Modelling Airport Air Quality

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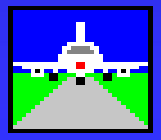
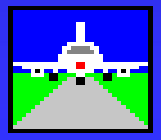
Safeguarding Airport Air Quality
Manchester 12 April 2007



Outline of talk

- Key factors affecting air quality at airports
- Features of ADMS-Airport
- Model performance and sensitivities - DfT PSDH Heathrow Model Inter-comparison (MIC)



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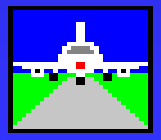
Key factors affecting air quality at airports

- Emissions
- Background concentrations
- Meteorology
- Near field dispersion processes
- Chemical reactions



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Features of ADMS-Airport

- An extension of ADMS-Urban – gaussian type model nested in regional trajectory model
- Includes chemical reaction scheme, meteorological preprocessor, Monin Obukhov and mixed layer scaling for boundary layer structure
- Allowance for up to 6500 sources: road (1500, each with up to 50 vertices), point, line area and volume (1500), grid sources (3000) and up to 500 runway sources (exhaust modelled as moving jets)
- Other airport features
  - Hour by hour time varying data
  - Multi-segment line sources e.g. taxi ways
  - GIS link displays line, volume and runway sources

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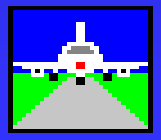
Features of ADMS-Airport

MODELLING EXHAUSTS AS MOVING JETS
IMPACTS OF WAKE VORTICES

- Models engine exhausts as moving jet sources
- As the aircraft accelerates
  - buoyancy and emissions increasingly spread along the runway
  - the exhaust jet sees a faster ambient wind speed, this affects the plume rise
- The plume from the faster aircraft rises less than that from a slower aircraft
- Allows for the impact wake vortices may have on jet plume rise – reduce buoyancy



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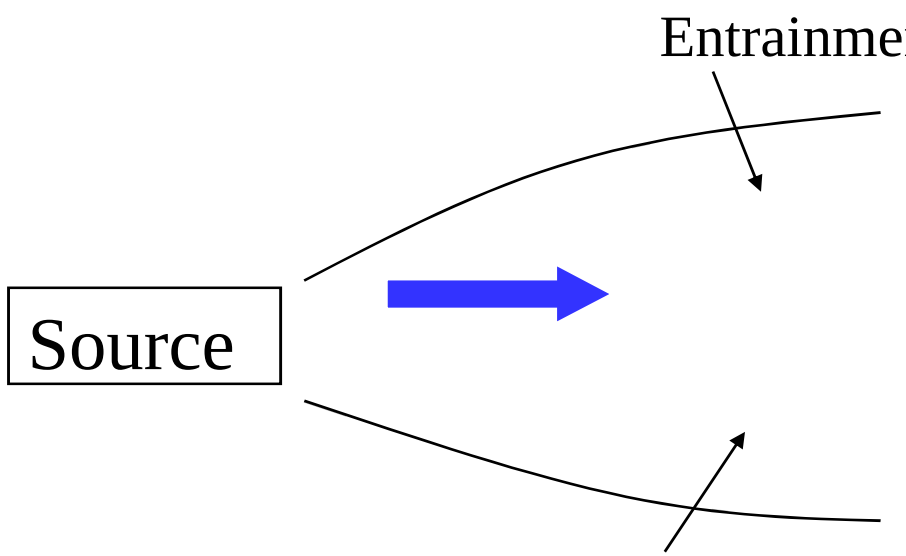
Features of ADMS-Airport

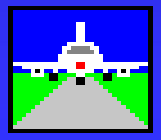
MODELLING EXHAUSTS AS MOVING JETS



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 sources; reduces effective buoyancy
  - Allowance for impact of wake vortices on jet plume trajectory



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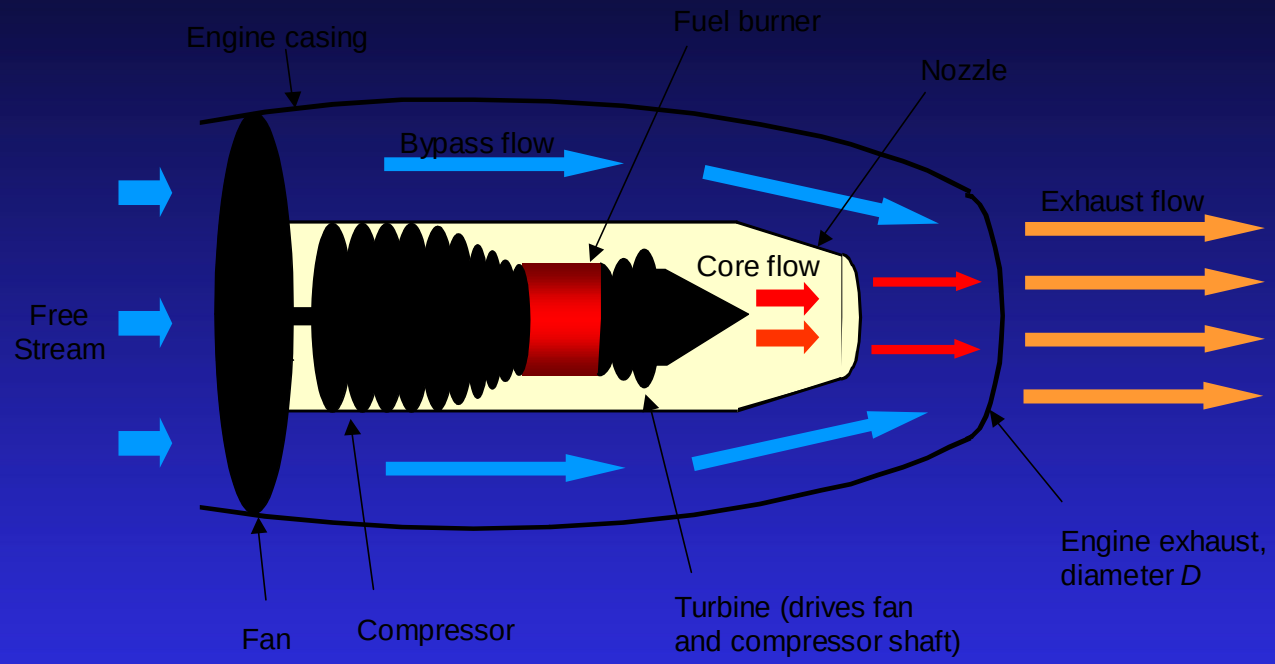
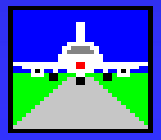
Schematic of Jet Engine



Input: jet model requires

1. Effective exit velocity (or volume flow rate) – from mass flow rate, thrust and fuel burn rate
2. Temperature
3. Effective exit diameter – derived from 1, 2



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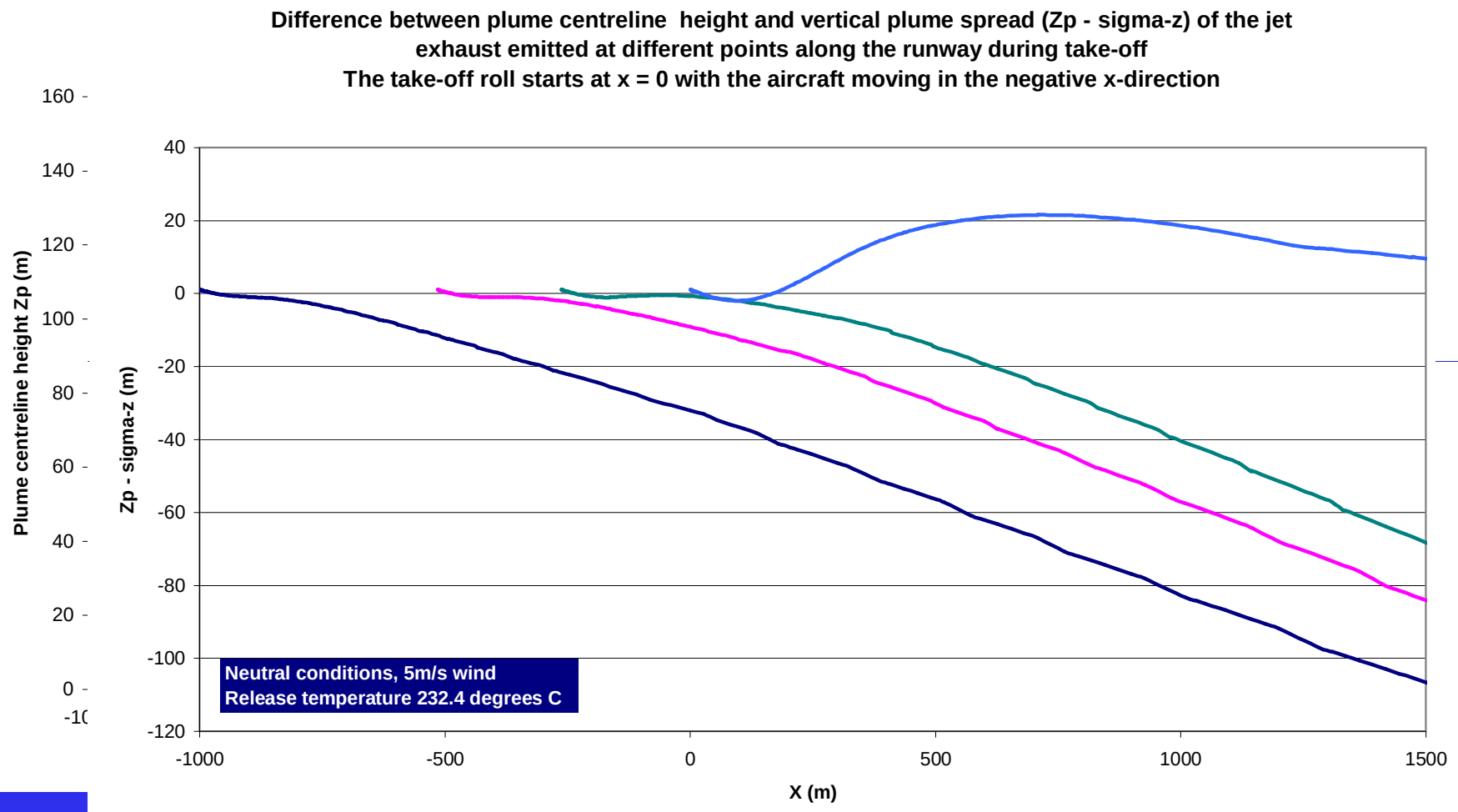
Neutral met conditions, plume trajectory (z_p) (1st), vertical spread (σ_z) (2nd) and z_p - σ_z (3rd)



