Intercomparison of five modelling methods including ADMS-Airport and EDMS for predicting air quality at London Heathrow Airport

presented by

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Project for the Sustainable Development of Heathrow

Panels for Emissions, Monitoring, Modelling

Model Intercomparison Exercise

- Models to represent emissions of all source types including aircraft and road traffic emissions and regional background.
- Dispersion of pollutants from the sources to include the impact of meteorology and other confounding factors.
- Models to includes conversion of NO to the NO_2 – key pollutant.
- Model intercomparisons, comparisons with data and an exacting set of model diagnostic tests.

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Candidate Models

Netcen Methodology - semi empirical, uses ADMS 3

EDMS - FAA model, uses AERMOD

ADMS-Airport

ERG – semi empirical uses ADMS 3

LASPORT – lagrangian particle model

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ADMS-Airport

ADMS-Airport is an extension of ADMS-Urban designed to model pollutant concentrations in the neighbourhood of an airport. It includes all features of ADMS-Urban including the following:

- Allowance for up to 6000 sources: road (1500, each with upto 50 vertices), industrial (1500), area sources (3000);
- Fully integrated street canyon model based on Danish OSPM model/impacts of noise barriers;
- Local and regional NO_x chemistry calculation (NO, NO_2 and O_3)
- ADMS-Urban based on ADMS 3;
- ‘Local’ ADMS dispersion model nested within trajectory model
- Integrated with GIS and Emissions Database. Output via GIS includes high resolution pollutant concentration maps;
- ADMS dispersion based on ADMS 3.

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ADMS-Airport

ADMS 3 is listed as an EPA Alternative model; a ‘new generation’ quasi gaussian type plume model (first version 1991) with many similar features to AERMOD. Significant differences/additions to AERMOD include:

- Plume may follow local streamline and is affected by variations in wind field;
- The integral ‘plume rise’ jet model can take account of non vertical sources;
- Complex flow model FLOWSTAR – allows treatment of hill wake effects;
- Concentration fluctuations model allows probabilistic assessment for short averaging times – no deterministic solution.

ADMS-Airport makes us of the jet model to explicitly model the impact of aircraft jet sources.

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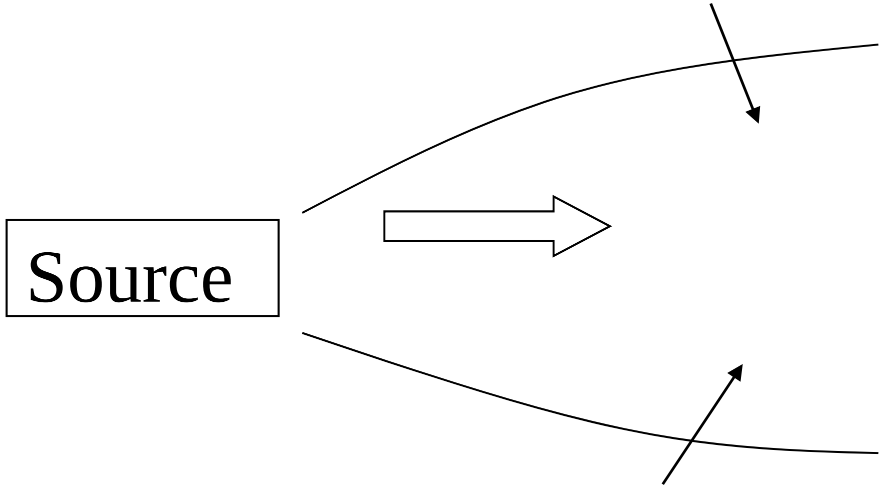
Schematic of ADMS 3 Integral Jet/Plume Model used in ADMS-Airport

Entrainment – depends on relative motion and ambient turbulence – entrainment coefficients.



drag depends on velocity perpendicular to plume axis - drag coefficient

Conservation of mass, momentum, heat and species

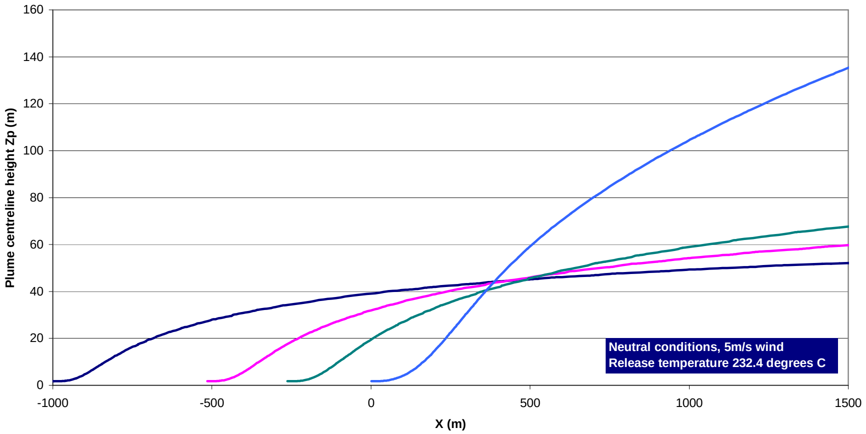
Modifications within ADMS-Airport:

-Allowance for movement of jet engine source; reduces effective bouyancy

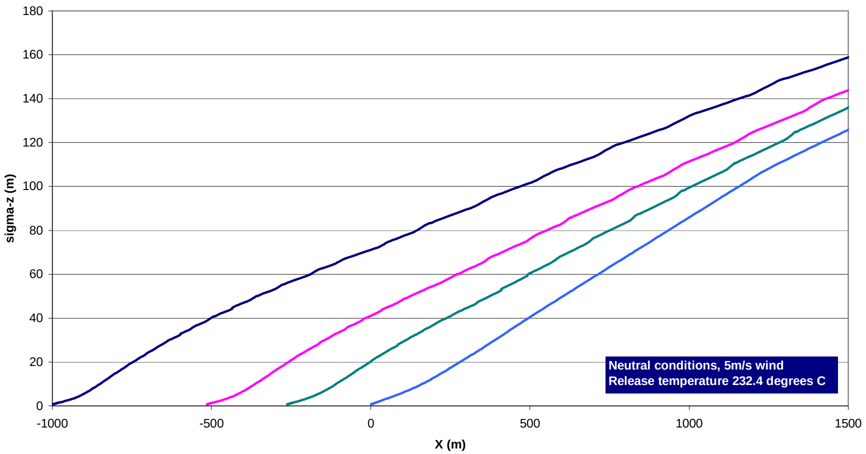
-Allowance for inpact of wake vortices on jet plume trajectory

Neutral met conditions, plume trajectory (z_p) (top), vertical spread (σ_z) (middle) and z_p - σ_z (bottom)

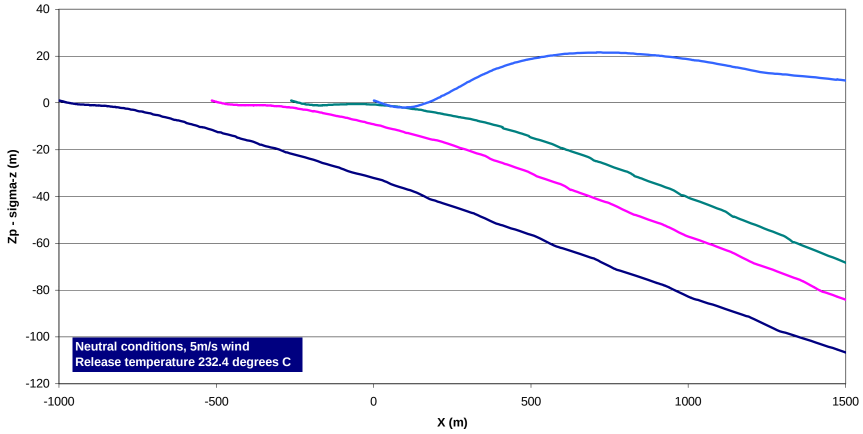
Plume centreline height of the jet exhaust emitted at different points along the runway during take-off
The take-off roll starts at x = 0 with the aircraft moving in the negative x-direction



Vertical plume spread of the jet exhaust emitted at different points along the runway during take-off
The take-off roll starts at x = 0 with the aircraft moving in the negative x-direction



Difference between plume centreline height and vertical plume spread (Zp - sigma-z) of the jet exhaust emitted at different points along the runway during take-off
The take-off roll starts at x = 0 with the aircraft moving in the negative x-direction



