Developments in ADMS-Airport to take account of near-field dispersion and its applications to Heathrow Airport

David Carruthers, Christine McHugh,
Mark Jackson & Kate Johnson
Cambridge Environmental Research Consultants

Harmo11, July 2007

Outline of talk

- Key factors affecting air quality at airports
- Features of ADMS-Airport
- Model performance and sensitivities - Department for Transport PSDH (Project for the Sustainable Development of Heathrow) Model Inter-comparison (MIC)

1) Key factors affecting air quality at airports

Key factors affecting air quality at airports

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

2) Features of ADMS-Airport

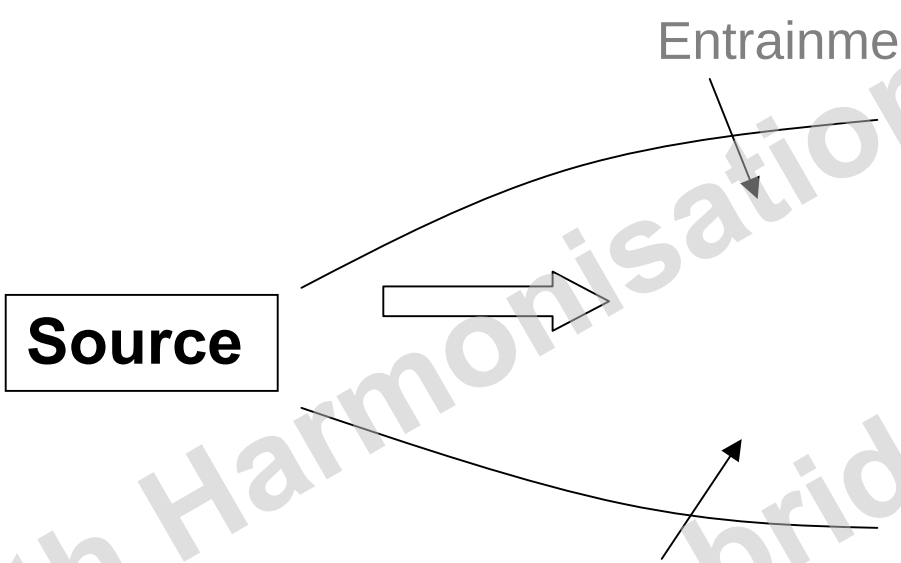
Features of ADMS-Airport

- 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
- Other airport features
  - Hour by hour time varying data

Features: MODELLING EXHAUSTS AS MOVING JETS & THE IMPACT OF WAKE VORTICES

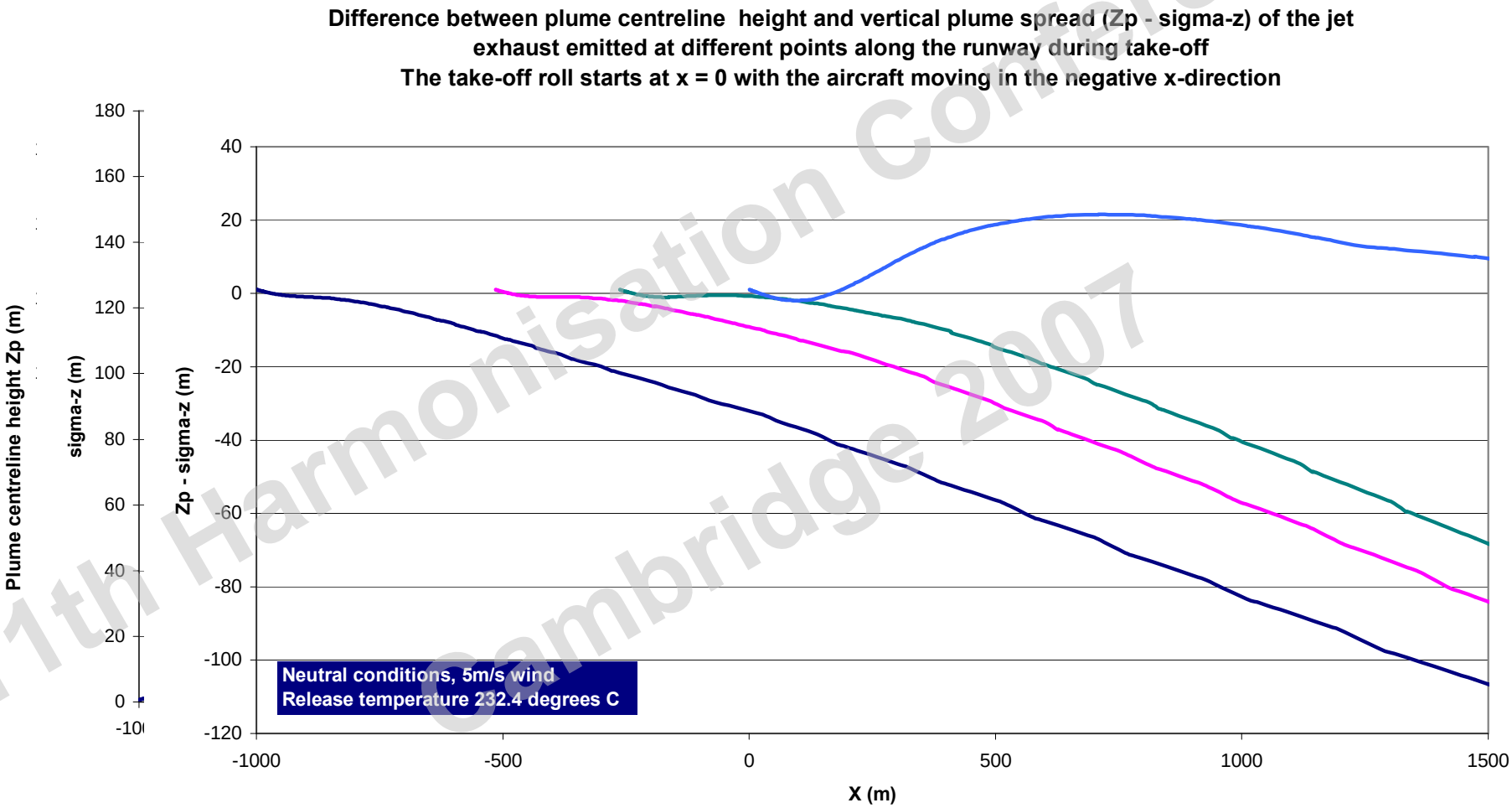
- Models engine exhausts as moving jet sources
- As the aircraft accelerates
  - buoyancy and emissions increasingly spread along the runway
  - the exhaust jet sees a faster ambient wind speed, this affects the plume rise
- The plume from the faster aircraft rises less than that from a slower aircraft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

