Air4EU

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Uncertainty Assessment and Mapping

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Overview

Uncertainties related to monitoring methods

Uncertainties related to modelling methods

Uncertainty mapping

Uncertainties related to monitoring methods

The **first step** is to define the **purposes of the measurements**.

Examples are:

- Determine compliance with air quality standards
- Determine the highest concentration in a predefined area
- Determine the representative concentration in areas of high population density
- Determine effects of particular emitters on the ambient air concentrations
- Determine background pollution levels.

The **following procedure** is to establish a **monitoring network design,** representing the continuous field of concentration pollutants over the area of interest and being in agreement with measurement purposes.

Uncertainties related to monitoring methods

It is highly recommended that cities:

- define Data Quality Objectives;
- approve and implement a Quality Assurance/Quality Control plan for their air quality measuring networks.

If **air quality data obtained on a monitoring site** are only for **air quality standards compliance assessment** then **quality objectives and indicators given in the EU Daughters Directives on air quality are compulsory.**

For **comparative purposes/mapping or trend analysis** it is **recommended** to follow **Data Quality Objectives and QA/QC plans (minimum or complete)** described in EEA Technical Report nº 12: Criteria for EUROAIRNET- The EEA Air Quality Monitoring and Information Network.

Uncertainties related to monitoring methods

Data Quality Objectives of some monitoring programmes

Monitoring programme/ Monitoring objective	Compounds	Accuracy	Precision	Data time coverage
EUROAIRNET Mapping, comparability		≤10%	≤2 ppb	≥90%
EU Regulatory Monitoring [1)] Detect non-compliance with directives	SO_2, NO_2 PM, Pb	15% [2)] 25% [2)]		90% annual -
EMEP Provide basis for control of models		15-25% [3)]		90% annual
WMO-GAW Detect trends over short term (5 years)	Examples: O_3 NO_2 $PM_{2.5}$	15% or 3 ppb 20% or 50 ppt 0.05+5% M	10% or 1 ppb 10% or 25 ppt 10%	80% monthly - 90% monthly

Data Quality Objectives (DQO) established for the implementation of QA/QC procedures under EUROAIRNET ensure that the data collected are sufficient and of adequate quality. **EUROAIRNET DQOs** are stricter than those defined by the EU Directive.

The **EU Directive DQOs** are set with a view to the practical measurement accuracy achievable in the field with typical present-day procedures.

The main basis for the **EMEP DQOs** is to provide measurements to control modelling results, and an accuracy of 15-25% is considered sufficient for that purpose. Its data completeness DQO is 90%.

Accuracy and precision defined for **WMO/GAW DQOs** vary between 10% and 20% for individual gases and, in absolute terms, is much higher in the WMO network than in urban networks.

Total model uncertainty estimation

TOTAL UNCERTAINTY = **MODEL** UNCERTAINTY + **VARIABILITY** + **DATA** UNCERTAINTY

with...

- Statistical analysis
- EPA Quality Indicators
- Data Quality Objectives of the Air Quality Framework Directive

Uncertainties related to modelling methods

Statistical analysis

QUALITY INDICATORS	Formula
Correlation coefficient	$r = \left[\frac{\sum_{i=1}^{N} (Co_i - \overline{C_o})(Cp_i - \overline{C_p})}{\sigma_0 \sigma_p} \right]$
Fractional bias	$Fb = \frac{\overline{Co} - \overline{Cp}}{0.5(\overline{Co} + \overline{Cp})}$
Root mean squared error	$RMS = \sqrt{\sum_{i=1}^{N} (Co_i - Cp_i)^2}$ RMSE
Normalized standard deviation	$NSD = \frac{\sigma Cp}{\sigma Co}$

QUALITY INDICATORS	Formula
Normalized mean square error	$NMSE = \frac{\overline{(Co - Cp)^2}}{\overline{Co}\,\overline{Cp}}$
Average normalized absolute bias	$ANB = \overline{\left(\frac{\lvert Co - Cp \rvert}{Co} \right)}$
Geometric mean bias	$MG = \exp(\overline{\ln Co} - \overline{\ln Cp})$
Geometric variance	$VG = \exp\left[(\overline{\ln Co} - \overline{\ln Cp})^2 \right]$
Fraction of predictions within a factor of 2 of observations	$0.5 \le \frac{Cp}{Co} \le 2.0$

Every statistical parameter plays a role in evaluation of model performance and uncertainties estimation, but some could be considered more important, useful and required for such an analysis, namely r, *Fb*, *NSD* and RMSE.

