RECOMMENDATIONS ON SPATIAL ASSESSMENT OF AIR QUALITY RESULTING FROM THE FP6 EU PROJECT AIR4EU

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INTRODUCTION

Air4EU (www.air4eu.nl) is an FP6 European project with the major aim of providing recommendations on methodologies for carrying out the spatial assessment of air quality on local, urban and regional scales. Emphasis is put on methodologies that combine monitoring and modelling and on spatial assessment for regulatory purposes, i.e. the EU daughter directives. The project includes both research partners and city users and the close co-operation with stakeholders promotes the practical applicability of the recommendations developed. The recommendations in Air4EU are intended as guidance for authorities involved in air quality assessment at city, national and European level as well as institutes involved in air quality research and application. Compounds addressed are those that are of most concern to many stakeholders and include particulate matter (PM), ozone (O_3) and nitrogen oxides (NO_2). The key outcomes of the project include:

- Reviews of current practices in spatial assessment (*Air4EU*, 2007; D3.1, D4.1 and D5.1)
- Recommendations of best practices in spatial assessment (*Air4EU*, 2007; D6.2-Parts I-IV)
- Case studies supporting these recommendations (*Air4EU*, 2007; D7.1 and D7.2)

This paper focuses on a number of highlights from the recommendation documents emerging from the project, particularly recommendations on the local and urban scale. It is not possible within this paper to list all the recommendations, however, some indicative examples are provided and readers are referred to the original Air4EU documents available at (www.air4eu.nl/reports_products.html).

STRUCTURE OF THE RECOMMENDATIONS

The recommendations deal with three differing scales, as outlined above, and these are treated individually in the recommendation documents (*Air4EU*, 2007; D6.2). The selected compounds, for which the recommendations are most relevant, are scale dependent.

1.	Local/hotspot	PM and NO_2	(*Air4EU*, 2007; D6.2-Part II)
2.	Urban/agglomeration	PM, O_3 and NO_2	(*Air4EU*, 2007; D6.2-Part III)
3.	Regional/continental	PM and O_3	(*Air4EU*, 2007; D6.2-Part IV)

For each scale three different methodologies for making assessments are identified and for each of these a number of recommendations on various aspects are given. These three methods are **monitoring** (*e.g. network design, monitoring methods, data quality, representativeness),* **modelling** (*e.g. meteorology, emissions, model processes, scale interactions), and* **combining modelling and monitoring** (*e.g. validation, data assimilation,* *source apportionment).* In addition to these three methods the issue of **uncertainty analysis** (*e.g. model assessment, representativeness, spatial mapping)* is addressed separately

The recommendations are provided at 3 levels of complexity, these being:

a) *Basic requirements:* Reflecting recommendations aimed at fulfilling the minimum requirements in reporting for the regulated pollutants as well as typical current practices and starting points.
b) *Best practice recommendations:* Reflecting the state of the art in achievable methods for city authorities and institutes already engaged in air quality assessment.
c) *Scientific recommendations:* Points to further research requirements to improve the spatial assessment of air quality

A number of cross cutting issues are treated within the recommendations. These include emissions, uncertainty analysis, representativeness, scale interactions and data assimilation. These issues provided a number of milestone reports (*Air4EU*, 2007; M.1-5). In addition to the recommendations 14 case studies, designed to test and demonstrate a number of recommendations, have been carried out (*Air4EU*, 2007; D7.1 and D7.2). Results from the case studies are included in the recommendation documents, providing examples of best practice techniques.

In the following sections some example recommendations are provided. The level of the recommendation is indicated by the abbreviations **basic**, **best** or **science** as described above. As introduction to each section a general overarching recommendation is provided.

MONITORING

Monitoring is the best established method for carrying out assessment and it is recommended to consult key documents on air quality monitoring methods when undertaking monitoring programmes.

