ETC-HE Report 2022/3

Status report of air quality in Europe for year 2021, using validated and up-to-date data

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Contents

1 Summary

The *2021 Status report of air quality in Europe* presents summarized information on the air quality data for the protection of health reported in the previous years. The reported 2021 data used in this analysis was reported as up-to-date (UTD) data, prior to final quality control and validated data reporting by the countries([1]). It provides information on the following pollutants, regulated by the Ambient Air Quality Directives:

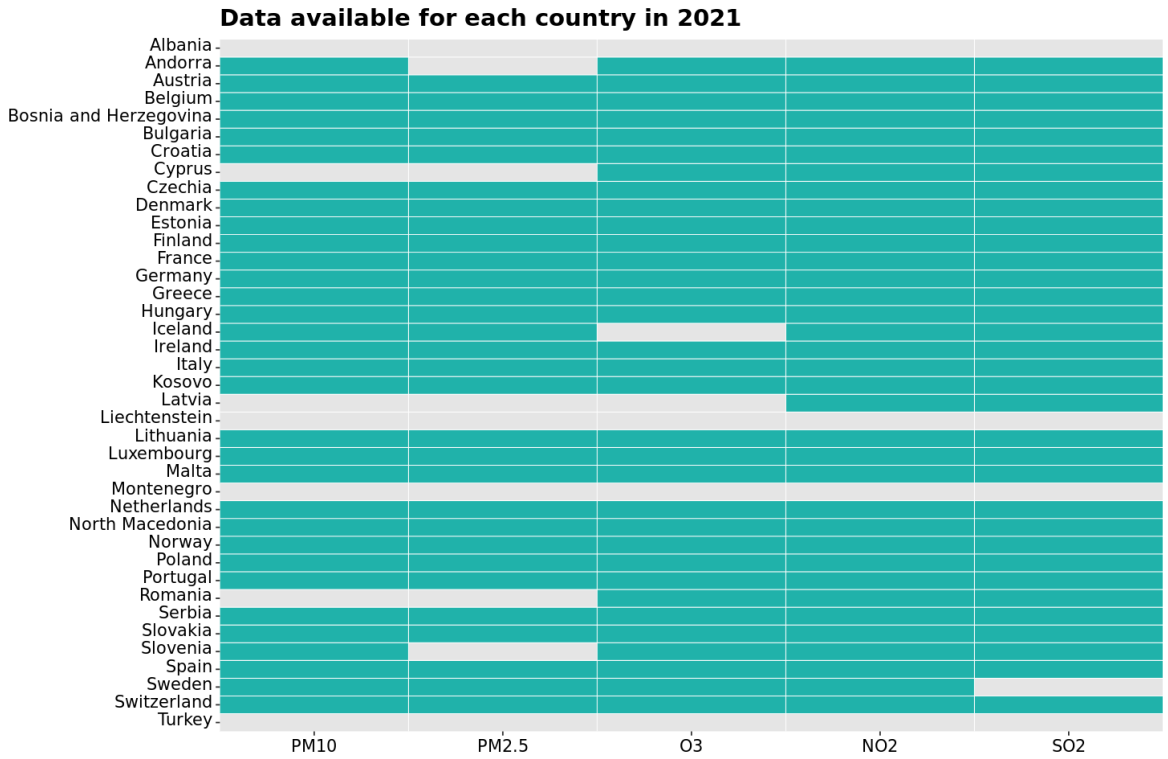
- PM_{10}: Particulate matter with a diameter of 10 µm or less
- $PM_{2.5}$: Particulate matter with a diameter of 2.5 µm or less
- O_3: Tropospheric ozone
- NO_2: Nitrogen dioxide
- SO_2: Sulphur dioxide

It also offers a comparison with the situation in the previous three years. For those years, validated data are considered.

Data included in this report was received by 24 March 2022 from the reporting countries. By that date the reporting status of 2021 up-to-date data is summarized in Figure 1, where a green box indicates that the referred pollutant was reported by the referred country and a grey box indicates the contrary (that the referred pollutant was not reported by the referred country). Please see editorial notes at the end of this Chapter on additional information on the data used. The number of stations by country reporting each pollutant is summarized in Table 3.

[1] https://aqportal.discomap.eea.europa.eu/index.php/reporters-corner/

Figure 1: Reporting status of 2021 air quality data by 24 March 2022



The countries included in Figure 1 are the EU-27 (Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain and Sweden); the five other member countries of the EEA (Iceland, Liechtenstein, Norway, Switzerland and Turkey) that, together with the EU-27 form the EEA-32; the six EEA's cooperating countries from the Western Balkans (Albania, Bosnia and Herzegovina, Kosovo under UN Security Council Resolution 1244/99, Montenegro, North Macedonia and Serbia) that, together with the EEA-32 form the EEA-38; and the voluntary reporting country of Andorra.

The air quality data are stored (UTD data only temporarily) at the EEA's e-reporting database ([2]). Therefore, this is the source for all maps and figures in the report.

1.1 Particulate matter

For PM_{10}, concentrations above the EU daily limit value (50 µg/m^3) were registered at 11 % of the reporting stations in 12 countries in EU-27 and in four other reporting countries. For $PM_{2.5}$,

[2] https://discomap.eea.europa.eu/map/fme/AirQualityExport.htm

concentrations above the annual limit value (25 µg/m^3) were registered at 2 % of the reporting stations in three countries in EU-27 and three other reporting countries.

The long-term world health organitzation air quality guidelines (WHO AQG) for PM_{10} (15 µg/m^3) was exceeded at 66 % of the stations in 24 countries of the EU-27 and 7 other reporting countries. The long-term WHO AQG for $PM_{2.5}$ (5 µg/m^3) was exceeded at 94 % of the stations located in 23 countries of the EU-27 and 7 other reporting countries.

1.2 Ozone

9 % of stations registered concentrations above the EU O_3 target value (120 µg/m^3) for the protection of human health. These stations were located in 16 countries of the EU-27 and four other reporting European countries. The long-term EU objective (120 µg/m^3) was met in only 19 % of the stations. The short-term WHO AQG for O_3 (100 µg/m^3) was exceeded in 92 % of all the reporting stations, and 98 % of stations registered concentrations above the long-term WHO AQG for O_3 (60 µg/m^3).

1.3 Nitrogen dioxide

Around 1 % of all the reporting stations recorded concentrations above the annual limit value for NO_2 (40 µg/m^3). These stations were located in 7 countries of the EU-27 and one other reporting countries. 100 % of concentrations above this limit value were observed at traffic stations.

On the contrary, 73 % of stations, located in 27 countries of the EU-27 and eight other reporting countries reported concentrations above the WHO AQG level of 10 µg/m^3.

1.4 Sulphur dioxide

Only 14 stations (out of more than 1178) in two countries of the EU-27 and one other reporting countries measured values for SO_2 above the EU daily limit value (125 µg/m^3). However, 4 % of all SO_2 stations, located in 13 reporting countries, measured SO_2 concentrations above the daily WHO AQG (40 µg/m^3).

1.5 Editorial note

France informed that a measurement change for PM_{10} was introduced in 2007, and that the number of $PM_{2.5}$ stations before 2008 was low. Both issues could affect the comparability over the years shown in the heatmaps.

Italy informed that the values of NO_2 and SO_2 from station IT2090A, Schiavonea are wrong.

2 Introduction

The *2021 Status report of air quality in Europe* presents summarized information on the air quality data reported in the previous years. 2021 data was reported as up-to-date (UTD) data in a continuous basis prior to final quality control and official reporting of validated data by the countries, which will be done under the 2022 September reporting cycle (validated assessment data for 2021, deadline of submission 30 September 2022). It aims at informing on the current status of ambient air quality in Europe, based on the most updated data available for the analysis of a complete calendar year. Furthermore, it informs on progress towards meeting the air quality standards established for the protection of health in the Ambient Air Quality Directive (EU, 2008) (Table 1) and the World Health Organization (WHO) air quality guidelines (WHO, 2000, 2006, 2021) (Table 2)([3]).

This report builds on the former EEA "Air quality in Europe report" (EEA, 2020) content, figures and maps regarding the status of monitored air quality in Europe. The report focuses on the analysis of the main pollutants, to allow a meaningful preliminary analysis of their concentration status in Europe. It provides:

- a European overview of the monitoring stations that reported UTD 2021 data, and of their concentrations in relation to the EU legal standards and WHO AQGs for each pollutant;
- a map with the 2021 UTD concentrations at station level for each pollutant;
- a boxplot graph summarizing for each country the range of concentrations (highlighting the lowest, highest, average and the 25 and 75 percentiles) for PM_{10}, $PM_{2.5}$, NO_2 and O_3.

Furthermore, it provides:

- maps with the situation at station level for the previous three years (using validated data). In this way, any significant change in the spatial distribution of the values above the set thresholds in the legends can be observed (assuming the UTD stations dataset is complete);

[3] Nevertheless, in this report the following standards and guidelines are not analysed: information and alert thresholds for O_3, alert threshold for NO_2, annual target value for BaP, alert threshold for SO_2, limit value for CO maximum daily 8-hour mean, annual limit value for C_6H_6, annual limit value for Pb, target value for As, target value for Cd, and target value for Ni in Table 1; and hourly air quality guideline for NO_2, reference level for annual mean of BaP, 10 minutes air quality guideline for SO_2, air quality guidelines for CO, reference level for annual mean of C_6H_6, air quality guideline for Pb, reference level for annual mean of As, air quality guideline for Cd, and reference level for annual mean of Ni in Table 2.

- heatmaps with the evolution of the mean and the maximum measured concentrations at country level since 2000 (using validated data for all years up to 2020).

Please be aware that the number of stations can vary once the validated dataset for 2021 is received by 30 September 2022. In some figures like the boxplots, the final order of the countries may vary once the validated data are submitted.

Table 1: Air quality standards for the protection of health, as given in the EU Ambient Air Quality Directives

Pollutant	Averaging period	Legal nature and concentration	Comments
PM_{10}	1 day	Limit value: 50 µg/m^3	Not to be exceeded on more than 35 days per year
	Calendar year	Limit value: 40 µg/m^3	
$PM_{2.5}$	Calendar year	Limit value: 25 µg/m^3	Stage 1
		Indicative limit value: 20 µg/m^3	Stage 2: indicative limit value to be reviewed by the Commission in 2013. It remained unchanged after that revision
		Exposure concentration obligation: 20 µg/m^3	Average Exposure Indicator (AEI) ([a]) in 2015 (2013-2015 average)
		National Exposure reduction target: 0-20 percentage reduction in exposure	AEI ([a]) in 2020, the percentage reduction depends on the initial AEI
O_3	Maximum daily 8-hour mean	Target value: 120 µg/m^3	Not to be exceeded on more than 25 days/year, averaged over 3 years ([b])
		Long term objective: 120 µg/m^3	
	1 hour	Information threshold: 180 µg/m^3 Alert threshold: 240 µg/m^3	
NO_2	1 hour	Limit value: 200 µg/m^3	Not to be exceeded on more than 18 hours per year
		Alert threshold: 400 µg/m^3	To be measured over 3 consecutive hours over 100 km^2 or an entire zone
	Calendar year	Limit value: 40 µg/m^3	
BaP	Calendar year	Target value: 1 ng/m^3	Measured as content in PM_{10}
SO_2	1 hour	Limit value: 350 µg/m^3	Not to be exceeded on more than 24 hours per year
		Alert threshold: 500 µg/m^3	To be measured over 3 consecutive hours over 100 km^2 or an entire zone
	1 day	Limit value: 125 µg/m^3	Not to be exceeded on more than 3 days per year
CO	Maximum daily 8-hour mean	Limit value: 10 mg/m^3	
C_6H_6	Calendar year	Limit value: 5 µg/m^3	
Pb	Calendar year	Limit value: 0.5 µg/m^3	Measured as content in PM_{10}
As	Calendar year	Target value: 6 ng/m^3	Measured as content in PM_{10}
Cd	Calendar year	Target value: 5 ng/m^3	Measured as content in PM_{10}
Ni	Calendar year	Target value: 20 ng/m^3	Measured as content in PM_{10}

Notes:

[a] AEI: based upon measurements in urban background locations established for this purpose by the Member States, assessed as a 3-year running annual mean.

[b] In the context of this report, only the maximum daily 8-hour means in 2021 are considered, so no average over the period 2019 - 2021 is presented.

Sources:

EU (2004, 2008).

Table 2: WHO air quality guidelines (AQGs) and estimated reference levels (RL) ([a])

Pollutant	Averaging period	AQG	RL	Comments
PM_{10}	1 day	45 µg/m^3		99th percentile (3-4 exceedance days per year). Updated 2021 guideline
	Calendar year	15 µg/m^3		Updated 2021 guideline
$PM_{2.5}$	1 day	15 µg/m^3		99th percentile (3-4 exceedance days per year). Updated 2021 guideline
	Calendar year	5 µg/m^3		Updated 2021 guideline
O_3	Maximum daily 8-hour mean	100 µg/m^3		99th percentile (3-4 exceedance days per year). New 2021 guideline
	Peak season ([b])	60 µg/m^3		New 2021 guideline
NO_2	1 hour	200 µg/m^3		
	1 day	25 µg/m^3		99th percentile (3-4 exceedance days per year). New 2021 guideline
	Calendar year	10 µg/m^3		Updated 2021 guideline
BaP	Calendar year		0.12 ng/m^3	
SO_2	10 minutes	500 µg/m^3		
	1 day	40 µg/m^3		99th percentile (3-4 exceedance days per year). New 2021 guideline
CO	1 hour	30 mg/m^3		
	Maximum daily 8-hour mean	10 mg/m^3		
	1 day	4 mg/m^3		99th percentile (3-4 exceedance days per year). New 2021 guideline
C_6H_6	Calendar year		1.7 µg/m^3	
Pb	Calendar year	0.5 µg/m^3		
As	Calendar year		6.6 ng/m^3	
Cd	Calendar year	5 ng/m^3 ([c])		
Ni	Calendar year		25 ng/m^3	

Notes:

[a] As WHO has not set an AQG for BaP, C_6H_6, As and Ni, the RL was estimated assuming an acceptable risk of additional lifetime cancer risk of approximately 1 in 100 000.

[b] Average of daily maximum 8-hour mean concentration in the six consecutive months with the highest six-month running average O_3 concentration.

[c] AQG set to prevent any further increase of Cd in agricultural soil, likely to increase the dietary intake of future generations.

Sources:

WHO (2000, 2006, 2021).

Box 1.1 Classification of monitoring stations

Fixed sampling points in Europe are situated at different types of stations following rules for macro- and micro-scale siting. Briefly, depending on the predominant emission sources, stations are classified as follows:

- traffic stations: located in close proximity to a single major road;
- industrial stations: located in close proximity to an industrial area or an industrial source;
- background stations: where pollution levels are representative of the average exposure of the general population or vegetation.

Depending on the distribution/density of buildings, the area surrounding the station is classified as follows:

- urban: continuously built-up urban area;
- suburban: largely built-up urban area;
- rural: all other areas.

For most of the pollutants, monitoring stations have to fulfil the criterion of reporting more than 75 % of valid data out of all the possible data in a year to be included in this assessment. Reporting stations not fulfilling the minimum data coverage could be found at the Annual AQ statistics table. Measurement data are rounded following the general recommendations under (EU, 2011). The number of considered decimals are indicated in the legend of the corresponding maps.
The assessments, in the cases of PM and SO_2, do not account for the fact that the Ambient Air Quality Directive (EU, 2008) provides Member States with the possibility of subtracting contributions to the measured concentrations from natural sources and winter road sanding/salting under specific circumstances.

3 Status of particulate matter ambient air concentrations

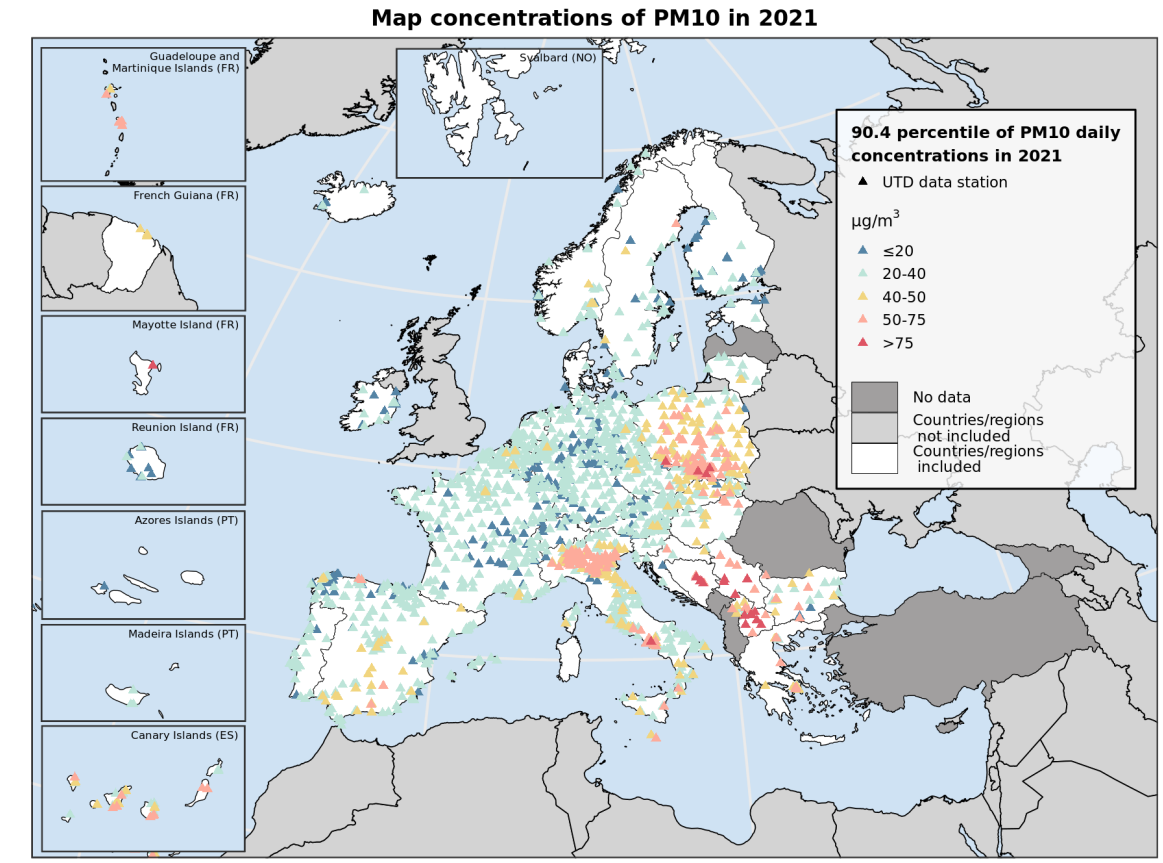
3.1 Status of PM_{10} concentrations

The EEA received PM_{10} data for 2021, with sufficient valid measurements from 2253 stations for the calculation of annual mean concentrations and from 2250 stations in relation to the daily limit value. The stations were located in all the reporting countries shown in Figure 1.

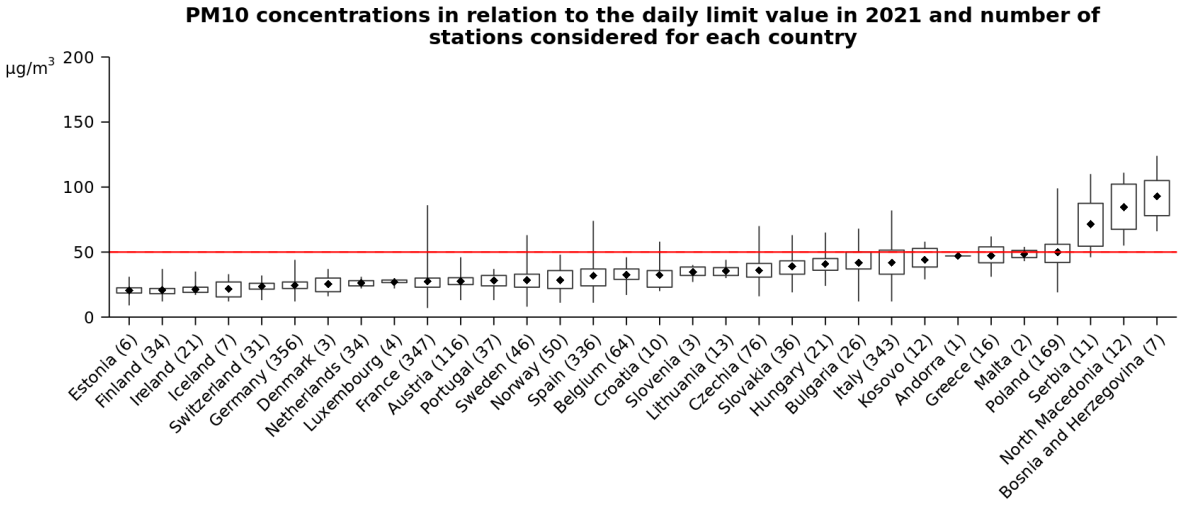
Twelve countries in EU-27, and four other reporting countries reported PM_{10} concentrations above the EU daily limit value of 50 µg/m^3 (Figure 2). This was the case for 11 % (240) of reporting stations. In total, 96 % of those stations were either urban (82 %) or suburban (14 %). The stricter value of the WHO AQG for PM_{10} daily mean (45 µg/m^3) was exceeded at 67 % (1514) of the stations in all the reporting countries (Figure 8).