Features: MODELLING EXHAUSTS AS MOVING JETS



- **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

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



CERC

Features: IMPACT OF WAKE VORTICES

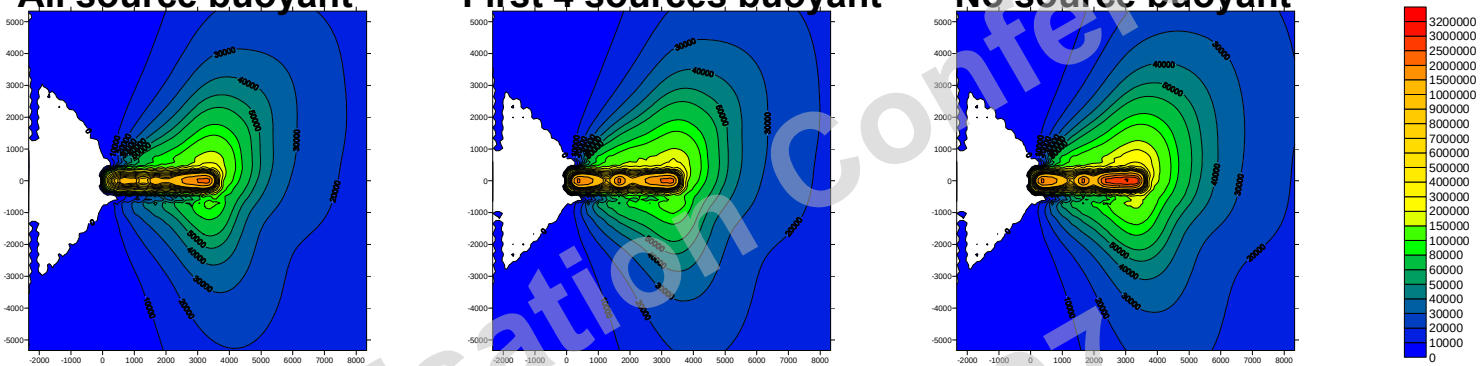
Impacts of reduced buoyancy to simulate possible effect of wake vortices

