

Impacts of EMEP aerosol module changes for UK PM_{2.5}

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Introduction

EMEP aerosol changes

EMEP rv5.0 used **MARS** aerosol module

EMEP v5.3 onwards uses **ISORROPIA** aerosol module by default, **MARS** and **EQSAM** also available; additional changes in aerosol water approaches

- Aerosol thermodynamics

Partitioning between gas and particle phases for NH_3 / NH_4^+ , NO_3^- , SO_4^{2-} , SOA

- Aerosol water content

Particle-associated water estimates, part of PM25_rh50 output for matching measurements at 50% relative humidity

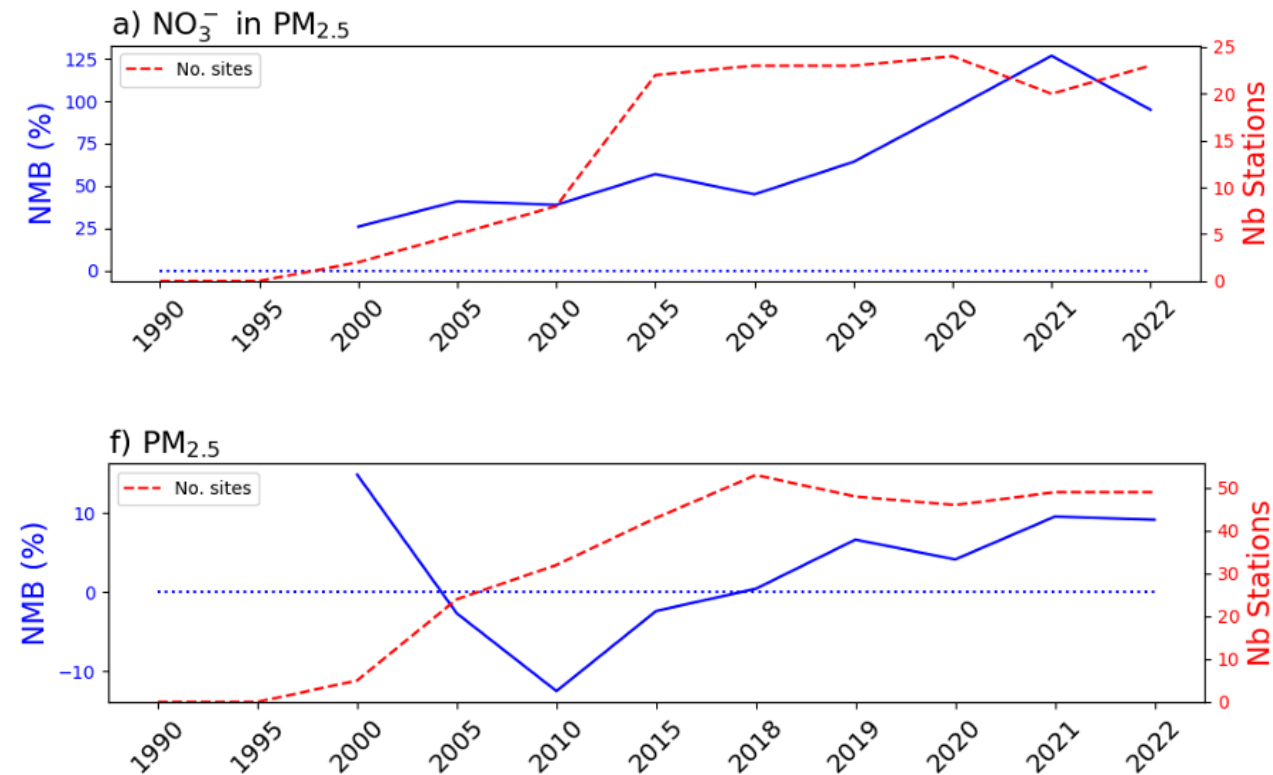
Introduction

EMEP aerosol changes

EMEP status report 1/2024 shows increase of normalised NO₃⁻ bias from rv5.3 with ISORROPIA compared to rv5.0 and increasing bias over time

Positive normalised bias in total PM_{2.5} for recent years also seen from rv5.3 with ISORROPIA compared to MARS and rv5.0

Further investigation suggested to rule out influence from measurement network/approach changes over time



