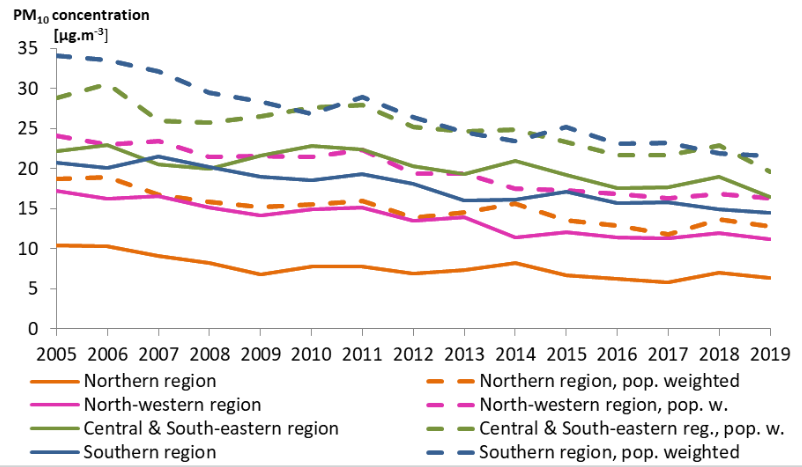
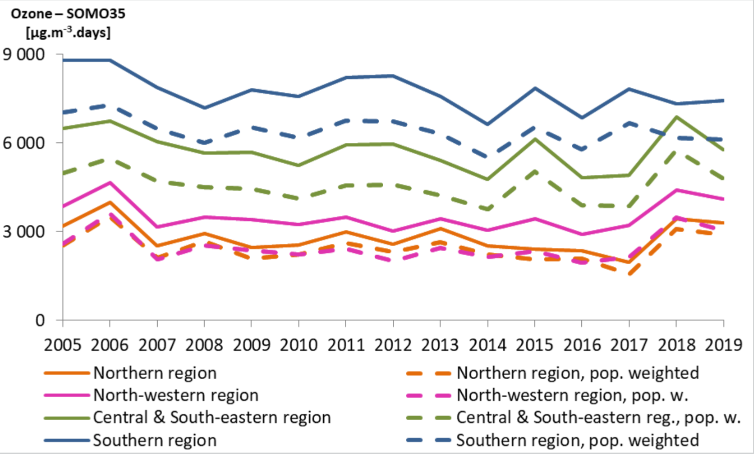
Eionet Report - ETC/ATNI 2021/11

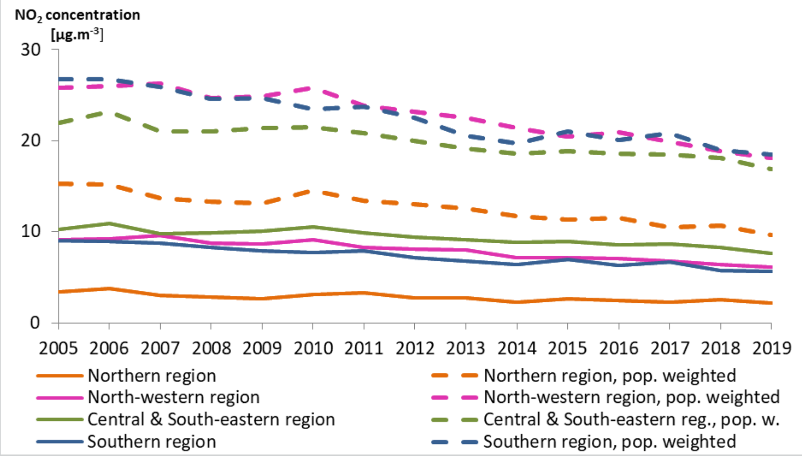
Air quality evolution and trends in Europe in 2005-2019 based on spatial maps

Trend analysis and population exposure using reconstructed consistent data fusion maps for PM_{10}, ozone and NO_2

December 2021







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Cover design: EEA
Cover picture: Time series 2005-2019 of PM_{10} annual mean (top left), ozone indicator SOMO35 (middle right) and NO_2 annual mean (bottom left) aggregated over four large regions (N/NW/CSE/S) of Europe. (This report, Figures 3.1, 4.1 and 5.1.)
Layout: ETC/ATNI

The withdrawal of the United Kingdom from the European Union did not affect the production of the report. Data reported by the United Kingdom are included in all analyses and assessments contained herein, unless otherwise indicated.

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Summary

This report analyses evolution and trends of air quality in Europe, based on a 15-year time series of spatial data fusion maps for the years 2005-2019. The analysis has been performed for PM_{10} annual average, the ozone indicator SOMO35 and NO_2 annual average. The mapping area covers all of Europe apart from its eastern part (i.e., apart from Belarus, Moldova, Ukraine and the European parts of Russia, Kazakhstan and Turkey).

For the purpose of the trend analysis, a consistent reconstruction of the full 15-year time series of air quality maps has been performed, based on a consistent mapping methodology and input data. For the reconstruction, the Regression – Interpolation – Merging Mapping (RIMM) methodology that combines monitoring, modelling and other supplementary data as routinely used in the regular annual mapping (Horálek et al., 2022, and reports cited therein) has been applied. Consistent EMEP MSC-W modelling results, ECMWF meteorological data and other supplementary data have been used. Measurement data only from stations with a sufficient temporal coverage (i.e. 75 % of years) have been considered, in order to apply as consistent set of measurement data among the years as possible.

In order to check the representativeness of this subset of the measurement stations, we have compared the maps created based on the subset with the maps created based on all stations available, for four years. Based on this analysis, it has been concluded that for most of the area, the differences in relative terms differ less than 25 %. In the case of PM_{10}, in the areas with higher differences, the subset was slightly adapted, in order to improve the results. Subsequently, the final reconstructed consistent maps have been prepared and further used for the trend analysis.

The trend analysis has been performed based on time series of the aggregated data for individual countries, for four large European regions, for EU-28([1]) and for the entire mapping area, both for spatial and population-weighted aggregations. For detecting the trends in time series of the annual values, the non-parametric Mann-Kendall test has been used. For estimating the slope of a linear trend, the non-parametric Sen's method has been executed.

For the European-wide PM_{10} annual average aggregations across the whole mapping area, statistically significant downward trend of -0.4 $\mu g.m^{-3}$ per year (or -2.2 % per year, in relative terms) for spatially averaged concentrations and of -0.7 $\mu g.m^{-3}$ per year (or -2.4 % per year) for population-weighted averaged concentrations have been estimated.

In the case of ozone, no significant trend was detected for the whole mapping area and for most countries. Although Sen´s slopes are mostly negative, the trends are not significant (according to the Mann-Kendall test) for most of the European countries and for the entire area. A significant decrease was detected for some countries of the Southern Europe.

For the European-wide NO_2 annual average aggregations across the whole mapping area, statistically significant downward trends of -0.2 $\mu g.m^{-3}$ per year (or -2.2 % per year, in relative terms) for spatially averaged concentrations and of -0.5 $\mu g.m^{-3}$ per year (or -2.0 % per year) for population-weighted averaged concentrations have been estimated.

The trends calculated based on the aggregated data for the whole mapping area have been compared to the statistics derived exclusively from observations in Solberg et al. (2022). Those estimates in the rural and the urban background sites are very consistent with the mapped trends when comparing the whole mapping area (i.e., the spatial averaged concentrations, constituted of a

([1]) The report covers a 15-year period 2005-2019 prior to the United Kingdom's withdrawal from the European Union. The withdrawal of the UK from the EU did not affect the data presented in this document. We have kept the terminology "EU-28" to refer to the current EU-27 and the UK. Note that in the most of the 15-year period, the EU consisted of the 28 countries.

majority of rural areas) and the population-weighted concentrations (mainly influenced by urban areas), respectively, both for PM_{10} and NO_2. For ozone, the SOMO35 trends based on observations were found not to be significant except at traffic sites (which are not considered here) in Solberg et al. (2022), i.e., similar findings as in this report were reported.

In addition, maps of trends have been constructed based on the trend estimates for all 1x1 km^2 grid cells of a map, following the approach applied by Denby et al. (2008, 2010). For PM_{10}, slight downward trend in the major part of the European area has been detected in general, with more prominent downward trend in the area of Po valley in northern Italy, in the Ostrava-Katowice industrial region near the Czech-Polish border and in some other areas. In the case of ozone, slight decline in parts of Southern and Central and South-Eastern Europe has been observed, while no clear trend has been detected in the rest of Europe. For NO_2, a slight downward trend in the major part of European area has been observed, with more prominent downward trend in the area of Po valley as well as in the areas around large European cities (London, Paris, Madrid, Napoli, Thessaloniki) and in Benelux.

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The preparation of the cover data and the trend maps layout was assisted by Pavel Kurfürst (CHMI).

1 Introduction

ETC/ATNI and its predecessors have been producing reference annual European-wide air quality maps for the main indicators for now fifteen years, using data fusion mapping (Horálek et al., 2022, and reports cited therein). The mapping methodology (Regression – Interpolation – Merging Mapping, RIMM) combines monitoring data, chemical transport model (CTM) results and other supplementary data. In 2019, the then available 12-year time series of existing maps were used for trend analysis. A statistical tool to assess slope and significance of the trends was applied to existing PM_{10} (annual average), $PM_{2.5}$ (annual average) and ozone (SOMO35) maps. In addition, several aggregation products (e.g. evolution by country, urban vs. rural, regional classification etc.) were proposed. However, the 2019 analysis faced limitations because of missing years, changes in mapping methodology, changes in EMEP model version used in the data fusion mapping and observation gaps in some countries.

Because of these limitations, it was decided to perform a consistent reconstruction of the full 15-year time series of air quality maps from 2005 through 2019. We have performed such a reconstruction based on consistent mapping methodology and input data. Consistent EMEP model results, ECMWF meteorological data and other supplementary data have been applied. Measurement data only from stations with sufficient data coverage (i.e. 75 % of years) have been used, in order to apply as consistent set of measurement data among the years as possible.

When preparing the reconstructed time series of the maps, we have gathered consistent input data over the whole period 2005-2019. In doing this, we have prepared a subset of air quality measurement stations with sufficient data coverage. In order to check the representativeness of this subset, we have compared the maps created based on this subset with the maps created based on all stations available, for four years. Following this, we have produced the 15-year period time series of the maps, using a slightly simplified methodology compared to routine map production, in order to allow an automatization of the map production. The mapping area covers all of Europe apart from Belarus, Moldova, Ukraine and the European parts of Russia, Kazakhstan and Turkey. The area of Turkey was not included (although is mapped in the regular mapping for most pollutants in the last years), due to a lack of enough measurement data in this area for the 15-year period.

Based on the reconstructed time series of maps, a trend analysis has been prepared for the period 2005-2019. The trend analysis has been performed based on time series of aggregated data for individual countries, for four large European regions, for EU-28 and for the entire mapping area, both for spatial and population-weighted aggregations. In addition, maps of trends have been constructed based on the trend estimates for all 1x1 km^2 grid cells of a map, following the approach applied by Denby et al. (2008, 2010).

Maps of three pollutants, i.e. PM_{10} (annual average), ozone (SOMO35) and NO_2 (annual average) have been analysed. Originally, we intended also to analyse $PM_{2.5}$ (annual average), however, due to the lack of $PM_{2.5}$ stations in the first years of the analysed period, it was not possible to easily prepare consistent 15-year time series of the maps for this pollutant.

Chapter 2 describes the methodology and the input data applied, including the production of the consistent 15-year time series of the air quality maps. Chapters 3, 4 and 5 present the results of the trend analysis for PM_{10}, ozone and NO_2, including graphs and maps. Chapter 6 provides conclusions and recommendations. Annex 1 presents the analysis of spatial coverage of the stations for consistent maps. Annex 2 gives the technical details of the maps and their uncertainty analysis. Annex 3 shows graphs at the country level comparing the results presented in this report with results based on the regular maps. Annex 4 gives the numerical results of the trend analysis.

2 Data and methodology

2.1 Reconstructed consistent air quality maps

European-wide air quality maps based on spatial interpolation and data fusion of measurement, modelled and other supplementary data have been reconstructed for years 2005-2019, based on a consistent mapping methodology and input data. Section 2.1.1 describes the mapping methodology. Section 2.1.2 presents the methodology for uncertainty analysis of the mapping results. Section 2.1.3 documents the input data applied in the 2005-2019 reconstructed maps. Section 2.1.4 presents the preparation and testing of the reconstructed consistent 15-year time series of the maps.

2.1.1 Mapping methodology

The mapping methodology used is the Regression – Interpolation – Merging Mapping (RIMM) as routinely used in the spatial mapping under the ETC/ATNI (Horálek et. al., 2022); it consists of a linear regression model followed by kriging of the residuals from that regression model (residual kriging):

$$\hat{Z}(s_0) = c + a_1 X_1(s_0) + a_2 X_2(s_0) + \cdots + a_n X_n(s_0) + \hat{\eta}(s_0) \qquad (2.1)$$

where $\hat{Z}(s_0)$ is the estimated concentration at a point s_o,
$\hat{Z}(s_0) X_1(s_0)$ is the chemical transport model (CTM) data at point s_o,
$X_2(s_0), \ldots, X_n(s_0)$ are *n-1* other supplementary variables at point s_o,
$c, a_1, a_2, \ldots, a_n$ are the *n+1* parameters of the linear regression model calculated based on the data at the points of measurement,
$\hat{\eta}(s_0)$ is the spatial interpolation of the residuals of the linear regression model at point s_o, based on the residuals at the points of measurement.

For different pollutants and area types (rural, urban background, and for PM_{10} and NO_2 also urban traffic), different supplementary data are used. The spatial interpolation of the regression residuals is carried out using ordinary kriging, according to

$$\hat{\eta}(s_0) = \sum_{i=1}^{N} \lambda_i \eta(s_i) \qquad \text{with } \sum_{i=1}^{N} \lambda_i = 1, \qquad (2.2)$$

where $\hat{\eta}(s_0)$ is the interpolated value at a point s_o,
N is the number of the measurement points used in the interpolation, which is fixed based on the variogram; in any case, $20 \le N \le 50$,
$\eta(s_i)$ is the residual of the linear regression model at the measurement point s_i,
$\lambda_1, \ldots, \lambda_N$ are the estimated weights based on the variogram, see Cressie (1993).

For PM_{10}, prior to linear regression and interpolation, a logarithmic transformation to measurements and CTM modelled concentrations is executed. After interpolation, a back-transformation is applied.

Separate map layers are created for rural and urban background areas on a grid at resolution of 1x1 km^2 (for PM_{10} and NO_2) and 10x10 km^2 (for ozone), and for urban traffic areas at 1x1 km^2 (for PM_{10} and NO_2). The rural background map layer is based on rural background stations, the urban background map layer on urban and suburban background stations and the potential urban traffic map layer is based on urban and suburban traffic stations.

The separate handling of the rural and urban background map layers is based on the assumption that the estimated rural map layer value is lower (PM_{10} and NO_2) or higher (ozone) than the estimated urban background map layer value. In areas where this criterion does not hold, a joint urban/rural background map layer (created using all background stations regardless their type) is applied and the rural and urban background map layers are adjusted by this layer.

Subsequently, the separate map layers are merged into one combined final map at 1x1 km^2 resolution, according to

$$\hat{Z}_F(s_0) = \left(1 - w_U(s_0)\right) \cdot \hat{Z}_R(s_0) + w_U(s_0)\left(1 - w_T(s_0)\right) \cdot \hat{Z}_{UB}(s_0) + w_T(s_0) \cdot \hat{Z}_{UT}(s_0)$$
for PM_{10} and NO_2

$$\hat{Z}_F(s_0) = \left(1 - w_U(s_0)\right) \cdot \hat{Z}_R(s_0) + w_U(s_0) \cdot \hat{Z}_{UB}(s_0) \quad \text{for ozone} \qquad (2.3)$$

where $\hat{Z}_F(s_0)$ is the resulting estimated concentration in a grid cell s_o for the final map,
$\hat{Z}_R(s_0)$, $\hat{Z}_{UB}(s_0)$ and $\hat{Z}_{UT}(s_0)$ are the estimated concentration in a grid cell s_o for the rural background, the urban background and urban traffic map layer, respectively,
$w_U(s_0)$ is the weight representing the ratio of the urban character of the grid cell s_o,
$w_T(s_0)$ is the weight representing the ratio of areas exposed to traffics in a grid cell s_o.

The weight $w_U(s_0)$ is based on the population density, while the weight $w_T(s_0)$ is based on the buffers around the roads. For details, see Horálek et al. (2022 and references therein).

In all calculations and map presentations, the EEA standard projection ETRS89-LAEA5210 (also known as ETRS89 / LAEA Europe, see www.epsg.io) is used. The interpolation and mapping domain consists of the areas of all EEA member and cooperating countries, and other microstates, as far as they fall into the EEA map extent *Map_2c* (EEA, 2018). The mapping domain covers the whole Europe apart from Belarus, Moldova, Ukraine and the European parts of Russia and Kazakhstan. Due to a lack of enough data across Turkey in the 15-year period, the area of Turkey has been excluded from the mapping area (see Section 2.1.3).

2.1.2 Methodology for uncertainty analysis of mapping results

The uncertainty estimation of the maps is based on the leave-one-out cross-validation (LOOCV) using the measurement data. This technique computes the spatial interpolation for each point of measurement from all available information except from the point in question (i.e., it withholds data of one point and then makes a prediction at the spatial location of that point). This procedure is repeated for all points of measurement in the available set. The predicted and measurement values at these points are compared using statistical indicators and scatter plots. The main indicators used are root mean square error (RMSE), relative root mean square error (RRMSE) and bias (mean prediction error, MPE):

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(\hat{Z}(s_i) - Z(s_i)\right)^2} \qquad (2.4)$$

$$RRMSE = \frac{RMSE}{\bar{Z}}.100 \qquad (2.5)$$

$$bias(MPE) = \frac{1}{N}\sum_{i=1}^{N}\left(\hat{Z}(s_i) - Z(s_i)\right) \qquad (2.6)$$

where $Z(s_i)$ is the air quality measured indicator value at the i^{th} point, $i = 1, ..., N$,
$\hat{Z}(s_i)$ is the air quality estimated indicator value at the i^{th} point using other information, without the indicator value derived from the measured concentration at the i^{th} point,
$\bar{Z}$ is the mean of the indicator values $Z(s_1), ..., Z(s_N)$, as measured at points $i = 1, ... , N$,
N is the number of the measuring points.

Other indicators are R^2 and the regression equation parameters *slope* and *intercept*, following from the scatter plot between the predicted (using cross-validation) and the observed concentrations.

RMSE and RRMSE should be as small as possible, bias (MPE) should be as close to zero as possible, R^2 should be as close to 1 as possible, slope a should be as close to 1 as possible, and intercept c should be as close to zero as possible (in the regression equation $y = a.x + c$).

2.1.3 Data used in mapping

The types of input data in this report are similar to those used in the regular mapping, see Horálek et al. (2022). The key data are the air quality measurements at the monitoring stations extracted from Air Quality e-Reporting database, including geographical coordinates. The supplementary data cover the whole mapping domain and have been converted into the EEA reference projection ETRS89-LAEA5210 on a 1x1 km^2 grid resolution (for PM_{10} and NO_2) and a 10x10 km^2 grid resolution (for ozone).

Air quality monitoring data

Air quality station monitoring data for relevant years has been used, as extracted from the official EEA´s Air Quality e-Reporting database (EEA, 2021) and its predecessor AirBase (EEA, 2013a) in July 2021. This data set has been supplemented with several EMEP rural stations from the database EBAS (NILU, 2021) not reported to the Air Quality e-Reporting database and AirBase. Specifically, six additional rural background stations for PM_{10} have been added. For PM_{10} and NO_2 we use the stations classified as background (for all the three types of area, i.e., rural, suburban and urban), and also traffic, for the suburban and urban area types. For ozone, we use only data from stations classified as background (for all area types). In the mapping, rural background stations are used for the rural map layer, urban and suburban background stations for the urban background map layer and urban and suburban traffic stations for the urban traffic layer.

The following pollutants and aggregations have been used:

PM_{10} – annual average [$\mu g \cdot m^{-3}$], years 2005-2019

Ozone – SOMO35 [$\mu g \cdot m^{-3} \cdot day$], years 2005-2019

NO_2 – annual average [$\mu g \cdot m^{-3}$], years 2005-2019

SOMO35 is the annual sum of the differences between maximum daily 8-hour concentrations above 70 $\mu g \cdot m^{-3}$ (i.e., 35 ppb) and 70 $\mu g \cdot m^{-3}$.

It should be noted that the PM_{10} data for 2005 were corrected where non-reference measurement methods have been used (de Leeuw and Fiala, 2009). This applies specifically for French stations; the data were multiplied by a factor of 1.4 for rural stations, by a factor of 1.34 for urban/suburban background stations and by a factor of 1.24 for urban/suburban traffic stations.

For the mapping of the individual years 2005-2019, we have prepared the subset of the stations with the temporal completeness criteria of at least 75 % of the years covered, with applying the rounding, i.e., at least 11 years of the period 2005-2019. For stations with different classification in the course of the 15-year period (mostly in the Airbase vs. in the AQ e-reporting database), we have used the most recent classification.

In order to check the representativeness of the subset, the analysis of the stations´ data coverage has been performed, see Section 2.1.4 and Annex 1. Based on the analysis, the subset was slightly adapted in the case of PM_{10}, as described in Annex 1.

In the case of PM_{10}, the adapted subset consists of 216 rural background stations, 753 urban and suburban stations, and 400 urban and suburban traffic stations. In the case of ozone, the subset consists of 411 rural background and 789 urban and suburban background stations. In the case of NO_2, the subset consists of 293 rural background, 883 urban and suburban stations, and 526 urban and suburban traffic stations.

Table 2.1 shows the number of stations applied in the individual years for the creation of the reconstruction maps (which were further used in this report).

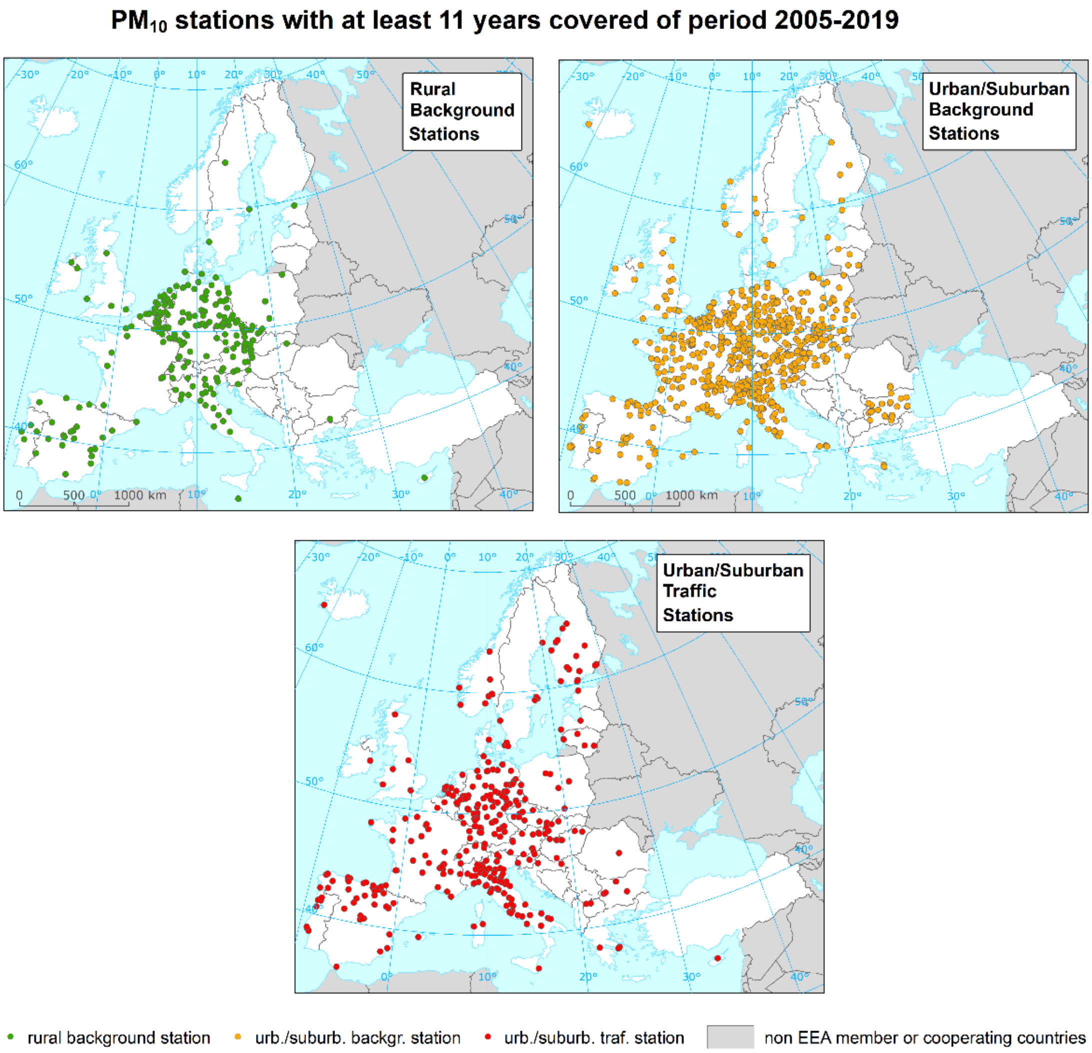
Table 2.1: Number of stations used for each pollutant and area type in individual years 2005–2019

Pollutant	Station type	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
PM_{10}	Rural background	147	156	176	191	203	212	209	207	194	202	197	210	209	212	210
	Urban/suburban backgr.	553	594	617	691	723	723	730	728	667	663	721	710	731	716	703
	Urban/suburban traffic	249	285	327	355	381	383	383	379	345	366	385	382	386	375	374
Ozone	Rural background	336	355	366	393	401	405	407	404	364	393	369	398	392	395	386
	Urban/suburban backgr.	633	679	690	758	780	776	771	770	695	741	579	770	739	737	724
NO_2	Rural background	230	232	247	272	283	284	287	287	249	274	290	282	282	282	283
	Urban/suburban backgr.	696	738	777	818	853	846	843	858	767	841	870	852	835	820	808
	Urban/suburban traffic	336	394	427	461	499	503	504	501	443	494	508	512	501	499	494

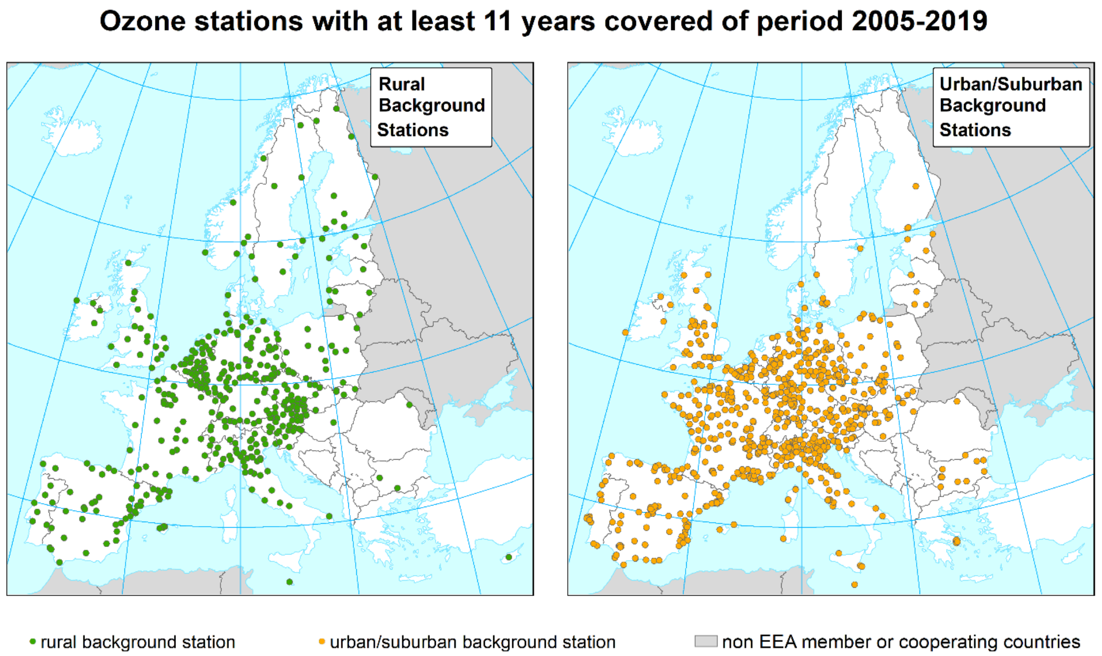
For the subset of the stations used for the mapping (separately for different station types), see Map 2.1 (for PM_{10}), Map 2.2 (for ozone) and Map 2.3 (for NO_2).

Due to the lack of the stations with the sufficient data coverage in Turkey and the fact that in the regular mapping, the area of Turkey was not mapped in years with a lack of Turkish data (due to a high mapping uncertainty for this area), we have decided not to present the maps for the area of Turkey.

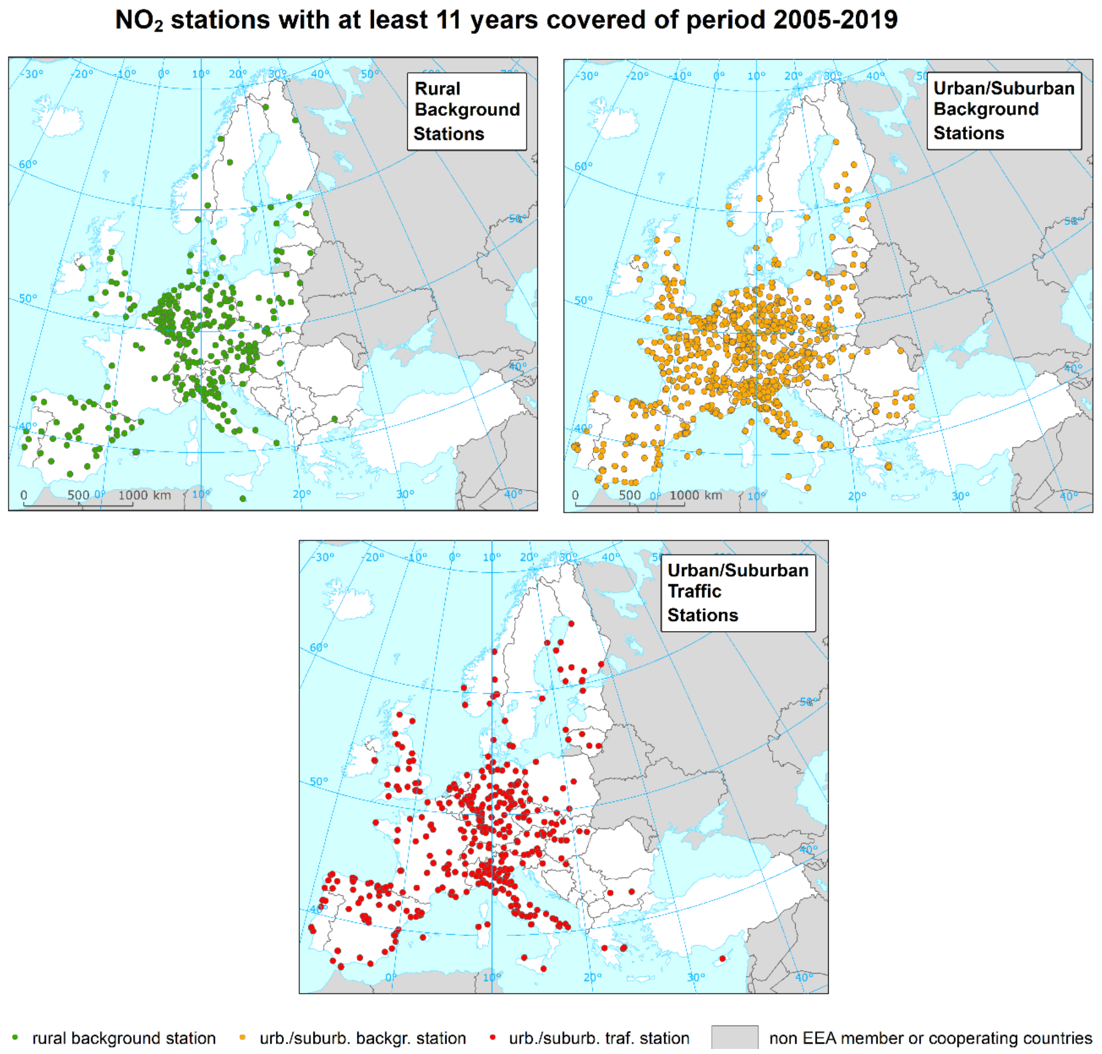
Map 2.1: Spatial distribution of the subset of PM_{10} stations for maps for trends 2005-2019



Map 2.2: Spatial distribution of the subset of ozone stations for maps for trends 2005-2019



Map 2.3: Spatial distribution of the subset of NO_2 stations for maps for trends 2005-2019



Chemical transport modelling (CTM) data

The chemical dispersion model used in this report is the EMEP MSC-W model, which is an Eulerian model. Simpson et al. (2012) and NMI (2021) describe the model in more detail. The modelling results for years 2005-2018 are based on the model version rv4.33 (EMEP, 2019, Mareckova et al., 2019), while the model output for 2019 on the version rv4.35 (EMEP, 2020, Mareckova et al., 2020). For years 2005-2017, both the emissions and the meteorology of the relevant year were used, while for 2018 and 2019, emissions of the previous years (i.e., 2017 and 2018) and ECMWF meteorology of the relevant years (i.e., 2018 and 2019) were used in the modelling. Although the model version applied for 2019 is not identical as the one used for the other years, we still consider 2019 model results comparable with the previous ones, as the two model versions do not differ considerably. One-year-older emissions have been used in the cases of the two years for specific reasons, namely in order to use the same model version as for the previous years (for 2018) and to include the most actual year in the analysis (for 2019). Note that the one-year-older emissions are routinely used in the regular mapping (Horálek et al., 2022).

The resolution of the model is 0.1°x0.1°, i.e., circa 10x10 km^2. We have downloaded the EMEP data from NMI (2019, 2020) in the form of annual aggregations. Then, we have spatially transformed the data to the reference EEA 1x1 km^2 and 10x10 km^2 grids. The same parameters as in the case of the measurement data are used: PM_{10} annual average, ozone indicator SOMO35 and NO_2 annual average for years 2005-2019.

Meteorological data

The meteorological data used are the ECWMF data extracted from the Climate Data Store (CDS), ECMWF (2021). Specifically, the hourly data of the reanalysed data set ERA5-Land in 0.1°x0.1° resolution have been used, which was complemented in the coastal areas by the data set ERA-5 in 0.25°x0.25° resolution. The hourly data have been derived into the parameters needed, aggregated into the annual statistics and converted into the reference EEA 1x1 km^2 (for PM and NO_2) and 10x10 km^2 (for ozone) grids. For details, see Horálek et al. (2022). Meteorological parameters used are *wind speed* (annual mean for years 2005-2019, in $m.s^{-1}$), *relative humidity* (annual mean for 2005-2019, in percent) and *surface net solar radiation* (annual means of daily sum for 2005-2019, in $MWs.m^{-2}$).

Satellite data

An annual average NO_2 dataset was constructed from data acquired by the *OMI* instrument onboard the Aura platform. While more recent instruments such as TROPOMI on Sentinel-5P have much improved spatial resolution, the OMI instrument was chosen because it is the only instrument with data coverage throughout the entire study period. The variable used is

NO_2 – annual average tropospheric vertical column density (VCD) [number of NO_2 molecules per cm^2 of earth surface], years 2005-2019 (aggregated from daily data).

The OMNO2d product generated by NASA was used as a basis, NASA (2021). The tropospheric column was used. All the orbits within a given day (typically observed between 13:00 and 14:00 local time) are mapped into a 0.25x0.25 degrees grid. For details, see Horálek et al. (2022).

Land cover

CORINE Land Cover 2006 (CLC2006), 2012 (CLC2012) and 2018 (CLC2018) data in 100 x 100 m^2 grid have been used. Namely, CLC2006 Version 17 12/2013 (EEA, 2013b), CLC2012 Version 18 09/2016 (EEA, 2016) and CLC2018 Version 2020_20 (EU, 2020) have been used. Like in Horálek et al. (2022), the 44 CLC classes have been re-grouped into the 8 more general classes. In this report, we use five of these general classes, namely high density residential areas (HDR), low density residential areas (LDR), agricultural areas (AGR), natural areas (NAT), and traffic areas (TRAF). For details, see Horálek et al. (2022). Two aggregations have been used, i.e., into 1x1 km^2 grid and into the circle with radius of 5 km. The aggregated grid value represents for each general class the total area of this class as percentage of the total area of the 1x1 km^2 square or the circle with radius of 5 km.

Altitude

We have used the altitude data field (in m) of Global Multi-resolution Terrain Elevation Data 2010 (GMTED2010), with an original grid resolution of 15x15 arcseconds coming from U.S. Geological Survey Earth Resources Observation and Science, see Danielson and Gesch (2011).

Population density and Road data

Population density (in inhabitants.km^{-2}, census 2011) is based on Geostat 2011 grid dataset (Eurostat, 2014). For regions not included in the Geostat 2011 dataset we use as alternative sources JRC (2009) and ORNL (EEA, 2010) data. For details, see Horálek et al. (2022).

GRIP vector road type data is used (Meijer et al., 2018). Based on these data (i.e., buffers around the roads), traffic map layers (Section 2.1) are merged into the final maps (Horálek et al., 2022).

2.1.4 Production and testing of reconstructed consistent air quality maps

Based on the consistent methodology (Section 2.1.1) and input data (Section 2.1.2), the reconstructed consistent maps have been prepared.

As a first step, a sensitivity analysis has been performed for four years, i.e., for 2005, 2010, 2015 and 2019 (for PM_{10} and NO_2) or 2018 (for ozone). In order to check whether the maps prepared based on the subset of the stations (see Section 2.1.3) truly reflect the whole mapping area, we have compared the maps created based on this subset with the maps created based on all stations available. Based on the analysis, it has been concluded that for most of the area, the differences in relative terms are less than 25 %. For the details of this analysis, see Annex 1. The main results are presented in the following paragraphs.

For PM_{10}, higher differences have been detected in the urban background areas in the centre and north of Romania and in the urban traffic areas in Cyprus: the subset of the stations include few stations only in this area. Based on the results of this analysis, we have decided to slightly adapt the subset of the stations (specifically, to include one additional Romanian urban background station with data in 10 years available and to merge the data of two nearby Cypriot traffic stations), in order to improve the results.

For ozone, high differences have been observed in Romania, especially in the urban background, but also in the rural areas. The map variants created based of all stations show lower results in this area, compared to the map variants based on the subset of the stations. Contrary to the PM_{10} mapping, it was not possible to supplement the subset of the stations with an additional ozone station in the area of Romania. Thus, for production of the 15-year time series of the reconstructed consistent ozone maps, the original subset of the stations has been used. We can suppose that the trend has been estimated correctly, however the estimated concentration values are somewhat overestimated compared to the measurement data.

For NO_2, no major differences in relative terms have been detected. Thus, no change in the subset of the stations was needed, so the original subset of the stations has been further used.

Subsequently to the sensitivity analysis, the 15-year time series of the reconstructed consistent maps have been prepared. For PM_{10}, the slightly adapted subset of the stations has been used, as described above. The maps have been prepared automatically, using a script based on R language that was earlier developed in the CHMI. For the individual pollutants and map layers, in general the similar set of supplementary variables as in the regular mapping (Horálek et al., 2022) was used, with some minor adaptations. Specifically, in the case of NO_2, the number of supplementary variables was somewhat reduced, in order to stabilize the set of the variables used throughout the years and to enable the automatization. The parameters of the variogram have been estimated automatically. For technical details of the maps, see Annex 2, Tables A2.1-A2.8.

Based on the cross-validation, the uncertainty of the maps have been evaluated. Comparing with the uncertainties of the maps routinely prepared (Horálek et al., 2022 and references therein), we can state that in general, the level of the mapping uncertainty is quite similar for both the regular and the reconstructed maps. For technical details of the maps, see Annex 2, Tables A2.1-A2.8.

2.2 Spatial average and population-weighted average concentrations

Based on the air quality concentration maps and the population data, the spatial average concentrations and population-weighted average concentrations have been calculated, namely (i) for individual countries, (ii) for four European regions, (iii) for the EU-28 and (iv) for Europe as a whole (i.e., the whole mapping area). The following equations were used

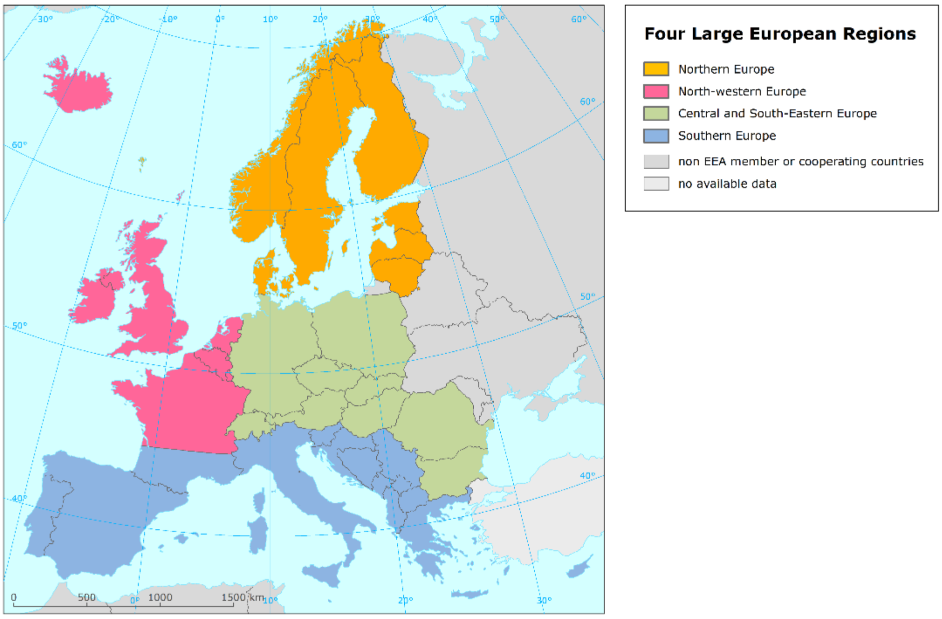
$$c_{popw\_avg} = \frac{\sum_{i=1}^{N} c(i) \cdot p(i)}{\sum_{i=1}^{N} p(i)} \quad (2.7)$$

$$c_{sp\_avg} = \frac{\sum_{i=1}^{N} c(i)}{\sum_{i=1}^{N} p(i)} \quad (2.8)$$

where c_{popw_avg} is the population-weighted average concentration in a given year,
c_{sp_avg} is the spatial average concentration in a given year,
p (i) is the population in the *i*-th grid cell,
c (i) is the mean concentration in the *i*-th grid cell (based on the air quality map),
N is the number of grid cells in Europe, EU-28, large region or individual country.

Four large European regions as used in Horálek et al. (2022) have been used, see Map 2.4. Specifically: *Northern Europe*: Denmark (apart from Faroe Islands), Estonia, Finland, Latvia, Lithuania, Norway, and Sweden. *North-western Europe*: Belgium, Faroe Islands, France north of 45 degrees latitude, Iceland, Ireland, Luxembourg, the Netherlands, and the United Kingdom. *Central and South-Eastern Europe*: Austria, Bulgaria, Czechia, Germany, Hungary, Liechtenstein, Poland, Romania, Slovakia, and Switzerland. *Southern Europe*: Albania, Andorra, Bosnia-Herzegovina, Croatia, Cyprus, France south of 45 degrees latitude, Greece, Italy, Malta, Monaco, Montenegro, North Macedonia, Portugal, San Marino, Serbia (including Kosovo under the UN Security Council Resolution 1244/99), Slovenia, and Spain.

Map 2.4: Four large European regions



2.3 Methodology for trend analysis

For detecting and estimating the trends in time series of the annual values, the non-parametric Mann-Kendall test for testing the presence of the monotonic increasing or decreasing trend has been used. Next to that, the non-parametric Sen's (or Sen-Theil) method for estimating the slope of a linear trend has been executed. For details, see Gilbert (1987). The significance of the Mann-Kendall test is shown by the usual way, i.e. + for 0.1, * for 0.05, ** for 0.01, and *** for 0.001. For the Sen's slope estimate, next to the estimated value Q of this trend, the probability margins of this trend Qmin95 and Qmax95 (showing the confidence interval at 95 % level) are also presented (apart from the trend maps).

The trend analysis is applied for the spatial average concentrations and for the population-weighted average concentrations, for the absolute and for the relative values. Each trend analysis is made for individual countries, for four European regions, for EU-28 and for Europe as a whole (i.e., the whole mapping area). The relative values (expressed in percent) are related to the linear fit for 2005 values, i.e. the beginning of the time series. The linear fit for 2005 is used instead of the actual 2005 data, in order to minimize the impact of inter-annual variability (if 2005 is an outstanding year).

Next to the described analysis, the same analysis is performed separately for rural and for urban areas. Distinguishing of the rural and the urban areas is performed based on the population density.

Additionally, we have prepared the trend maps, based on the trend analysis in each 1x1 km^2 grid cell of the map, similarly to Denby et al. (2008, 2010).

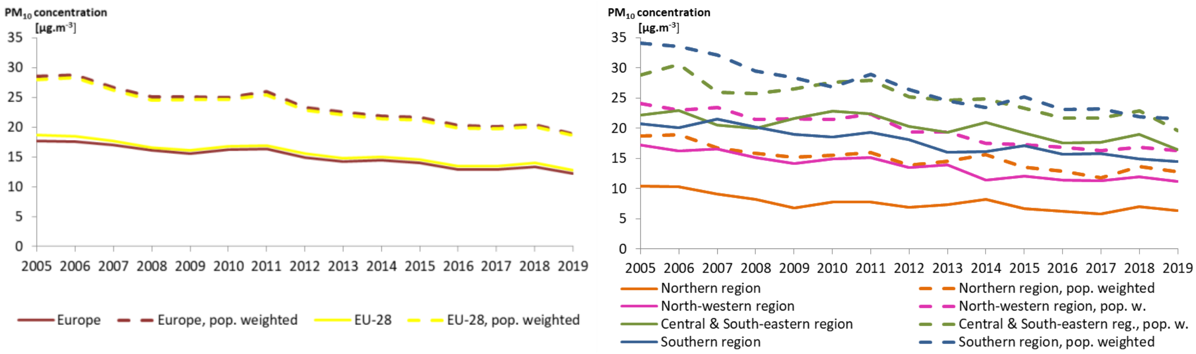
3 PM_{10} – Annual average

Annual average PM_{10} concentrations are evaluated in this chapter in terms of their evolution and trend for the 15-year period 2005-2019. The assessment is based on the concentration maps and the population data. The spatial average concentrations and population-weighted average concentrations for individual countries, for four European regions, for EU-28 and for Europe as a whole (i.e., the whole mapping area) have been calculated (for whole areas without division and after division into urban and rural areas). Apart from the absolute average concentrations, relative average concentrations have been also calculated for all years (see Section 2.3). Next to this, the trend maps have been constructed. The Mann-Kendall test has been used to evaluate trends in the time series of annual values of PM_{10}, and the nonparametric Sen´s method has been performed (for more details, see Section 2.3). Section 3.1 presents the time series and trend for spatial and population-weighted averages, while Section 3.2 for urban and rural areas. Section 3.3 shows the trend maps.

3.1 Time series and trends for spatial and population-weighted averages

The average time series of PM_{10} annual mean over the whole Europe (i.e. the entire mapping area), EU-28 and four large European regions is presented in Figure 3.1. It shows that the population-weighted exposure is systematically higher compared to the spatial average concentration. This is due to the occurrence of higher PM_{10} concentrations in areas with higher density of inhabitants connected with the intensive emission sources (local heating, traffic). Both display a consistent decline in time over all the areas. Comparing the aggregated data for four large regions, Northern Europe shows the lowest results, while Central and South-eastern Europe the highest results, in general. The decline in Central and South-eastern Europe is steeper than in the Southern Europe. The trend for spatial average concentration tends to be lower in amplitude (both in absolute and relative terms) than the trend for population-weighted concentration for both the whole Europe and EU-28.

Figure 3.1: Time series of annual mean PM_{10} aggregated over entire area and EU-28 (left) and large regions (N/NW/CSE/S) of Europe (right); solid lines mark spatial average, while dashed lines pop.-weighted average.



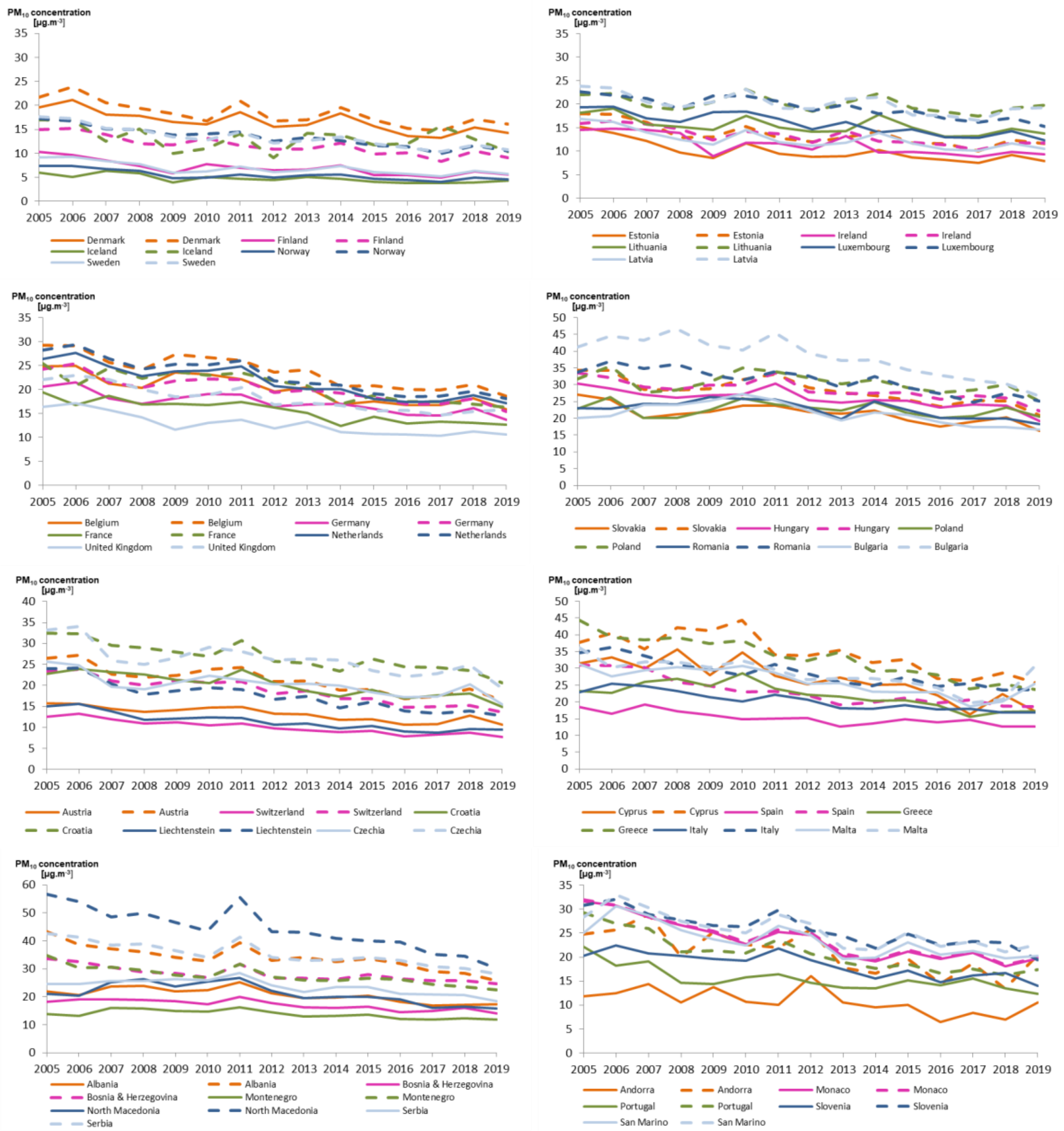
For the European-wide aggregations across the whole mapping area, a statistically significant downward trend of -0.39 $\mu g.m^{-3}$ per year (or -2.2 % per year, in relative terms) for spatially averaged concentrations and of -0.68 $\mu g.m^{-3}$ per year (or -2.4 % per year) for population-weighted averaged concentrations have been estimated, see Annex 4, Table A4.3. This means a decrease of about 30 % for spatial averaged PM_{10} annual mean concentrations and about 35 % for population-weighted averaged PM_{10} annual mean concentrations during the period 2005-2019.

Those estimates can be put in perspective with the statistics derived exclusively from observations in Solberg et al. (2022). As mentioned above, the main strength of the present assessment based on RIMM is to offer a more comprehensive spatial coverage/representativeness. Trend assessment based on in situ observations suffer from a very inhomogeneous spatial distribution of the network.

Nevertheless in situ observations constitute a key reference which needs to be confronted with the present estimates. When using only in situ data, the trend of the European median of PM_{10} annual average over 2005-2019 is estimated to be 0.68 $\mu g.m^{-3}.yr^{-1}$ and 0.42 $\mu g.m^{-3}.yr^{-1}$, at urban and rural sites respectively. Those estimates are therefore very consistent with the mapped trends when comparing the whole mapping area, i.e., the spatial averaged concentrations (constituted of a majority of rural areas) and population-weighted concentrations (mainly influenced by urban areas).

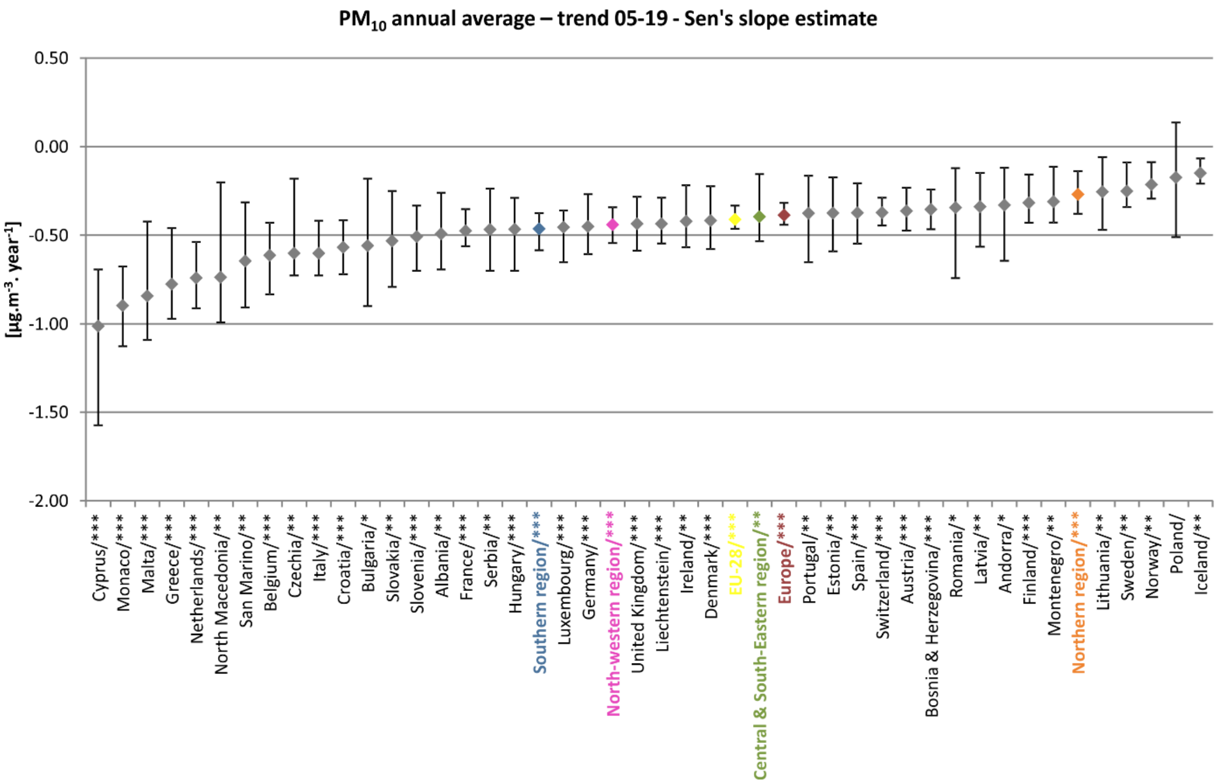
The time series averaged over all grid cells of the 40 available countries in the RIMM maps are presented in Figure 3.2. The main purpose of these plots is to present the long term evolution using a spatial aggregation which relies on RIMM maps and is more representative compared to an average of all trends at in-situ stations (as done in Colette and Rouïl, 2021) that suffers from the spatial inhomogeneities in the monitoring network. The time series have quite similar year-to-year development for most countries, except for example Cyprus and Andorra where some years appear somewhat outlying.

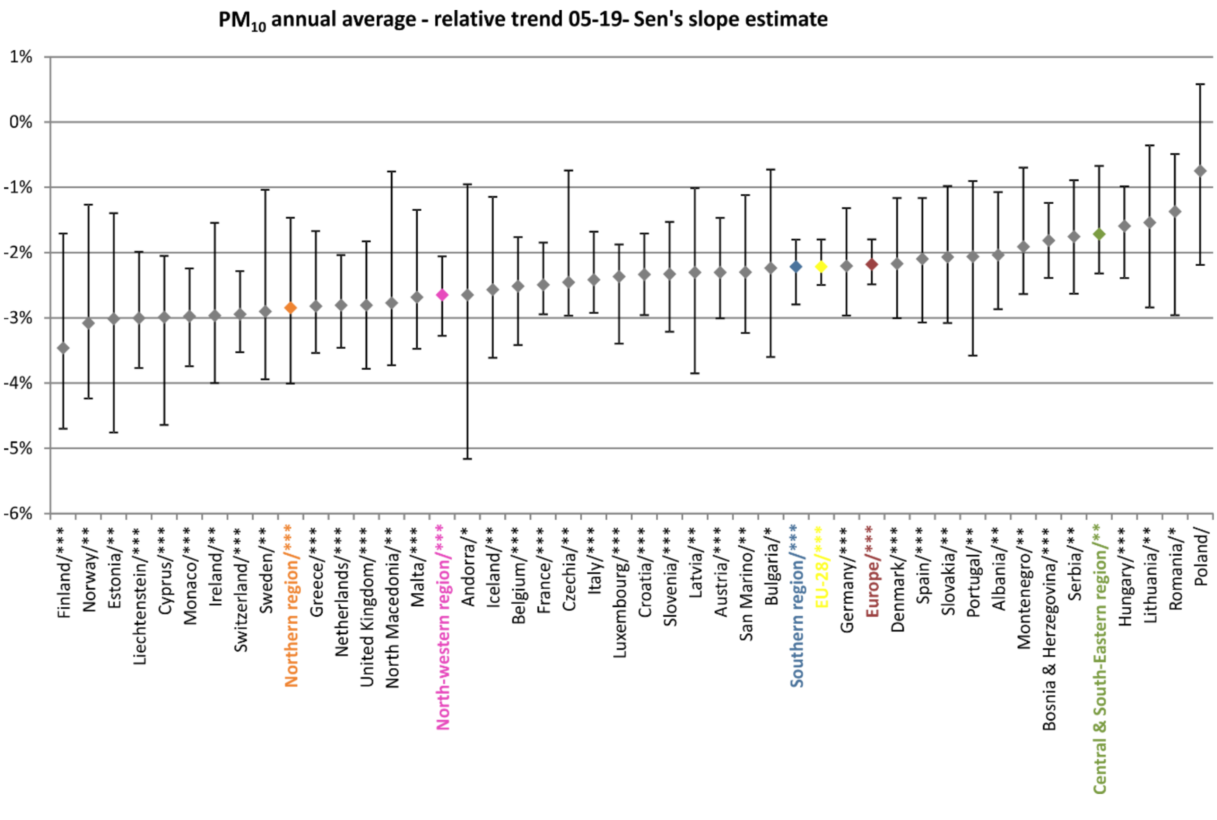
Figure 3.2: Time series of annual mean PM_{10} aggregated by country. Five countries are represented on each panel (solid lines spatial average, dashed lines pop.-weighted average).



The spatially averaged absolute and relative trends by country and over the whole Europe, EU-28 and large European regions are presented in Figure 3.3. These plots show that annual mean PM_{10} trends are significantly decreasing over most countries, i.e., all countries except for Poland.

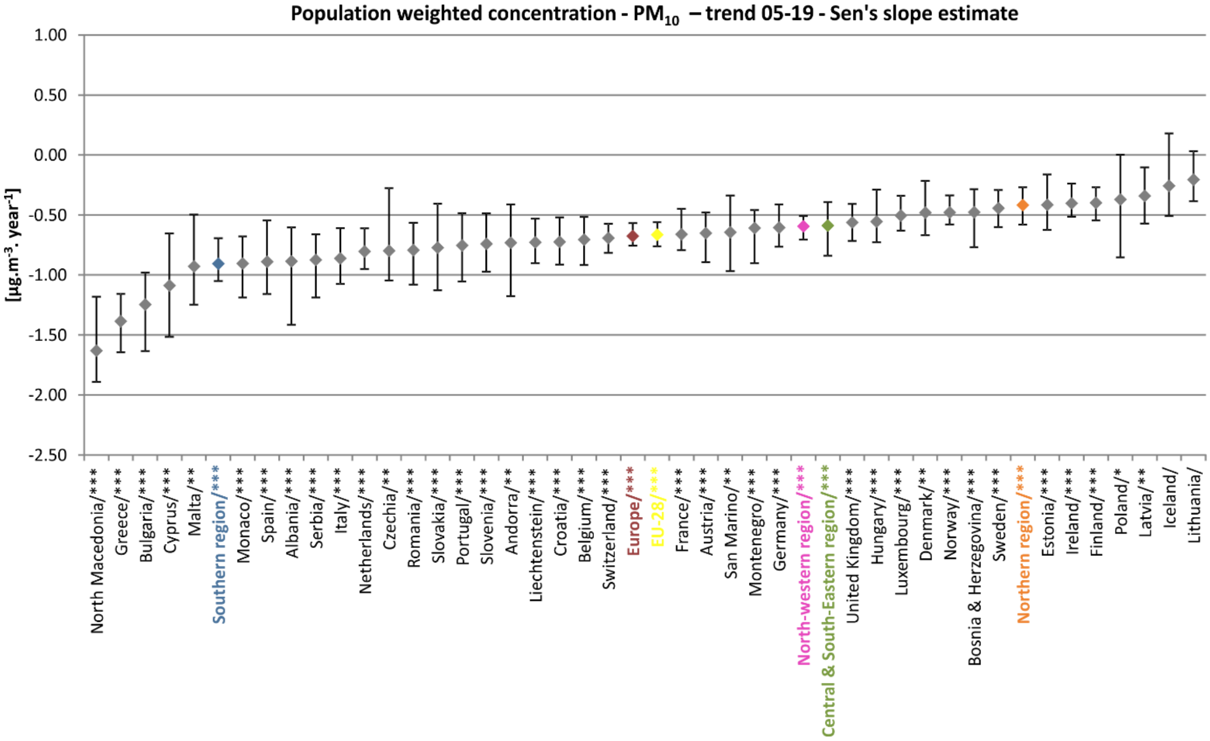
Figure 3.3: Sen´s trend of PM_{10} annual mean spatially averaged over countries, entire area, EU-28 and large European regions in absolute ($\mu g.m^{-3}.yr^{-1}$) and relative ($\%.yr^{-1}$) terms. The uncertainty bar is representative of trend significance, also indicated in the x-axis.

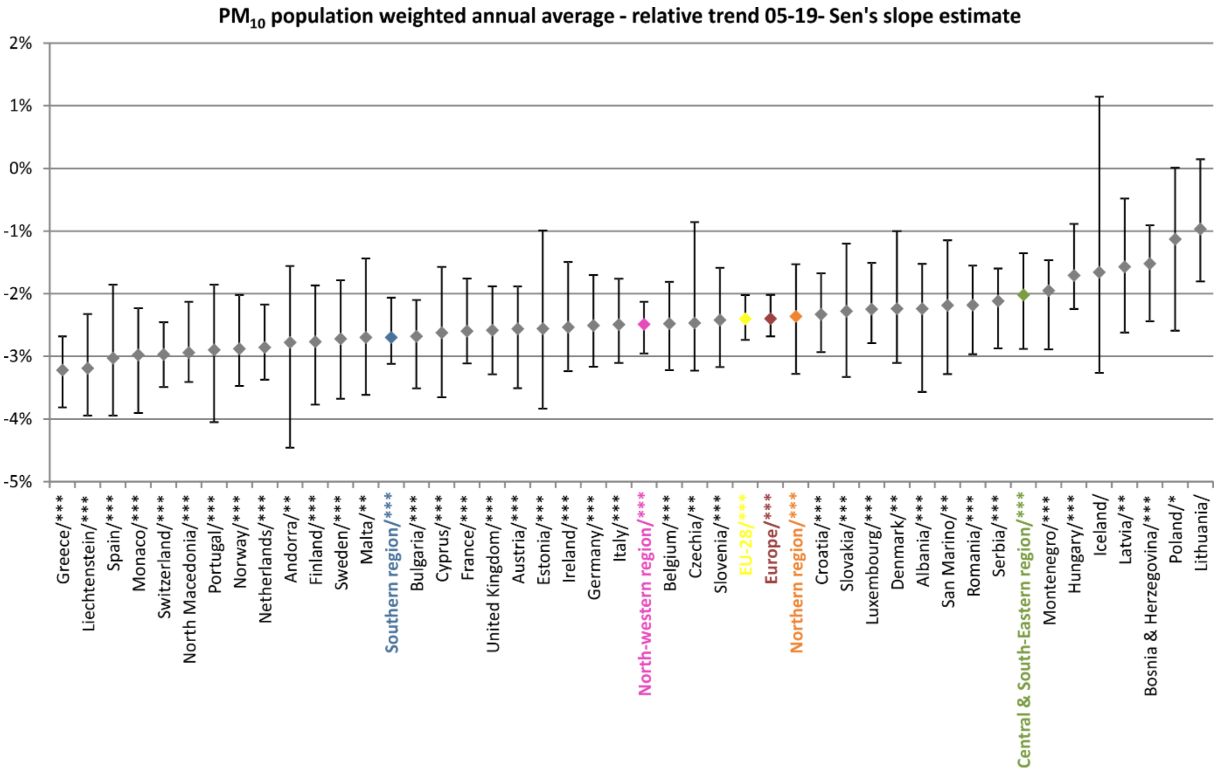




The absolute and relative trends of population-weighted averages by country and over the whole Europe, EU-28 and large European regions are presented in Figure 3.4.

Figure 3.4: Sen´s trend of PM_{10} annual mean, population-weighted averages over countries, entire Europe, EU-28 and large European regions in absolute ($\mu g.m^{-3}.yr^{-1}$) and relative ($\%.yr^{-1}$) terms. The uncertainty bar is representative of trend significance, also indicated in the x-axis.





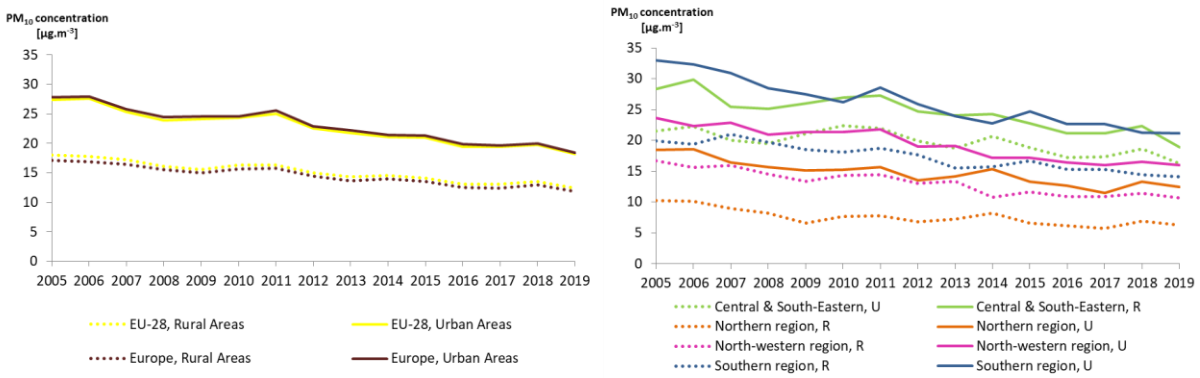
For each country, the Sen´s slope of the time series is presented as well as an indication of the significance of the trend: +/*/**/*** symbols as defined in Section 2.2, and uncertainty bar. The bars show the confidence interval of this trend at the 0.05 significance level. When the confidence interval overlaps zero, the trend is not significant. Relative trends are expressed relatively to the concentration value in the beginning of the record (2005), in percent of the relevant 2005 value per year.

For the numerical results of the times series and trends, see Annex, Tables A4.1-A4.3.

3.2 Time series and trends in urban versus rural areas

The time series of spatial average annual mean PM_{10} over the whole Europe, the EU-28 and four large European regions are presented in Figure 3.5, separately for urban and rural areas. The aim of this analysis is to compare the evolution in urban versus rural areas. Compared to Section 3.1, only the spatial average is considered, not the population-weighted average.

Figure 3.5: Time series of annual mean PM_{10} aggregated over entire area and EU-28 (left) and large regions (N/NW/CSE/S) of Europe (right); solid lines mark average over urban areas, dotted lines average over rural areas.



The time series of spatial average aggregated by country are presented in Figure 3.6, separately for urban and rural areas.

As expected, the PM_{10} levels are lower in rural areas, but it also appears that their decline in absolute values is less pronounced in most countries, compared to urban areas.

