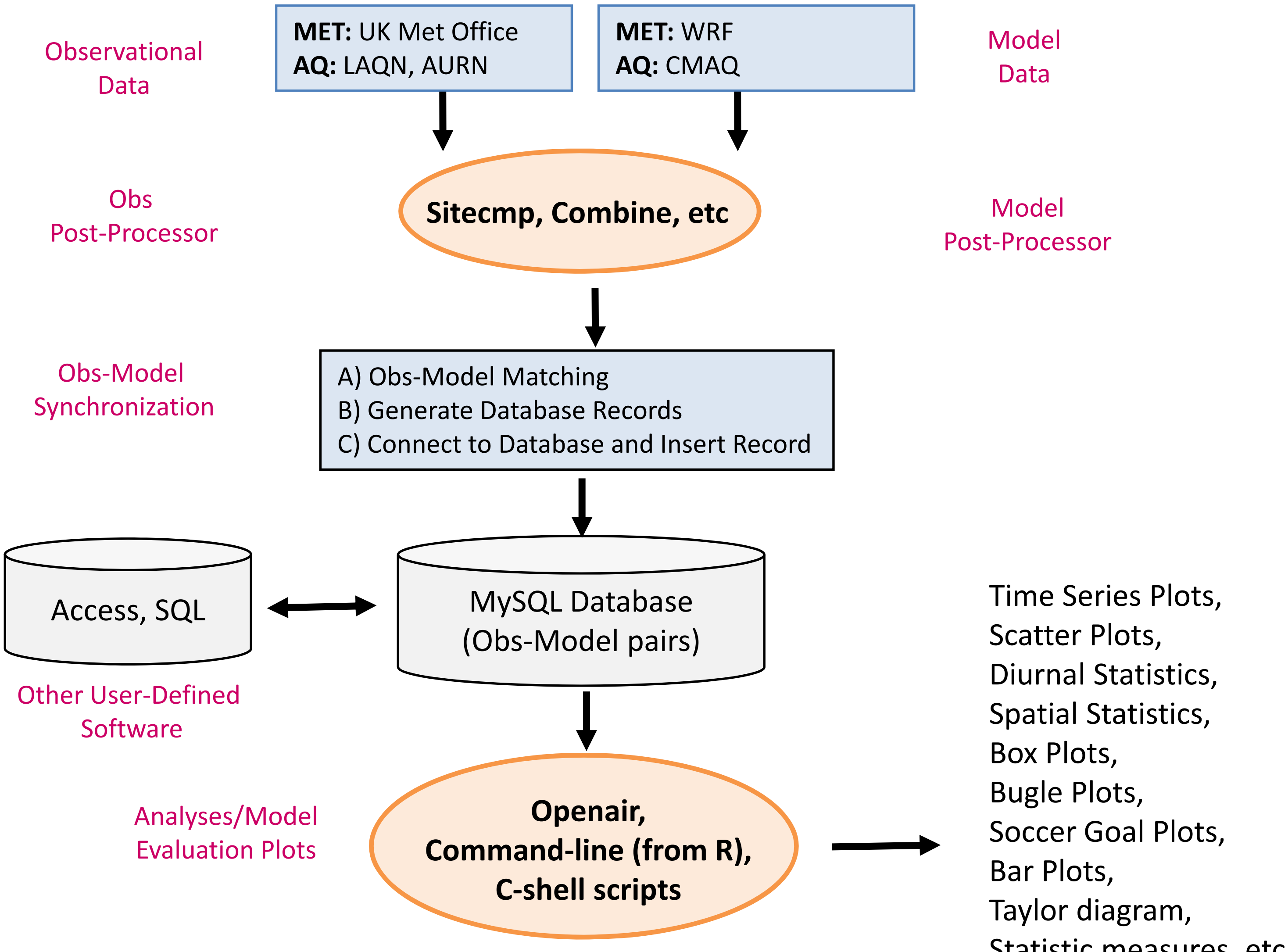

AMET (USEPA): http://www.cmascenter.org/

Openair project (David Carslaw, NERC-funded project) : http://www.openair-project.org/

Evaluation of WRF model

Synoptic scale: sea level pressure at 0 UTC, 3 Feb 2005

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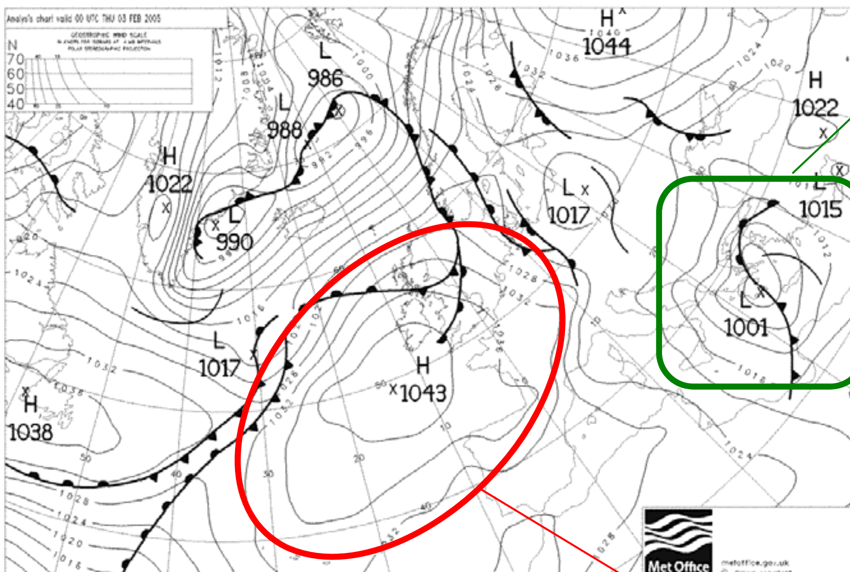
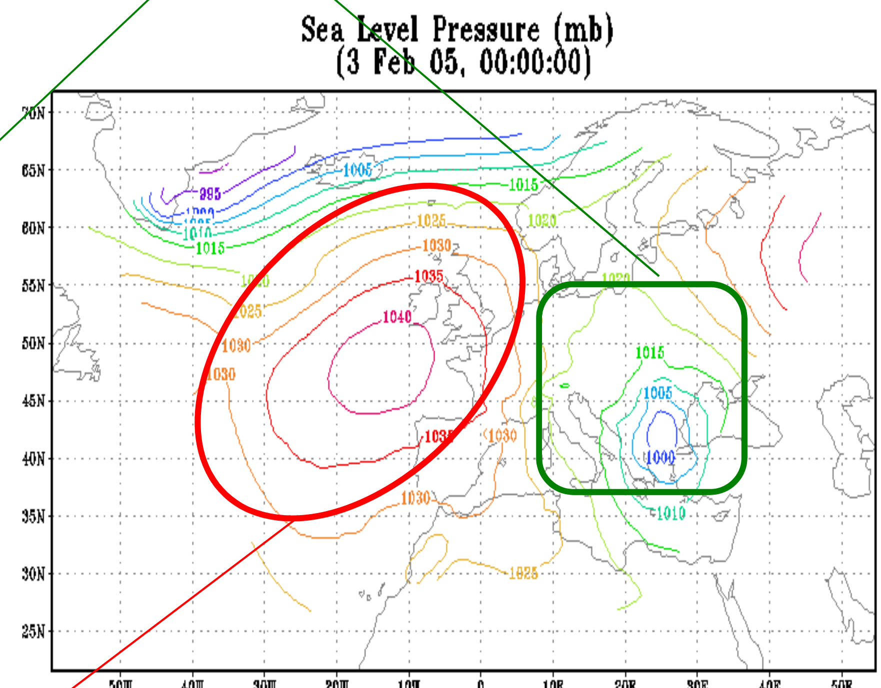
MRC
Health Protection Agency
Centre for Environment and Health

