Logika GROUP

Report

Calibrating Defra's 2021-based Background Maps against 2022, 2023 & 2024 Measurements

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Document Control

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1 Introduction

1.1.1 When using roadside[1] measurements of NOx and/or nitrogen dioxide (NO_2) to verify local-scale modelling, it is important that the local background concentration is predicted as accurately as possible for the year in which the verification is based. If the modelled background is too high, the local road component will be underestimated[2]. Conversely if the modelled background is too low, the local road component will be overestimated.

1.1.2 Particulate matter (PM_{10} and $PM_{2.5}$) concentrations in the UK are dominated by non-road emissions, even at the roadside. This means that the contribution of particulate matter from vehicles, even at the roadside, is a much smaller proportion of the total concentration compared to NOx and NO_2. Thus, when modelling impacts of PM from any emission source, if the background is too high, modelled concentrations will represent an overly conservative estimate.

1.1.3 Using inaccurate background concentrations may therefore have significant implications for any future year projections or impact assessments of these pollutants.

1.1.4 Defra has provided background NOx, NO_2, PM_{10} and $PM_{2.5}$ concentration predictions for 2022, 2023 and 2024[3]. Currently, these are included in its 2021-based maps. This means that they have been verified against measurements made in 2021, with the future year values being projected from this 2021 baseline.

1.1.5 This note compares Defra's (2021-based) background mapped concentration predictions for 2022, 2023 and 2024 against annual mean measured background concentrations for the same years at automatic monitoring sites with more than 75% data capture in the Automatic Urban and Rural Network (AURN), Scottish Air Quality Network (SAQN), Welsh Air Quality Network (WAQN), Air Quality England (AQE) network, Northern Ireland (NI) network and Imperial College (IC) network. It follows the approach taken by AQC previously when calibrating the background maps for use in impact assessments using measurements from earlier years[4].

1.1.6 At the time that this note was produced, 2024 was the most recent full calendar year of available measurements. Measurements from the latter part of 2024 are not all fully ratified, but any changes made during data ratification would be highly unlikely to significantly alter the conclusions of this note.

[1] Or other near-source measurements.
[2] This is because the local road increment of concentrations is typically taken to be the total roadside measurement minus the local background.
[3] These maps cover the whole country on a 1x1 km grid and are published for each year from 2021 until 2040, and can be downloaded from https://uk-air.defra.gov.uk/data/laqm-background-home.
[4] https://www.aqconsultants.co.uk/resources.

2 Derivation of Factors

2.1 NOx and NO_2

2.1.1 The mapped background NOx and NO_2 values in 2022, 2023 and 2024 were initially compared to those measured at the suitable background sites with more than 75% data capture (93 sites for NOx in all years, 96 for NO_2 in 2022 and 2023 and 94 in 2024), with individual factors derived for each site plotted to identify any geographical patterns in the data. One site was then removed as an outlier for NO_2 in 2022[5].

2.1.2 Initial investigation showed, as has been observed in previous AQC notes in this series[4], a clear delineation between the performance of the background maps inside London and across the rest of the UK. The data for sites outside London were thus examined separately from those within London.

Sites Outside London

2022

2.1.3 Figure 2-1 compares the 2022 predictions for background annual mean NOx against concurrent measurements (top left plot). There is clear scatter, but an overall negative bias of 20% on average. The top right plot in Figure 2-1 shows the same comparison for NO_2 with a similar overall fit, with the maps under-predicting by 21% on average. It is therefore considered suitable to apply an adjustment to the predictions for 2022 outside of London.

2.1.4 The factor for calibrating Defra's background maps for 2022-based assessments at sites outside London is thus **1.2427** (i.e. 1/0.8047 = 1.2427) for NOx and **1.2641** (i.e. 1/0.7911 = 1.2641) for NO_2.

2023

2.1.5 Figure 2-1 compares the 2023 predictions for background annual mean NOx against concurrent measurements (middle left plot) and NO_2 (middle right plot). The overall negative bias is 11% on average for both NOx and NO_2; lower than for 2022, but still appreciable. It is therefore considered suitable to apply an adjustment to the predictions for 2023 outside of London.

2.1.6 The factor for calibrating Defra's background maps for 2023-based assessments at sites outside London is thus **1.1237** (i.e. 1/0.8899 = 1.1237) for NOx and **1.1232** (i.e. 1/0.8903 = 1.1235) for NO_2.

2024

2.1.7 Figure 2-1 also compares the 2024 predictions for background annual mean NOx against concurrent measurements (bottom left plot) and NO_2 (bottom right plot). The overall negative bias is 8% on average for NOx and 3% for NO_2; again, an improvement on the previous year.

2.1.8 The factor for calibrating Defra's background maps for 2024-based assessments at sites outside London is thus **1.0826** (i.e. 1/0.9237 = 1.0826) for NOx and **1.0320** (i.e. 1/0.960 = 1.0320) for NO_2.

[5] Burnham Beeches was removed from the NO_2 data set due to the background NO_2 concentrations being significantly underpredicted. No NOx concentrations were measured at this site.