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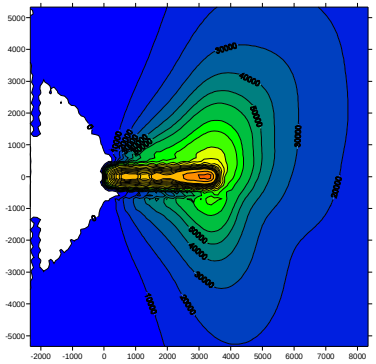
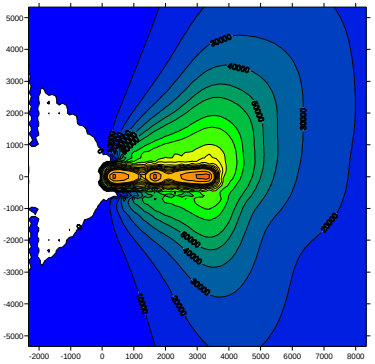
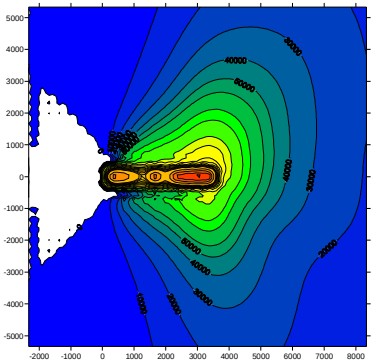
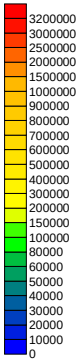
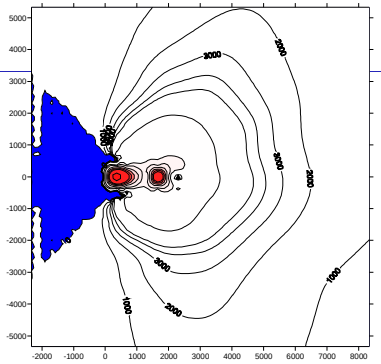
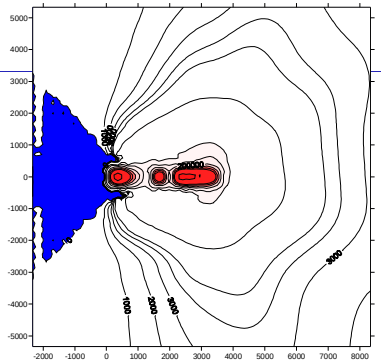
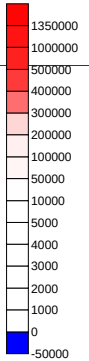
Impacts of reduced buoyancy to simulate possible effect of wake vortices B747 long term contour concentration and difference plots

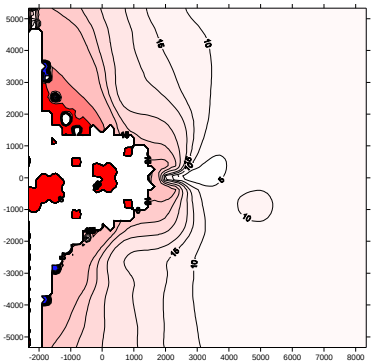
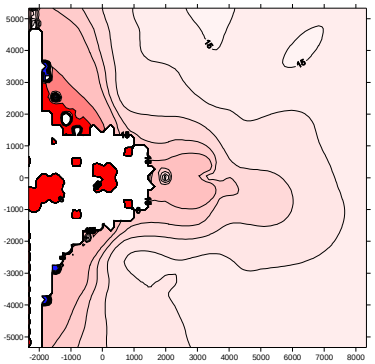
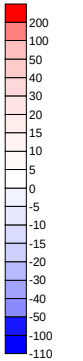
All source buoyant | **First 4 sources buoyant** | **No source buoyant**

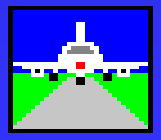





absolute difference →

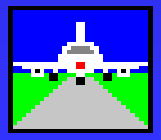
percentage difference →



Heathrow : emission sources

- Gridded sources for all of London
- Roads – local to Heathrow from LAEI (London Atmospheric Emissions Inventory) and the Heathrow Inventory
- LTO: taxi-in, taxi-out, landing, approach, initial climb, climb out
- Other: APU, airside vehicles, car parks, taxi ranks



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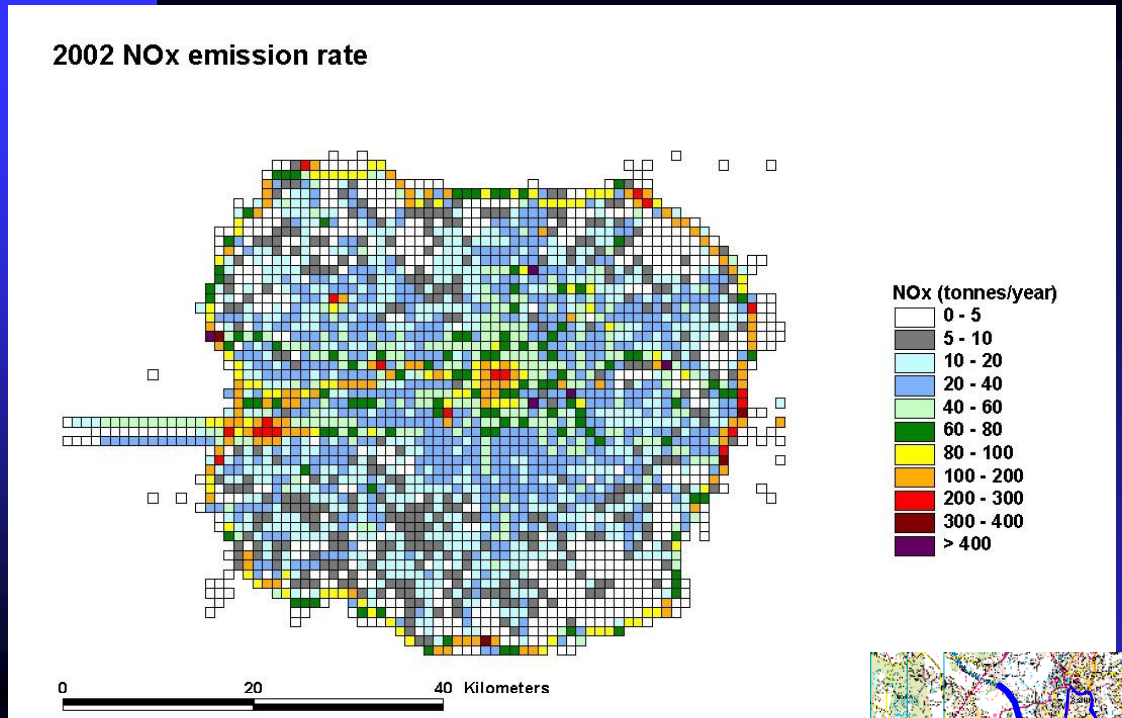
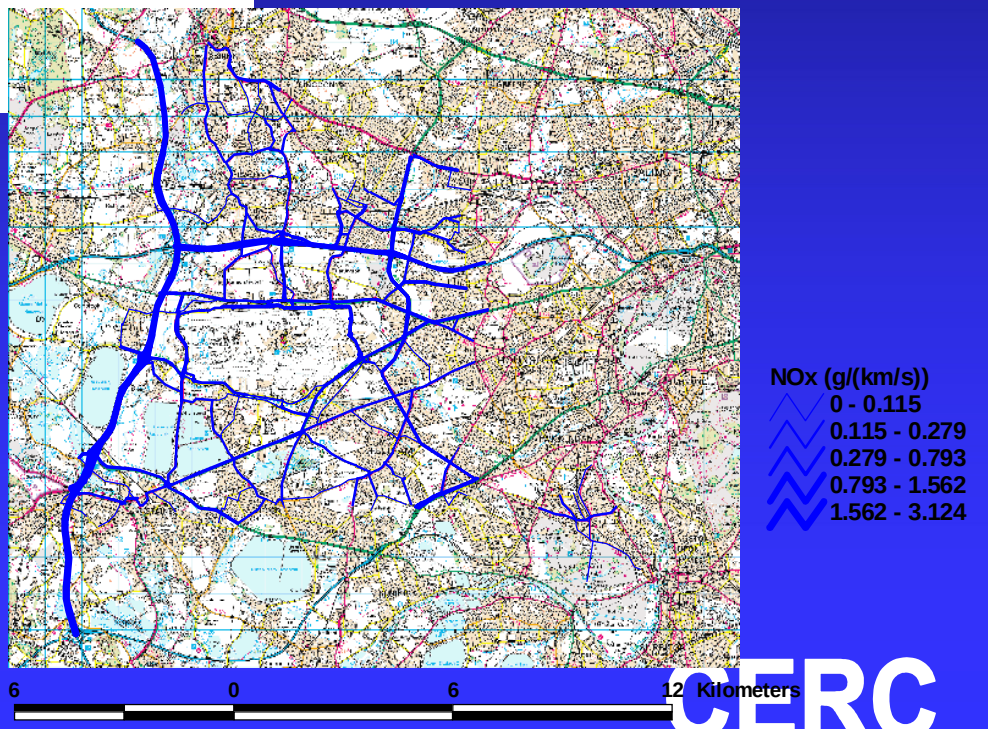
Grid sources from LAEI