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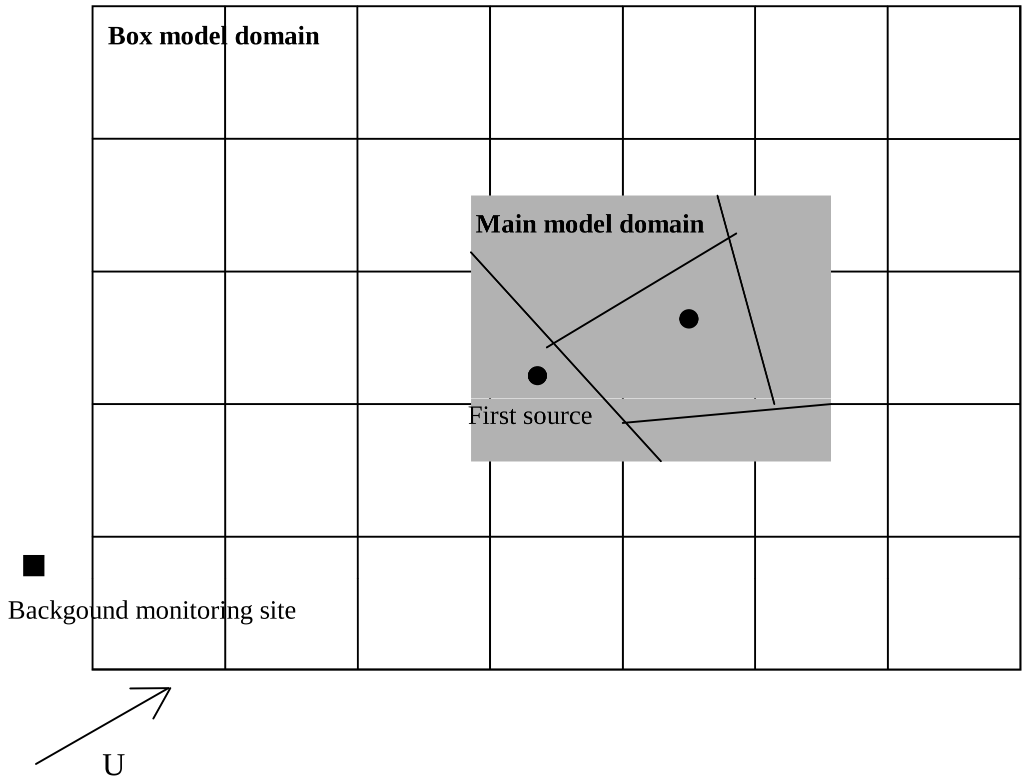
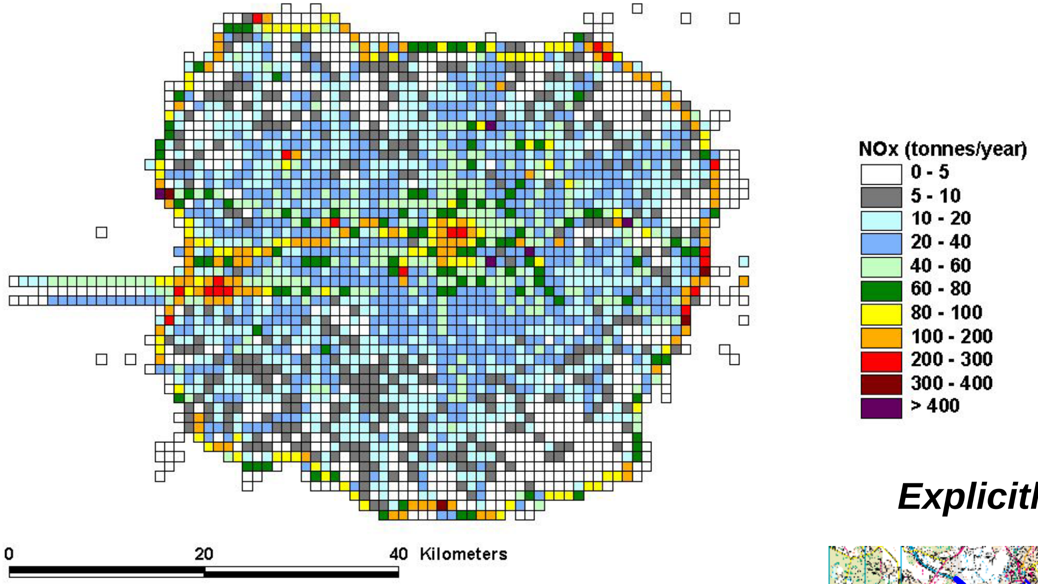
Local and Regional Scales