Uncertainties according to EU Directives

EU Directives establish requirements for air quality modeling as a measure of modeling results acceptability:

"maximum deviation of the measured and calculated values, over the period for calculating the appropriate threshold, without taking into account the timing of the events"

Pollutant	Quality Indicator	Quality Objective	Directive
SO_2, NO_2, NO_x	Hourly mean	50-60%	1999/30/EC 1)
	Daily mean	50%	
	Annual mean	30%	
PM, Pb	Annual mean	50%	
CO	8-hour mean	50%	2000/69/EC 2)
Benzene	Annual mean	50%	
Ozone	8-hour daily mean	50%	2002/03/EC 2)
	1-hour average	50%	

1) The term "Accuracy" is used in the Directive.
2) The term"Uncertainty" is used in the Directive.

Uncertainties according to EU Directives

EU directives **model quality measure** is interpreted as the relative maximum error without timing - largest concentration difference of all percentile differences normalized by the respective measured value

$$RME = \frac{\max(|Co_p - Cp_p|)}{Co_{p_{\max(Co_p - Cp_p)}}}$$

1) timing is **relevant for those hourly and daily limits**, or target values, which are defined as a number of allowed exceedances of a given threshold

2) there are **no differences between a short-term and long-term model** application accuracy analysis, being the first one in advantage due to the number of paired-in-time results

3) model quality objectives for the allowed uncertainty are given as a relative uncertainty, **without clear guidance** on how to calculate this relative uncertainty

Uncertainties according to EU Directives

an alternative model error measure is…

concentration relative error at the percentile corresponding to the allowed number of exceedances of the limit value normalized by the observation

$$RPE = \frac{\left| Co_p - Cp_p \right|}{Co_p}, p$$

(Relative Percentile Error)

p - percentile

1) more **robust** (uses the percentile instead of the maximum value)
2) **evaluates model** performance in the high concentration ranges
3) direct **link to the EU Directives**, since the model uncertainty is examined in the concentration range of the limit values

Uncertainties according to EU Directives

Practical example

EU model quality measure

SUGGESTED model quality measure

Pollutant	EU Directives indicators	RME (%)	Percentile (P)	RPE (%)
SO_2	Human health protection (hourly mean)	79	99.73 (25th max hourly mean)	
	Human health protection (daily mean)	66	99.18 (4th max daily mean)	57
	Vegetation protection	33	annual mean	
	Vegetation protection	44	winter mean	
NO_2	Human heath protection (hourly mean)	81	99.79 (19th max hourly mean)	
	Human heath protection	47	annual average	
O_3	Human heath protection (8h running daily mean)	69	93.15 (26th max 8h daily mean)	
	Vegetation protection	71	AOT40	

> 50%

only background monitoring stations

Calculated at the highest measured value
Model accuracy depends on the model performance in a concentration range having an extremely small probability

Quite total compliance with legislation accuracy requirement for all the pollutants indicators

Uncertainties related to modelling methods

The following recommendations are proposed to estimate the **total model uncertainty**:

Basic requirements

- Important to define the purpose of the uncertainty estimation process:

  *If the modelling results will be used as support for political decision, the **total model uncertainty is essential**, and the information about uncertainties associated with modelling results will be as important as the modelling results themselves.*

- Effective communication of model uncertainties to decision makers, so that model outputs can be correctly interpreted:

  *Presentation of a **qualitative** (e.g., graphical) and a **quantitative** (e.g., statistical) analysis of model results against measured values from the air quality network.*

Best practice recommendations

It is necessary to investigate the *contribution of different components of total model uncertainty* in order to improve model performance.