Figure 3.6: Time series of annual mean PM_{10} aggregated by country. Five countries are represented on each panel (solid lines average over urban areas, dotted lines average over rural areas).

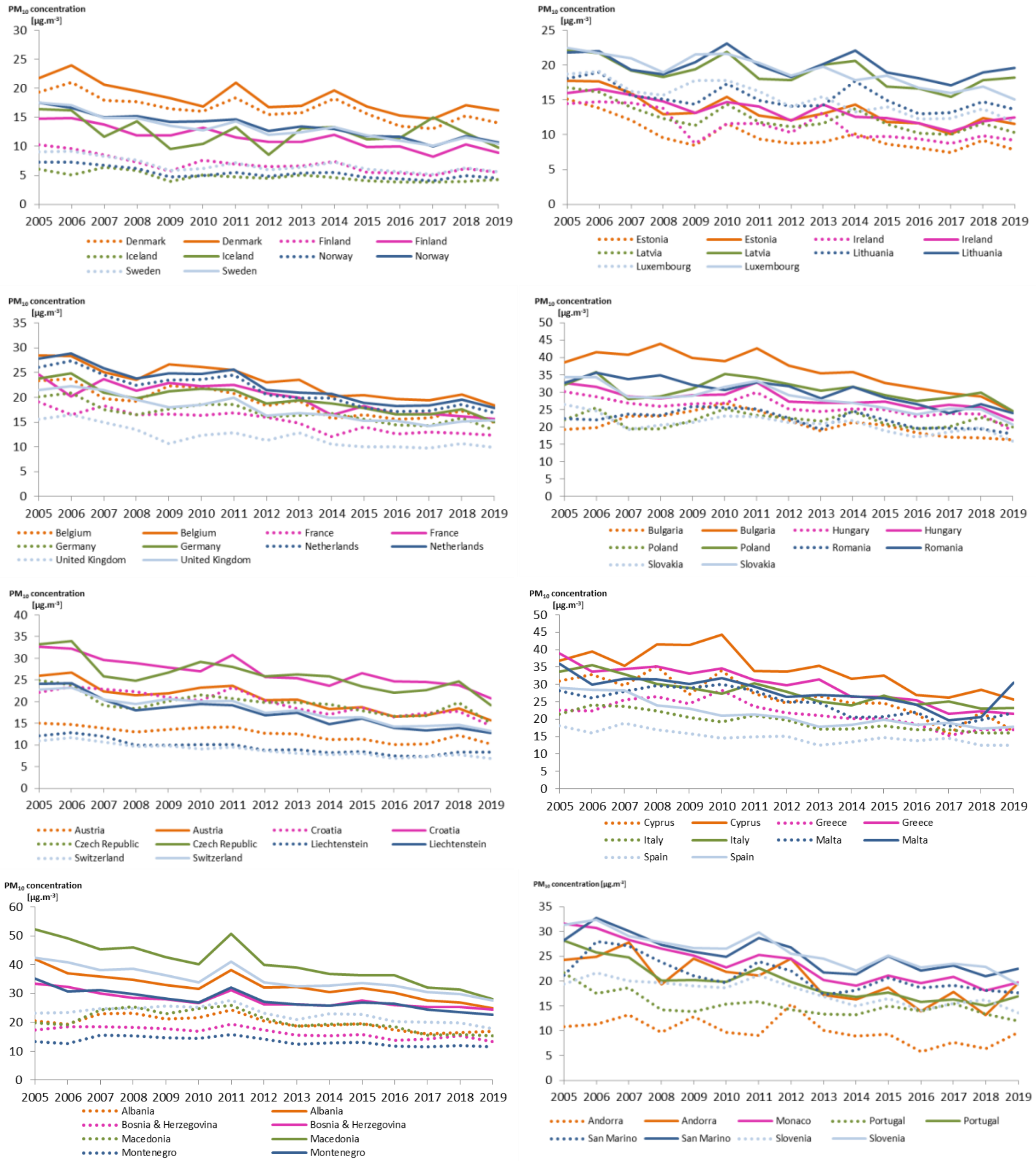
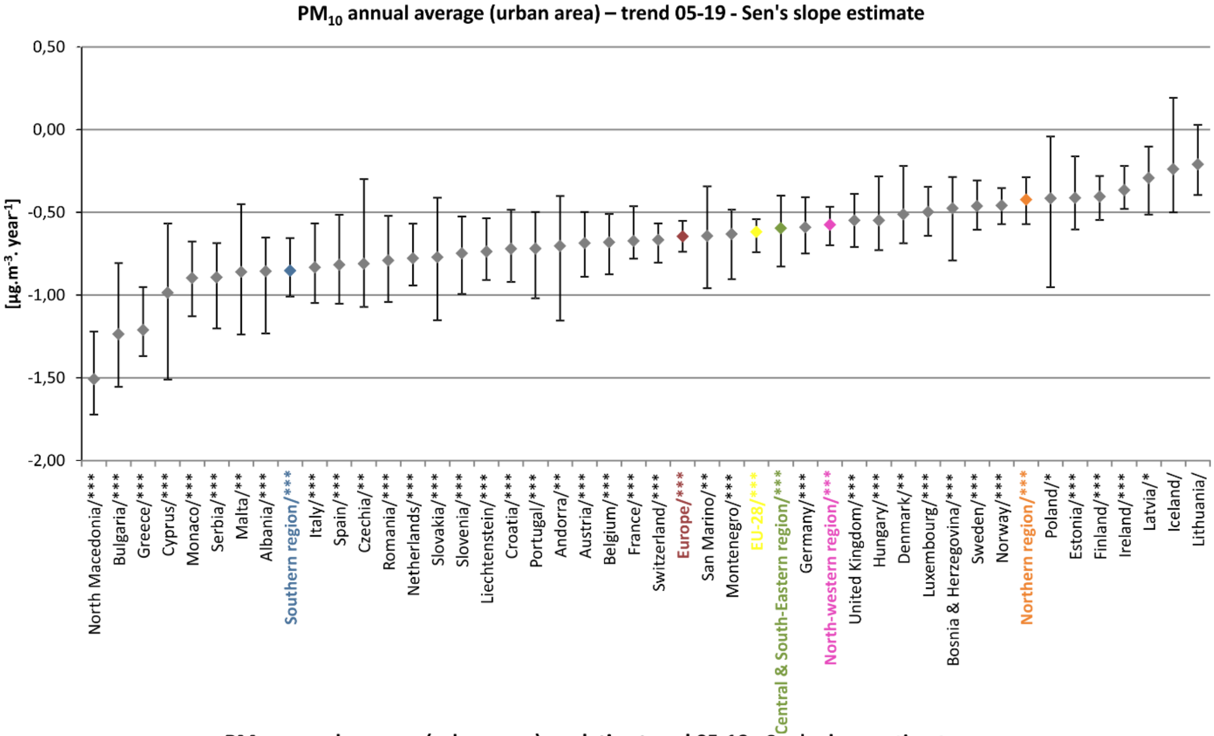


Figure 3.6 shows a gradual increase in PM_{10} concentrations in some urban areas of Lithuania, Latvia, Ireland over the last 3 years. A sharp increase in PM_{10} concentrations is shown for Malta and Andorra for urban areas in 2019. Nevertheless, it is influenced by the fact that there are no urban stations with sufficient data in these two small countries and thus by the higher uncertainty of the results.

The larger decline in urban areas compared to rural areas is also found in the absolute Sen´s slopes by country and over the whole Europe, EU-28 and large European regions represented in Figure 3.7 and Figure 3.8. These figures also show similar magnitude of relative declines over rural and urban areas.

For the numerical results of the trends, see Table A4.4.

Figure 3.7: Sen´s trend of PM_{10} annual mean by country and over entire Europe, EU-28 and large European regions in urban areas in absolute ($\mu g.m^{-3}.yr^{-1}$) and relative ($\%.yr^{-1}$) terms. The uncertainty bar is representative of trend significance, also indicated in the x-axis.



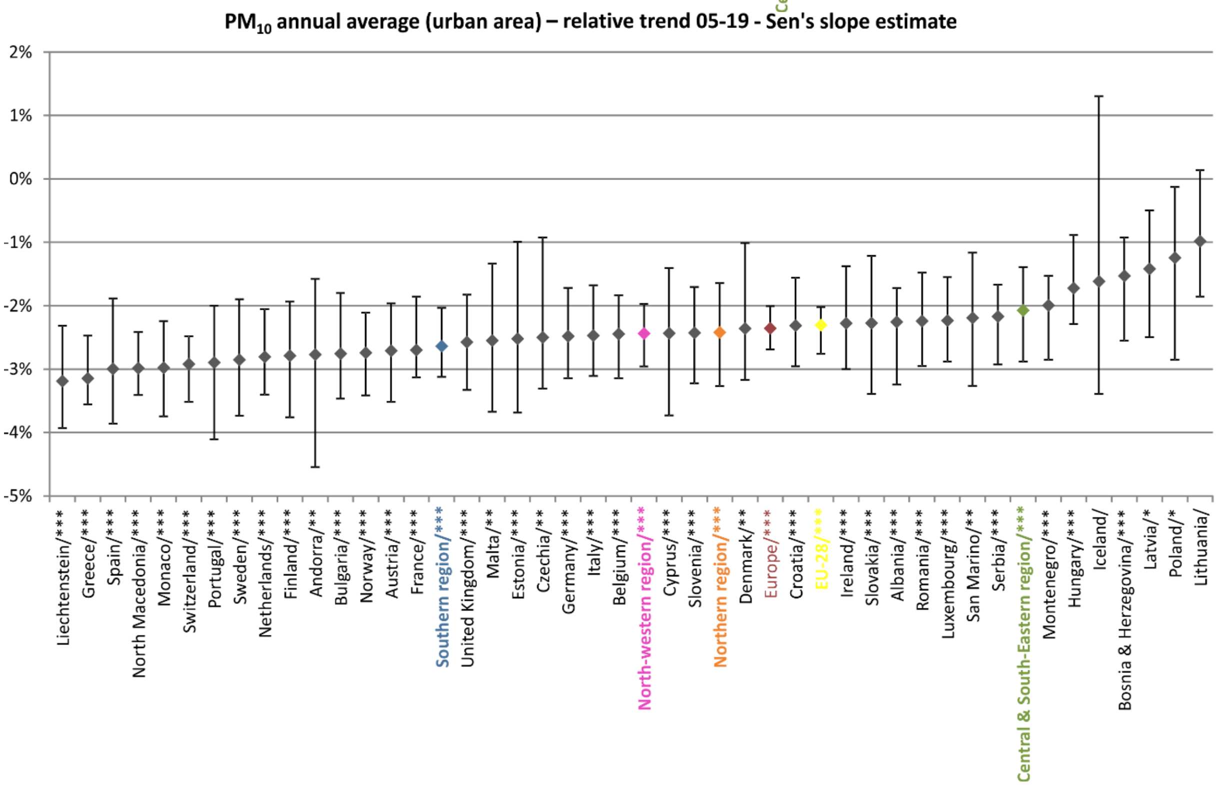
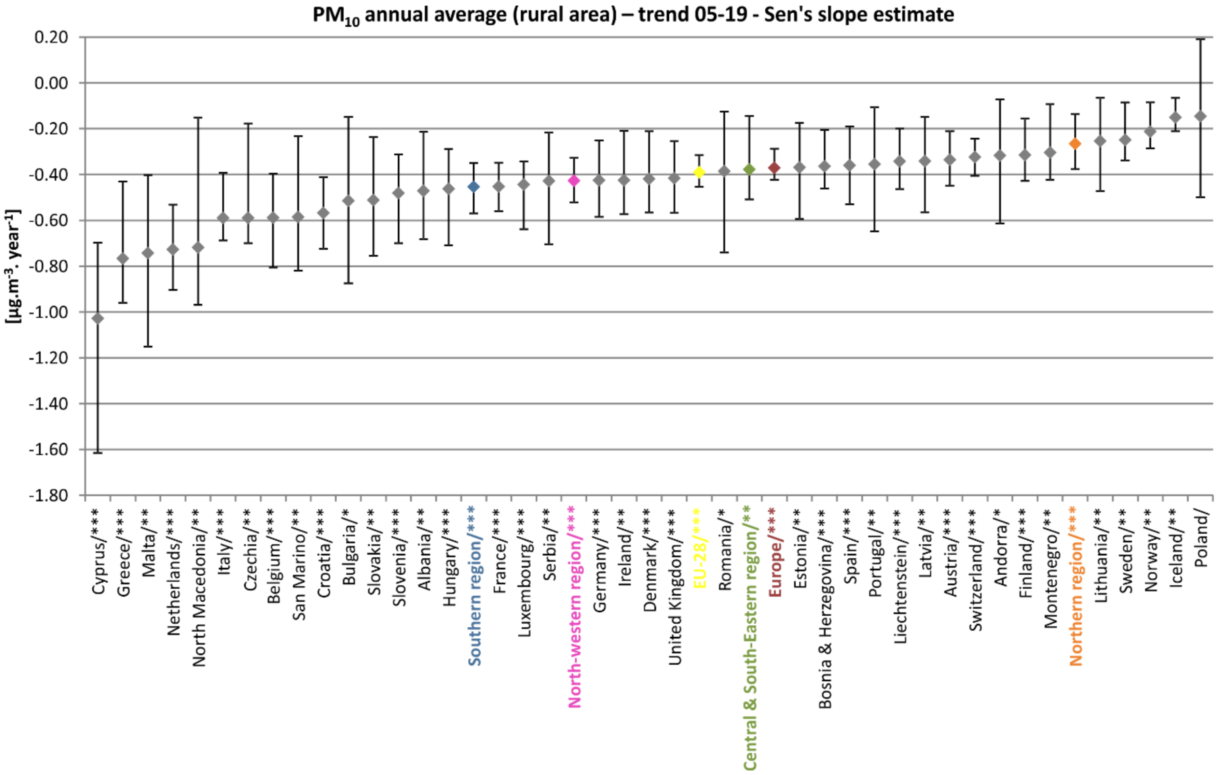
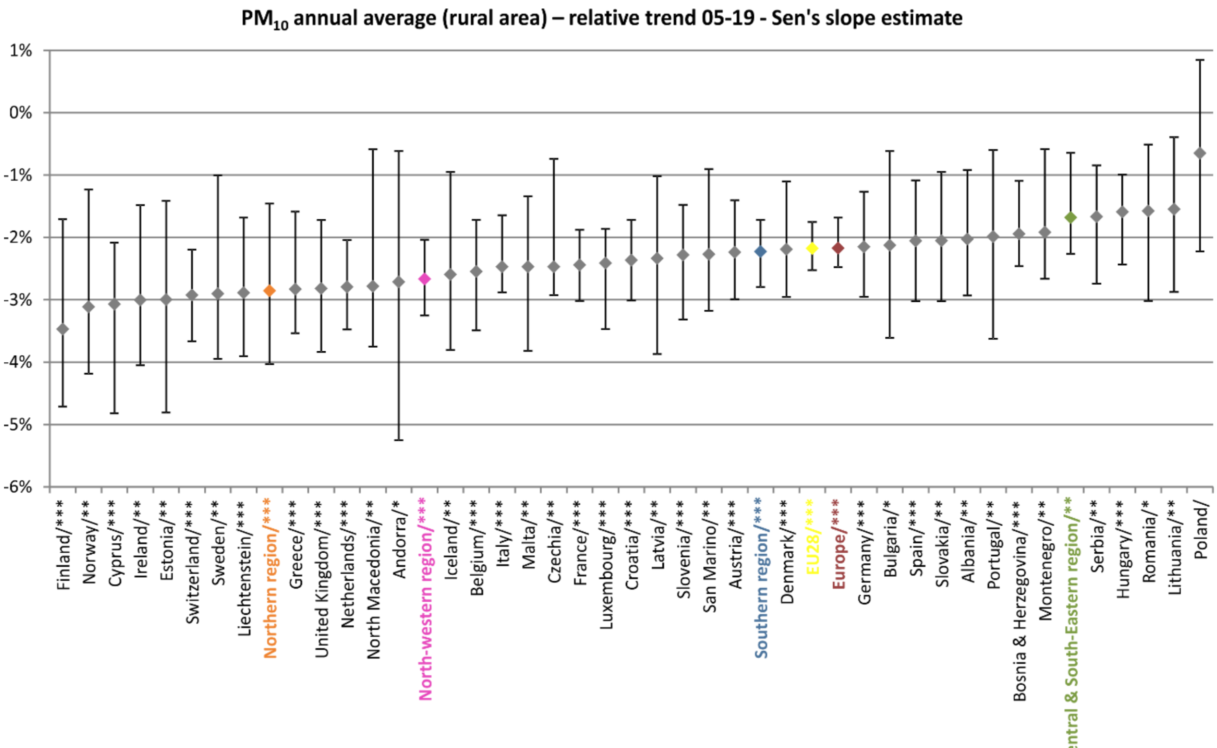


Figure 3.8: Sen´s trend of PM_{10} annual mean by country and over entire Europe, EU-28 and large European regions in rural areas in absolute ($\mu g.m^{-3}.yr^{-1}$) and relative ($\%.yr^{-1}$) terms. The uncertainty bar is representative of trend significance, also indicated in the x-axis.





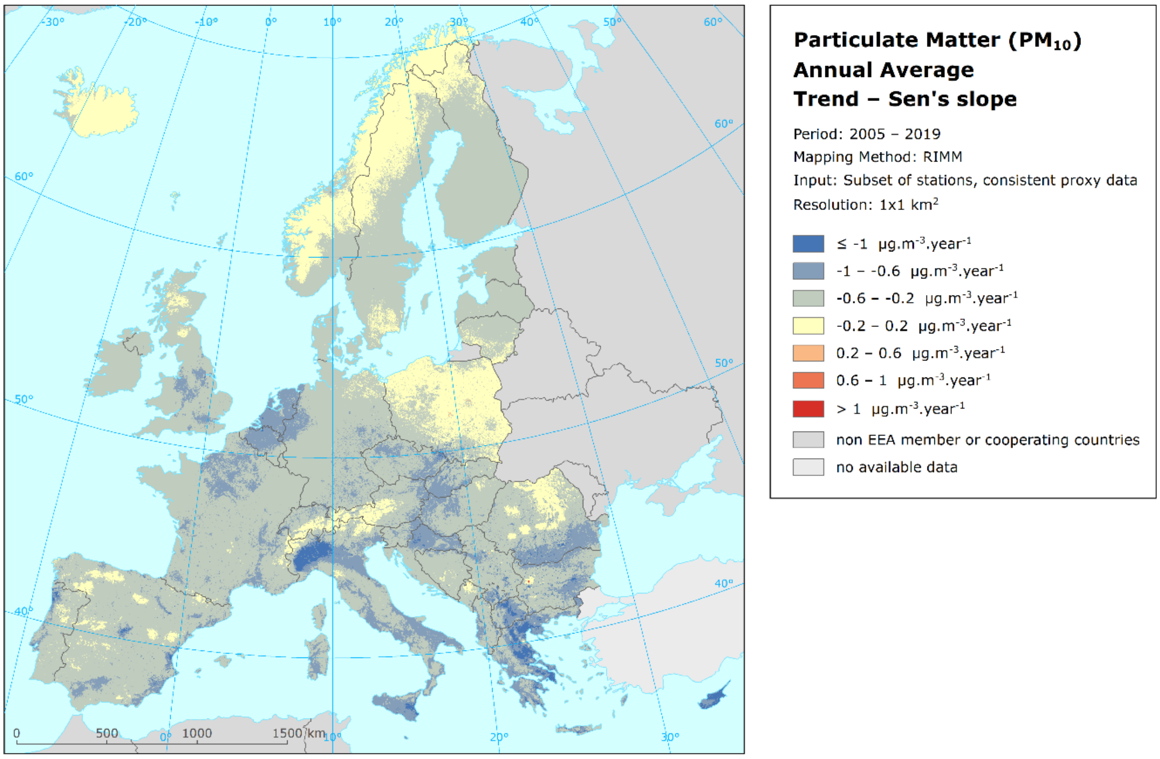
3.3 Trend maps

In this section, maps of trends in 2005-2019 are presented, showing the trends for all grid cells. In each 1x1 km^2 grid cell of the map, both the Sen's (or Sen-Theil) slope and the significance is calculated. Altogether, three maps are presented, i.e. the map showing the Sen´s slope, the map showing the significance and the combined map.

Map 3.1 presents the Sen´s slope trend estimate for PM_{10} annual average, as calculated for all grid cells. In general, one can see slight downward trend in the majority of the European area, with a more prominent downward trend in the area of Po valley in northern Italy, in the Ostrava-Katowice industrial region near the Czech-Polish border and in several other areas. No downward or upward trend is observed in Iceland, most of Norway, north-eastern Poland and some mountainous areas.

Whereas this type of maps constitutes an attempt to fill the gaps in the monitoring network using a robust mapping methodology, its limitations should be borne in mind. The concentration maps in the individual years remain highly dependent on the station coverage (see Section 2.1.3) and the changes in the stations used may influence the final trend map. The resulting trend map should be analysed keeping in consideration this limitation and the available station set presented in Map 2.1. Note that the trend map in areas with a poor measurement data coverage highly depends on the modelling results and the consistency of the data fusion time series.

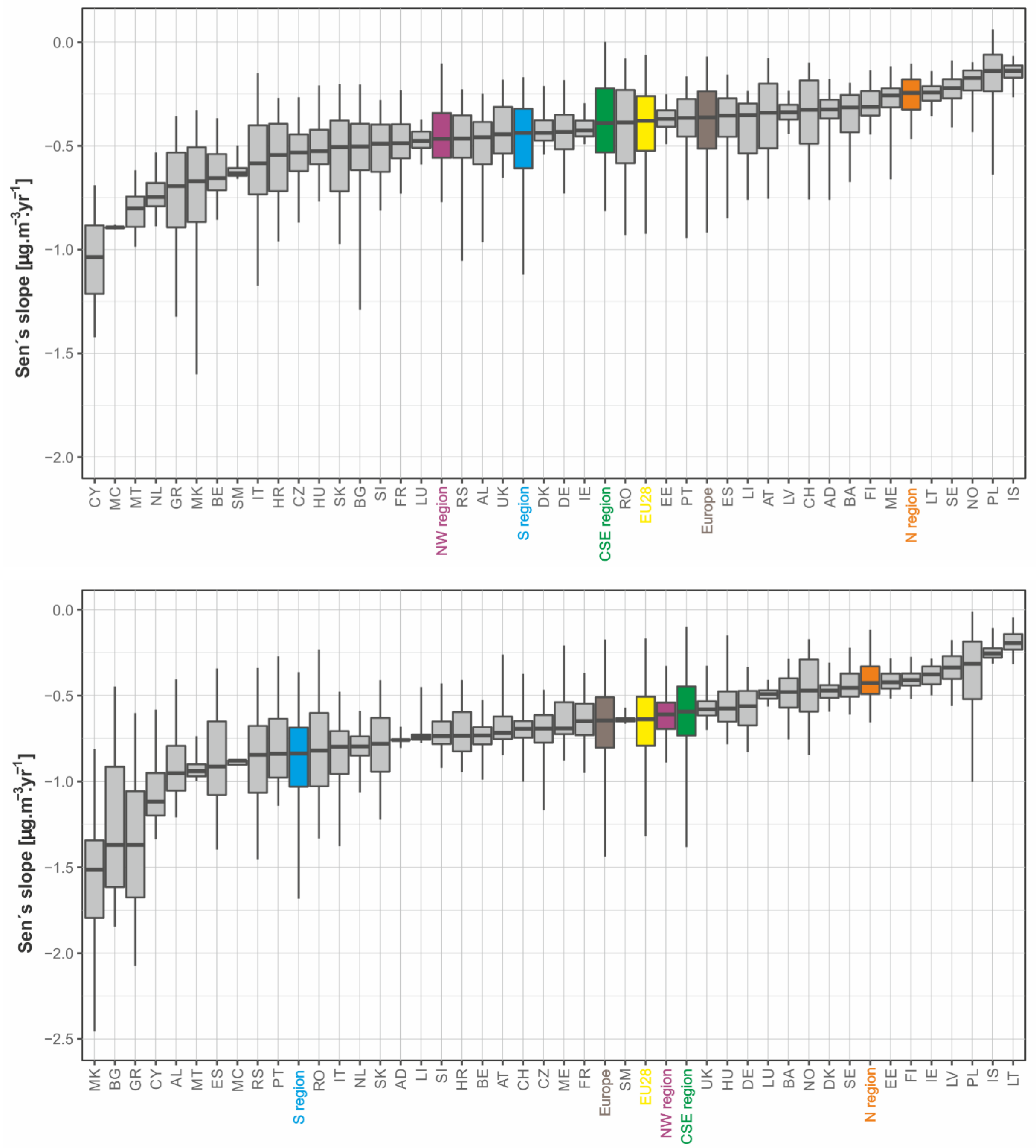
Map 3.1: Trend of PM_{10} annual average concentrations in period 2005-2019, Sen´s slope. Units: $\mu g.m^{-3}.yr^{-1}$.



The uncertainty of this map is presented in Annex 2, Table A2.9.

Based on the 1x1 km^2 gridded trend data, the percentiles of the Sen´s slopes have been calculated. Figure 3.9 presents the percentiles for the entire area, EU-28, large European regions and individual countries. The percentiles have been calculated in two variants, i.e., according to the area and the population living in this area.

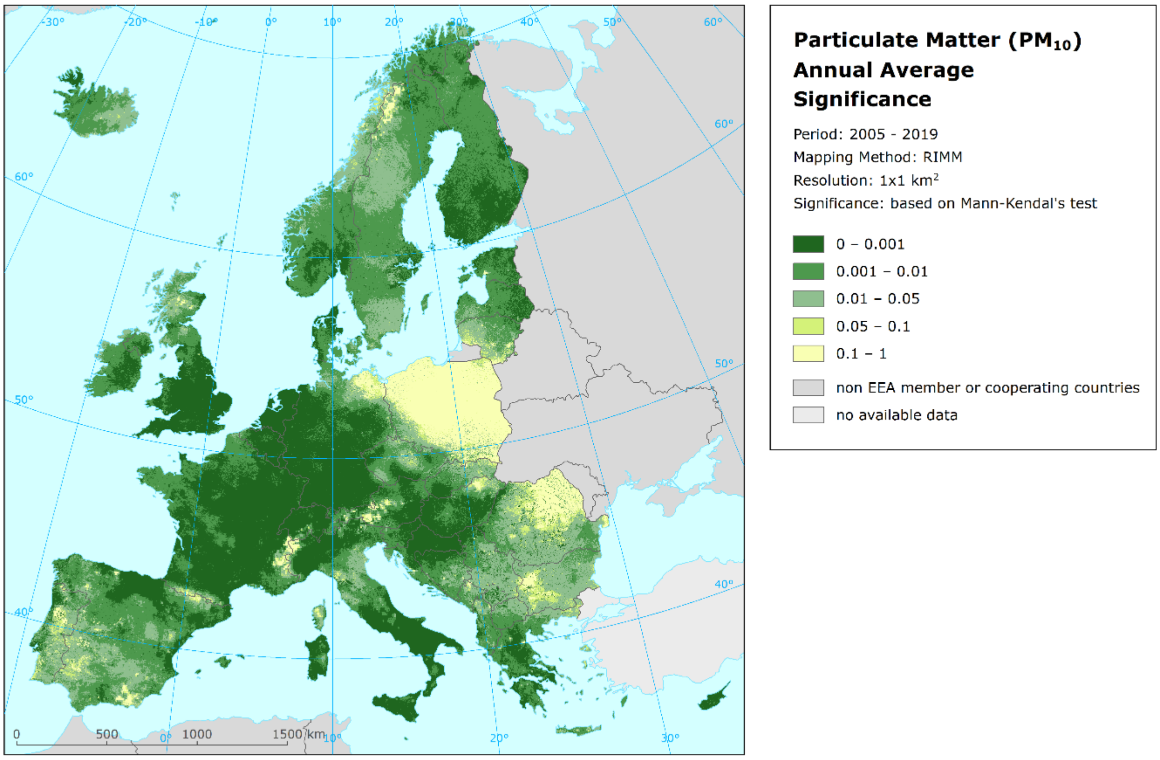
Figure 3.9 Percentiles of Sen´s slope based on 1x1 km² map of PM_{10} annual average trend in period 2005-2019 for entire area, EU-28, large regions and individual countries, according to area (top) and population (bottom). Black marker corresponds to median, the box's edges to 25 and 75 percentiles, and the whiskers' edges to 2 and 98 percentiles.



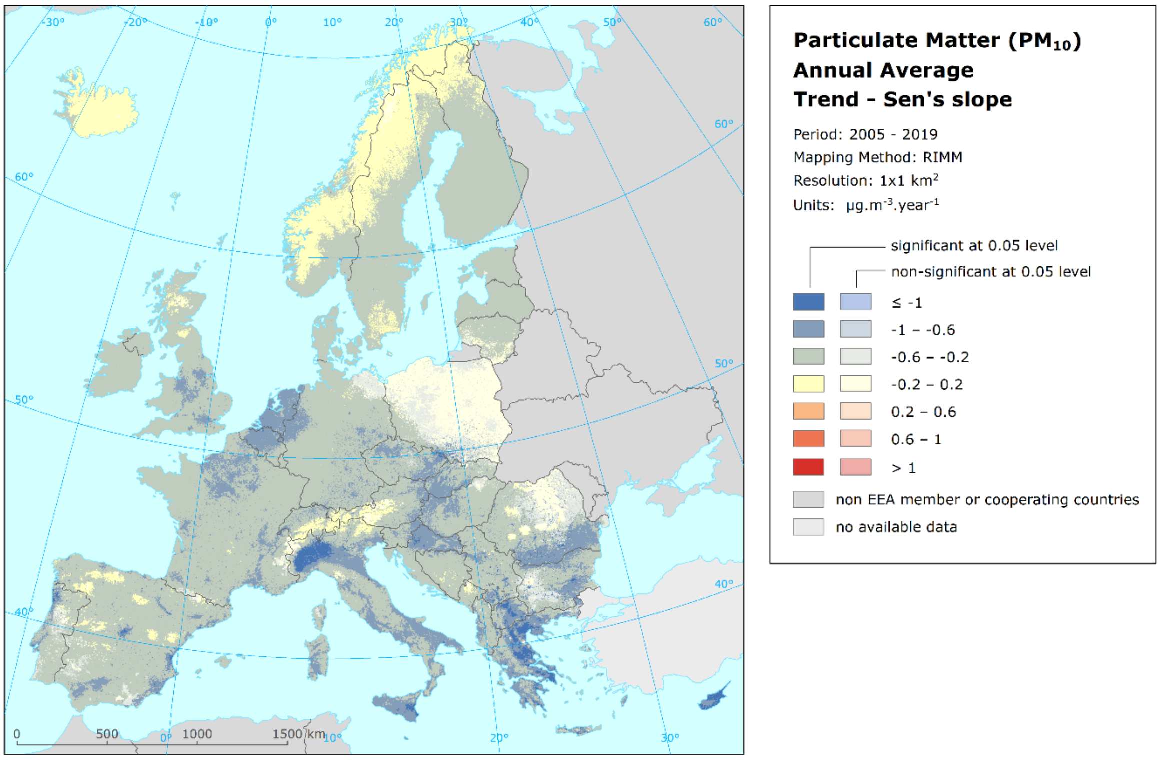
The results correspond to results presented in Figures 3.3 and 3.4. While Figures 3.3 and 3.4 present trends calculated for the average of the individual countries and regions, here the results are based on the trends calculated for all individual grid cells.

While the Sen´s slopes over Europe for PM_{10} are presented in Map 3.2, the corresponding significance with the Mann-Kendall test is given in Map 3.3. Map 3.3 is an attempt to merge both information sources by applying a shading where the trend is not significant. This map shows the same trend values as Map 3.1, but with shading (i.e. lighter colours) in areas of non-significant trend (at the 0.05 level of significance). This is an illustration of how a complete mapped information on trends (i.e. both trend value and its significance) can be displayed.

Map 3.2: Significance of the trend in PM_{10} annual average concentrations in period 2005-2019. The Mann-Kendall test.



Map 3.3: Trend of PM_{10} annual average concentrations in period 2005-2019, Sen´s slope. Units: $\mu g.m^{-3}.yr^{-1}$. Significance of the trend according to the Mann-Kendall test at the level of 0.05 is shown.



4 Ozone – SOMO35

For ozone, we evaluated SOMO35, i.e., the annually accumulated ozone maximum daily 8-hourly means in excess of 35 ppb (i.e., 70 $\mu g \cdot m^{-3}$). In this chapter, time series and trends for spatial and population-weighted averages for individual countries, for four European regions, for EU-28 and for Europe as a whole (i.e., the whole mapping area) have been calculated (for whole areas without division and after division into urban and rural areas).

In addition to the absolute average concentrations, relative average concentrations have been also calculated for all years. The Mann-Kendall test was used to evaluate trends in the time series of annual values of SOMO35, and the nonparametric Sen´s method was performed (for more details, see Section 2.3). Section 4.1 presents the time series and trend for spatial and population-weighted averages, while Section 4.2 for urban and rural areas. Section 4.3 shows the trend maps.

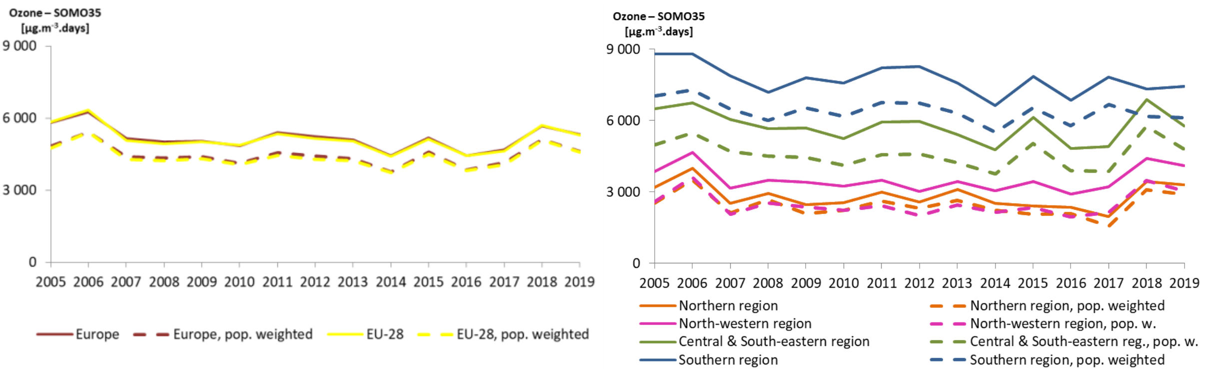
4.1 Time series and trends for spatial and population-weighted averages

The average time series over the whole Europe (i.e., the entire mapping area), EU-28 and four large European regions is presented in Figure 4.1. It shows that the population-weighted exposure is systematically lower compared to the spatial average concentration. This is due to the occurrence of higher ozone concentrations in low populated larger rural areas compared to lower ozone concentrations in densely populated urban areas. It is possible to state that SOMO35 values have been fluctuating since 2005 and no decline or increase in time series can be observed. Generally, maxima have been measured in 2006 and 2018.

Consequently, for the European-wide aggregations across the whole mapping area, no statistical significant trend was detected. Although the Sen´s slopes are negative (of -49 $\mu g.m^{-3}.d$ per year, which is -0.9 % per year in relative terms for spatially averaged values and of -24 $\mu g.m^{-3}.d$ per year, i.e., -0.5 % per year for population-weighted averaged values), the trends are not statistically significant.

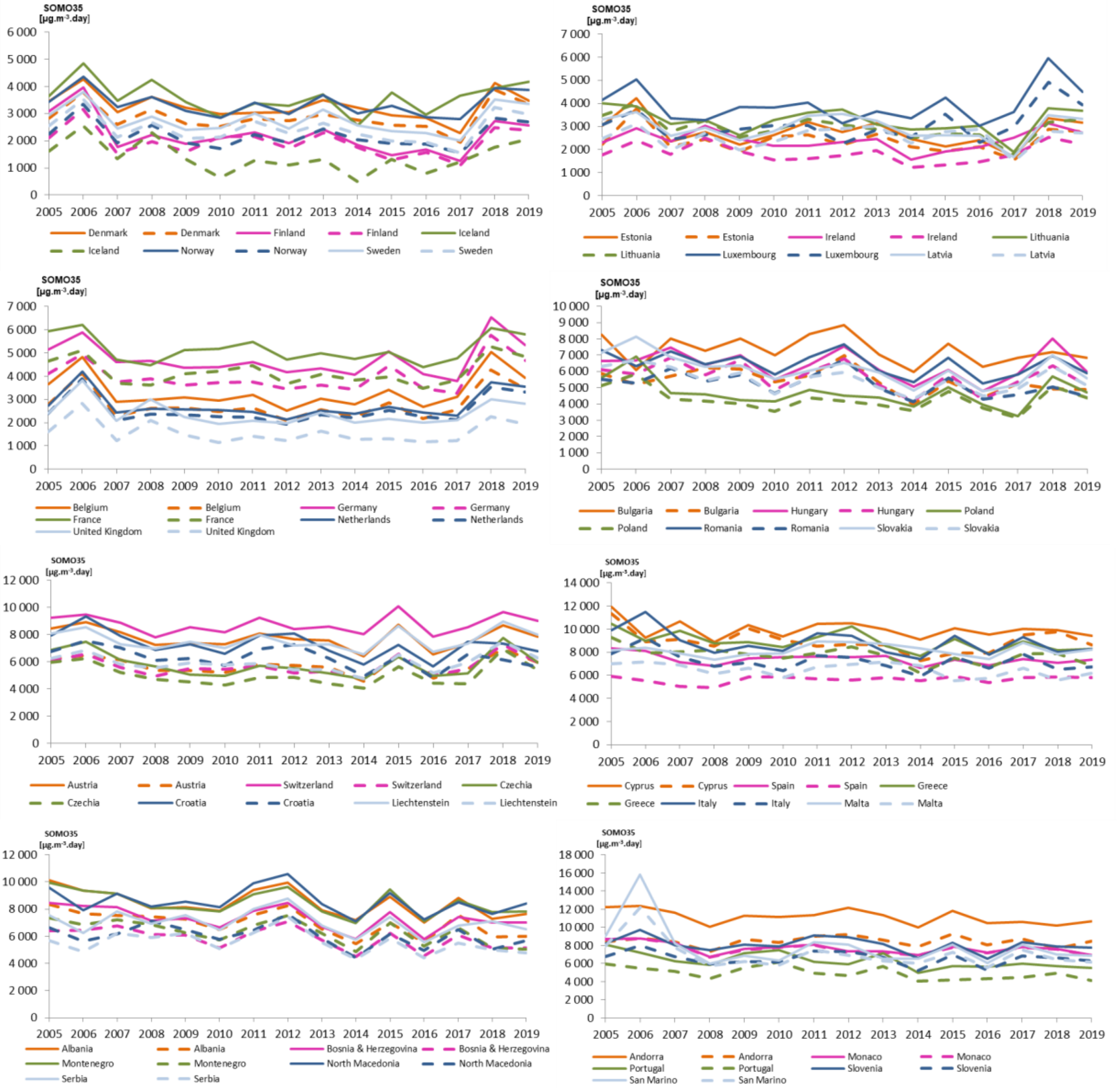
On the significance of the trend, similar findings were reported by Solberg et al. (2022) when considering only in situ observations. SOMO35 trends were found not to be significant except at traffic sites (which are not considered here). The actual values of the trend were however slightly different. At urban and rural sites negative SOMO35 trends were found: -5 $\mu g.m^{-3}.d.yr^{-1}$ and -12 $\mu g.m^{-3}.d.yr^{-1}$, respectively.

Figure 4.1: Time series of ozone indicator SOMO35 aggregated over entire area and EU-28 (left) and large regions (N/NW/CSE/S) of Europe (right); solid lines mark spatial average, dashed lines population-weighted average.



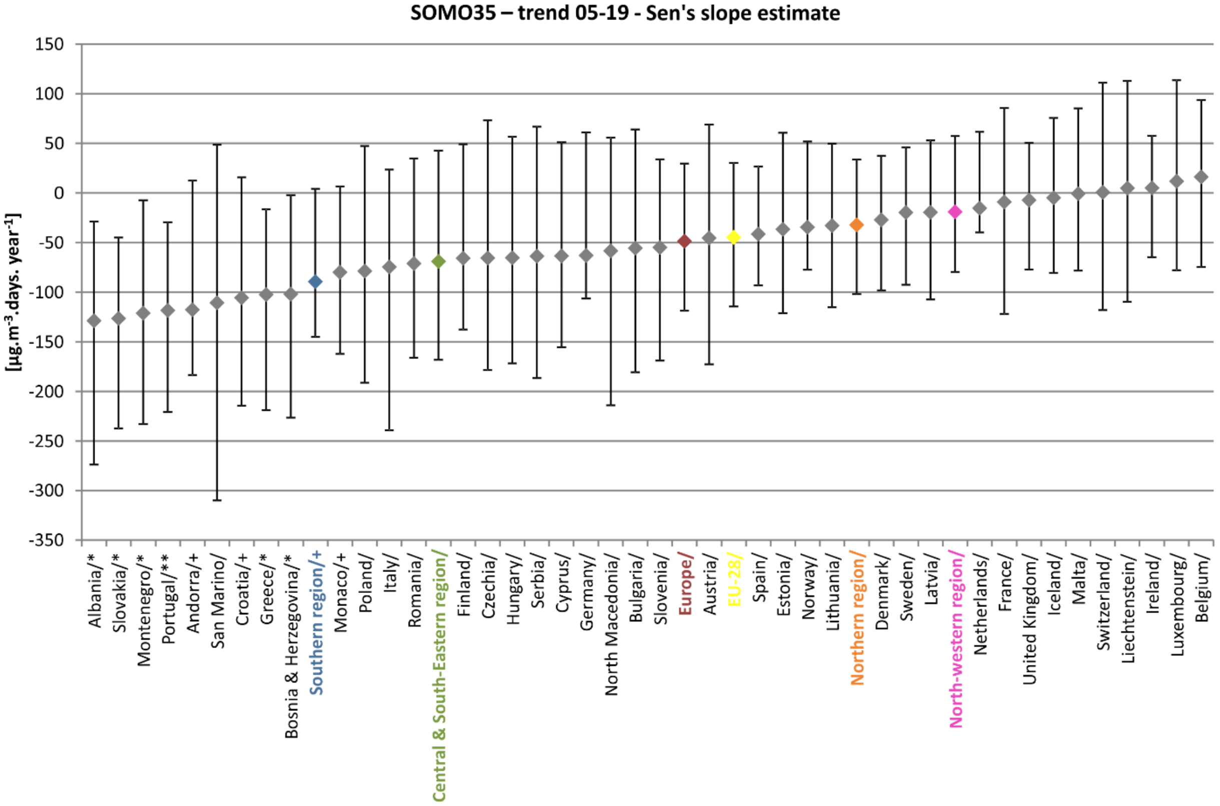
The aggregated time series per country are presented in Figure 4.2. The only more outlying country may seem to be Luxembourg in 2018. In contrast to PM, population-weighted averages are usually lower compared to the spatial SOMO35 average. This is due to the occurrence of higher ozone concentrations in low populated larger rural areas compared to urban areas. The time series have quite similar year-to-year development for most countries, except for example Iceland from 2009, Poland between 2007 and 2014 or Italy and San Marino in 2006 where SOMO35 values for these years appear somewhat outlying.

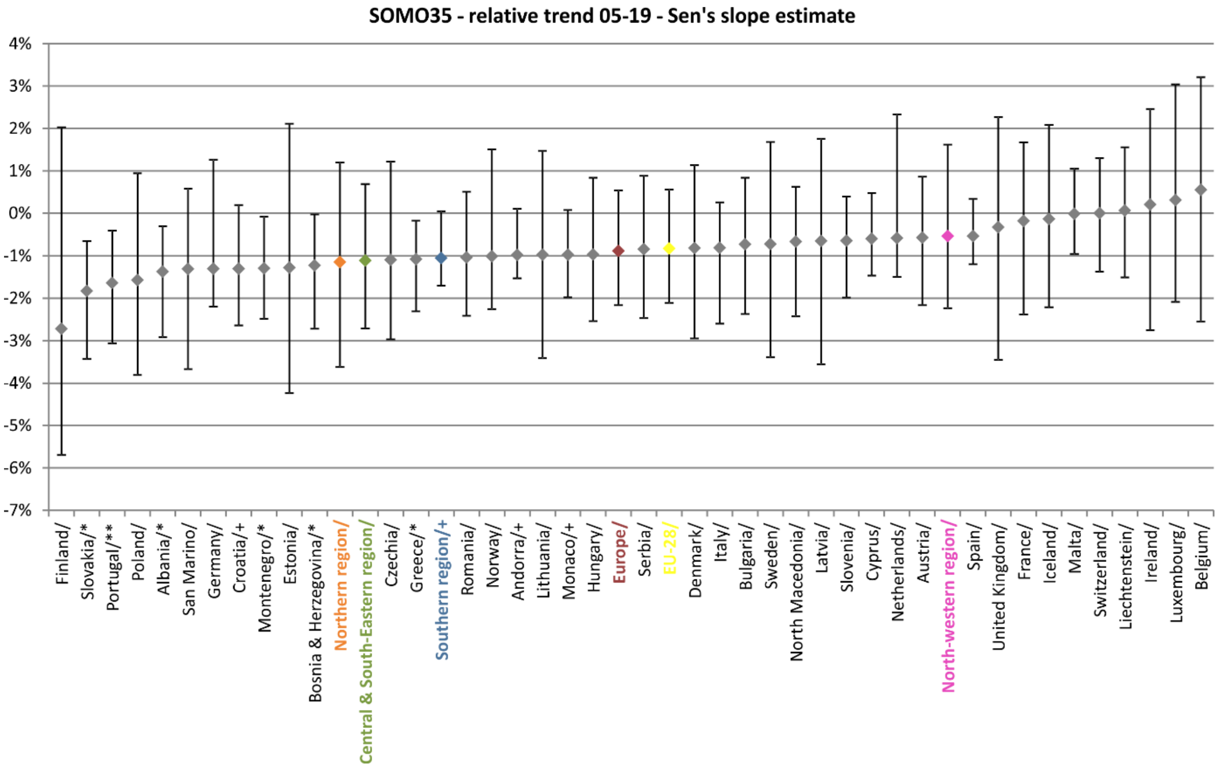
Figure 4.2: Time series of ozone indicator SOMO35 aggregated by country. Five countries are represented on each panel (solid lines spatial average, dashed lines pop-weighted average).



The spatial averaged trends by country and over the whole Europe, EU-28 and large European regions are presented in Figure 4.3, both the absolute and the relative ones. For each country, the Sen´s slope of the time series is presented as well as an indication of the significance of the trend: +/*/**/*** symbols as defined in Section 2.2, and uncertainty bar. The bars show the confidence interval of this trend at the 0.05 significance level. When the confidence interval overlaps zero, the trend is not significant. Relative trends are expressed relatively to the concentration value in the beginning of the record (2005), in percent of the relevant 2005 value per year. Although Sen´s slopes are negative for most countries, the trends are not significant (according to the Mann-Kendall test) for most of the European countries. The significant decrease were detected for some countries of the Southern Europe.

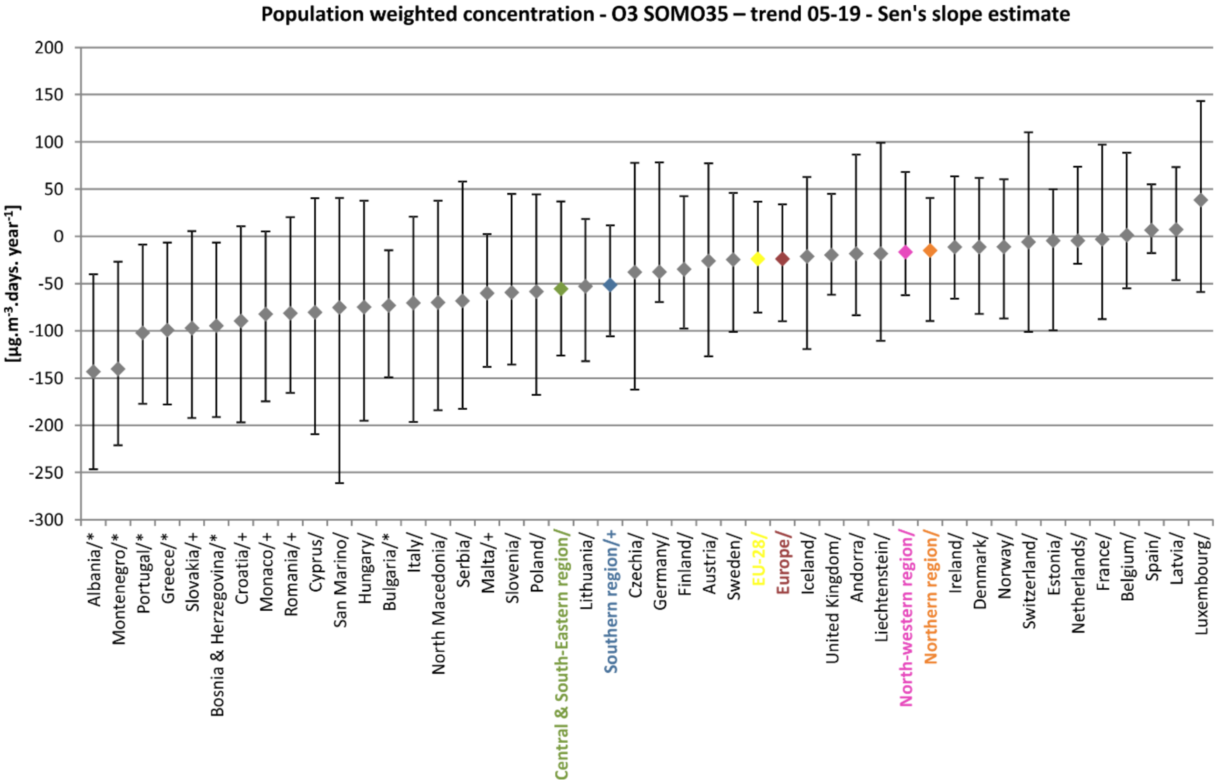
Figure 4.3: Sen´s trend of O_3 indicator SOMO35 spatially averaged over countries, entire area, EU-28 and large European regions in absolute ($\mu g.m^{-3}.d.yr^{-1}$) and relative ($\%.yr^{-1}$) terms. The uncertainty bar is representative of trend significance, also indicated in the x-axis.

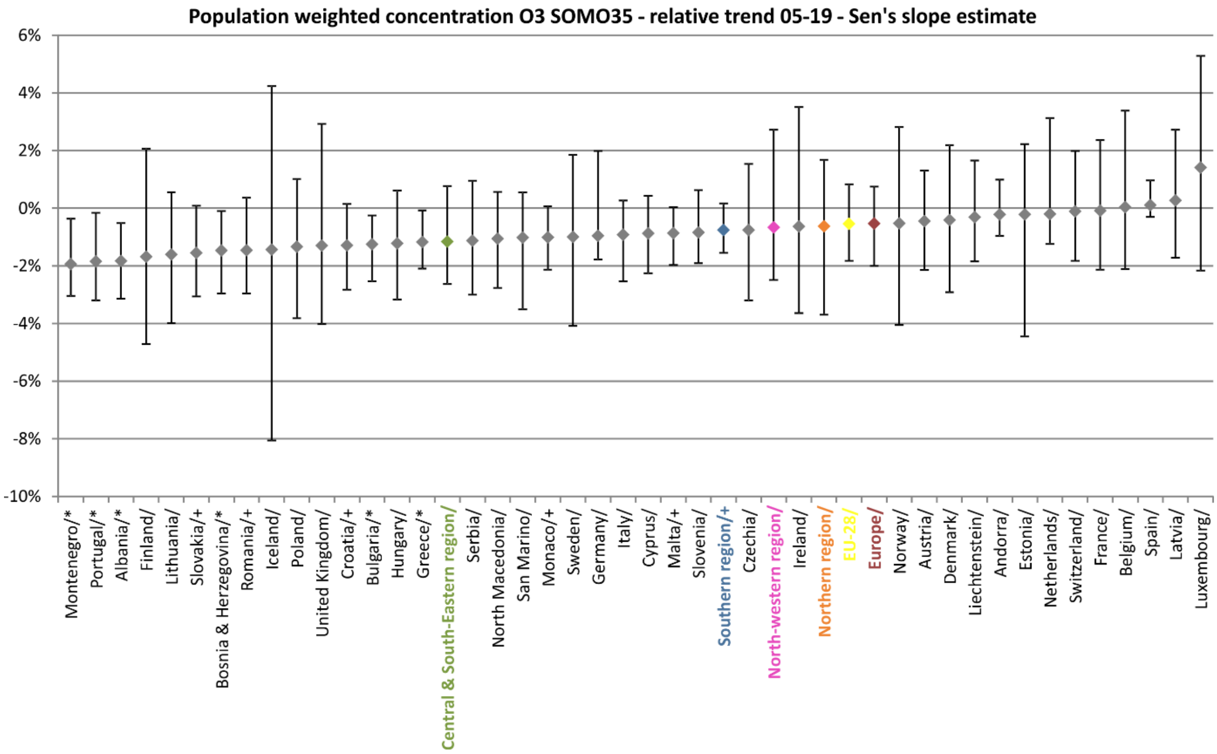




The absolute and relative trends of population-weighted averages by country and over the whole Europe, EU-28 and large European regions are presented in Figure 4.4.

Figure 4.4: Sen´s trend of ozone indicator SOMO35, population-weighted averages over countries, entire Europe, EU-28 and large European regions in absolute (μg.m^{-3}.d.yr^{-1}) and relative (%.yr^{-1}) terms. The uncertainty bar is representative of trend significance, also indicated in the x-axis.





For the numerical results of the times series and trends, see Annex, Tables A4.5-A4.7.

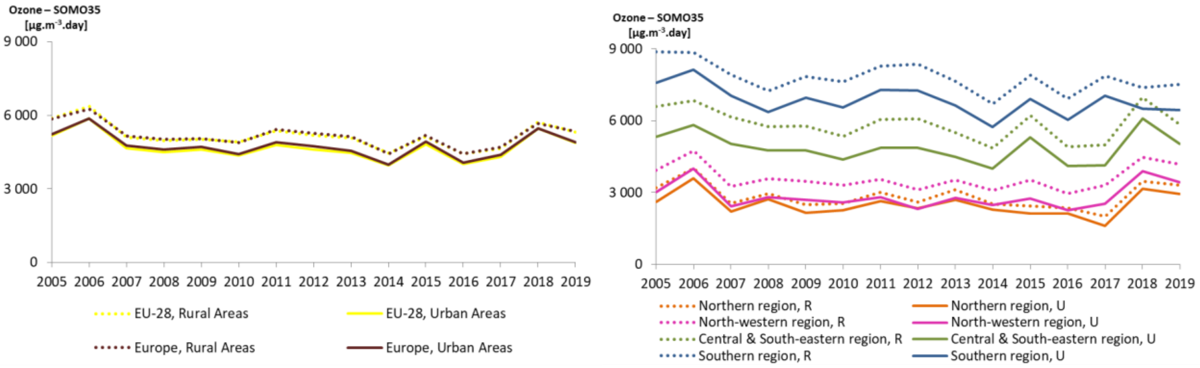
4.2 Time series and trends in urban versus rural areas

The spatial average time series over the whole Europe, the EU-28 and four large European regions for urban and rural areas is presented in Figure 4.5. Compared to Section 4.1, only the spatial average is considered, not the population-weighted average.

As expected, taking into account ozone atmospheric chemistry, the SOMO35 levels are higher in rural areas.

The SOMO35 values show the significant decreasing trend only in Southern Europe, both for urban and rural areas.

Figure 4.5: Time series of ozone indicator SOMO35 aggregated over entire area and EU-28 (left) and large regions (N/NW/CSE/S) of Europe (right); solid lines mark average over urban areas, dotted lines average over rural areas.



The time series of spatial average SOMO35 aggregated over urban or rural areas of individual countries are presented in Figure 4.6.

Figure 4.6: Time series of ozone indicator SOMO35 aggregated by country. Five countries are represented on each panel (solid lines average over urban areas, dotted lines average over rural areas).

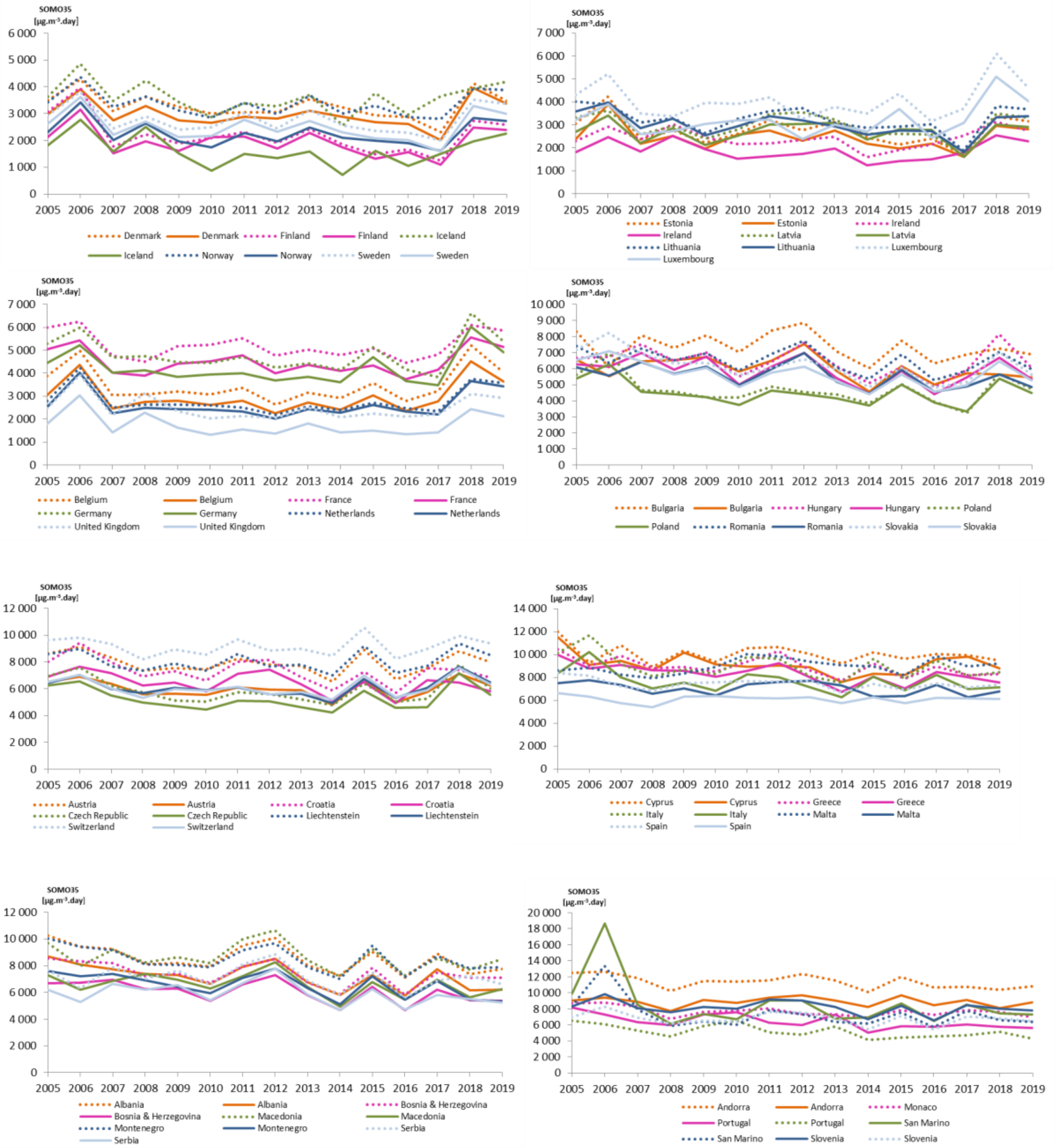
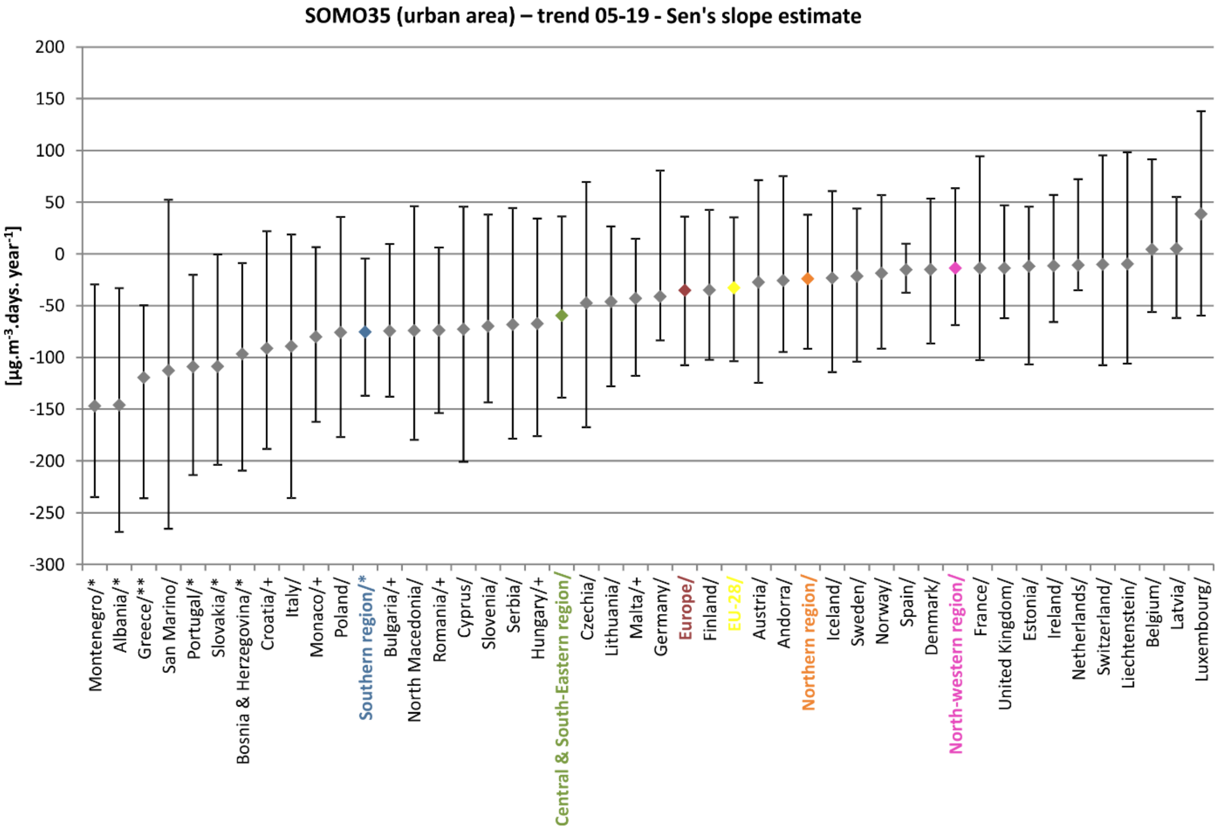


Figure 4.6 shows no clear development in most of the countries. The significant decreasing trend have been observed only in a few countries in Southern and also Central and south-eastern Europe (e.g., in Albania, Bosnia & Herzegovina, Croatia, Montenegro, Portugal).

Figure 4.7 and Figure 4.8 show the trend by country and over the whole Europe, EU-28 and four large European regions in urban and rural areas, respectively.

Figure 4.7: Sen´s trend of ozone indicator SOMO35 by country and over entire Europe, EU-28 and large European regions in urban areas in absolute (µg.m^{-3}.d.yr^{-1}) and relative (%.yr^{-1}) terms. The uncertainty bar is representative of trend significance, also indicated in the x-axis.



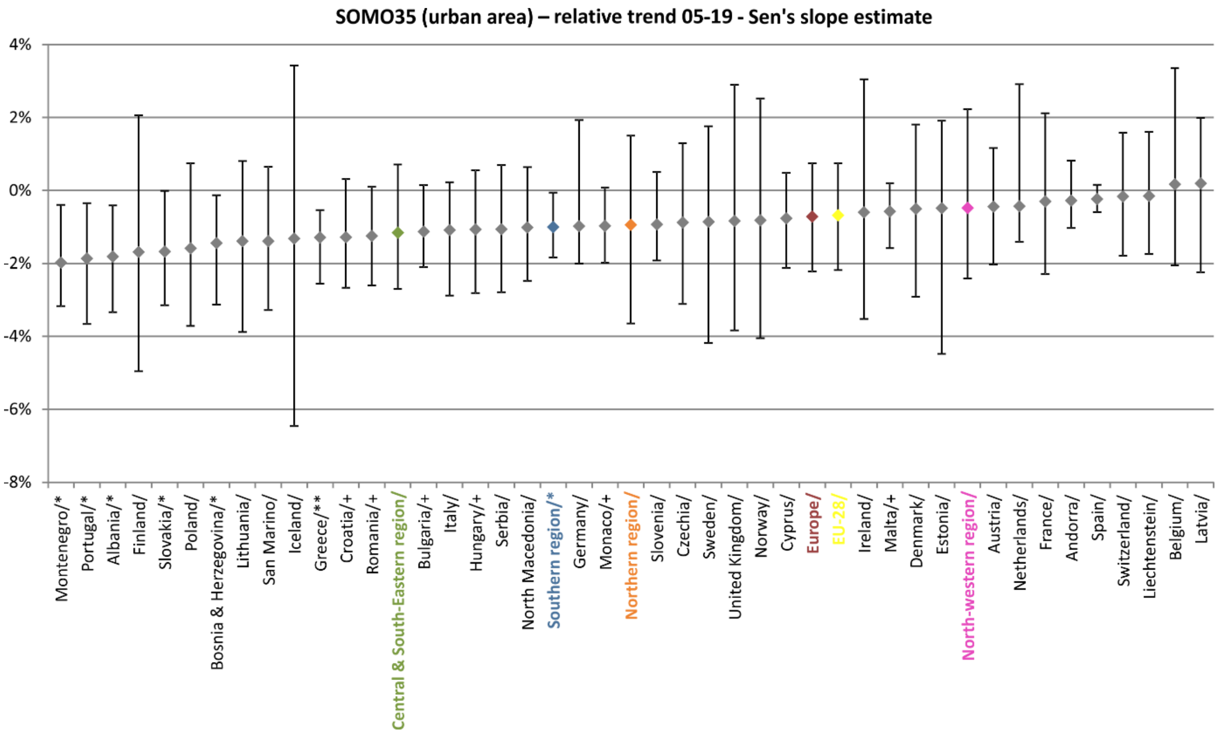
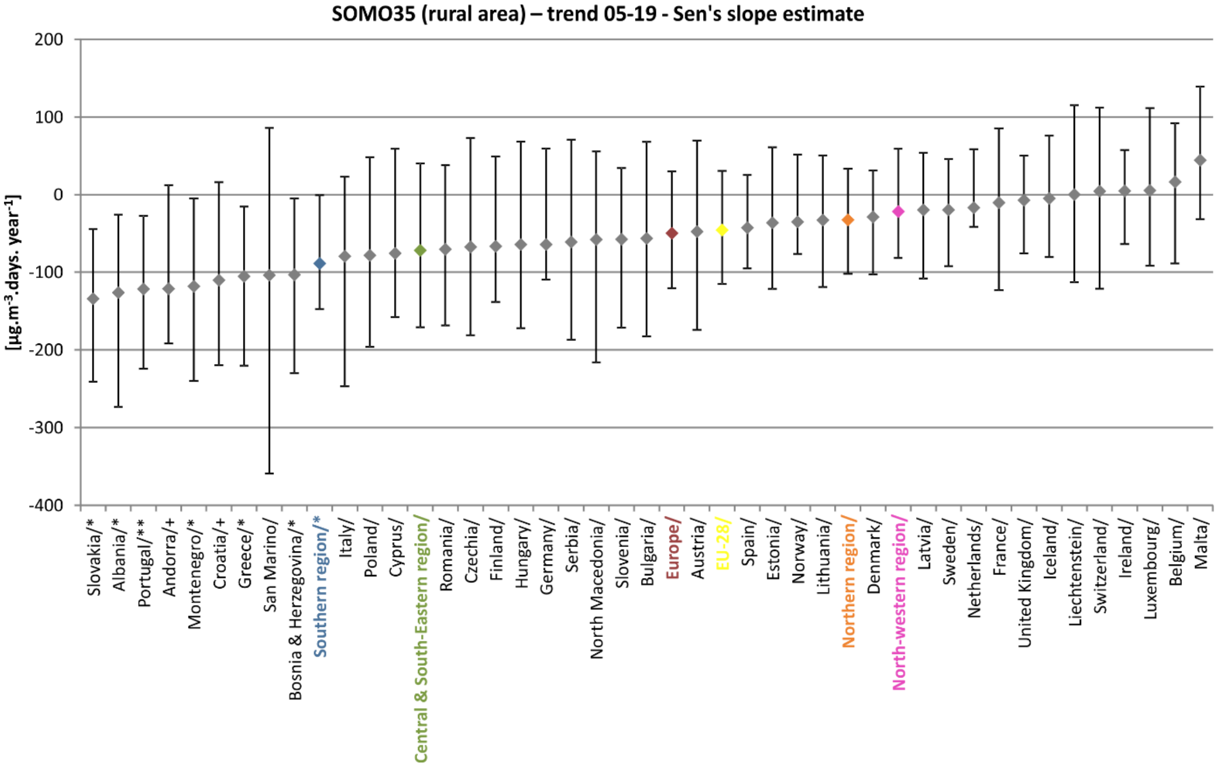
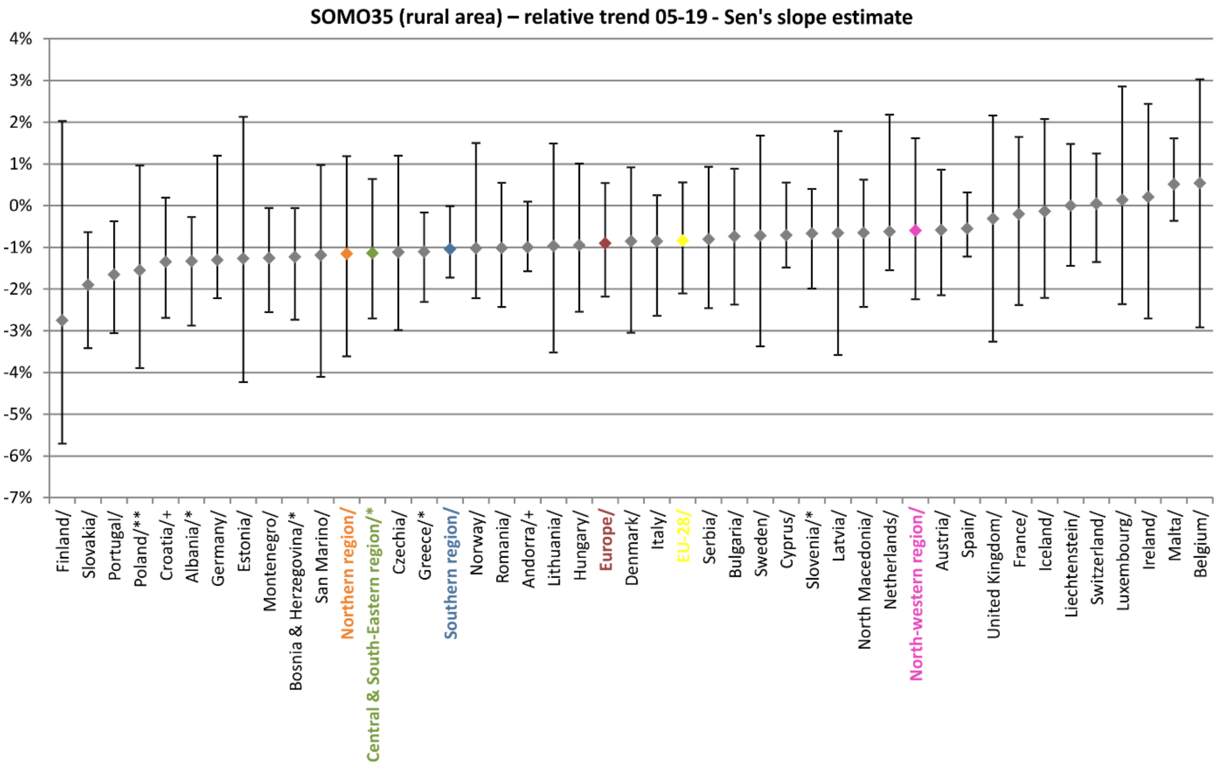


Figure 4.8: Same as for rural areas, i.e. Sen´s trend of ozone indicator SOMO35 by country and over entire Europe, EU-28 and large European regions in rural areas in absolute (µg.m-3.d.yr -1) and relative (%.yr-1) terms. The uncertainty bar is representative of trend significance, also indicated in the x-axis.





