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THE SUSTAINABLE DEVELOPMENT OF HEATHROW AIRPORT: MODEL INTERCOMPARISON STUDY

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ABSTRACT

The modelling of air quality near airports has received much attention recently due to the growing concern about the impact of emissions from aircrafts at and near ground level. The work presented here is part of the model inter-comparison (MIC) study undertaken for the Department of Transport in connection with air quality near Heathrow Airport. The results formed part of a submission to the government in July 2006. This study used the Emissions and Dispersion Modelling System (EDMS) (*FAA*, 2007) available from the US Federal Aviation Administration (FAA). Our contribution required the setting up and running of the model EDMS for Heathrow Airport and its surroundings. The model was used to simulate the year 2002 for which meteorology, emissions data and pollutant concentrations from several monitoring stations were available. The pollutants NO_X, NO_2 and PM_{10} were chosen for the study; these being of particular concern.

INTRODUCTION

The large growth of air traffic in Europe and worldwide in recent years has posed new questions about the effect of such an increase on local air quality. Most airports are placed in the vicinity of large highly populated urban centres, which may be affected by emissions from aircraft. This type of study is novel and may require large resources. To quantify the aircraft contribution it is necessary to determine the contribution from all pollutant sources by combining measured data (meteorology, pollutant concentrations), emission estimates from all contributing sources and finally dispersion modelling. In this study, that formed part of a model inter-comparison study, we used the EDMS model. EDMS has been developed in a US context and thus reflects US operations, regulatory status, data formatting and other US standards. The modelling approach adopted was to model the airport itself and a reduced network of roads in the vicinity of the airport. This approach requires the further specification of background concentrations of the airflow entering the modelled region. Meteorological data was obtained from the meteorological station on-site. We initially estimated emissions from aircraft and aircraft operations using the EDMS internal database. This approach was adopted because EDMS would automatically generate all aircraft source types suitable for the dispersion calculation. In addition some emissions were adjusted to reflect a separately estimated emissions inventory for Heathrow in 2002.

DATA INPUT PREPARATION

A preliminary but fundamental aspect of the modelling was the preparation of the geometrical input data. Many assumptions and simplifications were adopted during various phases that need to be taken into account when interpreting the final results. The geometry of the airport consists of runways, queuing areas, ground support equipment (GSE) and auxiliary power units (APUs) locations, gates, taxiways, buildings, car parks and other miscellaneous items. The location and geometric dimensions are derived from the HEI (2004) produced by NETCEN for the year 2002 together with the London Atmospheric Emissions Inventory (LAEI) for the year 2002. Within EDMS the layout of runways and taxiways was used to locate emissions from aircraft landing and take-off (LTO) cycles. The layout of the gates was used to locate emissions from APUs and GSE (Fig. 1).

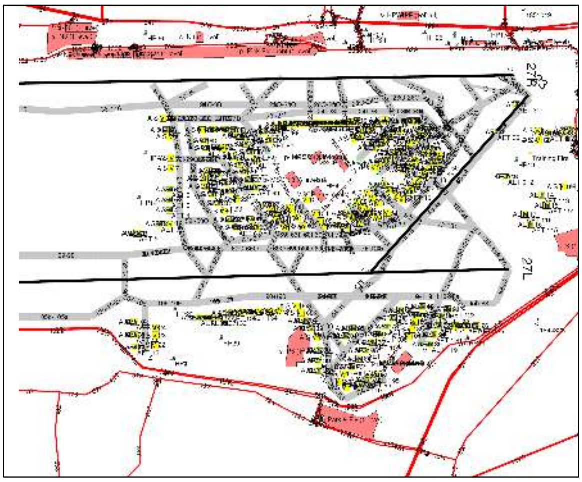

Fig. 1; Airport layout showing the position of the runways, taxiways, location of the car park and airside vehicles.

Road Network

We incorporated a road system close to Heathrow together with background concentrations to treat the more extensive road network and other sources. Outside, but near to the airport we used a near-airport portion of a simplified London road network taken from the London Area Emissions Inventory (LAEI) and made available by CERC to the study participants. This consists of 1342 links to form some 350 roads. The above-simplified network contains the near-perimeter roads that were agreed by the participants to be important for this study. EDMS, was developed primarily for airport studies. It assumes that all roadways have two-way traffic and that all vehicles traverse the length of the roadway twice (once on the way to the terminal building and one on the way out). This is referred to as a one-way vehicle count (even if it is on a two-way roadway). For one-way roadways, this is the same as the total number of vehicles. EDMS allows the inputting of an unlimited number of roads or roads links. This is facilitated by the use of suitable input files. These can be imported directly into the system provided that two pair of coordinates at the start and the end point of each link is specified. The user has also the option of importing the road coordinates only and specifying the emission through the interface. Fig. 1 shows details of all sources used within EDMS.