Low Pressure system





High Pressure system

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Evaluation of WRF model

Synoptic scale: sea level pressure at 0 UTC, 3 Jul 2005

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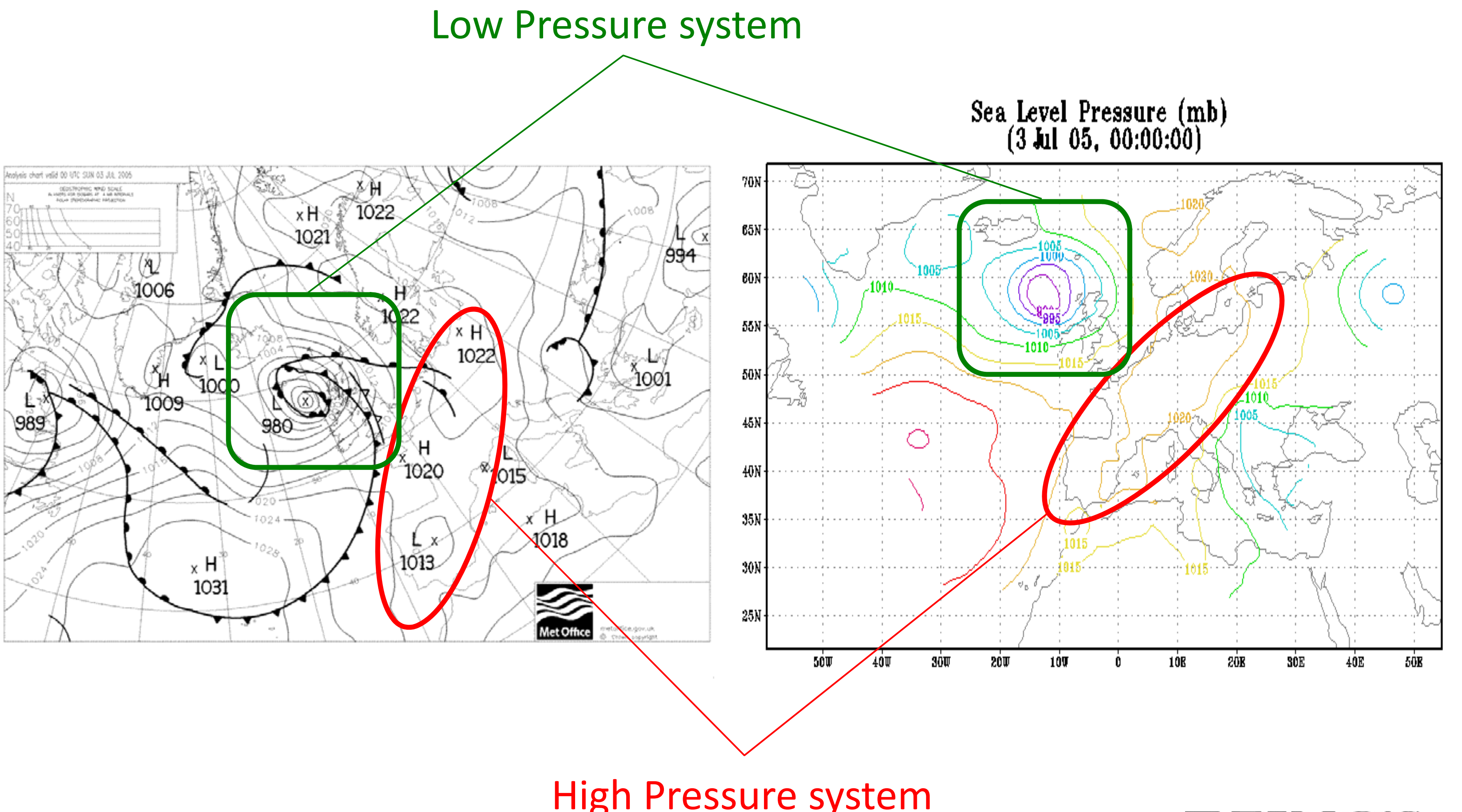
Health Protection Agency
Centre for Environment and Health



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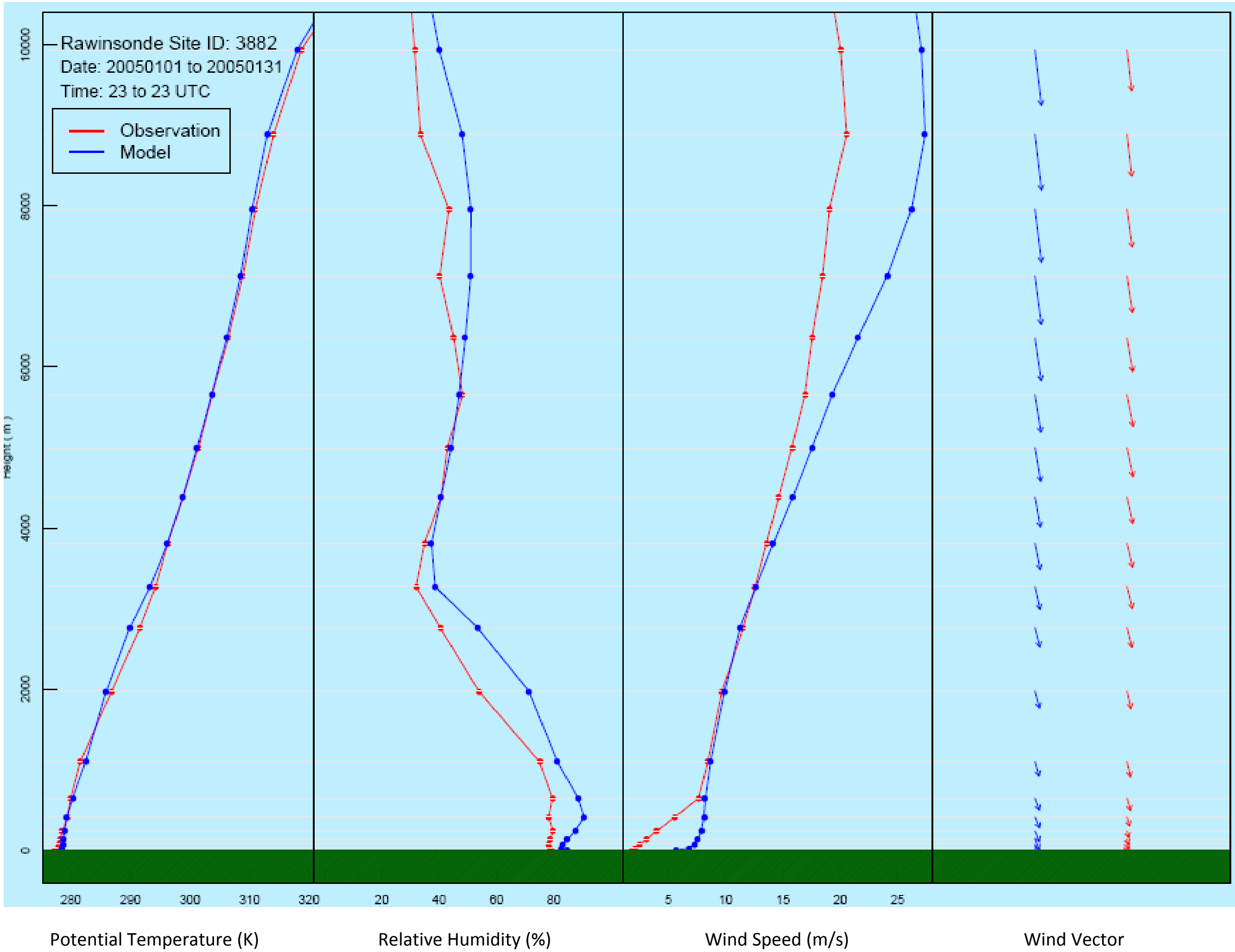
Vertical profiles of met. at Hermonceux
23 UTC, Jan 2005

Centre for Environment and Health



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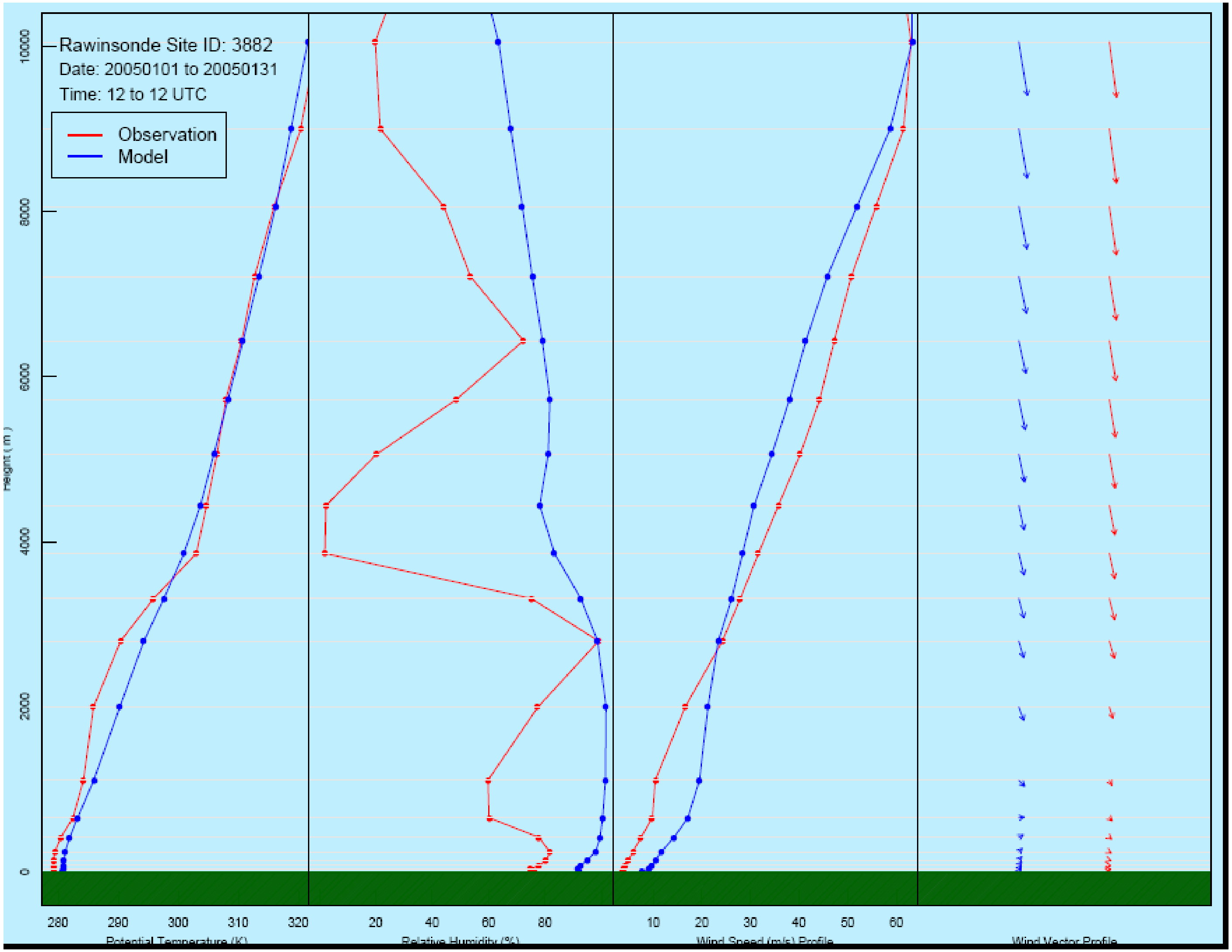
Vertical profiles of met. at Hermonceux