Explicitly modelled road sources

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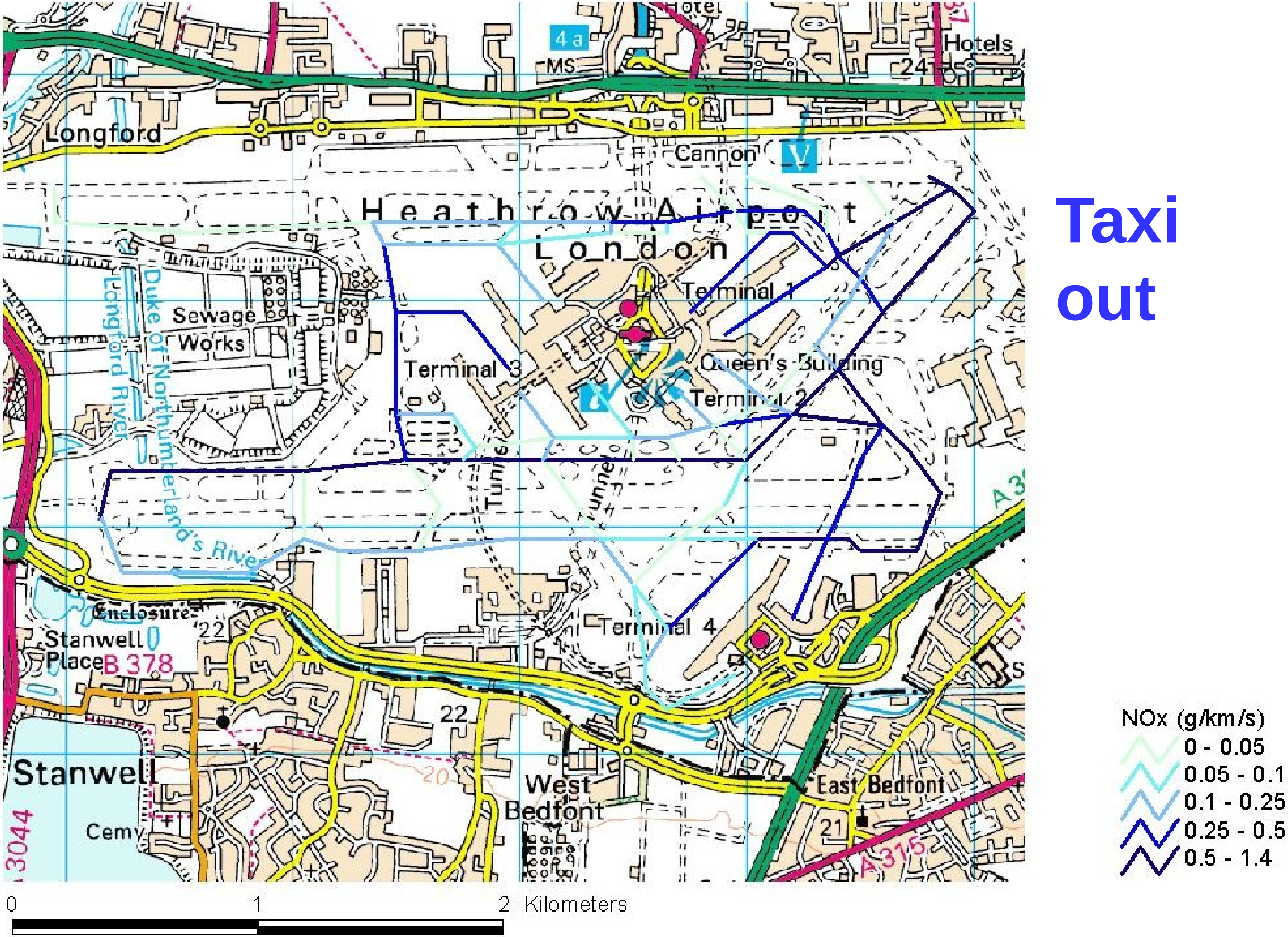
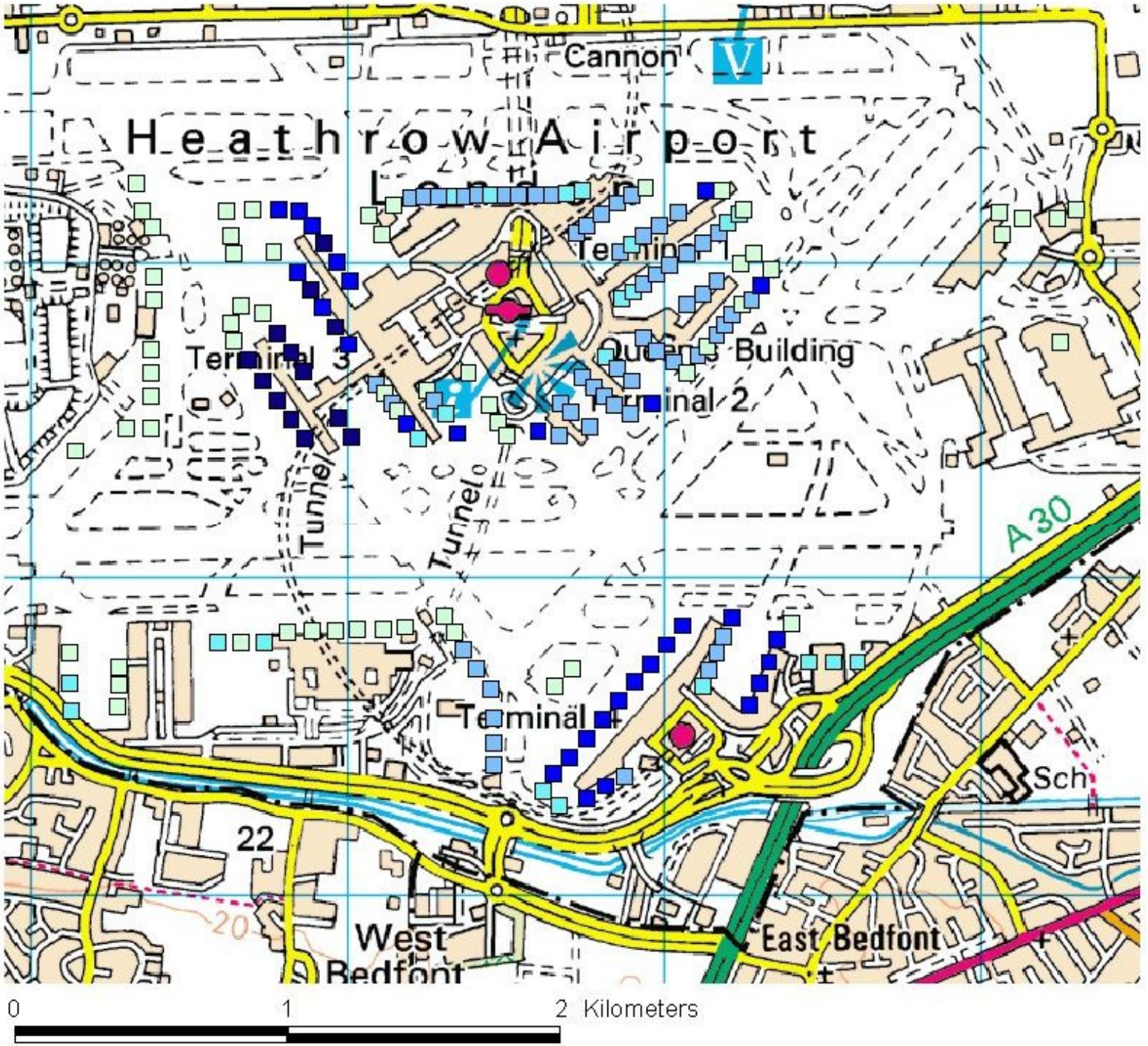
Taxi out



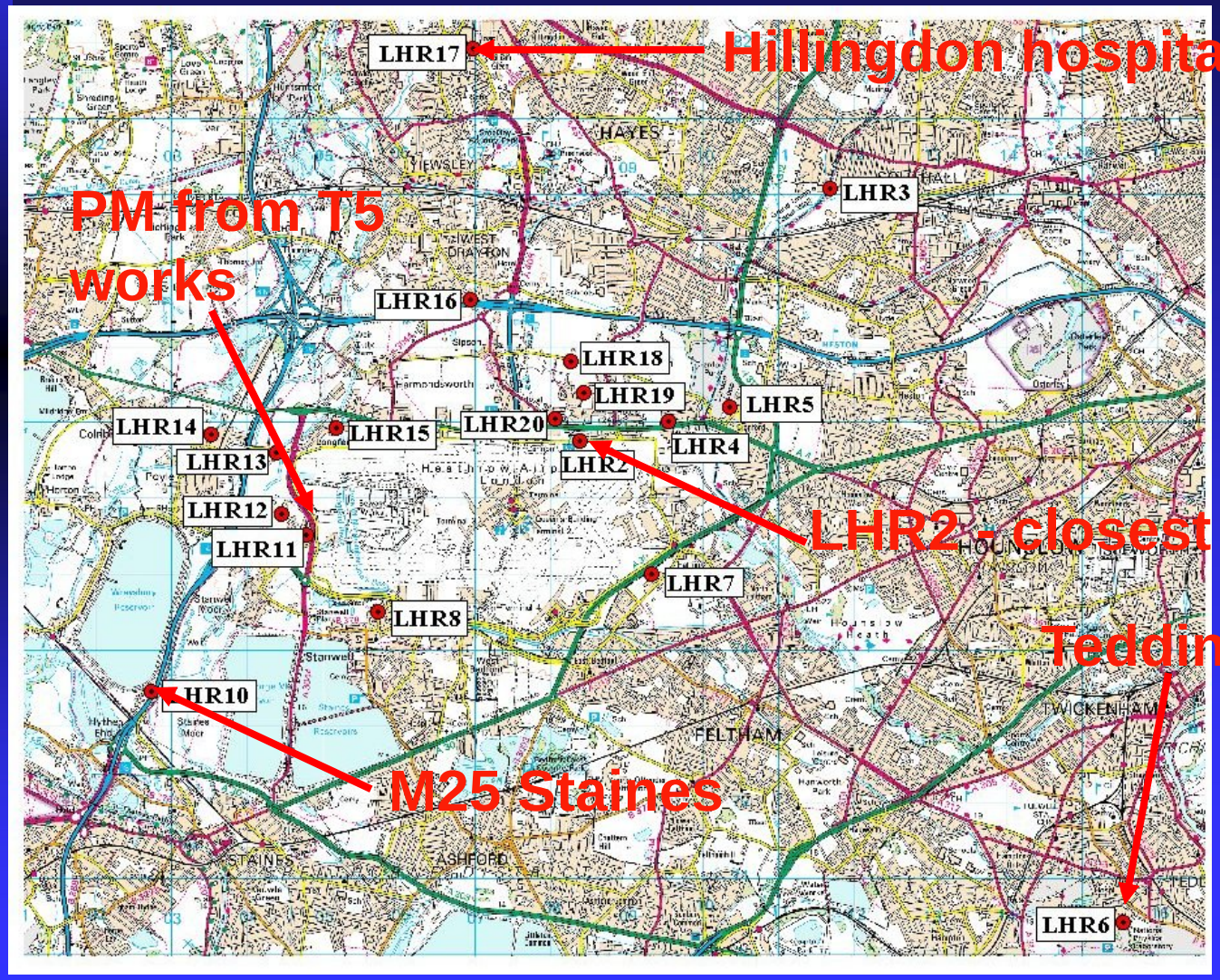
Longford
Cannon
Hotels
Heathrow Airport London
Terminal 1
Terminal 2
Terminal 3
Terminal 4
Queen's Building
Sewage Works
Longford River
Duke of Northumberland's River
Enclosure
Stanwell Place
B 378
Stanwell
Cemy
West Bedfont
East Bedfont
A 315
0
1
2 Kilometers
NOx (g/km/s)
0 - 0.05
0.05 - 0.1
0.1 - 0.25
0.25 - 0.5
0.5 - 1.4


Heathrow Airport
London
Cannon
Terminal 3
Queen's Building
Terminal 2
Tunnel
Tunnel
A30
Terminal 4
22
West Bedfont
East Bedfont
Sch
0
1
2 Kilometers
NOx (g/s)
0 - 0.012
0.012 - 0.030
0.030 - 0.054
0.054 - 0.093
0.093 - 0.132

