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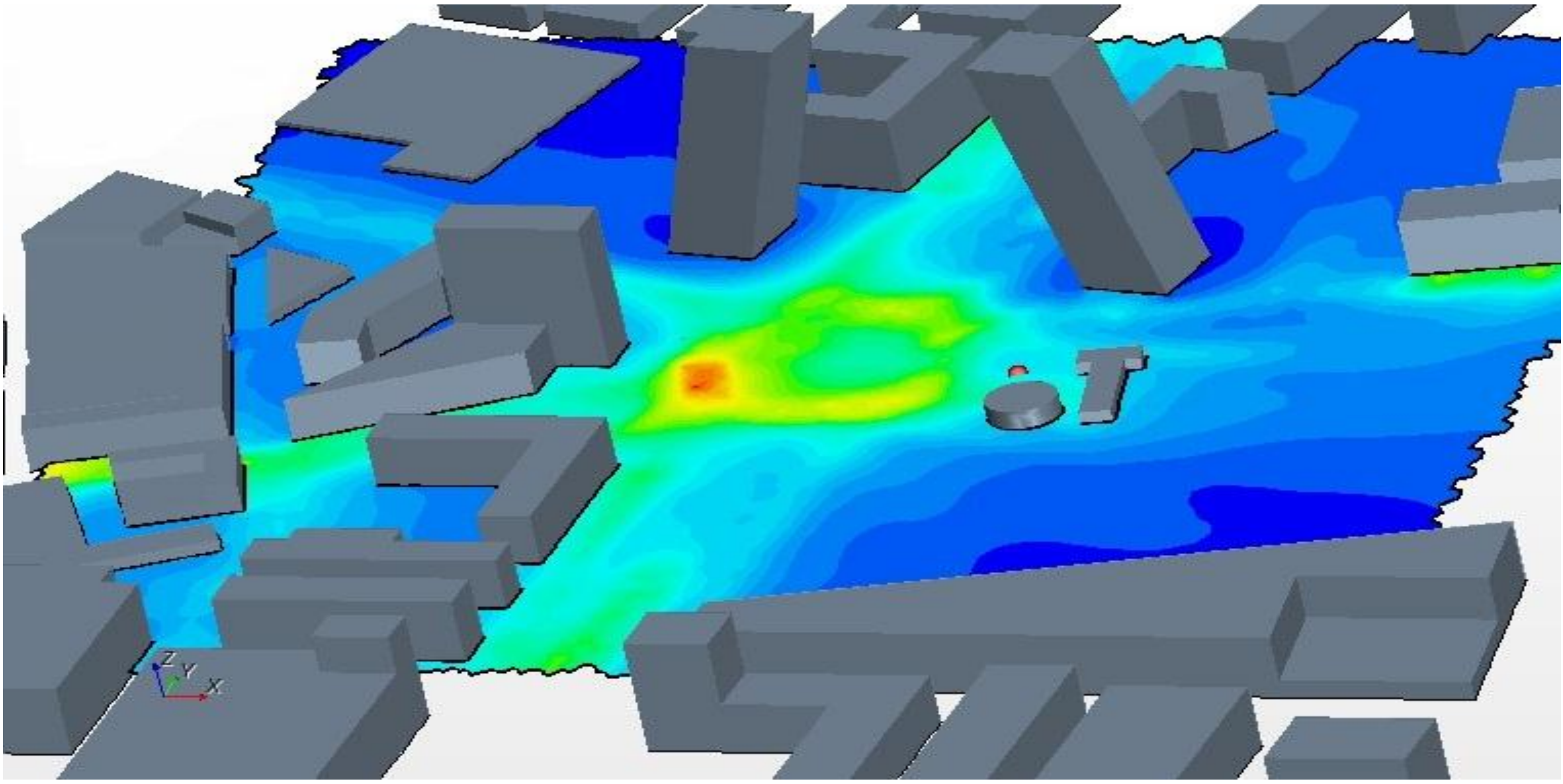

FAIRMODE Spatial representativeness feasibility study

Fernando Martín, José Luís Santiago, Oliver Kracht, Laura García and Michel Gerboles

2015

Report EUR 27385 EN

Joint Research Centre

European Commission
Joint Research Centre
Institute for Environment and Sustainability

Contact information
Michel Gerboles
Address: Joint Research Centre, Via E. Fermi, 2749, 21026 Ispra (VA))
E-mail: michel.gerboles@ec.europa.eu
Tel.: +39 0332 785652

JRC Science Hub
https://ec.europa.eu/jrc

JRC 96827

EUR 27385 EN

ISBN 978-92-79-50322-1 (PDF)

ISSN 1831-9424 (online)

doi: 10.2788/49487

Luxembourg: Publications Office of the European Union, 2015

Abstract
Within Fairmode, it is planned to organize an intercomparison exercise of methods for the assessment of the spatial representativeness of monitoring sites. It is expected that the outcomes of the proposed intercomparison exercise will substantially support future efforts towards a harmonized methodological framework to facilitate the reporting of spatial representativeness by the Member States. This report presents a feasibility study including a Bibliographical review of the studies done for experts published in scientific journals or technical reports , a tentative definition of the concept of spatial representativeness after reviewing the papers and reports found in the bibliographical review , the development of a questionnaire to get technical information of the methodologies used to estimate the area of representativeness of air quality monitoring stations by the main expert groups in Europe, an analysis of the survey results and a discussion about the feasibility of an intercomparison exercise for methodologies estimating the spatial representativeness of monitoring stations.

FAIRMODE Spatial representativeness feasibility study

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Fernando Martín[1], José Luís Santiago[1],

Oliver Kracht[2], Laura García[1]

Michel Gerboles[2]

[1] CIEMAT, SPAIN

[2] JRC, ITALY

July 14th, 2015

Executive summary

Within FAIRMODE, the Forum for Air Quality Modelling in Europe, it is planned to organize an intercomparison exercise of methods for the assessment of the spatial representativeness (SR) of monitoring sites. The main objective of this intercomparison exercise would be to explore the strengths and weaknesses of the different contemporary approaches for computing the spatial representativeness area by applying them to a jointly used example case study. It is expected that the outcomes of the proposed intercomparison exercise will substantially support future efforts towards a harmonized methodological framework to facilitate the reporting of spatial representativeness by the Member States.

This report presents a feasibility aiming at identifying prospective candidate methodologies to be considered in an intercomparison exercise, the requirements on shared datasets, the assessment of the comparability of the different types of SR results to be retrieved and the limitations to be expected of such an intercomparison exercise. In order to achieve these objectives, this report presents the results of a bibliographical review of the studies on spatial representativeness published in scientific journals or technical reports, a compilation of the definitions of the concept SR found in the bibliographical review, the design of a survey based on a questionnaire to get technical information concerning the methodologies used to estimate the SR of air quality monitoring stations by the main expert groups in Europe, an analysis of the survey results and a discussion about the feasibility of an intercomparison exercise for SR methodologies.

A total of 22 groups from 14 different countries answered the questionnaire providing information on 25 methodologies. Most of them (18 groups with 20 methodologies) intend to participate in the intercomparison exercise. From the replies obtained from these groups, SR studies were mostly done for regulatory purposes (air quality reporting, station sitting or network design, station classification) but also for data assimilation or model evaluation and population exposure. Most of the groups used methodologies based on modelling but also on measurements, proxies and station classification and generally for annual concentrations (average or percentiles from daily or hourly data). SR studies were done for wide range of pollutants but more frequently for NO_2/NO_x, PM_{10}, SO_2 and $PM_{2.5}$, but also ozone at the regional scale. Most of the groups applied their methodologies to all type of stations. The most used input variables are air quality data from measurements and/or modelling, meteorological and emission inventory data. The outputs are usually maps delimiting the SR areas and/or SR size parameters (e.g., surface areas or radius).

The responses of the questionnaire concerning methodology requirements and limitations show that the intercomparison exercise seems to be feasible with some conditions. In order to include as many participants and methodologies as possible an open exercise is proposed provided that all input data needed for each methodology is available. Due to a similar number of groups applying their methodologies for regional scale or for local/urban scales, the exercise should cover both spatial scales. For the urban/local scale, input data are available from a proposed dataset for the city of Antwerp, and for the regional scale it is

proposed to extend the domain according to the requirements of some methodologies. Hence, datasets are needed with features similar to those for the local/urban scale but with a coarser resolution. The types of input data required are: data from air quality monitoring, sampling campaigns, air quality modelling, emission inventories, meteorological or/and climatological data, and other surrogate data as land use/cover, traffic intensities, population density, building geometries or topography.

Within the proposed exercise, spatial representativeness should be estimated for NO_2 and PM_{10} at the local/urban scale and for NO_2, O_3 and PM_{10} at the regional scale. The results could be based on annual metrics of concentrations such as the average or percentiles from daily or hourly values. In addition, the exercise should be done at least for one traffic and two background stations covering the local/urban and regional scales.

It is proposed to do two types of comparisons:

1. To compare outputs from methodologies with the same definitions within subgroups, in order to analyse the variability in the SR area estimates obtained from similar methodologies or based on similar definitions

2. To compare outputs from all methodologies(analyse the variability of the SR area estimates provided by different methodologies or SR definitions) in order to have more information about a general definition of SR

The output variables to be used in the comparison exercise would be SR maps, dimensions of SR (area, radius) and intermediate maps (where applicable) such as concentration fields.

A sensitivity study has been proposed to evaluate the effect of some parameters as the concentration similarity threshold by immediately investigating these effects based on the modelled concentration fields.

Finally, more details about the input data, the methods for comparison of the SR results, the format of input and output files, etc have to be discussed and agreed on in the next preparation step.

List of Acronyms

ACRONYM	TEXT
AQ	Air Quality
AQMS	Air Quality Monitoring Station
AQUILA	Network of Air Quality Reference Laboratories
AR	Area of Representativeness
BSC	Barcelona Supercomputing Center
CFD	Computational Fluid Dynamics
CIEMAT	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
CTM	Chemical Transport Model
EC	European Commission
EMPA	ETH-Bereichs für Materialwissenschaften und Technologieentwicklung (Swiss Federal Laboratories for Materials Science and Technology)
ENEA	Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile (Italian National Agency for New Technologies, Energy and Sustainable Economic Development).
FAIRMODE	Forum for Air Quality Modelling in Europe
FMI	Finnish Meteorological Institute.
INERIS	Institut National de l'EnviRonnement Industriel et des Risques.
Helsinki RESA	Helsinki Region Environmental Services Authority
Irish EPA	Environmental Protection Agency of Ireland.
JRC	Joint Research Centre.
Kuopio, REPS	City of Kuopio, Regional Environmental Protection Services
LANUV	Landesamt für Natur, Umwelt und Verbraucherschutz NRW
RIVM	Rijksinstituut voor Volksgezondheid en Milieu (National Institute for Public Health and the Environment).
SR	Spatial Representativeness

TNO	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (Netherlands Organisation for Applied Scientific Research)
UA	Universidade de Aveiro.
UPM	Technical University of Madrid.
VITO	Vlaamse Instelling Voor Technologisch Onderzoek (Flemish institute for technological research).

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1. Introduction

Systematic monitoring and collection of ambient air quality data is a mandatory requirement for efficient air pollution management and robust decision making. Since the entry into force of the Council Decision 97/101/EC, and the amendments stipulated in the Commission Decision 2001/752/EC, European Member States have been obliged to monitor and reciprocally exchange measurements of ambient air pollution. Monitoring stations have traditionally been used to estimate the air quality over a territory.

The European Directives 2008/50/EC and 2004/107/EC endeavour to improve the quality of measurements and data collection, and to ensure that the information collected on air pollution is sufficiently representative and comparable across the Community. In addition, air quality monitoring stations have been deployed trying to cover most of the territory. However, as these data are point measurements, an outstanding question always arises: how representative are the monitoring sites? Furthermore, this question immediately implies other questions: How can the spatial representativeness be estimated? What does representativeness mean? What are the best locations for measuring ambient air pollution?

Directive 2008/50/EC points out the importance of using common criteria for the classification, number and location of measuring stations for the assessment of ambient air quality. Additionally, different provisions concerning the siting of fixed monitoring stations are given. Those include several considerations about the order of magnitude of the spatial representativeness, but the methods for assessing the spatial representativeness are not provided.

The Implementing Decision 2011/850/EU (IPR) states that Member States shall also make available information on the quality and traceability of the air quality assessment methods. For fixed measurement stations, this should include (where available):

(i) the spatial extent of the representative area (geometric description),

(ii) the evaluation of representativeness (interpretation of the representativeness area and constraints for using this information), and

(iii) the documentation of representativeness.

However, no detailed information on the methods for assessing the spatial representativeness is provided. In fact the Guidance on the Commission Implementing Decision 2011/850/EU (provided by DG ENV in version of 15 July 2013) explains that *"... there is as yet no definition of the spatial representativeness of monitoring stations in the AQ legislation and there is a need to develop tools for its quantitative assessment*". It furthermore points to the initiatives AQUILA (Network of Air Quality Reference Laboratories) and FAIRMODE (Forum for Air Quality Modelling in Europe), noting that *"... the evaluation of representativeness will be further evaluated in the framework of the collaboration between AQUILA/FAIRMODE*". In summary, reporting information on spatial representativeness is not mandatory and not harmonized (no reference method specified).

In practice, assessment of the spatial representativeness aims at delimitating areas of the concentration field with similar characteristics at specific locations. Characteristics, the similarity of which is being investigated, can either be concentration levels, (statistical) properties of the measured ambient air quality data, or external parameters influencing the air quality, like emissions and dispersion conditions (Spangl et al., 2007).

The concept of spatial representativeness is related to - but not necessarily identical to - the area of exceedance (the Member States' obligation to provide the public with information about the location and area of the exceedances being stipulated in ANNEX XVI of EC/50/2008). Spatial representativeness of monitoring sites regarding air quality assessment can for example be focused on (annual, daily, 8-hourly or hourly) limit/target values laid down in the EU directives, and on information or alert values (also related to short time scales). However, while for the former the timing of the exceedances is not relevant, for the latter it is. The timing of exceedances has to be met when monitoring station data are used for other purpose such as air quality control or forecast. Hence, quite different methods would be necessary to estimate the representative area depending on the purpose of the study.

On the other hand, a consistent classification of AQ monitoring sites across Europe is an important condition for a meaningful interpretation of data and for a harmonized assessment of trends and evolutions. Furthermore, the spatial representativeness of air quality monitoring stations is often closely related to the site classification. In fact, knowledge about spatial representativeness is frequently required as a prerequisite for the decisions to be taken about the classification of a monitoring site. Example given, representativeness is one of the macroscale siting criteria for classifying and locating sampling points for the assessments of ozone concentrations stipulated in ANNEX VIII of the directive 2008/50/EU.

FAIRMODE is highly interested in making progress in the assessment procedure of spatial representativeness and it is proposed to organize an intercomparison exercise of methods for the assessment of the spatial representativeness of monitoring sites. It is expected that the outcomes of this intercomparison exercise should substantially support future efforts towards a harmonized methodological framework to facilitate the reporting of spatial representativeness by the Member States. It is furthermore anticipated that increasing the harmonization, consistency and transparency of the methods will also serve as an important factor in motivating future reporting of spatial representativeness within the established exchange of information.

2. State of the art

The key question about spatial representativeness is as how far a point measurement is representative of the ambient air pollutant concentration around it. This "simple" question cannot be addressed in an easy way. For example, while in rural zones the concentration is more homogeneous; in urban zones a large concentration gradient between two nearby locations can be found. Hence, spatial representativeness is typically much higher for rural zones than for urban areas. This gradient of concentration is related to the emission characteristics (e.g. number, distance and the strength of emission sources) and the diffusion, dispersion and reaction of the pollutants affected by the complex flow field induced by buildings within urban zones. In addition, there are point measurements within a rural zone or an urban area that can have different features (representativeness depends on local conditions) and it is difficult to quantify their spatial representativeness. As commented in the introduction, this question is addressed in the air quality legislation but there is not well-established criterion or methodologies for spatial representativeness assessment so far. It is important to analyse the spatial representativeness of the air quality monitoring stations and to find out what could be the best locations in order to make the recorded pollutant concentration data as representative as possible. This question has been investigated and discussed intensively in the past. First works are from Ott and Elliasen (1973) who applied a survey technique by sampling air CO concentrations in streets and urban areas in order to estimate whether an air quality station represents all the urban area of San José (California). They found that moving the monitoring station by only a short distance can change measured CO concentration by a factor of two and concluded that it may be essential to establish a set of standardized criteria for the problem of siting of urban air monitoring stations (Ott, 1977). In this way, recent detailed experimental measurements have been analysed in order to assess the spatial representativeness (Blanchard et al., 1999; Fleming et al., 2005; Vardoulakis et al., 2005; Venegas and Mazzeo, 2010; Joly and Peuch, 2012; Thornburg et al., 2009; Blanchard et al., 2014). In order to provide a starting point and common basis about spatial representativeness, FAIRMODE carried out a survey to elicit expert opinion on the spatial representativeness of ground based monitoring data (Castell-Balaguer and Denby, 2012). Furthermore, JRC in collaboration with the working group (with experts from AQUILA and EEA) on "Siting criteria, classification and representativeness of air quality monitoring stations" (SCREAM) developed a JRC-AQUILA position paper on Assessment on siting criteria, classification and representativeness of air quality monitoring stations (Geiger at al., 2014).