For particular countries, the situation is not clear – in some countries, larger decline is observed in rural areas, but the opposite situation is in other countries. Nevertheless, the larger decline in rural areas compared to urban areas is found in the absolute Sen´s slopes over the whole Europe, EU-28 and large European regions. These figures also show similar magnitude of relative declines over rural and urban areas.

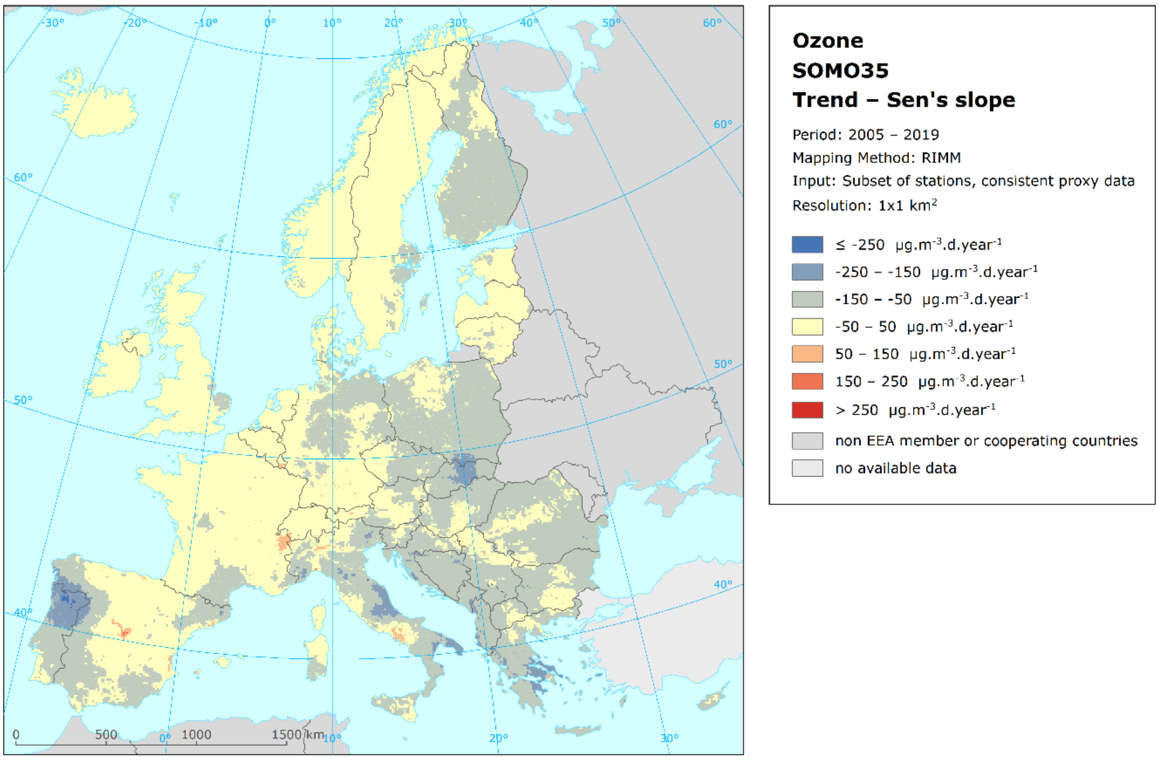
For the numerical results of the times series and trends, see Annex, Table A4.8.

4.3 Trend maps

Like in the case of PM_{10}, maps of trends in 2005–2019 are presented, showing the trends for all grid cells. In each 1x1 km^2 grid cell of the map, both the Sen´s slope and the significance is calculated. Altogether, three maps are presented, i.e., the map showing the Sen's slope, the map showing the significance and the combined map.

Map 4.1 presents the Sen´s slope trend estimate for SOMO35, as calculated for all grid cells. In general, one can see slight decline in parts of Southern and Central and South-Eastern Europe, with more prominent downward trend in the area of northern Portugal, central Slovakia and in several other areas in Italy and Greece. Nevertheless, no clear trend is observed in the rest of Europe (yellow areas in the Map 4.1).

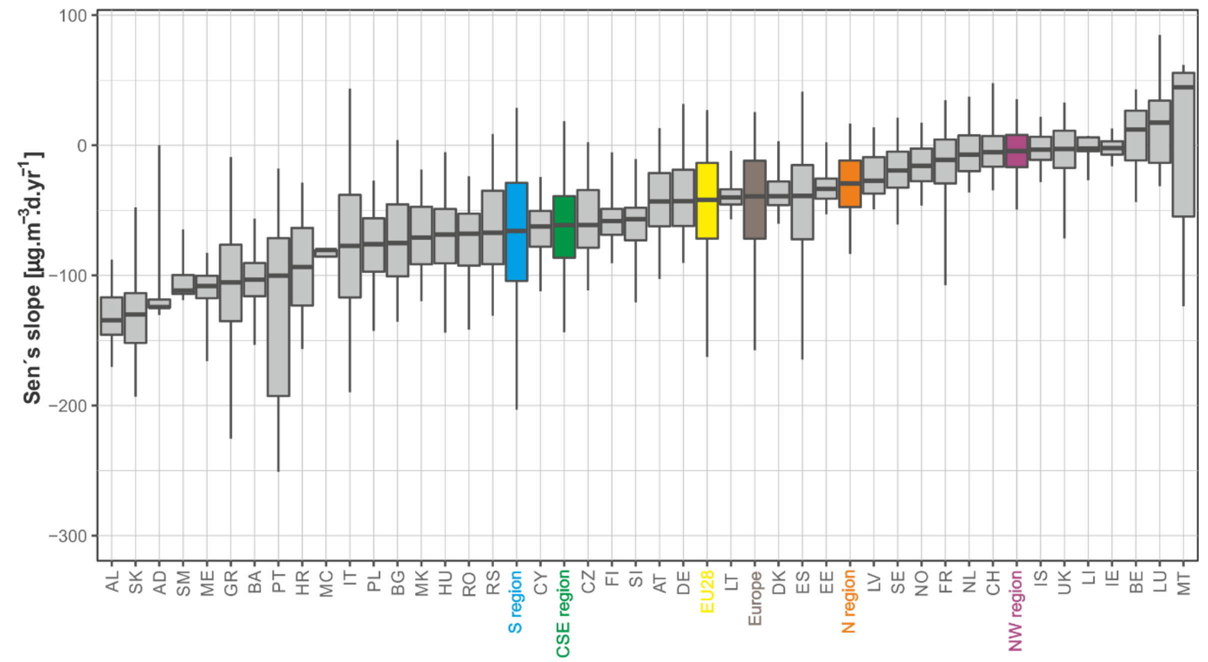
Map 4.1: Trend of ozone indicator SOMO35 values in period 2005-2019, Sen´s slope. Units: µg.m^{-3}.d.yr^{-1}.

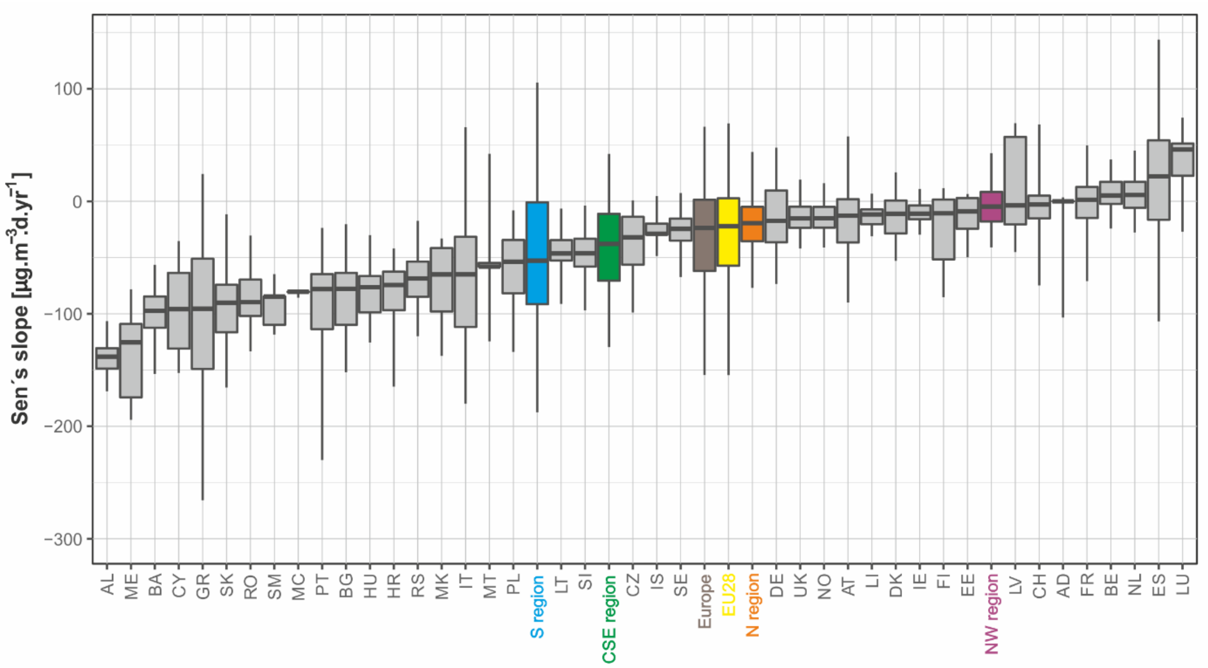


The uncertainty of this map is presented in Annex 2, Table A2.10.

Based on the 1x1 km^2 gridded trend data, the percentiles of the Sen´s slopes have been calculated. Figure 4.9 presents the percentiles for the entire area, EU-28, large European regions and individual countries. The percentiles have been calculated in two variants, i.e., according to the area and the population living in this area.

Figure 4.9 Percentiles of Sen´s slope based on 1x1 km² map of ozone indicator SOMO35 trend in period 2005-2019 for entire area, EU-28, large regions and individual countries, according to area (top) and population (bottom). Black marker corresponds to median, the box's edges to 25 and 75 percentiles, and the whiskers' edges to 2 and 98 percentiles.

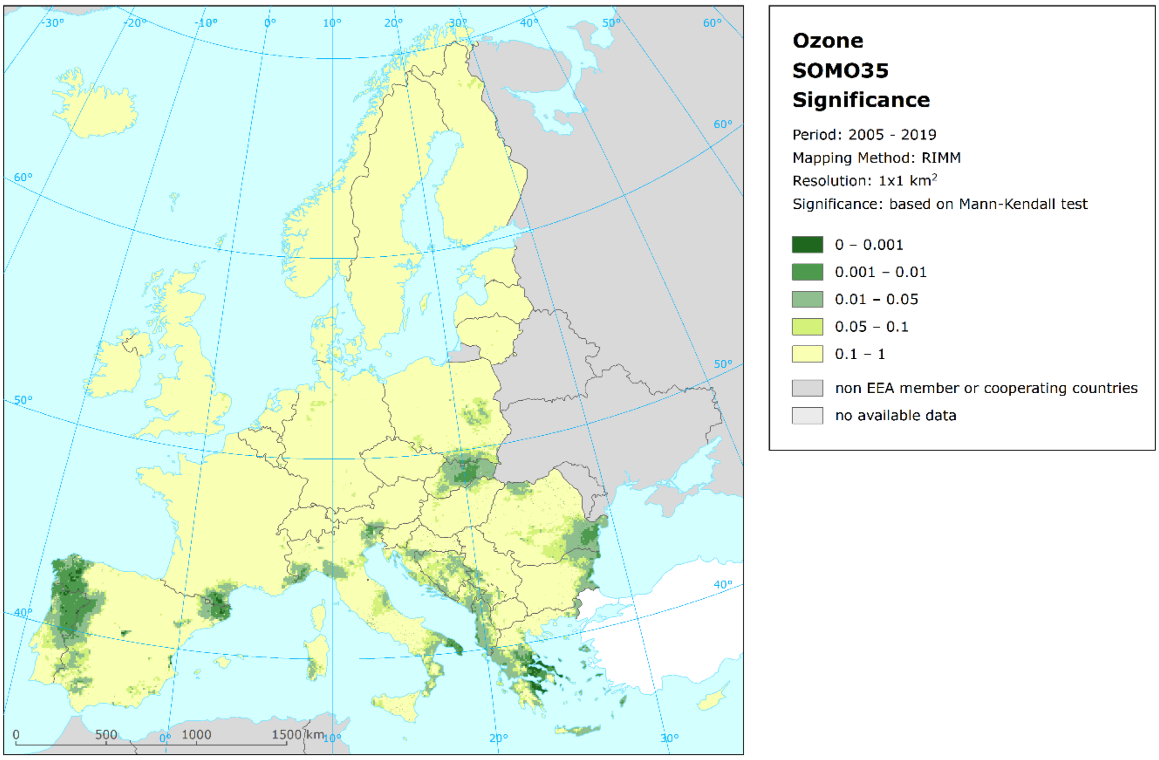




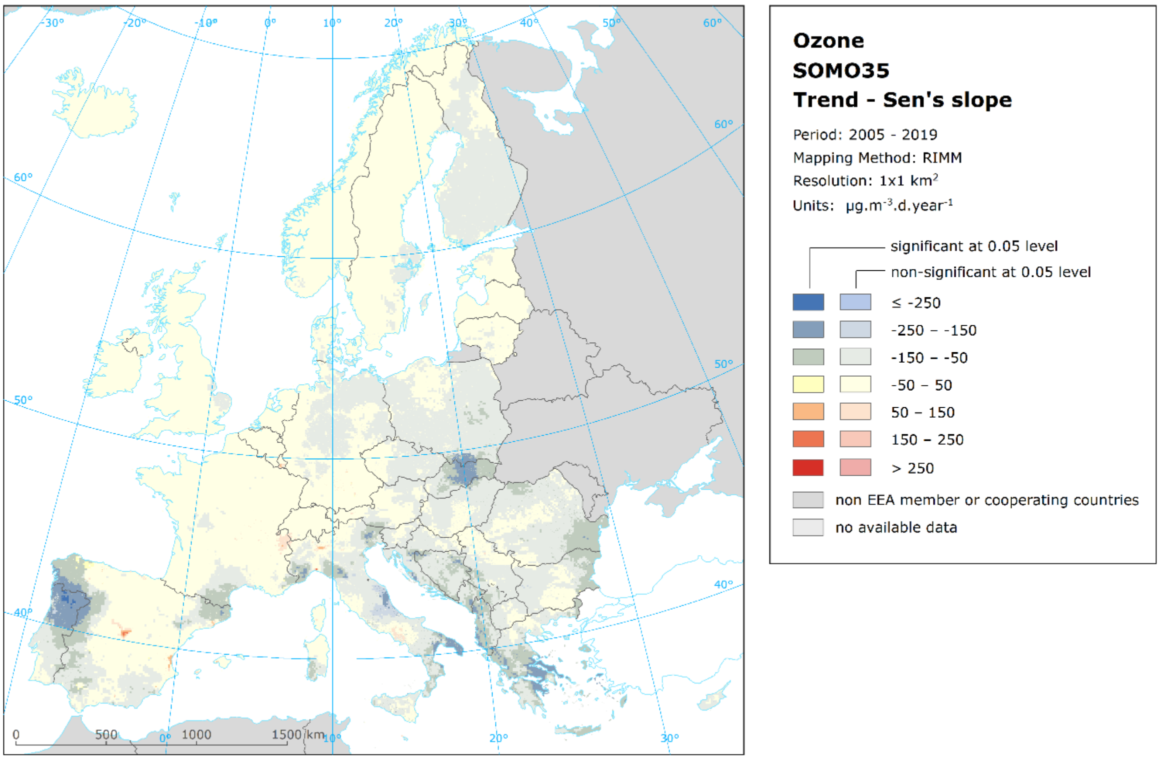
The results correspond to results presented in Figures 4.3 and 4.4. While Figures 4.3 and 4.4 present trends calculated for the average of the individual countries and regions, here the results are based on the trends calculated for all individual grid cells.

While the Sen´s slopes over Europe for SOMO35 are presented in Map 4.1, the corresponding significance with the Mann-Kendall test is given in Map 4.2. Map 4.3 is an attempt to merge both information sources by applying a shading where the trend is not significant. This map shows the same trend values as Map 4.1, but with shading (i.e. lighter colours) in areas of non-significant trend (at the 0.05 level of significance). This is an illustration of how a complete mapped information on trends (i.e. both trend value and its significance) can be displayed.

Map 4.2: Significance of the trend in ozone indicator SOMO35 values in 2005-2019. The Mann-Kendall test.



Map 4.3: Trend of ozone indicator SOMO35 values in period 2005-2019, Sen´s slope. Units: µg.m^{-3}.d.yr^{-1}. Significance of the trend according to the Mann-Kendall test at the level of 0.05 is shown.



5 NO_2 – Annual average

Annual average NO_2 concentrations are evaluated in this chapter in terms of their evolution and trend for the 15-year period 2005-2019. The assessment is based on the concentration maps and the population data. The spatial average concentrations and the population-weighted average concentrations for individual countries, for four European regions, for EU-28 and for Europe as a whole (i.e., whole mapping area) have been calculated (for whole areas without division and after division into urban and rural areas). Apart from the absolute average concentrations, relative average concentrations have been also calculated for all years.

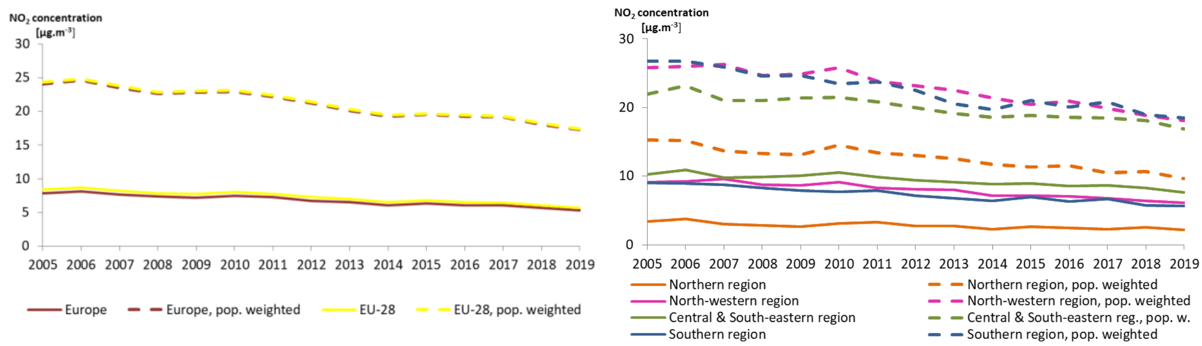
Next to this, the trend maps have been constructed. The Mann-Kendall test was used to evaluate trends in the time series of annual values of NO_2, and the nonparametric Sen´s method was performed (for more details, see Section 2.3). Section 5.1 presents the time series and trend for spatial and population-weighted averages, while Section 5.2 for urban and rural areas. Section 5.3 shows the trend maps.

5.1 Time series and trends for spatial and population-weighted averages

The average time series of annual mean NO_2 over the whole Europe (i.e. the entire mapping area), EU-28 and four large European regions is presented in Figure 5.1. It also shows that population-weighted exposure is systematically higher compared to the spatial average concentration.

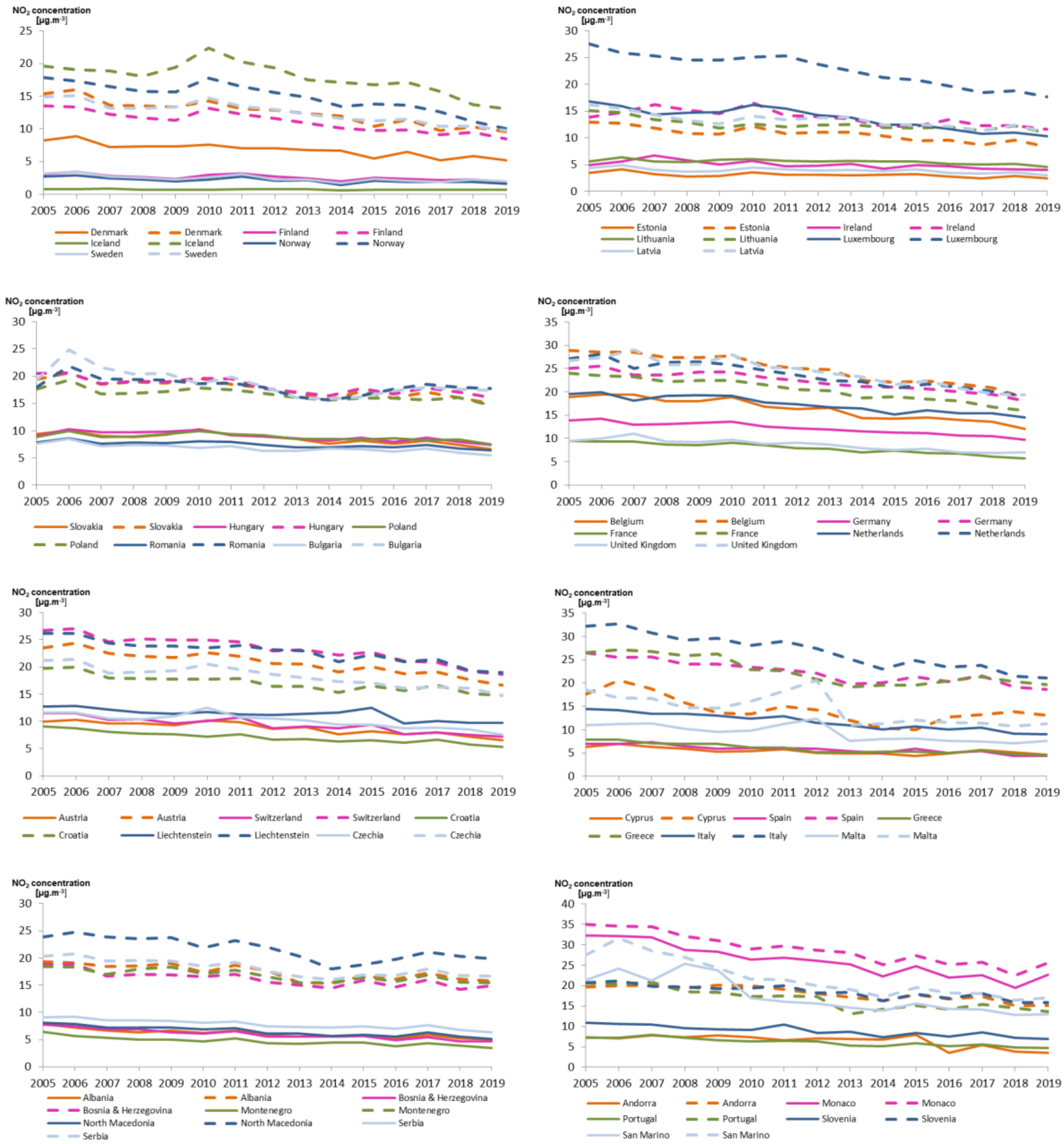
It is possible to state that slight decline in time series for spatial annual averages can be observed. Somewhat more pronounced decline can be observed for population-weighted concentration levels indicating probable NO_2 concentration decrease in more populated areas. Comparing the aggregated data for four large regions, Northern Europe shows the lowest results, while Central and South-eastern Europe the highest results, in general. Both the spatial average concentration and the population-weighted concentration levels and their trends for the whole Europe and EU-28 are similar.

Figure 5.1: Time series of annual mean NO_2 aggregated over entire area and EU-28 (left) and large regions (N/NW/CSE/S) of Europe (right); solid lines mark spatial average, dashed lines population-weighted average.



The time series averaged over all grid cells of the 40 available countries in the RIMM maps are presented in Figure 5.2.

Figure 5.2: Time series of annual mean NO_2 aggregated by country. Five countries are represented on each panel (solid lines spatial average, dashed lines pop-weighted average).

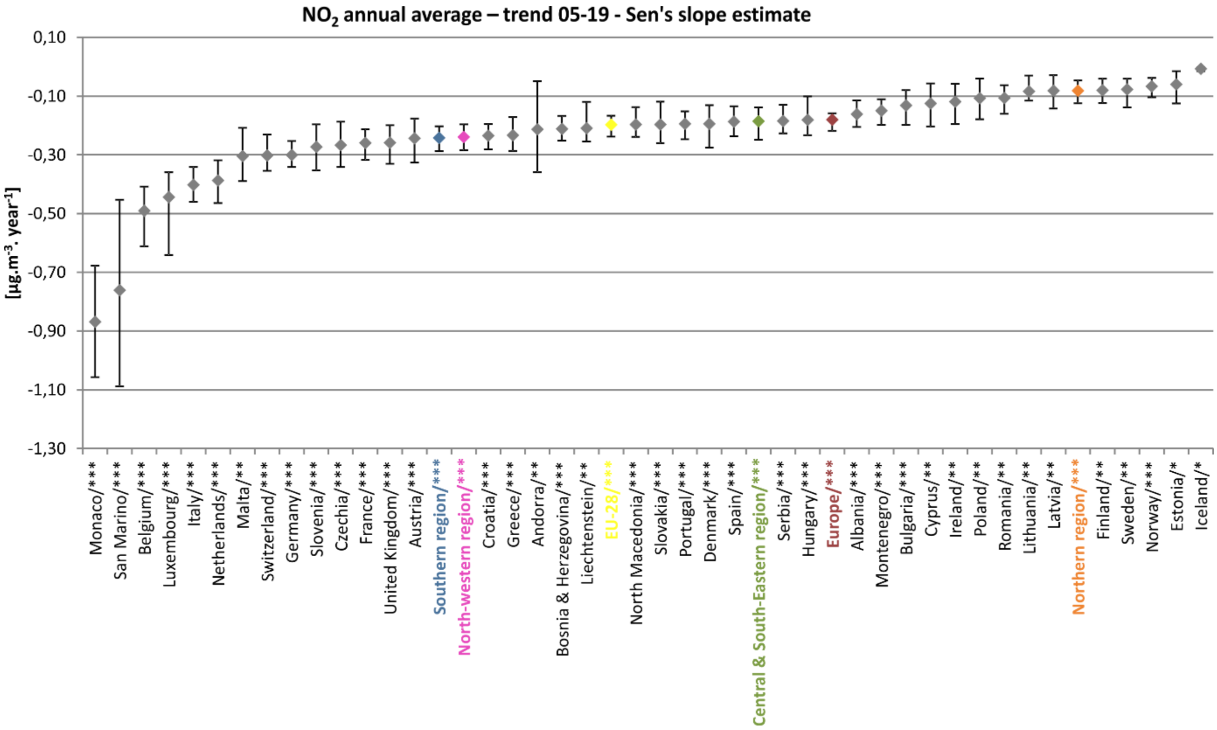


The time series have quite similar year-to-year development for most countries, except for example Lichtenstein in 2015 and San Marino between 2005 and 2009 where annual average values for these years appear somewhat outlying.

Similarly to PM_{10}, population-weighted averages are mostly higher compared to the spatial annual averages. This is due to the occurrence of higher NO_2 concentrations in areas with higher density of inhabitants connected with the intensive emission sources (road traffic in towns and cities).

The spatial averaged trends by country and over the whole Europe, EU-28 and large European regions are presented in Figure 5.3, both the absolute and the relative ones. For each country, the Sen´s slope of the time series is presented as well as an indication of the significance of the trend: +/*/**/*** symbols as defined in Section 2.2, and uncertainty bar. The bars show the confidence interval of this trend at the 0.05 significance level. When the confidence interval overlaps zero, the trend is not significant. Relative trends are expressed relatively to the concentration value in the beginning of the record (2005), in percent of the relevant 2005 value per year.

Figure 5.3: Sen´s trend of NO_2 annual mean spatially averaged over countries, entire area, EU-28 and large European regions in absolute ($\mu g.m^{-3}.yr^{-1}$) and relative ($\%.yr^{-1}$) terms. The uncertainty bar is representative of trend significance, also indicated in the x-axis.



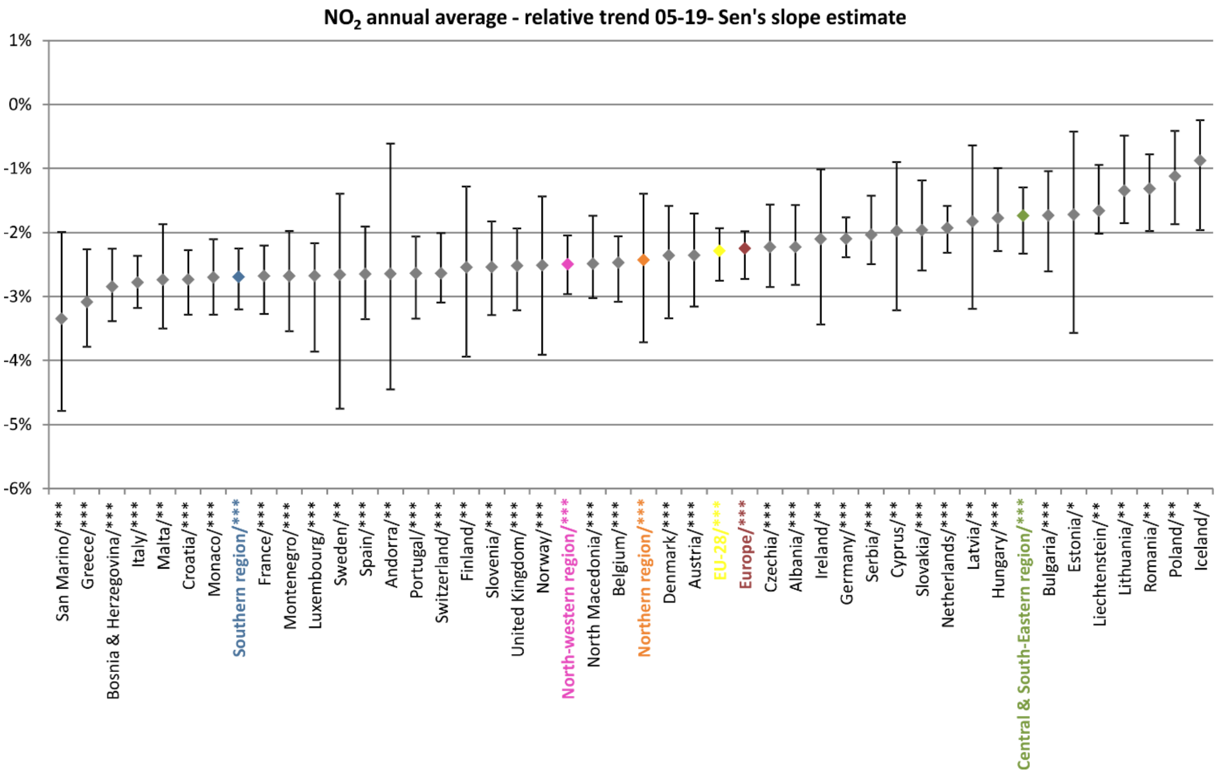
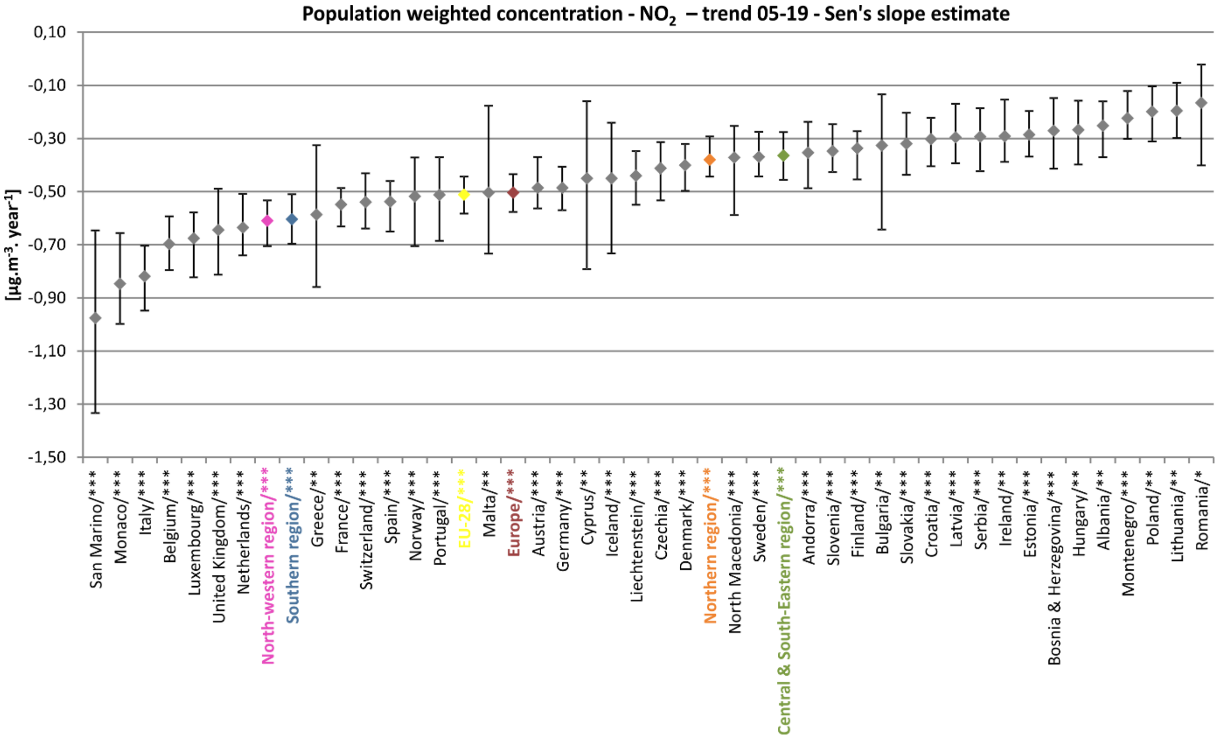
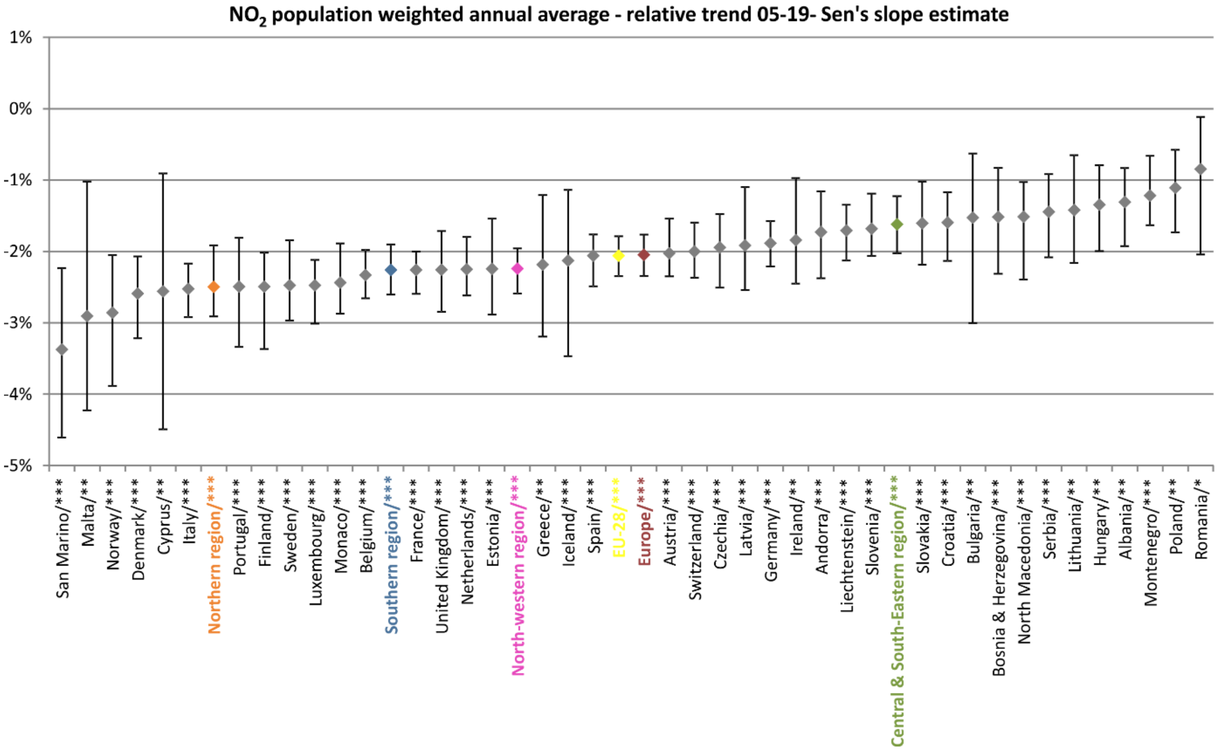


Figure 5.4: Sen´s trend of NO_2 annual mean, population-weighted averages over countries, entire Europe, EU-28 and large European regions in absolute ($\mu g.m^{-3}.yr^{-1}$) and relative ($\%.yr^{-1}$) terms. The uncertainty bar is representative of trend significance, also indicated in the x-axis.





These plots show that annual mean NO_2 trends are significantly decreasing over all countries. For the European-wide aggregations across the whole mapping area, statistically significant downward trend of -0.18 $\mu g.m^{-3}$ per year (and -2.2 % per year, in relative terms) for spatially averaged concentrations and of -0.52 $\mu g.m^{-3}$ per year (and -2.0 % per year) for population-weighted averaged concentrations have been estimated. This means a decrease of more than 30 % for spatial averaged NO_2 annual mean concentrations and about 30 % for population-weighted averaged NO_2 annual mean concentrations during the period 2005-2019. For the numerical results of the trends, see Annex 4, Table A4.11.

Those estimates can be put in perspective with the statistics derived exclusively from observations in Solberg et al. (2022). When using only in situ data, the trend of the European median of NO_2 annual average over 2005-2019 is estimated to 0.48 $\mu g.m^{-3}.yr^{-1}$ and 0.25 $\mu g.m^{-3}.yr^{-1}$, at urban background and rural sites respectively. Those estimates are therefore very consistent with the mapped trends when comparing the whole mapping area (constituted of a majority of rural areas) and population weighted concentrations (mainly influenced by urban areas).

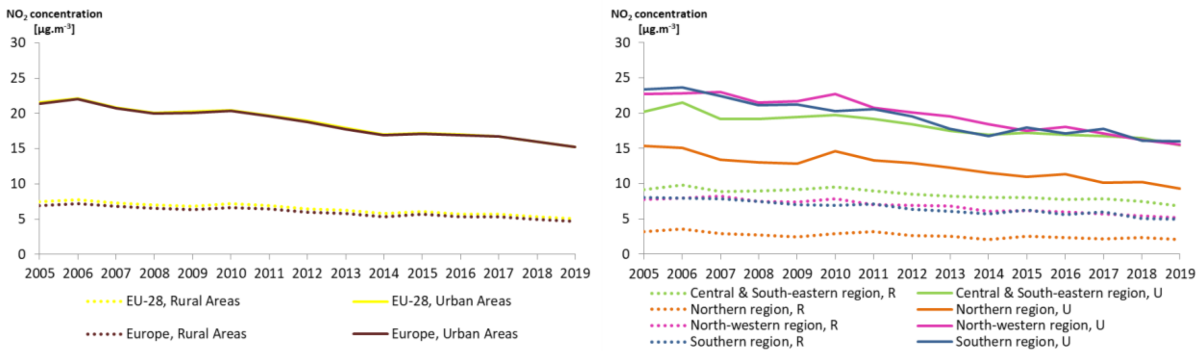
5.2 Time series and trends in urban versus rural areas

The spatial average time series over the whole Europe, the EU-28 and four large European regions for urban and rural areas is presented in Figure 5.5. The aim of this analysis is to compare the evolution in urban versus rural areas. Compared to Section 3.1, only spatial average is considered, not population-weighted average.

Similarly to PM_{10}, the NO_2 levels are lower in rural areas, but it also appears that their decline in absolute values is less pronounced in most countries, compared to urban areas.

The NO_2 values show the significant decreasing trend for the whole Europe, the EU-28 and all European regions and both areas. For details, see Annex 4.

Figure 5.5: Time series of annual mean NO_2 aggregated over entire area and EU-28 (left) and large regions (N/NW/CSE/S) of Europe (right); solid lines mark average over urban areas, dotted lines average over rural areas.



The time series of spatial average annual mean NO_2 aggregated by country are presented in Figure 5.6, separately for urban and rural areas.

Figure 5.6: Time series of annual mean NO_2 aggregated by country. Five countries are represented on each panel (solid lines average over urban areas, dotted lines average over rural areas).

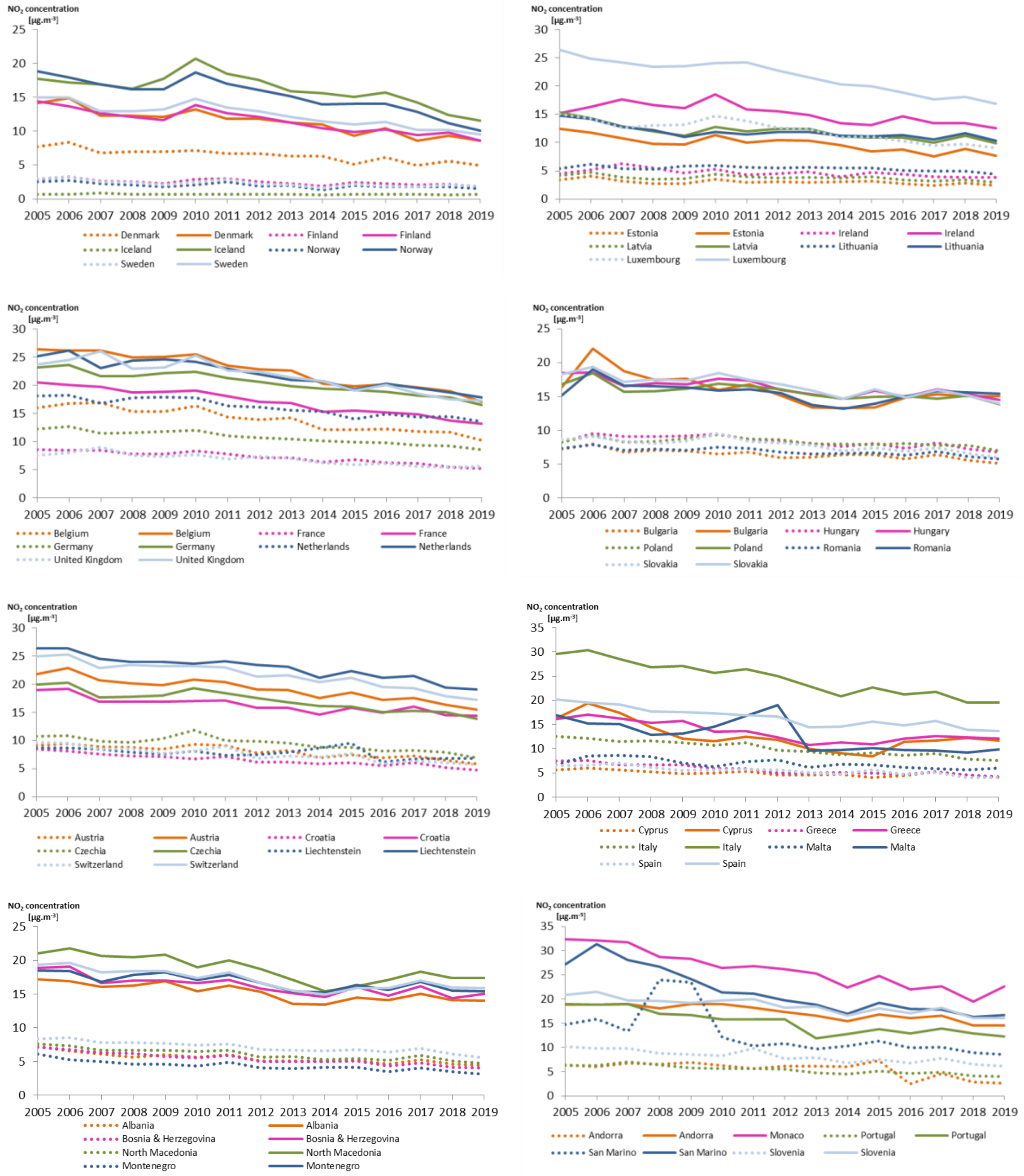
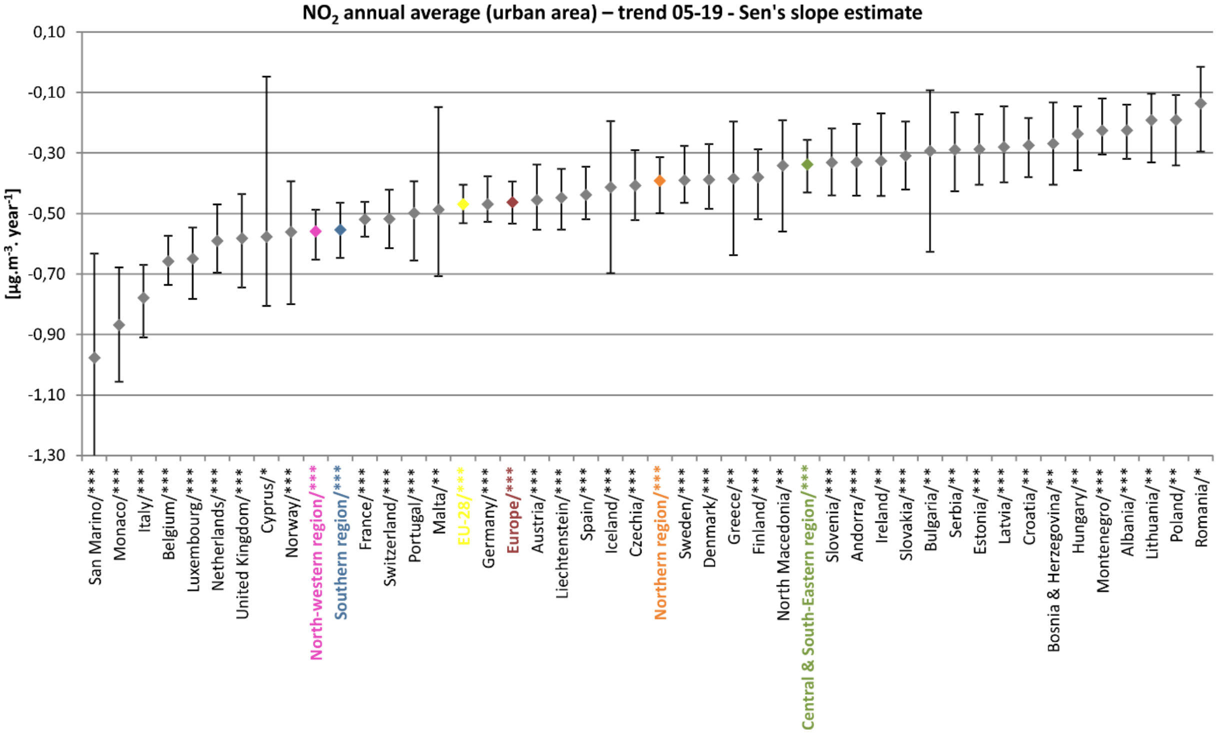


Figure 5.6 shows quite clear development in most of the countries, i.e. significant decreasing trends have been observed in all countries both for urban and rural areas (with the only exception of rural area of Liechtenstein).

The larger decline in urban areas compared to rural areas is also found in the absolute Sen´s slopes by country and over the whole Europe, EU-28 and large European regions represented in Figure 5.7 and Figure 5.8. These figures also show similar magnitude of relative declines over rural and urban areas.

For the numerical results of the trends, see Table A4.12.

Figure 5.7: Sen´s trend of NO_2 annual mean by country and over entire Europe, EU-28 and large European regions in urban areas in absolute ($\mu g.m^{-3}.yr^{-1}$) and relative ($\%.yr^{-1}$) terms. The uncertainty bar is representative of trend significance, also indicated in the x-axis.



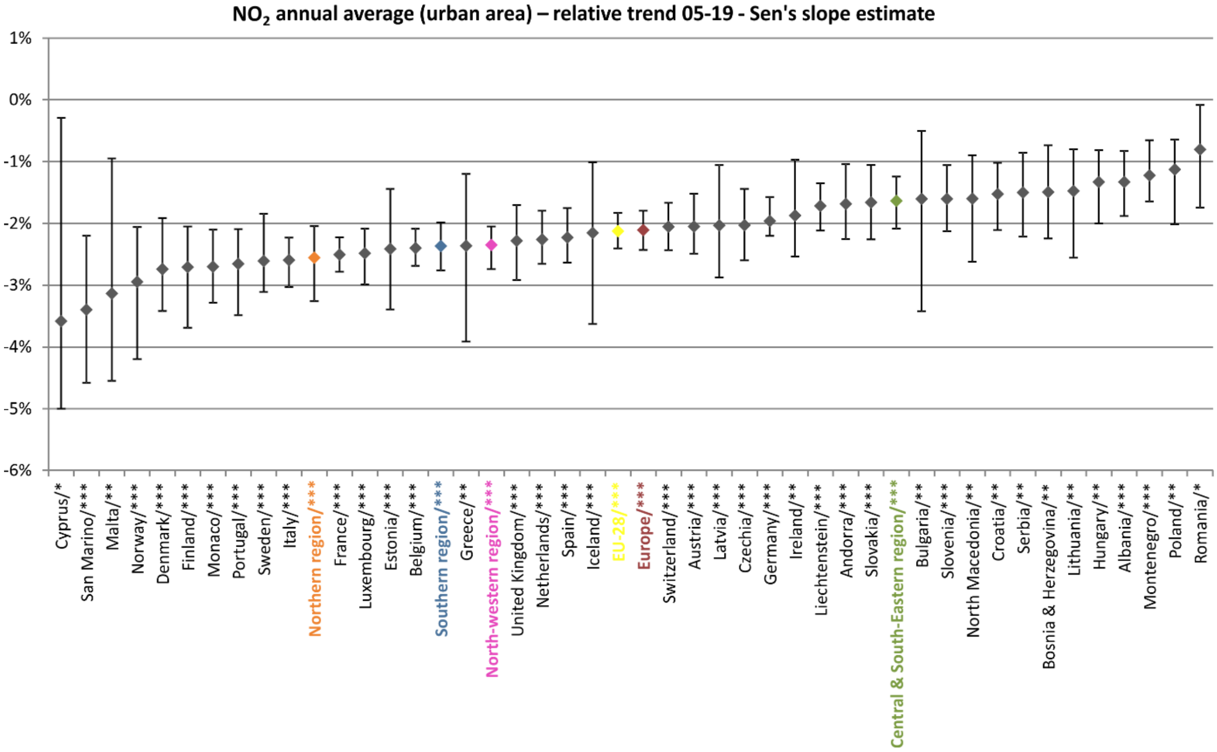
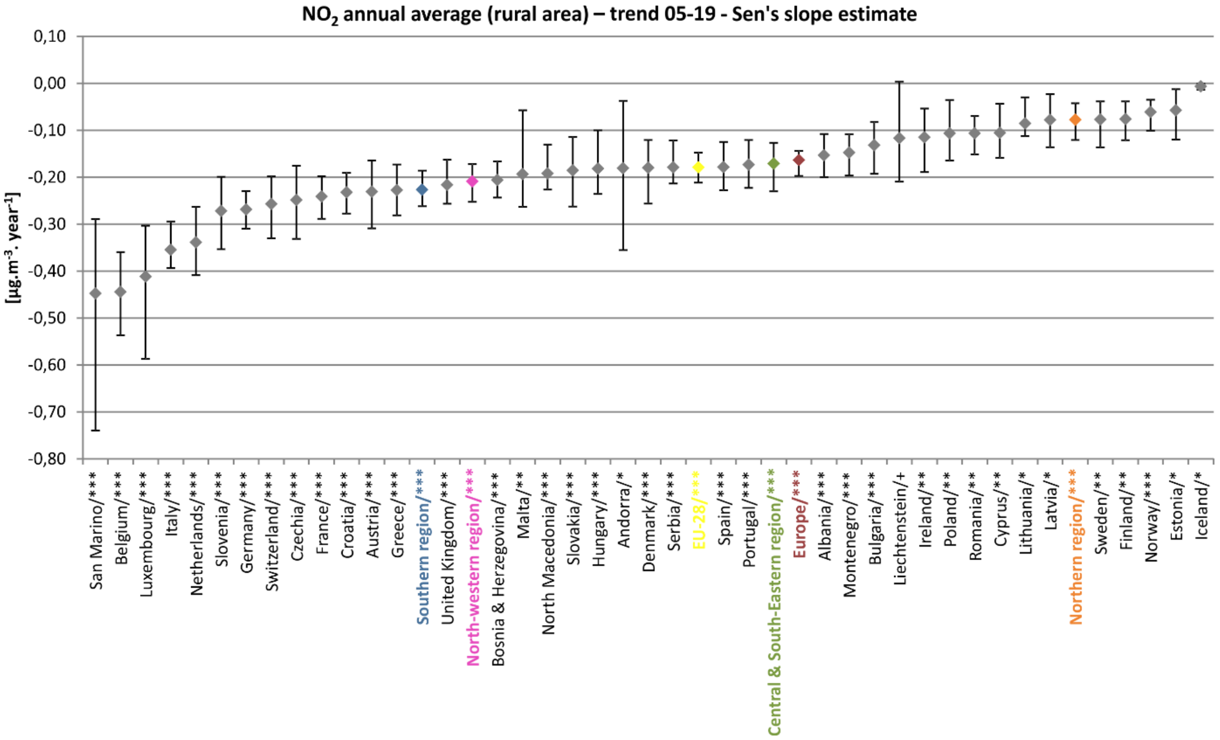
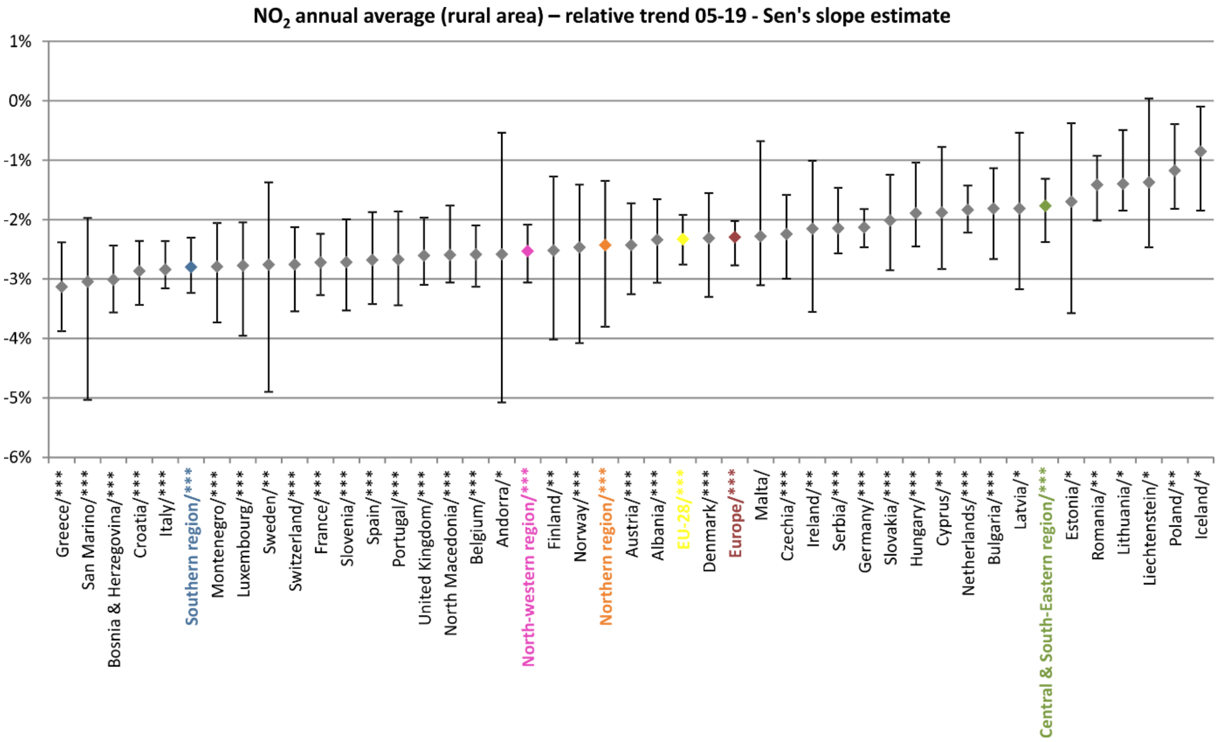


Figure 5.8: Sen´s trend of NO_2 annual mean by country and over entire Europe, EU-28 and large European regions in rural areas in absolute ($\mu g.m^{-3}.yr^{-1}$) and relative ($\%.yr^{-1}$) terms. The uncertainty bar is representative of trend significance, also indicated in the x-axis.



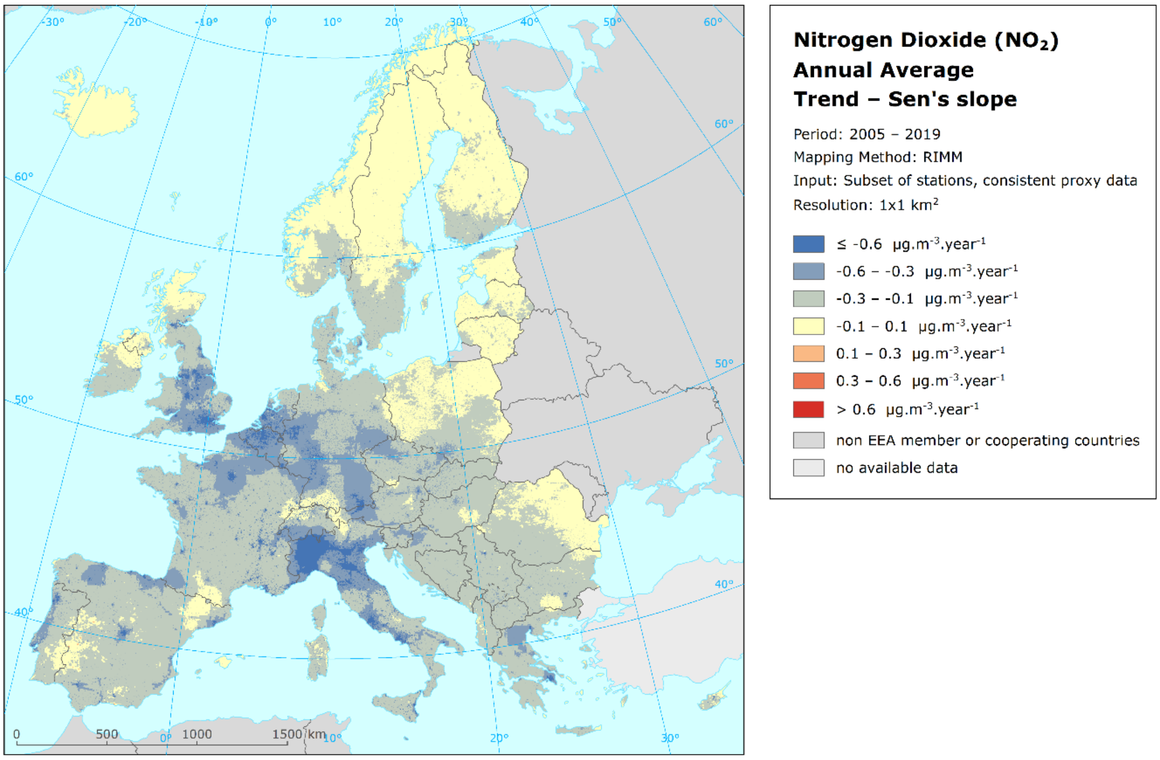


5.3 Trend maps

Like in the case of previous pollutants, maps of trends in 2005–2019 are presented, showing the trends for all grid cells. In each 1x1 km^2 grid cell of the map, both the Sen´s slope and the significance is calculated. Altogether, three maps are presented, i.e., the map showing the Sen´s slope, the map showing the significance and the combined map.

Map 5.1 presents the Sen´s slope trend estimate for NO_2 annual average, as calculated for all grid cells. In general, one can see slight downward trend in the majority of Europe, with a more prominent downward trend in the area of Po valley in northern Italy as well as in the areas around large European cities (London, Paris, Madrid, Naples, Thessaloniki) and in Benelux. The only upward trends are observed in the small area in the north of Poland and in Scandinavia.

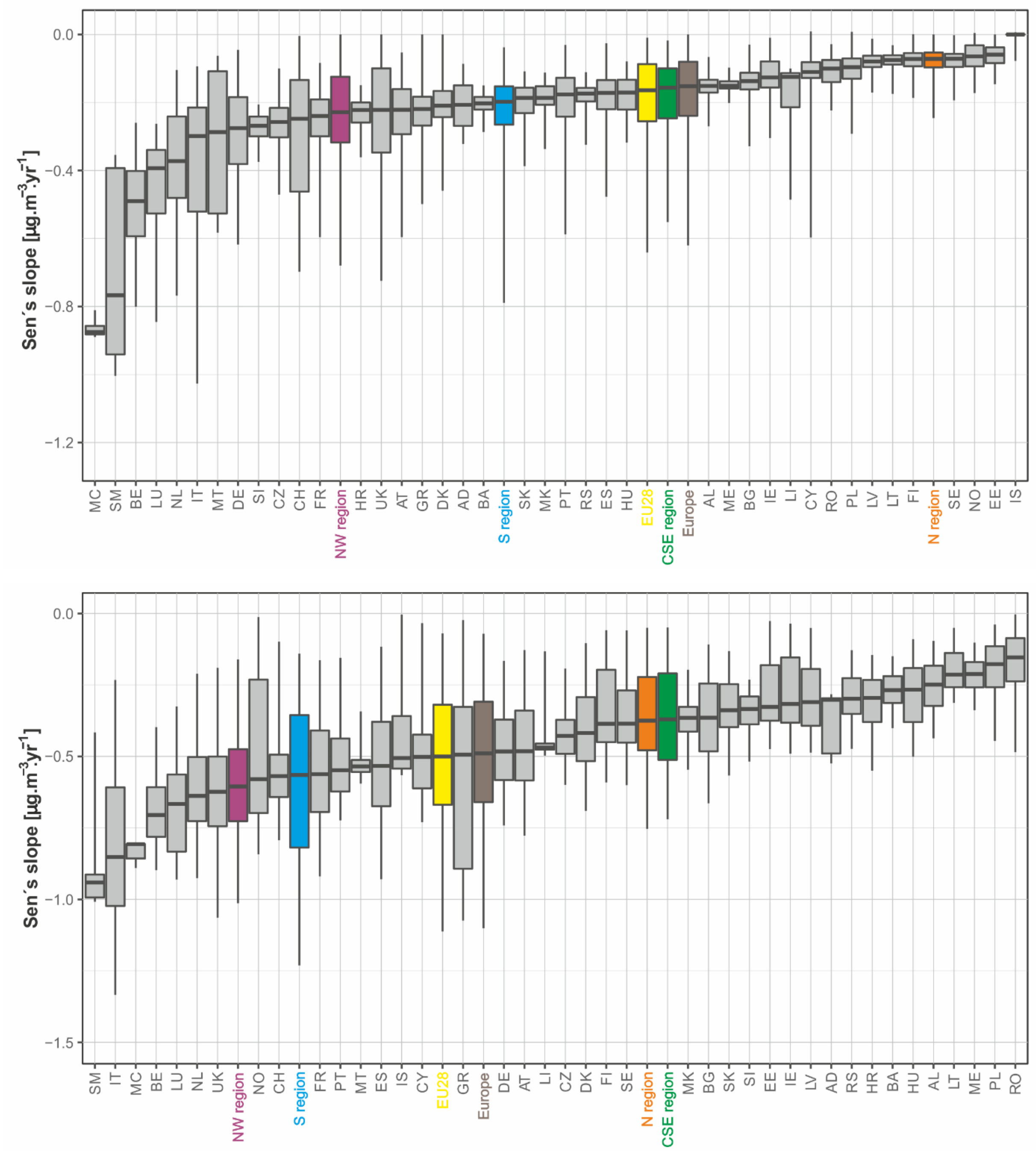
Map 5.1: Trend of NO_2 annual average concentrations in period 2005-2019, Sen´s slope. Units: $\mu g.m^{-3}.yr^{-1}$.



The uncertainty of this map is presented in Annex 2, Table A2.11.

Based on the 1x1 km^2 gridded trend data, the percentiles of the Sen´s slopes have been calculated. Figure 5.9 presents the percentiles for for the entire area, EU-28, large European regions and individual countries. The percentiles have been calculated in two variants, i.e., according to the area and the population living in this area.

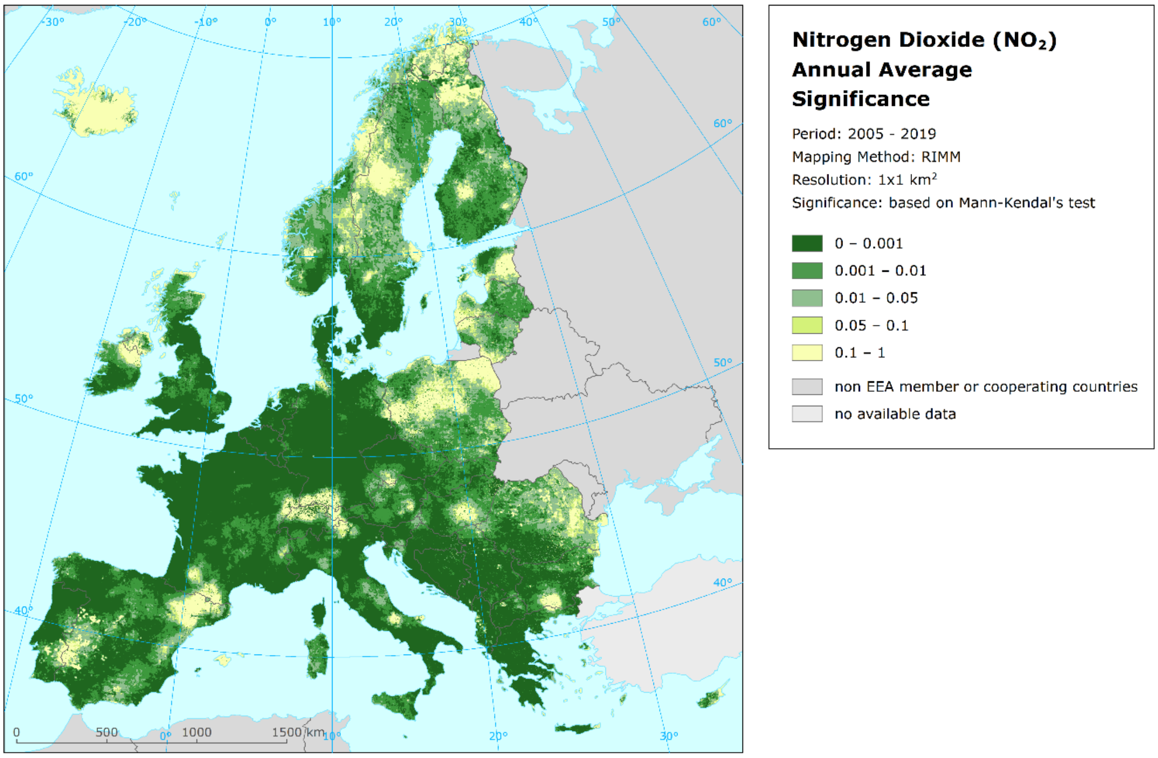
Figure 5.9 Percentiles of Sen´s slope based on 1x1 km² map of NO_2 annual average trend in period 2005-2019 for entire area, EU-28, large regions and individual countries, according to area (top) and population (bottom). Black marker corresponds to median, the box's edges to 25 and 75 percentiles, and the whiskers' edges to 2 and 98 percentiles.