Meteorological Data

Meteorological data was obtained as hourly sequential data from the Meteorological Office Heathrow Airport station for 2002. The wind rose for Heathrow is shown in Fig. 2 while EDMS uses AERMOD as its dispersion model. AERMOD requires information at upper levels in the atmosphere and these are not normally available in the UK. The EDMS users guide provides advice on this and refers to software available from Westlakes that will overcome this problem. However we used the ADMS meteorological pre-processor as an alternative in order to obtain the meteorological data actually used by AERMOD.

Two surface roughness lengths were used in the modelling. Initially a z_0 of 0.5 m. was used. This value was chosen to mitigate the effect of our not modelling the buildings at Heathrow. A sensitivity study was undertaken using a smaller z_0 of 0.2 m. Buildings were not explicitly modelled as previous experience with AERMOD indicated that inclusion of buildings might produce long run times. Data presented is that for a z_0 of 0.2 m. A minimum value of the Monin-Obukhov length of 30 m was used throughout.

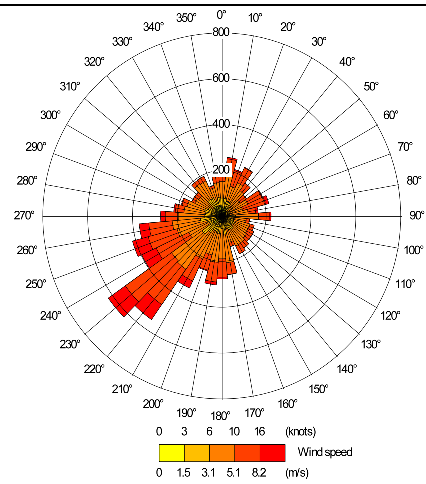

Fig. 2; Wind rose for Heathrow Airport used in the study.

Emissions

According *HEI* (2004), emissions are specified for the following types of sources: aircraft and aircraft related sources, car rentals (4 car park sources), fire training ground (a single source), heating plants (39 point sources), public and staff car parks (24 car parks), taxis (one car park and 4 taxi ranks). The inventory also includes some traffic emissions from roads in the region surrounding the airport. These traffic emissions were not included in the modelling, as more detailed road traffic data exist in the LAEI.

Aircraft and Aircraft Related Sources

Emissions from aircrafts are estimated by analysing each phase of aircraft movements and operation within the airport. This included the estimation of LTO cycles as split into 12 groups following the DORA categorisation. This is derived from the total number of movements during 2002. There were available for each of the groups the operational profiles (hourly, daily and monthly with the hour/day/month factor being expressed as a ratio between 0 and 1.0). EDMS recognizes four aircraft modes that constitute a complete landing and takeoff (LTO) cycle: takeoff, climb out, approach, and taxi/idle. A time in mode is the time, in minutes, which a specific aircraft spends in any one of these modes during an LTO cycle.

Background Concentrations

In order to take into account sources, not explicitly modelled, around London Heathrow airport we added background concentration. In the case of NO_X and NO_2 monitored concentrations from 2002 from West London (urban), Harwell (rural), Lullington Heath (rural) and Wicken Fen (rural) were used. Each hourly concentration datum was added to the calculated NO_X according to the wind direction for that hour. As an alternative approach the monitoring station at Teddington might be an used as a data source for the background concentration for the Heathrow Airport study. For the year 2002 the annual average concentrations were 38.6 for NOX and 25.3 for NO2.

RECEPTOR POSITIONS

For this inter-comparison study 91 receptor positions were chosen. All participants were requested to include those receptors in their modelling. Monitoring data were available for eleven receptors close to Heathrow airport.

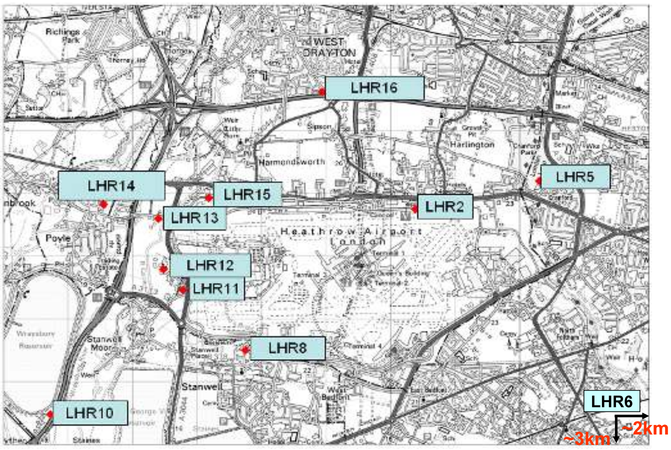

Fig. 3; Receptor positions for which measurements were available. Receptor LHR6 is outside the map as indicated.