The basic concept of spatial representativeness is based on determining the zone to where the information observed at a monitoring site can be extended. It is related to the variability of concentrations of a specific pollutant around the site. The legislation (European Directive 2008/50/EC) about air quality monitoring station classification does not define spatial representativeness but provides a qualitative concept based on simple geometric parameters depending on the type of station such as surface area around the station or length of a street segment. Similar definitions have been used by Chow et al. (2006), but in this case, spatial representativeness was defined as the radius of a circular area in which a species concentration varies by no more than ±20% as it extends outward from the monitoring site. However, the concept of circular area of representativeness should not generally be applicable due to the anisotropic distribution of pollutants around AQMS , especially within the cities (i.e. the variation of concentrations in each direction could be different depending on emission sources distribution and flow field) (Spangl et al., 2007). In the framework of FAIRMODE, the report of Castell-Balaguer and Denby (2012) compiled specific comments of experts that revealed the main following points:

A scientific objective methodology to determine the spatial representativeness of a monitoring station is necessary.

There are more parameters that should be considered in addition to pollutant and station classification of the air quality monitoring station.

The concept of circular area of representativeness is not applicable.

The more commonly used definition of SR is based on the similarity of concentrations of a specific pollutant. Hence, the representativeness area is defined as the area where the concentration does not differ from the concentration measured at the station by more than a specified threshold (Blanchard et al., 1999; Larsen et al., 1999; Chow et al., 2006; Spangl et al., 2007). The threshold can be absolute or relative as with percentage. This threshold is usually linked with measurement uncertainties. In many studies (Larsen et al., 1999; Chow et al., 2006; Piersanti et al., 2013; Santiago et al., 2013; Martin et la., 2014; Pay et al., 2014), a percentage of 20 % is used. Martin et al. (2014) used a higher threshold (100%) for lower values of SO_2 and NO_2 concentrations because the relative uncertainty grows as concentration decreases. Spangl et al. (2007) consider the threshold should be higher than the total measurement error but it has to be small enough to allow a clear distinction between areas with different pollution levels. Then, they propose to set the threshold values for average and percentiles at 10 % of the total concentration range of values observed in Europe. Blanchard et al. (1999) made an analysis of the sensitivity by changing the criteria of concentration similarity of PM_{10} from 20% to 10% and the spatial representativeness area was reduced about half of those obtained with the 20% criteria. Pay et al., (2014) carried out a test of the sensitivity of the threshold (5, 10, 15, 20%) for several pollutants to maxima discrepancy concluding that 20% for all the pollutants could be a conservative selection.

In addition to the similarity of concentrations some authors use further criteria to determine spatial representativeness. Nappo et al. (1982) define a point measurement to be representative of the average in a larger area (or volume) if the probability that the squared difference between the point and the area (volume) measurement is smaller than a certain threshold more than 90% of the time. The maximum tolerable difference has to be assessed for every individual problem; it should not be smaller than the uncertainty of the measurement. Vana and Tamm (2002) proposed that points around a given monitoring station can be considered to belong to the area of representativeness (AR) when time series of concentrations of two points for some time interval with constant wind direction are well correlated and the mean or instant concentrations for points within the area of representativeness must be predictable with some accuracy chosen on the basis of the time series of monitored concentration. The definition of representativeness proposed by Spangl et al. (2007) and Geiger et al. (2014) is based on the concept of “similarity of concentrations” and this similarity is caused by common external factors (emission sources and dispersion situation). Representativeness is assumed to be stable over time periods of at least one year (i.e. not related to shorter time periods) (Spangl et al, 2007; Geiger at al., 2014, and Martin et al., 2014). An additional criterion to the similarity of concentration used by Martin et al. (2014) is that the air quality in the station and in the representativeness area should have the same status regarding the air quality standards (limit or target value, assessment thresholds). In this way, the representativeness area can be directly related to the area of exceedance of the air quality standards. Some authors propose to limit the extension of the spatial representativeness areas especially for rural background stations. For example, Geiger et al. (2014) suggest limiting it to a maximum distance of 100 km from the station. Martin et al. (2014) use a limit of 200 km.

In some cases the methods to assess spatial representativeness are related to the definition of representativeness. However, these are two different issues. The definition provides the specification of criteria for representativeness while the methodology specifies how to estimate for which locations/area a station is representative following the similarity of concentration given in the definition.

Different methodologies have been developed to calculate the spatial representativeness area of air quality monitoring stations depending on the purpose of the study and the available data. A unique robust methodology to assess the representativeness of in-situ measurements has not yet been agreed. Depending on the computation of the representativeness area the methods can be classified into three main types:

1. Representativeness computed by using concentrations maps around monitoring sites.

   The maps can be computed from

   a. Measurements obtained during campaigns deploying a dense grid of samplers (passive) or monitors. Passive samplers are the most commonly used.

   b. Air quality models

2. Representativeness area computed from the distribution of related proxies or surrogated data as: land cover/use, emissions, population density, etc.

3. Methodologies linked with station classification.

In addition, other studies provide qualitative information of spatial representativeness according to a qualitative analysis such as expert knowledge.

1. *Representativeness computed by using concentrations maps around monitoring sites.*

The methodologies of this group compute spatial representativeness from detailed information (maps) of concentration. These maps can be obtained from air pollutant measurements (Blanchard et al., 1999; Blanchard et al., 2014; Chow et al., 2006) or from modelled air pollutant concentrations (Martin et al., 2013; Martin et al., 2014; Santiago et al., 2013). Larssen et al. (1999) did not apply any methodology but suggest that the representativeness area can be determined by extensive measurements or detailed dispersion model calculations. These would be based upon detailed emission inventories. They proposed that the factors to be taken into account for evaluating the area of representativeness are: 1) the emission variations in the immediate surroundings, 2) the possible localized influence of dominating sources, and 3) the topographical features (both buildings and natural) influencing the dispersion and transport of the emissions. In addition, Ott et al (2008) suggested to use traditional frequentist statistics to determine variability of pollutant around a monitoring stations (coefficient of variation, coefficient of correlation, coefficient of divergence and analysis of variance) in the cases when no spatial correlation can be evidenced between measurements. These methods are also mentioned in Spangl (2007) and Yatkin et al. (2012) made a comparison in a case study in Varese (IT).

1.a. Concentration maps obtained from measurements.

Concentration data can be obtained from regular air quality monitoring stations or from dedicated experimental intensive campaigns using passive samplers, microsensors or several monitors distributed around an air quality station. When air quality monitoring stations are used, the correlation between stations is an important factor when searching for stations with similar time evolution of measured concentrations in order to find out which stations fall in the same category. That is, the question of representativeness evolves to the subject of air quality station classification or redundancy, which can be out the scope of this work. Using intensive measurements in several locations deployed along an area, concentration maps can be estimated providing information on how the pollution is distributed around the air quality station. Hence, with suitable criteria, the spatial representativeness area of the station can be estimated. Some references related to this type of methodologies are Blanchard et al. (1999), Blanchard et al. (2014),Chow et al .(2006), Vana and Tamm (2002), Beauchamp et al. (2012). For example, the spatial representativeness of NO_2 monitoring stations, based on passive sampling campaigns and kriging estimate in a probabilistic framework was analysed by Beauchamp et al. (2011 and 2012); Bobbia et al. (2008); Cárdenas and Malherbe (2007). In addition, they map the probability of exceeding limit values using a criterion about the difference between the stations values and interpolated values.

1.b. Concentration maps obtained from air quality models.

Validated models can provide very detailed concentration maps with a good spatial resolution. Air pollution dispersion models include algorithms solving the equations representing the atmospheric process (transport, diffusion, chemical transformation and deposition) of the pollutants. Models need inputs like emission data (emission model or inventories), meteorological fields (from measurements or meteorological models), land use, topography and initial and boundary conditions (usually from higher scale models). Applying suitable criteria to the pollution maps, the spatial representativeness area of an air quality station can be estimated. Depending on the type of station (urban, rural, traffic, etc), an air quality model at different scale needs to be applied. For rural stations, mesoscale CTM models are used (Martin et al., 2013 and 2014; Pay et al., 2014). Models with finer resolution such CFD or street canyon models are needed for urban and traffic stations (Scarpedas and Colivile, 1999; Mazzeo and Venegas, 2004; Diegmann et al., 2013; Duyzer et al., 2015; Freitas et al., 2013; Lefebvre et al., 2013; Piersanti et al., 2013; Santiago et al., 2011; Santiago et al., 2013; Vitali et al., 2013).

In addition, hybrid methods exist that merge both measurements with modelling outputs or explanatories variables as proxies that are known all over the study area with a high resolution. For example, de Fouquet et al. (2007) combined an NO_2 passive sampling with Corine Land cover, population density and information about emission. Roth and Bournel-Bosson (2002) included NO_2 measurements with measurement error and the Corine Land Cover indicator for urbanism as indirect information. The typical computing method is kriging with external drift, or co-kriging.

2. *Representativeness area computed from distribution of related proxies or surrogated data (land cover uses, emissions, population density, etc).*

Sometimes it is not possible to use models or to carry out experimental campaigns to evaluate how the pollutants are spatially distributed in an area where one or several air quality monitoring stations are sited. In those cases, the use of emission data or emission inventories and/or emission proxies such as, land use data (land cover and land use), population density, road maps, etc can provide an approximated view of the spatial distribution of pollutants, that is, a pollution concentration map. It is based on the idea that higher concentrations of pollutants are expected to be close to the sources. Sometimes, the use of some additional information as meteorology or topography can improve the estimated pollution maps. Meteorological information gives a clue about the dominant paths followed by the pollutants due to the atmospheric circulations, which are also affected by the topography. Jansen et al. (2008) and Jansen et al. (2012) used land use data to characterize spatial representativeness of air quality monitoring stations. They applied a land use indicator (the β-parameter) that provides information about the relations between land use and air pollution levels. Piersanti et al. (2013) used similar methodologies. Other methodologies are based on emission variability, i.e. the correlation between the spatial distribution of atmospheric concentrations of pollutants and the corresponding distribution of emissions (Piersanti et al., 2013; Cremona et al., 2013; Righini et al., 2014). Henne et al. (2010) reported that the spatial distribution of emissions and deposition data could be appropriate proxies for the concentrations. However, since no kilometre-scale emission dataset were available for their study domain, they used a proxy variable (population) instead of the main parameter (emissions).

3. Methodologies linked with station classification.

Some methodologies use representativeness to classify the air quality stations. Classification methodologies were applied in some cases. They do not provide a geographical delimitation of the spatial representativeness area but characterize the behaviour of a station according to the temporal measurement variability (Joly and Peuch, 2012) or the station environment, thus delivering very useful information about the station representativeness (Delias and Malherbe, 2013, Malherbe et al., 2013). Some studies used time series for several years of pollutants such as O_3, NO_2, NO, PM_{10}, SO_2 and CO from national or regional air quality networks to classify air quality monitoring stations (Snel, 2004; Flemming et al., 2005; Tarasova et al., 2007; Ignaccolo et al., 2008; Kovac-Andric et al., 2010; Joly and Peuch, 2012). In addition to the time series data from air quality monitoring stations other studies used further surrogated variables such as emission inventories, population density, land-cover maps or meteorological fields (Spangl et al., 2007; Monjardino et al., 2009; Henne et al., 2010).

Furthermore, using geostatistical analysis of the air quality monitoring data some studies obtained information about spatial representativeness of monitoring stations taking into account time series of variogram parameters (Horalek et al., 2007; Kracht et al. 2013 and Kracht and Gerboles, 2014).

In summary, no final agreement on a procedure for assessing spatial representativeness has been identified yet. However, it is an important topic that has been widely studied in the literature using different approach.

The spatial representativeness depends on the type of station in terms of spatial scale and studies applied to all spatial scales have been carried out. Henne et al. (2010) analysed spatial representative for global background stations. However, most of the works have been applied to regional or local scales (rural and urban monitoring stations). For example, the representativeness for rural air quality monitoring stations has been analysed by Blanchard et al. (1999) or Martin et al (2013), and for traffic and urban stations by Lefebvre et al. (2013) or Santiago et al. (2013).

In addition, the spatial representativeness depends on the pollutant. The most commonly analysed pollutants are primary pollutants (NO, NO_2 and PM_{10}) and O_3 (Spangl et al., 2007; Martin et al 2013; Righini et al., 2014; Pay et al., 2014). Spatial representativeness of pollutant concentration is assessed by using metrics related to annual air quality standards (annual mean, percentile of daily mean values or percentile of daily maximum 8 hour mean values) (Spangl et al., 2007; Geiger et al., 2014; Martin et al., 2014).

Most of the spatial representativeness methodologies provide maps as outputs (e.g. Lefebvre et al., 2013; Martin et al., 2014), however other authors gives qualitative information like station classification (e.g. Henne et al., 2010; Vincent and Stedman, 2013).

The assessment of spatial representativeness is required for different tasks:

- Station classification and network design (Spangl et al, 2007; Henne et al., 2010; Malherbe et al., 2013). Information about spatial representativeness of air quality monitoring station is useful to classify the stations and to find out the best station locations for the design of new networks.

- Air quality and exposure assessment (Geiger at al., 2014; Martin et al., 2014). The spatial representativeness of monitoring data is required, for example, to estimate the air quality standards exceedances areas and to quantify the population exposure to the air pollution.

- Model validation and data assimilation (Jansen et al., 2012; Lefebvre et al., 2013). For model validation or data assimilation, it is important to know the spatial representativeness of the measurements and this should be in accordance to the spatial scale of the model.

All of these studies show that further progress is needed towards a harmonized methodological framework about spatial representativeness. In this way, FAIRMODE is highly concerned in advancing the assessment procedure of spatial representativeness. A next step would be to analyse the feasibility of an intercomparison exercise of methods for the assessment of the spatial representativeness of monitoring sites, which is the scope of this report.

3. Scope and methodology

As mentioned above, an agreement on a procedure for assessing spatial representativeness has not been identified yet. As a next step to reach such agreement, an intercomparison exercise of procedures for assessing the spatial representativeness of air quality stations is proposed. The main objective of this intercomparison exercise would be to explore the strengths and weaknesses of the different contemporary approaches for computing the spatial representativeness areas by applying them to a jointly used example case study. For this purpose, the total variety and diversity of procedures which are in use today (ranging from methods with moderate complexity, used for pragmatic purposes, to those which involve higher levels of data and computational requirements) will be taken into account.

However, previous to the intercomparison exercise, a feasibility study to investigate about the best way to compare the outcomes of the different spatial representativeness methods (i.e. to evaluate whether the intercomparison should rather be directed towards a comparison of methodologies or towards an actual validation) was found necessary.

The scope of this report is to analyse the feasibility of the intercomparison exercise and the objectives are the following:

1. The identification of prospective candidate methodologies to be considered in an intercomparison.

2. The requirements on shared datasets of the example case study.

3. The assessment of the comparability of the different types of spatial representativeness results to be retrieved. The methodological diversity of the different approaches is anticipated to impose significant challenges in this regard.

4. To identify the limitations to be expected.

The feasibility study has been carried by completing the following steps:

1. A bibliographical review of the studies published in scientific journals or technical reports.

2. Definition of the state of the art about spatial representativeness and identification of relevant experts in this field after reviewing the papers and reports found in the bibliographical review.

3. A survey based on a questionnaire for querying the experts about characteristics of the methodologies used by them.

4. Analysis of the survey results.

5. Evaluating the feasibility of an intercomparison exercise for methodologies estimating SR of monitoring stations.

4. Questionnaire

4.1. Design

In a first step a draft of the questionnaire was sent to a selected number of experts which provided reviews of aspects to be improved or replaced. These participants were recruited from the FAIRMODE Steering Group members and few representatives of the AQUILA-SCREAM group.

After completion of the final questionnaire it was disseminated to a comprehensive group of professionals. In specific, we have used the following contacts:

- the complete FAIRMODE distribution list (ca 600 email contacts)

- the FAIRMODE national contact points (33 email contacts)

- the members of AQUILA (37 national air quality reference laboratories)

- a selected group of international experts, who have been identified by the literature study (23 email contacts)

- the group of reviewers of the questionnaire (7 e-mail contacts)

A total of 22 groups from 14 different countries answered the questionnaire (Table 1). The representation of the groups (that replied) into countries is shown in Figure 1.

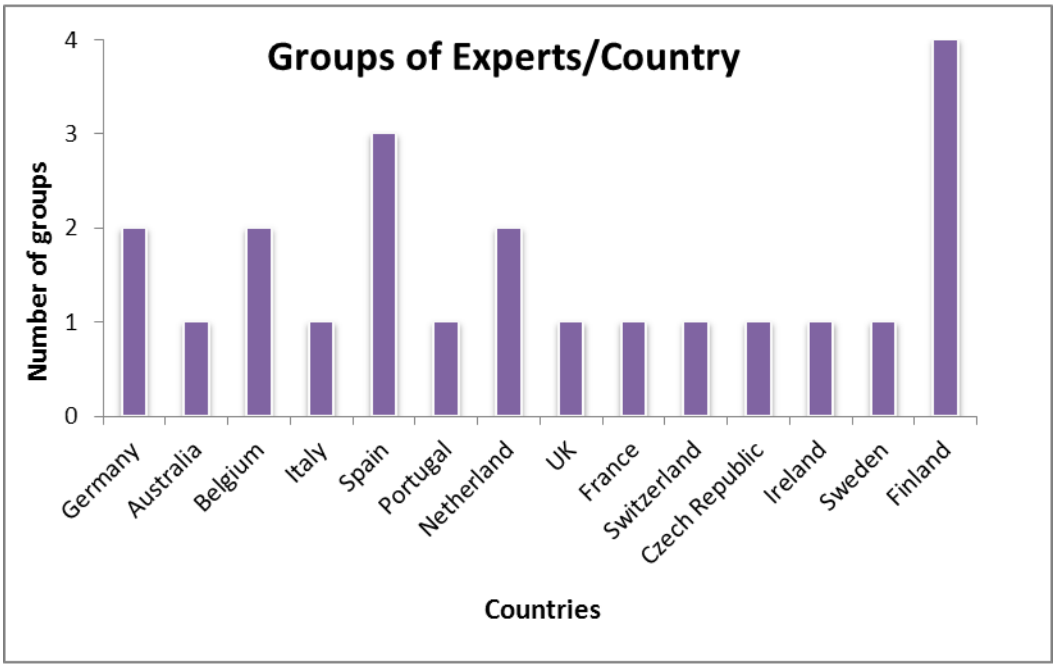

Figure 1.Groups that replied the questionnaire by countries.

