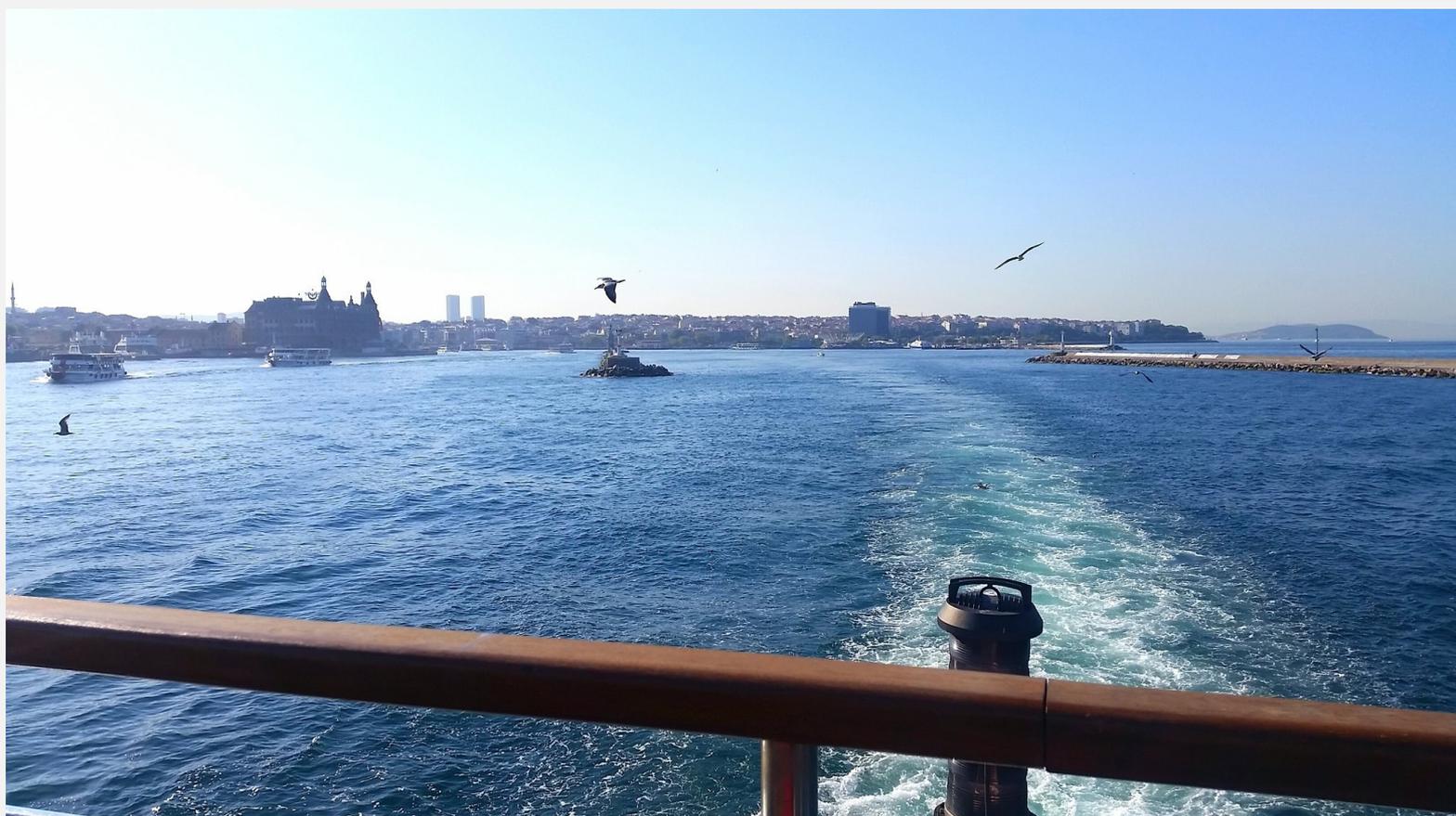


Air quality around ports



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Addendum to the ETC HE Report 2024/12, published 17 December 2024

In 2025, the ETC HE Report 2024/12 version 1 (Pozzoli et al., 2024) was complemented with additional analysis to include the most recent available information. It was considered appropriate to analyse the same pollutants as in the ETC HE Report 2025/7 (Pozzoli et al., 2025), Air quality around airports, focusing on NO₂ and PM_{2.5} for the year 2023 as an additional contribution to the EEA briefing on air quality around ports and airports. This updated version of the report includes the links to a fiche for each port. The rest of the report remains unchanged. The fiches include additional analysis using latest available and validated data for year 2023, measurements of NO₂ and PM_{2.5} (E1a validated data AQ e-Reporting). The maps in the fiches display the location of the sampling points (SPOs) around the ports. The tables include additional information on the annual mean concentrations of each SPO with available data (data coverage larger than 75%), distances of the SPOs from the port area, location of the SPO in one of the 8 wind sectors around the port (WS: N, NE, E, SE, S, SW, W, NW), population living in the WS within 10 km from the port, and trends of annual mean concentrations (2005-2023) when available. This information has been complemented with the latest EEA air quality annual maps for 2023 at 1 km horizontal resolution (Horalek et al., 2025), covering the whole area around the port and showing the mean concentrations over the port area compared to the surrounding region, including the weighted area means for different land cover classes.

List of additional fiches:

- Algeciras (ES): <https://www.eionet.europa.eu/etcs/etc-he/products/etc-he-products/etc-he-reports/etc-he-report-2024-12-air-quality-around-ports/etc-he-report-2024-12-air-quality-around-ports-v2-port-of-algeciras-es.pdf>
- Amsterdam (NL): <https://www.eionet.europa.eu/etcs/etc-he/products/etc-he-products/etc-he-reports/etc-he-report-2024-12-air-quality-around-ports/etc-he-report-2024-12-air-quality-around-ports-v2-port-of-amsterdam-nl.pdf>
- Antwerpen (BE): <https://www.eionet.europa.eu/etcs/etc-he/products/etc-he-products/etc-he-reports/etc-he-report-2024-12-air-quality-around-ports/etc-he-report-2024-12-air-quality-around-ports-v2-port-of-antwerpen-be.pdf>
- Barcelona (ES): <https://www.eionet.europa.eu/etcs/etc-he/products/etc-he-products/etc-he-reports/etc-he-report-2024-12-air-quality-around-ports/etc-he-report-2024-12-air-quality-around-ports-v2-port-of-barcelona-es.pdf>
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- Bremerhaven (DE): <https://www.eionet.europa.eu/etcs/etc-he/products/etc-he-products/etc-he-reports/etc-he-report-2024-12-air-quality-around-ports/etc-he-report-2024-12-air-quality-around-ports-v2-port-of-bremerhaven-de.pdf>
- Gdansk (PL): <https://www.eionet.europa.eu/etcs/etc-he/products/etc-he-products/etc-he-reports/etc-he-report-2024-12-air-quality-around-ports/etc-he-report-2024-12-air-quality-around-ports-v2-port-of-gdansk-pl.pdf>
- Genova (IT): <https://www.eionet.europa.eu/etcs/etc-he/products/etc-he-products/etc-he-reports/etc-he-report-2024-12-air-quality-around-ports/etc-he-report-2024-12-air-quality-around-ports-v2-port-of-genova-it.pdf>
- Gioia Tauro (IT): <https://www.eionet.europa.eu/etcs/etc-he/products/etc-he-products/etc-he-reports/etc-he-report-2024-12-air-quality-around-ports/etc-he-report-2024-12-air-quality-around-ports-v2-port-of-gioia-tauro-it.pdf>
- Hamburg (DE): <https://www.eionet.europa.eu/etcs/etc-he/products/etc-he-products/etc-he-reports/etc-he-report-2024-12-air-quality-around-ports/etc-he-report-2024-12-air-quality-around-ports-v2-port-of-hamburg-de.pdf>

- Le Havre (FR): <https://www.eionet.europa.eu/etcs/etc-he/products/etc-he-products/etc-he-reports/etc-he-report-2024-12-air-quality-around-ports/etc-he-report-2024-12-air-quality-around-ports-v2-port-of-le-havre-fr.pdf>
- Malta Freeport (MT): <https://www.eionet.europa.eu/etcs/etc-he/products/etc-he-products/etc-he-reports/etc-he-report-2024-12-air-quality-around-ports/etc-he-report-2024-12-air-quality-around-ports-v2-port-of-malta-freeport-mt.pdf>
- Marseille (FR): <https://www.eionet.europa.eu/etcs/etc-he/products/etc-he-products/etc-he-reports/etc-he-report-2024-12-air-quality-around-ports/etc-he-report-2024-12-air-quality-around-ports-v2-port-of-marseille-fr.pdf>
- Messina (IT): <https://www.eionet.europa.eu/etcs/etc-he/products/etc-he-products/etc-he-reports/etc-he-report-2024-12-air-quality-around-ports/etc-he-report-2024-12-air-quality-around-ports-v2-port-of-messina-it.pdf>
- Napoli (IT): <https://www.eionet.europa.eu/etcs/etc-he/products/etc-he-products/etc-he-reports/etc-he-report-2024-12-air-quality-around-ports/etc-he-report-2024-12-air-quality-around-ports-v2-port-of-napoli-it.pdf>
- Palma de Mallorca (ES): <https://www.eionet.europa.eu/etcs/etc-he/products/etc-he-products/etc-he-reports/etc-he-report-2024-12-air-quality-around-ports/etc-he-report-2024-12-air-quality-around-ports-v2-port-of-palma-de-mallorca-es.pdf>
- Piraeus (EL): <https://www.eionet.europa.eu/etcs/etc-he/products/etc-he-products/etc-he-reports/etc-he-report-2024-12-air-quality-around-ports/etc-he-report-2024-12-air-quality-around-ports-v2-port-of-piraeus-el.pdf>
- Reggio Calabria (IT): <https://www.eionet.europa.eu/etcs/etc-he/products/etc-he-products/etc-he-reports/etc-he-report-2024-12-air-quality-around-ports/etc-he-report-2024-12-air-quality-around-ports-v2-port-of-reggio-calabria-it.pdf>
- Rotterdam (NL): <https://www.eionet.europa.eu/etcs/etc-he/products/etc-he-products/etc-he-reports/etc-he-report-2024-12-air-quality-around-ports/etc-he-report-2024-12-air-quality-around-ports-v2-port-of-rotterdam-nl.pdf>
- Santa Cruz de Tenerife (ES): <https://www.eionet.europa.eu/etcs/etc-he/products/etc-he-products/etc-he-reports/etc-he-report-2024-12-air-quality-around-ports/etc-he-report-2024-12-air-quality-around-ports-v2-port-of-santa-cruz-de-tenerife-es.pdf>
- Stockholm (SE): <https://www.eionet.europa.eu/etcs/etc-he/products/etc-he-products/etc-he-reports/etc-he-report-2024-12-air-quality-around-ports/etc-he-report-2024-12-air-quality-around-ports-v2-port-of-stockholm-se.pdf>
- Trieste (IT): <https://www.eionet.europa.eu/etcs/etc-he/products/etc-he-products/etc-he-reports/etc-he-report-2024-12-air-quality-around-ports/etc-he-report-2024-12-air-quality-around-ports-v2-port-of-trieste-it.pdf>
- Valencia (ES): <https://www.eionet.europa.eu/etcs/etc-he/products/etc-he-products/etc-he-reports/etc-he-report-2024-12-air-quality-around-ports/etc-he-report-2024-12-air-quality-around-ports-v2-port-of-valencia-es.pdf>

Corrigendum to the ETC HE Report 2024/12, published 17 December 2024

The name of the port in Malta, Marsaxlokk, has been corrected and replaced with Malta Freeport, which identifies the port analysed in this study. The name has been corrected throughout the text in the report, in Figures 1.3, 3.1, 4.2, and in Tables 1.1, 3.1, 3.2, 4.1, 5.1 and 5.2.

Summary

Air pollutant concentrations in Europe have decreased over recent decades due to reduced emissions in various sectors. However, attention is now shifting to shipping emissions and activities in ports, which are becoming a more significant source of pollution. Future projections of emissions in Europe indicate that while road traffic emissions will decrease, shipping emissions and ports could become the main contributor to adverse health impacts in coastal cities by 2030. Monitoring air quality in ports and nearby cities is crucial to understanding the impact of shipping and port activities. This study focuses on air quality in 23 major European ports, examining how air quality is monitored, comparing pollutant concentrations in ports and nearby areas, identifying trends, and assessing the impact of international shipping on air quality for two case studies.

To address these research questions, the study followed several steps using various datasets. Port areas were identified using the CORINE Land Cover 2018 dataset. Air quality sampling point observations (SPOs) were identified in ports and nearby areas using validated data from the European e-reporting database, focusing on NO₂ and PM₁₀ data from 2021. Two main factors were considered for the assessment of the SPOs around ports and nearby cities, the distance of the SPO from the port areas and the wind directions at port location. The measured NO₂ and PM₁₀ concentrations were used to identify the potential impact of port activities in the nearby cities and surrounding regions with latest validated data from 2021, and when available the long-term trends (2005-2021) in NO₂ and PM₁₀ concentrations. Air quality maps with resolution of 1 km x 1km for 2021 were also used to provide a better geographical representation of air quality around ports, and regional differences. Finally, two case studies examined the impact of shipping emissions during pollution episodes in Antwerpen and Barcelona using the Air Control Toolbox of the Copernicus Atmosphere Monitoring Service. These steps aimed to understand air quality in and around ports, the impact of port activities, and trends in those pollutant concentrations.

Air quality SPOs in and around port areas are limited. Among 23 analysed ports, only 5 had at least one SPO for NO₂ and PM₁₀ inside the port areas. Most ports had at least one SPO within 1 km, but only few were downwind of the prevalent wind direction. Measurements at SPOs during downwind conditions from the ports showed increased NO₂ concentrations, with notable increases in cities like Napoli (over 100%), Algeciras (86%), and Hamburg (77%). PM₁₀ increases were smaller but still significant in some ports. The air quality maps for 2021 showed higher annual mean NO₂ and PM₁₀ concentrations in port areas compared to surrounding regions, with some port areas exceeding the new limit values (LV) set by the revised Ambient Air Quality Directive and to be attained by 2030. From 2005 to 2021, NO₂ concentrations in port areas and nearby cities decreased by about 40%, similar to reductions in nearby cities. PM₁₀ concentrations decreased by 40% in port areas and 45% within 20 km of ports. However, limited SPOs make it challenging to draw definitive conclusions for all ports. Only in the port of Antwerpen, the number and location of SPOs allowed to identify a different trend in NO₂ concentrations in the port compared to the rest of the city. Lower concentration reductions (from -25% to -33%) were found in the port, compared to largest NO₂ concentrations reductions in the city (from -39% to -47%), probably showing the impact of larger emission reductions in the city, such as road traffic.

High-resolution air quality modelling is needed for precise impact estimates. Two case studies using the Air Control Toolbox showed that international shipping significantly contributes to NO₂ concentrations during pollution episodes in Antwerpen (38%) and Barcelona (over 55%). PM₁₀ contributions from shipping were also significant but varied depending on other emission sources like agriculture and residential heating.

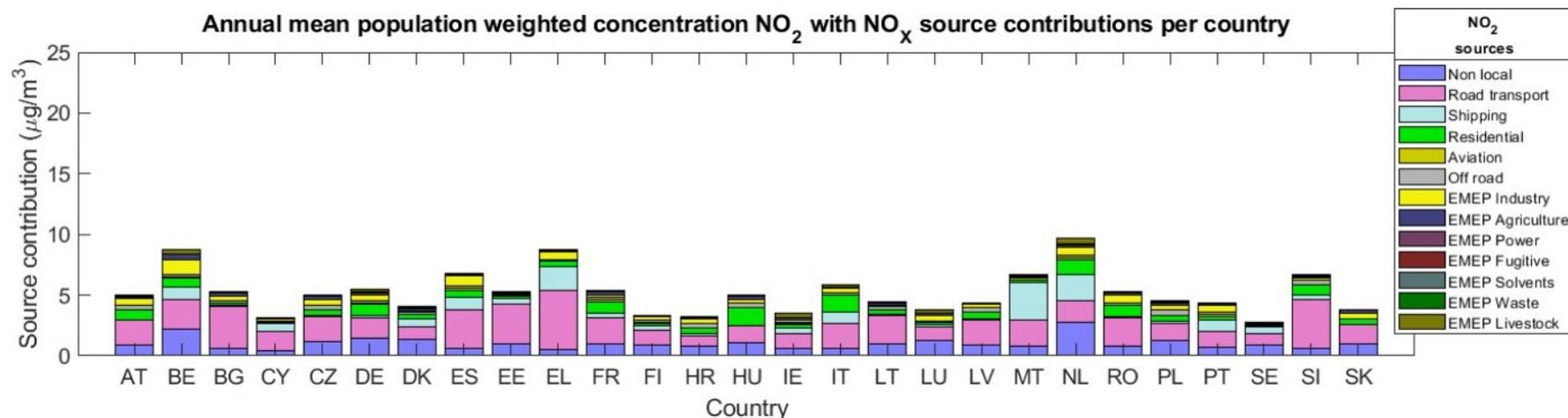
1 Introduction

Air pollutant concentrations in Europe have declined over the last decades due to reduced emissions in many sectors, such as road traffic (Gbangou and Colette, 2023, ETC HE Report 2023/8; EEA Report 08/2024). However, attention has now shifted to other sources like shipping which may become more relevant in the near future to further decrease pollution. Comparing 1990 to 2021 the contribution of the maritime sector to total transport emissions has increased from 20% to 39% for NO_x, and from 30% to 42% for PM_{2.5} (data drawn from the Long-Range Transboundary Air Pollution Convention, LRTAP⁽¹⁾, and EEA Report 08/2024). The relative contribution from international shipping to NO₂ annual mean concentrations in European ports is 22% on average, 5% for PM_{2.5} and 3% for PM₁₀ (Concawe, 2023). The Ambient Air Quality Directives (AAQDs, Directives 2004/107/EC and 2008/50/EC set the LVs for annual mean concentrations of PM_{2.5}, 20 µg/m³ to be met as of 1.1.2020, of PM₁₀, 40 µg/m³ to be met as of 1.1.2005, and of NO₂, 40 µg/m³ to be met as of 1.1.2010. The revised AAQD (EU 2024/2881) was recently published setting new LVs for annual mean concentrations of these pollutants, 10 µg/m³ for PM_{2.5}, 20 µg/m³ for PM₁₀ and NO₂, and to be attained by 1.1.2030. New LVs for daily mean concentrations were also set for PM_{2.5}, PM₁₀ and NO₂, respectively at to 25 µg/m³, 45 µg/m³ and 50 µg/m³, and not to be exceeded more than 18 times per calendar year. For NO₂ there is also a LV of 200 µg/m³ for hourly concentrations, not to be exceeded more than 3 times per calendar year. In this report only annual mean concentrations were assessed, while hourly concentrations were used in the analysis but not assessed towards the newer LVs.

Future emission projections indicate that the contribution of road traffic emissions to the population exposure to high NO₂ concentrations will decrease significantly, while shipping emissions could determine the main contribution to adverse health impacts in coastal European cities in 2030 (EC, DG ENV, 2022). Figure 1.1 shows that, despite road traffic emissions remain the main contributor to annual mean NO₂ concentration at national level, shipping emissions in 2030 will significantly contribute to the overall exposure of population to NO₂ in countries like Malta, the Netherlands, and Greece. The contribution of shipping emissions is smaller in other countries (e.g., Belgium, Spain, Italy and Portugal), but shipping is still one of the main sources of NO₂. At the European level, i.e., for the 27 Member States of the European Union (EU27), shipping is the main sector contributing to the exposure to high NO₂ concentrations. Shipping sector is contributing by 50% to NO₂ annual mean concentrations of 30 µg/m³. This contribution increases at higher concentrations ranges, more than 80% above 40 µg/m³ (Figure 1.2). Therefore, monitoring air quality in ports and the nearby cities will become more important in the next decades to understand the role of emissions from international shipping and from all port activities (road traffic, non-road machinery, bulk unloading and industrial installations). Shipping emissions and other port activities are also contributing to particulate matter concentrations, which are detrimental to human health. Thus PM₁₀ (particles with diameter below 10 µm) was also added to the analysis in this report. Despite shipping emission mainly contribute to the fine fraction of particulate matter (PM_{2.5}, i.e. particles with diameter below 2.5 µm), PM₁₀ measurements are available for a larger number of SPOs and for longer time series, which is an important factor to consider when assessing past trends.

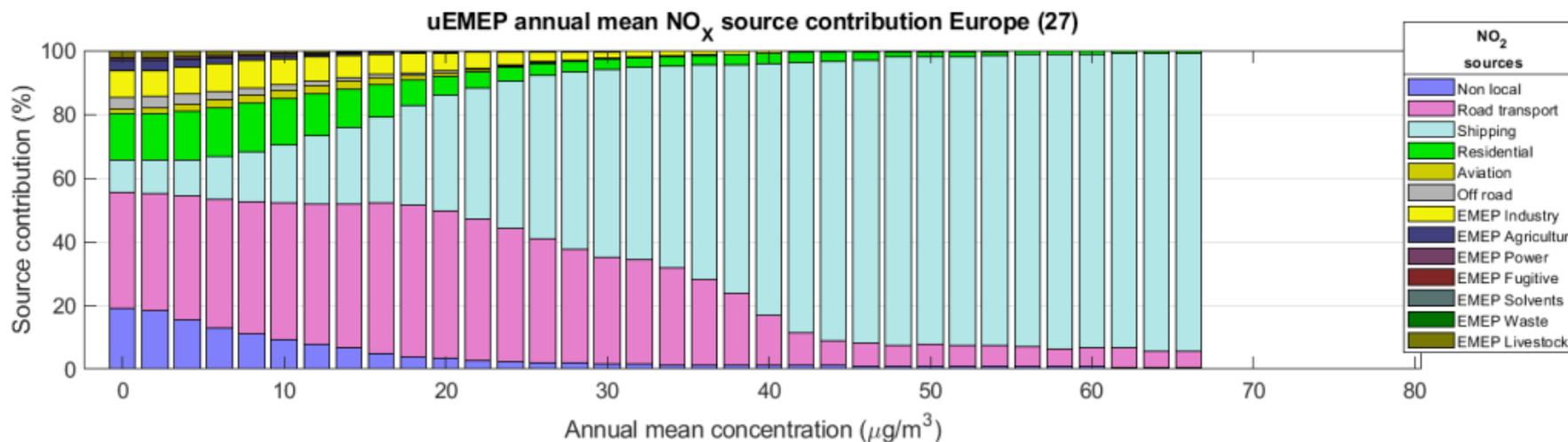
⁽¹⁾ [National emissions reported to the Convention on Long-range Transboundary Air Pollution \(LRTAP Convention\), v1.2, 2024](#)

Figure 1.1 Population weighted concentrations and source contributions per country in 2030



Source: Extracted from Figure 35 in EC, DG ENV, 2022.

Figure 1.2 Population exposure to NOx in 2030 with source contribution for the EU27



Source: Extracted from Figure 26 in EC, DG ENV, 2022.

As there are many ports in Europe, this study analyses air quality for a selection of European ports. The study focuses on 23 ports selected by the European Maritime Safety Agency (EMSA)⁽²⁾ and the European Environment Agency (EEA)⁽³⁾. The list includes some of the largest ports in Europe (such as Rotterdam, Antwerpen, Hamburg, Marseille and Barcelona), considering cargo, bulk carrier and passenger ports, and located in 10 different European countries. The full list of ports included in this analysis is provided in Table 1.1 and their geographical location in Figure 1.3.

Table 1.1 List of ports in Europe included in this study

Ports	Country	Country code
Algeciras	Spain	ES
Amsterdam	The Netherlands	NL
Antwerpen	Belgium	BE
Barcelona	Spain	ES
Bremen	Germany	DE
Bremerhaven	Germany	DE
Gdansk	Poland	PL
Genova	Italy	IT
Gioia Tauro	Italy	IT
Hamburg	Germany	DE
Le Havre	France	FR
Malta Freeport	Malta	MT
Marseille	France	FR
Messina	Italy	IT
Napoli	Italy	IT
Palma de Mallorca	Spain	ES
Piraeus	Greece	GR
Reggio Calabria	Italy	IT
Rotterdam	The Netherlands	NL
Santa Cruz de Tenerife	Spain	ES
Stockholm	Sweden	SE
Trieste	Italy	IT
Valencia	Spain	ES

The aim of this study is to answer the following questions:

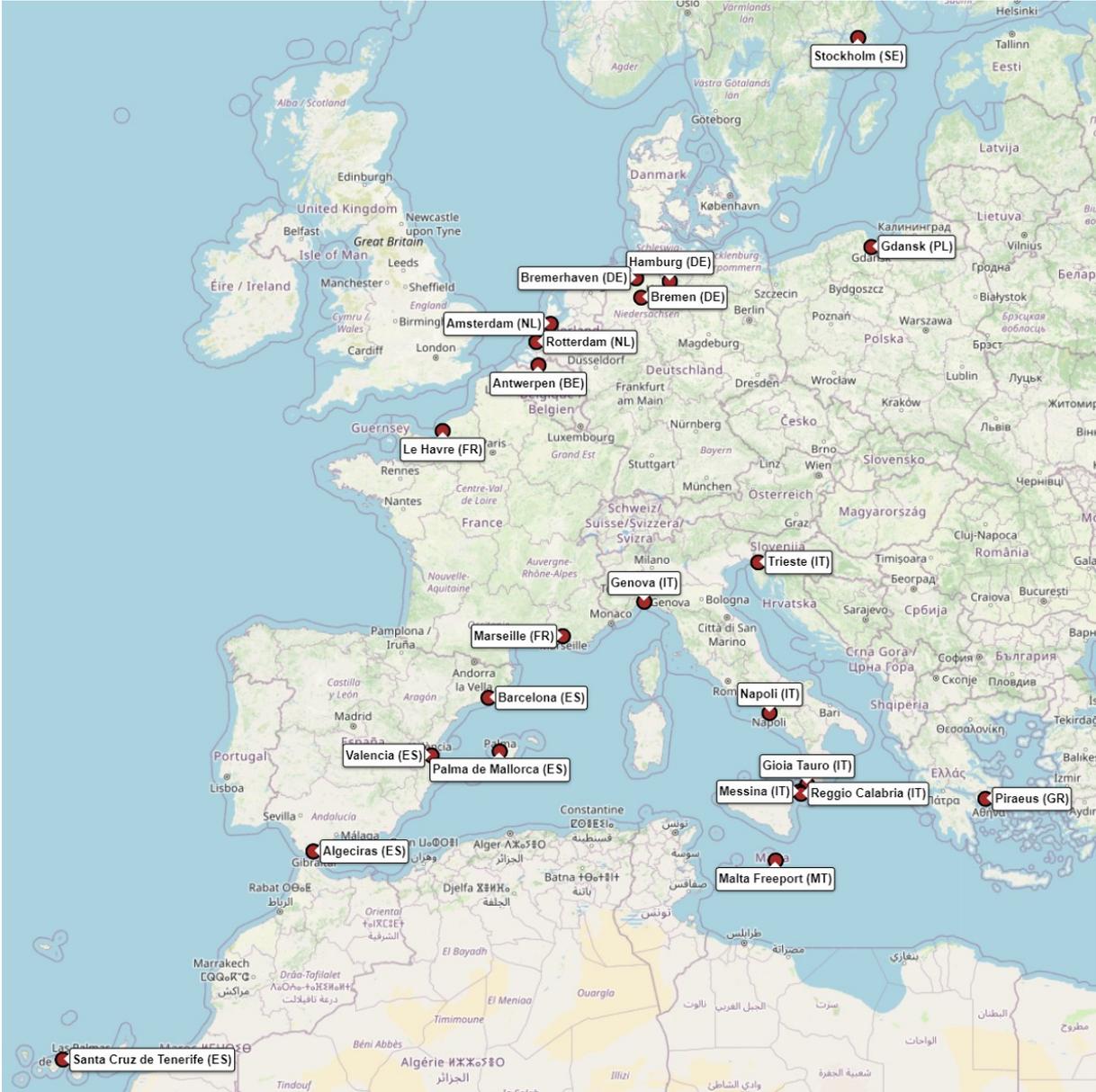
1. How is the air quality monitored inside or in the vicinity of ports?
2. How are the ambient air concentrations of NO₂ and PM₁₀ in and around ports compared to the nearby cities and regions?
3. What are the trends in pollutant concentrations in ports and nearby cities?
4. What is the potential impact of port activities and international shipping on air quality?

⁽²⁾ <https://emsa.europa.eu/>

⁽³⁾ <https://www.eea.europa.eu/en>

To address these questions, the study followed several steps using various datasets, including air pollutant concentrations, land cover, population and meteorology. The methodology and datasets are described in Section 2. The assessment of air quality monitoring around the 23 selected ports in Europe is presented in Section 3. The comparison of NO₂ and PM₁₀ concentrations between port areas and nearby cities and surrounding regions is presented in Section 4, and their trends in Section 5. Finally, two case studies are presented in Section 6 to show the impact of shipping emissions during pollution episodes.

Figure 1.3 Location of the 23 European ports analysed in this study



2 Methodology

In order to answer these questions, different datasets were used according to the following steps:

1. Identification of the port area for each city in Table 1.1: it was used the “port area” polygons classification of land cover (CLC Code 123) available in the **CORINE Land Cover 2018 dataset** from the Copernicus Land Monitoring Services (CLMS)⁽⁴⁾.
2. First air quality SPOs located in the ports and other that could be affected by the port activities in the vicinity of port were identified to be compared with SPOs in the nearby city and surrounding areas. The validated data available from the European e-reporting database⁽⁵⁾ were used. NO₂ and PM₁₀ SPOs were considered in the analysis with available data in 2021, which was, at the time of performing the study, the latest air quality validated data.
3. As different industrial activities are typically co-located in port areas, we considered the Directive 2008/50/EC, which specifies the micro- and macroscale siting of industrial SPOs. Industrial SPOs shall be sited at enough distance (> 250 m) from industrial installations and downwind of the industrial sources in the nearest residential area. All types of SPOs were considered in this analysis, industrial, traffic and background. Both the distance of SPOs from the port and the meteorology (frequency of wind direction blowing from the port area) were considered to assess the air quality monitoring in port areas.
4. For each port three types of SPOs were selected for the analysis:
 - a. **in port**: located inside the port area polygon
 - b. within a **distance of 1 km** from the port area polygon
 - c. within a **distance of 1 km to 10 km for NO₂**, and of **1 km to 20 km for PM₁₀** (a larger distance was considered for PM₁₀ as this pollutant can be transported at further distances due to its longer lifetime in the atmosphere). The 10 km and 20 km distances were calculated from the centroid of the port area polygons.

For the first two sets of SPOs (a and b) it was expected to see a stronger impact of the ports due to their proximity to the sources. The SPOs in group c were used to see if the port activities and shipping emissions are affecting the nearby cities and surrounding regions.

5. Meteorology is another important factor to take into account in the analysis. For each port it was considered the frequency (%) of wind blowing in different directions from the ports towards the surrounding areas. The European Centre for Medium-Range Weather Forecasts (ECMWF) re-analysis (i.e. a meteorological model simulation of past years corrected with observations, Berrisford et al., 2011) dataset at a resolution of 0.1 x 0.1 degrees resolution (approximately 10 km by 10 km). The timeseries of hourly wind directions of the year 2021 were extracted from the modelled gridded data at the location of the centroid of the port area polygon. The timeseries were used to calculate the frequency of wind directions blowing from the port centroid in the surrounding 8 wind sectors 45 degrees wide, centred at 45 degrees (North East, NE), 90 (East, E), 135 (South East, SE), 180 (South, S), 225 (South West, SW), 270 (West, W), 315 (North West, NW), and 360 (North, N).
6. The comparison of the NO₂ and PM₁₀ concentration in and around ports compared to the nearby cities and regions, was assessed by analysing the hourly concentrations measured at the selected SPOs for each port. The distribution of NO₂ and PM₁₀ concentrations when wind direction was coming from the port, was compared to the distribution of concentrations when wind was not blowing from the port. This comparison may provide a first indication if the air quality SPOs in different regions (wind sectors) around the ports are affected by the port activities. On the other hand, it must be noted that these differences may also be influenced at the same time by other emission sources.
7. Measurements from SPOs may not be available for all ports, and if available their location in relation to the ports may not be always optimal (distance and meteorology). The analysis

⁽⁴⁾ <https://land.copernicus.eu/>

⁽⁵⁾ <https://aqportal.discomap.eea.europa.eu/>

based on SPOs was complemented with the analysis of the EEA air quality maps⁽⁶⁾ for 2021 at the resolution of 1 km x 1 km (based on the combination of model simulations, observations, and supplementary data (Horálek et al, 2023, ETC HE Report 2023/3). These maps can provide a better geographical representation of air quality in the regions around ports and can be used to estimate the differences between NO₂ and PM₁₀ annual mean concentrations in ports compared to the nearby cities and regions.

8. A database of SPOs with long-term trends of air pollutants at European and national level 2005-2021 (Gbangou and Colette, 2023, ETC HE Report 2023/8) was used to assess differences in NO₂ and PM₁₀ trends at the SPOs identified in the previous steps of the analysis (1-3). The aim of this comparison was to evaluate if different trends in annual mean concentrations were observed in ports, or in their vicinity, compared to other SPOs in the surrounding region.
9. In order to better quantify the impact of shipping emissions and port activities and evaluate its contribution compared to other emission sectors, it would be necessary to perform air quality modelling studies at a high resolution for each port, which was behind the scope of this study. Nevertheless, case studies were analysed to illustrate the possible impact of shipping emissions and their contribution to the NO₂ and PM₁₀ concentrations during different pollution episodes in two cities, Antwerpen and Barcelona. The online Air Control Toolbox was used (Colette et al., 2022), a surrogate model of the Chimere chemistry transport model (Menut et al., 2024) and one of the air quality policy tools developed for the Copernicus Atmosphere Monitoring Services (CAMS)⁽⁷⁾.

Section 2 is a summary of how many SPOs are available for each port (question 1), while the results from the analysis of measurements from available SPOs and air quality maps are shown in Section 3 (question 2). Section 4 presents the analysis of observed trends at the identified SPOs (question 3). Section 5 illustrates examples of pollution episodes and the possible contribution from shipping emissions. Section 6 provides general conclusions. Annex 1 provides the complete analysis (graphics and maps) for each port.

3 Air quality monitoring around European ports

Different activities and emission sources are located in the port areas, including national and international shipping, road and non-road traffic, and industrial point sources. This chapter provides a general overview of air quality monitoring around ports. This analysis is not focused only on SPOs downwind of the port and in the nearest populated area, but all SPOs around a port were considered, taking into account the distance from the port, all types of SPOs (background, industrial or traffic), and all wind directions blowing from the port towards the SPOs.

Figure 3.1 shows an overview of the number of air quality SPOs found for each port inside the port area polygons, within 1 km from the port area, and between 1 km to 10 km for NO₂ SPOs and between 1 km to 20 km for PM₁₀. Among the 23 ports analysed in this study, only 5 ports have at least one air quality SPO for NO₂ and PM₁₀ located inside the port area: Amsterdam (NL), Antwerpen (BE), Genova (IT), Hamburg (DE), and Piraeus (GR).

Almost all analysed ports have at least one SPO in the vicinity of the port area (within 1 km distance). Only the ports of Malta Freeport (MT), Marseille (FR), Reggio Calabria (IT) and Stockholm (SE) do not have any SPOs or NO₂ and PM₁₀ within 1 km. In addition, the ports of Barcelona (ES), Messina (IT) and Santa Cruz de Tenerife (ES) do not have a SPO for PM₁₀ within 1 km.

When considering an area between 1 km to 10 km distance from the port areas, all ports and nearby cities have at least one SPOs for NO₂. The largest number of SPOs for NO₂ are found around the port

⁽⁶⁾ <https://sdi.eea.europa.eu/catalogue/datahub/eng/catalog.search#/metadata/82700fbd-2953-467b-be0a-78a520c3a7ef>

⁽⁷⁾ <https://policy.atmosphere.copernicus.eu/>

of Antwerpen (37 monitoring SPOs) (Figure 3.2). The ports Malta Freeport (MT), Messina (IT), and Reggio Calabria (IT) do not have any SPO for PM₁₀ within 20 km. The largest number of SPOs for PM₁₀ are found for the ports of Amsterdam (22) and Antwerpen (19) (Figure 3.2).

Figure 3.1 Number of monitoring SPOs of NO₂ (a) and PM₁₀ (b) around 23 European ports and nearby cities with validated measurements for year 2021

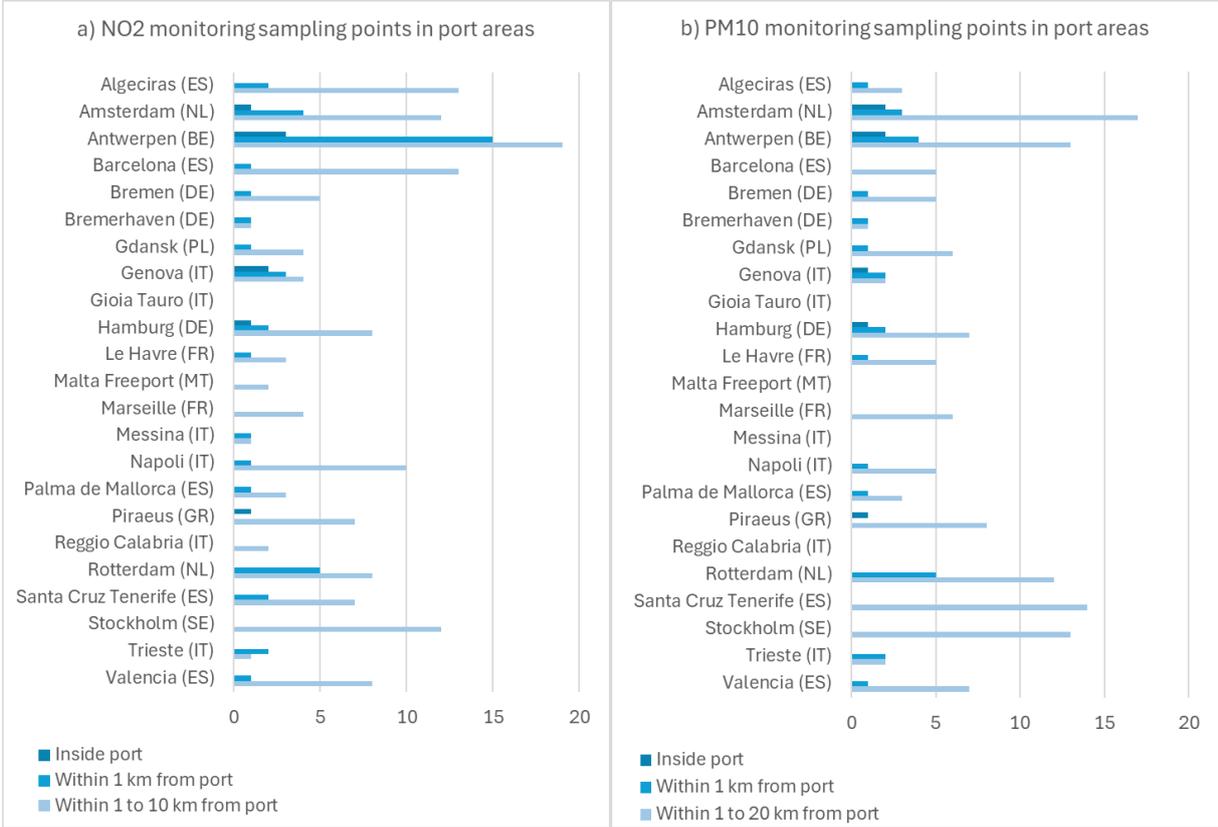


Figure 3.2 Air quality SPOs in the ports of Antwerpen (left) and Amsterdam (right)

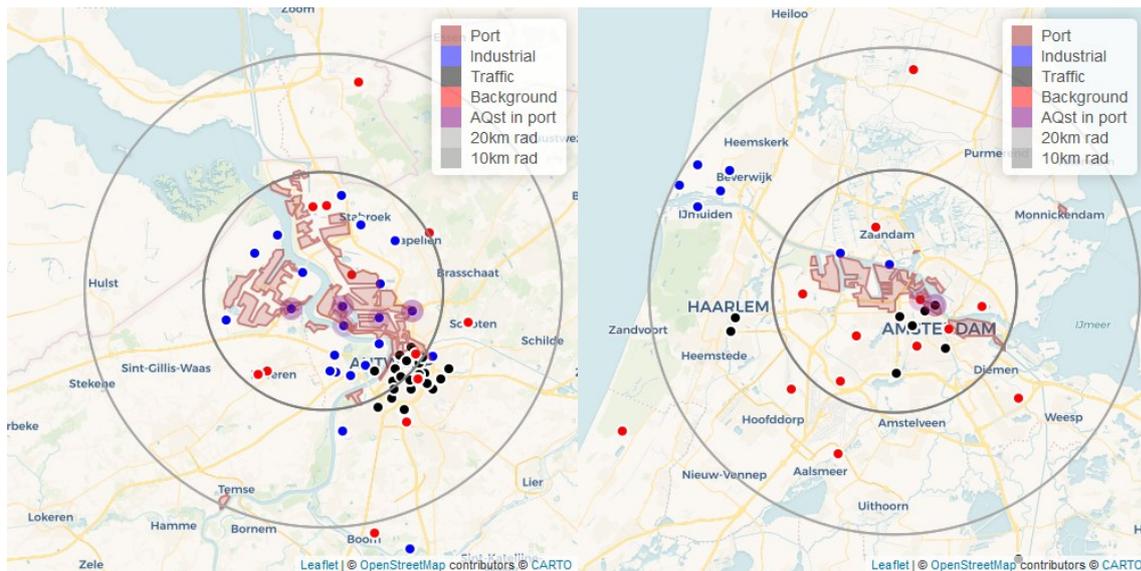


Table 3.1 and Figure 3.2 provide more details about the total number of SPOs identified for NO₂ (within 10 km from the port) and for PM₁₀ (within 20 km). For each port it is also indicated:

- how many SPOs are classified as background (B), traffic (T) or industrial (I);
- how many of the total number of SPOs are located inside the port area;
- how many of the total number of SPOs are located within 1 km from the port area;
- the mean distance of all SPOs from the port area in kilometres;
- the number of the wind 8 sectors where at least one SPO is located;
- the sum of the wind frequencies (%) blowing from the ports towards each sector where at least one monitoring SPO is located.

Most of the NO₂ SPOs found inside port areas are classified as traffic (T) SPOs (1 in Amsterdam, 2 in Genova, and 1 in Piraeus). In the port of Antwerpen 3 industrial (I) SPOs were found, and 1 SPO classified as background (B) is located inside the port of Hamburg.

The mean distances of SPOs from port areas are ranging between 0.6 km (Trieste) and 6.9 km (Piraeus). Only few of the identified SPOs are located downwind of the prevalent wind direction in the port areas. Only 5 ports (Algeciras, Antwerpen, Genova, Marseille, and Napoli) have at least one SPO for NO₂ located in a wind direction sector which is downwind of the port more than 25% of the time (Figure 3.3). The ports of Amsterdam and Antwerpen have SPOs in 7 of the 8 wind sectors around the port. The total frequency of wind directions from the ports toward the seven sectors with SPOs is 79% in Amsterdam, 91% in Antwerpen. The total wind frequency is above 50% in 8 of the 23 ports analysed.

Table 3.1 Number of SPOs within 10 km from a port, in port or within 1km from a port. SPOs in the list are those with available data for NO₂ in 2021

Port	Country code	SPO within 10 km (#)	SPO type	SPO in port (#, type)	SPO within 1 km from port (#, type)	Mean distance from port (km)	wind sectors with at least 1 SPO (#)	Total wind frequency covered by all SPOs
Algeciras	ES	15	1T, 1B, 13I		2I	3.1	5	54 %
Amsterdam	NL	17	6T, 9B, 2I	1T	1T, 2B, 2I	2.6	7	79 %
Antwerpen	BE	37	21T, 6B, 10I	3I	9T, 2B, 4I	1.4	7	91 %
Barcelona	ES	14	11T, 3B		1B	4.1	4	60 %
Bremen	DE	6	1T, 4B, 1I		1B	2.6	3	35 %
Bremerhaven	DE	2	1T, 1B		1B	1.6	2	21 %
Gdansk	PL	5	5B		1B	3	3	32 %
Genova	IT	9	5T, 4B	2T	1T, 2B	2.4	4	69 %
Gioia Tauro	IT	-	-	-	-	-	-	-
Hamburg	DE	11	5T, 4B, 2I	1B	1B, 1I	2.2	5	71 %
Le Havre	FR	4	1T, 2B, 1I		1B	1.8	2	29 %
Malta Freeport	MT	2	1T, 1B			6.3	2	39 %
Marseille	FR	4	1T, 3B			3.6	3	48 %
Messina	IT	2	1T, 1B		1T	1	2	15 %
Napoli	IT	11	5T, 4B, 2I		1T	5.5	6	78 %
Palma de Mallorca	ES	4	1T, 2B, 1I		1B	3.4	4	47 %
Piraeus	GR	8	4T, 2B, 2I	1T		6.9	3	40 %
Reggio Calabria	IT	2	1T, 1B			1.6	2	20 %

Port	Country code	SPO within 10 km (#)	SPO type	SPO in port (#, type)	SPO within 1 km from port (#, type)	Mean distance from port (km)	wind sectors with at least 1 SPO (#)	Total wind frequency covered by all SPOs
Rotterdam	NL	13	5T, 5B, 5I		1T, 3B, 1I	2.8	4	45 %
Santa Cruz Tenerife	ES	9	1T, 2B, 6I		1T, 1I	1.7	1	23 %
Stockholm	SE	12	10T, 2B			4.4	2	21 %
Trieste	IT	3	1T, 2B		2B	0.6	2	13 %
Valencia	ES	9	6T, 3B		1T	4.9	3	50 %

Table 3.2 Number of SPOs within 20 km from a port, in port or within 1km from a port. SPOs in the list are those with available data for PM₁₀ in 2021

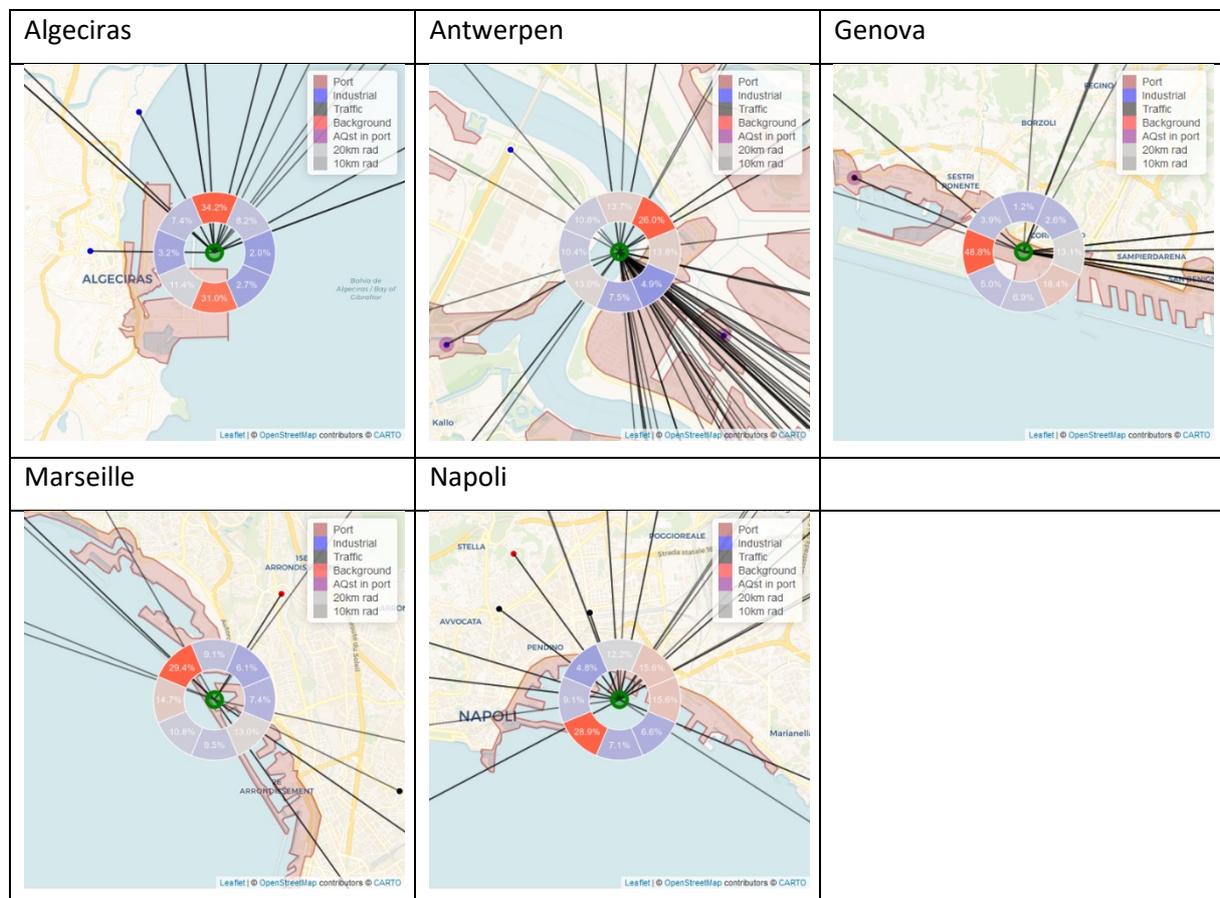
Port	Country code	SPO within 20 km (#)	SPO type	SPO in port (#, type)	SPO within 1 km from port (#, type)	Mean distance from port (km)	wind sectors with at least 1 SPO (#)	Total wind frequency covered by all SPOs
Algeciras	ES	4	4I		1I	2.8	4	46 %
Amsterdam	NL	22	6T, 9B, 7I	1T, 1B	1T, 2I	6.9	7	79 %
Antwerpen	BE	19	2T, 7B, 10I	2I	2B, 2I	2.4	8	100 %
Barcelona	ES	5	2T, 3B			10.6	4	58 %
Bremen	DE	6	1T, 4B, 1I		1B	2.6	3	35 %
Bremerhaven	DE	2	1T, 1B		1B	1.6	2	21 %
Gdansk	PL	7	7B		1B	6.9	3	32 %
Genova	IT	5	3T, 2B	1T	1T, 1B	1.3	2	17 %
Gioia Tauro	IT	-	-	-	-	-	-	-
Hamburg	DE	10	3T, 5B, 2I	1B	1B, 1I	3.1	5	71 %

Port	Country code	SPO within 20 km (#)	SPO type	SPO in port (#, type)	SPO within 1 km from port (#, type)	Mean distance from port (km)	wind sectors with at least 1 SPO (#)	Total wind frequency covered by all SPOs
Le Havre	FR	6	1T, 3B, 2I		1B	5.1	5	57 %
Malta Freeport	MT							
Marseille	FR	6	1T, 3B, 2I			7.5	4	63 %
Messina	IT							
Napoli	IT	6	3T, 3I		1T	4.8	4	42 %
Palma de Mallorca	ES	4	1T, 2B, 1I		1B	4.8	4	47 %
Piraeus	GR	9	2T, 6B, 1I	1T		10.6	3	40 %
Reggio Calabria	IT							
Rotterdam	NL	17	6T, 8B, 3I		1T, 3B, 1I	5.9	5	67 %
Santa Cruz Tenerife	ES	14	3B, 11I			6.6	1	23 %
Stockholm	SE	13	12T, 1B			7.7	3	37 %
Trieste	IT	4	1T, 2B, 1I		1B, 1I	1.6	4	31 %
Valencia	ES	8	5T, 2B, 1I		1T	7	3	50 %

Also, for PM₁₀, most of the SPOs found inside port areas are classified as traffic (T) (1 in Amsterdam, 2 in Genova, and 1 in Piraeus). In the port of Antwerpen 2 industrial (I) SPOs were found, and 2 SPOs classified as background (B) are located inside the ports of Amsterdam and Hamburg.