Network design and quality control and assurance

Basic: In regard to design of an urban AQ monitoring network, it is recommended to comply with the basic requirement in the AQ Directives for NO_2, O_3 and PM (*EC,* 1999; *EC,* 2002) and to consult a number of references including: Air4EU cross cutting issue report on representativeness (*Air4EU*, 2007; M3), the report 'Guidance to assessment under the EU AQ Directives', (http://ec.europa.eu/environment/air/pdf/guidanceunderairquality.pdf), and 'Guidance report on Preliminary Assessment under EC Air Quality Directives' (http://reports.eea.europa.eu/TEC11a/en/tech11.pdf)
Best: The requirements for a complete QA/QC plan have been described in the EUROAIRNET recommendations (*Larssen et al.,* 1999; Chapter 4.5.6).
Best: The use of station pairs or triplets is highly recommended for an improved understanding of the regional scale contributions to the urban and local air quality.
Science: It is recommended to carry out proper Source Apportionment (SA) studies using receptor models, by sampling PM at, at least, one of the stations according to SA procedures. See e.g. *Watson and Chow* (2004) for a review. The US EPA also provides some guidance on receptor modelling (www.epa.gov/scram001/receptorindex.htm).

MODELLING

An atmospheric dispersion model should be appropriate for the intended application in terms of it validity and limitations. It is important to justify the use of any particular model and understand these limitations. That is, the model should be fit for purpose.

General model types and applications

Basic: The temporal resolution of the model should be appropriate to the application. When only annual means are required then statistical or empirical models may be suitable. For daily mean concentrations a model really requires an hourly temporal resolution. Any model being applied to assess exceedances of the EU directives, with the exception of $PM_{2.5}$, thus requires a temporal resolution of 1 hour.

Basic: Gaussian models are suitable for screening purposes when generating urban air quality maps. They are recommended for long-term applications when applied to the urban scale or for hourly calculations where meteorology is spatially homogenous.

Best: The vertical resolution of a Eulerian model may have significant influence on the near surface concentrations, depending on the effective height of the emissions. The sensitivity of Eulerian models to vertical resolution should be assessed for the differing source categories.

Science: When modelling near road dispersion of traffic emissions more research is required to establish the effect of traffic induced turbulence on the initial dispersion of these pollutants.

Meteorology

Basic: Statistical meteorological fields are often sufficient for annual mean calculations, when applied to steady state dispersion models.

Science: Strong stability and weak wind conditions, that can often lead to pollution episodes, are generally poorly modelled by even advanced mesoscale models. Research into methodologies to improve this situation is required.

Emissions

Basic: Uncertainties of calculated emission data should be assessed and analysed. Basic procedures recommended are: transparent documentation, data archiving, cross checking of plausibility and completeness, external reviews and emission factor quality ratings (see e.g. EMEP/CORINAIR Guidebook, http://reports.eea.europa.eu/EMEPCORINAIR4).

Best: As far as possible and reasonable, basic data (e.g. emission factors, activity rates, temporal profiles) and methodologies applied (e.g. sectoral level of detail, spatial allocation, other assumptions) should be harmonised with already existing inventories on regional or national level. If possible, a bottom-up approach and local data/information should be used for emission and scenario calculations on local and urban scale.

Science: A further examination of fugitive PM emissions e.g. from agriculture, construction, material handling, industrial vents, barbecues and road dust suspension should be done. More size selective measurements at typical sites and a systematic analysis and determination of model parameters are required. In general, a more systematic validation of emissions factors and calculated emissions could help to significantly improve emission data.

Chemistry and aerosol processes

Basic: On the local and urban scale the influence of chemistry, secondary particle formation and aerosol dynamics on the total mass of the particles is limited. As such a model may neglect these processes as a good first estimate and treat PM as a totally inert species.

Best: For local scale modelling, using parameterised Gaussian models, the discrete parcel method (DPM), e.g. *Benson* (1984), which takes into account non-stationarity of the basic photochemical reactions, is recommended as an analytical technique, over the photo-stationary or ozone limiting methods, for the calculation of NO_2 concentrations.