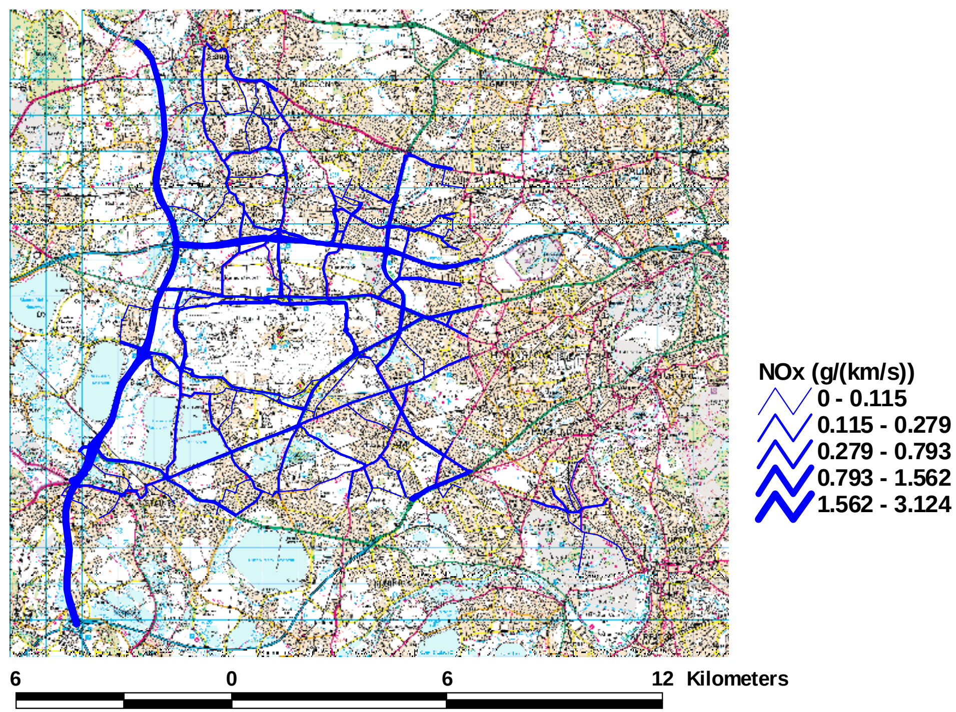


- Main model nested within large, area-wide trajectory model

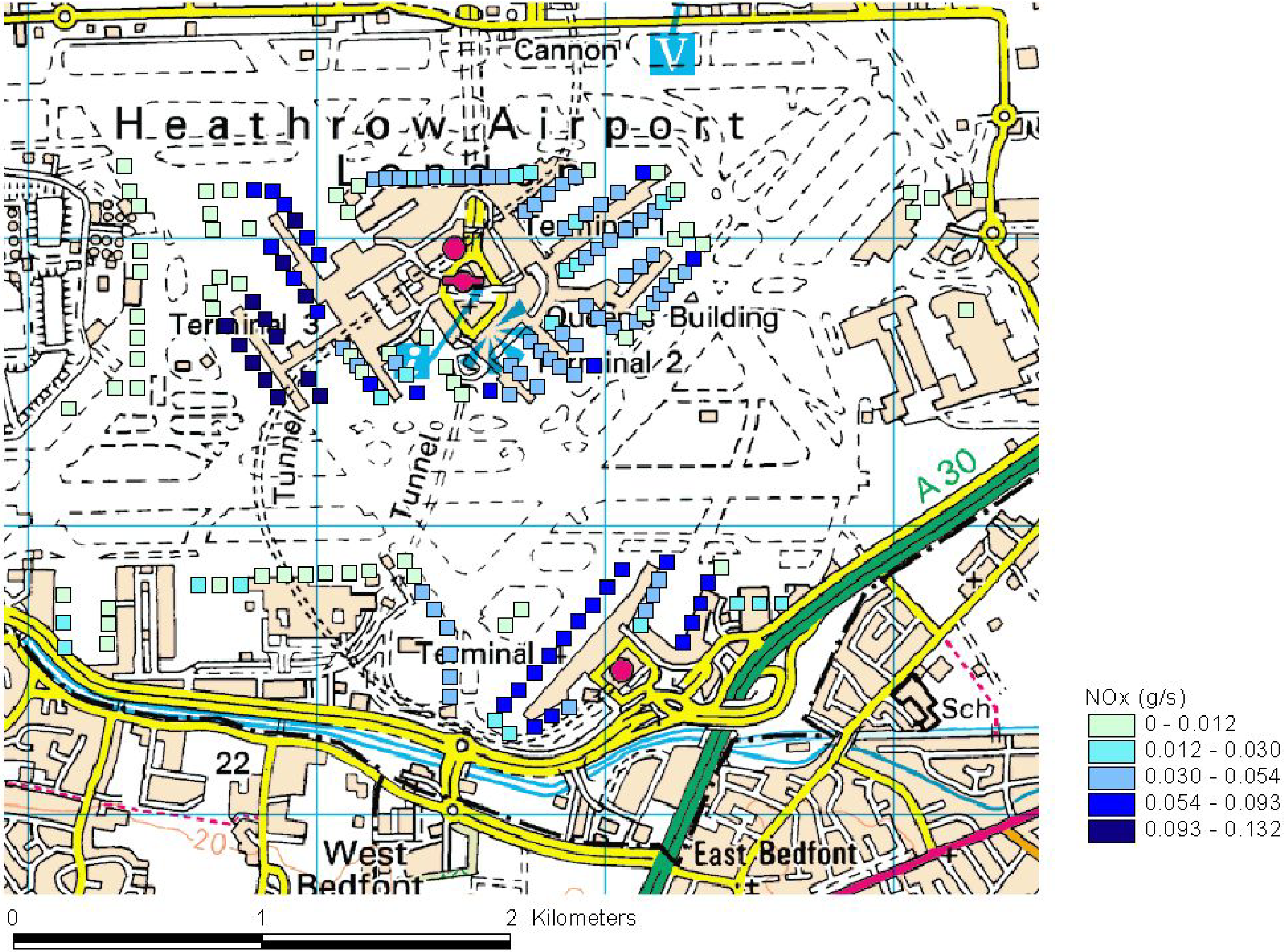
2002 NOx emission rate

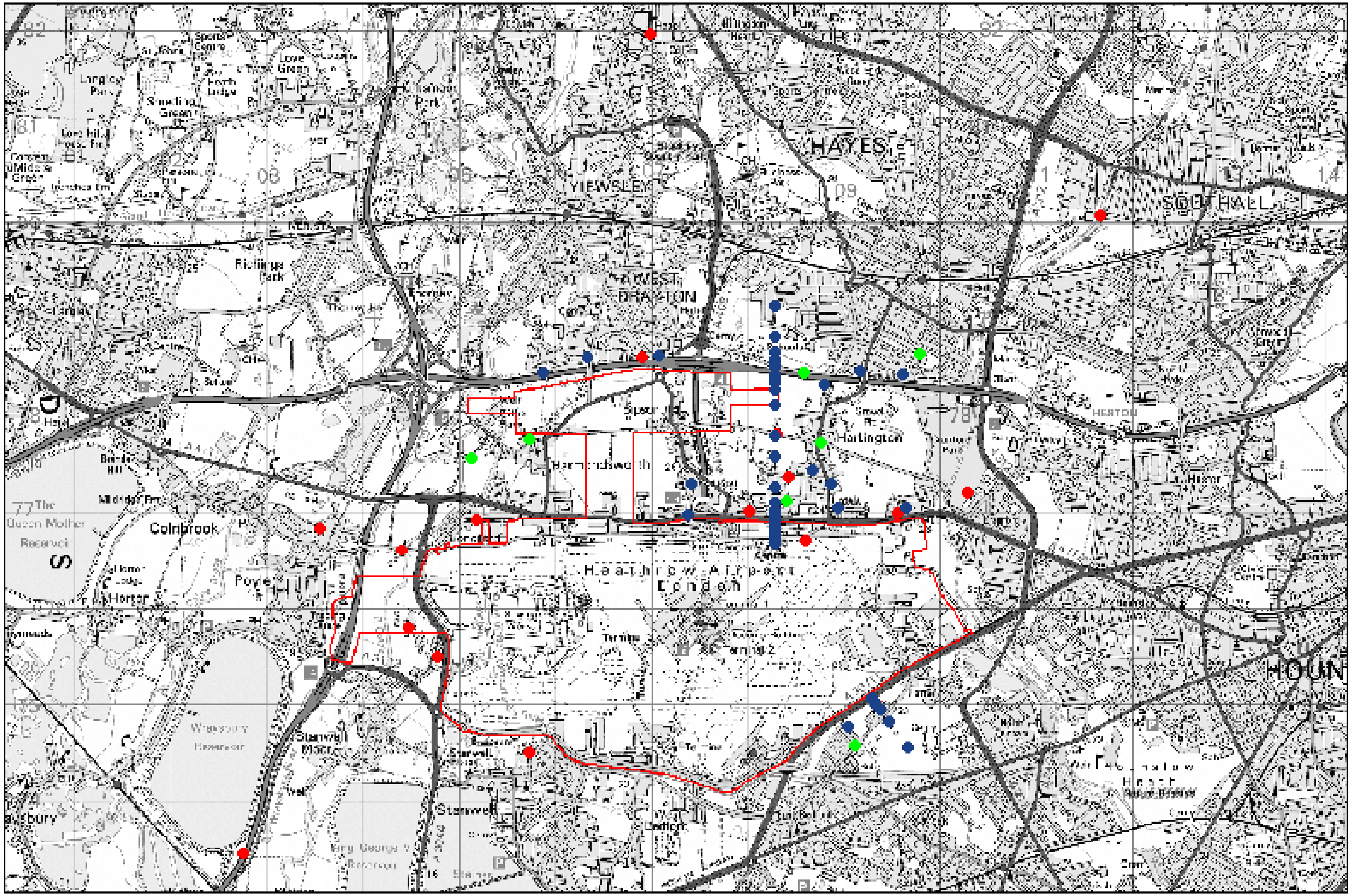


Explicitly modelled road sources



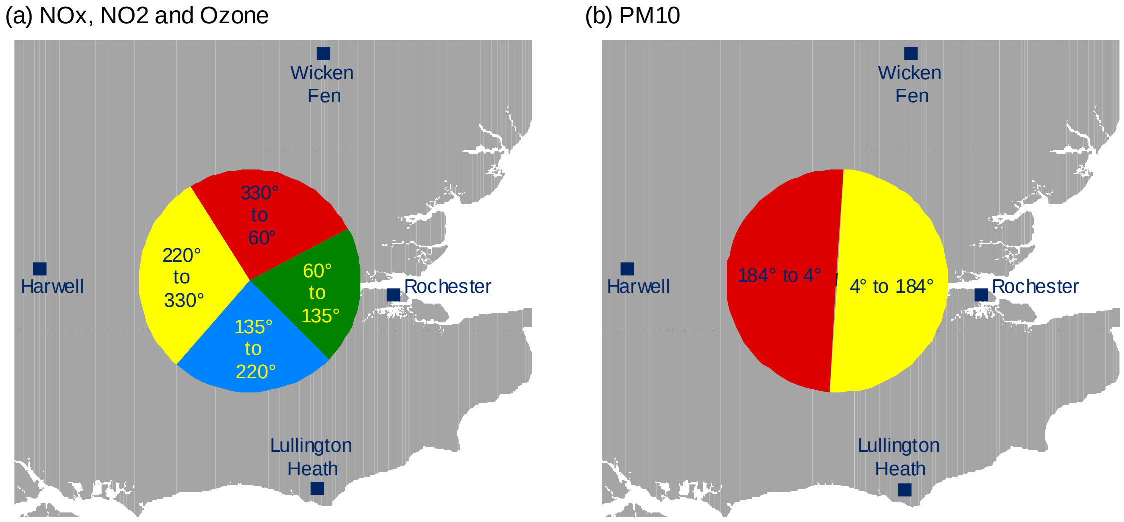
Example of emissions data -- Aircraft APUs





Monitoring Locations for model intercomparison

Red = automatic monitoring sites; Green = diffusion tube sites; Blue = receptors for modelling.