Expert	Institution	Country
Jutta Geiger	LANUV, FB 42	Germany
Wolfgang Spangl	Umweltbundesamt Austria	Austria
Jan Duyzer	TNO	Netherland
David Roet	Flemish Environment Agency (VMM)	Belgium
Antonio Piersanti	ENEA	Italy
Maria Teresa Pay	Barcelona Supercomputing Center	Spain
Ana Miranda	University of Aveiro	Portugal
Florian Pfäfflin	IVU Umwelt GmbH	Germany
Ronald Hoogerbrugge	National Institute for Public Health and the Environment	Netherland
Fernando Martin	CIEMAT	Spain
Daniel Brookes	Ricardo-AEA	UK
Laure Malherbe	INERIS	France
Stephan Henne	Empa	Switzerland
Stijn Janssen	VITO	Belgium
Roberto San Jose	Technical University of Madrid (UPM)	Spain
Jan Horálek	Czech Hydrometeorological Institute	Czech Republic
Kevin Delaney	Irish EPA	Ireland
Lars Gidhagen	Swedish Meteorological and Hydrological Institute	Sweden
Hannele Hakola	Finnish Meteorological Institute	Finland
Tarja Koskentalo	Helsinki Region Environmental Services Authority	Finland
Erkki Pärjälä	City of Kuopio, Regional Environmental Protection Services	Finland
Miika Meretoja	City of Turku / Environmental Division	Finland

Table 1: Experts, groups and countries that replied the questionnaire.

4.2. Description of the questionnaire

The questionnaire consists of 11 questions divided into 5 different blocks:

1. **<u>Context to evaluate the SR of AQMS</u>.** Question 1. In this question, the groups are asked for information about their application of spatial representativeness studies such as station sitting, data assimilation, model evaluation, AQ reporting, etc.

2. **<u>Legislative or regulatory purposes</u>.** Question 2. Some SR studies are carried out for legislative or regulatory purposes such as air quality management, legislation compliance or development of new legislation. The information obtained is concerning if groups are using these studies with this purpose.

3. **<u>Definition of SR</u>**. Question 3. There is no well-established definition of SR and in this question we ask about the particular definitions used for each methodology.

4. **<u>Methodologies</u>**. Questions 4-7. In these questions, descriptions of the different methodologies are requested. Note that there are groups that are using several methodologies.

- Question 4. A general description of the methodology including time and spatial scale, targeted pollutant, etc. is asked for.

- Question 5. This question is focused on the feature of input data needed for each SR methodology. For example: regular air quality monitoring data, air quality data from dedicated measuring campaigns, data derived from air quality modelling, emission inventories, meteorological data, other surrogate data, station classification, etc.

- Question 6. This question is focused on output data provided by each SR methodology. The outputs might range from a detailed geospatial description of the SR area by maps to simplified geometric concepts (e.g. size or radius of the SR area) or to qualitative descriptions of SR.

- Question 7. This question is concerning the generalization of the methodology and its transferability to other regions to another region county.

5. **<u>Intercomparison exercise.</u>** Questions 8 – 11. These questions are related to the proposed intercomparison exercise.

- Question 8. It is concerning the interest in the participation in the intercomparison exercise.

- Question 9. This question is about the range of input data needed to implement the SR methodology (set of pollutants, site requirements and data sets).

- Question 10. In this question, the groups are asked to provide their recommendations about the best way to compare the outputs of different methodologies.

- Question 11. This question is about confidentiality of the intercomparison exercise results.

4.3. Results and discussion

In this section, the answers of the survey are analysed in order to obtain information about contemporary methodologies to compute SR and about the feasibility of the proposed intercomparison exercise.

Question 1. Context

Figure 2 shows a bar diagram with the context in which each group uses SR studies. Note that the individual groups are using SR studies for a variety of applications. They are mostly applied to station siting and network design (72% of the groups), and to air quality reporting (68%). In addition, SR is also evaluated in the context of station classification (59%), data assimilation for modelling (50%), model benchmarking or evaluation (55%). Finally, 41% of the groups make population exposure studies. In addition to the applications proposed in the questionnaire, some groups use SR studies for other purposes (18 %) such as health impact studies in the context of EU projects, climate research, licensing and enforcement activities concerning emissions from licensed facilities, trend analysis, receptor modelling and city planning.

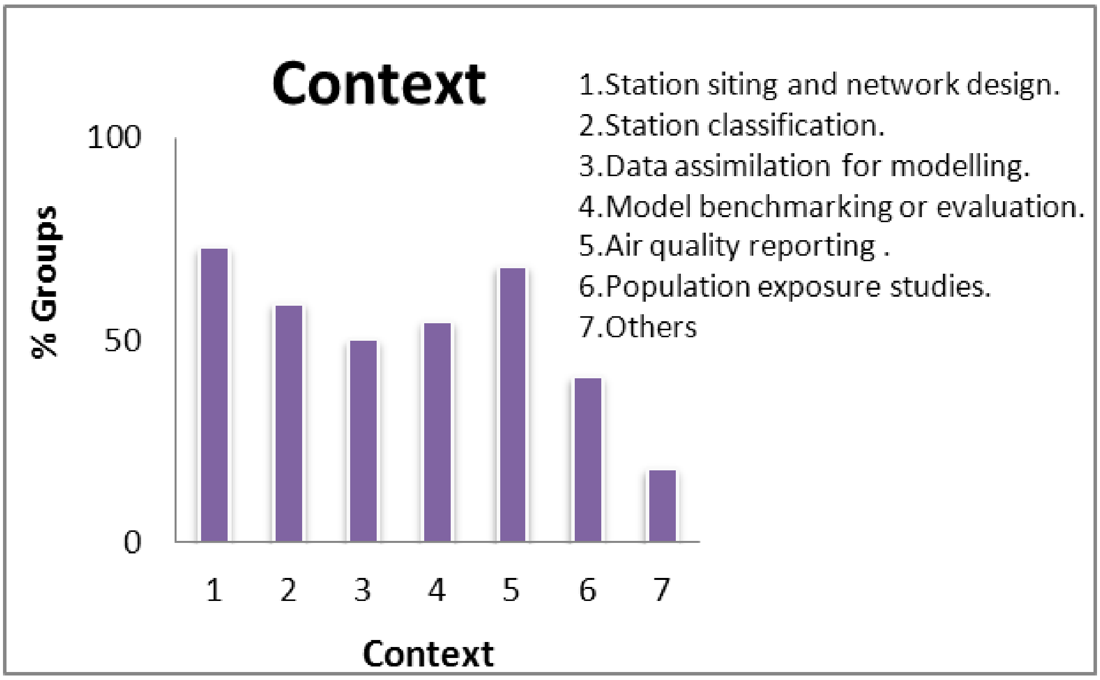

Figure 2. Answers to question 1: Context in which spatial representativeness studies are employed (% of Groups).

Context	Number of Groups
Station siting and network design	16
Station classification	13
Data assimilation for modelling	11
Model benchmarking or evaluation	12
Air quality reporting	15
Population exposure studies	9
Others	4

Table 2: Answers to question 1: Context in which spatial representativeness studies are employed.

Question 2. Regulatory purposes.

The majority of groups (68%) link their SR studies to legislative or regulatory purposes.

Question 3. Definition of Spatial Representativeness

Different definitions have been provided by each group. In order to analyse the answers (Figure and table 3), we classify the definitions in five groups.

1. **Similarity of concentration:** This criterion is based in the idea that the concentration in the SR area has to be similar to the concentration at the monitoring site. In 10 cases, this definition was used. However, other criteria are added in several cases. In some cases the additional criteria are related to the AQ legislation. For example, if the station meets the air quality standards (limit, target, alert values or assessment or public information thresholds) its SR area must also meet them or on the contrary, if the station does not meet AQ standards, its SR area must not meet them in addition to the concentration similarity (Martín et al, 2014). In other cases, the criteria include the similarity of the emissions and the dispersion conditions on regional and local scale (Spangl et al, 2007). Another additional criterion is that the concentration similarity has to be met along most part of the time series of concentrations in the SR area with respect to the monitoring site.

2. **Legislation**: 3 of the declared methodologies in the questionnaire replies use definitions based only on Air Quality Directives (e.g., 2008/50/EC, 2004/107/EC).

3. **Station classification**: 1 method uses a definition based on station classification.

4. **Emission variability**: 3 methods use a criterion based on the idea that if there is a high spatial variability of the emissions, there should also be a high variability in concentrations and then, the SR area should be small. On the contrary, if little spatial emission variability is observed the SR must be large. In fact, this criterion is strongly related to the concentration similarity criterion.

5. **Other definitions**: In one case, the following definition was given: “The level into which the station represents the relevant type of the area.”

It is important to note that in 7 cases no definition was provided.

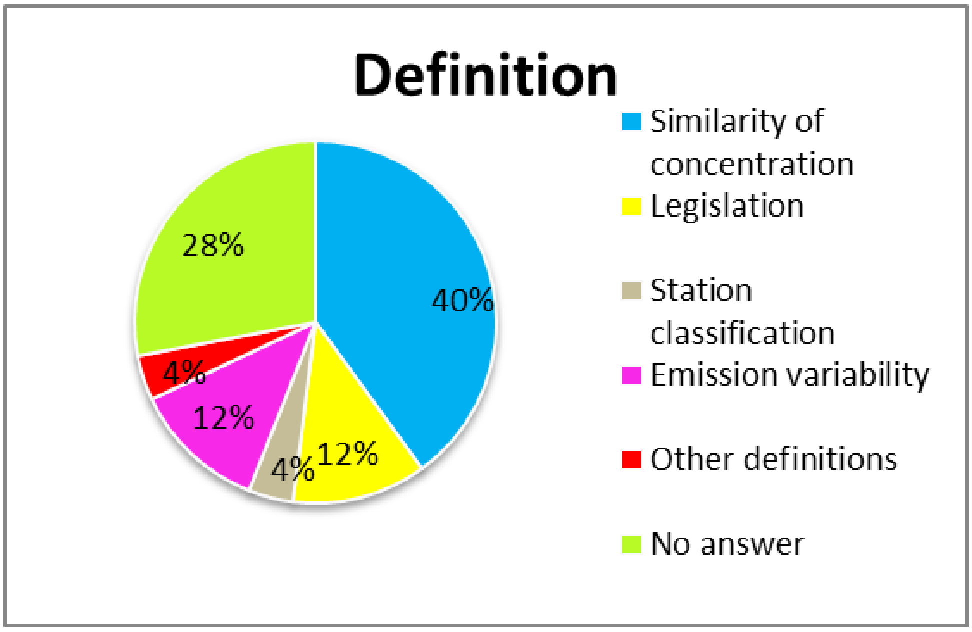

Figure 3. Answers to question 3: Definition of spatial representativeness of the declared methodologies (%).

Definition	**Number of Methodologies**
Similarity of concentration	10
Legislation	3
Station classification	1
Emission variability	3
Other definitions	1
No answer	7
Total	**25**

Table 3. Answers to question 3: Definition of spatial representativeness of the declared methodologies.

Question 4. Methodologies.

4.a. Type of methodologies

To this question, detailed descriptions of the methodologies were required. Three groups have declared two methodologies. The total declared methodologies were 25. In order to analyse the response we have classified the declared methodologies into four generalised types:

i. Methods which are immediately based on an estimate of the spatial distribution of pollutants (concentration fields derived from observations or modelling)

ii. Methods which are based on pollutant proxies and / or surrogate data

iii. Methods which are linked to the classification of stations or sites

iv. Other types of methods or combinations

Note that several groups classified their methodologies in more than one type.

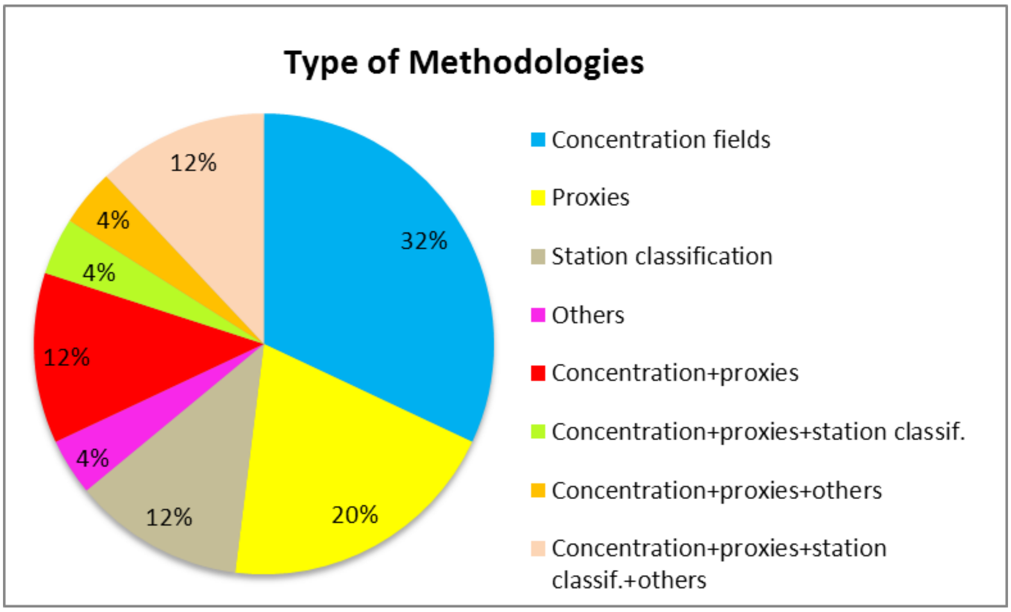

Figure 4. Answers to question 4a. Types of declared methodologies (%).

Type of Methodology	Number of Methodologies
Concentration fields	8
Proxies	5
Station classification	3
Others	1
Concentration+proxies	3
Concentration+proxies+station classif.	1
Concentration+proxies+others	1
Concentration+proxies+station classif.+others	3
Total	**25**

Table 4. Answers to question 4a. Types of declared methodologies.

Most of the groups (16) use methodologies based totally or partially on the spatial distribution of pollutant concentrations, 8 of them are also based on other types. 13 groups use methodologies based totally or partially on proxies or surrogate data. The station classification is totally or partially used by 7 groups. Other methodologies or combinations are used by 1 group. Many groups are working with more than one methodology (3 groups are using all the listed methodologies) either separately or in a combination of them. Furthermore, some groups apply other non-listed methodologies taking into account other aspects such as the local knowledge or expert evaluation by visiting the area around the station or considering other data like meteorological data (see Figure 4 and Table 4).

4.b. Type of stations

More than 70% of the methodologies have been or could be applied to all types of stations. Some groups declared to apply their methodologies for two or more types of stations (Figure 5 and Table 5). In very few cases, the methodologies are applied only to traffic, background or remote stations.

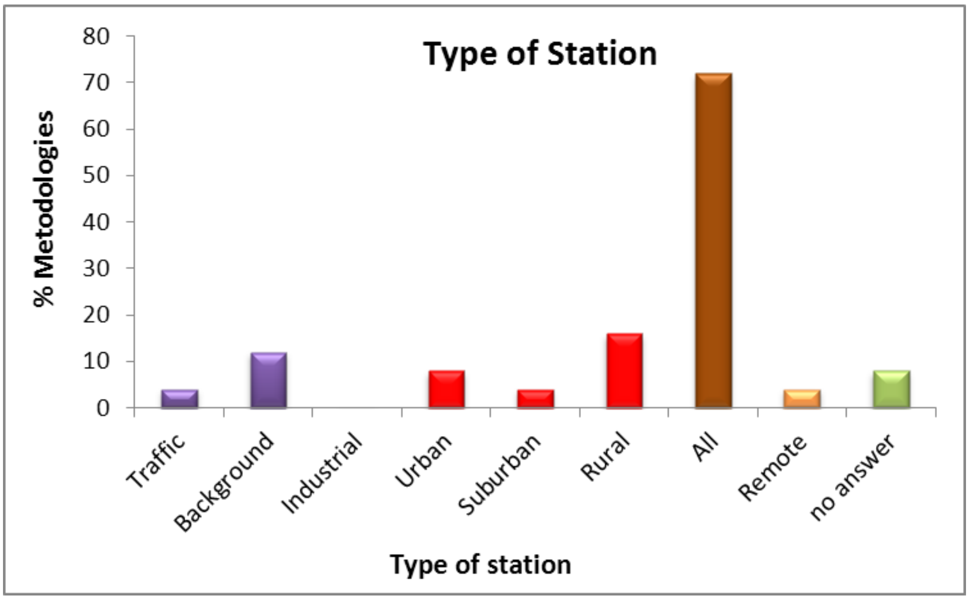

Figure 5. Answers to question 4b. Types of stations used by the declared methodologies (%).

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Type of station	Number of Methodologies
Traffic	1
Background	3
Industrial	0
Urban	2
Suburban	1
Rural	4
All	18
Remote	1
No answer	2

Table 5. Answers to question 4b. Types of stations used by the declared methodologies.

4.c. Main pollutants

Most of the methods can be applied to the main pollutants of the legislation (Figure 6 and Table 6). The more mentioned pollutants to which the methodologies have been or could be applied, are PM_{10} (22 methods out of 25), O_3 (17 out of 25), NO_2 (22 out of 25), SO_2 (19 out of 25) and $PM_{2.5}$ (19 out of 25). Some methodologies are restricted to the primary pollutants, others to the main pollutants of the Directives and others have no restriction about the pollutant.