APU

Heathrow

MONITORING DATA



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Heathrow

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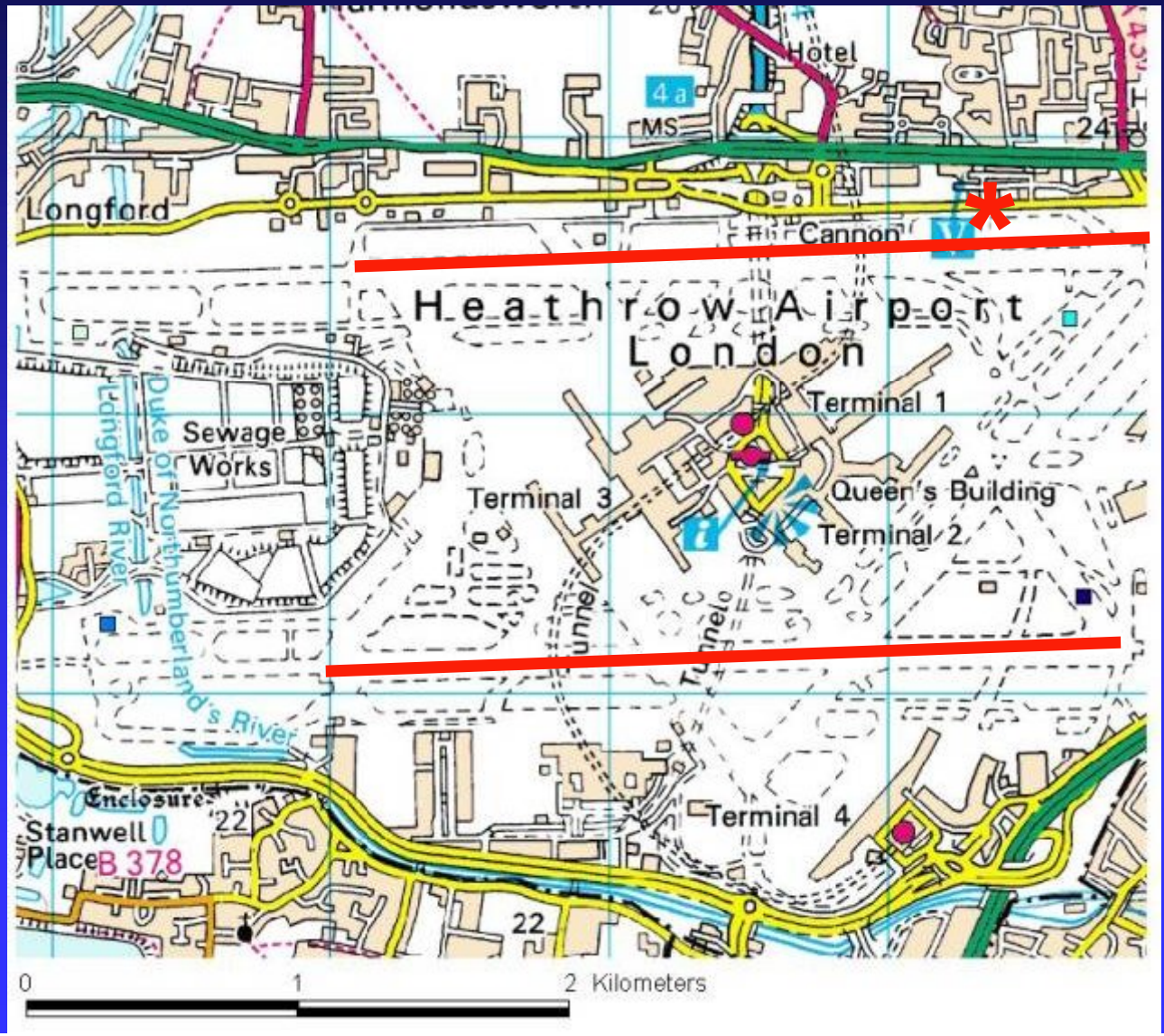
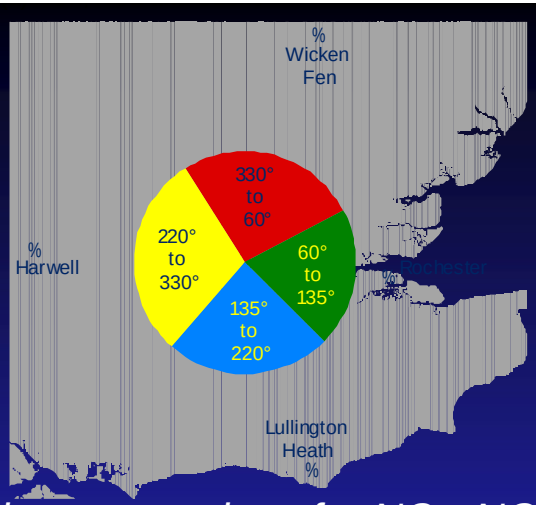
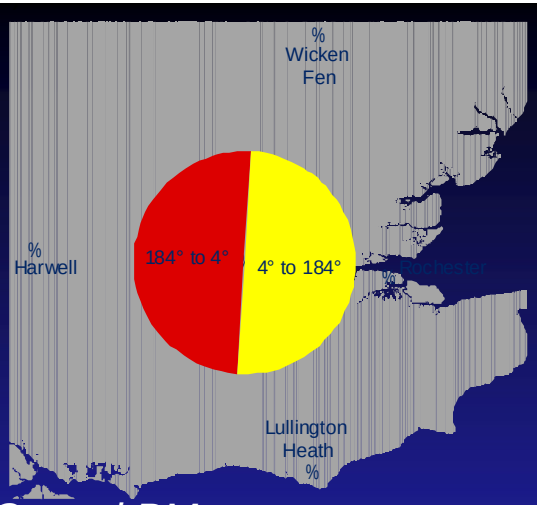


LHR2

CERC





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

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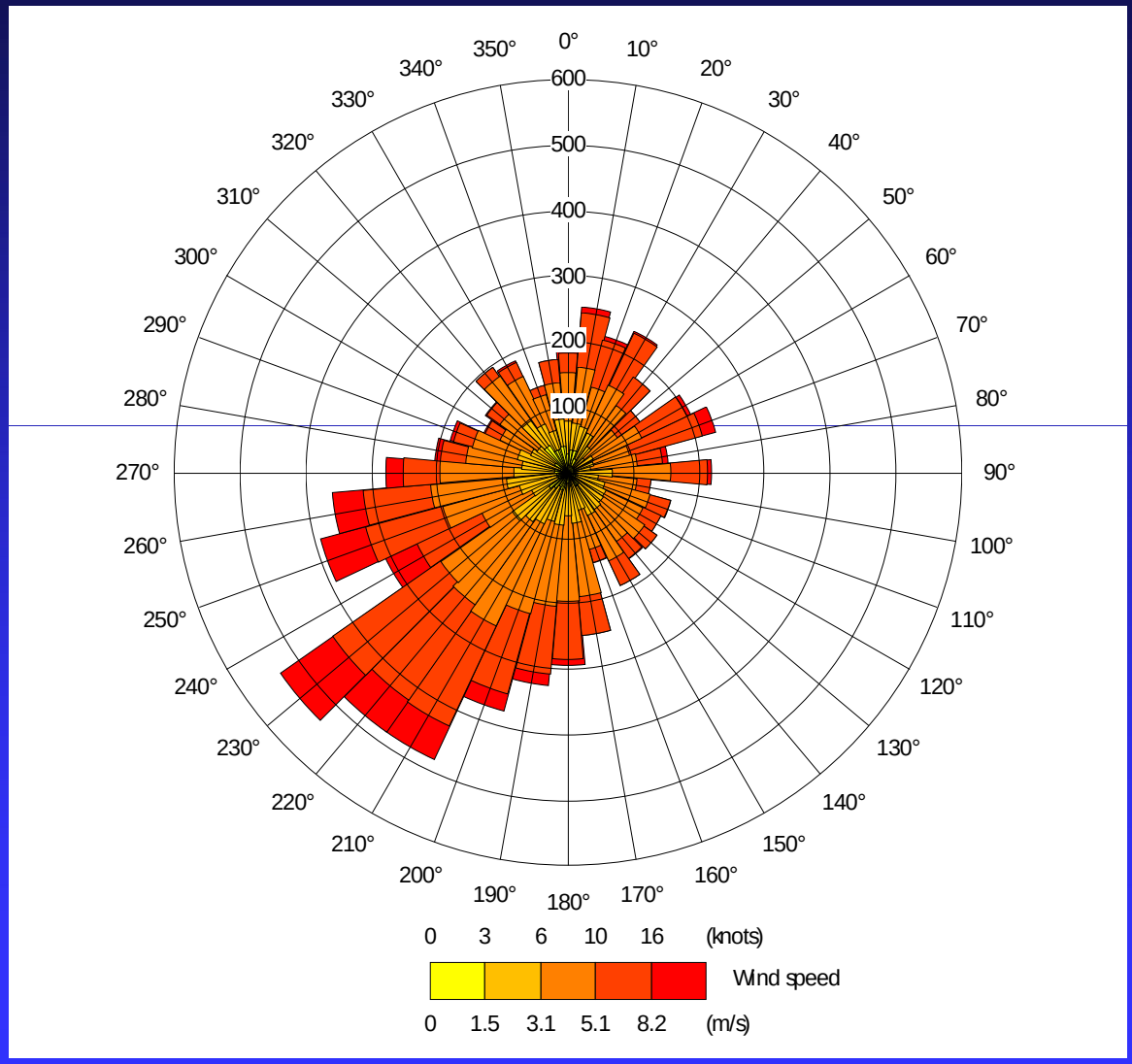
Heathrow