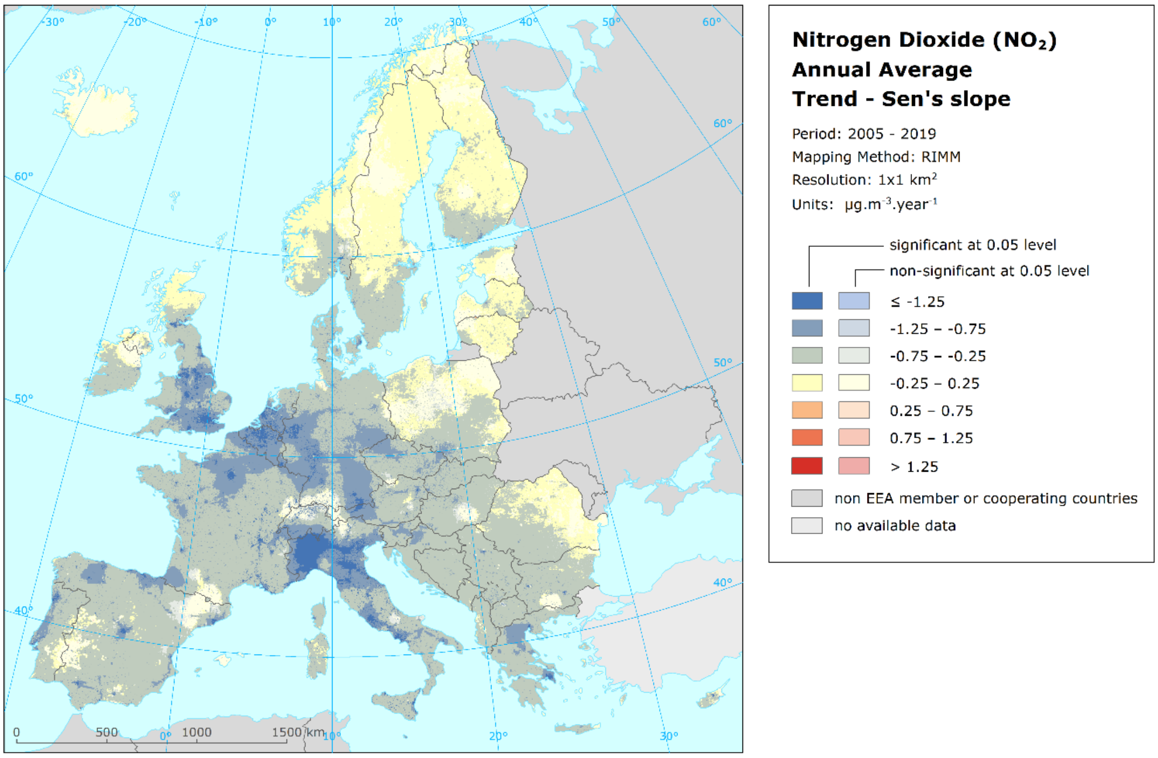
The results correspond to results presented in Figures 5.3 and 5.4. While Figures 5.3 and 5.4 present trends calculated for the average of the individual countries and regions, here the results are based on the trends calculated for all individual grid cells.

While the Sen´s slopes over Europe for NO_2 are presented in Map 5.1, the corresponding significance with the Mann-Kendall test is given in Map 5.2. Map 5.3 is an attempt to merge both information sources by applying a shading where the trend is not significant. This map shows the same trend values as Map 5.2, but with shading (i.e. lighter colours) in areas of non-significant trend (at the 0.05 level of significance). This is an illustration of how a complete mapped information on trends (i.e. both trend value and its significance) can be displayed.

Map 5.2: Significance of the trend in NO_2 annual average concentrations in period 2005-2019. The Mann-Kendall test.



Map 5.3: Trend of NO_2 annual average concentrations in period 2005-2019, Sen´s slope. Units: $\mu g.m^{-3}.yr^{-1}$. Significance of the trend according to the Mann-Kendall test at the level of 0.05 is shown.



6 Conclusions and Recommendations

In this report, we have analysed evolution and trends of air quality in Europe, based on a 15-year time series of spatial data fusion maps for the years 2005-2019. The spatial maps offer a better spatial representativeness for individual countries and regions compared to assessments based on in-situ stations, which suffer from important biases depending on the sampling completeness, uncertainties of measurements, and different strategies of measurement networks development of the various European countries. The analysis has been performed for PM_{10} annual average, the ozone indicator SOMO35 and NO_2 annual average.

For the purpose of the trend analysis, a consistent reconstruction of the full 15-year time series of air quality maps since 2005 till 2019 has been performed, based on a consistent mapping methodology and input data. For the reconstruction, the Regression – Interpolation – Merging Mapping (RIMM) methodology that combines monitoring, modelling and other supplementary data has been used. Consistent modelling results and other supplementary data have been applied. Measurement data only from stations with a sufficient temporal coverage (i.e. 75 % of years) have been used, in order to apply as consistent set of measurement data among the years as possible. In order to check the representativeness of this subset of the measurement stations, we have compared the maps created based on the subset with the maps created based on all stations available, for four years. Based on the analysis, it has been concluded that for most of the area, the differences in relative terms differ less than 25 %. In the case of PM_{10}, in the areas with higher differences, the subset was slightly adapted, in order to improve the results. Subsequently, the final reconstructed consistent maps have been prepared and further used for the trend analysis.

The trend analysis has been performed based on time series of the aggregated data for individual countries, for four large European regions, for EU-28 and for the entire mapping area, both for spatial and population-weighted aggregations.

For the European-wide PM_{10} annual average aggregations across the whole mapping area, statistically significant downward trend of -0.4 $\mu g.m^{-3}$ per year (or -2.2 % per year, in relative terms) for spatially averaged concentrations and of -0.7 $\mu g.m^{-3}$ per year (or -2.4 % per year) for population-weighted averaged concentrations have been estimated. This means a decrease of about 30 % for spatial averaged PM_{10} annual mean concentrations and about 35 % for population-weighted averaged PM_{10} annual mean concentrations during the period 2005-2019. The trend for spatial average concentration tends to be lower in amplitude (both in absolute and relative terms) compared to the trend for population-weighted concentration.

In the case of ozone, no significant trend was detected for the whole mapping area and for most countries. Although Sen´s slopes are mostly negative, the trends are not significant (according to the Mann-Kendall test) for most of the European countries and for the entire area. A significant decrease was detected for some countries of the Southern Europe.

For the European-wide NO_2 annual average aggregations across the whole mapping area, statistically significant downward trends of -0.2 $\mu g.m^{-3}$ per year (or -2.2 % per year, in relative terms) for spatially averaged concentrations and of -0.5 $\mu g.m^{-3}$ per year (or -2.0 % per year) for population-weighted averaged concentrations have been estimated. This means a decrease of more than 30 % for spatial averaged NO_2 annual mean concentrations and about 30 % for population-weighted averaged NO_2 annual mean concentrations during the period 2005-2019.

In addition, maps of trends have been constructed based on the trend estimates for all grid cells of a map. For PM_{10}, slight downward trend in the major part of the European area has been detected in general, with more prominent downward trend in the area of Po valley in northern Italy, in the Ostrava-Katowice industrial region near the Czech-Polish border and in some other areas. In the case of ozone, slight decline in parts of Southern and Central and South-Eastern Europe has been observed, while no clear trend has been detected in the rest of Europe. For NO_2, a slight downward trend in the major part of European area has been observed, with more prominent downward trend in the area of Po valley in northern Italy as well as in the areas around large European cities (London, Paris, Madrid, Napoli, Thessaloniki) and in Benelux.

The trends calculated based on the aggregated data for the whole mapping area have been compared to the statistics derived exclusively from observations in Solberg et al. (2022). Those estimates in the rural and the urban background sites are very consistent with the mapped trends when comparing the whole mapping area (i.e., the spatial averaged concentrations, constituted of a majority of rural areas) and the population-weighted concentrations (mainly influenced by urban areas), respectively, both for PM_{10} and NO_2. For ozone, in Solberg et al. (2022), the SOMO35 trends based on observations were found not to be significant except at traffic sites (which are not considered here), i.e., similar findings as in this report were reported.

Trend analysis based on the data fusion reconstructed maps have advantages compared to trend analysis based on either purely measurements or purely modelling results. Measurements suffer from spatial gaps, while concentration levels of modelling results are often biased. Thus, this methodology seems promising for future analysis of long term trends for the EEA. However, together with advantages, there are also limitations in this approach. The most prominent is the lack of the measurement data in earlier years thgroughout the whole Europe, which provides a challenge for creating data fusion maps prior to the year 2005. Another limitation is that although we have tried to prepare as consistent maps as possible, the sets of stations used for the mapping in different years still somewhat differ. For the future, it is recommended to include pseudo-observations modelled with machine learning approaches for missing years, in order to harmonise the set of stations for all years.

In a potential future development of the long-term reanalyses based on the data fusion maps, a change of the chemical transport model (CTM) used for the data fusion might be considered. Specifically, the CAMS regional long term reanalyses planned within Copernicus 2.0 (after 2021) might be used, if the emission used and the modelling approach will be as consistent as in the case of the EMEP model reconstructions.

Another recommendation for the future is the production of additional indicators. Initially, it should be $PM_{2.5}$ (for which the pseudo station calculations are needed) but also additional parameters such as the PM_{10} 90.4 percentile, ozone indicators 93.2 percentile, AOT40 for vegetation, and AOT40 for forests are promising candidates.

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Annex 1
Analysis of stations´ spatial coverage for consistent maps

This Annex 1 presents a sensitivity analysis of the reconstructed maps. In order to check whether the maps prepared based on the subset of the stations (see Section 2.1.3) truly reflect the whole mapping area, we have compared the maps created based on this subset with the maps created based on all stations available. The sensitivity analysis has been executed for four years, i.e., for 2005, 2010, 2015 and 2019 (for PM_{10} and NO_2) or 2018 (for ozone). Section A1.1 presents the analysis for PM_{10}, while Section A1.2 for ozone and Section A1.3 for NO_2.

A1.1 PM_{10}

For PM_{10}, we have analysed the rural and the urban background map layers, due to their major impact on the spatial and population-weighted exposure estimates. For the analysis purposes, we have calculated maps for four individual years (2005, 2010, 2015, and 2019) using the Regression – Interpolation – Merging Mapping (RIMM) methodology, using the script, based on

(i) the subset of the stations
(ii) all stations available

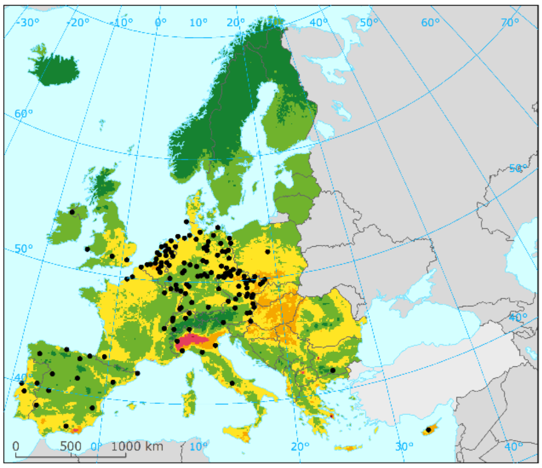
Subsequently, we have compared these two difference mapping results, for individual four year, separately for the rural and the urban background map layers.

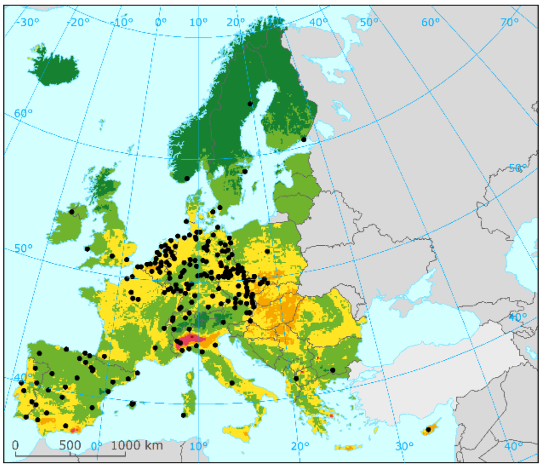
Map A.1 shows the results of two different mapping variants (i) and (ii), including the stations used for the mapping, while Map A.2 presents the difference between these two map variants, both for the rural map layer for 2005. Maps A.3 and A.4 present the similar map variants and their difference, for the urban background map layer for 2005. Maps A.5-A.8 present two map variants and their differences for rural and urban background map layers for 2010. Maps A.9-A.12 show the similar results for 2015, while Maps A.13-A.16 for 2019.

Looking at the results, one can see that for most of the area, differences in relative terms differ less than 25 %. The major differences can be seen in urban background areas in central and northern Romania: the subset of stations include few stations only in this area. For most of the years, the map variants created based of all stations show lower results in this area, compared to the map variants based on the subset of the stations. We can suppose that the trend has been estimated correctly, however the estimated concentration values are overestimated compared to the measurement data.

Based on the results of this analysis, we have decided to add one Romanian urban background station (namely RO0092A) with data in 10 years available to the subset, in order to improve the results. Next to this, based on the analysis on the urban traffic map layers (not presented here), we have decided to merge the data of two nearby Cypriot traffic stations, in order to obtain a sufficient time series (namely, stations CY0003A with 2005-2008 and CY0004A with 2009-2019 data). Further, for the production of the 15-year time series of the reconstructed consistent PM_{10} maps (see Section 2.1.4), this adapted subset of the stations has been used.

Map A.1: Rural map layer of PM_{10} annual average 2005, RIMM method using the subset of stations (left) and all stations (right). Applicable for rural areas only.





PM_{10} annual average, 2005
Rural Map Layer, Using Subset of Stations

Method: RIMM, Usning Script | Resolution: 10x10 km^2

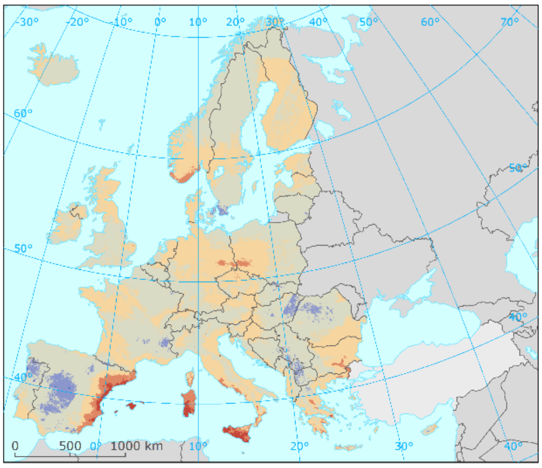
- ≤ 10 μg.m^{-3}
- 10 – 20 μg.m^{-3}
- 20 – 30 μg.m^{-3}
- 30 – 40 μg.m^{-3}
- 40 – 50 μg.m^{-3} (40 = LV)
- > 50 μg.m^{-3}
- No Available Data
- Outside Mapped Area
- • Rural Background Station Used in Mapping

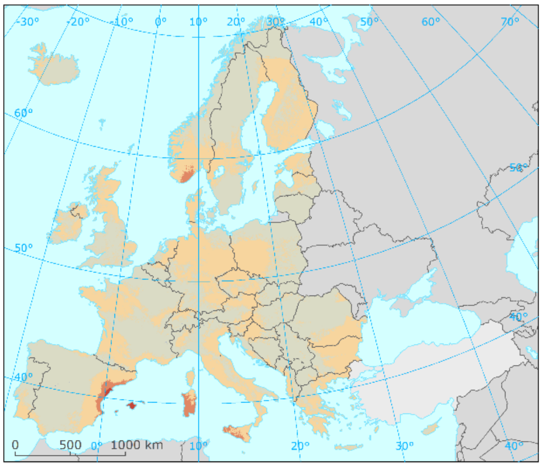
PM_{10} annual average, 2005
Rural Map Layer, Using All Stations

Method: RIMM, Usning Script | Resolution: 10x10 km^2

- ≤ 10 μg.m^{-3}
- 10 – 20 μg.m^{-3}
- 20 – 30 μg.m^{-3}
- 30 – 40 μg.m^{-3}
- 40 – 50 μg.m^{-3} (40 = LV)
- > 50 μg.m^{-3}
- No Available Data
- Outside Mapped Area
- • Rural Background Station Used in Mapping

Map A.2: Difference (left) and relative difference (right) between RIMM mapping variant (i) using the subset of stations and (ii) all stations for rural map layer of PM_{10} annual average 2005. Applicable for rural areas only.





PM_{10} Annual Average, 2005
Rural Map Layer, Difference Map

Difference: Using Subset of Stations - Using All Stations
Method: RIMM, Using Script | Resolution: 1x1 km^2

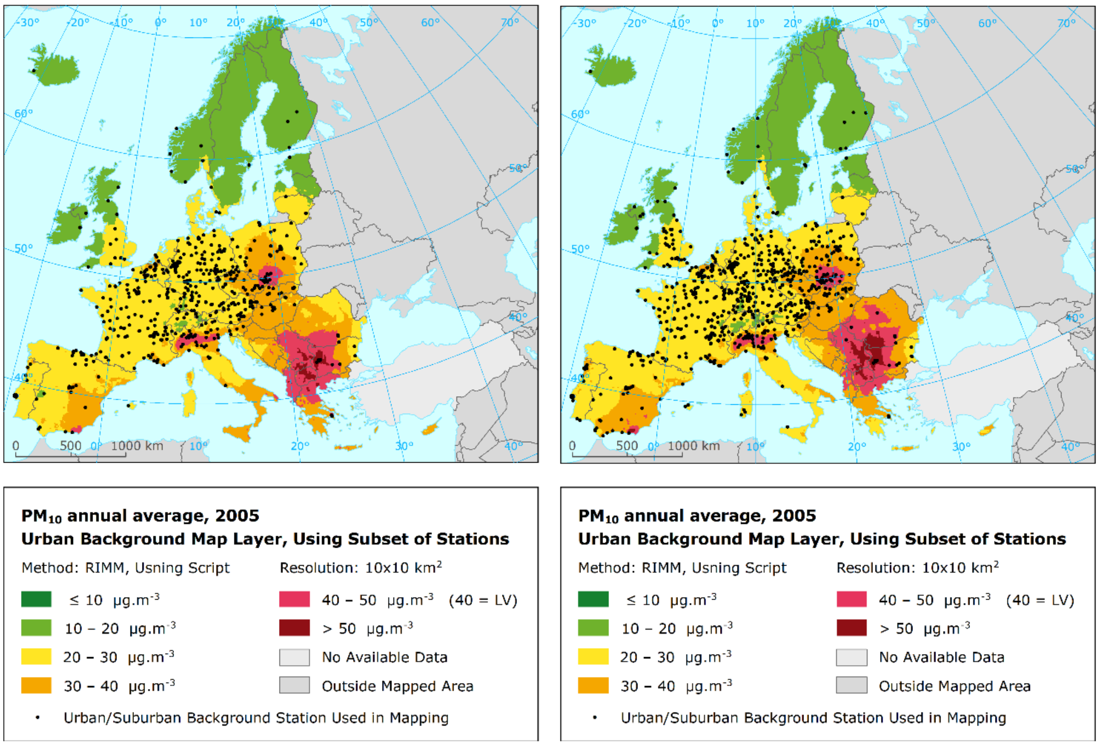
- ≤ - 5 μg.m^{-3}
- - 5 – - 2 μg.m^{-3}
- - 2 – 0 μg.m^{-3}
- 0 – 2 μg.m^{-3}
- 2 – 5 μg.m^{-3}
- > 5 μg.m^{-3}
- No Available Data
- Outside Mapping Area

PM_{10} Annual Average, 2005
Rural Map Layer, Relative Difference Map

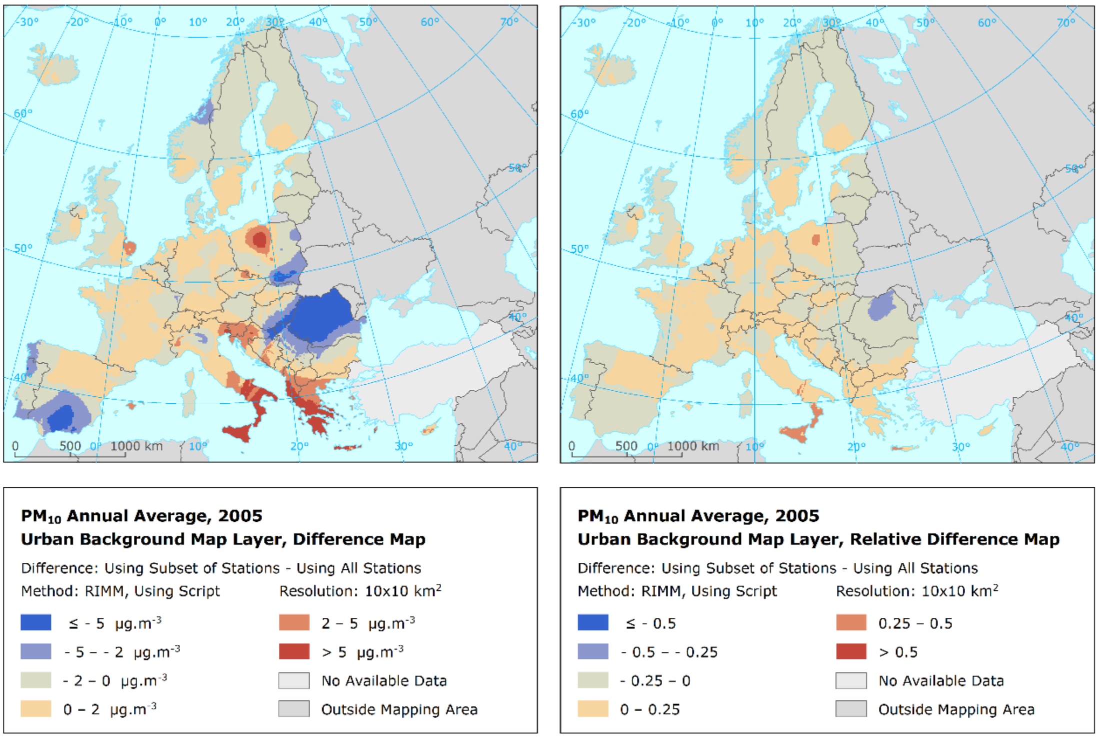
Difference: Using Subset of Stations - Using All Stations
Method: RIMM, Using Script | Resolution: 1x1 km^2

- ≤ - 0.5
- - 0.5 – - 0.25
- - 0.25 – 0
- 0 – 0.25
- 0.25 – 0.5
- > 0.5
- No Available Data
- Outside Mapping Area

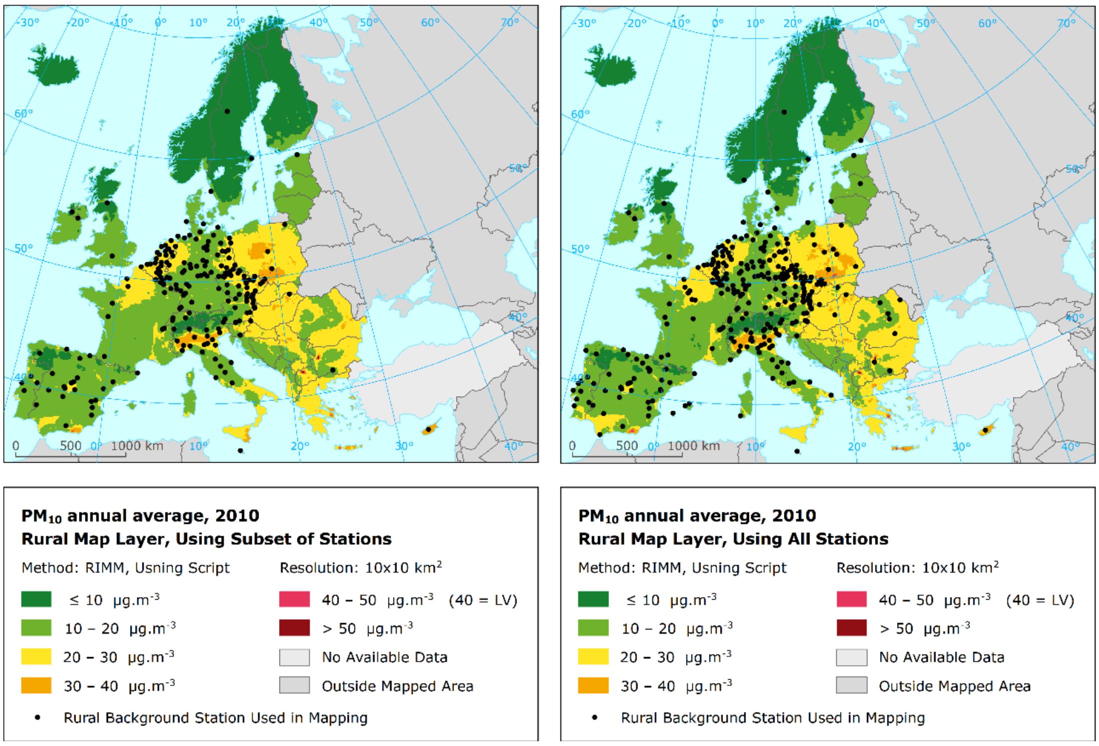
Map A.3: Urban background map layer of PM_{10} annual average 2005, RIMM method using the subset of stations (left) and all stations (right). Applicable for urban background areas only.



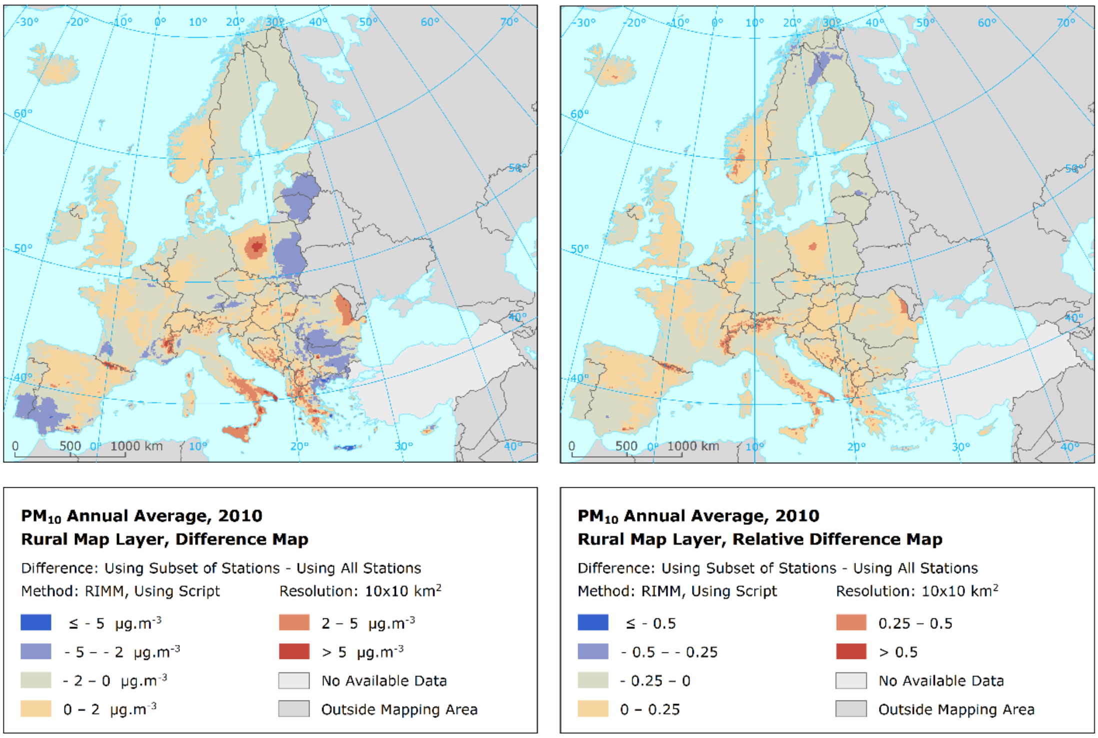
Map A.4: Difference (left) and relative difference (right) between RIMM mapping variant (i) using the subset of stations and (ii) all stations for urban background map layer of PM_{10} annual average 2005. Applicable for urban background areas only.



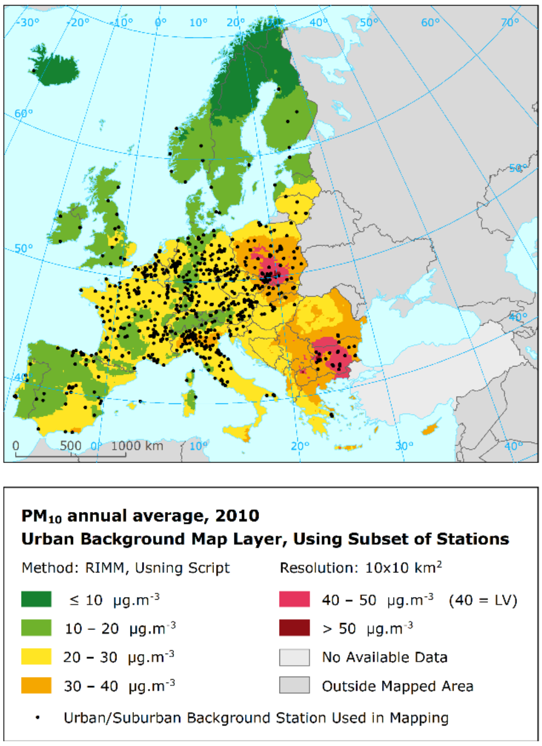
Map A.5: Rural map layer of PM_{10} annual average 2010, RIMM method using the subset of stations (left) and all stations (right). Applicable for rural areas only.

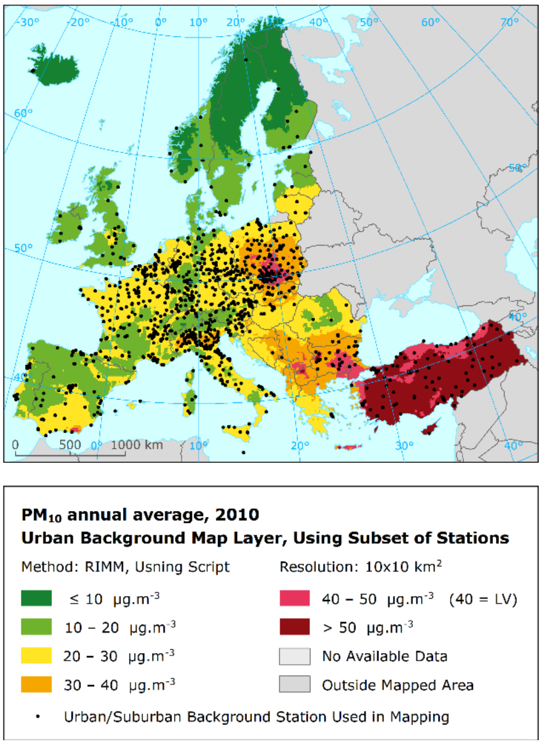


Map A.6: Difference (left) and relative difference (right) between RIMM mapping variant (i) using the subset of stations and (ii) all stations for rural map layer of PM_{10} annual average 2010. Applicable for rural areas only.

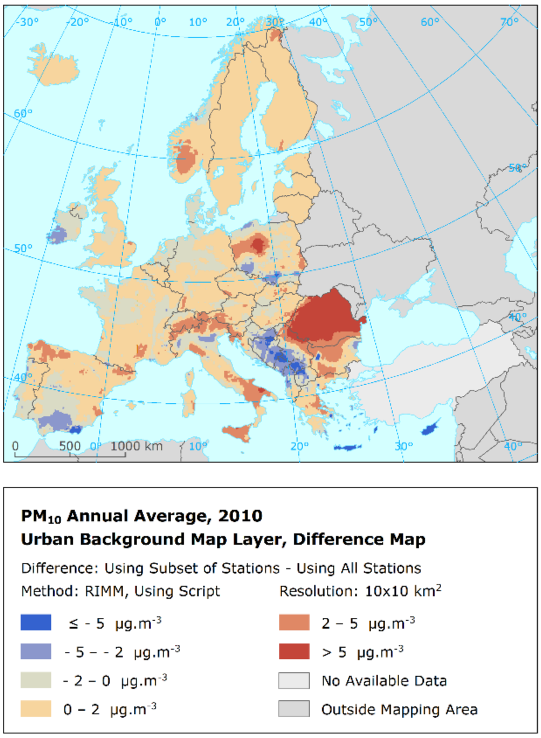


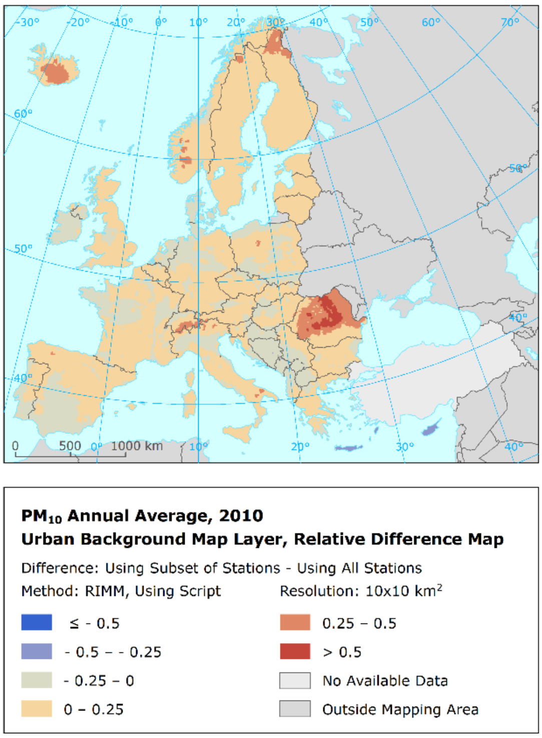
Map A.7: Urban background map layer of PM_{10} annual average 2010, RIMM method using the subset of stations (left) and all stations (right). Applicable for urban background areas only.



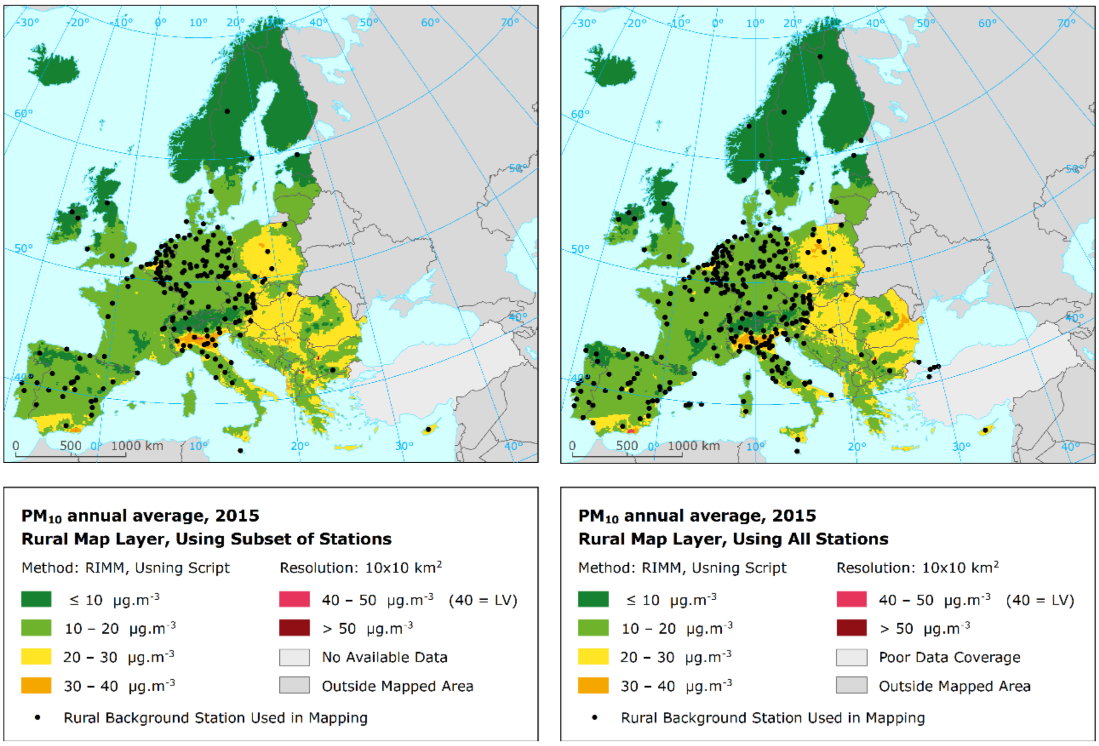


Map A.8: Difference (left) and relative difference (right)between RIMM mapping variant (i) using the subset of stations and (ii) all stations for urban background map layer of PM_{10} annual average 2010. Applicable for urban background areas only.

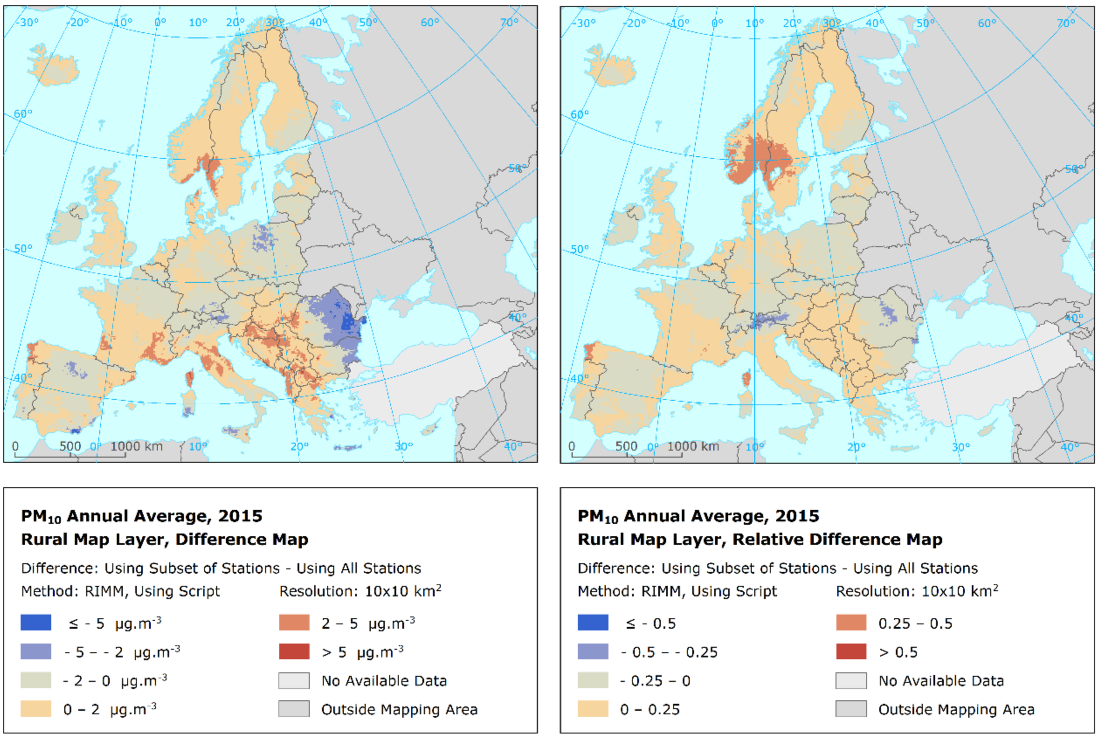




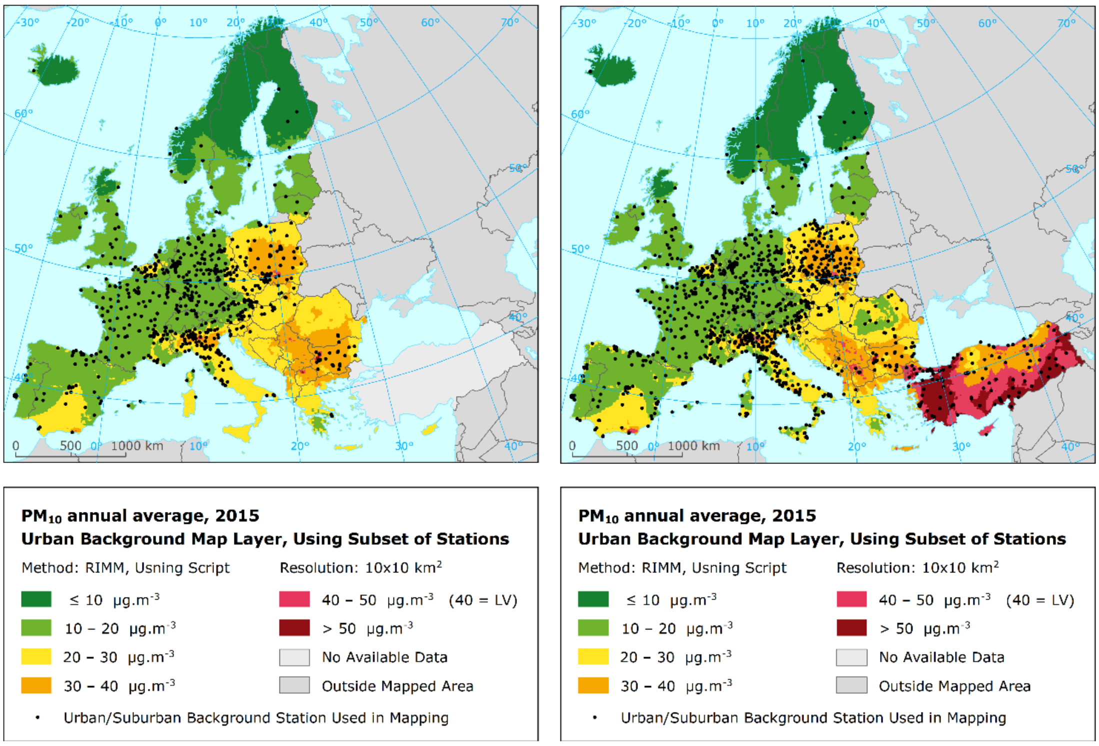
Map A.9: Rural map layer of PM_{10} annual average 2015, RIMM method using the subset of stations (left) and all stations (right). Applicable for rural areas only.



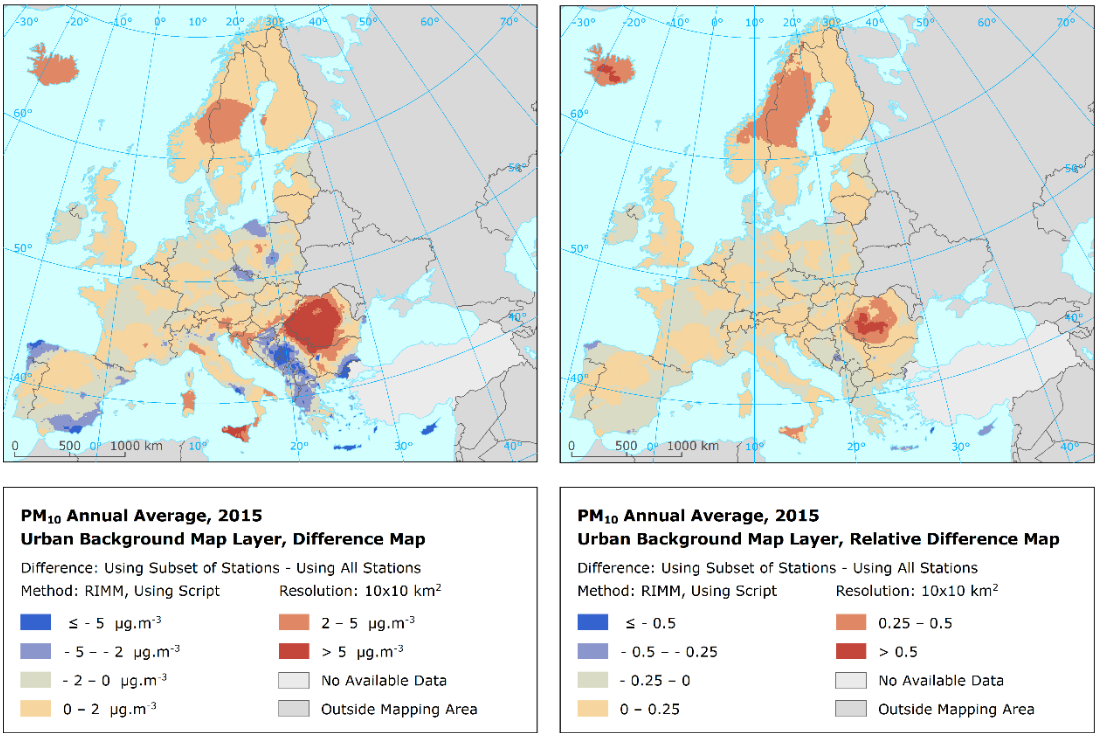
Map A.10: Difference (left) and relative difference (right)between RIMM mapping variant (i) using the subset of stations and (ii) all stations for rural map layer of PM_{10} annual average 2015. Applicable for rural areas only.



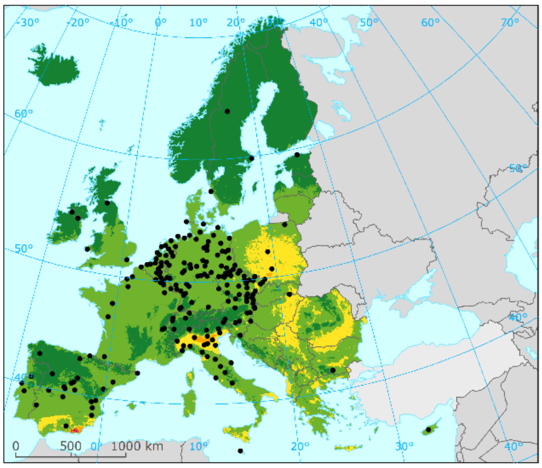
Map A.11: Urban background map layer of PM_{10} annual average 2015, RIMM method using the subset of stations (left) and all stations (right). Applicable for urban background areas only.

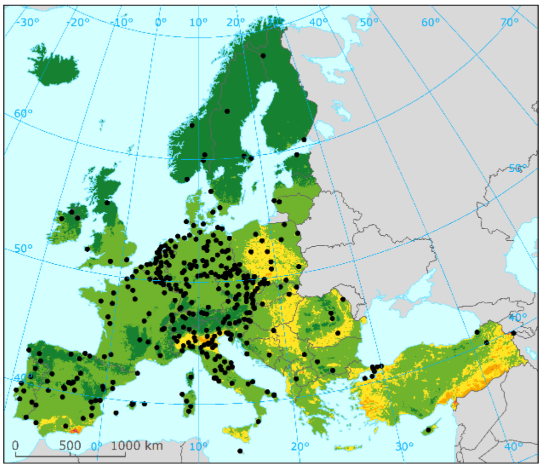


Map A.12: Difference (left) and relative difference (right)between RIMM mapping variant (i) using the subset of stations and (ii) all stations for urban background map layer of PM_{10} annual average 2015. Applicable for urban background areas only.



Map A.13: Rural map layer of PM_{10} annual average for 2019, RIMM method using the subset of stations (left) and all stations (right). Applicable for rural areas only.





PM_{10} annual average, 2019
Rural Map Layer, Using Subset of Stations

Method: RIMM, Usning Script — Resolution: 1x1 km²

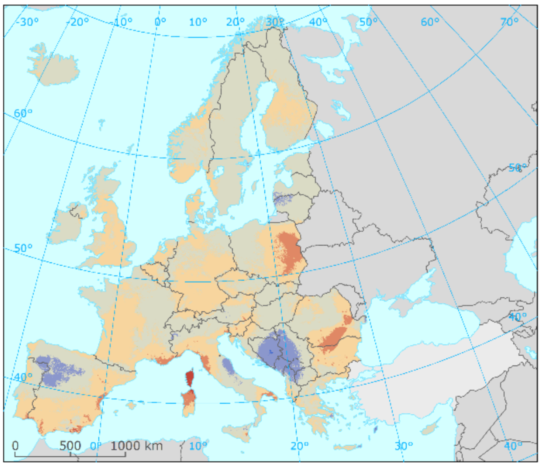
- ≤ 10 µg.m⁻³
- 10 – 20 µg.m⁻³
- 20 – 30 µg.m⁻³
- 30 – 40 µg.m⁻³
- 40 – 50 µg.m⁻³ (40 = LV)
- > 50 µg.m⁻³
- No Available Data
- Outside Mapped Area
- • Rural Background Station Used in Mapping

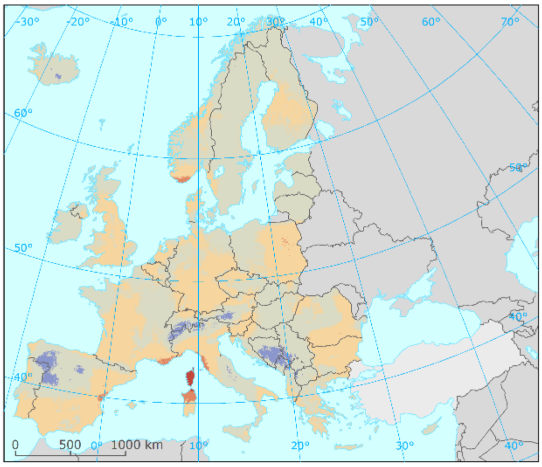
PM_{10} annual average, 2019
Rural Map Layer, Using All Stations

Method: RIMM, Usning Script — Resolution: 1x1 km²

- ≤ 10 µg.m⁻³
- 10 – 20 µg.m⁻³
- 20 – 30 µg.m⁻³
- 30 – 40 µg.m⁻³
- 40 – 50 µg.m⁻³ (40 = LV)
- > 50 µg.m⁻³
- No Available Data
- Outside Mapped Area
- • Rural Background Station Used in Mapping

Map A.14: Difference (left) and relative difference (right)between RIMM mapping variant (i) using the subset of stations and (ii) all stations for rural map layer of PM_{10} annual average 2019. Applicable for rural areas only.





PM_{10} Annual Average, 2019
Rural Map Layer, Difference Map

Difference: Using Subset of Stations - Using All Stations
Method: RIMM, Using Script — Resolution: 1x1 km²

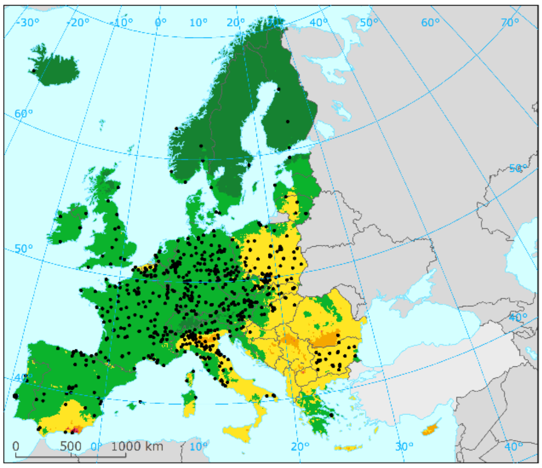
- ≤ - 5 µg.m⁻³
- - 5 – - 2 µg.m⁻³
- - 2 – 0 µg.m⁻³
- 0 – 2 µg.m⁻³
- 2 – 5 µg.m⁻³
- > 5 µg.m⁻³
- No Available Data
- Outside Mapping Area

PM_{10} Annual Average, 2019
Rural Map Layer, Relative Difference Map

Difference: Using Subset of Stations - Using All Stations
Method: RIMM, Using Script — Resolution: 1x1 km²

- ≤ - 0.5
- - 0.5 – - 0.25
- - 0.25 – 0
- 0 – 0.25
- 0.25 – 0.5
- > 0.5
- No Available Data
- Outside Mapping Area

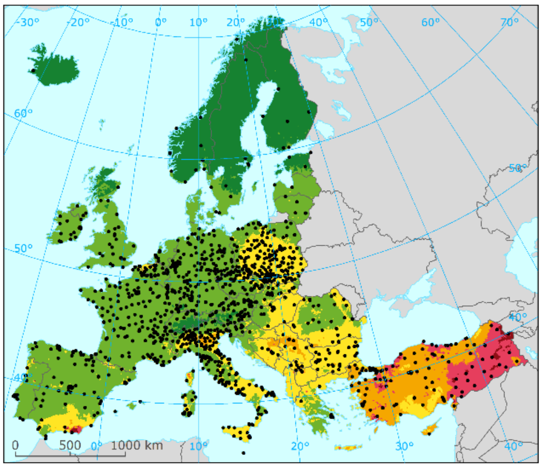
Map A.15: Urban background map layer of PM_{10} annual average for 2019, RIMM method using the subset of stations (left) and all stations (right). Applicable for urban background areas only.



PM_{10} annual average, 2019
Urban Background Map Layer, Using Subset of Stations

Method: RIMM, Usning Script   Resolution: 1x1 km²

- ≤ 10 μg.m⁻³
- 10 – 20 μg.m⁻³
- 20 – 30 μg.m⁻³
- 30 – 40 μg.m⁻³
- 40 – 50 μg.m⁻³ (40 = LV)
- > 50 μg.m⁻³
- No Available Data
- Outside Mapped Area
- • Urban/Suburban Background Station Used in Mapping

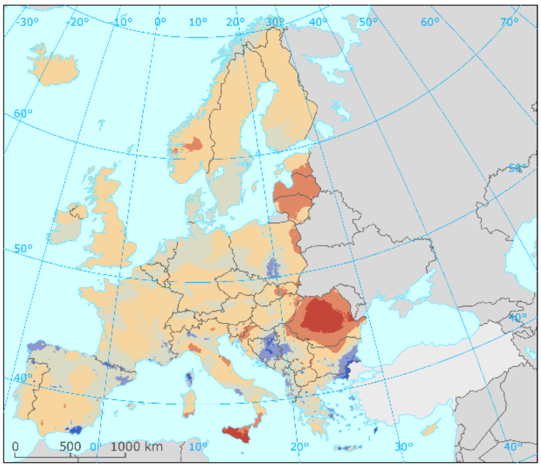


PM_{10} annual average, 2019
Urban Background Map Layer, Using Subset of Stations

Method: RIMM, Usning Script   Resolution: 1x1 km²

- ≤ 10 μg.m⁻³
- 10 – 20 μg.m⁻³
- 20 – 30 μg.m⁻³
- 30 – 40 μg.m⁻³
- 40 – 50 μg.m⁻³ (40 = LV)
- > 50 μg.m⁻³
- No Available Data
- Outside Mapped Area
- • Urban/Suburban Background Station Used in Mapping

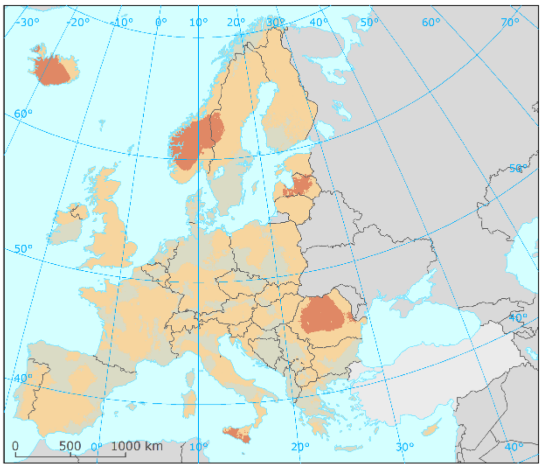
Map A.16: Difference (left) and relative difference (right)between RIMM mapping variant (i) using the subset of stations and (ii) all stations for urban background map layer of PM_{10} annual average 2019. Applicable for urban background areas only.



PM_{10} Annual Average, 2019
Urban Background Map Layer, Difference Map

Difference: Using Subset of Stations - Using All Stations
Method: RIMM, Using Script   Resolution: 1x1 km²

- ≤ - 5 μg.m⁻³
- - 5 – - 2 μg.m⁻³
- - 2 – 0 μg.m⁻³
- 0 – 2 μg.m⁻³
- 2 – 5 μg.m⁻³
- > 5 μg.m⁻³
- No Available Data
- Outside Mapping Area



PM_{10} Annual Average, 2019
Urban Background Map Layer, Relative Difference Map

Difference: Using Subset of Stations - Using All Stations
Method: RIMM, Using Script   Resolution: 1x1 km²

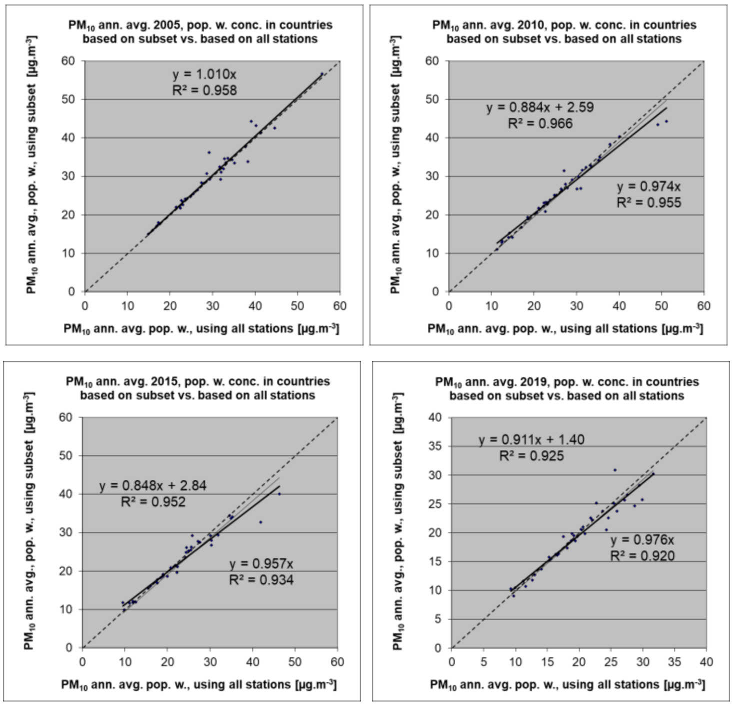
- ≤ - 0.5
- - 0.5 – - 0.25
- - 0.25 – 0
- 0 – 0.25
- 0.25 – 0.5
- > 0.5
- No Available Data
- Outside Mapping Area

Next to the mapping results, we have compared also the population weighted concentrations. Table A1.1 presents the results for the entire area for four years, for both (i) and (ii) mapping variants. Both variants give quite similar results. Figure A1.1 presents the relevant scatter plots per countries.

Table A1.1 Population weighted concentration for PM_{10} annual average in years 2005, 2010, 2015 and 2019 for two mapping variants. Units: $\mu g \cdot m^{-3}$.

Mapping variant	2005	2010	2015	2019
(i) Based on the subset of stations	28.5	25.0	21.7	18.9
(ii) Based on all stations available	28.5	24.9	21.9	19.0

Figure A1.1 Correlation between population weighted concentration for individual countries calculated based on RIMM mapping variant using (i) the subset of stations (y-axis) and (ii) all stations (x-axis), PM_{10} annual average for 2005, 2010, 2015 and 2019



A1.2 Ozone

For ozone, we have analysed both the rural and the urban background map layers. For the analysis purposes, we have calculated maps for four individual years (2005, 2010, 2015, and 2018) using the Regression – Interpolation – Merging Mapping (RIMM) methodology, using the script, based on

- (i) the subset of the stations
- (ii) all stations available

Subsequently, we have compared these two difference mapping results, for individual four year, separately for the rural and the urban background map layers.

Map A.17 shows the results of two different mapping variants (i) and (ii), including the stations used for the mapping, while Map A.18 presents the difference and the relative difference between these two map variants, in the both cases for the rural map layer for 2005. Maps A.19 and A.20 present the similar map variants and their difference, for the urban background map layer for 2005. Maps A.21-A.24 present two map variants and their differences for the rural and urban background map layers for 2010. Maps A.25-A.28 show the similar mapping results for 2015, while Maps A.29-A.32 for 2019.

Looking at the results, one can see that for most of the mapping area, the differences in relative terms differ less than 25 %. The major differences can be seen in the area of Romania: the subset of the stations include few stations only in this area due to the lack of data in the first years of the 15-year period. For most of the years, the map variants created based of all stations show lower results compared to the map variants based on the subset of the stations in this area, especially for urban background, but also for rural locations. We can suppose that the trend has been estimated correctly, however the estimated concentration values are somewhat overestimated compared to the measurement data. In connection with this issue, it should be noted that the ozone data measured in Romanian stations show quite suspiciously low values, compared to both the measurement data from neighbouring countries and the modelling results.

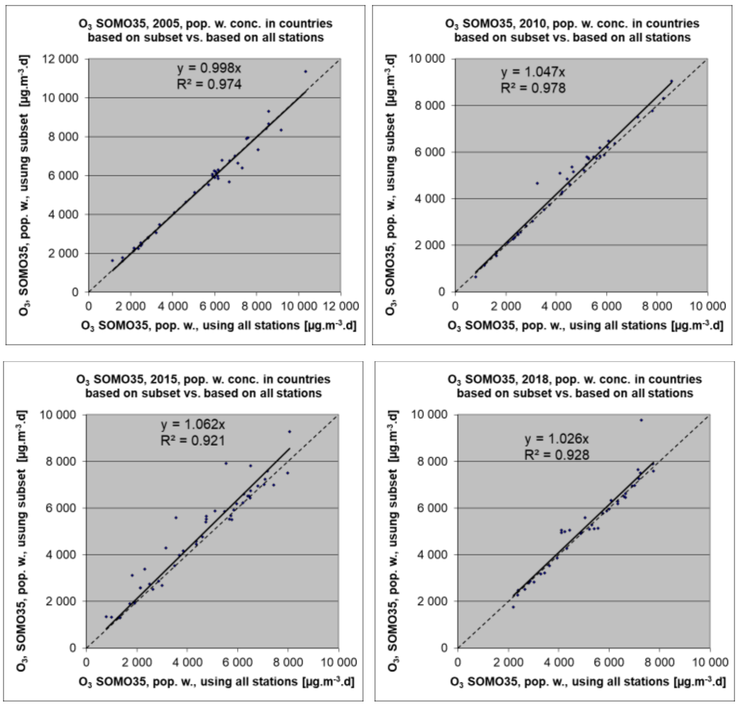
Contrary to the PM_{10} mapping, it was not possible to supplement the subset of the stations with additional ozone stations in the area of Romania. Thus, for the production of the 15-year time series of the reconstructed consistent ozone maps (see Section 2.1.4), the original subset of the stations has been used.

Next to the mapping results, we have compared also the population weighted concentrations. Table A1.2 presents the results for the entire area for four years, for both (i) and (ii) mapping variants. Slightly higher results in the variant (ii) using the subset of the stations are caused mainly by the higher results in Romania and surrounding areas. Figure A1.2 presents the relevant scatter plots per countries.

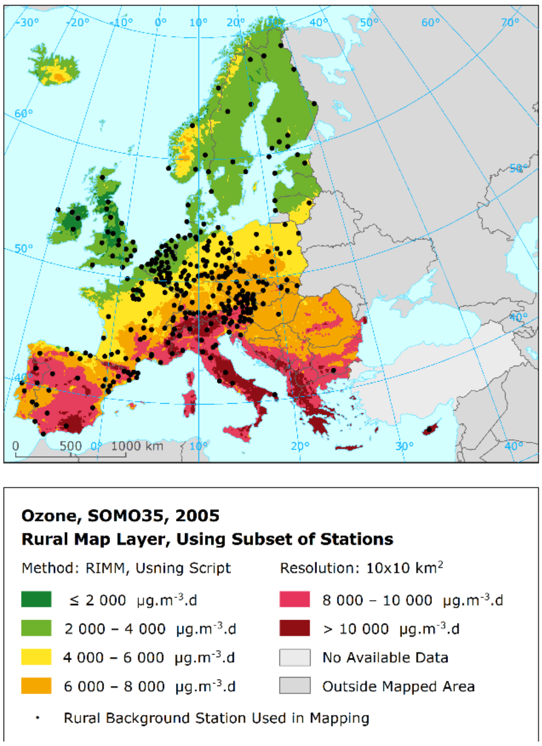
Table A1.2 Population weighted concentration for ozone indicator SOMO35 in years 2005, 2010, 2015 and 2019 for two mapping variants. Units: μg·m^{-3}·d.

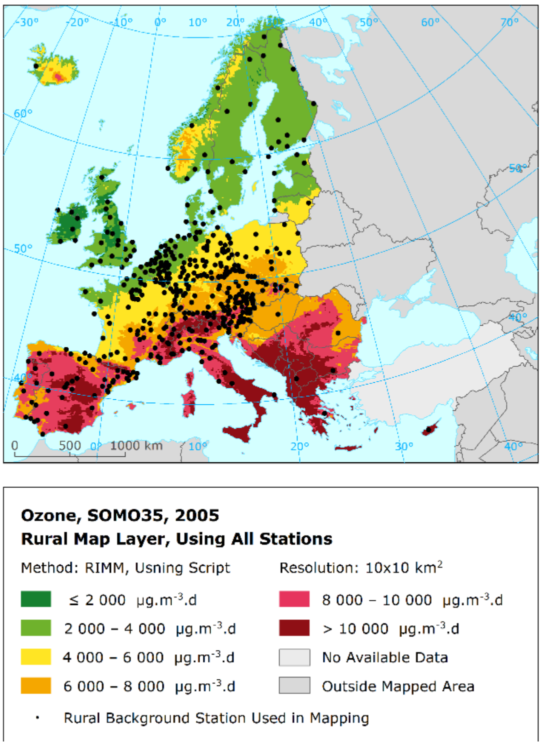
Mapping variant	2005	2010	2015	2019
(i) Based on the subset of stations	4 825	4 127	4 586	5 105
(ii) Based on all stations available	4 802	3 997	4 357	5 076

Figure A1.2 Correlation between population weighted concentration for individual countries calculated based on RIMM mapping variant using (i) the subset of stations (y-axis) and (ii) all stations (x-axis), ozone indicator SOMO35 in years 2005, 2010, 2015 and 2019

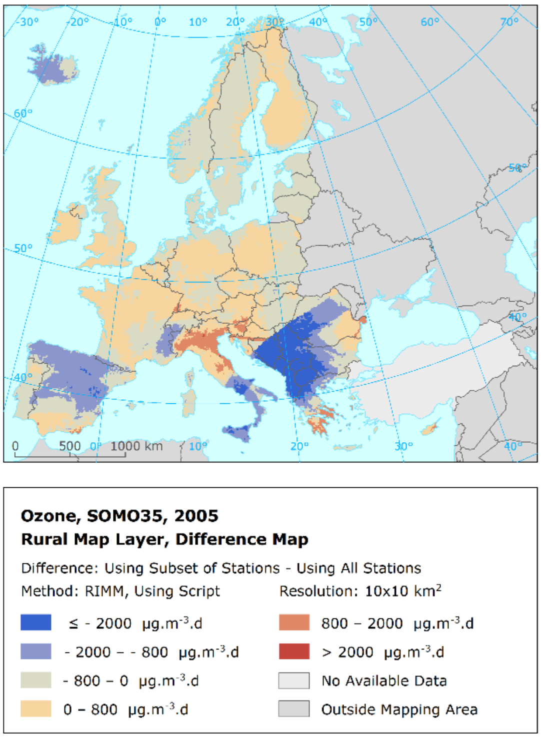


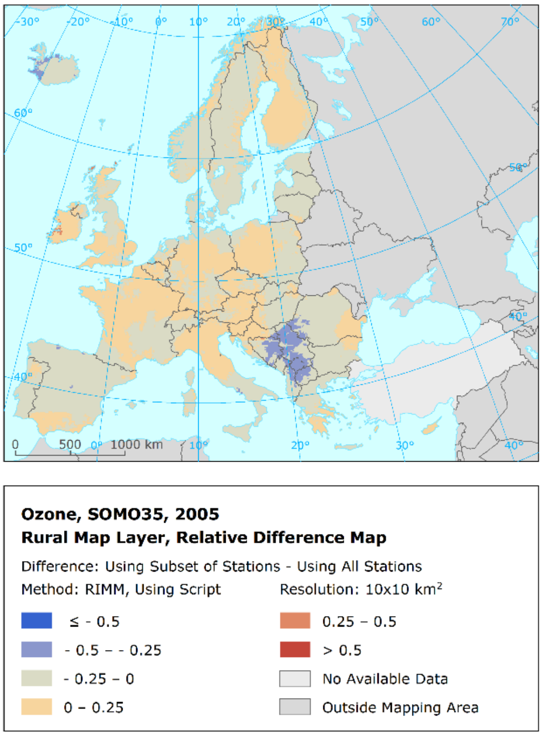
Map A.17: Rural map layer of ozone indicator SOMO35 for 2005, RIMM method using the subset of stations (left) and all stations (right). Applicable for rural areas only.