The mean distances of SPOs from port areas are ranging between 1.3 km (Genova) and 10.6 km (Piraeus and Barcelona). Only a few of the identified SPOs are located downwind of the prevalent wind direction in the port areas. Only 3 ports (Algeciras, Antwerpen, and Marseille) have at least one SPO for PM₁₀ located in a wind direction sector which is downwind of the port more than 25% of the time (Figure 3.3). The port of Antwerpen has SPOs in all the 8 wind sectors around the port (100% of the wind frequency). The port of Amsterdam has SPOs in 7 of the 8 wind sectors around the port (total frequency of 79% of wind directions from the ports toward the seven sectors with SPOs). The total wind frequency is above 50% in 8 of the 23 ports analysed.

Figure 3.3 Air quality SPOs and wind direction frequencies for the ports of Algeciras, Antwerpen, Genova, Marseille and Napoli



Note: A map with location of the air quality SPOs around ports and frequency of wind direction blowing from the ports towards 8 wind sectors is provided for all ports in the Annex 1.

4 Air quality in port areas compared to the nearby cities and regions

An analysis was conducted using wind directions from meteorological data and measured concentrations of the identified SPOs around each port. The change in pollutant concentrations measured at SPOs around the ports was assessed only during downwind conditions and compared to the rest of the observations. For each port the timeseries of hourly NO₂ and PM₁₀ concentrations for 2021 were analysed. The distribution of the concentrations for all SPOs located in the same wind sector around the port were compared for each port. As shown in the example in Figure 4.1, in the port of

Antwerpen there are three SPOs in the NE wind sector relative to the port, all of them have valid data for NO₂ concentrations, only one for PM₁₀. In these SPOs, the distribution of measured concentrations when air was blowing from the port (green line) was compared to conditions when air is not blowing from the port (blue line), and for all wind directions (red line). The wind blew 26% of the time during 2021 from the port of Antwerpen toward these the SPOs. When the air was coming from the port, the peak of the distribution of NO₂ concentrations increased from 6.8 µg/m³ (not from port) to 12 µg/m³ (from port). The median of NO₂ concentrations increased by 75% when air was coming from the port (21 µg/m³) compared to not from port conditions (12 µg/m³). For PM₁₀ concentrations in the same sector there is only one SPO, a similar increase was not observed, only a 12% increase in the peak of the distributions, and no change in the median between the two distributions of PM₁₀ concentrations. The different distributions of pollutant concentrations can indicate a possible impact of the port in a specific region (in this case NE from the port of Antwerpen), but it must be highlighted that it cannot be considered a precise estimate, as pollution from other sources in the region cannot be separated through this analysis. The same analysis is available in the Annex 1 for all ports and for all wind directions where measurements are available.

Figure 4.1 Distribution of hourly NO₂ (left) and PM₁₀ (right) concentrations for SPOs (3 for NO₂, 1 for PM₁₀) located in the NE wind sector relative to the port of Antwerpen. Three distributions are shown, for “all” wind directions (WD), for WD “from port” and for WD “not from port”. The number of hourly concentration values (# records) for each distribution is indicated in the legend.

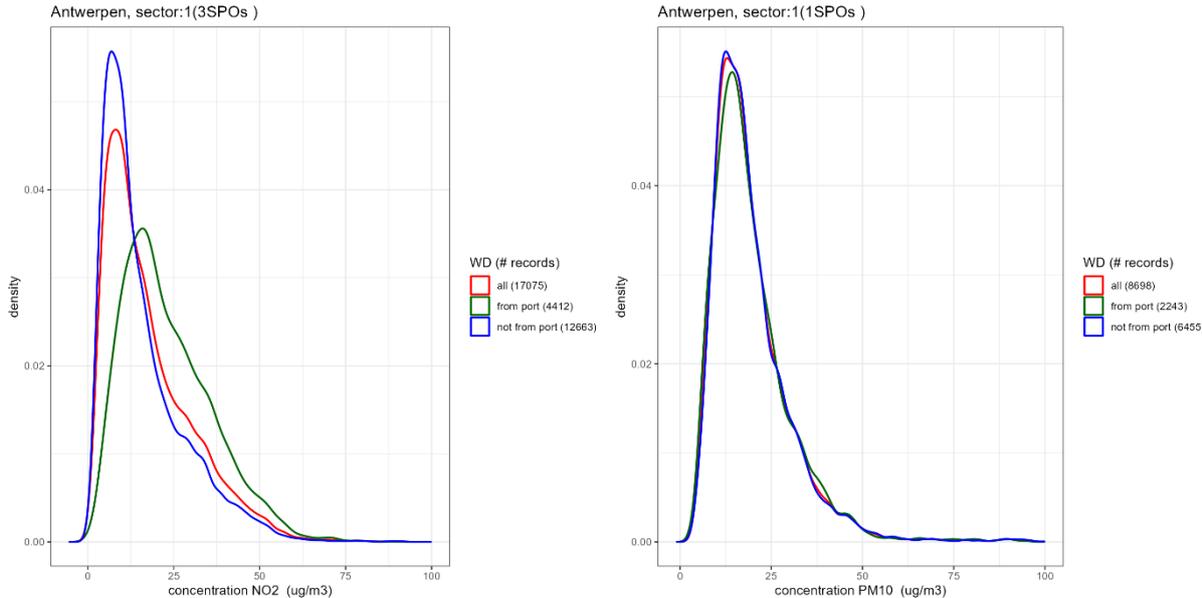


Table 4.1 Summary for all ports with main percentage changes in median NO₂ and PM₁₀ concentrations for measurements when air is blowing from the port

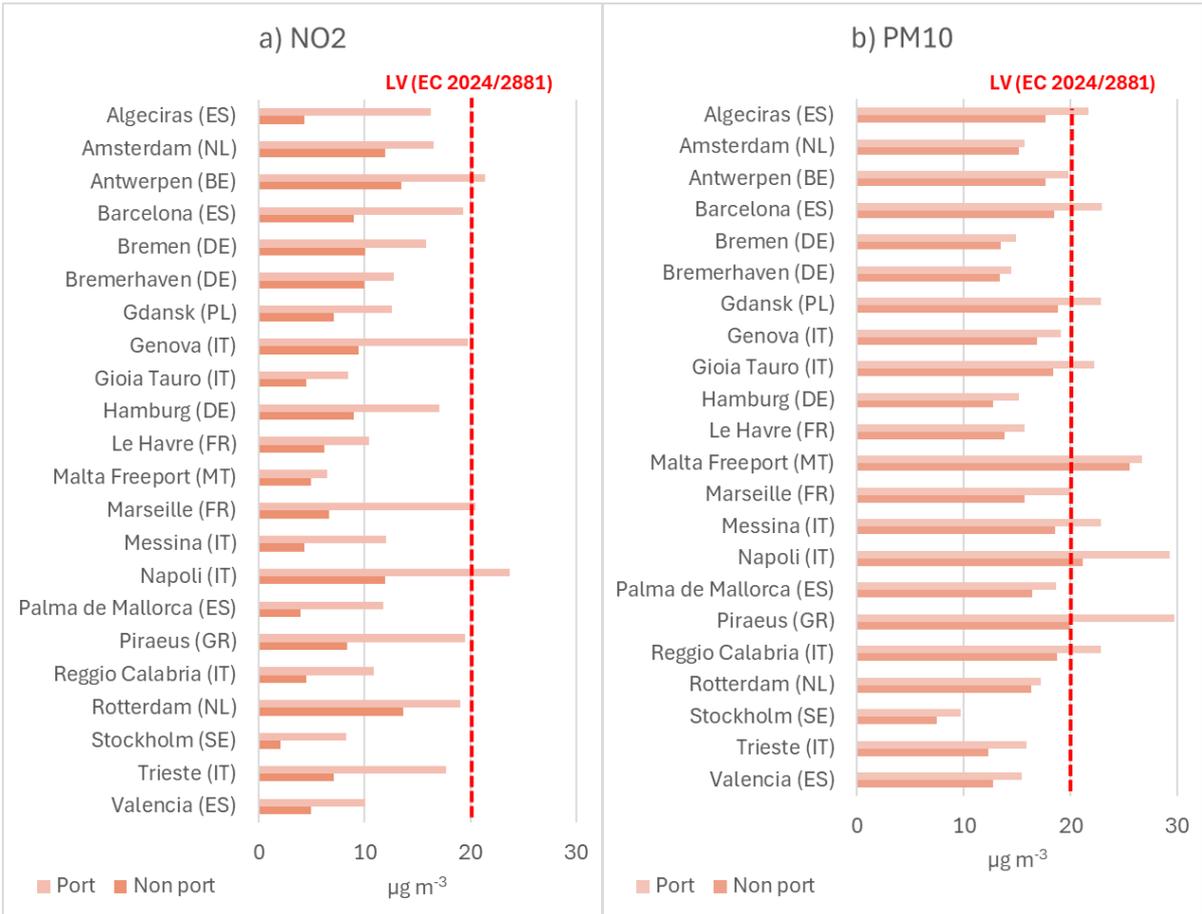
Port	NO ₂	PM ₁₀	Maps and figures
Algeciras	Data available in 5 wind sectors. Increase in 3 sectors from 40% (W) to 86% (NE).	Data available in 4 wind sectors. Increase in 2 sectors, 12% (E) and 19% (W).	Annex 1.1
Amsterdam	Data available in 7 wind sectors. Increase in 4 sectors from 13% (N) to 51% (W).	Data available in 7 wind sectors. Increase in 3 sectors from 7% (E) to 20% (SE).	Annex 1.2
Antwerpen	Data available in 6 wind sectors. Increase in 5 sectors from 6% (SW) to 75% (NE).	Data available in all 8 wind sectors. Increase in 4 sectors from 6% (E) to 26% (S).	Annex 1.3
Barcelona	Data available in 4 wind sectors. Increase in 2 sectors from 5% (NE) to 29% (SW).	Data available in 4 wind sectors. Increase in 1 sector of 5% (W).	Annex 1.4
Bremen	Data available in 3 wind sectors. Increase in 2 sectors, 21% (E) and 26% (SE).	Data available in 3 wind sectors. Increase in 2 sectors, 14% (E) and 25% (SE).	Annex 1.5
Bremerhaven	Data available in 2 wind sectors. No increase detected in both sectors (E and SE).	Data available in 2 wind sectors. Increase in 2 sectors, 13% (E) and 36% (SE).	Annex 1.6
Gdansk	Data available in 3 wind sectors. No increase detected in all sectors.	Data available in 3 wind sectors. Very small increase detected in one sector, 3% (SW).	Annex 1.7
Genova	Data available in 4 wind sectors. Increase detected in all sectors from 1% (NW) to 32% (W).	Data available in 2 wind sectors. Increase detected in all sectors, 2% (NW) and 11% (E).	Annex 1.8
Gioia Tauro	No data available.	No data available.	Annex 1.9
Hamburg	Data available in 5 wind sectors. Increase detected in 2 sectors, 26% (NE) and 77% (SW).	Data available in 5 wind sectors. Increase detected in 2 sectors, 17% (NE) and 32% (SE).	Annex 1.10
Le Havre	Data available in 2 wind sectors. Increase detected in 1 sector, 73% (NW).	Data available in 5 wind sectors. Increase detected in 1 sector, 15% (SE).	Annex 1.11
Malta Freeport	Data available in 2 wind sectors. Increase detected in 1 sector, 31% (N).	No data available.	Annex 1.12

Port	NO ₂	PM ₁₀	Maps and figures
Marseille	Data available in 3 wind sectors. Increase detected in 1 sector, 52% (NE).	Data available in 4 wind sectors. Increase detected in all 4 sectors, from 7% (W) to 25% (NE).	Annex 1.13
Messina	Data available in 2 wind sectors. Increase detected in 1 sector, 46% (SW).	No data available.	Annex 1.14
Napoli	Data available in 6 wind sectors. Increase detected in 4 sectors, from 5% (NW) to 115% (SW).	Data available in 4 wind sectors. No increase detected in all 4 sectors.	Annex 1.15
Palma de Mallorca	Data available in 4 wind sectors. No increase detected in all 4 sectors.	Data available in 4 wind sectors. Small increase detected in 2 sectors, 5% (NE and E).	Annex 1.16
Piraeus	Data available in 3 wind sectors. Increase detected in 1 sector, 45% (NE).	Data available in 3 wind sectors. Increase detected in 2 sectors, 8% (E) and 13% (NE).	Annex 1.17
Reggio Calabria	Data available in 2 wind sectors. No increase detected in both sectors.	No data available.	Annex 1.18
Rotterdam	Data available in 4 wind sectors. Increase detected in 3 sectors, from 35% (N) to 46% (SE).	Data available in 5 wind sectors. Increase detected in 3 sectors, from 9% (NE) to 26% (SE).	Annex 1.19
Santa Cruz Tenerife	Data available in 1 wind sector. Increase detected, 50% (SW).	Data available in 1 wind sector (SW). Increase not detected.	Annex 1.20
Stockholm	Data available in 2 wind sectors. Increase detected in 1 sector, 21% (SW).	Data available in 3 wind sectors. Increase detected in 1 sector, 25% (SW).	Annex 1.21
Trieste	Data available in 2 wind sectors. Increase detected in 1 sector, 41% (N).	Data available in 4 wind sectors. Increase detected in all 4 sectors, from 8% (NW) to 74% (N).	Annex 1.22
Valencia	Data available in 3 wind sectors. Increase detected in all 3 sectors, from 13% (W) to 40% (N).	Data available in 3 wind sectors. Very small increase detected in 1 sector, 4% (W).	Annex 1.23

The majority of the ports analysed do not have air quality SPOs inside port areas. Furthermore, most of the SPOs in the nearby cities are too sparse and often not located downwind of the ports. Thus, it was difficult to derive strong conclusions from the previous analysis based uniquely on measurements. The analysis of the EEA air quality maps⁽⁸⁾ (Horálek et al, 2023, ETC HE Report 2023/3) may represent better the differences between NO₂ and PM₁₀ concentrations in ports compared to the nearby cities and regional background levels. The maps are created as a data fusion between a model simulation, thus taking into account the impact of meteorology for a specific year, measurements reported by the Member States to the EEA and other ancillary data, such as land cover. The maps are used to downscale the model results, which have a rather coarse resolution, to a finer resolution of 1 km by 1km, and better geographical distribution of pollutants concentrations.

Figure 4.1 shows the differences between annual mean concentrations of NO₂ (a) and PM₁₀ (b) over port areas compared to the surrounding regions. The «Port» concentrations are calculated as the mean concentrations of all the grid cells, in the 1 km x 1 km air quality map, which are intersecting or within 1 km from the port area polygons. The «Non port» concentrations are calculated as the mean concentrations over all other grid cells around the port over a region within 0.5 degrees latitude and longitude (approximately a region of 100 km by 100 km).

Figure 4.2 Annual mean NO₂ (a) and PM₁₀ (b) concentrations in port areas and surrounding regions (“Non port”). The dashed red line represents the LV for NO₂ and PM₁₀ annual mean concentrations set by the revised AAQD (EC 2024/2881)



NO₂ concentrations in “Port” areas were larger than the “Non port” regional levels for all the ports analysed (data for Santa Cruz de Tenerife were not available as extra territories are not included in the

⁽⁸⁾ [EEA geospatial data catalogue European air quality data \(interpolated data\)- Series.](#)

EEA air quality maps). The differences in annual mean NO₂ concentrations ranges from 1.5 µg/m³ (Malta Freeport, MT) to 13.8 µg/m³ (Marseille, FR). The differences were above 10 µg/m³ in 7 ports, Algeciras (ES), Barcelona (ES), Genova (IT), Marseille (FR), Napoli (IT), Piraeus (GR), and Trieste (IT). The annual mean NO₂ concentrations were above 20 µg/m³ (the LV for the protection of human health set in the revised AAQD, EC 2024/2881, to be attained by 1/1/2030) in three ports, Antwerpen (BE), Marseille (FR), and Napoli (IT). Other ports which are very close to this LV were Barcelona (ES, 19.3 µg/m³), Genova (IT, 19.8 µg/m³), Piraeus (GR, 19.5 µg/m³), Rotterdam (NL, 19 µg/m³).

Also PM₁₀ concentrations in “Port” areas were larger than the “Non port” regional levels for all the port analysed. But, compared to NO₂, the differences were smaller, ranging from 0.5 µg/m³ (Amsterdam, NL) to 9.8 µg/m³ (Piraeus, GR). Only two ports stand out from the others with large differences, Piraeus (GR, 9.8 µg/m³) and Napoli (IT, 8.2 µg/m³). Differences in PM₁₀ concentrations in all other ports were below 4.4 µg/m³ (Barcelona, ES). The annual mean PM₁₀ concentrations were above 20 µg/m³ (the LV for the protection of human health set in the revised AAQD, EC 2024/2881, to be attained by 1/1/2030) in 10 ports, Algeciras (ES, 21.7 µg/m³), Barcelona (ES, 22.9 µg/m³), Gdansk (PL, 22.8 µg/m³), Gioia Tauro (IT, 22.3 µg/m³), Malta Freeport (MT, 26.7 µg/m³), Marseille (FR, 20 µg/m³), Messina (IT, 22.8 µg/m³), Napoli (IT, 29.3 µg/m³), Piraeus (GR, 29.7 µg/m³) and Reggio Calabria (IT, 22.9 µg/m³). Other ports which are very close to this LV are Antwerpen (BE, 19.8 µg/m³) and Genova (IT, 19.1 µg/m³).

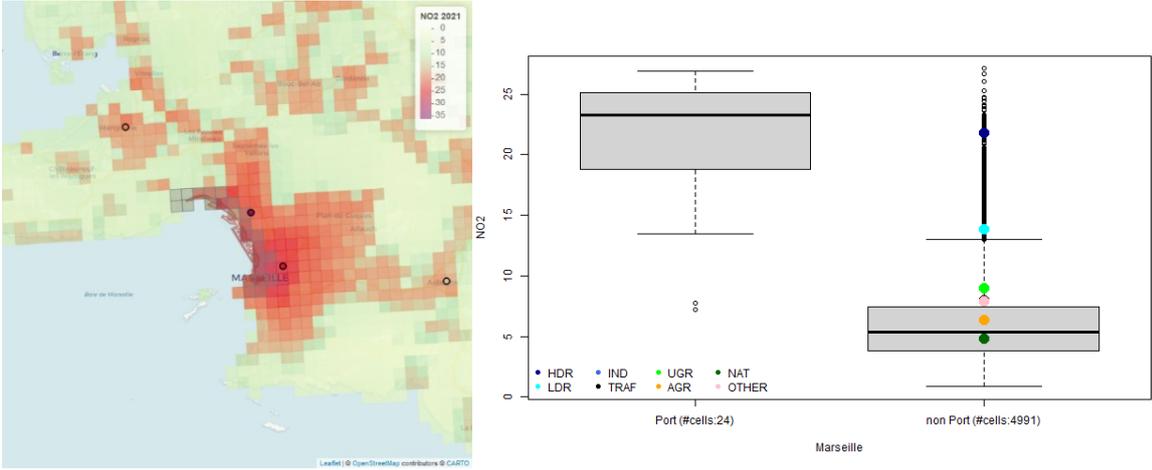
The EEA air quality maps give also the possibility to show a comparison between the mean concentrations in ports and area-weighted mean concentrations for different land covers (i.e. the sum of the concentrations multiplied by the area fraction covered by a specific land cover class, divided by the total area of that land cover). The land cover classes which are used as ancillary data to create the maps are listed in Table 4.2, and are also based on the CORINE CLC 2018 dataset used in this study to identify the port areas (CLC code 123). The port areas in the EEA air quality maps are included in a new class, traffic (TRAF), which includes the codes 122-124, road and rail networks and associated land, ports and airports. Two examples of more detailed comparisons are presented here for two ports where the largest differences in Figure 4.2 were identified, Marseille for NO₂ (Figure 4.3) and Piraeus for PM₁₀ (Figure 4.4). Maps of NO₂ and PM₁₀ concentrations and their distribution over port and non-port grid cells are available for each port in Annex 1.

Table 4.2 Land cover classes used as ancillary data in the EEA air quality maps

Label	General class description	CLC classes grid codes	CLC classes codes	CLC classes description
HDR	High density residential areas	1	111	Continuous urban fabric
LDR	Low density residential areas	2	112	Discontinuous urban fabric
IND	Industry	3, 7-9	121, 131-133	Industrial or commercial units, Mineral extraction sites, Dump sites, Construction sites
TRAF	Traffic	4-6	122-124	Road and rail networks and associated land, Ports , Airports
UGR	Urban green	10-11	141-142	Artificial, non-agricultural vegetated area
AGR	Agricultural areas	12-22	211-244	Agricultural areas
NAT	Natural areas	23-34	311-335	Forest and seminatural areas
OTH	Other areas	35-44	411-523	Wetlands, Water bodies

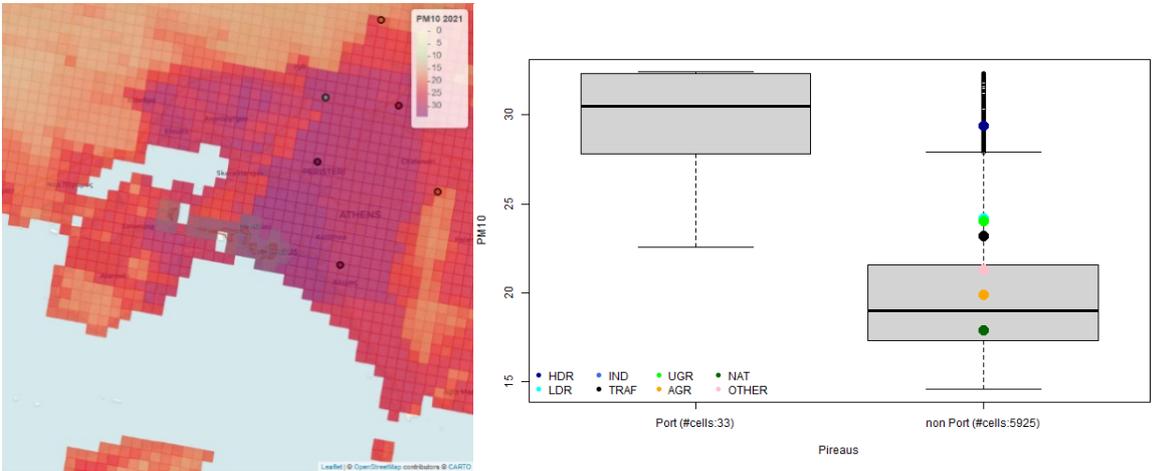
In Marseille, 24 grid cells of the EEA air quality maps are intersecting with the port area polygon (code 123 in CLC 2018) or within a distance of 1 km from it. The NO₂ mean concentration over the 24 port grid cells is 20.5 µg/m³ (median of 23.3 µg/m³), which is comparable only with the mean area-weighted concentration for high density residential areas (HDR), 21.8 µg/m³, while the area-weighted mean for all other land cover classes is ranging between 4.8 µg/m³ (natural areas, NAT) and 13.8 µg/m³ (low density residential areas, LDR).

Figure 4.3 EEA air quality map of NO₂ concentrations in Marseille and box-plot distribution of the concentrations over the port (grey shaded grid cells), compared to the surrounding region and area-weighted means for different land cover classes (Table 4.2)



In Piraeus, 33 grid cells of the EEA air quality maps are intersecting with the port area polygon or within a distance of 1 km from it. The PM₁₀ mean concentration over the 33 port grid cells is 29.7 µg/m³ (median of 30.5 µg/m³). Also in this case the mean PM₁₀ concentration in the port is comparable only with the mean area-weighted concentration for high density residential areas (HDR), 29.4 µg/m³, while the area-weighted mean for all other land cover classes is ranging between 17.9 µg/m³ (natural areas, NAT) and 24.2 µg/m³ (low density residential areas, LDR).

Figure 4.4 EEA air quality map of PM₁₀ concentrations in Piraeus and box-plot distribution of the concentrations over the port (grey shaded grid cells), compared to the surrounding region and area-weighted means for different land cover classes (Table 4.2)



5 Differences between air pollution trends in port areas and nearby cities

Long-term trends (2005-2021) of air pollutants at European and national level have been studied in Gbangou and Colette (2023, ETC HE Report 2023/8) by analysing the observations through linear statistics. These trends have been investigated to highlight the differences of the evolution of NO₂ and PM₁₀ concentrations in port areas and nearby cities.

The summary Table 5.1 and

Table 5.2 present the number of SPOs that are in the vicinity of the main ports, respectively for NO₂ and PM₁₀. SPOs showing trends over the period 2005-2021 are indicated along with the type of pollution influence, i.e. traffic (T), background (B) and industrial (I). The location of the SPOs is also specified, i.e. which SPOs are in the port and within a 1 km radius. The average distance of the SPOs from the port is also indicated.

Table 5.1 Number of NO₂ SPOs within 10 km from a port (#SPOs) and those for which long term measurements and the 2005-2021 trend are available (#w/trends). For the SPOs with trend, it is specified their type (background, B; transport, T; industrial, I), if located inside port (in port) or within 1 km, and the mean distance (in kilometres) from the port of all SPOs with trends.

Port	Country code	SPOs (#)	SPOs w/trends (#)	SPO type	SPO in port (#, type)	SPO within 1 km (#, type)	Mean distance from port in km
Amsterdam	NL	18	13	5T 7B 1I	1T	3T 1B 1I	1.6
Algeciras	ES	15	11	1T 10I	0	1I	3.3
Hamburg	DE	14	11	4T 3B 4I	0	1I	2.7
Barcelona	ES	14	10	3T 7B	0	1B	3.8
Antwerpen	BE	50	9	2B 7I	3I	4I	1.3
Genova	IT	10	5	4T 1B	1T	2T	2.2
Gdansk	PL	6	5	5B	0	1B	2.2
Rotterdam	NL	16	5	1T 3B 1I	0	2B 1I	2.8
Marseille	FR	5	4	2T 2B	0	0	1.9
Bremen	DE	6	4	1T 3B	0	0	3.5
Valencia	ES	11	3	2T 1B	0	1T	2.7
Napoli	IT	11	3	3T	0	1T	1.4
Stockholm	SE	19	3	2T 1B	0	0	3.7
Le Havre	FR	5	2	1B 1I	0	1B 1I	0.5
Palma de Mallorca	ES	4	2	1T 1B	0	1B	0.8
Bremerhaven	DE	2	2	1T 1B	0	1B	1.7
Piraeus	GR	14	2	1T 1I	0	0	7.2
Trieste	IT	8	0	0	0	0	
Santa Cruz de Tenerife	ES	12	0	0	0	0	

Port	Country code	SPOs (#)	SPOs w/trends (#)	SPO type	SPO in port (#, type)	SPO within 1 km (#, type)	Mean distance from port in km
Gioia Tauro	IT	0	0	0	0	0	
Malta Freeport	MT	2	0	0	0	0	
Messina	IT	2	0	0	0	0	
Reggio Calabria	IT	2	0	0	0	0	

Table 5.2 Number of PM₁₀ SPOs within 20 km from a port (#SPOs) and those for which long term measurements and the 2005-2021 trend are available (#w/trends). For the SPOs with trend, it is specified their type (background, B; transport, T; industrial, I), if located inside port (in port) or within 1 km, and the mean distance (in kilometres) from the port of all SPOs with trends

Port	Country code	SPOs (#)	SPOs w/trends (#)	SPO type	SPO in port (#, type)	SPO within 1 km (#, type)	Mean distance from port in km
Hamburg	DE	13	10	3T 4B 3I	0	1I	4.3
Rotterdam	NL	20	6	2T 4B	0	1B	10.2
Antwerpen	BE	29	6	2B 4I	1I	2I	1.9
Gdansk	PL	11	5	5B	0	1B	5.8
Marseille	FR	8	5	2B 3I	0	0	10.3
Stockholm	SE	19	5	4T 1B	0	0	5.4
Le Havre	FR	7	3	1B 2I	0	1B 1I	6.4
Palma de Mallorca	ES	5	3	1T 2B	0	2B	0.7
Bremen	DE	7	3	1T 2B	0	0	3.9
Genova	IT	17	2	2B	0	2B	0.3
Trieste	IT	13	2	2I	2I	2I	0
Bremerhaven	DE	2	2	1T 1B	0	1B	1.7
Amsterdam	NL	25	2	1T 1B	0	0	18.6
Valencia	ES	16	1	1B	0	0	2
Algeciras	ES	12	1	1I	0	0	3.9
Santa Cruz de Tenerife	ES	14	1	1B	0	0	19.7
Barcelona	ES	45	0	0	0	0	
Napoli	IT	17	0	0	0	0	
Piraeus	GR	15	0	0	0	0	

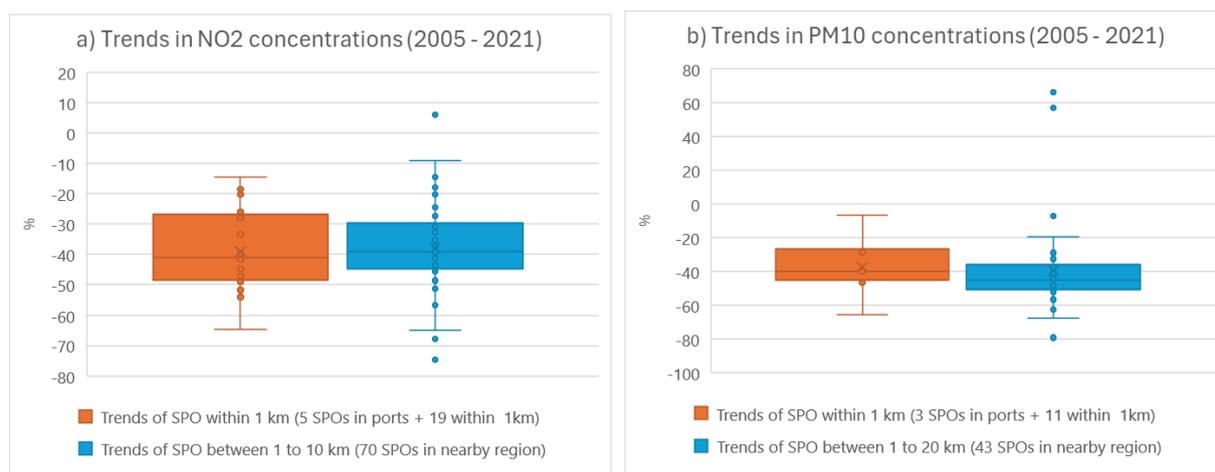
Port	Country code	SPOs (#)	SPOs w/trends (#)	SPO type	SPO in port (#, type)	SPO within 1 km (#, type)	Mean distance from port in km
Gioia Tauro	IT	1	0	0	0	0	
Malta Freeport	MT	6	0	0	0	0	
Messina	IT	4	0	0	0	0	
Reggio Calabria	IT	4	0	0	0	0	

On average the trends during the period 2005-2021 of NO₂ concentrations measured at SPOs located directly inside port areas or in the near vicinity of the port (within 1 km distance) are not significantly different from the trends observed in other SPOs between 1 km to 10 km from the port area in the nearby cities. Overall, the median trend for available SPOs in ports (5) or within 1 km distance (19) is a reduction of NO₂ concentrations of about 40%. This value is very similar to the median trend for all other SPOs located in nearby cities at distances between 1 to 10 km (70), which shows a decrease of about 39% (Figure 5.1a)

A slightly lower trend (-40%) was found in PM₁₀ concentrations for SPOs in ports (3) and within 1 km from the port (11), compared to the trend (-45%) for SPOs within 20 km from the ports (43) (Figure 5.1b).

On the other hand, it must be noted that it is difficult to derive a general conclusion for NO₂ and PM₁₀ trends for all ports. Only 3 ports have NO₂ SPOs inside the ports, and only 2 ports for PM₁₀. Even if it was available an overall larger number of ports with SPOs within 1 km from the port area, 13 ports for NO₂ and 11 ports for PM₁₀, it remains challenging to derive a clear conclusion on trends in ports compared to nearby cities and region based only on few SPOs.

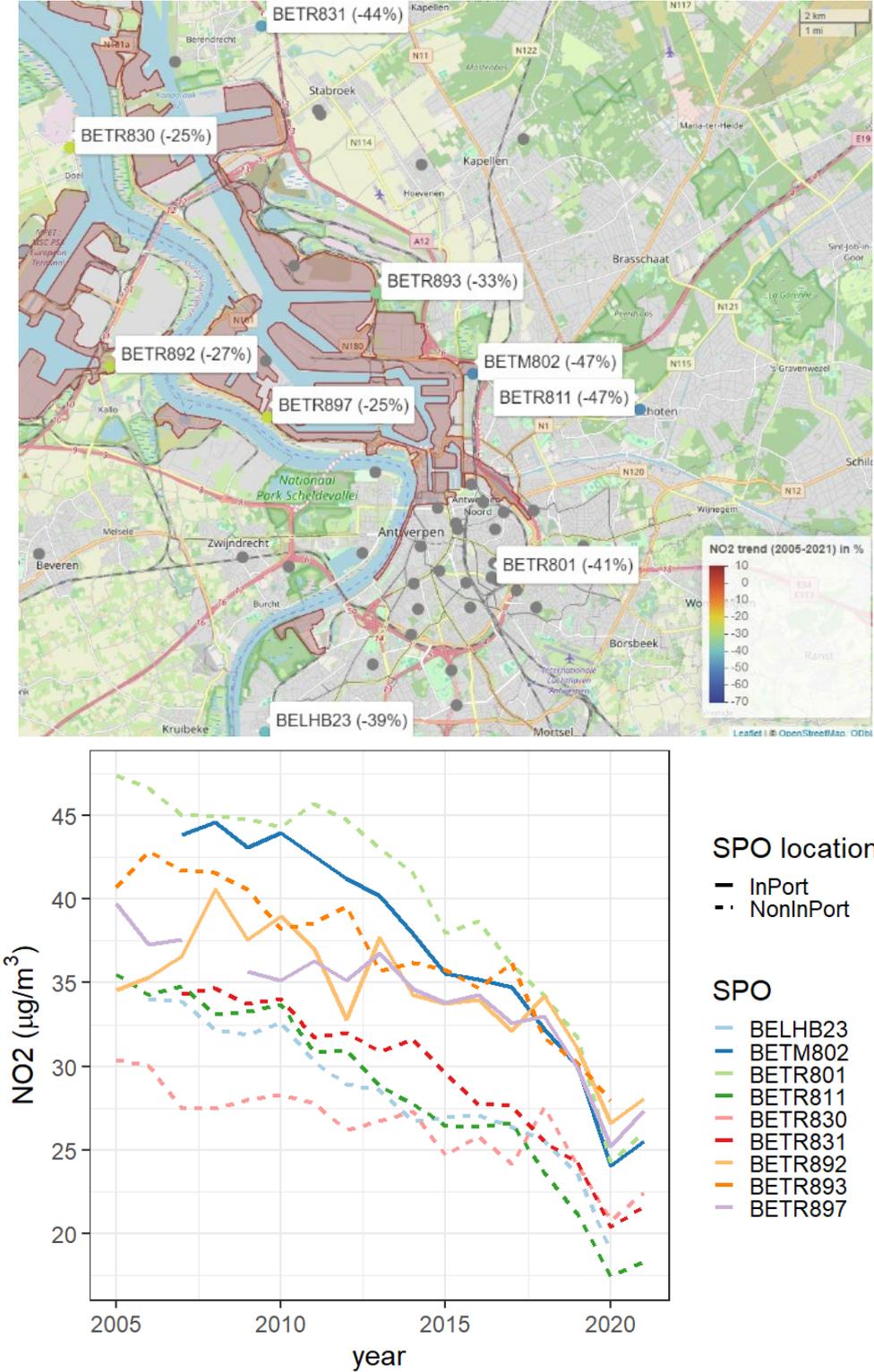
Figure 5.1 Distribution of trends in NO₂ (a) and PM₁₀ (b) concentrations at SPOs in ports or within 1 km distance compared to trends found at SPOs in the nearby city



Nevertheless, some differences were seen for the port in Antwerpen, where a larger number of SPOs with measured trends is available, both inside or near ports and in other parts of the city (6). In Antwerpen, three out of four SPOs located in port or near the port show a trend ranging between -25% to -33% in NO₂ concentrations. One SPO inside the port shows a larger reduction trend (-47%), which is comparable with trends observed in other parts of the city. This SPO inside the port area is also the closest to the high-density residential area and main roads. The same is observed for another

SPO in the north, close to the port areas but also to a main road. A gradient in NO₂ concentration trends is visible, with lower concentration reductions in the north-west (from -25% to -33%), where most of the port of Antwerpen is located, and largest NO₂ concentrations reductions in the east and south (from -39% to -47%), showing the impact of larger emission reductions from other source sectors, such as road traffic (Figure 5.2).

Figure 5.2 Trends in NO₂ concentrations at monitoring SPOs in the port and the city of Antwerpen



6 Impact of shipping emissions on the air quality of the nearby cities

Based on available observations, it is challenging to disentangle the impacts on air quality of the activities in the ports and international shipping from other sources in the nearby cities. The analysis presented in this report, shows that there are often insufficient SPOs for NO₂ and PM₁₀ and that their locations are not optimal for the purposes of monitoring the impact of port activities on air quality inside the ports and the nearby cities. As meteorology plays an important role on air quality, the SPOs must be located downwind (based on the prevailing wind direction) of the port in order to monitor the impacts in the surrounding region.

High resolution air quality modelling studies are a useful approach to disentangling the impact of port activities and international shipping from other emission sectors and their relative contribution to the air quality in nearby cities. The online ACT model (Colette et al., 2022), a surrogate model of the CHIMERE Chemistry-Transport Model (Menut et al., 2024), was used to analyse the impact of international shipping during pollution episodes in Antwerpen and Barcelona.

Note that the CHIMERE, from which the air quality simulations used for both the design of the numerical experiment and the every-day training of ACT, is not fitted to deal with local hotspot situations that can develop near a port and the associated activities and industrial sites. The model resolution is about 0.25° and is not sufficient to fully catch NO₂ concentrations at traffic and industrial sites, as it is not able to resolve the level detail needed (emissions, meteorology and chemistry) for these local scale occurrences. However, the model gives a good estimate of background concentrations levels. In addition, ACT allows us to estimate the impact of emission reductions related to shipping but not to emissions linked to other activities such as traffic and industrial activities in port.

Several pollution episodes in Antwerpen and Barcelona have been studied using the ACT estimates to better understand the origin of the high NO₂ and PM₁₀ concentrations and to assess the role of shipping emissions.

Antwerpen

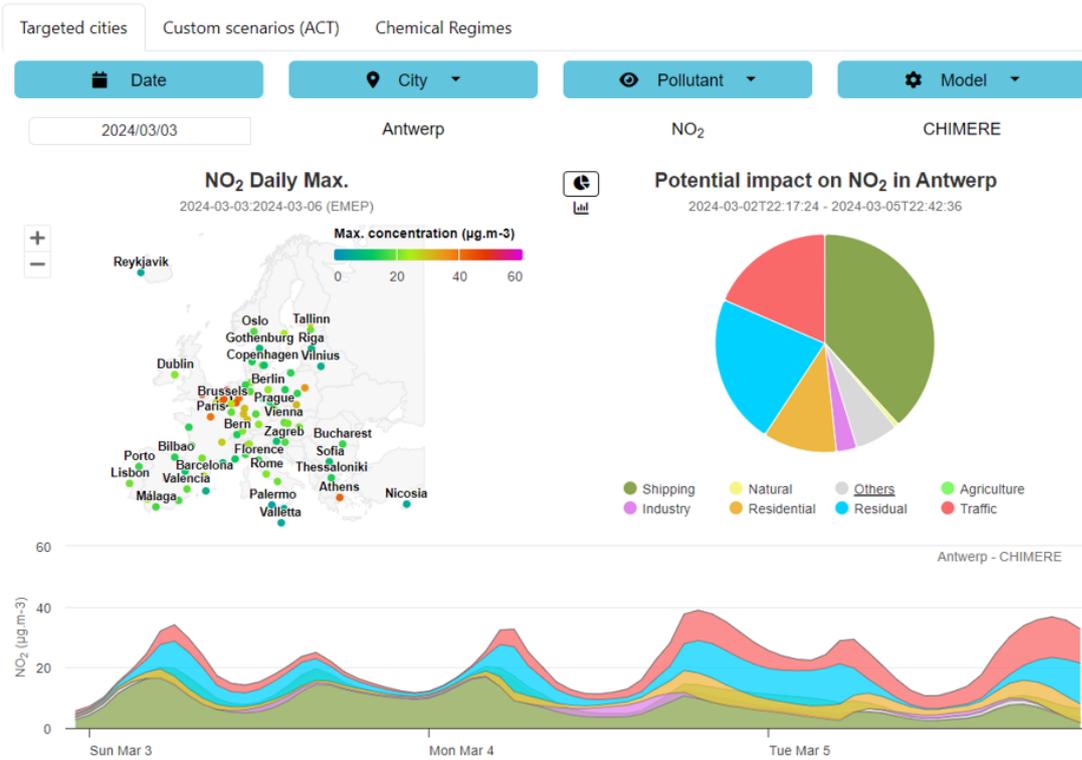
NO₂ episode, 3-7 March 2024

At the beginning of March 2024, a high pollution event in Antwerpen was simulated with NO₂ daily max concentrations of about 39 µg/m³ (Figure 6.1). High NO₂ concentrations persisted in and around Antwerpen for several days. During this episode, ACT estimated that international shipping was the main source sector contributing to the NO₂ concentrations (38%), more than residential (11%) and road traffic (19%) emissions.

ACT allows to test and directly estimate the impact on air quality of emission reduction scenarios. Therefore, to demonstrate and visualize the spatial impact of shipping-related emissions on this pollution episode, emissions from this sector have been reduced by 100% for instance on March 3, 2024, the day with the highest NO₂ concentration nearby Antwerpen (75 µg/m³, Figure 6.2).

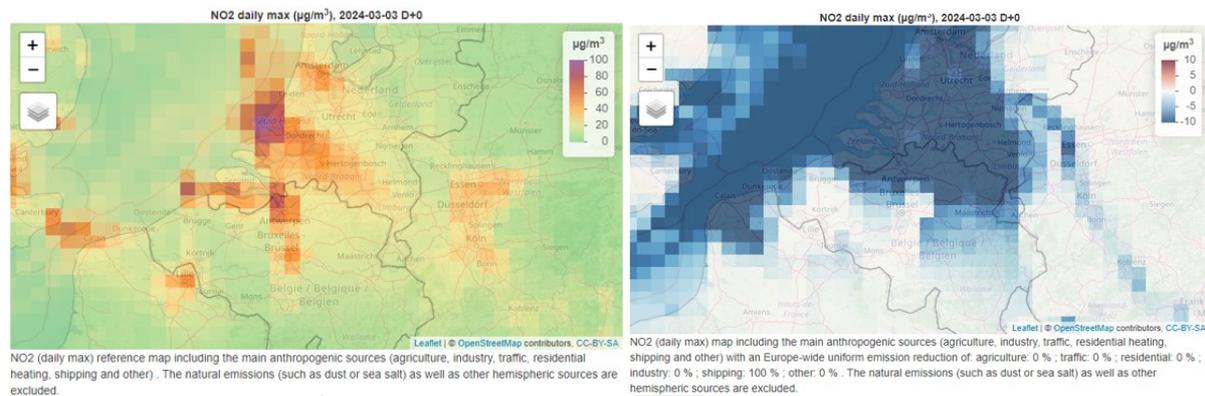
Reducing shipping emissions by 100% implies a significant decrease (up to 11 µg/m³) in NO₂ concentration in Antwerpen and in surroundings regions. This result is consistent with the sector allocation showing the shipping sector as the main contributor to NO₂ levels during this episode.

Figure 6.1 NO₂ pollution episode in Antwerpen, 3-7 March 2024



Source: [https://policy.atmosphere.copernicus.eu/daily_source_attribution/sector_apportionment.php?date=2024-03-03&pollutant=NO₂&city=Antwerp](https://policy.atmosphere.copernicus.eu/daily_source_attribution/sector_apportionment.php?date=2024-03-03&pollutant=NO2&city=Antwerp)

Figure 6.2 Impact of shipping emissions on NO₂ concentrations during a pollution episode in Antwerpen, 3 March 2024

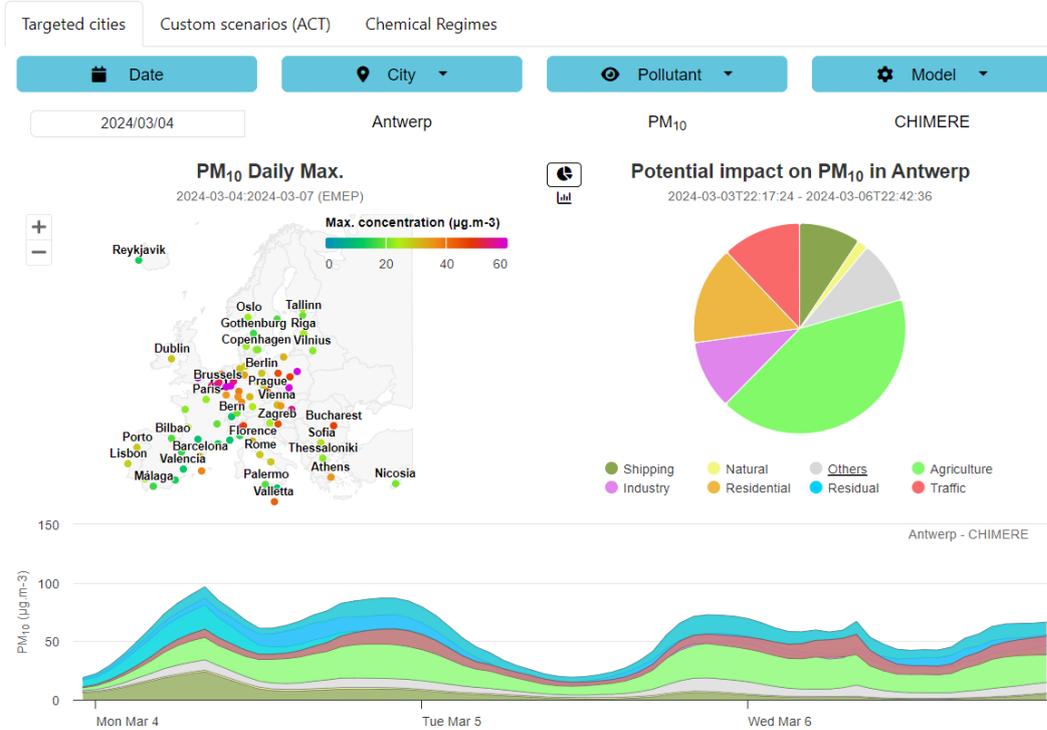


Source: https://policy.atmosphere.copernicus.eu/daily_source_attribution/sector_apportionment.php?date=2024-03-03&tab=nav-act-tab

PM₁₀ episode, 4-8 March 2024

In the same days, high daily PM₁₀ concentrations levels were simulated in the Antwerpen area (60 µg/m³). The potential impact on PM₁₀ concentrations from international shipping was 6%, which is less than the agricultural sector (43%), the residential (11%) and road traffic (10%) emissions but still significant (Figure 6.3).

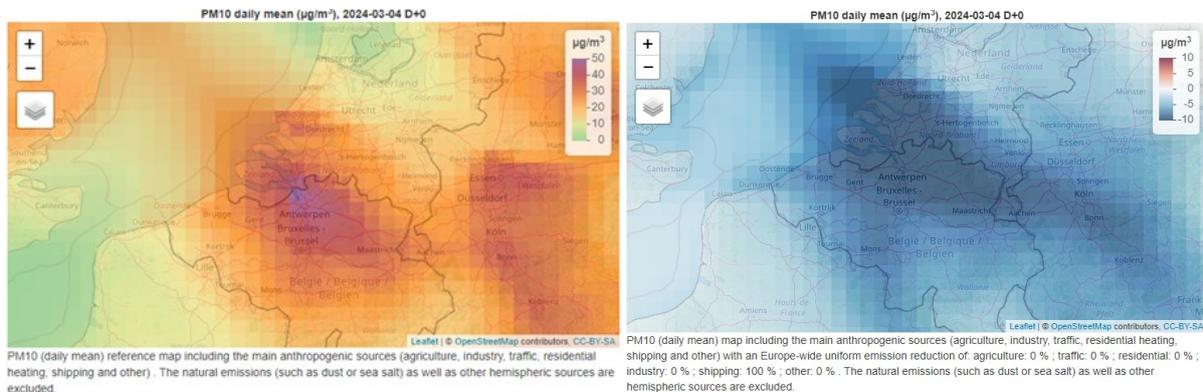
Figure 6.3 PM₁₀ pollution episode in Antwerpen, 3-7 March 2024



Source: [https://policy.atmosphere.copernicus.eu/daily_source_attribution/sector_apportionment.php?date=2024-03-04&pollutant=PM₁₀&city=Antwerp](https://policy.atmosphere.copernicus.eu/daily_source_attribution/sector_apportionment.php?date=2024-03-04&pollutant=PM10&city=Antwerp)

Reducing shipping related emissions by 100% on March 4, 2024, the day for which the highest PM₁₀ concentration is estimated (48 µg/m³) implies important decrease of the PM₁₀ levels (up to 15 µg/m³) from the North Sea to far inland, especially around Antwerpen (Figure 6.4).

