The Project for the Sustainable Development of Heathrow: Model Intercomparison Study

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Outline

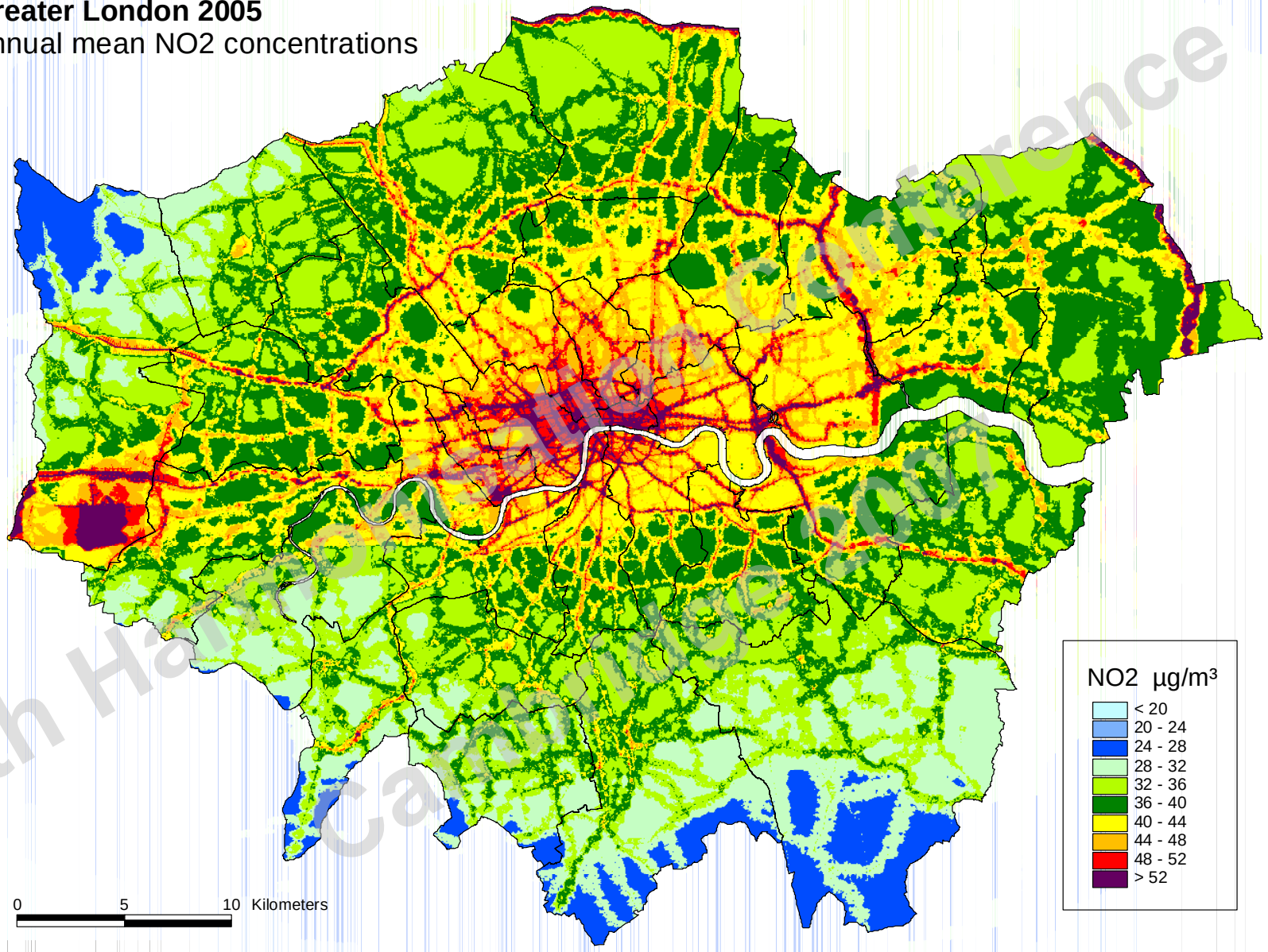
- Background and why
- Model intercomparison study
- Results
- Where are we now? Reflections…
- Conclusions

Background and why

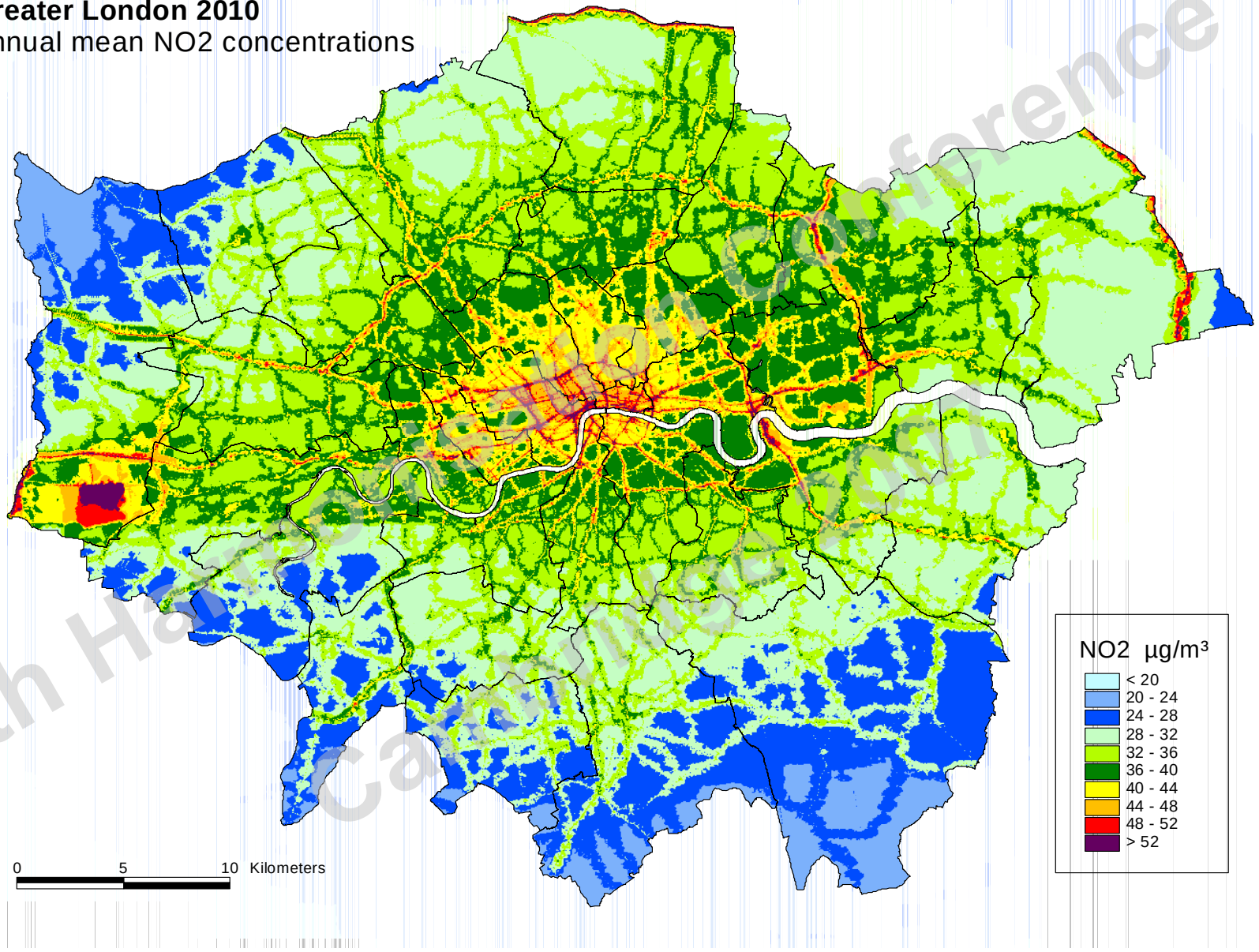
Pollutant	Monitored	Concentration	Enforced by
NO_2	Annual Mean	40 µg/m^3	1st Jan 2010
	1 Hour Mean	200 µg/m^3 (18 times)	1st Jan 2010
PM_{10}	Annual Mean	40 µg/m^3	2005
	24 Hour Mean	50 µg/m^3 (35 times)	2005
Ozone	Daily max 8 Hour Mean	100 µg/m^3 (10 times)	2005