An overall overview of the position of receptors used in the study is shown in Fig. 3. Note that this includes a substantial transect running North from the airport

MODEL OUTPUT

Annual average concentration at monitoring stations

Table 1 shows a comparison between the monitored NO_X annual average concentrations and those predicted by EDMS at the monitoring stations for which data were available. A similar comparison is also shown for NO_2. In the latter comparison it should be recalled that EDMS does not predict NO_2 concentrations so this comparison may be mainly reflecting the NO_X-NO_2 correlation that has been used rather than the EDMS model. The agreement between modelled and monitored annual average concentrations is satisfactory for both NO_X and NO_2 . The discrepancy between NO_X model predictions and monitored concentrations is within 5% and 12% at all receptor positions except for the receptor LHR5. At this site the model underestimates by about 16%.

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

Table 1. Comparison of monitored and modelled NO_X and NO_2 at the automatic monitoring sites.

These results are still satisfactory and well within the uncertainty introduced at the various stages of the modelling study. The discrepancy between NO_2 estimations and monitored concentrations is less than 20% at all receptor positions except for LHR5 where the discrepancy is 24%. This slightly higher discrepancy is the consequence of the NO_X model underestimation. Fig. 4 shows a bar chart with the comparison between monitored and modelled annual average NO_X and NO_2 concentrations. It is important to note that these monitoring stations are at specific co-ordinates and EDMS is calculating the concentrations at these specific and precise co-ordinate positions. This is quite different to calculations performed later to determine concentration contours by interpolation from a finite (small) number of receptor positions.

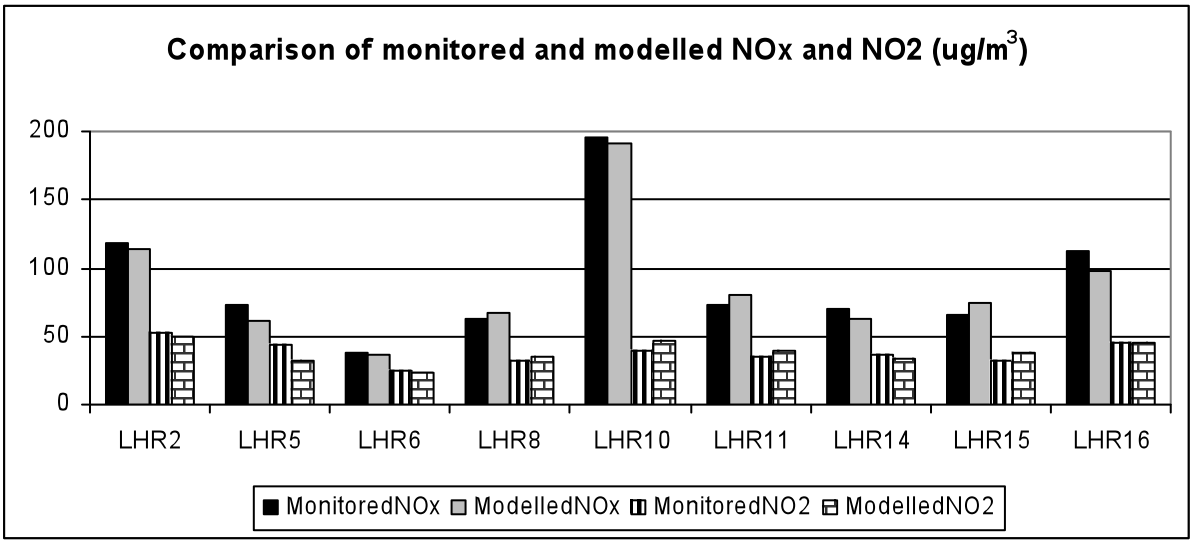

Fig. 4; Bar chart showing the comparison between monitored (on the left) and modelled (on the right) NO_X and NO_2 concentrations at the automatic monitoring sites.

CONCLUSIONS

Comparison of the annual average model outputs from EDMS with data from 10 monitoring stations within and near Heathrow was generally within 20% for NO_X and NO_2. More detailed analysis over a 2.5 km transect running North of the airport revealed some significant differences among the models however. The total NO_X predictions were quite similar for all the models though EDMS did produce low concentrations in the immediate vicinity of major roads. EDMS also tended to predict airport related concentrations that were at the higher end of the predicted range.

REFERENCES

Heathrow Emission Inventory, 2002: Part 1 (2004), Underwood B.Y., Walker C.T., Peirce M.J. produced by netcen for BAA Heathrow. Reference number netcen/ AEAT/ ENV/R/1657/Issue 1.

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