SPATIAL REPRESENTATIVENESS OF RURAL BACKGROUND MONITORING STATIONS IN SPAIN

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Abstract: The spatial representativeness of air quality stations is influenced by topography or obstacles, distribution of pollution sources, meteorological features, averaging time and pollutant type. There are several methods to estimate the spatial representativeness of stations. All of them try to find out how the pollution is distributed around the station and estimate the spatial representativeness by delimiting the area where the pollutant concentrations do not differ more than a certain percentage of the measured concentration at the station site. One of the methods consists of using air quality models. The advantage of using validated models is that the effects of the emission sources distribution and atmospheric pollutant processes are taken into account together composing a quite realistic view of the pollutant. In this work, the authors have applied the annual WRF-CHIMERE model simulations for the Iberian Peninsula in 2008, 2009 and 2010 to investigate how the air pollutants concentrations are distributed around the rural background stations. The criteria for delimiting the representativeness area are based on the idea that the concentration does not vary more than a certain percentage of the concentration at the station and the concentration in the representativeness area is in the same interval respect to the assessment thresholds and/or limits values. The results showed that there is a large variability in the size and shape of the representativeness area of the background rural stations in Spain, also depending on the pollutant and the limit or target value. In addition, the interannual variability of the representativeness areas has been analysed.

Key words: *Air quality assessment, stations representativeness, air quality modelling.*

INTRODUCTION

Air quality assessment in a territory requires the use of pollutant concentration data measured at monitoring stations. In this context, the question of how representative a station is rises. The spatial representativeness (SR) is influenced by topography or obstacles, air flows, distribution of pollution sources, averaging time and pollutant type.

There are several methods to estimate the SR of stations. The methods for estimating the SR area of a station try to find out how the pollution is distributed around the station and which is the area where where the pollutant concentrations do not differ more than a certain percentage of the measured concentration at the station site. One of the methods consists of specific measurement campaigns with passive samplers (Galán Madruga et al., 2001). The advantage is that these samplers are cheaper and smaller than the standard monitoring station itself. The disadvantage is that they can provide only long term concentration averages. Other methodologies are based on the use of some surrogate indicators related to emission sources distribution, but in this case, the effect of transport and dispersion of pollutants is not estimated (Janssen et al., 2012). Other methodologies are based on climatic-topographic criteria, which can be recommended specially for rural background stations (EC, 2011). Alternatively, air quality models are being used for estimating SR of air quality stations, including some studies for traffic stations using street-canyon models (Santiago et al, 2013). The advantage of using validated models is that the effects of the emission sources distribution and atmospheric pollutant processes are taken into account together composing a quite realistic view of the pollutant. A very complete review of the criteria and methods for air quality classification and representativeness estimate was made by Spangl et. al. (2007).

The aim of this study is to estimate the SR area of the rural background (RB) stations based on the analysis of the pollutant concentration distribution around the studied stations in the Iberian Peninsula and Balearic Islands obtained from annual WRF-CHIMERE model simulations combined with measurements of air quality stations for three years (2008-2010). The resulted SR areas are analysed and discussed by pollutant, limit or target value (air quality standards) and their interannual variability.

METHODOLOGY

The methodology to estimate the SR of RB stations in Spain is based on the analysis of the annual maps of pollutant concentrations of SO_2, O_3, NO_2 and PM_{10} for three years (2008-2010) computed routinely for annual air quality assessment in Spain (Martín et al., 2012). This maps have been obtained from annual simulations with the WRF-CHIMERE model system combined with measurements at air quality stations in order to get a more reliable view of how the pollutant are distributed. The maps are for annual mean concentrations and for limit and target values (see table 1).

Table 1. List of concentration maps computed for several pollutants and for 2008, 2009 and 2010.

Pollutant	Annual mean	Daily limit value (daily average)	Hourly limit value (hourly average)	Target value (8-hour average)	Information threshold (hourly average)
SO_2	Yes	4th upper value	25th upper value	No	No
O_3	No	No	No	26th upper value	Maximum value
NO_2	Yes	No	19th upper value	No	No
PM_{10}	Yes	36th upper value	No	No	No

The SR of a RB station is assumed as its surrounding area in which concentrations do not vary more than a specific percentage of the concentration at the site, and fall in the same air quality assessment classification, i.e., if the station concentration exceeds a limit value, the concentrations in the area of SR must be also above that limit value.