Background concentrations for NO_x, NO_2, O_3 and PM_{10}

		2002
NO_x as NO_2 (µg/m^3)	Annual average Maximum hourly average 99.79th percentile	15 215 127
NO_2 (µg/m^3)	Annual average Maximum hourly average 99.79th percentile	12 84 62
O_3 (µg/m^3)	Annual average Maximum hourly average 99.79th percentile	52 188 135
PM_{10} (µg/m^3)	Annual average Maximum hourly average 90.41st percentile of 24 hour averages 98.08th percentile of 24 hour averages	19 124 33 48

Model set up parameters

Minimum Monin-Obukhov length (m)	20m
Grid depth (m)	10
Surface roughness (m)	0.5
Meteorology	Heathrow 2002
Surface roughness at met site (m)	0.2
Percentage of primary NO_2 in NO_x by volume	10% all sources

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Comparison of monitored and calculated NO_X, NO_2 and ozone at automatic monitoring sites

	NO_X as NO_2 ($\mu g/m^3$)		NO_2 ($\mu g/m^3$)		O_3 ($\mu g/m^3$)	
Site	Monitored	Calculated	Monitored	Calculated	Monitored	Calculated
LHR2	119.49	116.00	52.08	53.06		21.02
LHR5	73.74	65.62	43.41	37.32	29.73	32.76
LHR6	38.92	48.48	25.47	29.12		39.63
LHR8	63.51	59.15	32.07	33.29		35.77
LHR10	198.05	211.95	39.29	61.81		21.37
LHR11	74.10	67.45	35.93	37.07		33.30
LHR14	71.18	51.58	36.30	29.41		38.93
LHR15	66.34	64.60	32.43	36.47		33.22
LHR16	113.26	108.86	45.26	49.64	25.40	25.40
LHR17	164.73	158.69	60.28	58.77		15.04
Overall mean*	**77.57**	**72.72**	**37.87**	**38.18**	-	**32.50**
Overall mean	**98.33**	**95.24**	**40.25**	**42.60**	-	**29.64**

*excluding LHR10 and LHR17

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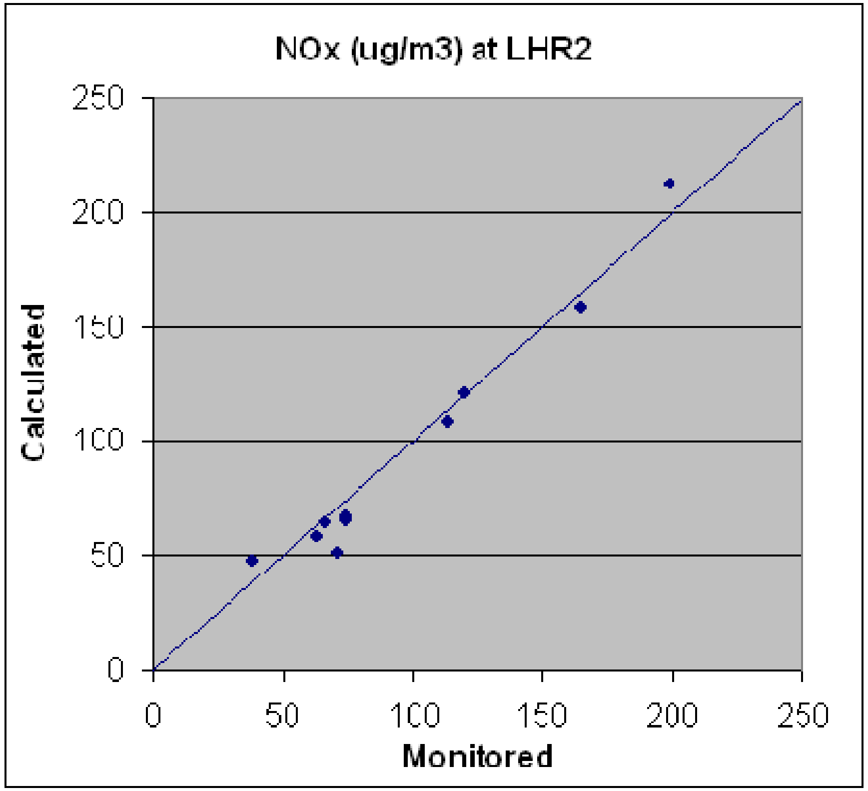
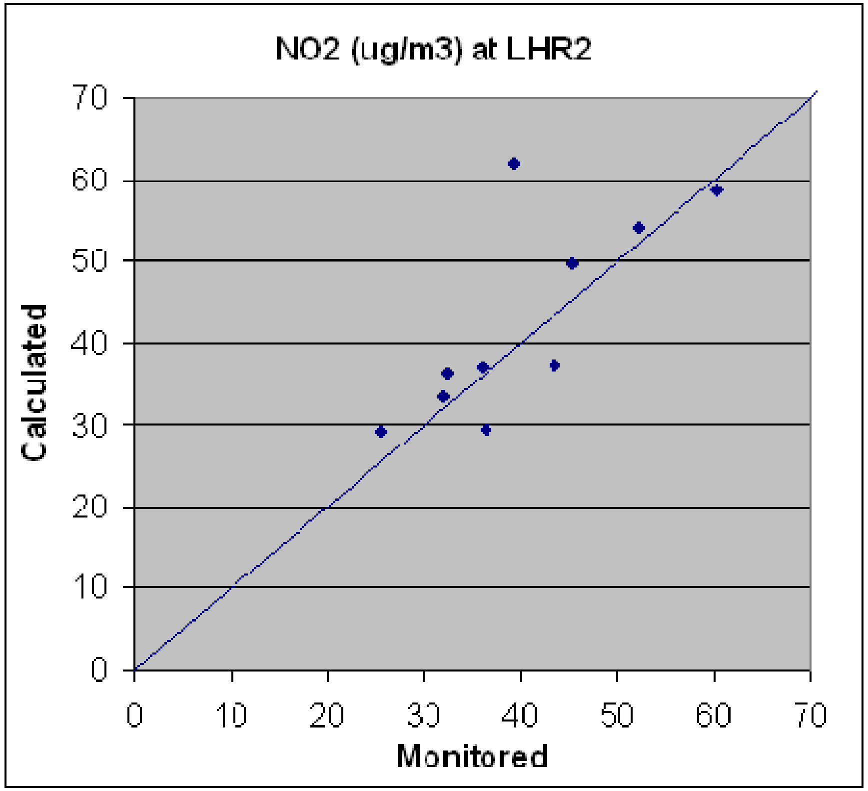
Scatter plot of monitored and ADMS-Airport calculated concentrations of NO_X (left) and NO_2 (right).