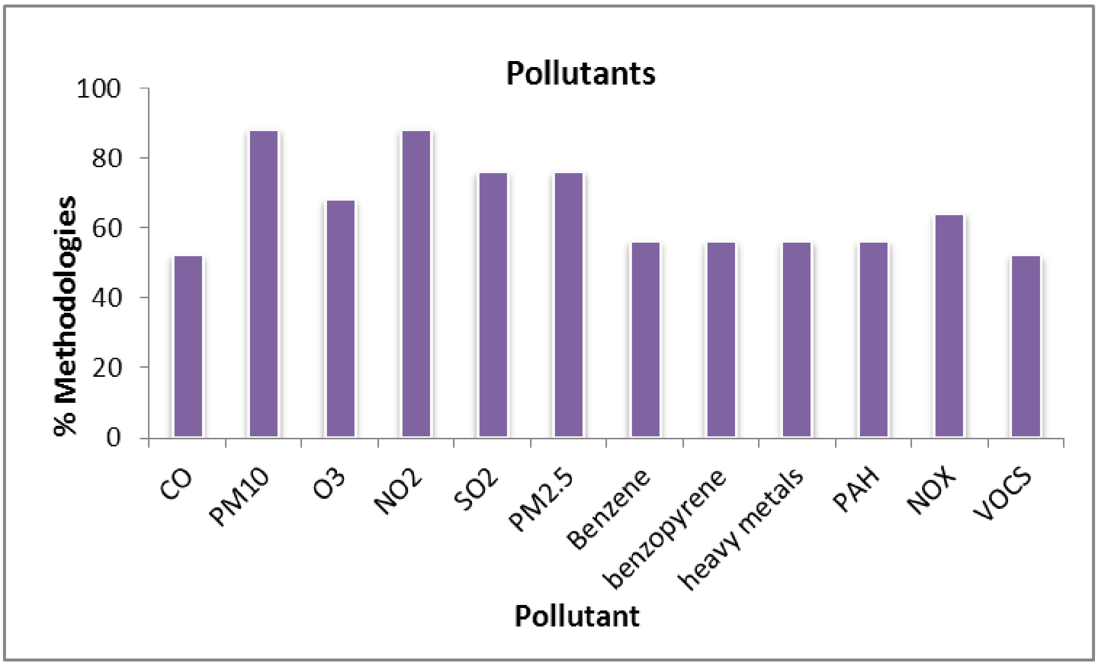

Figure 6. Answers to question 4c. Main pollutants used by the declared methodologies (%).

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Pollutants	Number of Methodologies
CO	13
PM10	22
O3	17
NO2	22
SO2	19
PM2.5	19
Benzene	14
Benzopyrene	14
Heavy metals	14
PAH	14
NOX	16
VOCs	13

Table 6. Answers to question 4c. Main pollutants used by the declared methodologies.

4.d Spatial and temporal scales, spatial and temporal resolutions

Regarding the temporal scale of the methodologies (see Figure 7 and Table 7), 10 methodologies can be applied to any scale. Others are restricted to annual (8) or daily (1) scales. Six groups did not answer to this question.

The time resolution is generally limited by the resolution of the input data (measurement of pollutant concentration, emission data, etc) or by the model resolution.

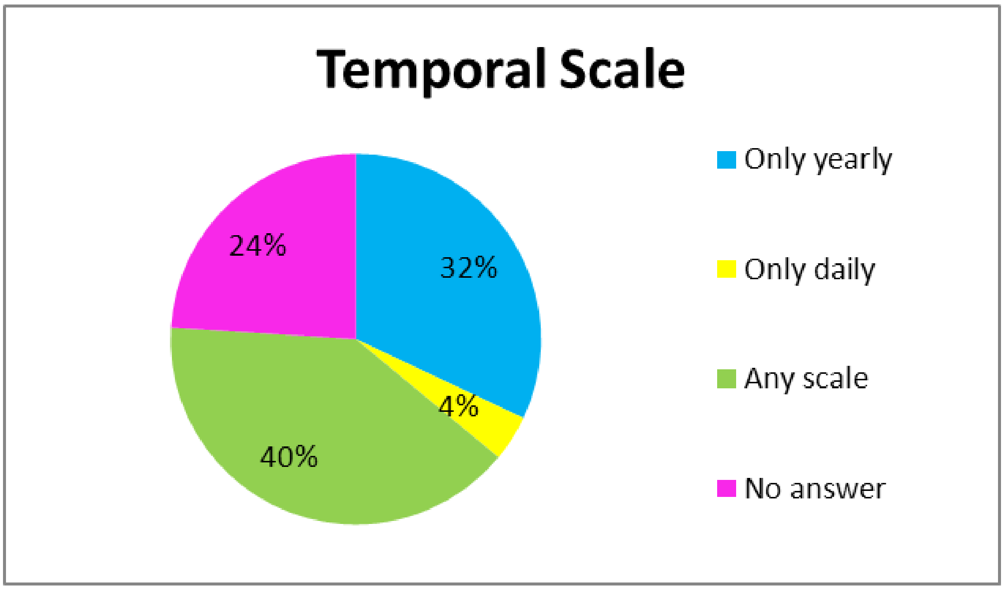

Figure 7: Answers to question 4.d. concerning the temporal scale of the declared methodologies (%).

Temporal Scale	**Number of Methodologies**
Only yearly	8
Only daily	1
Any scale	10
No answer	6
Total	**25**

Table 7: Answers to question 4.d. concerning the temporal scale of the declared methodologies.

Regarding the spatial scale, some groups did not explicitly declare the spatial scale but it can be deduced from the information provided about the spatial resolution. Spatial resolution depends on the spatial scales. For local scales, spatial resolution is a few meters; for urban, it is ranging from hundreds of meters up to 1 km, and for regional, it is more than 1 km.

The analysis of the questionnaire replies is shown in Figure 8 and Table 8. Many groups answered that their methodologies are multi-scale. Nine methodologies can be applied to scales ranging from local to regional, 5 from urban to regional, and 2 from local to urban. Other methodologies can be applied only to one scale. For example, 5 of them are only for regional scale, 1 only for urban scale and 1 for continental scale. Two groups did not answer to this question.

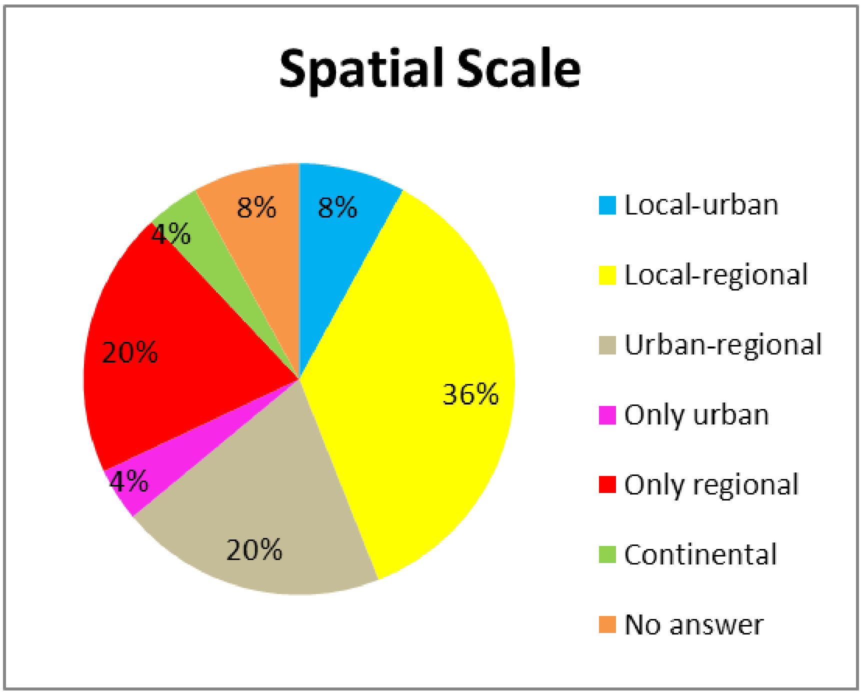

Figure 8: Answers to question 4.d. concerning the spatial scale of the declared methodologies (%).

Spatial Scale	**Number of Methodologies**
Local-urban	2
Local-regional	9
Urban-regional	5
Only urban	1
Only regional	5
Continental	1
No answer	2
Total	**25**

Table 8: Answers to question 4.d. concerning the spatial scale of the declared methodologies.

4.e Available information

Following the responses of the questionnaire, for 18 methodologies related documentation is available. For five of them, the experts can also provide research software that is used for the computations (Figure 9 and Table 9).

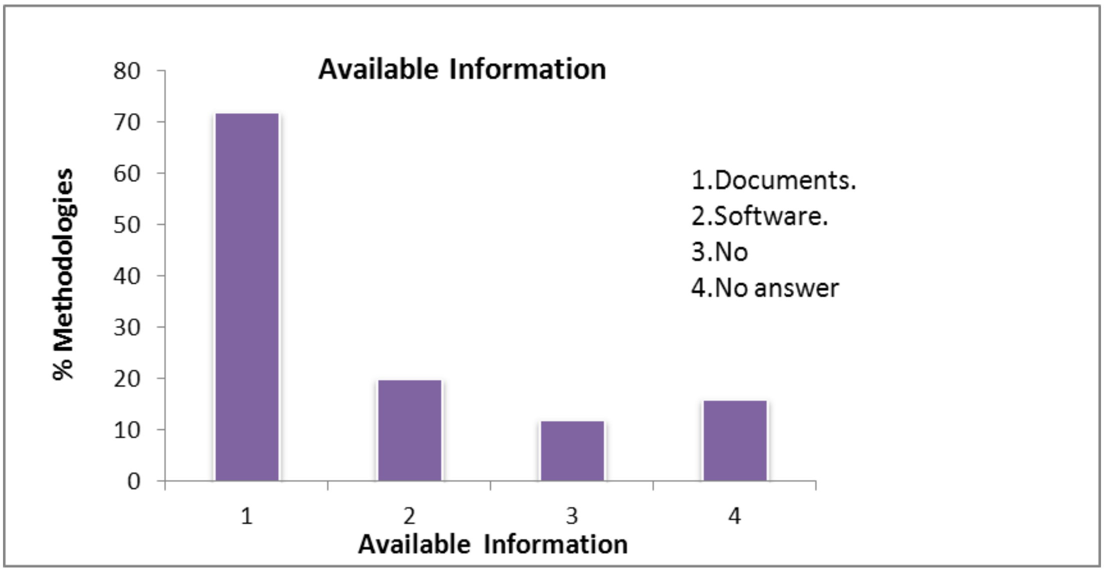

Figure 9: Answers to question 4.e. concerning the availability of information for the declared methodologies.

Available Information	**Number of Methodologies**
Documents	18
Software	5
No	3
No answer	4

Table 9: Answers to question 4.e. concerning the availability of information for the declared methodologies.

4.f. Can the method be used to estimate if an Air Quality Monitoring Station (AQMS) is representative of similar locations which are not located in the immediate vicinity of this specific AQMS?

The groups corresponding to 7 of the 25 declared methodologies did not answer to this question. In 3 cases, the answer was NO and in 13 cases, it was YES (Figure 10 and Table 10). Two participants said that it is a debatable question. One of them comments that this might be possible theoretically but not in the real cases, because "*Even if there were possible station sites measuring 'similar values' this might be due to different reasons.*"

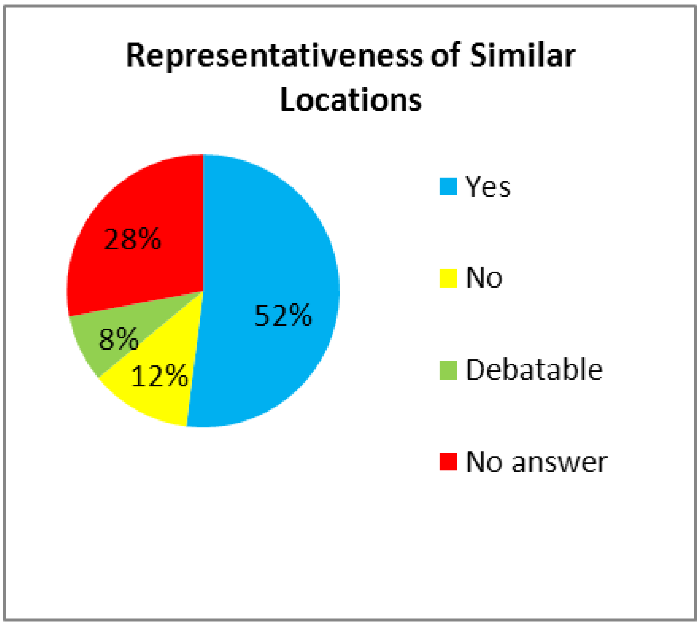

Figure 10: Answers to question 4.f. concerning representativeness of similar locations (% of the declared methodologies).

Representativeness of Similar Locations	**Number of Methodologies**
Yes	13
No	3
Debatable	2
No answer	7
Total	**25**

Table 10: Answers to question 4.f. concerning representativeness of similar locations

4.g. Limitations of the methodologies

Concerning the limitations of the methodologies, mostly they are limited to the availability (9) and uncertainties (10) of input data (emissions, meteorology, concentrations, land cover, traffic intensities, etc). Other frequent limitations were related to the modelling uncertainties (6) and the temporal and spatial resolution (7). Other limitations can rise from computational resources affecting the time and spatial resolution (4), definition of the methodology parameters (3), pollutants (2), local or expert knowledge (1) and modelling domain (1) (which limits the spatial scale). Only in two cases, the groups declared not to have limitations. There was no feedback in three cases.

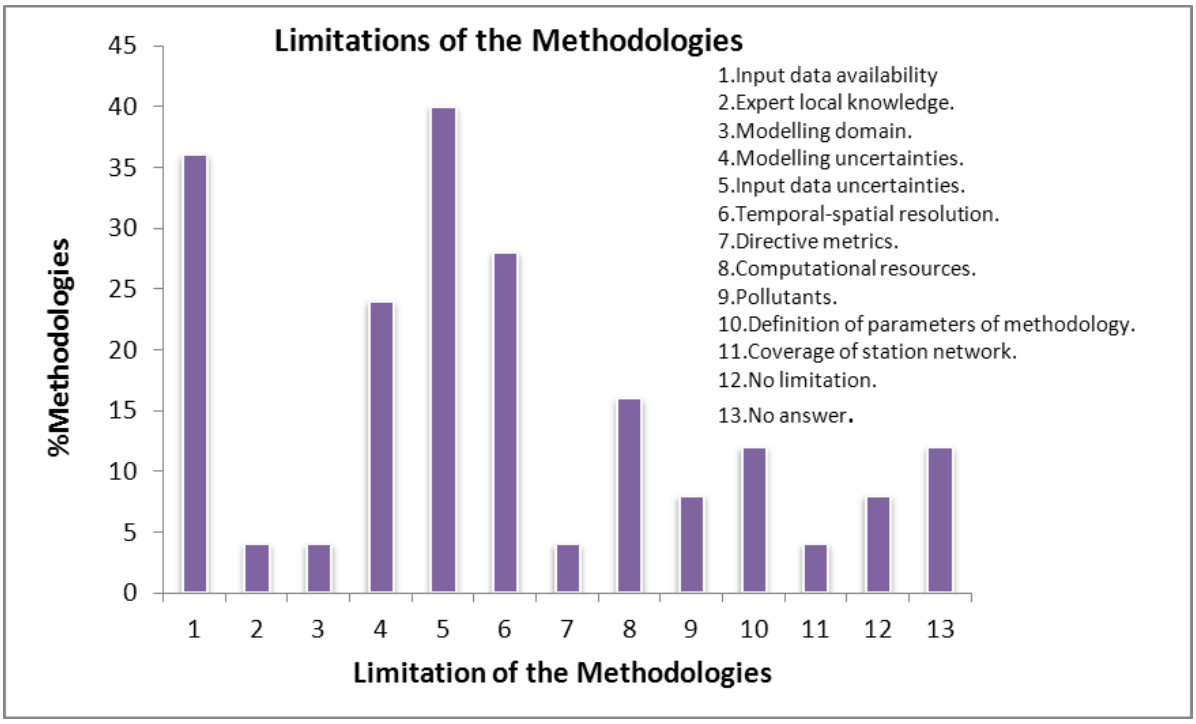

Figure 11: Answers to question 4.g. concerning limitations of methodologies

Limitation of the Methodologies	Number of Methodologies
Input data availability	9
Expert or local knowledge	1
Modelling domain	1
Modelling uncertainties	6
Input data uncertainties	10
Temporal-spatial resolution	7
Directive metrics	1
Computational resources	4
Pollutants	2
Definition of parameters of methodology	3
Coverage of station network	1
No limitation	2
No answer	3

Table 11: Answers to question 4.g. concerning limitations of methodologies

Question 5. Input data.

Most of methodologies require several types of input data. For example, for air quality modelling one needs emission inventories, meteorological data, etc.

In addition, some input data are used in a different way by different methodologies. For example, emission inventories are used as proxy data in some methodologies and other methodologies use them as input data for modelling.

Figure 12 and Table 12 show that most of the groups need emission inventories and meteorological or/and climatological data and air quality monitoring data (19 cases). A high percentage of methods use data from air quality modelling data (18) and other surrogate data (15). In addition, for 11 declared methodologies, data from measuring campaigns are needed and finally, station classification is required for 6 methodologies This means that all of these types of data are required in order to perform the intercomparison exercise. The lack of one of these input data would cause the exclusion of several methodologies.