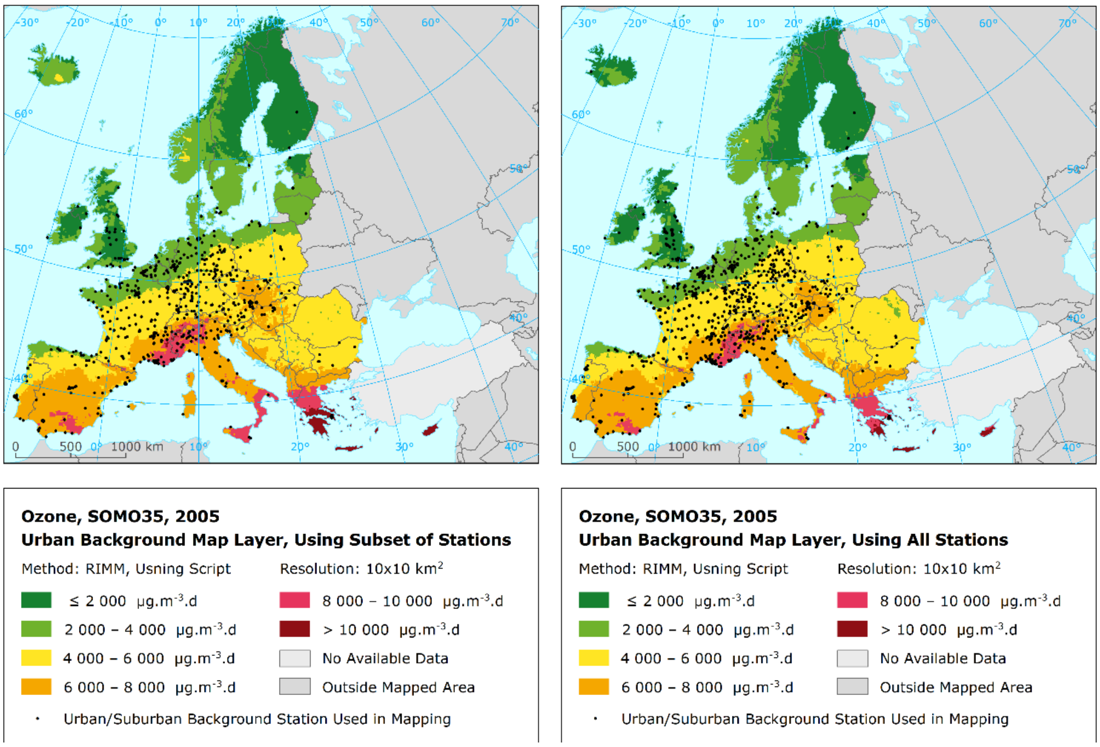


Map A.18: Difference (left) and relative difference (right) between RIMM mapping variant (i) using the subset of stations and (ii) all stations for rural map layer of ozone indicator SOMO35 for 2005. Applicable for rural areas only.

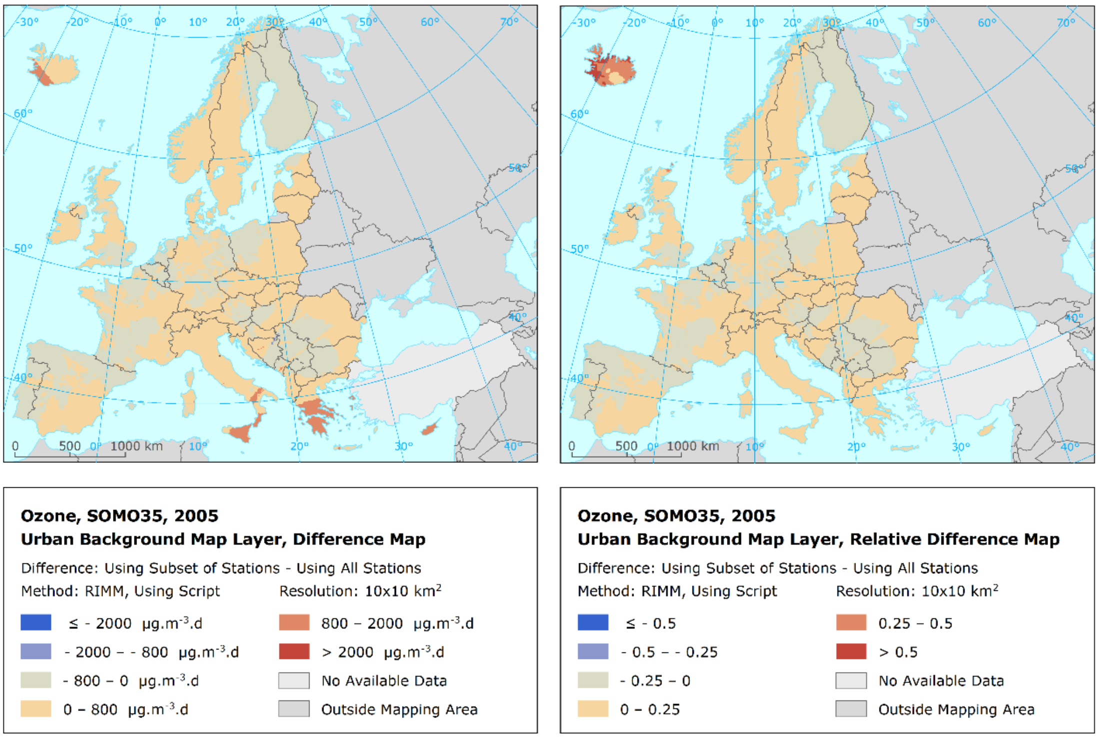




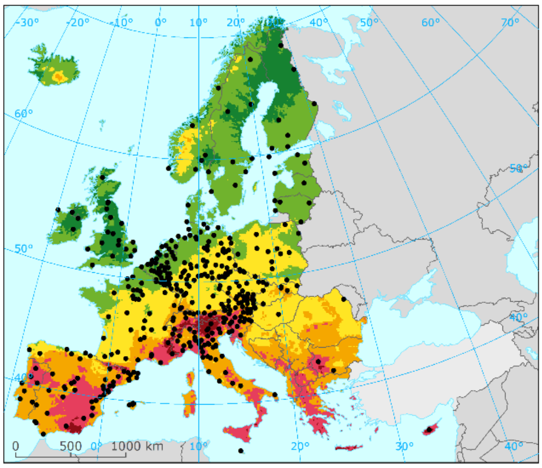
Map A.19: Urban background map layer of ozone indicator SOMO35 for 2005, RIMM method using the subset of stations (left) and all stations (right). Applicable for urban background areas only.



Map A.20: Difference (left) and relative difference (right) between RIMM mapping variant (i) using the subset of stations and (ii) all stations for urban background map layer of ozone indicator SOMO35 for 2005. Applicable for urban background areas only.



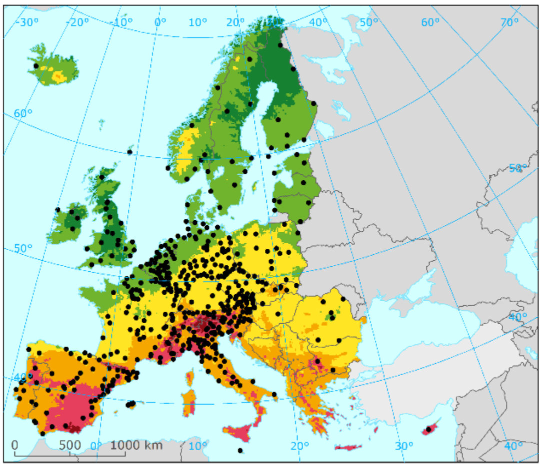
Map A.21: Rural map layer of ozone indicator SOMO35 for 2010, RIMM method using the subset of stations (left) and all stations (right). Applicable for rural areas only.



Ozone, SOMO35, 2010
Rural Map Layer, Using Subset of Stations

Method: RIMM, Usning Script — Resolution: 10x10 km²

- ≤ 2 000 µg.m^{-3}.d
- 2 000 – 4 000 µg.m^{-3}.d
- 4 000 – 6 000 µg.m^{-3}.d
- 6 000 – 8 000 µg.m^{-3}.d
- 8 000 – 10 000 µg.m^{-3}.d
- > 10 000 µg.m^{-3}.d
- No Available Data
- Outside Mapped Area
- • Rural Background Station Used in Mapping

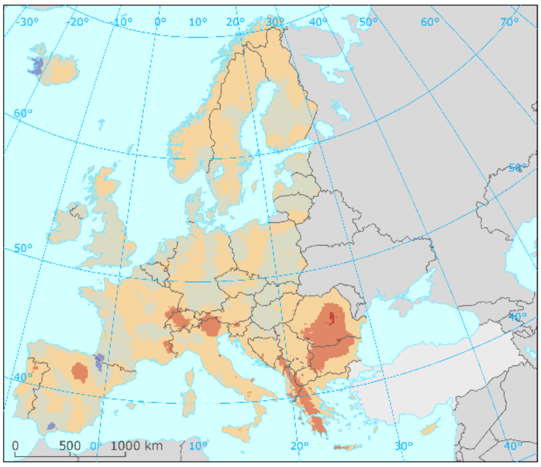


Ozone, SOMO35, 2010
Rural Map Layer, Using All Stations

Method: RIMM, Usning Script — Resolution: 10x10 km²

- ≤ 2 000 µg.m^{-3}.d
- 2 000 – 4 000 µg.m^{-3}.d
- 4 000 – 6 000 µg.m^{-3}.d
- 6 000 – 8 000 µg.m^{-3}.d
- 8 000 – 10 000 µg.m^{-3}.d
- > 10 000 µg.m^{-3}.d
- No Available Data
- Outside Mapped Area
- • Rural Background Station Used in Mapping

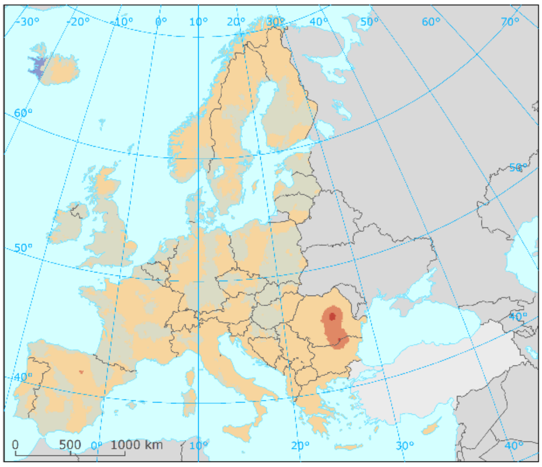
Map A.22: Difference (left) and relative difference (right) between RIMM mapping variant (i) using the subset of stations and (ii) all stations for rural map layer of ozone indicator SOMO35 for 2010. Applicable for rural areas only.



Ozone, SOMO35, 2010
Rural Map Layer, Difference Map

Difference: Using Subset of Stations - Using All Stations
Method: RIMM, Using Script — Resolution: 10x10 km²

- ≤ - 2000 µg.m^{-3}.d
- - 2000 – - 800 µg.m^{-3}.d
- - 800 – 0 µg.m^{-3}.d
- 0 – 800 µg.m^{-3}.d
- 800 – 2000 µg.m^{-3}.d
- > 2000 µg.m^{-3}.d
- No Available Data
- Outside Mapping Area

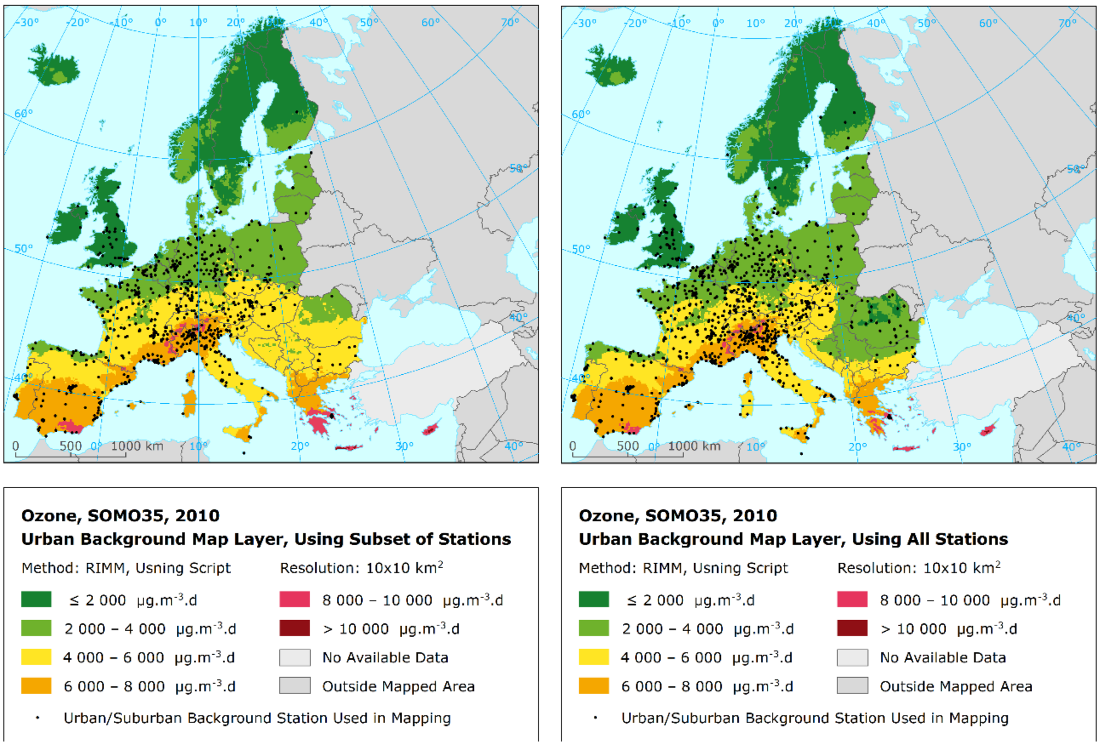


Ozone, SOMO35, 2010
Rural Map Layer, Relative Difference Map

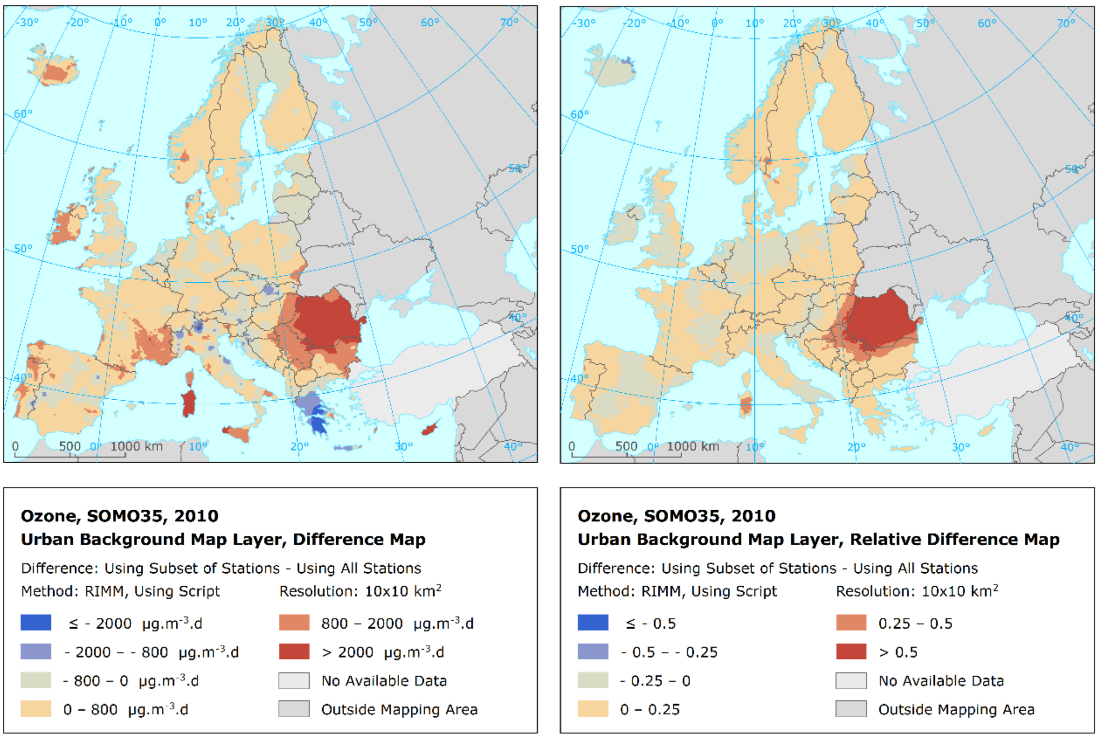
Difference: Using Subset of Stations - Using All Stations
Method: RIMM, Using Script — Resolution: 10x10 km²

- ≤ - 0.5
- - 0.5 – - 0.25
- - 0.25 – 0
- 0 – 0.25
- 0.25 – 0.5
- > 0.5
- No Available Data
- Outside Mapping Area

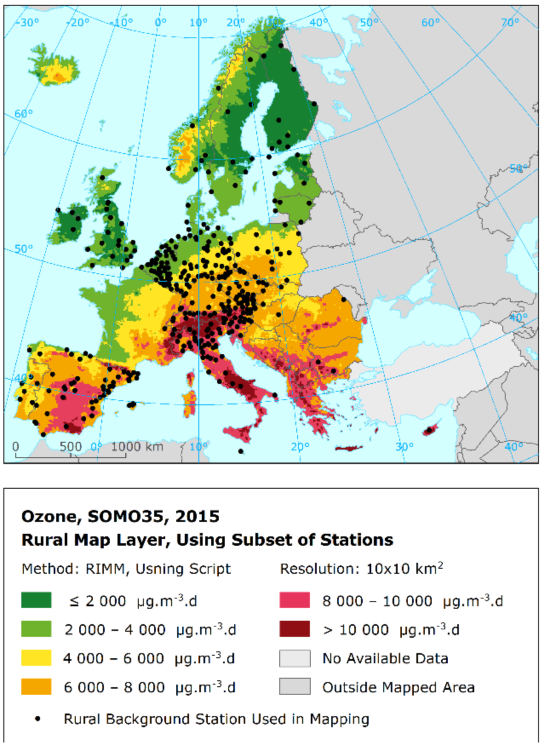
Map A.23: Urban background map layer of ozone indicator SOMO35 for 2010, RIMM method using the subset of stations (left) and all stations (right). Applicable for urban background areas only.

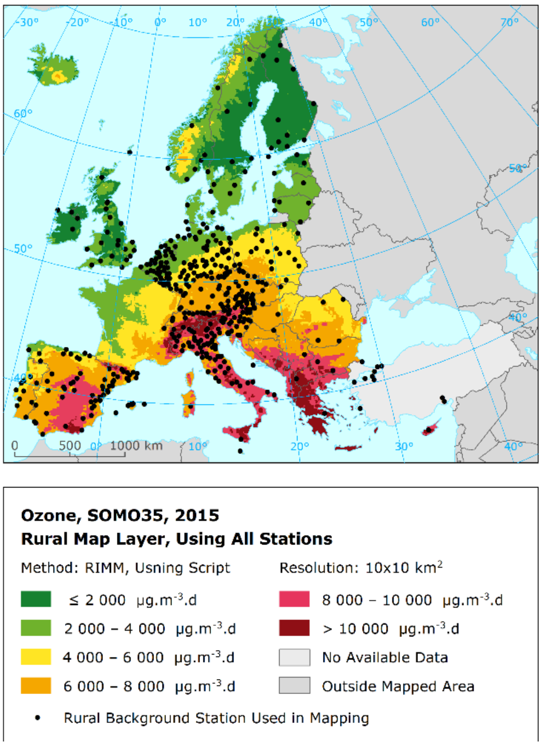


Map A.24: Difference (left) and relative difference (right) between RIMM mapping variant (i) using the subset of stations and (ii) all stations for urban background map layer of ozone indicator SOMO35 for 2010. Applicable for urban background areas only.

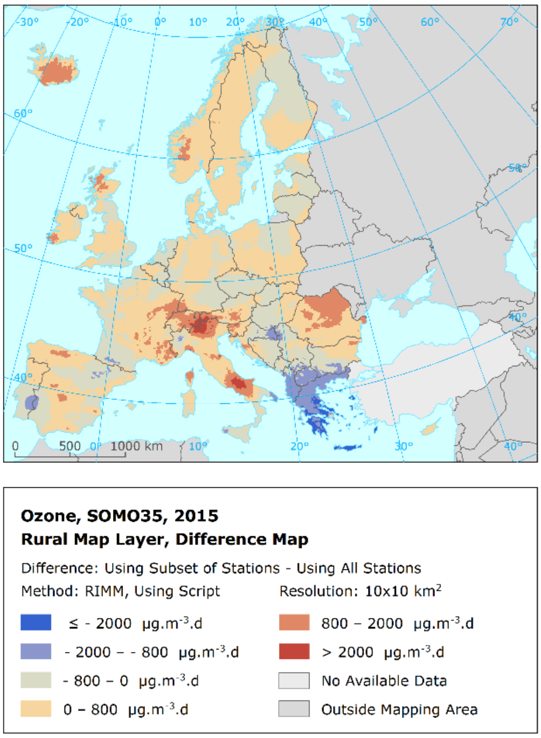


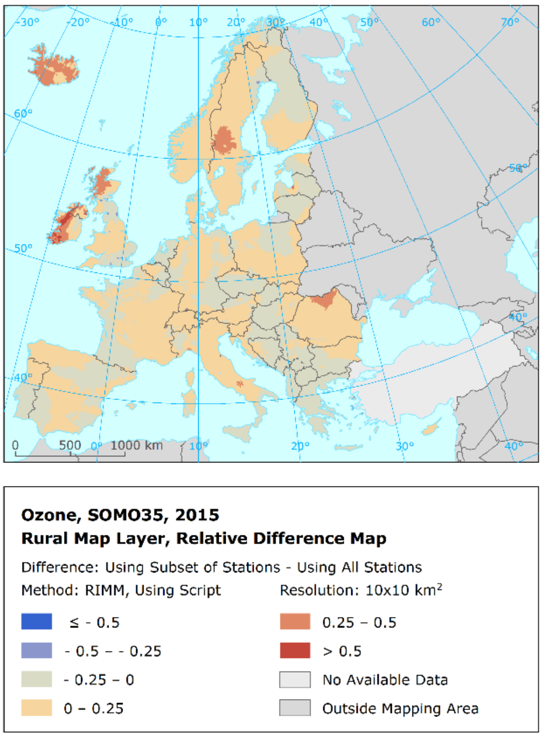
Map A.25: Rural map layer of ozone indicator SOMO35 for 2015, RIMM method using the subset of stations (left) and all stations (right). Applicable for rural areas only.



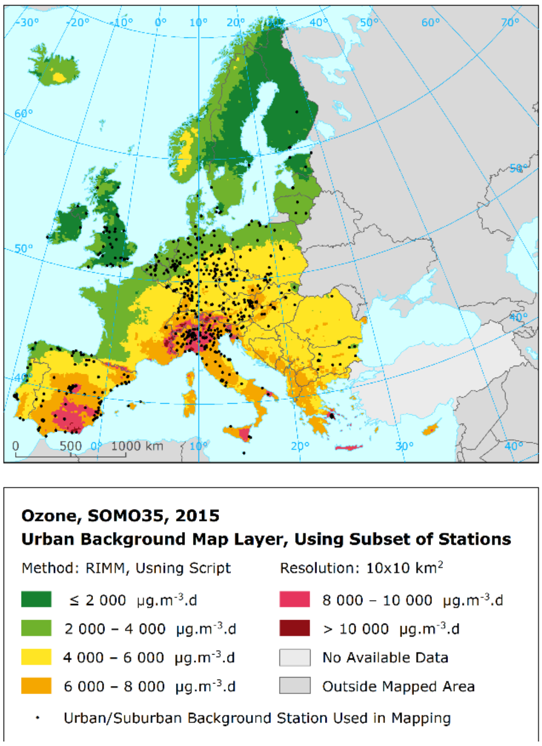


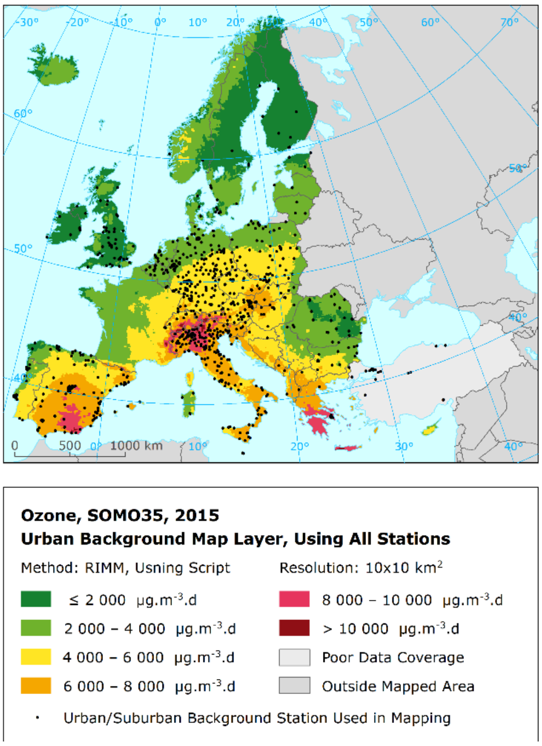
Map A.26: Difference (left) and relative difference (right) between RIMM mapping variant (i) using the subset of stations and (ii) all stations for rural map layer of ozone indicator SOMO35 for 2015. Applicable for rural areas only.



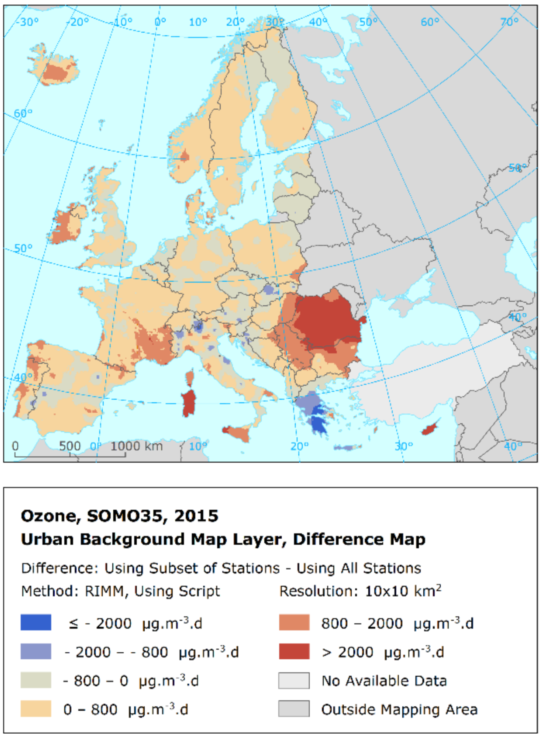


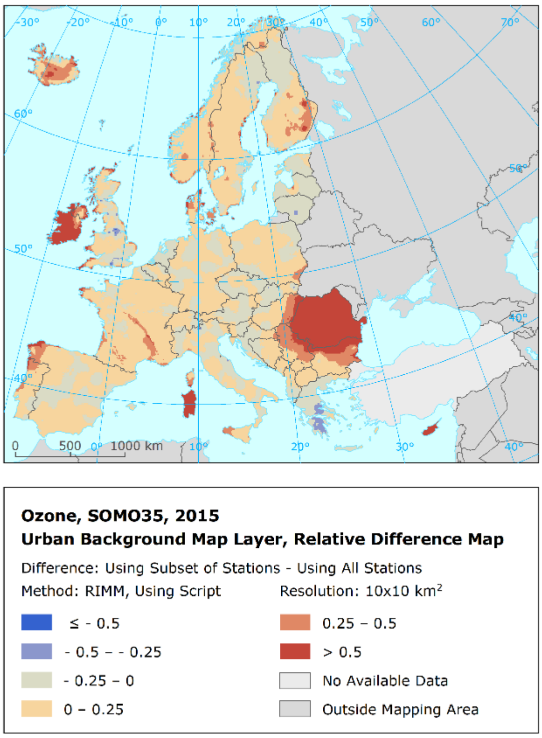
Map A.27: Urban background map layer of ozone indicator SOMO35 for 2015, RIMM method using the subset of stations (left) and all stations (right). Applicable for urban background areas only.



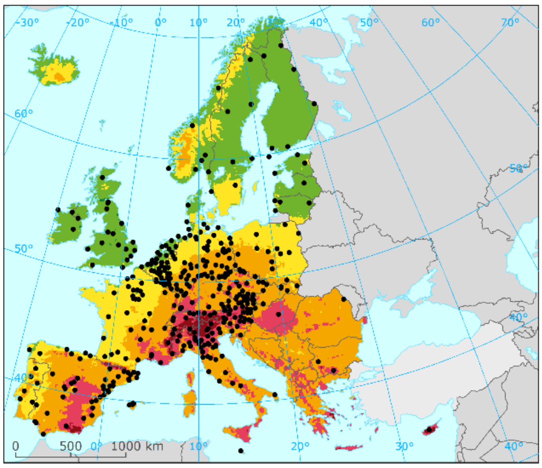


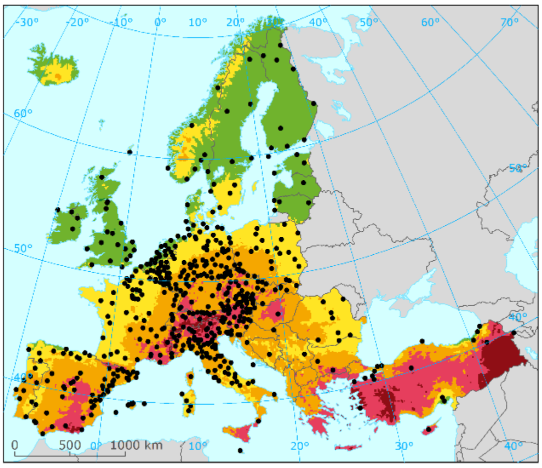
Map A.28: Difference (left) and relative difference (right) between RIMM mapping variant (i) using the subset of stations and (ii) all stations for urban background map layer of ozone indicator SOMO35 for 2015. Applicable for urban background areas only.





Map A.29: Rural map layer of ozone indicator SOMO35 for 2018, RIMM method using the subset of stations (left) and all stations (right). Applicable for rural areas only.





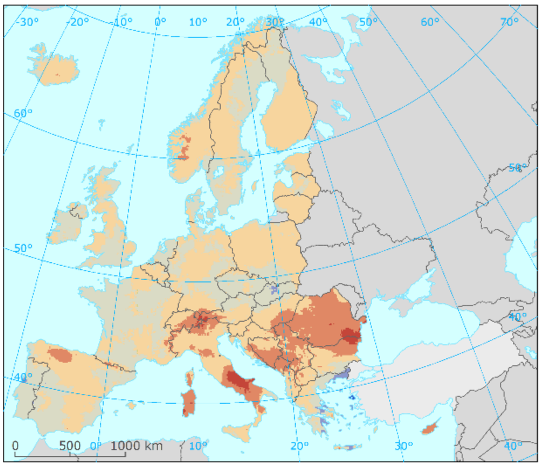
Ozone, SOMO35, 2018
Rural Map Layer, Using Subset of Stations
Method: RIMM, Usning Script   Resolution: 10x10 km^2

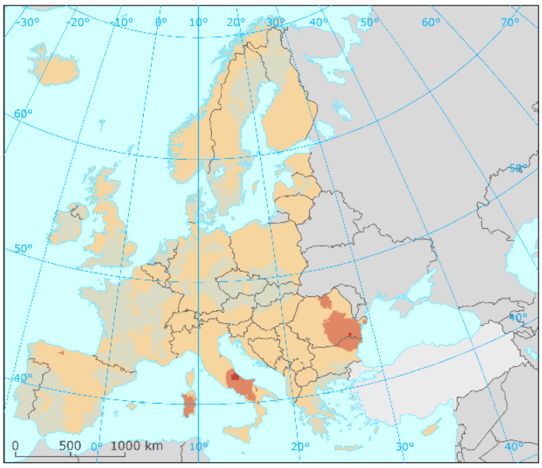
- ≤ 2 000 µg.m^{-3}.d
- 2 000 – 4 000 µg.m^{-3}.d
- 4 000 – 6 000 µg.m^{-3}.d
- 6 000 – 8 000 µg.m^{-3}.d
- 8 000 – 10 000 µg.m^{-3}.d
- > 10 000 µg.m^{-3}.d
- No Available Data
- Outside Mapped Area
- • Rural Background Station Used in Mapping

Ozone, SOMO35, 2018
Rural Map Layer, Using All Stations
Method: RIMM, Usning Script   Resolution: 10x10 km^2

- ≤ 2 000 µg.m^{-3}.d
- 2 000 – 4 000 µg.m^{-3}.d
- 4 000 – 6 000 µg.m^{-3}.d
- 6 000 – 8 000 µg.m^{-3}.d
- 8 000 – 10 000 µg.m^{-3}.d
- > 10 000 µg.m^{-3}.d
- No Available Data
- Outside Mapped Area
- • Rural Background Station Used in Mapping

Map A.30: Difference (left) and relative difference (right) between RIMM mapping variant (i) using the subset of stations and (ii) all stations for rural map layer of ozone indicator SOMO35 for 2018. Applicable for rural areas only.





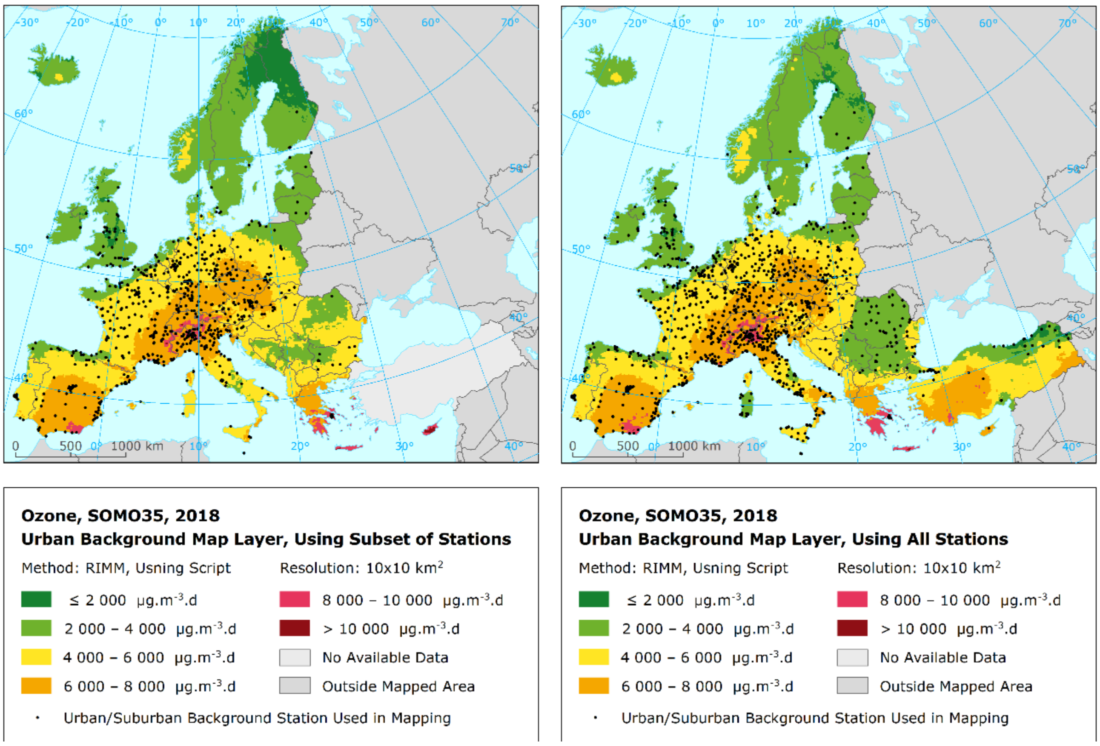
Ozone, SOMO35, 2018
Rural Map Layer, Difference Map
Difference: Using Subset of Stations - Using All Stations
Method: RIMM, Using Script   Resolution: 10x10 km^2

- ≤ - 2000 µg.m^{-3}.d
- - 2000 – - 800 µg.m^{-3}.d
- - 800 – 0 µg.m^{-3}.d
- 0 – 800 µg.m^{-3}.d
- 800 – 2000 µg.m^{-3}.d
- > 2000 µg.m^{-3}.d
- No Available Data
- Outside Mapping Area

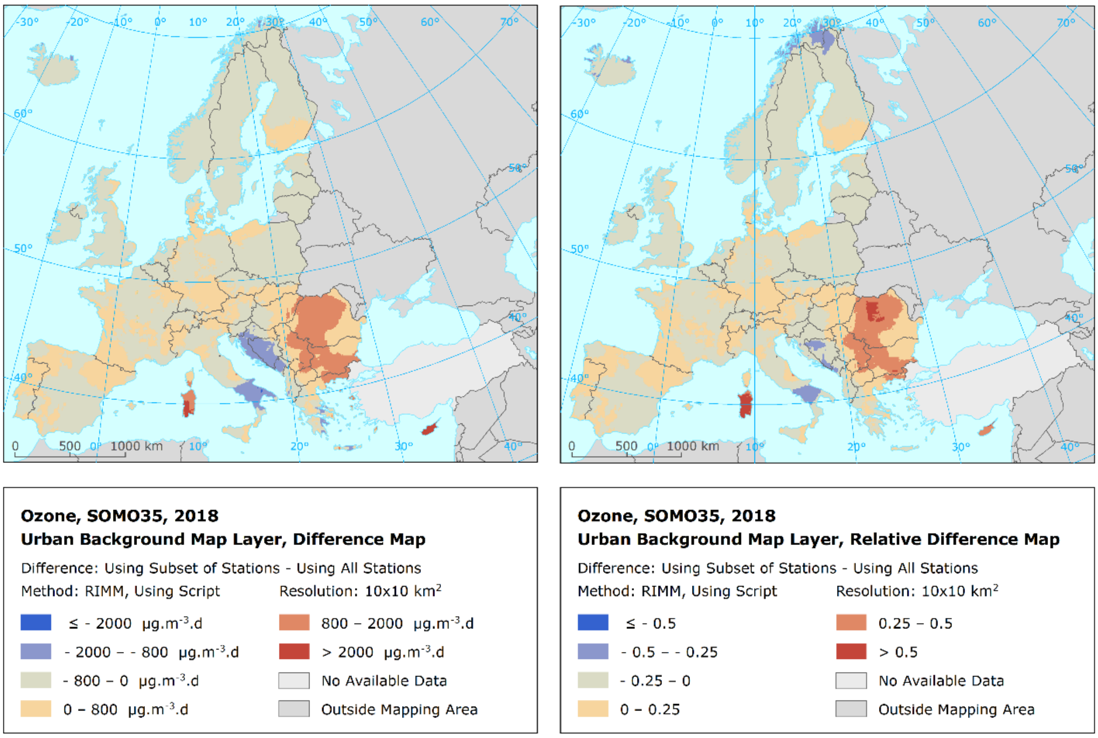
Ozone, SOMO35, 2018
Rural Map Layer, Relative Difference Map
Difference: Using Subset of Stations - Using All Stations
Method: RIMM, Using Script   Resolution: 10x10 km^2

- ≤ - 0.5
- - 0.5 – - 0.25
- - 0.25 – 0
- 0 – 0.25
- 0.25 – 0.5
- > 0.5
- No Available Data
- Outside Mapping Area

Map A.31: Urban background map layer of ozone indicator SOMO35 for 2018, RIMM method using the subset of stations (left) and all stations (right). Applicable for urban background areas only.



Map A.32: Difference (left) and relative difference (right) between RIMM mapping variant (i) using the subset of stations and (ii) all stations for urban background map layer of ozone indicator SOMO35 for 2018. Applicable for urban background areas only.



A1.3 NO_2

For NO_2, we have analysed all three map layers, i.e., the rural, the urban background and the urban traffic ones. For the analysis purposes, we have calculated maps for four individual years (2005, 2010, 2015, and 2019) using the Regression – Interpolation – Merging Mapping (RIMM) methodology, using the script, based on

(i) the subset of the stations
(ii) all stations available

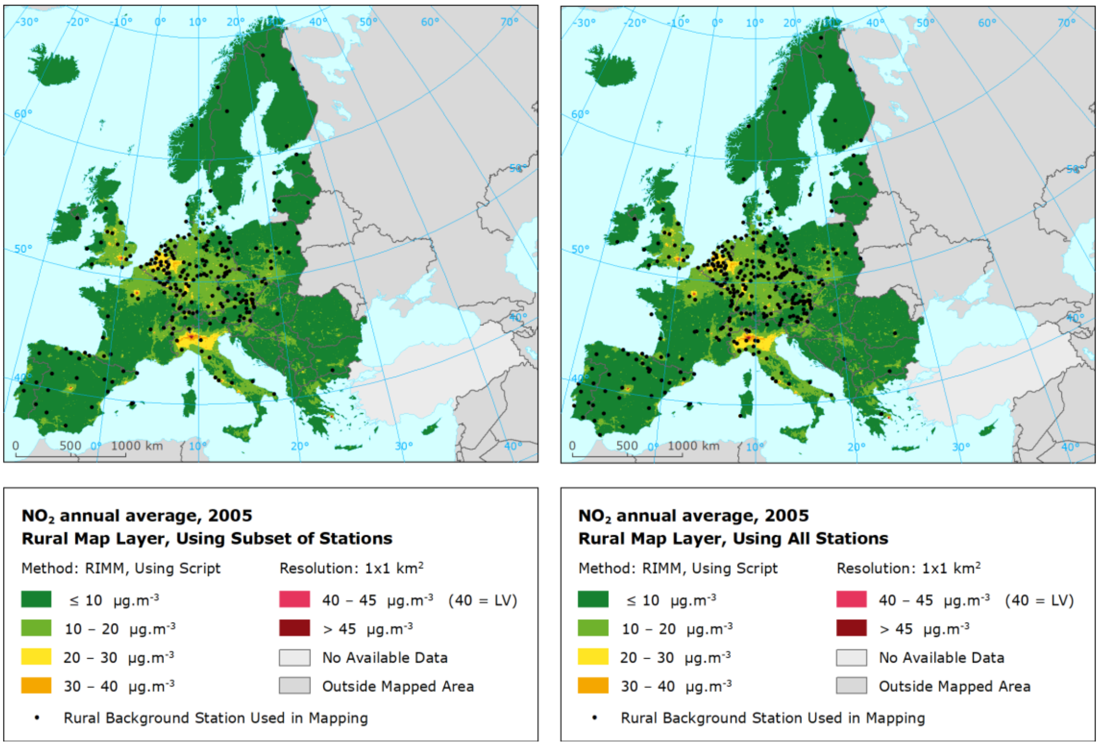
Subsequently, we have compared these two difference mapping results, for individual four year, separately for the rural, the urban background and the urban traffic map layers.

Map A.33 shows the results of two different mapping variants (i) and (ii), including the stations used for the mapping, while Map A.34 presents the difference and the relative difference between these two map variants, in the both cases for the rural map layer for 2005. Maps A.35 and A.36 present the similar map variants and their differences for the urban background map layers, while Maps A.37 and A.38 for the urban traffic map layers, in all cases for 2005.

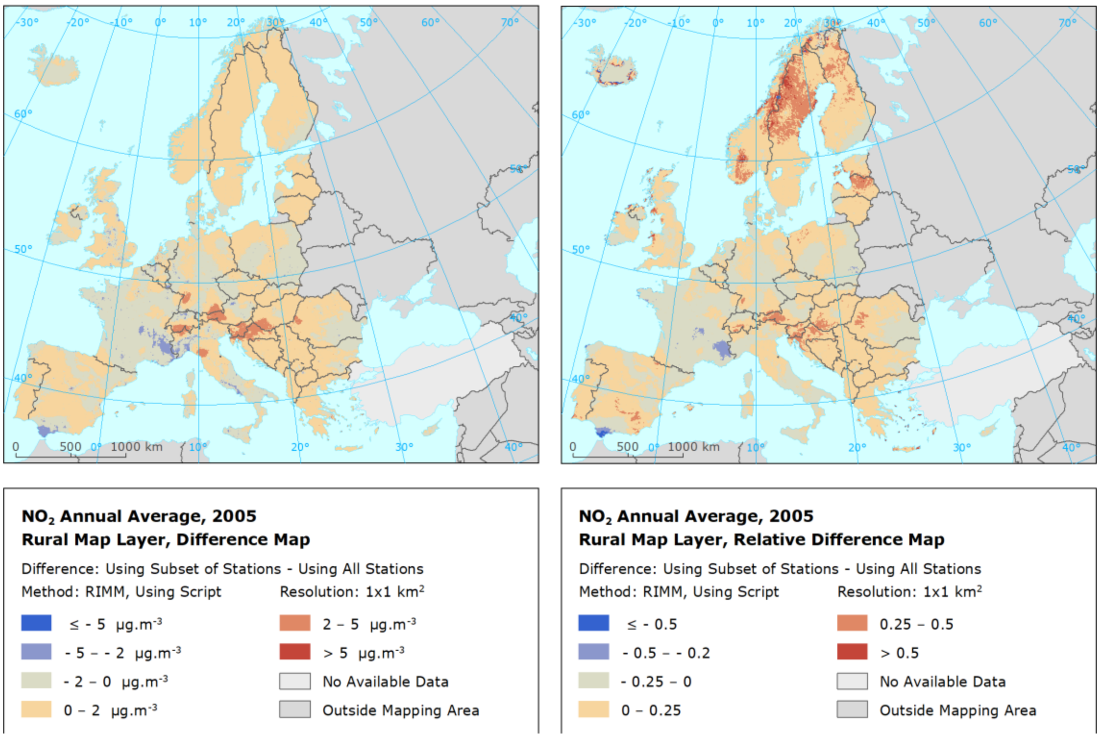
Maps A.39-A.44 present two map variants and their differences for the rural, urban background and urban traffic map layers for 2010. Maps A.45-A.50 show the similar mapping results for 2015, while Maps A.51-A.56 for 2019.

Looking at the results, one can see that for most of the mapping area, the differences in relative terms differ less than 25 %. Thus, no change in the subset of the stations was needed. Consequently, for the production of the 15-year time series of the reconstructed consistent NO_2 maps (see Section 2.1.4), the original subset of the stations has been used.

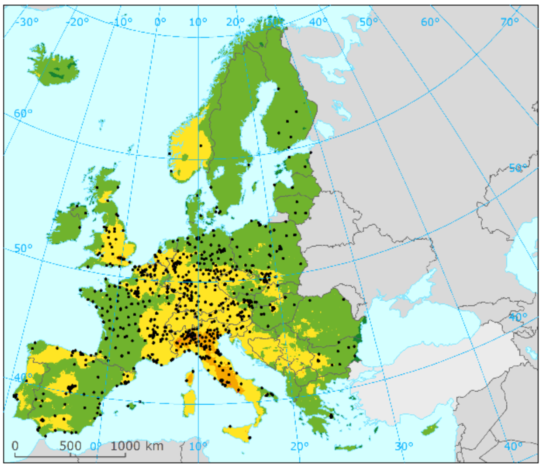
Map A.33: Rural map layer of NO_2 annual average 2005, RIMM method using the subset of stations (left) and all stations (right). Applicable for rural areas only.

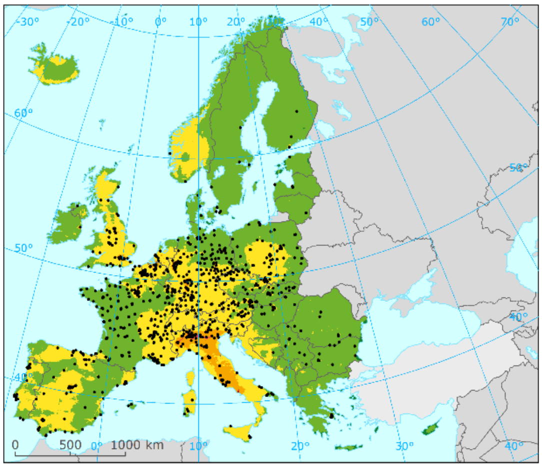


Map A.34: Difference (left) and relative difference (right) between RIMM mapping variant (i) using the subset of stations and (ii) all stations for rural map layer of NO_2 annual average 2005. Applicable for rural areas only.



Map A.35: Urban background map layer of NO_2 annual average 2005, RIMM method using the subset of stations (left) and all stations (right). Applicable for urban background areas only.





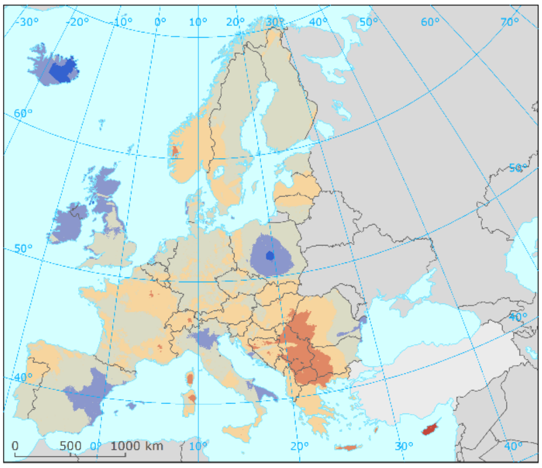
NO_2 annual average, 2005
Urban Background Map Layer, Using Subset of Stations
Method: RIMM, Using Script   Resolution: 1x1 km^2

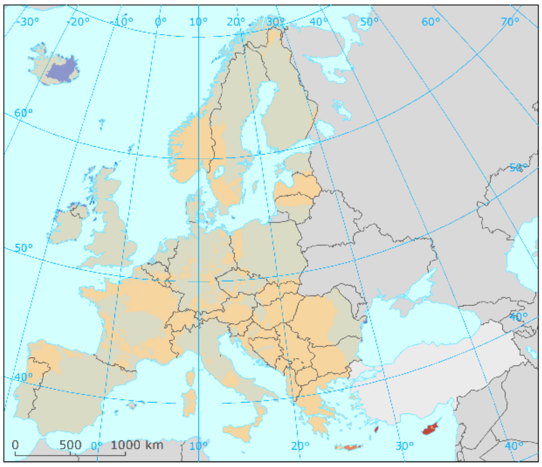
- ≤ 10 µg.m^{-3}
- 10 – 20 µg.m^{-3}
- 20 – 30 µg.m^{-3}
- 30 – 40 µg.m^{-3}
- 40 – 45 µg.m^{-3} (40 = LV)
- > 45 µg.m^{-3}
- No Available Data
- Outside Mapped Area
- • Rural Background Station Used in Mapping

NO_2 annual average, 2005
Urban Background Map Layer, Using All Stations
Method: RIMM, Using Script   Resolution: 1x1 km^2

- ≤ 10 µg.m^{-3}
- 10 – 20 µg.m^{-3}
- 20 – 30 µg.m^{-3}
- 30 – 40 µg.m^{-3}
- 40 – 45 µg.m^{-3} (40 = LV)
- > 45 µg.m^{-3}
- No Available Data
- Outside Mapped Area
- • Rural Background Station Used in Mapping

Map A.36: Difference (left) and relative difference (right) between RIMM mapping variant (i) using the subset of stations and (ii) all stations for urban background map layer of NO_2 annual average 2005. Applicable for urban background areas only.





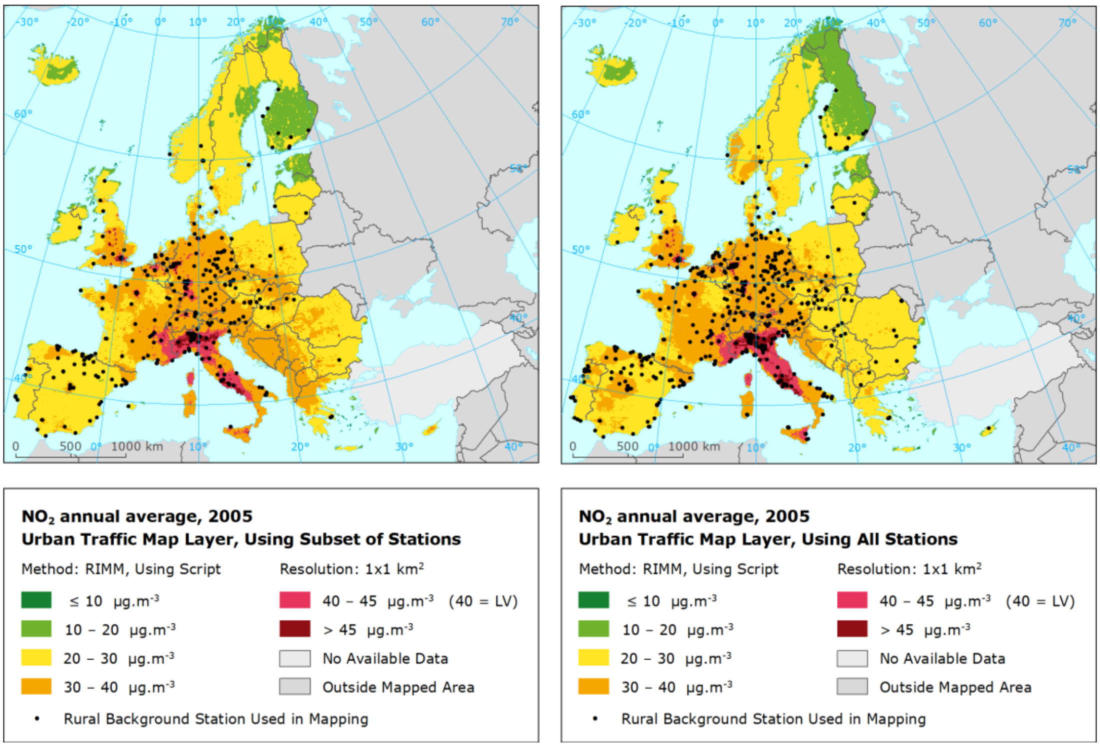
NO_2 Annual Average, 2005
Urban Background Map Layer, Difference Map
Difference: Using Subset of Stations - Using All Stations
Method: RIMM, Using Script   Resolution: 1x1 km^2

- ≤ - 5 µg.m^{-3}
- - 5 – - 2 µg.m^{-3}
- - 2 – 0 µg.m^{-3}
- 0 – 2 µg.m^{-3}
- 2 – 5 µg.m^{-3}
- > 5 µg.m^{-3}
- No Available Data
- Outside Mapping Area

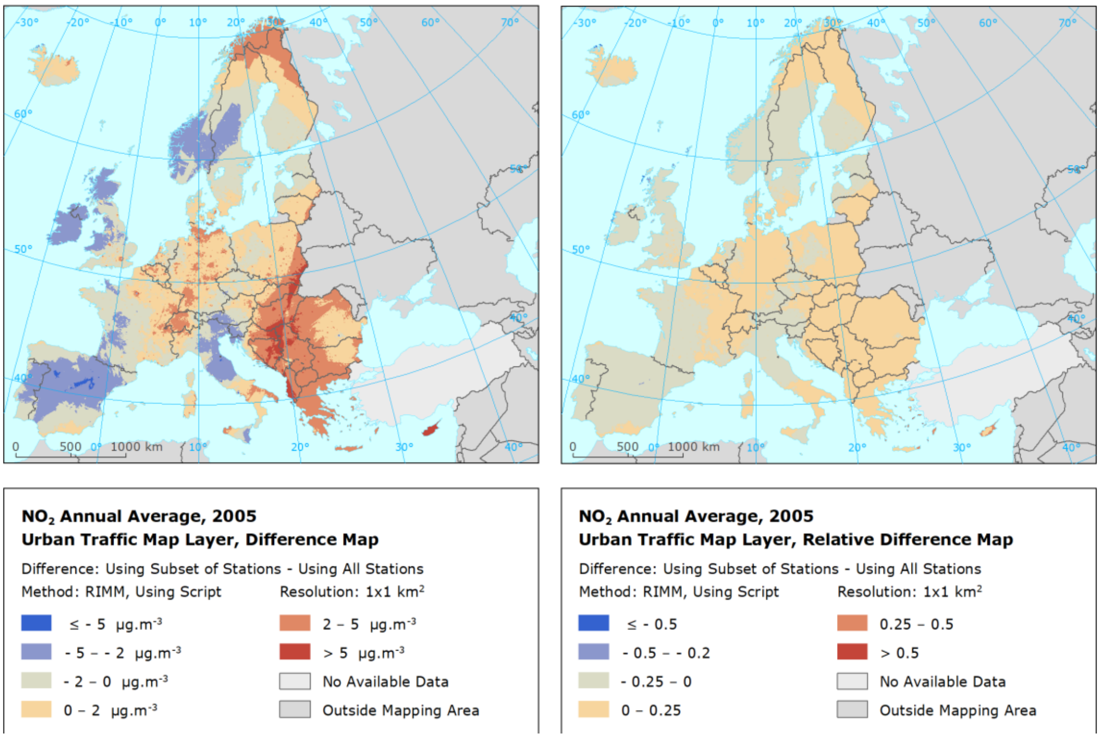
NO_2 Annual Average, 2005
Urban Background Map Layer, Relative Difference Map
Difference: Using Subset of Stations - Using All Stations
Method: RIMM, Using Script   Resolution: 1x1 km^2

- ≤ - 0.5
- - 0.5 – - 0.2
- - 0.25 – 0
- 0 – 0.25
- 0.25 – 0.5
- > 0.5
- No Available Data
- Outside Mapping Area

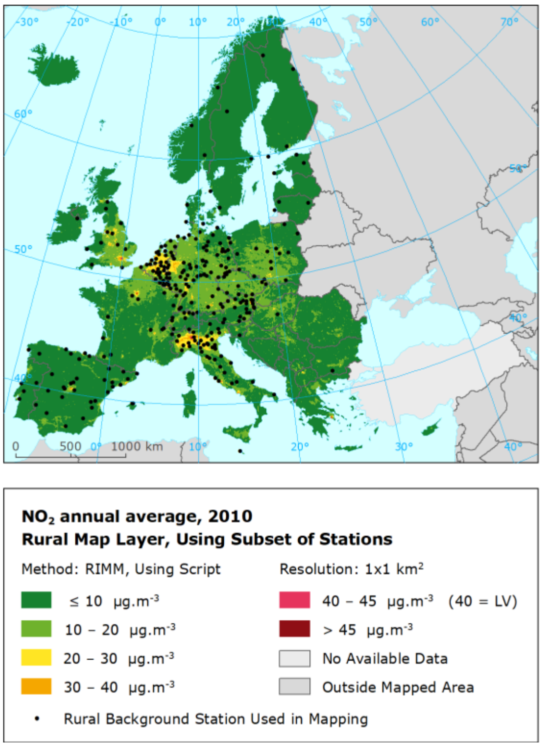
Map A.37: Urban traffic map layer of NO_2 annual average 2005, RIMM method using the subset of stations (left) and all stations (right). Applicable for urban traffic areas only.

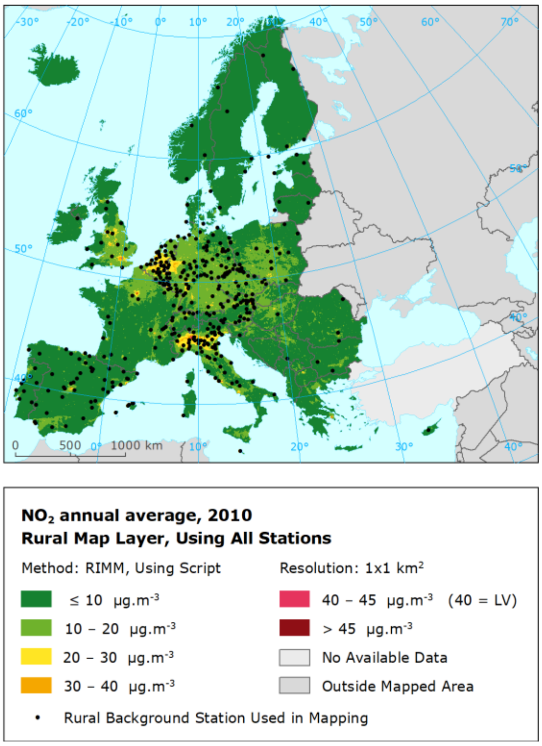


Map A.38: Difference (left) and relative difference (right) between RIMM mapping variant (i) using the subset of stations and (ii) all stations for urban traffic map layer of NO_2 annual average 2005. Applicable for urban traffic areas only.

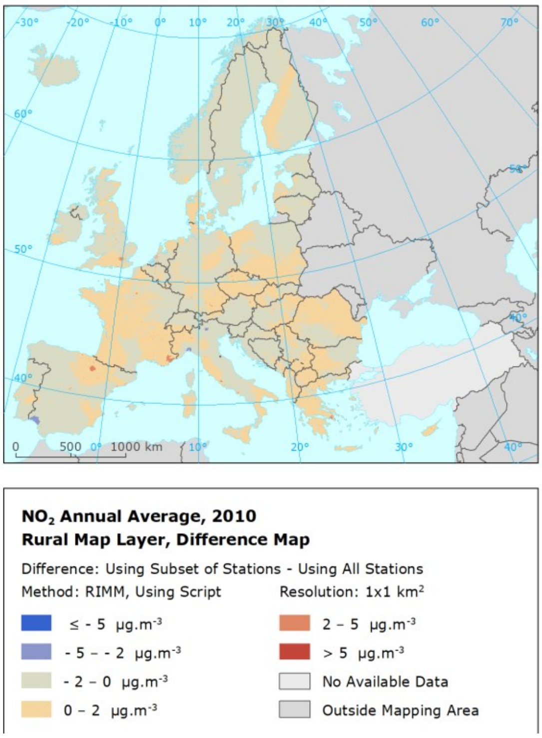


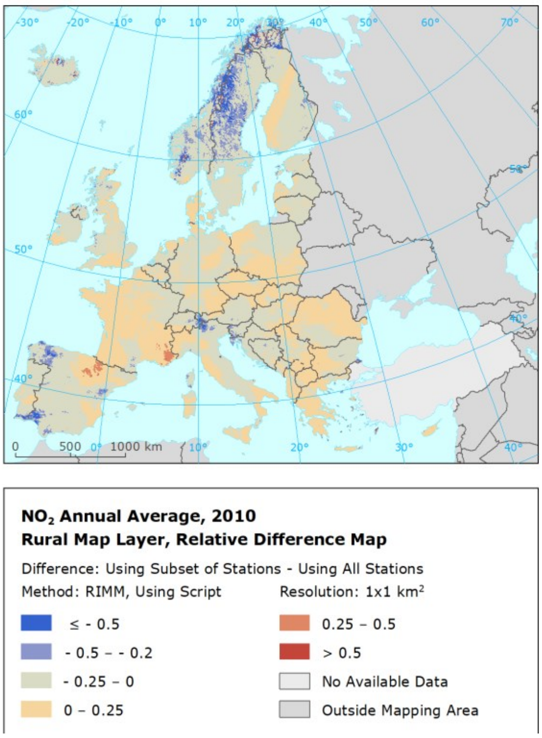
Map A.39: Rural map layer of NO_2 annual average 2010, RIMM method using the subset of stations (left) and all stations (right). Applicable for rural areas only.



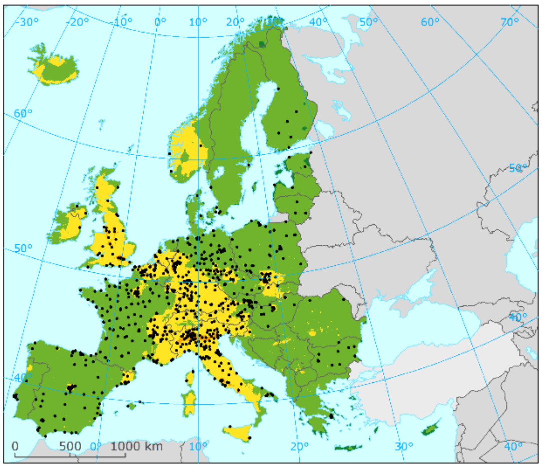


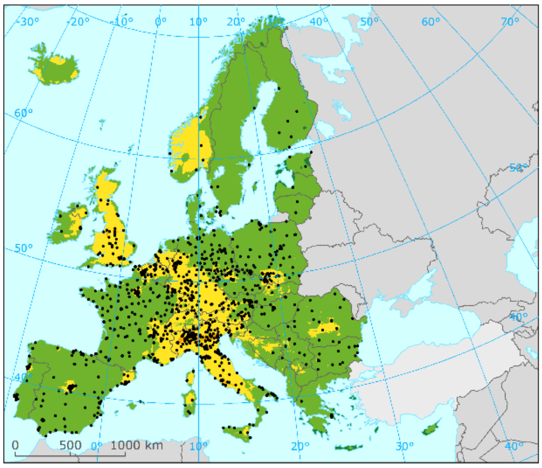
Map A.40: Difference (left) and relative difference (right) between RIMM mapping variant (i) using the subset of stations and (ii) all stations for rural map layer of NO_2 annual average 2010. Applicable for rural areas only.





Map A.41: Urban background map layer of NO_2 annual average 2010, RIMM method using the subset of stations (left) and all stations (right). Applicable for urban background areas only.





NO_2 annual average, 2010
Urban Background Map Layer, Using Subset of Stations

Method: RIMM, Using Script   Resolution: 1x1 km^2

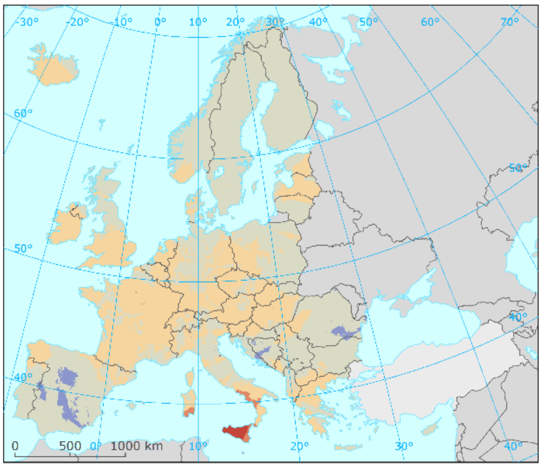
- ≤ 10 μg.m^{-3}
- 10 – 20 μg.m^{-3}
- 20 – 30 μg.m^{-3}
- 30 – 40 μg.m^{-3}
- 40 – 45 μg.m^{-3} (40 = LV)
- > 45 μg.m^{-3}
- No Available Data
- Outside Mapped Area
- • Rural Background Station Used in Mapping

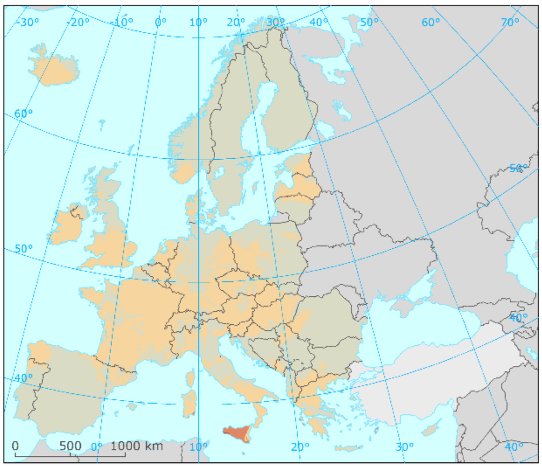
NO_2 annual average, 2010
Urban Background Map Layer, Using All Stations

Method: RIMM, Using Script   Resolution: 1x1 km^2

- ≤ 10 μg.m^{-3}
- 10 – 20 μg.m^{-3}
- 20 – 30 μg.m^{-3}
- 30 – 40 μg.m^{-3}
- 40 – 45 μg.m^{-3} (40 = LV)
- > 45 μg.m^{-3}
- No Available Data
- Outside Mapped Area
- • Rural Background Station Used in Mapping

Map A.42: Difference (left) and relative difference (right)between RIMM mapping variant (i) using the subset of stations and (ii) all stations for urban background map layer of NO_2 annual average 2010. Applicable for urban background areas only.