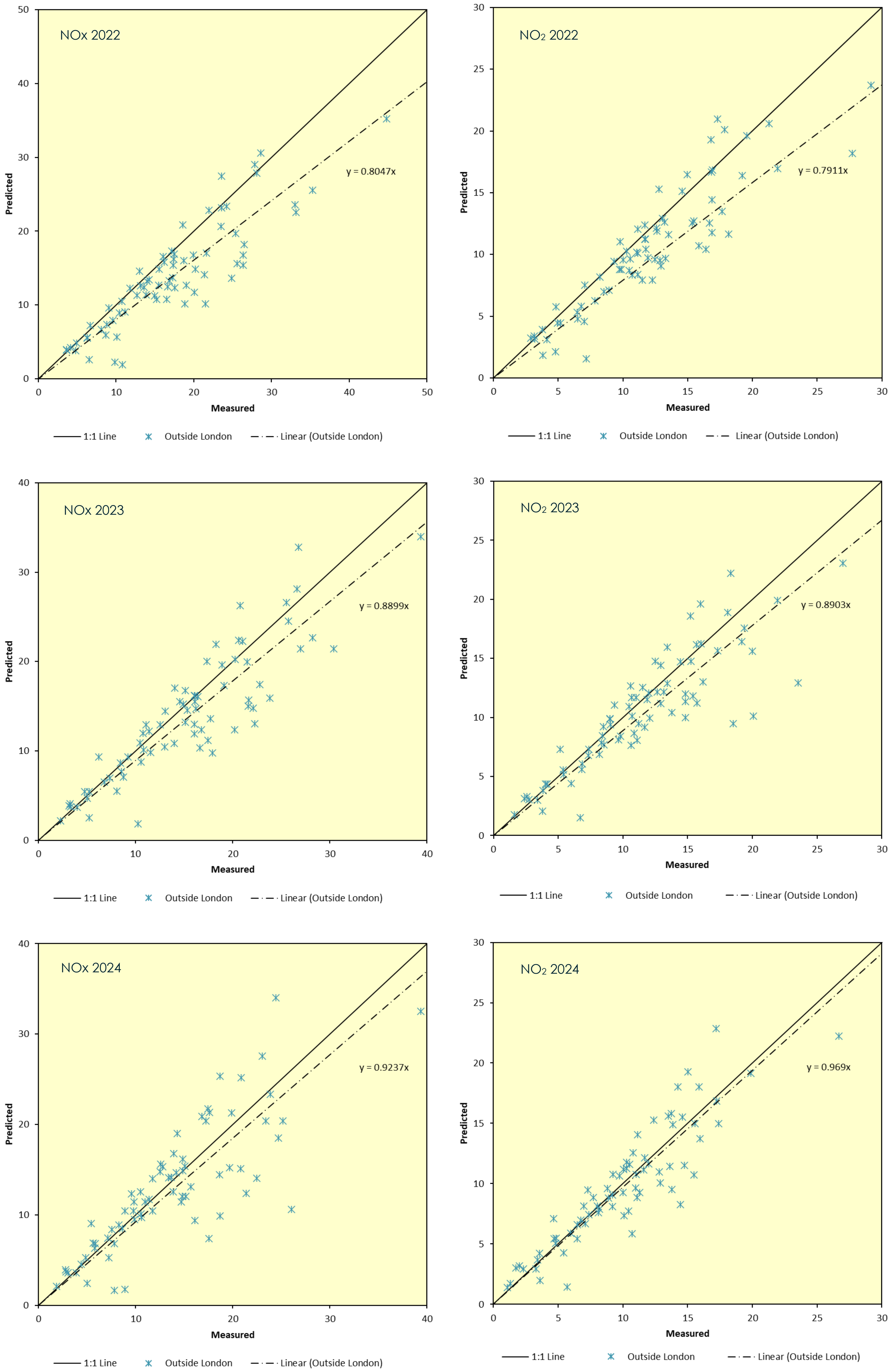

Figure 2-1: Predicted Mapped versus Measured Concentrations of NOx (left) and NO_2 (right) at Background Sites in the UK (Outside London) in 2022 (top), 2023 (middle) and 2024 (bottom)

Sites Inside London

2.1.9 Within London, there appears to be appreciable spatial variability; in central London, the mapped NOx concentrations at some sites are almost double the measurements, while across outer London there is, in general, much better agreement with the measurements (see Figure 2-2, top). The picture is similar for NO_2, albeit the over-predictions in central and inner London are less marked (Figure 2-2, bottom).

2.1.10 The observed differences may have been influenced by the Ultra Low Emission Zone (ULEZ). The ULEZ, originally covering the congestion charge zone, came into force in April 2019 (purple area shown in Figure 2-2), and was expanded outward to the North and South Circular Roads in October 2021 (i.e. before the end of the background map calibration year) (blue area in Figure 2-2). The ULEZ was expanded again to cover all London Boroughs (excluding the M25) at the end of August 2023 (green area in Figure 2-2). While the predicted background concentrations do take the influence of the ULEZ into account, the spatial pattern shown in Figure 2-2 indicates that the 2021-based predictions performed quite differently in central and inner London in 2022, 2023 and 2024 than they did elsewhere.