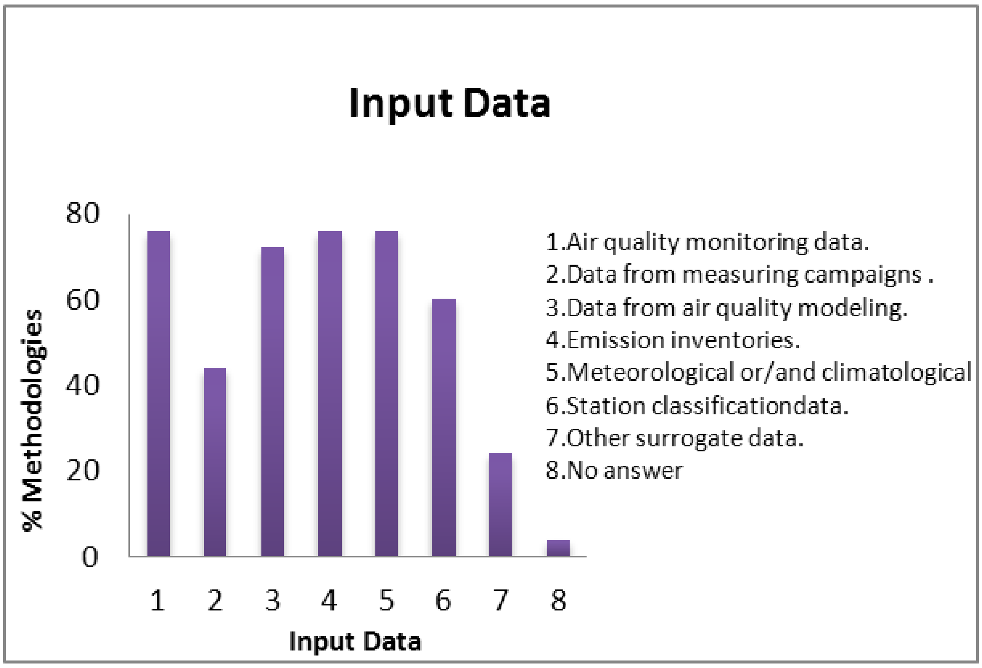

Figure 12. Answers to question 5 about types of input data (% of the declared methodologies).

Input Data	Number of Methodologies
Air quality monitoring data	19
Data from measuring campaigns	11
Data from air quality modelling	18
Emission inventories	19
Meteorological or/and climatological data	19
Other surrogate data	15
Station classification	6
No answer	1

Table 12. Answers to question 5 about types of input data.

Some groups provided more detail about requirements of the input data of their methodologies. Concerning regular air quality monitoring data, annual or daily averaged AQ network data form national, regional or local official networks for several years are required for some of the declared methodologies. However, in spite anyone asked for hourly data, we think they can be needed by many people. In addition, location and characteristics of stations are needed.

Some groups have used data from measuring campaigns, which have been carried out with passive samplers and mobile monitoring stations. One group explained that they deployed about 40-50 sampling points for an urban area and for traffic stations the sampling points were distributed along the roads and at increasing distances from the roads. Other group used passive sampling for NO_2 and mobile measurement for $PM_{2.5}$.

Modelling was frequently used for generating concentration maps. Different models are used depending on the scale or the pollutant such as Gaussian, Lagrangian, Eulerian, Chemical Transport Models (CTM), Computational Fluid Dynamics (CFD) modelling, etc. Some used models are Gaussian Plume model (IFDM), URBIS model, CALIOPE-AQFS model, AMS-MINNI model, lagrangian particle model SPRAY, CFD software (STAR CCM+), WRF-CHIMERE combined with measurements, PCM model, CAMx, SYMOS model, EMEP model and regional SILAM model. The spatial resolutions range from 1 m (for local-street scale) to several kilometres (for regional or continental scale).

Concerning emission inventory data, they have to cover all main sources (domestic sector, power generation, traffic, industry, etc) and taking into account area, line and point sources (including location and characteristics of stacks). In some cases the emission inventories cover a large range of pollutants. The spatial resolution depends on the spatial scale of the study (from a few meters to few kilometres). Some are gridded data but in other cases are provincial data. Temporal resolution is frequently yearly data but in some cases these data have to be distributed to hourly data considering the time profiles of source activity.

Meteorological input data used by the participants are from stations or from models. Meteorological measurements are from official networks providing hourly data of wind direction and speed, temperature, precipitation, etc and other kind of data such as sounding data, stability class or 3D satellite data. The models used are, for example, WRF, ECMWF or GFS (providing boundary conditions to the WRF model).

Several types of surrogate data are required by the participants: land cover/land use (CORINE Land Cover), population density, road network, traffic intensities, topographic information, street classifications, digital data of buildings, etc.

Concerning the station classification input requirements, many groups said that this is not an input but it could be an output after estimating the SR area of the stations. One of 6 methodologies, that need station classification as input data, required the station classification according to the Exchange of Information Directive (EoI, 97/101/EC that became COMMISSION DECISION of 17 October 2001).

Question 6. Output data

The outputs of most of the methodologies are reported with maps contouring the representativeness area (18 cases). From the 18 cases reporting maps, simplified geometric concepts like area or scale can be derived as many survey participants explained. However, simplified metrics of SR area or SR scale were explicitly mentioned for only 11 and 9 of the declared methodologies, respectively. Similarity of locations and spatial variance are declared outputs of 6 and 1 methodologies, respectively. In 5 cases, qualitative outputs (photos, qualitative description and station categorization) are reported. Three methodologies provide outputs classified as other statistical means (pattern recognition, index of representativeness and other statistics). There was no feedback for three methodologies (Figure 13 and Table 13).

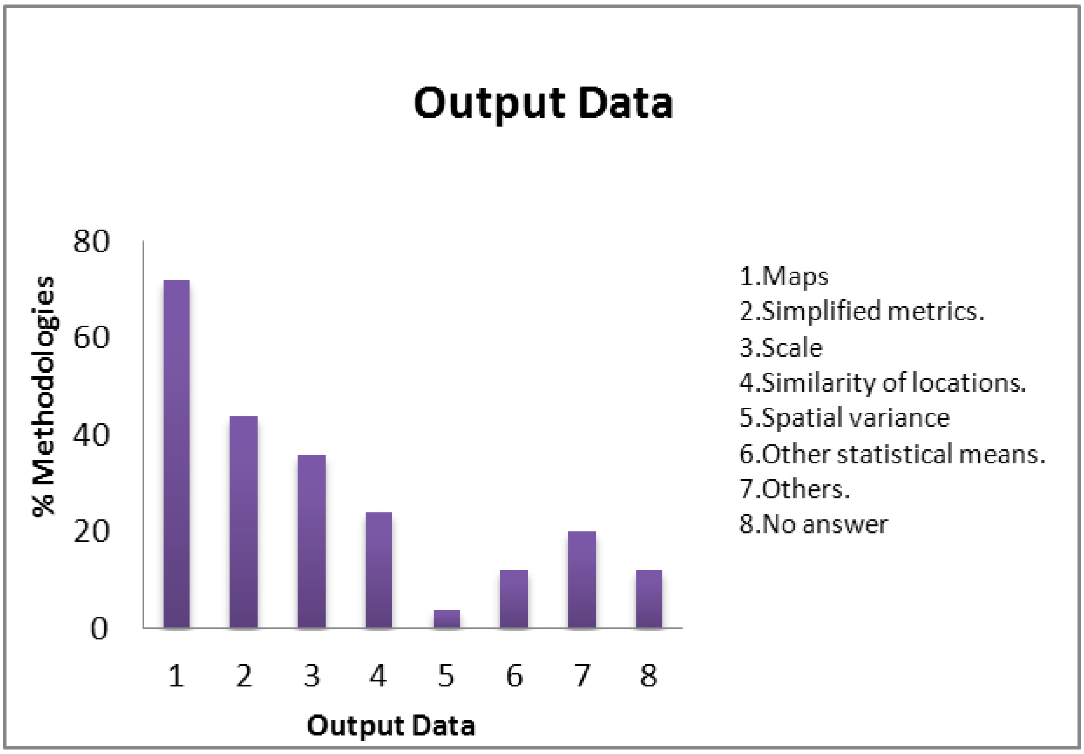

Figure 13. Answers to question 6 about types of output data (% of the declared methodologies).

Output Data	Number of Methodologies
Maps	18
Simplified metrics	11
Scale	9
Similarity of locations	6
Spatial variance	1
Other statistical means	3
Others	5
No answer	3

Table 13. Answers to question 6 about types of output data.

Question 7. Transferability of the methodology to other regions.

Most groups (21) consider their methodology transferable to other region or country with suitable input data (Figure 14 and Table 14). Two groups have concerns about the limitation of their methodology to flat or homogeneous terrains. One of the groups said that using its methodology to other regions would require a recalibration.

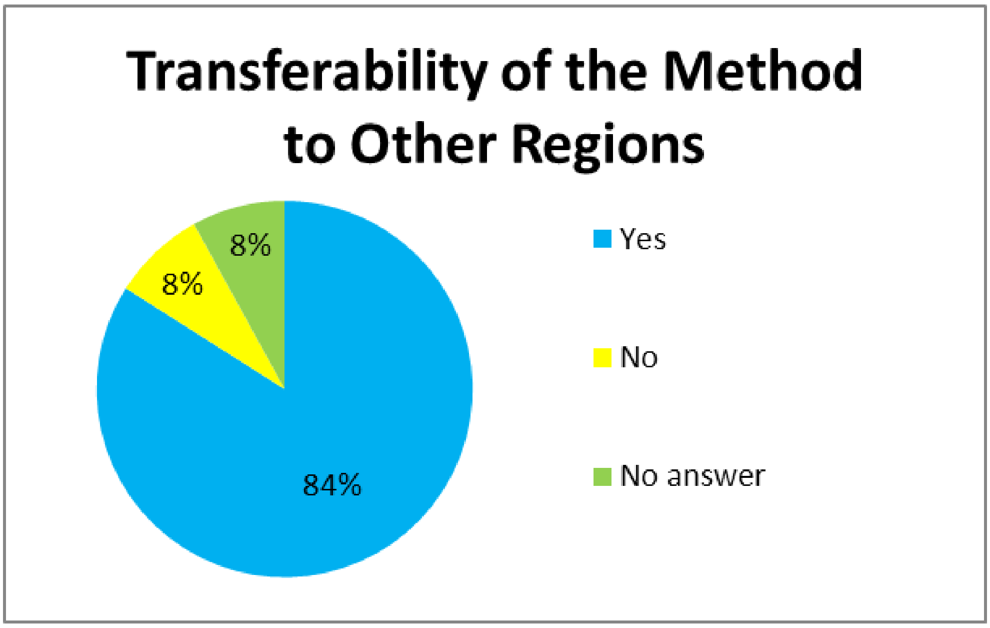

Figure 14. Answers to question 7.a. about transferability of the method to other regions (% of the declared methodologies).

Transferability of the Method to Other Regions	Number of Methodologies
Yes	21
No	2
No answer	2
Total	**25**

Table 14. Answers to question 7.a. about transferability of the method to other regions

Application the methodology to synthetic data sets would be possible for 16 methodologies and would not be possible for 6 (Figure 15 and Table 15). One of the groups said that the advice of an expert for generating a "simulated" experimental campaign data sets should be recommended.

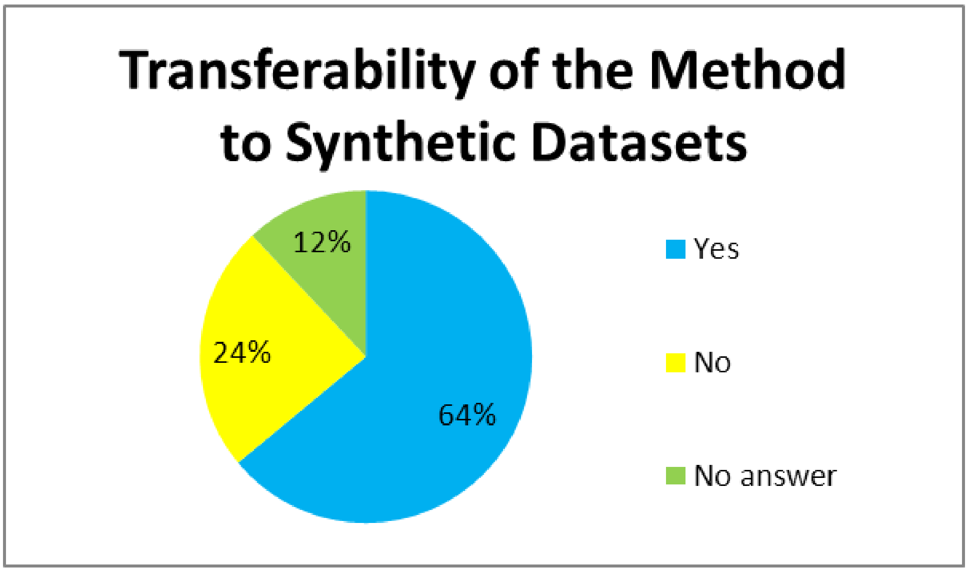

Figure 15. Answers to question 7.b. about transferability of the method to synthetic datasets (% of the Methodologies).

Transferability of the Method to Synthetic Datasets	Number of Methodologies
Yes	16
No	6
No answer	3
Total	**25**

Table 15. Answers to question 7.b. about transferability of the method to synthetic datasets.

Question 8. Participation in the intercomparison exercise:

Eighteen groups (corresponding to 20 methodologies) are interested to participate in the intercomparison exercise (though two of them have some doubts) (Figure 16 and Table 16).

The groups/institutions intending to participate are:

1. LANUV (Germany)
2. Umweltbundesamt (Austria)
3. TNO (Netherlands)
4. VMM (Belgium)
5. ENEA (Italy)

6. BSC (Spain)
7. UA (Portugal)
8. IVU Umwelt GmbH (Germany)
9. RIVM (Netherlands)
10. CIEMAT (Spain)
11. Ricardo-AEA (UK)
12. INERIS (France)
13. VITO (Belgium)
14. UPM (Spain)
15. FMI (Finland)
16. Helsinki RESA (Finland)
17. Kuopio, REPS (Finland)
18. Turku /ED (Finland)

Concerning the time schedule, the first half of year 2016 is convenient for all of the groups interested to participate.

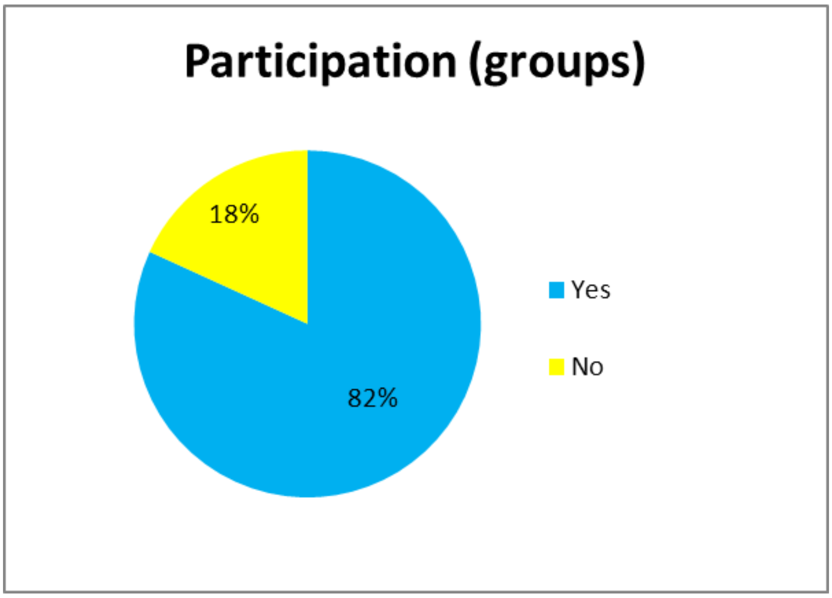

Figure 16. Answers to question 8 concerning the participation of groups in the intercomparison exercise (%)

Participation	Number of Groups
Yes	18
No	4
Total	**22**

Table 16. Answers to question 8 concerning the participation of groups in the intercomparison exercise

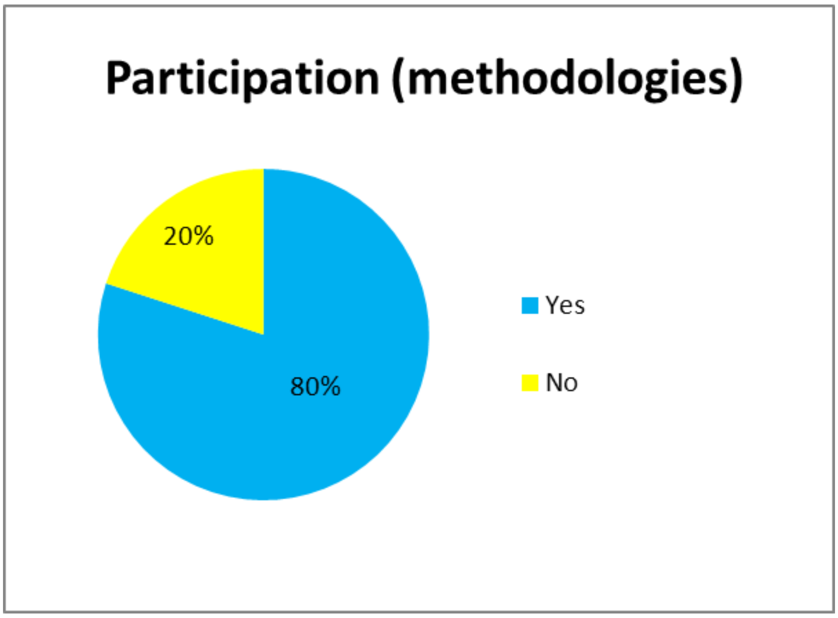

Figure 17. Answers to question 8 concerning the participation of methodologies in the intercomparison exercise (%).