B747 long term concentration contour and difference plots

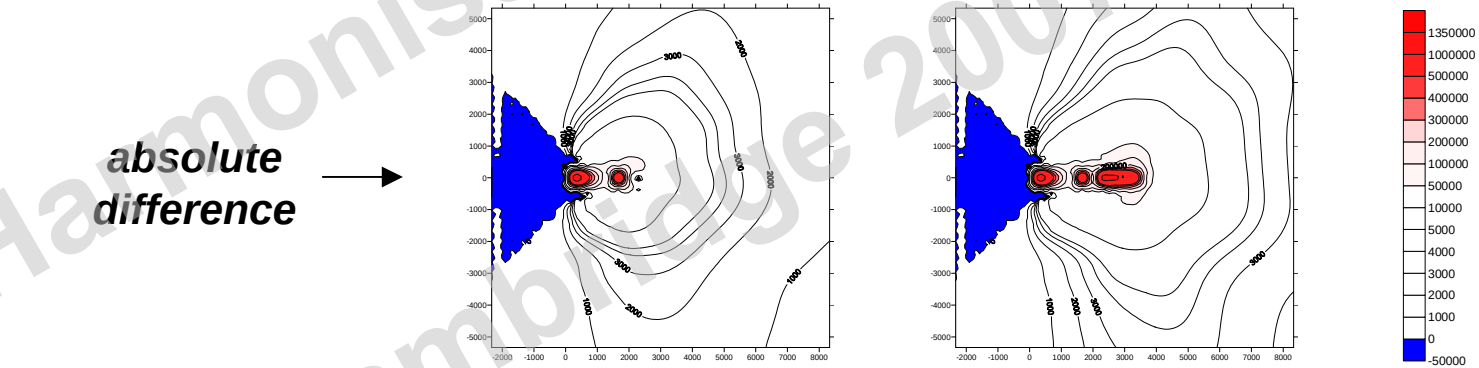
All source buoyant

First 4 sources buoyant

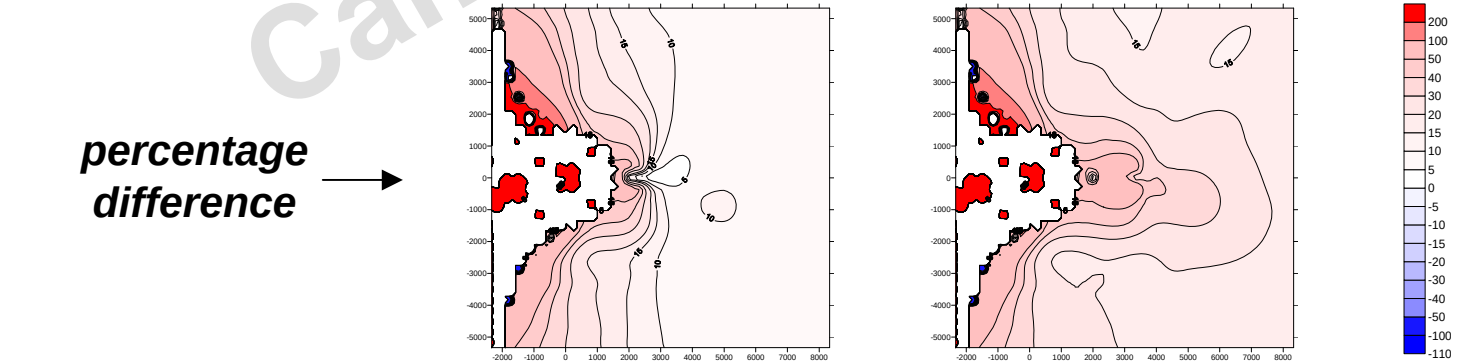
No source buoyant



absolute difference →

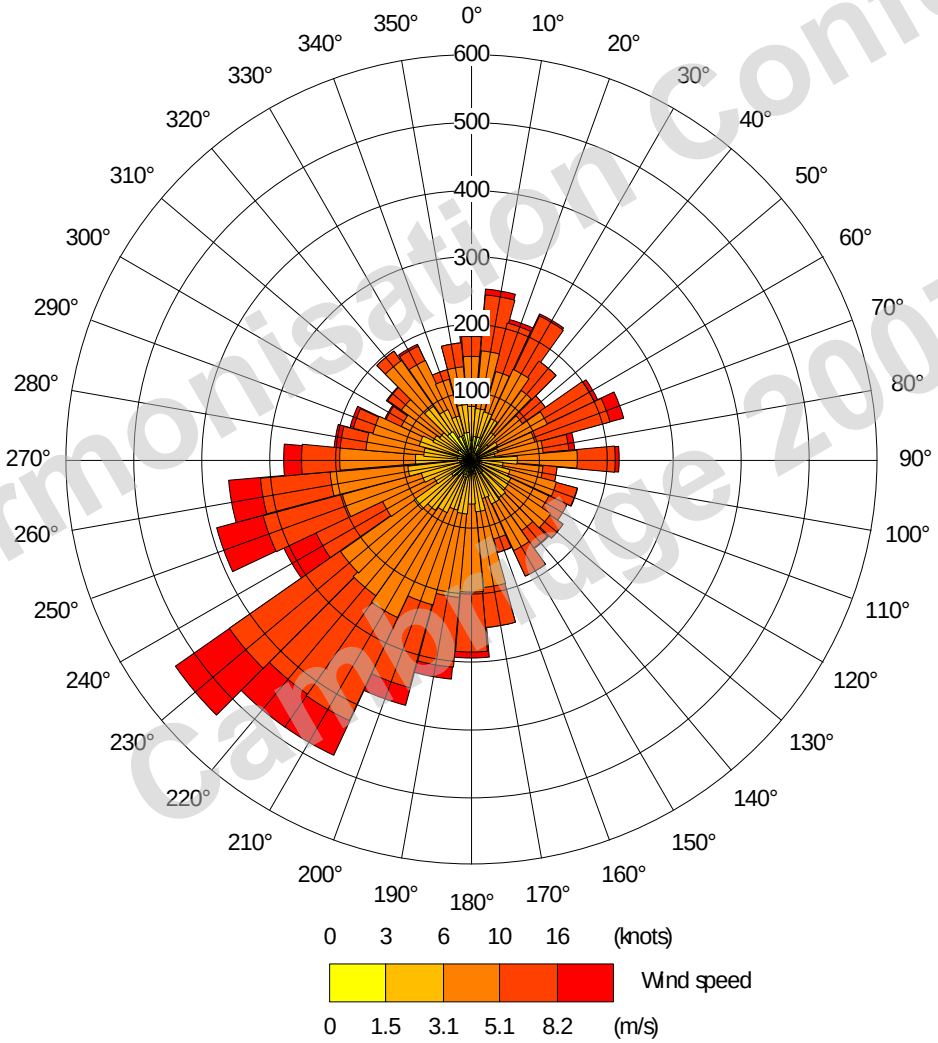


percentage difference →



3) Model performance and sensitivities: MODEL SET UP

Heathrow: METEOROLOGICAL DATA

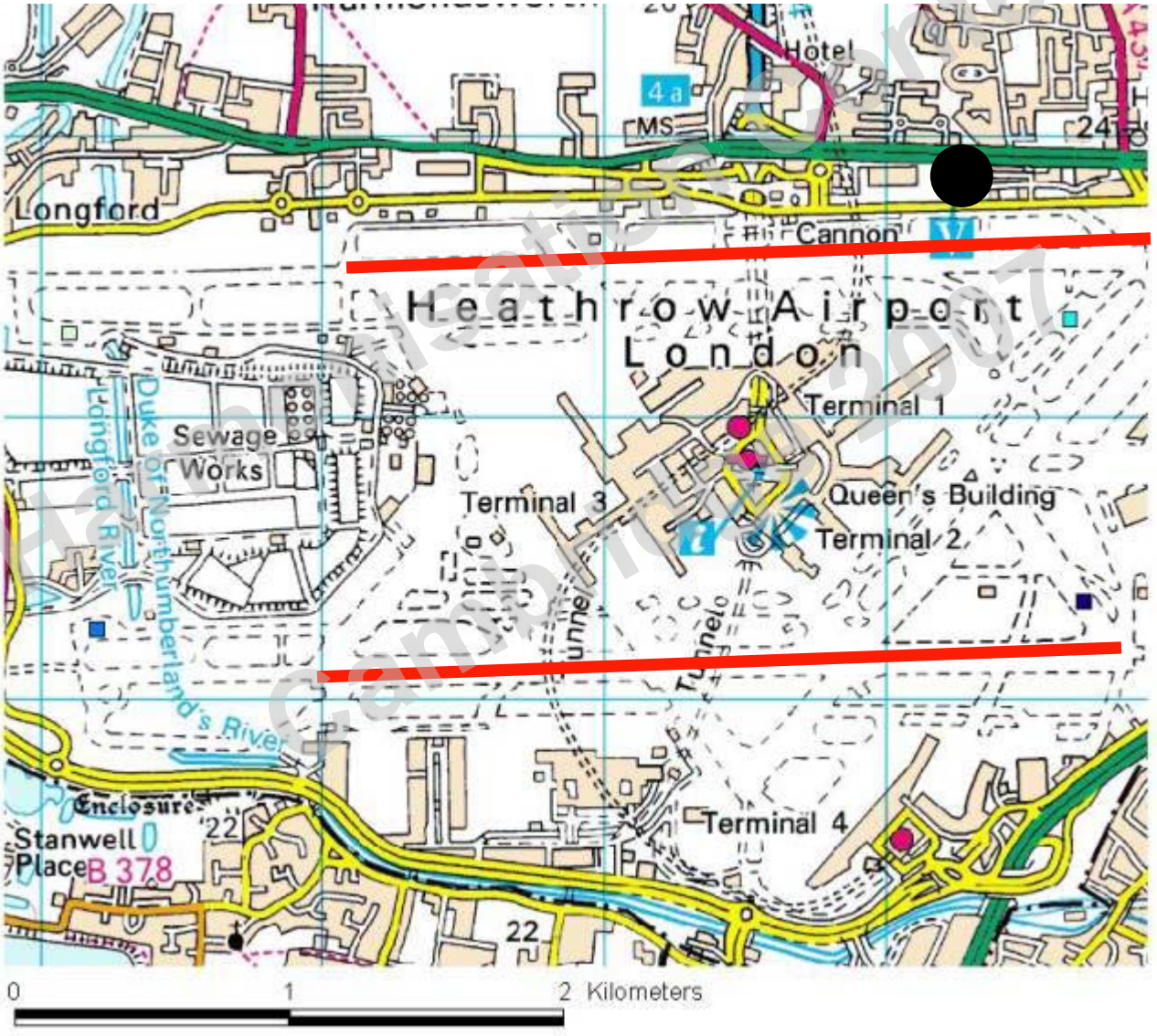


CERC

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 modelled as area or volume sources