NO_2 Annual Average, 2010
Urban Background Map Layer, Difference Map

Difference: Using Subset of Stations - Using All Stations
Method: RIMM, Using Script   Resolution: 1x1 km^2

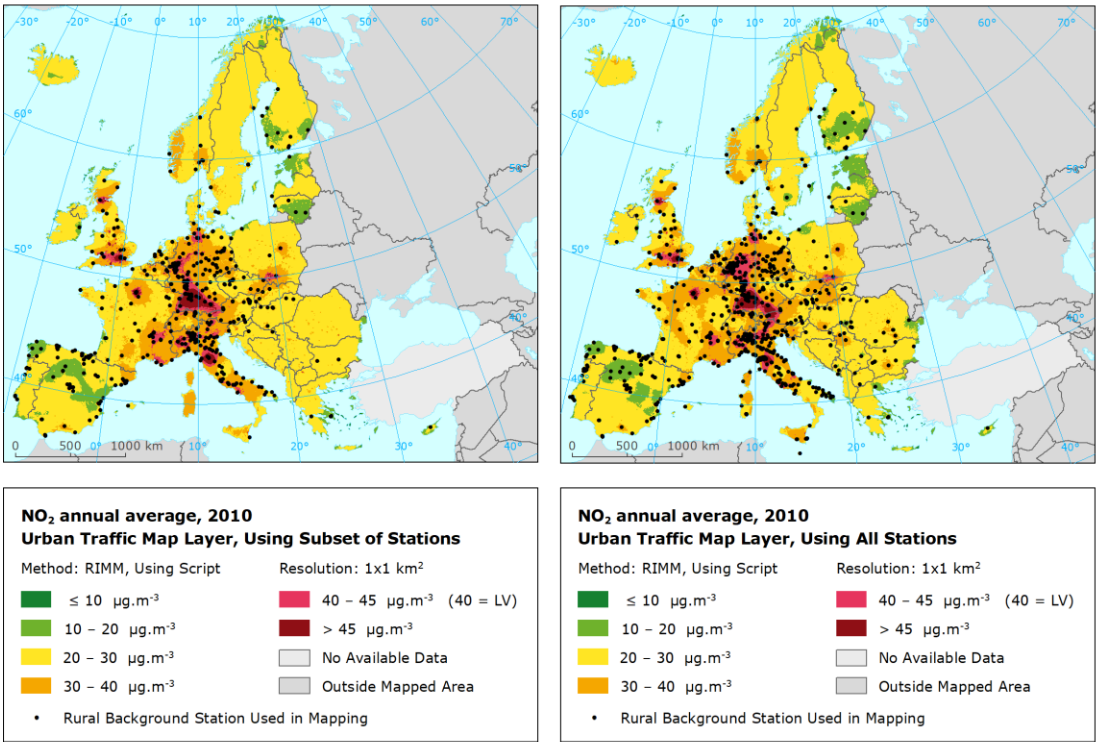
- ≤ - 5 μg.m^{-3}
- - 5 – - 2 μg.m^{-3}
- - 2 – 0 μg.m^{-3}
- 0 – 2 μg.m^{-3}
- 2 – 5 μg.m^{-3}
- > 5 μg.m^{-3}
- No Available Data
- Outside Mapping Area

NO_2 Annual Average, 2010
Urban Background Map Layer, Relative Difference Map

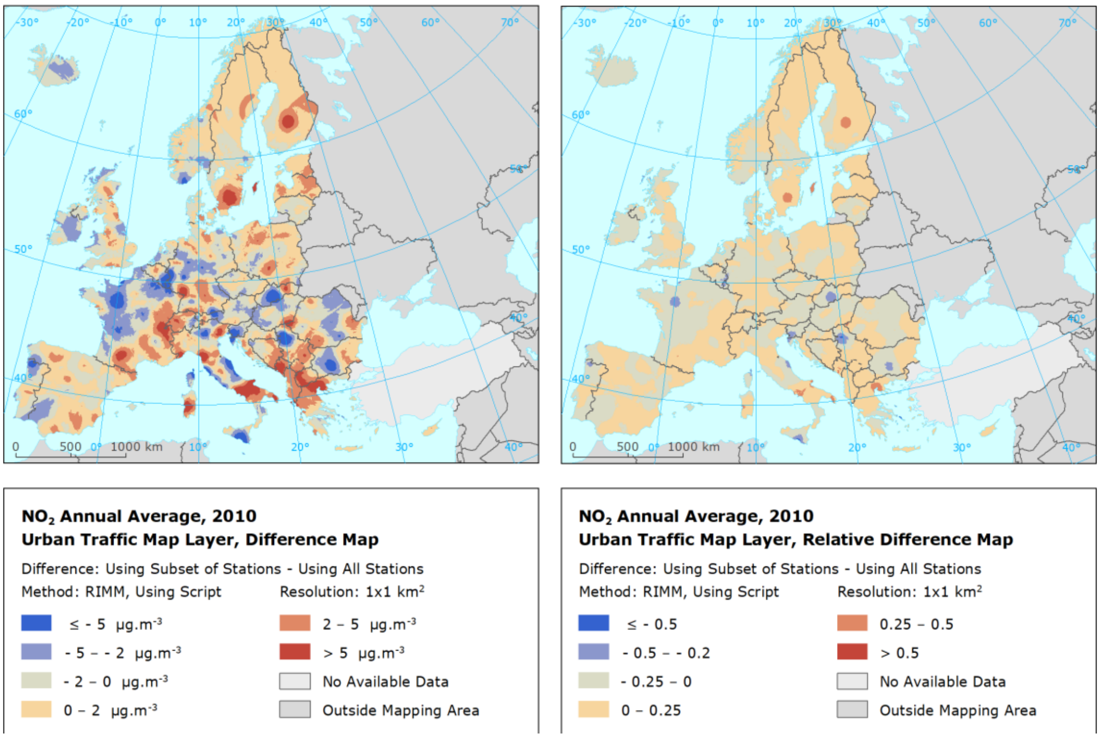
Difference: Using Subset of Stations - Using All Stations
Method: RIMM, Using Script   Resolution: 1x1 km^2

- ≤ - 0.5
- - 0.5 – - 0.2
- - 0.25 – 0
- 0 – 0.25
- 0.25 – 0.5
- > 0.5
- No Available Data
- Outside Mapping Area

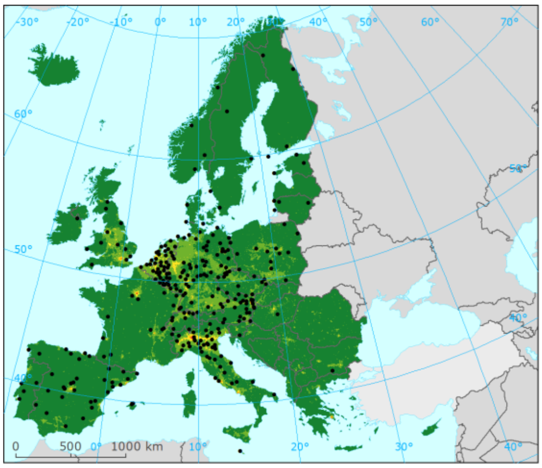
Map A.43: Urban traffic map layer of NO_2 annual average 2010, RIMM method using the subset of stations (left) and all stations (right). Applicable for urban traffic areas only.

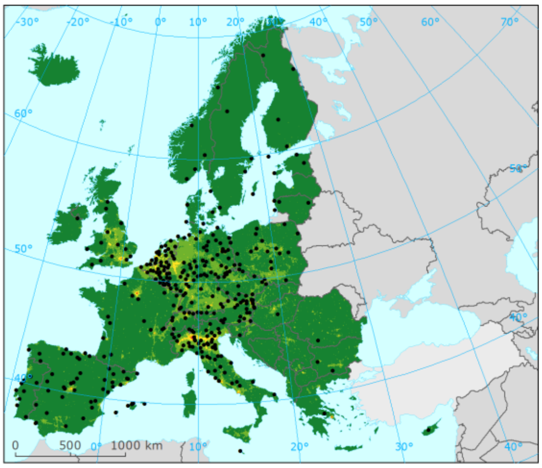


Map A.44: Difference (left) and relative difference (right) between RIMM mapping variant (i) using the subset of stations and (ii) all stations for urban traffic map layer of NO_2 annual average 2010. Applicable for urban traffic areas only.

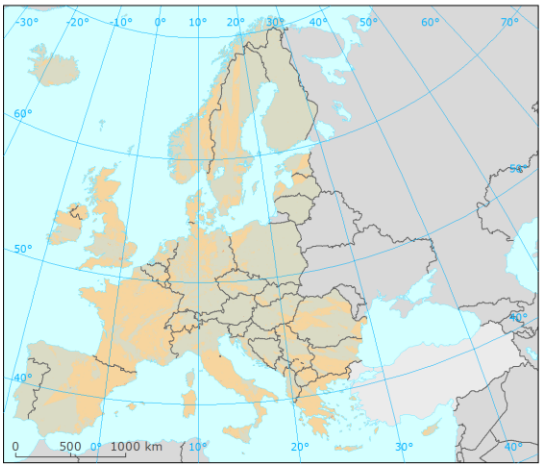


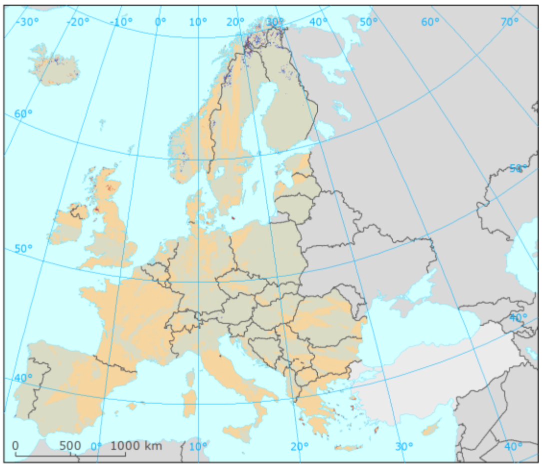
Map A.45: Rural map layer of NO_2 annual average 2015, RIMM method using the subset of stations (left) and all stations (right). Applicable for rural areas only.



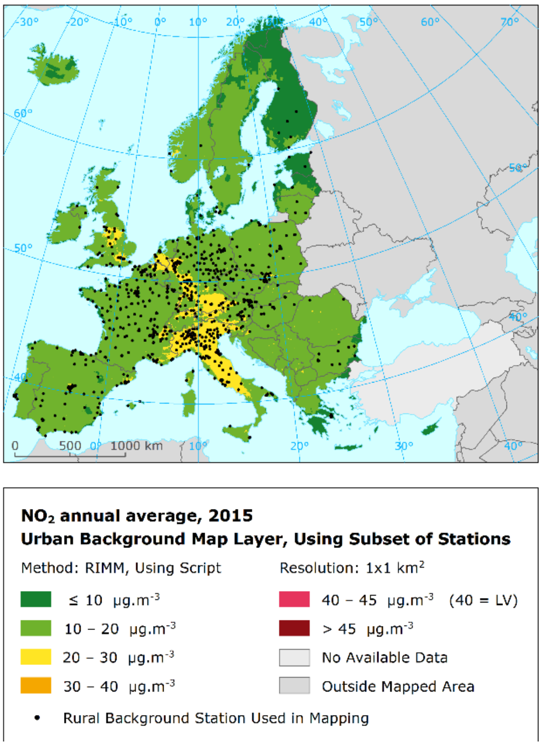


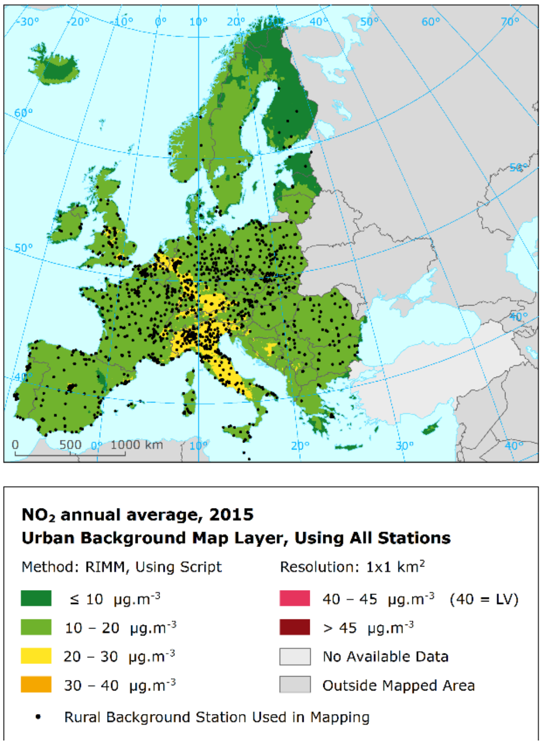
Map A.46: Difference (left) and relative difference (right)between RIMM mapping variant (i) using the subset of stations and (ii) all stations for rural map layer of NO_2 annual average 2015. Applicable for rural areas only.



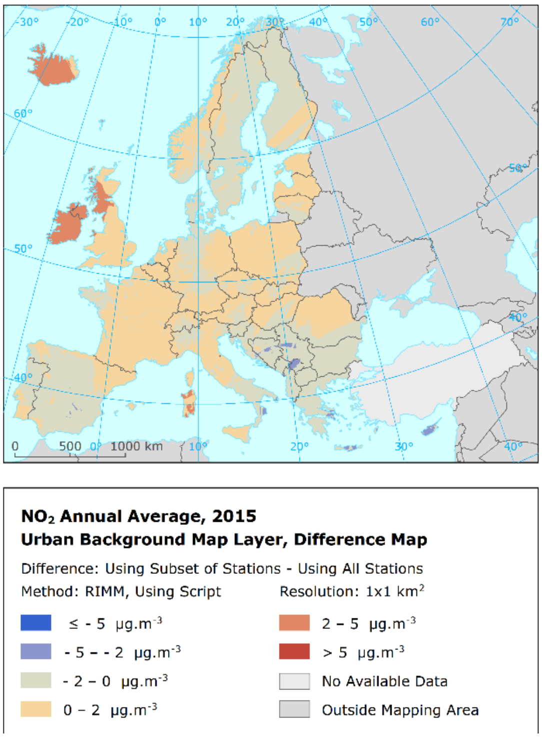


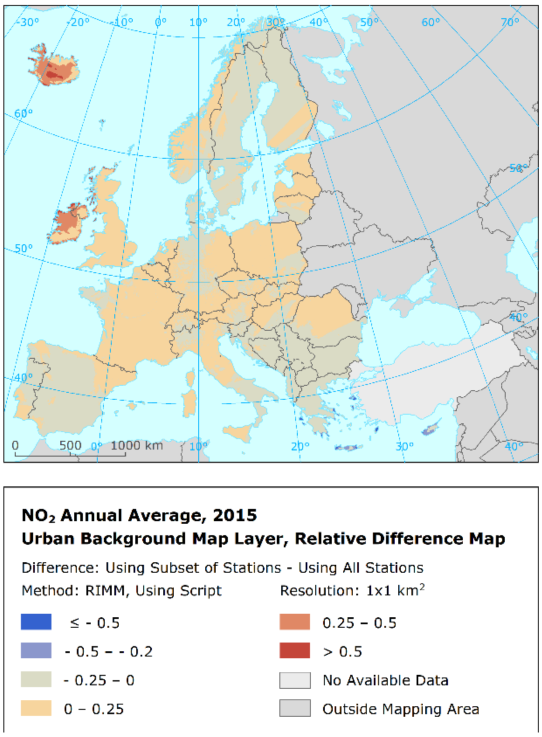
Map A.47: Urban background map layer of NO_2 annual average 2015, RIMM method using the subset of stations (left) and all stations (right). Applicable for urban background areas only.



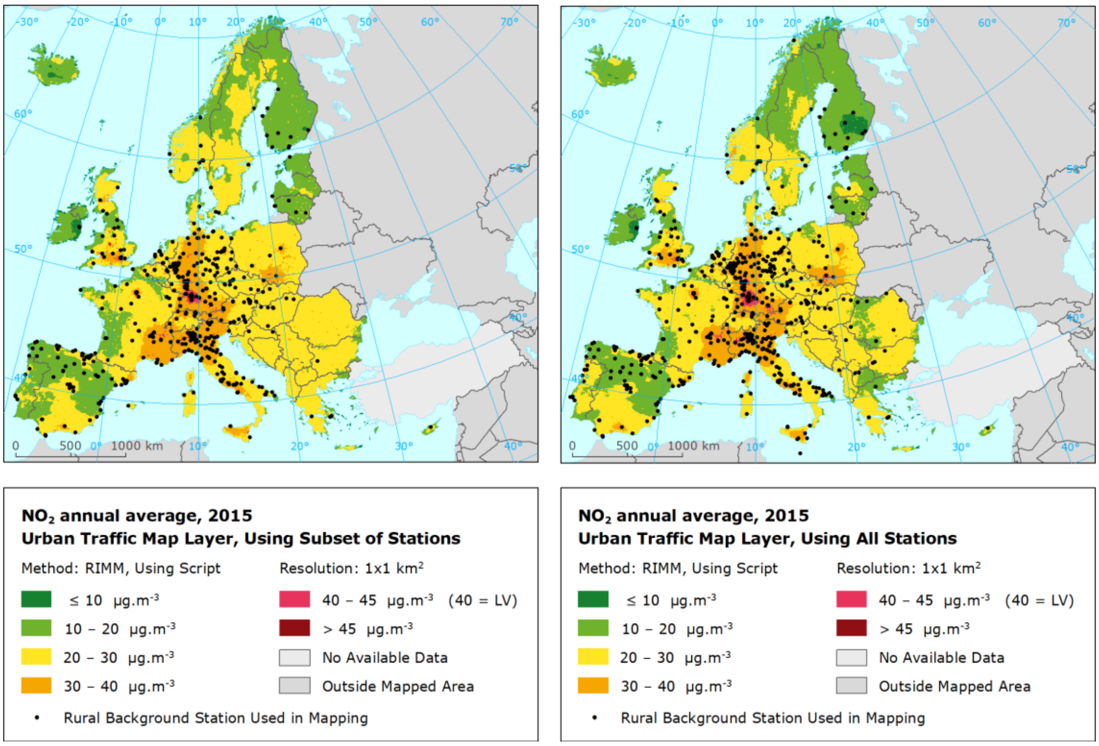


Map A.48: Difference (left) and relative difference (right)between RIMM mapping variant (i) using the subset of stations and (ii) all stations for urban background map layer of NO_2 annual average 2015. Applicable for urban background areas only.

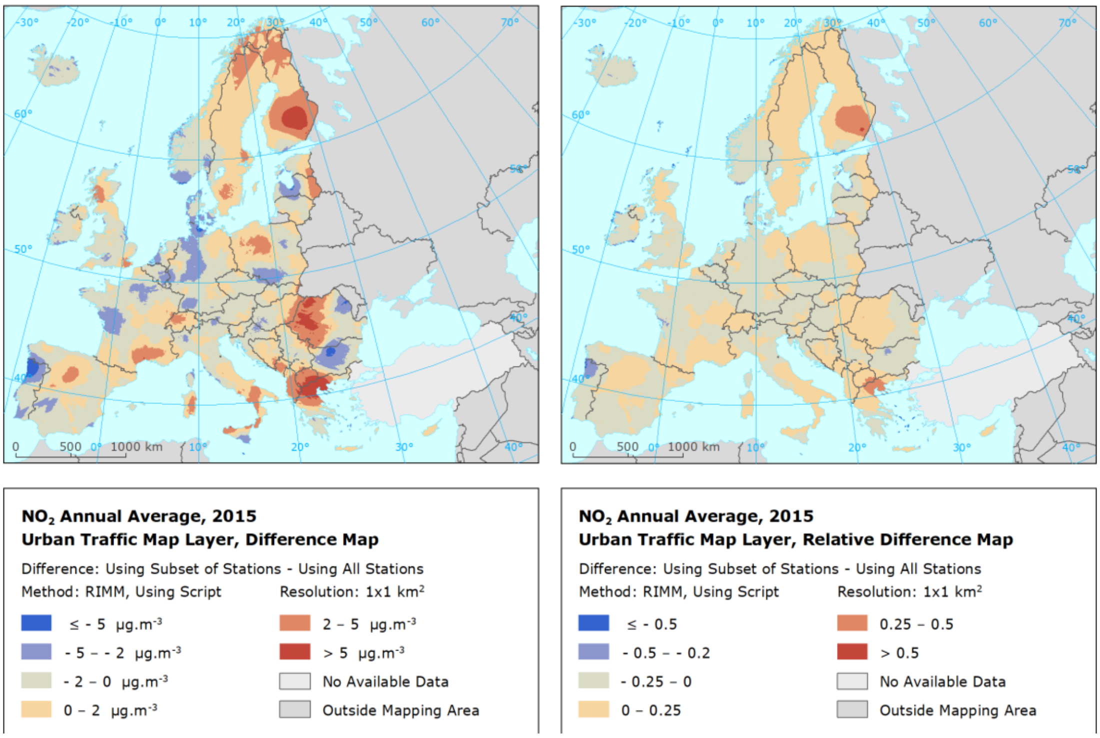




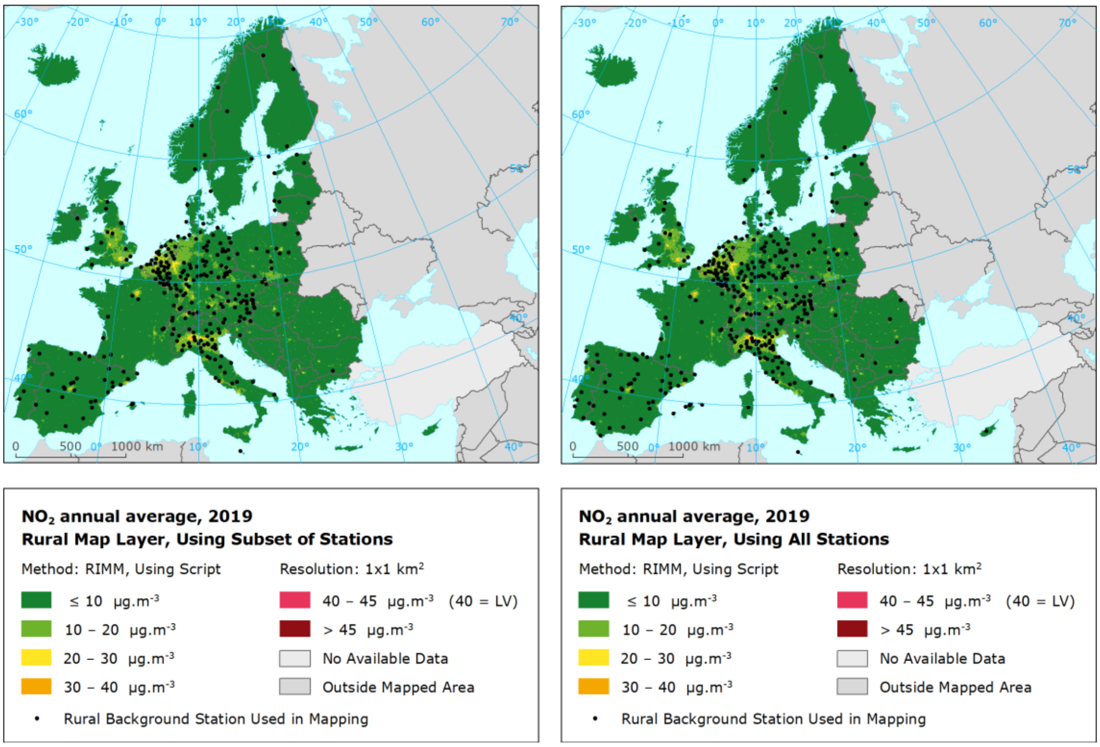
Map A.49: Urban traffic map layer of NO_2 annual average 2015, RIMM method using the subset of stations (left) and all stations (right). Applicable for urban traffic areas only.



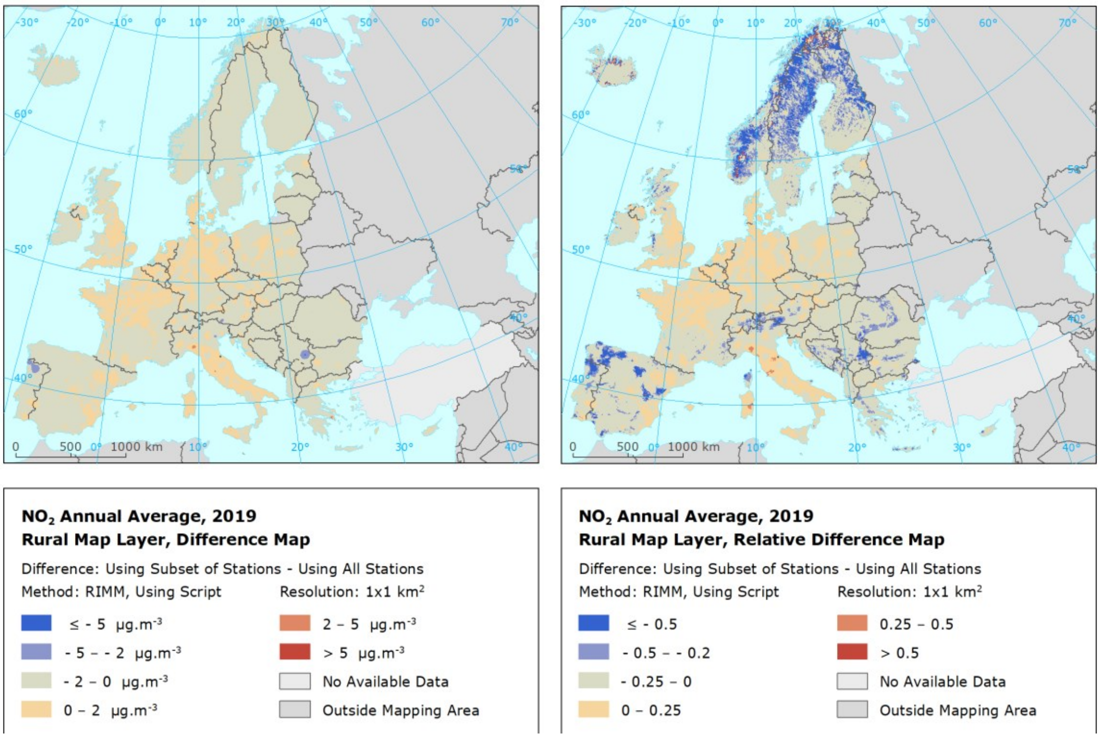
Map A.50: Difference (left) and relative difference (right)between RIMM mapping variant (i) using the subset of stations and (ii) all stations for urban traffic map layer of NO_2 annual average 2015. Applicable for urban traffic areas only.



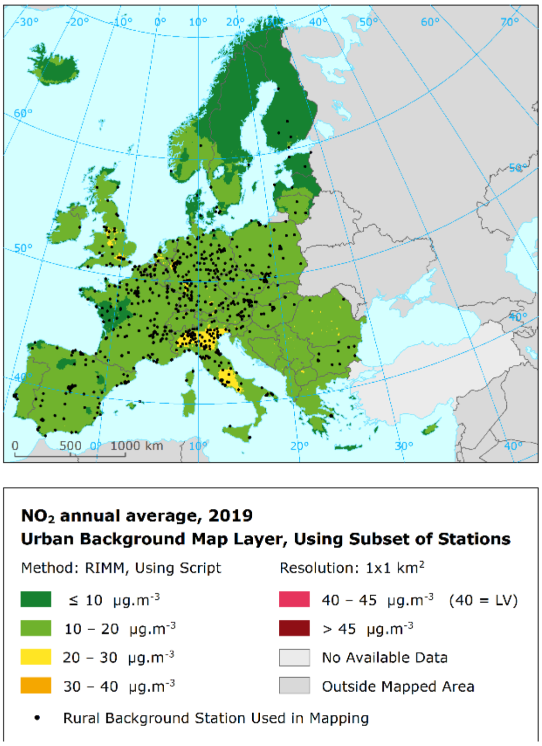
Map A.51: Rural map layer of NO_2 annual average for 2019, RIMM method using the subset of stations (left) and all stations (right). Applicable for rural areas only.

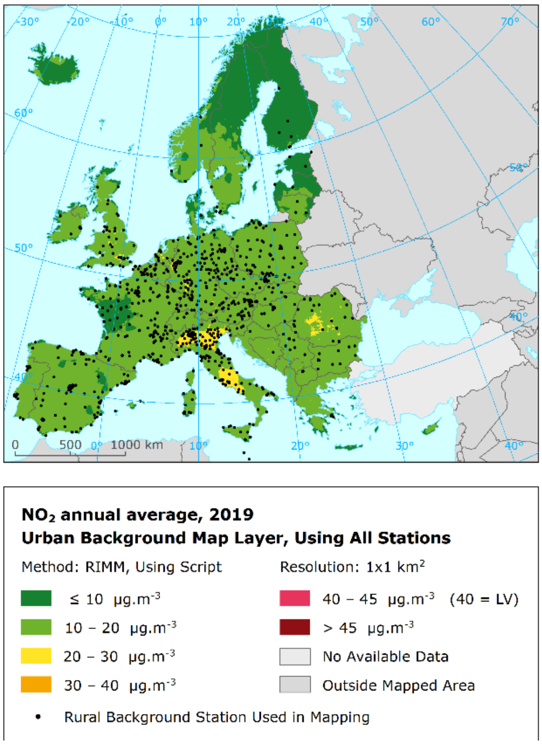


Map A.52: Difference (left) and relative difference (right)between RIMM mapping variant (i) using the subset of stations and (ii) all stations for rural map layer of NO_2 annual average 2019. Applicable for rural areas only.

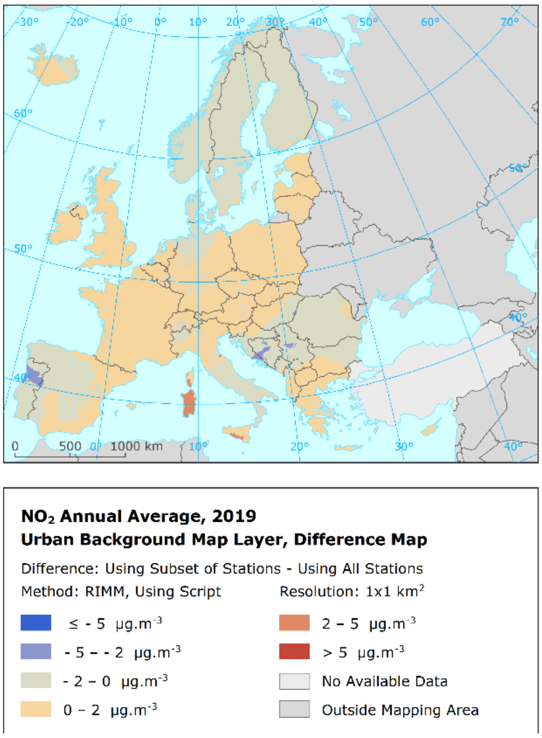


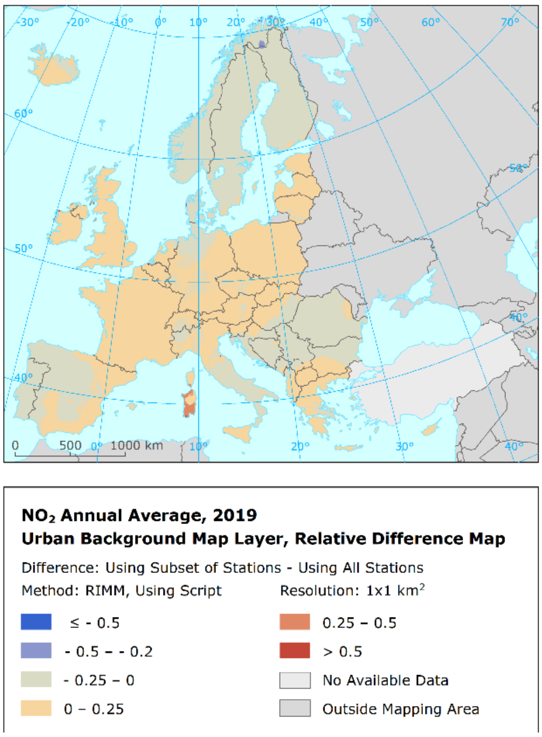
Map A.53: Urban background map layer of NO_2 annual average for 2019, RIMM method using the subset of stations (left) and all stations (right). Applicable for urban background areas only.



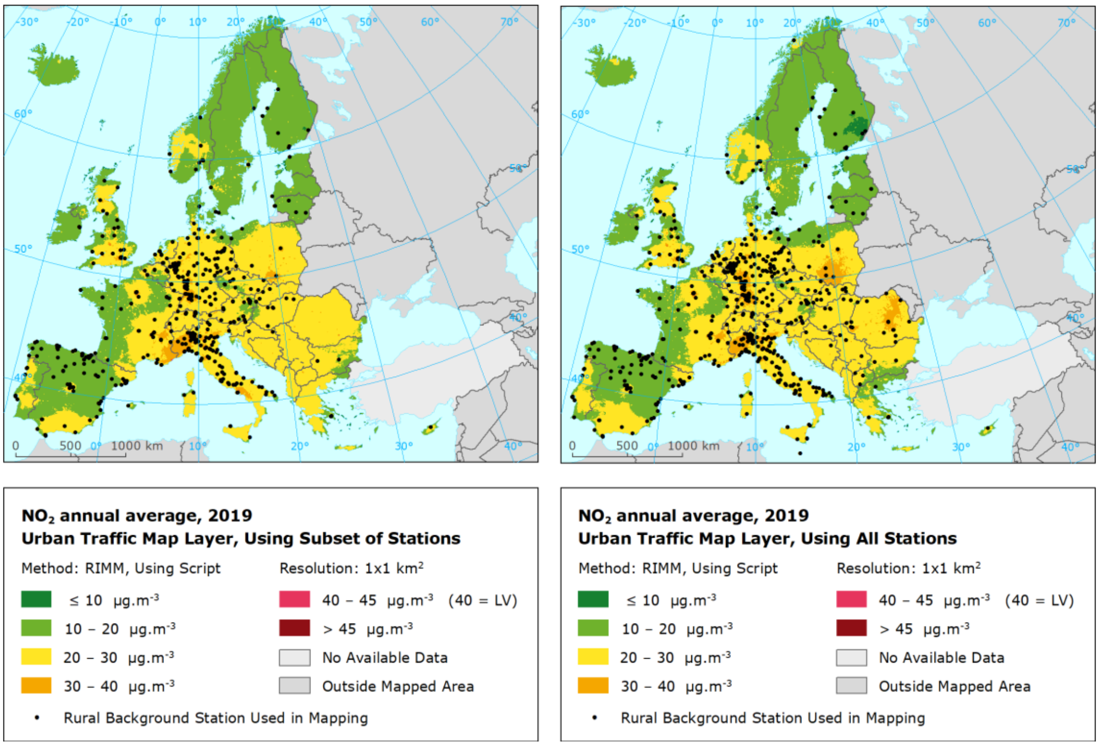


Map A.54: Difference (left) and relative difference (right)between RIMM mapping variant (i) using the subset of stations and (ii) all stations for urban background map layer of NO_2 annual average 2019. Applicable for urban background areas only.

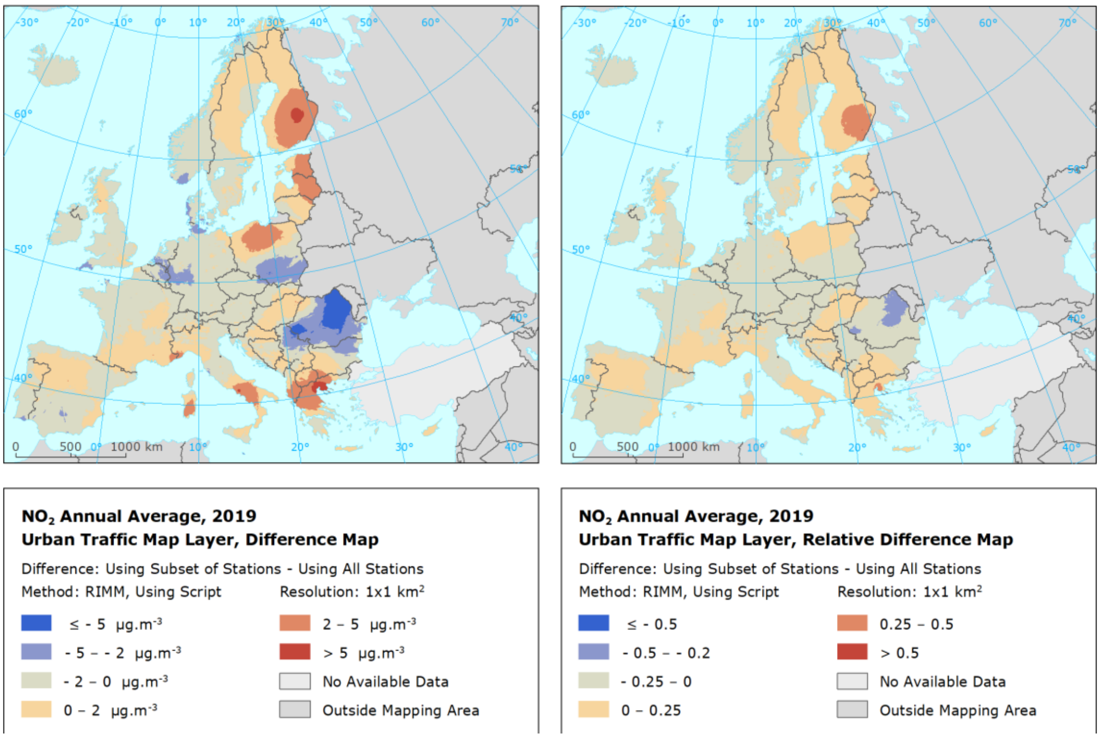




Map A.55: Urban traffic map layer of NO_2 annual average for 2019, RIMM method using the subset of stations (left) and all stations (right). Applicable for urban traffic areas only.



Map A.56: Difference (left) and relative difference (right)between RIMM mapping variant (i) using the subset of stations and (ii) all stations for urban traffic map layer of NO_2 annual average 2019. Applicable for urban traffic areas only.



Next to the mapping results, we have compared also the population weighted concentrations. Table A1.3 presents the results for the entire area for four years, for both (i) and (ii) mapping variants.

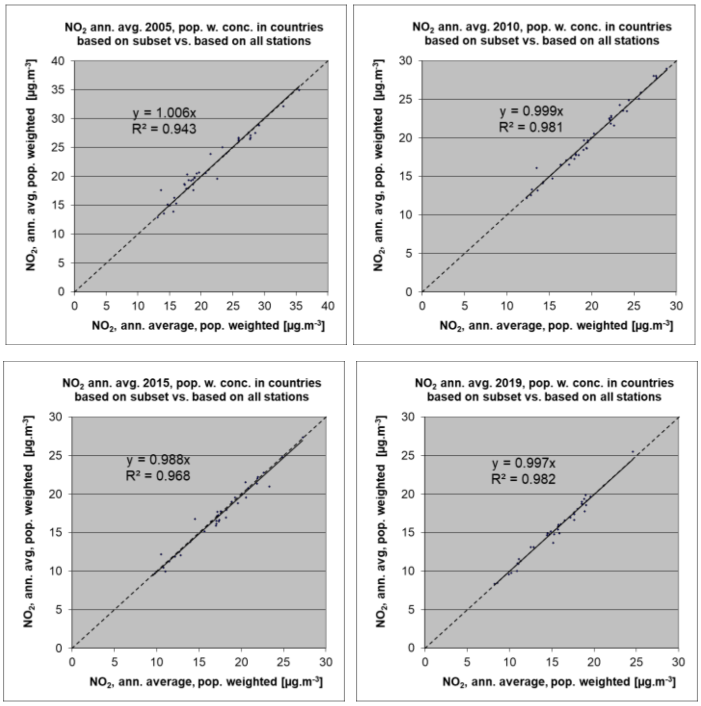
Table A1.3 Population weighted concentration for NO_2 annual average in years 2005, 2010, 2015 and 2019 for two mapping variants. Units: $\mu g{\cdot}m^{-3}$.

Mapping variant	2005	2010	2015	2019
(i) Based on the subset of stations	24.1	22.9	19.5	17.3
(ii) Based on all stations available	24.4	22.8	19.5	17.3

One can see that the population weighted concentration gives quite similar results or both mapping variants in the most of the years.

Figure A1.3 presents the relevant scatter plots per countries.

Figure A1.3 Correlation between population weighted concentration for individual countries calculated based on RIMM mapping variant using (i) the subset of stations (y-axis) and (ii) all stations (x-axis), NO_2 annual average for 2005, 2010, 2015 and 2019



Annex 2
Technical details and uncertainty of consistent maps

Technical details on the mapping and uncertainty estimates (see Section 2.1.2) of consisent maps 2005-2019 for PM_{10} annual average (Tables A2.1-A2.3), ozone indicator SOMO35 (Tables A2.4-A2.5) and NO_2 annual average (Table A2.6-A2.8) are presented in the first part of this Annex 2. The tables present the estimated parameters of the linear regression models (c, a_1, a_2, …) and of the residual kriging (nugget, sill, range) and shows the statistical indicators of both the regression and the kriging.

Table A2.1 Parameters and statistics of linear regression model (LRM) and ordinary kriging (OK) for PM_{10} annual average in rural areas for the consistent maps for trends, 2005-2019

PM_{10} Annual Average – Rural		**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
LRM	c (constant)	2.31	1.65	3.07	3.11	2.21	2.44	2.35	2.40
	a1 (log. EMEP model)	0.583	0.699	0.514	0.529	0.599	0.618	0.635	0.612
	a2 (altitude GMTED)	-0.00034	-0.00040	-0.00036	-0.00029	-0.00031	-0.00032	-0.00038	-0.00035
	a3 (wind speed)	-0.0618	-0.0795	-0.0542	-0.0736	-0.0635	-0.0537	-0.0663	-0.0678
	a4 (relative humidity)	-0.0068		-0.0171	-0.0175	-0.0062	-0.0099	-0.0096	-0.0102
	a5 (land cover NAT)	-0.0019	-0.0017	-0.0013	-0.0020	-0.0021	-0.0017	-0.0015	-0.0019
	Adjusted R^2	**0.56**	**0.70**	**0.64**	**0.64**	**0.66**	**0.67**	**0.76**	**0.71**
	Stand. Error [µg.m^{-3}]	**0.22**	**0.22**	**0.22**	**0.22**	**0.23**	**0.23**	**0.20**	**0.21**
OK	nugget	0.018	0.022	0.003	0.023	0.020	0.023	0.019	0.021
	sill	0.060	0.052	0.036	0.048	0.079	0.071	0.041	0.051
	range [km]	860	1089	108	428	2012	1584	880	791
LRM + OK	**RMSE [µg.m^{-3}]**	**4.5**	**4.3**	**3.8**	**3.7**	**3.6**	**3.8**	**3.2**	**3.3**
	Relative RMSE [%]	**20.6%**	**19.9%**	**19.9%**	**20.2%**	**19.2%**	**19.7%**	**16.2%**	**18.3%**
	Bias (MPE) [µg.m^{-3}]	**0.02**	**0.03**	**0.18**	**0.10**	**0.06**	**0.11**	**0.10**	**0.15**
	R^2 of regr. equation	**0.64**	**0.73**	**0.68**	**0.69**	**0.72**	**0.73**	**0.81**	**0.78**
	Slope of regr. eq.	**0.66**	**0.74**	**0.69**	**0.73**	**0.75**	**0.75**	**0.82**	**0.80**
	Intercept of regr. eq.	**7.4**	**5.8**	**6.1**	**5.1**	**4.9**	**5.0**	**3.6**	**3.8**

PM_{10} Annual Average – Rural		**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
LRM	c (constant)	2.23	2.22	2.40	2.77	2.41	2.26	1.50
	a1 (log. EMEP model)	0.605	0.660	0.613	0.599	0.590	0.662	0.694
	a2 (altitude GMTED)	-0.00038	-0.00038	-0.00039	-0.00037	-0.00040	-0.00027	-0.00039
	a3 (wind speed)	-0.0779	-0.0931	-0.0647	-0.0635	-0.0713	-0.0699	-0.0401
	a4 (relative humidity)	-0.0065	-0.0080	-0.0118	-0.0166	-0.0105	-0.0104	-0.0043
	a5 (land cover NAT)	-0.0015	-0.0013	-0.0014	-0.0016	-0.0016	-0.0016	-0.0010
	Adjusted R^2	0.72	0.69	0.76	0.76	0.72	0.71	0.74
	Stand. Error [µg.m^{-3}]	0.21	0.22	0.18	0.19	0.21	0.20	0.19
OK	nugget	0.013	0.017	0.016	0.022	0.022	0.017	0.015
	sill	0.048	0.058	0.039	0.041	0.051	0.043	0.037
	range [km]	718	1125	1344	1659	1541	1022	1062
LRM + OK	**RMSE [µg.m^{-3}]**	**2.8**	**2.8**	**2.6**	**2.8**	**2.7**	**2.5**	**2.2**
	Relative RMSE [%]	**16.3%**	**16.7%**	**16.2%**	**18.3%**	**17.4%**	**15.2%**	**15.6%**
	Bias (MPE) [µg.m^{-3}]	**0.06**	**0.10**	**0.04**	**0.14**	**0.12**	**0.18**	**0.08**
	R^2 of regr. equation	**0.80**	**0.79**	**0.80**	**0.75**	**0.81**	**0.82**	**0.81**
	Slope of regr. eq.	**0.81**	**0.82**	**0.81**	**0.82**	**0.79**	**0.86**	**0.82**
	Intercept of regr. eq.	**3.4**	**3.1**	**3.1**	**2.9**	**3.3**	**2.6**	**2.6**

Table A2.2 Parameters and statistics of linear regression model (LRM) and ordinary kriging (OK) for PM_{10} annual average in urban background areas for the consistent maps for trends, 2005-2019

PM_{10} Ann. Avg – Urban Backr.		2005	2006	2007	2008	2009	2010	2011	2012
LRM	c (constant)	2.55	2.27	2.24	2.26	2.39	2.44	2.24	2.08
	a1 (log. EMEP model)	0.288	0.389	0.382	0.365	0.331	0.322	0.397	0.429
	Adjusted R^2	0.11	0.13	0.20	0.18	0.15	0.14	0.18	0.20
	Stand. Error [µg.m^{-3}]	0.26	0.30	0.25	0.27	0.25	0.26	0.27	0.27
OK	nugget	0.021	0.020	0.016	0.019	0.018	0.015	0.013	0.013
	sill	0.102	1.343	0.079	0.121	0.113	0.135	0.111	0.104
	range [km]	1 842	23 425	1 466	2 330	2 566	2 886	2 037	1 712
LRM + OK	**RMSE [µg.m^{-3}]**	**5.4**	**6.0**	**4.9**	**4.6**	**4.5**	**4.3**	**4.5**	**3.9**
	Relative RMSE [%]	**18.9%**	**20.5%**	**18.5%**	**18.3%**	**17.3%**	**16.2%**	**16.6%**	**16.1%**
	Bias (MPE) [µg.m^{-3}]	**-0.04**	**-0.02**	**-0.01**	**-0.01**	**-0.03**	**-0.01**	**0.01**	**0.02**
	R^2 of regr. equation	**0.63**	**0.68**	**0.64**	**0.72**	**0.67**	**0.73**	**0.74**	**0.77**
	Slope of regr. eq.	**0.61**	**0.70**	**0.67**	**0.72**	**0.66**	**0.72**	**0.77**	**0.79**
	Intercept of regr. eq.	**11.1**	**8.8**	**8.9**	**7.0**	**8.8**	**7.3**	**6.3**	**5.3**

PM_{10} Ann. Avg – Urban Backr.		2013	2014	2015	2016	2017	2018	2019
LRM	c (constant)	2.15	2.17	2.11	2.03	1.93	1.91	1.47
	a1 (log. EMEP model)	0.403	0.374	0.391	0.403	0.452	0.469	0.562
	Adjusted R^2	0.19	0.14	0.18	0.20	0.21	0.24	0.28
	Stand. Error [µg.m^{-3}]	0.26	0.29	0.27	0.26	0.29	0.26	0.23
OK	nugget	0.013	0.016	0.012	0.012	0.013	0.012	0.015
	sill	0.146	0.196	0.156	0.096	0.149	1.229	0.053
	range [km]	2 992	3 410	3 157	1 640	2 421	30 167	728
LRM + OK	**RMSE [µg.m^{-3}]**	**3.8**	**4.0**	**3.5**	**3.3**	**3.6**	**3.4**	**3.2**
	Relative RMSE [%]	**15.9%**	**17.7%**	**15.6%**	**15.9%**	**17.1%**	**15.9%**	**16.8%**
	Bias (MPE) [µg.m^{-3}]	**0.00**	**0.01**	**-0.03**	**0.00**	**-0.02**	**0.01**	**0.08**
	R^2 of regr. equation	**0.76**	**0.74**	**0.76**	**0.76**	**0.76**	**0.75**	**0.69**
	Slope of regr. eq.	**0.77**	**0.76**	**0.77**	**0.77**	**0.79**	**0.79**	**0.76**
	Intercept of regr. eq.	**5.4**	**5.4**	**5.1**	**4.8**	**4.5**	**4.4**	**4.7**

Table A2.3 Parameters and statistics of linear regression model (LRM) and ordinary kriging (OK) for PM_{10} annual average in urban traffic areas for the consistent maps for trends, 2005-2019

PM_{10} Ann. Avg – Urban Traffic		2005	2006	2007	2008	2009	2010	2011	2012
LRM	c (constant)	2.47	2.42	2.37	2.40	2.39	2.39	2.33	2.29
	a1 (log. EMEP model)	0.448	0.464	0.432	0.418	0.409	0.372	0.437	0.428
	a2 (wind speed)	-0.0734	-0.0667	-0.0392	-0.0428	-0.0325	*n. sign.*	-0.0402	-0.0431
	Adjusted R^2	0.37	0.33	0.35	0.38	0.38	0.30	0.39	0.38
	Stand. Error [μg.m^{-3}]	0.25	0.25	0.26	0.24	0.22	0.22	0.22	0.23
OK	nugget	0.023	0.025	0.044	0.024	0.025	0.016	0.016	0.018
	sill	0.072	0.079	0.167	0.066	0.286	0.097	0.059	0.057
	range [km]	1476	1682	8913	1544	18253	4041	1765	1167
LRM + OK	**RMSE [μg.m^{-3}]**	**9.3**	**9.1**	**8.3**	**7.4**	**6.3**	**5.0**	**5.5**	**5.1**
	Relative RMSE [%]	**26.9%**	**26.0%**	**26.3%**	**24.7%**	**21.2%**	**17.7%**	**18.5%**	**19.2%**
	Bias (MPE) [μg.m^{-3}]	**-0.23**	**-0.25**	**-0.19**	**-0.23**	**-0.18**	**-0.13**	**-0.10**	**-0.07**
	R^2 of regr. equation	**0.39**	**0.39**	**0.42**	**0.49**	**0.54**	**0.54**	**0.60**	**0.62**
	Slope of regr. eq.	**0.42**	**0.42**	**0.42**	**0.50**	**0.52**	**0.56**	**0.59**	**0.61**
	Intercept of regr. eq.	**19.7**	**19.9**	**18.1**	**14.7**	**14.0**	**12.4**	**12.0**	**10.3**

PM_{10} Ann. Avg – Urban Traffic		2013	2014	2015	2016	2017	2018	2019
LRM	c (constant)	2.26	2.28	2.24	2.16	2.08	2.15	1.62
	a1 (log. EMEP model)	0.460	0.412	0.434	0.445	0.489	0.443	0.548
	a2 (wind speed)	-0.0605	-0.0409	-0.0547	-0.0518	-0.0562	-0.0324	*n. sign.*
	Adjusted R^2	0.38	0.28	0.37	0.38	0.43	0.36	0.42
	Stand. Error [μg.m^{-3}]	0.25	0.25	0.25	0.23	0.24	0.23	0.21
OK	nugget	0.020	0.019	0.020	0.020	0.023	0.018	0.018
	sill	0.085	0.078	0.077	0.065	0.097	0.105	0.044
	range [km]	2242	2040	1889	1747	3138	4037	693
LRM + OK	**RMSE [μg.m^{-3}]**	**7.4**	**6.4**	**7.7**	**5.2**	**4.7**	**4.3**	**3.7**
	Relative RMSE [%]	**28.2%**	**25.4%**	**30.5%**	**22.5%**	**20.2%**	**18.2%**	**17.6%**
	Bias (MPE) [μg.m^{-3}]	**-0.12**	**-0.14**	**-0.17**	**-0.09**	**-0.08**	**-0.08**	**-0.03**
	R^2 of regr. equation	**0.46**	**0.49**	**0.41**	**0.58**	**0.65**	**0.64**	**0.64**
	Slope of regr. eq.	**0.53**	**0.53**	**0.47**	**0.59**	**0.64**	**0.64**	**0.63**
	Intercept of regr. eq.	**12.2**	**11.7**	**13.3**	**9.5**	**8.3**	**8.4**	**7.8**

Table A2.4 Parameters and statistics of linear regression model (LRM) and ordinary kriging (OK) for ozone indicator SOMO35 in rural areas for the consistent maps for trends, 2005-2019

Ozone, SOMO35 - Rural		2005	2006	2007	2008	2009	2010	2011	2012
LRM	c (constant)	44	874	-576	398	-526	-1281	-690	-890
	a1 (EMEP model)	1.57	2.05	1.70	1.30	1.61	1.42	1.83	1.96
	a2 (altitude GMTED)	1.09		1.03	1.11	0.81	1.20	0.93	0.87
	a3 (surf. solar radiation)	0.435		0.364	0.283	0.411	0.802	0.448	0.412
	Adjusted R^2	**0.58**	**0.34**	**0.66**	**0.58**	**0.65**	**0.65**	**0.66**	**0.74**
	Stand. Error [μg.m^{-3}]	**1 864**	**2 891**	**1 576**	**1 493**	**1 605**	**1 533**	**1 682**	**1 461**
OK	nugget	1.7E+06	1.5E+06	2.1E+06	1.4E+06	1.4E+06	1.2E+06	1.6E+06	1.2E+06
	psill	3.3E+06	7.9E+06	7.3E+06	2.1E+06	2.5E+06	2.3E+06	2.6E+06	2.0E+06
	range [km]	744	519	24 150	317	254	214	278	213
LRM + OK	**RMSE [μg.m^{-3}]**	**1 880**	**2 332**	**1 545**	**1 430**	**1 500**	**1 458**	**1 636**	**1 408**
	Relative RMSE [%]	**31.6%**	**34.7%**	**28.6%**	**27.6%**	**27.4%**	**27.1%**	**28.2%**	**25.9%**
	Bias (MPE) [μg.m^{-3}]	**-14**	**34**	**24**	**14**	**5**	**19**	**3**	**-22**
	R^2 of regr. equation	**0.57**	**0.57**	**0.68**	**0.61**	**0.69**	**0.69**	**0.68**	**0.76**
	Slope of regr. eq.	**0.61**	**0.57**	**0.71**	**0.64**	**0.71**	**0.71**	**0.71**	**0.78**
	Intercept of regr. eq.	**2 323**	**2 896**	**1 616**	**1 889**	**1 600**	**1 599**	**1 685**	**1 198**

Ozone, SOMO35 - Rural		2013	2014	2015	2016	2017	2018	2019
LRM	c (constant)	-1447	-1864	-689	-1026	-1060	341	-46
	a1 (EMEP model)	1.51	1.23	1.89	1.58	1.89	1.65	1.57
	a2 (altitude GMTED)	1.06	1.06	1.31	0.88	0.85	1.03	1.15
	a3 (surf. solar radiation)	0.794	0.978	0.379	0.582	0.422	0.323	0.381
	Adjusted R^2	0.69	0.64	0.69	0.67	0.72	0.60	0.62
	Stand. Error [μg.m^{-3}]	1 429	1 322	1 606	1 378	1 517	1 490	1 472
OK	nugget	1.3E+06	1.2E+06	1.4E+06	1.3E+06	1.2E+06	1.3E+06	1.2E+06
	psill	2.1E+06	1.7E+06	2.4E+06	4.8E+05	2.0E+06	2.2E+06	2.0E+06
	range [km]	301	330	297	267	231	352	234
LRM + OK	**RMSE [μg.m^{-3}]**	**1 399**	**1 283**	**1 486**	**1 374**	**1 438**	**1 437**	**1 449**
	Relative RMSE [%]	**26.0%**	**27.3%**	**25.5%**	**28.1%**	**27.7%**	**22.1%**	**24.5%**
	Bias (MPE) [μg.m^{-3}]	**21**	**13**	**26**	**7**	**13**	**8**	**3**
	R^2 of regr. equation	**0.70**	**0.66**	**0.73**	**0.67**	**0.75**	**0.63**	**0.63**
	Slope of regr. eq.	**0.73**	**0.69**	**0.76**	**0.69**	**0.77**	**0.65**	**0.64**
	Intercept of regr. eq.	**1 492**	**1 476**	**1 395**	**1 498**	**1 209**	**2 295**	**2 109**

Table A2.5 Parameters and statistics of linear regression model (LRM) and ordinary kriging (OK) for ozone indicator SOMO35 in urban areas for the consistent maps for trends, 2005-2019

Ozone, SOMO35 - Urban		2005	2006	2007	2008	2009	2010	2011	2012
LRM	c (constant)	-976	577	-1076	-263	-1834	-1969	-1596	-1445
	a1 (EMEP model)	1.05	1.09	1.30	0.92	1.10	1.05	1.20	1.31
	a2 (surf. solar radiation)	0.871	0.486	0.649	0.629	0.974	1.106	0.926	0.799
	Adjusted R^2	**0.45**	**0.29**	**0.57**	**0.44**	**0.57**	**0.56**	**0.56**	**0.61**
	Stand. Error [μg.m^{-3}]	**1 751**	**2 153**	**1 476**	**1 437**	**1 510**	**1 391**	**1 519**	**1 434**
OK	nugget	1.6E+06	2.2E+06	1.1E+06	1.1E+06	1.4E+06	1.2E+06	1.4E+06	1.3E+06
	sill	9.0E+06	5.2E+06	1.7E+06	1.1E+07	7.7E+06	4.5E+06	2.0E+06	1.6E+06
	range [km]	10 763	1 226	433	19 071	13 675	9 784	440	253
LRM + OK	**RMSE [μg.m^{-3}]**	**1 562**	**2 075**	**1 298**	**1 239**	**1 354**	**1 255**	**1 340**	**1 297**
	Relative RMSE [%]	**33.1%**	**39.6%**	**29.1%**	**29.2%**	**30.0%**	**28.5%**	**28.4%**	**29.5%**
	Bias (MPE) [μg.m^{-3}]	**17**	**13**	**15**	**8**	**16**	**15**	**19**	**11**
	R^2 of regr. equation	**0.56**	**0.35**	**0.67**	**0.59**	**0.65**	**0.64**	**0.66**	**0.68**
	Slope of regr. eq.	**0.59**	**0.40**	**0.71**	**0.60**	**0.66**	**0.65**	**0.68**	**0.70**
	Intercept of regr. eq.	**1 966**	**3 144**	**1 289**	**1 724**	**1 529**	**1 548**	**1 534**	**1 310**

Ozone, SOMO35 - Urban		2013	2014	2015	2016	2017	2018	2019
LRM	c (constant)	-1474	-2217	-459	-1621	-1510	-102	-236
	a1 (EMEP model)	1.14	0.84	1.53	1.23	1.43	1.14	1.20
	a2 (surf. solar radiation)	0.908	1.186	0.455	0.820	0.708	0.661	0.564
	Adjusted R^2	0.56	0.54	0.60	0.55	0.67	0.43	0.49
	Stand. Error [μg.m^{-3}]	1 365	1 206	1 527	1 410	1 368	1 499	1 361
OK	nugget	9.3E+05	7.8E+05	7.2E+05	8.6E+05	1.2E+06	1.2E+06	1.2E+06
	sill	1.5E+06	1.2E+06	1.8E+06	7.9E+05	3.0E+06	3.1E+08	2.7E+06
	range [km]	166	234	113	172	7 168	397 756	5 476
LRM + OK	**RMSE [μg.m^{-3}]**	**1 197**	**1 045**	**1 263**	**1 146**	**1 210**	**1 213**	**1 250**
	Relative RMSE [%]	**27.1%**	**26.7%**	**25.3%**	**28.3%**	**27.4%**	**22.1%**	**25.2%**
	Bias (MPE) [μg.m^{-3}]	**32**	**27**	**79**	**33**	**19**	**8**	**18**
	R^2 of regr. equation	**0.67**	**0.66**	**0.73**	**0.70**	**0.74**	**0.62**	**0.57**
	Slope of regr. eq.	**0.68**	**0.66**	**0.76**	**0.73**	**0.76**	**0.62**	**0.59**
	Intercept of regr. eq.	**1 466**	**1 342**	**1 302**	**1 123**	**1 077**	**2 083**	**2 051**

Table A2.6 Parameters and statistics of linear regression model (LRM) and ordinary kriging (OK) for NO_2 annual average in rural areas for the consistent maps for trends, 2005-2019

NO_2 Annual Average – Rural		2005	2006	2007	2008	2009	2010	2011	2012
LRM	c (constant)	7.41	8.33	8.52	8.35	8.95	9.05	8.75	8.03
	a1 (EMEP model)	0.356	0.414	0.430	0.438	0.498	0.491	0.489	0.536
	a2 (satellite OMI)	1.043	0.894	0.919	0.920	0.998	0.909	0.835	0.751
	a3 (wind speed)	-1.131	-1.110	-1.139	-1.141	-1.364	-1.340	-1.385	-1.132
	a4 (population)	0.0020	0.0029	0.0022	0.0019	0.0024	0.0022	0.0022	0.0025
	a5 (land cover NAT)	-0.0005	-0.0006	-0.0007	-0.0007	-0.0008	-0.0007	-0.0006	-0.0007
	Adjusted R^2	**0.70**	**0.70**	**0.76**	**0.73**	**0.72**	**0.76**	**0.52**	**0.78**
	Stand. Error [$\mu g.m^{-3}$]	**3.30**	**3.38**	**3.08**	**3.23**	**3.45**	**3.09**	**4.91**	**2.82**
OK	nugget	4.44	5.10	3.81	2.38	3.49	6.10	1.72	4.85
	sill	10.63	11.65	9.47	10.37	12.56	10.24	25.89	8.62
	range [km]	204	194	147	145	138	263	126	301
LRM + OK	**RMSE [$\mu g.m^{-3}$]**	**3.2**	**3.4**	**3.1**	**3.3**	**3.4**	**3.0**	**5.1**	**2.7**
	Relative RMSE [%]	**29.1%**	**29.4%**	**28.7%**	**30.9%**	**31.4%**	**27.1%**	**47.6%**	**26.8%**
	Bias (MPE) [$\mu g.m^{-3}$]	**0.12**	**0.08**	**0.05**	**0.07**	**0.09**	**0.12**	**0.14**	**0.06**
	R^2 of regr. equation	**0.73**	**0.70**	**0.75**	**0.73**	**0.73**	**0.78**	**0.50**	**0.80**
	Slope of regr. eq.	**0.73**	**0.73**	**0.77**	**0.76**	**0.77**	**0.79**	**0.57**	**0.81**
	Intercept of regr. eq.	**3.1**	**3.2**	**2.5**	**2.6**	**2.6**	**2.4**	**4.7**	**2.0**

NO_2 Annual Average – Rural		2013	2014	2015	2016	2017	2018	2019
LRM	c (constant)	7.77	7.04	7.88	7.35	8.16	6.31	6.32
	a1 (log. EMEP model)	0.515	0.460	0.514	0.505	0.457	0.500	0.518
	a2 (altitude GMTED)	0.783	0.777	0.529	0.782	1.067	1.002	0.893
	a3 (wind speed)	-1.029	-0.821	-0.996	-0.929	-1.232	-0.912	-0.937
	a4 (relative humidity)	0.0014	0.0020	0.0020	0.0025	0.0024	0.0021	0.0019
	a5 (land cover NAT)	-0.0007	-0.0007	-0.0007	-0.0007	-0.0007	-0.0006	-0.0006
	Adjusted R^2	**0.76**	**0.75**	**0.72**	**0.78**	**0.76**	**0.78**	**0.78**
	Stand. Error [$\mu g.m^{-3}$]	**2.84**	**2.70**	**2.82**	**2.47**	**2.70**	**2.35**	**2.27**
OK	nugget	4.59	7.86	8.18	3.88	4.29	3.43	3.74
	sill	8.57	14.58	8.18	6.30	7.37	5.71	5.39
	range [km]	186	4645	458	213	166	113	112
LRM + OK	**RMSE [$\mu g.m^{-3}$]**	**2.8**	**2.7**	**2.8**	**2.5**	**2.7**	**2.4**	**2.2**
	Relative RMSE [%]	**28.6%**	**30.1%**	**30.8%**	**27.5%**	**30.2%**	**27.9%**	**28.3%**
	Bias (MPE) [$\mu g.m^{-3}$]	**0.09**	**-0.001**	**0.08**	**0.06**	**0.04**	**0.03**	**-0.01**
	R^2 of regr. equation	**0.76**	**0.74**	**0.72**	**0.78**	**0.75**	**0.78**	**0.79**
	Slope of regr. eq.	**0.79**	**0.75**	**0.72**	**0.81**	**0.79**	**0.79**	**0.80**
	Intercept of regr. eq.	**2.2**	**2.2**	**2.7**	**1.8**	**1.9**	**1.8**	**1.5**

Table A2.7 Parameters and statistics of linear regression model (LRM) and ordinary kriging (OK) for NO_2 annual average in urban background areas for the consistent maps for trends, 2005-2019

NO_2 Ann. Avg – Urban Backr.		2005	2006	2007	2008	2009	2010	2011	2012
LRM	c (constant)	23.26	23.96	22.81	20.90	19.95	20.08	20.51	19.23
	a1 (EMEP model)	0.258	0.270	0.255	0.264	0.247	0.245	0.309	0.334
	a2 (satellite OMI)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	a3 (wind speed)	-3.004	-3.151	-3.163	-2.730	-2.788	-2.524	-2.844	-2.507
	a4 (population density)	0.00017	0.00018	0.00023	0.00024	0.00022	0.00023	0.00019	0.00016
	a5 (land cover HDR)	0.0019	0.0014	0.0017	0.0017	0.0025	0.0023	0.0018	0.0017
	Adjusted R^2	**0.51**	**0.45**	**0.48**	**0.49**	**0.51**	**0.50**	**0.50**	**0.51**
	Stand. Error [μg.m^{-3}]	**6.41**	**6.87**	**6.70**	**6.29**	**6.38**	**5.95**	**5.99**	**5.62**
OK	nugget	26.22	27.53	26.78	27.77	29.29	26.12	25.28	21.31
	sill	45.36	50.59	50.27	45.62	215.77	1741.27	375.28	111.53
	range [km]	1293	994	1114	1648	22228	247370	43521	13282
LRM + OK	**RMSE [μg.m^{-3}]**	**5.8**	**6.1**	**5.8**	**5.7**	**5.8**	**5.4**	**5.4**	**5.1**
	Relative RMSE [%]	**21.8%**	**23.2%**	**22.9%**	**23.1%**	**23.3%**	**22.0%**	**22.5%**	**22.1%**
	Bias (MPE) [μg.m^{-3}]	**-0.02**	**0.00**	**0.01**	**0.01**	**-0.018**	**-0.05**	**-0.03**	**-0.044**
	R^2 of regr. equation	**0.60**	**0.56**	**0.61**	**0.58**	**0.60**	**0.59**	**0.60**	**0.60**
	Slope of regr. eq.	**0.59**	**0.56**	**0.61**	**0.59**	**0.60**	**0.58**	**0.59**	**0.60**
	Intercept of regr. eq.	**10.8**	**11.6**	**9.8**	**10.2**	**9.8**	**10.4**	**9.9**	**9.2**

NO_2 Ann. Avg – Urban Backr.		2013	2014	2015	2016	2017	2018	2019
LRM	c (constant)	17.80	15.75	18.60	17.23	18.53	16.40	16.16
	a1 (EMEP model)	0.289	0.279	0.339	0.299	0.281	0.267	0.286
	a2 (satellite OMI)	0.000	0.000	0.795	0.000	0.000	0.000	0.000
	a3 (wind speed)	-2.384	-1.956	-2.632	-2.339	-2.738	-2.126	-2.189
	a4 (population density)	0.00019	0.00022	0.00023	0.00020	0.00024	0.00022	0.00020
	a5 (land cover HDR)	0.0019	0.0017	0.0014	0.0018	0.0019	0.0015	0.0011
	Adjusted R^2	**0.55**	**0.53**	**0.53**	**0.53**	**0.55**	**0.53**	**0.51**
	Stand. Error [μg.m^{-3}]	**5.26**	**5.15**	**5.42**	**5.04**	**5.09**	**4.65**	**4.66**
OK	nugget	19.84	20.63	21.35	19.84	19.48	16.51	15.62
	sill	95.50	66.37	103.59	58.66	72.06	80.72	157.00
	range [km]	13939	11601	14753	10302	12109	18848	31343
LRM + OK	**RMSE [μg.m^{-3}]**	**4.7**	**4.7**	**4.9**	**4.6**	**4.6**	**4.3**	**4.2**
	Relative RMSE [%]	**21.1%**	**22.7%**	**22.7%**	**22.2%**	**22.2%**	**21.9%**	**22.5%**
	Bias (MPE) [μg.m^{-3}]	**-0.05**	**-0.04**	**-0.035**	**-0.06**	**-0.04**	**-0.04**	**-0.04**
	R^2 of regr. equation	**0.65**	**0.60**	**0.62**	**0.61**	**0.63**	**0.60**	**0.60**
	Slope of regr. eq.	**0.64**	**0.58**	**0.61**	**0.60**	**0.62**	**0.59**	**0.60**
	Intercept of regr. eq.	**7.8**	**8.7**	**8.3**	**8.2**	**7.8**	**8.0**	**7.5**

Table A2.8 Parameters and statistics of linear regression model (LRM) and ordinary kriging (OK) for NO_2 annual average in urban traffic areas for the consistent maps for trends, 2005-2019

NO_2 Ann. Avg – Urban Traffic		2005	2006	2007	2008	2009	2010	2011	2012
LRM	c (constant)	34.70	35.51	34.68	32.14	31.68	31.78	31.45	30.60
	a1 (EMEP model)	0.136	0.169	0.185	0.201	0.176	0.235	0.261	0.227
	a2 (satellite OMI)	0.997	1.155	1.203	1.267	1.858	1.318	1.437	1.392
	a3 (wind speed)	-3.294	-3.530	-3.301	-2.904	-3.138	-3.003	-3.492	-3.139
	a4 (land cover LDR)	0.0034	0.0036	0.0033	0.0033	0.0029	0.0033	0.0032	0.0029
	a5 (land cover HDR)	0.0061	0.0052	0.0049	0.0047	0.0051	0.0037	0.0036	0.0035
	Adjusted R^2	**0.44**	**0.37**	**0.34**	**0.36**	**0.35**	**0.34**	**0.36**	**0.34**
	Stand. Error [μg.m^{-3}]	**11.97**	**13.31**	**13.26**	**12.81**	**13.08**	**12.48**	**12.33**	**11.67**
OK	nugget	113.32	130.95	109.72	119.86	102.97	84.94	73.07	78.18
	sill	151.97	186.84	182.24	170.16	180.18	161.75	154.71	140.53
	range [km]	1226	310	222	319	242	211	177	208
LRM + OK	**RMSE [μg.m^{-3}]**	**11.2**	**11.8**	**11.4**	**11.1**	**11.1**	**10.6**	**10.2**	**10.1**
	Relative RMSE [%]	**24.8%**	**25.4%**	**25.5%**	**25.7%**	**26.0%**	**24.9%**	**24.5%**	**25.2%**
	Bias (MPE) [μg.m^{-3}]	**0.06**	**0.23**	**0.19**	**0.17**	**0.14**	**0.16**	**0.17**	**0.11**
	R^2 of regr. equation	**0.50**	**0.50**	**0.51**	**0.52**	**0.53**	**0.52**	**0.56**	**0.51**
	Slope of regr. eq.	**0.51**	**0.50**	**0.52**	**0.51**	**0.53**	**0.52**	**0.56**	**0.52**
	Intercept of regr. eq.	**22.4**	**23.5**	**21.7**	**21.3**	**20.3**	**20.7**	**18.5**	**19.4**

NO_2 Ann. Avg – Urban Traffic		2013	2014	2015	2016	2017	2018	2019
LRM	c (constant)	28.45	25.82	28.43	26.30	27.72	24.17	25.03
	a1 (EMEP model)	0.289	0.236	0.278	0.272	0.319	0.268	0.228
	a2 (satellite OMI)	1.095	1.361	1.091	1.299	1.151	1.135	0.976
	a3 (wind speed)	-2.549	-2.660	-3.420	-2.761	-3.140	-2.308	-2.522
	a4 (land cover LDR)	0.0027	0.0032	0.0031	0.0028	0.0025	0.0026	0.0022
	a5 (land cover HDR)	0.0028	0.0032	0.0039	0.0040	0.0042	0.0037	0.0034
	Adjusted R^2	**0.40**	**0.39**	**0.43**	**0.41**	**0.46**	**0.43**	**0.40**
	Stand. Error [μg.m^{-3}]	**10.27**	**10.53**	**10.28**	**9.89**	**9.11**	**8.77**	**8.13**
OK	nugget	60.16	64.98	66.96	67.93	56.05	55.56	40.60
	sill	103.17	115.48	108.24	99.77	82.90	76.62	61.43
	range [km]	255	359	350	460	444	427	317
LRM + OK	**RMSE [μg.m^{-3}]**	**9.1**	**9.0**	**9.1**	**8.7**	**8.3**	**8.1**	**7.5**
	Relative RMSE [%]	**23.8%**	**24.8%**	**24.6%**	**24.3%**	**23.6%**	**24.4%**	**24.3%**
	Bias (MPE) [μg.m^{-3}]	**0.17**	**0.12**	**0.09**	**0.06**	**0.05**	**0.04**	**0.02**
	R^2 of regr. equation	**0.53**	**0.55**	**0.55**	**0.55**	**0.55**	**0.52**	**0.49**
	Slope of regr. eq.	**0.54**	**0.54**	**0.55**	**0.54**	**0.56**	**0.52**	**0.50**
	Intercept of regr. eq.	**17.9**	**16.8**	**16.8**	**16.4**	**15.4**	**15.8**	**15.5**

Additionally, the uncertainty of the trend maps has been estimated.