METEOROLOGICAL DATA



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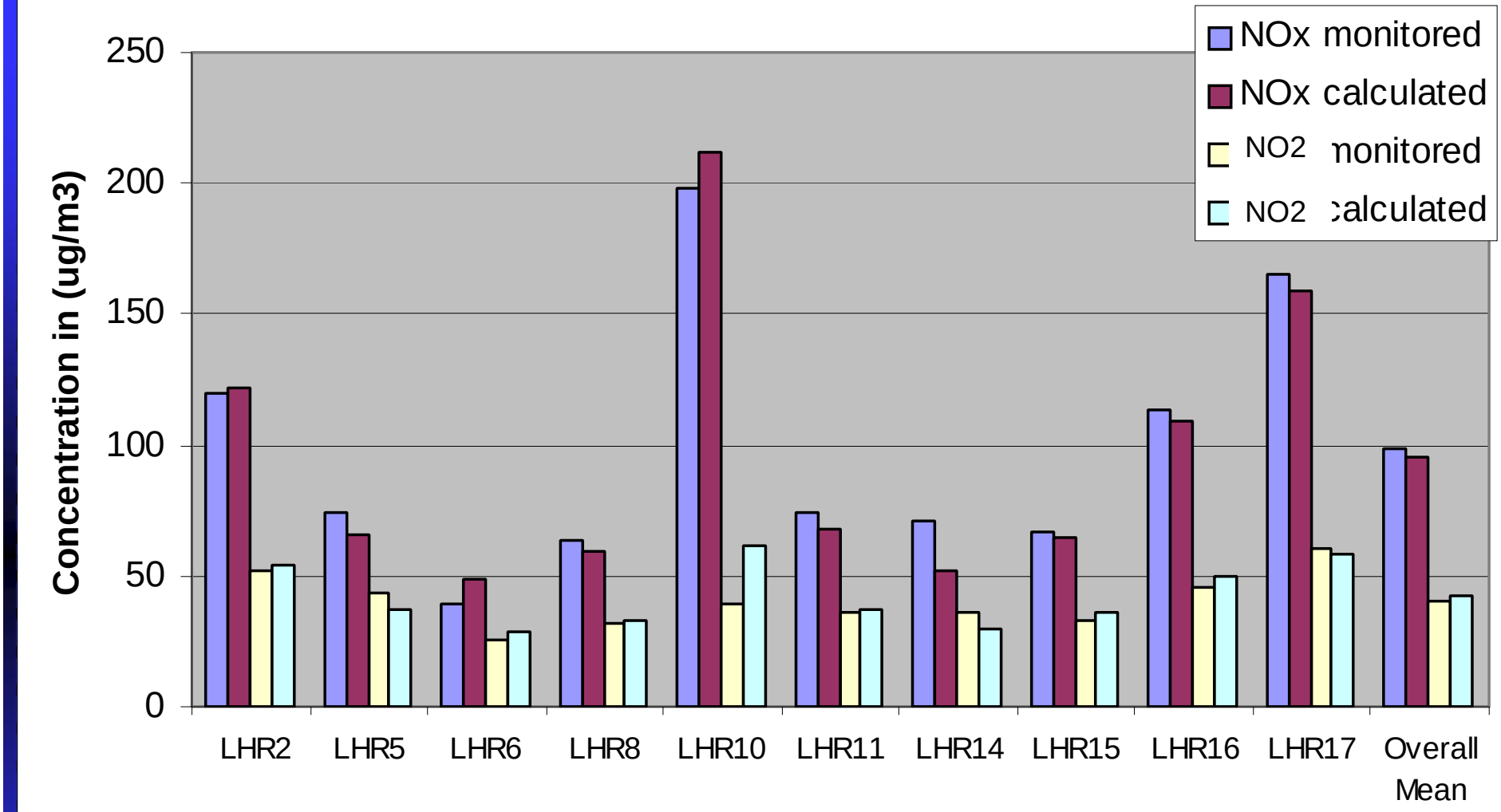

NOX (dark blue and red) and NO2 (yellow and light blue) monitored and calculated annual mean concentrations at the automatic monitoring sites

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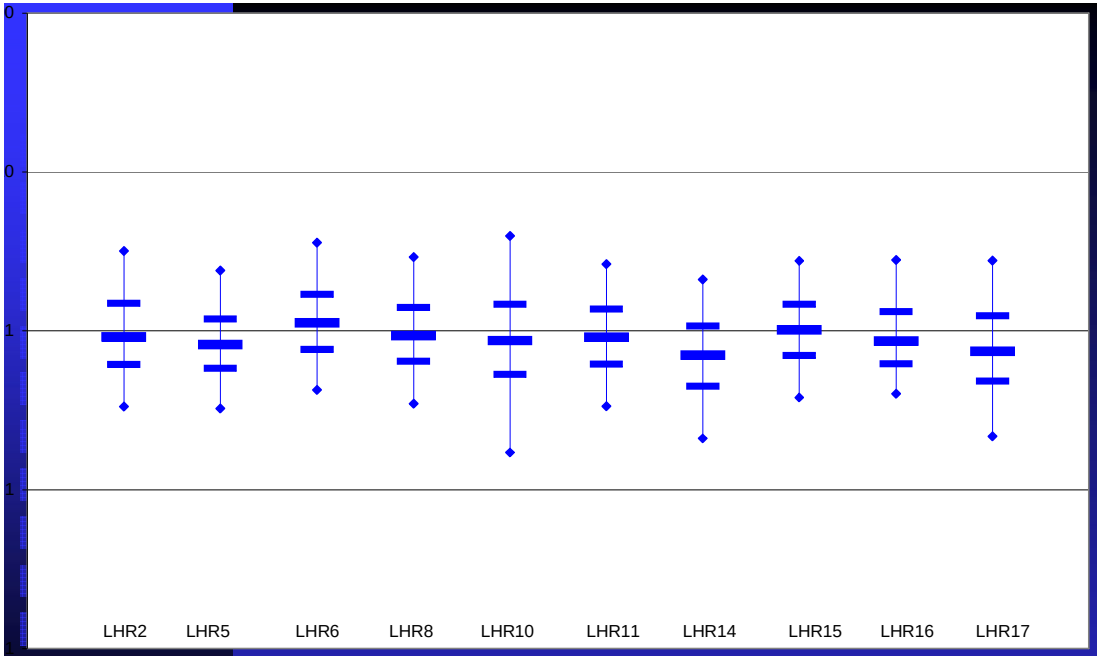
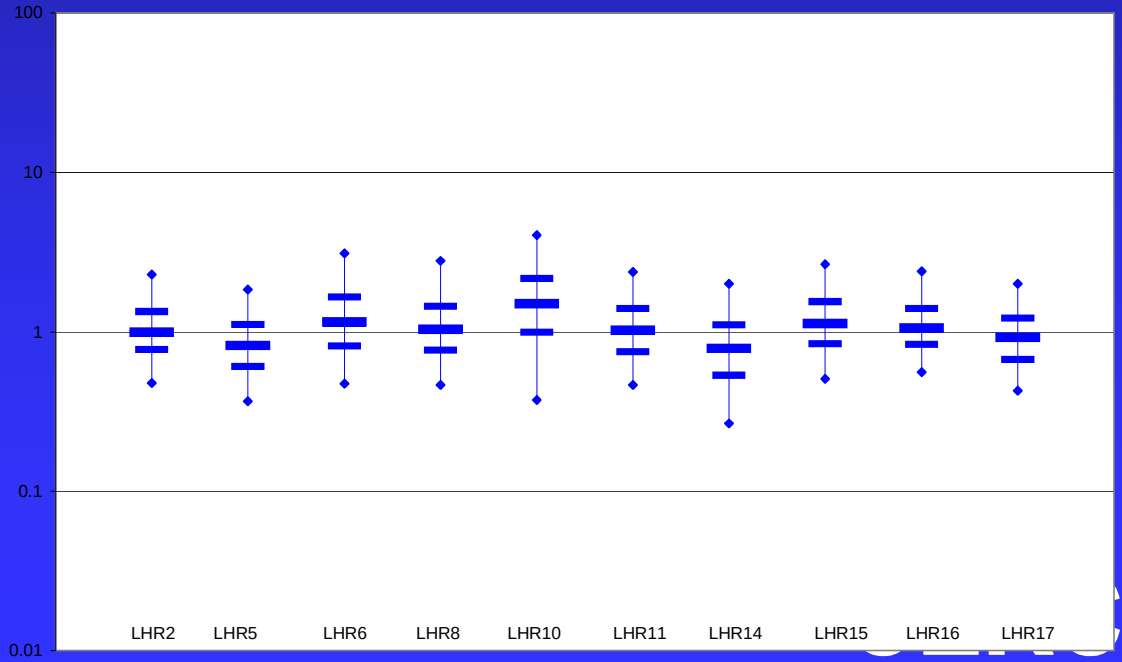
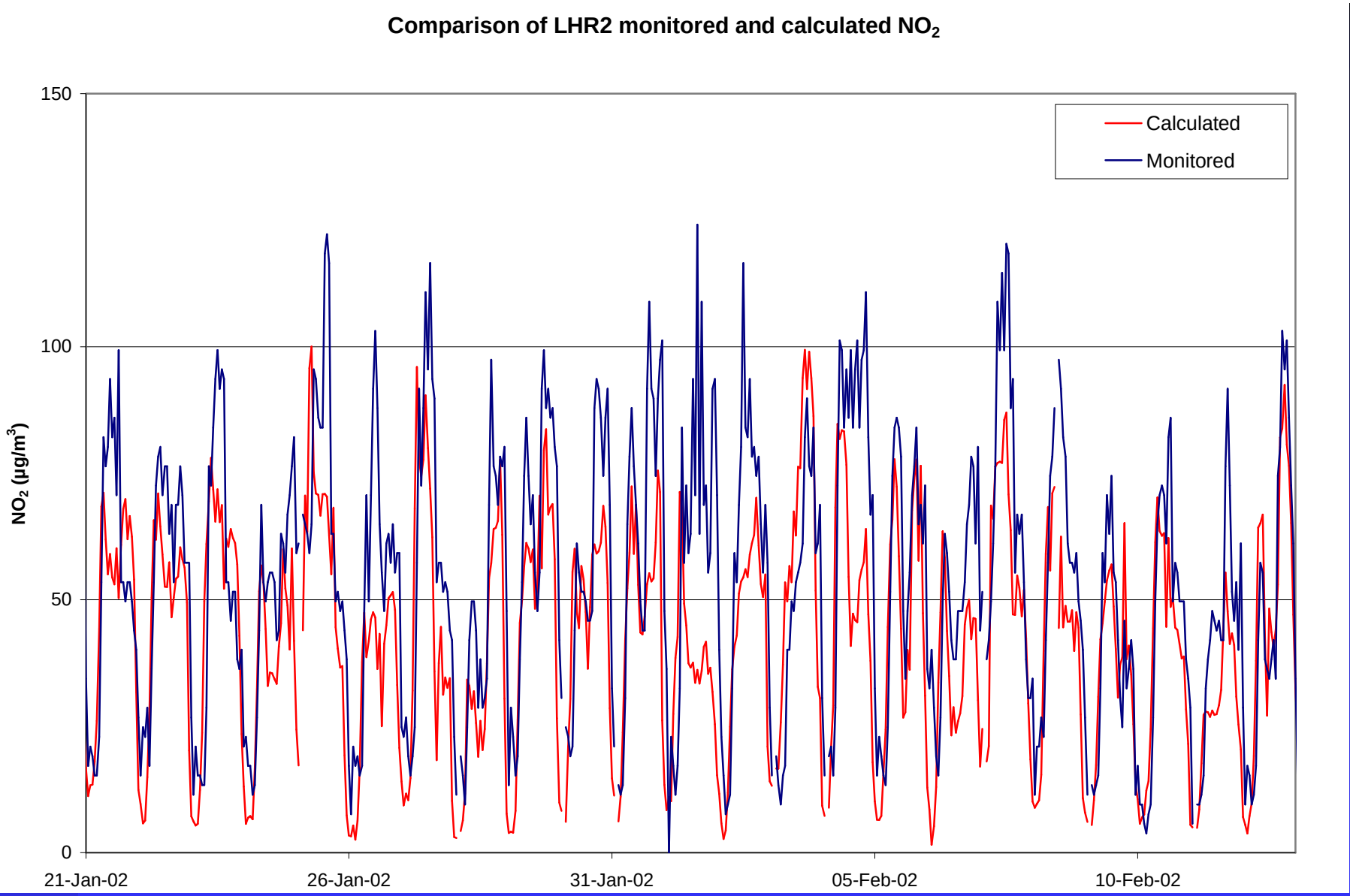


LHR2 "Box and whisker" plots for the ratio of (calculated/monitored) concentrations, NO_X (top) and NO_2 (bottom).