Heathrow: MONITORING DATA



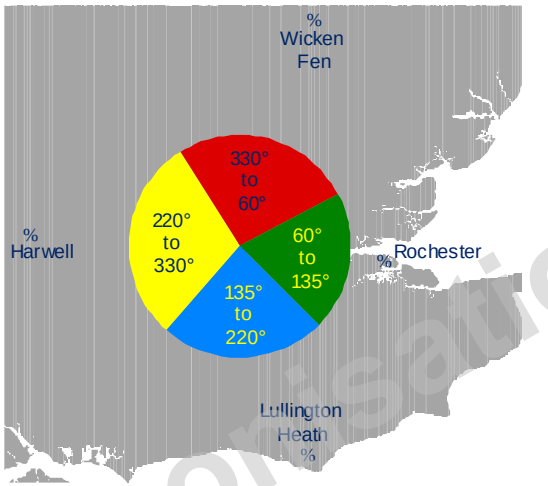
LHR2

CERC

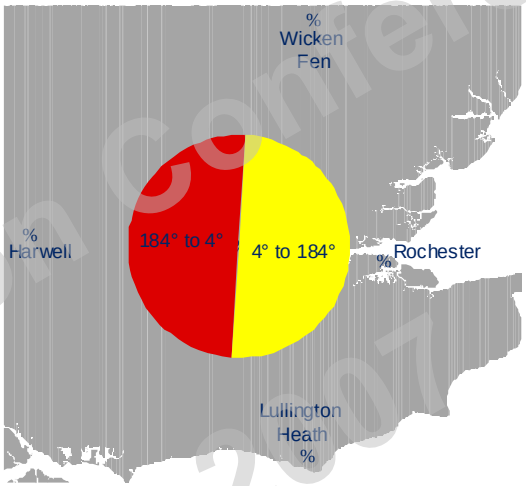
Heathrow : BACKGROUND CONCENTRATIONS

NO_x
NO_2
O_3

(a) NOx, NO2 and Ozone



(b) PM10

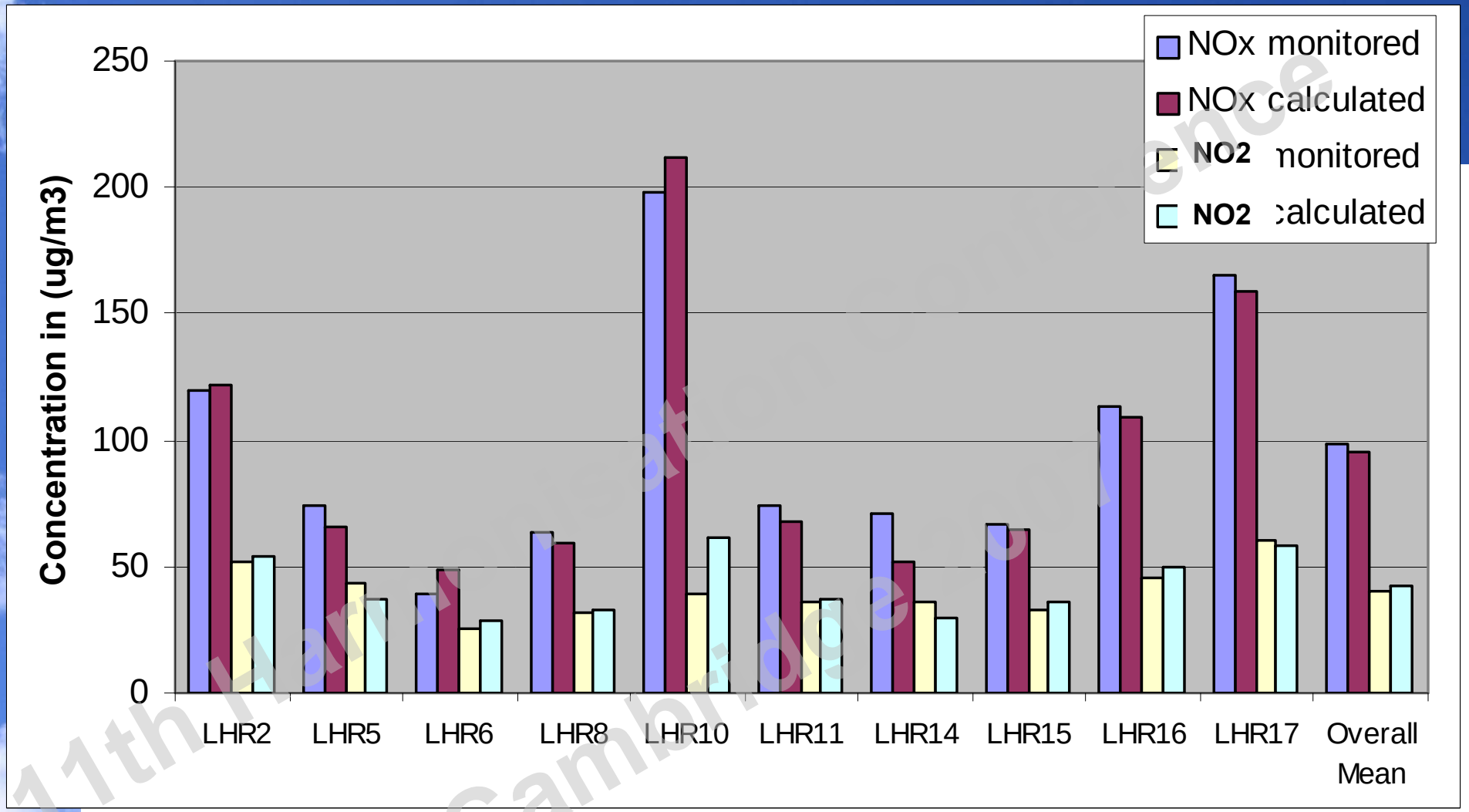


PM_{10}

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

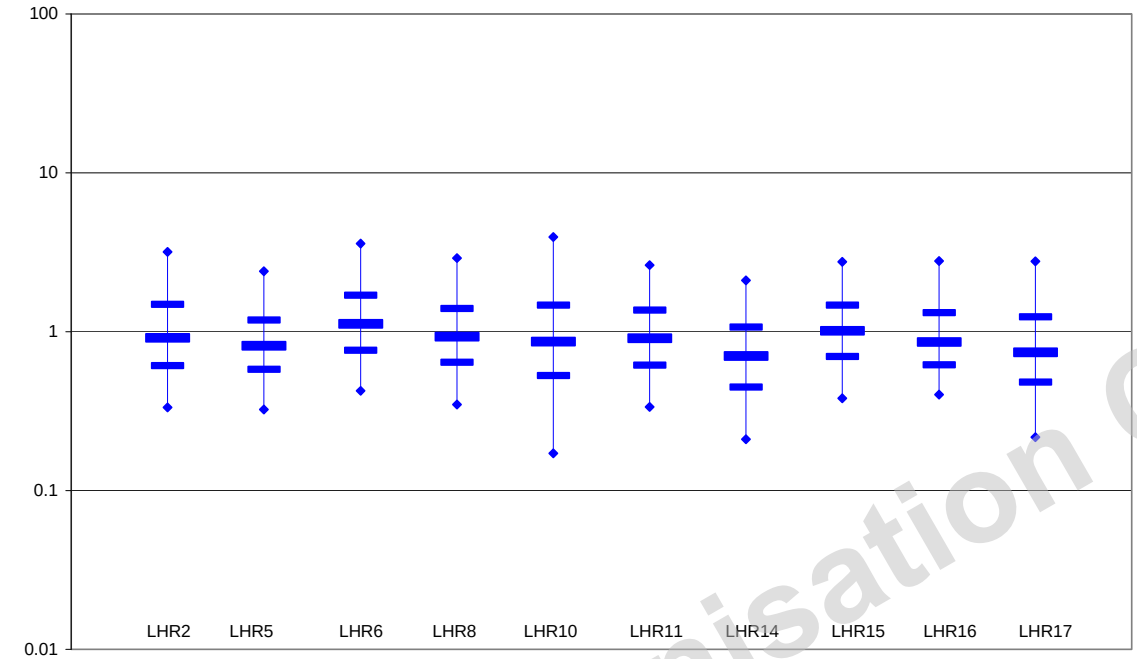
CERC

3) Model performance and sensitivities: ANALYSIS OF RESULTS



NO_X (dark blue and red) and NO_2 (yellow and light blue) monitored and calculated annual mean concentrations at the automatic monitoring sites