2.1.11 The central and inner zone delineated in Figure 2-2 has thus been used as the basis for deriving average factors to adjust the maps for 2022, 2023 and 2024, noting the relatively high degree of uncertainty in this approach. Separating inner and central London from outer London also broadly aligns with the different fleet mixes used within Defra's Emissions Factors Toolkit (EFT)[6].

[6] https://laqm.defra.gov.uk/air-quality/air-quality-assessment/emissions-factors-toolkit/

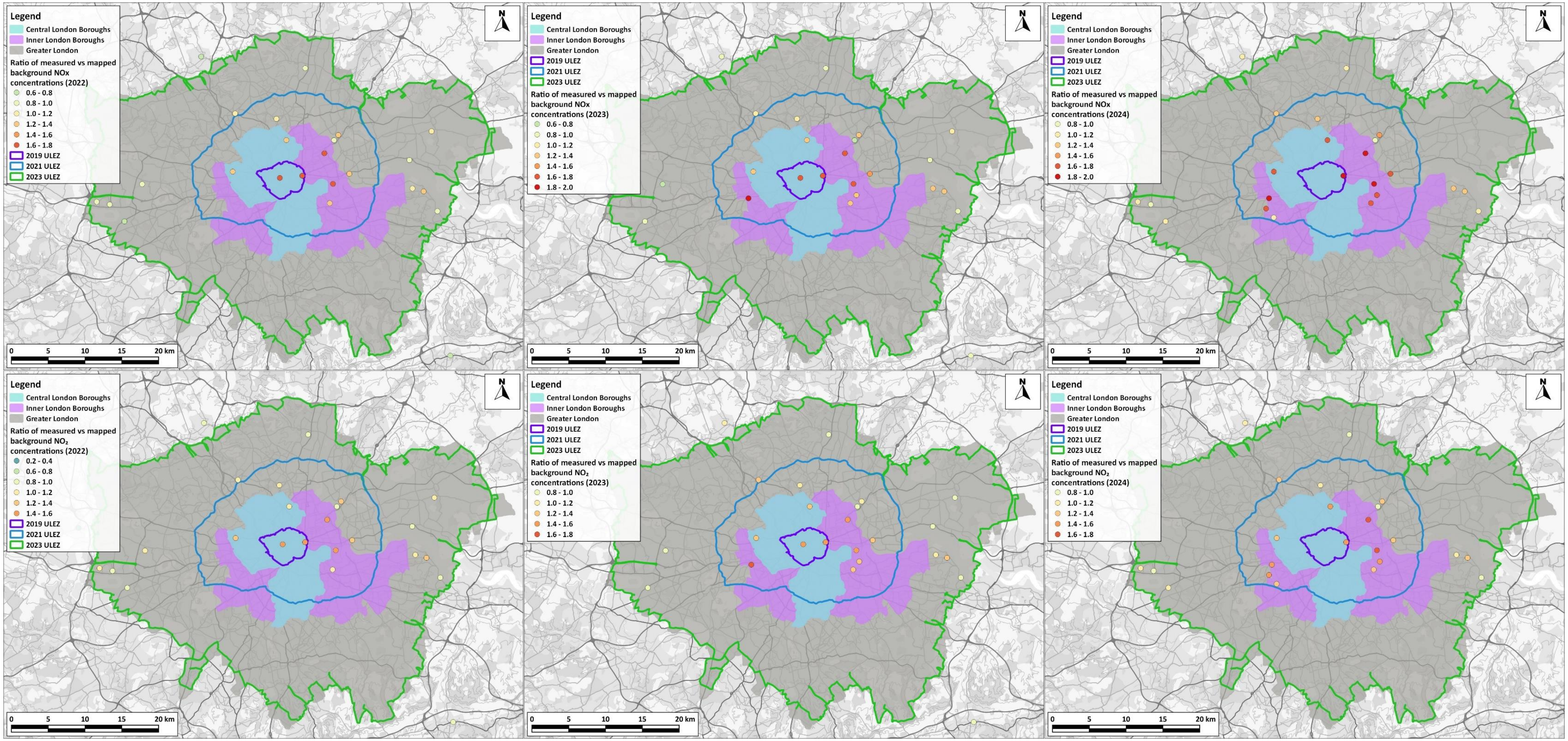

Figure 2-2: Mapped / Measured Annual Mean NOx (top) and NO_2 (bottom) Concentrations in 2022 (left), 2023 (middle) and 2024 (right) in London

Additional data sourced from third parties, including public sector information licensed under the Open Government Licence v3.0.

2022

2.1.12 Figure 2-3 (top left plot) compares the mapped background NOx concentrations in 2022 against the measurements for sites within central and inner London separately from the outer London sites. Figure 2-3 (top right plot) shows the equivalent for NO_2. This clearly shows an over estimation in the background maps in central and inner London, with an overall bias of 53% for NOx and 36% for NO_2, while outer London sites show good agreement, with a negative bias of just 3% for NOx and an overestimation of 3% for NO_2.