The lines indicate the 75th, 50th and 25th percentiles and the lines extend from the 95th to 5th percentile.





Detailed time series comparison of monitored (blue) and calculated (red) hourly concentrations at receptor LHR2. 2l Jan 2002 – mid February 2002

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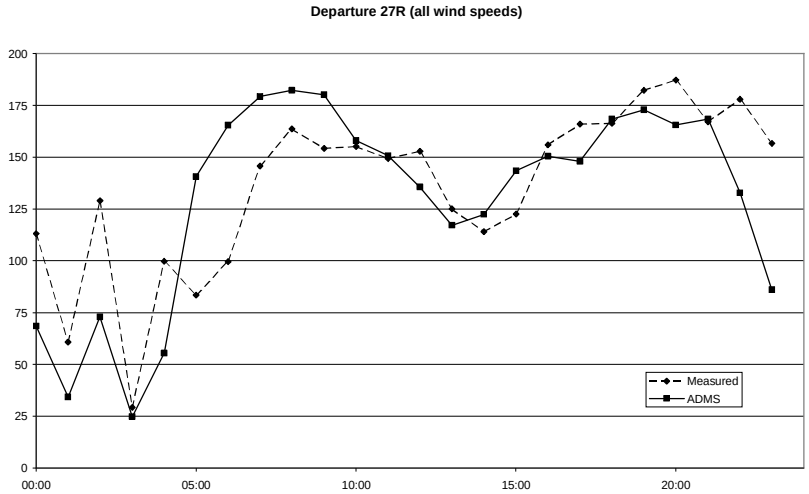
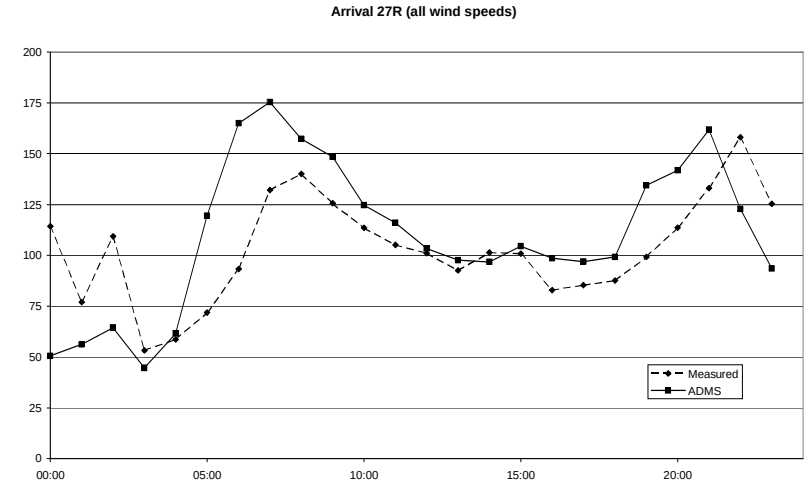
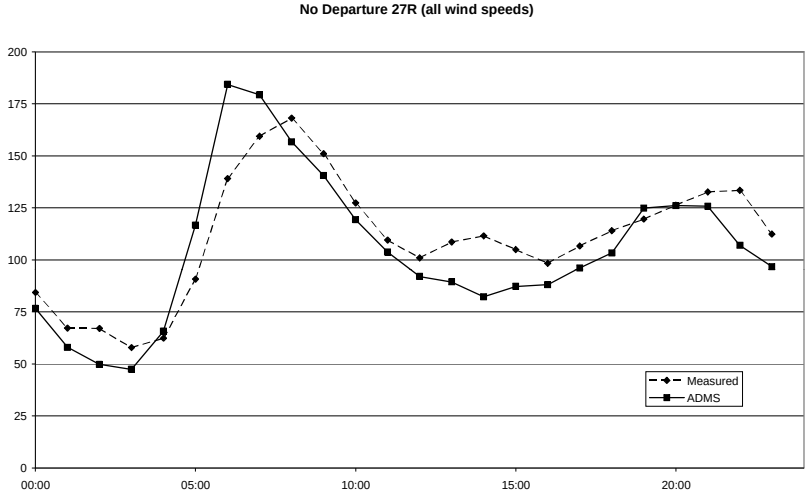
LHR2 Diurnal Variation ADMS-Airport compared with measured data Different Runway Use







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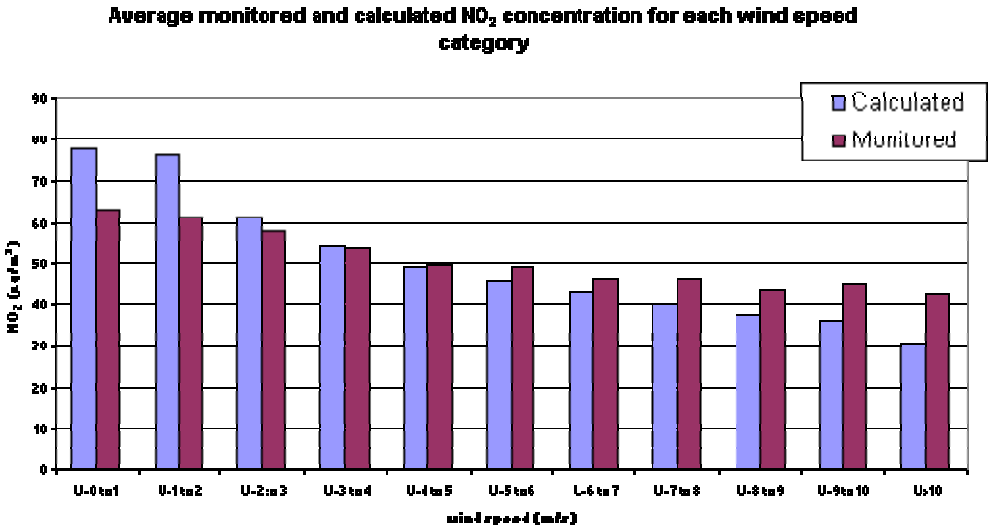
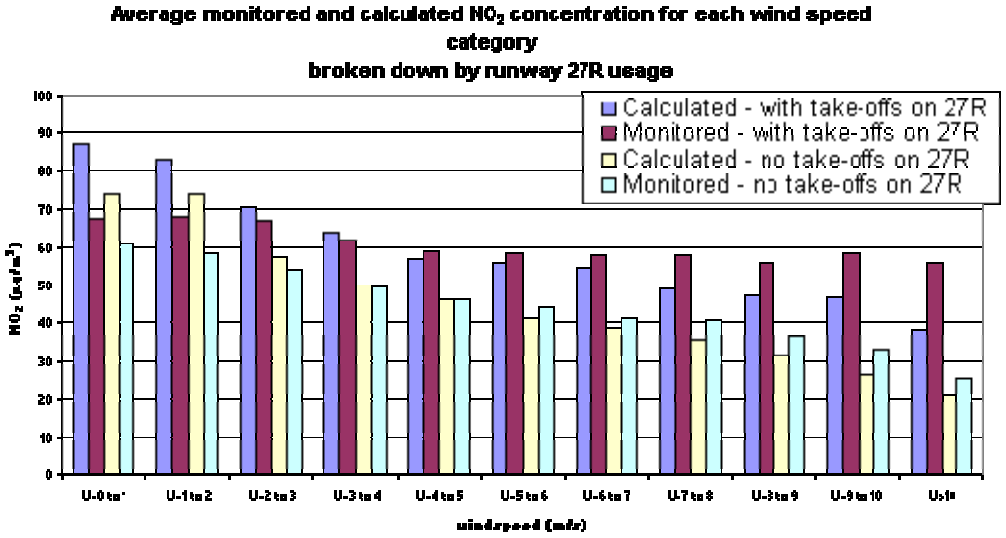
Comparison of monitored and calculated NO_2 in $\mu g/m^3$ at LHR2 as a function of wind speed. The top plot shows all hours. The bottom plot shows the hours when 27R is operational and the hours when it is not operational separately.





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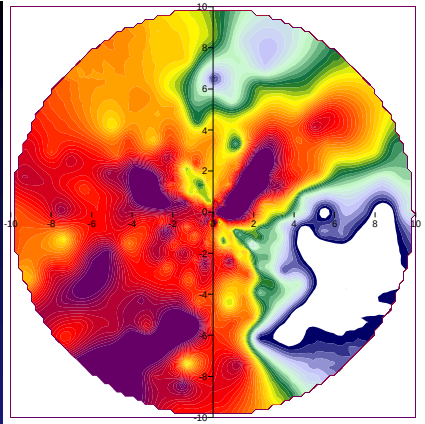
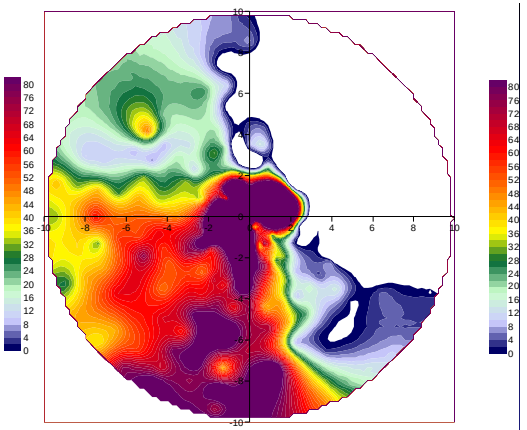
Measured v CERC >

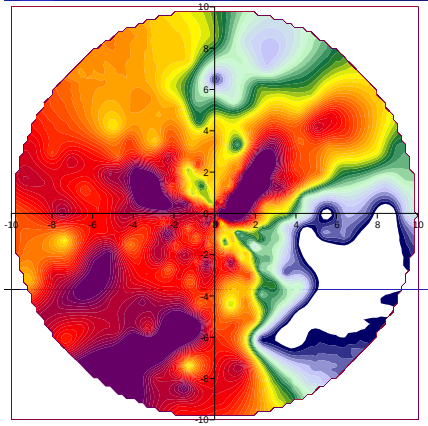


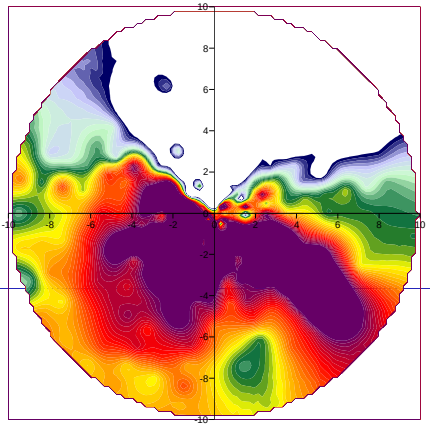


Measured LHR2

CERC predicted

Measured v EDMS

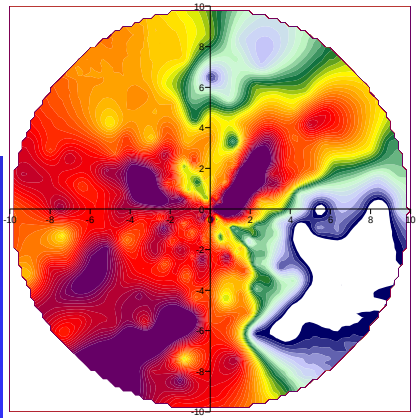


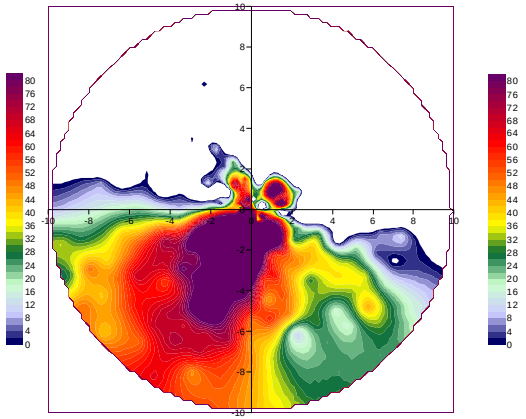


Measured LHR2

Cambridge predicted

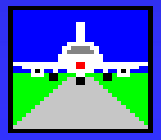
Measured v LASPORT





Measured LHR2

MMU predicted



Polar plots of NO_x at LHR2 with background concentrations subtracted. Radius: wind speed in m/s.