Air quality modelling and combination with station measurements

The WRF and CHIMERE models were used for meteorology and air pollutant dispersion, respectively. For the CHIMERE model, two nested domains were considered: first, an European domain with a resolution of 0.2ºx0.2º with boundary conditions provided by LMDz-INCA and LMZ-AERO and gridded EMEP emission data, and second, an Spanish domain of 0.1ºx0.1º resolution with gridded data from the National Emission Inventory. The meteorological model was also run for two nested domains: an European domain with 27x27 km resolution and a Spanish one with 9x9 km resolution. The CHIMERE simulations were done for 2008, 2009 and 2010 on an hourly basis. More details about the model setup can be found in Vivanco et al. (2012).

The pollutant concentration maps obtained by the CHIMERE model were combined with the measured pollutant concentrations at AQ stations following a methodology described by Martín et al, (2009). It basically consists of the kriging of model residuals, applied to model results in order to obtain a better agreement with measurements. This methodology is separately applied to rural and urban stations, leading to rural and urban pollution maps. Then both maps are combined according to the rural or urban character of each grid-cell, considering population density as the surrogate indicator.

SR delimiting criteria

The criteria for delimiting the representativeness area are based on two conditions: first, the concentration does not vary more than a certain percentage of the concentration at the station, and second, the concentration in the representativeness area falls in the same air quality assessment classification (assessment thresholds and/or limits values). It is assumed that the maximum SR area is a circle of 200 km of radius around the station, which corresponds to an area of 125664 km^2. The Directive EC 2008/50 states there should be one rural background station per 100000 km^2.

The criteria for delimiting the SR of the RB stations are summarized in the Table 2. Several concentration bins were set up for every pollutant and air quality standard. The limits of the concentrations bins were chosen by taking into account the limit and target values and the assessment or population information thresholds set by the Directive EC 2008/50. For stations with concentration (see Table 1) falling in a bin, the upper and lower limits of the concentration interval to comparison with concentrations around the station are computed by applying the factor F to the concentration at the station site. The SR area of a certain station will contain all the surrounding grid cells in a circle of 200 km of radius with concentrations falling into the interval. Except for very low concentrations, F is equal to 1.2. Additional conditions are applied to avoid the upper or lower interval limits exceed the limits of the concentration bins.

Table 2. Criteria for delimiting the SR of the RB stations for every pollutant and air quality standard. I = bins of concentrations (μgm^{-3}), F = factor applied to set the concentration interval respect to the reference concentration at the station, and L = limits (μgm^{-3}) applied to the upper and lower values of the intervals for each concentration bin.

Averaging time	**SO_2**			**O_3**			**NO_2**			**PM_{10}**		
	I	**F**	**L**	**I**	**F**	**L**	**I**	**F**	**L**	**I**	**F**	**L**
Annual mean	<4	2	max≤4				<13	2	max≤13			
	≥4	1.2	min≥4				≥13	1.2	min≥13	<20	1.2	max≤20
	<8		max≤8				<26		max≤26			
	≥8	1.2	min≥8				≥26	1.2	min≥26	≥20	1.2	min≥20
	<12		max≤12				<32		max≤32	<28		max≤28
	≥12	1.2	min≥12				≥32	1.2	min≥32	≥28	1.2	min≥28
	<20		max≤20				<40		max≤40	<40		max≤40
	≥20	1.2	min≥20				≥40	1.2	min≥40	≥40	1.2	min≥40
Daily average	<25	2	max≤25									
	≥25	1.2	min≥25							<25	1.2	max≤25
	<50		max≤50									
	≥50	1.2	min≥50							≥25	1.2	min≥25
	<75		max≤75							<35		max≤35
	≥75	1.2	min≥75							≥35	1.2	min≥35
	<125		max≤125							<50		max≤50
	≥125	1.2	min≥125							≥50	1.2	min≥50
Hourly average	<70	2	max≤70	<90	1.2	max≤90	<50	2	max≤50			
	≥70	1.2	min≥70	≥90	1.2	min≥90	≥50	1.2	min≥50			
	<140		max≤140	<135		max≤135	<100		max≤100			
	≥140	1.2	min≥140	≥135	1.2	min≥135	≥100	1.2	min≥100			
	<210		max≤210	<180		max≤180	<140		max≤140			
	≥210	1.2	min≥210	≥180	1.2	min≥180	≥140	1.2	min≥140			
	<350		max≤350	<210		max≤210	<200		max≤200			
	≥350	1.2	min≥350	≥210	1.2	min≥210	≥200	1.2	min≥200			
				<240		max≤240	<400		max≤400			
				≥240	1.2	min≥240	≥400	1.2	min≥400			
8-hour average				<84	1.2	max≤84						
				≥84	1.2	min≥84						
				<108		max≤108						
				≥108	1.2	min≥108						
				<120		max≤120						
				≥120	1.2	min≥120						
				<180		max≤180						
				≥180	1.2	min≥180						