Concentrations above the PM_{10} annual limit value (40 µg/m^3) were monitored in 1 % (24 stations) of all the reporting stations, located in 5 countries in EU-27, and 3 other reporting countries. The stricter value of the WHO AQG for PM_{10} annual mean (15 µg/m^3) was exceeded at 66 % (1486) of the stations in all the reporting countries, except in Iceland (Figure 5).

Figure 2: UTD Map and boxplot of PM_{10} concentrations in 2021 - daily limit value



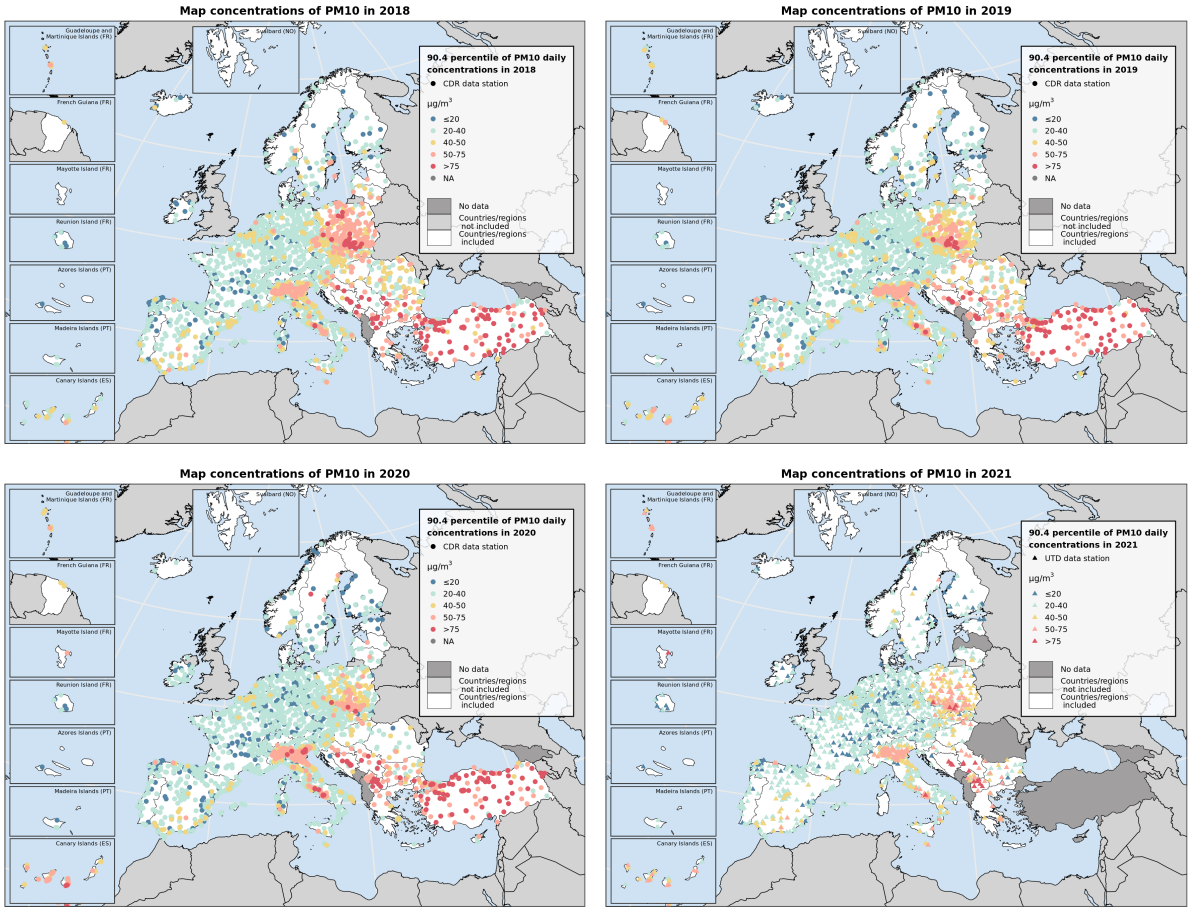
Note: Observed concentrations of PM10 in 2021. The possibility of subtracting contributions to the measured concentrations from natural sources and winter road sanding/salting has not been considered. The map shows the 90.4 percentile of the PM10 daily mean concentrations, representing the 36th highest value in a complete series. It is related to the PM10 daily limit value, allowing 35 exceedances of the 50 µg/m³ threshold over 1 year. The last two colour categories indicate stations with concentrations above this daily limit value. Only stations with more than 75 % of valid data, and more than 14 % in the case of fixed random measurements, have been included in the map.



Note: The graph is based, for each country, on the 90.4 percentile of daily mean concentration values corresponding to the 36th highest daily mean. For each country, the number of stations considered (in brackets) and the lowest, highest and average 90.4 percentile values (in µg/m³) recorded at its stations are given. The rectangles mark the 25th and 75th percentiles. At 25 % of the stations, levels are below the lower percentile; at 25 % of the stations, concentrations are above the upper percentile. The daily limit value set by EU legislation is marked by the horizontal line. The graph should be read in relation to the above map, as a country's situation depends on the number of stations considered.

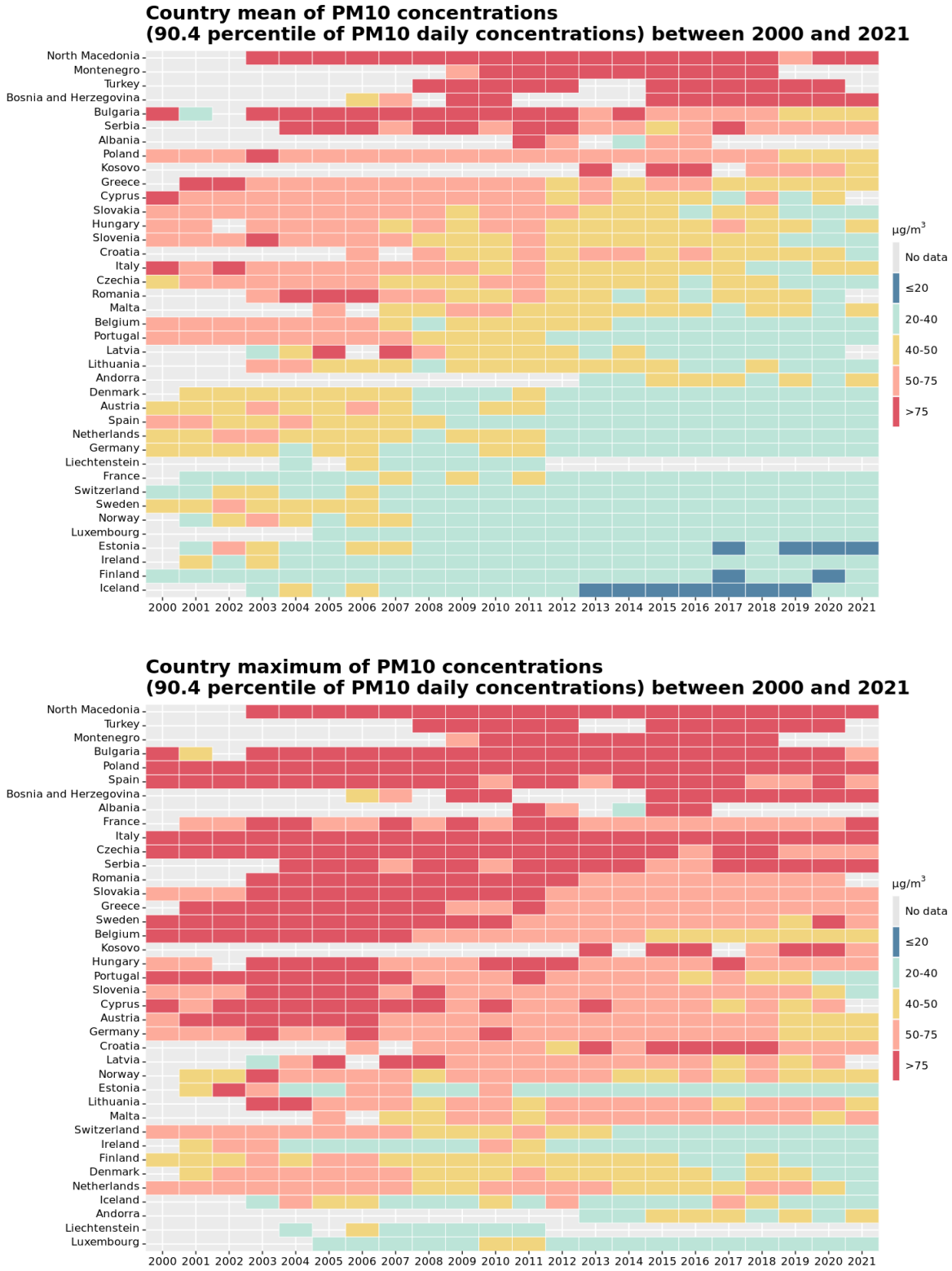
Figure 3 shows the maps of the 90.4 percentile of PM_{10} daily mean concentrations (equivalent to the PM_{10} daily limit value) for four years. In this way, any significant change in the spatial distribution of the values above the set thresholds in the legends can be observed. Note that only the last year's map (2021) is based on UTD data, while the previous three years are based on officially reported validated data (CDR).

Figure 3: Maps of PM_{10} concentrations (daily limit value) for the last 4 years



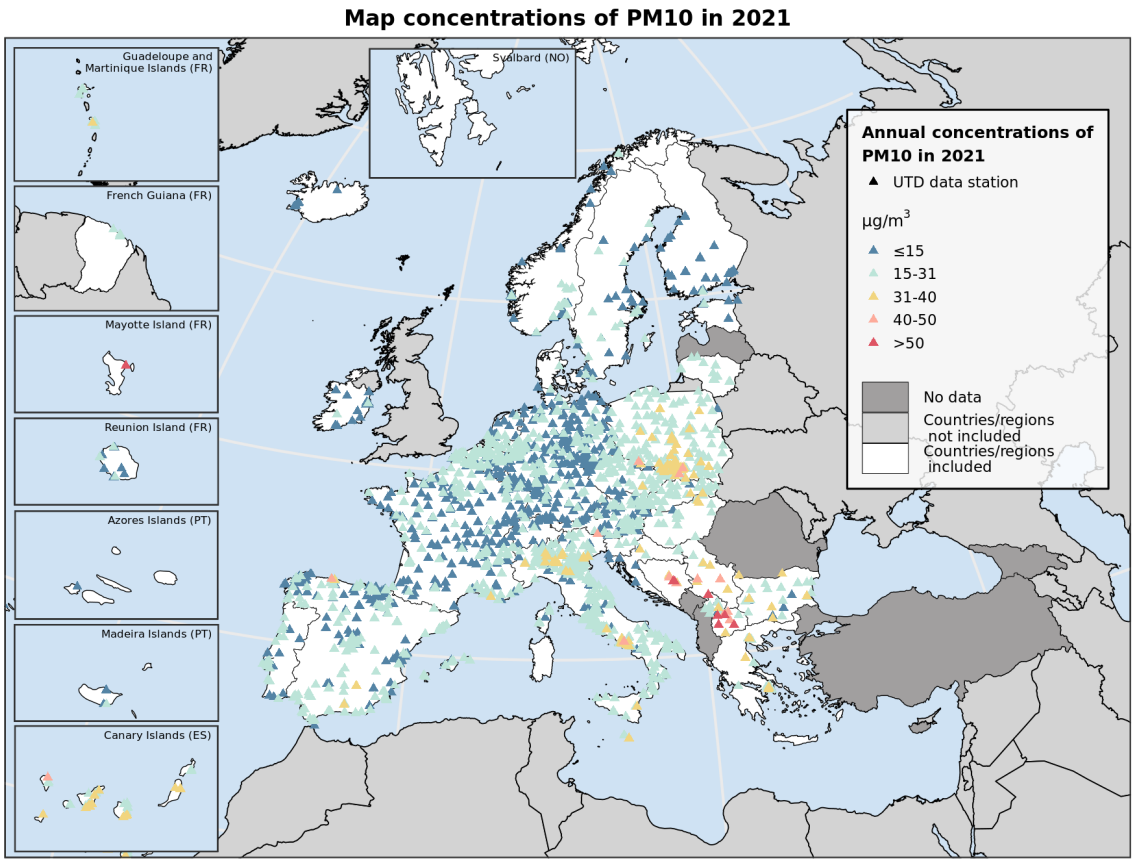
Heatmaps with the evolution from 2000 of the mean (top) and the maximum (bottom) 90.4 percentile of PM_{10} daily mean concentrations at country level are shown in figure 4. In this way, the evolution along years of the average and maximum measured concentration levels can be seen for each country. Note that meteorological variability has a considerable impact on year-to-year changes in ambient air concentrations of air pollutants (EEA, 2020), and the last year (2021) is based on UTD data, while the previous years are based on officially reported validated data.

Figure 4: Evolution of mean (top) and maximum (bottom) 90.4 percentile of PM_{10} daily mean concentrations (daily limit value) per country from 2000

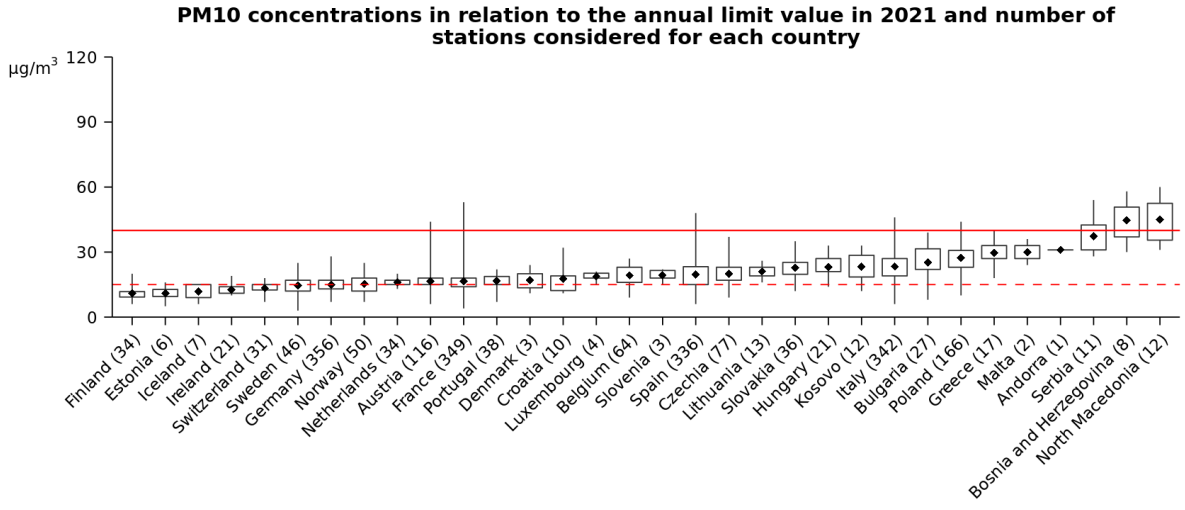


Note: It is important to note that the figure is not based on a consistent set of stations. The number, location and classification of the stations included may vary from year to year.

Figure 5: UTD Map and boxplot of PM_{10} concentrations in 2021 - annual limit value



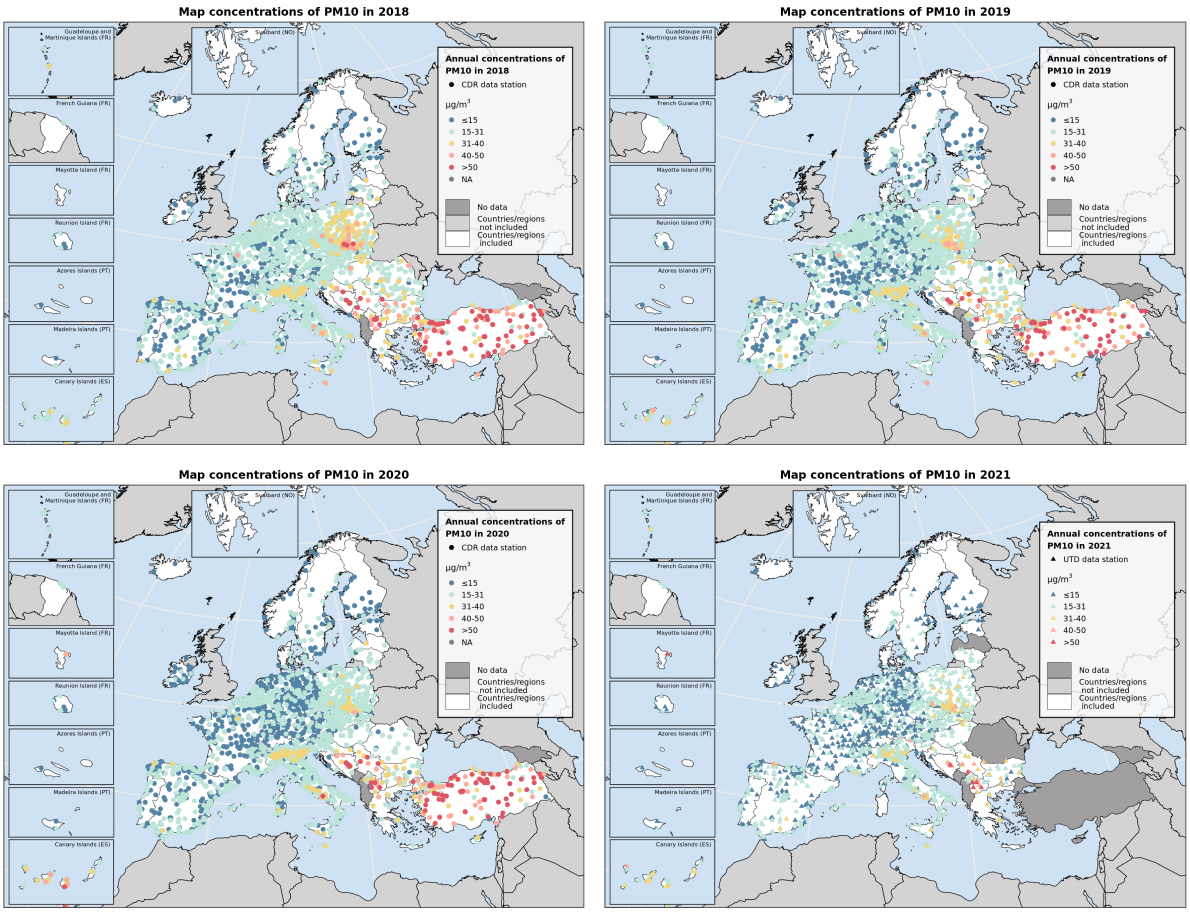
Note: Observed concentrations of PM10 in 2021. The possibility of subtracting contributions to the measured concentrations from natural sources and winter road sanding/salting has not been considered. The last two colour categories indicate stations reporting concentrations above the EU annual limit value (40 µg/m³). The first colour category indicate stations reporting values below the WHO AQG for PM10 (15 µg/m³). Only stations with more than 75 % of valid data, and more than 14 % in the case of fixed random measurements, have been included in the map.