12 UTC, Jan 2005

Centre for Environment and Health



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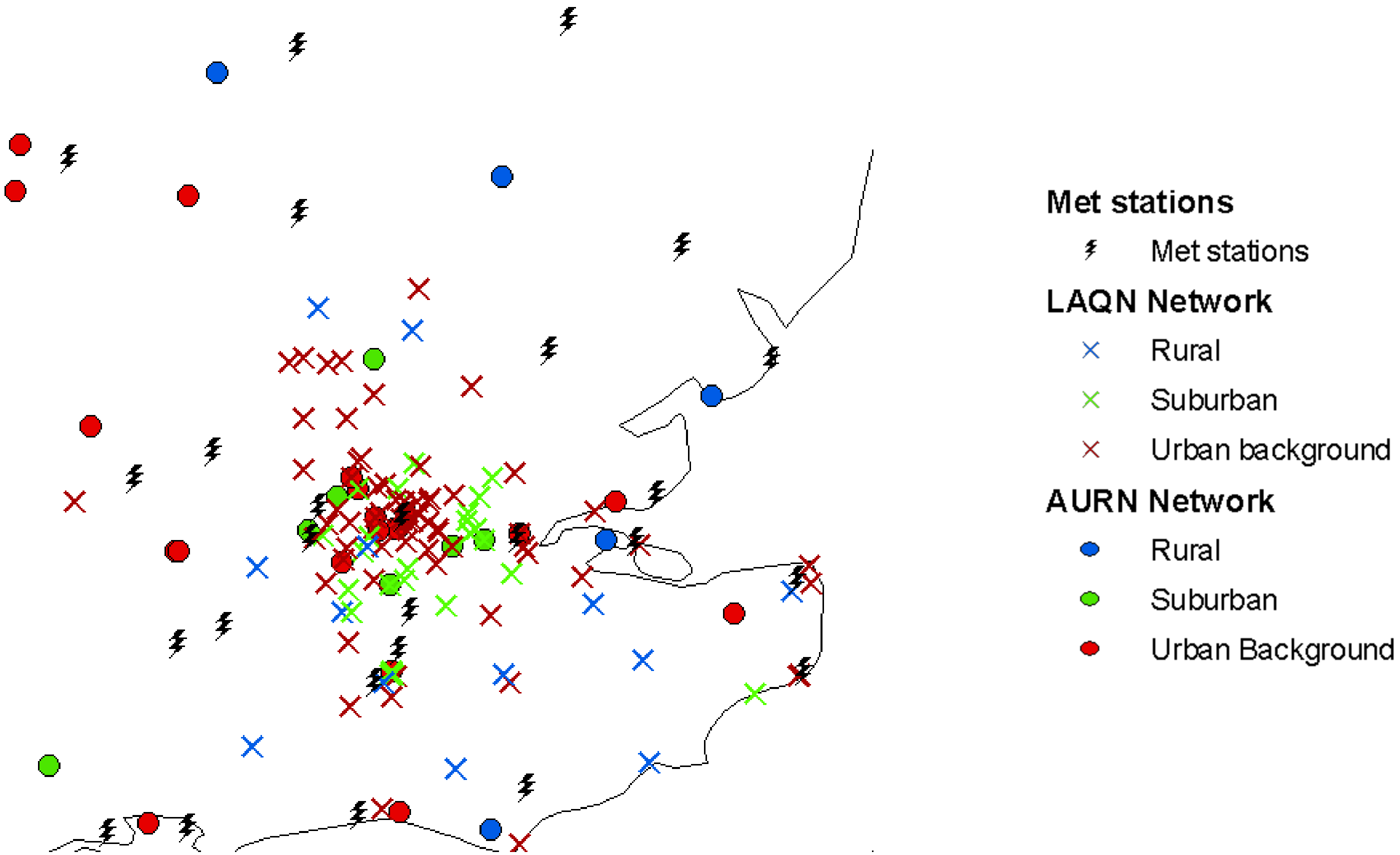
Operational evaluations

Meteorological and air quality monitoring networks

MRC Medical Research Council

Health Protection Agency

Centre for Environment and Health



26 met sites, 120 air quality monitoring sites
(76 urban background, 24 suburban and 20 rural sites)

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Time series and scatter plots of surface meteorology 2005

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Health Protection Agency
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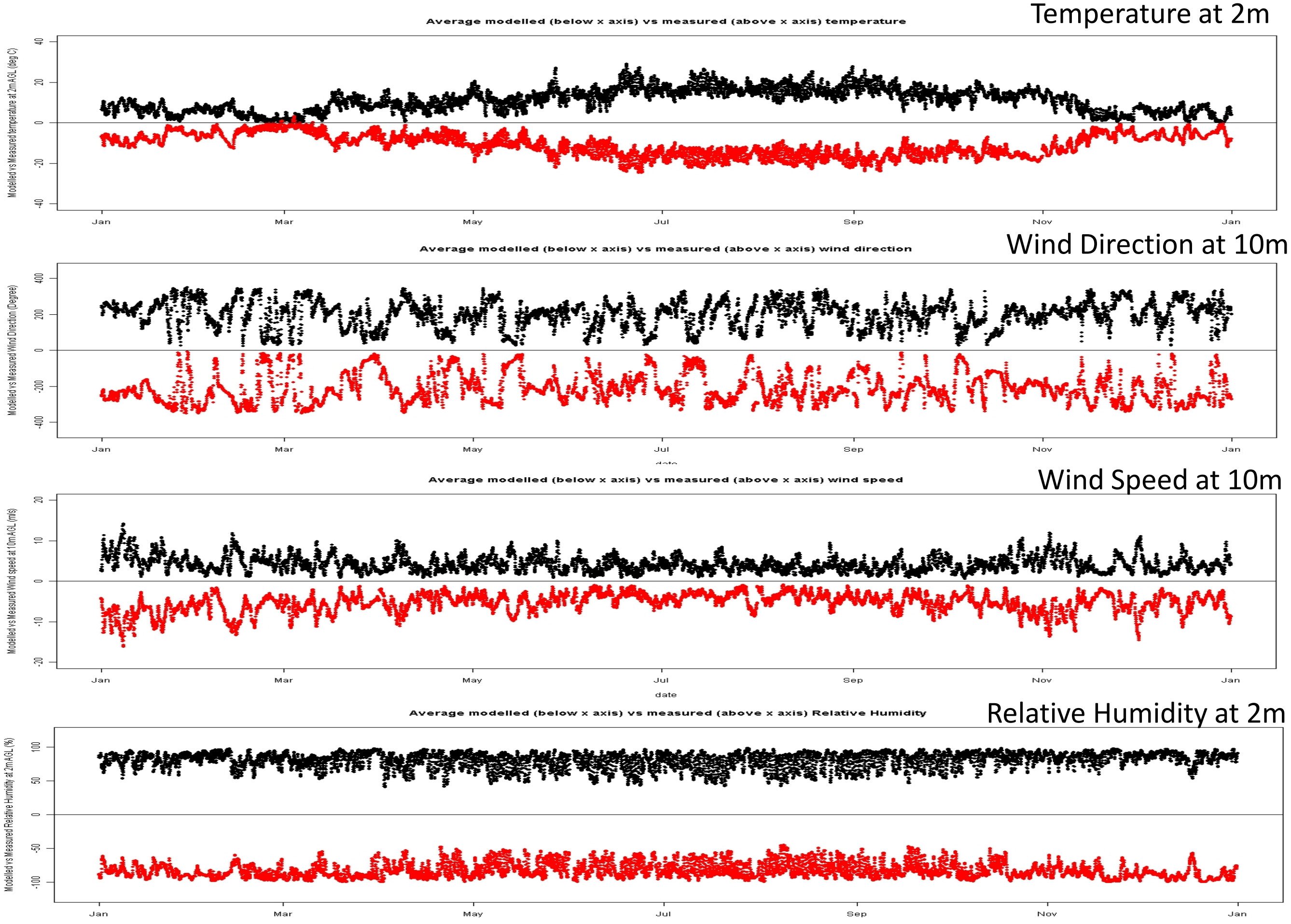
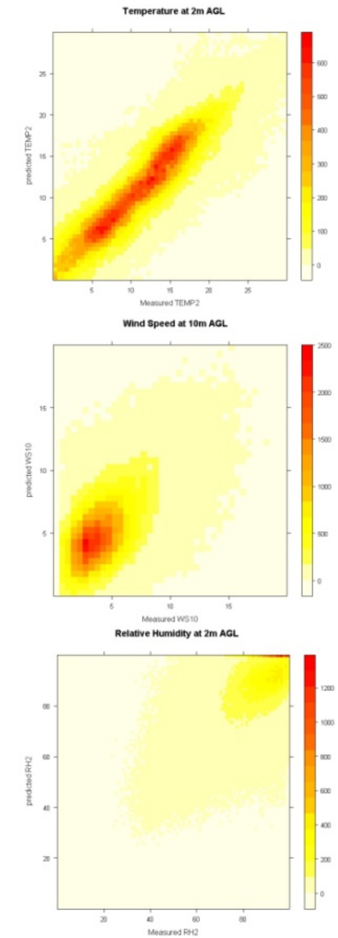
Temperature at 2m

Wind Direction at 10m

Wind Speed at 10m

Relative Humidity at 2m





Black = Observed Red = Modelled * (-1)