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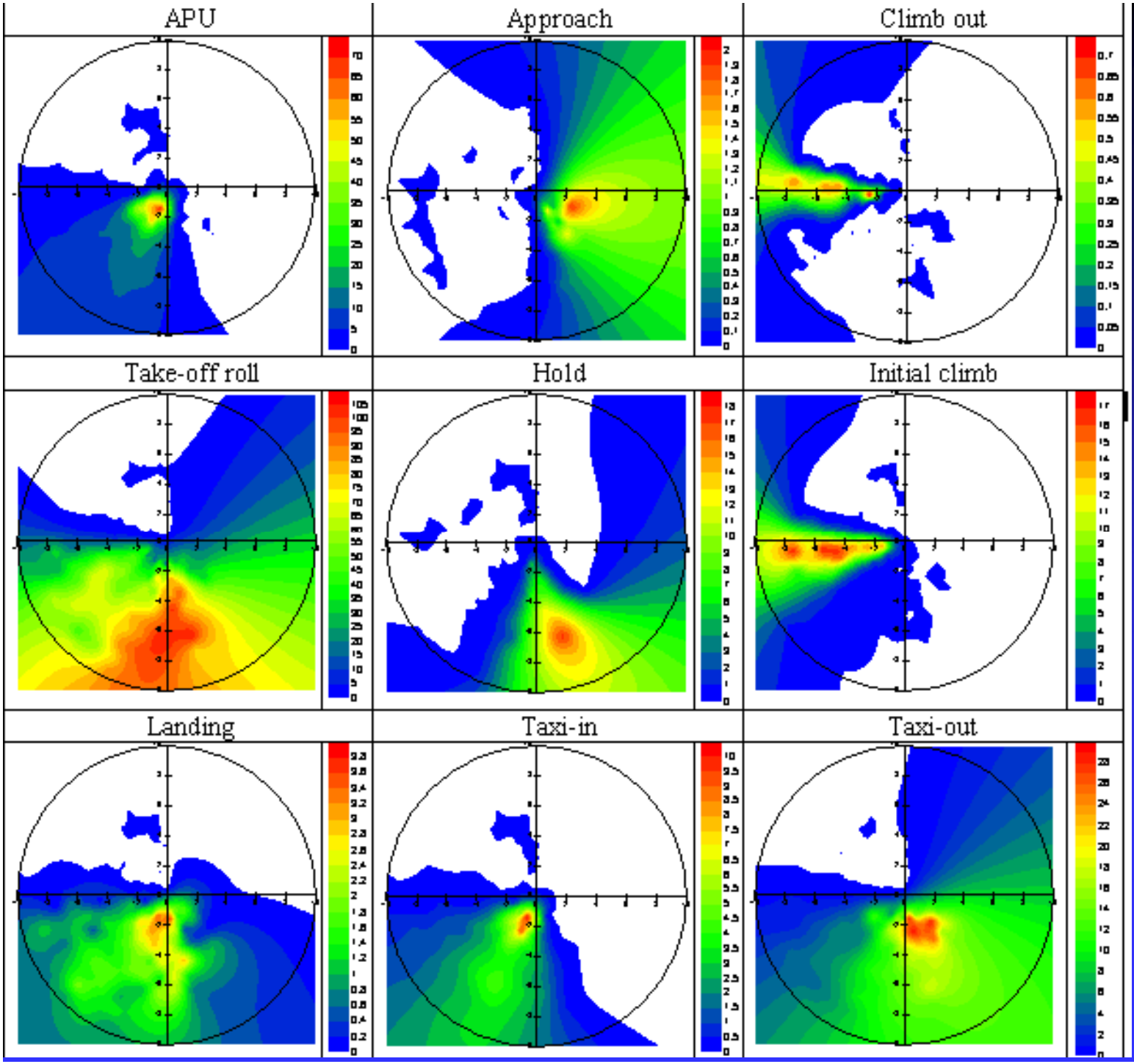

Polar plots for the components of the aircraft emissions:

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

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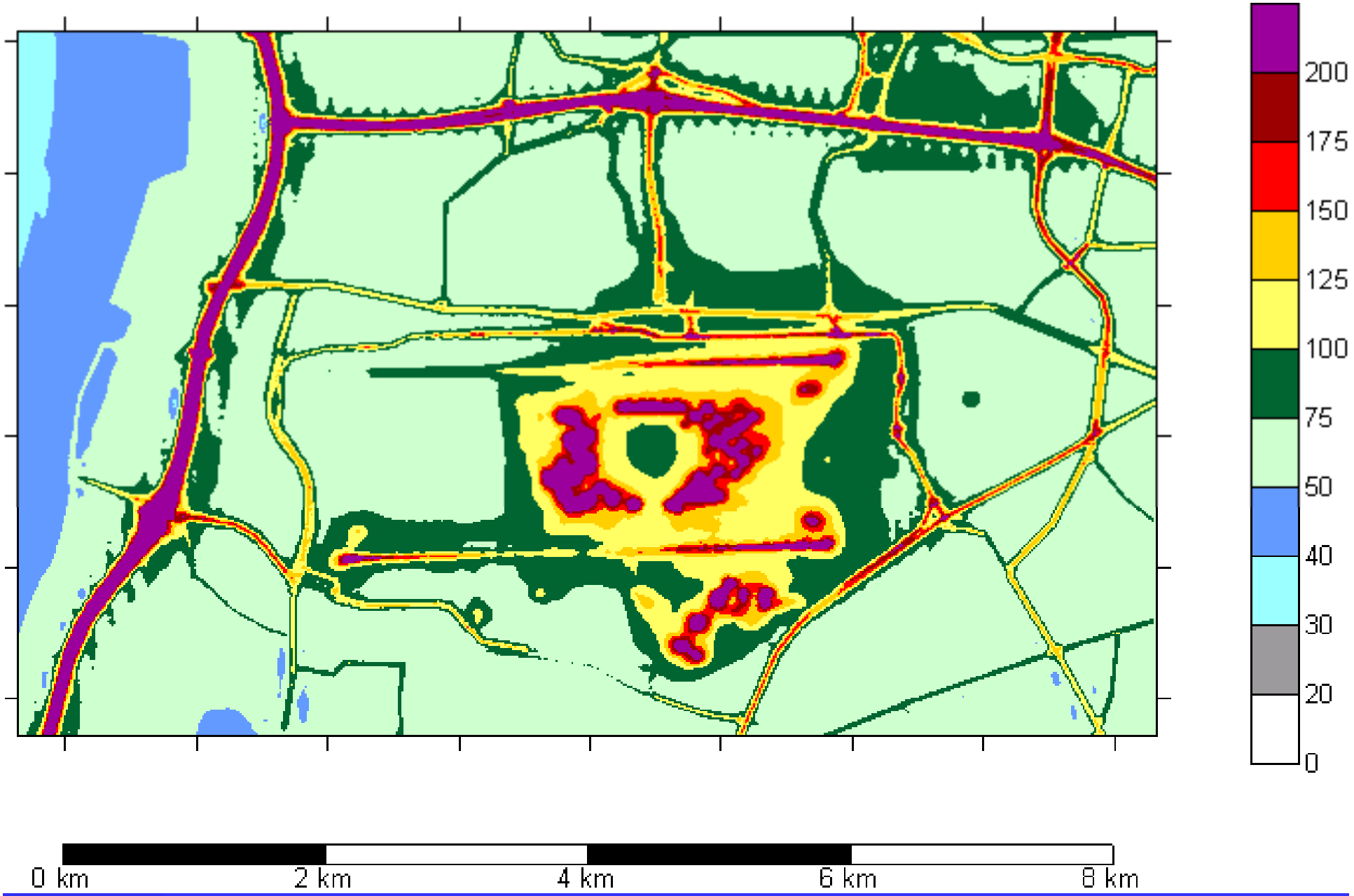