Note: The graph is based on annual mean concentration values. For each country, the number of stations considered (in brackets) and the lowest, highest and average values (in µg/m³) recorded at its stations are given. The rectangles mark the 25th and 75th percentiles. At 25 % of the stations, levels are below the lower percentile; at 25 % of the stations, concentrations are above the upper percentile. The annual limit value set by EU legislation is marked by the upper continuous horizontal line. The WHO AQG is marked by the lower dashed horizontal line. The graph should be read in relation to the above map, as a country's situation depends on the number of stations considered.

Figure 6 shows the maps of PM_{10} annual mean concentrations at station level for the last four years. In this way, any significant change in the spatial distribution of the values above the set thresholds in the legends can be observed. Note that only the last year's map (2021) is based on UTD data, while the previous three years are based on officially reported validated data (CDR).

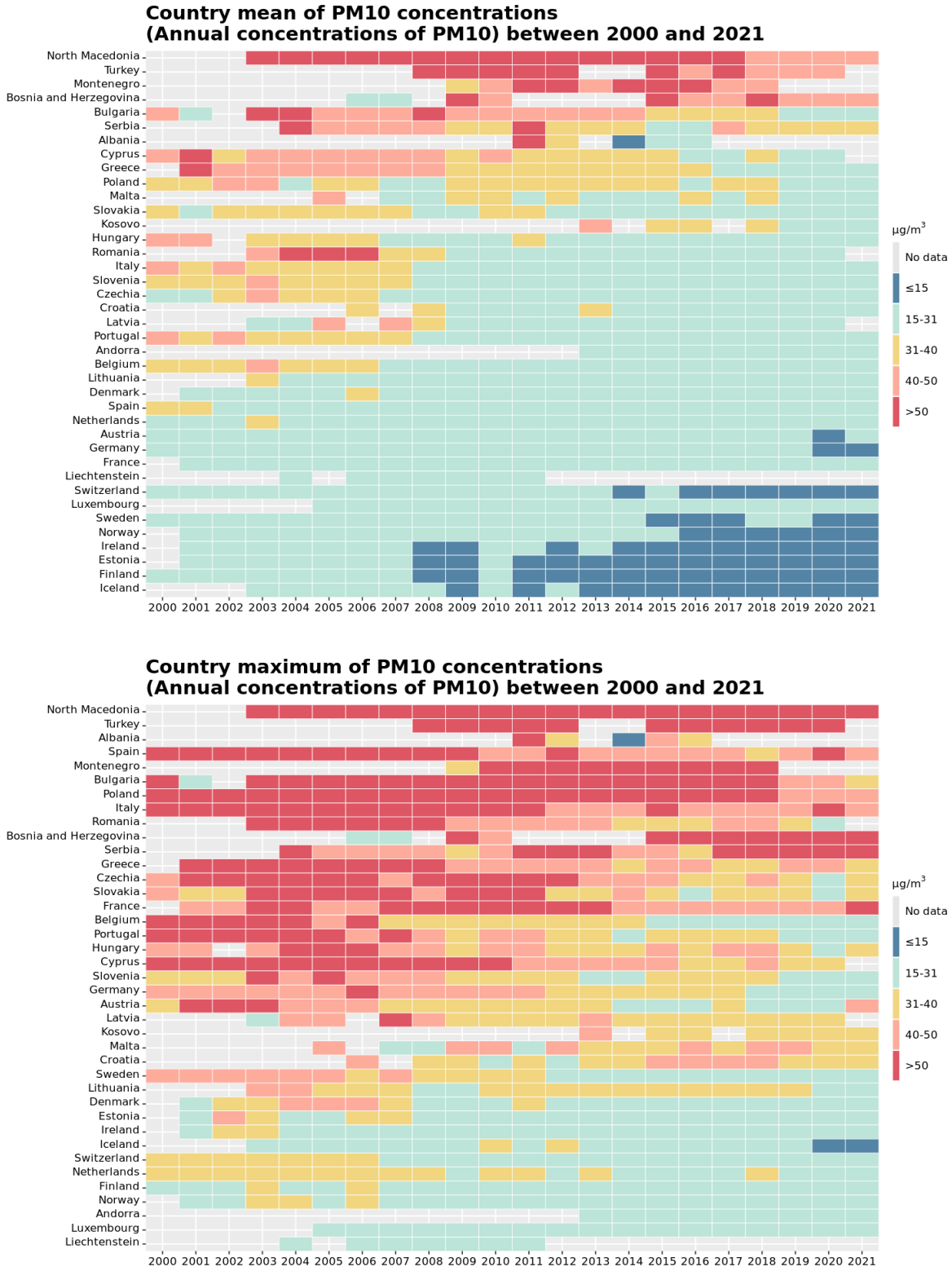
Figure 6: Maps of PM_{10} concentrations (annual limit value) for the last 4 years



Maps for years before 2020 are different to the ones published in previous reports because the bands in the legend have been modified to accomodate the 2021 WHO AQG level.

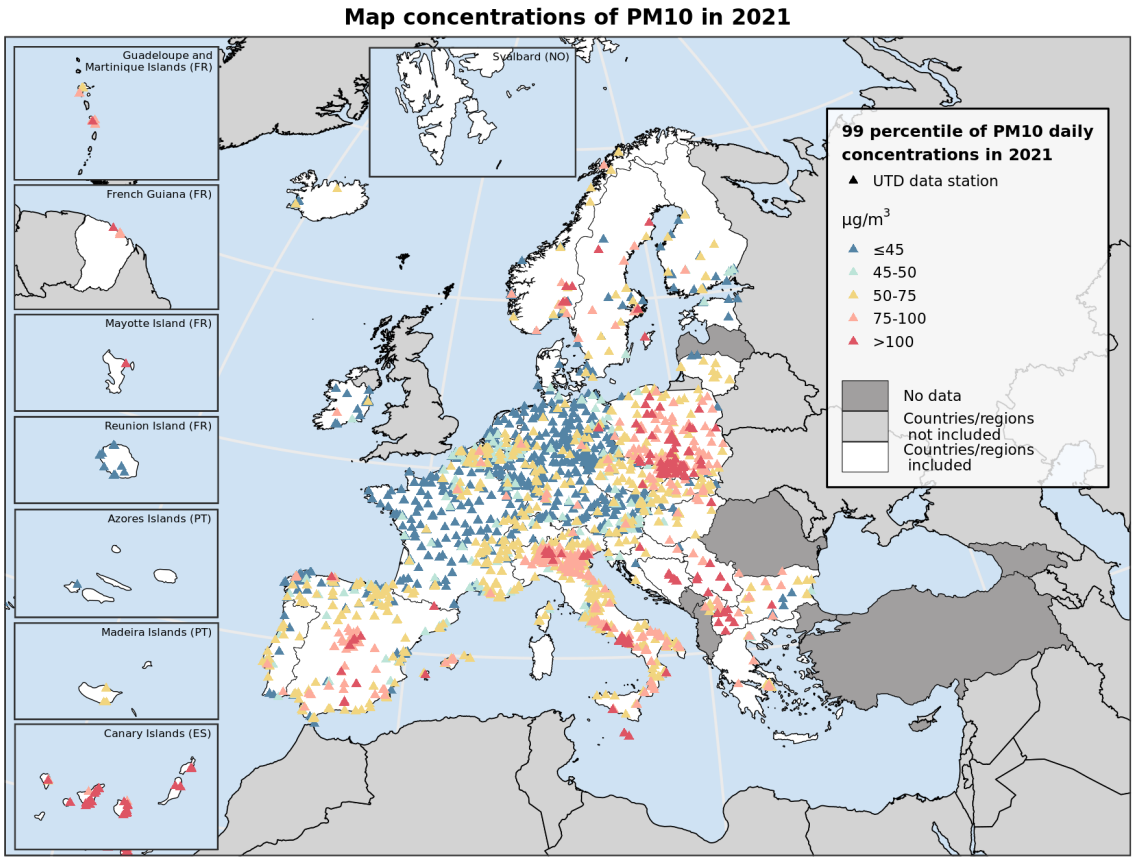
Heatmaps with the evolution from 2000 of the mean (top) and the maximum (bottom) annual mean PM_{10} concentrations at country level are shown in figure 7. In this way, the evolution along years of the average and maximum measured concentration levels can be seen for each country. Note that meteorological variability has a considerable impact on year-to-year changes in ambient air concentrations of air pollutants (EEA, 2020), and the last year (2021) is based on UTD data, while the previous years are based on officially reported validated data.

Figure 7: Evolution of mean (top) and maximum (bottom) PM_{10} annual mean concentrations (annual limit value) per country from 2000



Note: It is important to note that the figure is not based on a consistent set of stations. The number, location and classification of the stations included may vary from year to year.

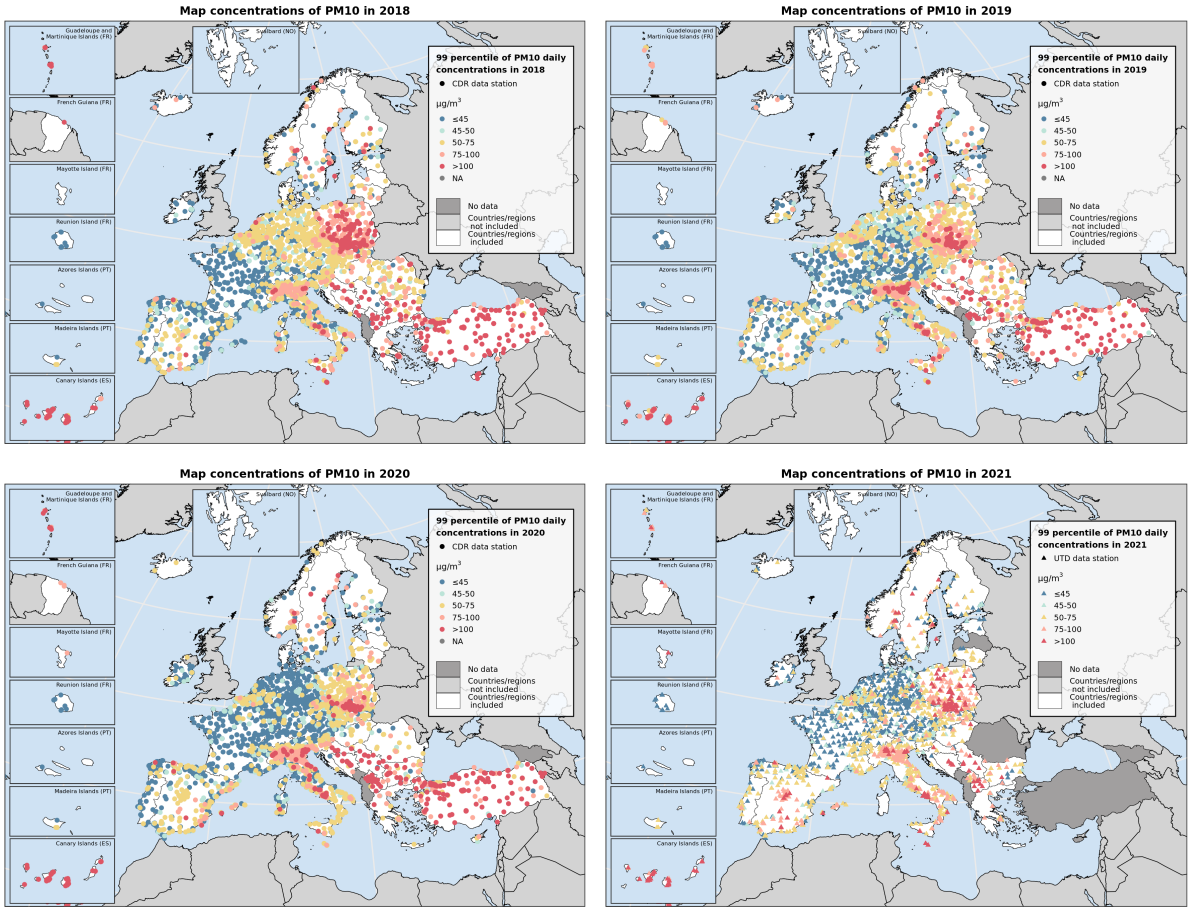
Figure 8: UTD Map of PM_{10} concentrations in 2021 - daily WHO AQG level



Note: Observed concentrations of PM10 in 2021. The map shows the 99 percentile of the PM10 daily mean concentrations, equivalent to 3−4 exceedance days per year, according to the definition of the daily WHO AQG level (45 µg/m³). The first colour category indicates stations with concentrations below this AQG level. Only stations with more than 75 % of valid data, and more than 14 % in the case of fixed random measurements, have been included in the map.

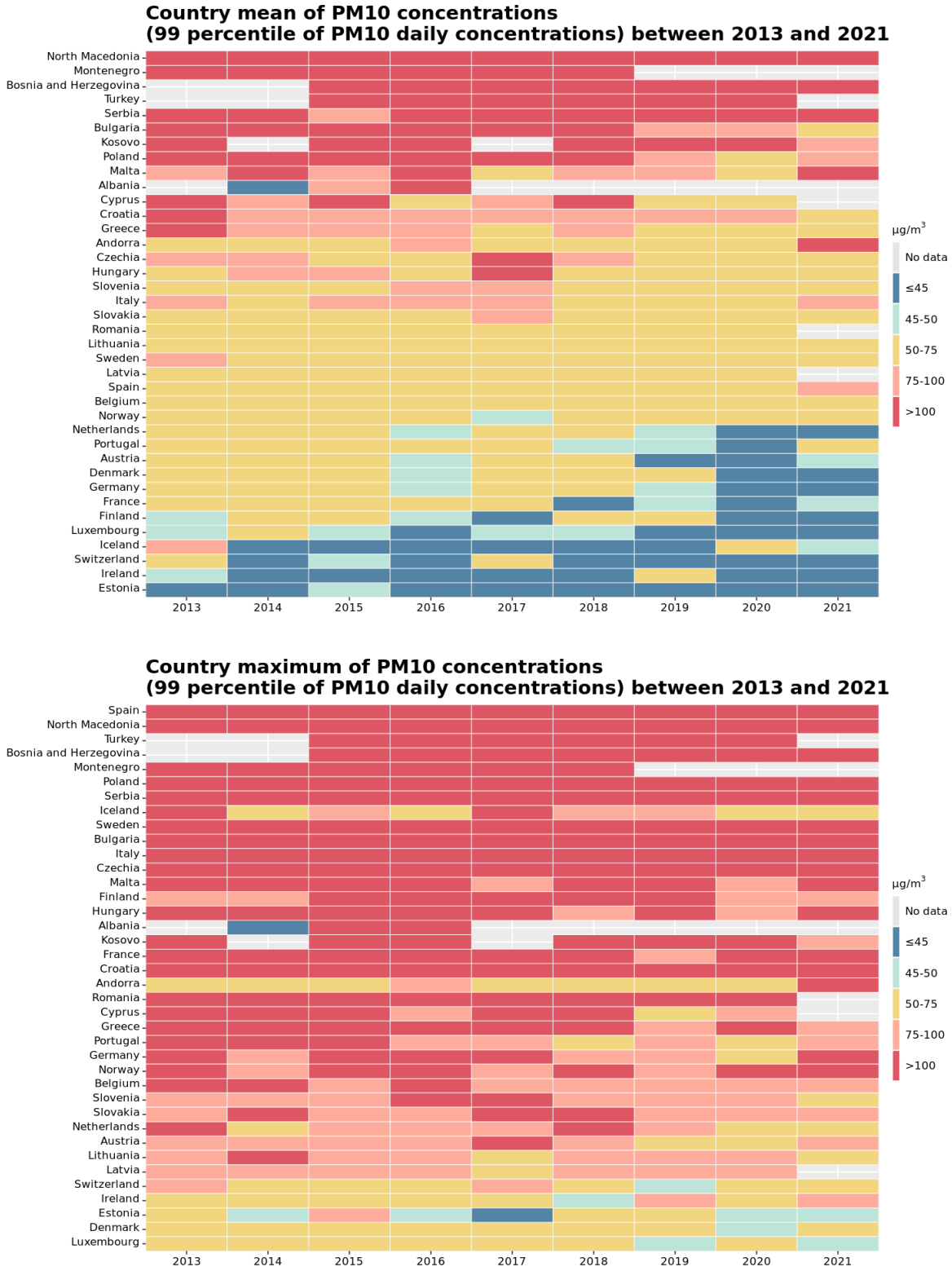
Figure 9 shows the maps of the 99 percentile of PM_{10} daily mean concentrations (equivalent to the WHO AQG for PM_{10} daily mean level) for the last four years. In this way, any significant change in the spatial distribution of the values above the set thresholds in the legends can be observed. Note that only the last year's map (2021) is based on UTD data, while the previous three years are based on officially reported validated data (CDR).

Figure 9: Maps of PM_{10} concentrations (daily WHO AQG level) for the last 4 years



Heatmaps with the evolution from 2013 of the mean (top) and the maximum (bottom) 99 percentile of PM_{10} daily mean concentrations at country level are shown in figure 10. In this way, the evolution along years of the average and maximum measured concentration levels can be seen for each country. Note that meteorological variability has a considerable impact on year-to-year changes in ambient air concentrations of air pollutants (EEA, 2020), and the last year (2021) is based on UTD data, while the previous years are based on officially reported validated data.

Figure 10: Evolution of mean (top) and maximum (bottom) 99 percentile of PM_{10} daily mean concentrations (daily WHO AQG level) per country from 2013



Note: It is important to note that the figure is not based on a consistent set of stations. The number, location and classification of the stations included may vary from year to year.

3.2 Status of $PM_{2.5}$ concentrations

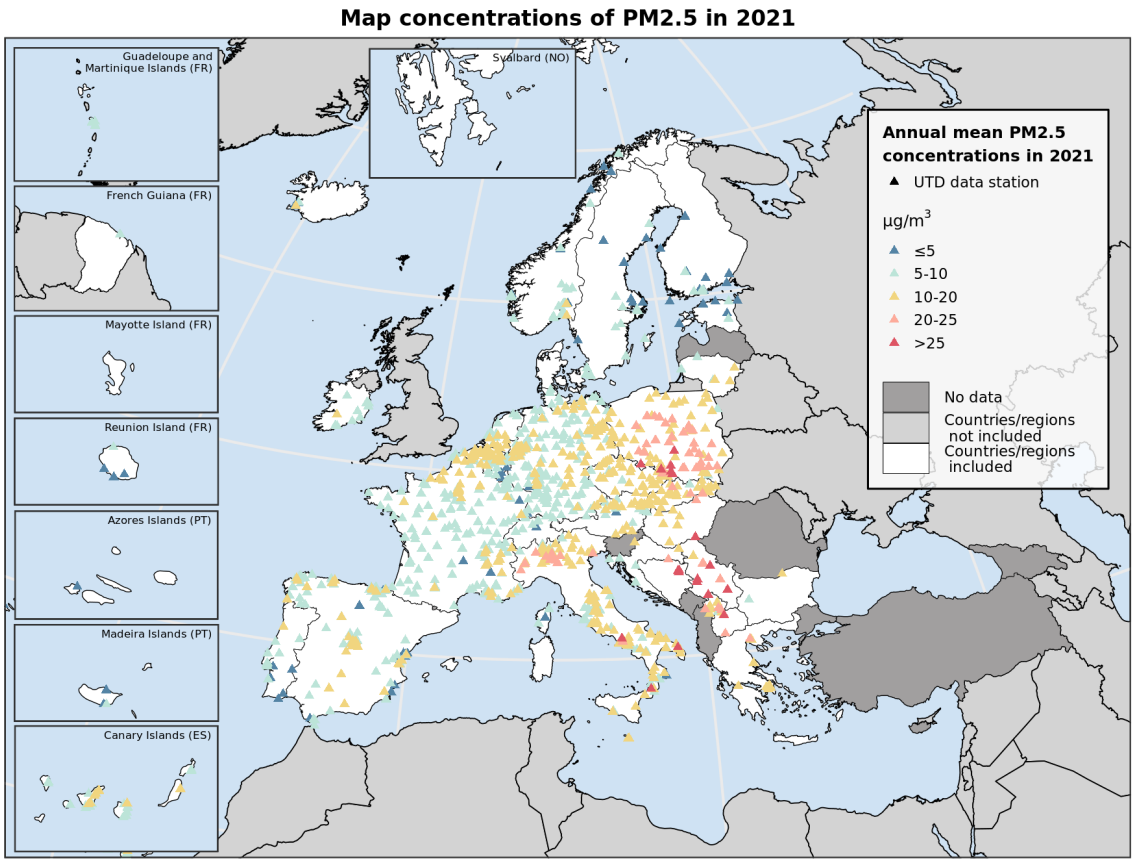
Regarding $PM_{2.5}$, data with sufficient valid measurements were received from 1248 stations for the calculation of annual mean concentrations and from 1246 stations in relation to the short-term WHO AQG. These stations were located in all the reporting countries shown in Figure 1.