Figure 6.4 Impact of shipping emissions on PM₁₀ concentrations during a pollution episode in Antwerpen, 4 March 2024



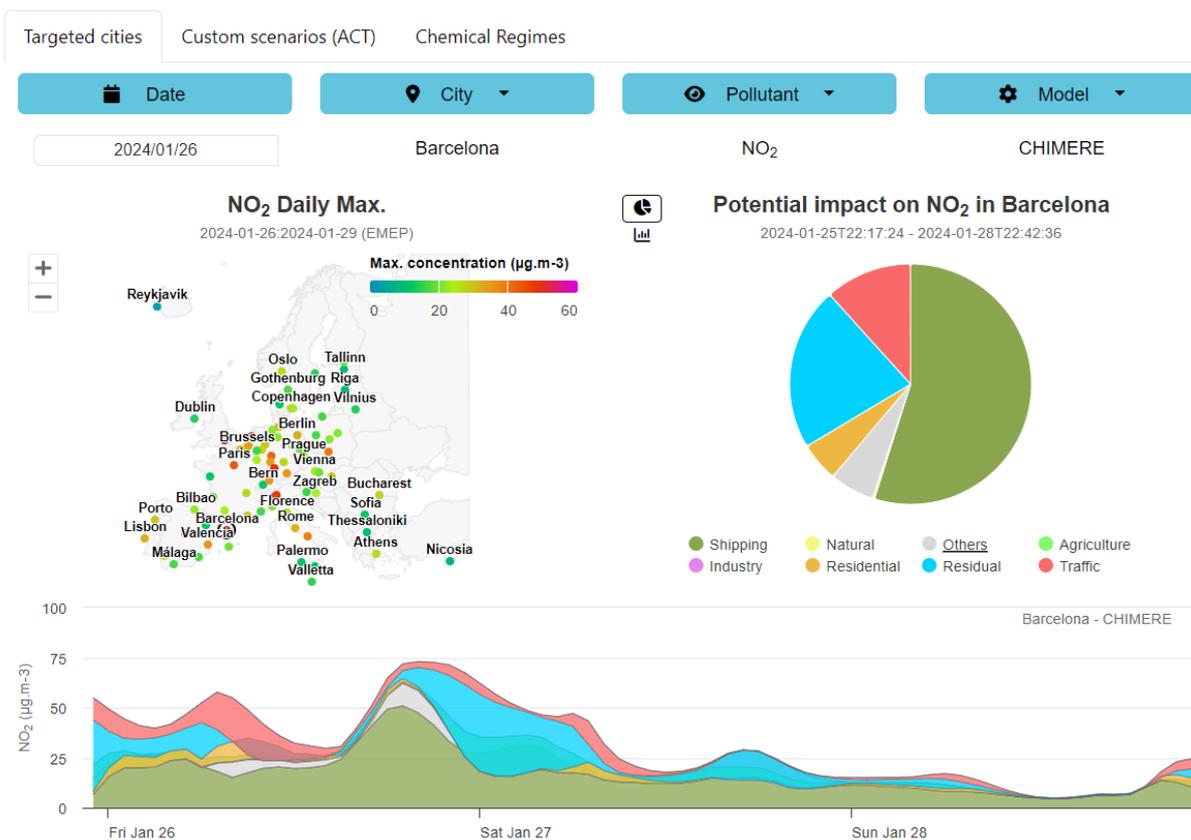
Source: https://policy.atmosphere.copernicus.eu/daily_source_attribution/sector_apportionment.php?date=2024-03-04&tab=nav-act-tab

Barcelona

NO₂ episode, 23-28 January 2024

Even larger contributions were found for another pollution episode at the end of January 2024 in Barcelona, with NO₂ daily concentrations reaching 73 µg/m³ (Figure 6.5). During this episode international shipping contributed, on average, to more than 55% of the NO₂ concentrations, ahead of road traffic (12%) and residential (5%) emissions.

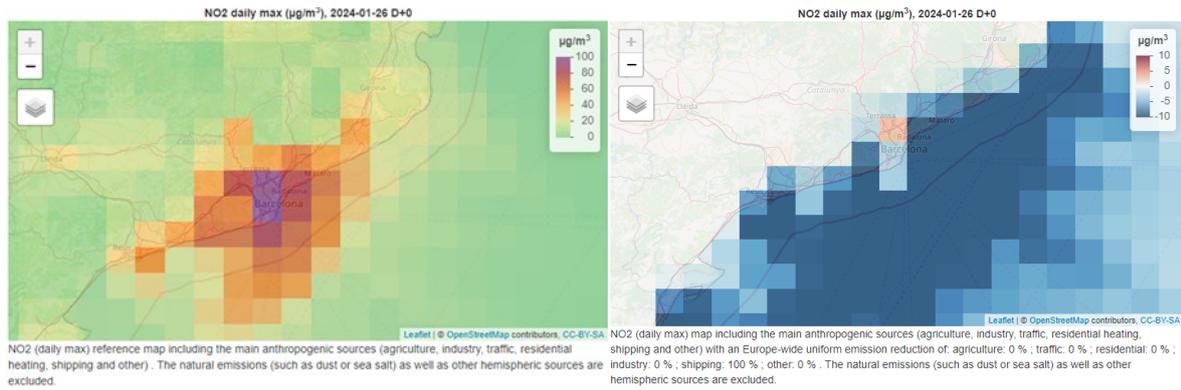
Figure 6.5 NO₂ pollution episode in Barcelona, 23-28 January 2024



Source: [https://policy.atmosphere.copernicus.eu/daily_source_attribution/sector_apportionment.php?date=2024-01-26&pollutant=NO₂&city=Barcelona](https://policy.atmosphere.copernicus.eu/daily_source_attribution/sector_apportionment.php?date=2024-01-26&pollutant=NO2&city=Barcelona)

The highest daily NO₂ concentration estimated by the model nearby Barcelona was 103 µg/m³ on January 26, 2024. Reducing the shipping related emissions by 100% on this day implies a decrease of NO₂ levels (up to 5 µg/m³) in most neighbouring areas (Figure 6.6).

Figure 6.6 Impact of shipping emissions on NO₂ concentrations during a pollution episode in Barcelona, 26 January 2024

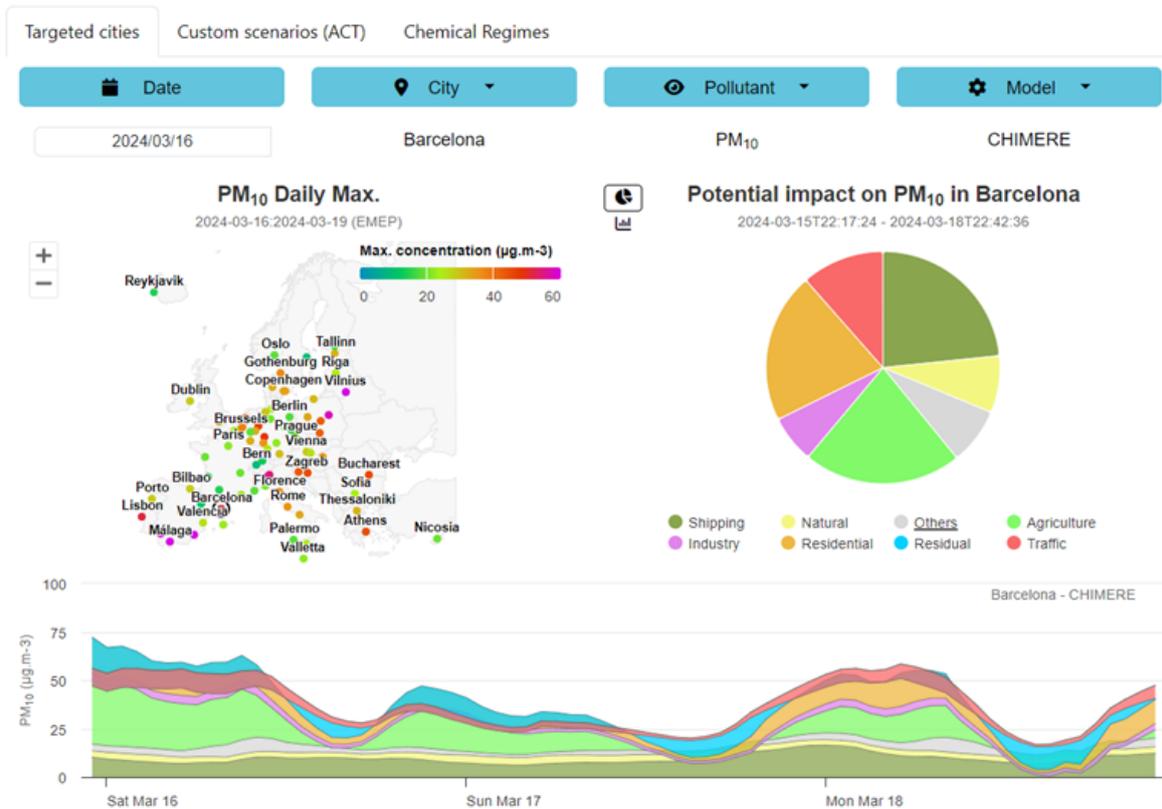


Source: https://policy.atmosphere.copernicus.eu/daily_source_attribution/sector_apportionment.php?date=2024-01-26&tab=nav-act-tab

PM₁₀ episode, 15-20 March 2024

During another episode in Barcelona in March 2024, concentration levels up to daily 57 µg/m³ of PM₁₀ have been observed. The potential impact on PM₁₀ concentrations of international shipping emissions was significant (23%) even though residential (21%) and agriculture (22%) emissions were prevailing (Figure 6.7).

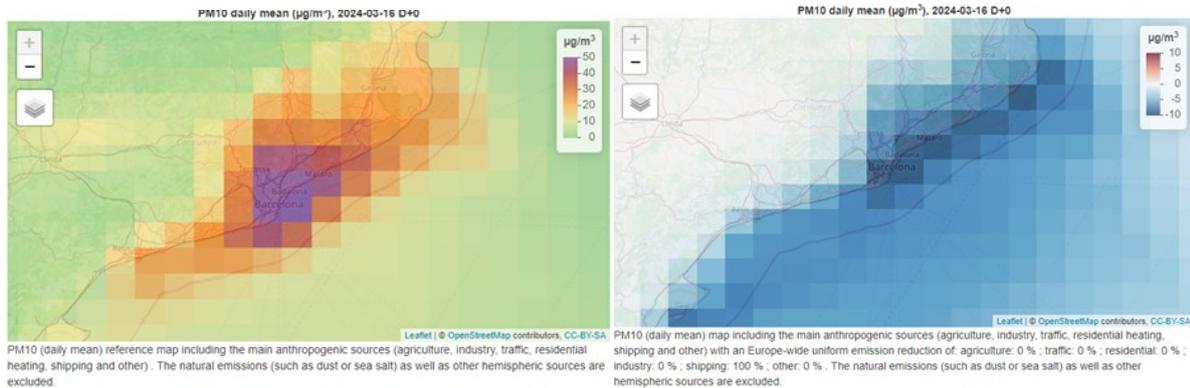
Figure 6.7 PM₁₀ pollution episode in Barcelona, 15-20 March 2024



Source: https://policy.atmosphere.copernicus.eu/daily_source_attribution/sector_apportionment.php?date=2024-03-16&pollutant=PM10&city=Barcelona

Reducing the shipping emissions by 100% on March 16, 2024, when the highest PM₁₀ daily concentration levels were calculated (up to 64 µg/m³) allows to decrease by up to 15 µg/m³ the PM₁₀ concentrations in the vicinity of Barcelona (Figure 6.8).

Figure 6.8 Impact of shipping emissions on PM₁₀ concentrations during a pollution episode in Antwerpen, March 16, 2024



Source: https://policy.atmosphere.copernicus.eu/daily_source_attribution/sector_apportionment.php?date=2024-03-16&tab=nav-act-tab

7 Conclusions

Concentrations of NO₂ and PM₁₀ in Europe have declined over the last decades due to reduced emissions in many sectors, such as road traffic. The relative contribution of shipping to air pollution in Europe is increasing. Monitoring air quality in ports and the nearby cities will become more important in the next decades to understand the role of emissions from international shipping, but also from all port activities (road traffic, non-road machinery, bulk unloading and industrial installations). In this report 4 questions were addressed, and the following conclusions were derived:

1. How is the air quality monitored inside or in the vicinity of ports?

The availability of SPOs in and around port areas is limited. Given the increasing share of shipping and other port-related emissions, there is a need for increased knowledge of air quality in these areas. Among the 23 ports analysed, only 5 ports had at least one air quality SPO for NO₂ and PM₁₀ located inside the port area. Almost all analysed ports had at least one SPO in the vicinity (within 1 km distance) of the port area. On the other hand, only a few of the identified SPOs are located downwind of the prevalent wind direction of the port areas.

2. How are the ambient air concentrations of NO₂ and PM₁₀ in and around ports compared to the nearby cities and regions?

As meteorology plays an important role in air quality, the SPOs must be located downwind (based on the prevailing wind direction) of the port to monitor the impacts on air quality in the surrounding region. An analysis was completed using meteorological data to assess the change in pollutant concentrations during downwind conditions (i.e. wind coming from the port) and compared to all other observations. A significant increase in NO₂ median concentrations was found at several SPOs around ports in different cities, for example in Napoli (above 100% increase), Algeciras (86%), Hamburg (77%), Antwerpen (75%), Le Havre (73%), Marseille (52%), Amsterdam (51%), Santa Cruz de Tenerife (50%), Rotterdam (46%), Messina (46%), Piraeus (45%). The same analysis showed smaller increases in median PM₁₀ concentrations at some of the SPOs around ports (74% in Trieste, 36% in Bremerhaven, 32% in Hamburg, 31% in Trieste, 26% in Rotterdam, and 26% in Antwerpen). On the other hand, these differences were not consistent for all wind sectors around the port and may be influenced also by other pollution sources in the cities.

Due to the low numbers of SPOs in ports and surrounding areas, it is difficult to assess the differences between air pollutant concentrations in ports and the nearby cities and regions, based only on monitoring data. Therefore, EEA air quality maps for 2021 were used to estimate the distribution and differences of air pollutants in ports and the surrounding regions. Annual mean NO₂ concentrations in port areas in 2021 were higher than the mean concentrations in the surrounding regions, ranging between 1.5 µg/m³ (Malta Freeport) to more than 10 µg/m³ (Algeciras, Barcelona, Genova, Marseille, Napoli, Piraeus, and Trieste). In Antwerpen, Marseille and Napoli the annual mean NO₂ concentrations in ports were above the LV of 20 µg/m³ for the protection of human health to be attained by 1 January 2030 of the revised Ambient Air Quality Directive. Also, annual mean PM₁₀ concentrations in 2021 were higher in port areas compared to the surrounding regions. The difference was below 5 µg/m³ for almost all the ports analysed, except for Napoli and Piraeus. In nine ports (Algeciras, Barcelona, Gdansk, Gioia Tauro, Malta Freeport, Messina, Napoli, Piraeus and Reggio Calabria) the annual mean PM₁₀ concentrations were above the new LV of 20 µg/m³ for the protection of human health to be attained by 1 January 2030.

3. What are the trends in pollutant concentrations in ports and nearby cities?

Long-term trends (2005-2021) of NO₂ and PM₁₀ air pollutants were analysed at the identified SPOs in European port areas and nearby cities. The findings show that on average NO₂ concentrations in port areas and within 1 km decreased by about 40%, similar to the 39% reduction in nearby cities. PM₁₀ concentrations decreased by 40% in port areas and 45% within 20 km of ports. However, due to the limited number of SPOs identified in this report, it is challenging to draw definitive conclusions about trends in all ports.

In the port of Antwerpen, a gradient in NO₂ concentration trends is visible, with lower concentration reductions in the north-west (from -25% to -33%), where the port of Antwerpen is located, and largest NO₂ concentrations reductions in the city (from -39% to -47%), probably showing the impact of larger emission reductions from other source sectors, such as road traffic.

4. What is the potential impact of port activities and international shipping on air quality?

Only high-resolution air quality modelling studies specific for each port could provide an estimate of the impact of port activities and international shipping on air quality in the nearby city. In this study the online Air Control Toolbox (ACT) was used, which is one of the air quality policy tools developed for the Copernicus Atmosphere Monitoring Services (CAMS). The ACT was used to analyse the impact of international shipping during pollution episodes in Antwerpen and Barcelona. In Antwerpen, international shipping was the main source sector contributing to the NO₂ concentrations (38%) during a pollution episode in March 2024. In the same days, the contribution to PM₁₀ concentrations from international shipping was 6%, which is less than the agricultural sector (43%) the residential (11%) and road traffic (9%) emissions but still significant. Even larger contributions were found in another pollution episode at the end of January 2024 in Barcelona. During this episode international shipping contributed, on average, more than 55% to the NO₂ concentrations. On the other hand, PM₁₀ concentrations were high on March 15-20, 2024, the potential impact on PM₁₀ concentrations of international shipping emissions was significant (23%) even though residential (21%) and agriculture (22%) emissions were prevailing in this episode. These case studies show that international shipping emissions may be the main contributors to NO₂ in port cities. This is more nuanced for PM₁₀ whose formation is associated with complex chemical processes, and which can be heavily impacted by emissions from the agricultural and residential sectors depending on the city location and other factors (e.g. residential heating).

List of abbreviations

Abbreviation	Name	Reference
AAQD	Ambient Air Quality Directives	https://environment.ec.europa.eu/topics/air/air-quality_en
ACT	Air Control Toolbox	https://policy.atmosphere.copernicus.eu/act.php
AGR	Agricultural areas	
CAMS	Copernicus Atmosphere Monitoring Service	https://atmosphere.copernicus.eu/
CLC	CORINE Land Cover	https://land.copernicus.eu/pan-european/corineland-cover
CLMS	Copernicus Land Monitoring Service	https://land.copernicus.eu/en
CORINE	Co-ORdinated INformation on the Environment	https://land.copernicus.eu/pan-european/corineland-cover
DG ENV	The Directorate-General for Environment	https://commission.europa.eu/about/departments-and-executive-agencies/environment_en
EC	European Commission	https://commission.europa.eu/index_en
ECMWF	European Centre for Medium-Range Weather Forecasts	https://www.ecmwf.int/
EEA	European Environment Agency	www.eea.europa.eu
EMSA	European Maritime Safety Agency	https://emsa.europa.eu/
ETC HE	European Topic Centre on Human health and environment	https://www.eionet.europa.eu/etcs/etc-he
EU27	European Union 27 member states	
HDR	High density residential areas	
IND	Industry	
LDR	High density residential areas	
LRTAP	Convention on Long-Range Transboundary Air Pollution	https://unece.org/environmental-policy-1/air
LV	Limit value	
NAT	Natural areas	
NO ₂	Nitrogen dioxide	
NO _x	Nitrogen oxides	
OTH	Other areas	
PM _{2.5}	Particulate Matter with a diameter of 2.5 micrometres or less	
PM ₁₀	Particulate Matter with a diameter of 10 micrometres or less	
SPO	Sampling point observation	
TRAF	Traffic	
UGR	Urban green	

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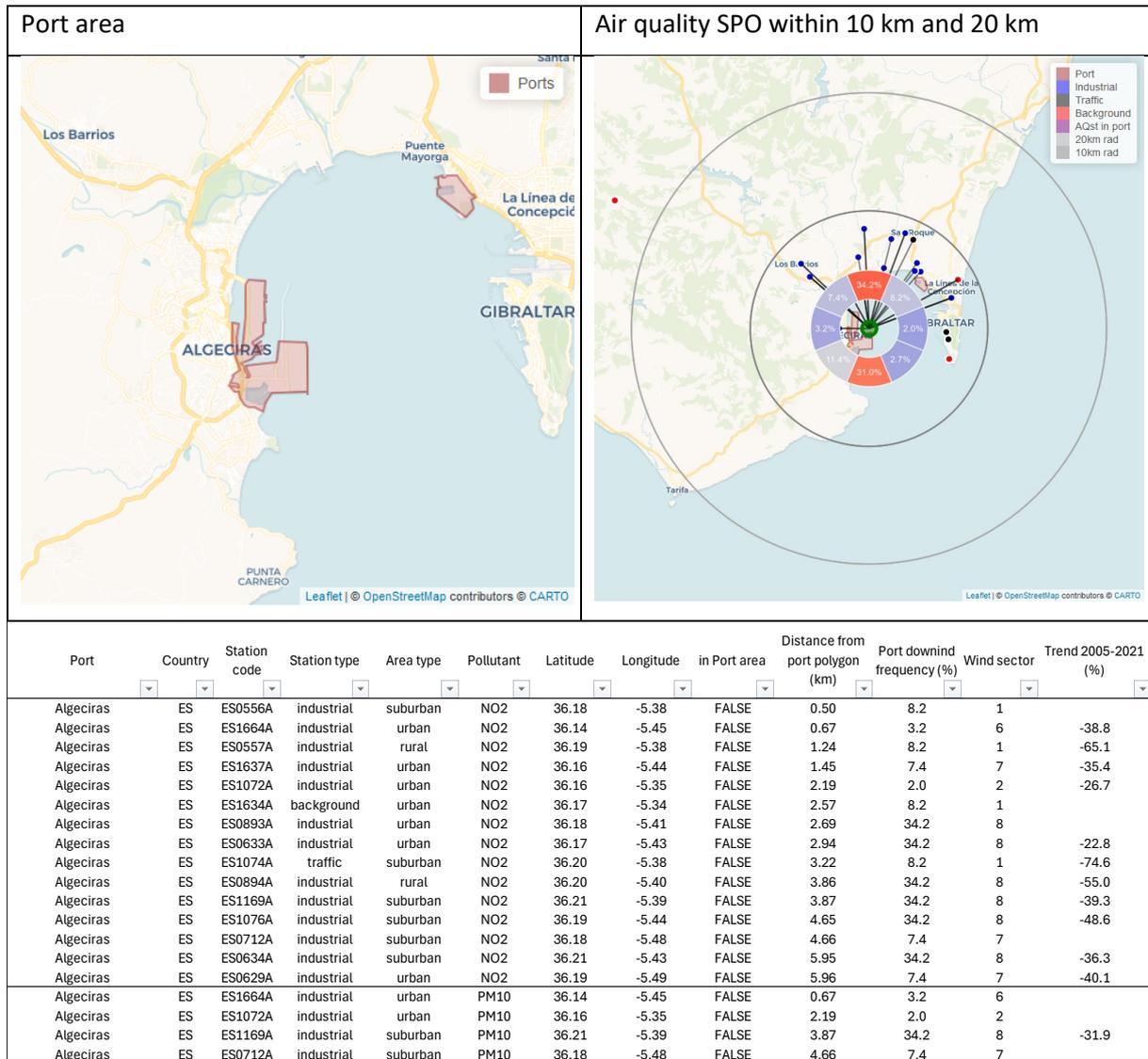
Pozzoli, L., et al., 2025, *Air quality around airports* (Eionet Report – ETC HE 2025/7). European Topic Centre on Human Health and the Environment (<https://doi.org/10.5281/zenodo.17432053>)

Annex 1 Maps and tables for each port

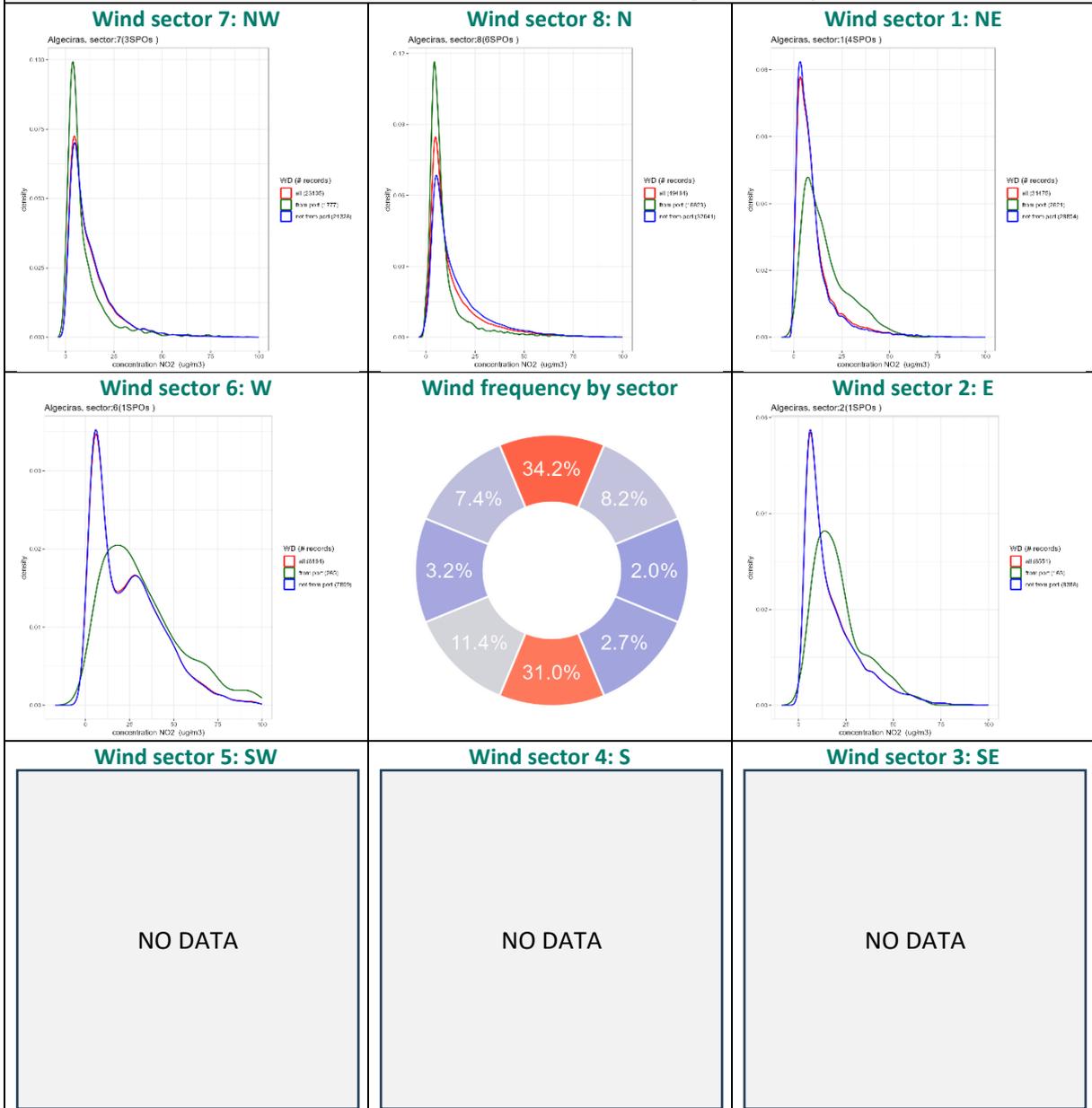
This Annex contains the full analysis with all plots for each port with the following structure:

- Map of the port area (CL20218, code 123 polygon) and map with location of identified air quality SPOs within 10 km for NO₂ and 20 km for PM₁₀ from the port polygon centroid. The frequency of wind directions blowing from the port centroid towards 8 different sectors (45 degrees wide sectors centred at directions NE, E, SE, S, SW, W, NW, N) is also displayed.
- Table with identified air quality SPOs and their description, including distance from the port polygon, in which wind sector they are located relative to port centroid and wind frequency in that sector, observed long-term trend (2005-2021) if available.
- Distribution of hourly NO₂ concentrations for monitoring SPOs located in the 8 wind sectors relative to the port. Three distributions are displayed for each direction if data are available: hourly concentration corresponding to wind from all directions (red); hourly concentration corresponding to wind blowing from the port (green); hourly concentration corresponding to wind not blowing from the port (blue). In the centre of the figure the wind frequency in each sector is reported.
- Distribution of hourly PM₁₀ concentrations for monitoring SPOs located in the 8 wind sectors relative to the port. In the centre of the figure the wind frequency in each sector is reported. Three distributions are displayed for each direction if data are available: hourly concentration corresponding to wind from all directions (red); hourly concentration corresponding to wind blowing from the port (green); hourly concentration corresponding to wind not blowing from the port (blue). In the centre of the figure the wind frequency in each sector is reported.
- EEA air quality maps of NO₂ and PM₁₀ concentrations at the resolution of 1 km by 1km for 2021.
- Box-plot distribution of NO₂ and PM₁₀ concentrations over the port (grey shaded grid cells), compared to the surrounding region, including area-weighted means for different land cover classes.

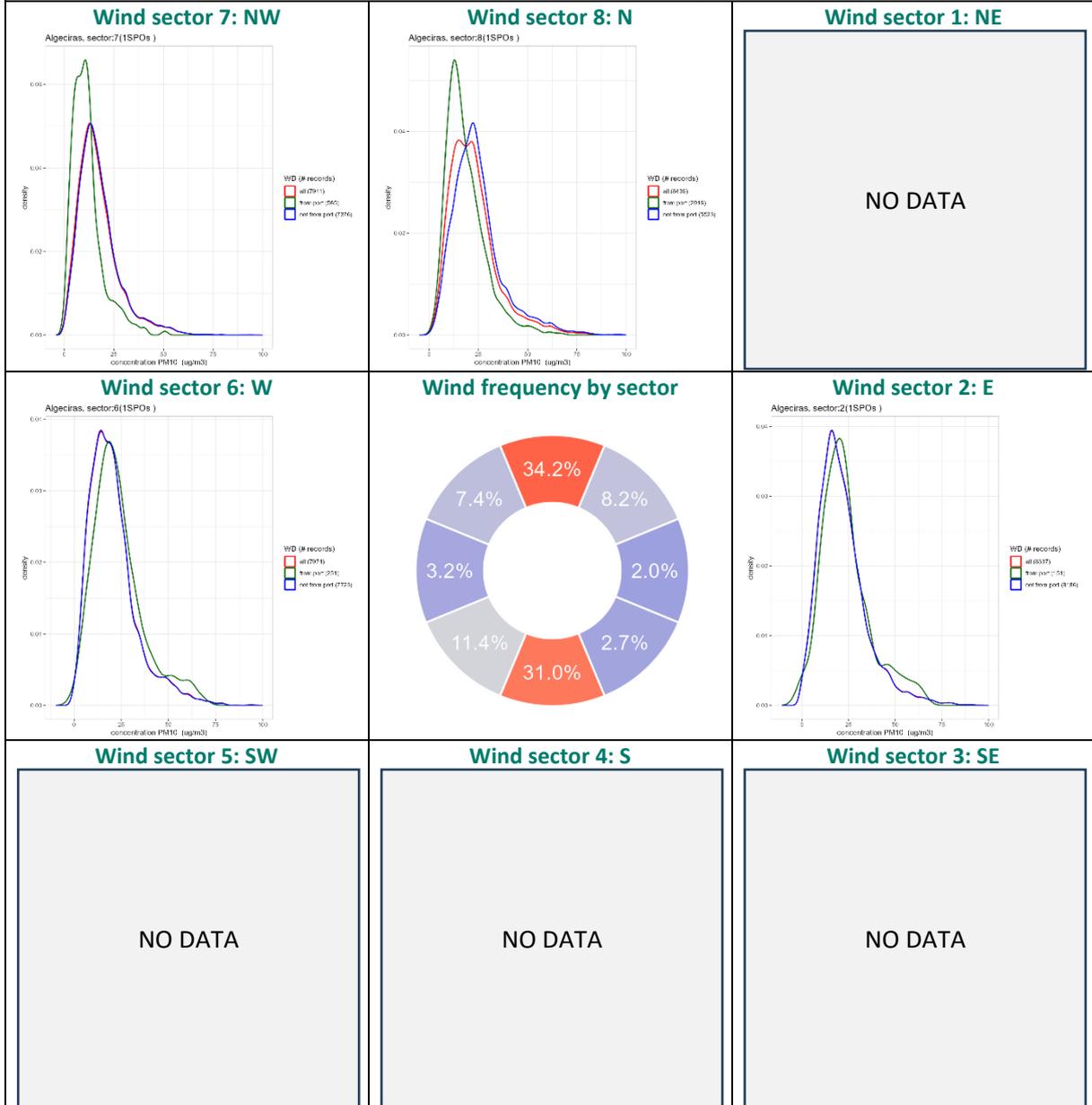
Annex 1.1 Algeciras



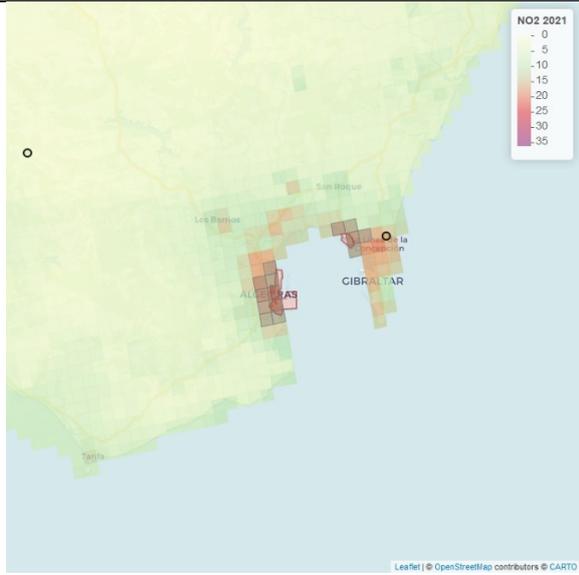
NO₂ concentrations when wind is blowing from the port



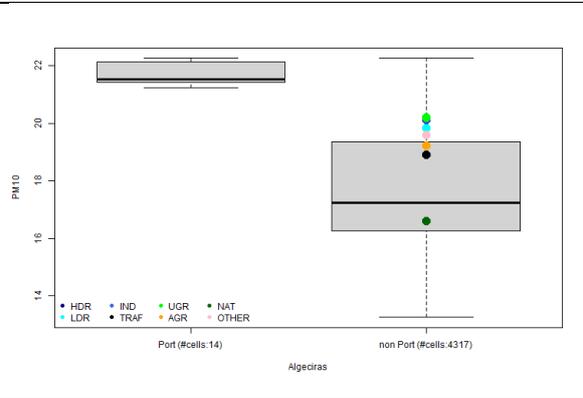
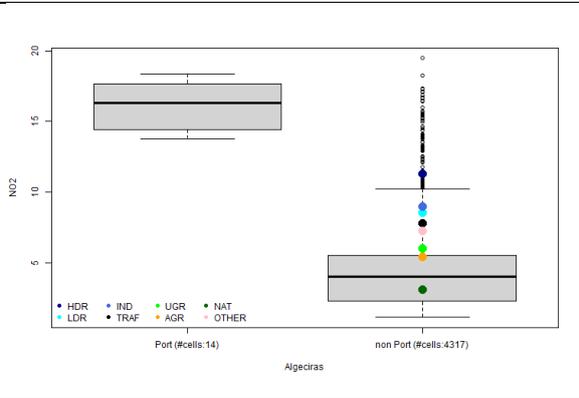
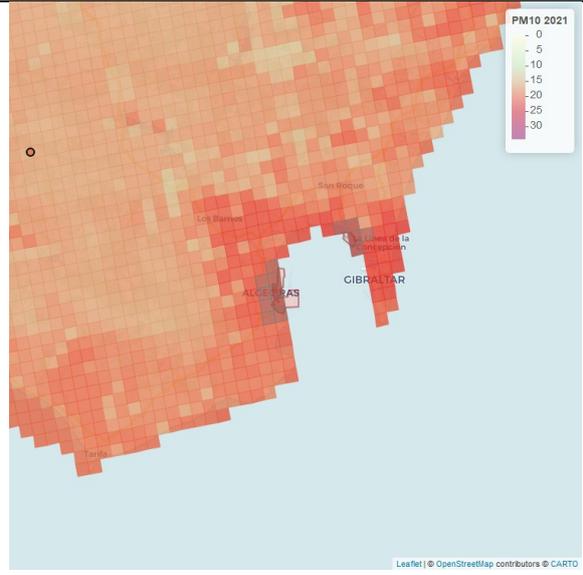
PM₁₀ concentrations when wind is blowing from the port



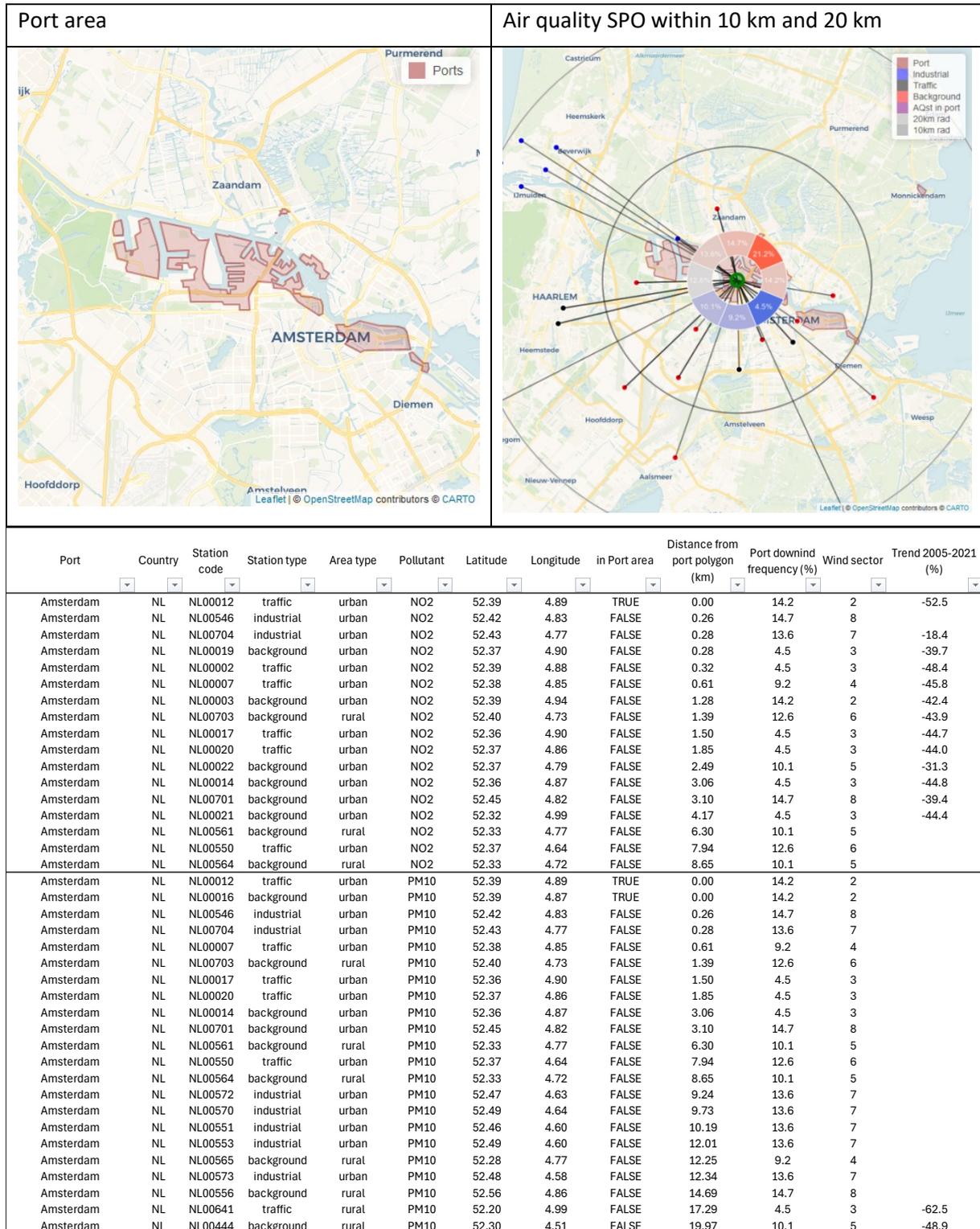
NO₂



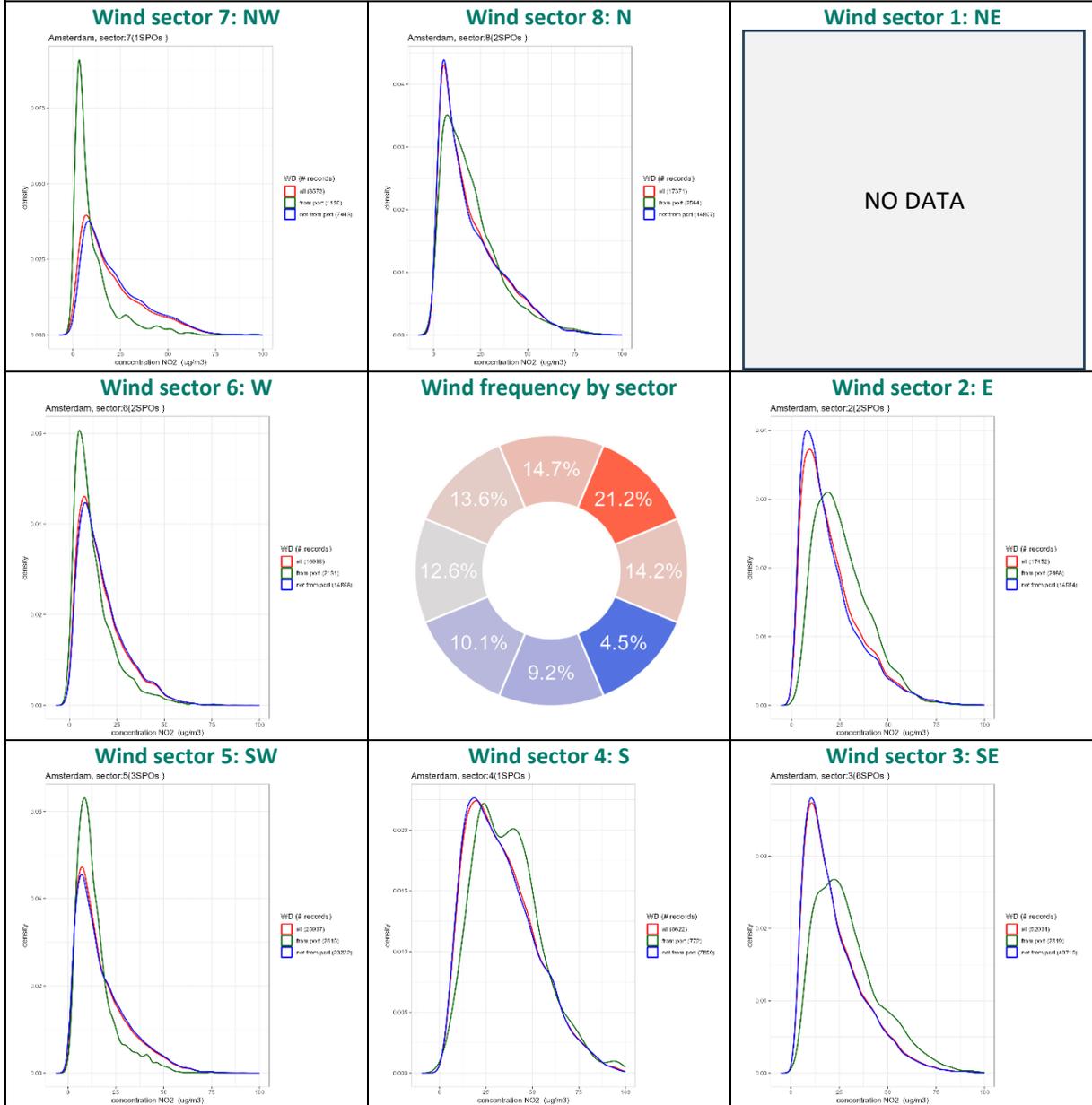
PM₁₀



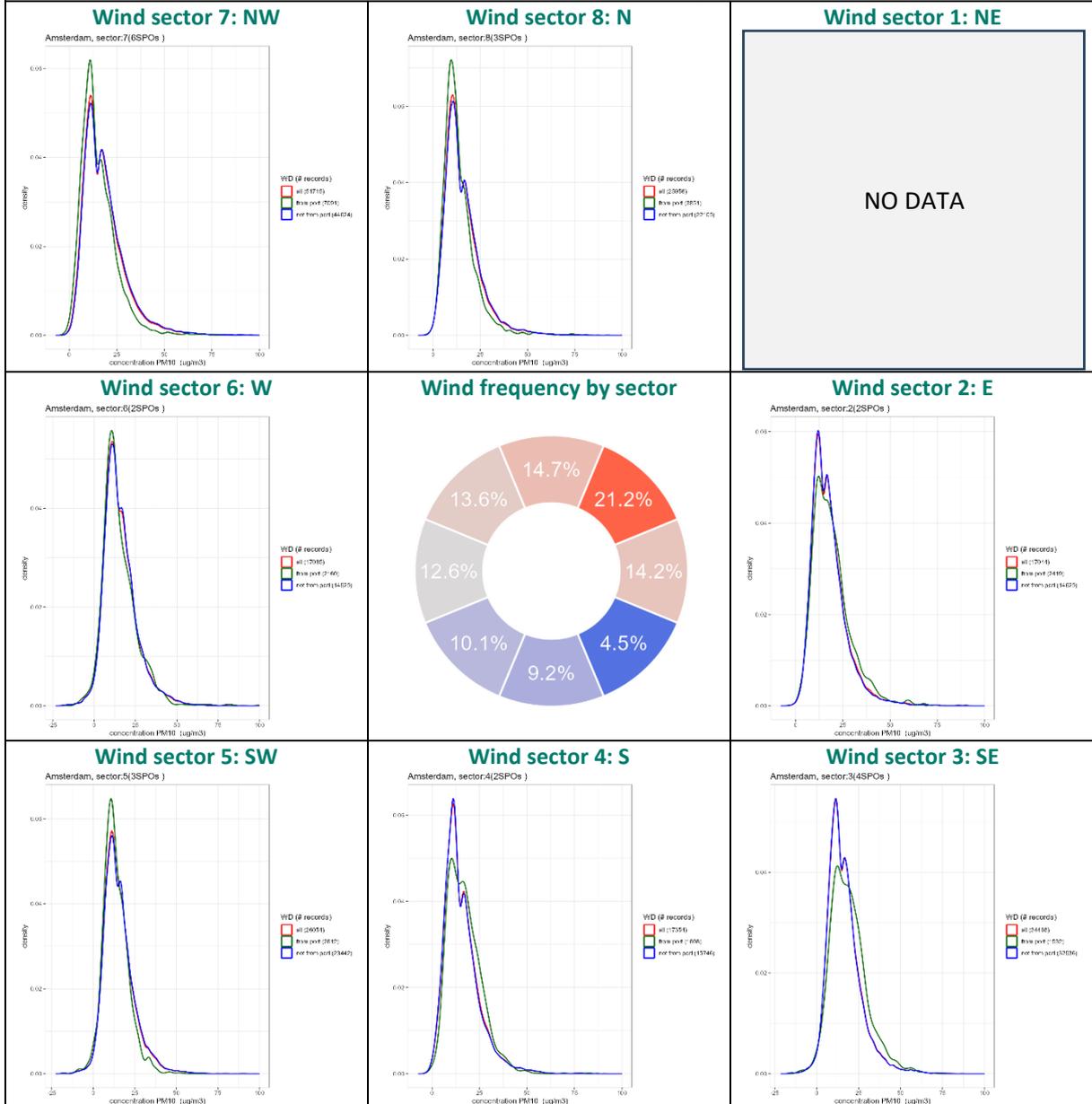
Annex 1.2 Amsterdam



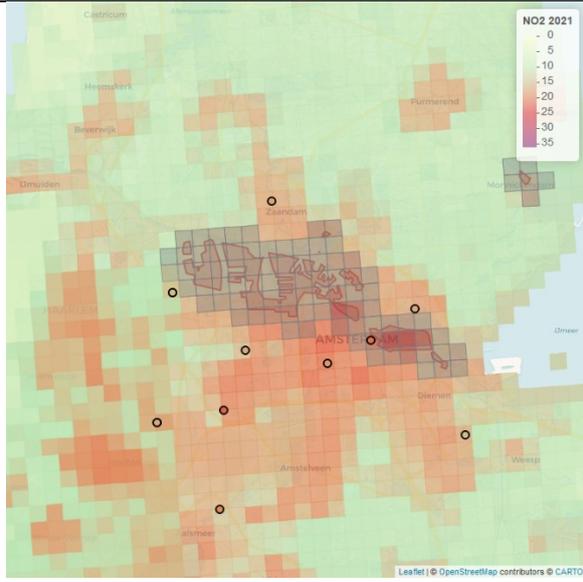
NO₂ concentrations when wind is blowing from the port



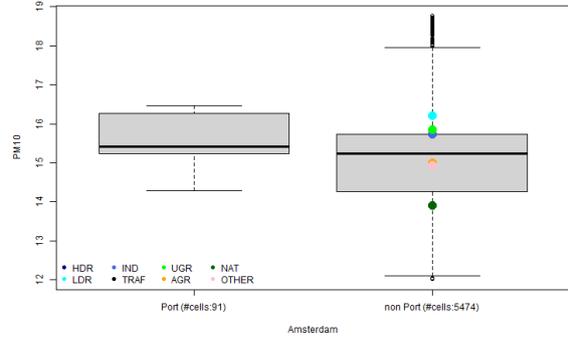
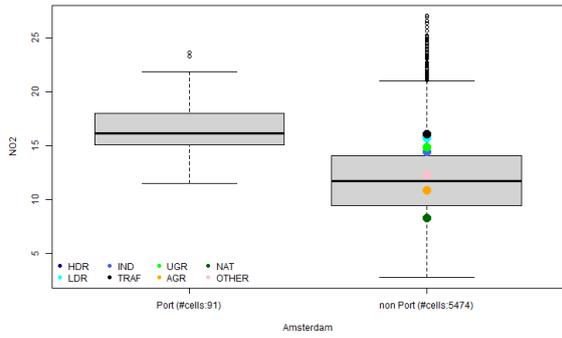
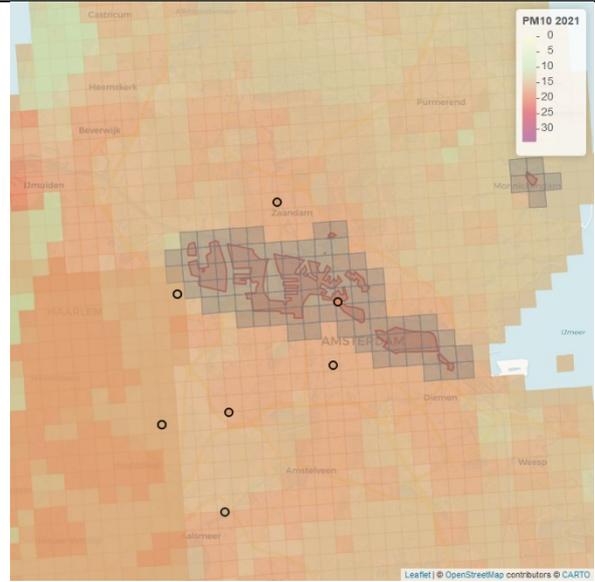
PM₁₀ concentrations when wind is blowing from the port