2.1.13 The factor for calibrating Defra's background maps for 2022-based assessments at sites within central and inner London is thus **0.6528** (i.e. 1/1.5319 = 0.6528) for NOx and **0.7345** (i.e. 1/1.3615 = 0.7345) for NO_2. For outer London, the factor is **1.0294** (i.e. 1/0.9714 = 1.0294) for NOx and **0.9664** (i.e. 1/1.0348 = 0.9664) for NO_2.

2023

2.1.14 Figure 2-3 (middle left plot and middle right plot) compares the mapped NOx and NO_2 concentrations, respectively, for 2023 against the measurements. Again, there is clearly an over estimation in the background maps in central and inner London, with an overall bias of 58% for NOx and 40% for NO_2 (higher than for 2022), while outer London sites show better agreement with an underestimation of 1% on average for NOx and an overestimation of 2% for NO_2.

2.1.15 The factor for calibrating Defra's background maps for 2023-based assessments at sites within central and inner London is thus **0.6339** (i.e. 1/1.5775 = 0.6339) for NOx and **0.7127** (i.e. 1/1.4032 = 0.7127) for NO_2. For outer London, the factor is **1.0105** (i.e. 1/0.9896 = 1.0105) for NOx and **0.9777** (i.e. 1/1.0228 = 0.9777) for NO_2.

2024

2.1.16 Figure 2-3 (bottom left plot and bottom right plot) compares the mapped background NOx concentrations and NO_2 concentrations, respectively, in 2024 against the measurements. The overestimation in the background maps in central and inner London is more pronounced for 2024 than for 2022 or 2023, with an overall bias of 70% for NOx and 48% for NO_2. Outer London sites also show worse agreement than previous years, with an overestimation of 18% on average for NOx and 12% for NO_2. This might reflect the expansion of the ULEZ, although appreciable delineation remains between outer London and inner & central London.

2.1.17 The factor for calibrating Defra's background maps for 2024-based assessments at sites within central and inner London is thus **0.5866** (i.e. 1/1.7048 = 0.5866) for NOx and **0.6740** (i.e. 1/1.4837 = 0.3740) for NO_2. For outer London, the factor is **0.8501** (i.e. 1/1.1763 = 0.8501) for NOx and **0.8917** (i.e. 1/1.1215 = 0.8917) for NO_2.