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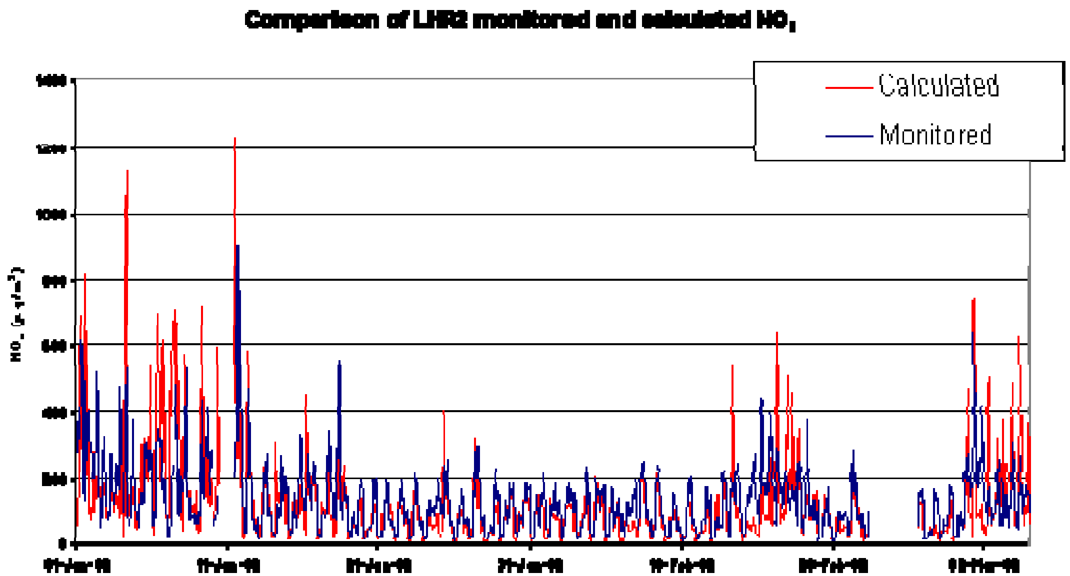
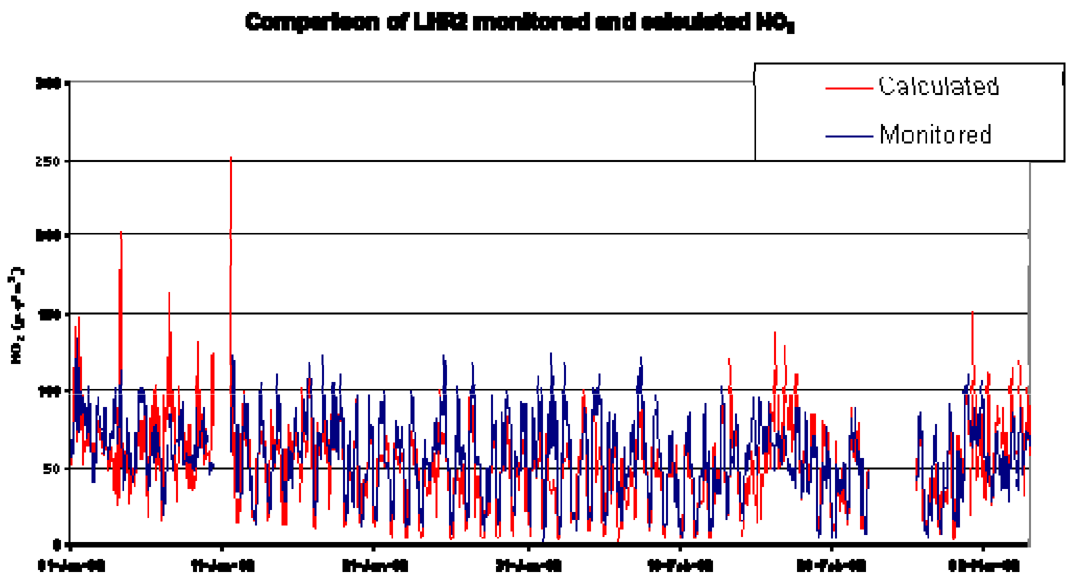
Time series of monitored and calculated NO_X (top) and NO_2 (bottom) in $\mu g/m^3$ at LHR2





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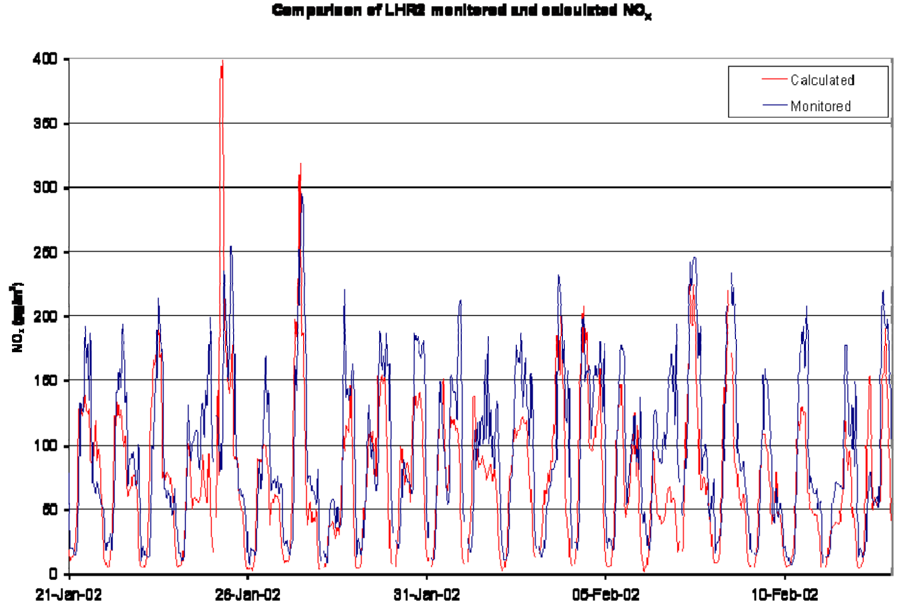
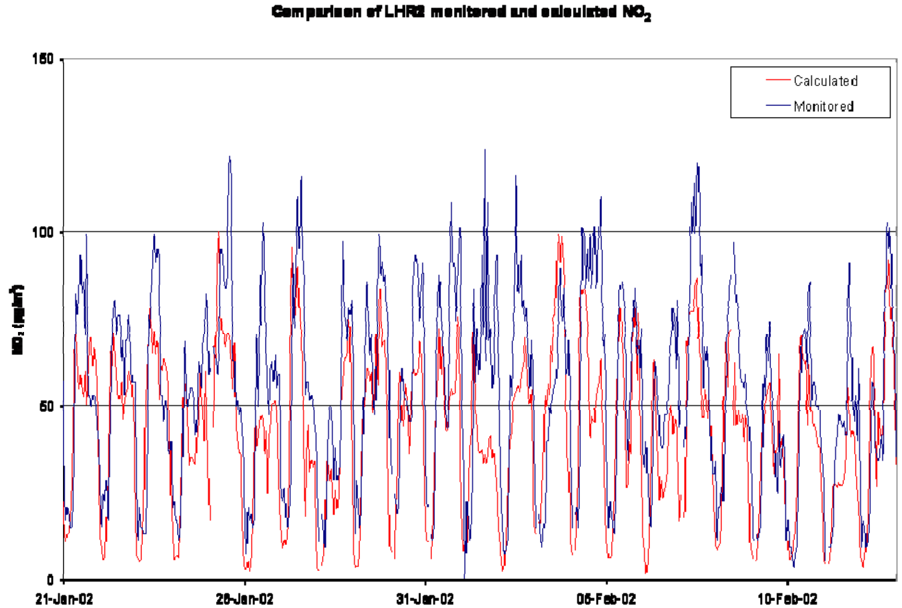
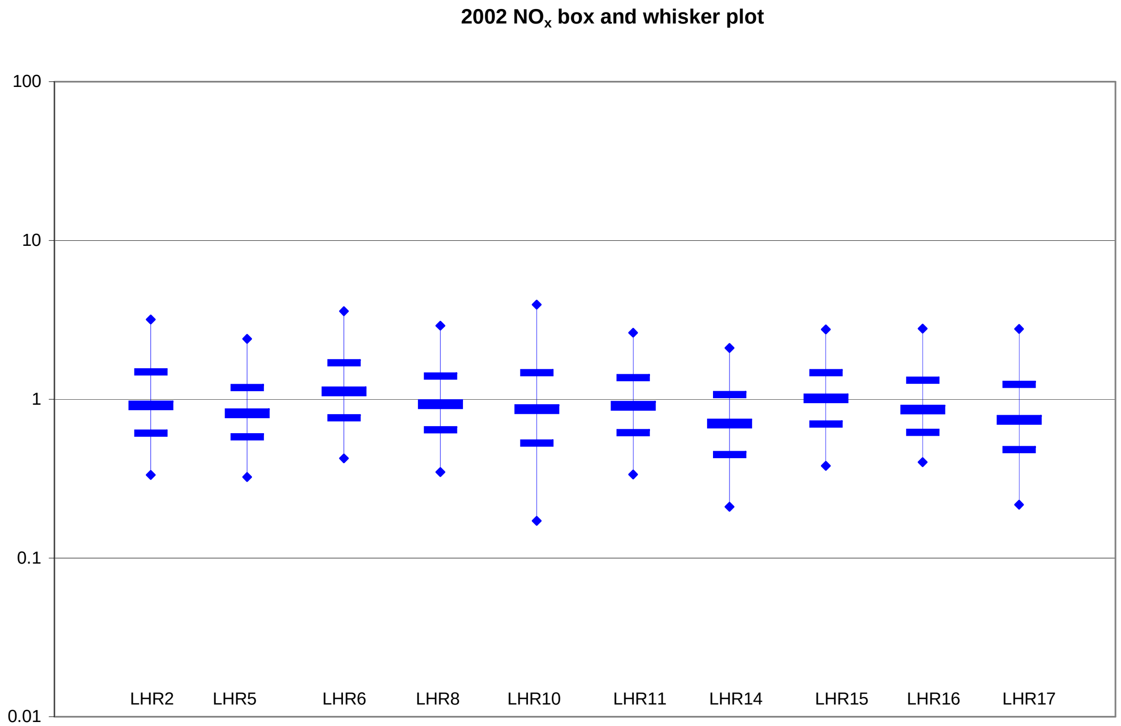
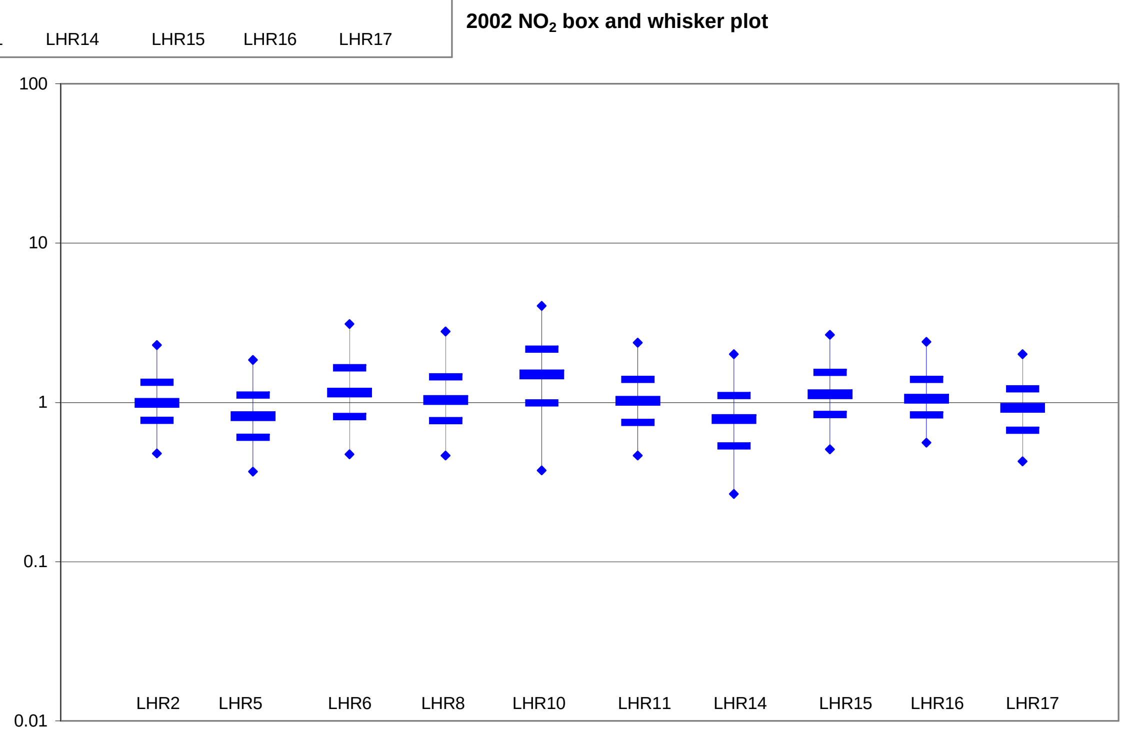
Time series of monitored and calculated NO_X (top) and NO_2 (bottom) in $\mu g/m^3$ at LHR2 (zoomed in view of previous slide).