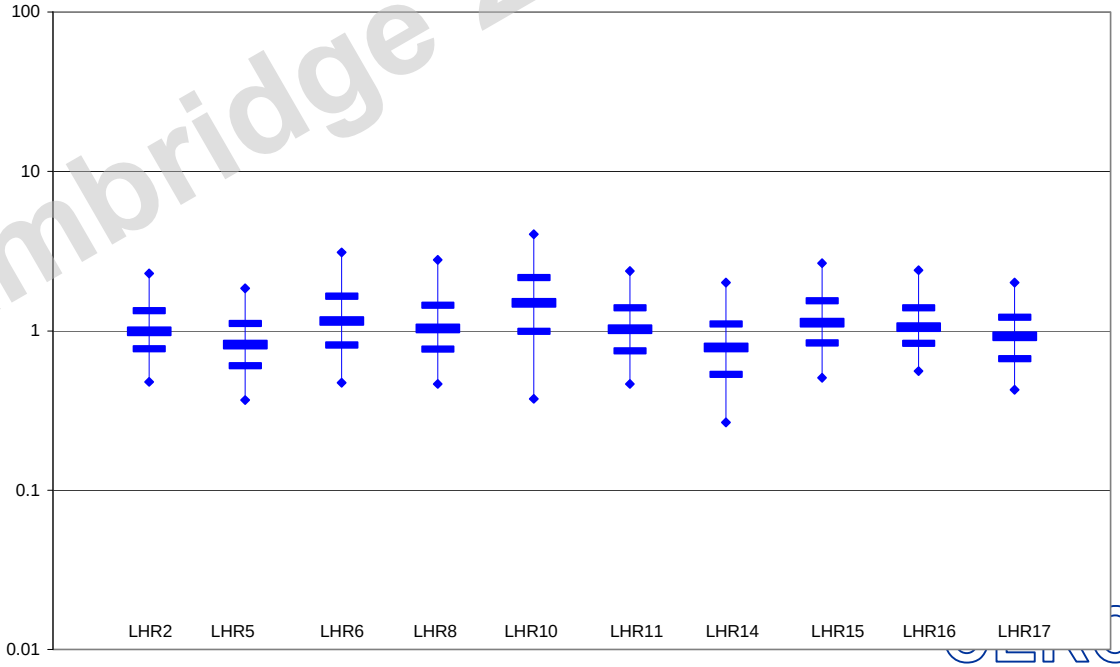
CERC

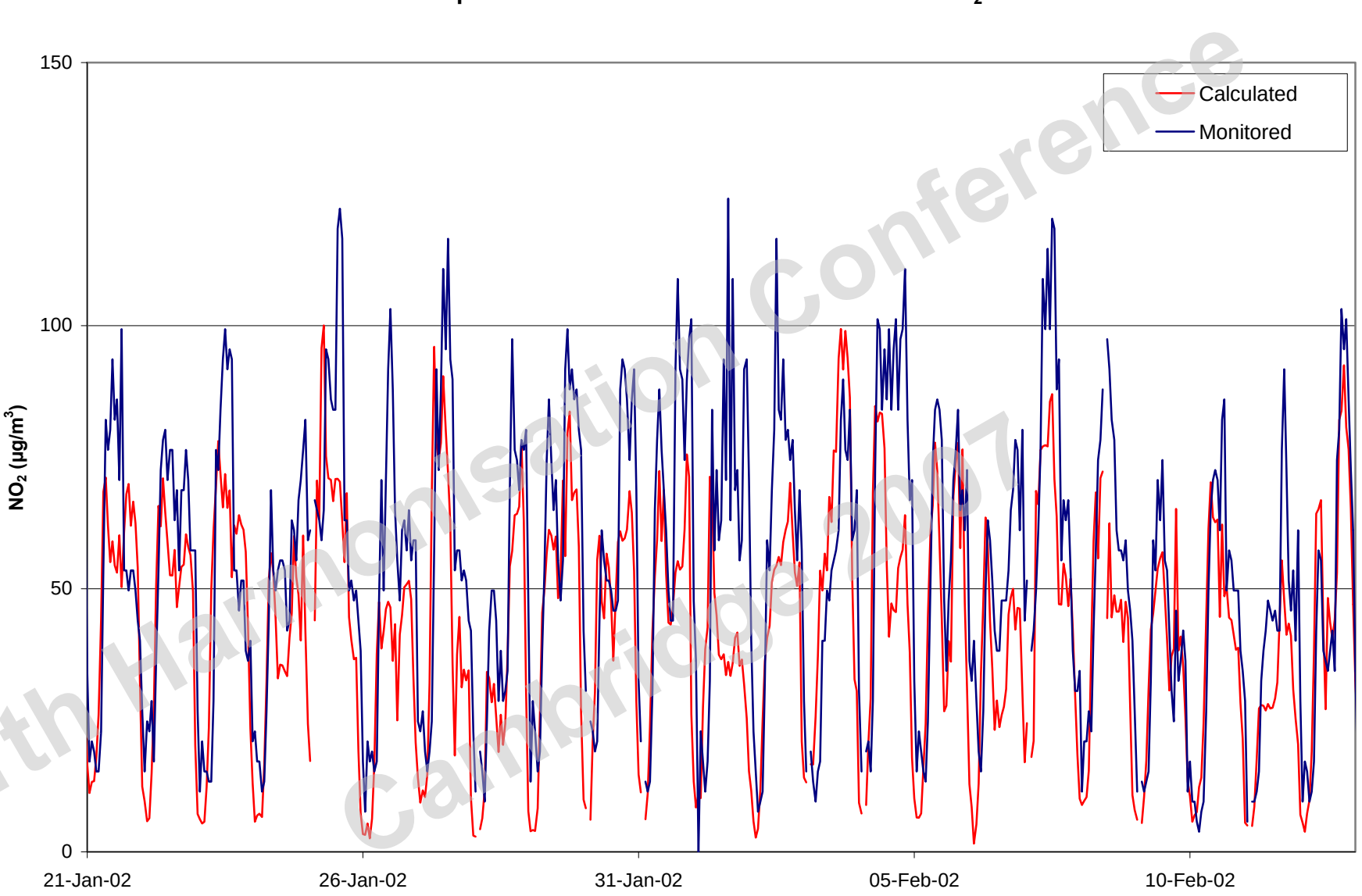


LHR2 "Box and whisker" plots for the ratio of (calculated/monitored) concentrations, NO_x (top) and NO_2 (bottom).

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

2002 NO_2 box and whisker plot



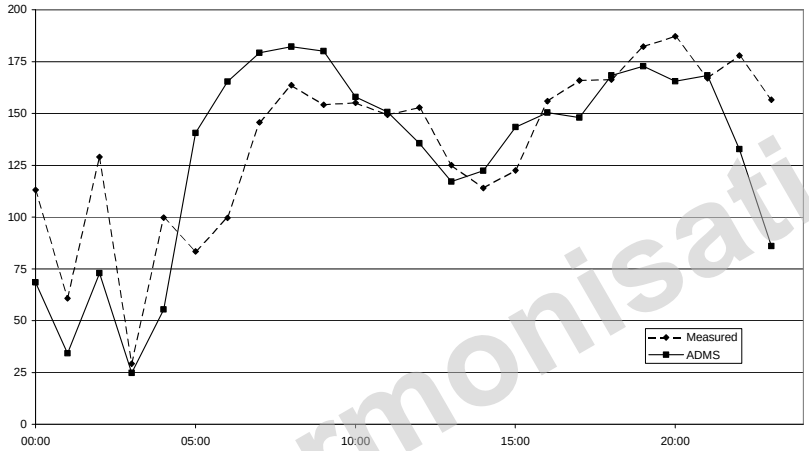


Detailed <u>time series comparison</u> of monitored (blue) and calculated (red) hourly concentrations at receptor LHR2. 2l Jan 2002 – mid February 2002

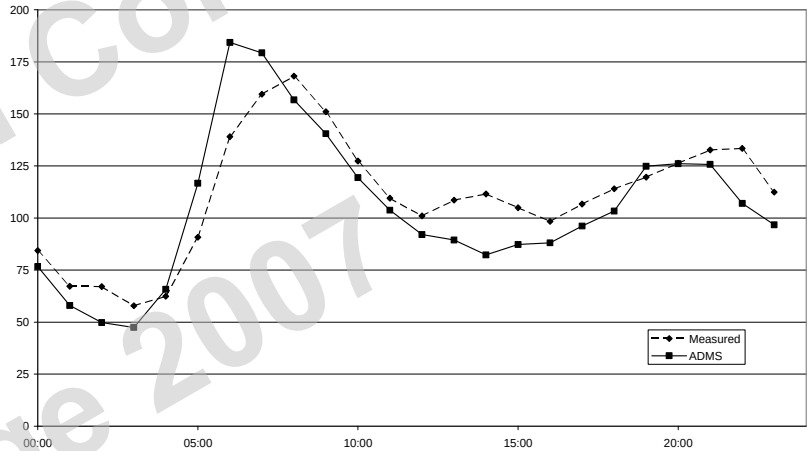
CERC

LHR2 diurnal variation ADMS-Airport (solid line) compared with measured data (dotted line), different runway use