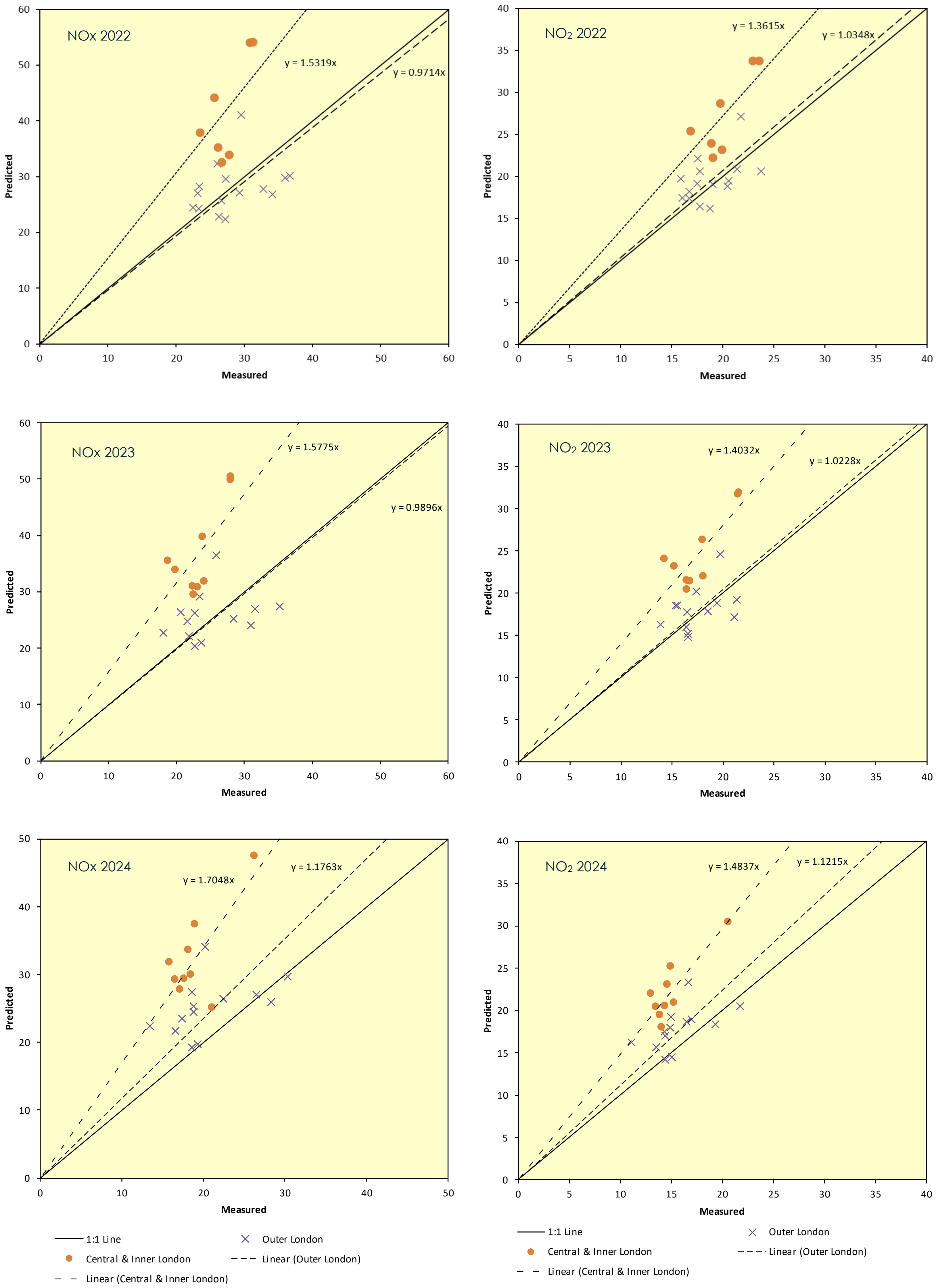

Figure 2-3: Predicted Mapped versus Measured Concentrations of NOx (left) and NO_2 (right) at Background Sites within London in 2022 (top), 2023 (middle) and 2024 (bottom)

2.2 PM_{10} and $PM_{2.5}$

2.2.1 The mapped background PM_{10} and $PM_{2.5}$ values in 2022, 2023 and 2024 were initially compared to those measured at the suitable background sites with more than 75% data capture (65 sites for PM_{10} and 54 sites for $PM_{2.5}$ in 2022, 85 sites for PM_{10} and 74 for $PM_{2.5}$ in 2023 and 88 sites for PM_{10} and 85 for $PM_{2.5}$ in 2024), with individual factors derived for each site plotted to identify any geographical patterns in the data[7].

2.2.2 The plots are shown in Figure 2-4 (PM_{10} shown on the left, $PM_{2.5}$ on the right, with 2022 at the top, 2023 middle and 2024 bottom). London sites highlighted in orange. While there does appear to be some overprediction in background maps at London sites on average, there is no clear differentiation between performance inside vs outside London in any year. Figure 2-5 and Figure 2-6 show the spatial patterns in PM_{10} and $PM_{2.5}$ across the UK. The greatest geographical pattern in these figures is what appears to be a systematic underprediction at most coastal sites for both pollutants, particularly those on the south coast of England. This is highlighted in Figure 2-7, which identifies the $PM_{2.5}$ monitoring sites within 5 km of the south and southeast coast of England (stretching from Plymouth to St. Osyth). The patterns are insufficient to allow separate treatment of coastal sites, but do indicate that the background maps may underestimate the local effects of sea salt[8].

2.2.3 While it is considered that there is a level of overprediction in the background maps within London in 2023 and 2024, the spatial patterns Figure 2-5 and Figure 2-6 highlight that PM concentrations in the UK are complex and dominated by non-road emissions, and it is therefore not considered appropriate to apply a calibration factor for PM_{10} or $PM_{2.5}$ anywhere in the UK.

[7] Three PM_{10} sites were removed in 2022 as outliers (Burnham Beeches, Hounslow Hatton Cross and Newtonstewart, due to the background concentrations being significantly underpredicted. Newtonstewart was also removed in 2023 and 2024 for the same reason. Newtonstewart was also removed as an outlier for $PM_{2.5}$ in all years, and Westminster – Covent Garden was removed in 2024.
[8] If the effect related to transport from the continent, it would be seen over wider areas and not be constrained to within a few kilometres of the coast.