"Box and whisker" plots for the ratio of (calculated/monitored) concentrations, NO_X (top) and NO_2 (bottom). The lines indicate the 75th, 50th and 25th percentiles and the lines extend from the 95th to 5th percentile.



Average concentration at LHR2 during 2002 with 27R operational and non-operational

	NO_x as NO_2 (µg/m^3)			NO_2 (µg/m^3)			PM_{10} (µg/m^3)		
	Monitored	Calculated	Background	Monitored	Calculated	Background	Monitored	Calculated	Background
With take offs on 27R	147.84	152.55	11.98	61.29	62.07	9.60	26.56	32.01	19.09
No take offs on 27R	106.84	107.61	16.75	47.98	50.61	13.00	28.28	30.63	22.37

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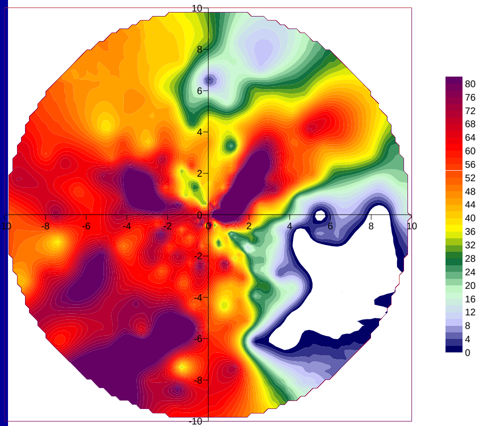
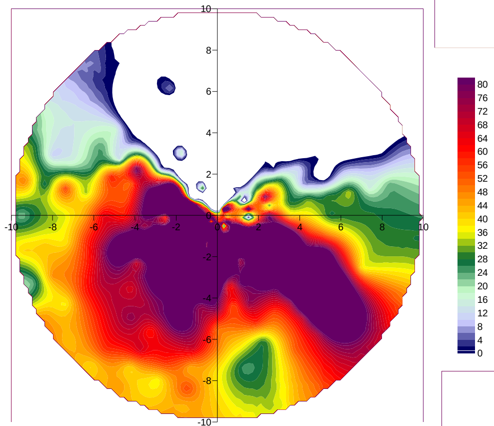
Contribution of different components of aircraft sources to annual average NO_X concentrations at LHR2

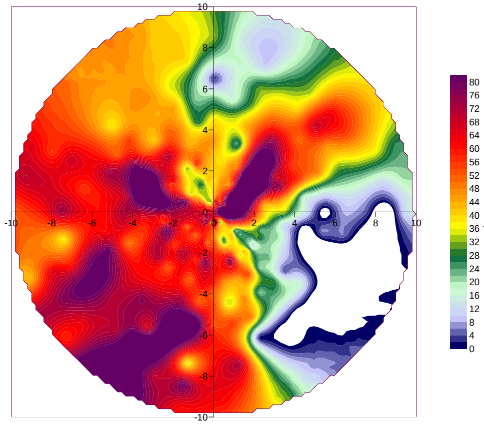
Component	Average emission rate (g/s)	NO_X concentration at LHR2 in µg/m³		
		Volume sources, diurnal profiles	Volume sources, hour by hour data	Jet sources, hour by hour data
Take-off roll (100%)	26			13.3
Take-off roll (80%)				14.3
Approach	24		0.03	
Landing roll	2		3.93	1.4
Climb out	41		0.03	
Initial climb	31		0.84	1.2
Hold	4	2.7	2.30	1.1
APU	10	4.8		
Taxi in	5	2.8		1.3
Taxi out	9	5.7		3.1



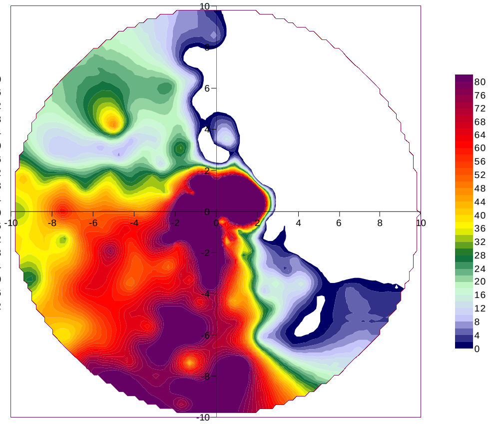
Measured LHR2



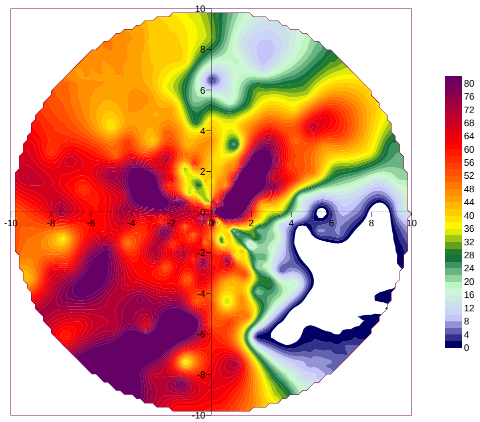
Cambridge predicted



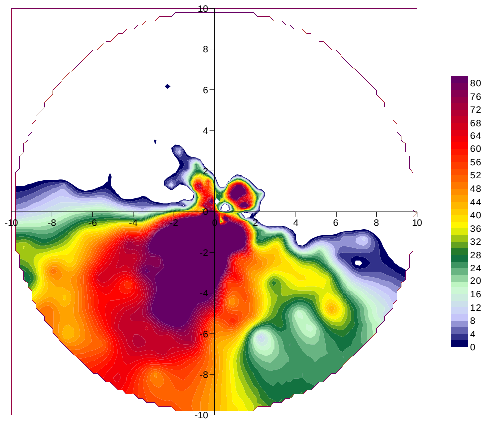
Measured LHR2



CERC predicted



Measured LHR2



MMU predicted

Polar plots of NO_x at LHR2 with background concentrations subtracted.

