NUMERICAL WEATHER PREDICTION – AN ALTERNATIVE TO METEOROLOCIAL OBSERVATIONS FOR DISPERSION MODELLING

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1. ABSTRACT

Short range atmospheric dispersion modelling is a key tool for the assessment of local environmental impacts. Dispersion models typically use hourly meteorological observations from quality-controlled sites. However, it is often difficult to find an observation site near enough to be representative of the site under investigation. Numerical Weather Prediction (NWP) modelling, used to produce weather forecasts, could provide an alternative source of input data.

To assess the applicability of NWP data, studies were undertaken to predict, using the atmospheric dispersion model ADMS 3.1 [1], ground level concentrations from typical power station emissions. The model was driven by observed meteorological data and by NWP supplied by the Met Office in the UK. Two resolutions of NWP were investigated.

The basic input meteorological parameters were compared, together with predicted ground-level concentrations. The modelled concentrations for several power stations were also compared with local monitoring data.

NWP resolution was found to have little effect on predicted concentrations.

Predicted concentrations using NWP input were generally close (±10%) to those based on observed meteorology, although occasionally there were differences of a factor of 2.

The results show that the use of NWP output for short and long term dispersion modelling produces no significant changes on the accuracy of predictions compared with the use of observed weather data. Therefore NWP is a viable alternative to observed weather data, especially if it is not possible to obtain representative weather data.

2. INTRODUCTION

Dispersion models are used to assess the impact of power stations on local air quality. The environmental regulators and industry use modelling to estimate these impacts and thus modelling is an important tool for planning and compliance checking.

To carry out dispersion calculations, the models require an input of meteorological data such as wind speed, wind direction and cloud cover. Dispersion models use the base meteorological data to estimate boundary layer depth and stability necessary for the dispersion calculations. Typically, for local air quality modelling around power stations, hourly meteorological data are taken from a single observational site run by the national weather service. It is important that the meteorological data recorded at the observing site is appropriate for the source being modelled. Obtaining representative observed meteorological data can be problematic; ‘representative’ implies that the site has similar frequency distributions of the key meteorology. For a weather recording site to be ‘representative’ of a remote site requires they are relatively close together (e.g. within 50 km), but also that neither (or both) have similar orography and vicinity to water sources such as rivers or lakes.

2.1 ADMS VERSION 3.1

ADMS (Atmospheric Dispersion Modelling System) is a ‘new generation’ dispersion model [1] that defines the boundary layer by height and Monin-Obukhov length, rather than using the Pasquill Classes employed in models during the 1980s and early 1990s. Under convective conditions ADMS also uses a skewed Gaussian concentration distribution. It solves the conservation equations to model plume rise rather than using empirical relations. ADMS requires details of the pollutant emission and the meteorological conditions to determine dispersion calculations and to predict concentrations remote from the source (usually within a 20-30 km radius). The minimum meteorological data required as input are wind speed (measured at a specified height, ms^{-1}), wind direction (degrees), and day, hour and cloud cover (oktas), which can be replaced by sensible surface heat flux (Wm^{-2}). To improve accuracy of the calculations, near surface air temperature is usually provided.

For advanced users, ADMS can be provided with a range of other meteorological information which may improve the dispersion calculations, for example, boundary layer height and the above boundary layer stability. Since these are often not known, ADMS either calculates these or uses default values.

2.2 NWP DATA

An alternative solution to using observed meteorological records is to use Numerical Weather Prediction data [2, 3]. Atmospheric NWP models are used for operational weather forecasting; they contain gridded information about a variety of weather parameters, including all of those required by ADMS. To run a NWP model it requires an initial field on which to begin forecast calculations. This initial field is a blend of observed weather data and a model background field, the background field is a frame from a previous model run valid at the appropriate data time. These analysis fields are archived and used as ‘real’ meteorological data for a variety of modelling purposes; this is true for several national weather services including NCEP/NCAR in the USA and ECMWF in Europe. The UK Met Office analysis fields are available at three hourly intervals and these data are linearly interpolated to provide hourly data to ADMS. However, analysis fields are often only freely available at 6 or 12 hour intervals.

NWP consists of three-dimensional gridded information, but for ADMS only surface information is required. The UK Met Office runs NWP at two resolutions: the global model, which has a latitude-longitude grid covering the globe with a grid length of about 60 km over the UK; the mesoscale model is used to provide finer detail weather information over the UK and has a grid length of 12 km.

NWP has some advantages over observed meteorological data. NWP grid points are representative of an entire grid box and therefore provide data that are applicable to an area rather than being subject to localised effects which could introduce inaccuracies when modelling a remote site. Since NWP simulates many atmospheric processes in a spatially and temporal consistent way and they can provide a range of parameters to the dispersion model – for example, boundary layer depth derived in NWP could be provided directly for modelling rather than allowing the dispersion model to calculate this.