Science: There are still a large number of uncertainties in many of the aerosol processes and continued research is required to improve these. This includes the formation of secondary organic aerosols as well as the heterogeneous effects associated with water solubility and particle growth.

Regional background for urban scale models

Best: Regional scale models can provide boundary conditions for urban scale models directly only when meteorology is consistent between the scales. When this is not the case then the urban model domain should be expanded to be significantly larger than the urban region so that no 'double counting' takes place.
Best: Nesting, where larger and smaller scale models directly interact with one another, is highly recommended as a consistent methodology for including regional background concentrations into an urban scale model

COMBINING MODELLING AND MONITORING

Combining model results with measurements can reduce uncertainties inherent in both, and is strongly recommended in order to achieve a better depiction of the real situation in the area of interest.

Basic: When model results are poor, in relation to the evaluation process, or with strong bias then it is not recommended to carry out data assimilation but rather to improve the model description.
Best: When a number of measurement stations are available then a robust and simple method of data assimilation is to create a linear regression model, based on the air quality model. The regression should take into account background concentrations, which may or may not be part of the model itself.
Best: Urban air quality has a typical spatial variation that is much higher than the distance between monitoring stations when local scale sources are included. Interpolation methods such as optimal interpolation and kriging, when applied solely on monitoring data, will not capture this variation. These methods should only be applied in combination with models that can represent the spatial variation, i.e. models.
Best: For all data assimilation purposes the spatial representativeness of the model and observations should match as closely as possible.

UNCERTAINTY ANALYSIS

An assessment of known model error or estimated uncertainty is always required when modelling results are presented.

Model assessment

Basic: For the application of the Quality Objectives of the Air Quality Framework Directive it is recommended to use the alternative model error Relative Percentile Error (RPE) when dealing with percentiles.
Science: For the estimation of uncertainty related to input data a sensitivity analysis (based for e.g. on Monte Carlo simulations) to input parameters (like initial and boundary conditions, meteorological parameters, emissions, land use and topography) is recommended

Combination of monitoring and modelling

Best: The recommended technique for assessing uncertainty when using data assimilation is the processes of cross-validation. A recommended measure to indicate this is the RMSE.
Science: There is a significant gap in the understanding of spatial representativeness and its effect on monitoring uncertainty. This needs to be addressed before more meaningful uncertainty assessment using data assimilation can be carried out.
Science: Bias in models, particularly for PM, remains a problem in regard to assimilation techniques since most of these techniques are applicable only when there is little or no bias present. Bias is best dealt with by improvement of the model.

Uncertainty mapping

Basic: When plotting contour or gridded maps using colour coding it is recommended to use a contour spacing that reflects the estimated uncertainty, e.g. using a rounded value of the standard deviation as the contour spacing, as this provides a good visual indication of the uncertainty of the mapped result.
Best: When data assimilation techniques are used that provide their own uncertainty estimates, e.g. kriging and ensemble methods, then the variance or standard deviations should be used to represent uncertainty in a map.
Science: Other methods that use uncertainty, such as the probability of exceedence, should be further investigated to assess their usefulness as uncertainty indicators.

CONCLUDING REMARKS

There is much to be considered when carrying out air quality assessment. The list of recommended basic requirements and best practices given in the recommendation documents, numbering more than 250 separate recommendations on the urban scale alone, describe a wide variety of issues that need to be considered when carrying out such assessment. However, there are always real world limitations that will not allow all of the best practice recommendations to be carried out, nor indeed some of the basic requirements. Despite this, the recommendation documents provided by Air4EU should serve as a guide to give both city users of air quality assessments and the institutes carrying them out an overview of the many methods, of varying quality or effectiveness, available. These recommendations are intended to steer decisions that need to be made on how assessment is carried out, from monitoring network design and modelling applications through to their eventual combination. This will not only achieve the best assessment of air quality but will also improve the understanding of the causes and effects that lead to the current and future air quality situation.

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