UK/EU METRICS

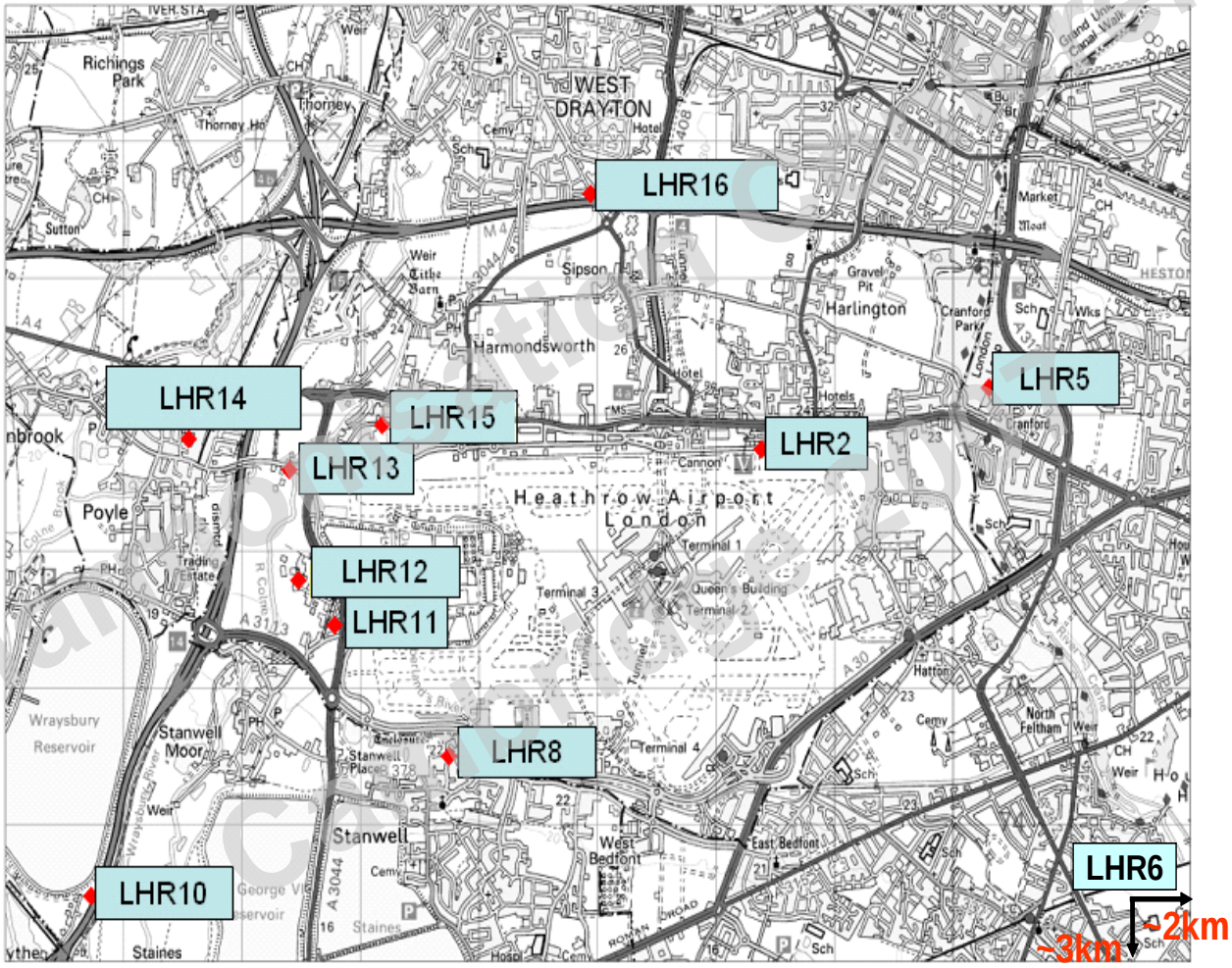
Greater London 2005
Annual mean NO2 concentrations



Greater London 2010
Annual mean NO2 concentrations



Background and why



MONITORING SITES NEAR HEATHROW

Background and why

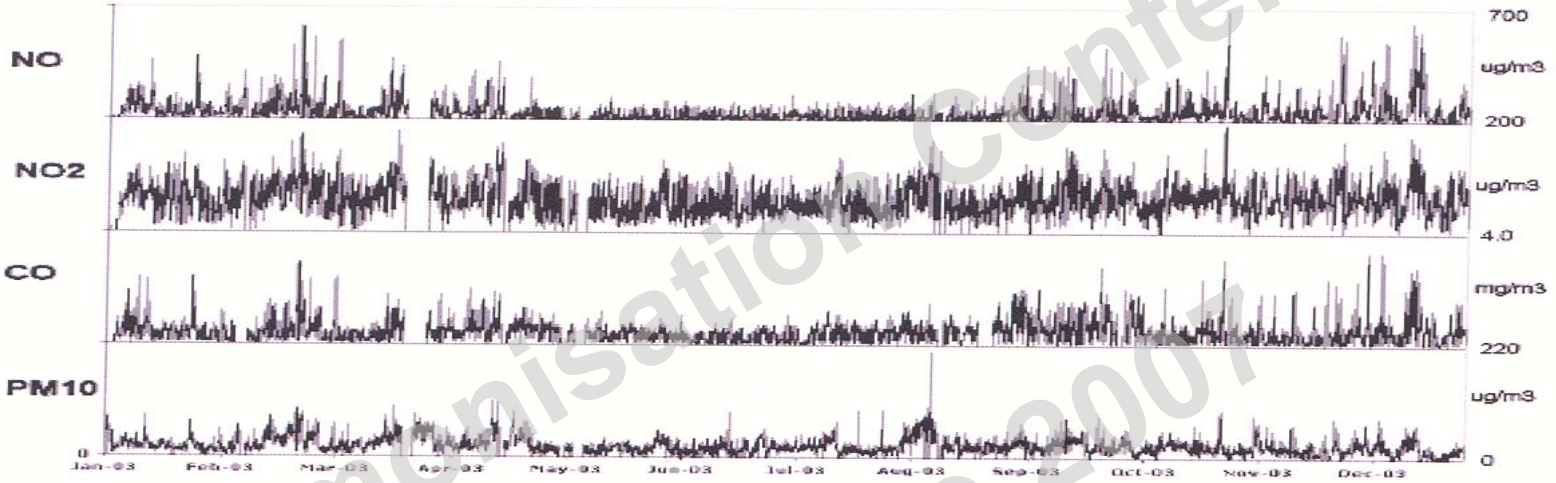


Figure 4. Time Series of Hourly Averaged Concentrations at LHR2 – 2003

Table 5. Monthly Average Air Pollutant Concentrations at LHR2 and Harlington, 2003

	LHR2											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
NO $\mu g\ m^{-3}$	59	68	54	43	21	23	26	29	53	59	59	87
NO_2 $\mu g\ m^{-3}$	57	67	65	63	47	47	49	57	64	63	63	64
NO_x $\mu g\ m^{-3}$	147	171	148	128	79	82	89	102	146	153	154	197
CO mgm^{-3}	0.5	0.5	0.4	0.6	0.4	0.3	0.4	0.5	0.8	0.5	0.4	0.6
PM_{10} $\mu g\ m^{-3}$ (TEOM)	21	31	30	29	17	18	21	31	27	23	21	21

WHITE PAPER "THE FUTURE OF AIR TRANSPORT" DECEMBER 2003

- Government support for third runway at Heathrow if compliance with air quality limits can be met
- Timing 2015-2020
- Action to be taken to tackle NO_2 **problem**
- Government would institute a programme of action to consider how these conditions can be met
- This commitment carried forward through project for the sustainable development of Heathrow (PSDH)

PROJECT FOR THE SUSTAINABLE DEVELOPMENT OF HEATHROW (PSDH)

Three panels of air quality-related experts:

- **Dispersion modelling**
- Monitoring of air pollution
- Emission source data

- Each panel …. balanced membership
- Human health related air quality standards
- Primary focus on annual average concentrations of nitrogen dioxide NO_2 and secondly by particulate matter PM_{10}
- PSDH report from DfT July 2006, submitted to parliament July 19 2006; openly available

Model Intercomparison

PANEL 1: Modelling

- What is current status of airport modelling?
- Is this adequate for making predictions of consequence?
- Model quality (fitness-for-purpose) and its communication
- How might the model quality be improved?
- Centred around a model intercomparison based on the year 2002 for which emissions inventories existed and extensive monitoring data was available

Models employed

- ADMS AIRPORT
- EDMS
- LASPORT
- AEA/NETCEN
- ENV RES GROUP ERG
  KINGS COLLEGE LONDON

ADMS-URBAN

AERMOD

LASAT

USES ADMS3 AS A KERNEL

LONDON TOOLKIT AIRPORT MODEL

❖ These have similar components but with some slight differences e.g. initial sigma.

❖ Some phenomena included in some models but not in others e.g. buoyant plume rise, vortex driven descent

EMISSIONS AND DISPERSION MODELLING SYSTEM (EDMS)

- From US Federal Aviation Administration
- Comprehensive model – integrated emission database for large variety of aircrafts + AERMOD dispersion model
- Comprehensive list of most types of APU/GSE's in US
- Data input requirements are different from those currently in use in the UK (Europe)

Met data: EDMS requires upper level measurements
All sources require extra data than currently available
Workarounds are currently necessary

EDMS Simulation setup

- Roads — cut down network (from CERC)
- Airport layout — from Heathrow Inventory (2002)
- Buildings — not modelled explicitly
- Aircrafts — from Heathrow Inventory (2002)
- Meteorology — modified (2002) data set. Roughness length of 0.5 m to compensate for not modelling buildings. Sensitivity tests with different roughness length values.
- Background — from relevant monitoring sites
- Other — from Heathrow Inventory (2002)

Further comments on EDMS

- NO_2 IS NOT PREDICTED BY THE MODEL
- EDMS IS INTENDED FOR OPERATIONAL USE AT A PARTICULAR AIRPORT – ONCE SET UP IT IS PROBABLY STRAIGHT FORWARD TO USE
- LOW COST (AVAILABLE FOR $50)
- LIMITED INTEGRATED GRAPHIC TOOLS
- RUN TIME INCREASES SUBSTANTIALLY WITH THE NUMBER OF RECEPTORS (7 DAYS FOR ~ 800 RECEPTORS ON A PENTIUM 4 PROCESSOR AND 1GB RAM)