Average of 26 met sites

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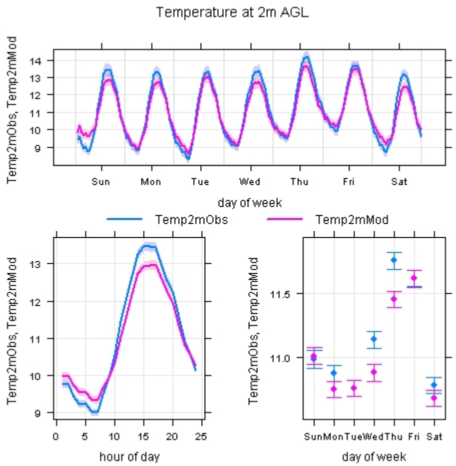
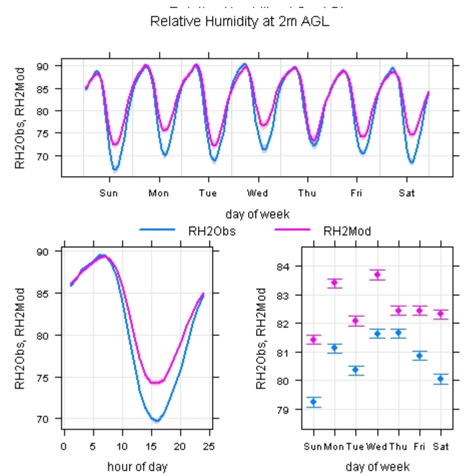
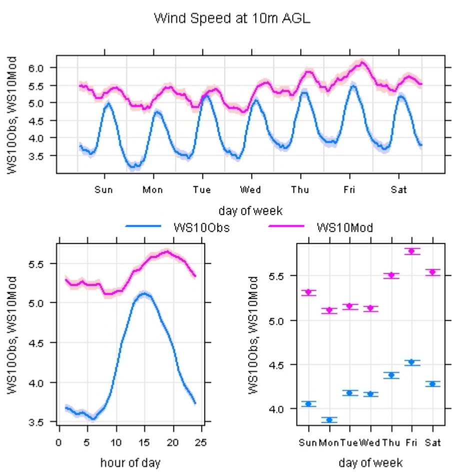
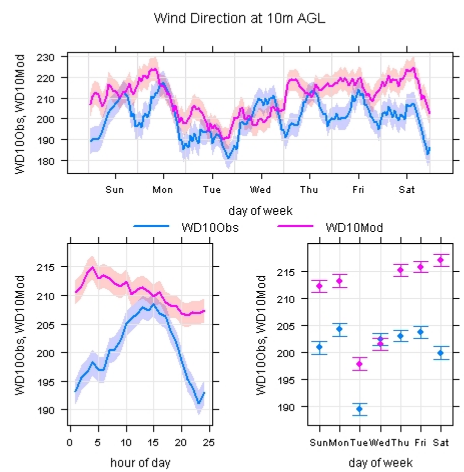
Diurnal variations of surface meteorology
Average of 26 sites (2005)

Medical Research Council
Health Protection Agency
Centre for Environment and Health









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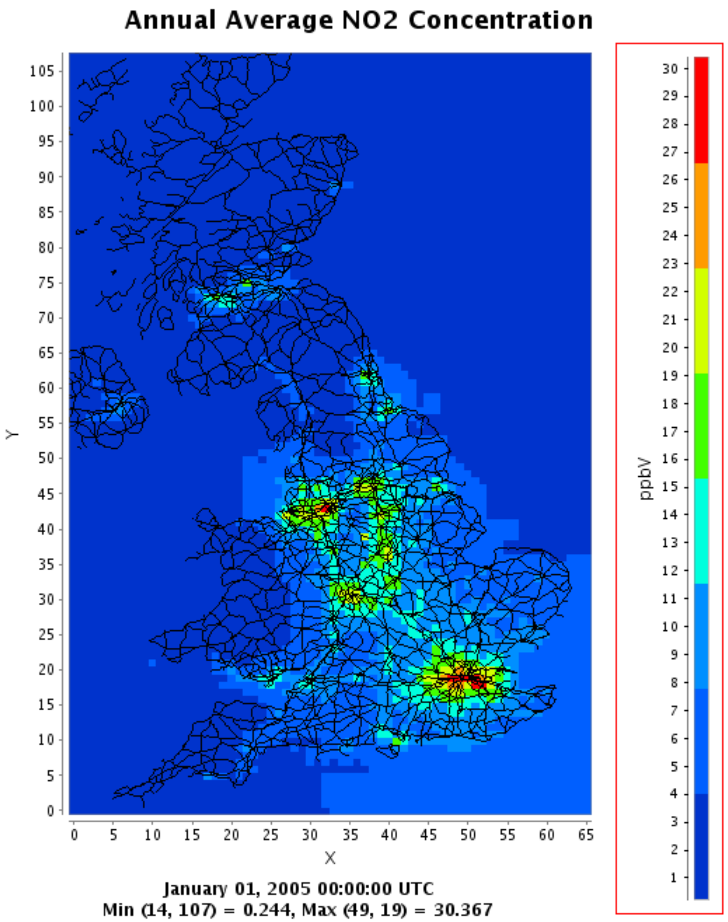
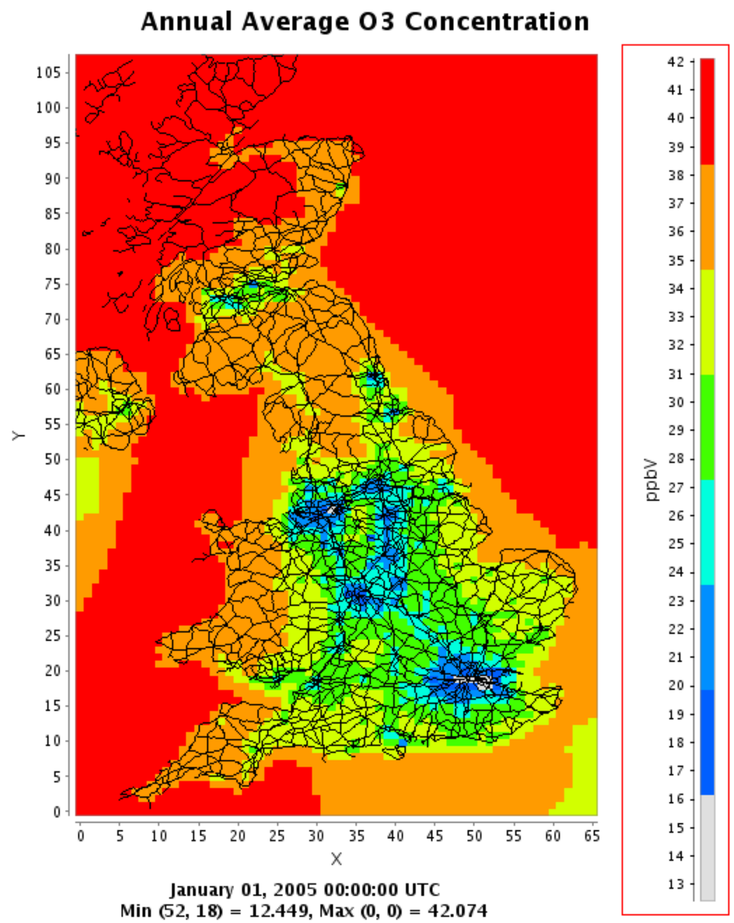
Horizontal distribution of surface pollutants

2005 annual average of NO_2 and O_3 concentration

Centre for Environment and Health





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Time series and scatter plots of NO_2 and O_3 concentration (2005)