The $PM_{2.5}$ concentrations were higher than the annual limit value (25 µg/m^3) in three countries in EU-27 and three other reporting countries (Figure 11). These concentrations above the limit value were registered in 2 % of all the reporting stations and occurred primarily (100 % of cases) in urban (70 %) or suburban (30 %) areas.

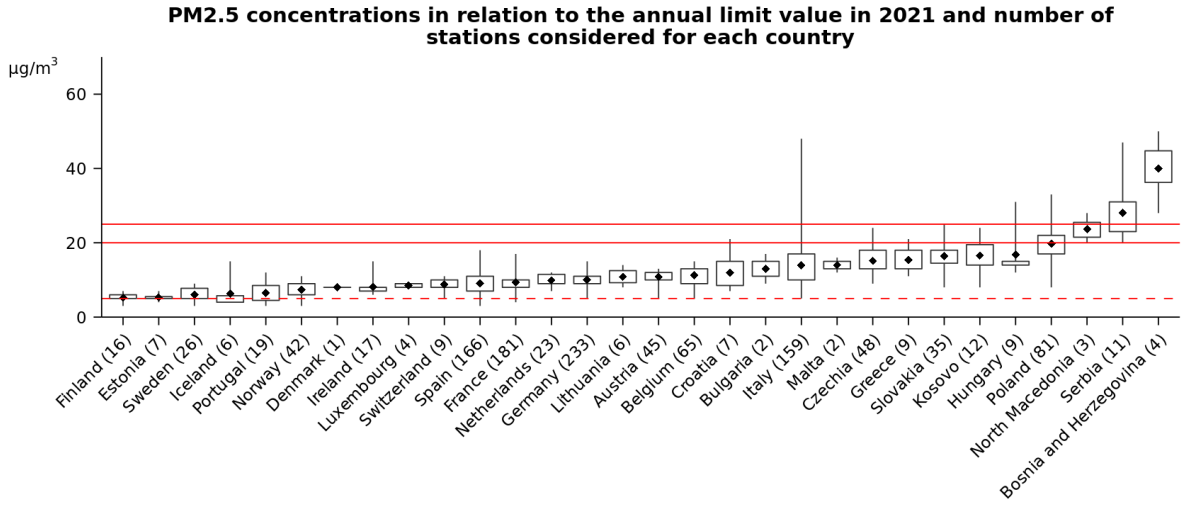
The WHO AQG for $PM_{2.5}$ annual mean (5 µg/m^3) was exceeded at 94 % of the stations, located in 30 of the 30 countries reporting $PM_{2.5}$ data (Figure 11).

Although the EU has not set any short-term standard for $PM_{2.5}$, the WHO defined in 2021 a daily AQG level of 15 µg/m^3, expresed as percentile 99. It was exceeded at 98 % (1224 stations) of the stations in all the reporting countries (Figure 14).

Figure 11: UTD Map and boxplot of $PM_{2.5}$ concentrations in 2021 - annual limit value



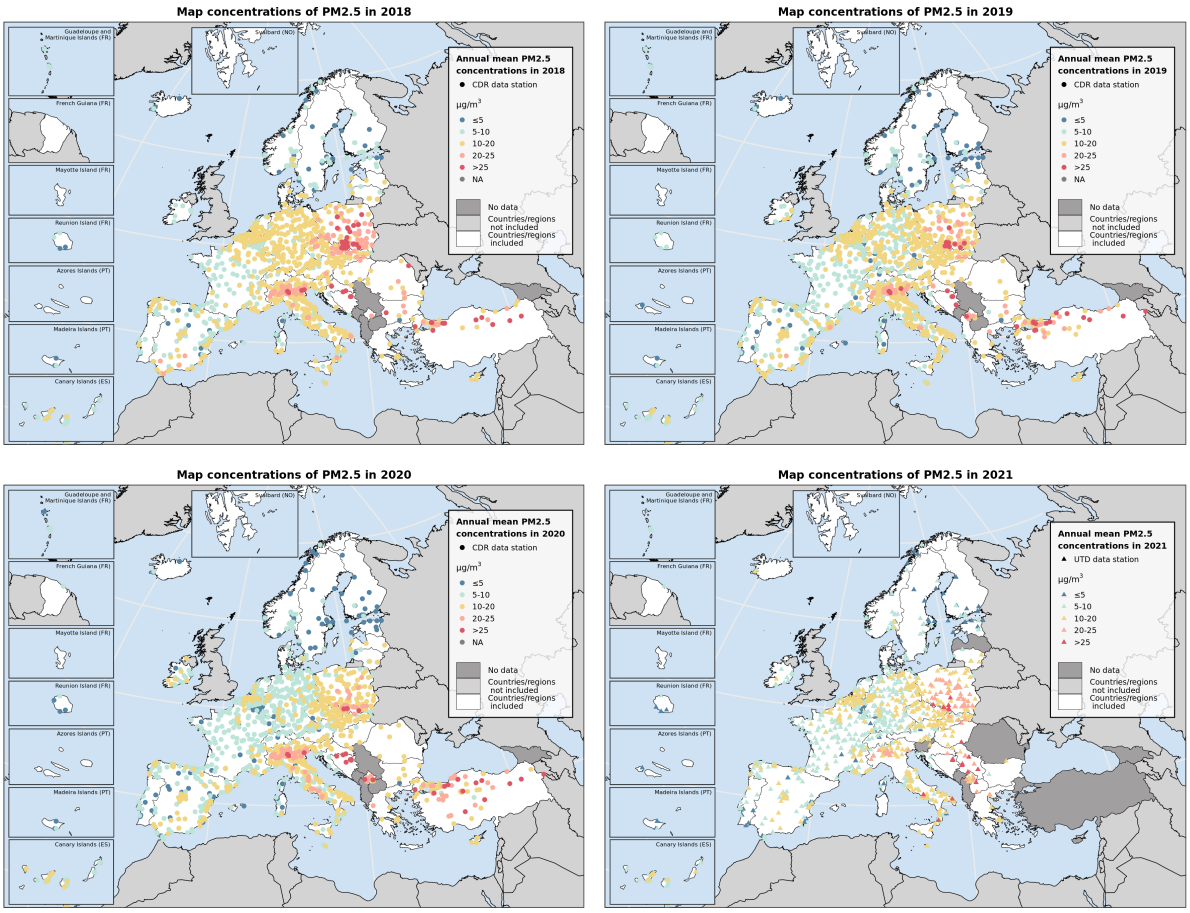
Note: Observed concentrations of PM2.5 in 2021. The possibility of subtracting contributions to the measured concentrations from natural sources and winter road sanding/salting has not been considered. The last two colour categories indicate stations reporting concentrations above the EU indicative annual limit value (20 µg/m³) or the EU annual limit value (25 µg/m³). The first colour category indicates stations reporting values below the WHO AQG for PM2.5 (5 µg/m³). Only stations with more than 75 % of valid data, and more than 14% in the case of fixed random measurements, have been included in the map.



Note: The graph is based on annual mean concentration values. For each country, the number of stations considered (in brackets) and the lowest, highest and average values (in µg/m³) recorded at its stations are given. The rectangles mark the 25th and 75th percentiles. At 25 % of the stations, levels are below the lower percentile; at 25 % of the stations, concentrations are above the upper percentile. The annual limit value and the indicative annual limit value set by EU legislation are marked by the upper continuous horizontal lines at 25 and 20, respectively. The WHO AQG is marked by the lower dashed horizontal line. The graph should be read in relation to the above map, as a country's situation depends on the number of stations considered.

Figure 12 shows the maps of measured $PM_{2.5}$ annual mean concentrations for the last four years. In this way, any significant change in the spatial distribution of the values above the set thresholds in the legends can be observed. Note that only the last year's map (2021) is based on UTD data, while the previous three years are based on officially reported validated data (CDR).

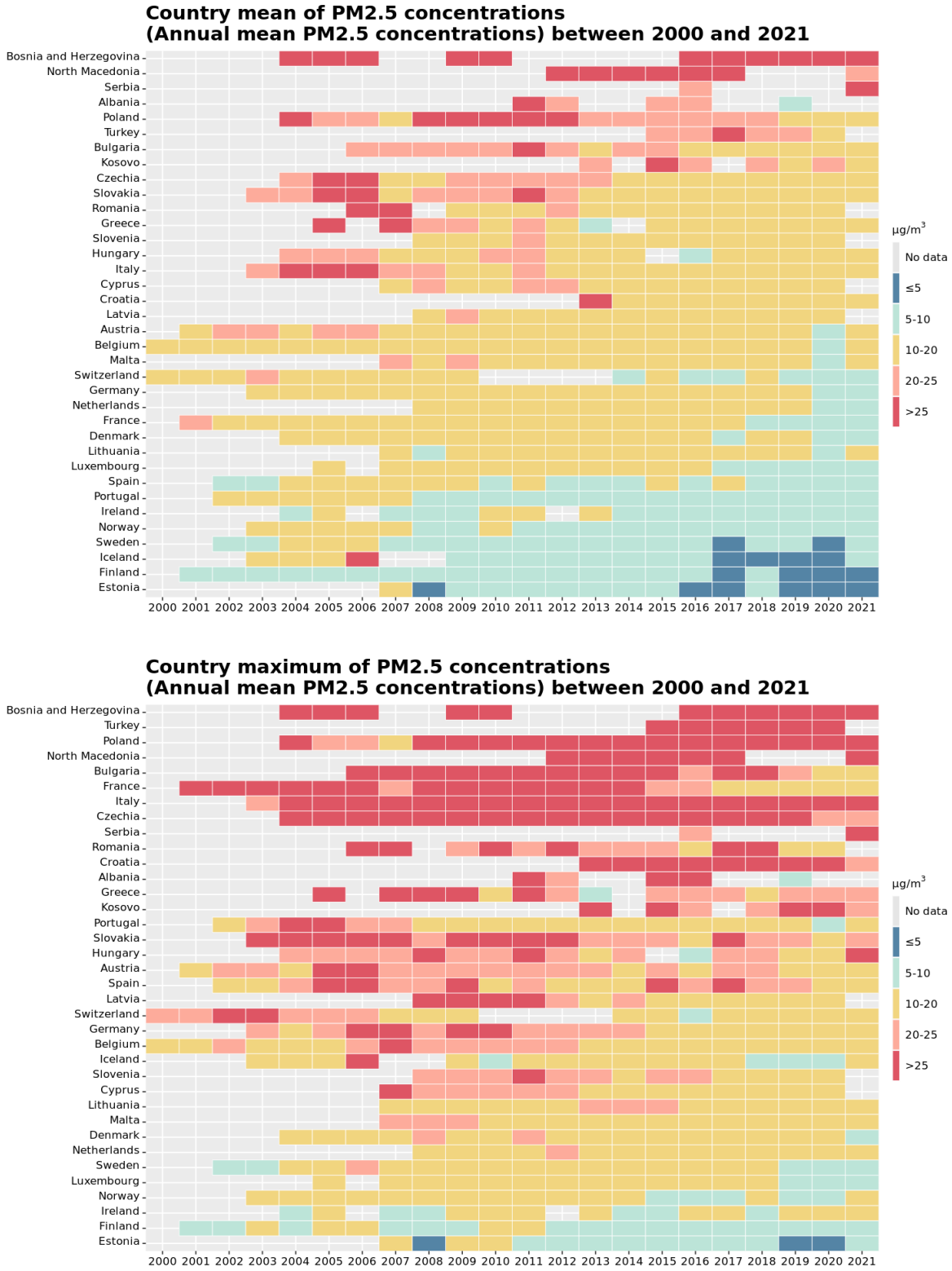
Figure 12: Maps of $PM_{2.5}$ concentrations (annual limit value) for the last 4 years



Maps for years before 2020 are different to the ones published in previous reports because the bands in the legend have been modified to accomodate the 2021 WHO AQG level.

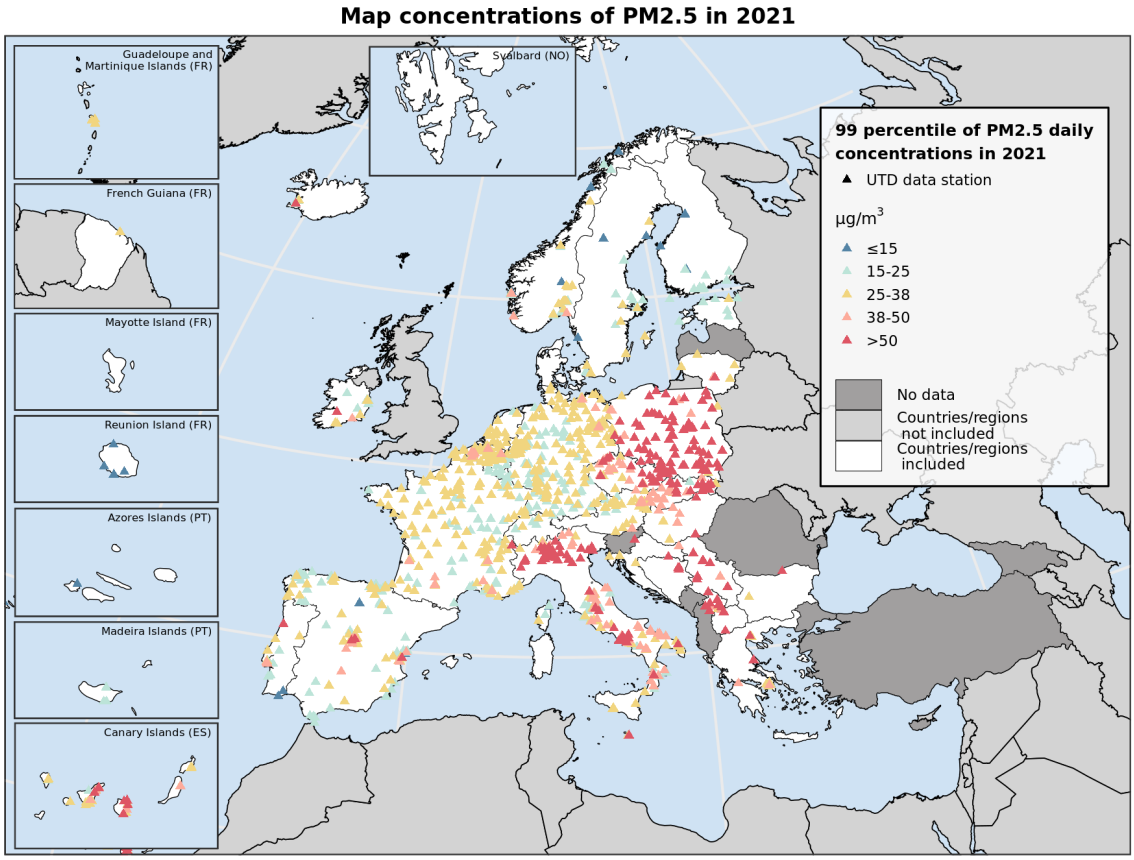
Heatmaps with the evolution from 2000 of the mean (top) and the maximum (bottom) $PM_{2.5}$ annual mean concentrations at country level are shown in figure 13. In this way, the evolution along years of the average and maximum measured concentration levels can be seen for each country. Note that meteorological variability has a considerable impact on year-to-year changes in ambient air concentrations of air pollutants (EEA, 2020), and the last year (2021) is based on UTD data, while the previous years are based on officially reported validated data.

Figure 13: Evolution of mean (top) and maximum (bottom) $PM_{2.5}$ annual mean concentrations (annual limit value) per country from 2000



Note: It is important to note that the figure is not based on a consistent set of stations. The number, location and classification of the stations included may vary from year to year.

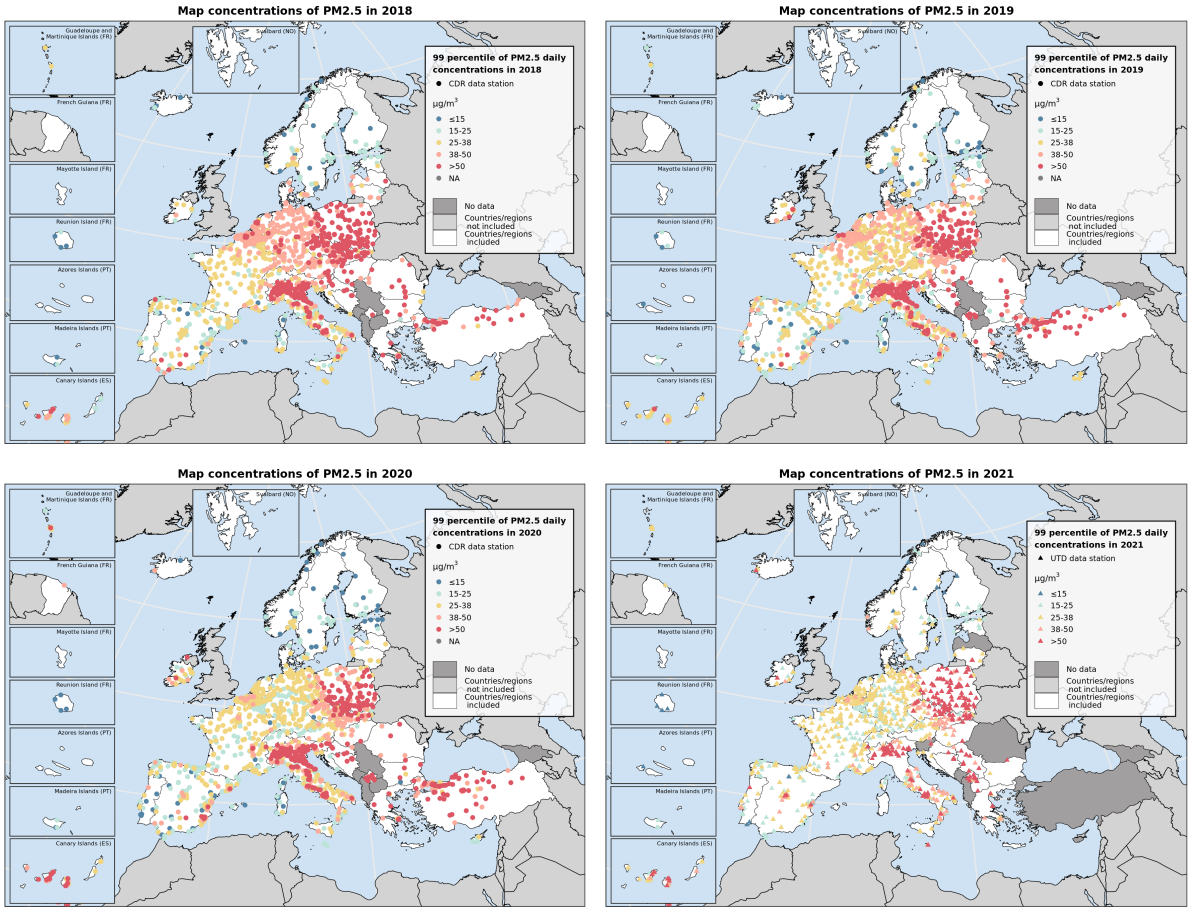
Figure 14: UTD Map of $PM_{2.5}$ concentrations in 2021 - daily WHO AQG level



Note: Observed concentrations of PM2.5 in 2021. The map shows the 99 percentile of the PM2.5 daily mean concentrations, equivalent to 3−4 exceedance days per year, according to the definition of the daily WHO AQG level (15 µg/m³). The first colour category indicates stations with concentrations below this AQG level. Only stations with more than 75 % of valid data, and more than 14 % in the case of fixed random measurements, have been included in the map.

Figure 15 shows the maps of the 99 percentile of $PM_{2.5}$ daily mean concentrations (equivalent to the WHO AQG for $PM_{2.5}$ daily mean level) for the last four years. In this way, any significant change in the spatial distribution of the values above the set thresholds in the legends can be observed. Note that only the last year's map (2021) is based on UTD data, while the previous three years are based on officially reported validated data (CDR).