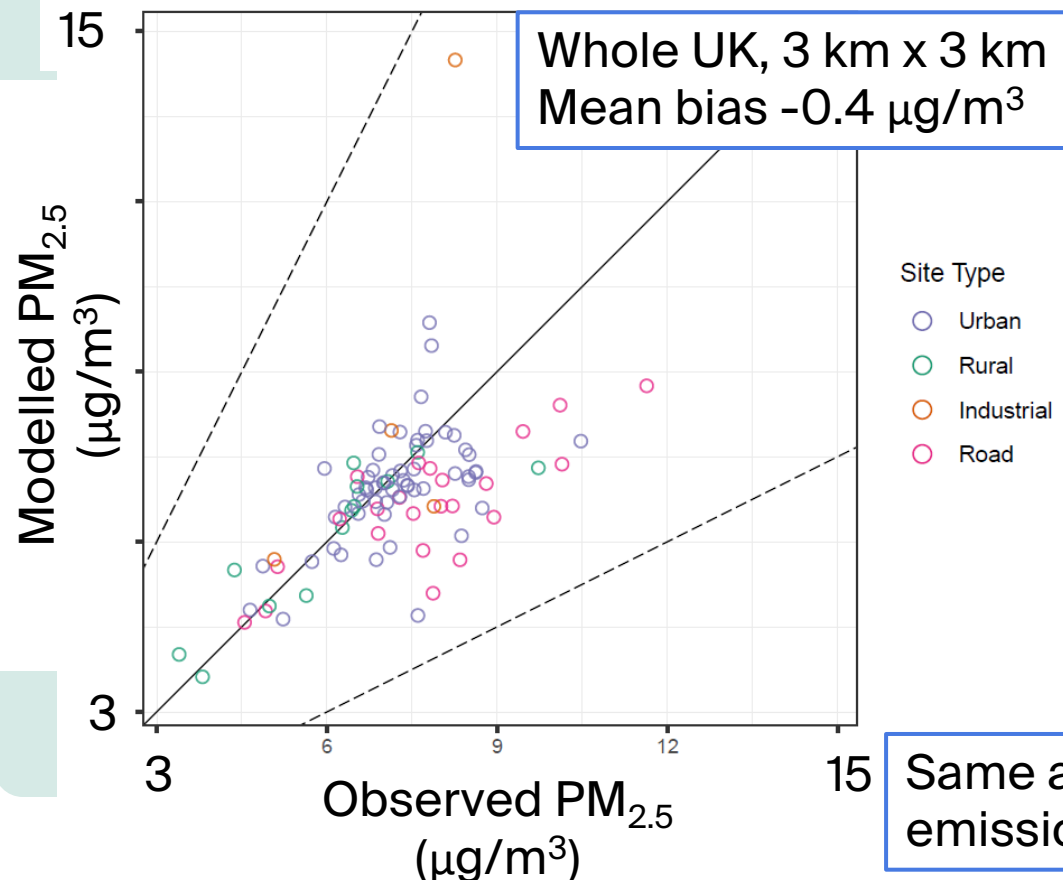
EMEP status report 1/2024, Figure 10.2

https://emep.int/publ/reports/2024/EMEP_Status_Report_1_2024.pdf

Introduction

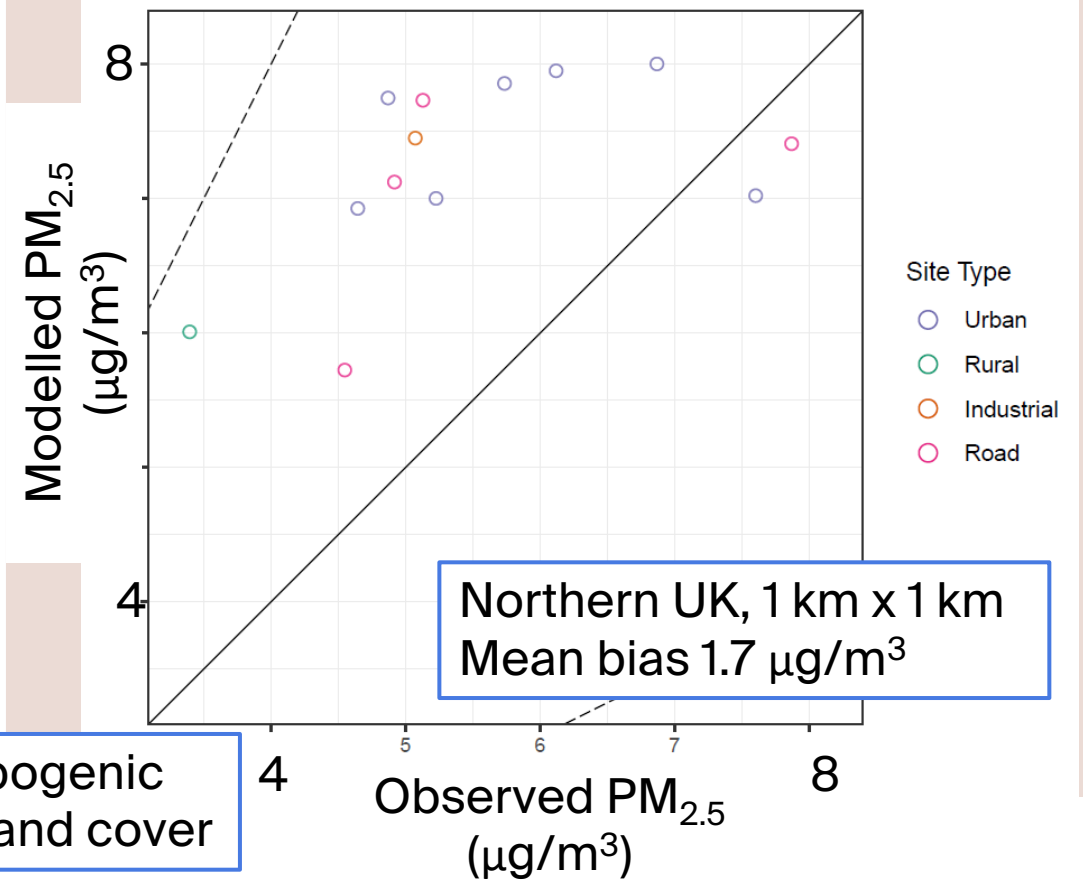
UK PM_{2.5} case study: 2023 annual averages

EMEP v5.0 (modified wet deposition)



Same anthropogenic emissions & land cover

EMEP v5.5



Introduction

Consequences of model bias

Estimate of deaths in Scotland due to population-weighted mean concentration of PM_{2.5} increases by ~380 for each additional $\mu\text{g}/\text{m}^3$

~2 $\mu\text{g}/\text{m}^3$ over-estimate of population-weighted PM_{2.5} concentration leads to additional 760 estimated deaths

Relative impact of absolute bias exacerbated by low absolute PM_{2.5} concentrations (3-8 $\mu\text{g}/\text{m}^3$)