Participation	Number of Methodologies
Yes	20
No	5
Total	**25**

Table 17. Answers to question 8 concerning the participation of methodologies in the intercomparison exercise

Question 9. Requirements related to the SR methodology:

No limitations about pollutants have been declared for most the methodologies (15) (Figure 18 and Table 18). Four methodologies have limited to some specific pollutants (primary pollutants or NO_2, PM_{10}, O_3 or $PM_{2.5}$).

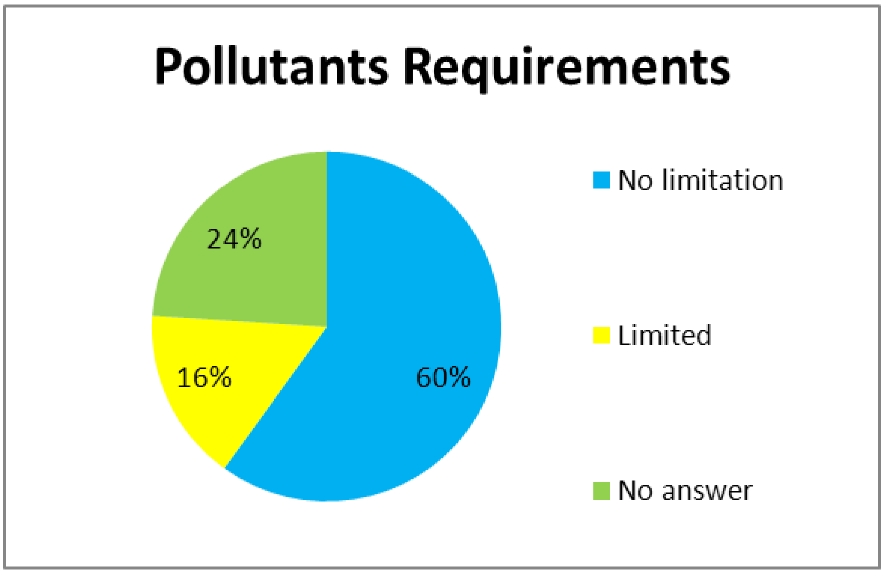

Figure 18. Answers to question 9.a concerning pollutant requirements (% of the declared methodologies).

Pollutants Requirements	**Number of Methodologies**
No limitation	15
Limited	4
No answer	6
Total	25

Table 18. Answers to question 9.a concerning pollutant requirements

Related to the site requirements, no limitation for 5 methodologies has been declared. There are 6 methodologies limited to the type of the stations, 4 are limited to the type of area and 5 to the extent of domain (Figure 19 and Table 19). Some comments are related to limitations to spatial scale, model resolution and type of terrain.

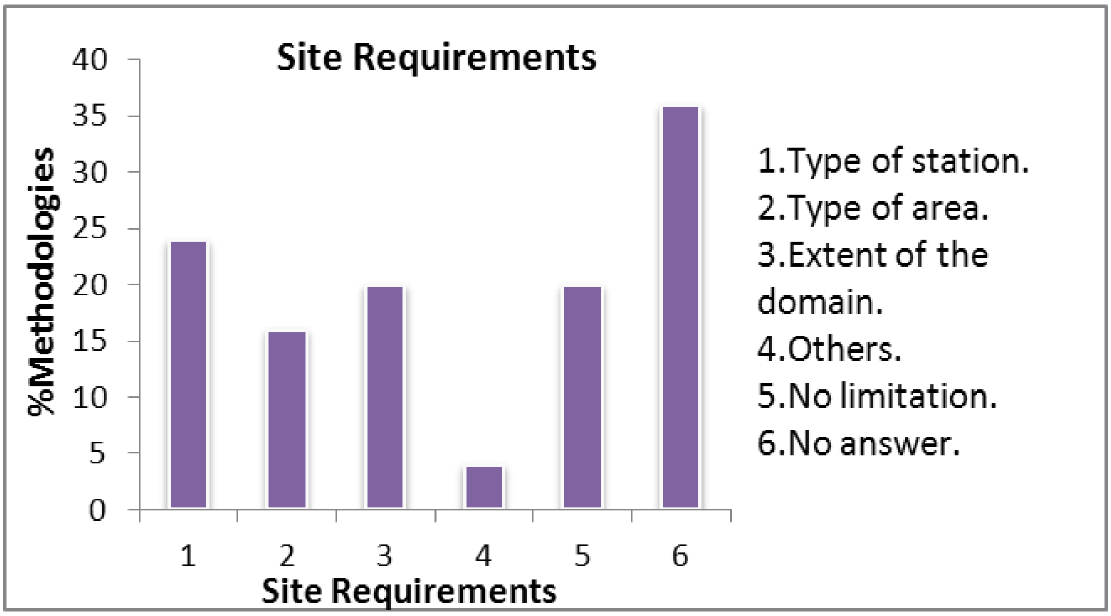

Figure 19. Answers to question 9.b concerning site requirements (% of the declared methodologies).

Site Requirements	Number of Methodologies
Type of station	6
Type of area	4
Extent of the domain	5
Others	1
No limitation	5
No answer	9

Table 19. Answers to question 9.b concerning site requirements

Finally, most of methodologies are limited to the availability of the input data (emissions, meteorology, concentrations, land cover, traffic intensities, etc.). Many participants require metadata information such as geographical coordinates of the station locations. Someone asks for data for at least one year, others require high resolution proxy data such as CORINE Land Cover, topography, building structure for traffic sites or special format such NETCDF files. Other requirements are that concentration measurements has to be according to these stated by the EU Directive 2008/50, climate information, hourly meteorological data, annual, daily, 8-hourly and hourly mean concentration data, AOT40 (May-July), percentiles related to target and limit values of pollutant concentrations.

Concerning emission data, some methodologies required spatially disaggregated emissions for the considered pollutants for the 3 source categories road traffic, residential heating, and industry.

Question 10. Recommendations

With respect to the question "Comparing the SR estimates between themselves?" most of the responses prefer to compare the extent (contour maps) of the SR areas (where applicable) (13 cases), but also there are several answers recommending to compare specific (statistical) attributes of the SR areas (e.g., order of magnitude) (10 cases). For 2 methodologies, comparing the area of exceedances is recommended (Figure 20 and Table 20).

One participant suggests that "it could be interesting to examine if the similarities or discrepancies between the SR estimates are more or less significant according to the concentration levels measured by the station". Another participant said that "the methods which are based upon proxy data, …, could yield very discontiguous representativity zones. This would make it hard to compare the area or worse, specific statistical attributes with methods that stick to zones around each station".

Another participant did an interesting comment related to some aspects to taken into account prior to the comparison. He pointed out that an agreement about the time scale, metrics (temporal aggregation of concentration values), SR parameters and criteria for similarity or representativeness has been reached before. He proposed that only the results of SR methodologies with the same definitions can be compared between each other.

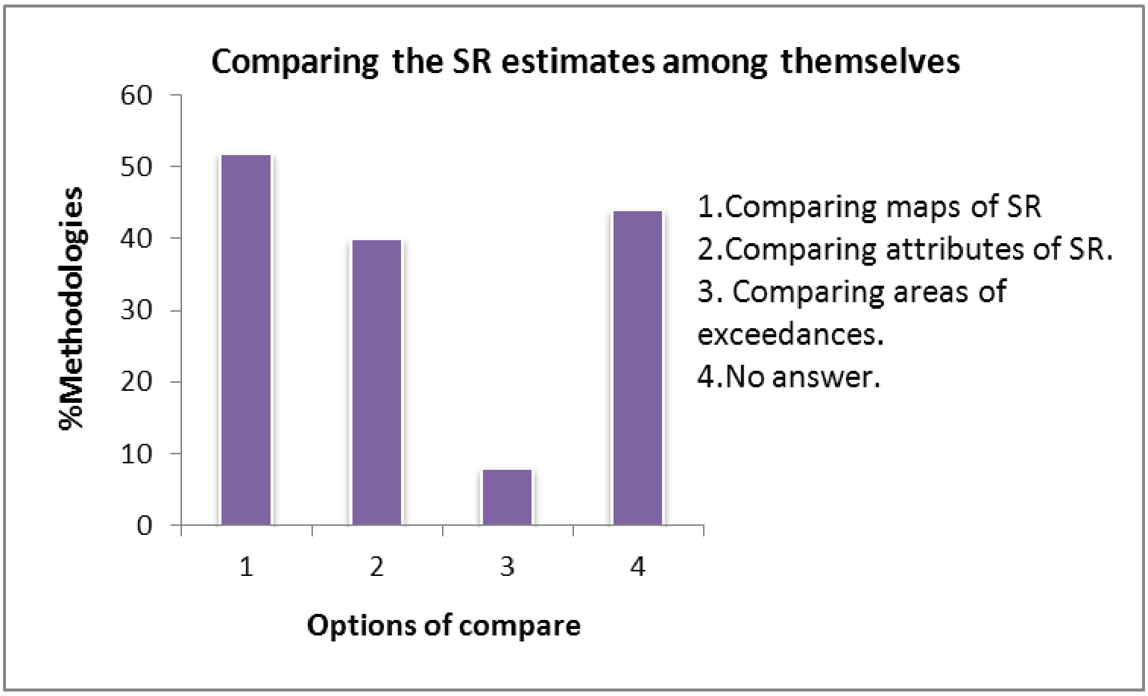

Figure 20. Answers to question 10.a concerning comparing the spatial representativeness estimates among themselves (% of the declared methodologies).

Comparing the SR estimates among themselves	**Number of Methodologies**
Comparing maps of SR	13
Comparing attributes of SR	10
Comparing areas of exceedances	2
No answer	11

Table 20. Answers to question 10.a concerning comparing the SR estimates among themselves

Concerning the question "*Comparing the SR estimates with a unified reference SR computed from detailed maps of measured concentration?*", an affirmative answer is for 10 cases, negative for 4 cases and it is not answered for 11 cases (Figure 21 and Table 21).

Several participants highlighted that there is no unified reference SR to compare but it should be useful to intercompare among the results from different types of methodologies. One participant also said it should be interesting to "*discuss the criteria used to obtain SR from the concentration map (or from surrogated variables) related with the purpose of the study of SR"*.

Other participant suggest the need of an agreement on the "unified standard SR" prior to the exercise and that "such comparison is then only possible – and easily performed – if the candidate SR follows the same definitions concerning time scale, metrics and parameters considered for SR as the reference SR".

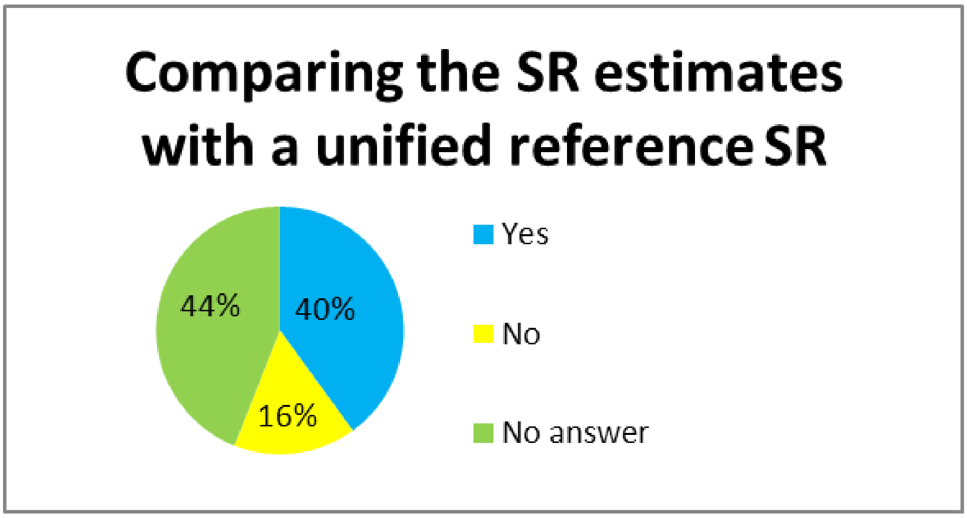

Figure 21. Answers to question 10.b concerning comparing the SR estimates with a unified reference SR (% of the declared methodologies).

Comparing the SR estimates with a unified reference SR	Number of Methodologies
Yes	10
No	4
No answer	11
Total	25

Table 21. Answers to question 10.b concerning comparing the SR estimates with a unified reference SR

Referring to the question "*Comparing the results of intermediate steps (where applicable)?*", many participants considered it useful to compare results (as modeling concentration maps or emission maps) of intermediate steps (10 cases) (Figure 22 and Table 22). One of the participants said that the main focus of the exercise should be put on the SR assessment methodologies, the input data used and the sensitivity of the results depending on the input data and their quality.

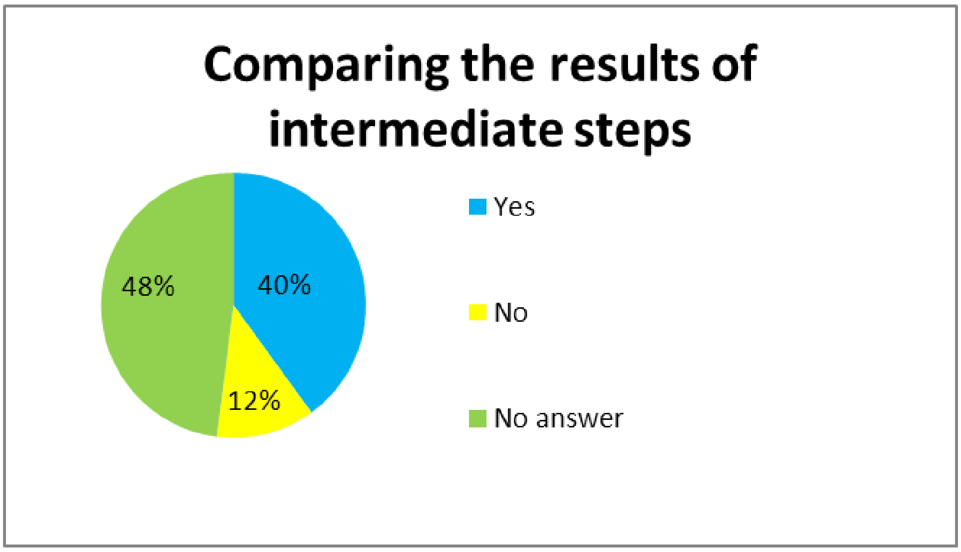

Figure 22. Answers to question 10.c concerning comparing the results of intermediate steps (% of the declared methodologies).

Comparing the results of intermediate steps	Number of Methodologies
Yes	10
No	3
No answer	12
Total	**25**

Table 22. Answers to question 10.c concerning comparing the results of intermediate steps

Question 11.Confidentiality of the intercomparison exercise

There is no concerns regarding confidentiality for most of the methodologies (16) (see Figure 23 and Table 23). Only one group has concerns about it.

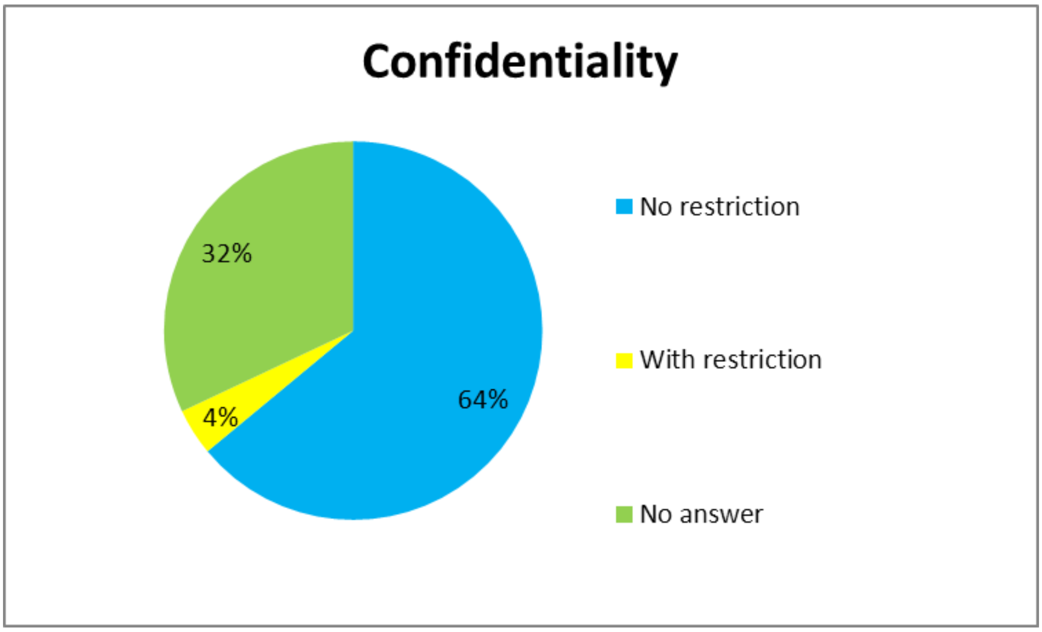

Figure 23. Answers to question 11 concerning confidentiality of the intercomparison exercise (% of the declared methodologies)

Confidentiality	**Number of Methodologies**
No restriction	16
With restriction	1
No answer	8
Total	**25**

Table 23. Answers to question 11 concerning confidentiality of the intercomparison exercise

5. Feasibility Study

5.1. Problems and objectives of the intercomparison exercise

The main objective of the intercomparison exercise will be to analyse the different contemporary methodologies to compute SR of air quality monitoring stations by applying them to a jointly used example case study. However, some problems should be solved in order to achieve this objective. The responses to the questionnaire show a large variety of methodologies and criteria about important issues as definition of SR, even also, some groups answer that they do not use any definition of SR. In most cases the definition depends on the methodology used. In this situation it is difficult to harmonize the criteria to define the SR area.

Other important problems are the limitations of each methodology such as spatial scale, temporal scale, type of pollutants, etc. In addition, each methodology needs specific input data. These issues should be taken into account in the design of the intercomparison exercise in order to open the exercise to as methodologies as possible. These questions are analysed in the next sections. First, a classification of the candidate methodologies to participate in the exercise is made in section5.2. In section 5.3a description of the proposed dataset is done.