NWP has some disadvantages. Model improvements are implemented once or more a year, such updates are beyond the users control but could affect the dispersion calculations. The interpolation of NWP data between the time steps available and interpolation in space between grid points, in order to extract at a point tend to smooth the input data and therefore extremes may be missed compared to hourly observations.

3. MODELLING LOCAL AIR QUALITY AROUND DIDCOT POWER STATION

Whilst NWP studies have been carried out for a variety of power stations and for the global (60 km) and mesoscale (12 km) grid lengths [4, 5], the application of global model NWP at Didcot is presented in detail here. The period of study was one year beginning on 1st September 2002. This period was chosen to fit in with obtaining a whole year of NWP available after the implementation of a major model change, the 'New Dynamics' [6].

RWE npower operate Didcot A, a 2000MWe coal fired power station in Oxfordshire. The terrain around Didcot is rolling, open countryside and the power station is 2.5 km from the Thames. To provide the most accurate representation of the power station emissions the hourly varying generation pattern was used to determine the sulphur dioxide (SO_2) emissions.

The Air Quality Strategy Objective [7] for local air quality that is most onerous for coal fired plant is that the 15 minute averaged ground level concentration of SO_2 should not exceed 266 μgm^{-3} more than 35 times per year (35 exceedances of the 35,000 15 minutes in a year corresponds to the 99.9th percentile). This Standard is to be achieved by 31 December 2005.

The meteorological data used for the study were hourly observations of wind, cloud cover and air temperature, taken from RAF Brize Norton, located in similar countryside and 20 km northwest of Didcot. The NWP data were taken from the Met Office global model, from a spatial interpolation of data centred on Didcot.

4. RESULTS

The modelled values of the 99.9th percentile of 15-minute averaged SO_2 ground level concentrations were compared to the values recorded at three air quality monitoring sites around Didcot. The ADMS predicted values were generated by using the observed meteorological data from Brize Norton and the NWP data from Didcot. The basic NWP data used consists of wind speed and direction, cloud cover and air temperature. The boundary layer depth and sensible surface heat flux were also extracted from the NWP and used in a separate ADMS modelling study. The results are summarised in figure 1.

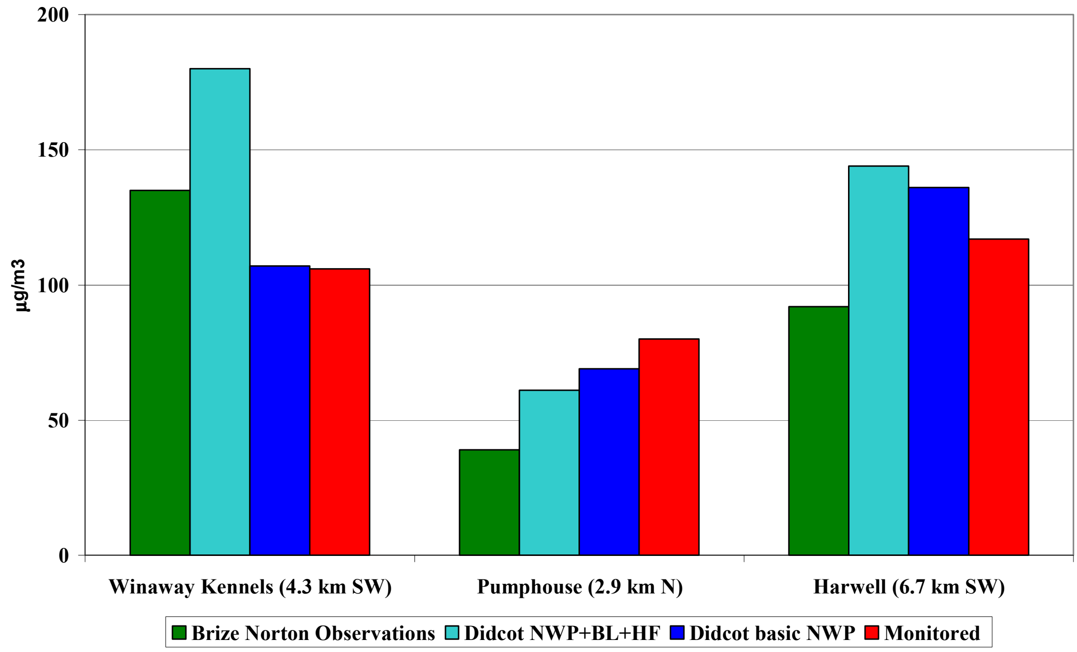

Figure 1: modelled and monitored 15 minute 99.9th percentile SO_2 concentrations in the vicinity of Didcot, one year beginning 1st September 2002.

To illustrate the spatial variation due to the use of observations and NWP, contour plots of the annual average SO_2 ground level concentration are included as figure 2. Corresponding values for the three monitoring sites are included in table 1.