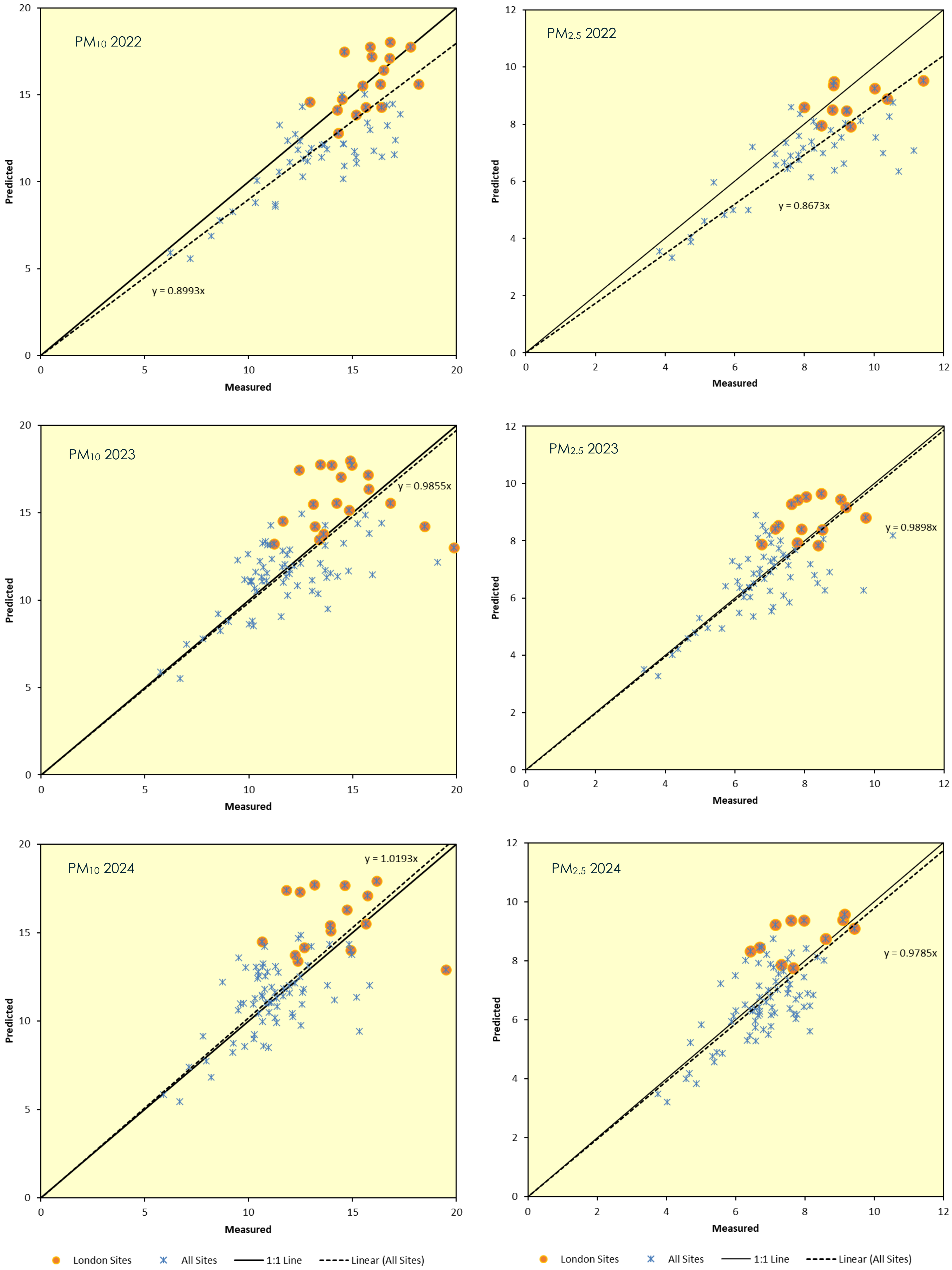

Figure 2-4: Predicted Mapped versus Measured Concentrations of PM_{10} (left) and $PM_{2.5}$ (right) at Background Sites across the UK, Highlighting those within London in 2022 (top), 2023 (middle) and 2024 (bottom)