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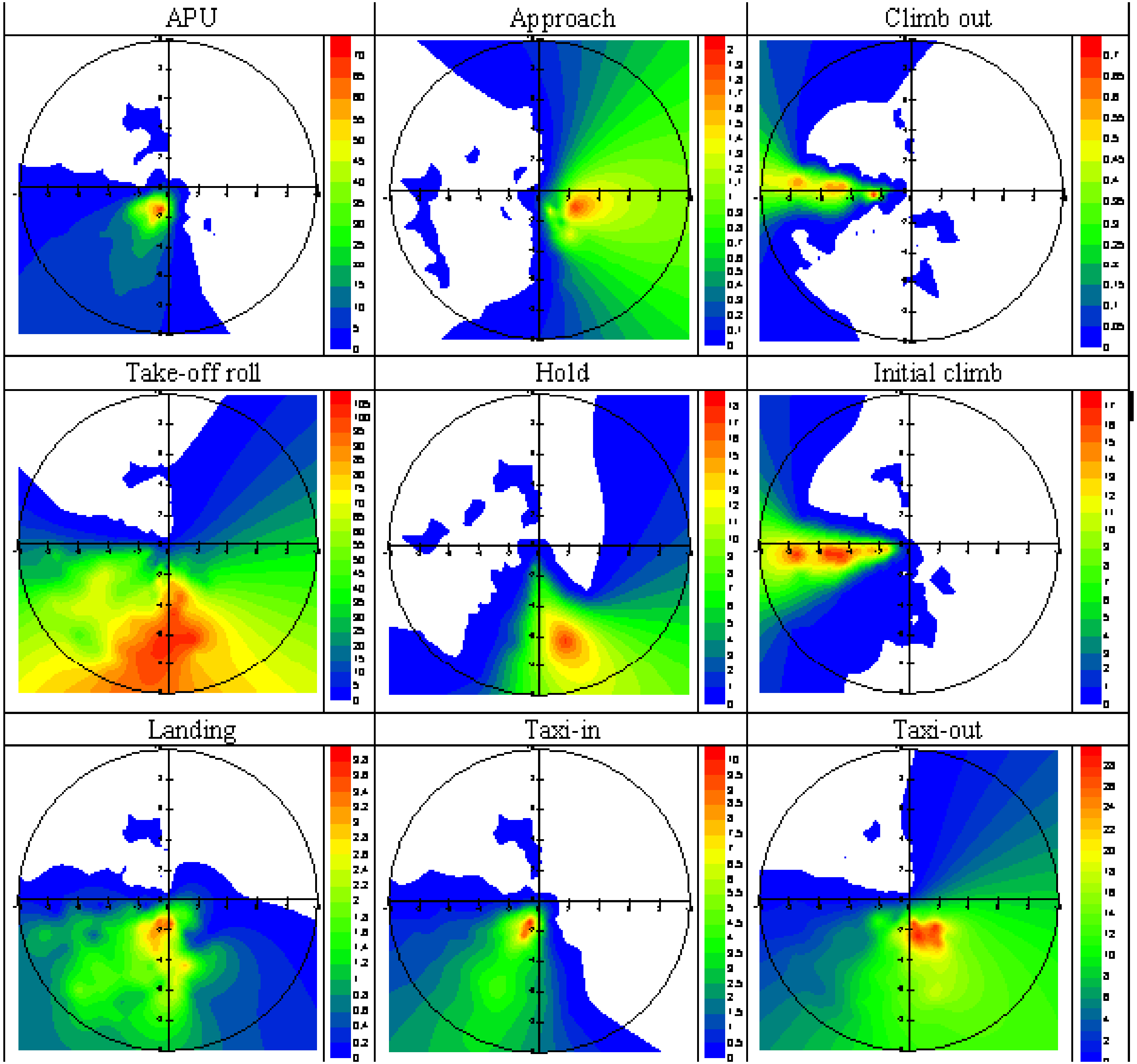
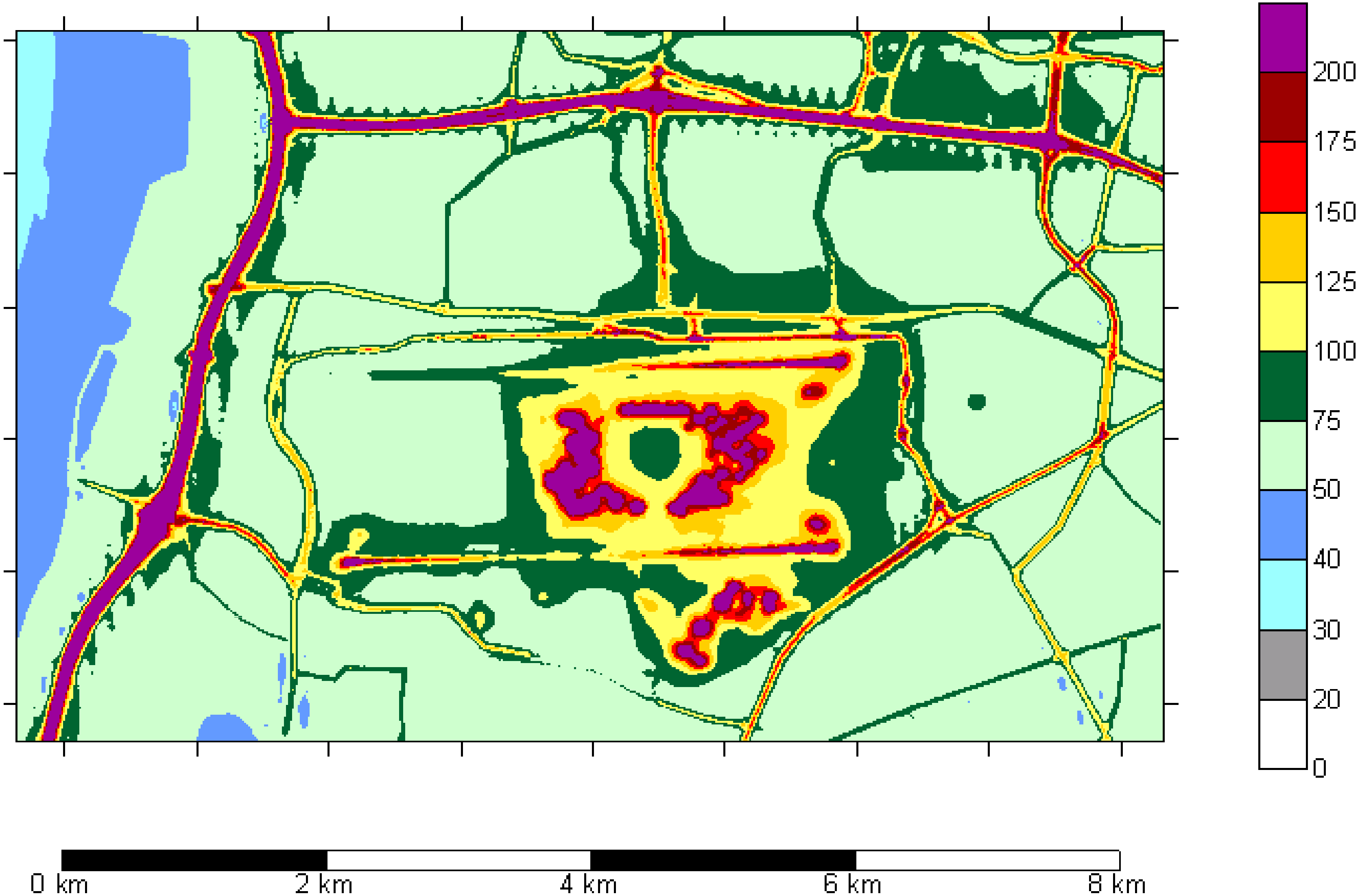