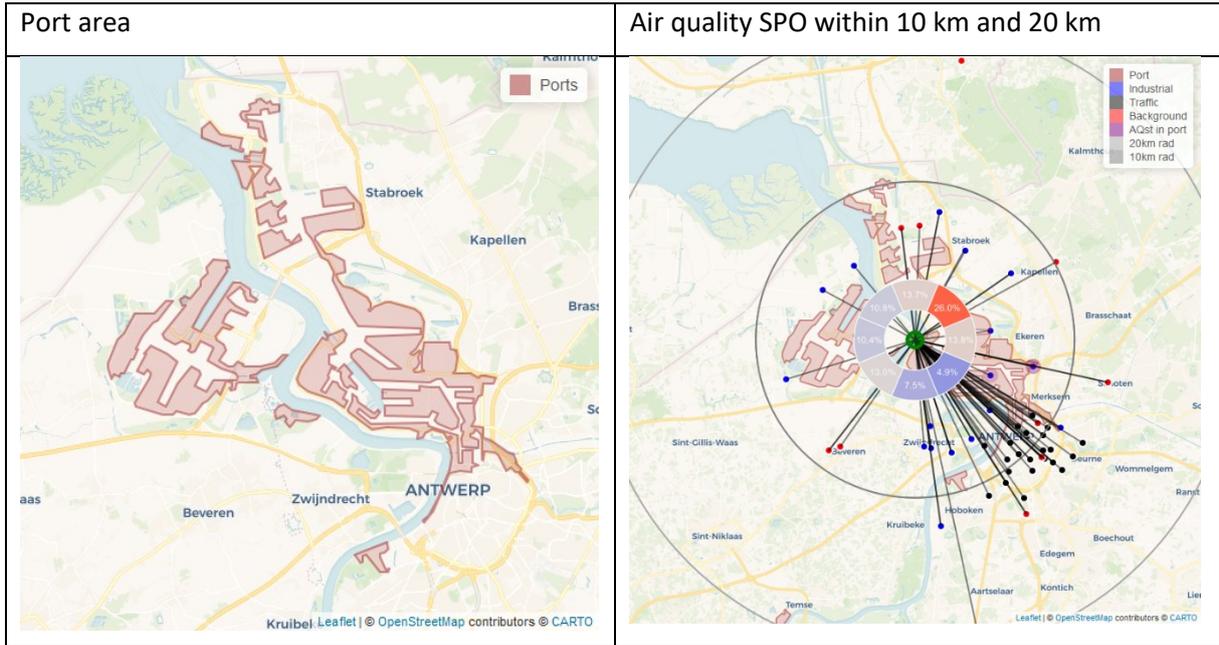
NO₂



PM₁₀



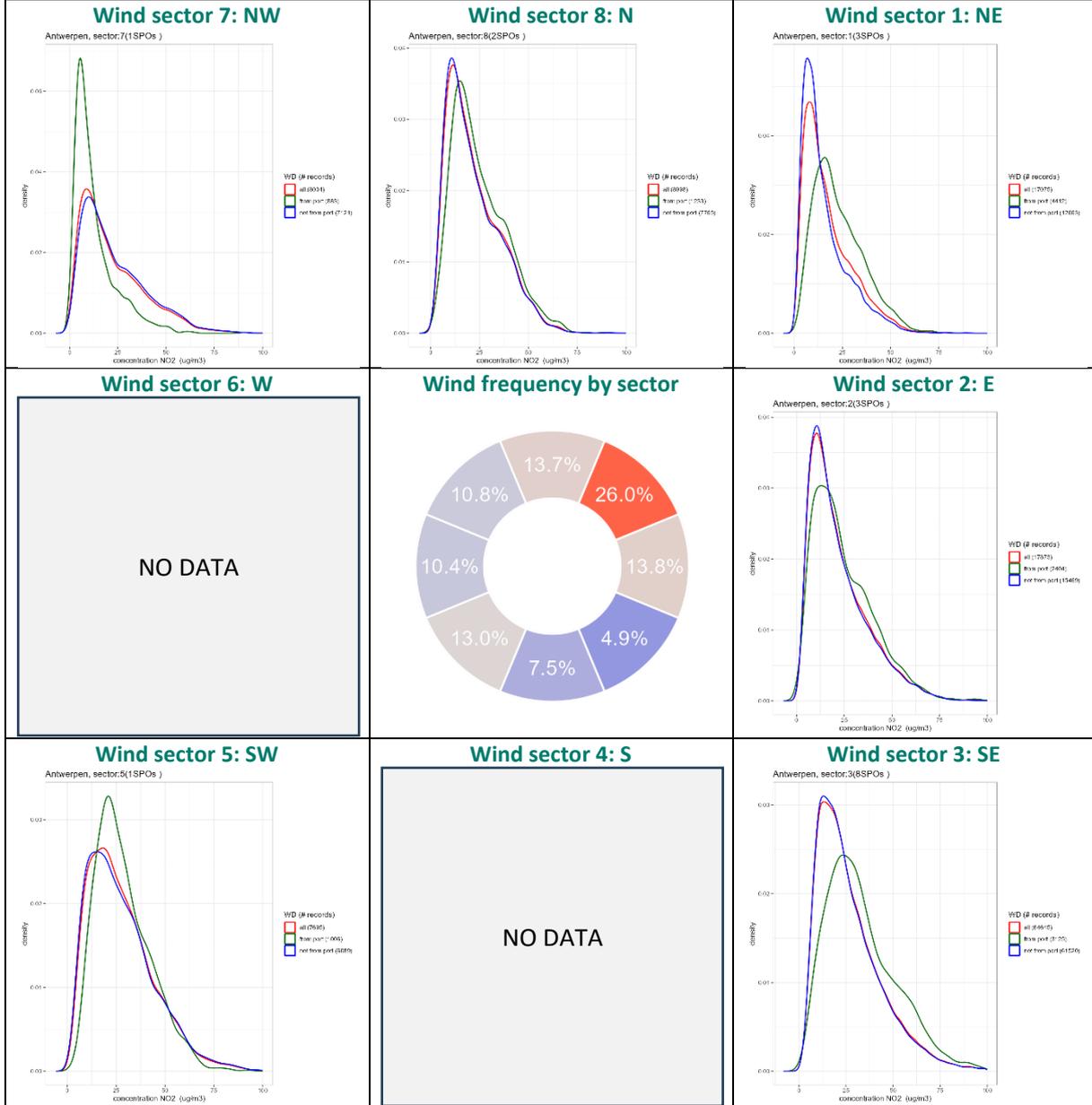
Annex 1.3 Antwerpen



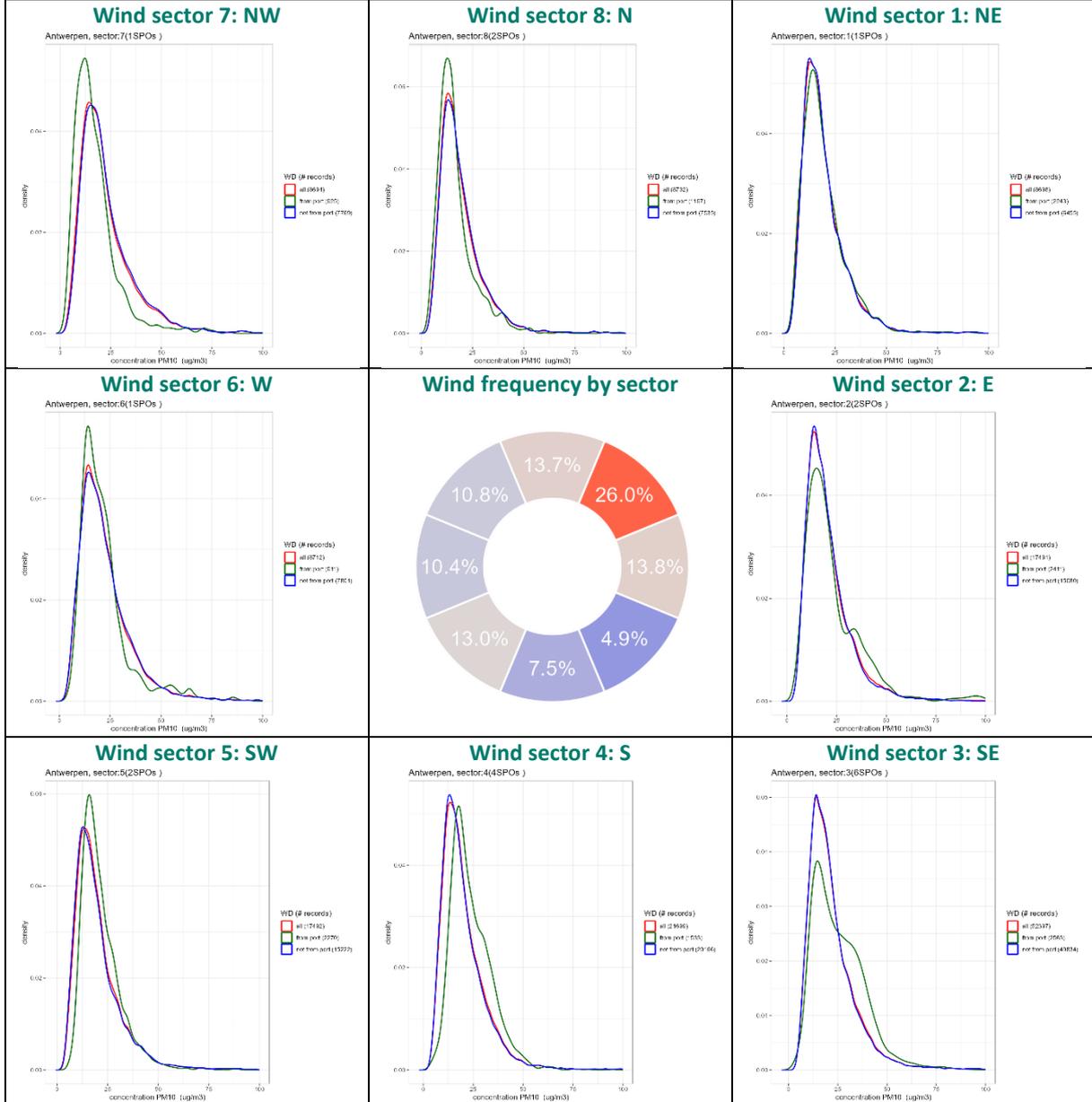
Port	Country	Station code	Station type	Area type	Pollutant	Latitude	Longitude	in Port area	Distance from port polygon (km)	Port downwind frequency (%)	Wind sector	Trend 2005-2021 (%)
Antwerpen	BE	BETM802	industrial	suburban	NO2	51.26	4.42	TRUE	0.00	13.8	2	-47.0
Antwerpen	BE	BETR897	industrial	suburban	NO2	51.25	4.34	TRUE	0.00	4.9	3	-25.3
Antwerpen	BE	BETR892	industrial	rural	NO2	51.26	4.28	TRUE	0.00	13.0	5	-26.6
Antwerpen	BE	BETR893	industrial	suburban	NO2	51.28	4.39	FALSE	0.03	13.8	2	-33.2
Antwerpen	BE	BENAT38	traffic	urban	NO2	51.23	4.41	FALSE	0.11	4.9	3	
Antwerpen	BE	BENAT43	traffic	urban	NO2	51.23	4.42	FALSE	0.17	4.9	3	
Antwerpen	BE	BENAT46	traffic	urban	NO2	51.23	4.44	FALSE	0.30	4.9	3	
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Antwerpen	BE	BENAT49	traffic	urban	NO2	51.19	4.38	FALSE	1.39	4.9	3	
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Antwerpen	BE	BENBT03	traffic	urban	NO2	51.21	4.43	FALSE	1.54	4.9	3	
Antwerpen	BE	BETR831	industrial	rural	NO2	51.35	4.34	FALSE	1.58	13.7	8	-43.7
Antwerpen	BE	BENDU05	traffic	urban	NO2	51.22	4.47	FALSE	1.65	4.9	3	
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Antwerpen	BE	BETR802	traffic	urban	NO2	51.21	4.43	FALSE	1.92	4.9	3	
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Antwerpen	BE	BETR817	background	suburban	NO2	51.18	4.42	FALSE	4.00	4.9	3	
Antwerpen	BE	BETR811	background	suburban	NO2	51.25	4.49	FALSE	4.14	13.8	2	-47.4
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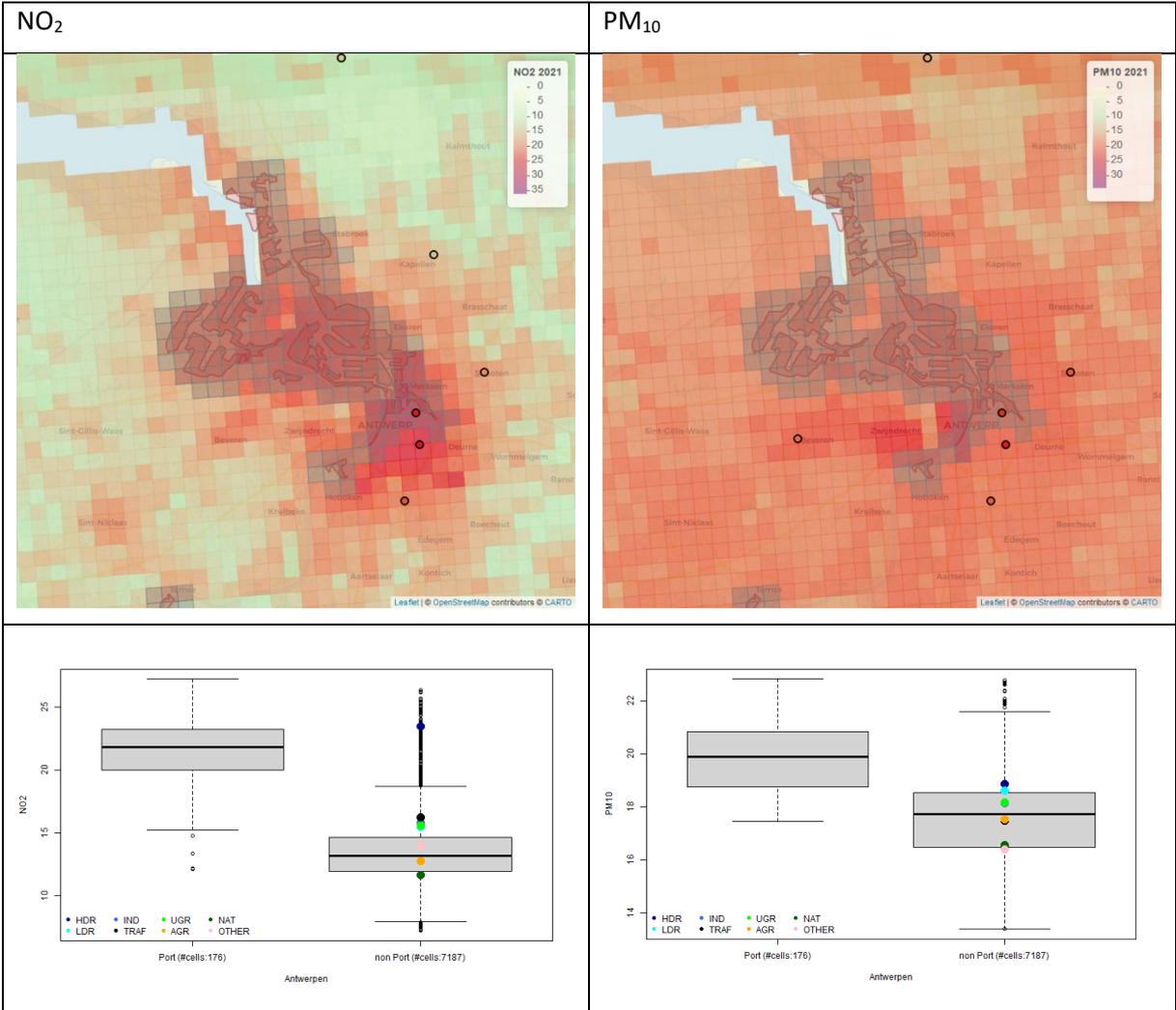
Port	Country	Station code	Station type	Area type	Pollutant	Latitude	Longitude	in Port area	Distance from port polygon (km)	Port downwind frequency (%)	Wind sector	Trend 2005-2021 (%)
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Antwerpen	BE	BELAL05	industrial	rural	PM10	51.26	4.28	TRUE	0.00	13.0	5	
Antwerpen	BE	BETR803	background	urban	PM10	51.23	4.43	FALSE	0.30	4.9	3	
Antwerpen	BE	BELAL01	industrial	suburban	PM10	51.24	4.39	FALSE	0.50	4.9	3	-26.6
Antwerpen	BE	BELAT83	background	urban	PM10	51.34	4.30	FALSE	0.56	13.7	8	
Antwerpen	BE	BELAL03	industrial	rural	PM10	51.25	4.20	FALSE	0.89	10.4	6	
Antwerpen	BE	BELAL02	industrial	rural	PM10	51.30	4.23	FALSE	1.37	10.8	7	
Antwerpen	BE	BETR831	industrial	rural	PM10	51.35	4.34	FALSE	1.58	13.7	8	
Antwerpen	BE	BETR801	background	urban	PM10	51.21	4.43	FALSE	1.91	4.9	3	-32.5
Antwerpen	BE	BETR802	traffic	urban	PM10	51.21	4.43	FALSE	1.92	4.9	3	
Antwerpen	BE	BETR805	traffic	urban	PM10	51.21	4.42	FALSE	2.14	4.9	3	
Antwerpen	BE	BETZD08	industrial	suburban	PM10	51.23	4.33	FALSE	2.38	7.5	4	
Antwerpen	BE	BETZD01	industrial	suburban	PM10	51.22	4.33	FALSE	2.46	7.5	4	
Antwerpen	BE	BELHB23	industrial	suburban	PM10	51.17	4.34	FALSE	2.57	7.5	4	-45.2
Antwerpen	BE	BELSA04	industrial	rural	PM10	51.31	4.40	FALSE	3.22	26.0	1	
Antwerpen	BE	BETR817	background	suburban	PM10	51.18	4.42	FALSE	4.00	4.9	3	
Antwerpen	BE	BETR823	background	suburban	PM10	51.21	4.24	FALSE	4.01	13.0	5	
Antwerpen	BE	BETR811	background	suburban	PM10	51.25	4.49	FALSE	4.14	13.8	2	-36.4
Antwerpen	BE	BETR834	background	suburban	PM10	51.09	4.38	FALSE	10.96	7.5	4	

NO₂ concentrations when wind is blowing from the port

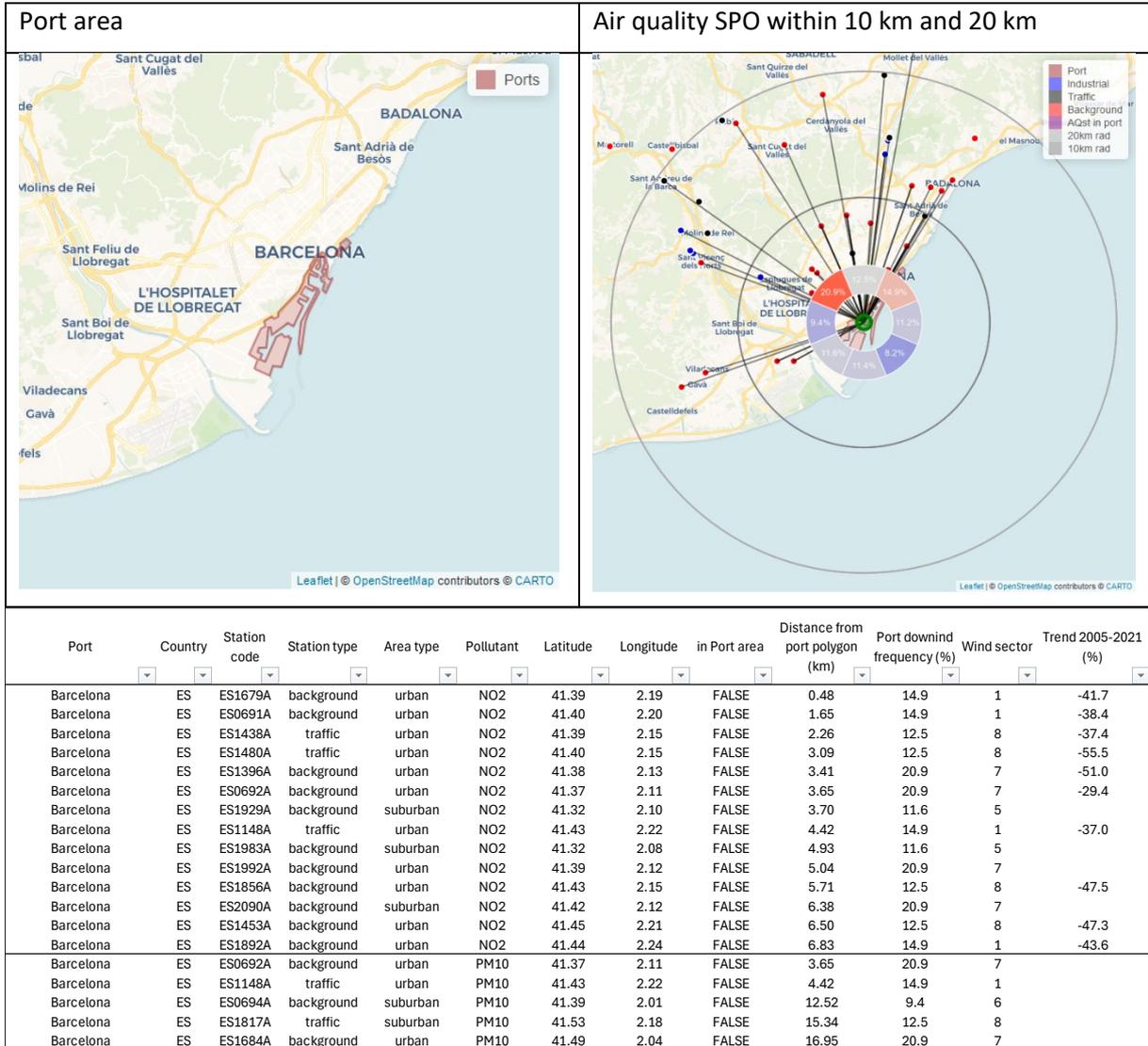


PM₁₀ concentrations when wind is blowing from the port

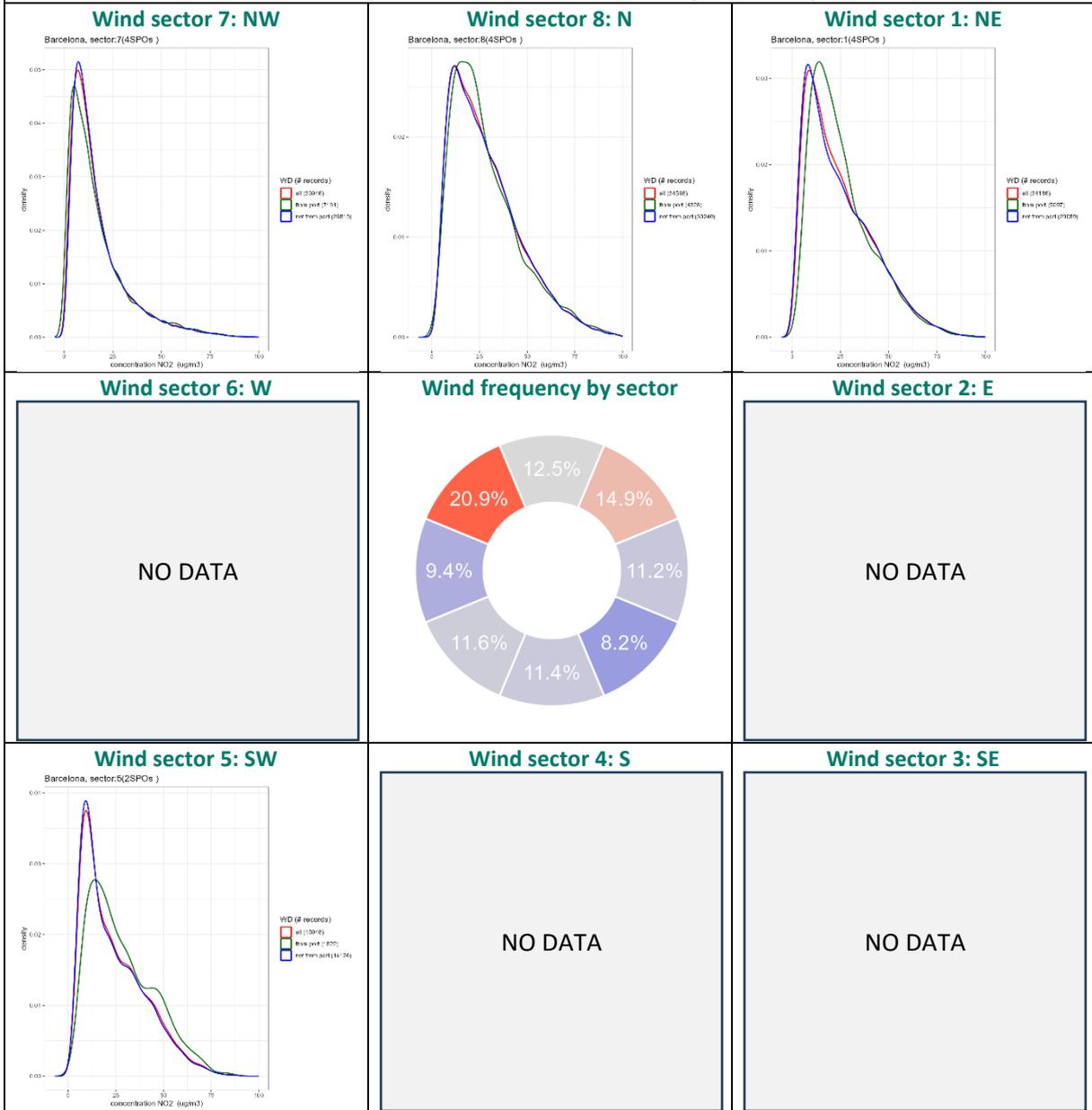




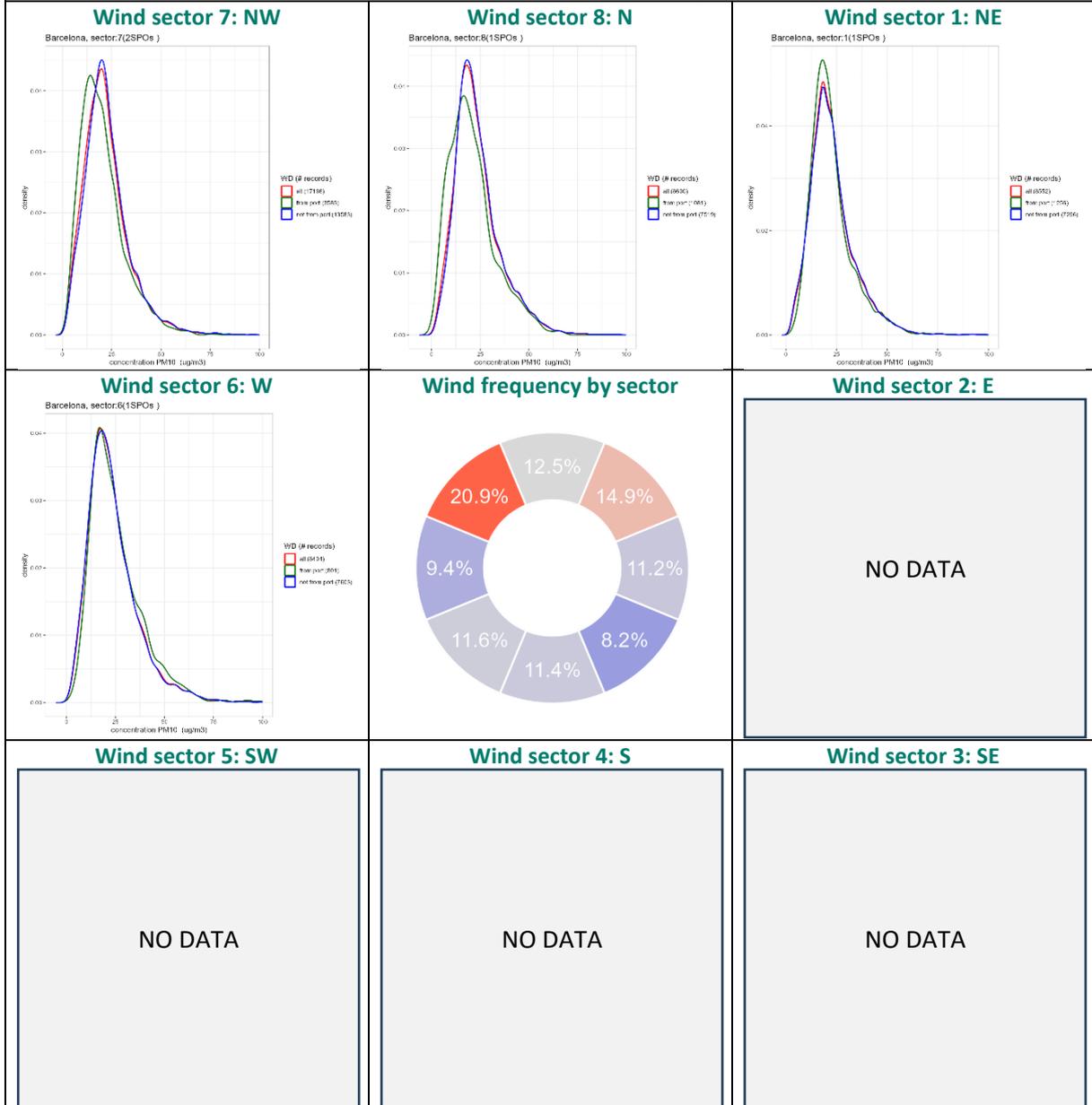
Annex 1.4 Barcelona



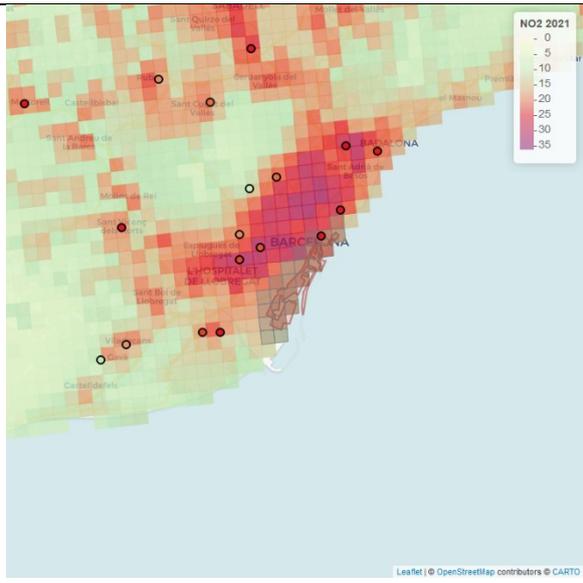
NO₂ concentrations when wind is blowing from the port



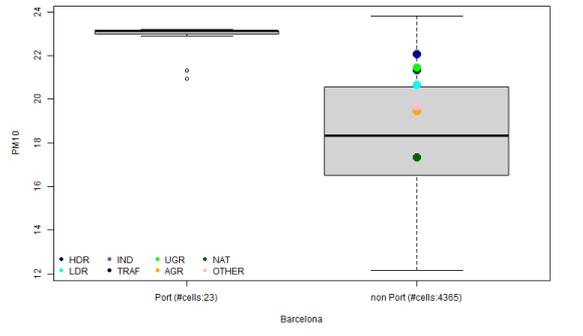
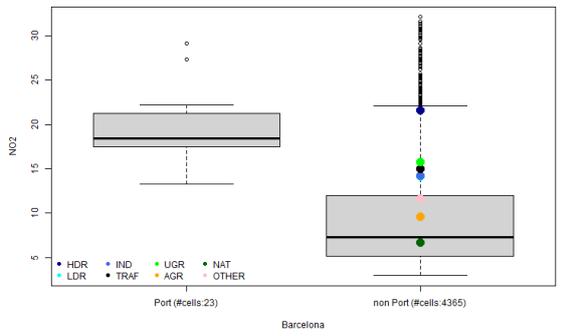
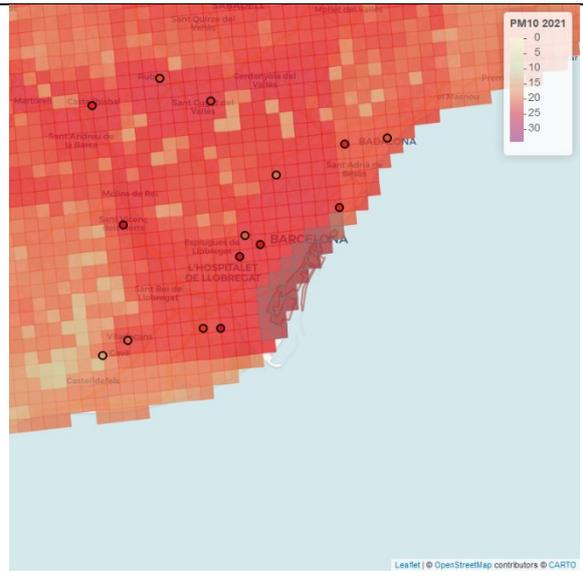
PM₁₀ concentrations when wind is blowing from the port



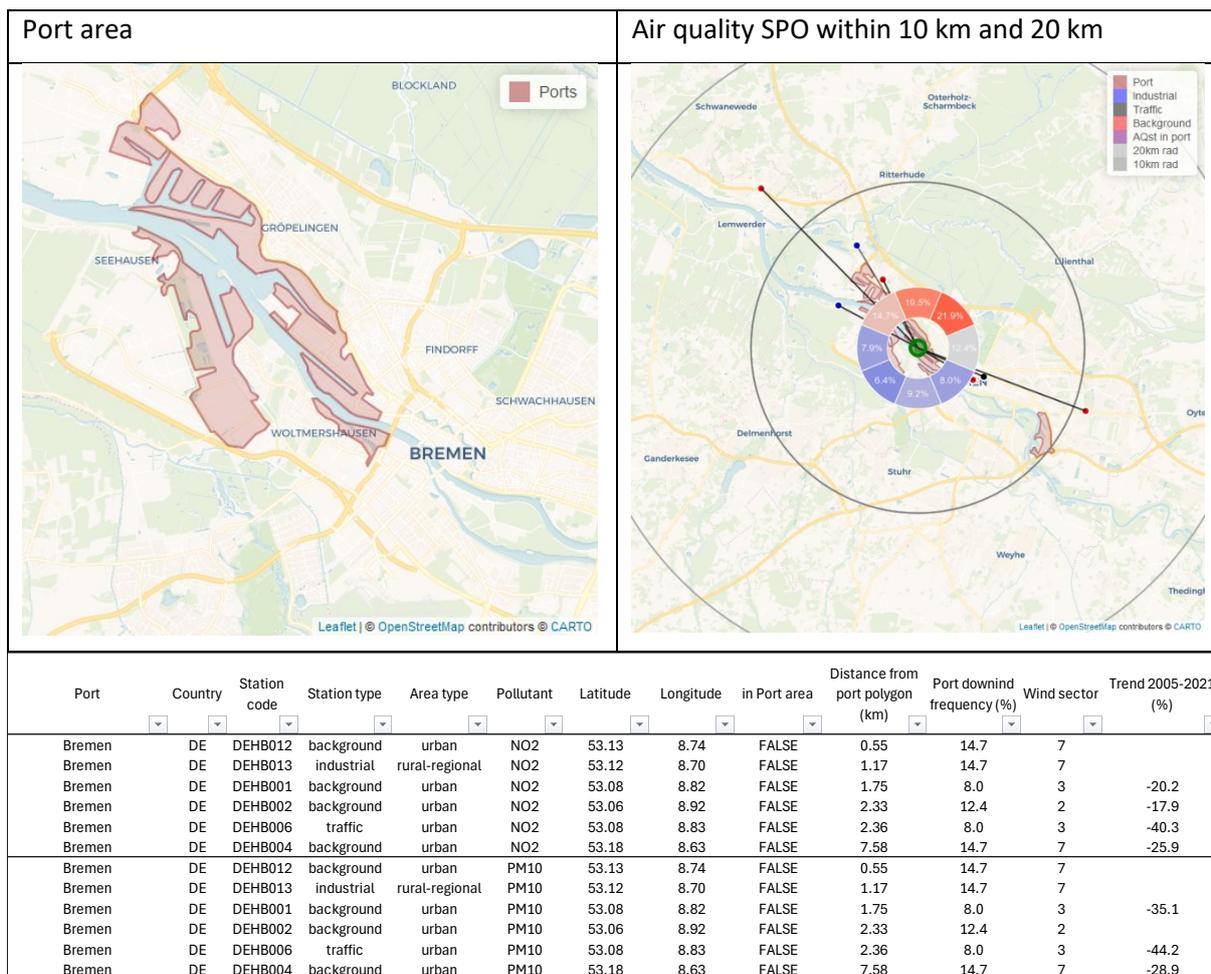
NO₂



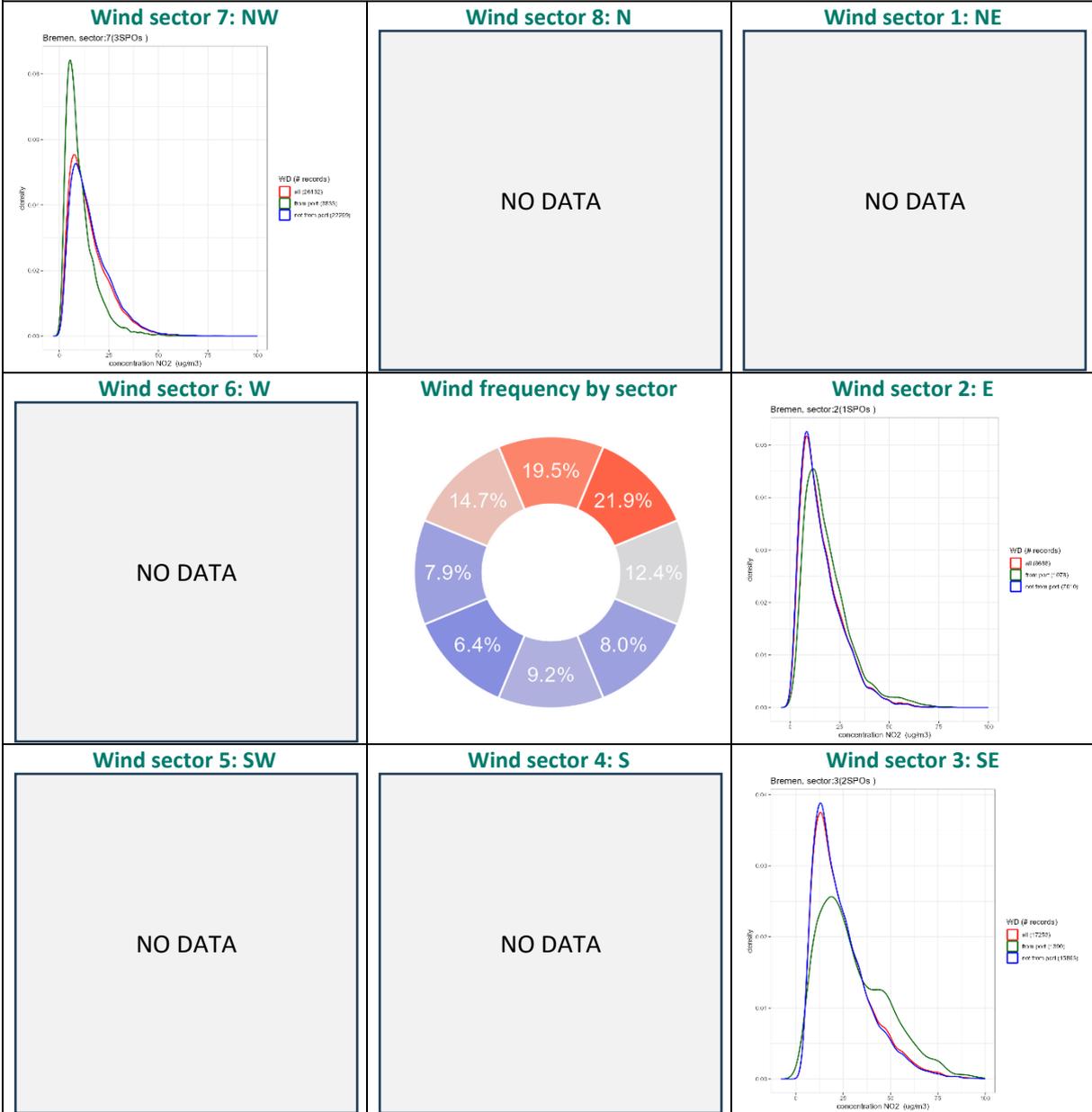
PM₁₀



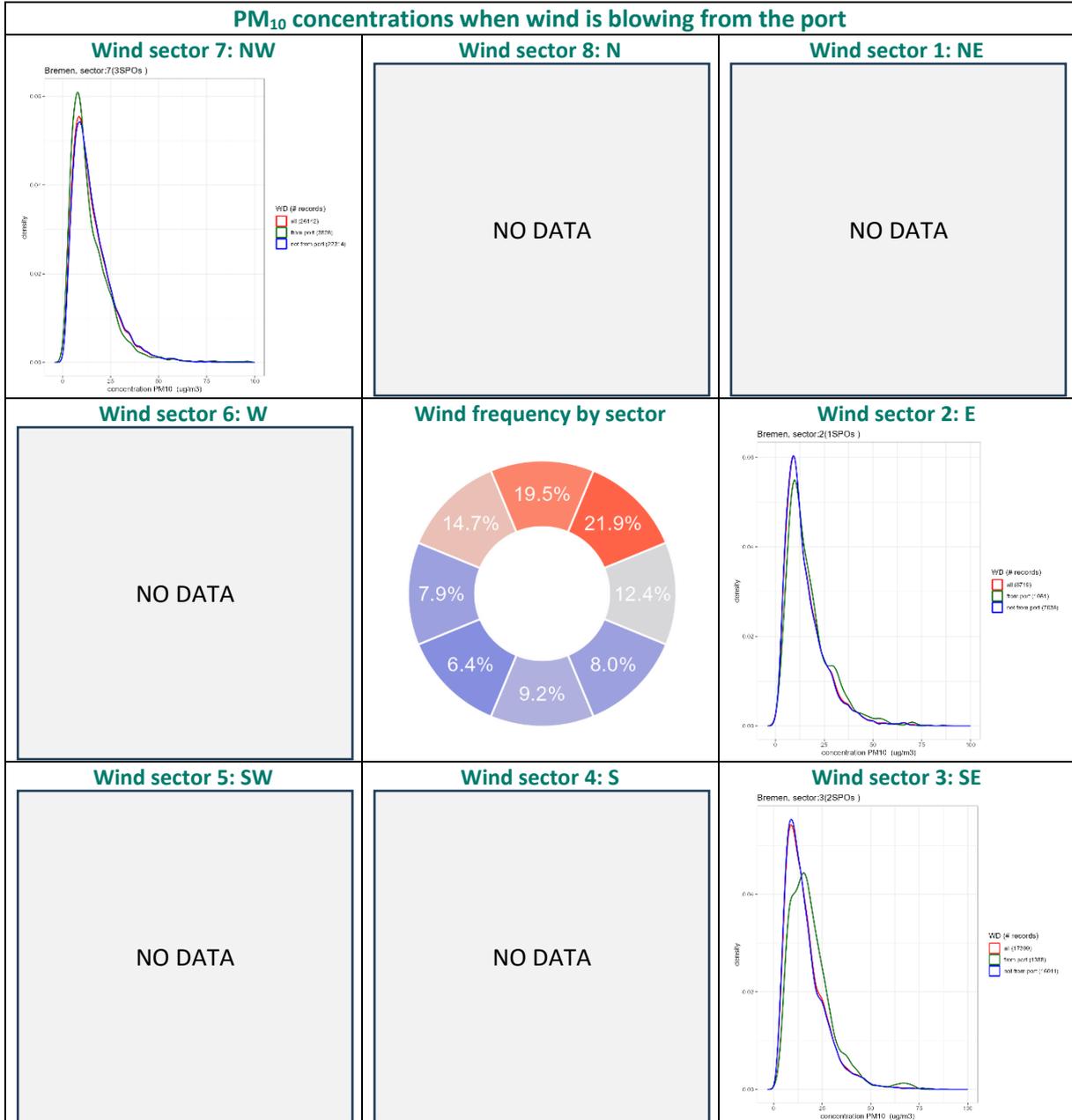
Annex 1.5 Bremen



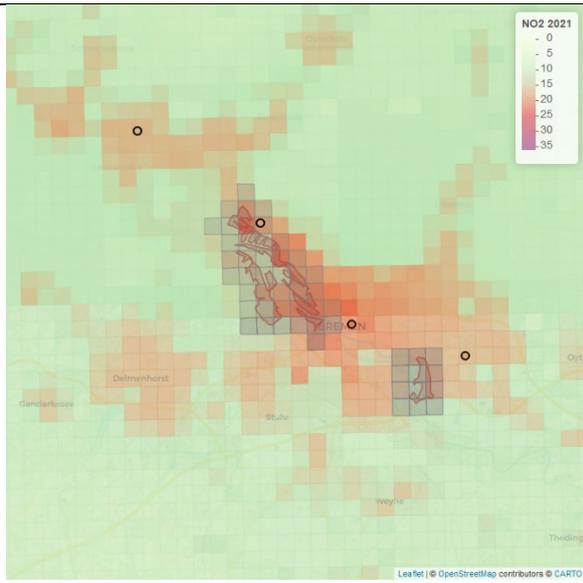
NO₂ concentrations when wind is blowing from the port



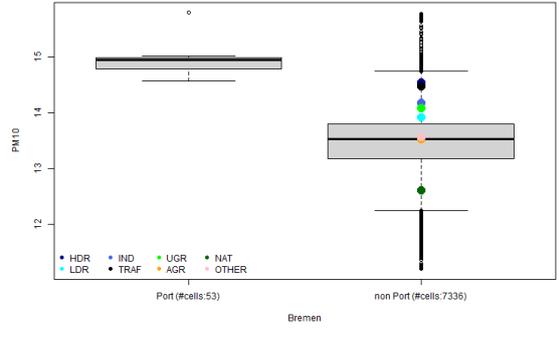
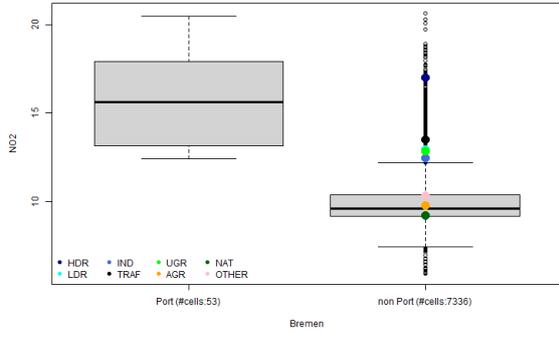
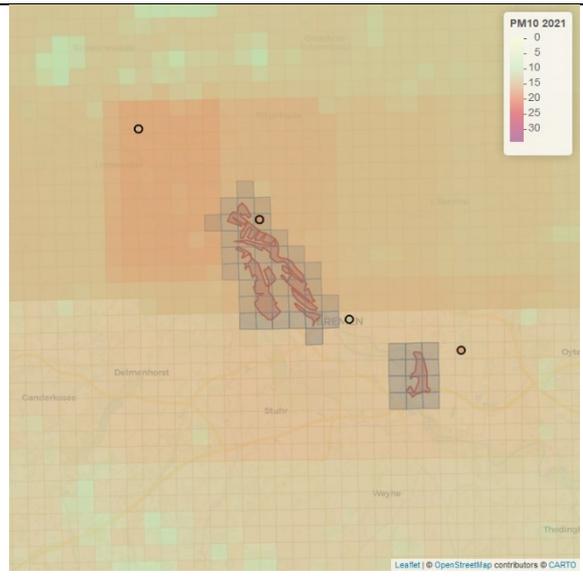
PM₁₀ concentrations when wind is blowing from the port