Introduction

Key questions

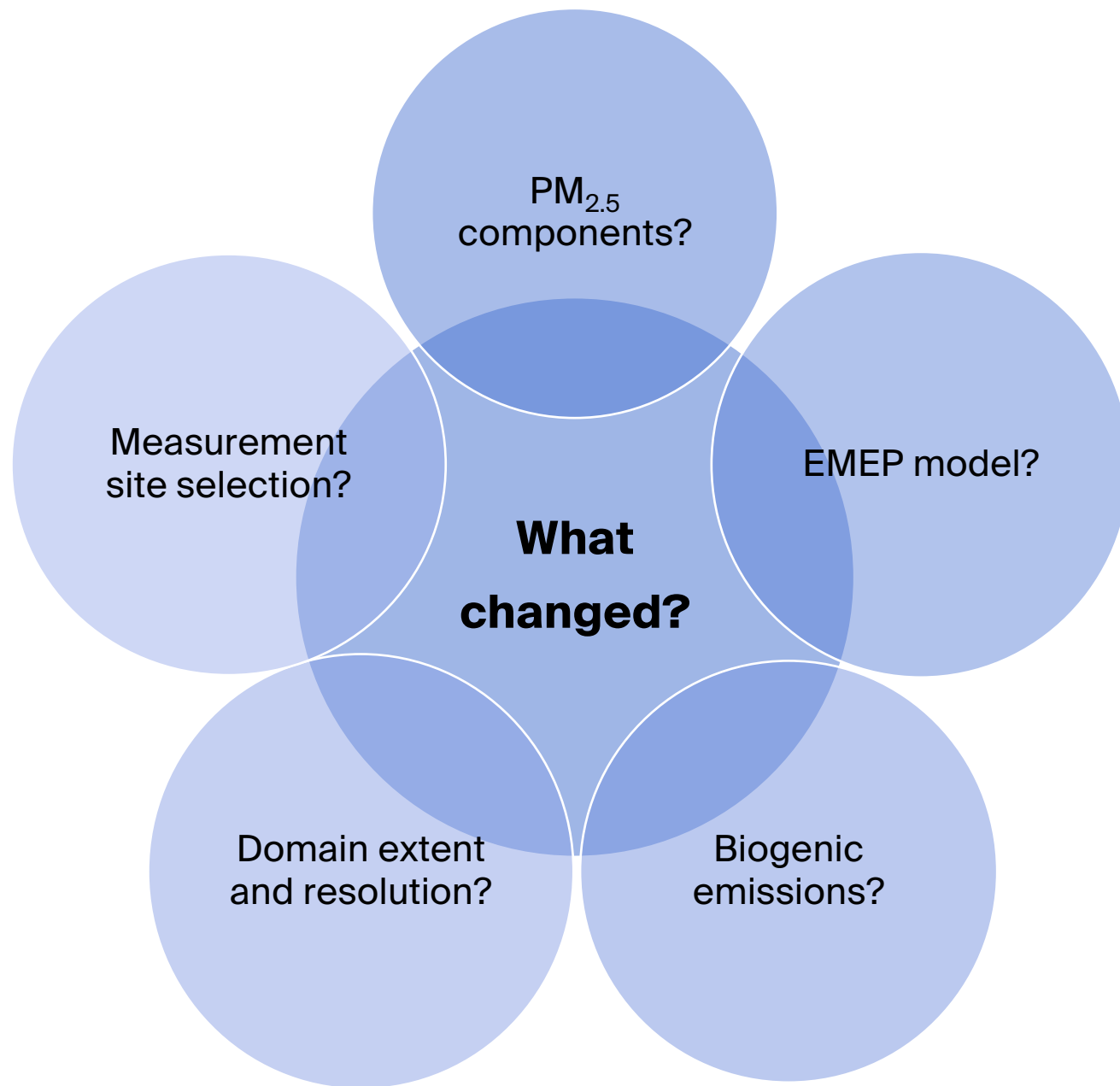
Constraints

- Limited HPC capacity
- Limited time available

Approach