RESULTS

The SR area of the RB stations was estimated for each of the three years (2008, 2009 and 2010). The SR of stations changes year to year, but in most of the cases some part of yearly SR remains in the three years. Hence, the multiyear SR area can be estimated computing the intersection of the yearly SR areas. The results showed there is a large variability in the size and shape of the SR area of the RB stations in Spain (Figure 1), also depending on the pollutant (Figure 2) or the averaging time (Figure 3).

In Figure 4, the histograms of station SR sizes for every pollutant and averaging times are shown. Large SR areas are more frequent for hourly and daily SO_2, hourly O_3 and annual NO_2. However, there are more small or medium SR areas for PM_{10} and 8-hourly averages of O_3. Generally, the SR areas ranging from 300 to 700 grid cells (0.1ºx0.1º) are less frequent.

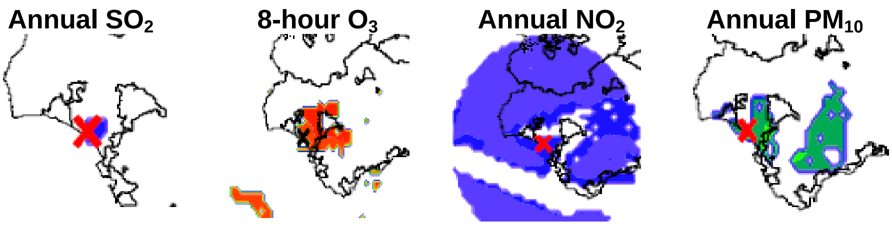

Figure 1. Spatial representativeness area of the Doñana station for different pollutant and averaging time.

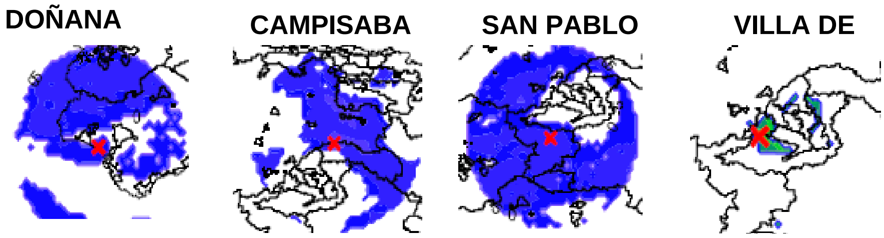

Figure 2. Spatial representativeness area of the several stations for hourly NO_2 concentrations.

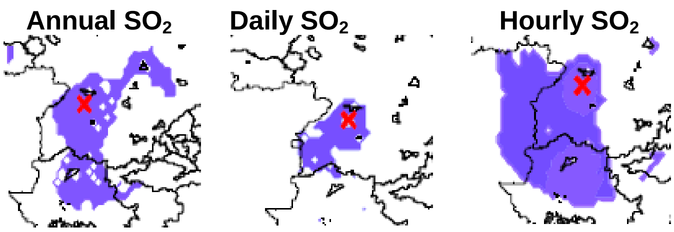

Figure 3. Spatial representativeness area of the Peñausende station for different averaging times of SO_2.