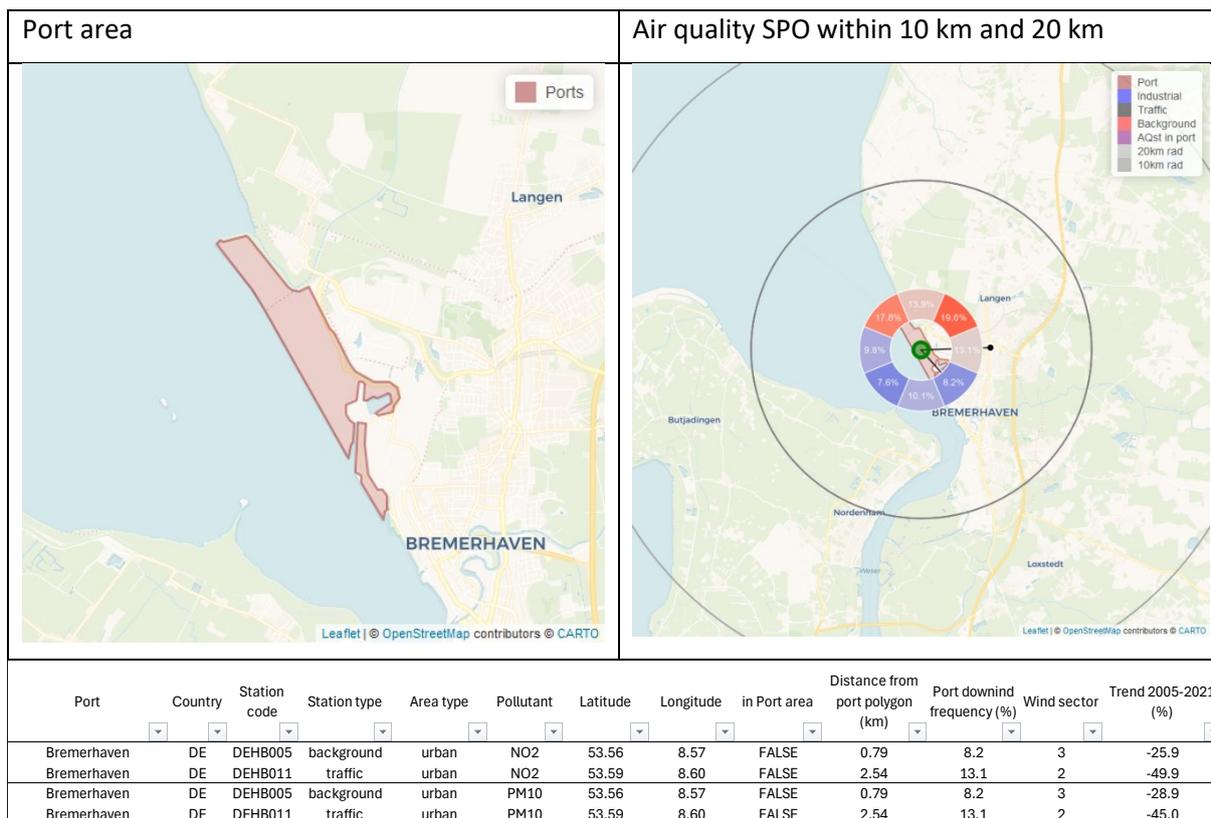
NO₂



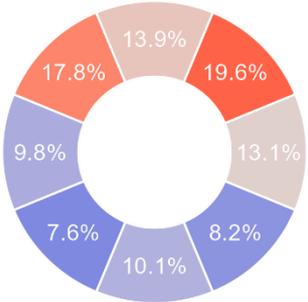
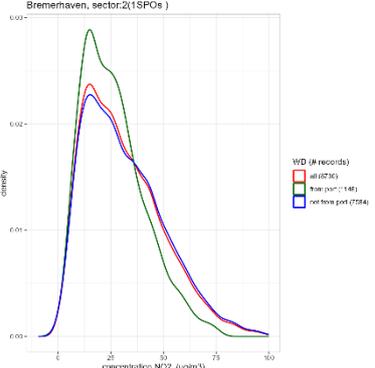
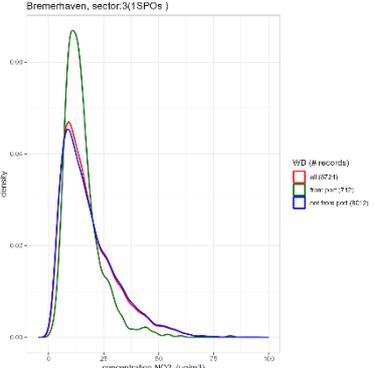
PM₁₀



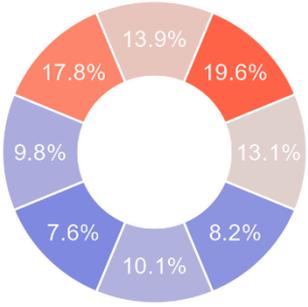
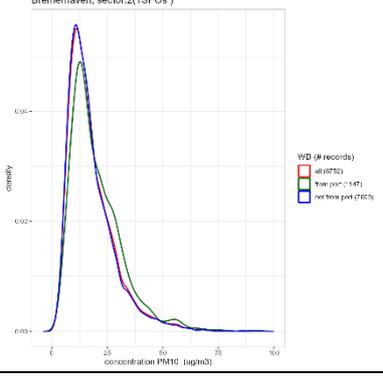
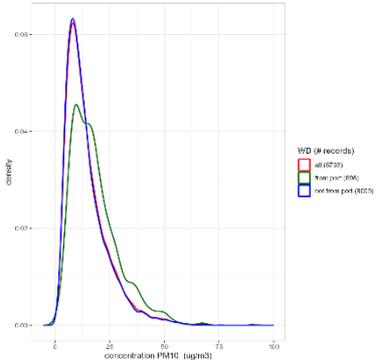
Annex 1.6 Bremerhaven

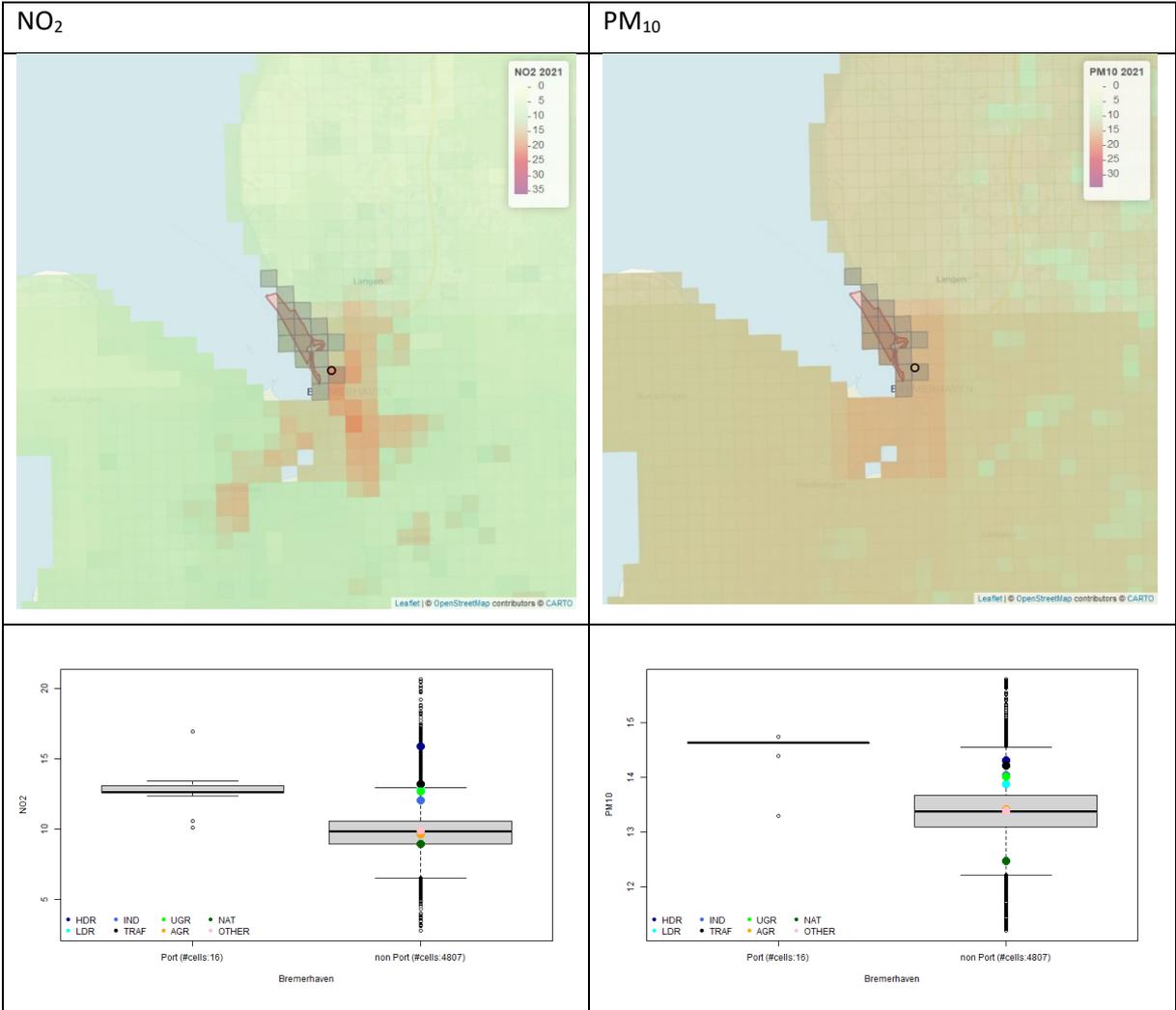


NO₂ concentrations when wind is blowing from the port

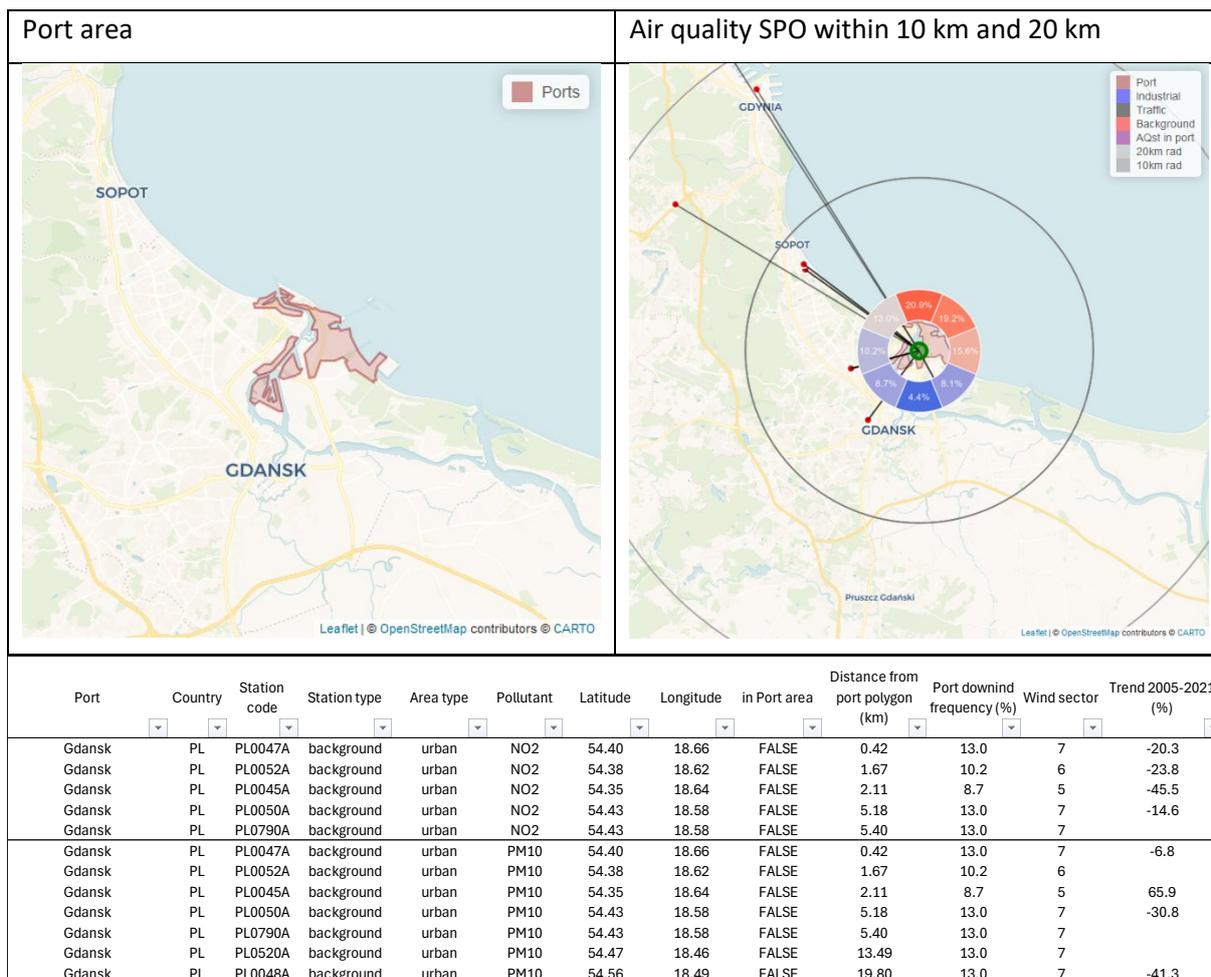
<p>Wind sector 7: NW</p> <p>NO DATA</p>	<p>Wind sector 8: N</p> <p>NO DATA</p>	<p>Wind sector 1: NE</p> <p>NO DATA</p>																		
<p>Wind sector 6: W</p> <p>NO DATA</p>	<p>Wind frequency by sector</p>  <table border="1"> <caption>Wind frequency by sector data</caption> <thead> <tr> <th>Sector</th> <th>Frequency (%)</th> </tr> </thead> <tbody> <tr><td>1</td><td>13.9%</td></tr> <tr><td>2</td><td>19.6%</td></tr> <tr><td>3</td><td>13.1%</td></tr> <tr><td>4</td><td>8.2%</td></tr> <tr><td>5</td><td>10.1%</td></tr> <tr><td>6</td><td>7.6%</td></tr> <tr><td>7</td><td>9.8%</td></tr> <tr><td>8</td><td>17.8%</td></tr> </tbody> </table>	Sector	Frequency (%)	1	13.9%	2	19.6%	3	13.1%	4	8.2%	5	10.1%	6	7.6%	7	9.8%	8	17.8%	<p>Wind sector 2: E</p> <p>Bremerhaven, sector:2(1SP0s)</p>  <p>WD (# records) █ all (6276) █ from port (1461) █ not from port (4815)</p>
Sector	Frequency (%)																			
1	13.9%																			
2	19.6%																			
3	13.1%																			
4	8.2%																			
5	10.1%																			
6	7.6%																			
7	9.8%																			
8	17.8%																			
<p>Wind sector 5: SW</p> <p>NO DATA</p>	<p>Wind sector 4: S</p> <p>NO DATA</p>	<p>Wind sector 3: SE</p> <p>Bremerhaven, sector:3(1SP0s)</p>  <p>WD (# records) █ all (6276) █ from port (710) █ not from port (5566)</p>																		

PM₁₀ concentrations when wind is blowing from the port

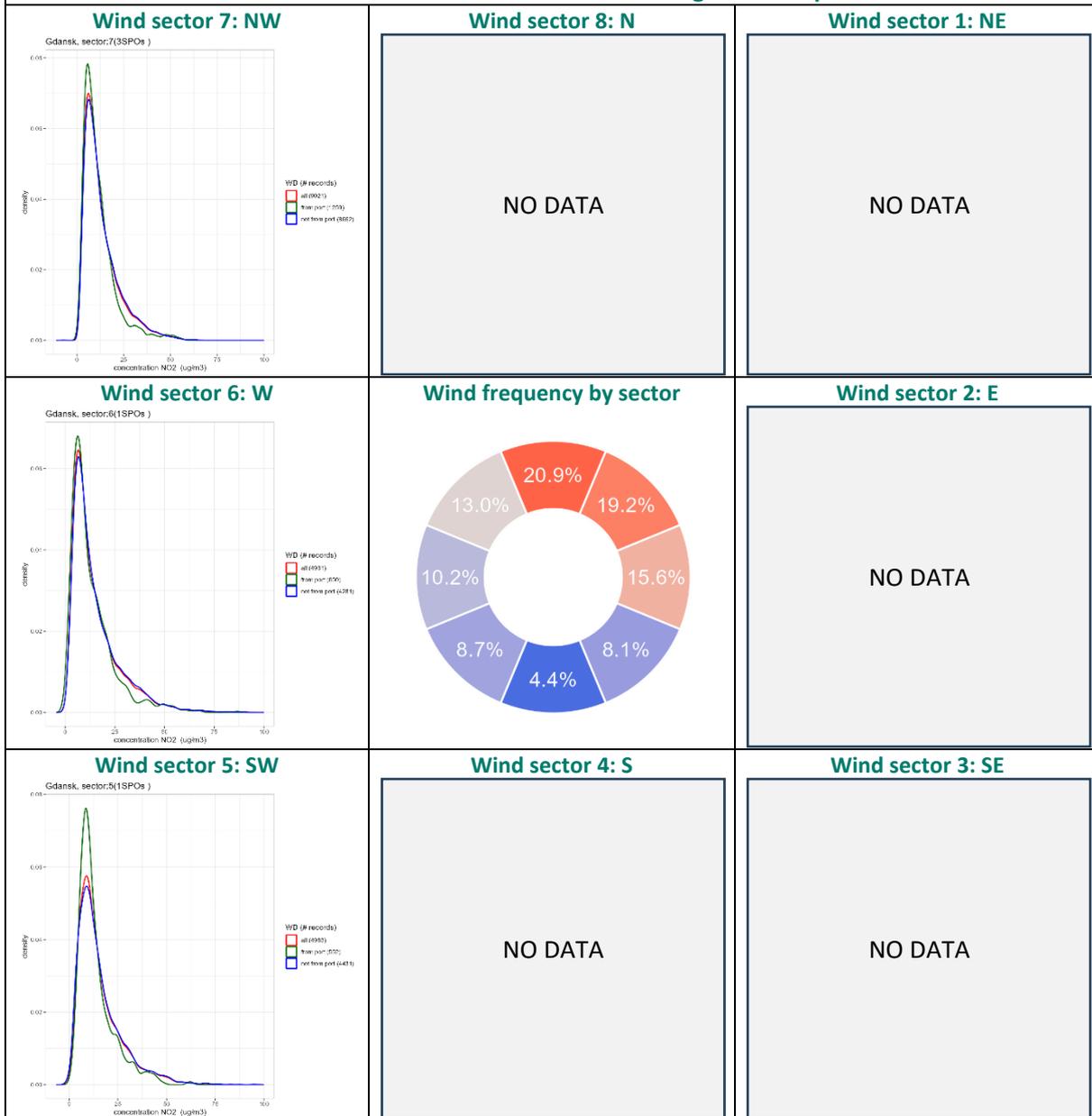
<p>Wind sector 7: NW</p> <p>NO DATA</p>	<p>Wind sector 8: N</p> <p>NO DATA</p>	<p>Wind sector 1: NE</p> <p>NO DATA</p>																		
<p>Wind sector 6: W</p> <p>NO DATA</p>	<p>Wind frequency by sector</p>  <table border="1"> <caption>Wind frequency by sector data</caption> <thead> <tr> <th>Sector</th> <th>Frequency (%)</th> </tr> </thead> <tbody> <tr><td>1</td><td>19.6%</td></tr> <tr><td>2</td><td>13.1%</td></tr> <tr><td>3</td><td>8.2%</td></tr> <tr><td>4</td><td>10.1%</td></tr> <tr><td>5</td><td>7.6%</td></tr> <tr><td>6</td><td>9.8%</td></tr> <tr><td>7</td><td>17.8%</td></tr> <tr><td>8</td><td>13.9%</td></tr> </tbody> </table>	Sector	Frequency (%)	1	19.6%	2	13.1%	3	8.2%	4	10.1%	5	7.6%	6	9.8%	7	17.8%	8	13.9%	<p>Wind sector 2: E</p> <p>Bremerhaven, sector:2(1SP0s)</p> 
Sector	Frequency (%)																			
1	19.6%																			
2	13.1%																			
3	8.2%																			
4	10.1%																			
5	7.6%																			
6	9.8%																			
7	17.8%																			
8	13.9%																			
<p>Wind sector 5: SW</p> <p>NO DATA</p>	<p>Wind sector 4: S</p> <p>NO DATA</p>	<p>Wind sector 3: SE</p> <p>Bremerhaven, sector:3(1SP0s)</p> 																		



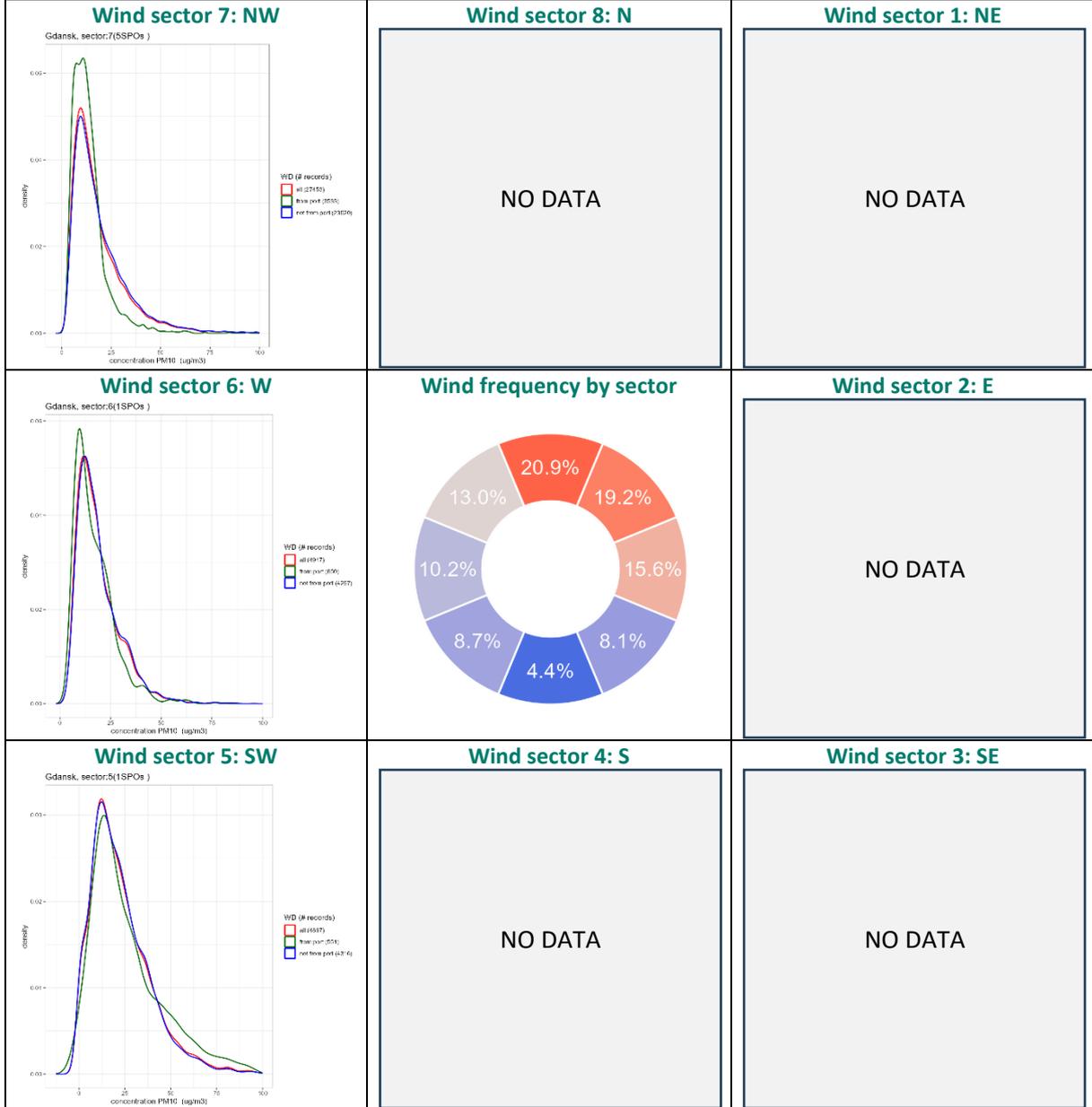
Annex 1.7 Gdansk

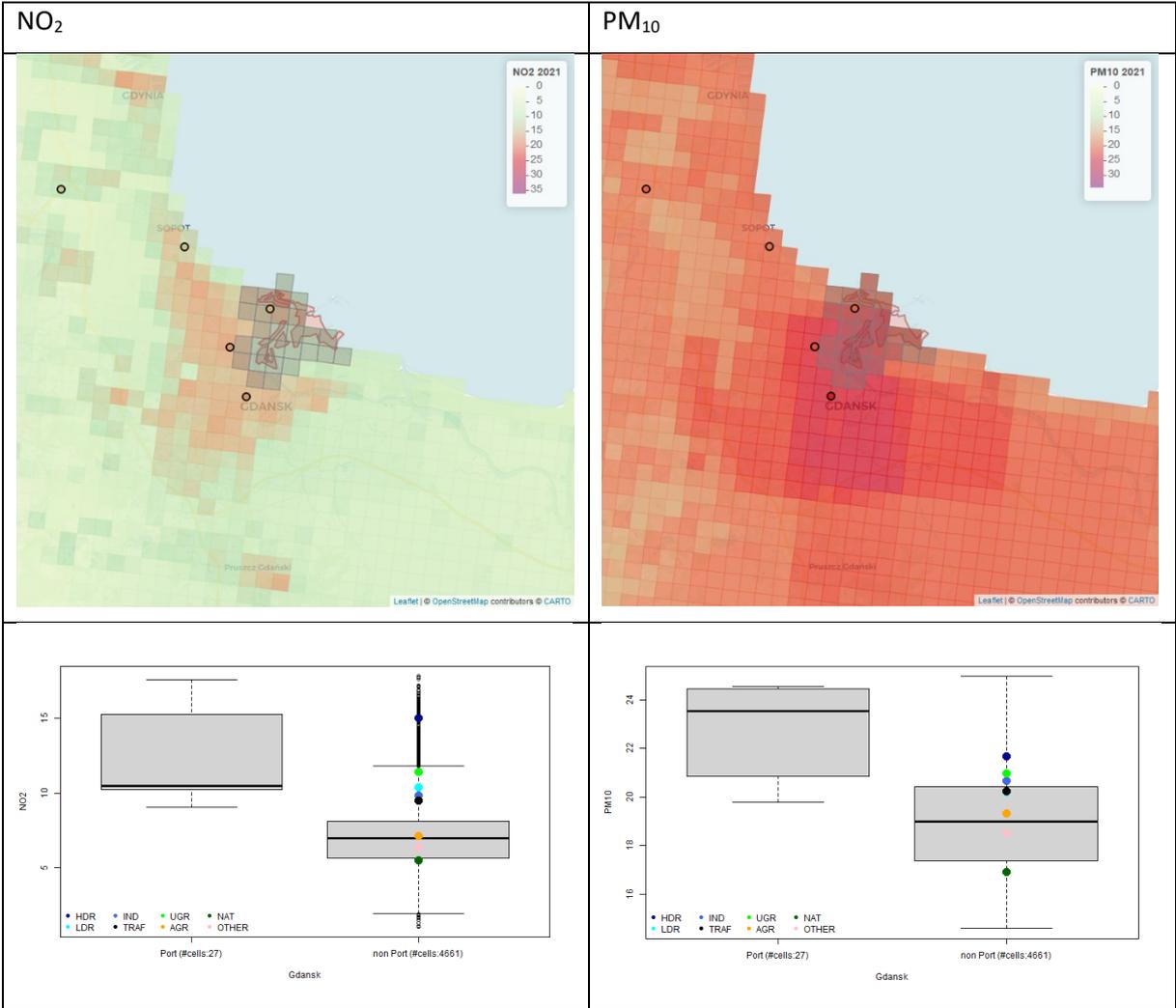


NO₂ concentrations when wind is blowing from the port

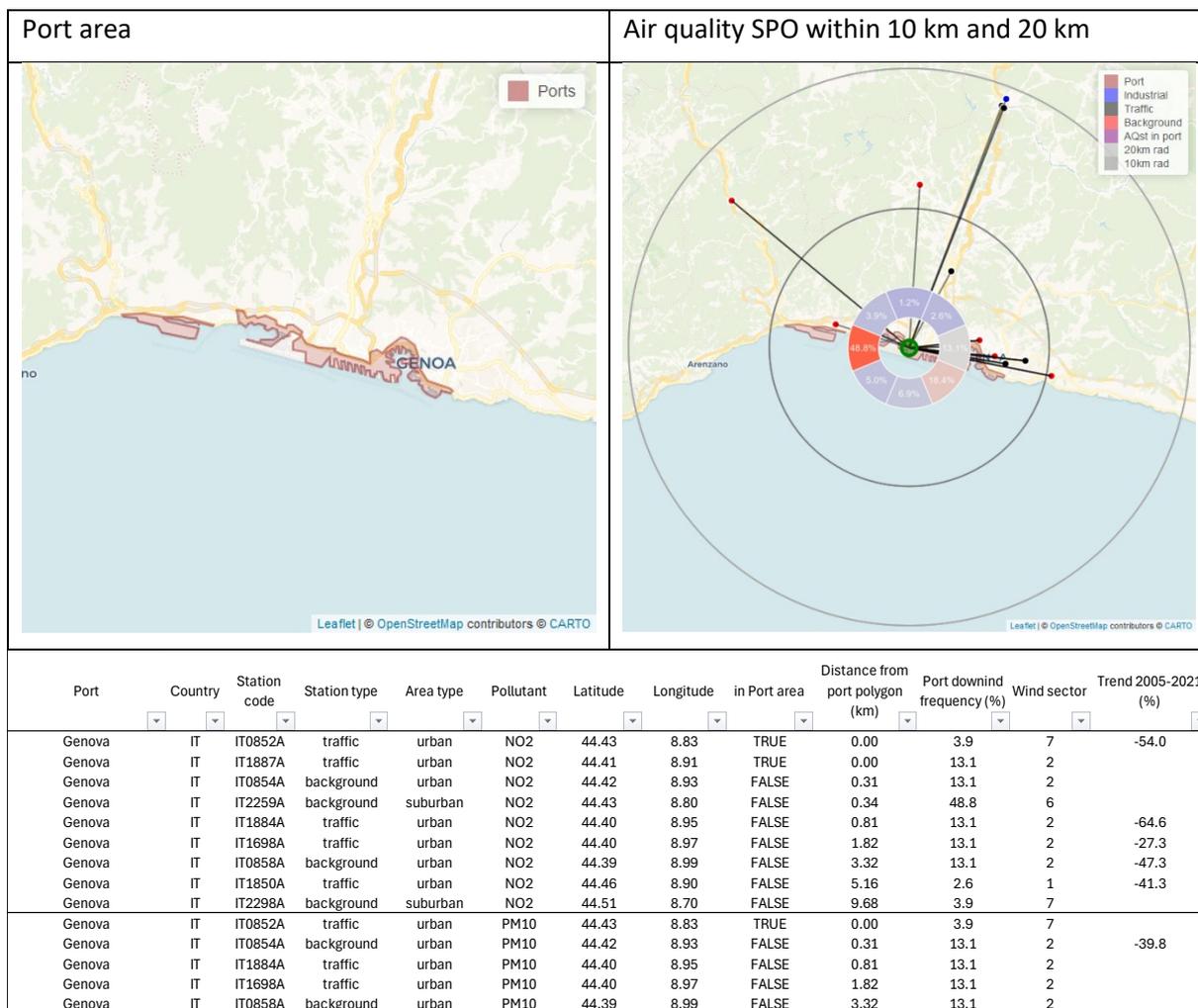


PM₁₀ concentrations when wind is blowing from the port

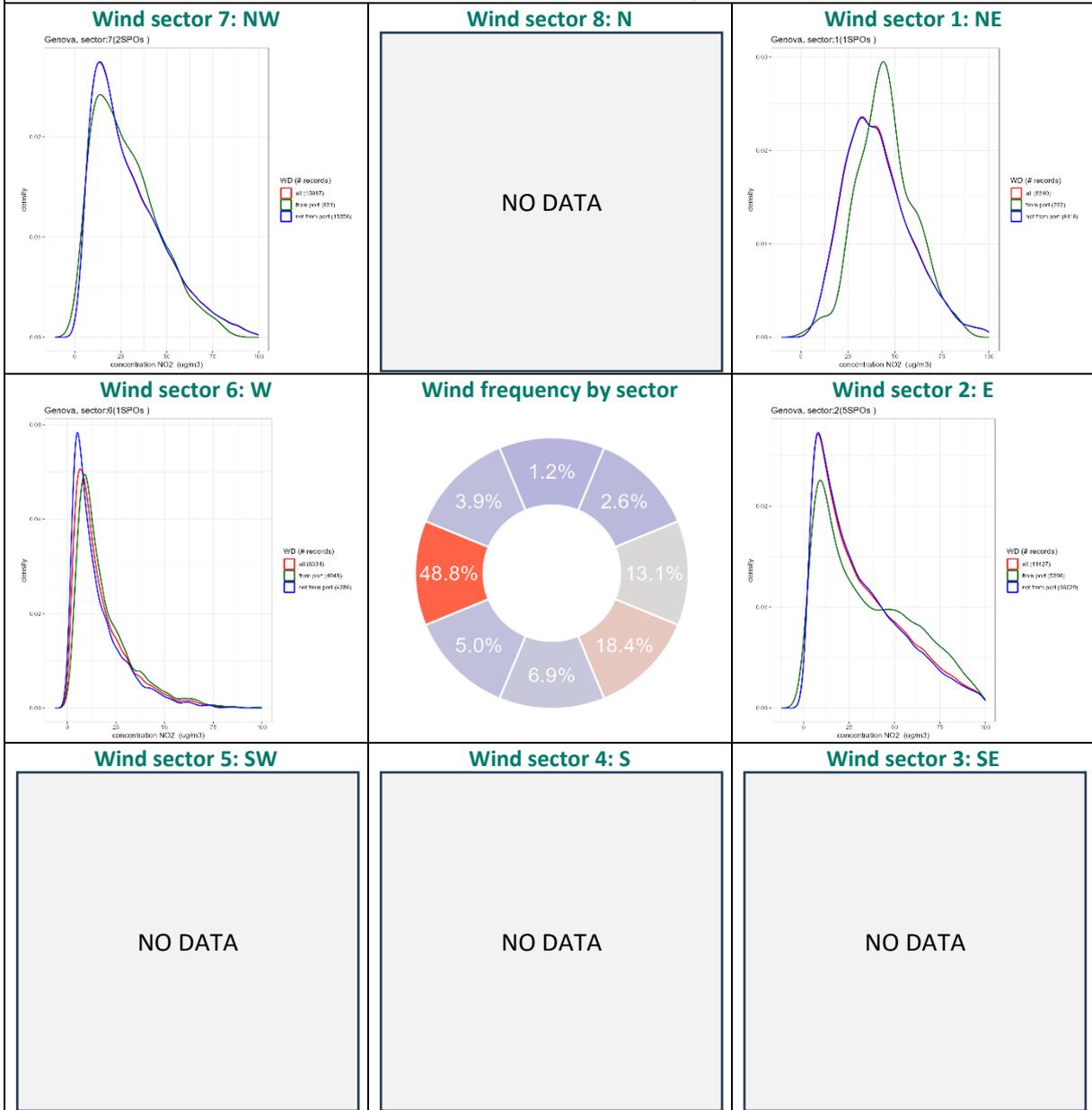




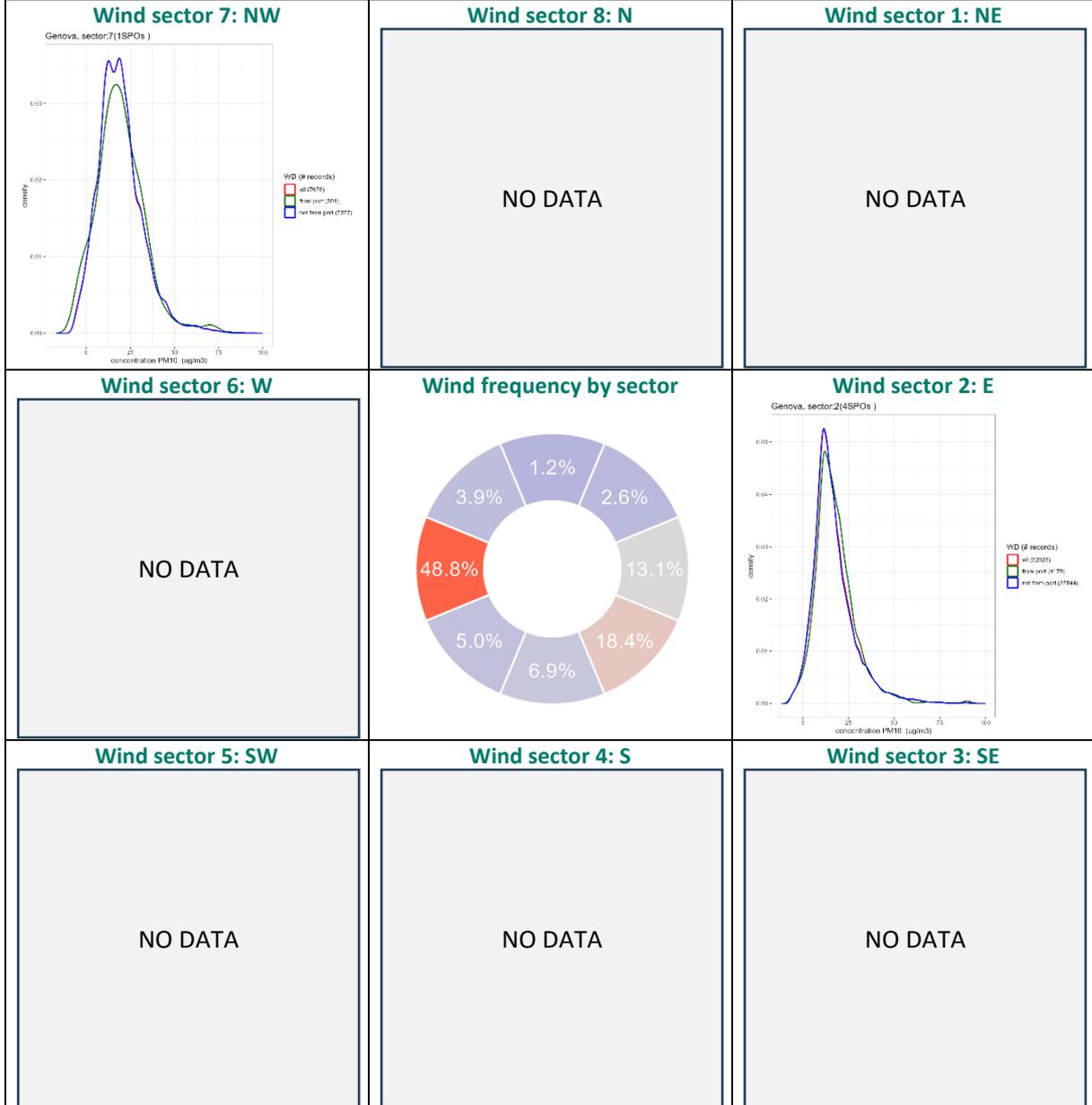
Annex 1.8 Genova

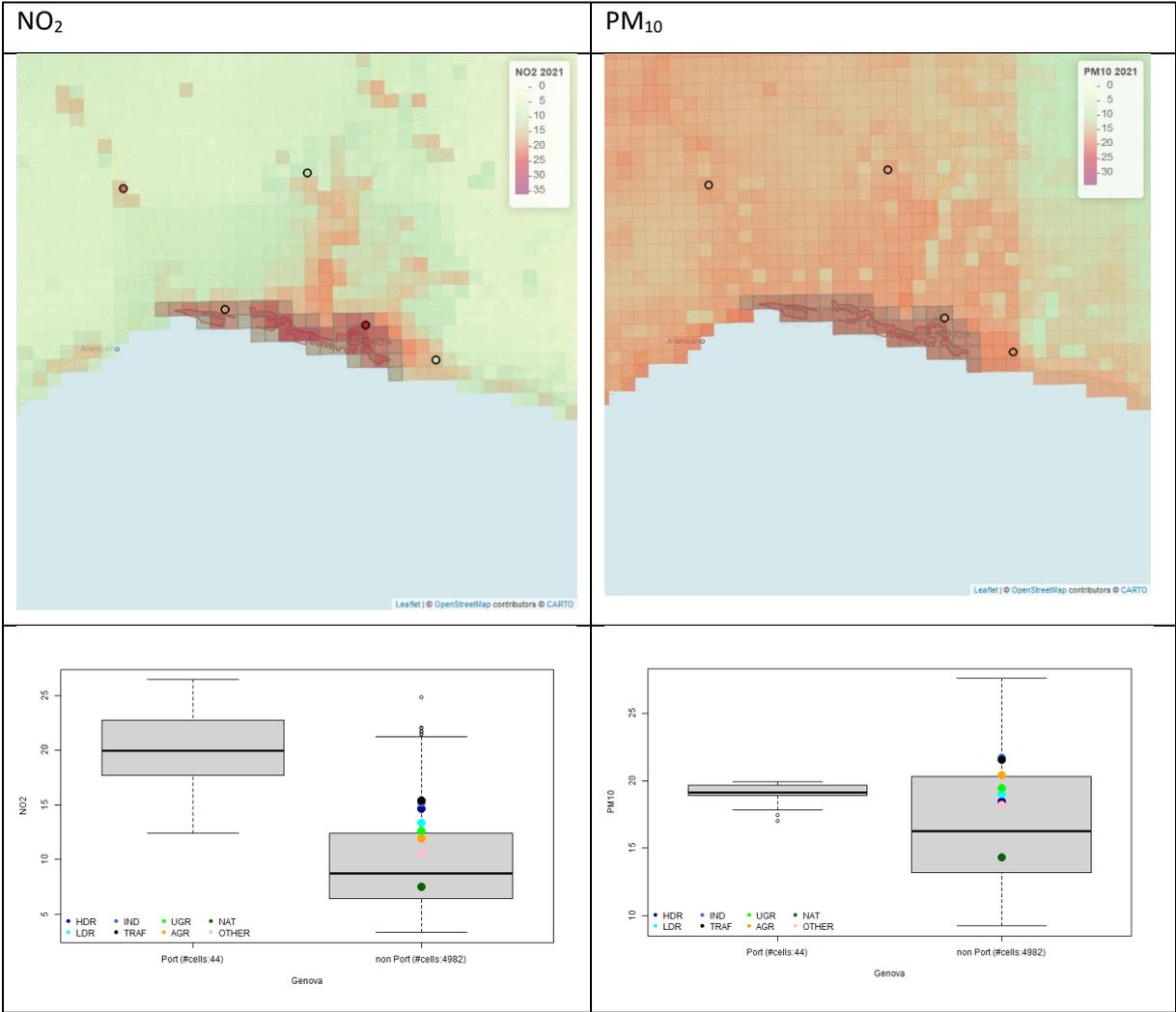


NO₂ concentrations when wind is blowing from the port

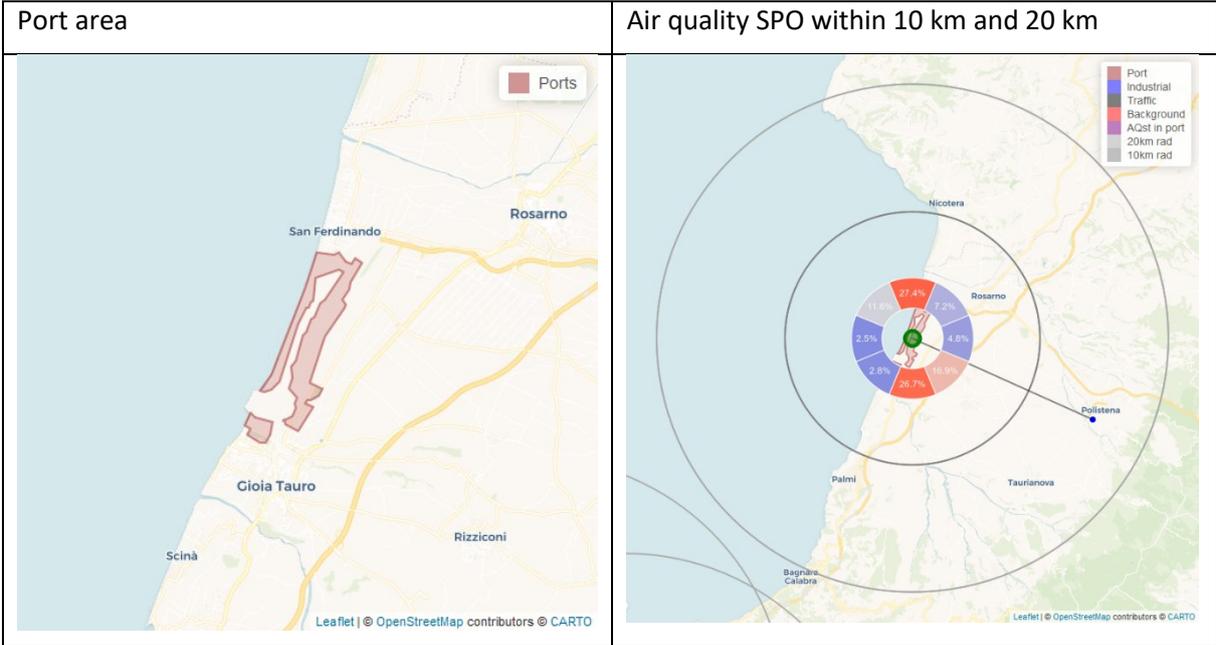


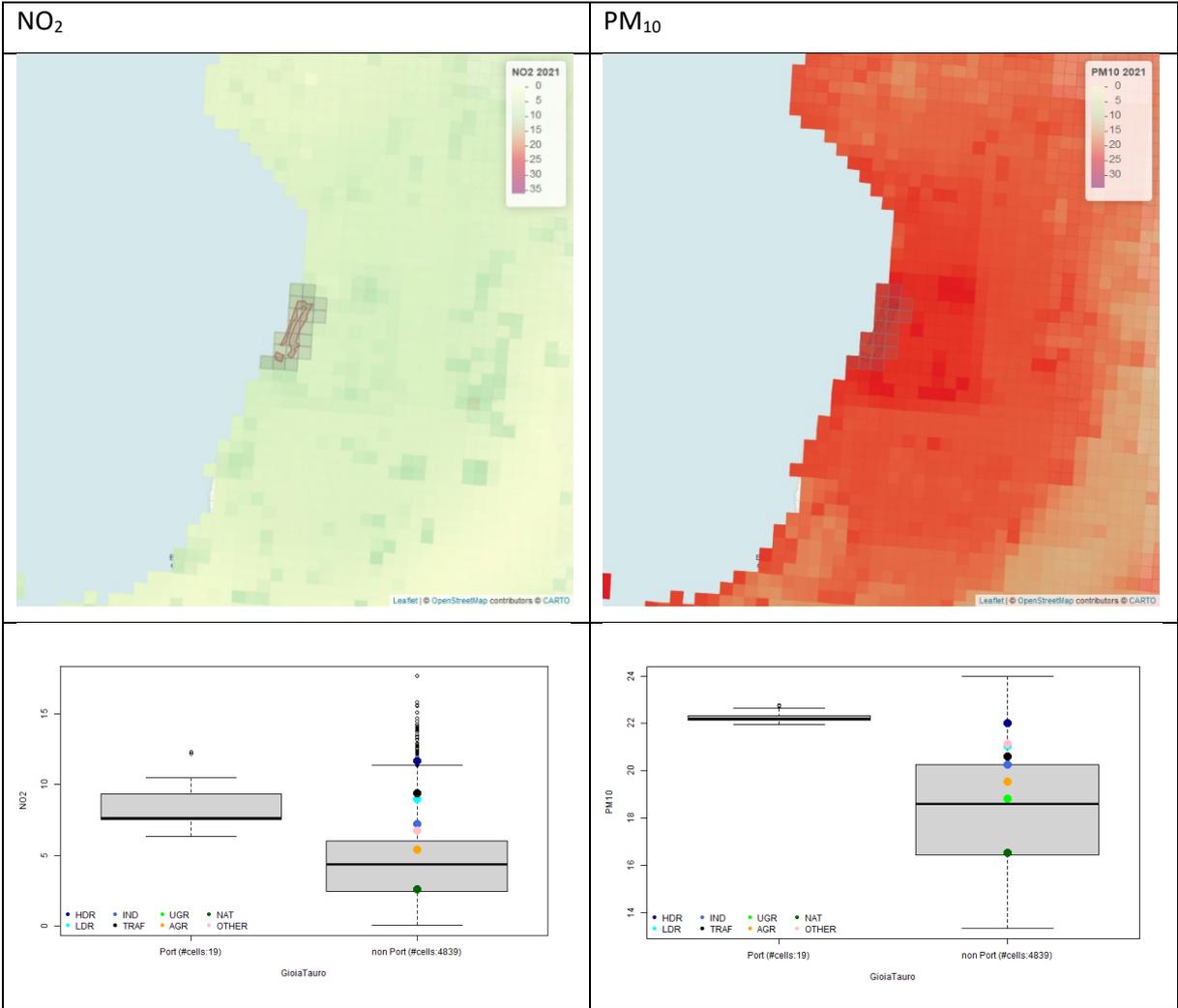
PM₁₀ concentrations when wind is blowing from the port