Emission Inventory

	Estimated airport-related annual NO_x emissions for 2002 (tonnes/year)	EDMS NO_x modelled emissions (tonnes/year)
AIRCRAFTS (all modes)	4459.2	4460
APU/GSE	312.2	314.5
Engine testing	8.6	16.5
Airside vehicles	236.8	237.3
Car parks and taxis	26.4	23.6
Heating plant	178.8	178.6
Fire training ground	0.14	0.14
Network non-airport road vehicles*	2750.3	2619.2
Airport roads*	902	900

*** Only around 350 roads with about 1300 links explicitly modelled. All remaining roads were treated as background;**
*** Modelled as an area source**

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

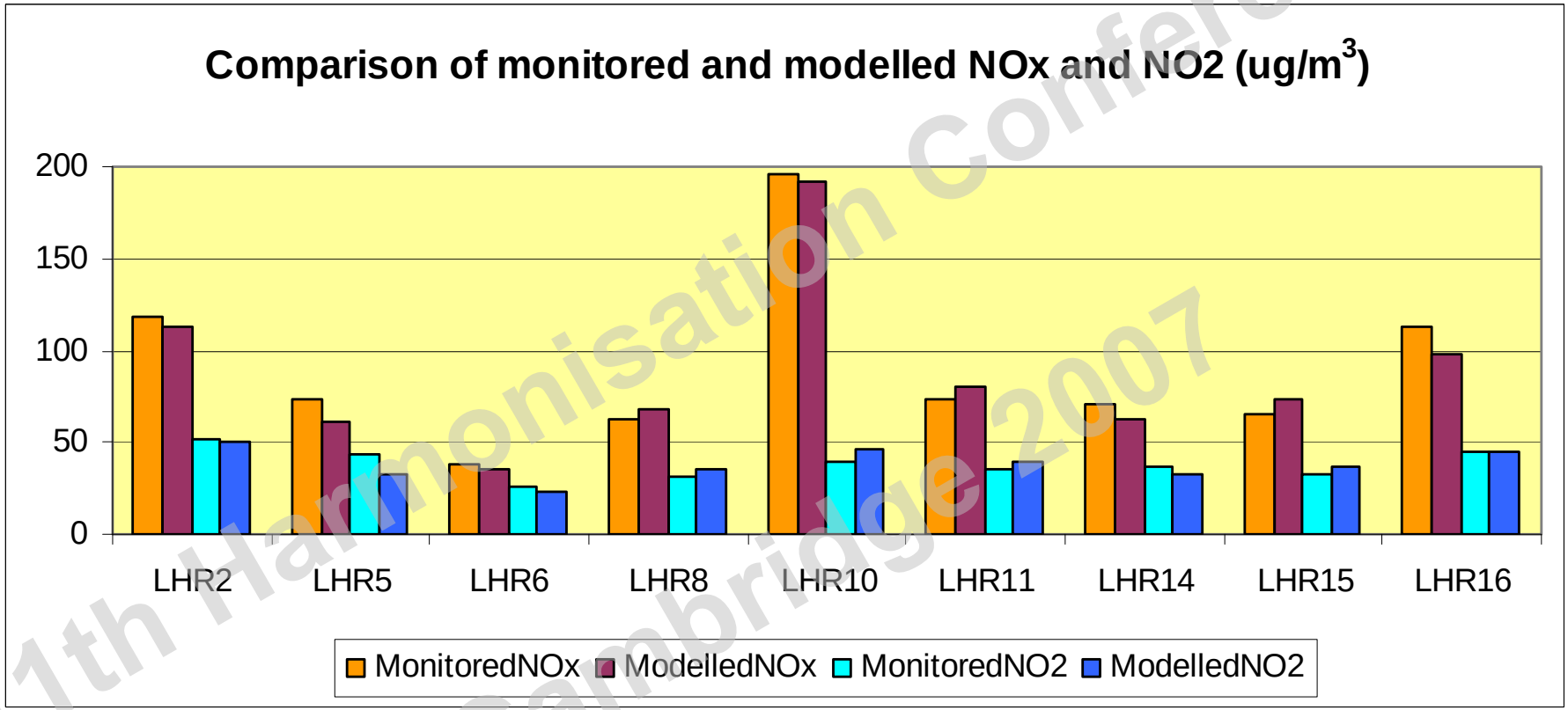
		2002
NO_x as NO_2 (µg/m³)	Annual average	31
	Maximum hourly average	592
	99.79th percentile	348
NO_2 (µg/m³)	Annual average	19
	Maximum hourly average	134
	99.79th percentile	103
PM_{10} (µg/m³)	Annual average	26
	Maximum hourly average	130
	90.41st percentile of 24 hour averages	54
	98.08th percentile of 24 hour averages	80

Results

Receptor ID	NO_X (µg/m^3)		NO_2 (µg/m^3)	
	Monitored	Modelled	Monitored	Modelled
LHR2	118.9	**113.4**	52.0	**50.2**
LHR5	73.1	**61.1**	43.2	**32.8**
LHR6	38.6	**35.9**	25.3	**22.7**
LHR8	62.8	**67.8**	31.7	**35.2**
LHR10	196.1	**191.2**	39.1	**46.8***
LHR11	73.3	**80.8**	35.6	**39.8**
LHR14	70.4	**62.4**	36.1	**33.3**
LHR15	65.7	**73.9**	32.1	**37.4**
LHR16	112.9	**98.2**	45.2	**45.4**