Annual average NO_x µg/m³

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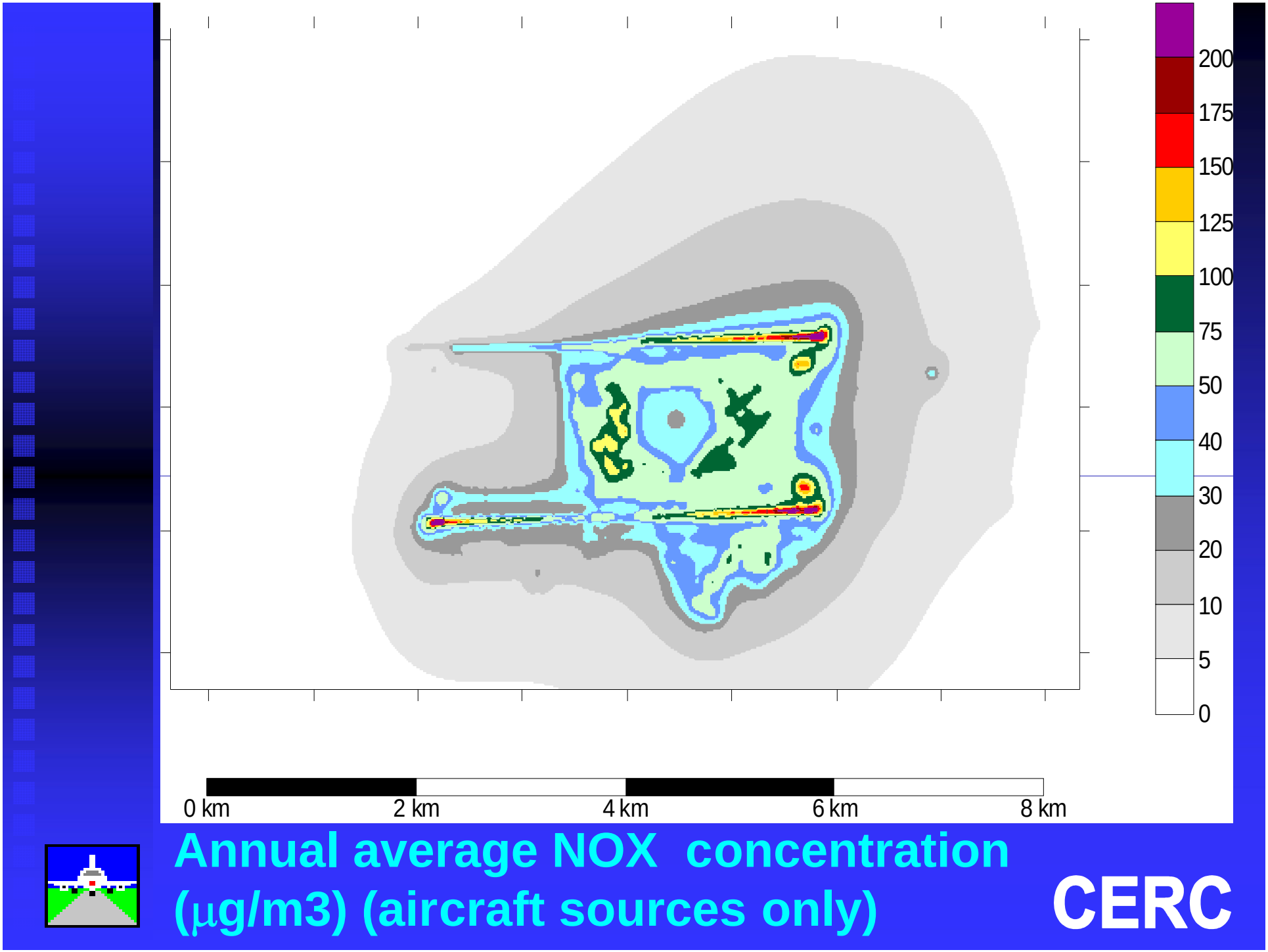
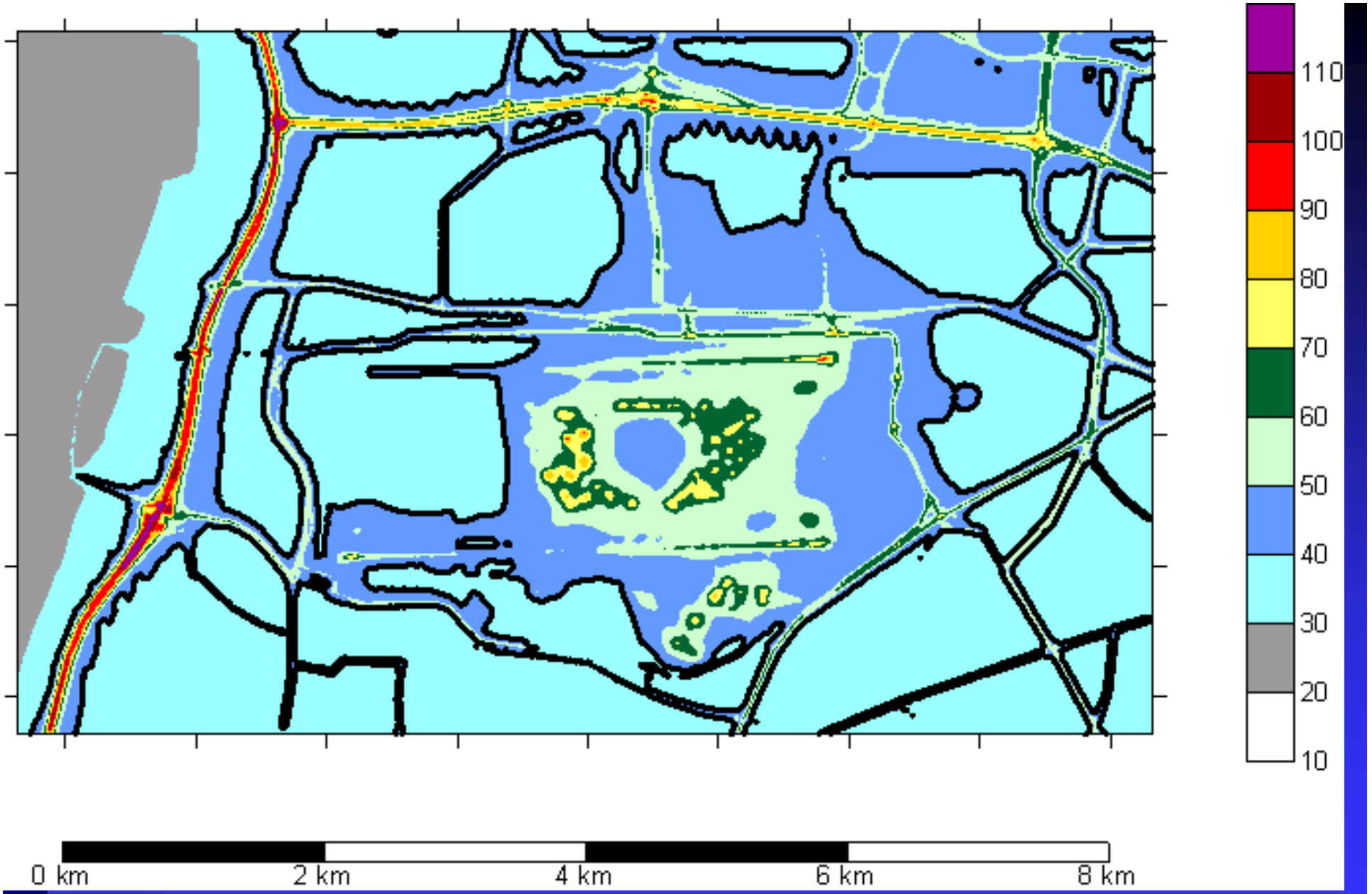


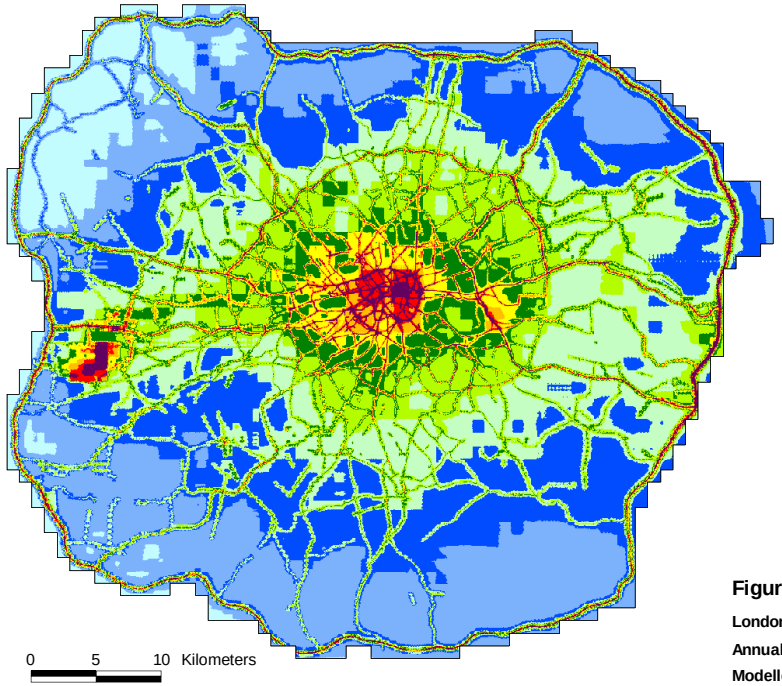
Annual average NOX concentration (μg/m3) (aircraft sources only)

CERC



Annual average NO_2 µg/m³, limit shown in bold

CERC



CERC

Figure 4.1a

London 2010 - 10% NO2

Annual average NO2 concentration

Modelled using ADMS-Urban

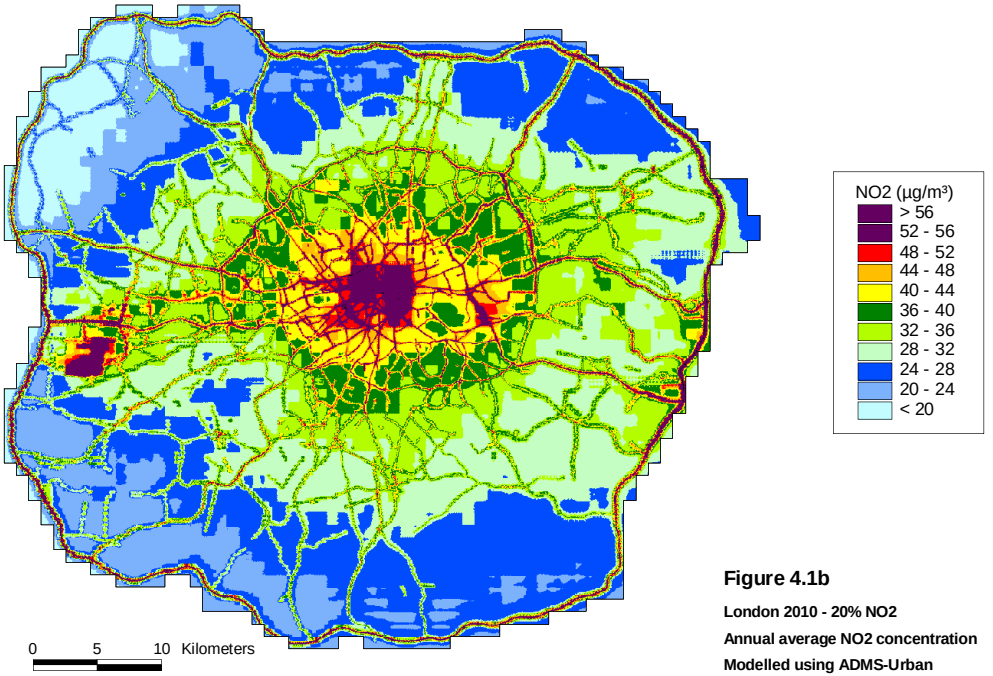


Figure 4.1b

London 2010 - 20% NO2

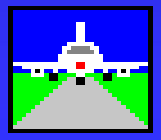
Annual average NO2 concentration

Modelled using ADMS-Urban

Conclusions

Key factors affecting pollutant concentrations in the neighbourhood of airports include the following:

- Emissions including primary NO2
- Background concentrations
- Meteorology
- Near field dispersion proceses
- Chemical reactions



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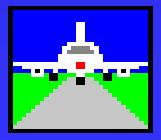
Component	Average emission rate (g/s)	NO_X concentration at LHR2 in $\mu g/m^3$		
		Volume sources, diurnal profiles	Volume sources, hour by hour data	Jet sources, hour by hour data
Take-off roll (100%)	26			13.3
Take-off roll (80%)				14.3
Approach	24		0.03	
Landing roll	2		3.93	1.4
Climb out	41		0.03	
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



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

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