In addition, the type of the outputs (features of SR) is different depending on methodology. In most cases, the SR area is represented by means of maps but in others it is qualitatively described. Therefore, the comparison of methodologies cannot be direct. In the section 5.4, this issue is discussed taking into account the responses to the questionnaire and what would be the best way to compare the outcomes of the different methodologies.

Finally, a proposal of the main features of the intercomparison exercise is shown in section 5.5.

5.2. Identification of methodologies

The responses about spatial scale show that, in order to open the exercise to as many participants and methodologies as possible, it is necessary that the intercomparison exercise should consist of two different spatial scales: local-urban scale and regional scale. Many groups can apply their methodologies at any scale but there are 5 of them restricted to regional scale and 2 to local-urban scale. In addition, the proposed exercise for two different spatial scales would provide valuable information about how SR features vary and how the different methodologies work depending on the scale.

Concerning the type of stations, most of the methodologies can be applied to all type of stations, but some cases are restricted to some particular types. This is related also to the spatial scale. The answer of the questionnaire revealed several site requirements for different methodologies. Table 24 shows the site requirements including information about the methodologies and groups interested to participate in the exercise.

Site Requirements	Number of Methodologies	Number of methodologies interested to participate in the intercomparison exercise	Number of groups interested to participate in the intercomparison exercise
Type of station	6	5	5
Type of area	4	3	2
Extent of the domain	5	5	5
Others	1	0	0
No limitation	5	5	5
No answer	9	6	6

Table 24. Site requirements of each methodology and group which intend to participate in the intercomparison exercise.

Concerning the pollutants, there is no limitation for most of the methodologies. However others are limited to the main pollutants of the legislation such as PM_{10}, $PM_{2.5}$, SO_2, O_3 and NO_x/NO_2. SR results can be only compared for the same pollutant. Taking into account the questionnaire replies of each group (Table 25) and the relevance of each pollutant, we propose the exercise to compute SR for PM_{10} and NO_2 in urban sites and PM_{10}, NO_2 and O_3 in regional sites. However, the participants could choose to do the exercise for all pollutants or for some of them. NO_2 is a pollutant closely related to the traffic, while PM_{10} is also affected by other sources. Ozone is a secondary pollutant reaching higher values in the rural areas surrounding the cities.

Pollutants Requirements	Number of Methodologies	Number of methodologies interested to participate in the intercomparison exercise	Number of groups interested to participate in the intercomparison exercise
No limitation	15	13	12
Limited	4	4	3
No answer	6	3	3
Total	25	20	18

Table 25. Pollutant requirements of each methodology and group which intend to participate in the intercomparison exercise.

As noted previously, the methodologies can be classified into 4 types (one divided into two subtypes:

- Concentrations maps around monitoring sites computed by:

  - Models: maps from model outputs
  - Measurements: maps computed with measurements obtained during campaigns deploying a dense grid of samplers (passive) or monitors. Passive samplers are the most frequently used.

- Proxies: spatial representativeness calculation with proxies.

- Station classification: spatial representativeness estimated depending on the features of the station.

- Qualitative analysis: spatial representativeness calculation according qualitative analysis.

Table 26 shows the methodologies used by each group, which intends to participate in the intercomparison exercise. Note that some groups use more than one method. As can be observed, there are a similar number of methodologies that can be applied to local/urban or to regional scale. Most of methodologies use models but the use of measurements, proxies and station classification is also relevant. Almost all groups provide maps for the SR areas, from which other parameters (such as areas, equivalent radius, etc) can be deduced.

Group	Methodology					Scale		Output
	Model	Measure.	Proxies	Station classification	Others	Local/ Urban	Regional	Maps
LANUV (Germany)	x	x	x	x	x	x	x	
Umweltbundesamt (Austria)	x	x	x			x	x	x
TNO (Netherlands)	x					x		x
VMM (Belgium)	x		x	x		x		x
ENEA (Italy)	x					x	x	x
			x			x	x	x
BSC (Spain)	x						x	x
			x				x	x
UA (Portugal)	x	x				x	x	x
IVU Umwelt GmbH (Germany)	x					x		x
RIVM (Netherlands)				x		x	x	x
CIEMAT (Spain)	x	x				x	x	x
Ricardo-AEA (UK)				x		x	x	
INERIS (France)	x	x				x	x	x
VITO (Belgium)			x			x	x	x
UPM (Spain)	x		x			x	x	x
FMI (Finland)				x			x	x
Helsinki RESA (Finland)	x	x	x	x	x			
Kuopio, REPS (Finland)	x	x	x			x	x	
Turku /ED (Finland)	x	x	x		x		x	
TOTAL A*	14	8	10	6	3	15	16	15
EMPA (Switzerland)			x				x	
Czech Hydrometeorological Institute (Czech Republic)	x	x				x	x	x
					x	x	x	
Irish EPA (Ireland)		x	x	x	x	x	x	x
Swedish Meteorological and Hydrological Institute (Sweden)			x			x	x	x
TOTAL B**	15	10	13	7	5	19	21	18

*Table 26. Classification of methodologies, scale and outputs used by the groups, which intend to participate in the intercomparison exercise. Note that BSC and ENEA provide information about two methodologies as indicated in the table. At the end of the table, the four groups which indicated to not participate are included (grey background colour). *TOTAL A refers to the groups intending to participate in the intercomperison exercise. **TOTAL B refers to TOTAL A plus the groups which indicated to not participate.*

5.3. Description for Shared Datasets

a) Description of the dataset requirements

The responses to the questionnaire show the type of data required for the exercise. In order to that as many types of methodologies as possible can participate in the exercise the shared dataset should contain: air quality monitoring data, data from sampling campaigns, data from air quality modelling, emission inventories, meteorological and/or climatological data and other surrogate data as land use/cover, traffic intensities, population density, building geometries or topography (Table 27). This information should be available at local/urban and regional scale with a resolution according with the spatial scale.

The level of detail of the information provided in the replies is very diverse. A few replies provide quite detailed information while others provided some generic description. Hence, it was not possible to produce a detailed list. We suggest that another survey for compiling very detailed information about the required inputs of each methodology has to be carried out during the design of the intercomparison exercise.

b) Description of the proposed Antwerp dataset

The shared dataset proposed for this intercomparison study is a set of modelling data from the city of Antwerp. This dataset contains information at a very high spatial (street-level) and temporal (hourly) resolution for the main pollutants (PM_{10}, Ozone and NO_2), over the whole city (more than 100 km^2). This information is attributed to the local scale. Due to the large number of methodologies at regional scale, it is recommended to extend the exercise on this scale. Then, datasets for the regional scale are needed with similar features of that for the local/urban scale but with a coarser resolution.

The Antwerp dataset proposed in the results from a Gaussian dispersion model (IFDM) where contributions of all sources are calculated for each receptor point for every hour of a year. Hourly background concentration is taken from a Chemical Transport Model (CTM) or from spatial interpolation between measurement stations. In addition, point, line and surface emission sources from industry, traffic and domestic heating, building geometry and meteorological data (temperature, wind speed and direction) can be provided. Other information like population density and land use is not used in this case but should be provided in the exercise for some methodologies. Other methodologies need also some passive samplers at different locations in order to construct a map using interpolation. For these cases, some values from the concentration map of the shared data emulating virtual passive sampler data can be supplied to be used. Another important issue is to extend the exercise to regional scale with the same kind of data (concentration, meteorology, emissions, land use, topography, etc) but with a resolution in accordance with the spatial scale.

INPUTS	**Number of Methodologies**
1. Air quality data:	
i. monitoring, mainly from networks of air quality monitoring stations.	19
ii. sampling campaigns, with passive samplers or mobile stations.	11
iii. modelling. Many groups use their own model results and they will not need modelling data as input. But maybe, it can be useful for some other groups as an additional input for their methodologies.	18
2. Other input data for modelling:	
i. emission inventories, preferably gridded data for the different type of sources including point and line sources.	19
ii. meteorological or/and climatological data, mainly wind (speed and direction), temperature and precipitation from stations or from meteorological models	19
3. Surrogate data:	15
i. land use/cover, CORINE Land Cover database is used by several groups,	
ii. traffic intensities,	
iii. population density,	
iv. building geometries and topography.	
v. Emission data. Some groups use this information as proxies of their methodologies	
4. Station classification (Metadata)	6

Table 27. Inputs required by methodologies for the intercomparison exercise.

5.4. How to compare the outputs of the different SR methods

The diverse types of outputs from the different methodologies make it difficult to compare them. Taking into account the responses of the questionnaire and some comments of the participants, different types of comparison could be carried out.

Most of the candidate methodologies provide maps of the SR are and the groups proposed in the questionnaire a comparison between methodologies based on these maps (Table 28). An agreement on the geographical projection and file formats will be necessary and the comparison can be based on estimating the intersection of the SR maps computed by the different methodologies. In addition, we have to take into account that other methodologies provide simplified description (attributes) of SR areas. Comparison of SR maps from different methodologies would also allow for easily comparing attributes of the SR areas such as surface areas, sizes or equivalent radius.

Comparing the SR estimates between themselves	**Number of Methodologies**	**Number of methodologies interested to participate in the intercomparison exercise**
Comparing maps of SR	13	12
Comparing attributes of SR	10	9
Comparing areas of exceedances	2	2
No answer	11	7

Table 28. Suggestions by candidate methodologies about the comparison between methodologies of SR estimates.

Most of the candidate methodologies provide concentration maps. Therefore, an intermediate comparison of these concentration maps could be done in these cases. This intermediate intercomparison could be useful in order to gain more insight about the causes of the differences in the SR maps. For the computed SR maps, similar comparison could be made for these methodologies taking into account that in some cases they use different criteria for SR (Table 29). In this way, in the FAIRMODE Technical Meeting of Aveiro (June 2015), some expert pointed out the usefulness of performing a sensitivity analysis of criteria for SR computations (e.g. influence of similarity concentration threshold on SR maps). Another possibility would be to define a unique SR criterion for all methodologies and use it in the intercomparison.

Comparing the results of intermediate steps	Number of methodologies	Number of methodologies interested to participate in the intercomparison exercise
Yes	10	10
No	3	3
No answer	12	7
Total	25	20

Table 29. Suggestions by candidate methodologies about the comparison the results of intermediate step.

Some challenges arise in the case of the few methodologies providing only qualitative description of the SR area. In those cases, we could analyse whether the qualitative description (e.g. based on expert qualitative analyses) could be compared with the maps obtained from more complex methodologies. It is a very difficult issue and a solution is not foreseen so far.

In further preparing the intercomparison exercise, more discussion is needed to reach an agreement on how to compare the outputs. This agreement needs to include the statistical parameters (correlations, variance, etc) to be used for compare the results (SR maps, surface areas, equivalent radius, etc) provided by the participants.

5.5. Proposal of intercomparison exercise

We have found different SR definitions, different methodologies for estimating SR areas and different types of inputs and outputs. In addition, a same SR definition can be used for different methodologies and different SR definitions can be applied to the same methodology.

The definitions and methodologies are also related to the purpose of the study. Most of the participants declared they need to estimate SR areas for legislative purpose (air quality reporting, station classification or sitting and network design). Air quality reporting is related to the air quality assessment, that is, air quality standards exceedances and area of exceedances without taken into account the timing. However, for other purposes as air quality forecast or control, timing is important. Then, different definitions or criteria have to be used in each case. Additionally, most of the candidate methodologies are used to estimate the SR areas on an annual basis. Hence, in order to that as many methodologies as possible should participate it is recommended to do the exercise using annual metrics of concentrations such as average or percentiles (related to limit or target values) from daily or hourly input values. Time series of hourly or daily input data could be necessary for some methodologies which are based on the similarity of concentrations during a time period

As one participant suggested, it could be recommendable to find a prior agreement about the definition of SR and to compare only outputs from methods sharing the same definition.

However, this could limit the participation of groups in the exercise. Hence, we think that the proposed intercomparison exercise should have an open concept. As many methodologies as possible should participate in the exercise providing their estimates of SR areas. However, the statistical intercomparison should be done for:

1. the outputs of all the methodologies. It should answer to the question: are different definitions or methodologies equivalent or not in terms of their results? Analysing the similarity of the SR area estimates resulting from different SR methodologies or SR definitions could help to understand whether different definitions or methodologies are equivalent or not in terms of their results.

2. the outputs for subgroups with similar methodologies or similar SR definitions. It would be interesting to analyse the variability in the SR area estimates obtained from similar SR methodologies or SR definitions, as compared to those resulting from different methodologies or definitions. That is, is the variability of the estimated SR area higher or lower resulting from applying similar methodologies (e.g., methodologies based on modelling) or from applying dissimilar methodologies (e.g., passive sampler, modelling, proxies, etc)?

The intercomparison exercise should consist of an exercise covering two different spatial scales with several relevant pollutants at each one:

1. Local-urban scale for NO_2 and PM_{10}.
2. Regional scale for NO_2, O_3 and PM_{10}.

The results could be based on annual metrics of concentrations such as average or percentiles (related to limit or target values) from daily or hourly input values. Furthermore, hourly or daily input data could be necessary for some methodologies which are based on the similarity of concentrations during a time period.

Regarding inputs requirements, due to the different types of methodologies, a wide range of input data is necessary such as:

1. Air quality data:
   i. monitoring, mainly from networks of air quality monitoring stations.
   ii. sampling campaigns, with passive samplers or mobile stations.
   iii. modelling. Many groups use their own model results and they will not need modelling data as input. But maybe, it can be useful for some other groups as an additional input for their methodologies.
2. Other input data for modelling:
   i. emission inventories, preferably gridded data for the different type of sources including point and line sources.

ii. meteorological or/and climatological data, mainly wind (speed and direction), temperature and precipitation from stations or from meteorological models

3. Surrogate data:

   i. land use/cover, CORINE Land Cover database is used by several groups,

   ii. traffic intensities,

   iii. population density,

   iv. building geometries and topography,

   v. emission data. Some groups use this information as proxies of their methodologies

These data should be available for both spatial scales of the exercise and with a resolution according with each scale. The temporal resolution should be hourly for air quality data from monitoring stations, modelling, emission inventories, meteorology and some surrogate data (e.g., traffic intensities).

The outputs to be compared could be:

1. SR maps. An agreement on the geographical projection and file formats should be necessary. The comparison of maps can be based on analysing the intersection of the maps.

2. Areas, sizes or equivalent radius of the SR.

3. Concentrations fields computed by the air quality models used in the exercises. This would serve as an intermediate intercomparison in order to gain more insight about the causes of the differences in the SR maps.

4. The classification of stations for the methods that are able to estimate this parameter or that are used for the purpose of checking station classification.

With regard to how many stations should be considered for the intercomparison exercise, we need to take into account the computational burden, which could be high when high resolution modelling is used (for example, CFD or CTM models). It could limit the maximal number of stations to estimate SR. Hence, taking into account some expert comments in FAIRMODE Technical Meeting (Aveiro, June 2015), the exercise should be applied to, at least, one traffic and two background stations covering both scales (urban and regional).

During the FAIRMODE Technical Meeting, some experts also declared their interest in a sensitivity analysis of criteria for SR computations investigating the influence of concentration similarity threshold for determining SR areas. We think it is a very interesting task and it can be a voluntary part of the exercise.

From the 22 responders to the questionnaire, eighteen are interested in taking part in the intercomparison exercise. Most of them provide SR maps as output. With suitable input data, as those described for the Antwerp dataset, these groups would be able to apply their methodologies and then, participate in the intercomparison exercise at least for the local/urban scale. However, other groups can only apply their methodology to the regional scale, and then the Antwerp dataset should be extended to a regional scale.

Other possible limitation would be that some groups provide only qualitative information about the SR areas. It poses a drawback for comparing these results with quantitative information of SR provided by most of the groups. In those cases, we could analyse whether the qualitative description is comparable with the maps obtained from more quantitative methodologies.

Finally, details about the required final dataset (e.g. temporal and spatial resolution of input data, file formats, synthetic data simulating virtual measurement campaigns, etc) need be discussed and agreed in the next step of designing the intercomparison exercise.

6. Summary and conclusions

A feasibility study for an intercomparison exercise of methodologies to estimating spatial representativeness of air quality monitoring stations has been carried out by CIEMAT for FAIRMODE (Forum of Air Quality Modeling in Europe) through a contract with JRC. To carry out this study, firstly a bibliographical review was conducted to assess the state of the art about spatial representativeness. Afterwards, a survey was done based on a questionnaire about main aspects of the SR methodologies, which was sent to a large group of experts. The analysis of the survey results was used to discuss about the feasibility of the intercomparison exercise for methodologies estimating SR of monitoring stations. The intercomparison exercise should be open to as many participants and methodologies as possible.

Twenty two groups, which provided 25 methodologies, replied the questionnaire. The analysis of the responses to the questionnaire shows that most of the groups intend to participate in the intercomparison exercises (18 groups intend to participate with 20 methodologies). SR studies are being used mostly for regulatory purposes (air quality reporting, station sitting or network design, station classification) but also for data assimilation for modelling, model evaluation and population exposure. Two different scales for estimating SR areas have been identified (local/urban scale and regional scale). Most of the groups use methodologies based on modelling but also on measurements, proxies and station classification. Methodologies are generally aimed for annual concentrations (average or percentiles from daily or hourly data). SR studies were done for a wide range of pollutants, but more frequently for NO_2/NO_x, PM_{10}, SO_2 and $PM_{2.5}$,and also O_3 at the regional scale. Most of the groups applied their methodologies to all type of stations, mostly for annual metrics of pollutant concentrations.