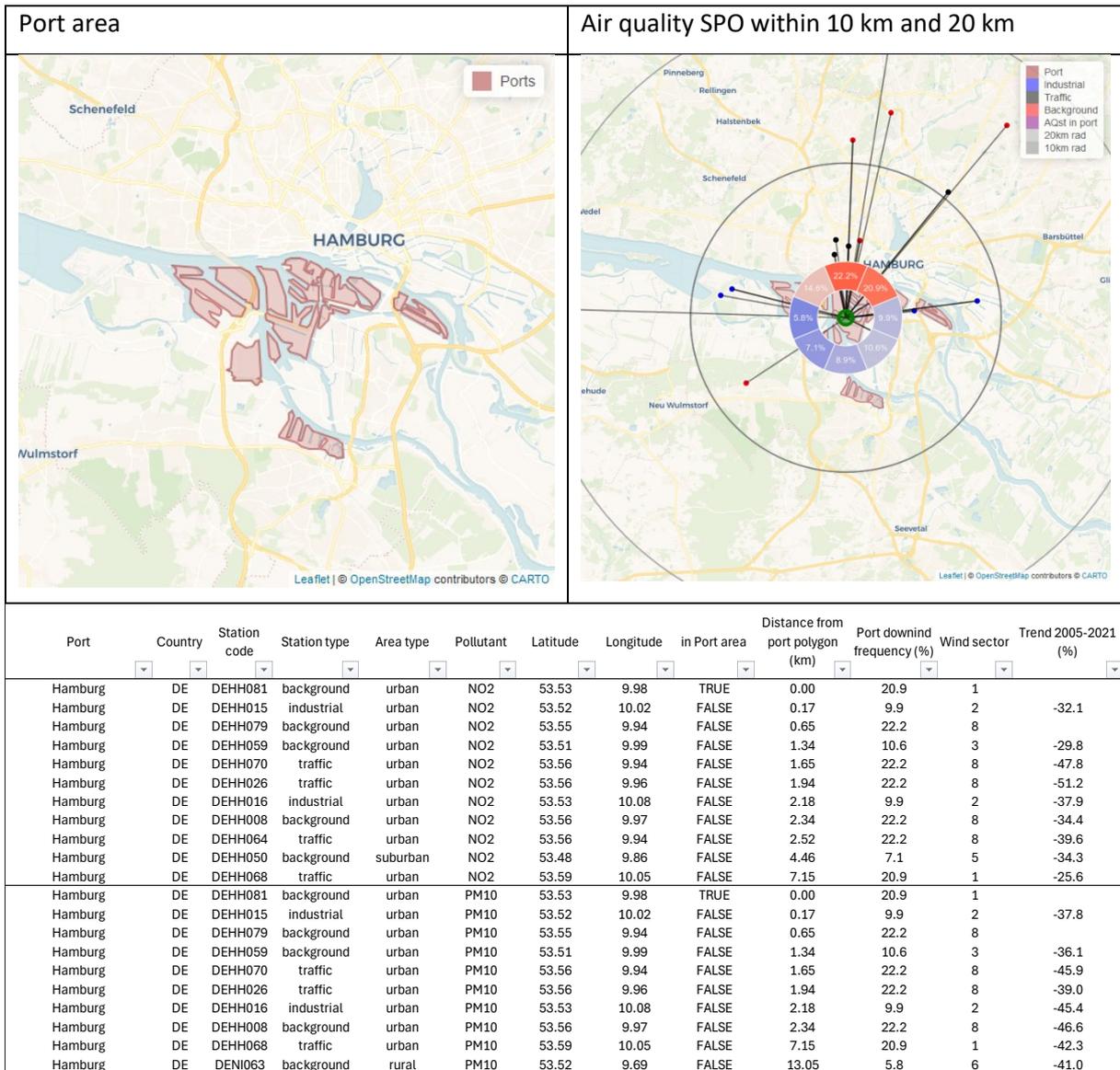


Annex 1.9 Gioia Tauro





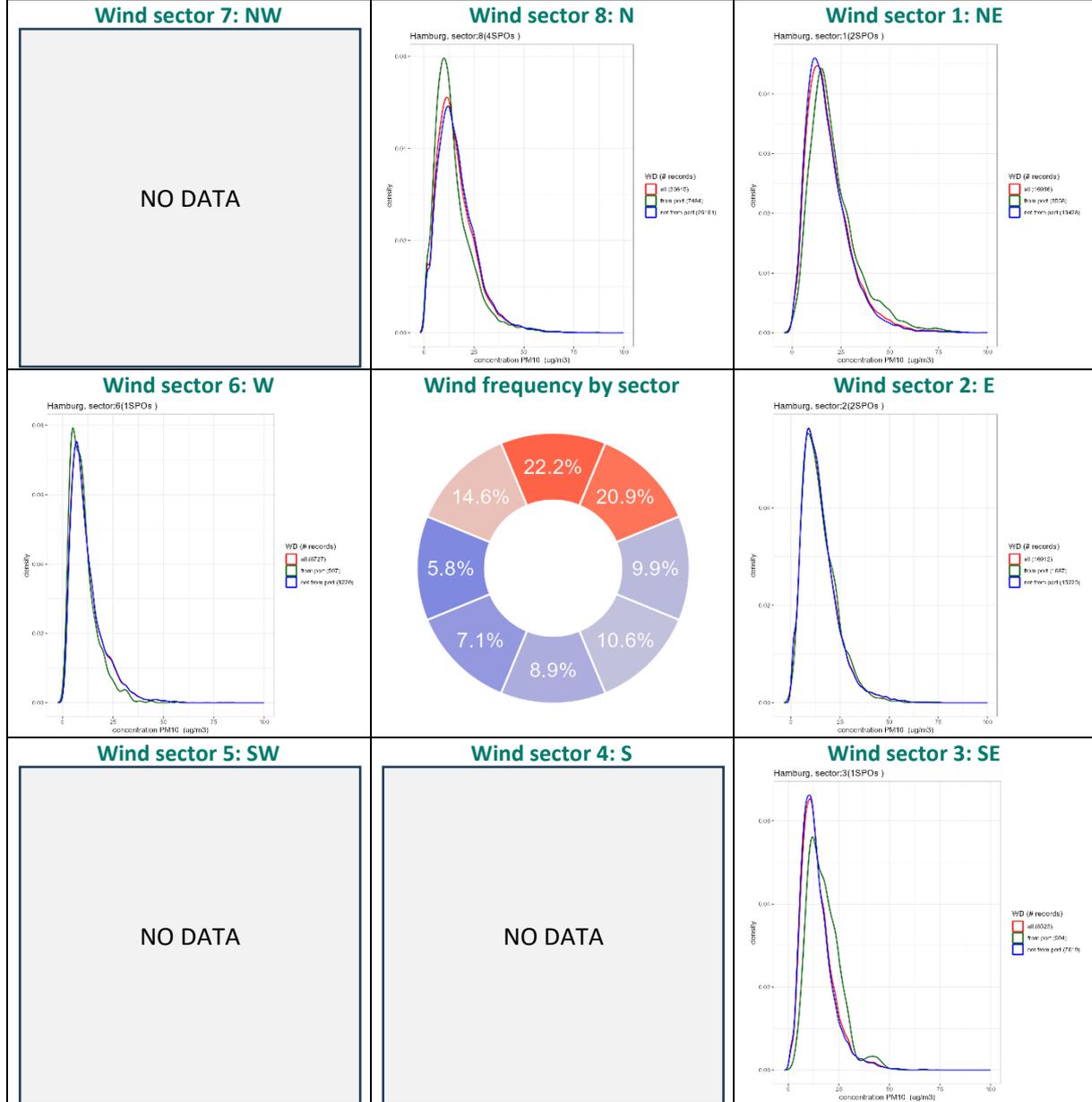
Annex 1.10 Hamburg



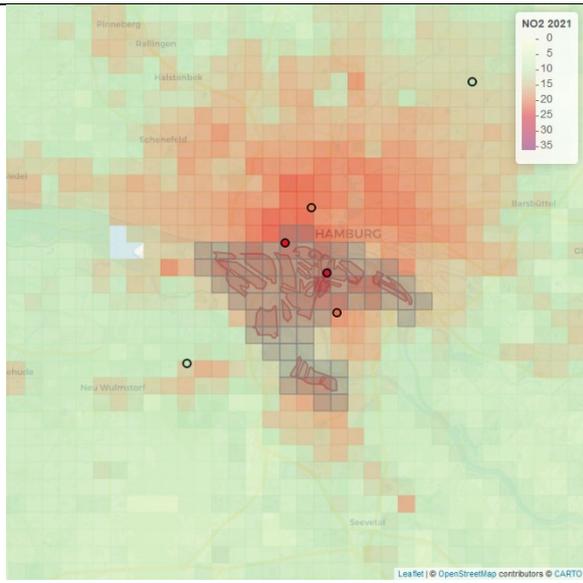
NO₂ concentrations when wind is blowing from the port



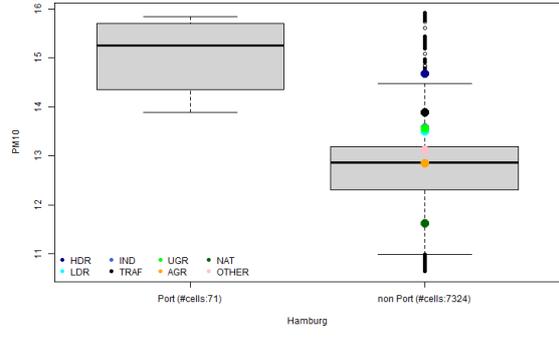
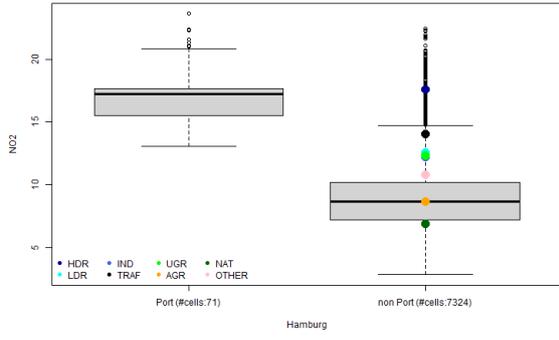
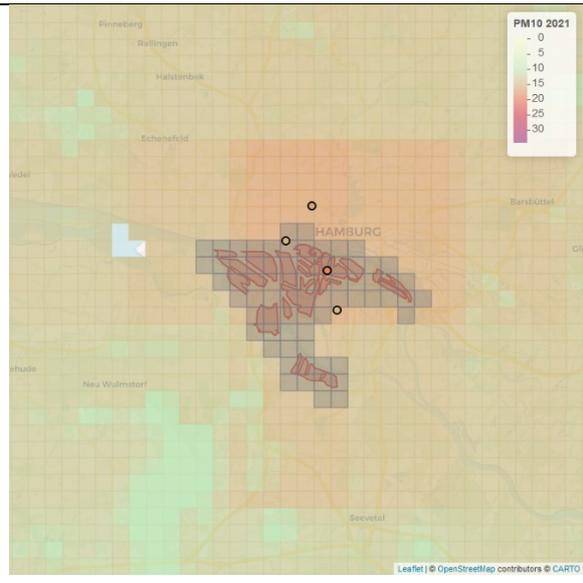
PM₁₀ concentrations when wind is blowing from the port



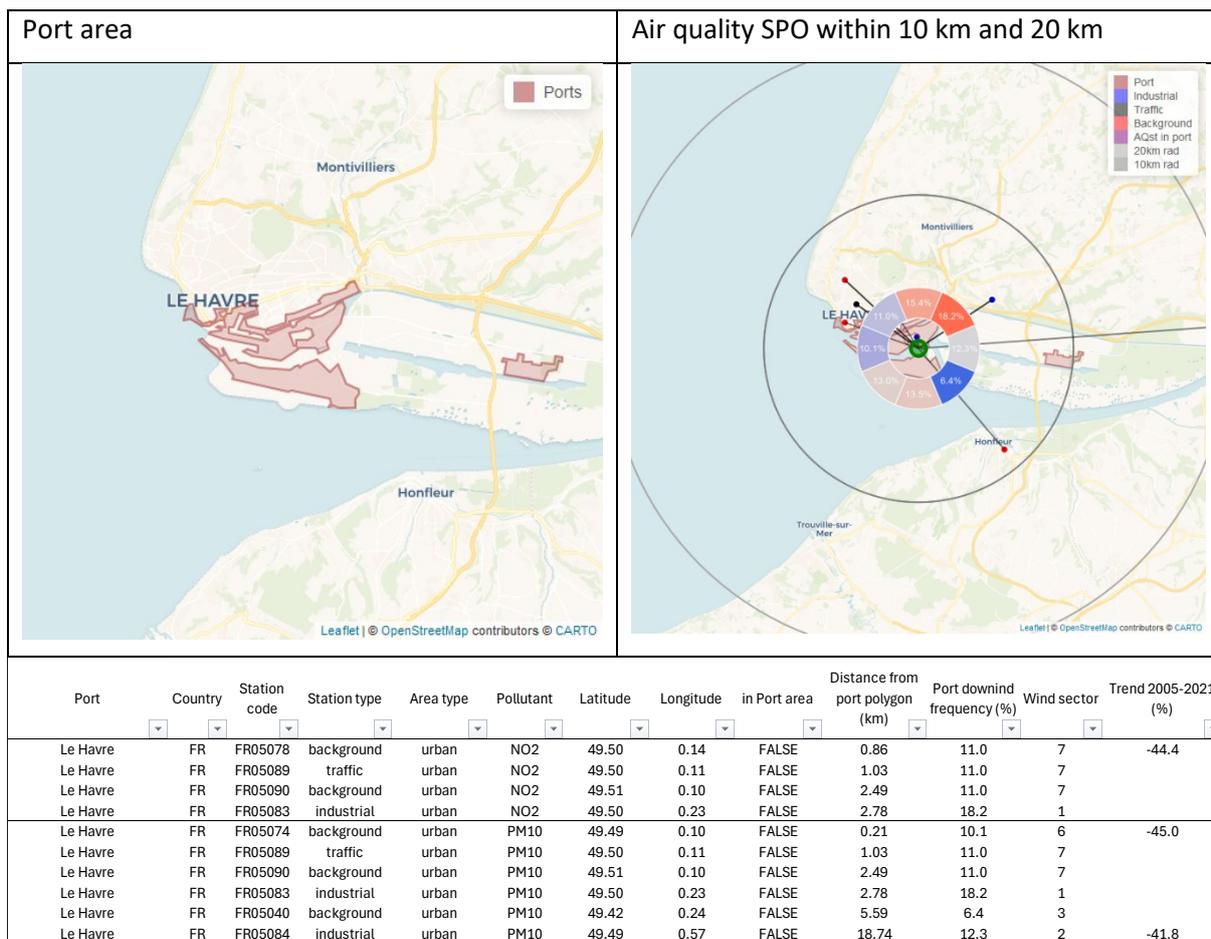
NO₂



PM₁₀



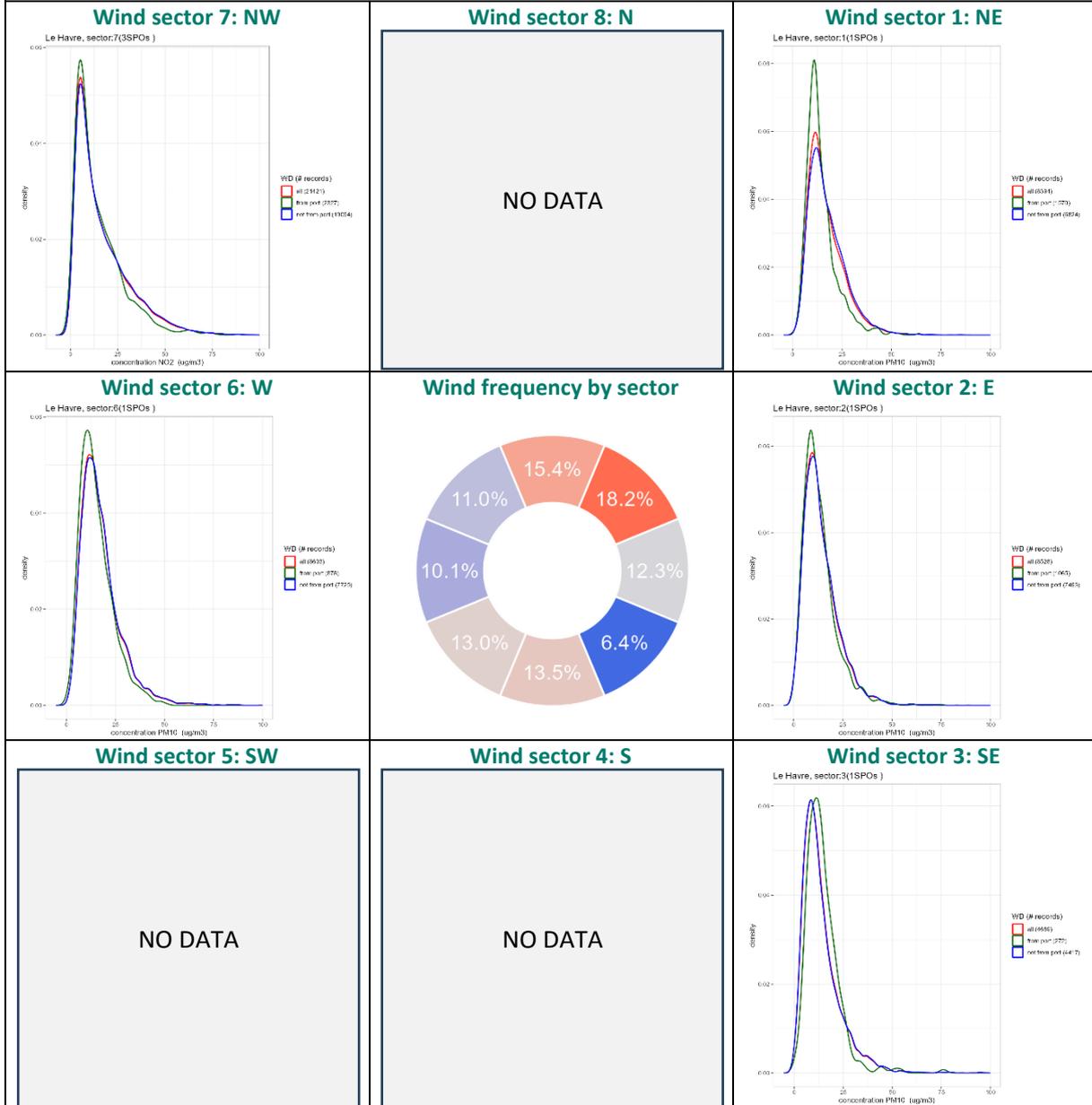
Annex 1.11 Le Havre

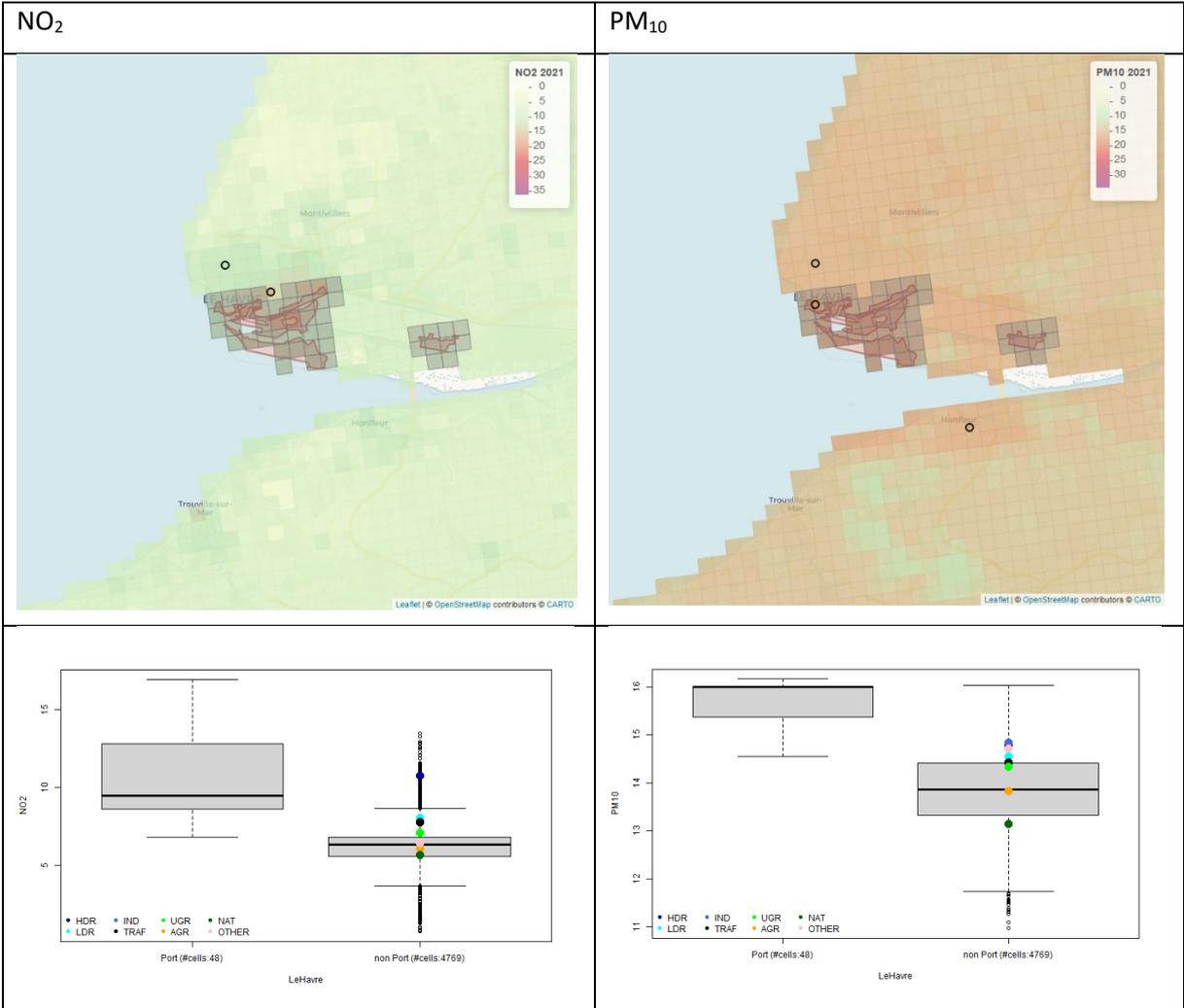


NO₂ concentrations when wind is blowing from the port

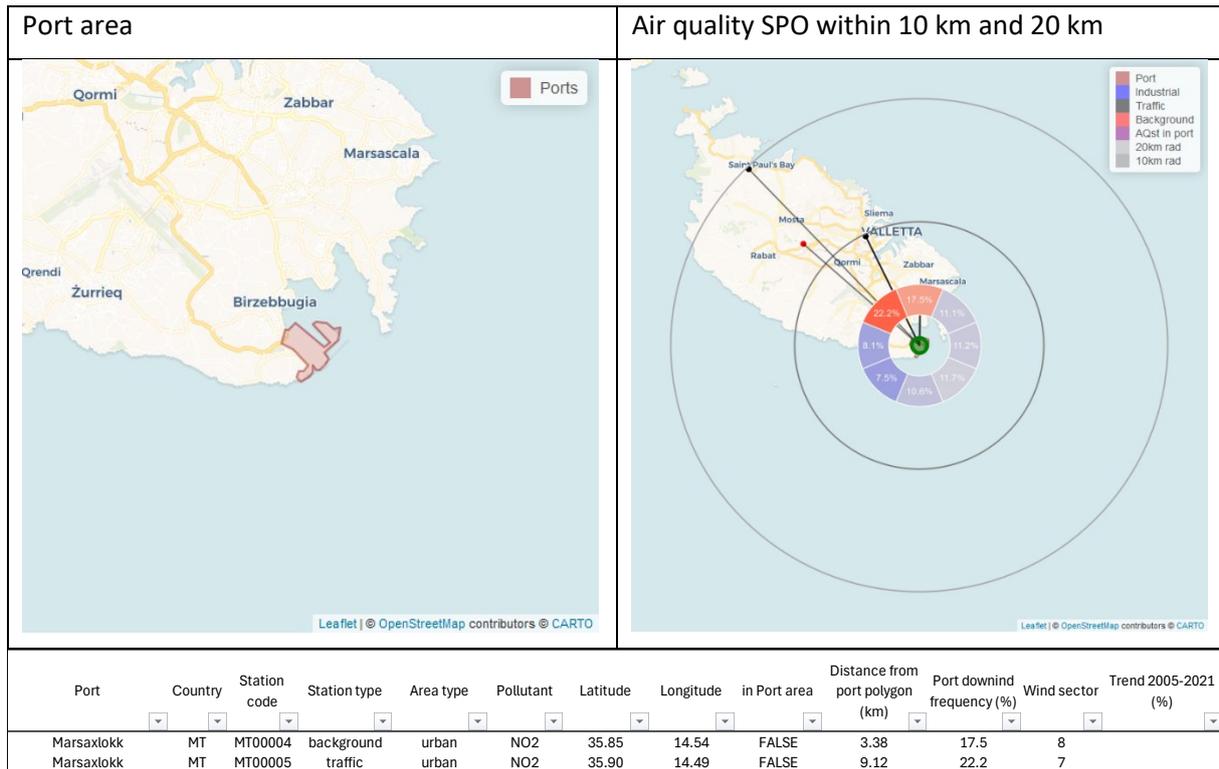


PM₁₀ concentrations when wind is blowing from the port



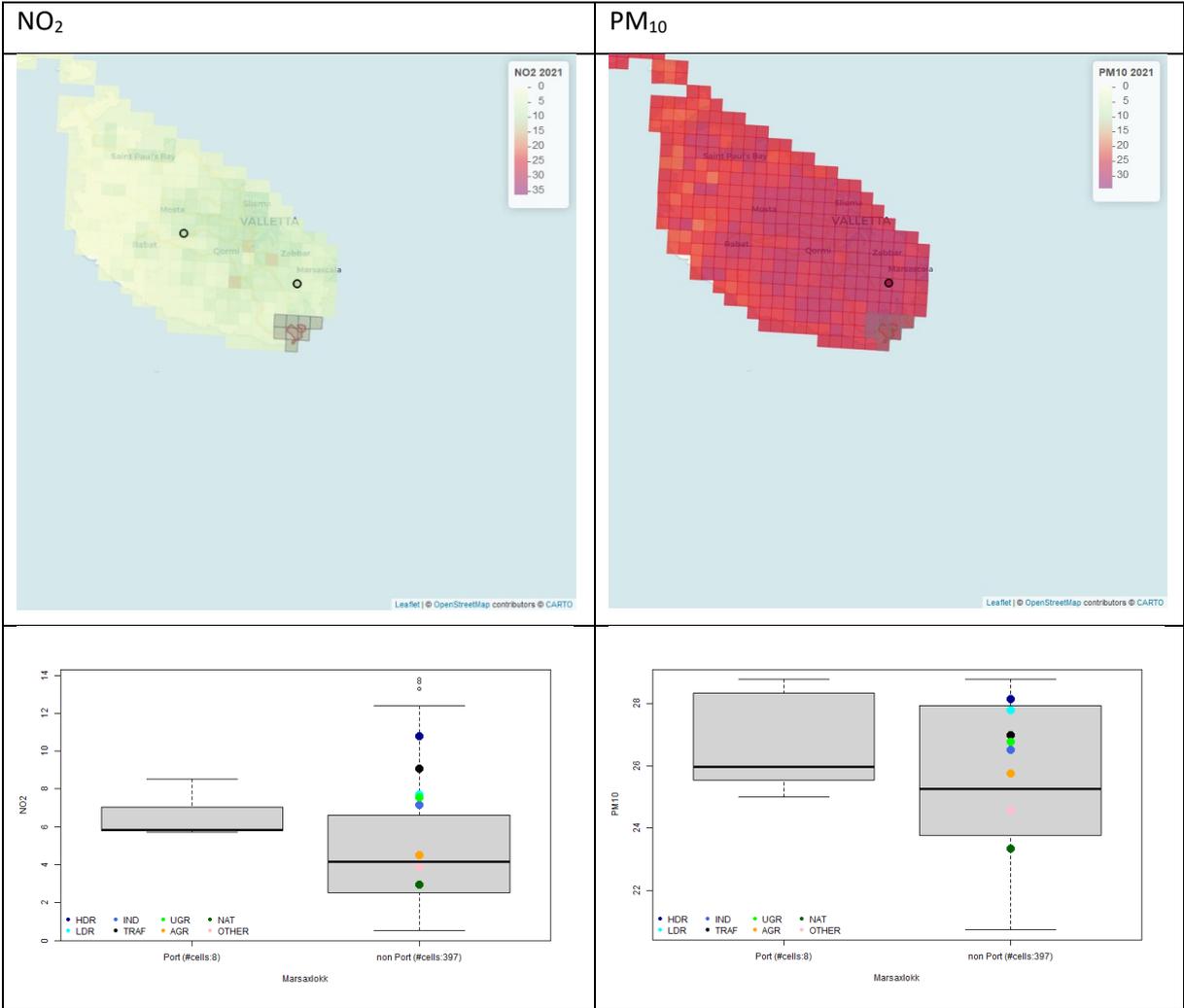


Annex 1.12 Malta Freeport

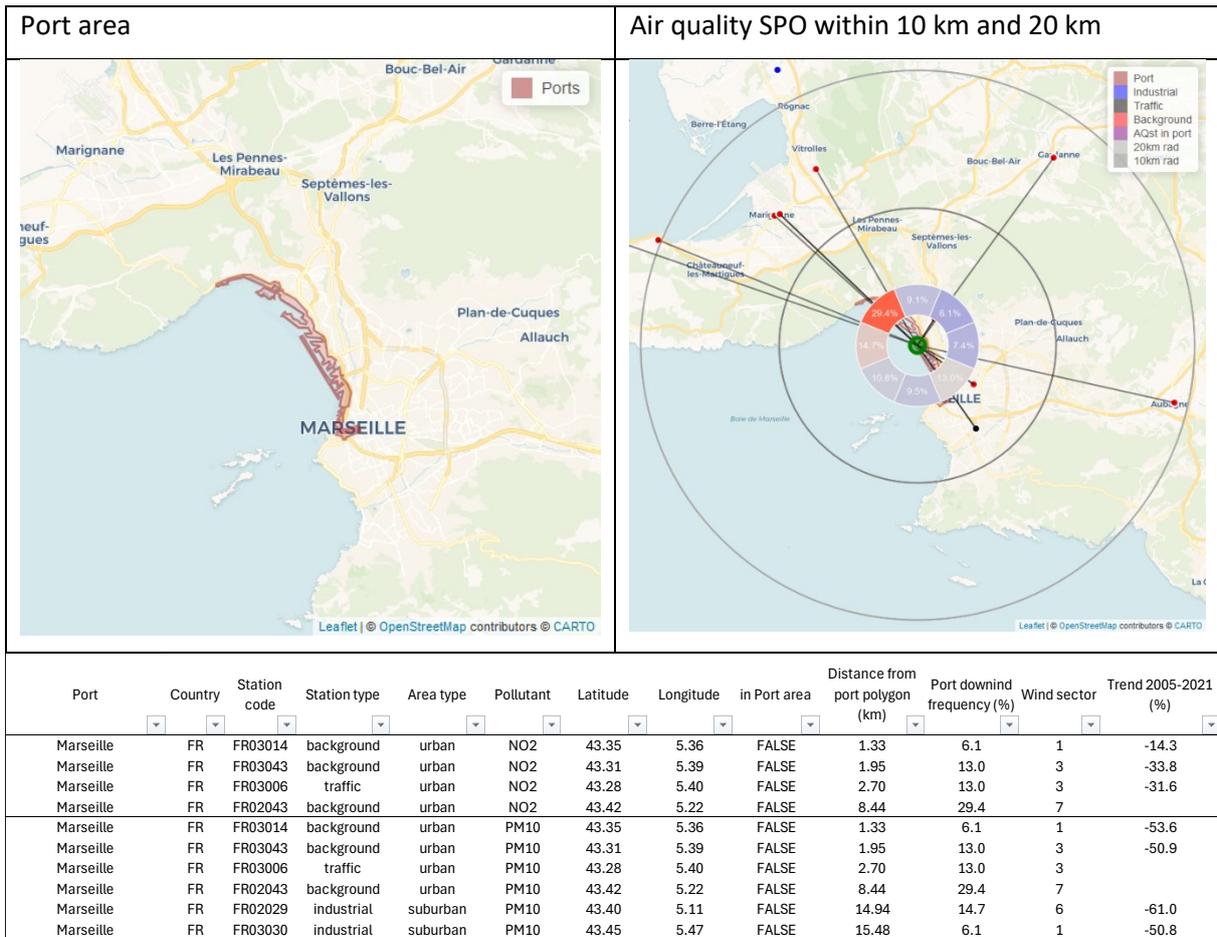


NO₂ concentrations when wind is blowing from the port





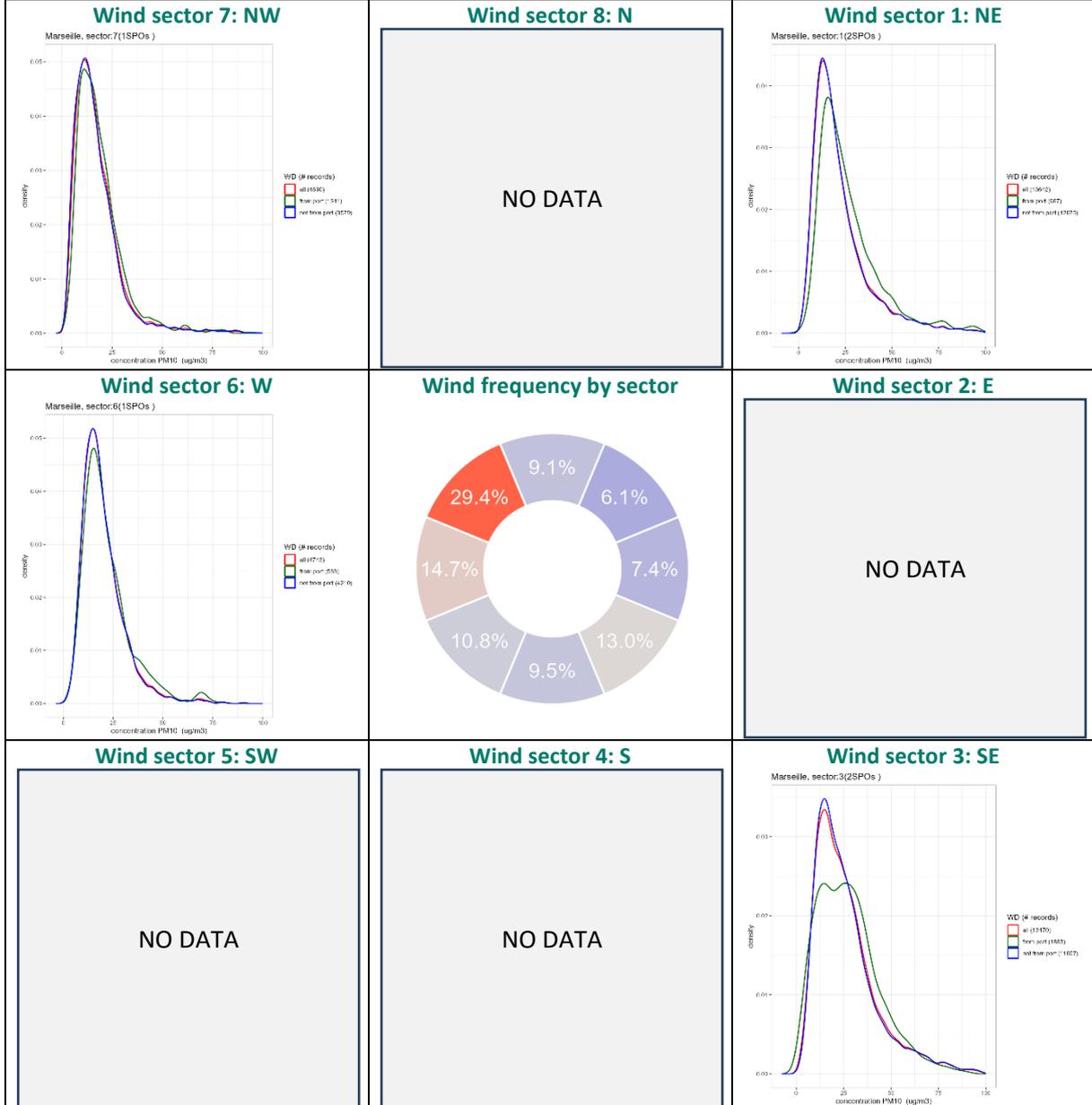
Annex 1.13 Marseille



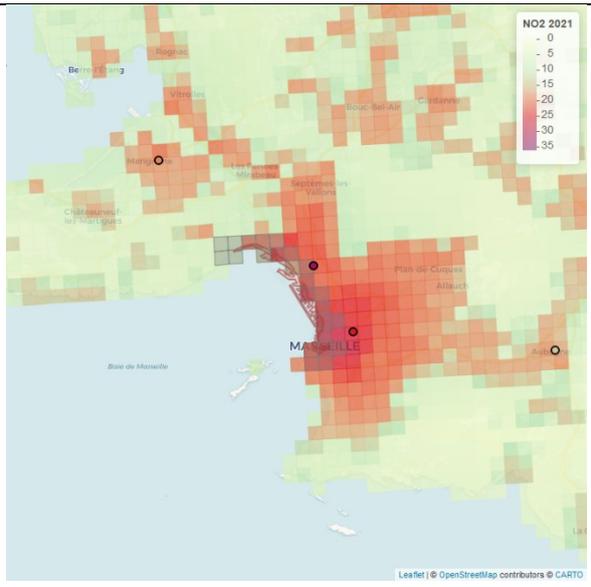
NO₂ concentrations when wind is blowing from the port



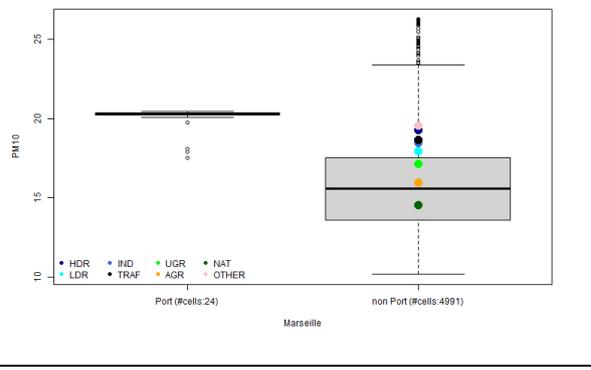
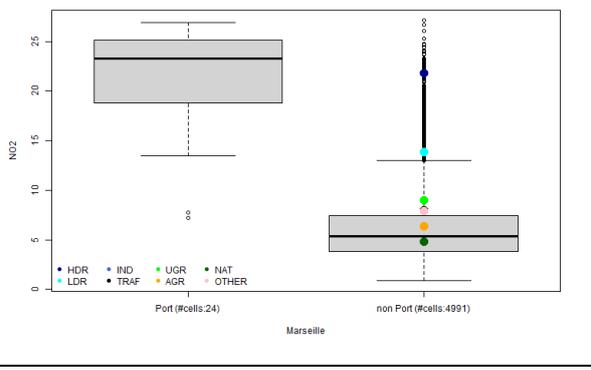
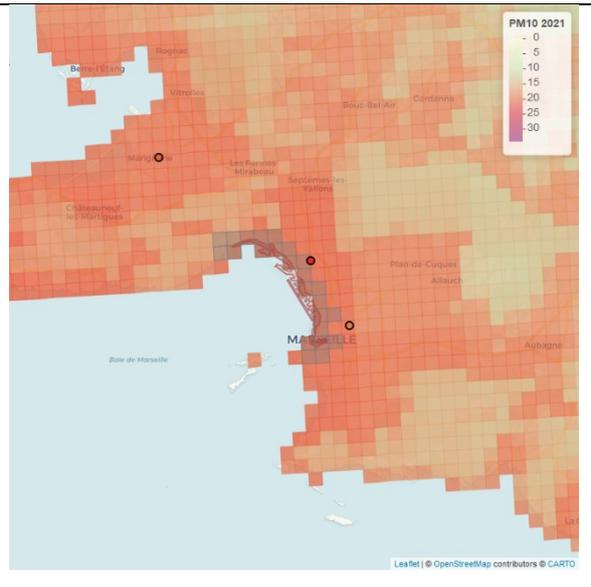
PM₁₀ concentrations when wind is blowing from the port



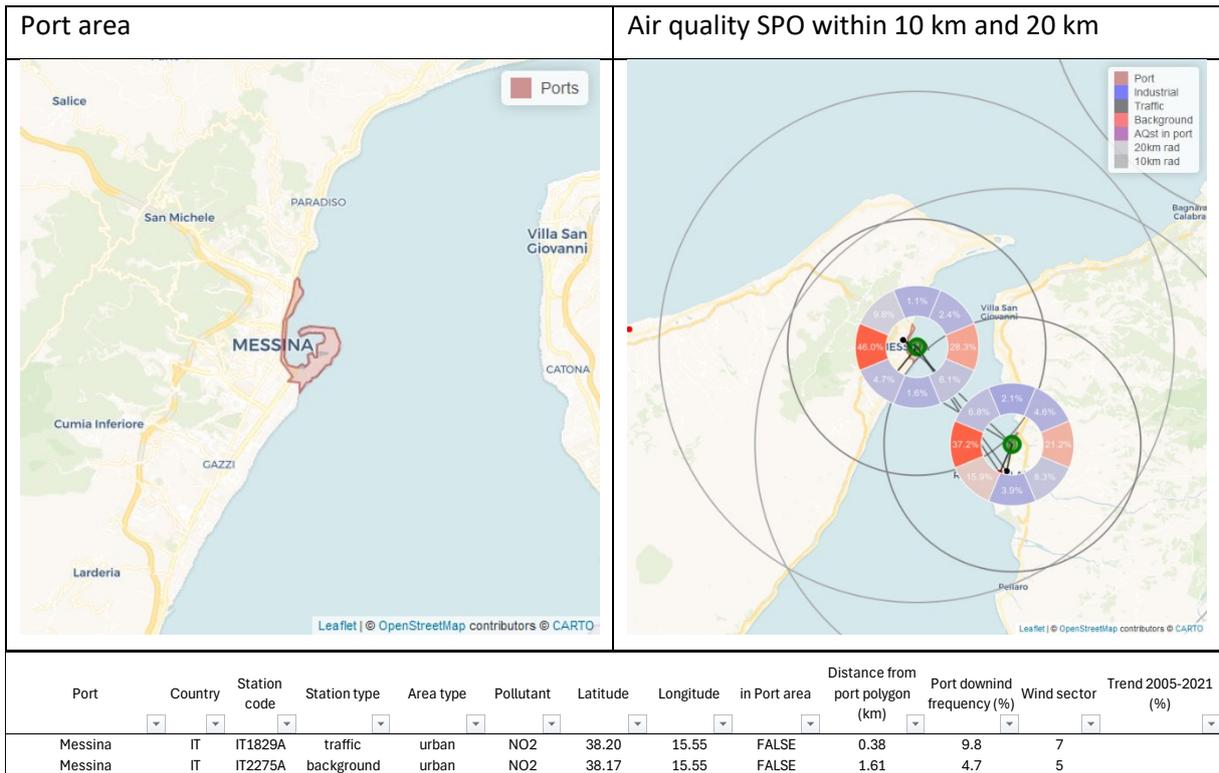
NO₂



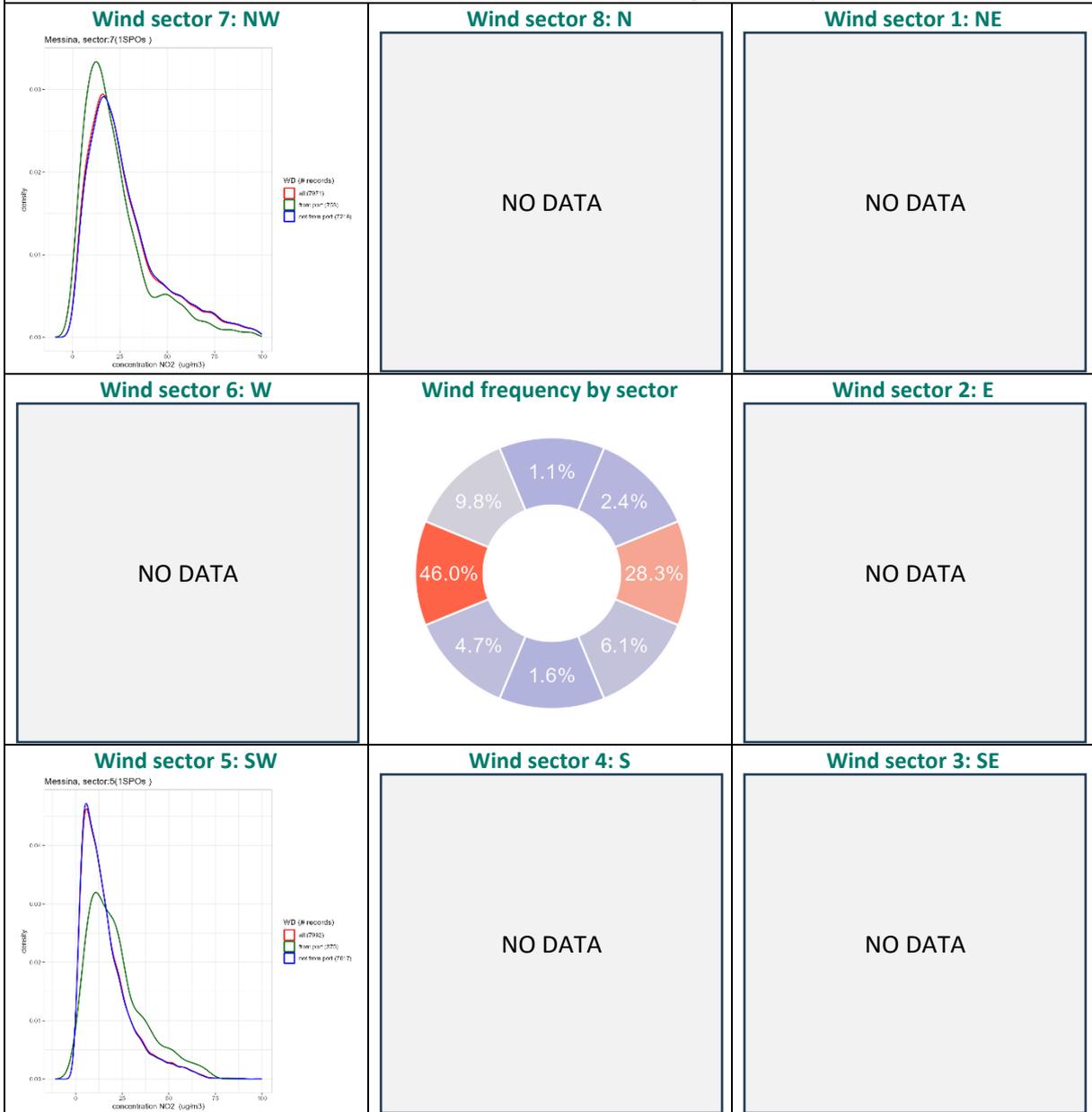
PM₁₀

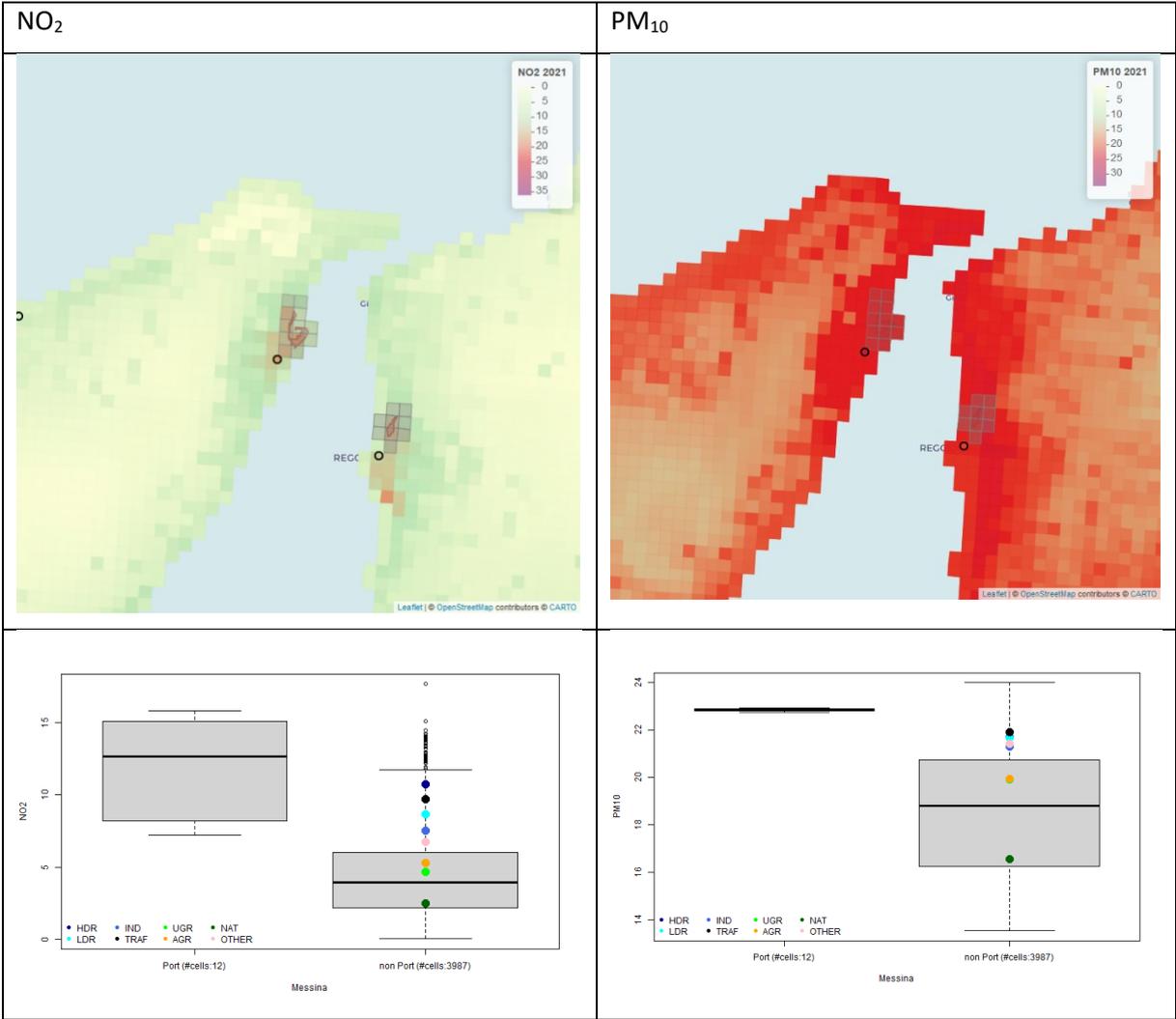


Annex 1.14 Messina

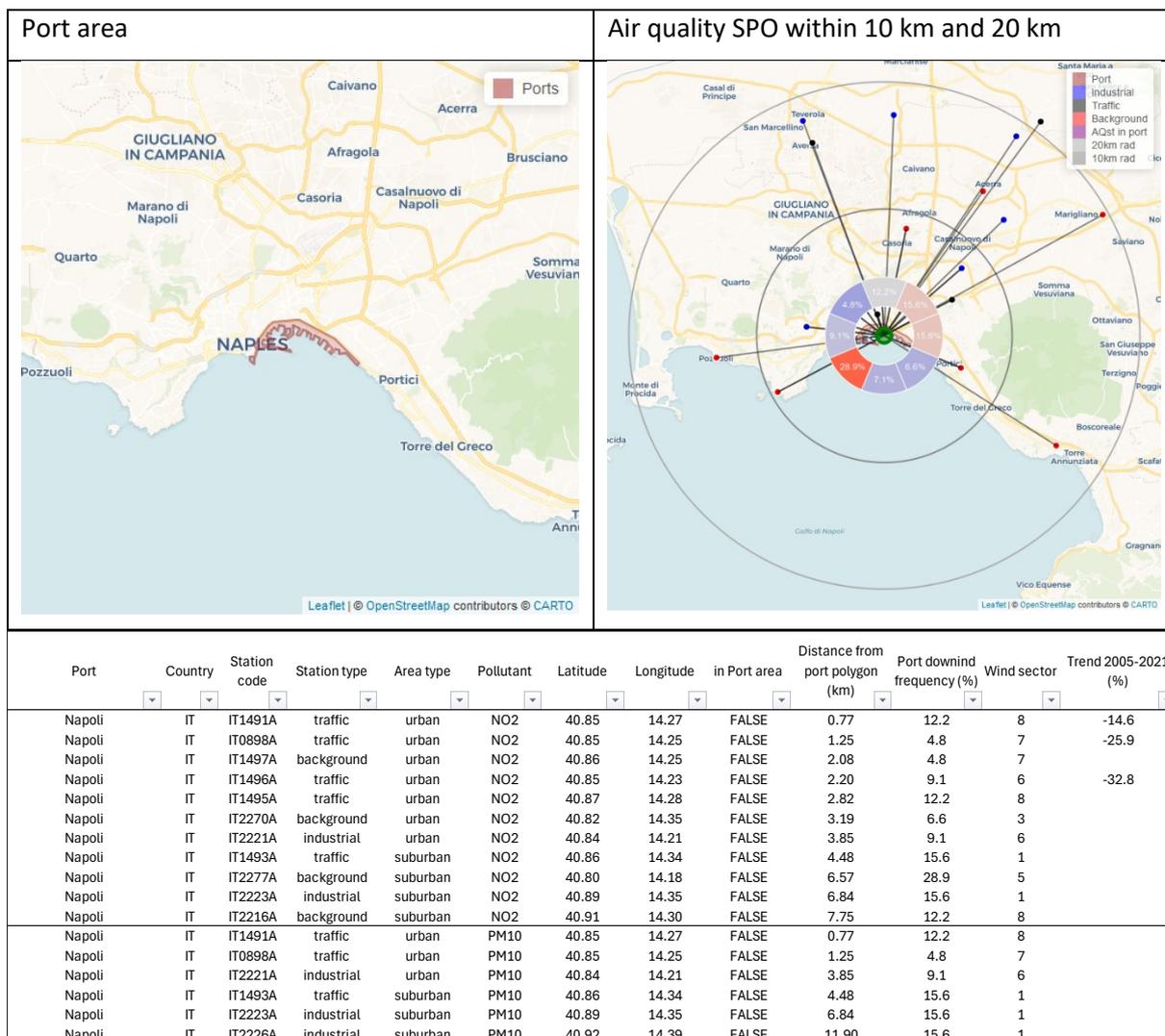


NO₂ concentrations when wind is blowing from the port

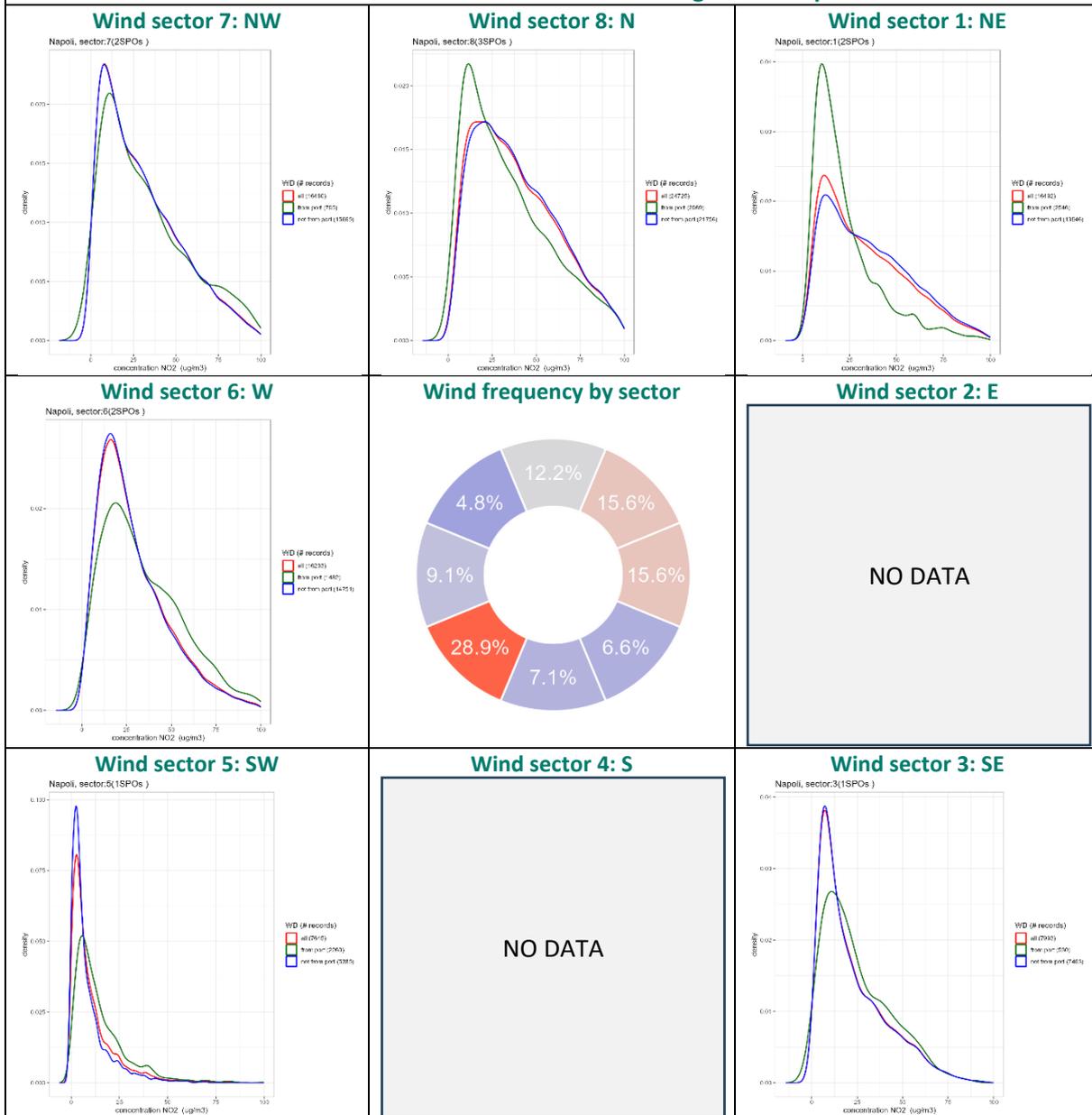




Annex 1.15 Napoli



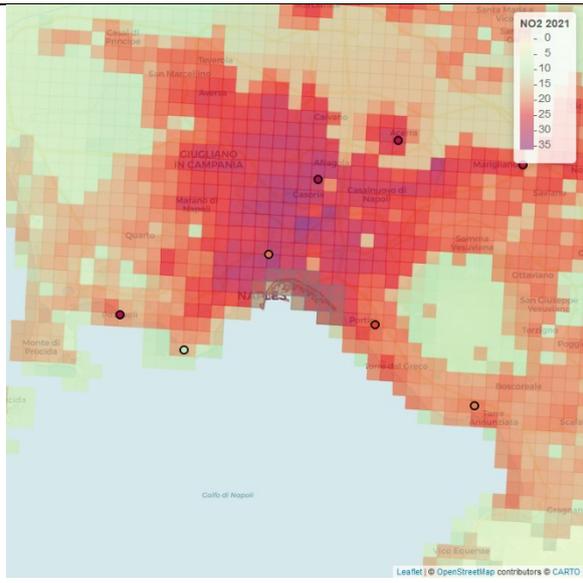
NO₂ concentrations when wind is blowing from the port