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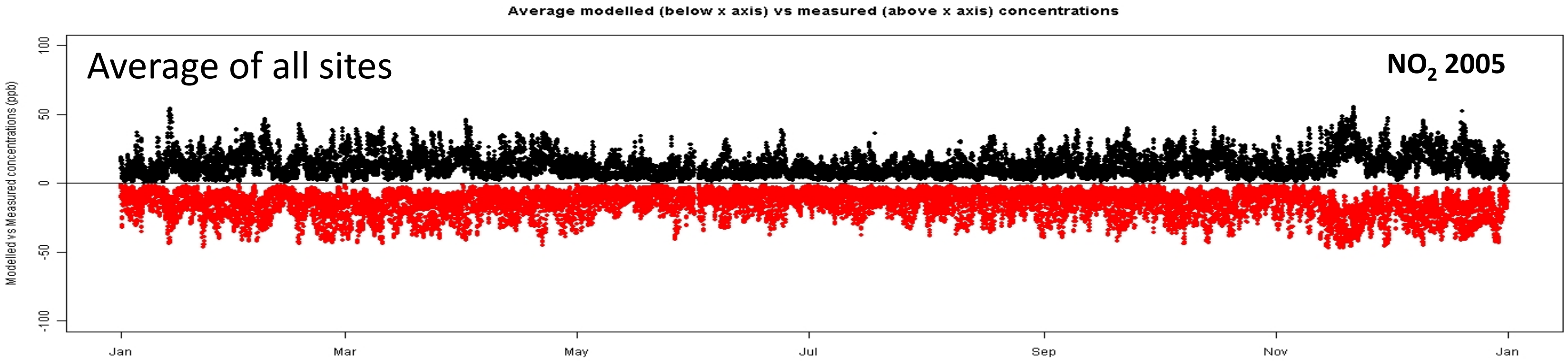
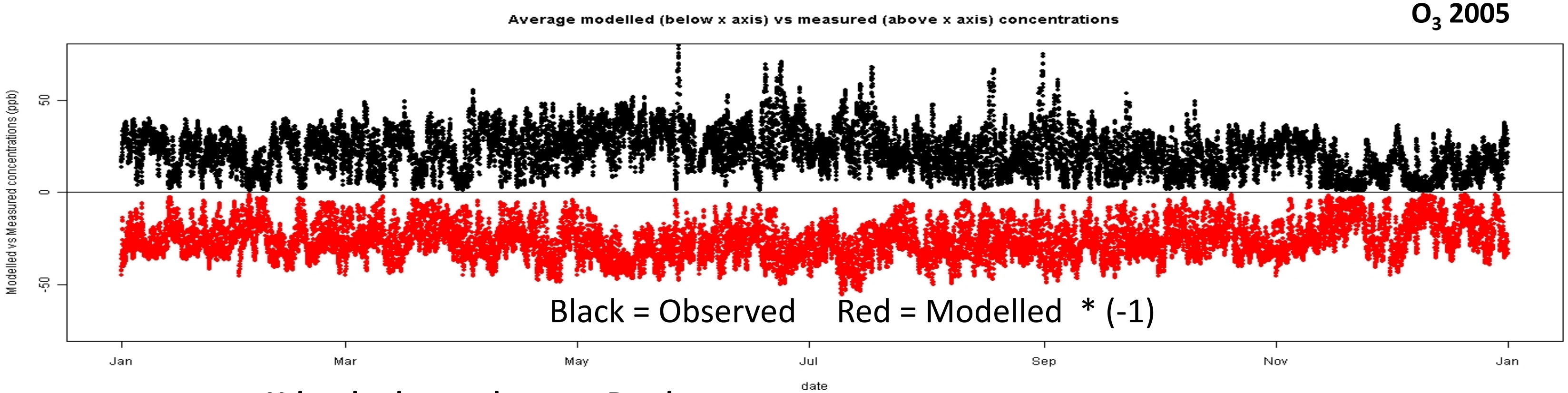
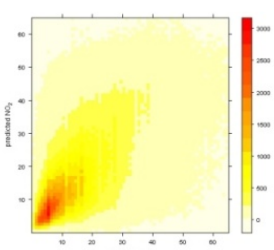
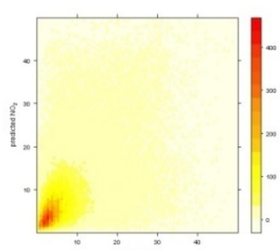




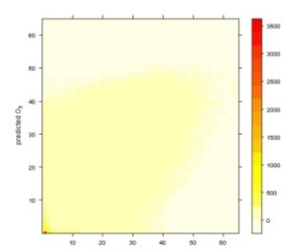
Urban background **Rural**

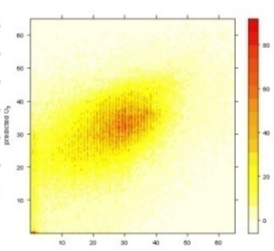




NO_2

Urban background **Rural**



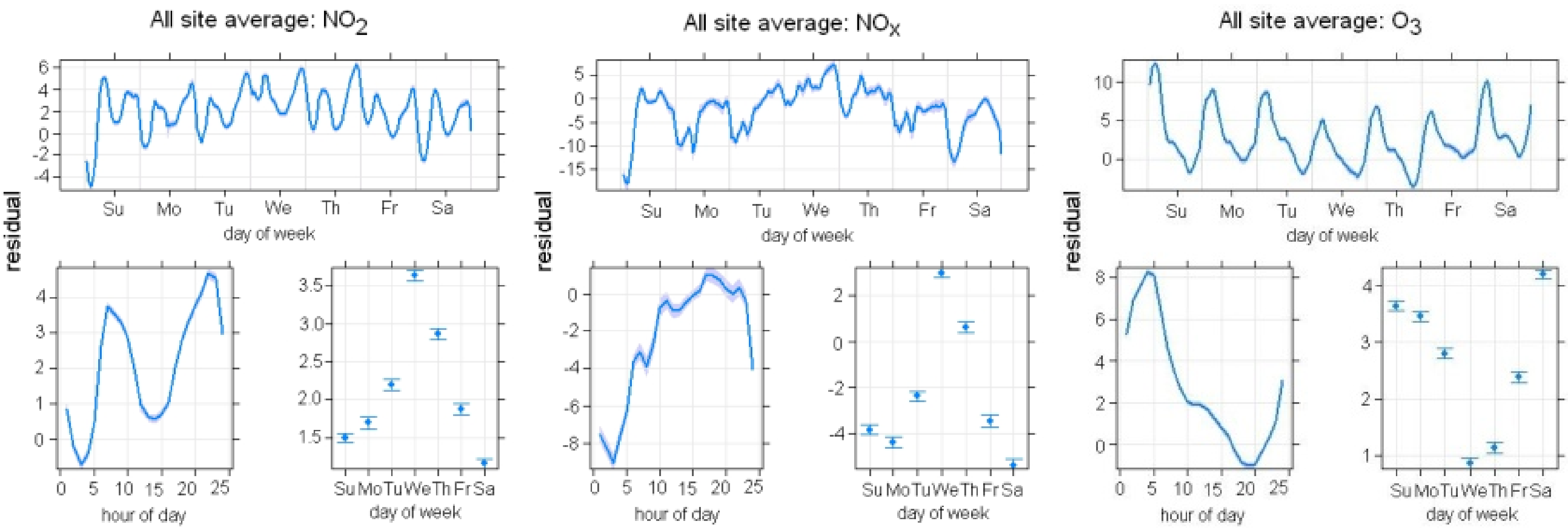


O_3

Diurnal error of NO_2, NO_x and O_3

Average of all sites (2005)

Centre for Environment and Health



Residual = modelled - observed

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Operational Evaluation

Diurnal error of wind speed at 10m

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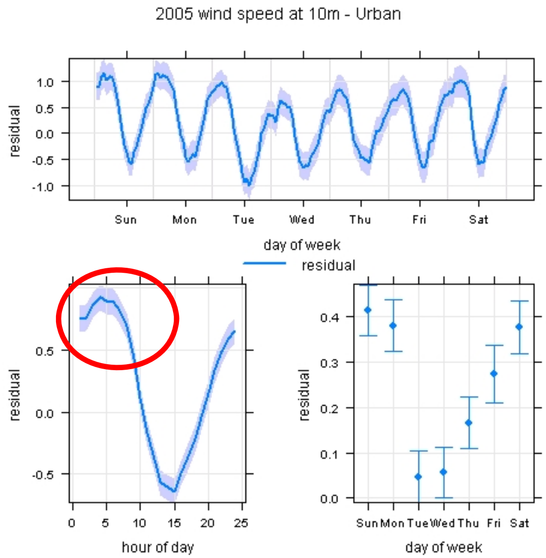
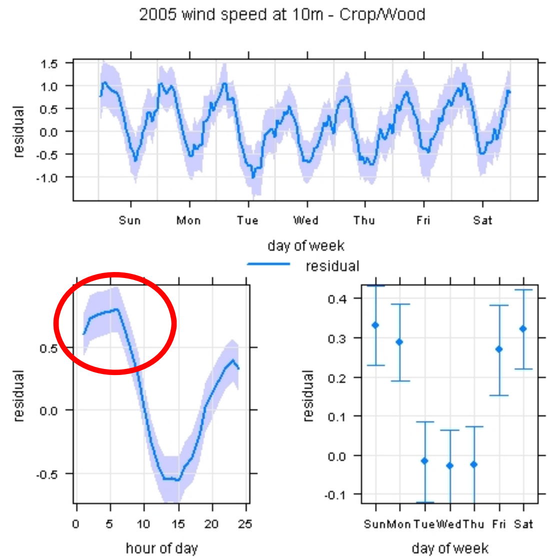
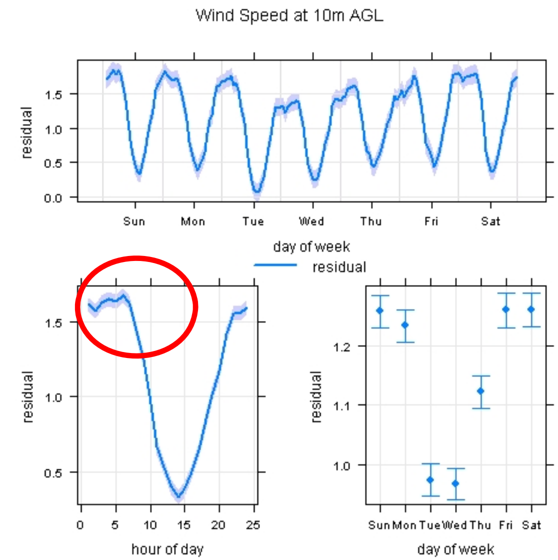
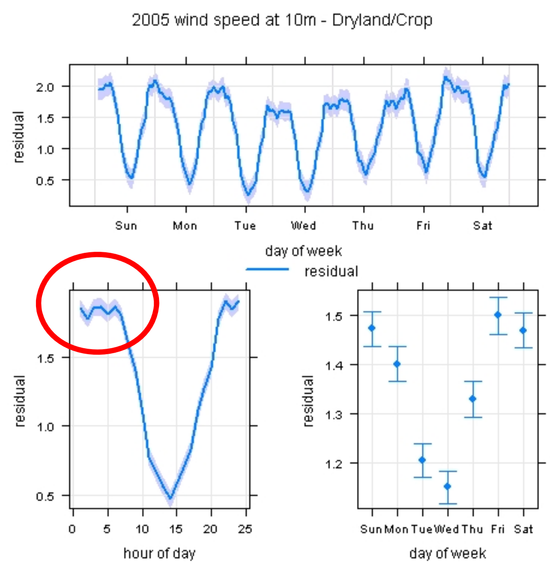
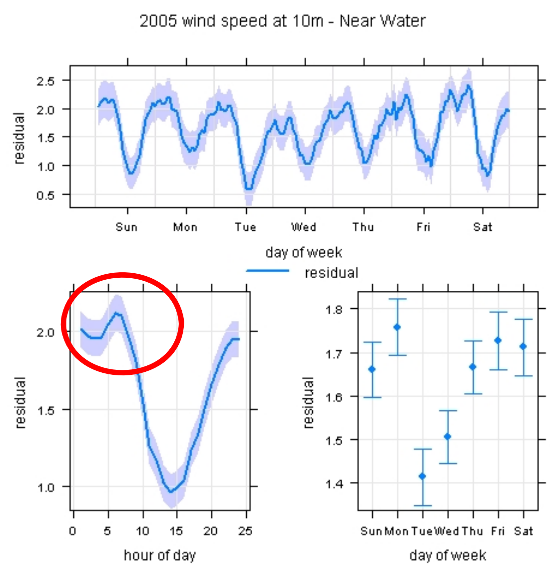