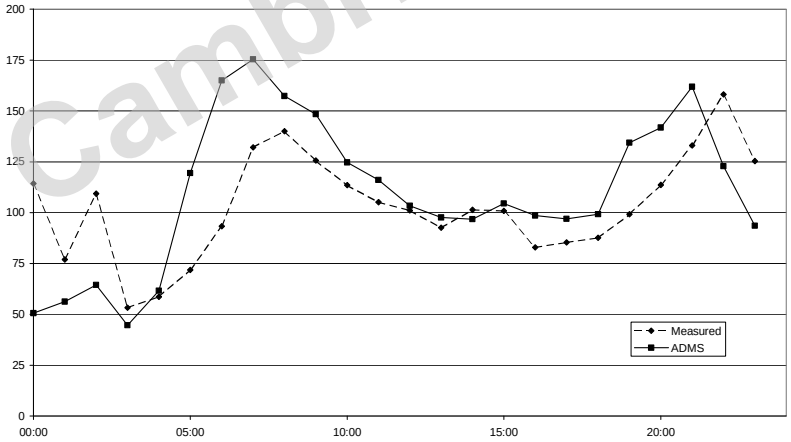
Departure on 27 R



No departure on 27 R

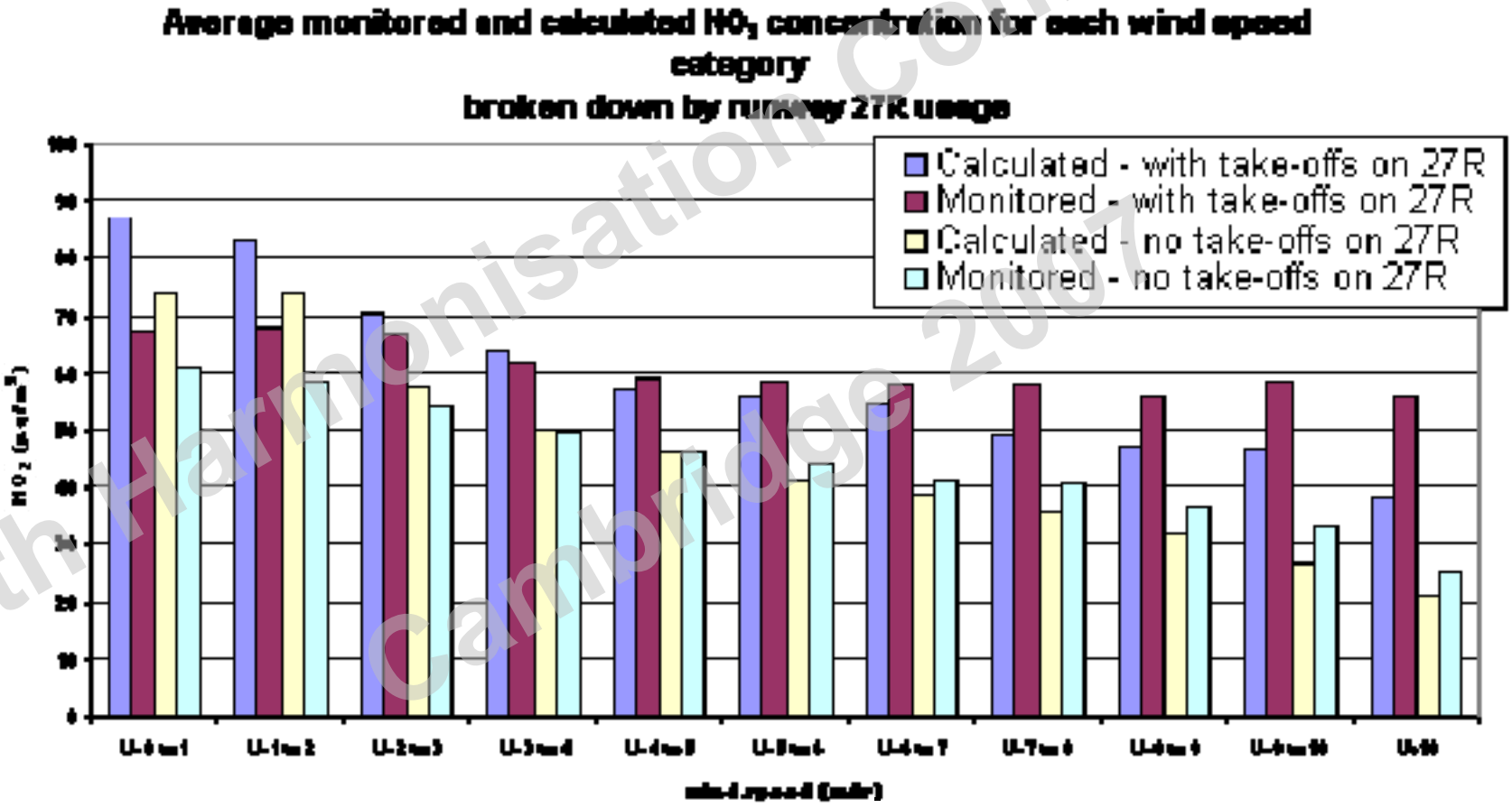


Arrival on 27R



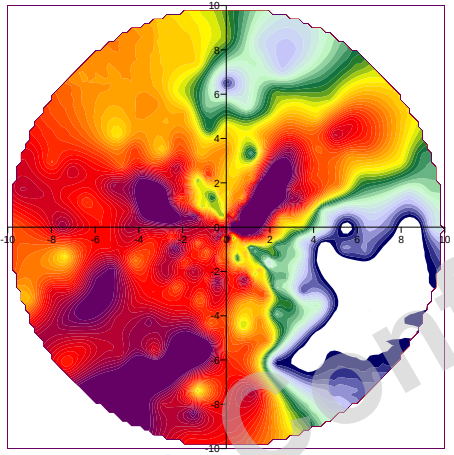
CERC

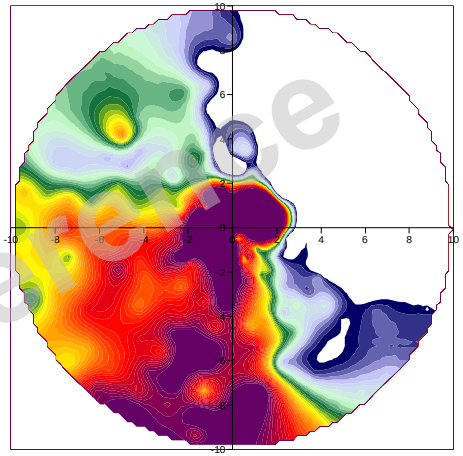
Comparison of monitored and calculated NO_2 in $\mu g/m^3$ at LHR2 as a function of wind speed for the hours when 27R is operational (blue an red) and the hours when it is not operational (cream and pale blue) separately.