The analysis has been performed separately for rural and urban/suburban background stations representing the rural and the urban background areas. At first, it compares the Sen´s slopes calculated based on the cross-validation predictions and the measurement data. Note that the Sen´s trend is calculated based on the measurement data available, i.e. for many stations based on an incomplete time series. Additionally, the simple comparison of the Sen´s slopes based on measurements and the underlying grid predictions have been performed, both for the separate (rural or urban background) map layers and for the final map. Note that while for measurements the Sen´s slope was calculated based on (in general) incomplete time series, for the predicted grid values it was calculated based on the complete 15-year time series of the maps. This limitation of this analysis should be taken in mind.

Table A2.9 gives the results of the uncertainty analysis of the trend map for PM_{10} annual average, as presented in Map 3.1.

Table A2.9 Statistical indicators from scatter plots for cross-validated point values and predicted grid values from separate (rural, urban background) map layers and final combined map versus measurement point values for rural (left) and urban/suburban background (right) stations for PM_{10} annual average Sen´s trend in 2005-2019. Units: $\mu g \cdot m^{-3} \cdot yr^{-1}$ apart from R^2.

PM_{10} annual average trend 2005-2019	Rural backgr. stations				Urban/suburban backgr. stations			
	RMSE	Bias	R^2	Lin. r. equation	RMSE	Bias	R^2	Lin. r. equation
Cross-val. prediction, separate (r or ub) map layer	0.28	-0.02	0.243	y = 0.312x - 0.33	0.38	0.01	0.309	y = 0.366x - 0.44
Grid prediction, 1x1 km^2 separ. (r or ub) map layer	0.24	-0.02	0.440	y = 0.398x - 0.29	0.33	0.00	0.455	y = 0.426x - 0.41
Grid prediction, 1x1 km^2 final combined map	0.24	-0.04	0.451	y = 0.428x - 0.30	0.34	-0.01	0.416	y = 0.397x - 0.44

Table A2.10 gives the results of the uncertainty analysis of the trend map for ozone indicator SOMO35, as presented in Map 4.1.

Table A2.10 Statistical indicators from scatter plots for cross-validated point values and predicted grid values from separate (rural, urban background) map layers and final combined map versus measurement point values for rural (left) and urban/suburban background (right) stations for Sen´s trend of ozone indicator SOMO35 in 2005-2019. Units: $\mu g \cdot m^{-3} \cdot d \cdot yr^{-1}$ apart from R^2.

Ozone SOMO35 trend 2005-2019	Rural backgr. stations				Urban/suburban backgr. stations			
	RMSE	Bias	R^2	Lin. r. equation	RMSE	Bias	R^2	Lin. r. equation
Cross-val. prediction, separate (r or ub) map layer	123.4	-1.3	0.081	y = 0.116x - 35.11	104.9	-3.8	0.158	y = 0.162x - 12.8
Grid prediction, 1x1 km^2 separ. (r or ub) map layer	102.2	-4.1	0.435	y = 0.253x - 31.9	108.9	-4.6	0.246	y = 0.200x - 12.8
Grid prediction, 1x1 km^2 final combined map	132.9	37.3	0.421	y = 0.247x - 30.7	123.0	10.2	0.231	y = 0.192x - 13.9

Table A2.11 gives the results of the uncertainty analysis of the trend map for NO_2 annual average, as presented in Map 5.1.

Table A2.11 Statistical indicators from scatter plots for cross-validated point values and predicted grid values from separate (rural, urban background) map layers and final combined map versus measurement point values for rural (left) and urban/suburban background (right) stations for NO_2 annual average Sen´s trend in 2005-2019. Units: $\mu g \cdot m^{-3} \cdot yr^{-1}$ apart from R^2.

NO_2 annual average trend 2005-2019	Rural backgr. stations				Urban/suburban backgr. stations			
	RMSE	Bias	R^2	Lin. r. equation	RMSE	Bias	R^2	Lin. r. equation
Cross-val. prediction, separate (r or ub) map layer	0.20	-0.02	0.270	y = 0.376x - 0.18	0.31	-0.01	0.315	y = 0.351x - 0.37
Grid prediction, 1x1 km^2 separ. (r or ub) map layer	0.14	-0.02	0.640	y = 0.615x - 0.12	0.19	-0.01	0.395	y = 0.389x - 0.36
Grid prediction, 1x1 km^2 final combined map	0.15	-0.04	0.590	y = 0.650x - 0.13	0.20	-0.04	0.354	y = 0.374x - 0.39

In general, the uncertainty anaslysis gives satisfactory results in terms of bias for all pollutants, both in the rural and urban background areas. However, regression relation between trend estimates based on measurement data and based on both cross-validated and simple predictions is quite poor in terms of R^2 and slope.

Annex 3
Comparison with results based on regular maps

This Annex 3 presents a comparison of the results based on the maps as presented in this paper with the results based on the regular maps (Horálek et al., 2022 and references therein). The comparison has been done for the population-weighted averaged concentrations.

A3.1 PM_{10}

For the European-wide PM_{10} annual average aggregations across the whole mapping area, a statistically significant downward trend of -0.69 $\mu g.m^{-3}$ per year (in terms of Sen´s slope) for population-weighted averaged concentrations have been estimated. This is almost the same as -0.68 $\mu g.m^{-3}$ per year estimated in this report. Figure A3.1 presents the time series of population-weighted averaged concentrations for the entire area and for EU-28, based on the mapping for trends as presented in this report and based on the regular maps. Figure A3.2 presents the same comparison for individual countries.

Figure A3.1 Time series of population-weighted concentration for PM_{10} annual average based on mapping for trends (blue) and regular mapping (red) for entire area and EU28, 2005-2019

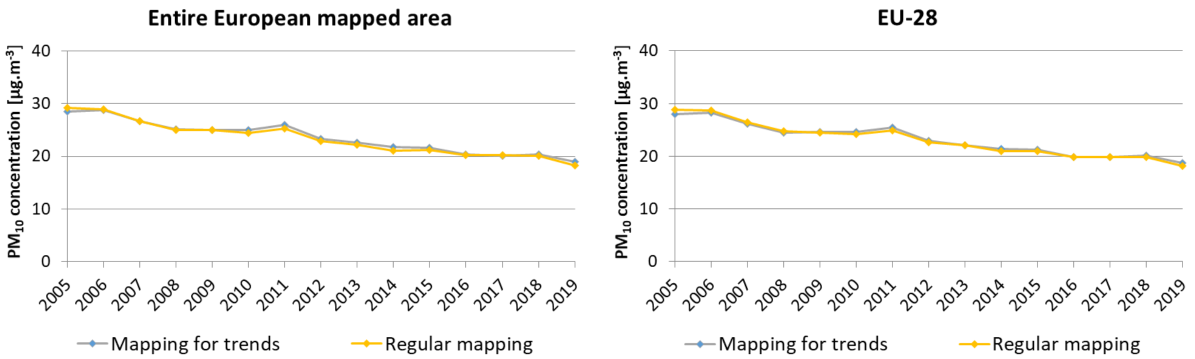
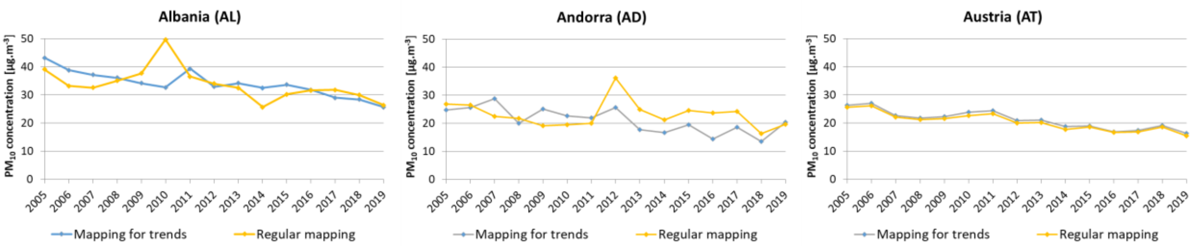
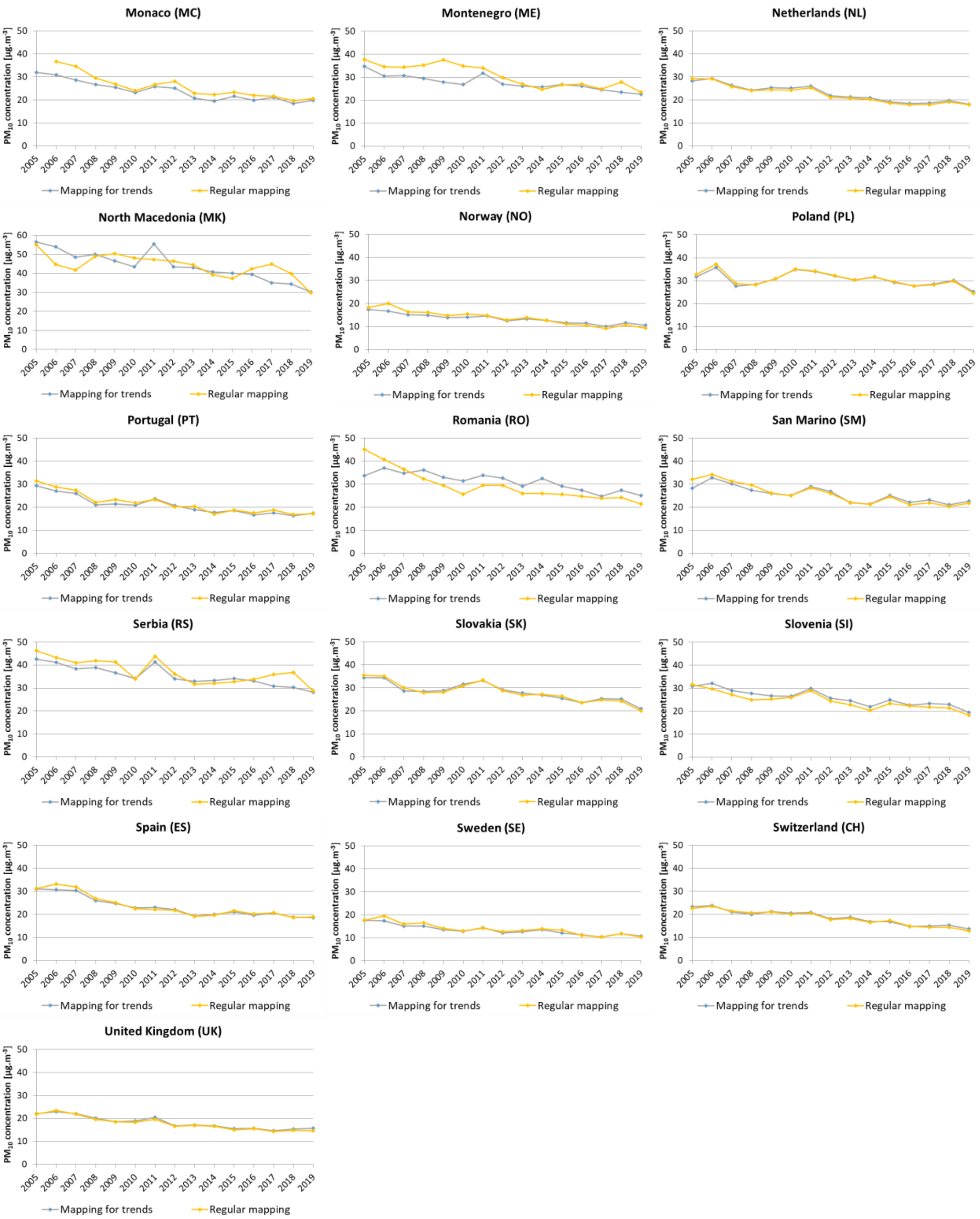


Figure A3.2 Time series of population-weighted concentration for PM_{10} annual average based on mapping for trends (blue) and regular mapping (red) for individual countries, 2005-2019




Belgium (BE)
Bosnia and Herzegovina (BA)
Bulgaria (BG)
Croatia (HR)
Cyprus (CY)
Czechia (CZ)
Denmark (DK)
Estonia (EE)
Finland (FI)
France (FR)
Germany (DE)
Greece (GR)
Hungary (HU)
Iceland (IS)
Ireland (IE)
Italy (IT)
Latvia (LT)
Liechtenstein (LI)
Lithuania (LV)
Luxembourg (LU)
Malta (MT)
PM$_{10}$ concentration [µg.m^{-3}]
Mapping for trends
Regular mapping



A3.2 Ozone

For the European-wide aggregations of ozone indicator SOMO35 across the whole mapping area, no statistical significant trend has been detected (with negative Sen´s slope of -24 µg.m^{-3}.d per year). This is in agreement with the results presented in this report. Figure A3.3 presents the time series of population-weighted averaged concentrations for the entire area and for EU-28, based on the mapping for trends as presented in this report and based on the regular maps. Figure A3.4 presents the same comparison for individual countries.

Figure A3.3 Time series of population-weighted concentration for ozone indicator SOMO35 based on mapping for trends (blue) and regular mapping (red) for entire area and EU28, 2005-2019

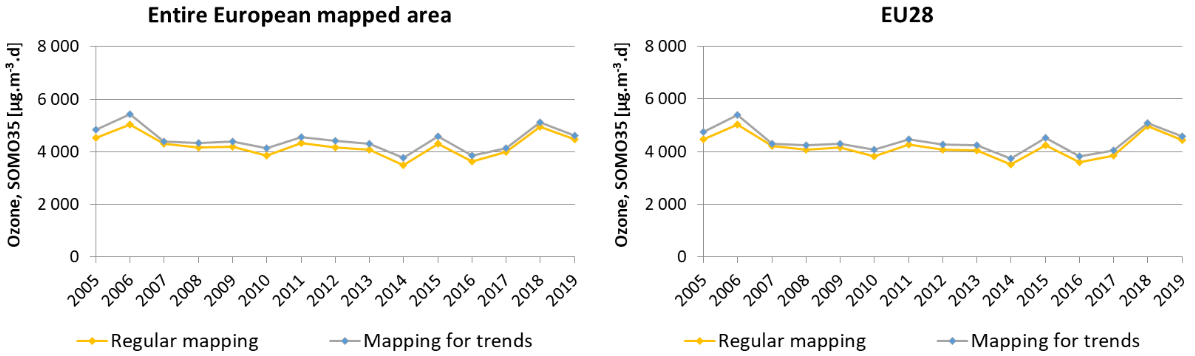
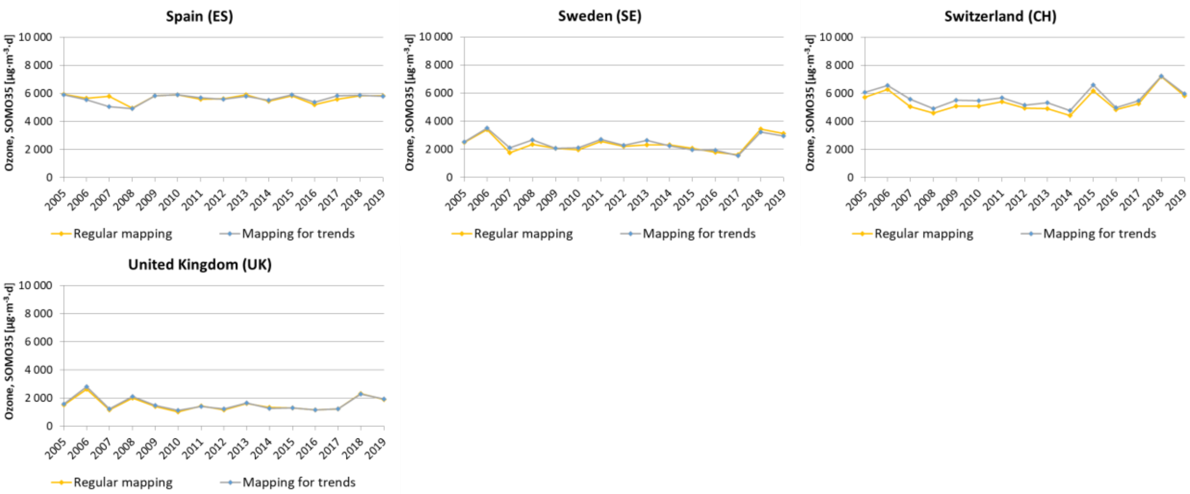


Figure A3.4 Time series of population-weighted concentration for ozone indicator SOMO35 based on mapping for trends (blue) and regular mapping (red) for individual countries, 2005-2019


Hungary (HU)
Iceland (IS)
Ireland (IE)
Italy (IT)
Latvia (LT)
Liechtenstein (LI)
Lithuania (LV)
Luxembourg (LU)
Malta (MT)
Monaco (MC)
Montenegro (ME)
Netherlands (NL)
North Macedonia (MK)
Norway (NO)
Poland (PL)
Portugal (PT)
Romania (RO)
San Marino (SM)
Serbia (RS)
Slovakia (SK)
Slovenia (SI)
Ozone, SOMO35 [µg·m-3·d]
Regular mapping
Mapping for trends



A3.3 NO_2

For the European-wide NO_2 annual average aggregations across the whole mapping area, a statistically significant downward trend of -0.49 µg.m^{-3} per year for population-weighted averaged concentrations have been estimated. This is almost the same as -0.52 µg.m^{-3} per year estimated in this report.

Figure A3.5 Time series of population-weighted concentration for NO_2 annual average based on mapping for trends (blue) and regular mapping (red) for entire area and EU28, 2005-2019

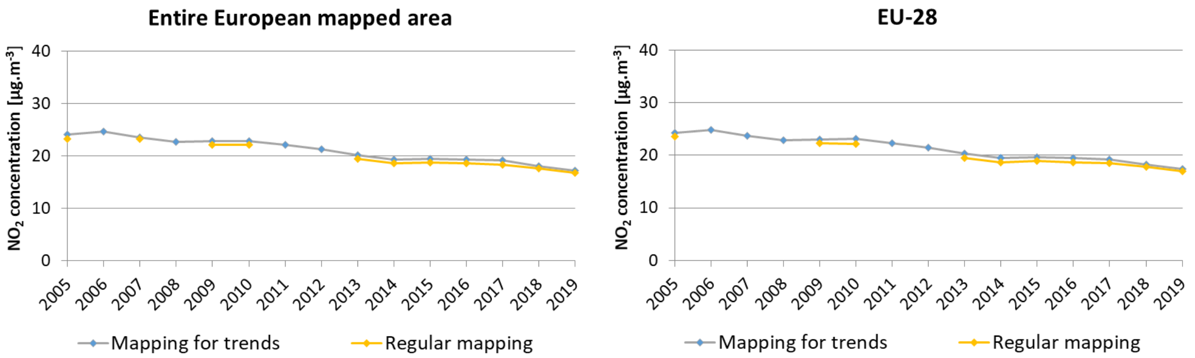
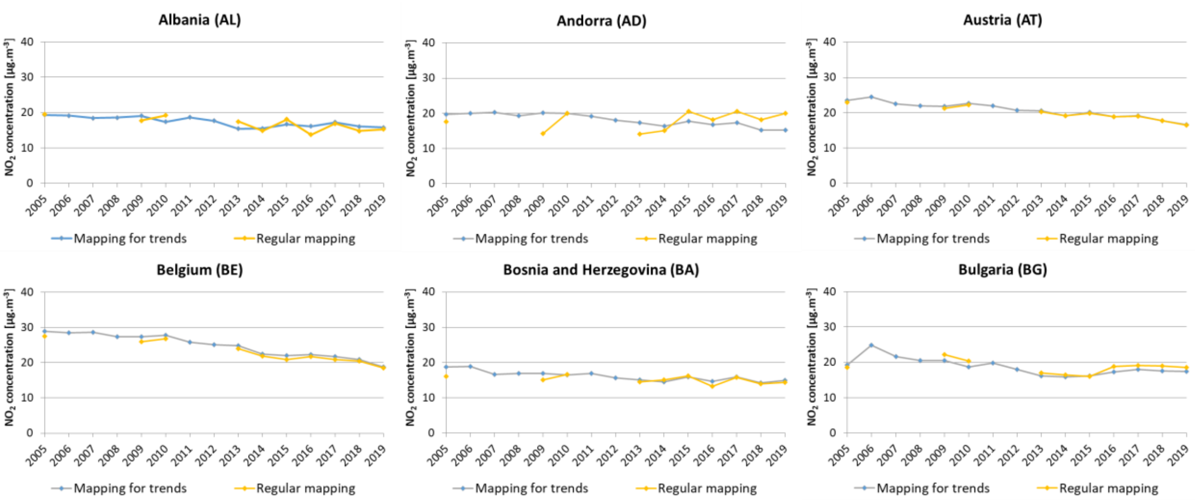
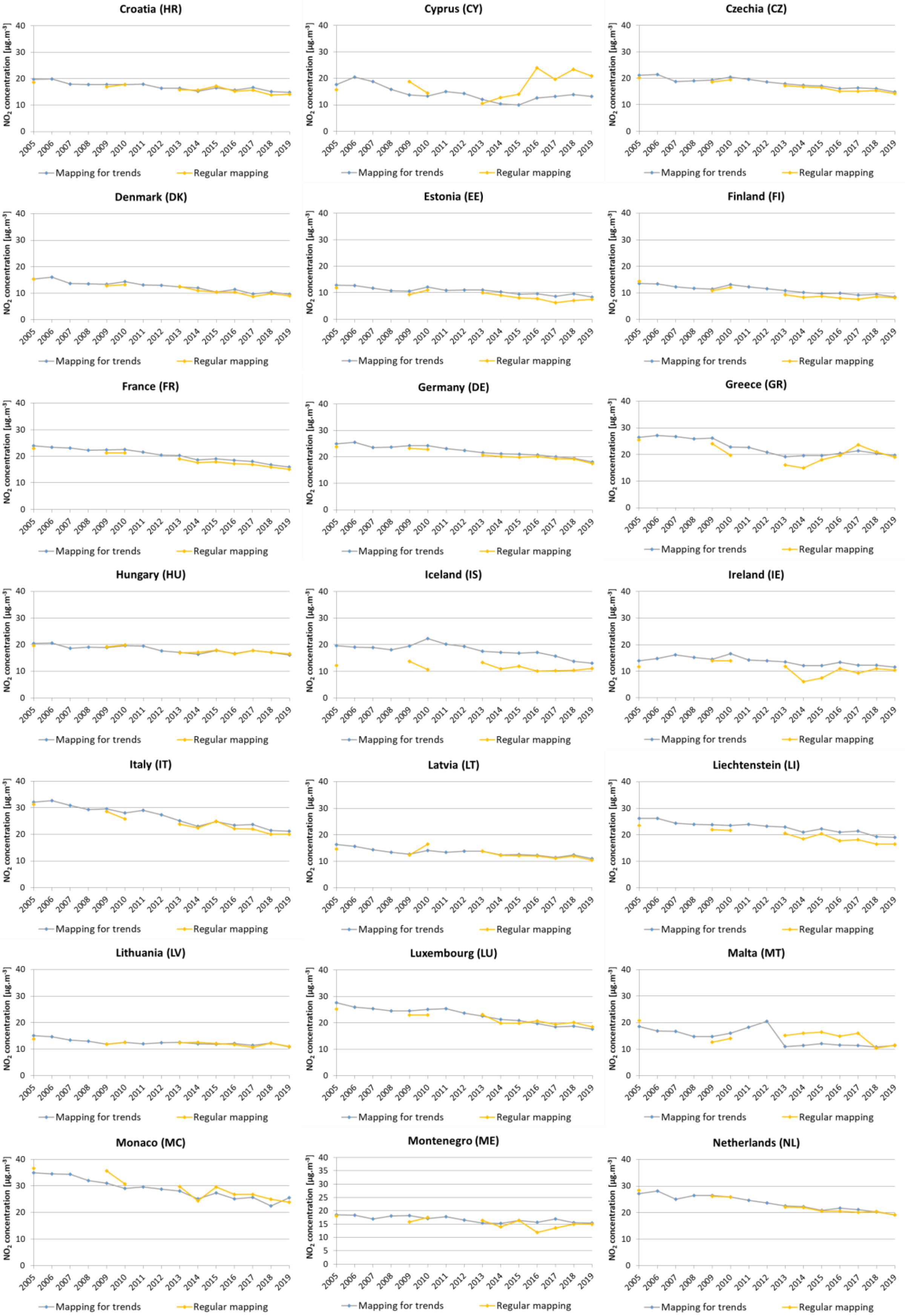
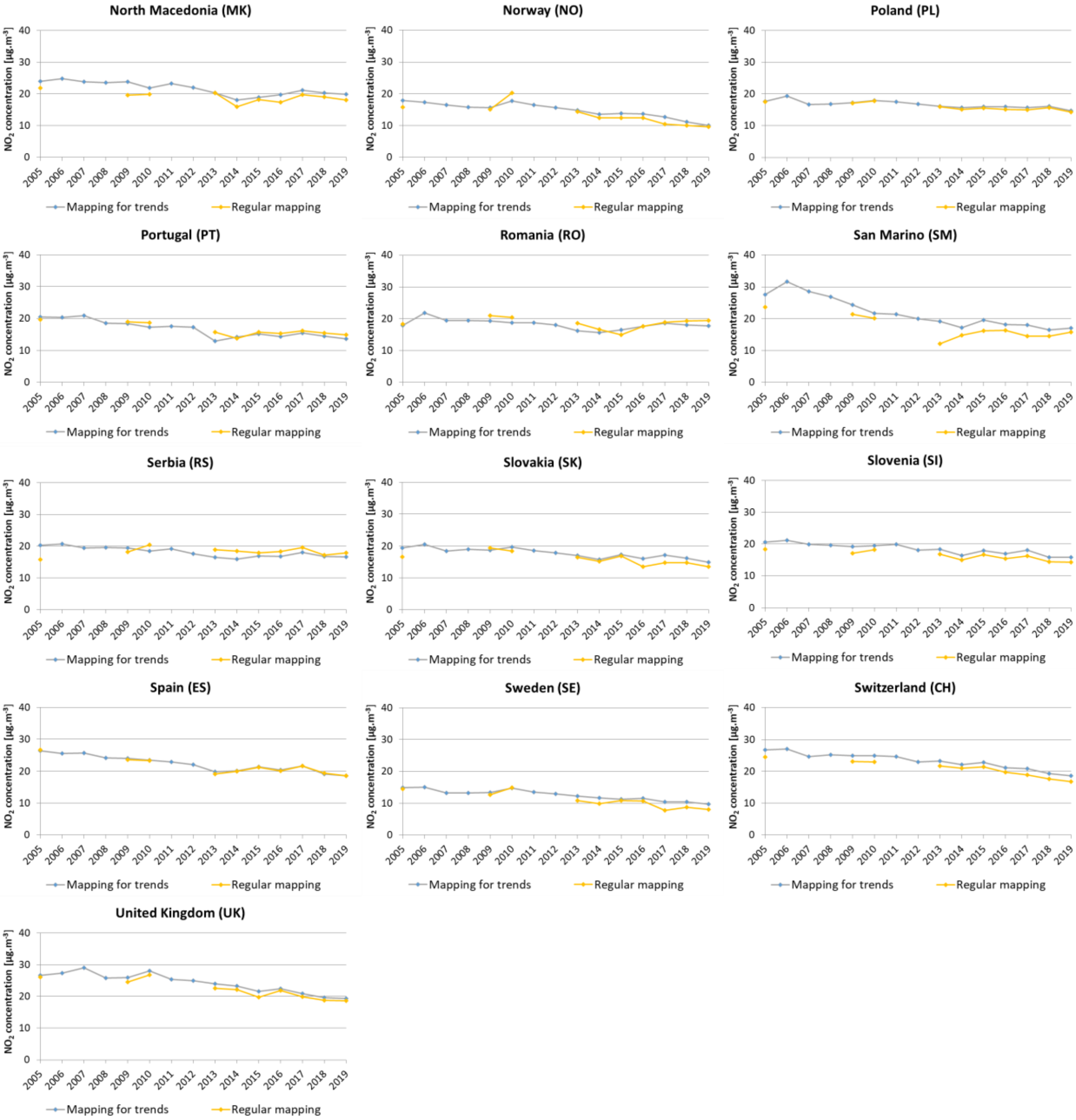


Figure A3.6 Time series of population-weighted concentration for NO_2 annual average based on mapping for trends (blue) and regular mapping (red) for individual countries, 2005-2019




Croatia (HR)
Cyprus (CY)
Czechia (CZ)
Denmark (DK)
Estonia (EE)
Finland (FI)
France (FR)
Germany (DE)
Greece (GR)
Hungary (HU)
Iceland (IS)
Ireland (IE)
Italy (IT)
Latvia (LT)
Liechtenstein (LI)
Lithuania (LV)
Luxembourg (LU)
Malta (MT)
Monaco (MC)
Montenegro (ME)
Netherlands (NL)
NO_2 concentration [µg.m^{-3}]
Mapping for trends
Regular mapping
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019


North Macedonia (MK)
Norway (NO)
Poland (PL)
Portugal (PT)
Romania (RO)
San Marino (SM)
Serbia (RS)
Slovakia (SK)
Slovenia (SI)
Spain (ES)
Sweden (SE)
Switzerland (CH)
United Kingdom (UK)
NO_2 concentration [μg.m^{-3}]
0
10
20
30
40
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
Mapping for trends
Regular mapping

Annex 4
Tables with time series and trends

This Annex 4 shows the numerical results of the air quality time series and trend analysis presented in this report. Tables A4.1 and A4.2 give the concentration values for PM_{10} annual average, for spatial averages and population-weighted averages, respectively. Table A4.3 shows the trend estimates and the relative trend estimates for spatial averages and population-weighted averages. Table A4.4 presents the trend estimates and the relative trend estimates for spatial averages, separately for urban and rural areas.

Tables A4.5-A4.8 present the results for ozone indicator SOMO35, in the same structure as Tables A4.1-A4.4 do for PM_{10} annual average. Tables A4.9-A4.12 show the results for NO_2 annual average.

All results are presented for the individual countries, for the entire area, for the EU-28 and for four large European regions.

Table A4.1: Concentration values for PM_{10} annual average, spatial average concentration in 2005-2019

Country, region		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Albania	AL	21.9	20.6	23.7	24.0	22.0	22.3	25.1	21.3	19.6	19.8	20.4	18.2	16.8	17.1	17.4
Andorra	AD	11.8	12.4	14.4	10.5	13.8	10.7	10.0	16.1	10.6	9.5	10.0	6.4	8.4	7.0	10.5
Austria	AT	15.8	15.5	14.4	13.7	14.1	14.7	14.9	13.3	13.1	11.7	12.0	10.5	10.8	12.8	10.7
Belgium	BE	24.8	25.0	21.2	20.4	23.5	23.1	22.1	19.6	20.4	16.9	17.6	16.7	16.8	18.1	15.8
Bosnia & Herzegovina	BA	18.2	19.2	19.1	18.9	18.5	17.4	20.1	17.9	16.3	16.0	16.5	14.5	14.9	16.0	14.0
Bulgaria	BG	20.1	20.7	23.9	24.0	25.2	27.2	25.5	22.4	19.4	21.8	21.0	18.9	17.5	17.3	16.7
Croatia	HR	22.7	23.9	23.2	22.7	21.3	20.6	23.7	20.5	18.7	17.4	19.0	17.0	17.7	18.1	14.8
Cyprus	CY	31.4	33.4	30.0	35.6	28.0	34.7	27.8	25.3	27.2	25.1	25.2	21.9	16.3	22.4	17.2
Czechia	CZ	25.6	24.8	19.7	19.0	20.7	22.3	21.3	20.3	20.3	20.0	18.4	17.2	17.3	20.2	15.5
Denmark	DK	19.6	21.2	18.1	17.8	16.6	16.1	18.5	15.6	15.9	18.4	15.7	13.7	13.2	15.4	14.3
Estonia	EE	15.1	13.8	12.2	9.7	8.5	11.6	9.5	8.8	9.0	10.2	8.7	8.1	7.5	9.2	7.9
Finland	FI	10.3	9.7	8.5	7.3	5.8	7.7	7.0	6.5	6.6	7.5	5.5	5.5	5.0	6.2	5.6
France	FR	19.5	16.8	18.7	16.8	17.0	16.7	17.3	16.3	15.1	12.4	14.3	12.9	13.2	13.0	12.6
Germany	DE	20.6	21.5	18.1	17.0	18.2	19.0	19.0	16.5	16.8	17.0	16.0	14.7	14.6	16.1	13.6
Greece	GR	23.2	22.8	25.9	26.9	24.8	28.5	24.0	22.1	21.6	20.4	20.5	19.0	15.6	17.1	17.2
Hungary	HU	30.4	28.9	27.0	26.1	26.9	27.0	30.3	25.4	24.7	25.4	25.2	23.2	24.1	23.8	19.2
Iceland	IS	6.0	5.1	6.4	5.9	4.0	5.1	4.7	4.5	5.1	4.7	4.0	3.8	3.8	3.9	4.3
Ireland	IE	14.5	14.8	14.6	13.8	8.9	11.7	11.7	10.4	13.2	9.8	9.8	9.5	8.8	9.9	9.3
Italy	IT	22.9	25.5	24.7	23.3	21.4	20.1	22.1	20.7	18.1	18.0	19.1	17.8	17.9	16.9	16.8
Latvia	LV	16.9	16.2	14.0	12.4	11.4	14.5	11.9	11.2	11.8	13.8	11.6	10.3	10.1	11.7	10.5
Liechtenstein	LI	15.0	15.5	13.9	11.8	12.0	12.3	12.2	10.7	10.9	9.7	10.3	9.0	8.7	9.6	9.4
Lithuania	LT	18.2	19.1	15.7	15.2	14.5	17.5	15.0	14.2	14.3	17.8	15.0	13.1	13.3	14.8	13.8
Luxembourg	LU	19.3	19.5	16.9	16.2	18.4	18.4	16.9	14.7	16.2	14.0	14.7	13.0	12.9	14.3	12.3
Malta	MT	31.3	27.7	29.5	30.4	29.4	30.7	28.7	25.5	25.6	23.1	22.9	22.8	18.6	20.1	25.4
Monaco	MC	31.6	30.8	28.4	26.6	25.1	22.7	25.3	24.5	20.2	19.1	21.2	19.6	20.9	18.1	19.8
Montenegro	ME	13.8	13.1	16.0	15.8	15.0	14.7	16.3	14.5	12.9	13.2	13.6	12.1	11.8	12.2	11.8
Netherlands	NL	26.4	27.7	24.8	22.7	23.8	23.9	24.8	20.7	20.1	20.1	18.1	17.4	17.5	18.8	17.1
North Macedonia	MK	21.1	20.3	25.1	26.2	23.7	25.4	26.8	22.1	19.4	20.0	19.9	19.0	16.1	16.5	15.8
Norway	NO	7.4	7.4	6.8	6.3	4.8	5.0	5.6	4.9	5.5	5.6	4.7	4.4	4.1	5.0	4.5
Poland	PL	22.9	26.3	20.1	20.1	22.5	25.9	24.1	23.3	22.3	24.9	21.6	20.1	20.7	23.3	20.4
Portugal	PT	22.1	18.2	19.2	14.7	14.3	15.7	16.4	14.6	13.6	13.5	15.2	14.1	15.6	13.4	12.4
Romania	RO	23.1	22.8	24.4	24.1	26.4	25.8	25.6	23.2	19.8	25.1	22.4	20.1	20.0	20.0	18.4
San Marino	SM	24.9	30.6	28.7	25.7	23.7	22.5	26.5	24.6	19.7	19.9	23.0	20.5	21.3	19.7	20.2
Serbia	RS	24.5	24.6	25.7	25.6	26.4	25.8	28.5	24.0	21.8	23.6	23.4	21.1	20.8	20.5	18.5
Slovakia	SK	27.1	25.5	20.1	21.3	21.9	23.8	23.9	22.0	21.5	22.3	19.4	17.6	19.0	20.2	16.3
Slovenia	SI	20.3	22.5	20.7	20.3	19.6	19.3	21.8	19.4	17.5	15.5	17.1	14.7	16.1	16.7	14.0
Spain	ES	18.4	16.5	19.2	17.2	16.0	14.8	15.0	15.2	12.7	13.5	14.9	14.0	14.6	12.7	12.7
Sweden	SE	9.2	9.3	8.4	7.7	6.0	6.2	7.2	6.0	6.5	7.4	6.2	5.7	5.2	6.4	5.7
Switzerland	CH	12.5	13.2	12.0	10.9	11.1	10.5	10.9	9.8	9.4	8.8	9.1	7.8	8.3	8.7	7.8
United Kingdom	UK	16.3	17.1	15.7	14.2	11.6	13.0	13.7	11.9	13.3	11.2	10.7	10.7	10.3	11.2	10.6
Total		**17.7**	**17.6**	**17.1**	**16.1**	**15.6**	**16.2**	**16.4**	**14.9**	**14.2**	**14.5**	**14.0**	**12.9**	**12.9**	**13.4**	**12.3**
EU-28		**18.7**	**18.5**	**17.7**	**16.6**	**16.2**	**16.8**	**16.9**	**15.5**	**14.8**	**15.0**	**14.6**	**13.5**	**13.5**	**14.0**	**12.8**
Northern		**10.4**	**10.3**	**9.1**	**8.3**	**6.8**	**7.8**	**7.8**	**6.9**	**7.3**	**8.3**	**6.7**	**6.3**	**5.9**	**7.0**	**6.4**
North-western		**17.3**	**16.2**	**16.6**	**15.1**	**14.1**	**14.9**	**15.1**	**13.5**	**13.9**	**11.4**	**12.1**	**11.4**	**11.4**	**11.9**	**11.2**
Central & South-eastern		**22.2**	**23.0**	**20.5**	**20.0**	**21.6**	**22.8**	**22.4**	**20.3**	**19.3**	**21.0**	**19.2**	**17.6**	**17.7**	**19.0**	**16.5**
Southern		**20.7**	**20.1**	**21.5**	**20.2**	**19.0**	**18.6**	**19.4**	**18.2**	**16.1**	**16.1**	**17.1**	**15.7**	**15.8**	**14.9**	**14.5**
Serbia without Kosovo	RS	24.6	24.9	25.6	25.6	26.6	25.9	28.6	24.0	21.8	23.7	23.6	21.2	21.1	20.7	18.6
Kosovo	KS	23.8	22.9	26.5	25.8	24.8	25.1	28.2	24.1	21.2	22.5	21.8	20.5	18.8	19.5	17.7

Table A4.2: Concentration values for PM_{10} annual average, population-weighted average concentration in 2005-2019

Country, region		**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Albania	AL	43.2	38.8	37.2	36.1	34.2	32.7	39.3	33.0	34.1	32.5	33.7	31.8	29.0	28.4	25.7
Andorra	AD	24.8	25.6	28.8	20.1	25.2	22.7	22.0	25.7	17.8	16.7	19.6	14.4	18.7	13.5	20.5
Austria	AT	26.4	27.1	22.7	21.9	22.3	23.9	24.3	20.9	21.0	18.8	19.0	16.9	17.4	19.2	16.4
Belgium	BE	29.2	29.1	25.7	24.2	27.3	26.7	26.1	23.5	24.1	20.7	20.8	20.0	19.8	21.1	18.6
Bosnia & Herzegovina	BA	33.5	32.5	30.5	28.8	28.4	26.9	31.6	26.7	26.7	26.2	27.9	26.4	25.7	25.8	24.7
Bulgaria	BG	41.3	44.5	43.3	46.8	41.8	40.3	45.5	39.5	37.2	37.3	34.5	32.8	31.3	30.4	26.6
Croatia	HR	32.4	32.3	29.6	28.9	27.9	27.0	30.6	25.8	25.2	23.5	26.3	24.4	24.3	23.6	20.6
Cyprus	CY	37.7	40.5	35.8	42.1	41.2	44.3	34.1	33.7	35.4	31.8	32.7	27.0	26.2	28.7	25.7
Czechia	CZ	33.1	34.1	26.0	24.9	26.7	29.1	28.1	26.0	26.3	26.0	23.5	22.1	22.8	24.9	19.4
Denmark	DK	21.7	23.9	20.6	19.4	18.2	16.8	20.9	16.8	17.0	19.6	17.0	15.2	14.8	17.1	16.1
Estonia	EE	18.0	17.8	16.1	12.9	13.0	15.3	12.8	12.0	13.0	14.2	11.8	11.6	10.0	12.3	11.6
Finland	FI	15.0	15.3	14.0	12.0	11.8	13.2	11.7	10.9	10.9	12.1	9.9	10.1	8.4	10.5	9.1
France	FR	25.4	20.8	24.5	22.3	23.7	22.9	23.5	21.8	20.8	16.9	18.8	17.4	17.4	16.9	16.2
Germany	DE	24.2	25.4	21.5	20.4	21.8	22.2	22.1	19.3	19.9	19.3	18.3	16.9	16.9	18.0	15.4
Greece	GR	44.3	39.3	38.5	39.2	37.4	38.3	33.8	32.3	34.8	29.2	29.3	28.1	24.0	25.3	23.7
Hungary	HU	33.5	32.2	29.3	28.6	29.9	29.9	33.6	27.9	27.4	27.5	27.7	25.6	26.8	26.1	22.2
Iceland	IS	17.0	16.9	12.6	15.0	10.0	11.0	14.1	9.1	14.2	13.8	11.8	12.0	15.8	12.9	10.3
Ireland	IE	15.9	16.5	15.7	14.7	12.4	14.2	13.6	11.8	14.3	12.1	11.9	11.4	10.3	11.8	11.8
Italy	IT	34.6	36.3	33.7	31.0	29.7	28.0	31.1	28.5	25.9	24.8	27.4	24.7	25.4	23.5	23.7
Latvia	LV	23.8	23.4	20.4	19.4	20.5	23.1	19.1	19.0	21.1	21.5	17.7	17.5	16.5	19.0	19.3
Liechtenstein	LI	24.0	24.2	20.3	17.9	18.7	19.4	19.0	16.7	17.4	14.7	16.1	13.9	13.3	13.9	12.7
Lithuania	LT	22.0	22.2	19.5	18.8	20.5	23.2	20.2	18.5	20.3	22.2	19.1	18.3	17.4	19.1	19.8
Luxembourg	LU	22.6	21.8	21.2	19.0	21.7	21.8	20.5	18.6	19.9	18.0	18.6	16.9	16.2	17.1	15.2
Malta	MT	36.2	30.3	32.0	32.0	30.3	32.3	29.8	26.7	27.0	26.9	26.0	24.3	19.6	20.8	30.9
Monaco	MC	31.9	30.8	28.6	26.7	25.5	23.2	25.7	25.1	20.6	19.4	21.5	19.8	21.1	18.5	19.9
Montenegro	ME	34.7	30.4	30.6	29.4	27.8	26.8	31.7	27.0	26.0	25.7	26.7	26.2	24.4	23.5	22.6
Netherlands	NL	28.2	29.3	26.4	24.3	25.3	25.1	26.0	21.8	21.2	21.0	19.1	18.5	18.5	19.6	18.1
North Macedonia	MK	56.6	54.1	48.5	49.9	46.6	43.4	55.5	43.4	43.0	40.8	40.0	39.5	35.1	34.4	30.2
Norway	NO	17.3	16.7	15.0	15.0	13.8	14.1	14.5	12.5	13.3	12.7	11.6	11.4	9.9	11.7	10.5
Poland	PL	31.8	35.7	27.7	28.4	30.8	34.9	33.9	32.0	30.3	31.6	29.2	27.7	28.5	30.1	25.1
Portugal	PT	29.3	27.0	26.0	21.1	21.4	20.9	23.6	20.7	18.9	17.6	18.6	16.6	17.6	16.3	17.3
Romania	RO	33.8	37.0	34.8	36.1	33.1	31.4	34.0	32.7	29.2	32.5	29.2	27.4	24.7	27.5	25.1
San Marino	SM	28.3	32.9	30.2	27.4	26.0	25.1	28.9	26.9	21.9	21.5	25.2	22.2	23.2	21.1	22.6
Serbia	RS	42.5	41.2	38.4	38.9	36.6	34.1	41.3	34.0	33.0	33.2	34.1	33.1	30.9	30.2	28.2
Slovakia	SK	34.3	34.4	28.7	28.4	28.9	31.5	33.2	29.1	27.7	26.9	25.5	23.6	25.3	25.1	21.0
Slovenia	SI	30.8	32.1	28.9	27.7	26.6	26.4	29.8	25.5	24.5	21.9	24.8	22.5	23.3	23.0	19.5
Spain	ES	31.0	30.7	30.3	26.0	24.7	22.9	23.1	22.0	19.2	19.9	21.1	19.6	20.5	18.8	18.6
Sweden	SE	17.6	17.3	15.2	15.0	13.5	12.8	14.5	12.1	12.7	13.5	12.1	11.2	10.4	11.8	10.7
Switzerland	CH	23.4	23.9	21.1	20.1	21.2	20.6	20.9	18.0	18.8	16.9	16.9	14.7	15.0	15.3	13.7
United Kingdom	UK	22.1	22.9	22.1	20.0	18.5	18.8	20.4	16.8	17.1	16.7	15.5	15.7	14.6	15.4	15.7
Total		**28.5**	**28.7**	**26.6**	**25.1**	**25.0**	**25.0**	**26.0**	**23.3**	**22.6**	**21.8**	**21.7**	**20.3**	**20.1**	**20.4**	**18.9**
EU-28		**28.0**	**28.3**	**26.2**	**24.5**	**24.6**	**24.6**	**25.4**	**22.9**	**22.1**	**21.4**	**21.2**	**19.9**	**19.8**	**20.1**	**18.6**
Northern		**18.7**	**18.9**	**16.7**	**15.9**	**15.2**	**15.5**	**15.9**	**13.9**	**14.5**	**15.6**	**13.5**	**12.9**	**11.8**	**13.7**	**12.8**
North-western		**24.1**	**23.0**	**23.4**	**21.4**	**21.6**	**21.5**	**22.3**	**19.3**	**19.4**	**17.5**	**17.3**	**16.8**	**16.3**	**16.8**	**16.3**
Central & South-eastern		**28.8**	**30.6**	**26.0**	**25.7**	**26.5**	**27.6**	**28.0**	**25.2**	**24.7**	**24.8**	**23.3**	**21.7**	**21.7**	**22.9**	**19.6**
Southern		**34.0**	**33.5**	**32.1**	**29.4**	**28.3**	**26.9**	**29.0**	**26.4**	**24.5**	**23.4**	**25.2**	**23.1**	**23.2**	**21.9**	**21.5**
Serbia without Kosovo	RS	41.7	40.9	37.6	38.7	36.4	33.9	40.5	33.5	32.7	33.1	34.2	32.9	30.9	30.2	28.4
Kosovo	KS	45.7	42.4	41.5	39.9	37.3	34.9	44.4	36.3	34.0	33.7	33.5	34.0	30.9	30.6	27.5

Table A4.3: Trend estimates and relative trend estimates for PM_{10} annual average, spatial average (left) and population-weighted average (right) concentration in 2005-2019. Trend indicators show significance of trends (Mann-Kendall test) and Sen´s slope estimate Q with its confidence interval (Qmin95, Qmax95) at 95 %.

Country, region		PM_{10} annual average, spatial average								PM_{10} annual mean, population-weighted average							
		Sign.	Slope [µg.m^{-3}.yr^{-1}]			Sign.	Slope [%.yr^{-1}]			Sign.	Slope [µg.m^{-3}.yr^{-1}]			Sign.	Slope [%.yr^{-1}]		
			Q	Qmin95	Qmax95		Q	Qmin95	Qmax95		Q	Qmin95	Qmax95		Q	Qmin95	Qmax95
Albania	AL	**	-0.49	-0.69	-0.26	**	-2.04	-2.87	-1.07	***	-0.89	-1.41	-0.60	***	-2.24	-3.56	-1.52
Andorra	AD	*	-0.33	-0.64	-0.12	*	-2.65	-5.16	-0.95	**	-0.73	-1.18	-0.41	**	-2.78	-4.46	-1.56
Austria	AT	***	-0.36	-0.47	-0.23	***	-2.30	-3.01	-1.47	***	-0.65	-0.89	-0.48	***	-2.56	-3.51	-1.88
Belgium	BE	***	-0.61	-0.83	-0.43	***	-2.51	-3.42	-1.76	***	-0.71	-0.92	-0.52	***	-2.48	-3.22	-1.81
Bosnia & Herzegovina	BA	***	-0.35	-0.47	-0.24	***	-1.81	-2.39	-1.24	***	-0.48	-0.77	-0.29	***	-1.52	-2.44	-0.91
Bulgaria	BG	*	-0.56	-0.90	-0.18	*	-2.24	-3.60	-0.72	***	-1.25	-1.63	-0.98	***	-2.68	-3.51	-2.10
Croatia	HR	***	-0.57	-0.72	-0.42	***	-2.82	-3.54	-1.67	***	-0.72	-0.91	-0.52	***	-3.22	-3.81	-2.68
Cyprus	CY	***	-1.01	-1.57	-0.69	***	-2.94	-3.53	-2.28	***	-1.09	-1.52	-0.65	***	-2.97	-3.49	-2.46
Czechia	CZ	**	-0.60	-0.73	-0.18	***	-2.99	-4.64	-2.05	**	-0.80	-1.05	-0.28	***	-2.62	-3.65	-1.57
Denmark	DK	***	-0.42	-0.58	-0.22	***	-2.21	-2.97	-1.32	**	-0.48	-0.67	-0.22	***	-2.51	-3.17	-1.70
Estonia	EE	**	-0.38	-0.59	-0.17	***	-2.17	-3.01	-1.17	***	-0.42	-0.62	-0.16	**	-2.24	-3.11	-1.00
Finland	FI	***	-0.32	-0.43	-0.16	***	-2.10	-3.07	-1.16	***	-0.40	-0.55	-0.27	***	-3.03	-3.94	-1.86
France	FR	***	-0.48	-0.56	-0.35	***	-3.46	-4.70	-1.71	***	-0.66	-0.79	-0.45	***	-2.76	-3.77	-1.87
Germany	DE	***	-0.45	-0.61	-0.27	**	-2.45	-2.97	-0.74	***	-0.61	-0.77	-0.41	**	-2.47	-3.23	-0.86
Greece	GR	***	-0.78	-0.97	-0.46	***	-2.49	-2.95	-1.85	***	-1.39	-1.64	-1.16	***	-2.60	-3.11	-1.76
Hungary	HU	***	-0.47	-0.70	-0.29	***	-2.33	-2.96	-1.71	***	-0.56	-0.73	-0.29	***	-2.33	-2.93	-1.68
Iceland	IS	**	-0.15	-0.22	-0.06	**	-2.56	-3.80	-0.96		-0.26	-0.51	0.18		-1.66	-3.26	1.15
Ireland	IE	**	-0.42	-0.57	-0.22	**	-2.97	-4.00	-1.54	***	-0.40	-0.52	-0.24	***	-2.54	-3.24	-1.49
Italy	IT	***	-0.60	-0.73	-0.42	***	-2.42	-2.92	-1.68	***	-0.86	-1.07	-0.61	***	-2.49	-3.10	-1.76
Latvia	LV	**	-0.34	-0.57	-0.15	**	-2.30	-3.85	-1.02	**	-0.34	-0.57	-0.11	**	-1.57	-2.62	-0.48
Liechtenstein	LI	***	-0.44	-0.55	-0.29	***	-3.00	-3.77	-1.99	***	-0.73	-0.90	-0.53	***	-3.19	-3.95	-2.32
Lithuania	LT	**	-0.26	-0.47	-0.06	**	-1.54	-2.84	-0.36		-0.21	-0.39	0.03		-0.96	-1.80	0.15
Luxembourg	LU	***	-0.45	-0.65	-0.36	***	-2.36	-3.40	-1.88	***	-0.51	-0.63	-0.34	***	-2.25	-2.79	-1.51
Malta	MT	***	-0.84	-1.09	-0.42	***	-2.68	-3.48	-1.34	**	-0.93	-1.25	-0.50	**	-2.70	-3.62	-1.44
Monaco	MC	***	-0.90	-1.13	-0.68	***	-2.98	-3.74	-2.24	***	-0.91	-1.19	-0.68	***	-2.98	-3.90	-2.23
Montenegro	ME	**	-0.31	-0.43	-0.11	**	-1.91	-2.64	-0.70	***	-0.61	-0.90	-0.46	***	-1.95	-2.89	-1.47
Netherlands	NL	***	-0.74	-0.91	-0.54	***	-2.81	-3.46	-2.04	***	-0.81	-0.95	-0.61	***	-2.86	-3.37	-2.17
North Macedonia	MK	**	-0.74	-0.99	-0.20	**	-2.77	-3.73	-0.76	***	-1.63	-1.89	-1.18	***	-2.94	-3.41	-2.13
Norway	NO	**	-0.21	-0.29	-0.09	**	-3.08	-4.24	-1.27	***	-0.48	-0.58	-0.34	***	-2.88	-3.47	-2.02
Poland	PL		-0.17	-0.51	0.14		-0.75	-2.19	0.58	*	-0.37	-0.85	0.00	*	-1.13	-2.59	0.01
Portugal	PT	**	-0.38	-0.65	-0.16	**	-2.06	-3.58	-0.90	***	-0.75	-1.06	-0.48	***	-2.89	-4.05	-1.86
Romania	RO	*	-0.34	-0.74	-0.12	*	-1.37	-2.96	-0.49	***	-0.79	-1.08	-0.56	***	-2.18	-2.97	-1.55
San Marino	SM	**	-0.65	-0.91	-0.31	**	-2.30	-3.23	-1.12	**	-0.64	-0.97	-0.34	**	-2.18	-3.28	-1.15
Serbia	RS	**	-0.47	-0.70	-0.24	**	-1.75	-2.63	-0.89	***	-0.88	-1.19	-0.66	***	-2.12	-2.87	-1.60
Slovakia	SK	**	-0.53	-0.79	-0.25	**	-2.07	-3.08	-0.98	***	-0.77	-1.13	-0.41	***	-2.28	-3.33	-1.20
Slovenia	SI	***	-0.51	-0.70	-0.33	***	-2.33	-3.21	-1.53	***	-0.74	-0.97	-0.49	***	-2.42	-3.17	-1.59
Spain	ES	***	-0.37	-0.55	-0.21	**	-3.01	-4.76	-1.39	***	-0.89	-1.16	-0.55	***	-2.56	-3.83	-0.99
Sweden	SE	**	-0.25	-0.34	-0.09	**	-2.90	-3.94	-1.03	***	-0.44	-0.60	-0.29	***	-2.72	-3.68	-1.79
Switzerland	CH	***	-0.37	-0.45	-0.29	***	-1.59	-2.39	-0.99	***	-0.69	-0.82	-0.57	***	-1.71	-2.24	-0.89
United Kingdom	UK	***	-0.44	-0.59	-0.28	***	-2.81	-3.78	-1.83	***	-0.56	-0.72	-0.41	***	-2.58	-3.29	-1.88
Total		***	**-0.39**	**-0.44**	**-0.32**	***	**-2.18**	**-2.49**	**-1.79**	***	**-0.68**	**-0.76**	**-0.57**	***	**-2.40**	**-2.68**	**-2.02**
EU-28		***	**-0.41**	**-0.46**	**-0.33**	***	**-2.22**	**-2.50**	**-1.80**	***	**-0.67**	**-0.76**	**-0.56**	***	**-2.40**	**-2.74**	**-2.02**
Northern		***	**-0.27**	**-0.38**	**-0.14**	***	**-2.84**	**-4.01**	**-1.47**	***	**-0.42**	**-0.58**	**-0.27**	***	**-2.36**	**-3.28**	**-1.53**
North-western		***	**-0.44**	**-0.55**	**-0.34**	***	**-2.65**	**-3.28**	**-2.06**	***	**-0.60**	**-0.71**	**-0.51**	***	**-2.49**	**-2.95**	**-2.13**
Central & South-eastern		**	**-0.40**	**-0.54**	**-0.16**	**	**-1.71**	**-2.32**	**-0.67**	***	**-0.59**	**-0.84**	**-0.39**	***	**-2.02**	**-2.88**	**-1.35**
Southern		***	**-0.46**	**-0.58**	**-0.38**	***	**-2.22**	**-2.80**	**-1.80**	***	**-0.91**	**-1.05**	**-0.69**	***	**-2.70**	**-3.12**	**-2.06**
Serbia without Kosovo	RS	**	-0.45	-0.69	-0.18	**	-1.68	-2.60	-0.67	***	-0.82	-1.15	-0.63	***	-2.02	-2.82	-1.55
Kosovo	KS	**	-0.60	-0.77	-0.33	**	-2.19	-2.83	-1.21	***	-1.05	-1.31	-0.82	***	-2.41	-3.00	-1.89

Table A4.4: Trend estimates and relative trend estimates for PM_{10} annual average, spatial average concentration in 2005-2019, urban (left) and rural (right) areas. Trend indicators show significance of trends (Mann-Kendall test) and Sen´s slope estimate Q with its confidence interval (Qmin95, Qmax95) at 95 %.

Country, region		PM_{10} annual average, spatial average, urban areas								PM_{10} annual average, spatial average, rural areas							
		Sign.	Slope [µg.m^{-3}.yr^{-1}]			Sign.	Slope [%.yr^{-1}]			Sign.	Slope [µg.m^{-3}.yr^{-1}]			Sign.	Slope [%.yr^{-1}]		
			Q	Qmin95	Qmax95		Q	Qmin95	Qmax95		Q	Qmin95	Qmax95		Q	Qmin95	Qmax95
Albania	AL	***	-0.65	-0.58	-1.23	***	-2.25	-3.24	-1.72	**	-0.47	-0.68	-0.21	**	-2.02	-2.93	-0.92
Andorra	AD	**	-0.40	-0.11	-1.15	**	-2.77	-4.54	-1.58	*	-0.32	-0.61	-0.07	*	-2.71	-5.25	-0.61
Austria	AT	***	-0.50	-0.39	-0.89	***	-2.71	-3.52	-1.96	***	-0.34	-0.45	-0.21	***	-2.23	-2.99	-1.40
Belgium	BE	***	-0.51	-0.46	-0.88	***	-2.45	-3.15	-1.83	***	-0.59	-0.81	-0.40	***	-2.55	-3.49	-1.72
Bosnia & Herzegovina	BA	***	-0.29	-0.21	-0.79	***	-1.53	-2.55	-0.92	***	-0.36	-0.46	-0.21	***	-1.94	-2.46	-1.09
Bulgaria	BG	***	-0.81	-0.71	-1.55	***	-2.76	-3.47	-1.80	*	-0.51	-0.88	-0.15	*	-2.12	-3.61	-0.61
Croatia	HR	***	-0.95	-0.87	-1.37	***	-3.15	-3.56	-2.47	***	-0.77	-0.96	-0.43	***	-2.83	-3.54	-1.58
Cyprus	CY	***	-0.57	-0.52	-0.80	***	-2.92	-3.52	-2.48	***	-0.32	-0.41	-0.24	***	-2.92	-3.66	-2.19
Czechia	CZ	***	-0.57	-0.36	-1.51	***	-2.43	-3.73	-1.40	***	-1.03	-1.61	-0.70	***	-3.07	-4.82	-2.08
Denmark	DK	***	-0.41	-0.30	-0.75	***	-2.48	-3.14	-1.72	***	-0.43	-0.58	-0.25	***	-2.15	-2.95	-1.27
Estonia	EE	**	-0.22	-0.10	-0.69	**	-2.36	-3.17	-1.01	***	-0.42	-0.57	-0.21	***	-2.19	-2.95	-1.10
Finland	FI	***	-0.51	-0.42	-1.05	***	-3.00	-3.86	-1.89	***	-0.36	-0.53	-0.19	***	-2.05	-3.02	-1.08
France	FR	***	-0.28	-0.23	-0.54	***	-2.79	-3.76	-1.94	***	-0.32	-0.43	-0.16	***	-3.47	-4.71	-1.71
Germany	DE	**	-0.30	-0.20	-1.07	**	-2.50	-3.31	-0.92	**	-0.59	-0.70	-0.18	**	-2.47	-2.93	-0.74
Greece	GR	***	-0.46	-0.34	-0.78	***	-2.70	-3.13	-1.86	***	-0.45	-0.56	-0.35	***	-2.44	-3.02	-1.88
Hungary	HU	***	-0.49	-0.41	-0.92	***	-2.31	-2.96	-1.56	***	-0.57	-0.72	-0.41	***	-2.36	-3.01	-1.72
Iceland	IS		0.19	0.28	-0.50		-1.61	-3.39	1.31	**	-0.15	-0.22	-0.06	**	-2.59	-3.80	-0.95
Ireland	IE	***	-0.22	-0.14	-0.48	***	-2.27	-3.00	-1.37	**	-0.42	-0.57	-0.21	**	-3.00	-4.05	-1.48
Italy	IT	***	-0.57	-0.48	-1.05	***	-2.47	-3.11	-1.68	***	-0.59	-0.69	-0.39	***	-2.47	-2.88	-1.64
Latvia	LV	*	-0.10	0.02	-0.51	*	-1.42	-2.50	-0.49	**	-0.34	-0.57	-0.15	**	-2.34	-3.87	-1.02
Liechtenstein	LI	***	-0.53	-0.47	-0.91	***	-3.19	-3.93	-2.31	***	-0.34	-0.46	-0.20	***	-2.89	-3.90	-1.68
Lithuania	LT		0.03	0.15	-0.40		-0.98	-1.86	0.14	**	-0.25	-0.47	-0.06	**	-1.54	-2.87	-0.39
Luxembourg	LU	***	-0.35	-0.27	-0.64	***	-2.23	-2.88	-1.55	***	-0.44	-0.64	-0.34	***	-2.41	-3.47	-1.87
Malta	MT	**	-0.45	-0.26	-1.24	**	-2.55	-3.67	-1.33	**	-0.74	-1.15	-0.40	**	-2.47	-3.82	-1.34
Monaco	MC	***	-0.68	-0.53	-1.13	***	-2.98	-3.74	-2.24								
Montenegro	ME	***	-0.48	-0.43	-0.90	***	-1.99	-2.85	-1.53	**	-0.30	-0.42	-0.09	**	-1.92	-2.66	-0.58
Netherlands	NL	***	-0.57	-0.51	-0.94	***	-2.81	-3.40	-2.05	***	-0.73	-0.90	-0.53	***	-2.79	-3.47	-2.04
North Macedonia	MK	***	-1.22	-1.08	-1.72	***	-2.98	-3.41	-2.41	**	-0.72	-0.97	-0.15	**	-2.78	-3.75	-0.58
Norway	NO	***	-0.35	-0.31	-0.57	***	-2.74	-3.41	-2.11	**	-0.21	-0.29	-0.08	**	-3.11	-4.19	-1.23
Poland	PL	*	-0.04	0.14	-0.95	*	-1.24	-2.85	-0.13		-0.15	-0.50	0.19		-0.65	-2.23	0.85
Portugal	PT	***	-0.50	-0.42	-1.02	***	-2.89	-4.10	-2.00	**	-0.36	-0.65	-0.11	**	-1.99	-3.62	-0.60
Romania	RO	***	-0.52	-0.41	-1.04	***	-2.24	-2.95	-1.48	*	-0.39	-0.74	-0.12	*	-1.57	-3.02	-0.51
San Marino	SM	**	-0.34	-0.26	-0.96	**	-2.19	-3.26	-1.16	**	-0.59	-0.82	-0.23	**	-2.27	-3.18	-0.90
Serbia	RS	***	-0.68	-0.57	-1.20	***	-2.17	-2.92	-1.67	**	-0.43	-0.70	-0.22	**	-1.67	-2.74	-0.84
Slovakia	SK	***	-0.41	-0.31	-1.15	***	-2.27	-3.39	-1.21	**	-0.51	-0.75	-0.24	**	-2.05	-3.03	-0.95
Slovenia	SI	***	-0.52	-0.44	-0.99	***	-2.43	-3.22	-1.70	***	-0.48	-0.70	-0.31	***	-2.28	-3.31	-1.48
Spain	ES	***	-0.16	-0.09	-0.60	***	-2.52	-3.68	-0.99	**	-0.37	-0.59	-0.17	**	-2.99	-4.81	-1.41
Sweden	SE	***	-0.31	-0.24	-0.61	***	-2.85	-3.74	-1.90	**	-0.25	-0.34	-0.09	**	-2.90	-3.95	-1.01
Switzerland	CH	***	-0.28	-0.24	-0.73	***	-1.72	-2.29	-0.89	***	-0.46	-0.71	-0.29	***	-1.59	-2.44	-0.99
United Kingdom	UK	***	-0.39	-0.32	-0.71	***	-2.57	-3.33	-1.83	***	-0.42	-0.57	-0.25	***	-2.82	-3.83	-1.72
Total		***	**-0.55**	**-0.50**	**-0.74**	***	**-2.35**	**-2.69**	**-2.01**	***	**-0.37**	**-0.42**	**-0.29**	***	**-2.17**	**-2.48**	**-1.68**
EU-28		***	**-0.54**	**-0.50**	**-0.74**	***	**-2.30**	**-2.76**	**-2.02**	***	**-0.39**	**-0.45**	**-0.31**	***	**-2.17**	**-2.52**	**-1.75**
Northern		***	**-0.29**	**-0.22**	**-0.57**	***	**-2.42**	**-3.26**	**-1.64**	***	**-0.27**	**-0.38**	**-0.14**	***	**-2.85**	**-4.03**	**-1.46**
North-western		***	**-0.47**	**-0.40**	**-0.70**	***	**-2.43**	**-2.96**	**-1.97**	***	**-0.43**	**-0.52**	**-0.33**	***	**-2.66**	**-3.25**	**-2.04**
Central & South-eastern		***	**-0.40**	**-0.28**	**-0.83**	***	**-2.07**	**-2.88**	**-1.39**	**	**-0.38**	**-0.51**	**-0.14**	**	**-1.68**	**-2.26**	**-0.64**
Southern		***	**-0.66**	**-0.60**	**-1.01**	***	**-2.64**	**-3.12**	**-2.03**	***	**-0.45**	**-0.57**	**-0.35**	***	**-2.23**	**-2.80**	**-1.71**
Serbia without Kosovo	RS	***	-0.84	-1.18	-0.65	***	-2.08	-2.91	-1.60	**	-0.44	-0.69	-0.17	**	-1.69	-2.68	-0.65
Kosovo	KS	***	-1.04	-1.30	-0.82	***	-2.42	-3.03	-1.91	**	-0.55	-0.73	-0.20	**	-2.21	-2.94	-0.81

Table A4.5: Concentration values for ozone indicator SOMO35, spatial average concentration in 2005-2019