All Site average







Residual = modelled - observed

Statistical measures

Met, NO_2, NO_x and O_3 concentrations (2005)

Medical Research Council
Health Protection Agency
Centre for Environment and Health

Parameters	IA	CORR	RMSE	NMB	MB
WSPD10	0.73	0.58	2.73	27.4	1.15
TEMP2	0.95	0.9	2.58	-1	-0.11
RH2	0.78	0.61	12.59	2.3	1.88
NO_2	0.77	0.61	11.08	13	2.17
NO_x	0.68	0.52	34.23	-6	-1.77
O_3	0.75	0.56	12.4	14	2.84

UK DEFRA acceptable values (+/- 20%)

IA = Index of Agreement, CORR = correlation coefficient,
RMSE = root mean square error, NMB = normalised mean bias,
MB = mean bias

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Operational Evaluation

Taylor Diagram: Site representativeness

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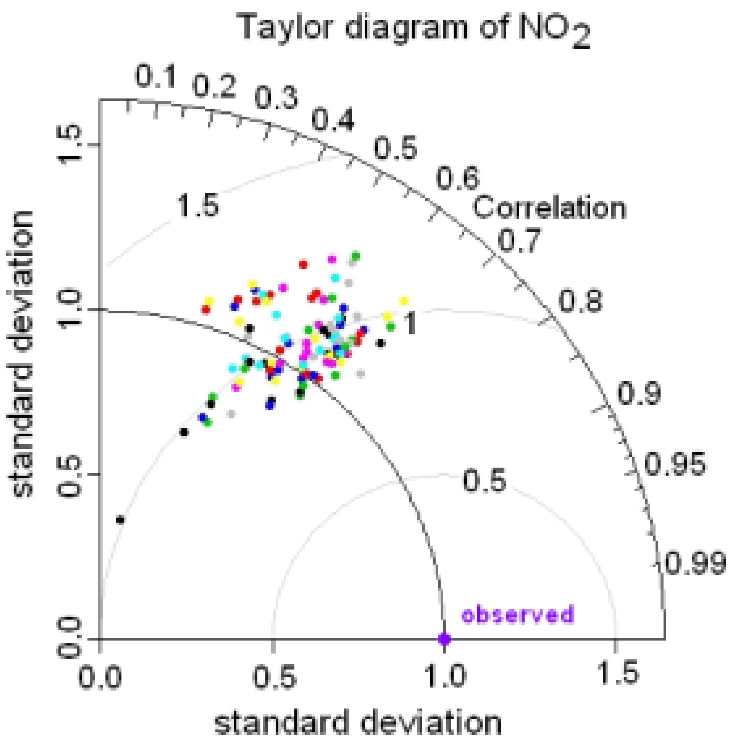

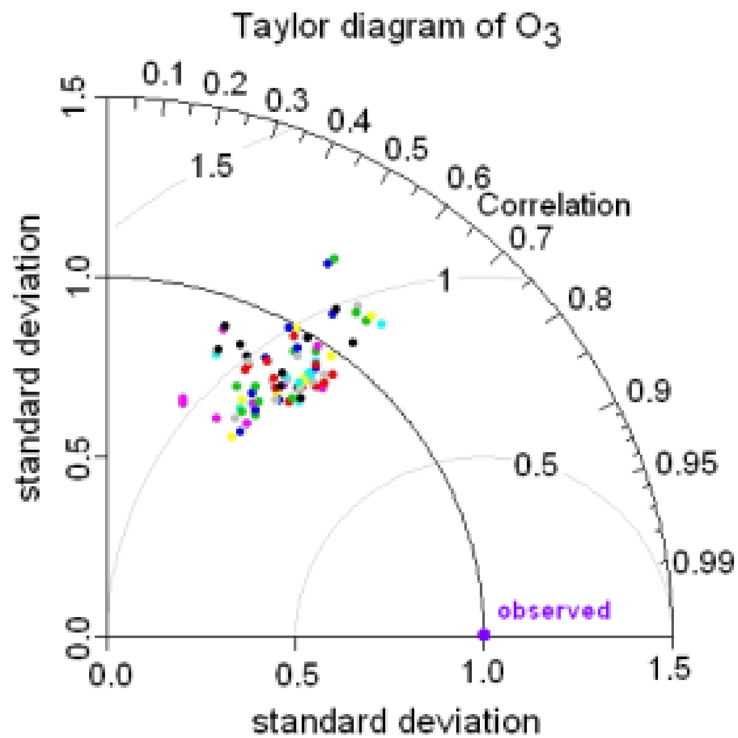

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Comparison of point measurements and grid models (NO_X) - site representativeness

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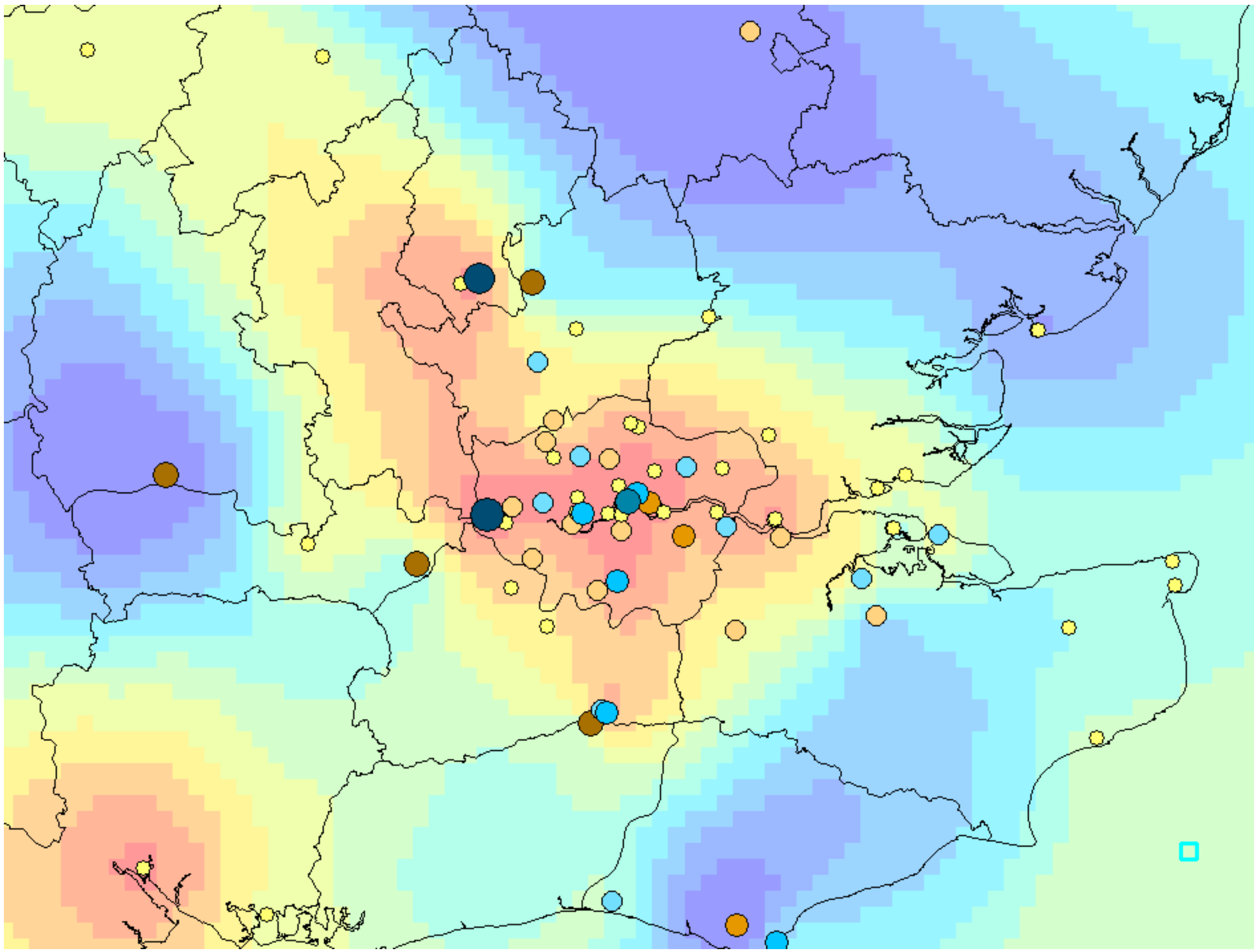

Model - observation

- -23.5 - -20.0
- -19.9 - -16.0
- -15.9 - -12.0
- -11.9 - -8.0
- -7.9 - -4.0
- -3.9 - 0.0
- 0.1 - 4.0
- 4.1 - 8.0
- 8.1 - 12.0
- 12.1 - 16.0