CERC

Measured v ADMS modelled

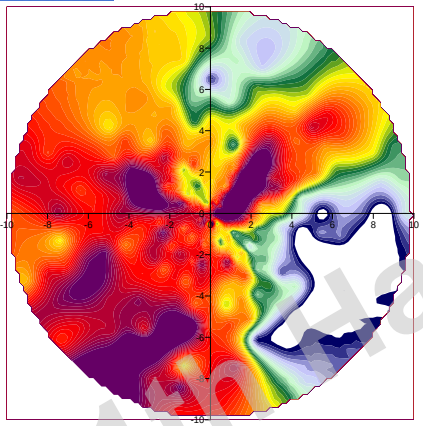


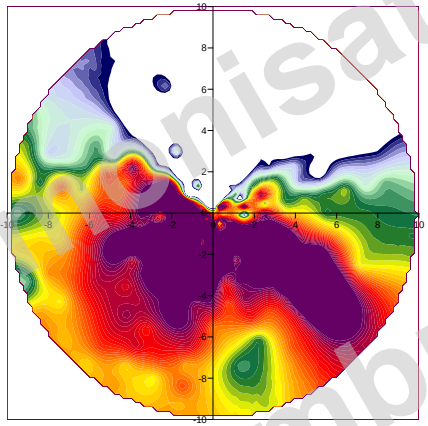


Measured LHR2

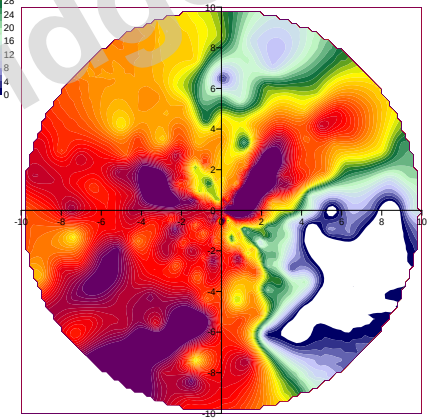
CERC predicted

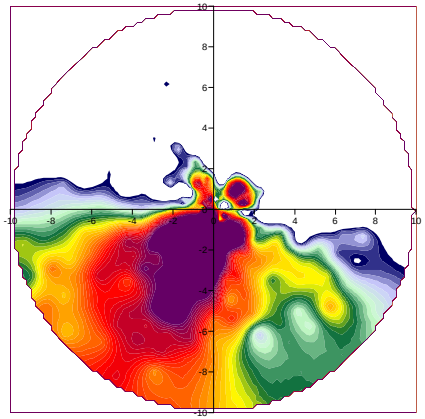
Measured v Model 2





Measured v Model 3



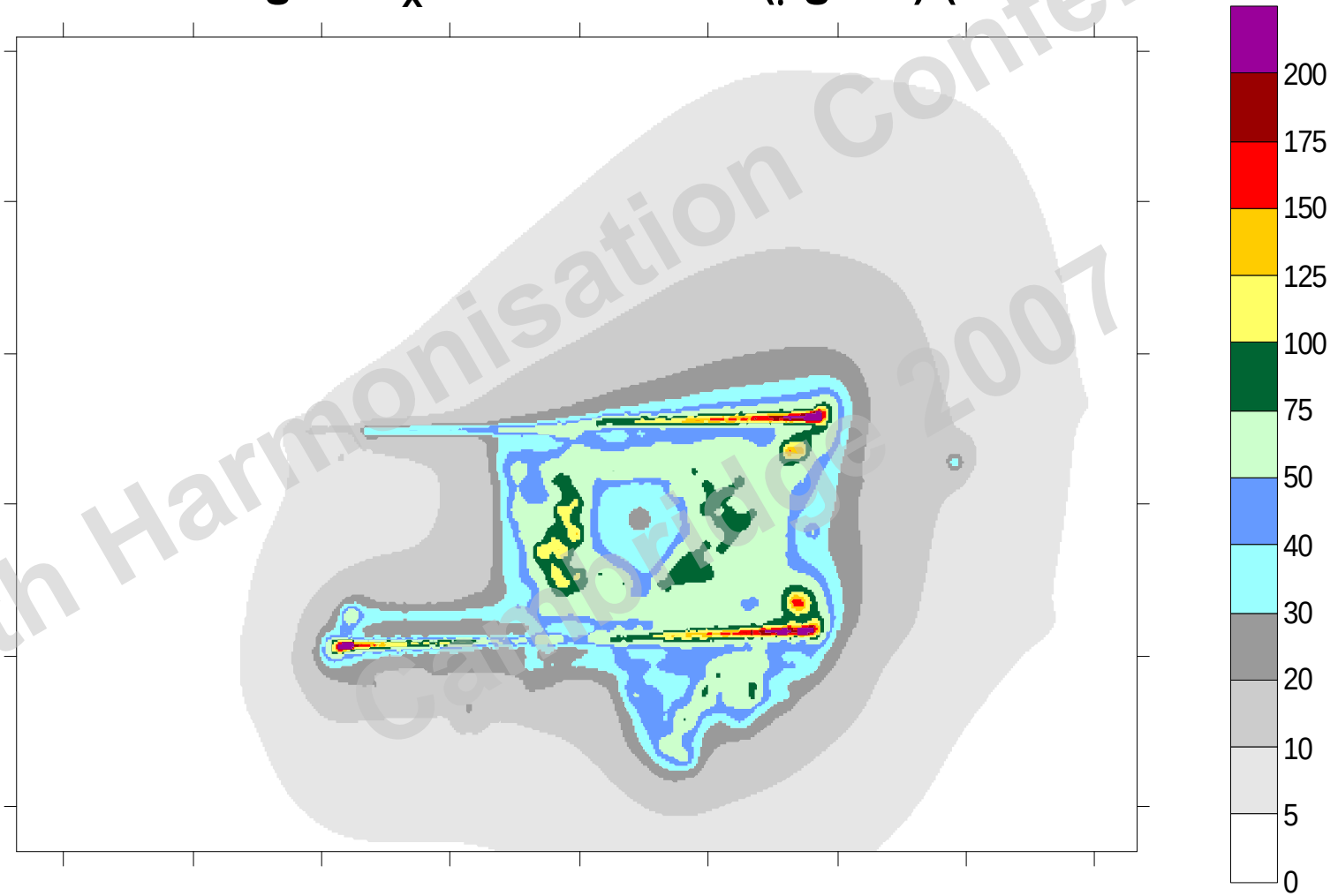


<u>Polar plots</u> of NO_x at LHR2 with background concentrations subtracted. Radius: <u>wind speed</u> in m/s.