Presently, the shared data set proposed to be used in the intercomparison exercise is for the city of Antwerp representing a local/urban scale. This dataset contains information at a very high spatial (street-level) and temporal (hourly) resolution for the main pollutants (PM_{10}, Ozone and NO_2) to be considered, over the whole city (more than 100 km^2). In order to cover the regional scale in the exercise, it is planned to extend Antwerp dataset to this scale.

Taking into account the responses of the questionnaire, the intercomparison exercise seems feasible and the main objectives could be achieved if all needed input data are available at both suggested scales. However, the intercomparison exercise should have the following characteristics in order to make sure that as many methodologies as possible can participate and that the intercomparison against results of different methodologies can be carried out:

1) The exercise should cover two spatial scales: the local/urban scale and the regional scale.

2) SR should be estimated for NO_2 and PM_{10} at local/urban scale and for NO_2, O_3 and PM_{10} at regional the scale.

3) The results could be based on annual metrics of concentrations such as averages or percentiles from daily or hourly values. Regarding inputs requirements, due to the different types of methodologies, a wide range of input data is necessary such as data from air quality monitoring, sampling campaigns, air quality modelling, emission inventories, meteorological or/and climatological data and other surrogate data, as land use/cover, traffic intensities, population density, building geometries or topography. These data should be available for both suggested spatial scales and with a resolution according to each scale. Hourly data should be required for air quality data from monitoring stations, modelling, emission inventories, meteorology and some surrogate data (e.g., traffic intensities).

4) We propose two types of comparison of the results:

    a. To compare outputs from methodologies with the same definitions within subgroups

    b. To compare outputs from all methodologies in order to have more information about the variability in the SR estimates from the range of applied methodologies.

5) The outputs to compare should be SR maps, dimensions of the SR (areas, radii) and concentration fields (when possible).

6) The exercise can be done at least for one traffic and two background stations covering both scales (urban and regional).

7) Some expert declared their interest about doing a sensitivity analysis of criteria for SR computations (e.g. influence of concentration threshold on SR maps). This part of the exercise could be voluntary.

8) Some few participants would be interested in comparing estimates of the classification of stations for the methodologies able to produce a station classification.

One possible limitation will be how to compare the qualitative outputs from those participants to the quantitative information provided by the majority. For these cases, we could analyse whether qualitative descriptions are compatible with quantitative results of more complex methodologies.

Finally, more details about the input data, the comparison between methodologies, the format of input and output files, etc need to be discussed and agreed in the next step for the design of the intercomparison exercise.

Acknowledgements

Authors thank the reviewers of the questionnaire for their interesting comments and suggestions, which have clearly contributed to improve the questionnaire. Special thanks are going to 22 experts who answered the questionnaire providing very useful information, which allow us to get more insight about what methodologies are being applied and to analyse the feasibility of an intercomparison exercise. Finally, we appreciate the contribution of the participants in the very interesting debate developed during the FAIRMODE Technical Meeting hold in Aveiro, June 25th, 2015.

This work has been financially supported by the JRC-Ispra.

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Annex I. Questionnaire

FAIRMODE Survey about Methodologies for Estimating the Spatial Representativeness (SR) of Air Quality Monitoring Stations (AQMS)

final version for distribution (January 26th, 2015)

Jose Luis Santiago, Fernando Martin and Laura García (CIEMAT)
Oliver Kracht (JRC)

In every section and subsection, more than one answer is possible. If more than one spatial representativeness method has been applied, please give individual answer for each of them (where applicable). Please add additional lines to the form as required to provide sufficient space for your answers.

Abbreviations:
SR: Spatial Representativeness
AQMS: Air Quality Monitoring Stations

Return (email) address: fernando.martin@ciemat.es; jl.santiago@ciemat.es; laura.garcia@ciemat.es

Please, send your replies before March 2nd, 2015

Important request: We would appreciate if you could let us know by February 10th if you are intending to participate in the survey. We would like to use this feedback for the discussion about the survey in the course of the spatial representativeness session during the upcoming FAIRMODE plenary meeting in Baveno (12 / 13 February 2015).

Contact information

Name:
Institution/Department/Group:
Address:
Phone:
E-mail:
Position:
Responsibilities concerning air quality management:

1. **In which context do you evaluate the SR of AQMS?** (more than one answer is possible)

   Please also answer likewise if you have evaluated SR in the past, or if you are planning to evaluate SR in the future.

   a. Station siting and network design?

   please indicate details:

   b. Station classification?

   please indicate details:

   c. Data assimilation for modelling?

   please indicate details:

   d. Model benchmarking or evaluation?

   please indicate the context:

   e. Air quality reporting (including reporting of exceedances)?

   please indicate details:

   (If you are using SR in the context of different types of air quality reporting, please indicate details for each.)

   f. Population exposure studies?

   please indicate details:

   g. Other kind of research?

   please indicate details:

   h. Other purposes?

   please indicate details:

2. **Are your SR studies linked to legislative or regulatory purposes (e.g., air quality management, legislation compliance or development of new legislation)?**
   please indicate details:

3. **What are the definitions of SR used for your applications?**
   please describe briefly the definition(s) of SR used for your studies:

4. **Types of methodologies:** (if more than one method has been applied, please provide an individual answer for each).

   If you have different definitions of SR depending on the applications (question 2), please also indicate in the next questions which method is linked to which definition.

   a. Which methodologies do you use?

      Explanation: We expect that the set of methods would comprise for example (but it shall definitely not be limited to):

      i. methods which are immediately based on an estimate of the spatial distribution of pollutants (concentration fields derived from observations or modeling)
      ii. methods which are based on pollutant proxies and / or surrogate data
      iii. methods which are linked to the classification of stations or sites
      iv. other types of methods or combinations

      please provide details about the methods used:

   b. To what type of AQMS (traffic, background, industrial or urban, suburban, rural) do you apply the method?

      please indicate details:

   c. For which pollutants do you use the method?

      please indicate details:

   d. To what spatial scale, time scale, spatial resolution and temporal resolution is your method applied?

      please indicate details:

   e. Could you make available documentation, tools and/or software for the methodology?

please indicate details:

f. Can the method be used to estimate if an AQMS is representative of similar locations which are not located in the immediate vicinity of this specific AQMS?

Explanation: This question refers to the notes on "similar locations" given in ANNEX III and ANNEX VI of directive 2008/50/EC.

please indicate details:

g. Does the methodology have any limitations?

please indicate and describe in details:

5. **Types of input data:** (if more than one method has been applied, individual answers for each methods might be needed)

   Which type of input data do you use? In example, this might comprise:

a. Regular air quality monitoring data

   please indicate details:

b. Air quality data from dedicated sampling campaigns

   please provide some information about the campaign, sampling methods, etc.:

c. Data derived from air quality modeling

   please indicate the models and model setups used:

d. Emission inventories

   please indicate time and spatial resolution, included sources, etc.:

e. Meteorological data

   please indicate the type of data, variables, etc.:

f. Other surrogate data, like topography, land cover and land use, traffic intensities, population density, etc

please indicate details:

g. Station classification

Explanation: Does your methodology link SR with the results of a classification scheme (e.g. the classification of station and classification of the area as listed in decision 2011/850/EU - ANNEX II - D, or the classification related to ozone from ANNEX VIII of directive 2008/50/EC, or others)?

Please describe the classification scheme and the mechanism used to attribute a SR estimate to a certain class. Please also distinguish if in your approach an estimate of SR is resulting from classification, or if in the other way around an estimate of SR is a necessary prerequisite for classification:

6. **How do you report your estimates of the spatial representativeness? What are your output variables?** (more than one answer is possible)

a. A detailed geospatial description of the area of representativeness (e.g. a map or a spatial polygon)?

please indicate details:

b. Metrics related to simplified geometric concepts (e.g. a radius of the area or a length of the street for which a station is representative of)?

please indicate details:

c. A quantification of the scale or the order of magnitude of the area that the measurement is supposed to be representative of?

please indicate details:

d. Similarities of locations, not necessarily in the immediate vicinity of the monitoring site, resulting in homogeneous areas regarding population exposure to air pollution?

please indicate details:

e. An estimated spatial variance (for example as being described by a variogram model)?

Explanation: such concepts might for example be used for model benchmarking involving non-collocated grids.

please indicate details:

f. By other statistical means?

please indicate details:

g. Other means of reporting, including qualitative descriptions?

please indicate details:

7. **Transferability of the method:**

   a. Is your method applicable to datasets from another region country?

      Explanation: Your method could possibly include assumptions or specific empirical relationships that cannot straightforwardly be transferred into another regional context?

      please indicate details:

   b. Would your method also be applicable to a purely synthetic datasets (e.g. a dataset based on numerical model outcomes)? Would this depend on if specific relationships had been introduced into the numerical model structure?

      Explanation: Your method could possibly include specific assumptions or empirical relationships that are not necessarily reproduced by every numerical air quality model. As an example this might be a specific relationship between population density and emissions, or an implicit correlation between traffic patterns and the spread of pollutants or pollutant pathways.

      please indicate details:

8. **Would you like to take part in an intercomparison exercise about methodologies for estimating SR of AQMS?**

   If wanting to take part into the intercomparison exercise, could you provide us an estimate of your processing time needed from receiving the shared data set until the delivering of your results?

   We are currently envisaging the intercomparison exercise to be performed at a date falling within the first half of year 2016. Would this be convenient for your participation?

   please indicate:

9. **What would be your input data requirements and site limitations?**

   a. **Set of pollutants:**

      Your methodological limitations about the type of pollutants

      please indicate details:

   b. **Site requirements:**

      Your methodological limitations concerning the

i. type of stations (traffic, industrial, background, ...)
ii. type of areas (street, city, urban area, suburban area, rural area, ...)
iii. extent of the domain
iv. other requirements and other limitations

please indicate details:

c. **Data sets**

Your specific data requirements in order to apply your methodologies within the prospective intercomparison exercise: input variables and metadata needed (coordinates, temporal resolution, spatial resolution, measurement methods, other estimations of input variables, …)

please indicate details:

10. Do you have any recommendations about the characteristics of the intercomparison exercise? How do you think it is the best way to compare the outcomes of the methods?

a. Comparing the SR estimates between themselves?

i. compare the extent of the SR areas (where applicable), compare the estimated pollution maps obtained for several methods around the stations sites?
ii. compare specific (statistical) attributes of the SR areas (e.g., order of magnitude)?
iii. compare the methods' skills in forecasting correctly an area of exceedances?

please answer in detail:

b. Comparing the SR estimates with a unified reference SR computed from detailed maps of measured concentration?

If a reference SR would be computed from detailed maps of concentrations following certain criteria (e.g. an interval around the concentration at the station site), is it possible to compute an equivalent SR with your method following the same criteria? The answer for this question is evident for some methodologies (for example based on model results) but not so evident for other methodologies, for example based on surrogated data. How do think it is the best way to do a quantitative comparison of both SR?

please answer in detail:

c. Comparing the results of intermediate steps (where applicable)?

Estimating the SR of a station, is often a two phase processes: (i) to estimate directly or indirectly the spatial distribution of pollutants (concentration field) or pollutant proxies (surrogate data) around the station, and (ii) to apply certain criteria of similarity of the pollutant concentrations between the station site and its possible SR area. Hence, where applicable, it could be preferable to do the intercomparison of methods separately for both working steps?

Explanation: If we have a good estimate of the concentration field (i.e. pollution maps) around a station site but inappropriate similarity criteria, the estimated SR area would be not reasonable. Otherwise, good similarity criteria are not enough if we have a bad estimate of the concentration field. The causes of a non-reasonable estimate of the SR area can therefore be two: incorrect pollution maps or inappropriate similarity criteria.

please answer in detail:

d. Other type of comparisons

please answer in detail:

11. If taking part into the intercomparison exercise, would you have any requirements or restrictions about the confidentiality of your results?

Explanation: For example, do you think it is preferable to keep anonymity of the participants when reporting and summarizing the results? Or is it preferable to keep full transparency?

In this context, it might be important to consider that the foreseen intercomparison exercise will aim at exploring the diversity and the strengths and weaknesses of current SR methods, rather than to test for the "correctness" of their application.

please indicate:

Annex II. Minutes of the FAIRMODE Technical Meeting, 24-25 June 2015, Aveiro (PT)

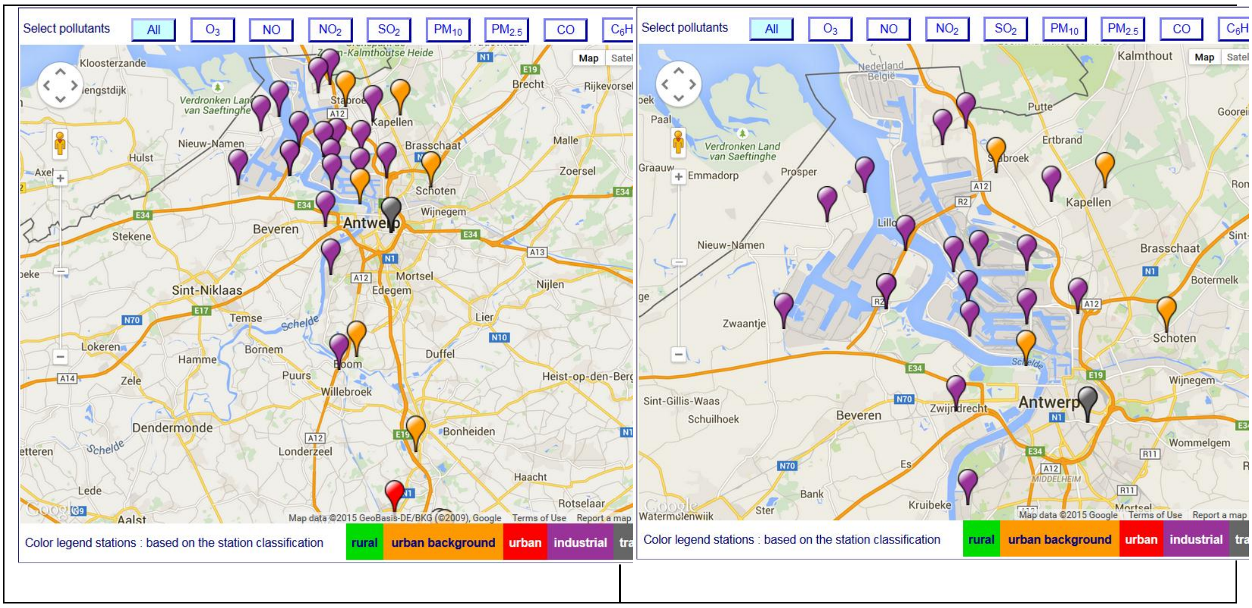
Minutes of the FAIRMODE Technical Meeting, 24-25 June 2015, Aveiro (PT)

Aveiro (PT), 24-25 June 2015, Working Group 1 – Session 5, “cross-cutting activity on spatial representativeness of monitoring stations”

During the Fairmode meeting in Aveiro, 24-25 June 2015, Working Group 1 – Session 5, “cross-cutting activity on spatial representativeness of monitoring stations”, we discussed technical and organisational aspects in view of carrying out an intercomparison exercise (IE) for the evaluation of the area of spatial representativeness (SR) of monitoring stations. The following points were agreed between the WG participants during the session:

The first objective of IE is to estimate the SR of Air Quality Monitoring Stations (AQMS) located in the urban area of the city of Antwerp. Three stations are within the Antwerp urban area where monitoring, emission, density and mobility data are known with the highest resolution. These stations are classified as following: 1 traffic station and two urban background station.

As a second objective of the IE, other stations can be selected. One possibility is to choose one of the industrial stations around the harbour of Antwerp located (as in the maps below). Additionally, the participants agreed that, a number of virtual stations may be simulated by extraction of the existing gridded output of a model. The SR estimated by participants for the virtual stations will be submitted to the same data treatment of the IE as for the 3 other AQMS. It was acknowledge that in the area of Antwerp there is no rural area. Consequently, no rural background station will be proposed even within the simulated stations.



It was decided that the IE would aim at assessing the outputs of the participants'methods of SR estimation for PM_{10} and NO_2 at the traffic station and for PM_{10}, NO_2 and O_3 at the two urban background stations.

The methods of expected participants used for the estimation of the SR generally need input data either of an urban domain or of a regional domain. It was decided the output of these methods will be treated together without grouping by the size of the domain of input data

The data treatment of the results of the IE will focus on the comparison of the area of SR of AQMS estimated by all methods of participants. This will include quantitative estimation, as maps for examples and qualitative estimation or non-continuous area. In order to simplify the data treatment of the results of the IE, the WG participants agreed that for the method whose output consists of a contour map of the area of SR, a consensus reference area of SR can be computed using the intersection of all the SR maps.

A few participants proposed to test the threshold parameter defining the extent of the area of SR using sensitivity analysis at a 2^{nd} step of the data treatment. The possibility to compare the classification of AQMS was marginally cited for the methods that are able to estimate this classification.

A few methods need input data consisting of uncertainties for measurements, modelled data, emission … While it was checked that measurement uncertainties are available in the Antwerp dataset, it must still be ascertained that other type of uncertainties are available. Consequently, a precise list of available inputs of the Antwerp datasets must be established and a precise list of all input data needed by each possible participant in order to check consistency between data availability and data request including all input data and uncertainties, the needed spatio/temporal resolution and extent, the coordinate system, the data format ...

European Commission
EUR 27385 EN – Joint Research Centre – Institute for Environment and Sustainability

Title: **FAIRMODE Spatial representativeness feasibility study**

Authors: Fernando Martín, José Luís Santiago, Oliver Kracht, Laura García and Michel Gerboles

Luxembourg: Publications Office of the European Union

2015 – 72 pp. – 21.0 x 29.7 cm

EUR – Scientific and Technical Research series – ISSN 1831-9424 (online)

ISBN 978-92-79-50322-1 (PDF)

doi: 10.2788/49487

LB-NA-27385-EN-N

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ISBN 978-92-79-50322-1

Publications Office