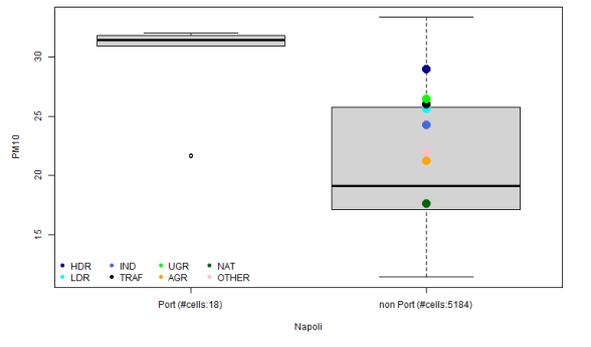
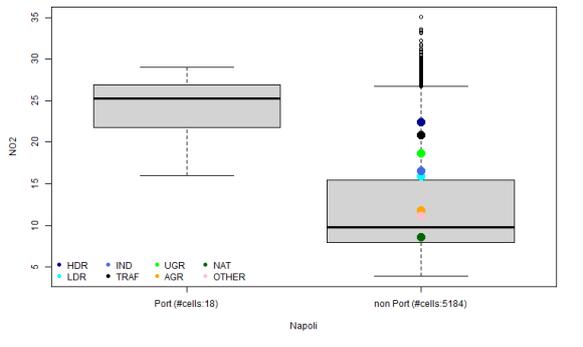
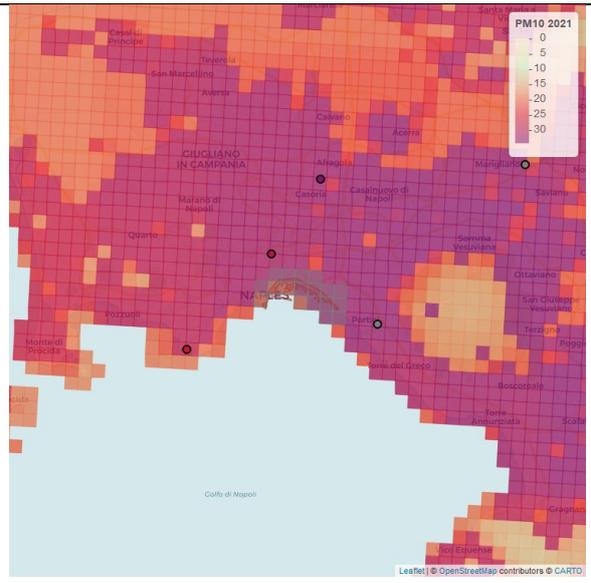
PM₁₀ concentrations when wind is blowing from the port



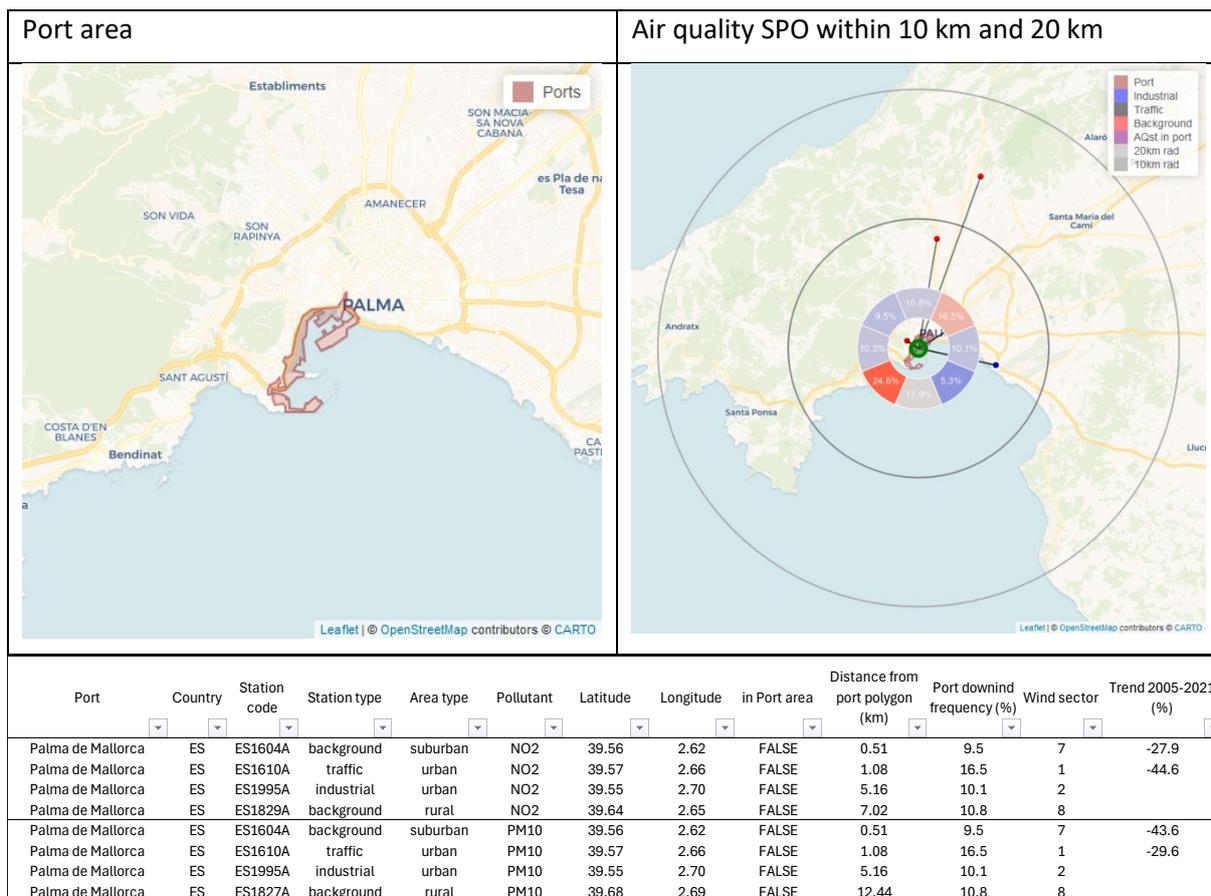
NO₂



PM₁₀



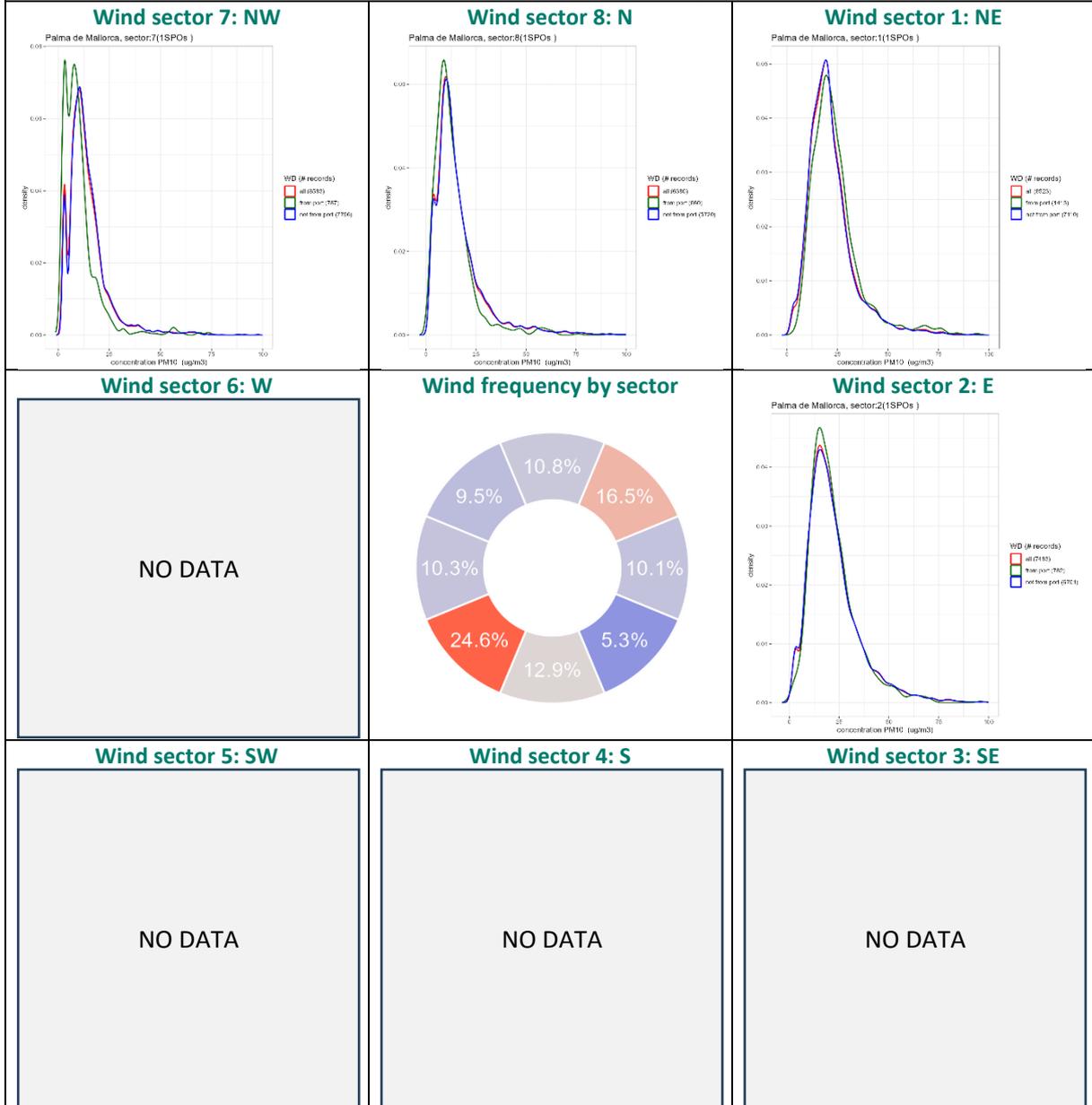
Annex 1.16 Palma de Mallorca

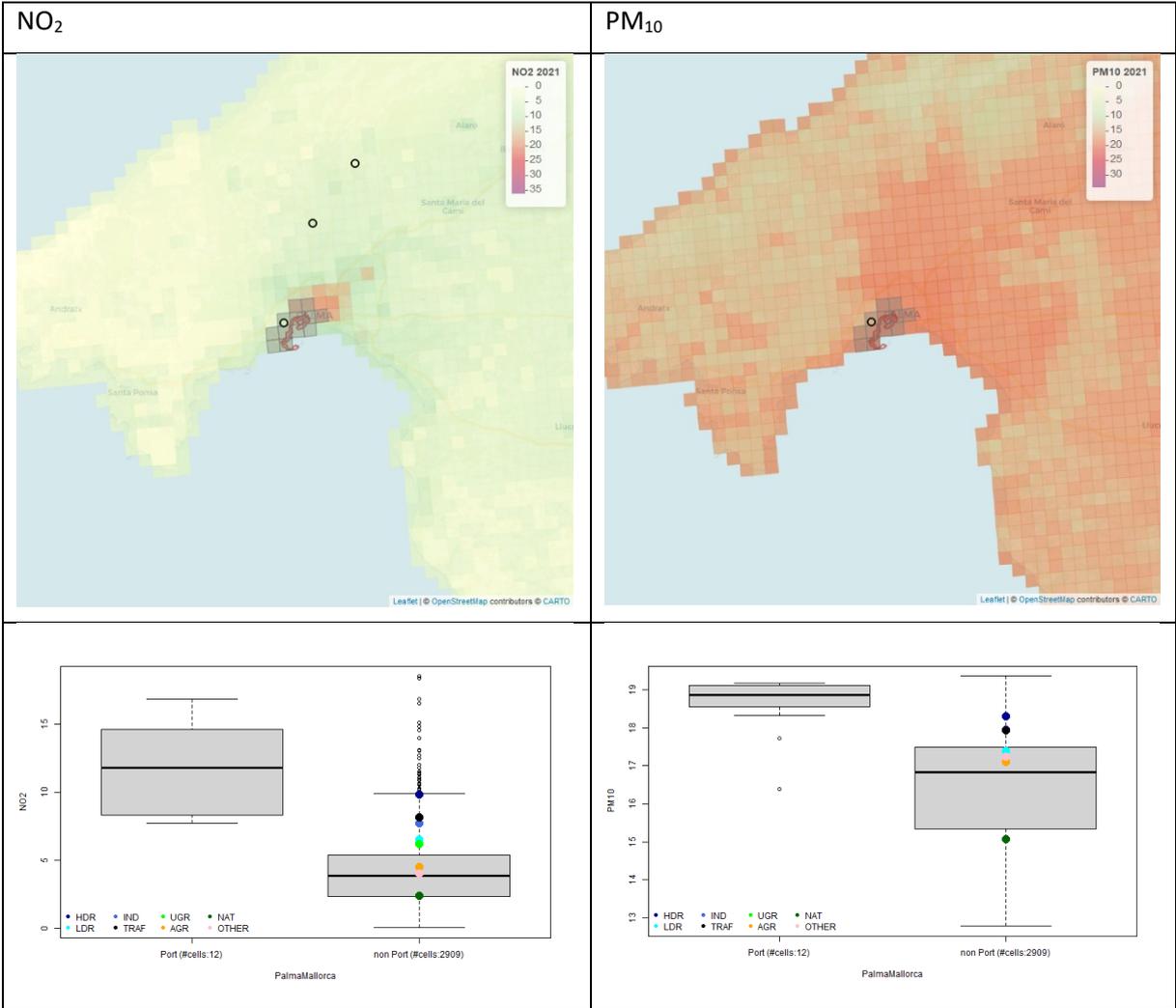


NO₂ concentrations when wind is blowing from the port

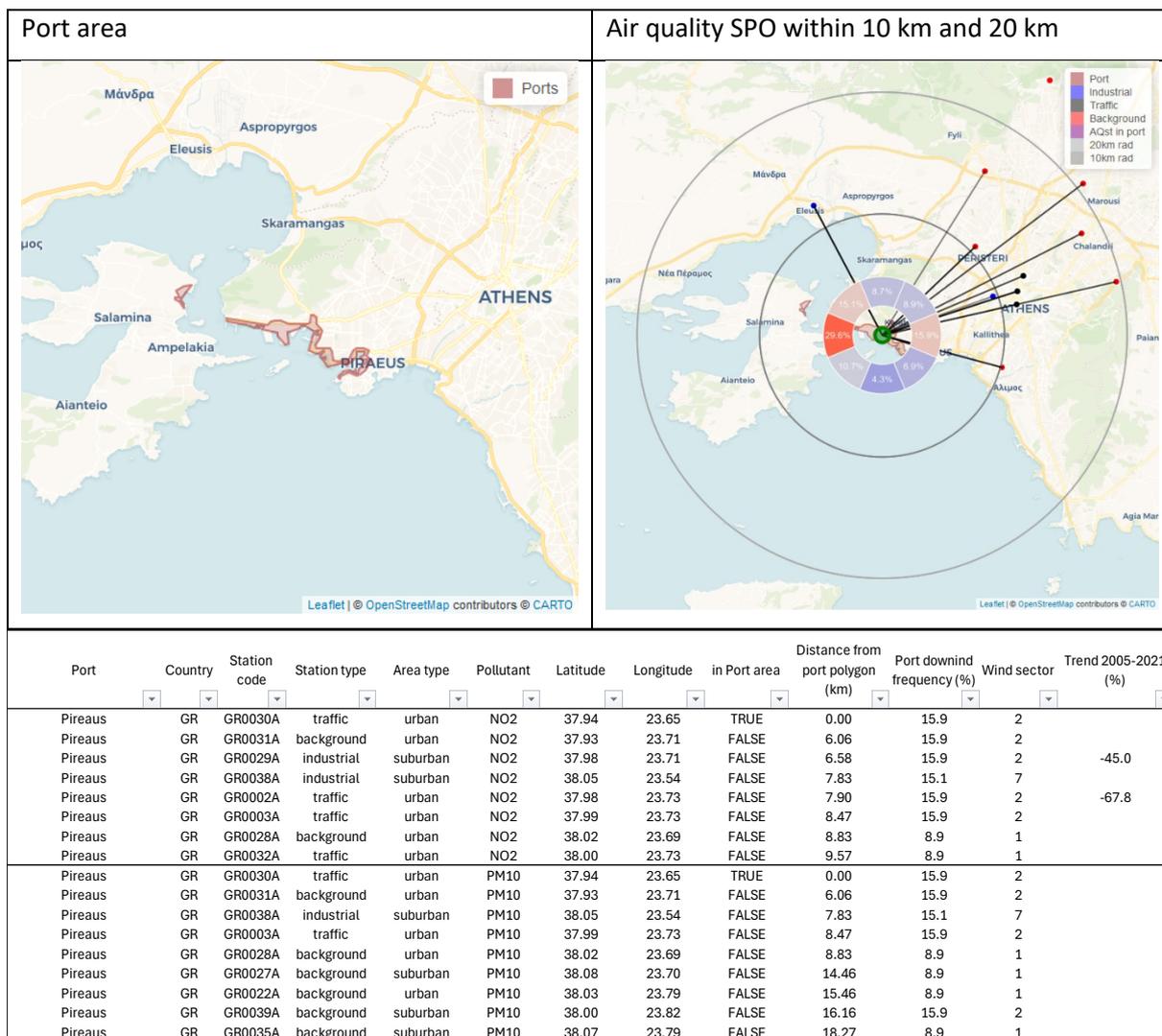


PM₁₀ concentrations when wind is blowing from the port





Annex 1.17 Piraeus



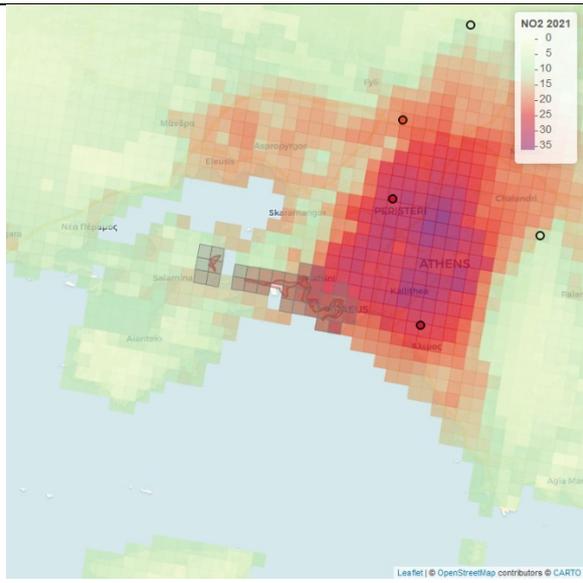
NO₂ concentrations when wind is blowing from the port



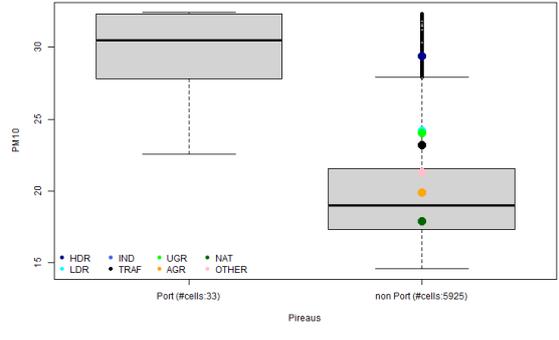
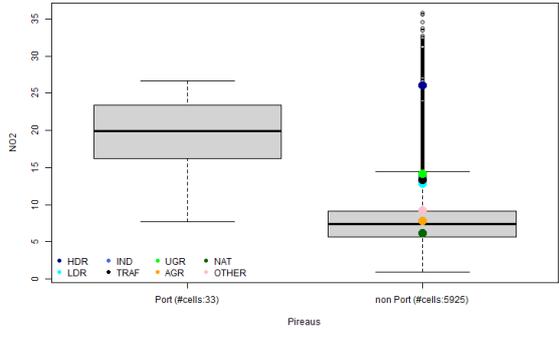
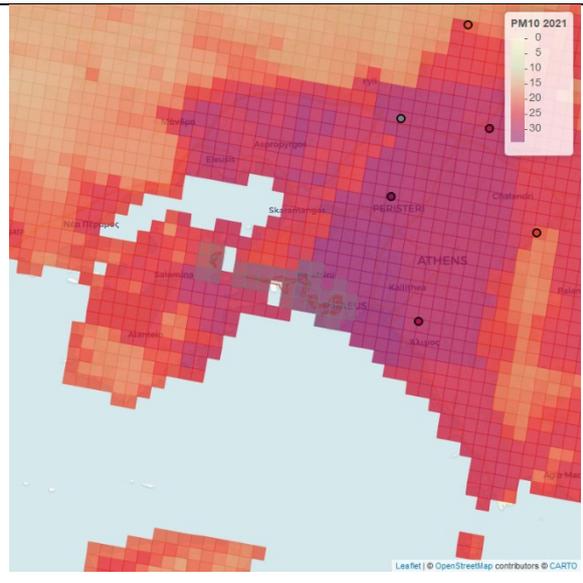
PM₁₀ concentrations when wind is blowing from the port



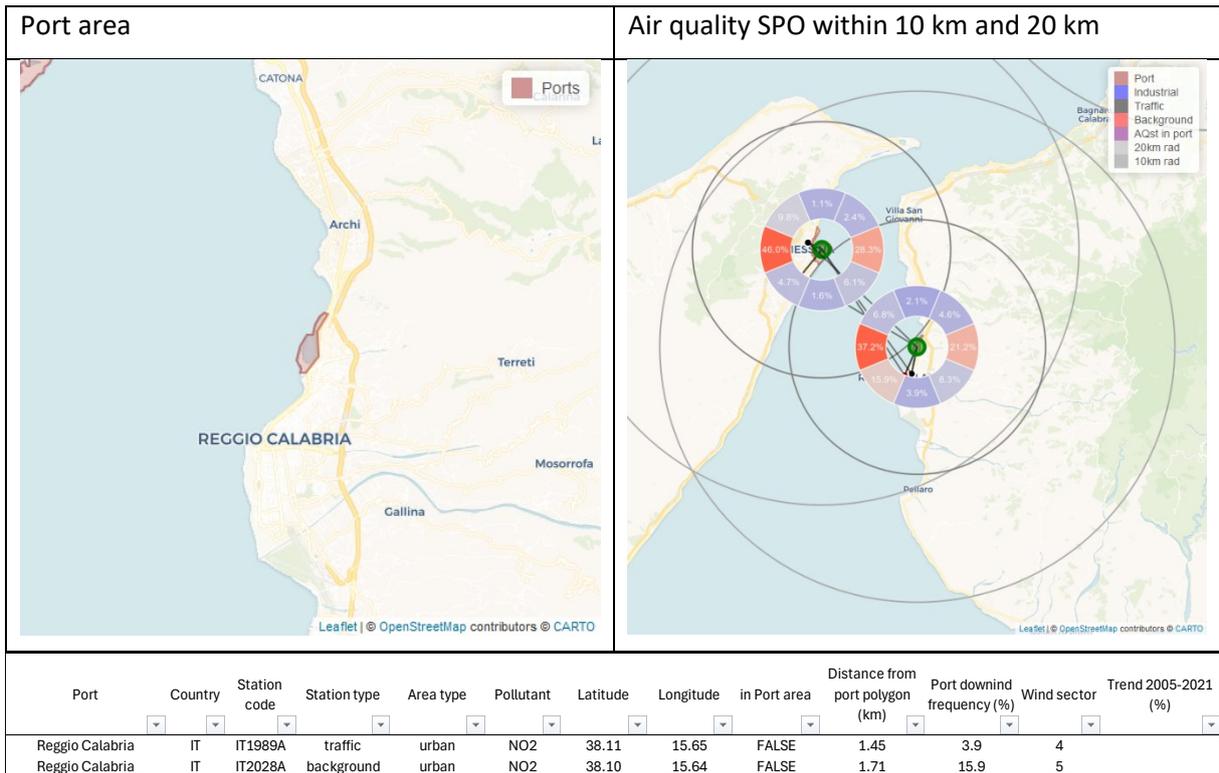
NO₂



PM₁₀

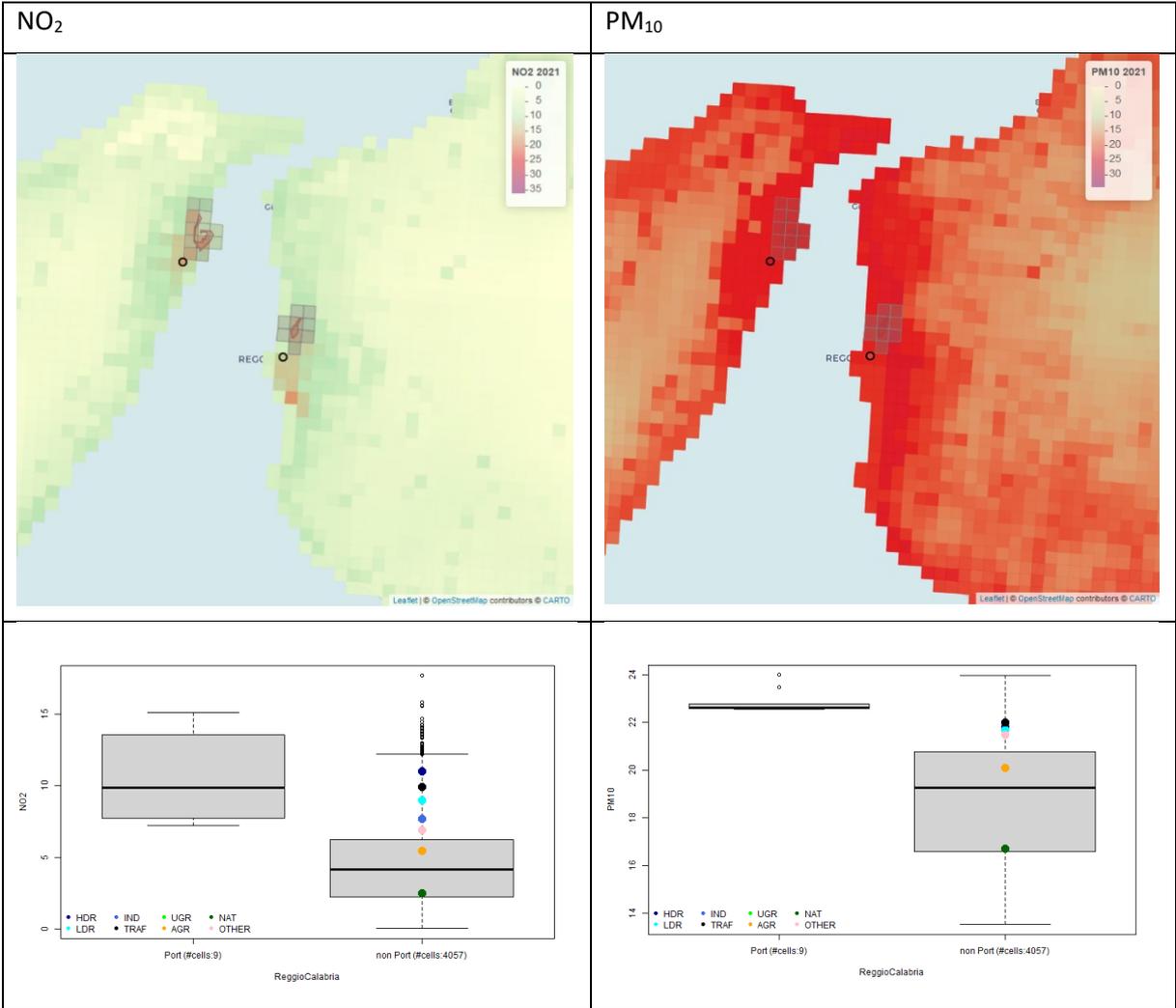


Annex 1.18 Reggio Calabria

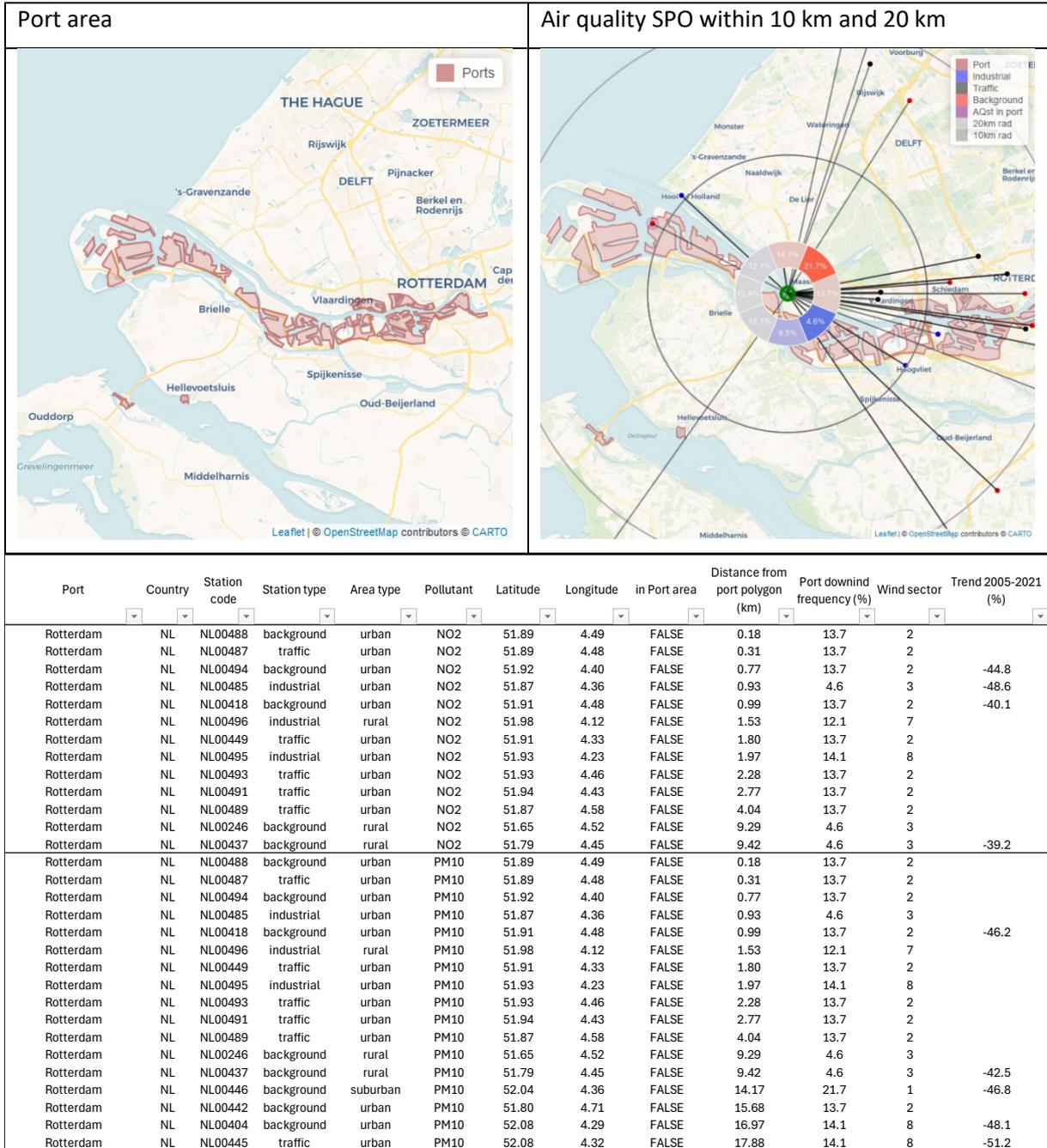


NO₂ concentrations when wind is blowing from the port

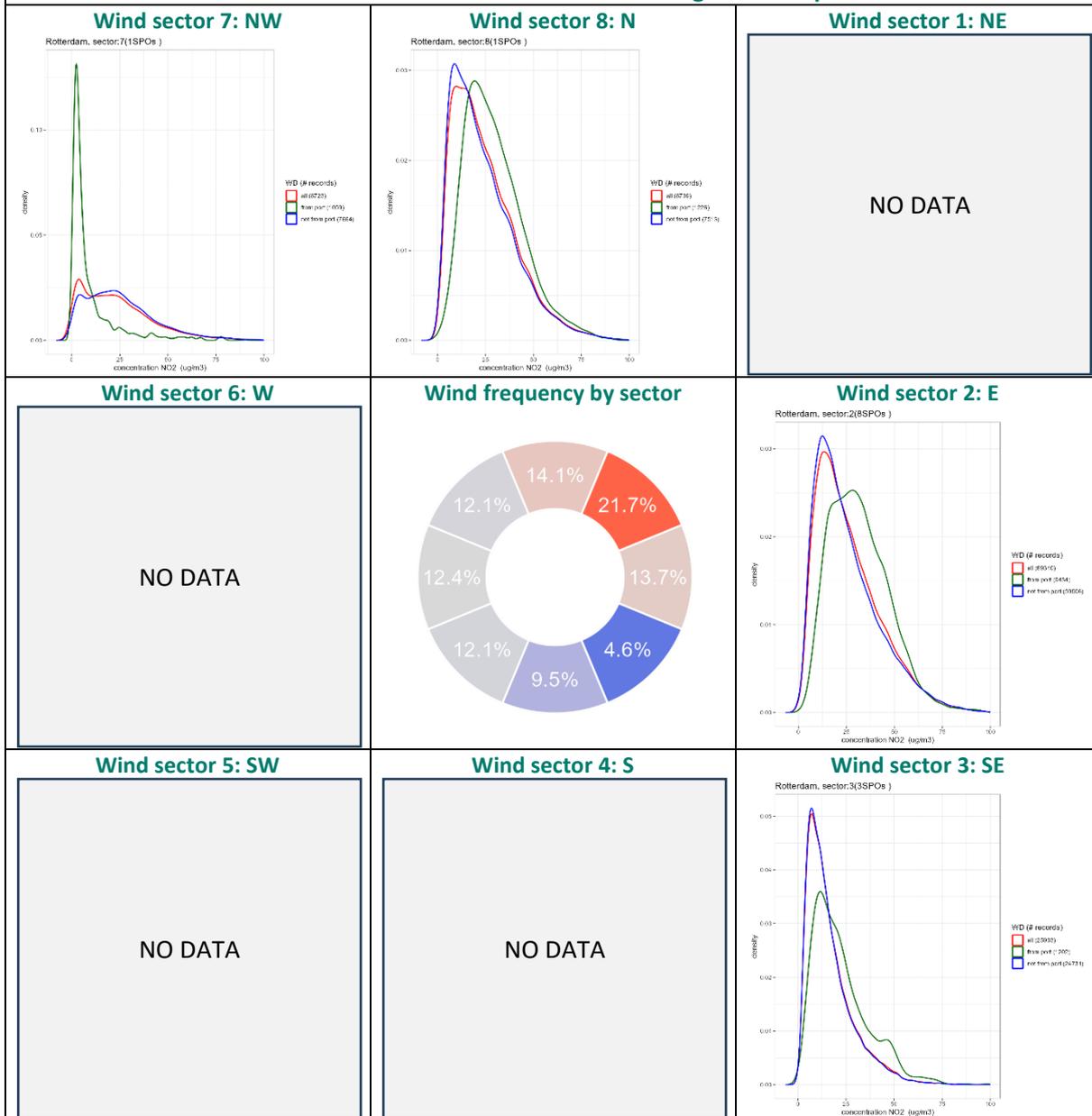




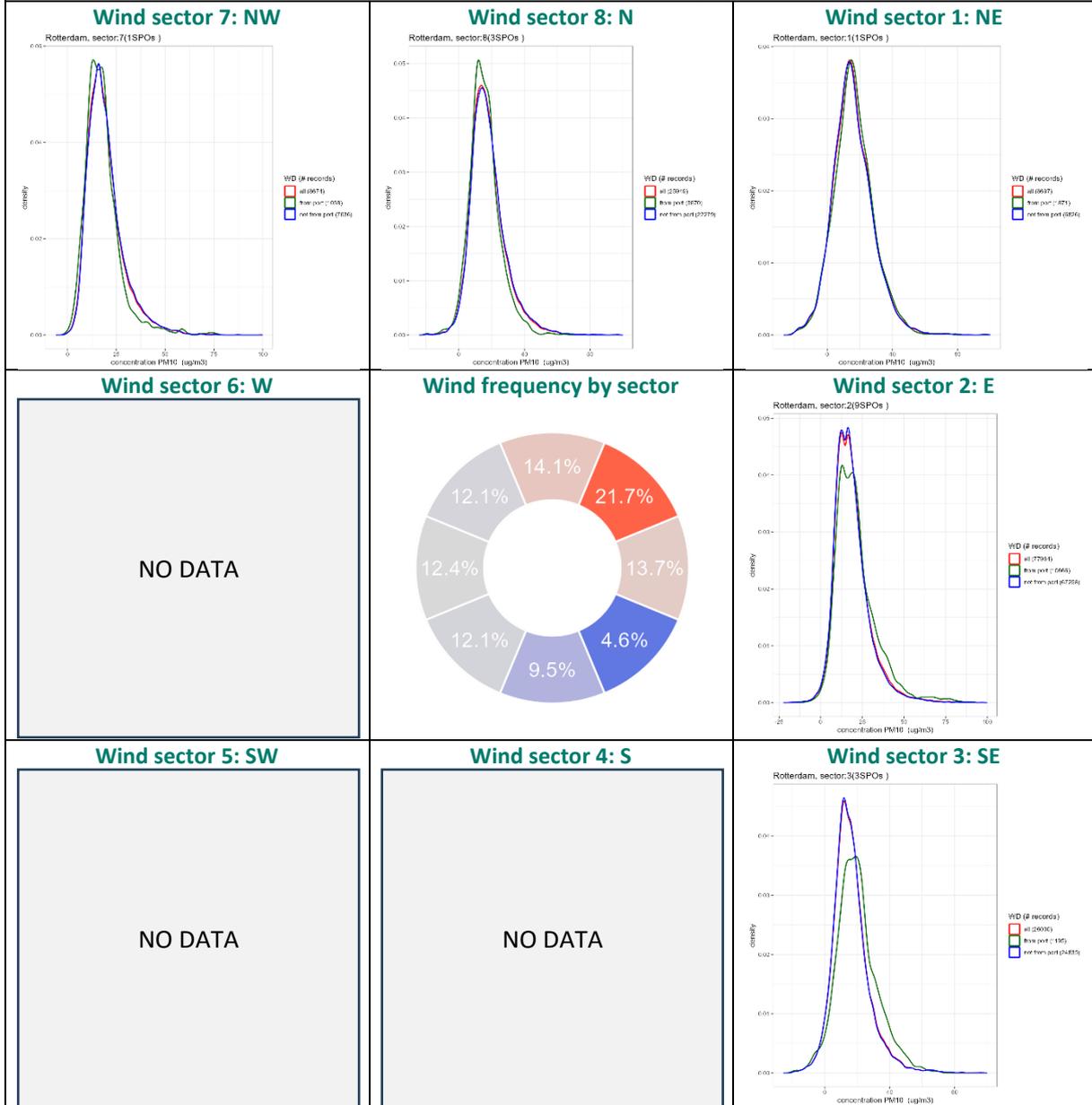
Annex 1.19 Rotterdam



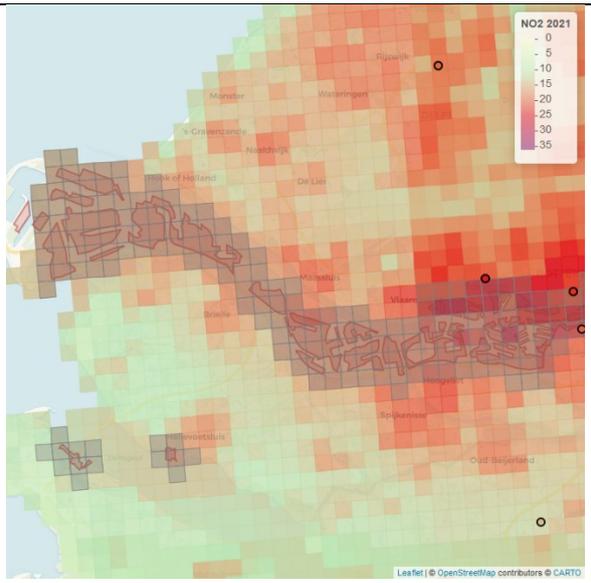
NO₂ concentrations when wind is blowing from the port



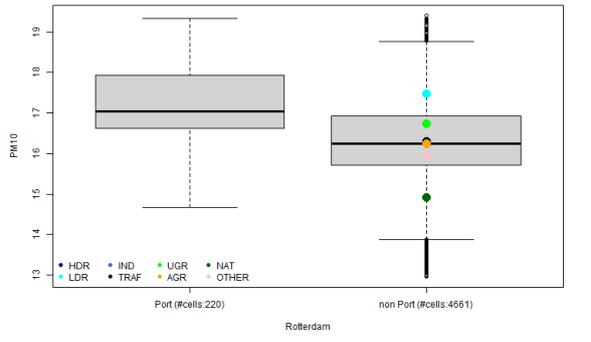
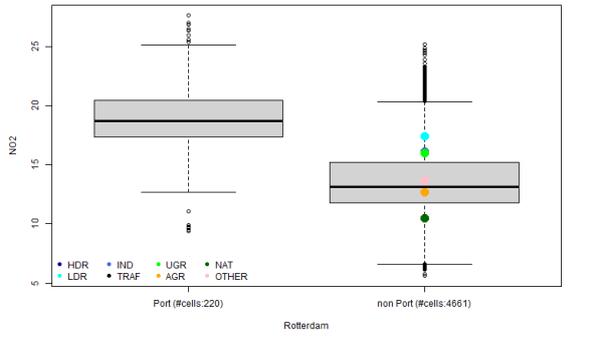
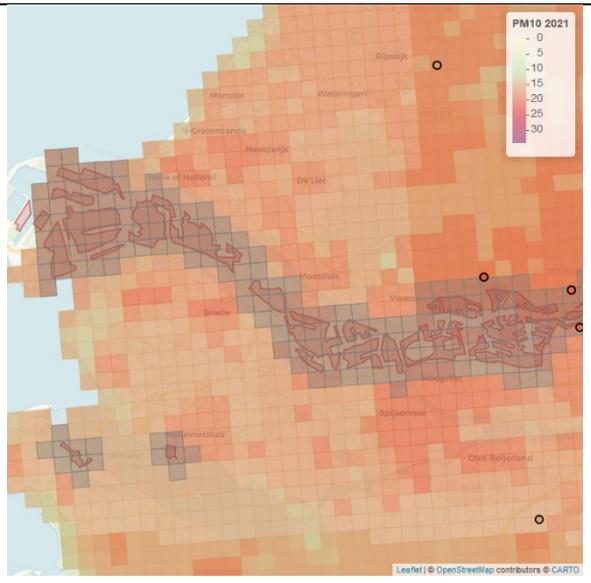
PM₁₀ concentrations when wind is blowing from the port