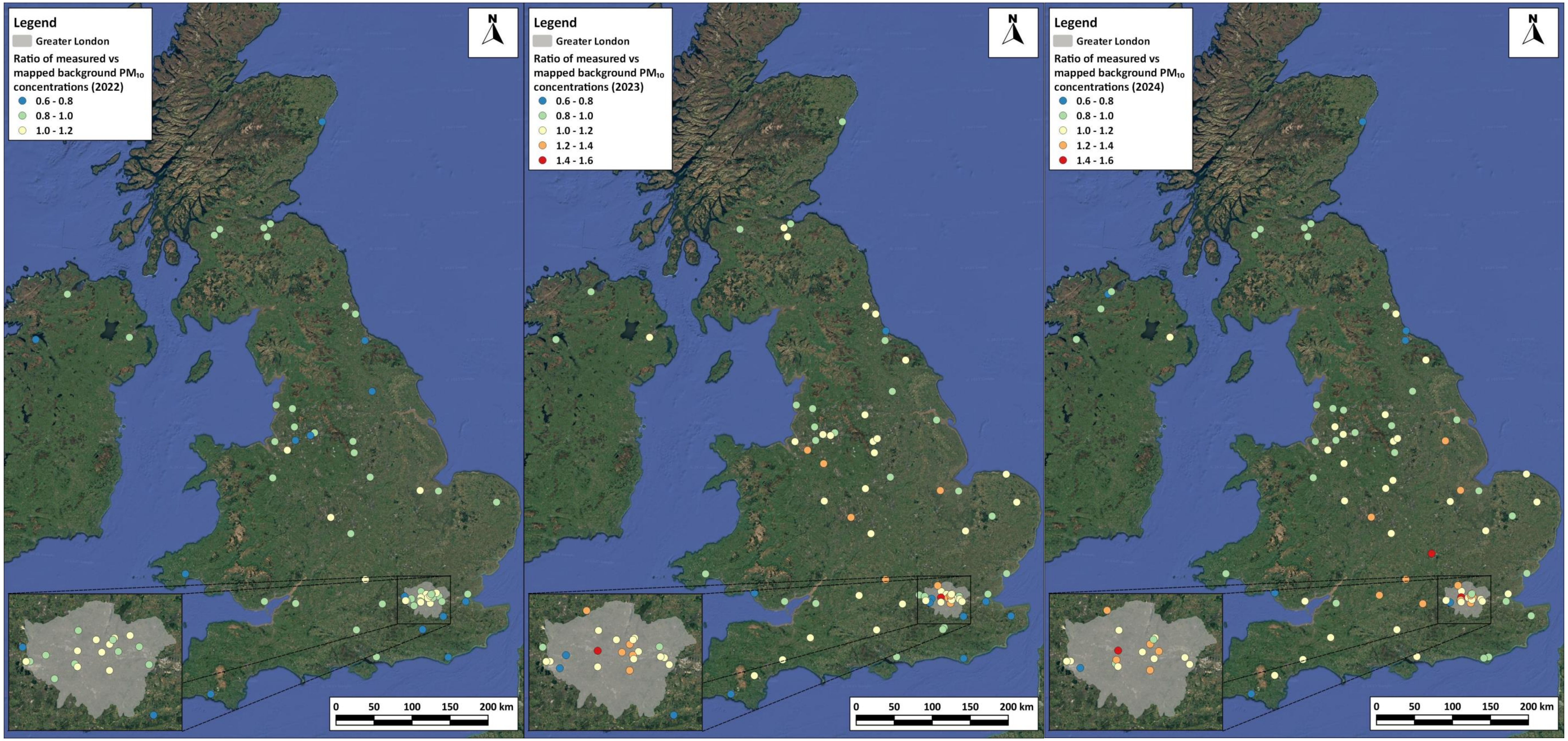

Figure 2-5: Mapped / Measured Annual Mean PM_{10} Concentrations in 2022 (left), 2023 (middle) and 2024 (right)

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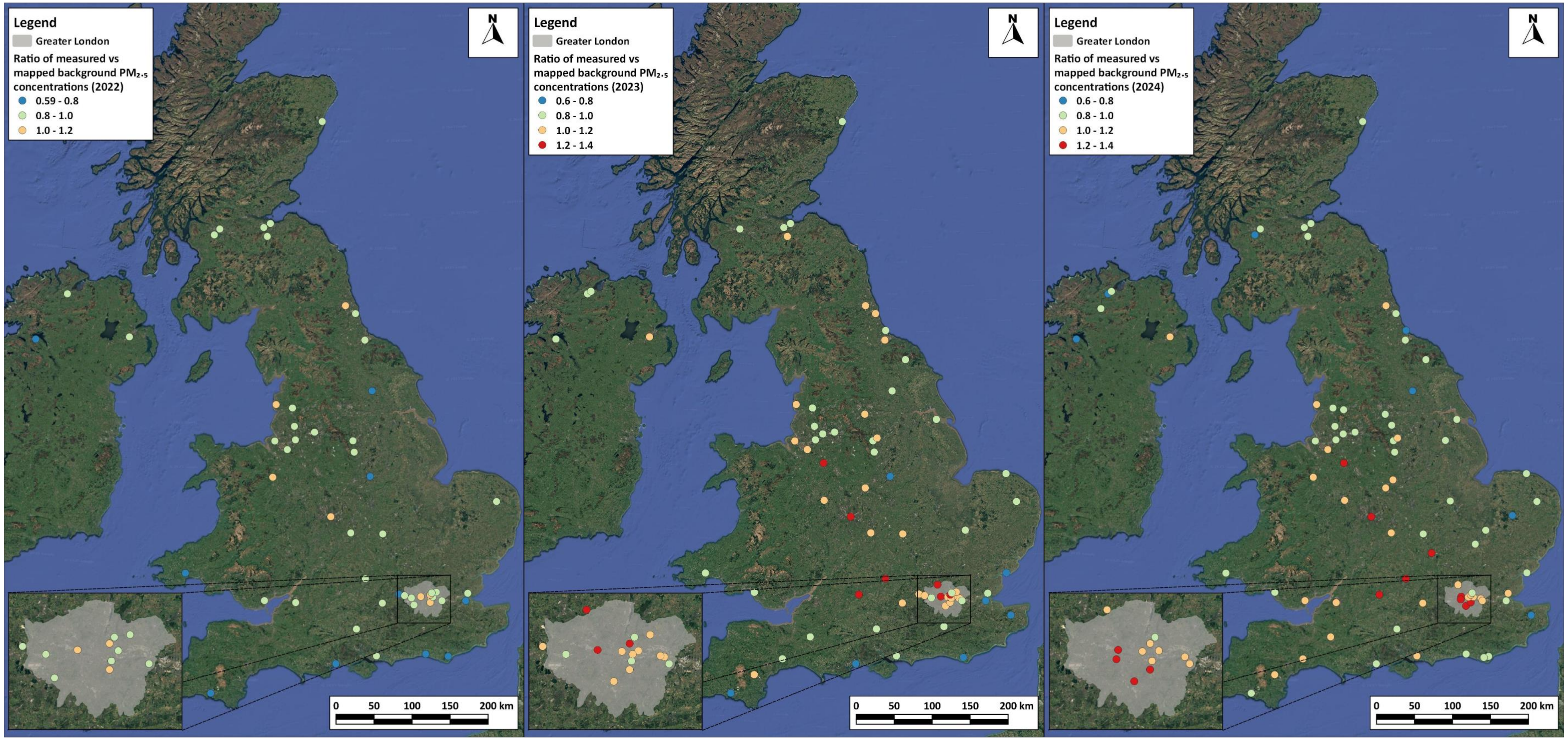