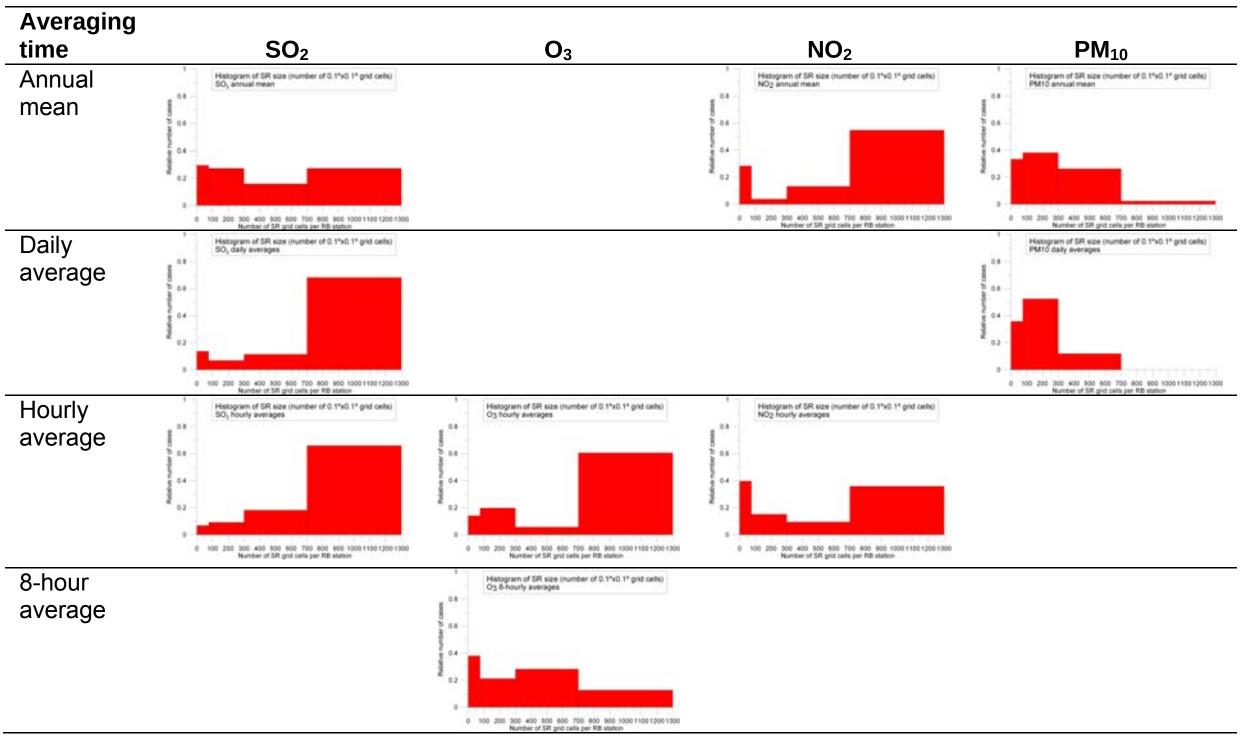

Figure 4. Histograms showing the distribution of SR sizes (number of 0.1ºx0.1º grid cells) of RB air quality stations for different pollutants and averaging time of concentrations for the period 2008-2010. The bins of grid cell numbers are 0-75, 75-300, 300-700 and 700-1300.

In addition, the interannual variability of the representativeness areas has been analysed by computing a persistence index *P* defined by:

$$P = \min\left[\frac{SR_T}{SR_Y}\right]$$

where SR_Y is the spatial representativeness area of a station for the year *Y* (2008, 2009 or 2010) and SR_T is the multiyear spatial representativeness area of the same station, i.e. the intersection of SR_Y of each of the year *Y. P* varies between 0 and 1, 0 means no persistency in the SR whilst 1 means that the SR is the same for the three years.

In Table 3, the number of stations for three intervals of persistence factor *P* is shown. It is noted that for daily and hourly SO_2concentrations the SR of most of the stations has a high persistence, however it is very low for annual concentrations. For O_3, SR persistence is higher for hourly concentrations than for 8-hour average. In the case of NO_2, SR areas for annual concentrations are more constant than for hourly concentrations. Finally, the P values for PM_{10} are mostly lower than 0.7.

Table 3. Number of stations for three intervals of persistence factor *P*. Low persistence ($P<0.3$), medium ($0.3\leq P<0.7$) and high ($P\geq0.7$).

Persistence Factor	SO_2			O_3		NO_2		PM_{10}	
	annual	**daily**	**hourly**	**8-hour**	**hourly**	**annual**	**hourly**	**annual**	**daily**
0.0 - 0.3	23	8	7	34	21	14	21	22	20
0.3 - 0.7	10	7	8	29	11	12	16	17	22
0.7 - 1.0	11	29	29	8	39	27	16	3	0
Total	44	44	44	71	71	53	53	42	42

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