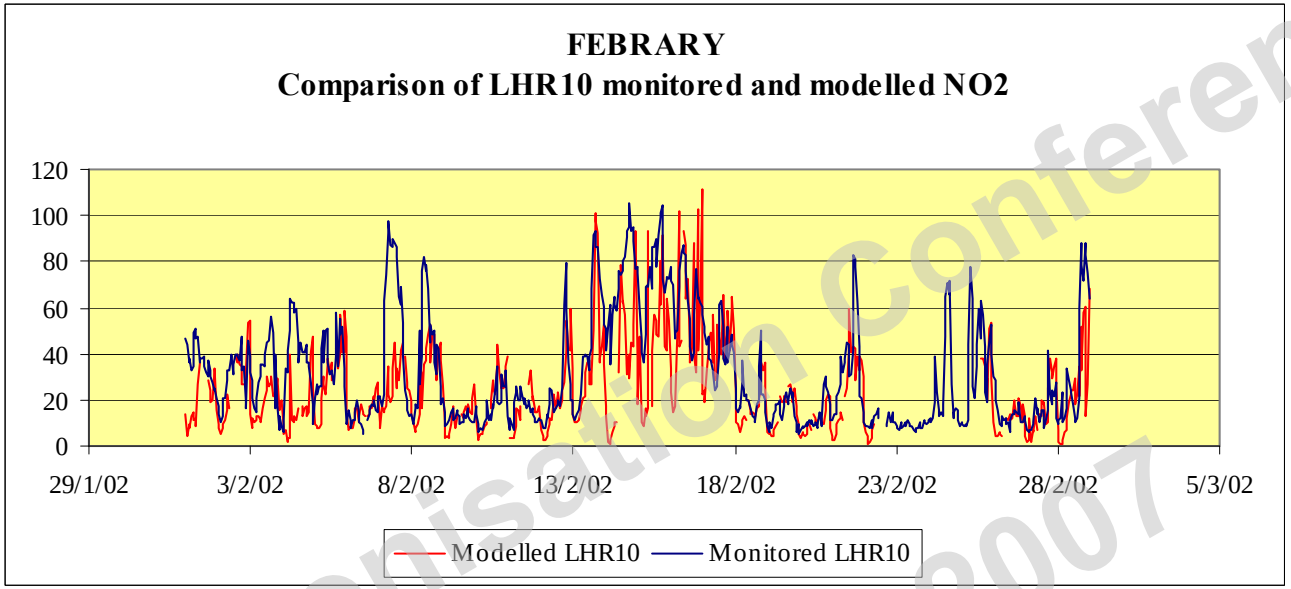
COMPARISON OF ANNUAL AVERAGE MODELLED AND MONITORED CONCENTRATIONS

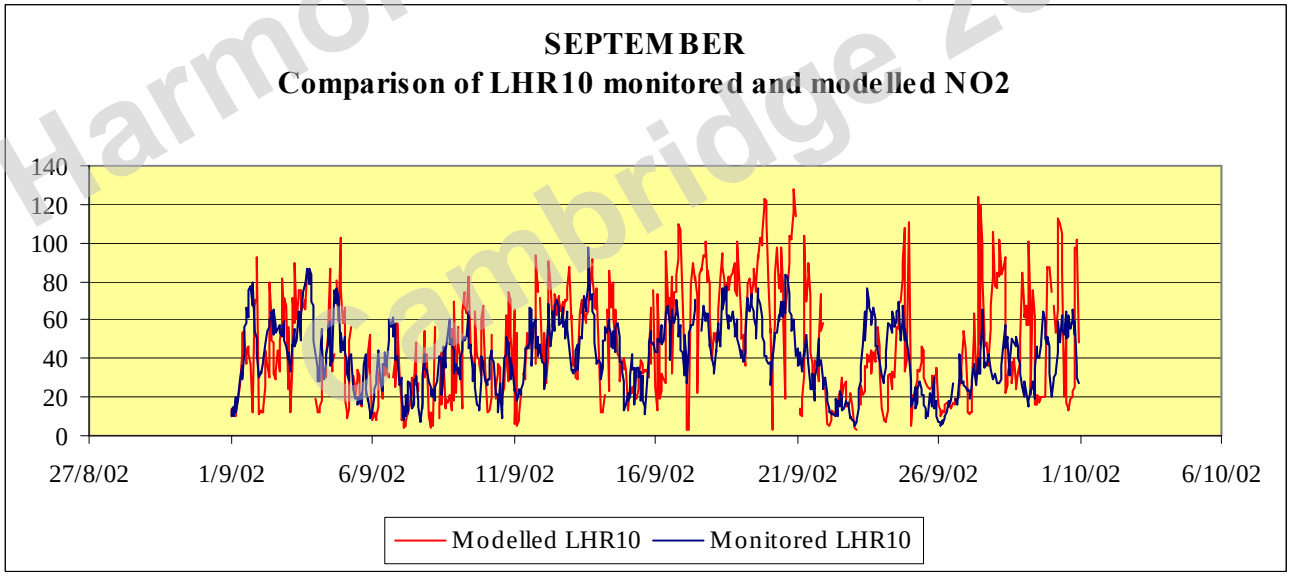
Results



COMPARISON OF ANNUAL AVERAGE MODELLED AND MONITORED CONCENTRATIONS

NO_2 TIME SERIES FOR LHR10





RMS Error for Annual Mean NO_2 Predictions

Model/Group	RMS error ($\mu g/m^3$	RMS error without the M25 ($\mu g/m^3$)
Netcen	14.5	6.7
Cambridge University	5.2	4.8
CERC	8.5	4.1
ERG	16.9	4.6
MMU	5.9	5.3

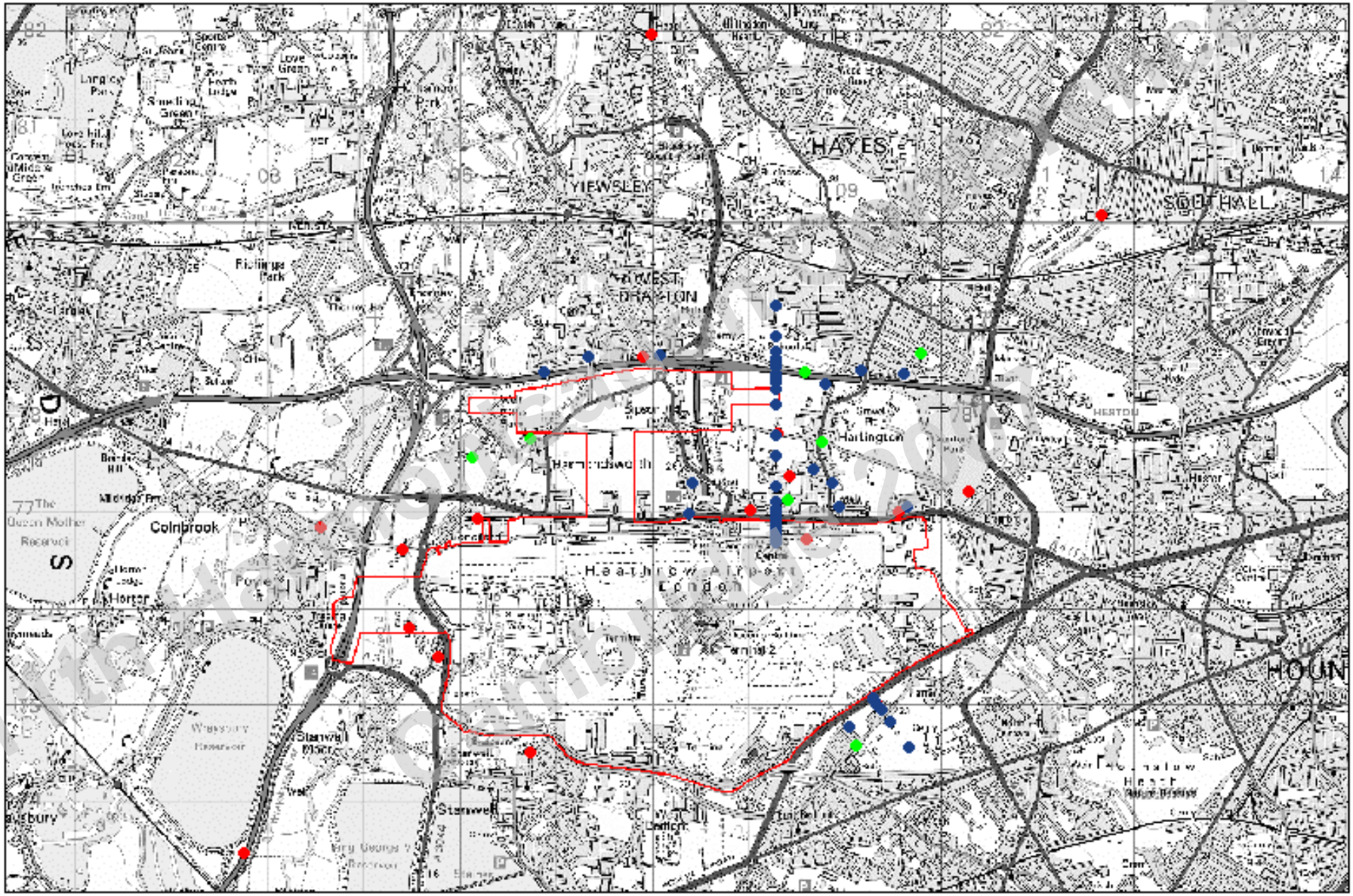
Results

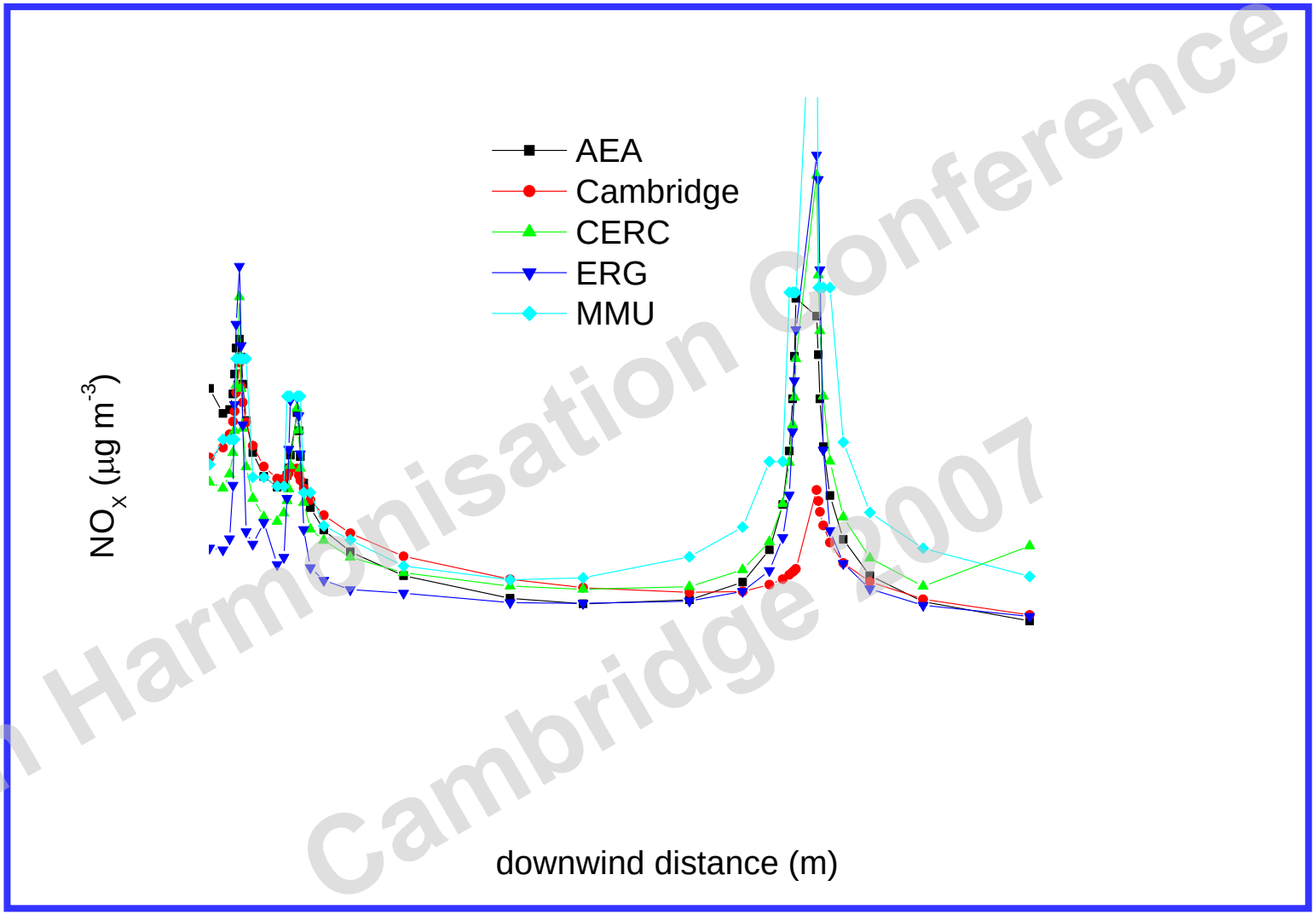
Receptor ID	PM_{10} (µg/m³)			
	Monitored	Modelled (total)	Modelled (without background)	Background
LHR2	27.7	**27.4**	1.4	26.0
LHR5	22.9	**26.4**	0.4	26.0
LHR8	19.1	**26.5**	0.5	26.0
LHR10	29.9	**29.0**	3.0	26.0
LHR11	27.4	**26.6**	0.6	26.0
LHR12	22.6	**26.1**	0.1	26.0
LHR13	25.8	**26.5**	0.5	26.0
LHR14	24.0	**26.3**	0.3	26.0
LHR15	19.0	**26.5**	0.5	26.0
LHR16	24.4	**26.8**	0.8	26.0