ADMS meteorological input	Monitoring site (in relation to power station)		
	Winaway Kennels (4.3 km SW)	Pumphouse (2.9 km N)	Harwell (6.7 km SW)
Brize Norton observations	0.4	0.2	0.4
Didcot NWP+BL+HF	0.8	0.2	0.7
Didcot basic NWP	0.5	0.5	0.6
Monitored data	**0.5**	**0.3**	**0.8**

Table 1: modelled and monitored annual mean SO_2 concentration (μgm^{-3}) in the vicinity of Didcot for one year beginning 1st September 2002.

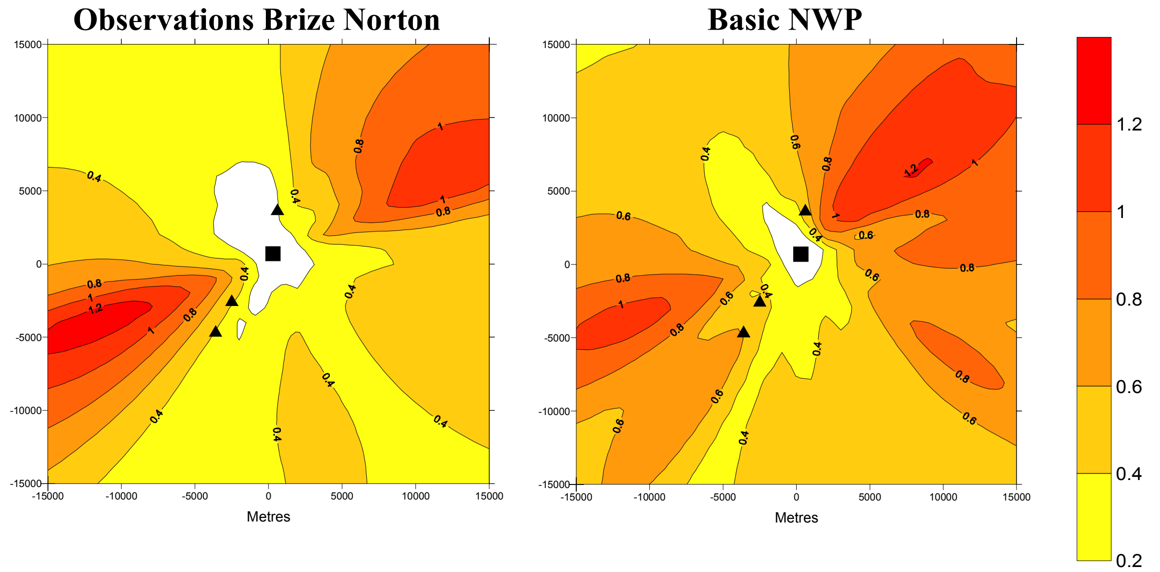

Figure 2: modelled annual hourly mean ground level SO_2 due to Didcot power station – based on different meteorological inputs, one year beginning 1st September 2002. The three SO_2 monitoring sites are marked with triangles.

5. DISCUSSION AND CONCLUSIONS

The data shown for Didcot are representative of the results of several modelling studies [4, 5]. Figure 1 and table 1 for Didcot show that data obtained by ADMS for both the 99.9th percentile and the annual mean are between 50% and 170% of the measured values. Average differences over several monitoring sites are typically within 10% of the measured values, but, as the Didcot data show, the differences for individual comparisons can be up to a factor of two for both observational meteorological data and NWP.

The contour plot of annual average SO_2, figure 2, is highly dependent on the frequency of wind directions provided by the meteorological input. A more evenly spread direction distribution in NWP tends to broaden the contour values, whilst the greater directional frequencies provided by the characteristics of observational sites create smaller areas of higher values.

The conclusions of the study are:

- Over a year, short term and long term air concentration predictions from the dispersion model ADMS are similar whether using observed weather data or NWP. The use of NWP as the meteorological input does not have a significant effect on the accuracy of model predictions and is therefore suitable for use in modelling studies.
- Whilst there is no compelling advantage to using NWP in preference to observed data, it would be appropriate to use NWP if representative observed meteorological data were not available.

- The Didcot study used NWP with a grid length of 60 km. Other work using finer resolution NWP produces dispersion results of a similar accuracy – dispersion modelling may not be sensitive to the differences in these meteorological data. This may change with future refinements of NWP and dispersion modelling.
- The use of advance meteorological parameters available from NWP, i.e. boundary layer height and sensible surface heat flux, did not produce a consistent improvement in ADMS model predictions. The Didcot example shows that NWP does provide an improvement over observed meteorology, but this is not the case for other sites. Future advances in dispersion modelling and NWP are likely to improve the accuracy of dispersion predictions and the sensitivity of dispersion modelling to different inputs may increase.

6. REFERENCES

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