Kriging interpolated surface observation

- 8.2 - 10.6
- 10.7 - 12.2
- 12.3 - 13.6
- 13.7 - 15.1
- 15.2 - 16.4
- 16.5 - 18.3
- 18.4 - 20.8
- 20.9 - 23.8
- 23.9 - 27.2
- 27.3 - 32.0
- 32.1 - 48.0

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Dynamic Evaluation

Surface meteorology prediction of 2005 and 2008

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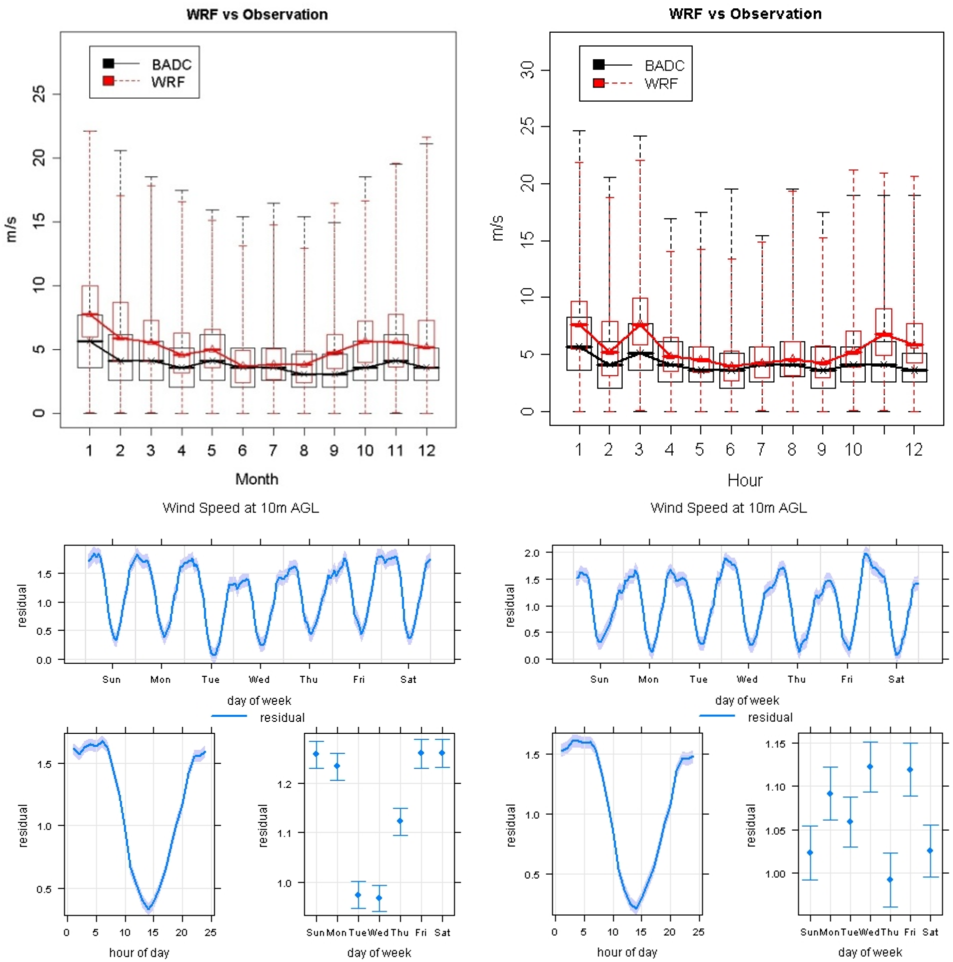

Residual = modelled - observed

- Statically predict temperature and relative humidity well
- Overpredicts night time wind speed especially in winter

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Dynamic evaluation

Meteorological prediction 2005 vs 2008

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Parameters	IA		CORR		RMSE		NMB		MB	
	2005	**2008**	**2005**	**2008**	**2005**	**2008**	**2005**	**2008**	**2005**	**2008**
WS10	0.73	0.75	0.58	0.6	2.73	2.75	27.4	23.2	1.15	1.06
T2	0.95	0.94	0.9	0.89	2.58	2.49	-1	-0.5	-0.11	-0.06

IA = Index of Agreement, CORR = correlation coefficient,
RMSE = root mean square error, NMB = normalised mean bias,
MB = mean bias

Time series and scatter plots of NO_2 and O_3

Average of all sites – 2008

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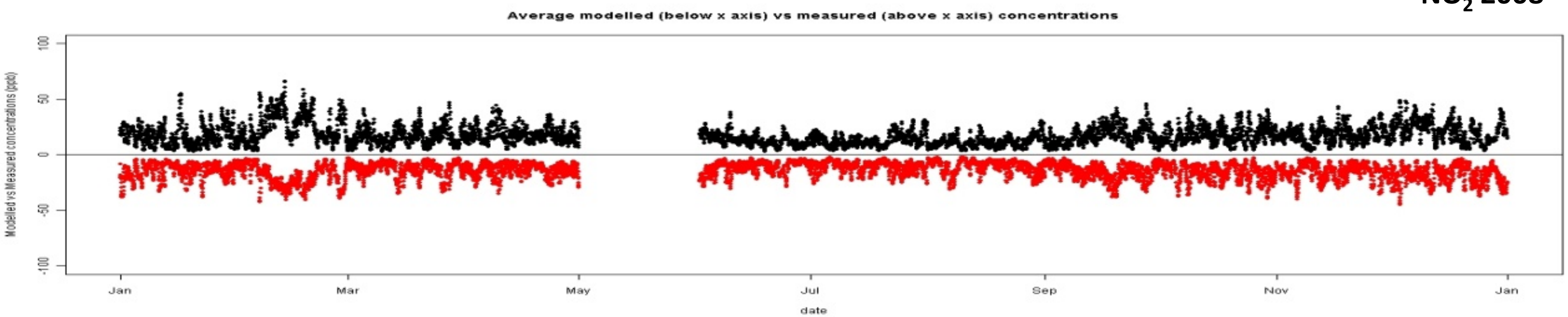
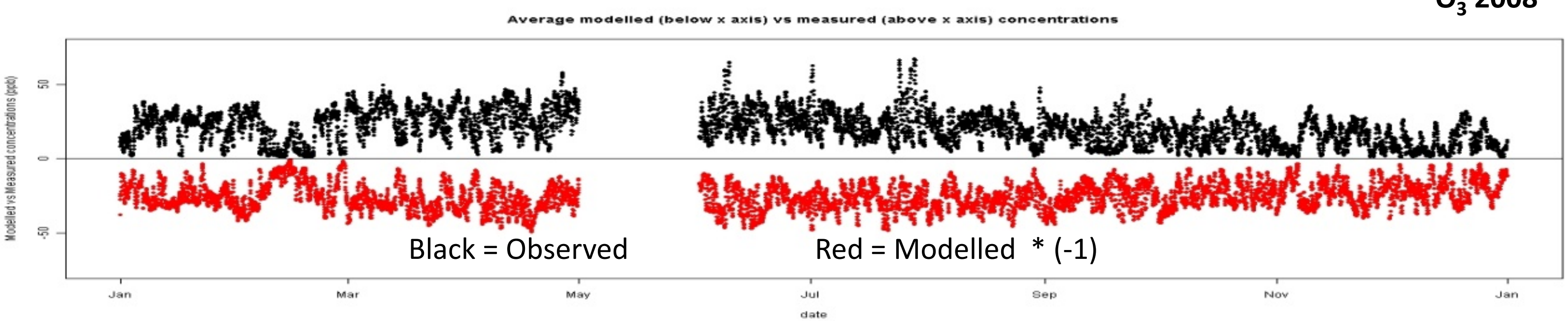
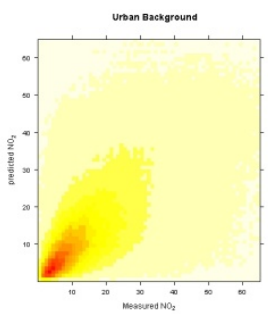
NO_2 2008

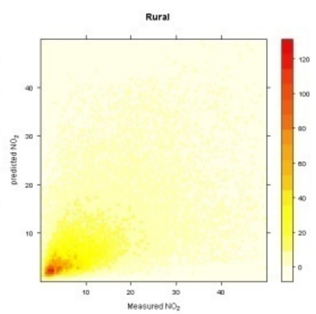


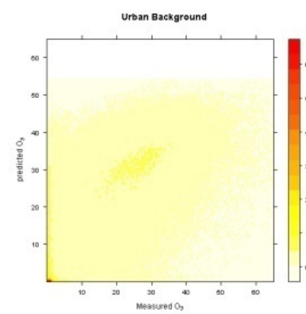
O_3 2008

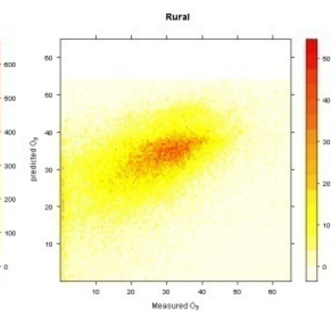


Urban background **Rural** **Urban background** **Rural**









NO_2 O_3

Statistical measures for NO_2 and O_3

2005 and 2008

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Health Protection Agency
Centre for Environment and Health

Note! 2005 simulation uses CMAQ 4.6 while 2008 uses CMAQ 4.7
NO_x emissions are also different between 2005 and 2008, hence incomparable

Pollutants	IA		CORR		RMSE		NMB		MB	
	2005	2008	2005	2008	2005	2008	2005	2008	2005	2008
NO_2	0.77	0.78	0.61	0.62	11.08	10.38	13	-4.6	2.17	-0.78
O_3	0.75	0.73	0.56	0.58	12.4	12.54	14	26.1	2.84	5.39