COMPARISON OF ANNUAL AVERAGE MODELLED AND MONITORED CONCENTRATIONS

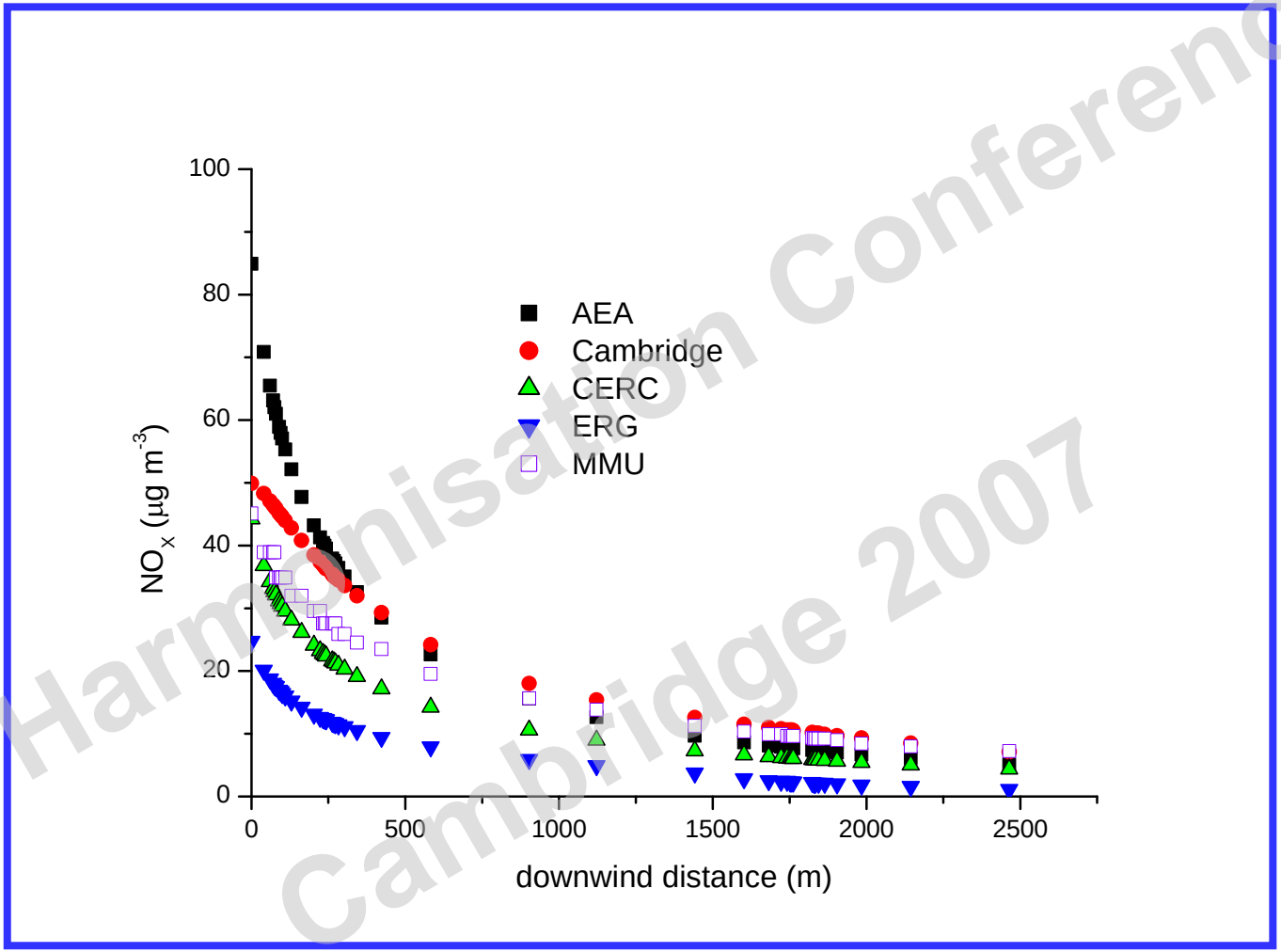
Source Apportionment

Receptor ID	NO_X – All Modelled Sources	NO_X - Aircraft	NO_X - Roadways	NO_X- Background	NO_X - Other Sources	NO_X Total	NO_2 Total
LHR2	82.4	46.4	25.1	31.0	10.9	**113.4**	**50.2**
LHR3	15.1	3.6	10.6	31.0	0.9	**46.1**	**27.0**
LHR4	42.3	17.0	21.3	31.0	3.9	**73.3**	**37.2**
LHR5	30.1	8.6	19.4	31.0	2.1	**61.1**	**32.8**
LHR6	4.9	0.9	3.7	31.0	0.3	**35.9**	**22.7**
LHR7	56.8	18.8	33.5	31.0	4.5	**87.8**	**42.1**
LHR8	36.8	17.4	16.8	31.0	2.6	**67.8**	**35.2**
LHR10	160.2	2.4	157.3	31.0	0.5	**191.2**	**71.9**
LHR11	49.8	12.9	35.2	31.0	1.7	**80.8**	**39.8**
LHR12	46.1	8.7	36.0	31.0	1.4	**77.1**	**38.5**
LHR13	63.9	6.1	56.6	31.0	1.2	**94.9**	**44.4**
LHR14	31.4	4.0	26.6	31.0	0.8	**62.4**	**33.3**
LHR15	42.9	9.2	31.8	31.0	1.9	**73.9**	**37.4**
LHR16	67.2	7.6	57.4	31.0	2.2	**98.2**	**45.4**
LHR17	19.3	2.6	16.0	31.0	0.6	**50.3**	**28.7**
LHR18	38.3	15.2	18.9	31.0	4.2	**69.3**	**35.8**
LHR19	45.5	21.4	18.3	31.0	5.8	**76.5**	**38.3**

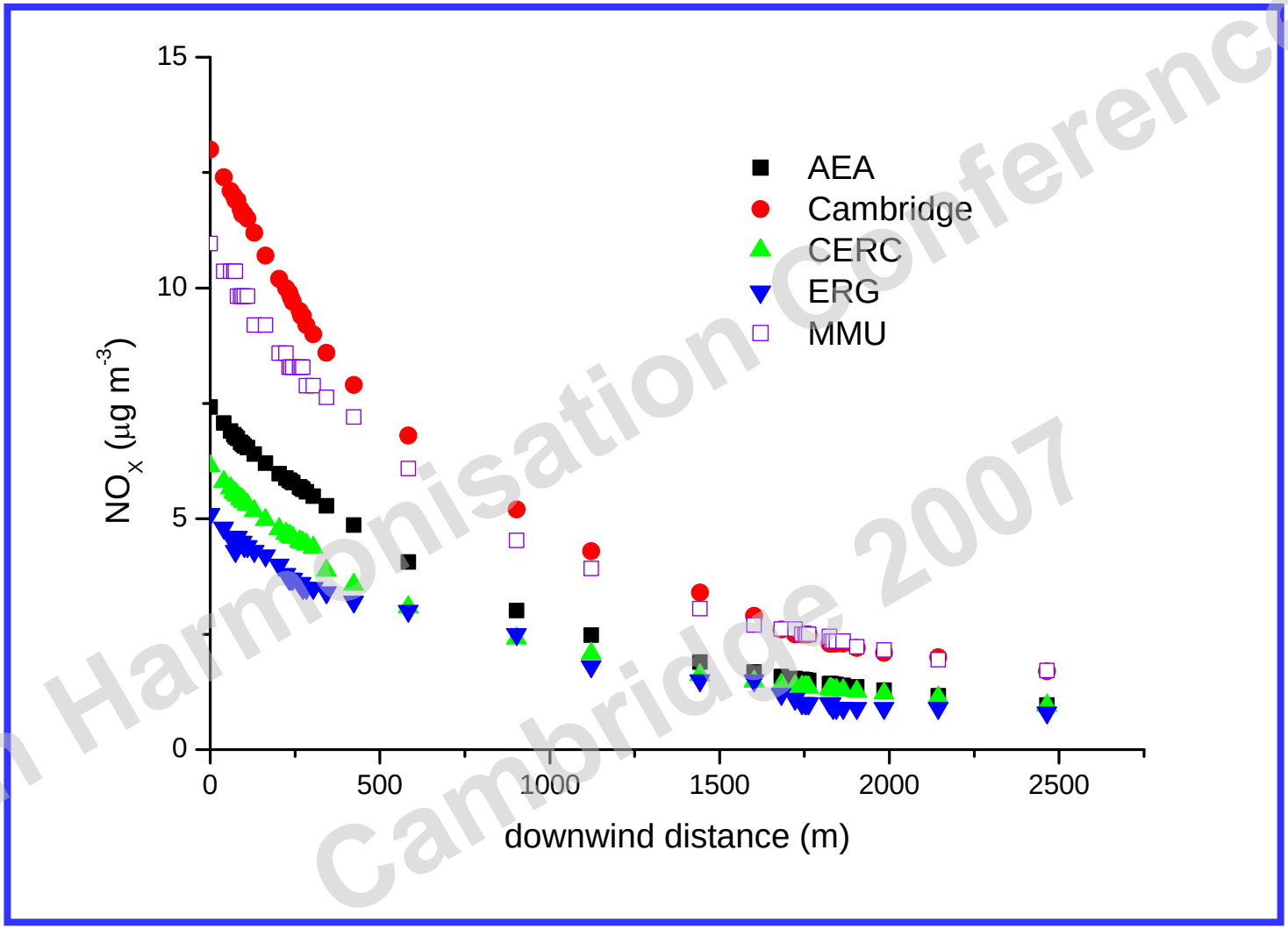

HAYES
YIEWSLEY
SOUTHALL
WEST DRAYTON
Harlington
Colnbrook
Heathrow Airport
London
HOUN
Stanwell
Stanwell Moor