Stochastic variability

The contribution of stochastic variations in the total model uncertainty **should be examined separately**, since it cannot be reduced.

To analyse the uncertainty related to variability it is **recommended:**

- to filter out stochastic processes from the monitoring data based on spectral analysis and to quantify model uncertainty without the influence of stochastic variations.
- that the analysis must be taken when assessment is **based on hourly means** but this **is not required for annual means**.

Uncertainties related to modelling methods

Scientific recommendations

For a complete knowledge of the *components of total model uncertainty* it is **recommended**:

- to perform a sensitivity analysis and/or model intercomparison to evaluate the different model modules (Chemical mechanisms, physical parameterisations and numerical algorithms) to determine **intrinsic model uncertainty.**

- To perform a sensitivity analysis to input parameters (initial and boundary conditions, meteorological parameters, emissions, land use and topography), for example, using Monte Carlo approach, for the estimation of **uncertainty related to input data**.

Appropriate measure for **intrinsic model uncertainty** and **input data uncertainty** is the **standard deviation** and **normalised bias** of the results of sensitivity tests.

Uncertainty mapping

The spatial representation of uncertainty parameters should always follow any assessment map!

Estimation of the total model uncertainty parameters by comparison between modelled data and measured data, at the measuring point.

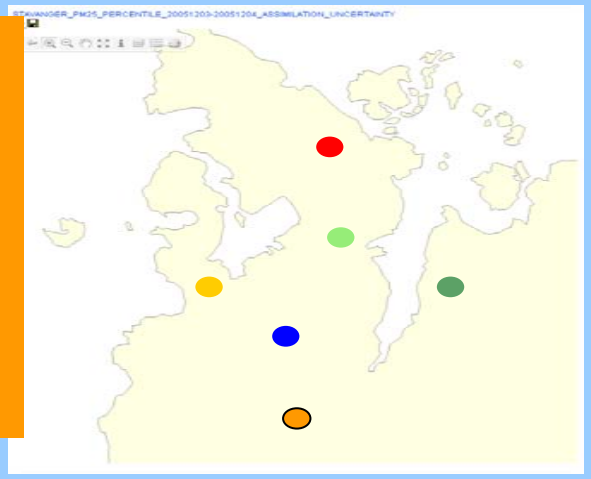
How to show the uncertainty parameters?

Maps of **RPE** for daily or hourly averages and **RME** for annual averages for **directive purposes**

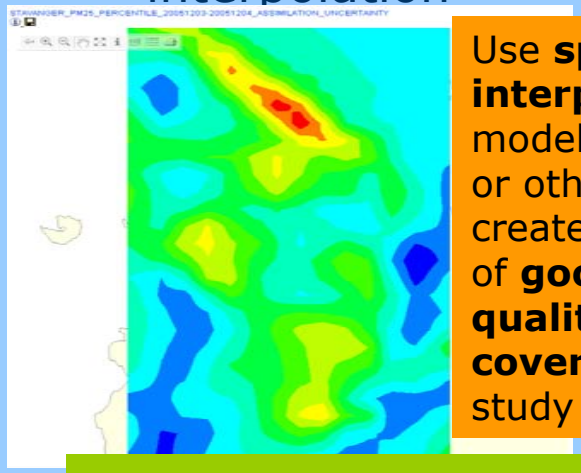
Also maps of **RMSE** (Root Mean Square Error) and **Fb** (Fractional Bias)

In case of **deficient spatial air quality network coverage** is recommendable to use **point representation** of model errors.

post maps



interpolation



Use **spatial interpolation** of the model errors (kriging or other method) to create **maps**, in case of **good spatial air quality network coverage** of the study domain

Interpolation adds uncertainty to the process