APU
Approach
Climb out
Take-off roll
Hold
Initial climb
Landing
Taxi-in
Taxi-out

Annual average NO_X concentration ($\mu g/m^3$) (all sources)



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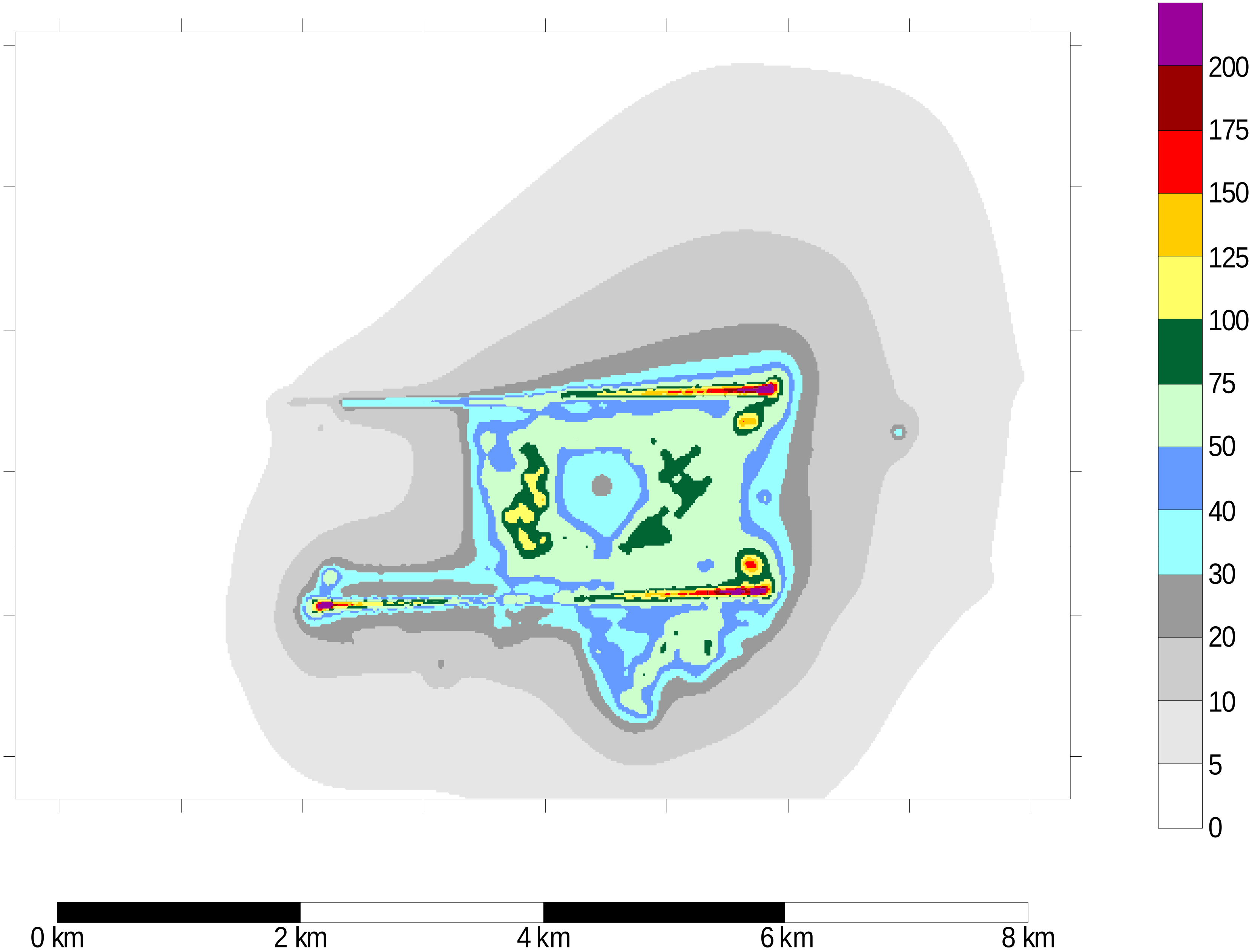
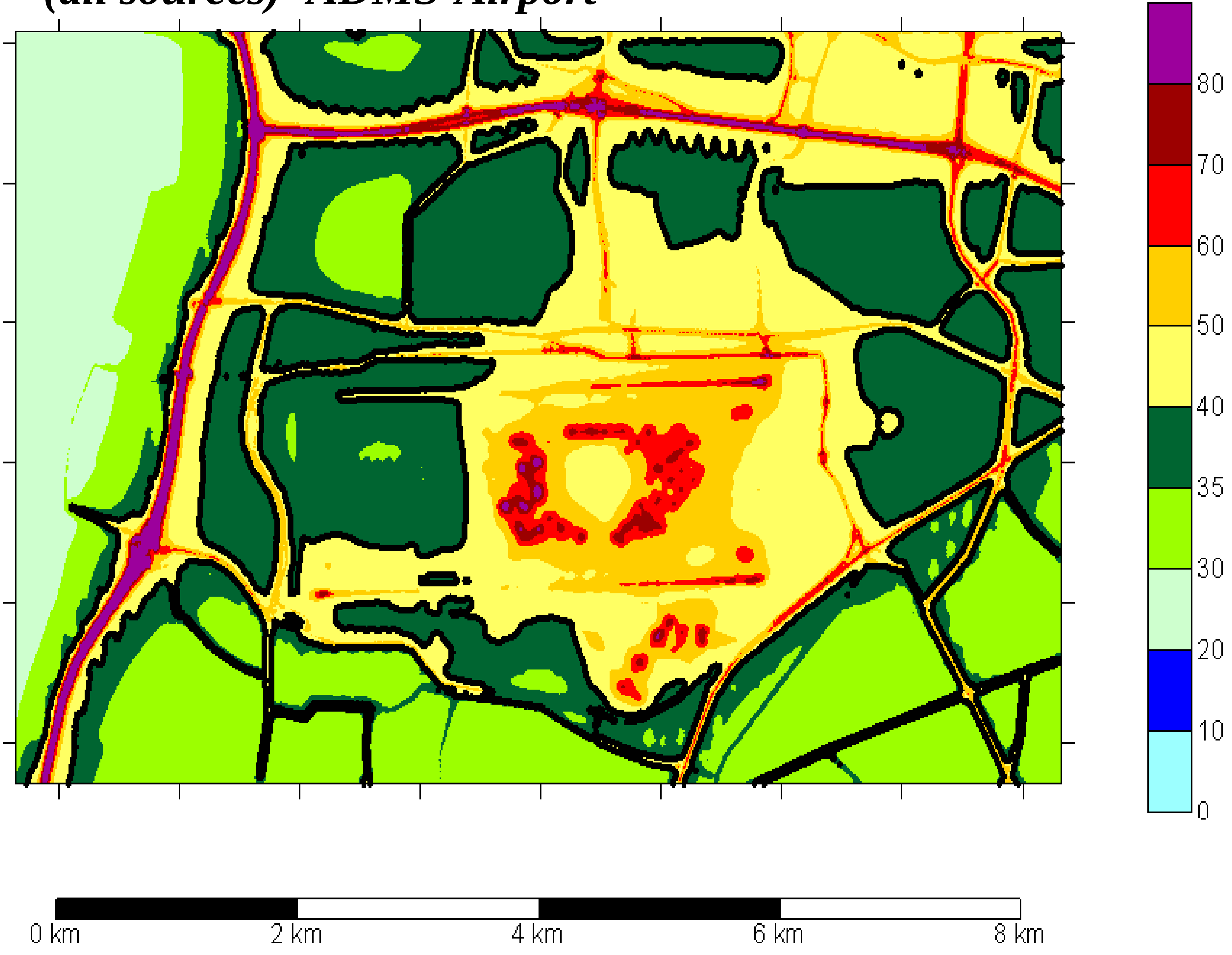
Annual average NOX concentration (mg/m3) (aircraft sources only)



Modelled Annual average NO2 concentration (mg/m3) (all sources)- ADMS-Airport



Conclusions

Model Intercomparison (MIC) of five different modelling methods for air quality in vicinity of airports

- Focus of the presentation ADMS-Airport – includes representation of jet engine emissisions as jet sources.
- An exacting series of model tests included annual means and statistics, sensitivity to windspeed, sensitivity to runway usage, transects including source apportionment, contour plots and areas of exceedences with comparisons with measured data where appropriate.

- *The study was sponsored by the UK Department for Transport. The full study will be published on* www.dft.gov.uk

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