Figure 15: Maps of $PM_{2.5}$ concentrations (daily WHO AQG level) for the last 4 years



Heatmaps with the evolution from 2013 of the mean (top) and the maximum (bottom) 99 percentile of $PM_{2.5}$ daily mean concentrations at country level are shown in figure 16. In this way, the evolution along years of the average and maximum measured concentration levels can be seen for each country. Note that meteorological variability has a considerable impact on year-to-year changes in ambient air concentrations of air pollutants (EEA, 2020), and the last year (2021) is based on UTD data, while the previous years are based on officially reported validated data.

Figure 16: Evolution of mean (top) and maximum (bottom) 99 percentile of $PM_{2.5}$ daily mean concentrations (daily WHO AQG level) per country from 2013

Note: It is important to note that the figure is not based on a consistent set of stations. The number, location and classification of the stations included may vary from year to year.

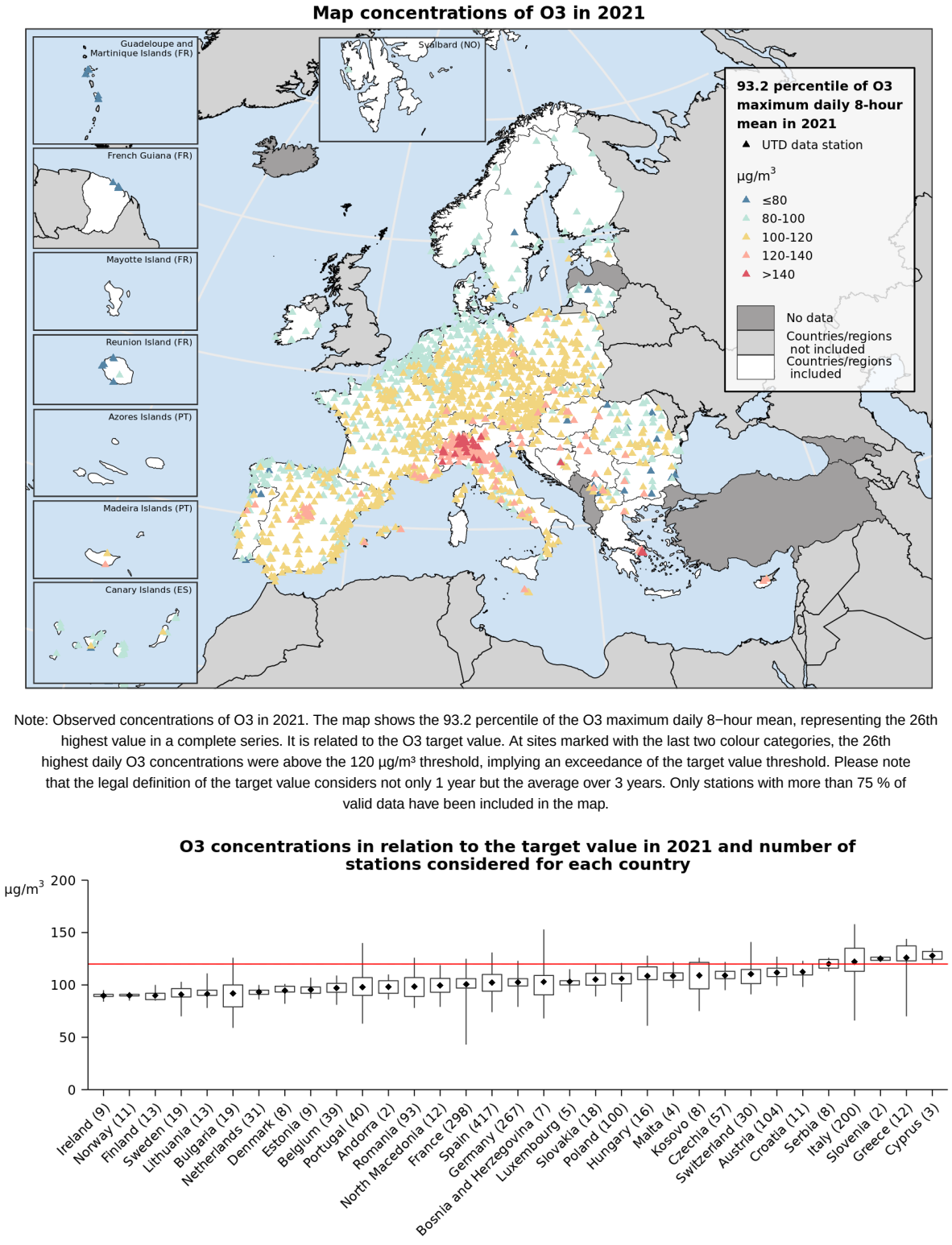
4 Status of ozone ambient air concentrations

Data for O_3 were reported from 1885 stations for the calculation of EU standards, from 1885 stations in relation to the short-term WHO AQG, and from 1754 stations for the long-term WHO AQG. These stations were located in all the reporting countries shown in Figure 1.

16 countries in EU-27 and 4 other reporting countries registered concentrations above the O_3 target value (120 µg/m^3) more than 25 times (Figure 17). In total, 9 % of all stations reporting O_3 showed concentrations above the target value for the protection of human health. In addition, only 20 % (367) of all stations fulfilled the long-term objective (120 µg/m^3). 86 % of the stations with values above the long-term objective were background stations.

8 % (150) of all stations and only 20 of the 484 reported rural background stations had values below the short-term WHO AQG value for O_3 (100 µg/m^3) (Figure 20), set for the protection of human health. The long-term (peak season) WHO AQG level (60 µg/m^3) was exceeded in 98 % (1726) of all stations located in 26 countries in EU-27 and 7 other reporting countries. Only 0 of the 469 reported rural background stations had values below this AQG level (Figure 23).

Figure 17: UTD Map and boxplot of O_3 concentrations in 2021

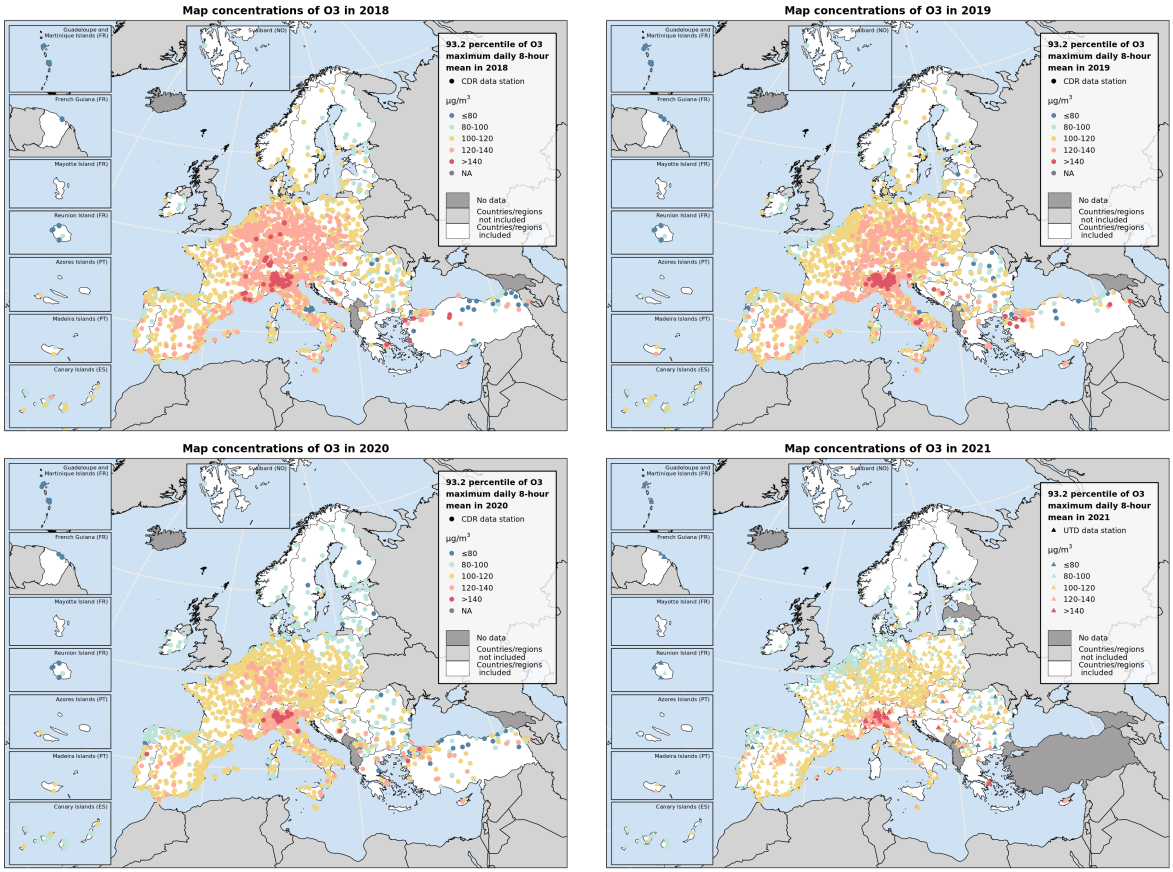


Note: Observed concentrations of O3 in 2021. The map shows the 93.2 percentile of the O3 maximum daily 8−hour mean, representing the 26th highest value in a complete series. It is related to the O3 target value. At sites marked with the last two colour categories, the 26th highest daily O3 concentrations were above the 120 µg/m³ threshold, implying an exceedance of the target value threshold. Please note that the legal definition of the target value considers not only 1 year but the average over 3 years. Only stations with more than 75 % of valid data have been included in the map.

Note: The graph is based, for each country, on the 93.2 percentile of the maximum daily 8−hour mean concentration values, corresponding to the 26th highest daily maximum of the running 8−hour mean. For each country, the number of stations considered (in brackets), and the lowest, highest and average values (in µg/m³) recorded at its stations are given. The rectangles mark the 25th and 75th percentiles. At 25 % of the stations, levels are below the lower percentile; at 25 % of the stations, concentrations are above the upper percentile. The target value threshold set by the EU legislation is marked by the horizontal line. Please note that the legal definition of the target value considers not only 1 year but the average over 3 years. The graph should be read in relation to the above map, as a country's situation depends on the number of stations considered.

Figure 18 shows the maps of the observed 93.2 percentile of the O_3 maximum daily 8-hour mean concentrations (O_3 target value) for the last four years. In this way, any significant change in the spatial distribution of the values above the set thresholds in the legends can be observed. Note that only the last year's map (2021) is based on UTD data, while the previous three years are based on officially reported validated data (CDR).

Figure 18: Maps of O_3 concentrations (related to the target value) for the last 4 years

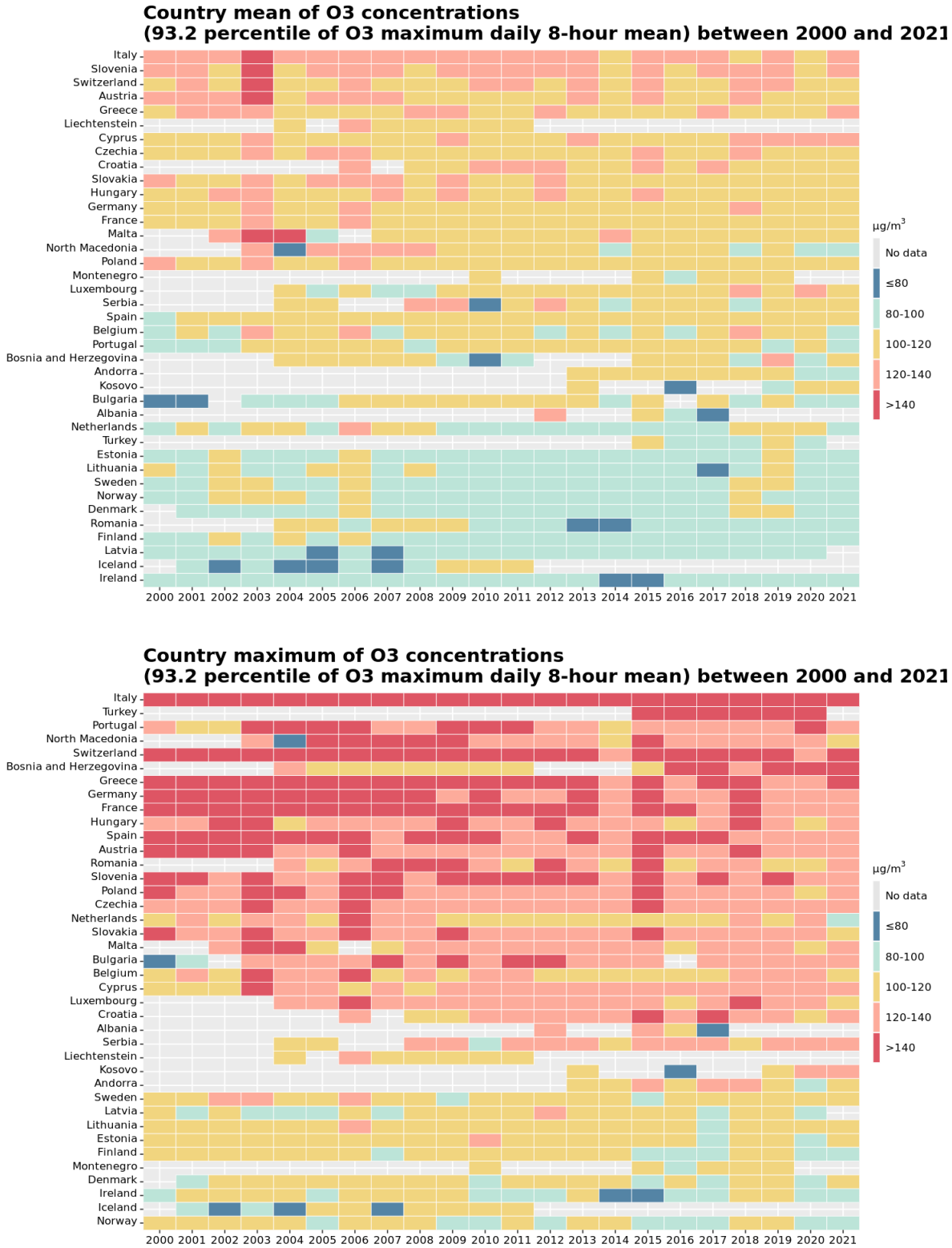


Note: Please be aware that the TV considers the average over 3 years and the maps only show the situation for one specific year.

Heatmaps with the evolution from 2000 of the mean (top) and the maximum (bottom) O_3 concentrations (93.2 percentile of the maximum daily 8-hour mean concentration, target value) at country level are shown in figure 19. In this way, the evolution along years of the average and maximum measured concentration levels can be seen for each country. Note that meteorological variability has a considerable impact on year-to-year changes in ambient air concentrations of air pollutants (EEA, 2020), especially for O_3 as higher atmospheric temperature leads to

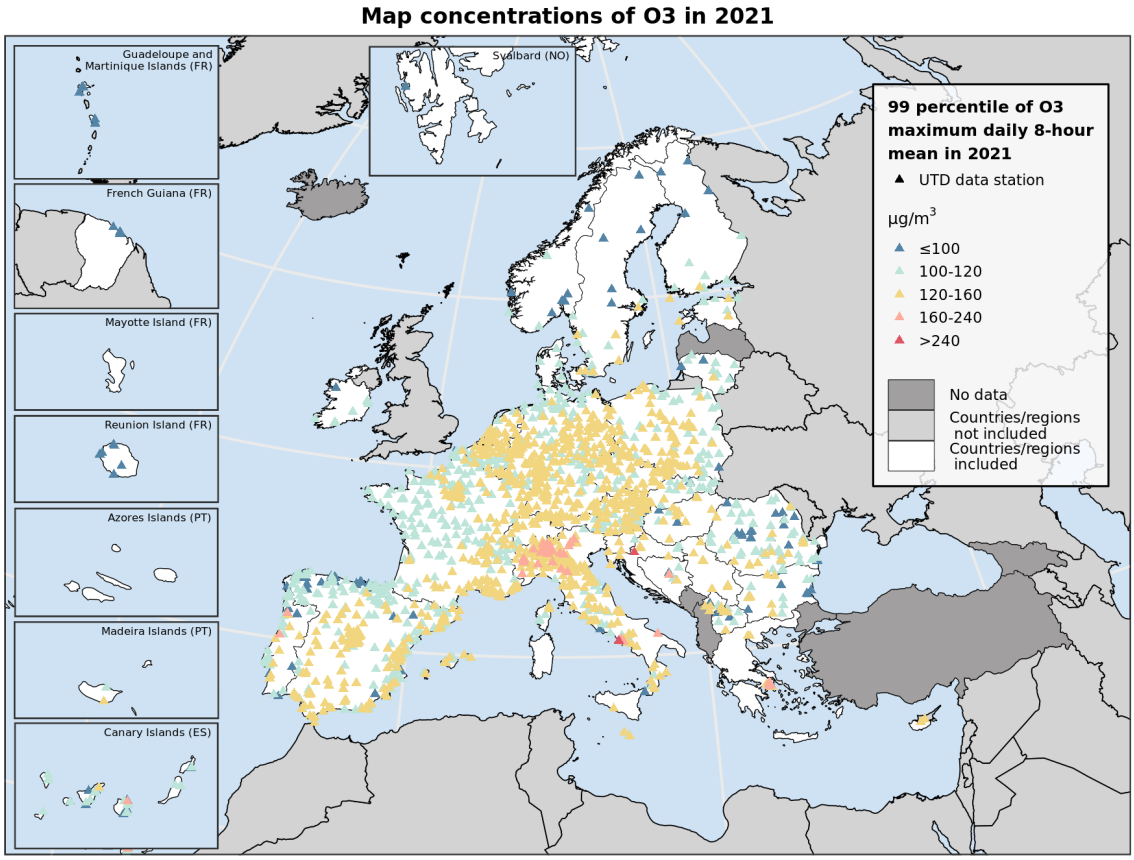
enhanced photochemical reactions and O_3 formation. The last year (2021) is based on UTD data, while the previous years are based on officially reported validated data.

Figure 19: Evolution of mean (top) and maximum (bottom) O_3 concentrations (93.2 percentile of the maximum daily 8-hour mean concentration, related to the target value) per country from 2000



Note: It is important to note that the figure is not based on a consistent set of stations. The number, location and classification of the stations included may vary from year to year.