Figure 2-6: Mapped / Measured Annual Mean $PM_{2.5}$ Concentrations in 2022 (left), 2023 (middle) and 2024 (right)

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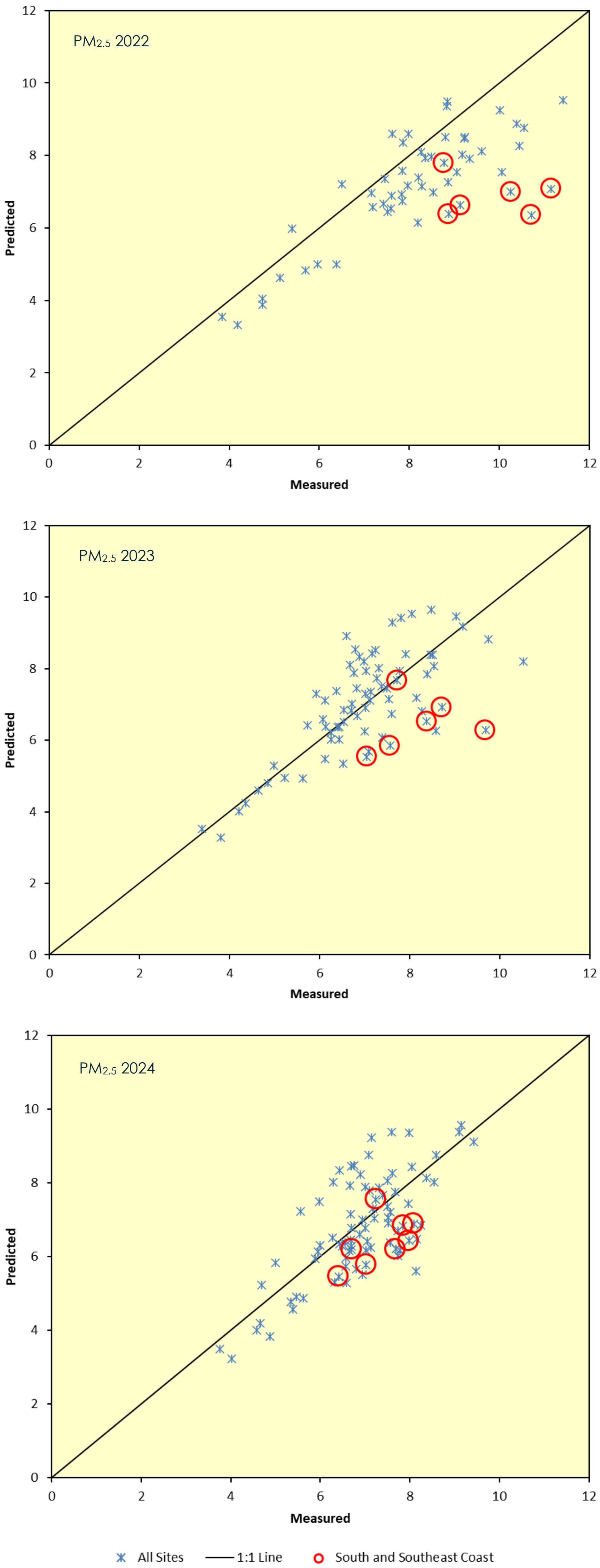

Figure 2-7: Predicted Mapped versus Measured $PM_{2.5}$ Concentrations at Background Sites across the UK, Highlighting those within 5 km of the South and Southeast Coast 2022 (top), 2023 (middle) and 2024 (bottom)

3 Summary

3.1.1 Based on analysis of the relationships between Defra's 2021-based mapped concentrations of NOx, NO_2, PM_{10} and $PM_{2.5}$, it is considered appropriate to apply separate calibration factors to the background mapped concentrations for NOx and NO_2 for sites within central and inner London, outer London and at locations outside London. It is not considered appropriate to apply calibration to the PM_{10} or $PM_{2.5}$ mapped concentrations.

3.1.2 The calibration factors for NOx and NO_2 are set out in Table 1. Mapped concentrations for the base year and each future year should simply be multiplied by the relevant factor. Overall and on average, the maps appear to overestimate concentrations within central and inner London, with this effect becoming more marked with time. In outer London, the maps perform well in 2022 and 2023, but underestimate concentrations on average in 2024. Across the rest of the UK, the maps underestimate concentrations in all years, but this appears to improve with time.

Table 1: Factors to be Applied to Total Background NOx and NO_2 Concentrations for 2022, 2023 and 2024

Location	NOx	NO_2
2022		
Central and Inner London	0.6528	0.7345
Outer London	1.0294	0.9664
Rest of the UK	1.2427	1.2641
2023		
Central and Inner London	0.6339	0.7127
Outer London	1.0105	0.9777
Rest of the UK	1.1237	1.1232
2024		
Central and Inner London	0.5866	0.6740
Outer London	0.8501	0.8917
Rest of the UK	1.0826	1.0320

3.1.3 Given the apparent spatial variability in the performance of the background maps, particular care should be taken close to boundaries where the factors change. It is also important to consider local factors which might ideally be informed by local background measurements, if the monitors are appropriately sited.

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