Work with existing model outputs

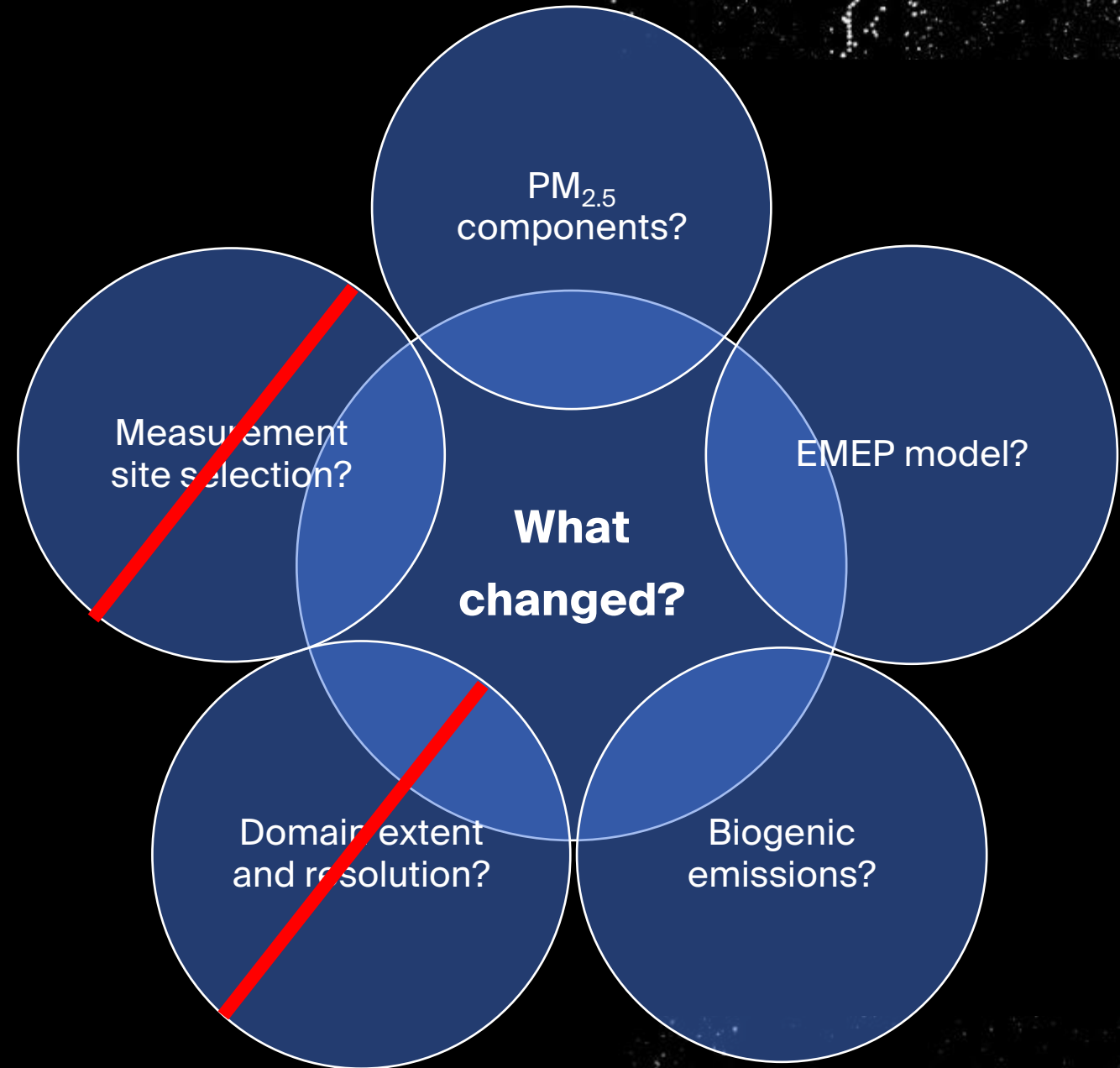
- Comparable low-resolution EU domains
- Single year (2023)