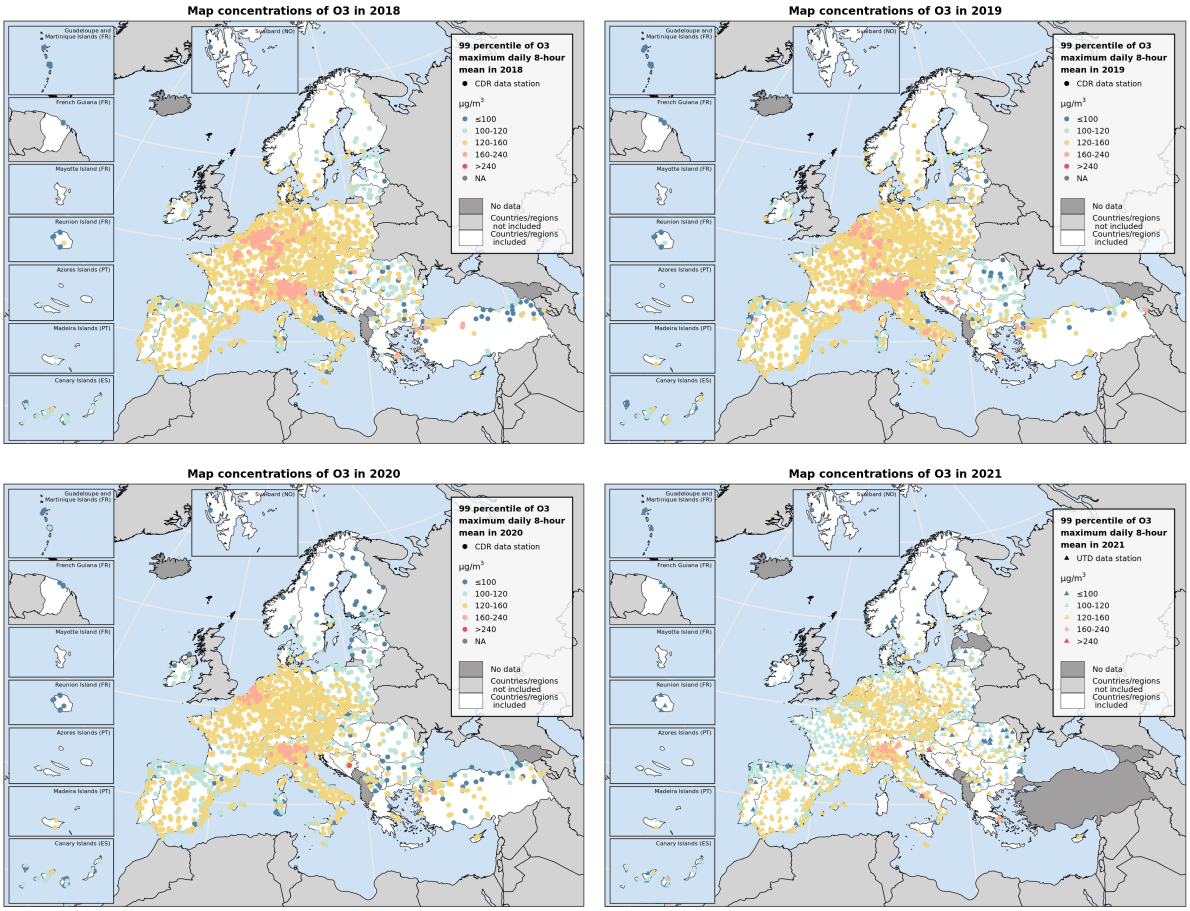
Figure 20: UTD Map of O_3 concentrations in 2021 - short-term WHO AQG level



Note: Observed concentrations of O3 in 2021. The map shows the 99 percentile of the O3 maximum daily 8−hour mean concentrations, equivalent to 3−4 exceedance days per year, according to the definition of the short−term WHO AQG (100 µg/m³).
The first colour category indicates stations with concentrations below this AQG level.
Only stations with more than 75 % of valid data have been included in the map.

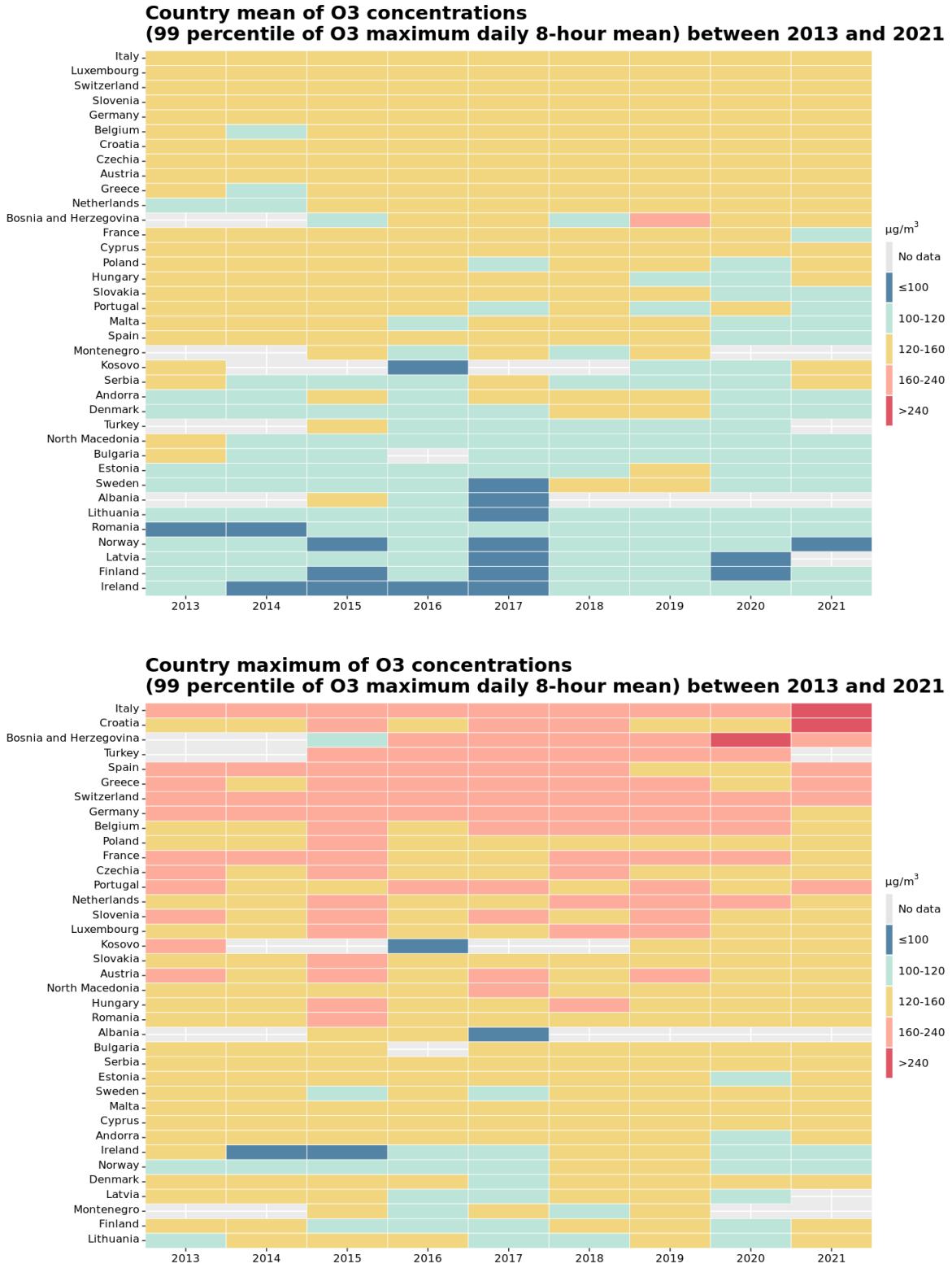
Figure 21 shows the maps of the 99 percentile of the O_3 maximum daily 8-hour mean concentrations (equivalent to the short-term WHO AQG level) for the last four years. In this way, any significant change in the spatial distribution of the values above the set thresholds in the legends can be observed. Note that only the last year's map (2021) is based on UTD data, while the previous three years are based on officially reported validated data (CDR).

Figure 21: Maps of O_3 concentrations (short-term WHO AQG level) for the last 4 years



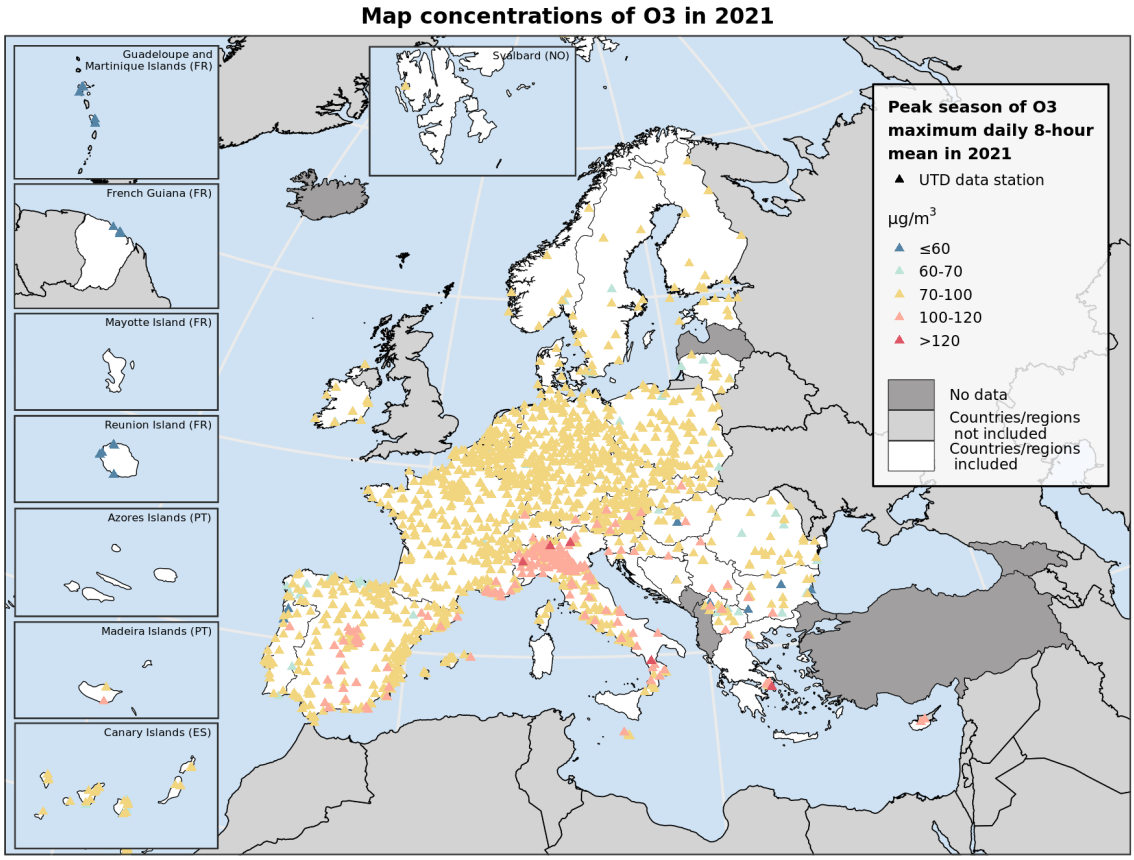
Heatmaps with the evolution from 2013 of the mean (top) and the maximum (bottom) 99 percentile of the O_3 maximum daily 8-hour mean concentrations at country level are shown in figure 22. In this way, the evolution along years of the average and maximum measured concentration levels can be seen for each country. Note that meteorological variability has a considerable impact on year-to-year changes in ambient air concentrations of air pollutants (EEA, 2020), and the last year (2021) is based on UTD data, while the previous years are based on officially reported validated data.

Figure 22: Evolution of mean (top) and maximum (bottom) 99 percentile of the O_3 maximum daily 8-hour mean concentrations per country from 2013



Note: It is important to note that the figure is not based on a consistent set of stations. The number, location and classification of the stations included may vary from year to year.

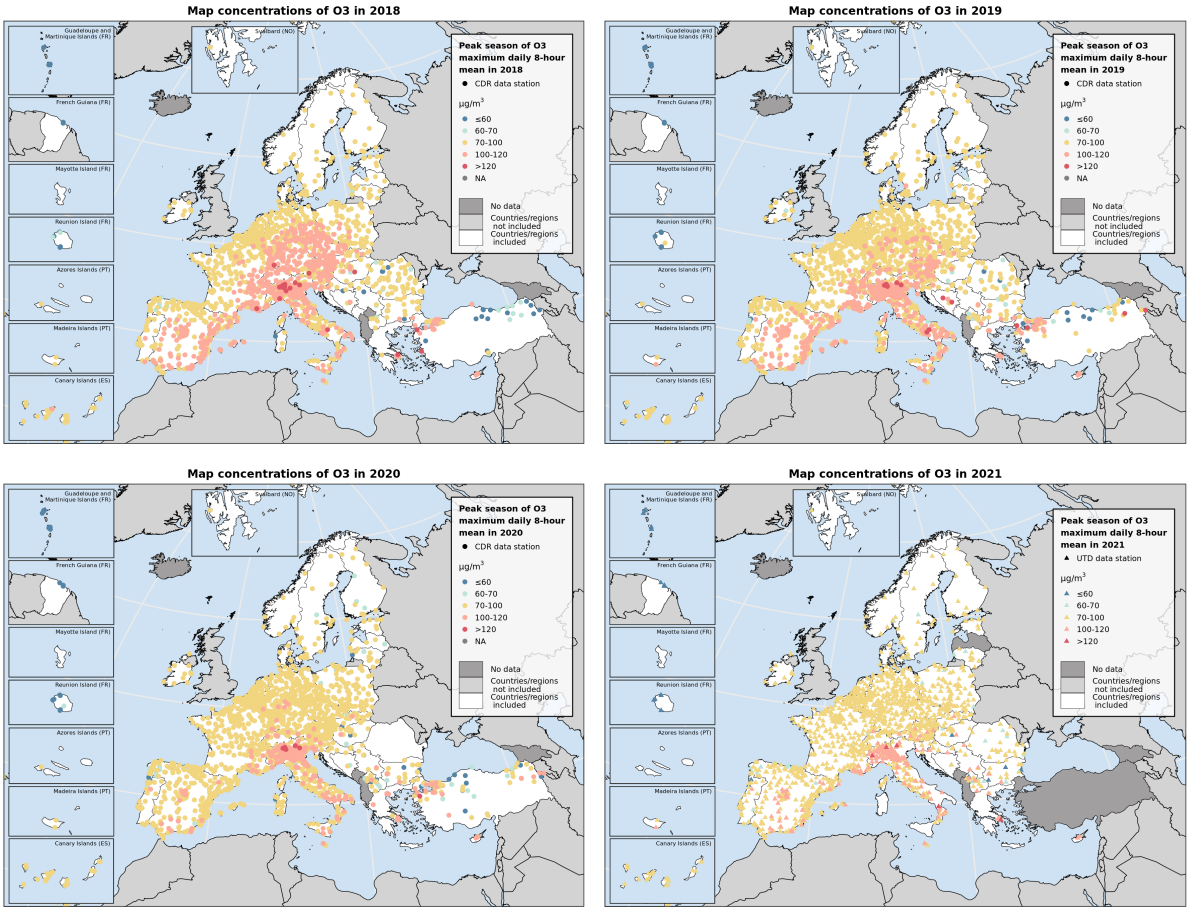
Figure 23: UTD Map of peak season O_3 concentrations in 2021



Note: Observed concentrations of O3 in 2021. The map shows the average of the daily maximum 8−hour mean O3 concentration in the six consecutive months with the highest six−month running−average O3 concentration. The first colour category represents stations fulfilling the peak season O3 AQG level. Only stations with more than 75 % of valid data have been included in the map.

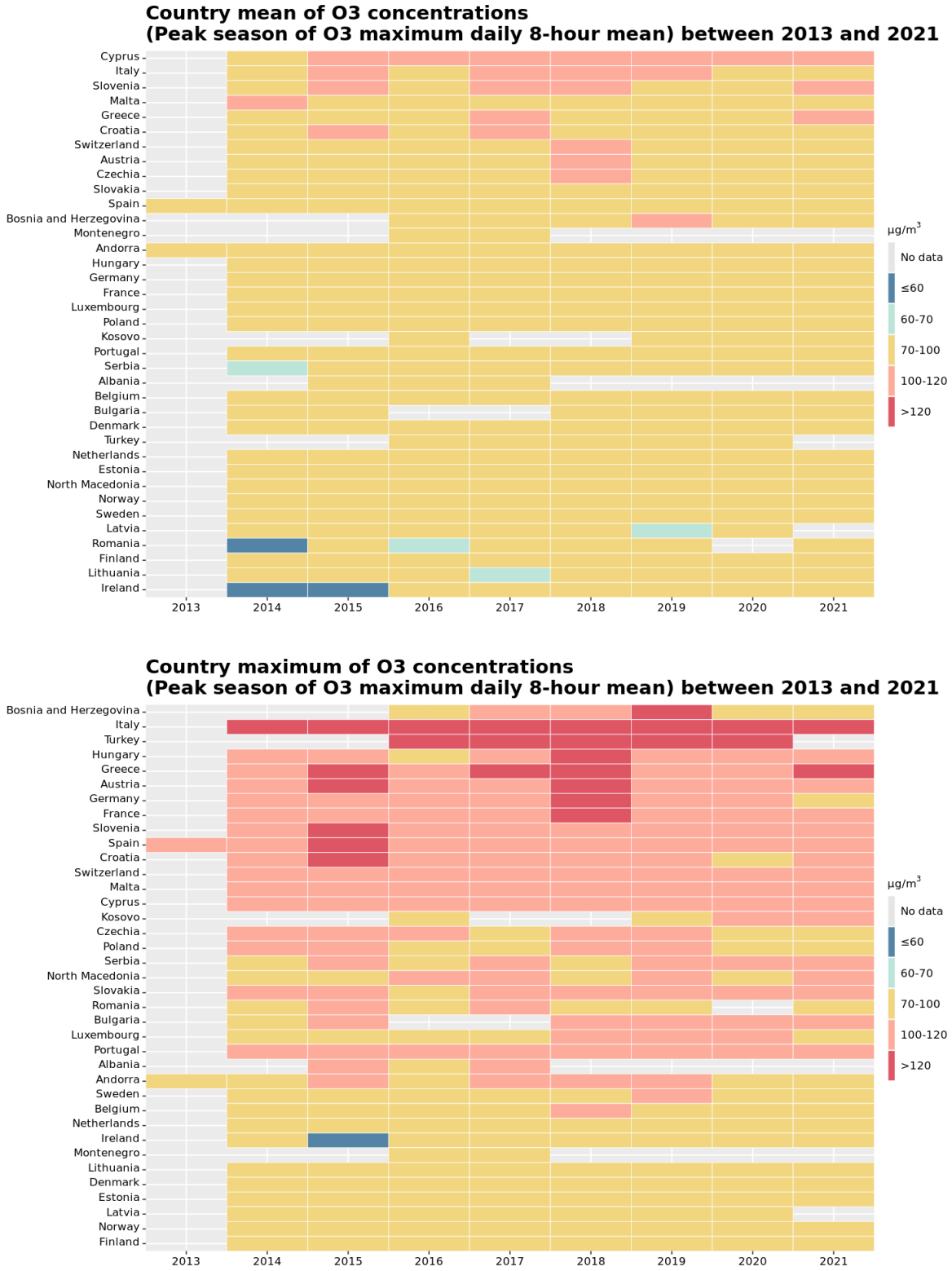
Figure 24 shows the maps of the peak season O_3 concentrations (equivalent to the long-term WHO AQG level) for the last four years. In this way, any significant change in the spatial distribution of the values above the set thresholds in the legends can be observed. Note that only the last year's map (2021) is based on UTD data, while the previous three years are based on officially reported validated data (CDR).

Figure 24: Maps of peak season O_3 concentrations for the last 4 years



Heatmaps with the evolution from 2013 of the mean (top) and the maximum (bottom) peak season O_3 concentrations at country level are shown in figure 25. In this way, the evolution along years of the average and maximum measured concentration levels can be seen for each country. Note that meteorological variability has a considerable impact on year-to-year changes in ambient air concentrations of air pollutants (EEA, 2020), and the last year (2021) is based on UTD data, while the previous years are based on officially reported validated data.

Figure 25: Evolution of mean (top) and maximum (bottom) peak season O_3 concentrations per country from 2013



Note: It is important to note that the figure is not based on a consistent set of stations. The number, location and classification of the stations included may vary from year to year.

5 Status of nitrogen dioxide ambient air concentrations

The reporting countries shown in Figure 1 submitted NO_2 data from 2702 stations for the annual limit value, 2697 stations for the hourly limit value, and 2694 stations for the daily WHO AQG level.