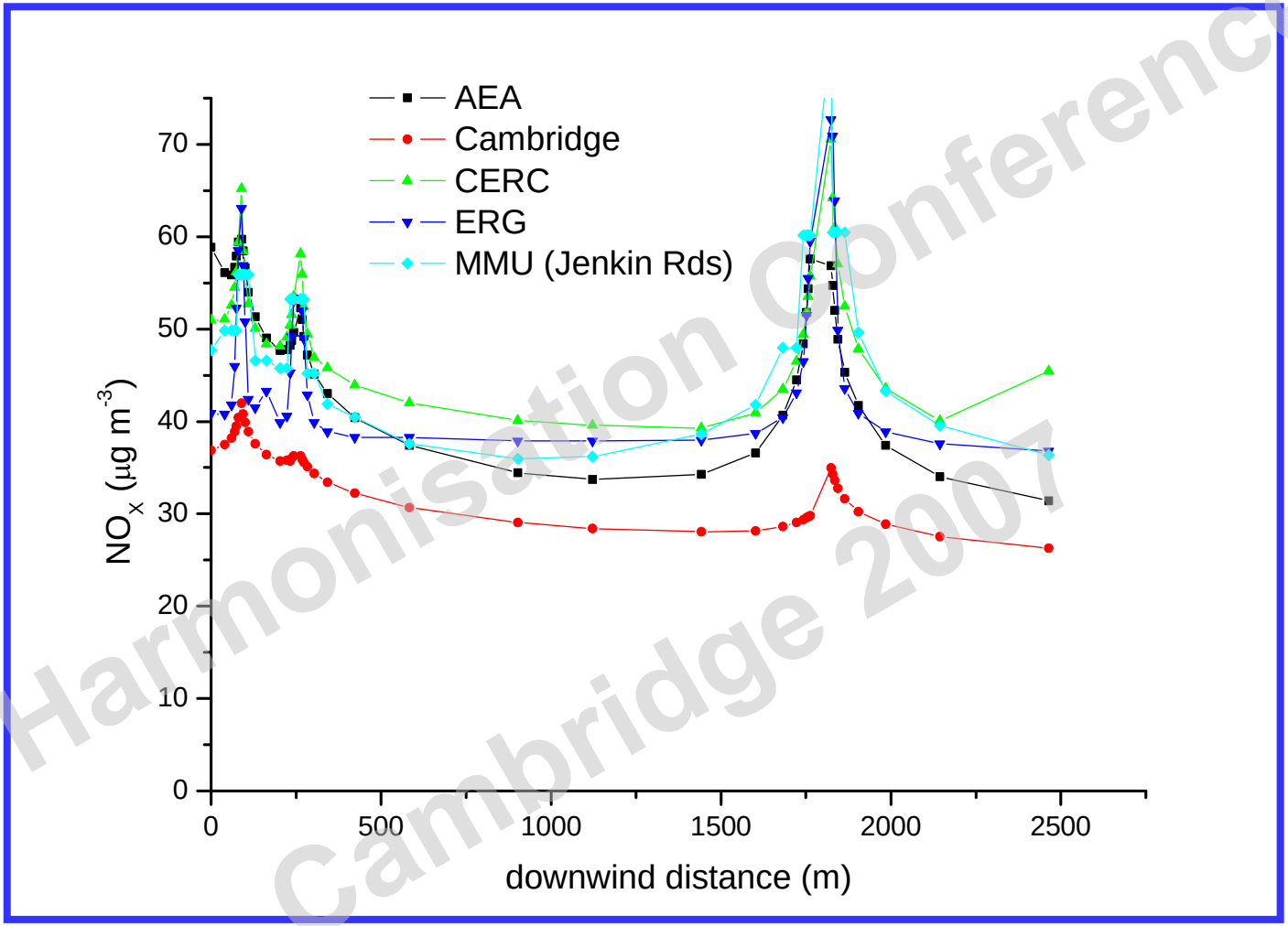
TOTAL NO_x



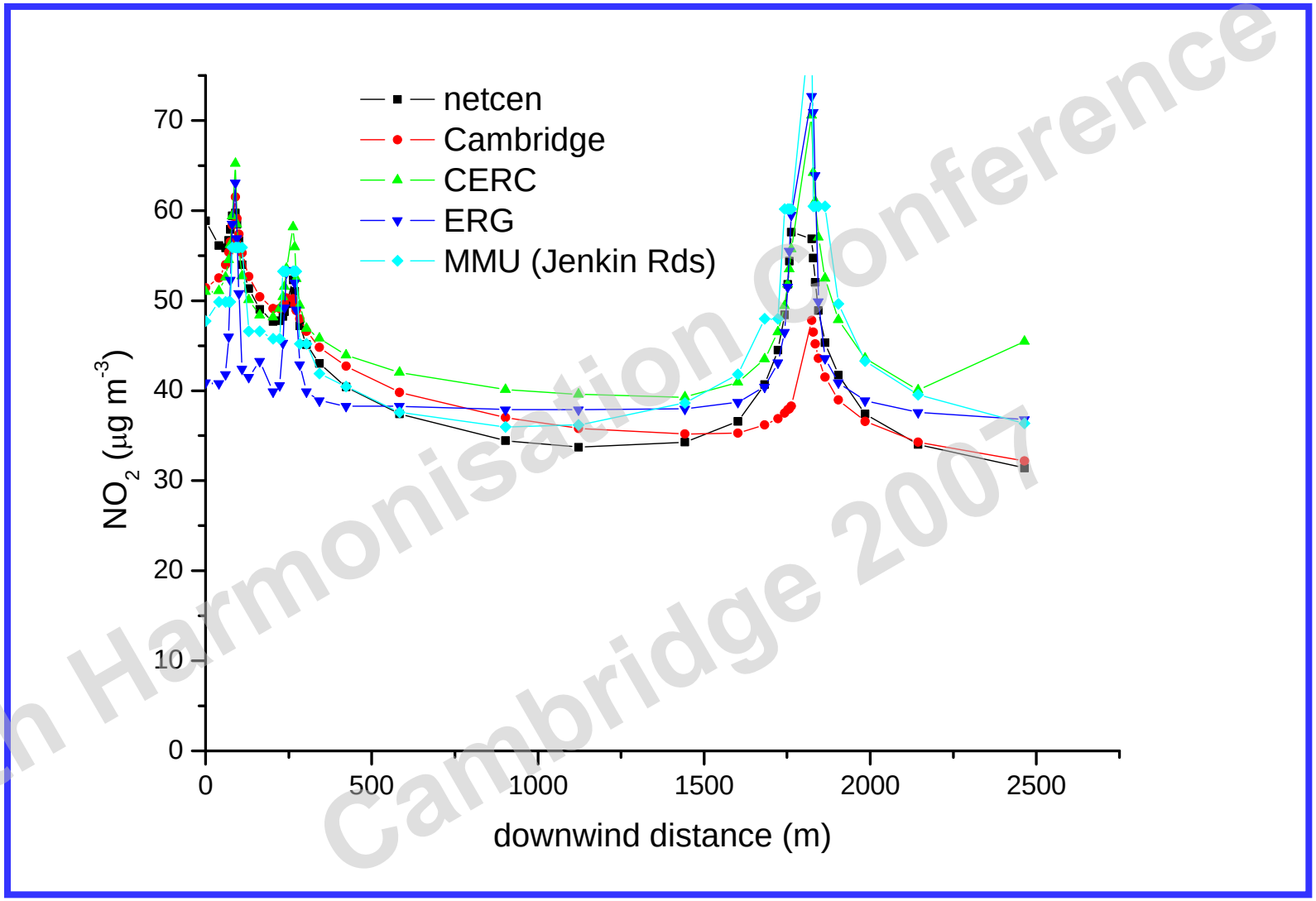
AIRCRAFT NO_x



NON-AIRCRAFT, AIRPORT RELATED NO_x

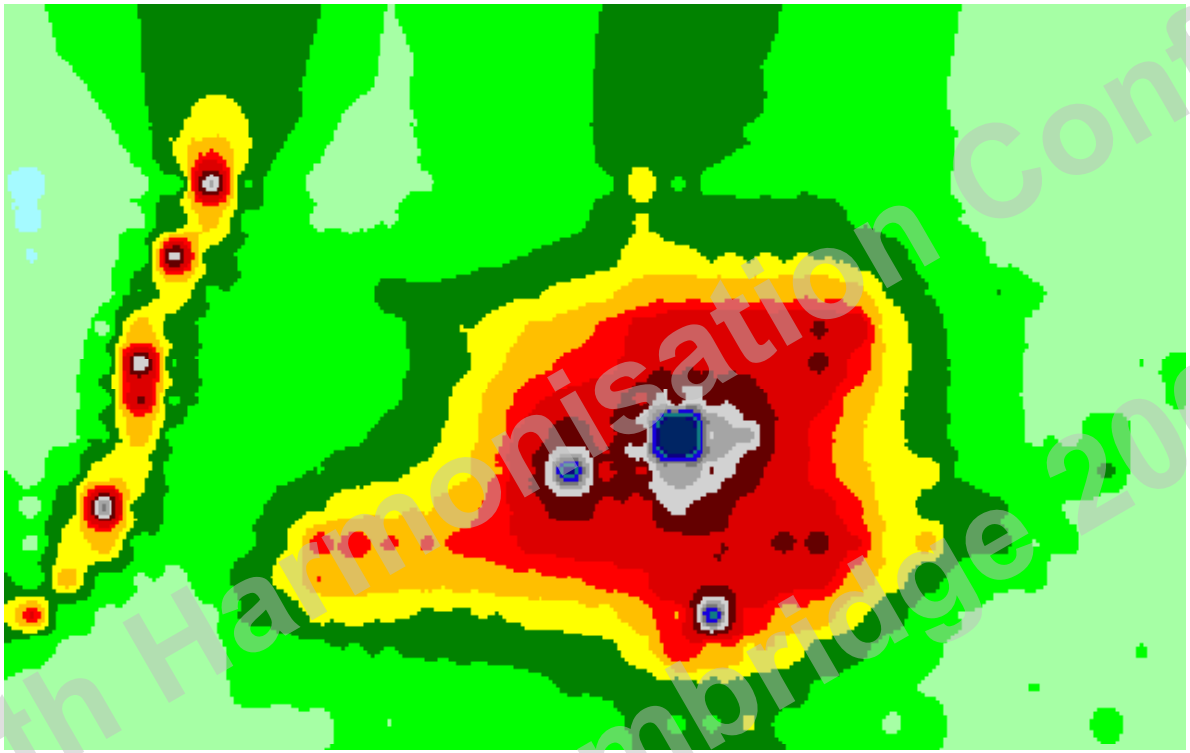


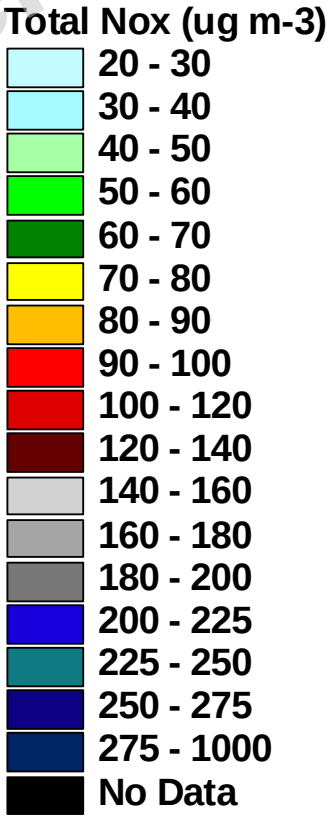
ALL VEHICLES ROADS NO_x (NOT JUST AIRPORT RELATED TRAFFIC)