IA = index of agreement, CORR = correlation coefficient,
RMSE = root mean square error, NMB = normalised mean bias,
MB = mean bias

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Dynamic evaluation

30% NO_x and VOC emission reductions (1-14 July 2005)

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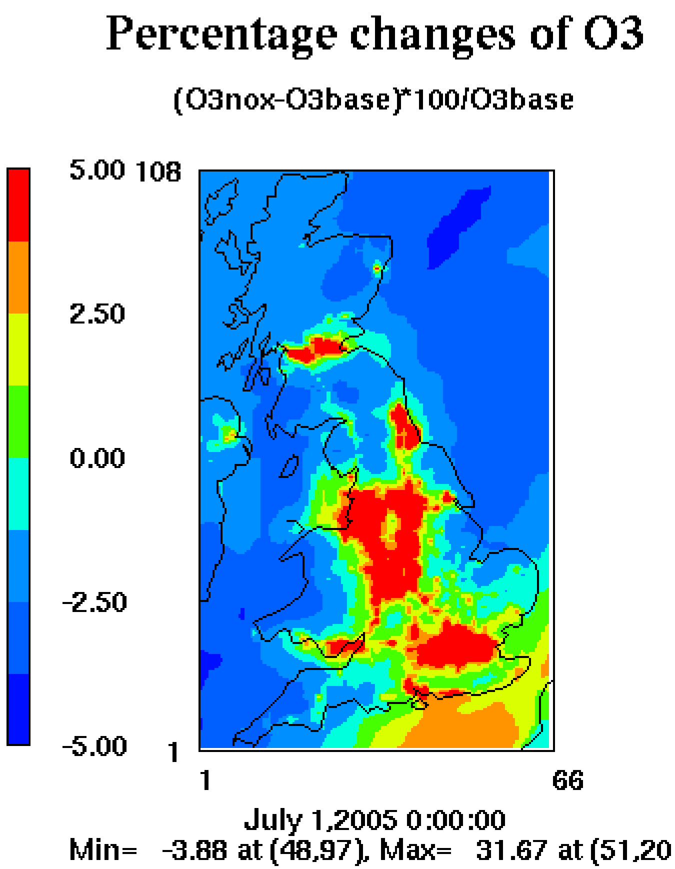

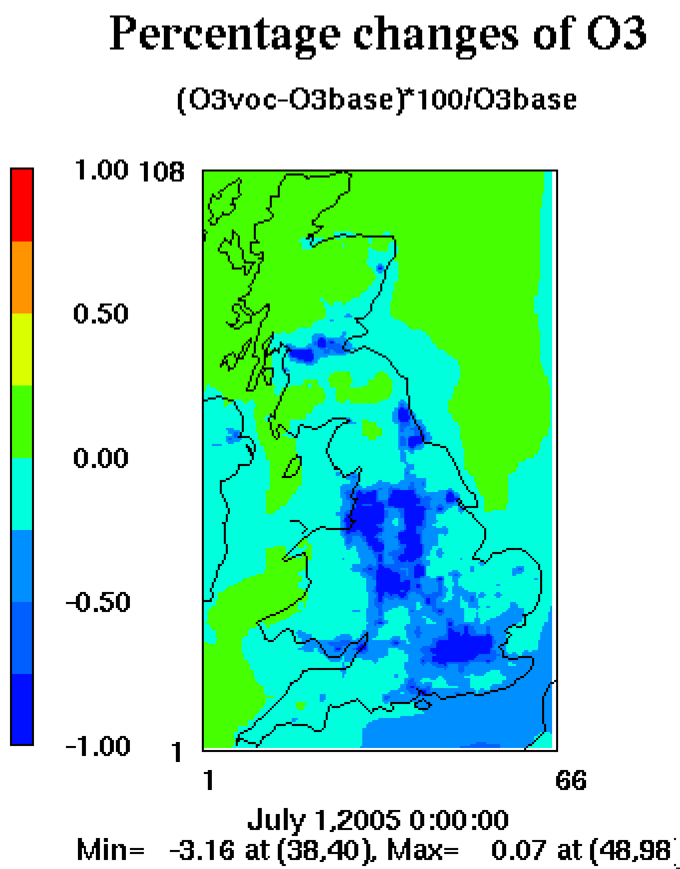

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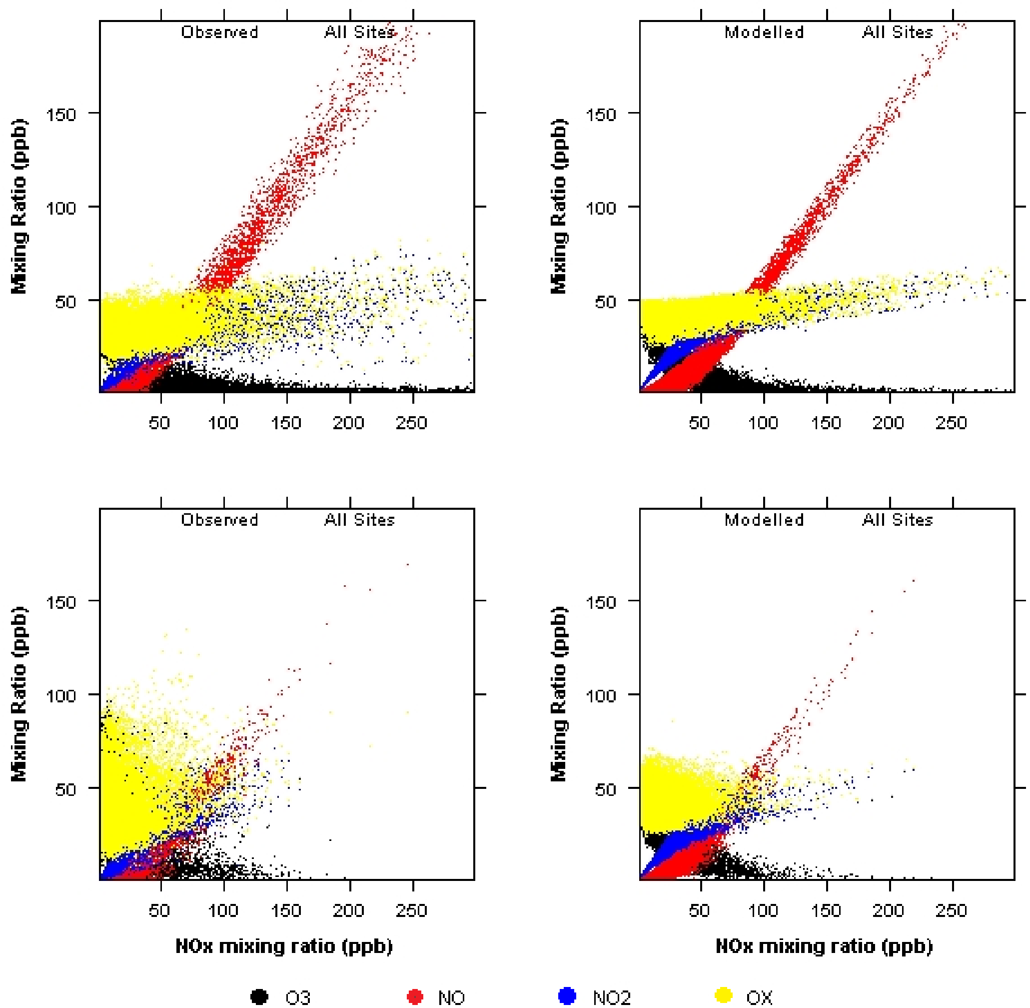
Diagnostic evaluation - 2005

CMAQ NO_2-NO_x-O_3 chemistry: daytime in winter and summer

Medical Research Council
MRC
Health Protection Agency
Centre for Environment and Health



Winter

OX = O3 + NO2

Summer

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Diagnostic evaluation - 2005

CMAQ NO_2-NO_x-O_3 chemistry:

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Observed and modelled daytime local and regional contribution to oxidant at all sites

Season	Observed local OX (ppb ppb-1 NO_X)	Modelled local OX (ppb ppb-1 NO_X)	Observed regional OX (ppb)	Modelled regional OX (ppb)
Winter	0.07	0.06	34.02	39.68
Spring	0.05	0.03	42.55	42.85
Summer	0.13	0.01	37.33	42.16
Autumn	0.09	0.07	33.33	40.05

OX = O3 + NO2

OX = localOX*NOx + regionalOX

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Summary of model evaluation

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Operational evaluation:

- WRF predicts some bias on vertical profiles of wind speed and relative humidity
- WRF predicts synoptic scale features and surface meteorological conditions well but over-predicts night-time wind speed especially in winter
- CMAQ overestimates night-time O_3 which may be due to over-prediction of wind speed and dilution of NO_x
- Bias of the model may also be due to site representativeness issue

Dynamic evaluation:

- WRF/CMAQ is able to capture changes of meteorology and emissions

Diagnostic evaluation:

- The model predicts the correlation between NO_2,NO_x and O_3 well
- This evaluation indicates that the model under-predicts local NO_x and over-predicts O_3. The reasons may be the same as explained in operational evaluation

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Future Work

- To further investigate and hopefully improve night-time wind speed prediction
- To assess the model performance on PMs prediction
- To develop further model evaluation techniques such as spectral time series analysis to quantify the model performance on temporal and spatial variation
- To resolve site representativeness issues using technique such as spectral time series analysis
- To identify uncertainty of the model through the probabilistic evaluation

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Thank you for your attention…

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