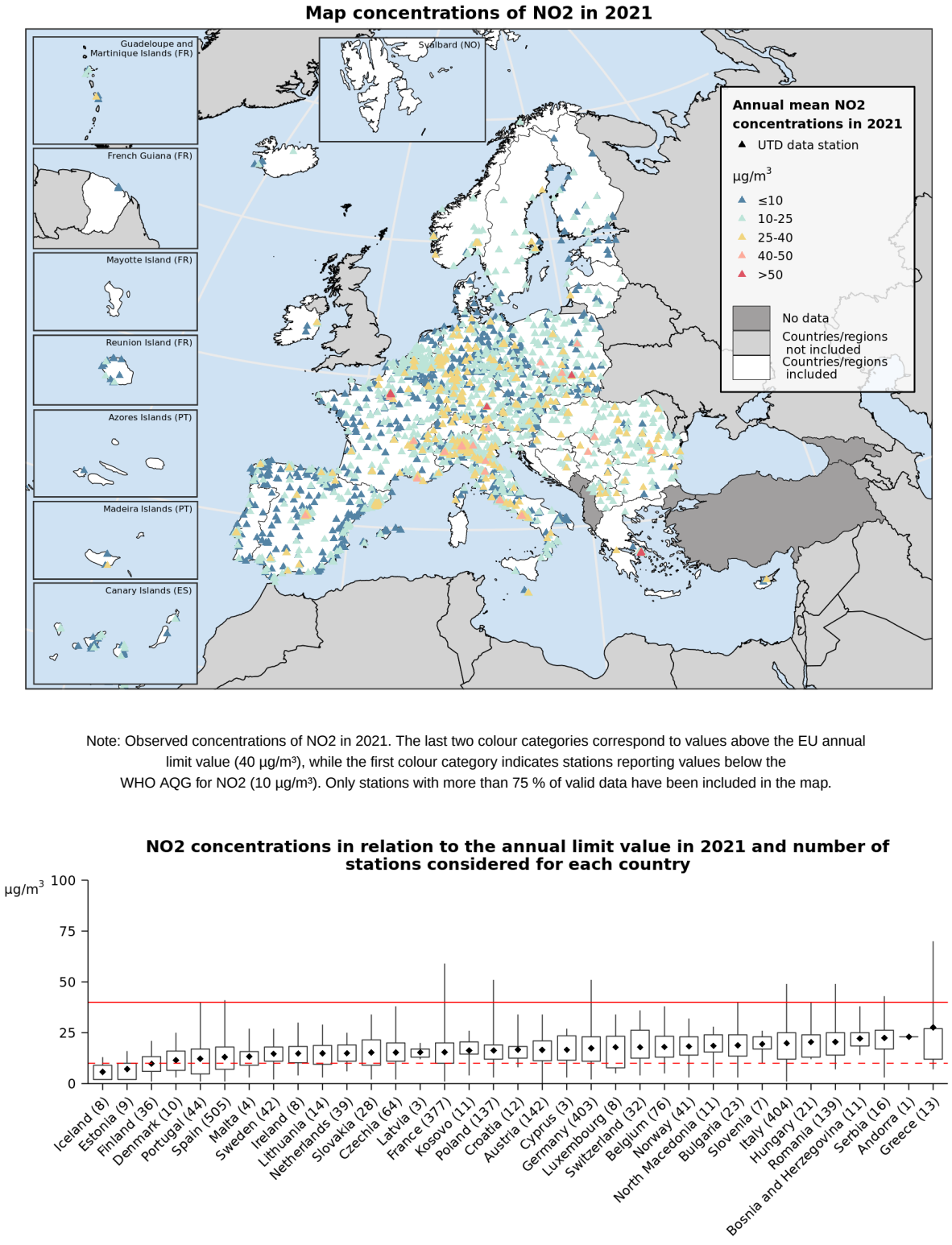
7 of the countries in EU-27 and 1 other reporting countries (Figure 26) recorded concentrations above the annual limit value (40 µg/m^3). This happened in 1 % of all the stations measuring NO_2. On the contrary, 73 % of stations, located in 27 of the countries in EU-27 and 8 other reporting countries reported concentrations above the WHO AQG level of 10 µg/m^3. Figure 26 shows the measured annual mean NO_2 concentrations.

100 % of all values above the annual limit value were observed at traffic stations. Furthermore, 100 % of the stations with concentrations above the annual limit value were located in urban or suburban areas.

Concentrations above the hourly limit value (200 µg/m^3) were observed in 0.2 % (5 stations) of all reporting stations, mostly at urban traffic stations. They were observed in four countries (number stations): Italy (two), Serbia (one), Spain (one) and Sweden (one).

Finally, concentrations above the daily NO_2 WHO AQG level (25 µg/m^3) were registered in 78 % (2109 stations) of all the reporting stations in 27 of the countries in EU-27 and 8 other reporting countries (Figure 29).

Figure 26: UTD Map and boxplot of NO_2 concentrations in 2021

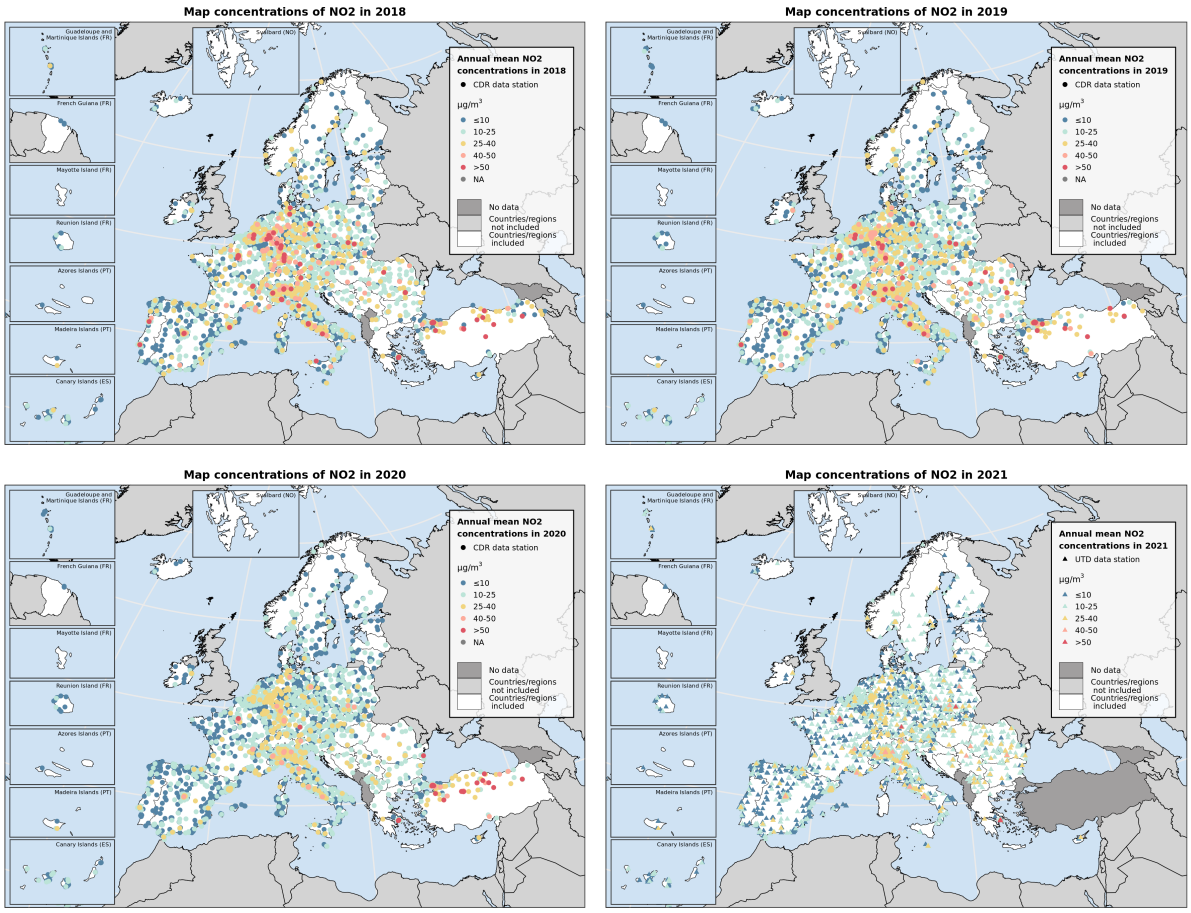


Note: Observed concentrations of NO2 in 2021. The last two colour categories correspond to values above the EU annual limit value (40 µg/m³), while the first colour category indicates stations reporting values below the WHO AQG for NO2 (10 µg/m³). Only stations with more than 75 % of valid data have been included in the map.

Note: The graph is based on the annual mean concentration values. For each country, the number of stations considered (in brackets) and the lowest, highest and average values (in µg/m³) recorded at its stations are given. The rectangles mark the 25th and 75th percentiles. At 25 % of the stations, levels are below the lower percentile; at 25 % of the stations, concentrations are above the upper percentile. The limit value set by EU legislation is marked by the horizontal line. The WHO AQG level is marked by the lower dashed horizontal line. The graph should be read in relation to the above map, as a country's situation depends on the number of stations considered.

Figure 27 shows the maps of the observed NO_2 annual mean concentrations for the last four years. In this way, any significant change in the spatial distribution of the values above the set thresholds in the legends can be observed. Note that only the last year's map (2021) is based on UTD data, while the previous three years are based on officially reported validated data (CDR).

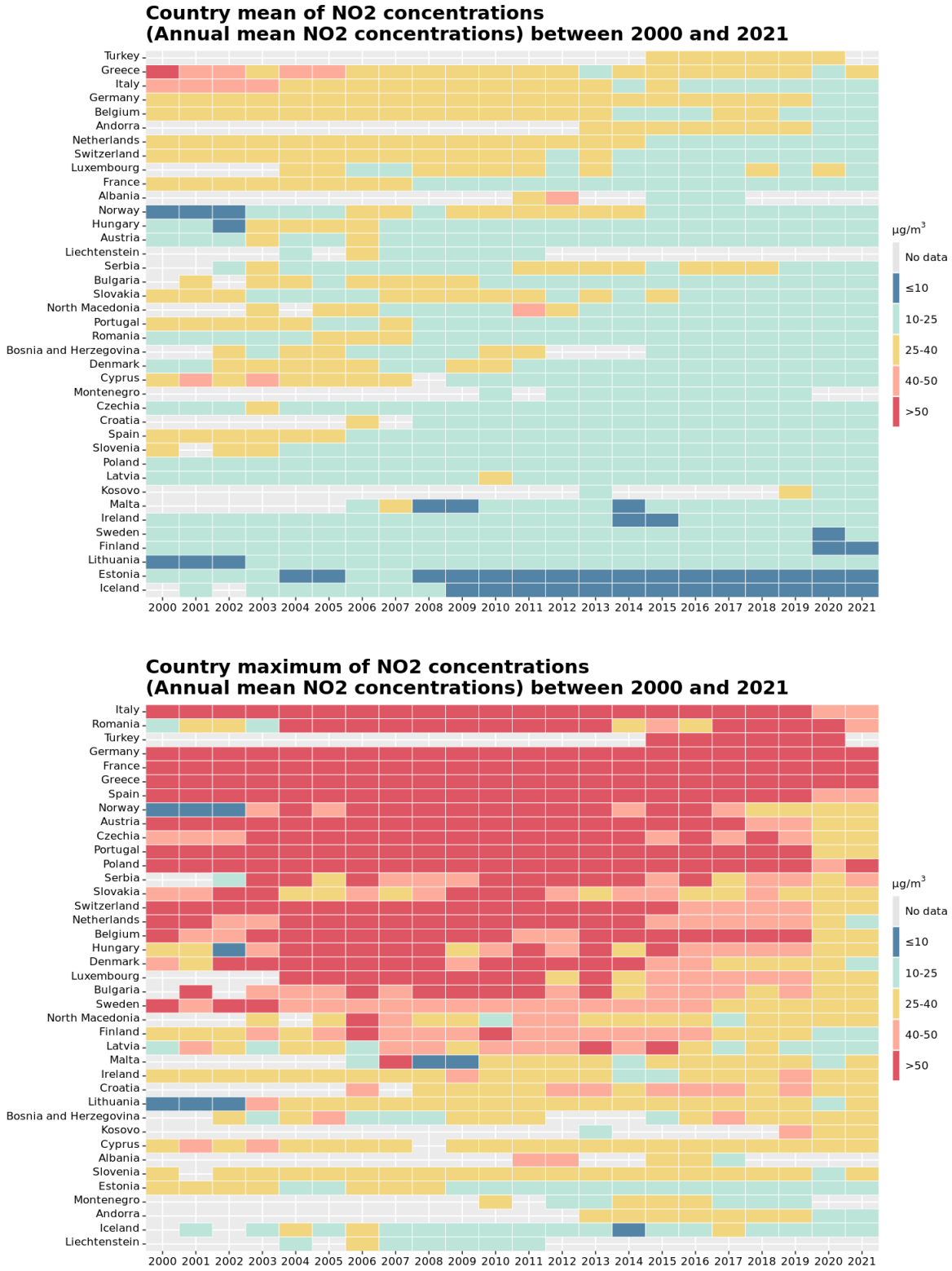
Figure 27: Map of NO_2 concentrations (annual mean) for the last 4 years



Maps for years before 2020 are different to the ones published in previous reports because the bands in the legend have been modified to accomodate the 2021 WHO AQG level.

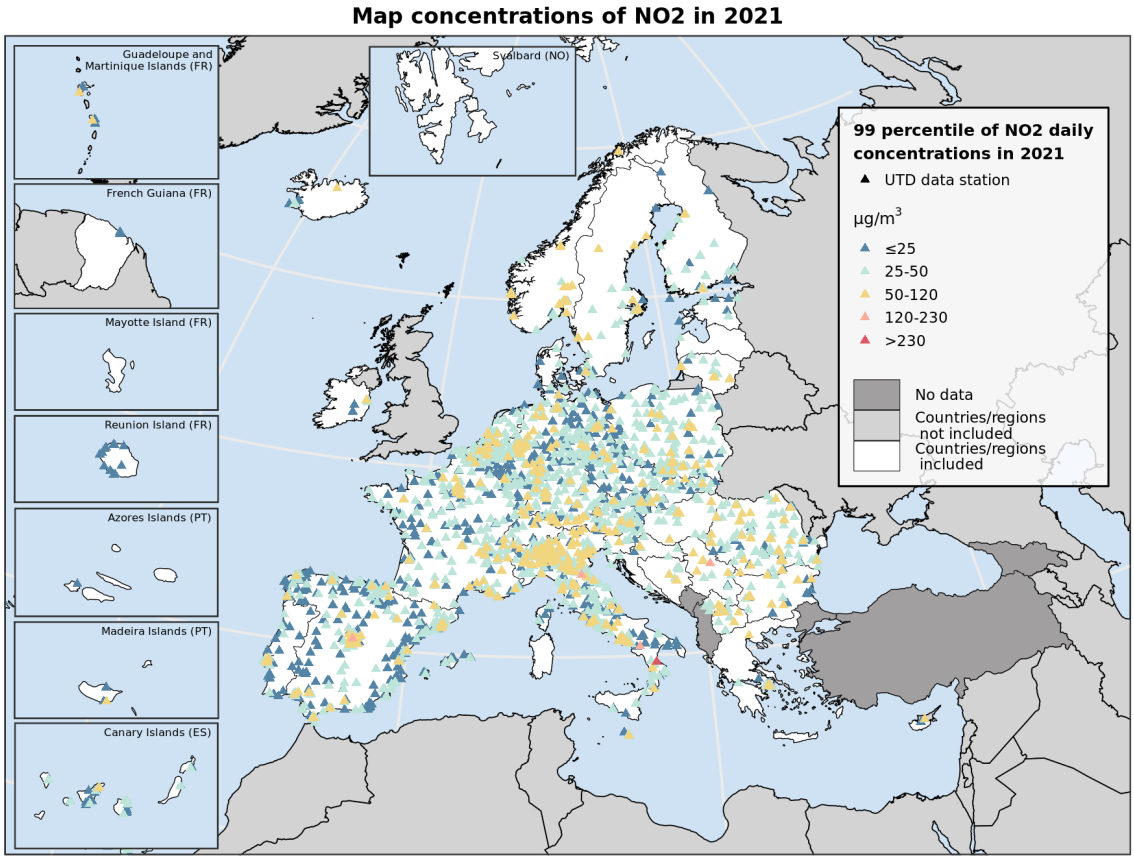
Heatmaps with the evolution from 2000 of the mean (top) and the maximum (bottom) NO_2 annual mean concentrations at country level are shown in figure 28. In this way, the evolution along years of the average and maximum measured concentration levels can be seen for each country. Note that meteorological variability has a considerable impact on year-to-year changes in ambient air concentrations of air pollutants (EEA, 2020), and the last year (2021) is based on UTD data, while the previous years are based on officially reported validated data.

Figure 28: Evolution of mean (top) and maximum (bottom) NO_2 annual mean concentrations (annual limit value) per country from 2000



Note: It is important to note that the figure is not based on a consistent set of stations. The number, location and classification of the stations included may vary from year to year.

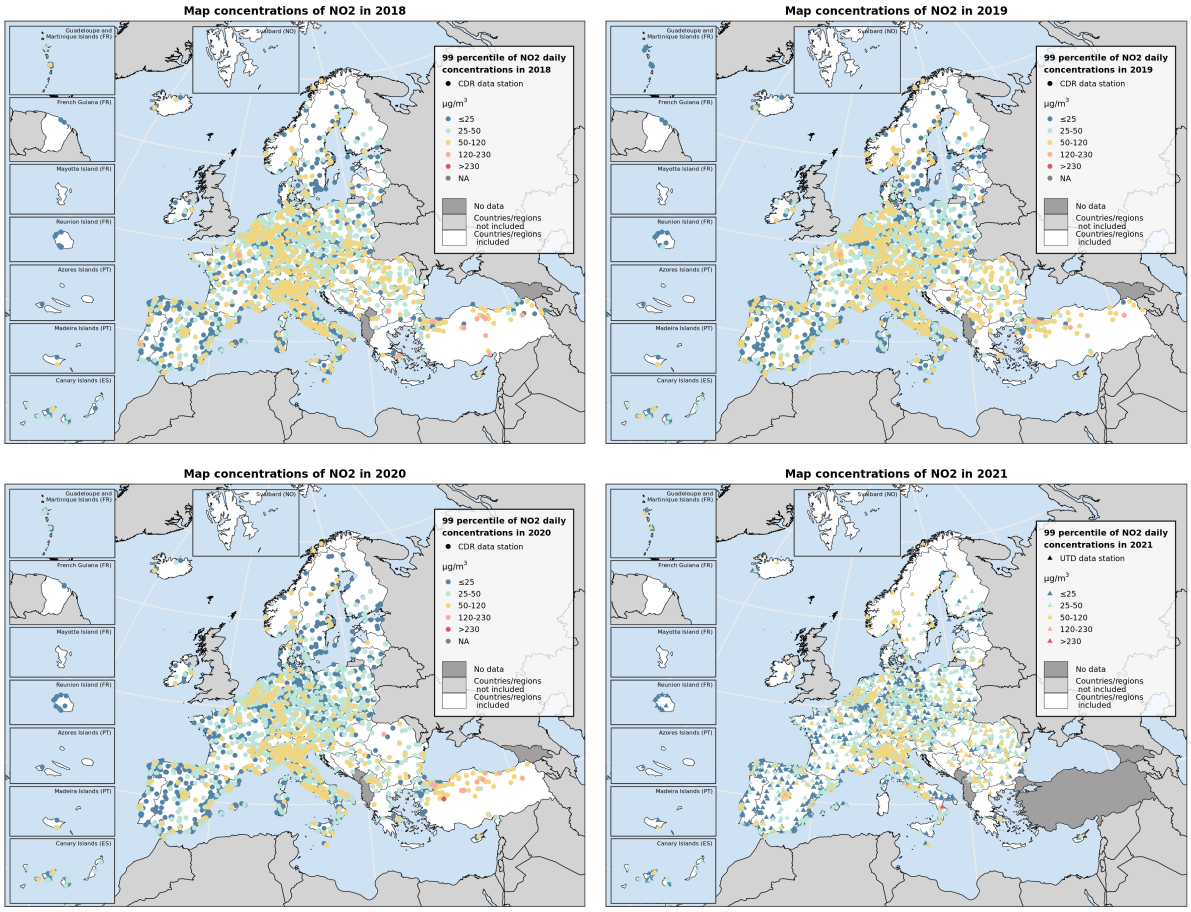
Figure 29: UTD Map of NO_2 concentrations in 2021 - daily WHO AQG level



Note: Observed concentrations of NO2 in 2021. The map shows the 99 percentile of the NO2 daily mean concentrations, equivalent to 3−4 exceedance days per year, according to the definition of the daily WHO AQG level (25 µg/m³). The first colour category indicates stations with concentrations below this AQG level. Only stations with more than 75 % of valid data have been included in the map.