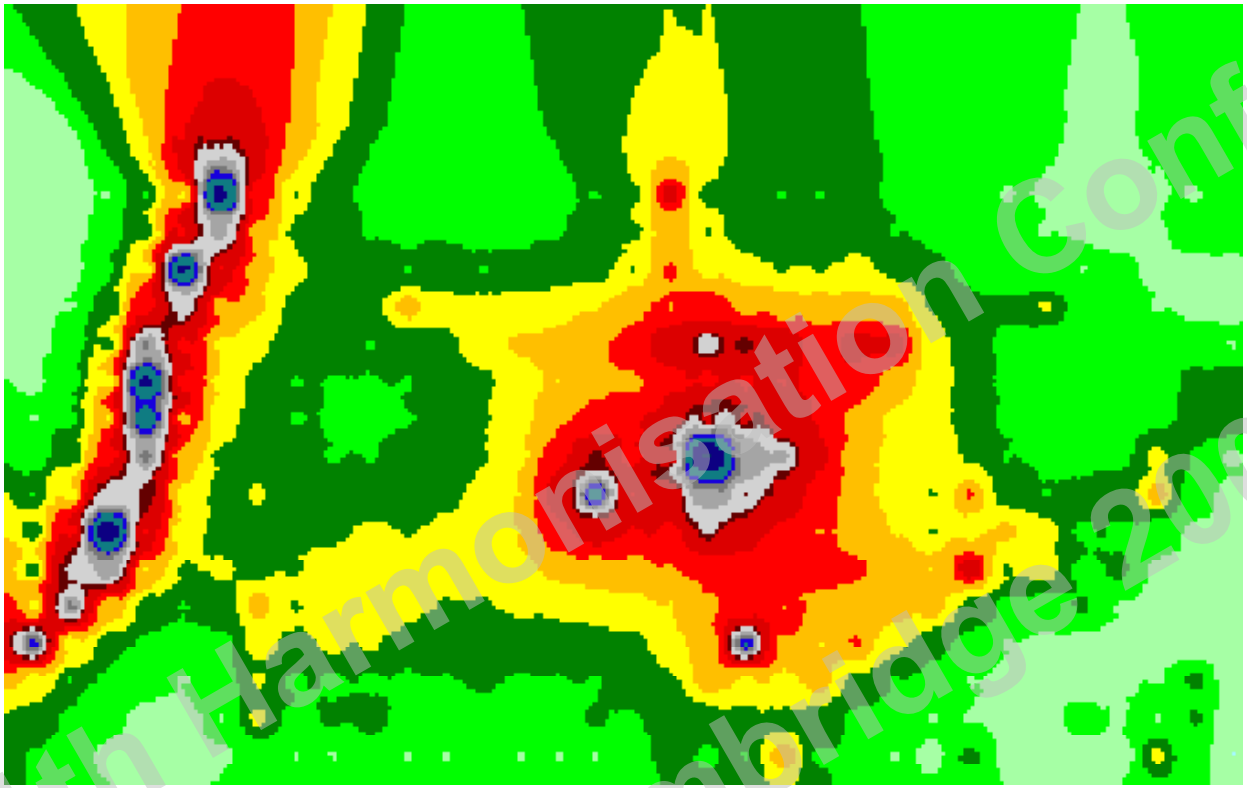
TOTAL NO_2 ; ANNUAL AVERAGE

EDMS TOTAL NO_x



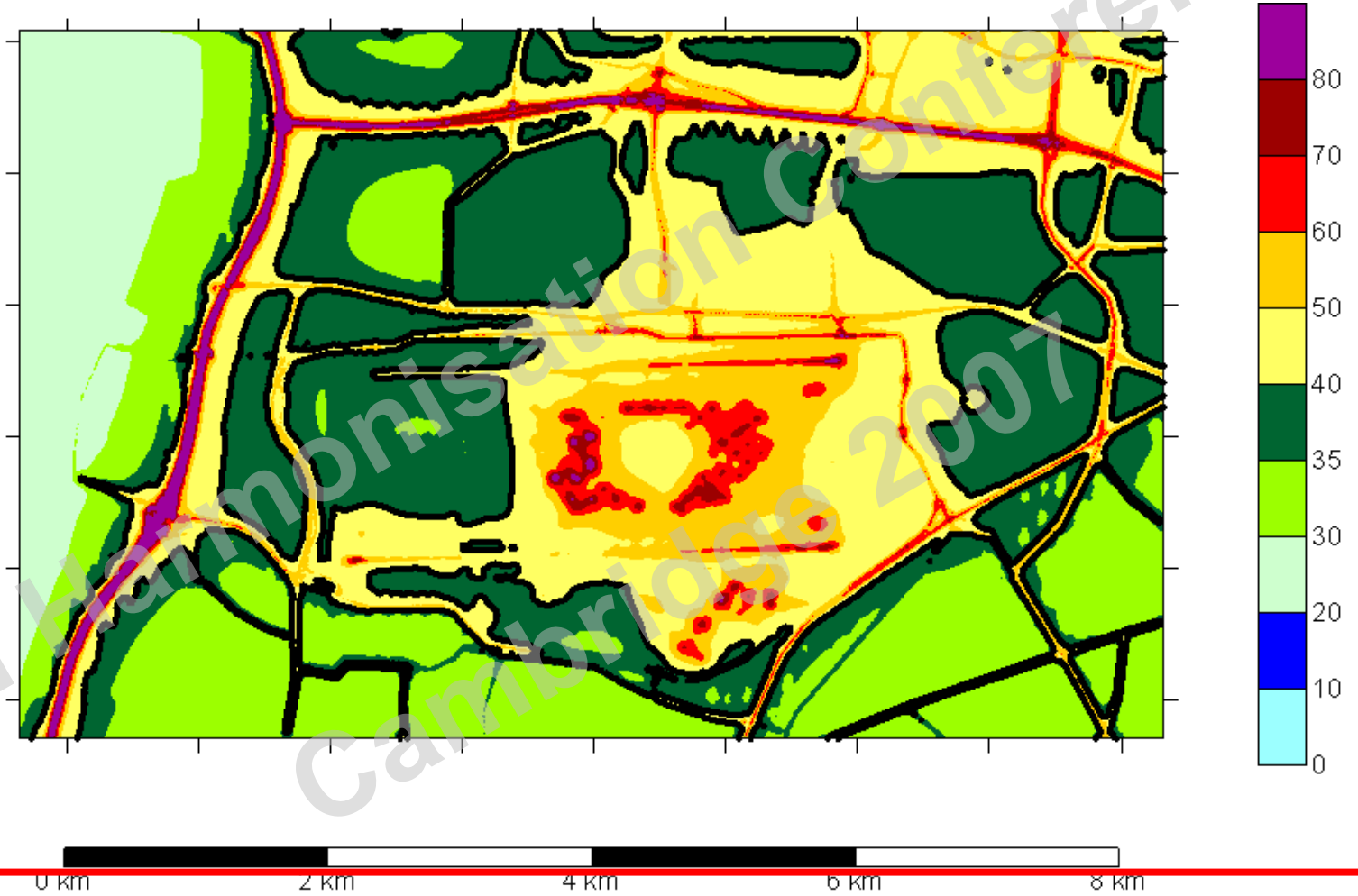


EDMS TOTAL NO_2



Total NO2 (ug m-3)
- 20 - 24
- 24 - 28
- 28 - 32
- 32 - 36
- 36 - 40
- 40 - 44
- 44 - 48
- 48 - 52
- 52 - 58
- 58 - 60
- 60 - 65
- 65 - 70
- 70 - 75
- 70 - 80
- 80 - 100
- 100 - 150
- 150 - 250
- No Data

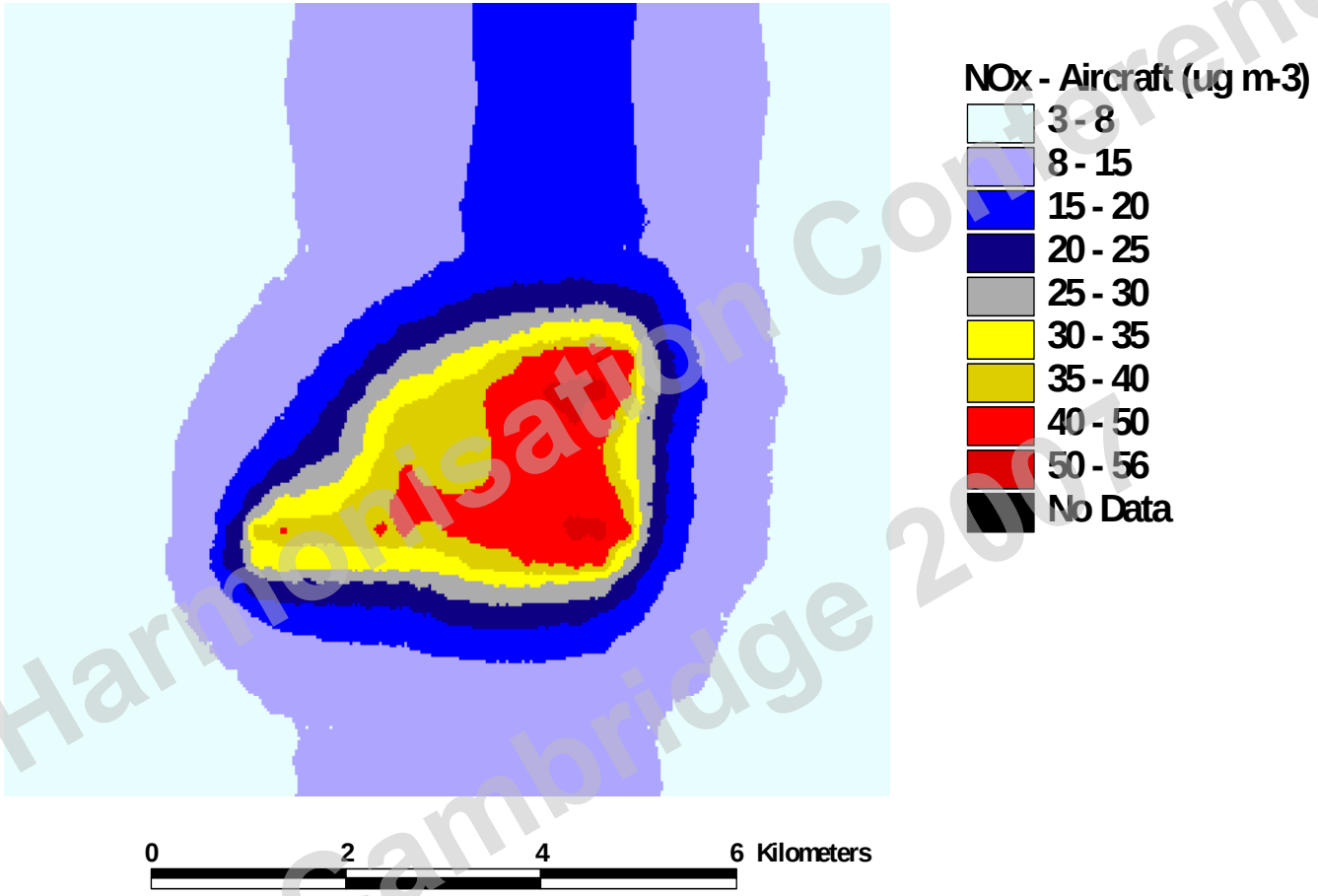
0 2 4 6 Kilometers



TOTAL NO_2

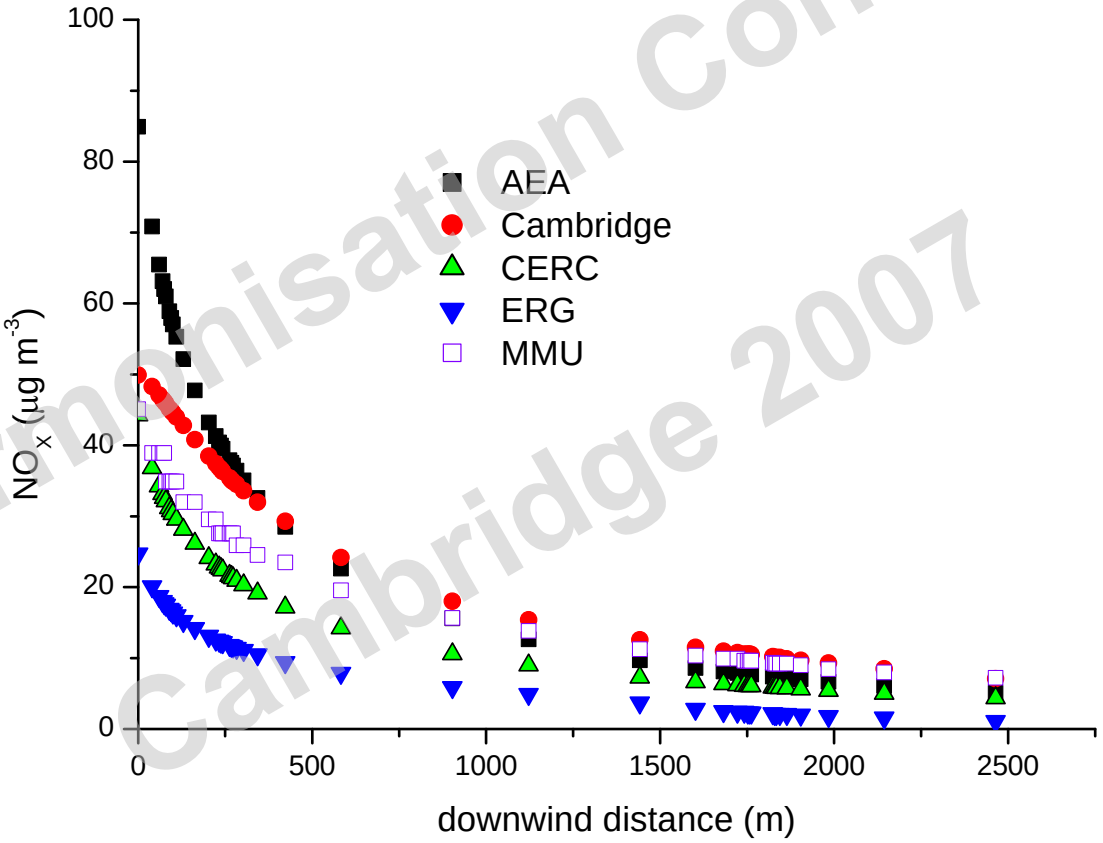
Model	% area > 40 µg/m^3 NO2
Netcen	32
Cambridge University	39
CERC	47
ERG	31
MMU	49

PREDICTED PERCENTAGE AREA > 40 µg/m3 ANNUAL AVERAGE NO_2



ANNUAL AVERAGE NO_X FROM AIRCRAFT BUT WITHOUT APU AND GSE CONTRIBUTION

Where are we now?



Aircraft NO_x contribution along the northern transect. Comparison with the other models.

Reflections

Activity

Emissions (**control based on NO_X**

Dispersion/Reaction/Deposition

Concentrations (**control based on NO_2**

Exposure

Health Effects

Conclusions

- Long term mean concentrations seem well-predicted and this is critical regulatory parameter for NO_2

- Note that annual mean regulatory standard is 40 µg m^3. London has great difficulty in meeting this standard. This is less than half the annual mean federal regulatory standard in the US.

- We are probably looking at the wrong problem…

- **WHY?**

THANK YOU!