CERC

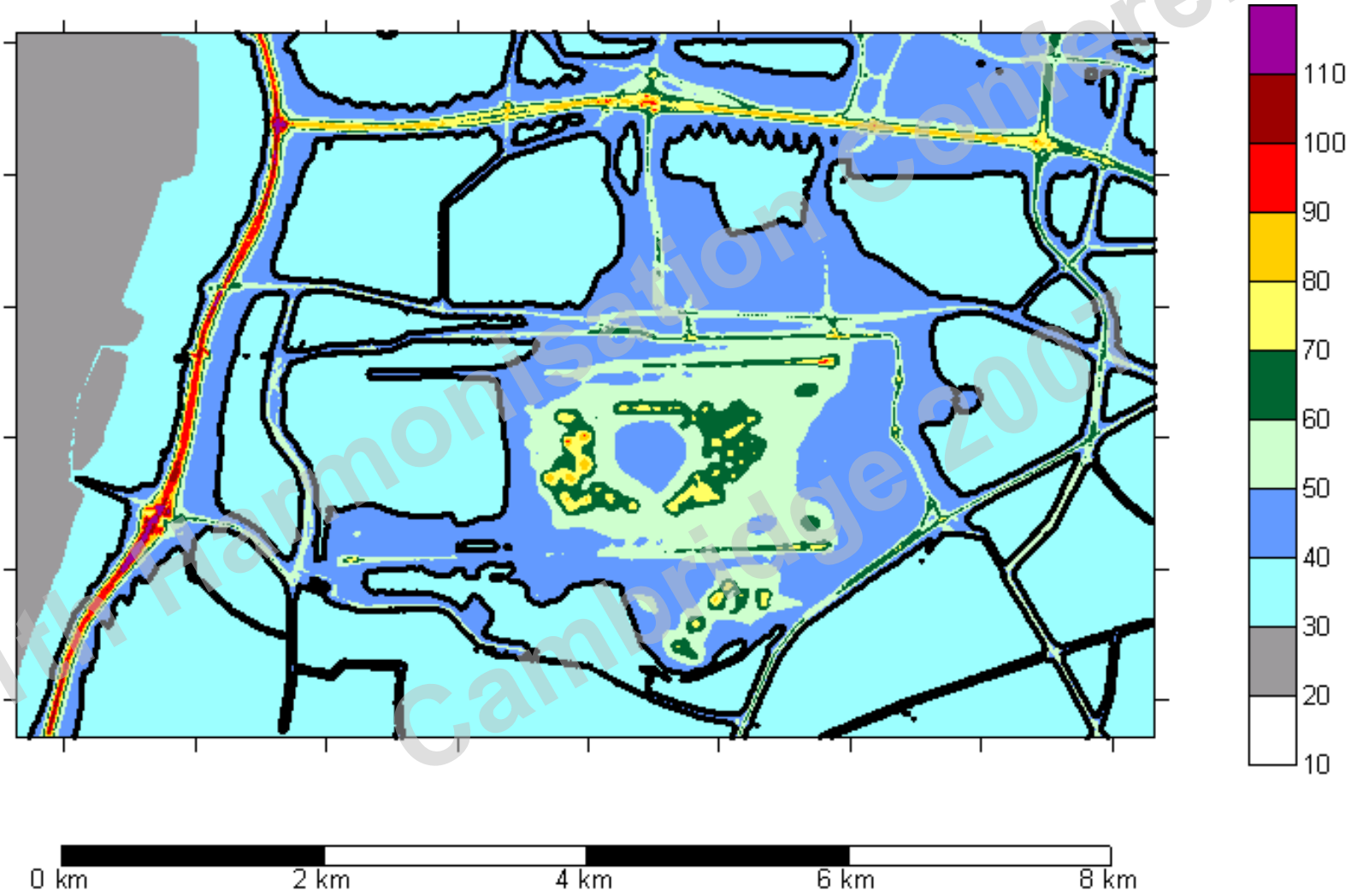
Source apportionment: AIRCRAFT SOURCES

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



CERC

Contours: ANNUAL AVERAGE NO_2

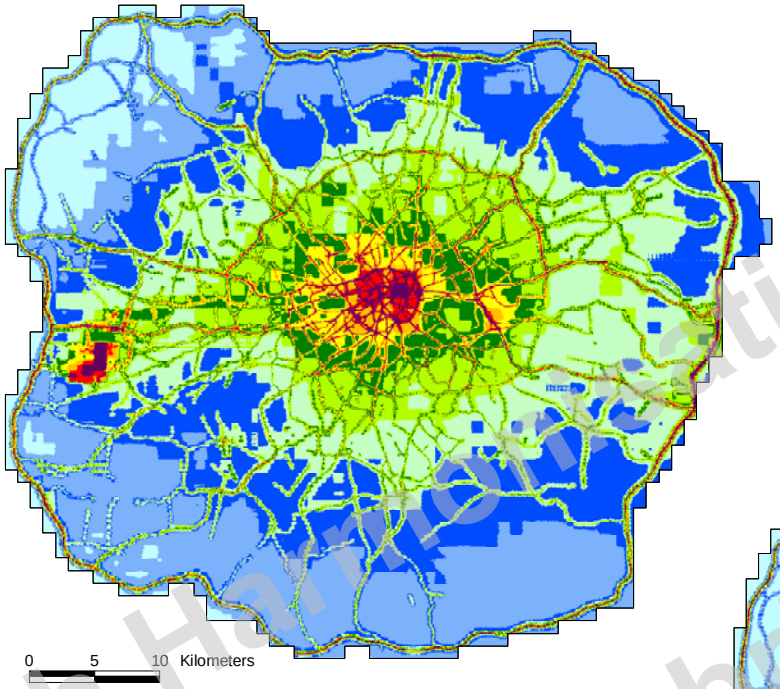


40 μg/m³ limit shown in bold

CERC

Emissions: SENSITIVITY TO PRIMARY NO_2

- Annual average NO_2 2010
- Primary NO_2, 10% (top) and 20% (bottom)



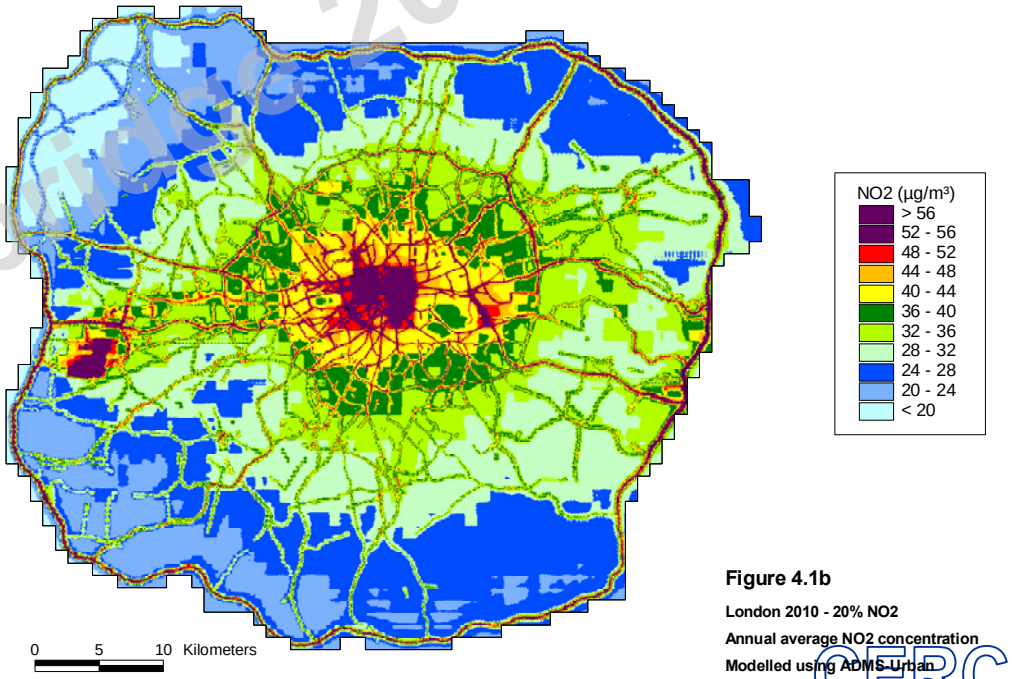


Figure 4.1b

London 2010 - 20% NO2

Annual average NO2 concentration

Modelled using ADMS-Urban

CERC

Conclusions

Key factors affecting pollutant concentrations in the neighbourhood of airports that should be modelled include the following:

- Emissions including primary NO_2
- Background concentrations e.g. O_3
- Meteorology
- Near field dispersion processes, buoyancy of the aircraft exhausts
- Chemical reactions