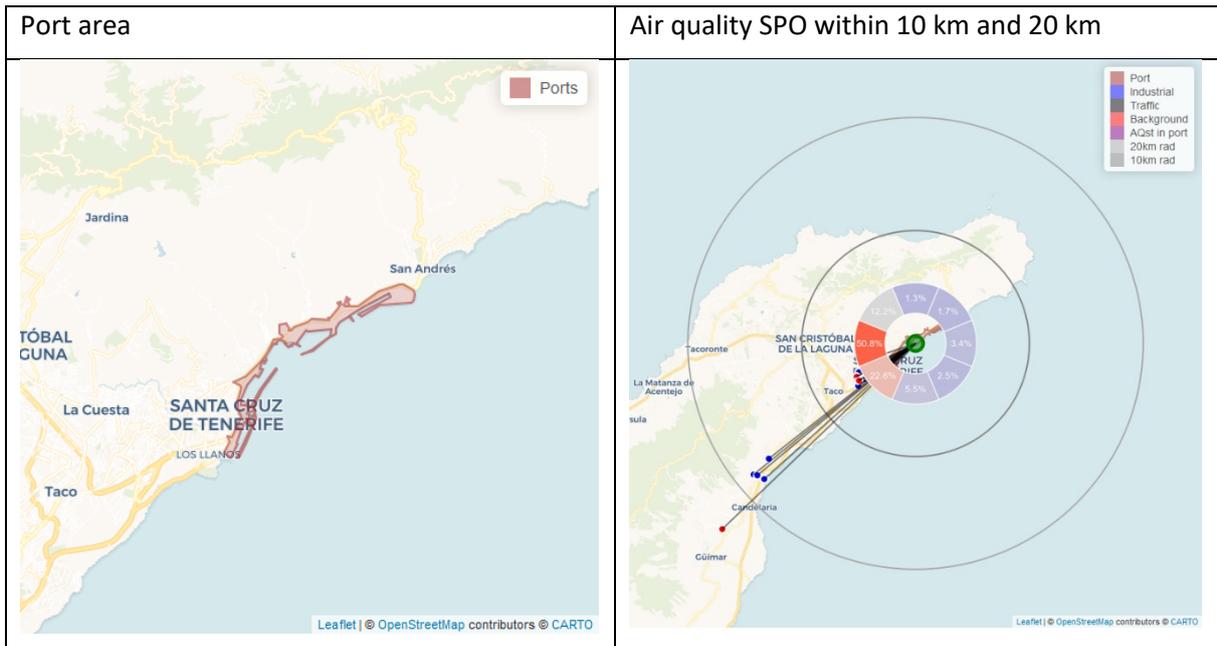
NO₂



PM₁₀



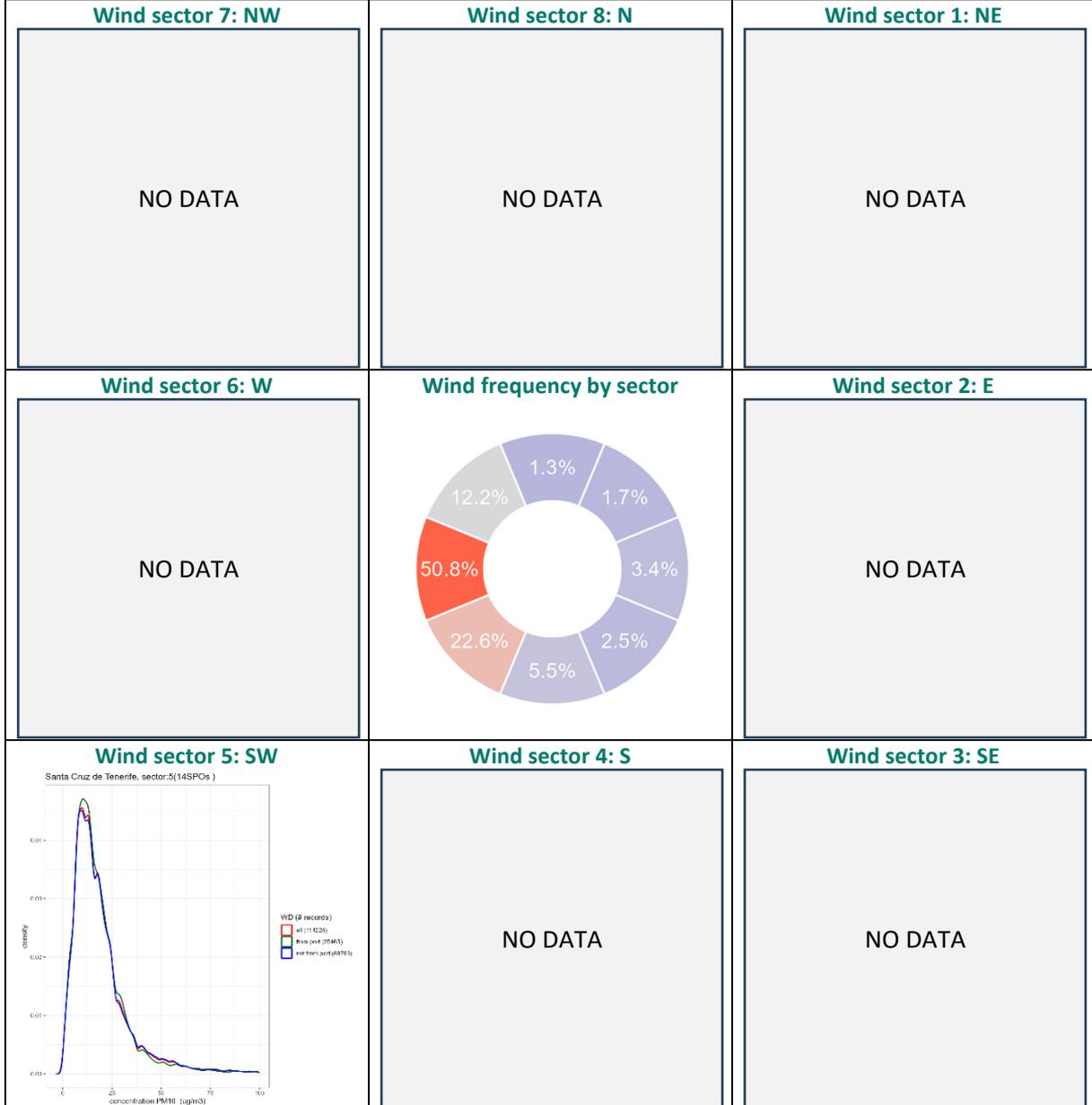
Annex 1.20 Santa Cruz de Tenerife



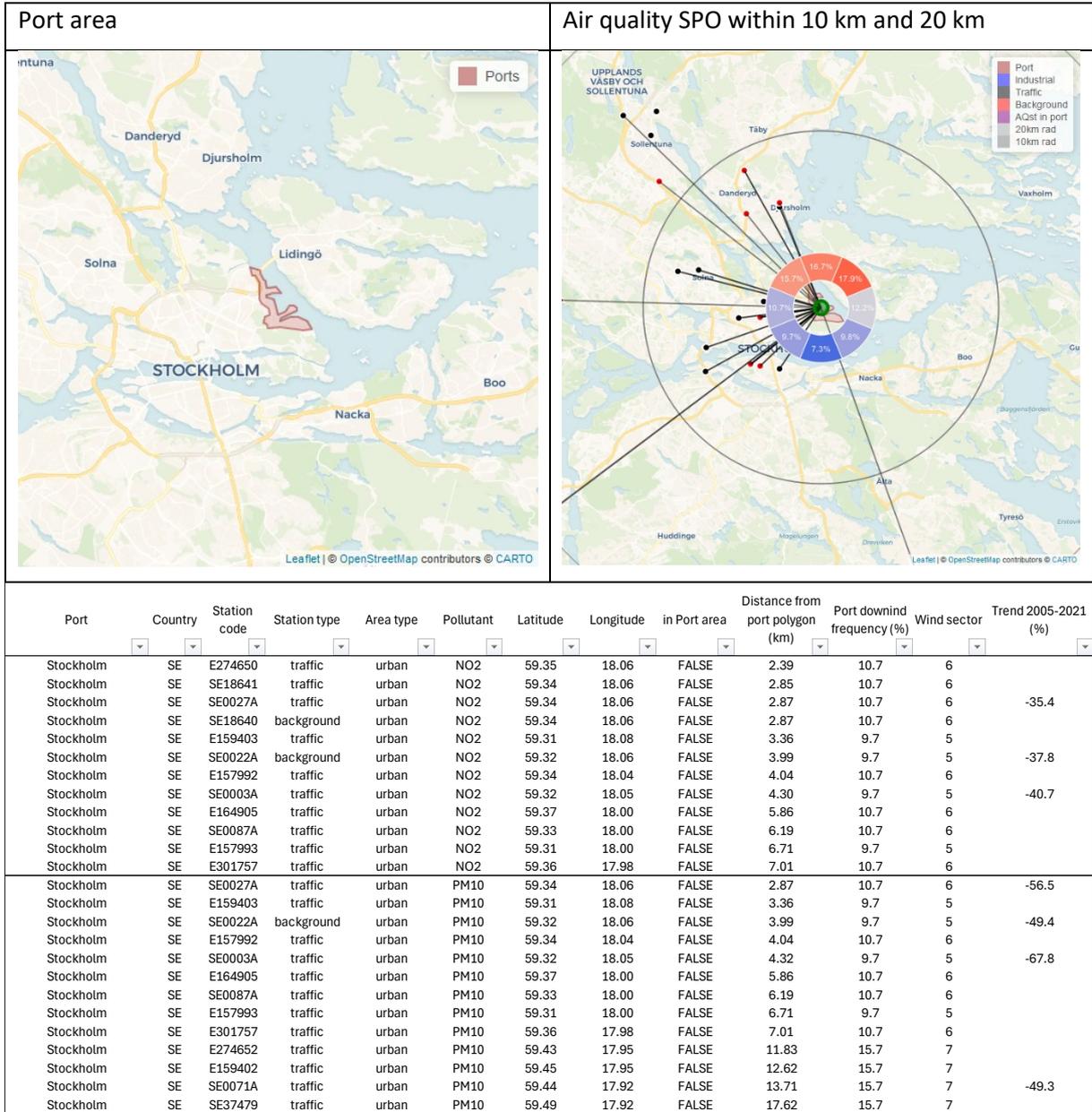
Port	Country	Station code	Station type	Area type	Pollutant	Latitude	Longitude	in Port area	Distance from port polygon (km)	Port downwind frequency (%)	Wind sector	Trend 2005-2021 (%)
Santa Cruz de Tenerife	ES	ES2115A	traffic	urban	NO2	28.46	-16.25	FALSE	0.02	22.6	5	
Santa Cruz de Tenerife	ES	ES2114A	industrial	urban	NO2	28.46	-16.26	FALSE	0.91	22.6	5	
Santa Cruz de Tenerife	ES	ES2000A	industrial	urban	NO2	28.46	-16.26	FALSE	1.14	22.6	5	
Santa Cruz de Tenerife	ES	ES2021A	industrial	urban	NO2	28.46	-16.26	FALSE	1.42	22.6	5	
Santa Cruz de Tenerife	ES	ES2020A	industrial	urban	NO2	28.46	-16.27	FALSE	1.97	22.6	5	
Santa Cruz de Tenerife	ES	ES2003A	background	urban	NO2	28.46	-16.28	FALSE	2.46	22.6	5	
Santa Cruz de Tenerife	ES	ES1976A	industrial	urban	NO2	28.46	-16.28	FALSE	2.50	22.6	5	
Santa Cruz de Tenerife	ES	ES1759A	industrial	urban	NO2	28.45	-16.28	FALSE	2.63	22.6	5	
Santa Cruz de Tenerife	ES	ES1975A	background	urban	NO2	28.46	-16.28	FALSE	2.65	22.6	5	
Santa Cruz de Tenerife	ES	ES1131A	industrial	urban	PM10	28.46	-16.26	FALSE	1.12	22.6	5	
Santa Cruz de Tenerife	ES	ES2000A	industrial	urban	PM10	28.46	-16.26	FALSE	1.14	22.6	5	
Santa Cruz de Tenerife	ES	ES2021A	industrial	urban	PM10	28.46	-16.26	FALSE	1.42	22.6	5	
Santa Cruz de Tenerife	ES	ES2038A	industrial	urban	PM10	28.46	-16.27	FALSE	1.83	22.6	5	
Santa Cruz de Tenerife	ES	ES2020A	industrial	urban	PM10	28.46	-16.27	FALSE	1.97	22.6	5	
Santa Cruz de Tenerife	ES	ES2003A	background	urban	PM10	28.46	-16.28	FALSE	2.46	22.6	5	
Santa Cruz de Tenerife	ES	ES1976A	industrial	urban	PM10	28.46	-16.28	FALSE	2.50	22.6	5	
Santa Cruz de Tenerife	ES	ES1759A	industrial	urban	PM10	28.45	-16.28	FALSE	2.63	22.6	5	
Santa Cruz de Tenerife	ES	ES1975A	background	urban	PM10	28.46	-16.28	FALSE	2.65	22.6	5	
Santa Cruz de Tenerife	ES	ES1772A	industrial	suburban	PM10	28.39	-16.36	FALSE	12.57	22.6	5	
Santa Cruz de Tenerife	ES	ES1756A	industrial	urban	PM10	28.38	-16.36	FALSE	13.99	22.6	5	
Santa Cruz de Tenerife	ES	ES2022A	industrial	suburban	PM10	28.38	-16.37	FALSE	14.24	22.6	5	
Santa Cruz de Tenerife	ES	ES1764A	industrial	suburban	PM10	28.38	-16.37	FALSE	14.51	22.6	5	
Santa Cruz de Tenerife	ES	ES1920A	background	suburban	PM10	28.34	-16.40	FALSE	19.66	22.6	5	56.7



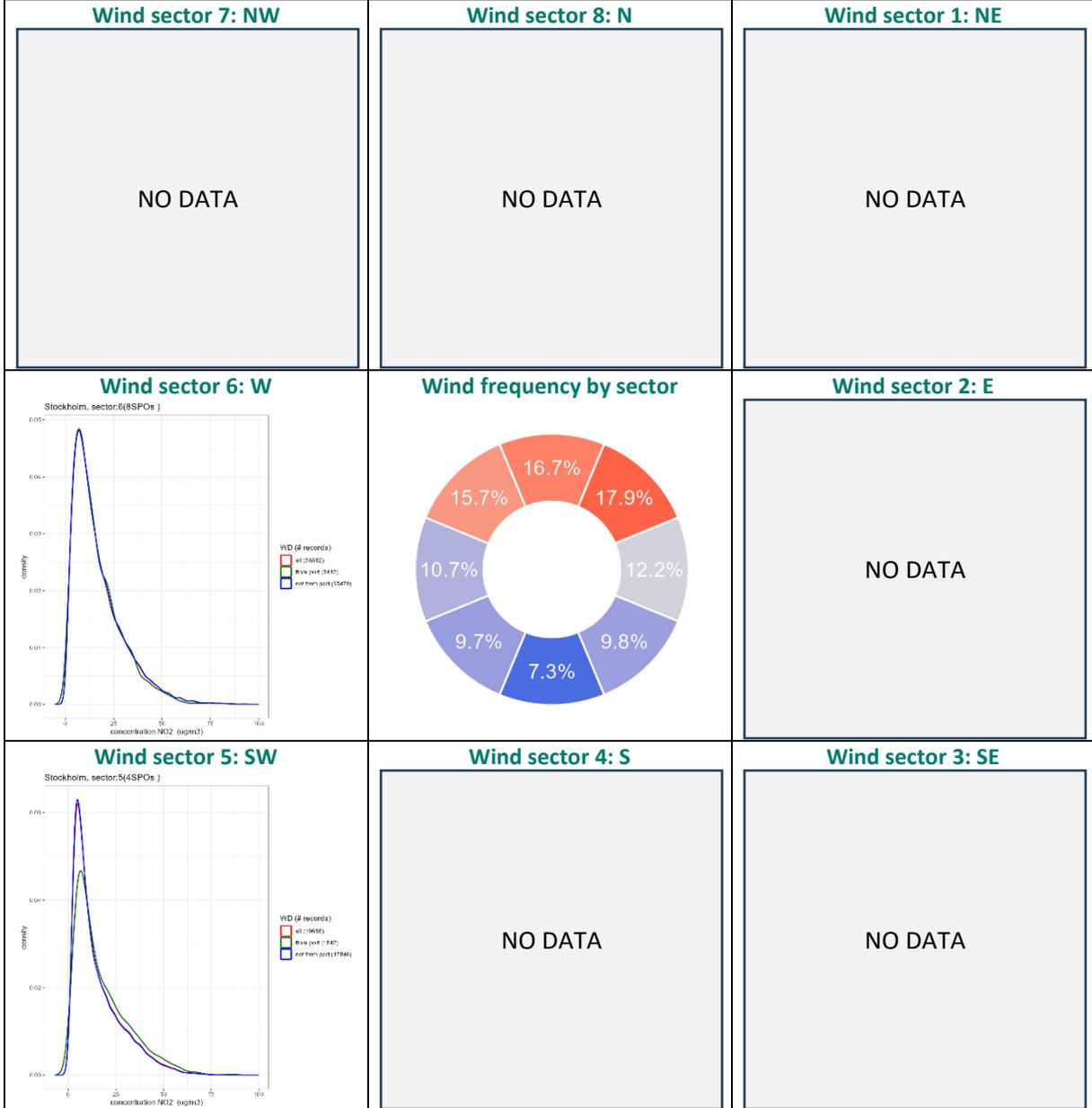
PM₁₀ concentrations when wind is blowing from the port



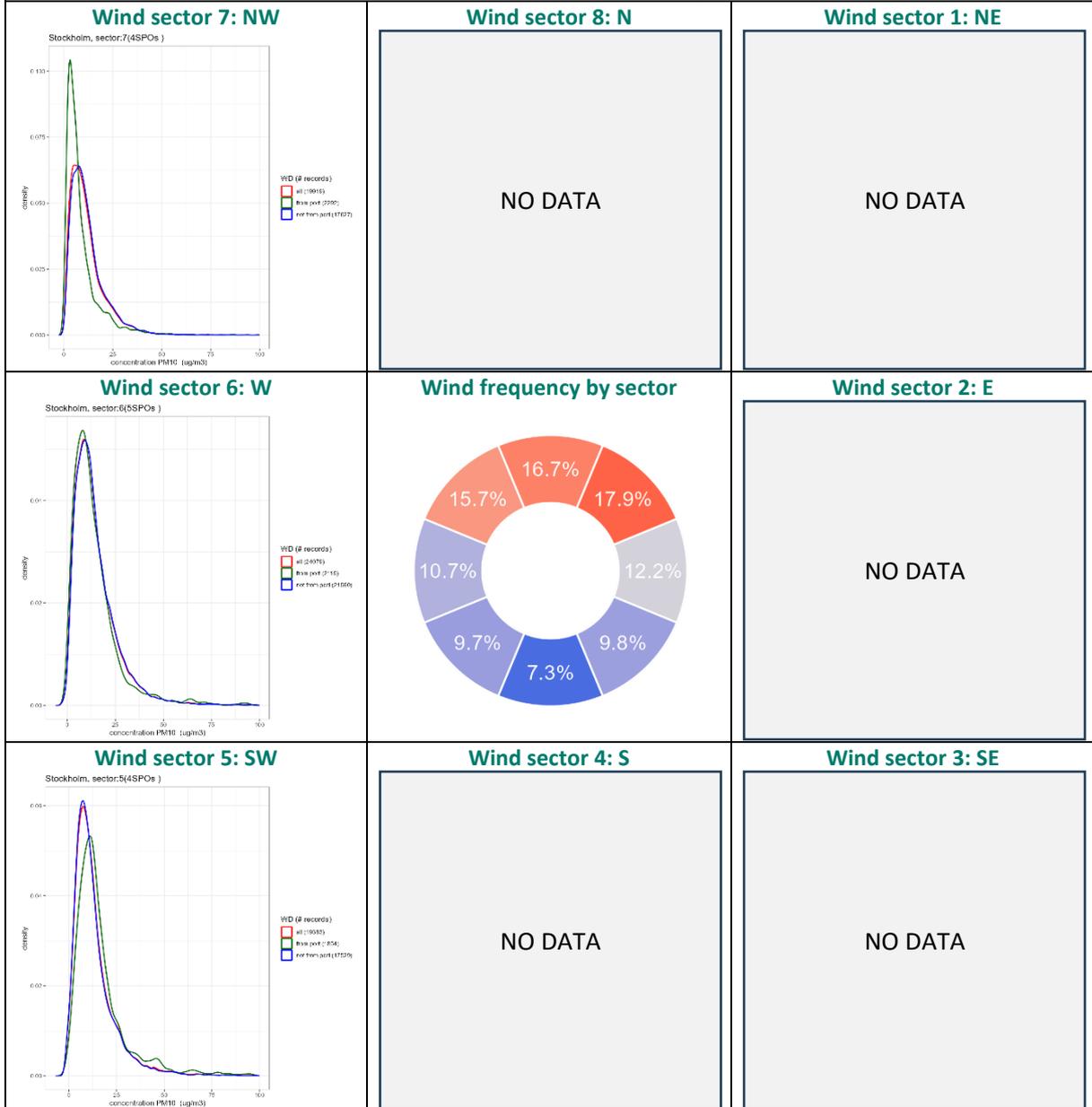
Annex 1.21 Stockholm



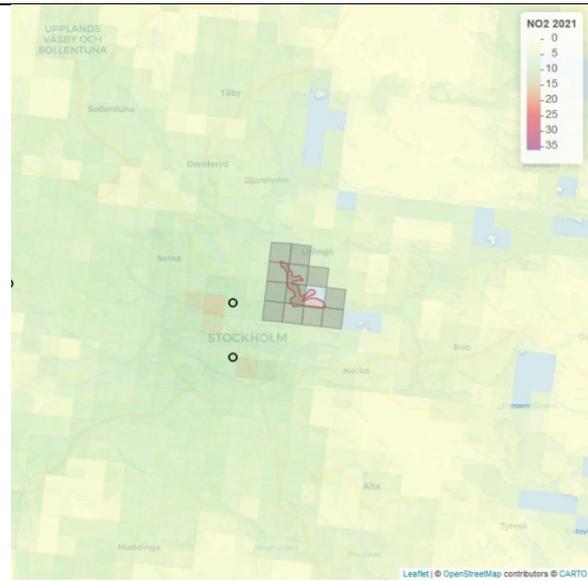
NO₂ concentrations when wind is blowing from the port



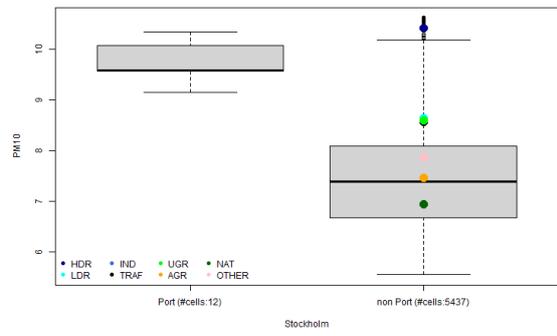
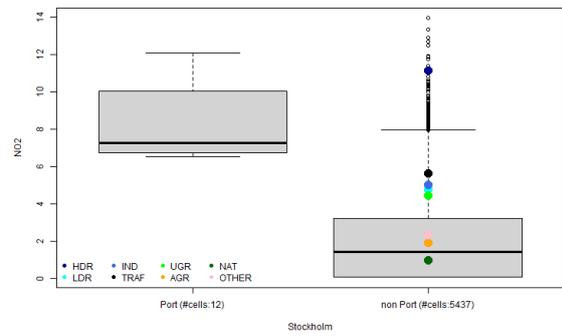
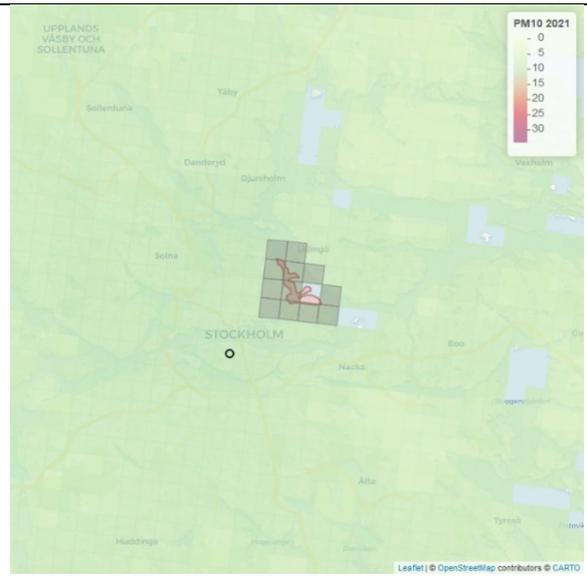
PM₁₀ concentrations when wind is blowing from the port



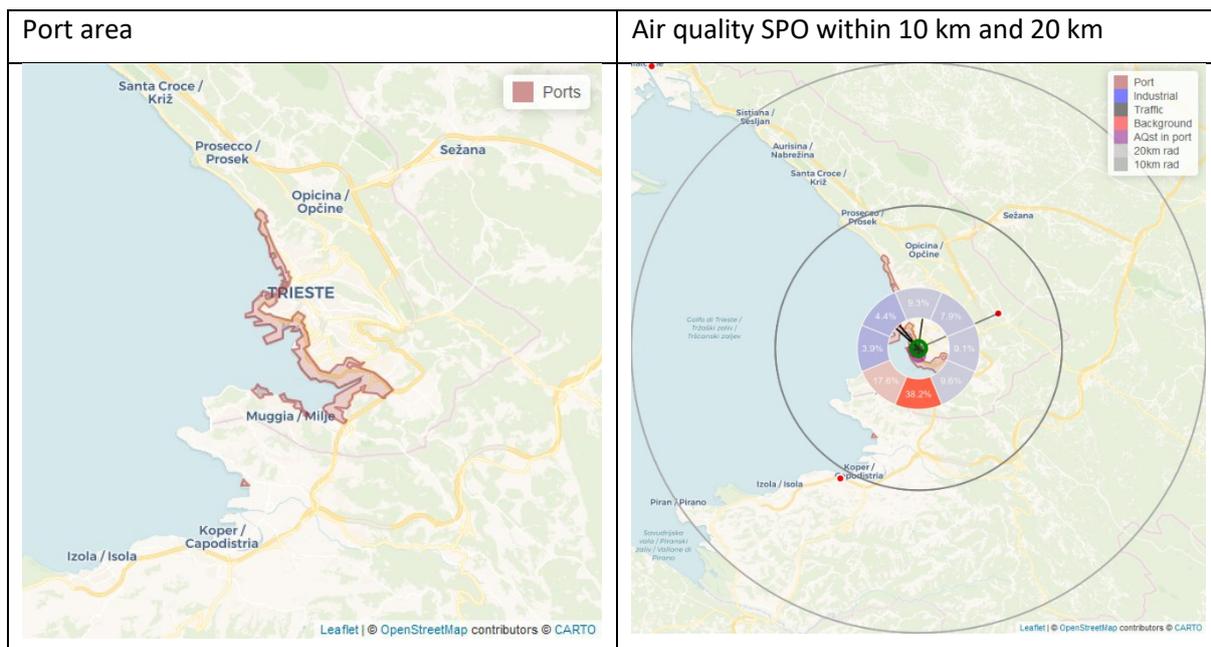
NO₂



PM₁₀



Annex 1.22 Trieste

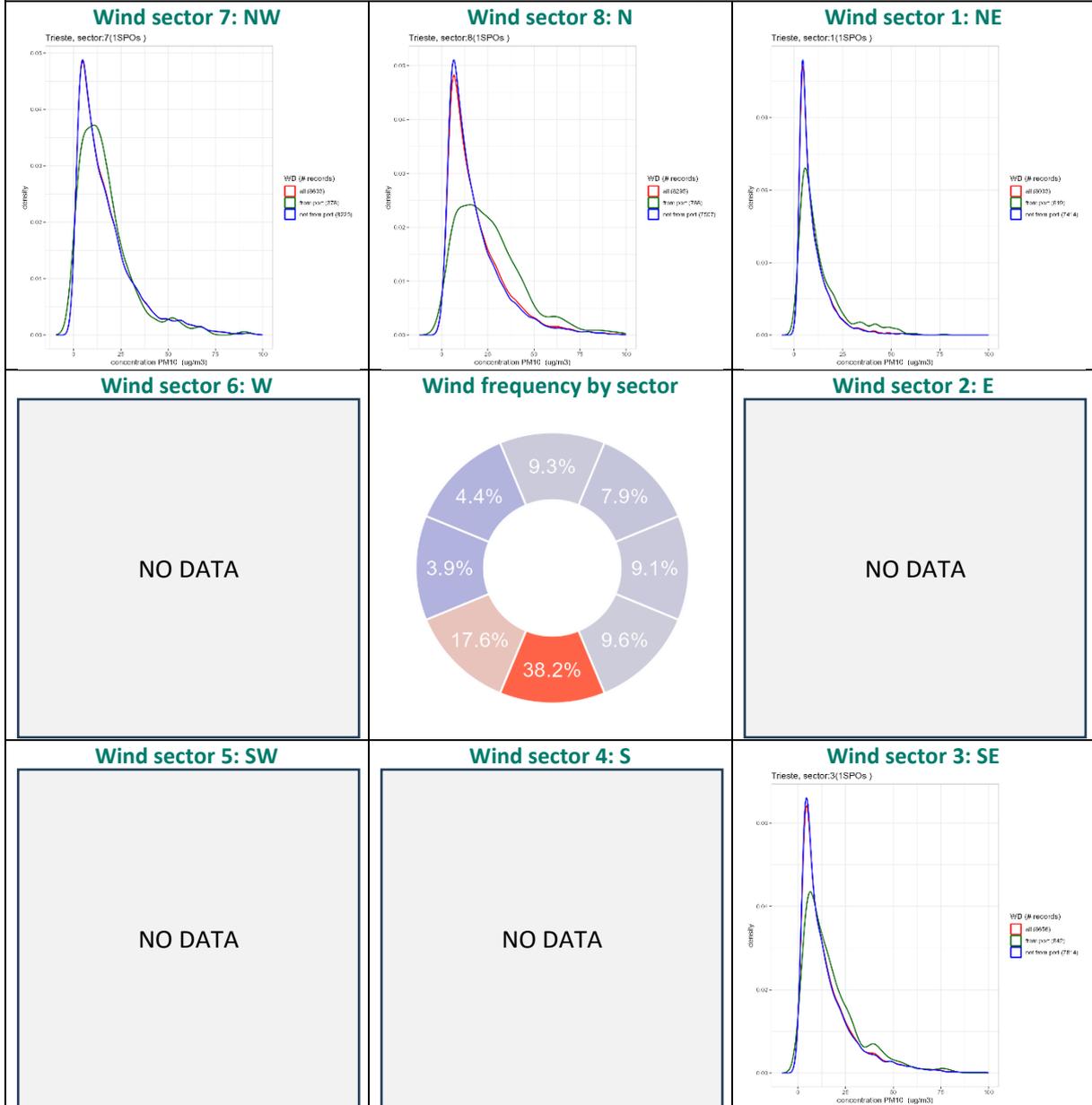


Port	Country	Station code	Station type	Area type	Pollutant	Latitude	Longitude	in Port area	Distance from port polygon (km)	Port downwind frequency (%)	Wind sector	Trend 2005-2021 (%)
Trieste	IT	IT2262A	background	urban	NO2	45.64	13.76	FALSE	0.19	4.4	7	
Trieste	IT	IT2280A	background	urban	NO2	45.64	13.77	FALSE	0.20	4.4	7	
Trieste	IT	IT2261A	traffic	urban	NO2	45.65	13.79	FALSE	1.38	9.3	8	
Trieste	IT	IT2262A	background	urban	PM10	45.64	13.76	FALSE	0.19	4.4	7	
Trieste	IT	IT1090A	industrial	suburban	PM10	45.62	13.79	FALSE	0.37	9.6	3	
Trieste	IT	IT2261A	traffic	urban	PM10	45.65	13.79	FALSE	1.38	9.3	8	
Trieste	IT	IT2260A	background	rural-nearcity	PM10	45.65	13.85	FALSE	4.36	7.9	1	

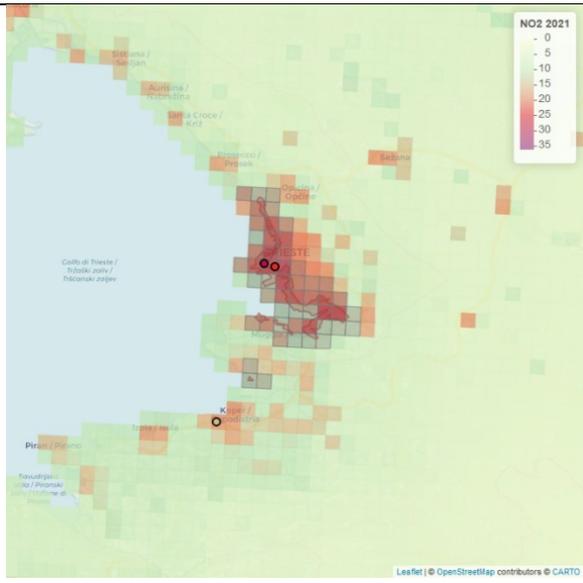
NO₂ concentrations when wind is blowing from the port



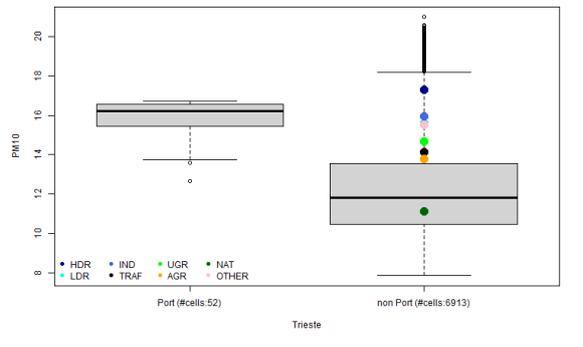
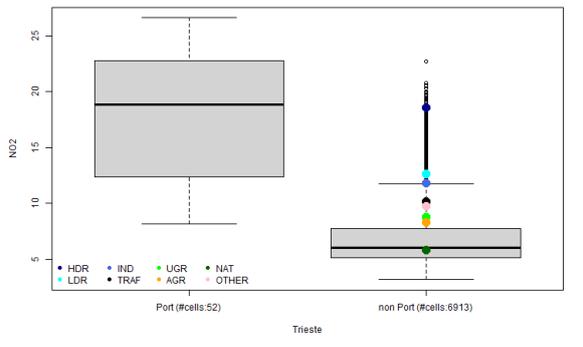
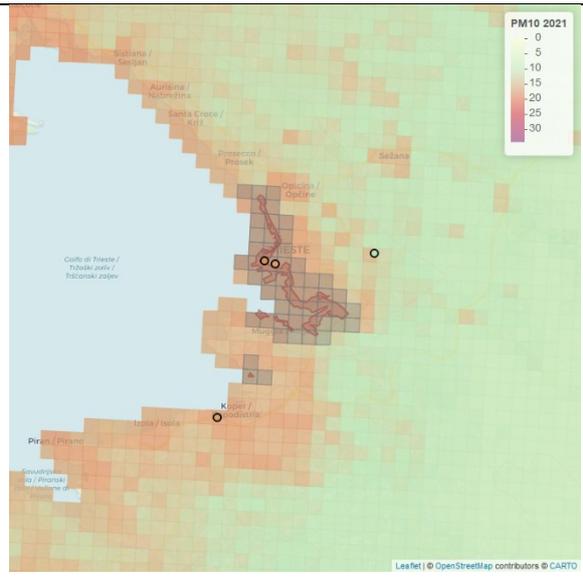
PM₁₀ concentrations when wind is blowing from the port



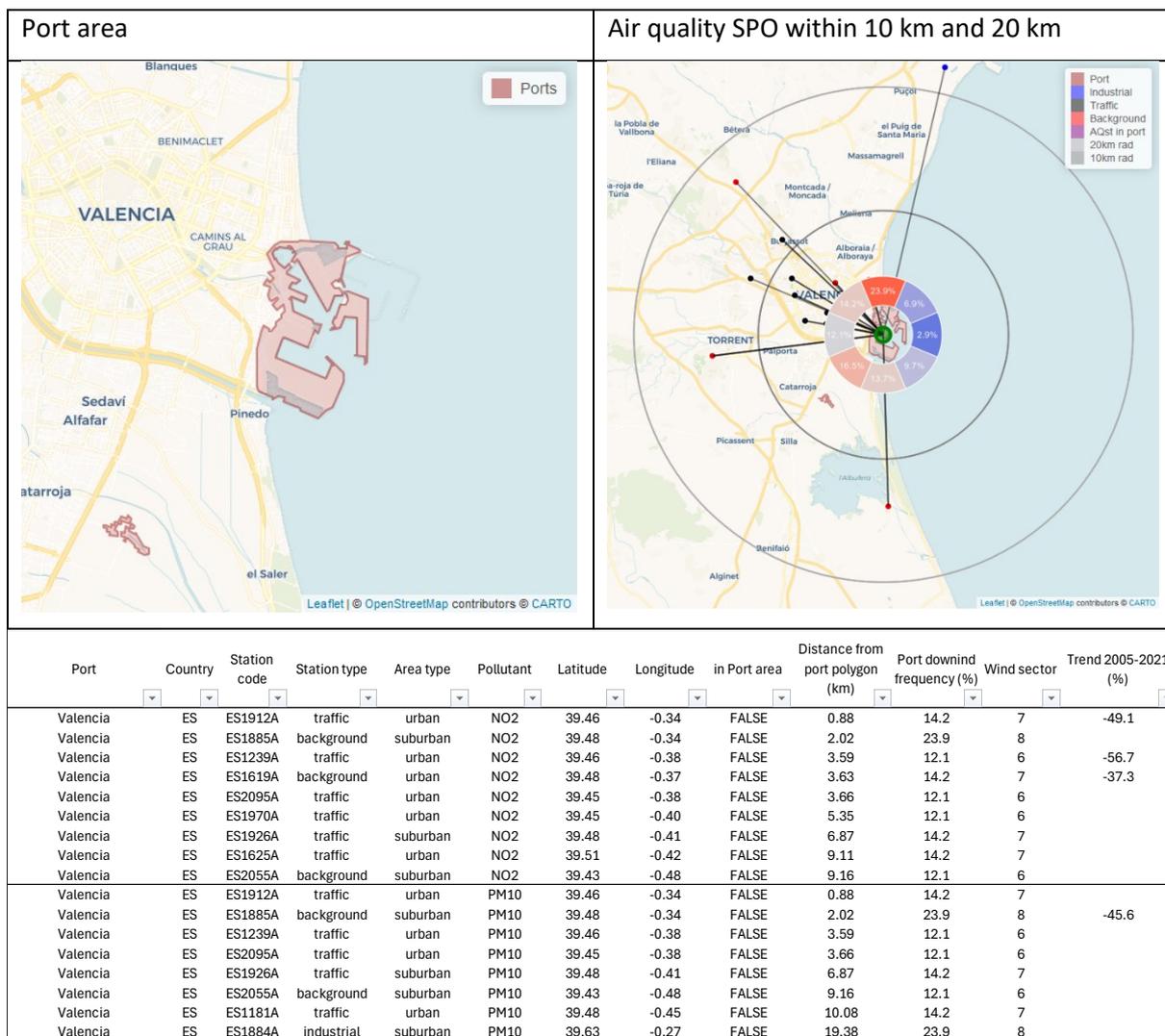
NO₂



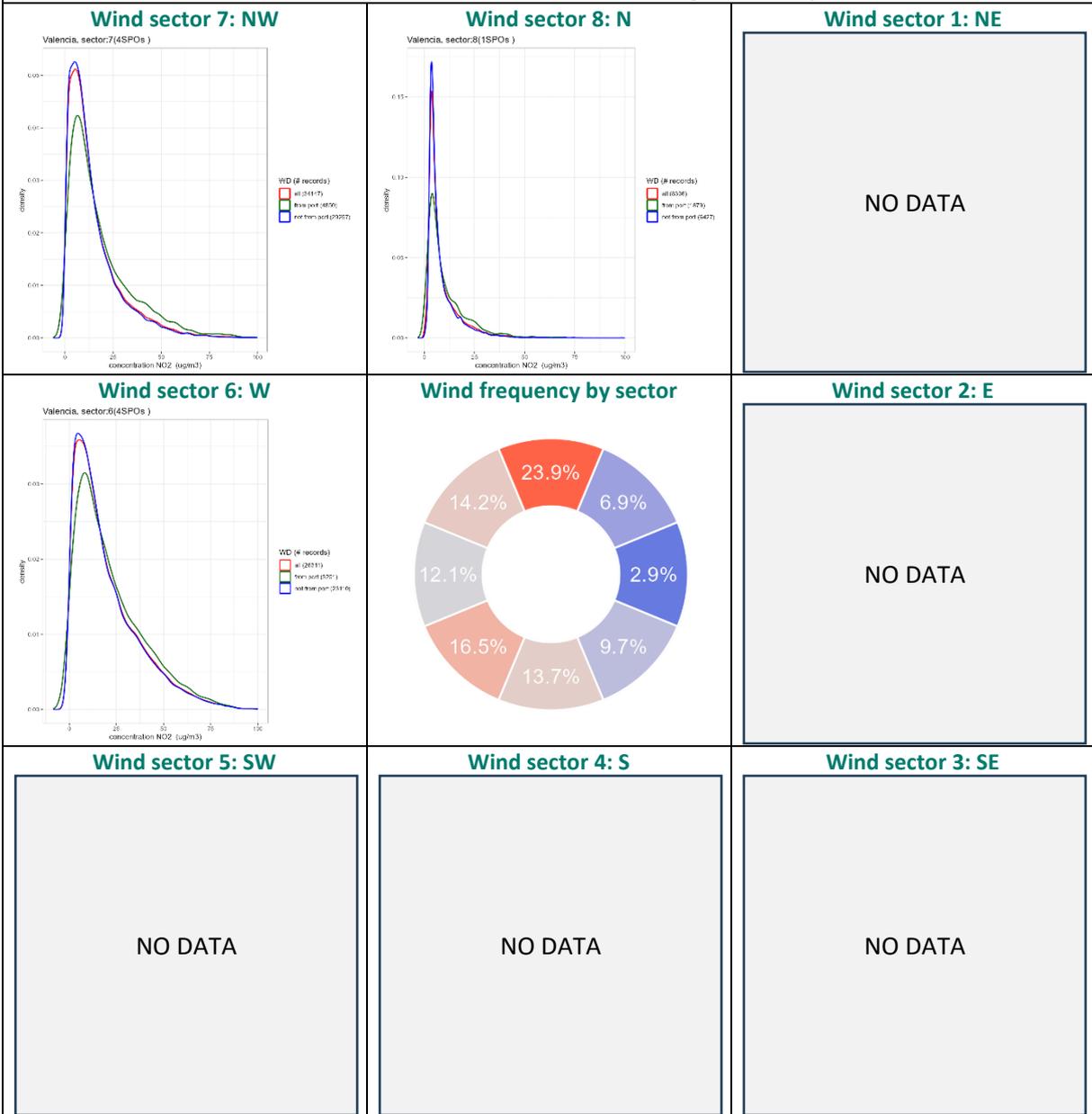
PM₁₀



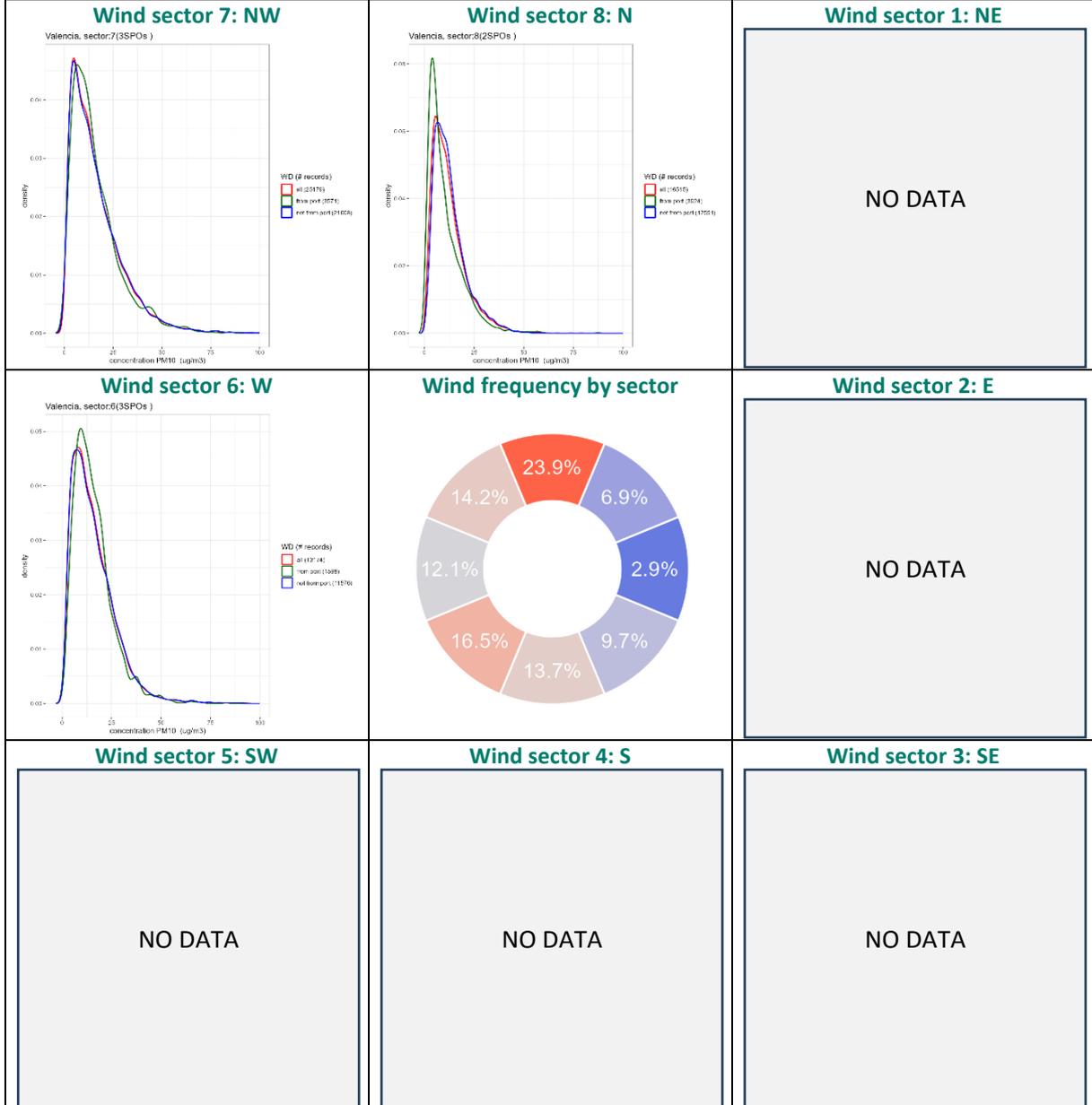
Annex 1.23 Valencia



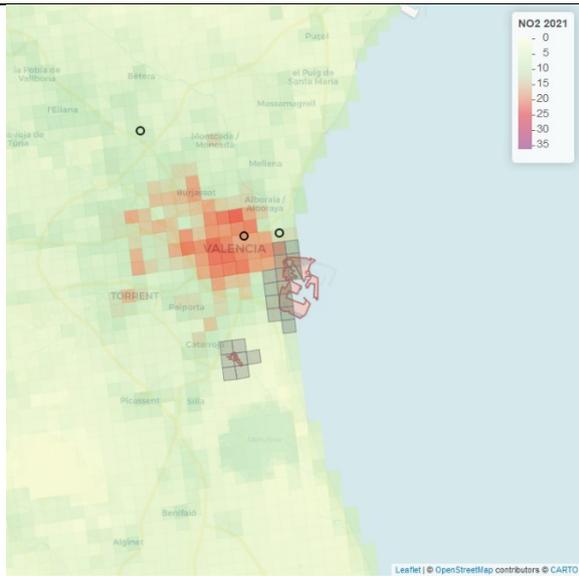
NO₂ concentrations when wind is blowing from the port



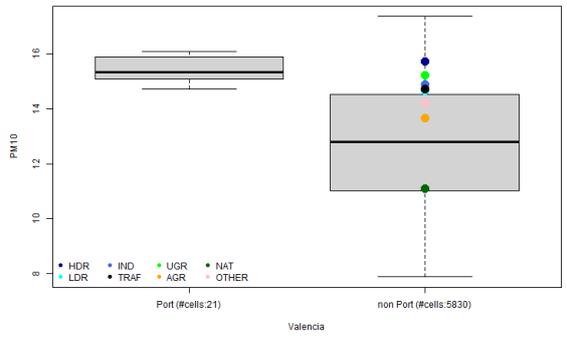
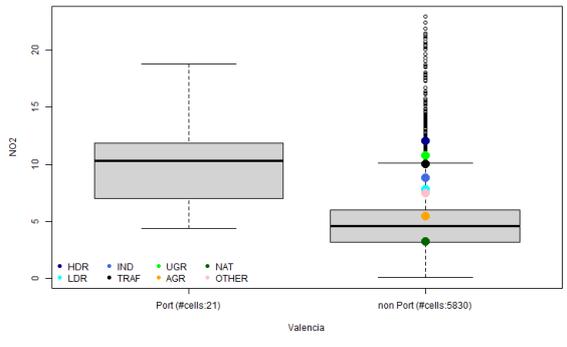
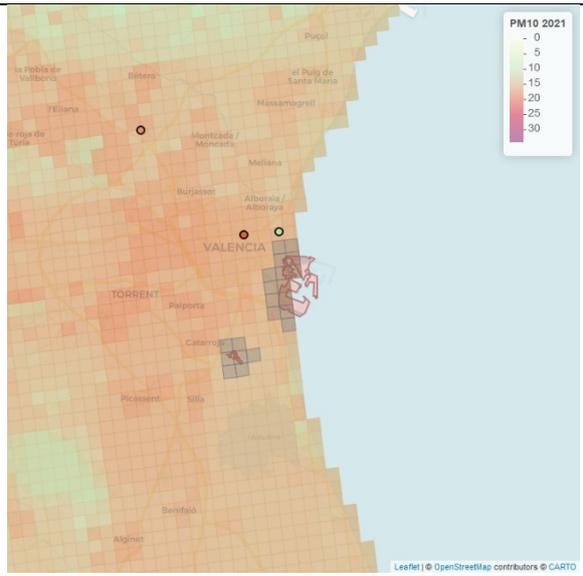
PM₁₀ concentrations when wind is blowing from the port



NO₂



PM₁₀



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