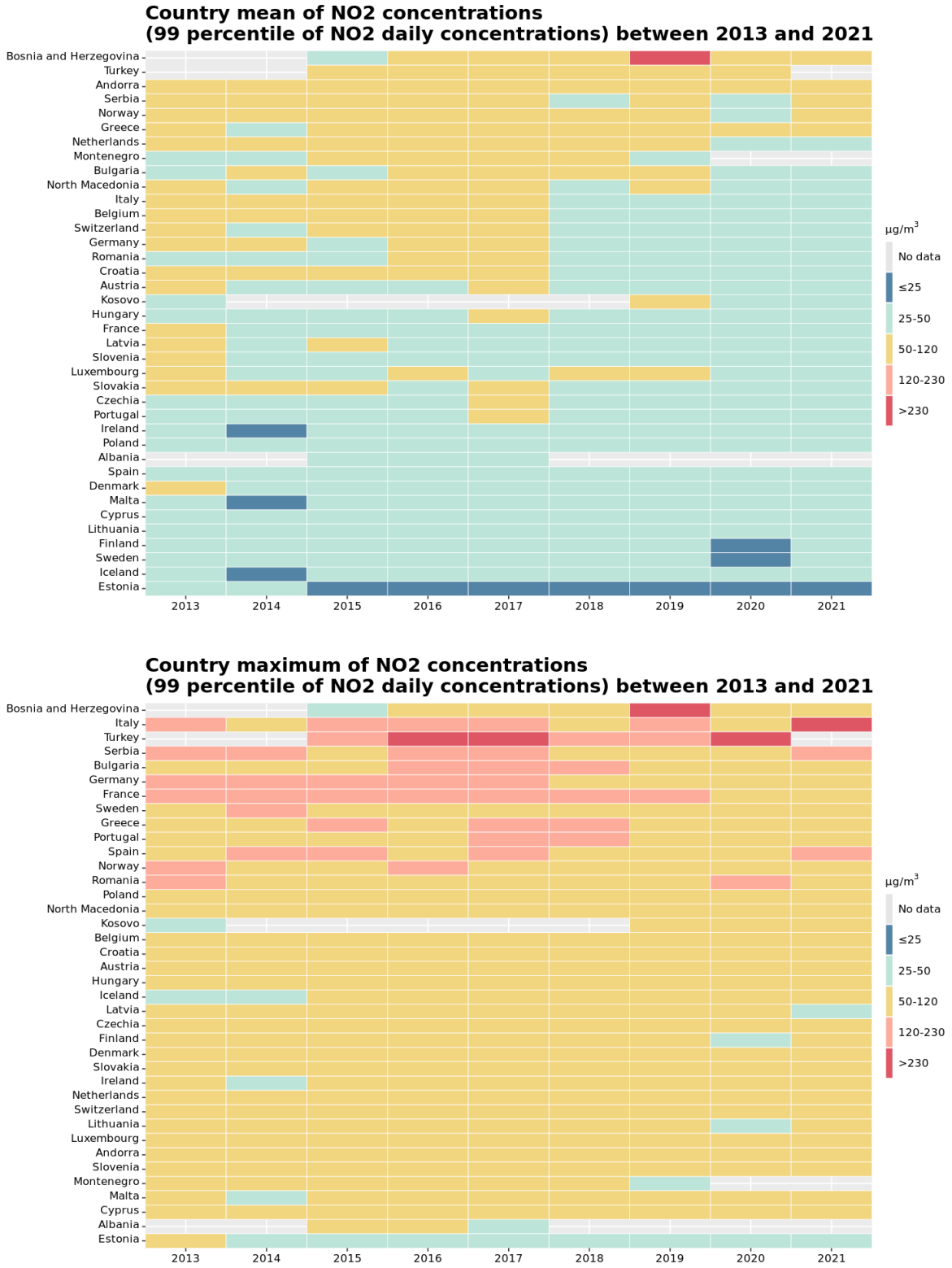
Figure 30 shows the maps of the 99 percentile of NO_2 daily mean concentrations (equivalent to the WHO AQG for NO_2 daily mean level) for the last four years. In this way, any significant change in the spatial distribution of the values above the set thresholds in the legends can be observed. Note that only the last year's map (2021) is based on UTD data, while the previous three years are based on officially reported validated data (CDR).

Figure 30: Maps of NO_2 concentrations (daily WHO AQG level) for the last 4 years



Heatmaps with the evolution from 2013 of the mean (top) and the maximum (bottom) 99 percentile of NO_2 daily mean concentrations at country level are shown in figure 31. In this way, the evolution along years of the average and maximum measured concentration levels can be seen for each country. Note that meteorological variability has a considerable impact on year-to-year changes in ambient air concentrations of air pollutants (EEA, 2020), and the last year (2021) is based on UTD data, while the previous years are based on officially reported validated data.

Figure 31: Evolution of mean (top) and maximum (bottom) 99 percentile of NO_2 daily mean concentrations (daily WHO AQG level) per country from 2013



Note: It is important to note that the figure is not based on a consistent set of stations. The number, location and classification of the stations included may vary from year to year.

6 Status of sulphur dioxide ambient air concentrations

The reporting countries shown in Figure 1 reported measurements of SO_2 from 1179 stations for the hourly limit value and 1178 stations for the daily limit value.

14 stations ([4]) registered concentrations above the hourly limit value (350 µg/m^3); and 14 stations ([5]) registered concentrations above the daily limit of 125 µg/m^3 for SO_2 (Figure 32).

On the contrary, 53 (4 %) of all the stations reporting SO_2 levels, located in 13 reporting countries ([6]), measured SO_2 concentrations above the WHO AQG of 40 µg/m^3 for daily mean concentrations ([7]).

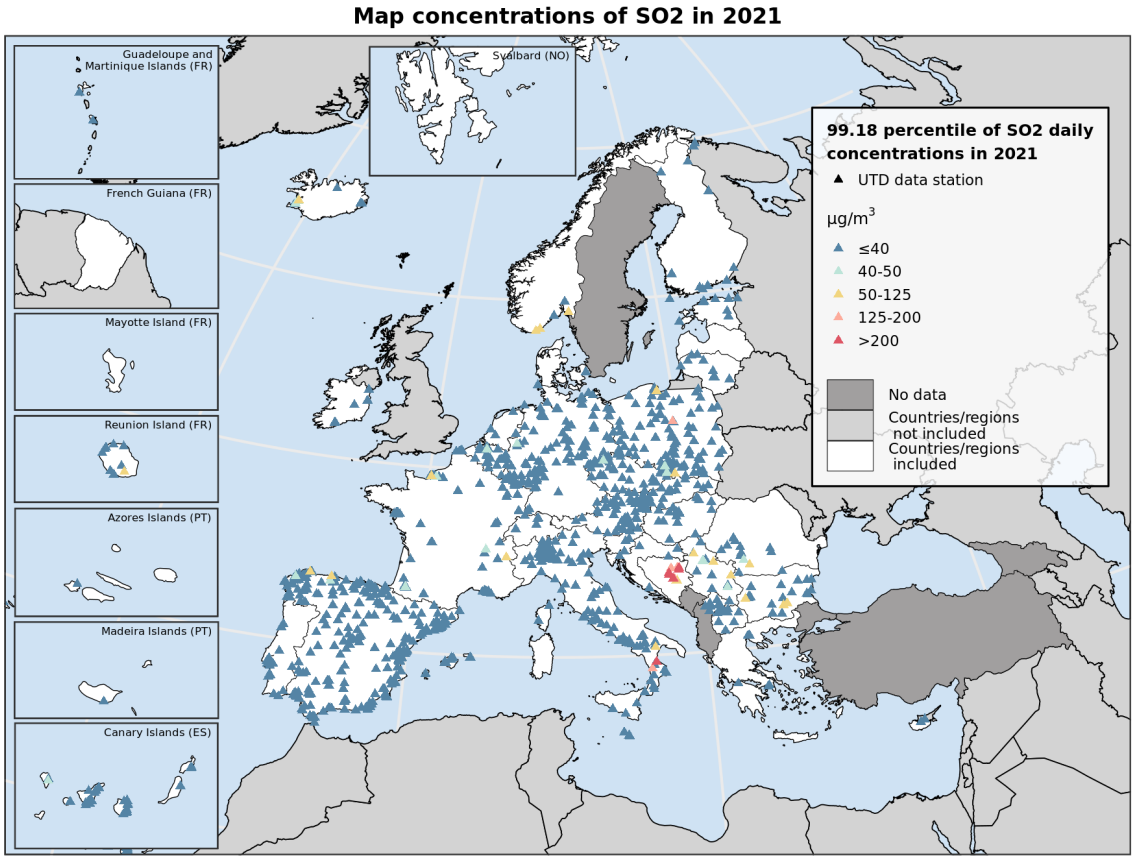
[4] Bosnia and Herzegovina (eleven), Bulgaria (one), Italy (one) and Poland (one)

[5] Bosnia and Herzegovina (eleven), Italy (two) and Poland (one).

[6] All reporting countries except Andorra, Austria, Croatia, Cyprus, Denmark, Estonia, Finland, Greece, Hungary, Ireland, Kosovo, Lithuania, Luxembourg, Malta, Netherlands, North Macedonia, Portugal, Slovakia, Slovenia and Switzerland.

[7] Although the WHO AQG level for daily means refers to the percentile 99 (3-4 exceedance days), here we have used the percentile 99.18 (3 exceedance days), so the daily WHO AQG level can be directly compared with the EU daily LV.

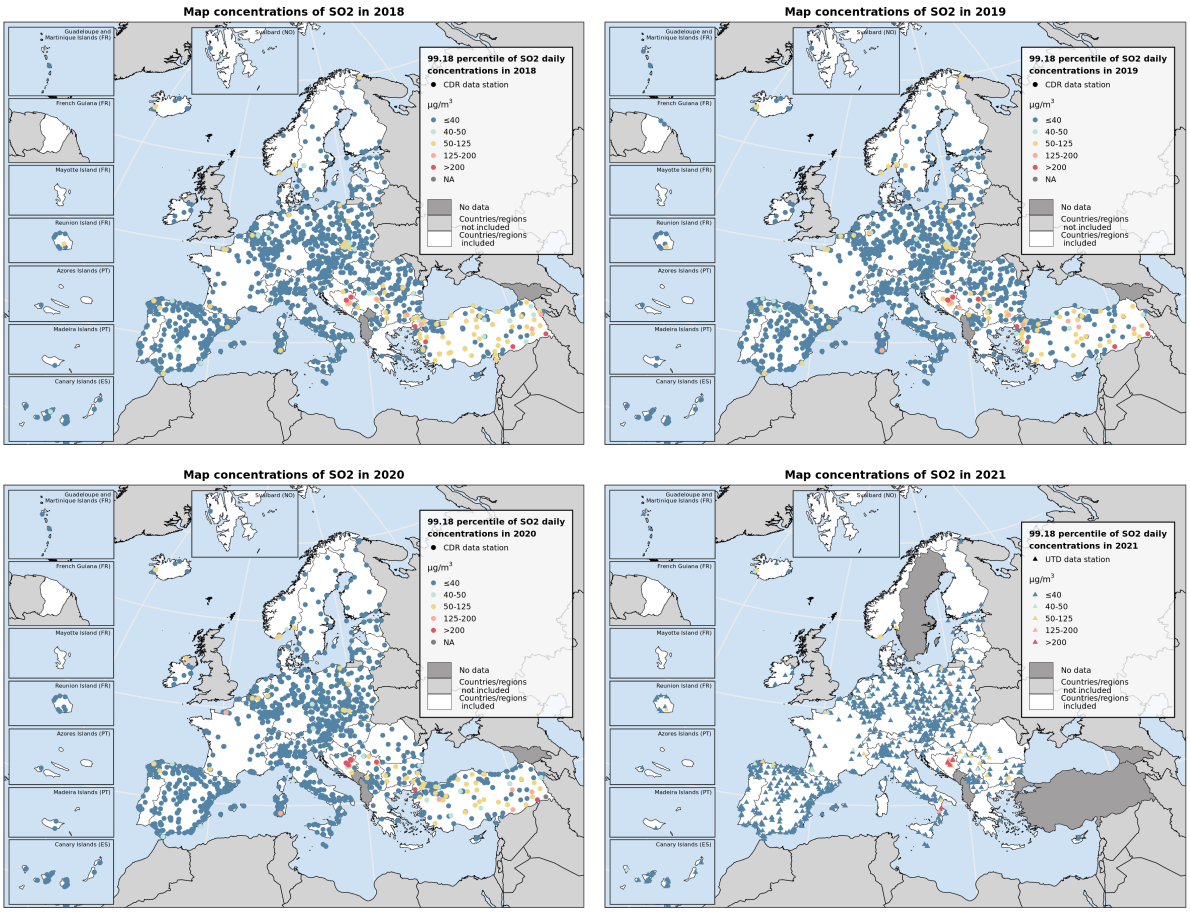
Figure 32: Map of SO_2 daily concentrations in 2021



Note: Observed concentrations of SO2 in 2021. The map shows the percentile 99 of SO2 daily means, indicating 3 exceedance days. It relates to the EU daily limit value (125 µg/m³) and to the WHO daily AQG level (40 µg/m³). Only stations with more than 75 % of valid data have been included in the map.

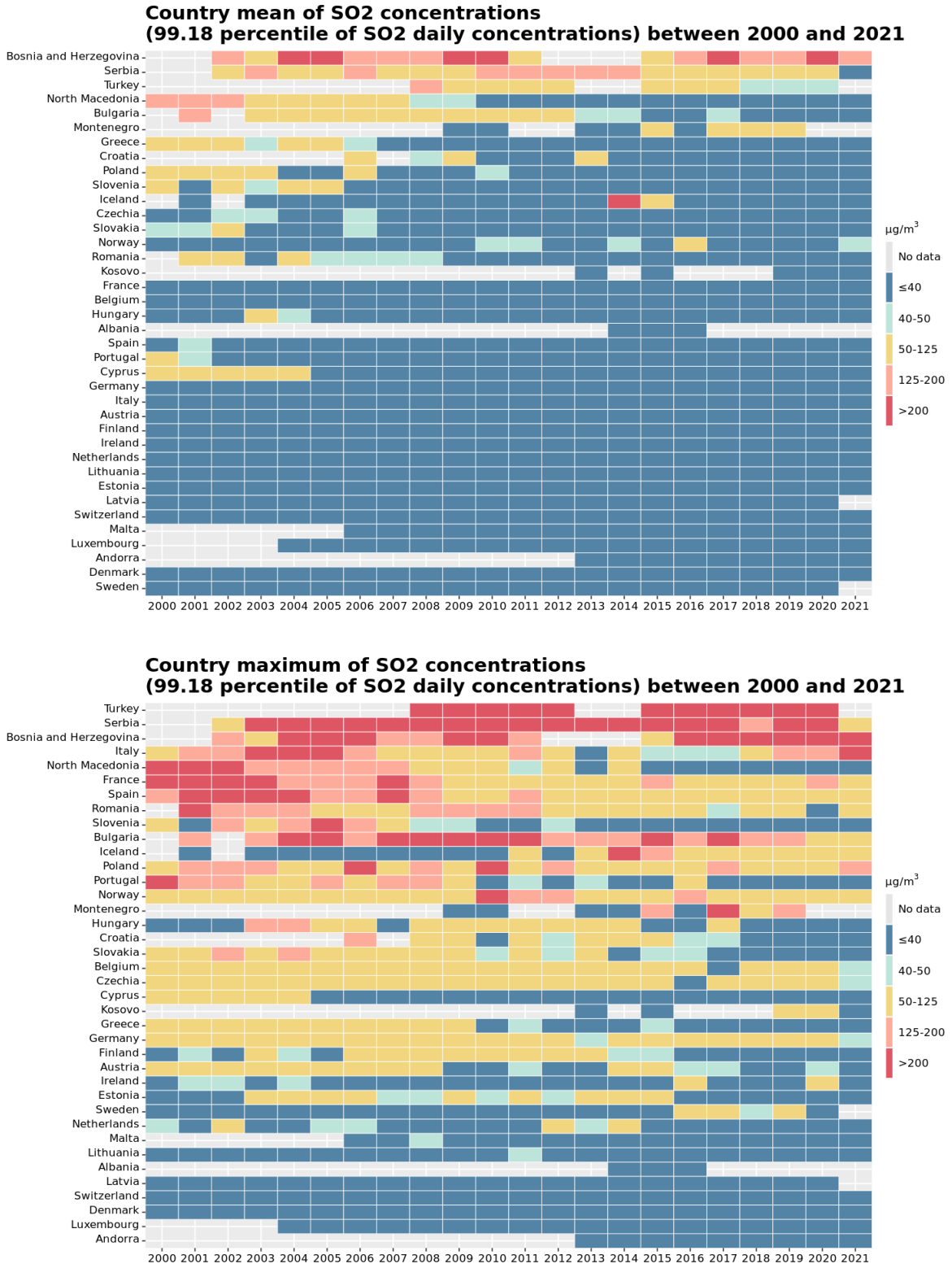
Figure 33 shows the maps of the observed SO_2 daily mean concentrations for the last four years. In this way, any significant change in the spatial distribution of the values above the set thresholds in the legends can be observed. Note that only the last year's map (2021) is based on UTD data, while the previous three years are based on officially reported validated data (CDR).

Figure 33: Maps of SO_2 concentrations (daily mean) for the last 4 years



Heatmaps with the evolution from 2000 of the mean (top) and the maximum (bottom) SO_2 daily mean concentrations at country level are shown in figure 34. In this way, the evolution along years of the average and maximum measured concentration levels can be seen for each country. Note that meteorological variability has a considerable impact on year-to-year changes in ambient air concentrations of air pollutants (EEA, 2020), and the last year (2021) is based on UTD data, while the previous years are based on officially reported validated data.

Figure 34: Evolution of mean (top) and maximum (bottom) SO_2 99.18 percentile of daily mean concentrations (EU LV (125 µg/m^3) and WHO AQG level (40 µg/m^3)) per country from 2000



Note: It is important to note that the figure is not based on a consistent set of stations. The number, location and classification of the stations included may vary from year to year.

7 Abbreviations, units and symbols

$\mu g/m^3$: microgram(s) per cubic metre

AQG: Air quality guideline

CDR: Central data repository

EEA: European Environment Agency

ETC HE: European Topic Centre on Human health and the Environment

EU: European Union

LV: limit value

NO_2: Nitrogen dioxide

O_3: Ozone

PM: Particulate matter

$PM_{2.5}$: Particulate matter with a diameter of 2.5 µm or less

PM_{10}: Particulate matter with a diameter of 10 µm or less

RL: Reference level

SO_2: Sulphur dioxide

TV: target value

UTD: up-to-date

WHO: World Health Organization

8 Annex

Data included in this report was received by 24 March 2022 from the reporting countries. By that date the number of stations by country reporting each pollutant is summarized in Table 3:

Table 3: Reporting status of 2021 air quality data by 24 March 2022

Country	PM10	PM2.5	O3	NO2	SO2
Albania	0	0	0	0	0
Andorra	1	0	2	1	1
Austria	116	45	104	142	65
Belgium	64	65	39	76	25
Bosnia and Herzegovina	8	4	7	11	14
Bulgaria	27	2	19	23	25
Croatia	10	7	12	12	7
Cyprus	0	0	3	3	3
Czechia	77	48	57	64	42
Denmark	3	1	8	10	1
Estonia	6	7	9	9	9
Finland	34	16	13	36	11
France	349	181	299	377	89
Germany	356	233	267	403	109
Greece	17	9	12	13	7
Hungary	21	9	16	21	22
Iceland	7	6	0	8	11
Ireland	21	17	12	8	7
Italy	345	159	201	411	119
Kosovo	12	12	8	11	11
Latvia	0	0	0	3	2
Liechtenstein	0	0	0	0	0
Lithuania	13	6	13	14	10
Luxembourg	4	4	5	8	3

Table 3: Reporting status of 2021 air quality data by 24 March 2022 (continued)

Country	PM10	PM2.5	O3	NO2	SO2
Malta	2	2	4	4	3
Montenegro	0	0	0	0	0
Netherlands	34	23	31	39	6
North Macedonia	12	3	12	12	11
Norway	50	42	11	41	7
Poland	169	82	100	138	96
Portugal	38	19	41	44	20
Romania	0	0	93	140	12
Serbia	11	11	8	16	16
Slovakia	36	35	18	28	15
Slovenia	3	0	2	7	3
Spain	336	166	418	505	399
Sweden	46	26	19	42	0
Switzerland	31	9	30	32	8
Turkey	0	0	0	0	0
EU27	2127	1162	1815	2580	1110
Total	2259	1249	1893	2712	1189

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