Country, region		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Albania	AL	10 140	9 351	9 149	8 071	8 122	7 849	9 416	9 961	7 925	7 179	8 925	7 025	8 808	7 281	7 660
Andorra	AD	12 201	12 368	11 629	10 076	11 297	11 164	11 384	12 154	11 353	9 981	11 816	10 470	10 610	10 194	10 646
Austria	AT	8 472	8 935	8 189	7 229	7 381	7 312	8 074	7 655	7 597	6 423	8 736	6 563	7 400	8 701	7 834
Belgium	BE	3 653	4 815	2 885	2 978	3 101	2 954	3 210	2 532	3 040	2 777	3 424	2 672	3 105	5 027	3 935
Bosnia & Herzegovina	BA	8 453	8 228	8 122	7 169	7 327	6 635	7 864	8 448	6 695	5 795	7 773	5 790	7 415	7 004	7 014
Bulgaria	BG	8 256	6 105	8 025	7 257	8 014	6 983	8 291	8 828	7 035	5 989	7 699	6 269	6 830	7 193	6 842
Croatia	HR	7 951	9 336	7 915	6 896	7 275	6 579	7 969	8 099	6 852	5 819	7 237	5 666	7 487	7 348	6 769
Cyprus	CY	11 927	9 240	10 685	8 863	10 346	9 351	10 443	10 514	9 973	9 096	10 064	9 521	9 995	9 921	9 403
Czechia	CZ	6 883	7 481	6 143	5 657	5 087	4 987	5 693	5 548	5 149	4 725	6 351	4 977	5 180	7 750	5 964
Denmark	DK	3 451	4 261	3 064	3 609	3 216	2 984	3 030	3 042	3 498	3 206	2 928	2 852	2 284	4 117	3 472
Estonia	EE	3 036	4 229	2 364	2 755	2 220	2 616	3 194	2 757	3 135	2 447	2 133	2 396	1 701	3 362	3 160
Finland	FI	3 072	3 953	1 781	2 221	1 877	2 089	2 308	1 906	2 416	1 851	1 479	1 668	1 248	2 731	2 574
France	FR	5 932	6 200	4 717	4 458	5 132	5 180	5 472	4 719	4 992	4 745	5 031	4 399	4 762	6 058	5 806
Germany	DE	5 158	5 882	4 593	4 648	4 374	4 385	4 607	4 163	4 333	4 057	5 067	4 081	3 786	6 529	5 325
Greece	GR	10 439	9 000	9 865	8 792	8 878	8 453	9 316	10 235	8 562	7 674	9 154	7 851	8 949	8 160	8 257
Hungary	HU	6 626	6 688	7 465	6 424	6 990	5 489	6 410	7 535	6 079	5 063	6 098	4 802	5 872	8 036	5 979
Iceland	IS	3 636	4 844	3 462	4 235	3 426	2 873	3 379	3 276	3 697	2 561	3 770	2 960	3 656	3 934	4 182
Ireland	IE	2 292	2 922	2 355	3 019	2 449	2 161	2 173	2 323	2 469	1 572	1 905	2 111	2 519	3 124	2 728
Italy	IT	9 936	11 509	9 044	7 950	8 571	8 104	9 613	9 414	7 994	7 392	9 444	7 777	9 324	7 989	8 300
Latvia	LV	3 309	3 633	2 582	2 960	2 393	2 794	3 471	3 552	3 237	2 607	2 610	2 587	1 679	3 499	3 315
Liechtenstein	LI	8 086	8 538	7 280	6 971	7 477	7 005	7 995	7 195	7 287	6 533	8 635	6 757	7 329	8 982	8 003
Lithuania	LT	3 997	3 882	3 106	3 279	2 623	3 260	3 604	3 721	3 088	2 877	2 919	3 015	1 886	3 785	3 675
Luxembourg	LU	4 128	5 022	3 352	3 277	3 830	3 802	4 040	3 128	3 663	3 366	4 245	3 036	3 617	5 945	4 502
Malta	MT	8 154	8 396	7 872	7 364	7 821	7 895	8 932	8 895	8 695	8 328	7 866	7 419	8 807	7 835	8 228
Monaco	MC	8 679	8 785	8 298	6 741	7 614	7 798	8 095	7 329	7 336	6 910	7 867	7 241	7 845	7 640	6 944
Montenegro	ME	9 959	9 354	9 128	8 082	8 040	7 829	9 089	9 620	7 843	6 972	9 452	7 102	8 656	7 762	7 815
Netherlands	NL	2 722	4 201	2 449	2 600	2 584	2 558	2 473	2 144	2 528	2 374	2 680	2 437	2 306	3 730	3 544
North Macedonia	MK	9 590	7 924	9 141	8 205	8 559	8 125	9 902	10 567	8 364	7 092	9 163	7 220	8 493	7 657	8 403
Norway	NO	3 426	4 364	3 249	3 620	3 105	2 840	3 396	2 983	3 670	3 001	3 279	2 862	2 786	3 934	3 865
Poland	PL	5 605	6 909	4 654	4 585	4 222	4 162	4 874	4 522	4 393	3 832	5 028	3 954	3 263	5 680	4 709
Portugal	PT	8 076	7 212	6 274	5 847	7 165	7 515	6 177	5 914	7 170	4 978	5 703	5 650	5 973	5 744	5 552
Romania	RO	7 317	6 311	7 225	6 463	6 903	5 823	6 861	7 683	6 011	5 325	6 824	5 261	5 822	6 956	5 884
San Marino	SM	9 071	15 826	8 218	5 989	6 897	6 358	8 387	8 121	6 564	6 536	8 078	6 085	8 106	7 000	6 843
Serbia	RS	7 576	6 256	7 812	6 945	7 548	6 489	8 003	8 792	6 796	5 737	7 400	5 568	6 799	7 110	6 515
Slovakia	SK	7 142	8 134	6 891	6 288	6 350	5 542	6 052	6 538	5 913	4 821	6 051	4 783	5 176	6 983	5 594
Slovenia	SI	8 241	9 745	8 030	7 515	8 100	7 918	9 083	8 914	8 176	6 596	8 293	6 504	8 373	7 901	7 732
Spain	ES	8 323	8 098	7 145	6 806	7 453	7 549	7 625	7 588	7 669	6 630	7 356	6 873	7 424	7 079	7 329
Sweden	SE	2 932	3 800	2 441	2 900	2 402	2 477	3 017	2 452	3 135	2 552	2 360	2 287	1 994	3 523	3 349
Switzerland	CH	9 230	9 458	8 896	7 806	8 547	8 193	9 234	8 429	8 578	8 035	10 091	7 856	8 570	9 658	8 997
United Kingdom	UK	2 397	3 830	2 073	3 017	2 247	1 945	2 073	1 972	2 424	2 003	2 161	2 007	2 117	3 016	2 821
Total		**5 819**	**6 252**	**5 149**	**5 005**	**5 045**	**4 857**	**5 394**	**5 235**	**5 091**	**4 423**	**5 177**	**4 425**	**4 685**	**5 669**	**5 311**
EU-28		**5 836**	**6 346**	**5 078**	**4 935**	**5 000**	**4 876**	**5 343**	**5 151**	**5 054**	**4 421**	**5 112**	**4 423**	**4 630**	**5 697**	**5 293**
Northern		**3 181**	**4 005**	**2 535**	**2 950**	**2 478**	**2 546**	**2 989**	**2 591**	**3 104**	**2 527**	**2 419**	**2 348**	**1 984**	**3 454**	**3 295**
North-western		**3 859**	**4 671**	**3 175**	**3 500**	**3 401**	**3 253**	**3 484**	**3 039**	**3 454**	**3 042**	**3 449**	**2 900**	**3 225**	**4 415**	**4 116**
Central & South-eastern		**6 486**	**6 733**	**6 063**	**5 654**	**5 677**	**5 242**	**5 950**	**5 976**	**5 410**	**4 784**	**6 135**	**4 828**	**4 908**	**6 881**	**5 762**
Southern		**8 786**	**8 806**	**7 873**	**7 184**	**7 791**	**7 570**	**8 218**	**8 277**	**7 587**	**6 647**	**7 848**	**6 860**	**7 817**	**7 328**	**7 453**
Serbia without Kosovo	RS	7 393	6 032	7 713	6 858	7 499	6 376	7 885	8 669	6 704	5 618	7 242	5 447	6 676	7 103	6 404
Kosovo	KS	8 875	7 849	8 516	7 566	7 901	7 297	8 846	9 673	7 456	6 581	8 530	6 432	7 683	7 161	7 306

Table A4.6: Concentration values for ozone indicator SOMO35, population-weighted average concentration in 2005-2019

Country, region		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Albania	AL	8 351	7 680	7 537	7 441	7 265	6 482	7 557	8 239	6 545	5 456	6 982	5 550	7 566	5 957	5 978
Andorra	AD	8 421	8 786	8 376	7 328	8 672	8 312	9 007	9 183	8 584	7 889	9 283	8 030	8 761	7 648	8 473
Austria	AT	6 190	6 504	6 138	5 363	5 353	5 220	5 837	5 733	5 616	4 585	6 507	4 793	5 518	6 943	5 992
Belgium	BE	2 786	4 129	2 296	2 613	2 651	2 464	2 634	2 094	2 554	2 267	2 869	2 193	2 558	4 274	3 460
Bosnia & Herzegovina	BA	6 397	6 442	6 758	6 135	6 085	5 147	6 345	7 062	5 713	4 487	6 238	4 554	6 065	5 120	5 138
Bulgaria	BG	5 859	5 216	5 723	6 243	6 162	5 358	5 746	6 964	5 307	3 990	5 400	4 397	5 252	4 941	4 887
Croatia	HR	6 774	7 560	7 022	6 129	6 272	5 728	6 970	7 285	6 249	4 956	6 441	4 822	6 575	6 178	5 663
Cyprus	CY	11 368	8 928	9 116	8 548	10 046	9 041	8 549	8 714	8 629	7 266	7 916	7 918	9 477	9 773	8 631
Czechia	CZ	5 975	6 243	5 213	4 698	4 527	4 293	4 836	4 850	4 395	4 056	5 666	4 448	4 410	6 963	5 426
Denmark	DK	2 823	3 790	2 588	3 152	2 614	2 527	2 805	2 743	2 971	2 756	2 585	2 529	1 934	3 870	3 340
Estonia	EE	2 240	3 784	2 128	2 435	1 895	2 566	2 642	2 207	2 666	2 112	1 917	2 128	1 551	2 874	2 759
Finland	FI	2 108	3 157	1 522	1 965	1 608	2 149	2 152	1 712	2 292	1 756	1 294	1 564	1 102	2 490	2 400
France	FR	4 641	5 099	3 692	3 621	4 101	4 216	4 465	3 681	4 088	3 845	3 980	3 488	3 836	5 281	4 846
Germany	DE	4 097	4 947	3 755	3 893	3 604	3 736	3 740	3 448	3 627	3 417	4 455	3 475	3 264	5 768	4 678
Greece	GR	9 308	7 941	8 061	8 214	7 806	7 494	7 902	8 469	7 717	6 204	7 498	6 689	7 850	7 898	6 834
Hungary	HU	6 097	5 826	6 847	5 799	6 697	4 855	6 005	6 790	5 170	4 181	5 852	4 274	5 365	6 329	5 111
Iceland	IS	1 630	2 544	1 342	2 298	1 305	641	1 272	1 114	1 325	503	1 325	804	1 226	1 753	2 065
Ireland	IE	1 766	2 387	1 789	2 493	1 924	1 552	1 614	1 727	1 950	1 225	1 346	1 479	1 779	2 523	2 238
Italy	IT	7 887	9 234	7 577	6 769	7 090	6 378	7 682	7 533	6 820	5 919	7 591	6 596	7 825	6 498	6 750
Latvia	LV	2 474	3 131	1 971	2 713	1 987	2 339	2 819	2 898	3 026	2 280	2 760	2 889	1 494	2 785	2 715
Liechtenstein	LI	6 233	6 863	5 850	5 547	5 924	5 795	5 899	5 435	5 453	4 766	6 508	5 159	5 953	7 496	6 293
Lithuania	LT	3 469	3 995	2 779	3 256	2 516	2 830	3 305	3 062	2 883	2 498	2 689	2 637	1 766	3 187	3 308
Luxembourg	LU	3 062	3 725	2 433	2 633	2 867	3 043	3 052	2 244	2 861	2 539	3 540	2 310	2 979	4 909	3 942
Malta	MT	7 004	7 178	6 884	6 125	6 614	5 797	6 712	6 962	7 191	6 848	5 525	5 777	6 601	5 588	6 162
Monaco	MC	8 657	8 733	8 298	6 711	7 541	7 762	8 073	7 178	7 240	6 910	7 818	7 180	7 797	7 586	6 932
Montenegro	ME	7 332	6 868	7 238	6 843	6 263	5 715	6 813	7 553	6 234	4 885	7 011	5 282	6 632	5 129	5 041
Netherlands	NL	2 395	3 894	2 108	2 381	2 340	2 267	2 242	1 935	2 335	2 203	2 524	2 261	2 120	3 525	3 327
North Macedonia	MK	6 646	5 650	6 199	7 147	6 482	5 764	6 470	7 633	5 852	4 393	6 178	4 951	6 506	5 059	5 693
Norway	NO	2 259	3 344	1 926	2 563	1 925	1 724	2 231	1 915	2 442	2 047	1 897	1 870	1 549	2 821	2 700
Poland	PL	5 133	5 839	4 283	4 186	4 005	3 532	4 381	4 195	3 932	3 570	4 762	3 759	3 149	5 089	4 359
Portugal	PT	5 970	5 460	5 165	4 327	5 558	6 195	4 943	4 673	5 664	4 056	4 173	4 315	4 488	4 942	4 125
Romania	RO	5 534	5 286	6 177	5 415	5 814	4 661	5 652	6 738	4 949	4 131	5 595	4 279	4 556	5 059	4 464
San Marino	SM	7 936	12 226	7 787	5 757	6 228	5 843	7 526	6 909	6 276	6 037	7 240	5 545	7 542	6 457	6 195
Serbia	RS	5 675	4 851	6 232	5 889	6 211	5 089	6 276	7 459	5 539	4 304	5 870	4 431	5 482	4 997	4 791
Slovakia	SK	6 298	6 705	6 274	5 424	5 895	4 617	5 670	5 963	5 004	4 307	5 531	4 484	4 912	6 289	5 143
Slovenia	SI	6 776	8 023	6 764	5 970	6 245	6 197	7 374	7 315	6 709	5 244	6 947	5 298	6 850	6 617	6 278
Spain	ES	5 887	5 557	5 069	4 910	5 850	5 886	5 707	5 597	5 808	5 508	5 917	5 363	5 828	5 868	5 795
Sweden	SE	2 540	3 528	2 135	2 668	2 097	2 134	2 716	2 280	2 642	2 255	1 995	1 952	1 555	3 233	2 961
Switzerland	CH	6 063	6 568	5 593	4 931	5 525	5 470	5 678	5 181	5 329	4 764	6 590	5 007	5 483	7 253	5 980
United Kingdom	UK	1 598	2 826	1 240	2 109	1 468	1 138	1 419	1 243	1 645	1 281	1 310	1 164	1 238	2 273	1 924
Total		**4 825**	**5 415**	**4 384**	**4 329**	**4 391**	**4 127**	**4 547**	**4 421**	**4 301**	**3 774**	**4 586**	**3 847**	**4 134**	**5 105**	**4 610**
EU-28		**4 758**	**5 408**	**4 290**	**4 234**	**4 299**	**4 066**	**4 462**	**4 283**	**4 235**	**3 745**	**4 511**	**3 810**	**4 051**	**5 095**	**4 584**
Northern		**2 545**	**3 511**	**2 129**	**2 667**	**2 102**	**2 240**	**2 621**	**2 321**	**2 659**	**2 246**	**2 077**	**2 109**	**1 558**	**3 108**	**2 901**
North-western		**2 604**	**3 621**	**2 076**	**2 548**	**2 359**	**2 225**	**2 434**	**2 010**	**2 459**	**2 159**	**2 339**	**1 960**	**2 155**	**3 487**	**3 042**
Central & South-eastern		**4 980**	**5 482**	**4 699**	**4 506**	**4 462**	**4 111**	**4 565**	**4 591**	**4 220**	**3 757**	**5 030**	**3 903**	**3 872**	**5 747**	**4 789**
Southern		**7 034**	**7 278**	**6 485**	**6 009**	**6 532**	**6 178**	**6 749**	**6 745**	**6 326**	**5 504**	**6 534**	**5 774**	**6 666**	**6 177**	**6 111**
Serbia without Kosovo	RS	5 343	4 567	6 072	5 632	6 091	4 874	6 080	7 272	5 365	4 131	5 657	4 212	5 233	4 899	4 559
Kosovo	KS	7 033	6 012	6 885	6 940	6 702	5 965	7 077	8 223	6 250	5 008	6 741	5 326	6 501	5 398	5 738

Table A4.7: Trend estimates and relative trend estimates for ozone indicator SOMO35, spatial average (left) and population-weighted average (right)concentration in 2005-2019. Trend indicators show significance of trends (Mann-Kendall test) and Sen´s slope estimate Q with its confidence interval (Qmin95, Qmax95) at 95 %.

Country, region		Ozone, SOMO35, spatial average								Ozone, SOMO35, population-weighted average							
		Sign.	Slope [μg.m^{-3}.yr^{-1}]			Sign.	Slope [%.yr^{-1}]			Sign.	Slope [μg.m^{-3}.yr^{-1}]			Sign.	Slope [%.yr^{-1}]		
			Q	Qmin95	Qmax95		Q	Qmin95	Qmax95		Q	Qmin95	Qmax95		Q	Qmin95	Qmax95
Albania	AL	*	-128.9	-273.8	-28.8	*	-1.37	-2.91	-0.31	*	-143.4	-246.8	-40.4	*	-1.83	-3.15	-0.52
Andorra	AD	+	-117.8	-183.6	12.5	+	-0.98	-1.53	0.10		-18.4	-83.4	86.7		-0.21	-0.95	0.99
Austria	AT		-45.6	-172.6	68.9		-0.57	-2.16	0.86		-26.1	-126.9	77.1		-0.44	-2.14	1.30
Belgium	BE		16.2	-74.7	93.9		0.55	-2.55	3.20		1.2	-55.1	88.4		0.04	-2.11	3.39
Bosnia & Herzegovina	BA	*	-102.0	-226.4	-2.0	*	-1.22	-2.72	-0.02	*	-94.6	-191.5	-6.5	*	-1.46	-2.96	-0.10
Bulgaria	BG		-55.7	-180.7	64.0		-0.73	-2.37	0.84	*	-73.3	-149.2	-14.8	*	-1.24	-2.53	-0.25
Croatia	HR	*	-102.4	-219.1	-16.6	*	-1.08	-2.31	-0.17	*	-99.3	-178.0	-6.4	*	-1.17	-2.10	-0.08
Cyprus	CY		0.7	-117.9	111.2		0.01	-1.37	1.30		-6.0	-101.3	110.1		-0.11	-1.82	1.98
Czechia	CZ		-63.5	-155.6	51.2		-0.60	-1.47	0.48		-80.4	-209.6	40.4		-0.87	-2.26	0.44
Denmark	DK		-63.1	-106.4	61.2		-1.30	-2.20	1.26		-37.6	-69.6	78.0		-0.96	-1.77	1.99
Estonia	EE		-27.2	-98.1	37.6		-0.82	-2.95	1.13		-11.4	-82.2	61.8		-0.40	-2.91	2.19
Finland	FI		-41.6	-93.2	26.7		-0.54	-1.20	0.34		6.5	-17.6	55.0		0.11	-0.31	0.96
France	FR		-65.8	-137.6	49.0		-2.72	-5.69	2.03		-34.7	-97.7	42.7		-1.68	-4.72	2.06
Germany	DE		-65.6	-178.5	73.1		-1.09	-2.97	1.22		-38.0	-162.1	77.9		-0.75	-3.20	1.54
Greece	GR		-9.0	-121.9	85.8		-0.18	-2.38	1.67		-3.2	-87.8	97.2		-0.08	-2.13	2.36
Hungary	HU	+	-105.8	-214.5	15.7	+	-1.30	-2.64	0.19	+	-89.5	-196.9	10.7	+	-1.29	-2.83	0.15
Iceland	IS		-4.8	-80.5	75.8		-0.13	-2.21	2.08		-21.3	-119.4	62.8		-1.44	-8.06	4.24
Ireland	IE		5.0	-64.7	57.7		0.21	-2.76	2.46		-11.4	-66.0	63.6		-0.63	-3.64	3.51
Italy	IT		-74.6	-239.1	23.7		-0.81	-2.60	0.26		-70.5	-196.5	20.8		-0.91	-2.55	0.27
Latvia	LV		-19.5	-107.3	52.9		-0.65	-3.55	1.75		7.2	-46.5	73.2		0.27	-1.73	2.72
Liechtenstein	LI		4.9	-109.5	113.0		0.07	-1.51	1.55		-18.4	-110.8	99.1		-0.31	-1.85	1.65
Lithuania	LT		-33.0	-115.3	49.8		-0.98	-3.41	1.47		-52.9	-132.1	18.5		-1.60	-4.00	0.56
Luxembourg	LU		11.7	-78.0	113.8		0.31	-2.08	3.04		38.4	-58.8	143.4		1.42	-2.17	5.29
Malta	MT		-0.8	-78.4	85.3		-0.01	-0.96	1.05	+	-60.2	-138.1	2.3	+	-0.86	-1.97	0.03
Monaco	MC	+	-79.9	-162.3	6.6	+	-0.97	-1.98	0.08	+	-82.4	-174.7	5.0	+	-1.01	-2.14	0.06
Montenegro	ME	*	-121.2	-232.8	-7.3	*	-1.29	-2.48	-0.08	*	-140.5	-221.0	-26.9	*	-1.93	-3.04	-0.37
Netherlands	NL		-15.4	-39.7	61.5		-0.58	-1.50	2.32		-4.7	-29.2	73.8		-0.20	-1.24	3.13
North Macedonia	MK		-58.6	-214.1	55.7		-0.66	-2.42	0.63		-69.9	-184.1	37.7		-1.05	-2.77	0.57
Norway	NO		-34.7	-77.4	51.8		-1.01	-2.26	1.51		-11.2	-87.1	60.4		-0.52	-4.06	2.81
Poland	PL		-78.9	-191.2	47.4		-1.57	-3.81	0.94		-58.6	-167.9	44.5		-1.33	-3.81	1.01
Portugal	PT	**	-118.4	-220.8	-29.6	**	-1.64	-3.06	-0.41	*	-102.2	-177.3	-8.9	*	-1.84	-3.19	-0.16
Romania	RO		-71.3	-166.3	34.9		-1.04	-2.42	0.51	+	-81.5	-165.9	20.4	+	-1.45	-2.96	0.36
San Marino	SM		-110.7	-310.1	48.7		-1.31	-3.67	0.58		-75.4	-261.1	40.7		-1.01	-3.51	0.55
Serbia	RS		-63.8	-186.7	66.9		-0.84	-2.47	0.88		-68.4	-182.4	58.0		-1.12	-3.00	0.95
Slovakia	SK	*	-126.5	-237.3	-44.9	*	-1.83	-3.43	-0.65	+	-97.1	-192.4	5.6	+	-1.55	-3.06	0.09
Slovenia	SI		-55.0	-168.9	34.1		-0.65	-1.99	0.40		-59.4	-135.9	44.7		-0.84	-1.91	0.63
Spain	ES		-36.6	-121.2	60.5		-1.28	-4.23	2.11		-4.7	-99.6	49.9		-0.21	-4.45	2.23
Sweden	SE		-19.7	-92.5	45.9		-0.72	-3.39	1.68		-24.6	-101.2	45.9		-0.99	-4.09	1.85
Switzerland	CH		-65.5	-171.7	56.7		-0.97	-2.54	0.84		-75.0	-195.1	37.6		-1.22	-3.17	0.61
United Kingdom	UK		-7.3	-77.1	50.6		-0.33	-3.45	2.27		-19.9	-61.8	45.0		-1.29	-4.02	2.93
Total			**-48.7**	**-118.6**	**29.6**		**-0.89**	**-2.16**	**0.54**		**-23.9**	**-89.8**	**33.8**		**-0.53**	**-2.00**	**0.75**
EU-28			**-44.8**	**-114.4**	**30.2**		**-0.83**	**-2.11**	**0.56**		**-23.9**	**-80.7**	**36.6**		**-0.54**	**-1.82**	**0.83**
Northern			**-32.3**	**-102.0**	**33.7**		**-1.15**	**-3.62**	**1.19**		**-15.1**	**-89.7**	**40.6**		**-0.62**	**-3.70**	**1.67**
North-western			**-19.0**	**-79.6**	**57.5**		**-0.54**	**-2.24**	**1.62**		**-16.6**	**-62.3**	**68.0**		**-0.66**	**-2.49**	**2.72**
Central & South-eastern			**-69.0**	**-168.3**	**42.9**		**-1.11**	**-2.71**	**0.69**		**-55.6**	**-126.3**	**37.0**		**-1.16**	**-2.63**	**0.77**
Southern		**+**	**-89.6**	**-145.2**	**4.0**	**+**	**-1.05**	**-1.71**	**0.05**	**+**	**-51.4**	**-105.7**	**11.5**	**+**	**-0.75**	**-1.55**	**0.17**
Serbia without Kosovo	RS		-51.7	-180.5	83.1		-0.71	-2.47	1.14		-56.0	-178.7	54.1		-0.97	-3.08	0.93
Kosovo	KS	+	-99.4	-198.7	5.2	+	-1.18	-2.35	0.06	+	-85.5	-171.3	34.7	+	-1.22	-2.44	0.49

Table A4.8: Trend estimates and relative trend estimates for ozone indicator SOMO35, spatial average concentration in 2005-2019, urban (left) and rural (right) areas. Trend indicators show significance of trends (Mann-Kendall test) and Sen´s slope estimate Q with its confidence interval (Qmin95, Qmax95) at 95 %.

Country, region		Ozone, SOMO35, spatial average, urban areas								Ozone, SOMO35, spatial average, rural areas							
		Sign.	Slope [$\mu g.m^{-3}.yr^{-1}$]			Sign.	Slope [$\%.yr^{-1}$]			Sign.	Slope [$\mu g.m^{-3}.yr^{-1}$]			Sign.	Slope [$\%.yr^{-1}$]		
			Q	Qmin95	Qmax95		Q	Qmin95	Qmax95		Q	Qmin95	Qmax95		Q	Qmin95	Qmax95
Albania	AL	*	-145.8	-268.6	-33.1	*	-1.81	-3.34	-0.41	*	-126.0	-273.1	-25.8	*	-1.33	-2.88	-0.27
Andorra	AD		-25.7	-94.6	75.3		-0.28	-1.03	0.82	+	-121.1	-191.7	12.1	+	-0.99	-1.57	0.10
Austria	AT		-27.2	-124.4	71.4		-0.44	-2.03	1.16		-47.4	-174.2	69.6		-0.58	-2.15	0.86
Belgium	BE		4.6	-56.1	91.4		0.17	-2.06	3.36		16.5	-88.4	91.7		0.54	-2.92	3.03
Bosnia & Herzegovina	BA	*	-96.6	-209.5	-8.8	*	-1.44	-3.13	-0.13	*	-103.2	-229.8	-5.0	*	-1.23	-2.73	-0.06
Bulgaria	BG	+	-74.4	-138.0	9.6	+	-1.13	-2.09	0.15		-56.2	-182.4	67.9		-0.73	-2.37	0.88
Croatia	HR	**	-119.2	-236.1	-49.7	**	-1.29	-2.56	-0.54	*	-105.0	-220.1	-15.4	*	-1.10	-2.31	-0.16
Cyprus	CY		-10.0	-107.4	95.4		-0.17	-1.79	1.59		4.4	-121.0	111.9		0.05	-1.35	1.25
Czechia	CZ		-72.5	-200.9	45.6		-0.76	-2.12	0.48		-75.4	-157.6	58.8		-0.71	-1.48	0.55
Denmark	DK		-41.1	-83.5	80.5		-0.98	-2.00	1.93		-64.1	-109.4	59.1		-1.30	-2.22	1.20
Estonia	EE		-15.0	-86.4	53.6		-0.51	-2.91	1.81		-28.6	-102.7	30.9		-0.85	-3.05	0.92
Finland	FI		-15.1	-37.5	9.9		-0.24	-0.59	0.16		-42.5	-95.3	25.3		-0.54	-1.22	0.32
France	FR		-34.8	-102.2	42.5		-1.69	-4.96	2.06		-66.5	-138.3	49.1		-2.75	-5.71	2.02
Germany	DE		-47.4	-167.4	69.7		-0.88	-3.11	1.30		-67.4	-180.9	72.9		-1.11	-2.98	1.20
Greece	GR		-13.6	-102.5	94.5		-0.30	-2.29	2.11		-10.3	-123.3	85.4		-0.20	-2.38	1.65
Hungary	HU	+	-91.0	-188.4	22.0	+	-1.29	-2.66	0.31	+	-110.0	-219.7	16.0	+	-1.35	-2.69	0.20
Iceland	IS		-23.3	-114.1	60.6		-1.32	-6.46	3.43		-4.8	-80.5	75.8		-0.13	-2.21	2.08
Ireland	IE		-11.2	-65.9	57.0		-0.60	-3.52	3.05		5.0	-63.8	57.6		0.21	-2.70	2.44
Italy	IT		-89.2	-235.9	18.6		-1.09	-2.88	0.23		-79.3	-246.7	23.0		-0.85	-2.64	0.25
Latvia	LV		5.2	-62.0	55.0		0.19	-2.24	1.99		-19.7	-108.0	53.9		-0.65	-3.58	1.79
Liechtenstein	LI		-9.5	-106.2	98.2		-0.16	-1.74	1.61		0.2	-112.6	115.2		0.00	-1.45	1.48
Lithuania	LT		-46.0	-128.1	26.6		-1.39	-3.88	0.80		-32.5	-119.0	50.4		-0.96	-3.52	1.49
Luxembourg	LU		38.7	-59.6	138.0		1.35	-2.07	4.79		5.4	-91.7	111.2		0.14	-2.36	2.86
Malta	MT	+	-43.0	-117.8	14.6	+	-0.58	-1.58	0.20		44.4	-31.5	138.9		0.52	-0.37	1.61
Monaco	MC	+	-79.9	-162.3	6.6	+	-0.97	-1.98	0.08								
Montenegro	ME	*	-146.7	-234.9	-29.4	*	-1.98	-3.17	-0.40	*	-117.8	-240.0	-5.0	*	-1.25	-2.55	-0.05
Netherlands	NL		-10.7	-35.0	72.4		-0.43	-1.41	2.91		-16.7	-41.5	58.4		-0.62	-1.55	2.18
North Macedonia	MK		-74.0	-179.7	46.2		-1.02	-2.48	0.64		-57.7	-216.0	55.4		-0.65	-2.43	0.62
Norway	NO		-18.5	-91.6	56.9		-0.82	-4.05	2.52		-34.9	-76.2	51.7		-1.02	-2.22	1.50
Poland	PL		-75.8	-177.0	35.5		-1.59	-3.71	0.74		-78.0	-195.8	48.2		-1.55	-3.89	0.96
Portugal	PT	*	-108.9	-213.6	-20.3	*	-1.87	-3.66	-0.35	**	-121.5	-224.5	-27.4	**	-1.65	-3.05	-0.37
Romania	RO	+	-73.8	-153.8	6.1	+	-1.25	-2.61	0.10		-70.2	-168.5	38.1		-1.01	-2.43	0.55
San Marino	SM		-112.7	-265.7	52.3		-1.39	-3.28	0.65		-103.6	-359.4	85.6		-1.18	-4.10	0.98
Serbia	RS		-68.2	-178.5	44.4		-1.07	-2.79	0.69		-61.0	-186.8	70.9		-0.80	-2.46	0.93
Slovakia	SK	*	-108.7	-203.9	-0.6	*	-1.68	-3.15	-0.01	*	-133.8	-241.0	-44.7	*	-1.90	-3.42	-0.63
Slovenia	SI		-69.8	-143.4	38.0		-0.94	-1.92	0.51		-57.5	-171.5	34.2		-0.67	-1.99	0.40
Spain	ES		-11.7	-106.8	45.6		-0.49	-4.48	1.91		-36.3	-121.3	61.0		-1.26	-4.23	2.13
Sweden	SE		-21.5	-104.1	43.9		-0.86	-4.18	1.76		-19.5	-92.1	46.0		-0.71	-3.37	1.68
Switzerland	CH	+	-67.2	-176.2	34.4	+	-1.07	-2.82	0.55		-64.1	-172.0	68.1		-0.95	-2.55	1.01
United Kingdom	UK		-13.6	-62.2	46.9		-0.84	-3.84	2.90		-7.2	-75.6	50.4		-0.31	-3.25	2.17
Total			**-35.0**	**-107.5**	**36.1**		**-0.72**	**-2.22**	**0.74**		**-49.6**	**-120.4**	**29.8**		**-0.90**	**-2.18**	**0.54**
EU-28			**-32.5**	**-103.7**	**35.3**		**-0.68**	**-2.18**	**0.74**		**-45.5**	**-114.9**	**30.4**		**-0.83**	**-2.10**	**0.56**
Northern			**-23.8**	**-91.7**	**37.8**		**-0.94**	**-3.65**	**1.50**		**-32.4**	**-102.0**	**33.5**		**-1.15**	**-3.61**	**1.19**
North-western			**-13.7**	**-68.8**	**63.4**		**-0.48**	**-2.41**	**2.22**		**-21.5**	**-81.5**	**58.9**		**-0.59**	**-2.24**	**1.62**
Central & South-eastern			**-59.4**	**-138.7**	**36.3**		**-1.16**	**-2.70**	**0.71**		**-71.6**	**-170.9**	**40.2**		**-1.13**	**-2.71**	**0.64**
Southern		*	**-75.2**	**-137.0**	**-4.4**	*	**-1.01**	**-1.83**	**-0.06**	*	**-88.5**	**-147.2**	**-0.8**	*	**-1.04**	**-1.72**	**-0.01**
Serbia without Kosovo	RS		-55.2	-158.5	48.4		-0.91	-2.63	0.80		-51.9	-186.6	86.5		-0.70	-2.53	1.17
Kosovo	KS	+	-97.4	-184.2	17.3	+	-1.31	-2.48	0.23	+	-101.4	-208.5	4.2	+	-1.17	-2.40	0.05

Table A4.9: Concentration values for NO_2 annual average, spatial average concentration in 2005-2019

Country, region		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Albania	AL	7.8	7.2	6.7	6.3	6.7	6.2	6.6	5.8	5.6	5.6	5.8	5.2	5.9	5.2	5.0
Andorra	AD	7.4	7.1	7.7	7.4	7.8	7.3	6.6	7.0	7.0	6.8	8.0	3.6	5.5	3.8	3.6
Austria	AT	10.0	10.3	9.7	9.6	9.2	10.2	9.9	8.6	9.0	7.7	8.2	7.6	7.9	7.2	6.5
Belgium	BE	18.9	19.4	19.4	18.0	18.0	18.8	16.8	16.4	16.5	14.4	14.3	14.5	14.0	13.7	12.1
Bosnia & Herzegovina	BA	7.8	7.4	6.8	6.8	6.4	6.2	6.5	5.6	5.5	5.5	5.7	4.9	5.4	4.7	4.7
Bulgaria	BG	7.6	8.5	7.2	7.4	7.3	6.9	7.1	6.3	6.3	6.7	6.7	6.1	6.7	5.9	5.5
Croatia	HR	9.0	8.7	8.1	7.7	7.6	7.2	7.6	6.6	6.7	6.3	6.5	6.0	6.6	5.7	5.3
Cyprus	CY	6.4	6.9	6.4	5.9	5.3	5.4	5.8	5.0	4.9	5.0	4.3	4.9	5.7	5.1	4.6
Czechia	CZ	11.6	11.7	10.5	10.4	11.0	12.5	10.7	10.5	10.2	9.4	9.4	8.7	8.8	8.5	7.6
Denmark	DK	8.2	8.9	7.2	7.3	7.3	7.6	7.1	7.1	6.8	6.7	5.5	6.5	5.2	5.9	5.2
Estonia	EE	3.5	4.1	3.2	2.8	2.8	3.6	3.1	3.1	3.0	3.1	3.3	2.8	2.4	2.9	2.5
Finland	FI	3.1	3.4	2.8	2.6	2.3	3.0	3.2	2.7	2.4	2.0	2.5	2.4	2.2	2.3	1.9
France	FR	9.5	9.3	9.3	8.6	8.6	9.1	8.5	7.9	7.8	7.0	7.4	6.9	6.8	6.1	5.8
Germany	DE	13.8	14.3	13.0	13.1	13.4	13.6	12.6	12.2	11.9	11.6	11.3	11.1	10.7	10.5	9.8
Greece	GR	7.8	7.9	7.0	6.9	7.0	6.2	6.2	5.2	5.1	5.3	5.2	5.0	5.5	4.8	4.5
Hungary	HU	9.1	10.3	9.7	9.7	9.8	10.1	9.3	8.9	8.6	8.2	8.7	8.0	8.7	7.9	7.4
Iceland	IS	0.8	0.8	0.9	0.7	0.7	0.7	0.8	0.8	0.8	0.6	0.7	0.7	0.7	0.7	0.7
Ireland	IE	4.9	5.6	6.7	5.8	5.0	5.7	4.7	4.8	5.1	4.2	4.9	4.7	4.2	4.1	4.1
Italy	IT	14.4	14.2	13.4	13.4	13.1	12.4	12.9	11.4	10.9	10.1	10.7	10.0	10.4	9.2	9.0
Latvia	LV	4.4	4.9	4.0	3.7	3.8	4.5	4.1	3.9	4.0	3.8	4.1	3.5	3.3	3.6	3.0
Liechtenstein	LI	12.8	12.8	12.2	11.6	11.4	11.7	11.2	11.1	11.4	11.6	12.5	9.7	10.1	9.8	9.7
Lithuania	LT	5.6	6.3	5.6	5.4	5.9	6.1	5.7	5.6	5.7	5.6	5.6	5.2	5.1	5.1	4.5
Luxembourg	LU	16.9	16.0	14.4	14.6	14.8	16.1	15.5	14.2	13.8	12.4	12.4	11.6	10.8	11.0	10.3
Malta	MT	10.9	11.2	11.3	10.2	9.5	9.7	11.2	12.3	7.6	8.0	8.1	7.7	7.4	7.1	7.6
Monaco	MC	32.3	32.1	31.8	28.7	28.3	26.4	26.8	26.1	25.2	22.3	24.7	22.0	22.6	19.5	22.7
Montenegro	ME	6.4	5.6	5.3	5.0	5.0	4.7	5.2	4.3	4.3	4.4	4.4	3.8	4.4	3.9	3.5
Netherlands	NL	19.6	19.9	18.1	19.2	19.3	19.1	17.7	17.4	16.7	16.5	15.1	16.1	15.5	15.4	14.5
North Macedonia	MK	8.1	7.8	7.2	7.2	7.2	6.9	7.2	6.1	6.2	5.7	5.8	5.6	6.3	5.6	5.2
Norway	NO	2.7	2.9	2.4	2.2	2.0	2.3	2.7	2.0	2.1	1.5	2.1	1.9	1.9	1.9	1.6
Poland	PL	8.9	10.0	8.8	8.9	9.4	10.0	9.3	9.1	8.5	8.5	8.4	8.6	8.3	8.4	7.5
Portugal	PT	7.2	7.2	7.9	7.2	6.6	6.4	6.5	6.3	5.3	5.1	5.8	5.2	5.5	4.8	4.7
Romania	RO	7.8	8.6	7.6	7.8	7.7	8.0	7.9	7.3	6.9	7.0	7.2	6.9	7.4	6.7	6.4
San Marino	SM	21.4	24.1	21.2	25.4	23.8	17.0	16.1	15.6	14.6	13.8	15.6	14.2	14.2	12.8	13.0
Serbia	RS	9.1	9.3	8.5	8.5	8.4	8.1	8.3	7.4	7.3	7.2	7.4	7.0	7.6	6.8	6.3
Slovakia	SK	9.4	10.0	9.1	8.8	9.2	10.3	9.1	8.9	8.4	7.6	8.2	7.5	8.1	7.4	6.6
Slovenia	SI	11.0	10.7	10.5	9.5	9.3	9.1	10.5	8.5	8.7	7.4	8.3	7.6	8.6	7.2	6.9
Spain	ES	6.9	7.0	7.4	6.5	5.9	6.0	6.0	6.0	5.4	5.0	5.9	5.0	5.4	4.4	4.4
Sweden	SE	3.2	3.5	2.7	2.6	2.2	2.6	3.1	2.3	2.2	1.7	2.3	2.1	1.9	2.2	2.0
Switzerland	CH	11.6	11.5	10.3	10.4	9.6	10.1	10.8	8.7	9.1	8.7	9.4	7.6	8.0	7.5	7.2
United Kingdom	UK	9.5	10.0	11.0	9.4	9.2	9.8	8.8	9.1	8.7	7.9	7.5	7.8	7.1	6.9	7.0
Total		**7.8**	**8.1**	**7.7**	**7.3**	**7.2**	**7.5**	**7.3**	**6.8**	**6.5**	**6.1**	**6.4**	**6.0**	**6.1**	**5.7**	**5.3**
EU-28		**8.4**	**8.7**	**8.2**	**7.9**	**7.8**	**8.1**	**7.8**	**7.3**	**7.0**	**6.5**	**6.8**	**6.5**	**6.5**	**6.1**	**5.7**
Northern		**3.4**	**3.7**	**3.0**	**2.9**	**2.6**	**3.1**	**3.3**	**2.8**	**2.7**	**2.2**	**2.7**	**2.5**	**2.3**	**2.5**	**2.2**
North-western		**9.1**	**9.2**	**9.6**	**8.7**	**8.6**	**9.2**	**8.3**	**8.1**	**8.0**	**7.2**	**7.2**	**7.1**	**6.7**	**6.4**	**6.1**
Central & South-eastern		**10.2**	**10.9**	**9.8**	**9.9**	**10.1**	**10.5**	**9.9**	**9.4**	**9.1**	**8.8**	**8.9**	**8.6**	**8.7**	**8.3**	**7.6**
Southern		**9.0**	**8.9**	**8.7**	**8.3**	**7.9**	**7.7**	**7.9**	**7.2**	**6.8**	**6.4**	**7.0**	**6.3**	**6.7**	**5.8**	**5.6**
Serbia without Kosovo	RS	8.9	9.1	8.4	8.4	8.3	7.9	8.2	7.3	7.2	7.1	7.3	6.9	7.5	6.6	6.2
Kosovo	KS	10.3	10.2	9.5	9.4	9.4	8.9	9.4	8.3	8.1	7.8	8.1	7.8	8.5	7.8	7.1

Table A4.10: Concentration values for NO_2 annual average, population-weighted average concentration in 2005-2019

Country, region		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Albania	AL	19.3	19.1	18.4	18.5	19.0	17.4	18.7	17.6	15.4	15.4	16.7	16.1	17.2	16.1	15.8
Andorra	AD	19.7	19.9	20.2	19.3	20.1	20.0	19.1	18.0	17.2	16.3	17.7	16.7	17.3	15.2	15.2
Austria	AT	23.5	24.4	22.5	22.0	21.8	22.7	21.9	20.6	20.5	19.1	20.1	18.8	19.1	17.7	16.6
Belgium	BE	28.8	28.5	28.5	27.3	27.3	27.8	25.8	25.1	24.8	22.5	22.0	22.3	21.7	20.9	18.8
Bosnia & Herzegovina	BA	18.7	18.8	16.7	17.0	16.9	16.5	17.0	15.6	15.0	14.5	15.9	14.6	16.0	14.3	14.9
Bulgaria	BG	19.3	24.8	21.7	20.4	20.6	18.6	19.8	18.0	16.1	15.8	16.2	17.3	18.0	17.6	17.4
Croatia	HR	19.7	19.9	17.9	17.8	17.8	17.7	17.9	16.4	16.4	15.3	16.5	15.6	16.7	15.1	14.8
Cyprus	CY	17.6	20.5	18.8	15.8	13.7	13.3	15.0	14.3	12.1	10.4	10.0	12.7	13.2	13.8	13.1
Czechia	CZ	21.2	21.4	18.8	19.0	19.3	20.5	19.6	18.6	17.9	17.3	17.1	16.1	16.4	16.1	14.8
Denmark	DK	15.3	16.0	13.6	13.5	13.3	14.3	13.1	12.9	12.4	11.9	10.4	11.4	9.7	10.3	9.6
Estonia	EE	12.9	12.7	11.8	10.8	10.7	12.2	10.8	11.1	11.1	10.4	9.5	9.6	8.7	9.6	8.3
Finland	FI	13.5	13.3	12.3	11.7	11.4	13.2	12.2	11.6	10.9	10.1	9.7	9.8	9.1	9.5	8.5
France	FR	24.0	23.4	23.2	22.2	22.5	22.5	21.5	20.5	20.3	18.7	19.0	18.5	18.1	16.8	16.0
Germany	DE	25.0	25.5	23.6	23.6	24.2	24.2	23.1	22.4	21.6	21.2	21.0	20.7	20.0	19.5	18.0
Greece	GR	26.4	27.2	26.7	25.8	26.2	22.8	22.7	20.8	19.2	19.6	19.6	20.4	21.3	20.3	19.7
Hungary	HU	20.5	20.6	18.6	19.0	18.9	19.7	19.5	17.7	17.1	16.4	17.8	16.7	17.8	17.1	16.1
Iceland	IS	19.6	19.0	18.9	18.0	19.4	22.3	20.2	19.3	17.5	17.1	16.8	17.1	15.8	13.7	13.1
Ireland	IE	13.9	14.8	16.2	15.2	14.5	16.5	14.2	14.0	13.5	12.2	12.2	13.4	12.3	12.3	11.6
Italy	IT	32.2	32.7	30.8	29.3	29.6	28.0	29.0	27.3	25.2	23.0	24.8	23.4	23.8	21.5	21.1
Latvia	LV	16.3	15.6	14.3	13.3	12.6	14.1	13.4	13.8	13.8	12.4	12.5	12.2	11.4	12.4	11.0
Liechtenstein	LI	26.2	26.1	24.3	23.9	23.8	23.5	23.9	23.2	22.9	21.0	22.2	21.0	21.4	19.3	19.0
Lithuania	LT	15.1	14.7	13.4	13.0	11.8	12.6	12.0	12.4	12.6	12.0	11.9	12.1	11.4	12.3	10.9
Luxembourg	LU	27.6	25.9	25.3	24.5	24.5	25.0	25.3	23.7	22.5	21.2	20.8	19.7	18.5	18.8	17.7
Malta	MT	18.6	16.9	16.7	14.7	14.7	16.1	18.3	20.5	11.0	11.3	12.1	11.5	11.4	10.8	11.3
Monaco	MC	35.0	34.6	34.4	32.1	31.0	29.0	29.7	28.7	28.1	25.2	27.3	25.1	25.7	22.5	25.5
Montenegro	ME	18.5	18.4	17.0	18.0	18.3	17.1	17.8	16.6	15.4	15.3	16.4	15.6	16.9	15.6	15.4
Netherlands	NL	27.1	28.2	25.0	26.4	26.5	25.8	24.6	23.6	22.5	22.2	20.8	21.7	21.0	20.2	19.1
North Macedonia	MK	23.9	24.7	23.8	23.5	23.7	21.9	23.2	22.0	20.3	18.0	18.8	19.8	21.1	20.3	19.8
Norway	NO	17.9	17.3	16.5	15.7	15.6	17.8	16.5	15.5	14.8	13.5	13.8	13.6	12.7	11.1	10.0
Poland	PL	17.6	19.3	16.7	16.9	17.2	17.9	17.6	16.8	16.1	15.7	15.9	16.0	15.7	16.1	14.7
Portugal	PT	20.5	20.4	20.9	18.5	18.3	17.3	17.5	17.3	13.0	14.2	15.2	14.3	15.4	14.5	13.7
Romania	RO	17.9	21.9	19.5	19.4	19.3	18.7	18.7	18.0	16.2	15.7	16.4	17.7	18.6	18.0	17.8
San Marino	SM	27.5	31.6	28.5	26.8	24.3	21.6	21.4	20.0	19.2	17.2	19.5	18.2	18.1	16.5	17.0
Serbia	RS	20.3	20.7	19.4	19.5	19.5	18.4	19.2	17.6	16.6	16.0	16.9	16.8	18.0	16.8	16.6
Slovakia	SK	19.4	20.6	18.5	18.9	18.7	19.7	18.5	17.8	17.0	15.7	17.2	16.0	17.1	16.1	14.9
Slovenia	SI	20.7	21.2	19.9	19.6	19.2	19.4	19.9	18.1	18.3	16.3	17.9	16.9	18.1	15.9	15.8
Spain	ES	26.5	25.5	25.6	24.1	24.1	23.4	22.9	22.1	19.8	20.0	21.4	20.3	21.6	19.2	18.6
Sweden	SE	14.9	15.1	13.2	13.2	13.4	14.7	13.4	12.9	12.3	11.6	11.2	11.5	10.4	10.4	9.7
Switzerland	CH	26.7	27.0	24.6	25.2	24.9	24.9	24.6	23.0	23.2	22.1	22.7	21.1	20.8	19.2	18.6
United Kingdom	UK	26.7	27.4	29.0	25.8	26.0	28.0	25.3	25.0	23.9	23.3	21.5	22.4	20.8	19.6	19.4
Total		**24.1**	**24.6**	**23.5**	**22.7**	**22.8**	**22.9**	**22.1**	**21.2**	**20.1**	**19.3**	**19.5**	**19.3**	**19.1**	**18.1**	**17.3**
EU-28		**24.3**	**24.8**	**23.8**	**22.8**	**23.0**	**23.1**	**22.3**	**21.4**	**20.3**	**19.5**	**19.7**	**19.4**	**19.2**	**18.2**	**17.4**
Northern		**15.3**	**15.2**	**13.7**	**13.3**	**13.1**	**14.5**	**13.4**	**13.1**	**12.5**	**11.7**	**11.3**	**11.5**	**10.5**	**10.6**	**9.7**
North-western		**25.8**	**26.0**	**26.3**	**24.7**	**24.8**	**25.8**	**23.9**	**23.2**	**22.5**	**21.4**	**20.5**	**20.9**	**19.9**	**18.8**	**18.1**
Central & South-eastern		**21.9**	**23.2**	**21.0**	**21.0**	**21.3**	**21.5**	**20.9**	**20.0**	**19.1**	**18.6**	**18.8**	**18.6**	**18.5**	**18.1**	**16.9**
Southern		**26.7**	**26.7**	**25.9**	**24.5**	**24.7**	**23.5**	**23.8**	**22.5**	**20.5**	**19.7**	**21.0**	**20.1**	**20.8**	**18.9**	**18.5**
Serbia without Kosovo	RS	20.3	20.7	19.4	19.5	19.5	18.6	19.2	17.7	16.7	16.1	17.0	16.9	18.1	16.8	16.7
Kosovo	KS	20.3	20.8	19.5	19.5	19.5	17.8	19.0	17.3	16.1	15.5	16.5	16.6	17.7	16.8	16.3

Table A4.11: Trend estimates and relative trend estimates for NO_2 annual average, spatial average (left) and population-weighted average (right) concentration in 2005-2019. Trend indicators show significance of trends (Mann-Kendall test) and Sen´s slope estimate Q with its confidence interval (Qmin95, Qmax95) at 95 %.

Country, region		NO_2 annual average, spatial average								NO_2 annual mean, population-weighted average							
		Sign.	Slope [µg.m^{-3}.yr^{-1}]			Sign.	Slope [%.yr^{-1}]			Sign.	Slope [µg.m^{-3}.yr^{-1}]			Sign.	Slope [%.yr^{-1}]		
			Q	Qmin95	Qmax95		Q	Qmin95	Qmax95		Q	Qmin95	Qmax95		Q	Qmin95	Qmax95
Albania	AL	***	-0.16	-0.21	-0.11	***	-2.23	-2.82	-1.57	**	-0.25	-0.37	-0.16	**	-1.31	-1.92	-0.83
Andorra	AD	**	-0.21	-0.36	-0.05	**	-2.64	-4.45	-0.61	***	-0.35	-0.49	-0.24	***	-1.73	-2.38	-1.16
Austria	AT	***	-0.24	-0.33	-0.18	***	-2.35	-3.16	-1.70	***	-0.49	-0.56	-0.37	***	-2.03	-2.35	-1.54
Belgium	BE	***	-0.49	-0.61	-0.41	***	-2.47	-3.08	-2.06	***	-0.70	-0.80	-0.59	***	-2.33	-2.66	-1.98
Bosnia & Herzegovina	BA	***	-0.21	-0.25	-0.17	***	-2.85	-3.39	-2.25	***	-0.27	-0.41	-0.15	***	-1.52	-2.31	-0.83
Bulgaria	BG	***	-0.13	-0.20	-0.08	***	-1.73	-2.61	-1.04	**	-0.33	-0.64	-0.13	**	-1.52	-3.00	-0.63
Croatia	HR	***	-0.23	-0.28	-0.20	***	-2.74	-3.28	-2.28	***	-0.30	-0.41	-0.22	***	-1.59	-2.13	-1.17
Cyprus	CY	**	-0.12	-0.20	-0.06	**	-1.98	-3.22	-0.90	**	-0.45	-0.79	-0.16	**	-2.56	-4.49	-0.91
Czechia	CZ	***	-0.27	-0.34	-0.19	***	-2.23	-2.85	-1.56	***	-0.41	-0.53	-0.31	***	-1.94	-2.51	-1.47
Denmark	DK	***	-0.19	-0.28	-0.13	***	-2.36	-3.34	-1.59	***	-0.40	-0.50	-0.32	***	-2.59	-3.22	-2.07
Estonia	EE	*	-0.06	-0.12	-0.01	*	-1.72	-3.57	-0.42	***	-0.29	-0.37	-0.20	***	-2.24	-2.89	-1.54
Finland	FI	**	-0.08	-0.12	-0.04	**	-2.54	-3.94	-1.28	***	-0.34	-0.46	-0.27	***	-2.49	-3.37	-2.02
France	FR	***	-0.26	-0.32	-0.21	***	-2.68	-3.28	-2.20	***	-0.55	-0.63	-0.49	***	-2.26	-2.59	-2.00
Germany	DE	***	-0.30	-0.34	-0.25	***	-2.10	-2.39	-1.76	***	-0.49	-0.57	-0.41	***	-1.88	-2.21	-1.58
Greece	GR	***	-0.23	-0.29	-0.17	***	-3.09	-3.78	-2.26	**	-0.59	-0.86	-0.33	**	-2.18	-3.20	-1.21
Hungary	HU	***	-0.18	-0.23	-0.10	***	-1.78	-2.29	-0.99	**	-0.27	-0.40	-0.16	**	-1.34	-1.99	-0.79
Iceland	IS	*	-0.01	-0.02	0.00	*	-0.88	-1.96	-0.25	***	-0.45	-0.73	-0.24	***	-2.13	-3.47	-1.14
Ireland	IE	**	-0.12	-0.20	-0.06	**	-2.10	-3.44	-1.01	**	-0.29	-0.39	-0.15	**	-1.84	-2.45	-0.97
Italy	IT	***	-0.40	-0.46	-0.34	***	-2.78	-3.18	-2.36	***	-0.82	-0.95	-0.70	***	-2.52	-2.92	-2.17
Latvia	LV	**	-0.08	-0.14	-0.03	**	-1.83	-3.19	-0.64	***	-0.30	-0.39	-0.17	***	-1.92	-2.54	-1.10
Liechtenstein	LI	**	-0.21	-0.25	-0.12	**	-1.66	-2.02	-0.95	***	-0.44	-0.55	-0.35	***	-1.71	-2.13	-1.35
Lithuania	LT	**	-0.08	-0.12	-0.03	**	-1.35	-1.85	-0.49	**	-0.20	-0.30	-0.09	**	-1.42	-2.16	-0.65
Luxembourg	LU	***	-0.44	-0.64	-0.36	***	-2.68	-3.86	-2.17	***	-0.68	-0.82	-0.58	***	-2.47	-3.01	-2.12
Malta	MT	**	-0.30	-0.39	-0.21	**	-2.74	-3.50	-1.87	**	-0.50	-0.73	-0.18	**	-2.90	-4.23	-1.02
Monaco	MC	***	-0.87	-1.06	-0.68	***	-2.70	-3.28	-2.10	***	-0.85	-1.00	-0.66	***	-2.44	-2.87	-1.89
Montenegro	ME	***	-0.15	-0.20	-0.11	***	-2.68	-3.54	-1.98	***	-0.22	-0.30	-0.12	***	-1.21	-1.63	-0.66
Netherlands	NL	***	-0.39	-0.46	-0.32	***	-1.93	-2.31	-1.59	***	-0.64	-0.74	-0.51	***	-2.25	-2.62	-1.80
North Macedonia	MK	***	-0.20	-0.24	-0.14	***	-2.49	-3.02	-1.74	***	-0.37	-0.59	-0.25	***	-1.51	-2.39	-1.03
Norway	NO	***	-0.07	-0.10	-0.04	***	-2.51	-3.91	-1.44	***	-0.52	-0.71	-0.37	***	-2.86	-3.89	-2.05
Poland	PL	**	-0.11	-0.18	-0.04	**	-1.12	-1.87	-0.41	**	-0.20	-0.31	-0.10	**	-1.11	-1.73	-0.57
Portugal	PT	***	-0.19	-0.25	-0.15	***	-2.64	-3.35	-2.06	***	-0.51	-0.69	-0.37	***	-2.49	-3.34	-1.81
Romania	RO	**	-0.11	-0.16	-0.06	**	-1.31	-1.98	-0.78	*	-0.17	-0.40	-0.02	*	-0.84	-2.04	-0.11
San Marino	SM	***	-0.76	-1.09	-0.45	***	-3.35	-4.79	-1.99	***	-0.98	-1.33	-0.65	***	-3.37	-4.61	-2.23
Serbia	RS	***	-0.18	-0.23	-0.13	***	-2.03	-2.50	-1.43	***	-0.29	-0.42	-0.19	***	-1.44	-2.08	-0.91
Slovakia	SK	***	-0.20	-0.26	-0.12	***	-1.96	-2.60	-1.19	***	-0.32	-0.44	-0.20	***	-1.60	-2.19	-1.02
Slovenia	SI	***	-0.27	-0.35	-0.20	***	-2.54	-3.29	-1.83	***	-0.35	-0.43	-0.25	***	-1.68	-2.06	-1.19
Spain	ES	***	-0.19	-0.24	-0.13	***	-2.65	-3.35	-1.91	***	-0.54	-0.65	-0.46	***	-2.06	-2.49	-1.76
Sweden	SE	**	-0.08	-0.14	-0.04	**	-2.66	-4.76	-1.39	***	-0.37	-0.44	-0.28	***	-2.47	-2.97	-1.84
Switzerland	CH	***	-0.30	-0.35	-0.23	***	-2.64	-3.09	-2.01	***	-0.54	-0.64	-0.43	***	-2.00	-2.37	-1.60
United Kingdom	UK	***	-0.26	-0.33	-0.20	***	-2.52	-3.22	-1.94	***	-0.64	-0.81	-0.49	***	-2.26	-2.85	-1.71
Total		***	**-0.18**	**-0.22**	**-0.16**	***	**-2.25**	**-2.72**	**-1.98**	***	**-0.50**	**-0.58**	**-0.43**	***	**-2.05**	**-2.34**	**-1.76**
EU-28		***	**-0.20**	**-0.24**	**-0.17**	***	**-2.29**	**-2.75**	**-1.93**	***	**-0.51**	**-0.58**	**-0.44**	***	**-2.06**	**-2.35**	**-1.79**
Northern		***	**-0.08**	**-0.12**	**-0.05**	***	**-2.43**	**-3.72**	**-1.39**	***	**-0.38**	**-0.44**	**-0.29**	***	**-2.49**	**-2.91**	**-1.92**
North-western		***	**-0.24**	**-0.28**	**-0.20**	***	**-2.49**	**-2.96**	**-2.05**	***	**-0.61**	**-0.70**	**-0.53**	***	**-2.24**	**-2.59**	**-1.96**
Central & South-eastern		***	**-0.19**	**-0.25**	**-0.14**	***	**-1.74**	**-2.33**	**-1.30**	***	**-0.36**	**-0.46**	**-0.28**	***	**-1.62**	**-2.02**	**-1.22**
Southern		***	**-0.24**	**-0.29**	**-0.20**	***	**-2.69**	**-3.20**	**-2.25**	***	**-0.60**	**-0.70**	**-0.51**	***	**-2.26**	**-2.60**	**-1.90**
Serbia without Kosovo	RS	***	-0.18	-0.22	-0.13	***	-2.07	-2.49	-1.41	***	-0.29	-0.42	-0.17	***	-1.40	-2.08	-0.82
Kosovo	KS	***	-0.21	-0.26	-0.15	***	-2.04	-2.53	-1.48	***	-0.31	-0.49	-0.19	***	-1.55	-2.43	-0.94

Table A4.12: Trend estimates and relative trend estimates for NO_2 annual average, spatial average concentration in 2005-2019, urban (left) and rural (right) areas. Trend indicators show significance of trends (Mann-Kendall test) and Sen´s slope estimate Q with its confidence interval (Qmin95, Qmax95) at 95 %.

Country, region		NO_2 annual average, spatial average, urban areas								NO_2 annual average, spatial average, rural areas							
		Sign.	Slope [μg.m^{-3}.yr^{-1}]			Sign.	Slope [%.yr^{-1}]			Sign.	Slope [μg.m^{-3}.yr^{-1}]			Sign.	Slope [%.yr^{-1}]		
			Q	Qmin95	Qmax95		Q	Qmin95	Qmax95		Q	Qmin95	Qmax95		Q	Qmin95	Qmax95
Albania	AL	***	-0,22	-0,32	-0,14	***	-1,33	-1,88	-0,83	***	-0,15	-0,20	-0,11	***	-2,34	-3,06	-1,65
Andorra	AD	***	-0,33	-0,44	-0,20	***	-1,69	-2,25	-1,04	*	-0,18	-0,36	-0,04	*	-2,58	-5,07	-0,53
Austria	AT	***	-0,46	-0,55	-0,34	***	-2,05	-2,49	-1,52	***	-0,23	-0,31	-0,16	***	-2,43	-3,25	-1,73
Belgium	BE	***	-0,66	-0,74	-0,57	***	-2,40	-2,69	-2,09	***	-0,44	-0,54	-0,36	***	-2,58	-3,13	-2,09
Bosnia & Herzegovina	BA	**	-0,27	-0,40	-0,13	**	-1,49	-2,25	-0,73	***	-0,21	-0,24	-0,17	***	-3,01	-3,56	-2,43
Bulgaria	BG	**	-0,29	-0,63	-0,09	**	-1,60	-3,42	-0,50	***	-0,13	-0,19	-0,08	***	-1,81	-2,66	-1,13
Croatia	HR	**	-0,28	-0,38	-0,18	**	-1,52	-2,11	-1,02	***	-0,23	-0,28	-0,19	***	-2,86	-3,43	-2,36
Cyprus	CY	*	-0,58	-0,81	-0,05	*	-3,58	-5,00	-0,29	**	-0,11	-0,16	-0,04	**	-1,88	-2,83	-0,78
Czechia	CZ	***	-0,41	-0,52	-0,29	***	-2,03	-2,60	-1,44	***	-0,25	-0,33	-0,18	***	-2,24	-2,99	-1,58
Denmark	DK	***	-0,39	-0,48	-0,27	***	-2,74	-3,42	-1,91	***	-0,18	-0,26	-0,12	***	-2,31	-3,30	-1,55
Estonia	EE	***	-0,29	-0,41	-0,17	***	-2,41	-3,39	-1,44	*	-0,06	-0,12	-0,01	*	-1,69	-3,57	-0,38
Finland	FI	***	-0,38	-0,52	-0,29	***	-2,71	-3,69	-2,05	**	-0,08	-0,12	-0,04	**	-2,51	-4,02	-1,27
France	FR	***	-0,52	-0,58	-0,46	***	-2,51	-2,78	-2,23	***	-0,24	-0,29	-0,20	***	-2,72	-3,27	-2,24
Germany	DE	***	-0,47	-0,53	-0,38	***	-1,96	-2,20	-1,58	***	-0,27	-0,31	-0,23	***	-2,13	-2,46	-1,82
Greece	GR	**	-0,38	-0,64	-0,20	**	-2,36	-3,91	-1,20	***	-0,23	-0,28	-0,17	***	-3,13	-3,87	-2,38
Hungary	HU	**	-0,24	-0,36	-0,15	**	-1,33	-2,00	-0,82	***	-0,18	-0,24	-0,10	***	-1,89	-2,45	-1,04
Iceland	IS	***	-0,41	-0,70	-0,19	***	-2,15	-3,63	-1,01	*	-0,01	-0,01	0,00	*	-0,85	-1,85	-0,10
Ireland	IE	**	-0,33	-0,44	-0,17	**	-1,87	-2,54	-0,97	**	-0,11	-0,19	-0,05	**	-2,15	-3,55	-1,01
Italy	IT	***	-0,78	-0,91	-0,67	***	-2,59	-3,03	-2,23	***	-0,35	-0,39	-0,29	***	-2,84	-3,16	-2,36
Latvia	LV	***	-0,28	-0,40	-0,15	***	-2,03	-2,88	-1,05	*	-0,08	-0,14	-0,02	*	-1,81	-3,17	-0,53
Liechtenstein	LI	***	-0,45	-0,55	-0,35	***	-1,72	-2,12	-1,35	+	-0,12	-0,21	0,00	*	-1,37	-2,46	0,04
Lithuania	LT	**	-0,19	-0,33	-0,10	**	-1,48	-2,56	-0,80	*	-0,08	-0,11	-0,03	*	-1,40	-1,85	-0,49
Luxembourg	LU	***	-0,65	-0,78	-0,55	***	-2,48	-2,99	-2,09	***	-0,41	-0,59	-0,30	***	-2,77	-3,95	-2,04
Malta	MT	**	-0,49	-0,71	-0,15	**	-3,13	-4,55	-0,95	**	-0,19	-0,26	-0,06		-2,28	-3,10	-0,68
Monaco	MC	***	-0,87	-1,06	-0,68	***	-2,70	-3,28	-2,10						0,00	0,00	0,00
Montenegro	ME	***	-0,23	-0,30	-0,12	***	-1,22	-1,65	-0,65	***	-0,15	-0,20	-0,11	***	-2,79	-3,73	-2,06
Netherlands	NL	***	-0,59	-0,69	-0,47	***	-2,26	-2,66	-1,79	***	-0,34	-0,41	-0,26	***	-1,83	-2,22	-1,43
North Macedonia	MK	**	-0,34	-0,56	-0,19	**	-1,60	-2,62	-0,90	***	-0,19	-0,23	-0,13	***	-2,59	-3,06	-1,76
Norway	NO	***	-0,56	-0,80	-0,39	***	-2,95	-4,20	-2,06	***	-0,06	-0,10	-0,03	***	-2,46	-4,08	-1,41
Poland	PL	**	-0,19	-0,34	-0,11	**	-1,12	-2,02	-0,64	**	-0,11	-0,16	-0,04	**	-1,17	-1,82	-0,39
Portugal	PT	***	-0,50	-0,66	-0,39	***	-2,65	-3,49	-2,09	***	-0,17	-0,22	-0,12	***	-2,67	-3,44	-1,86
Romania	RO	*	-0,14	-0,30	-0,01	*	-0,80	-1,75	-0,09	**	-0,11	-0,15	-0,07	**	-1,41	-2,01	-0,93
San Marino	SM	***	-0,98	-1,32	-0,63	***	-3,40	-4,58	-2,20	***	-0,45	-0,74	-0,29	***	-3,04	-5,04	-1,97
Serbia	RS	**	-0,29	-0,43	-0,17	**	-1,50	-2,21	-0,86	***	-0,18	-0,21	-0,12	***	-2,14	-2,56	-1,46
Slovakia	SK	***	-0,31	-0,42	-0,20	***	-1,66	-2,26	-1,05	***	-0,19	-0,26	-0,11	***	-2,01	-2,85	-1,24
Slovenia	SI	***	-0,33	-0,44	-0,22	***	-1,60	-2,13	-1,06	***	-0,27	-0,35	-0,20	***	-2,71	-3,53	-1,99
Spain	ES	***	-0,44	-0,52	-0,34	***	-2,23	-2,64	-1,75	***	-0,18	-0,23	-0,12	***	-2,68	-3,42	-1,87
Sweden	SE	***	-0,39	-0,47	-0,28	***	-2,61	-3,11	-1,85	**	-0,08	-0,14	-0,04	**	-2,75	-4,90	-1,37
Switzerland	CH	***	-0,52	-0,61	-0,42	***	-2,05	-2,43	-1,67	***	-0,26	-0,33	-0,20	***	-2,75	-3,54	-2,13
United Kingdom	UK	***	-0,58	-0,74	-0,44	***	-2,28	-2,92	-1,71	***	-0,22	-0,26	-0,16	***	-2,60	-3,10	-1,97
Total		***	**-0,46**	**-0,53**	**-0,39**	***	**-2,11**	**-2,43**	**-1,80**	***	**-0,16**	**-0,20**	**-0,14**	***	**-2,29**	**-2,77**	**-2,02**
EU-28		***	**-0,47**	**-0,53**	**-0,40**	***	**-2,12**	**-2,41**	**-1,83**	***	**-0,18**	**-0,21**	**-0,15**	***	**-2,32**	**-2,76**	**-1,92**
Northern		***	**-0,39**	**-0,50**	**-0,31**	***	**-2,55**	**-3,26**	**-2,05**	***	**-0,08**	**-0,12**	**-0,04**	***	**-2,43**	**-3,80**	**-1,35**
North-western		***	**-0,56**	**-0,65**	**-0,49**	***	**-2,35**	**-2,74**	**-2,05**	***	**-0,21**	**-0,25**	**-0,17**	***	**-2,53**	**-3,06**	**-2,08**
Central & South-eastern		***	**-0,34**	**-0,43**	**-0,26**	***	**-1,63**	**-2,08**	**-1,24**	***	**-0,17**	**-0,23**	**-0,13**	***	**-1,76**	**-2,38**	**-1,31**
Southern		***	**-0,55**	**-0,65**	**-0,46**	***	**-2,37**	**-2,76**	**-1,98**	***	**-0,23**	**-0,26**	**-0,19**	***	**-2,80**	**-3,23**	**-2,30**
Serbia without Kosovo	RS	**	-0,27	-0,40	-0,16	**	-1,42	-2,11	-0,82	***	-0,18	-0,21	-0,13	***	-2,17	-2,57	-1,56
Kosovo	KS	**	-0,30	-0,50	-0,19	**	-1,54	-2,53	-0,98	***	-0,18	-0,23	-0,13	***	-2,12	-2,66	-1,59

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