Testing aerosol modules

EU domain comparisons

Evaluation with UK measurements

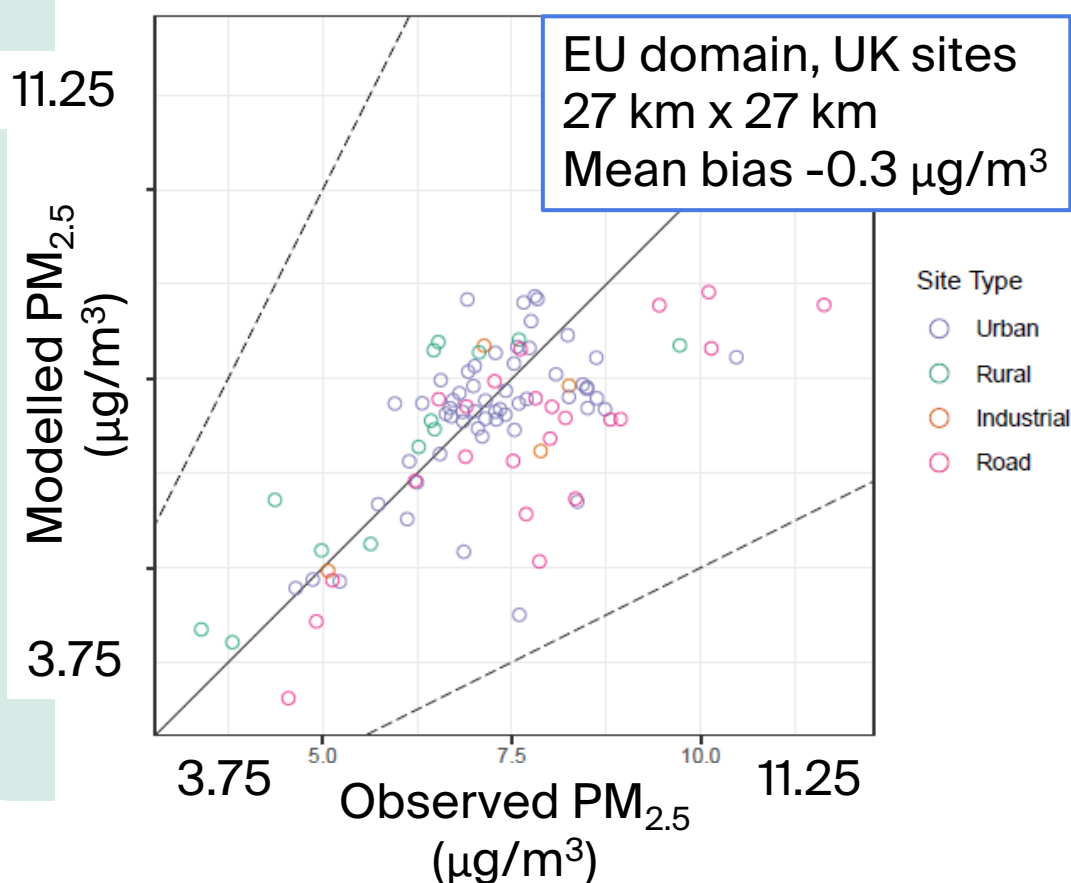


EU domain comparisons

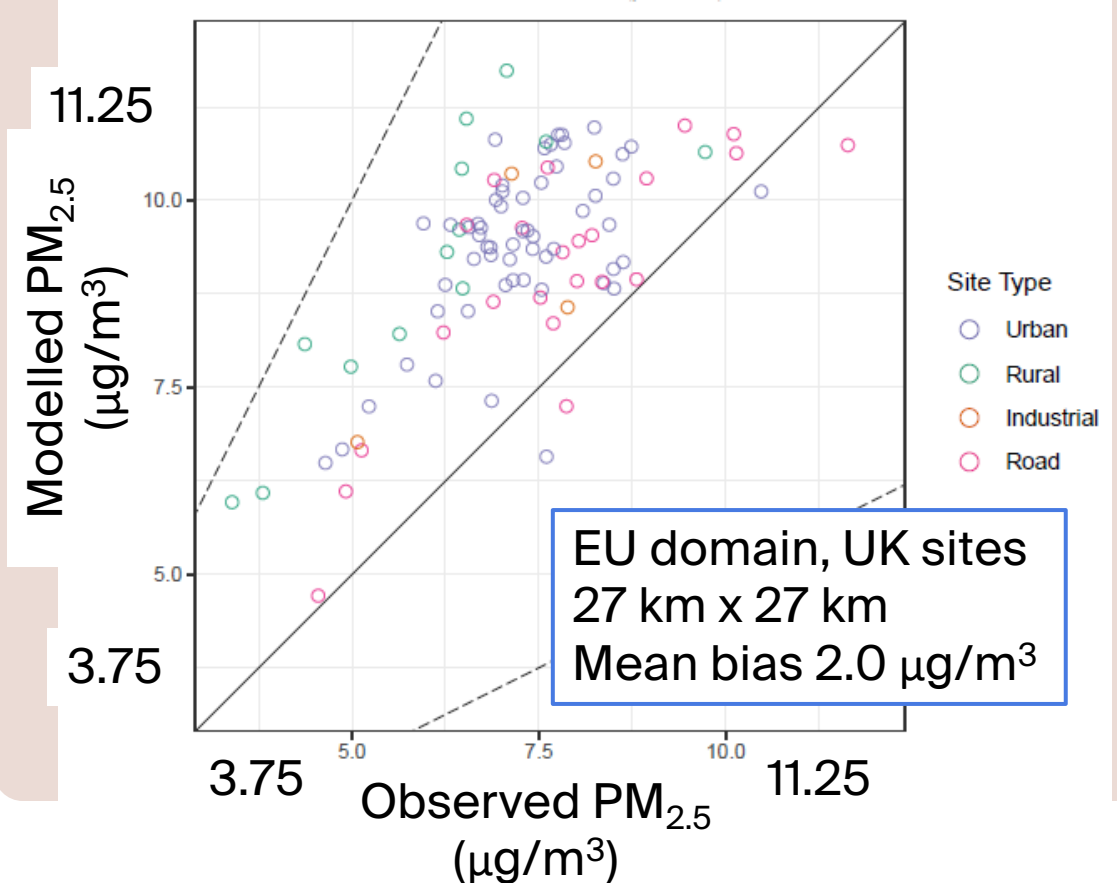
Observed PM_{2.5} from UK Automatic Urban & Rural Network via R openair package

UK PM_{2.5}: 2023 annual averages

EMEP v5.0 (modified wet deposition)



EMEP v5.5



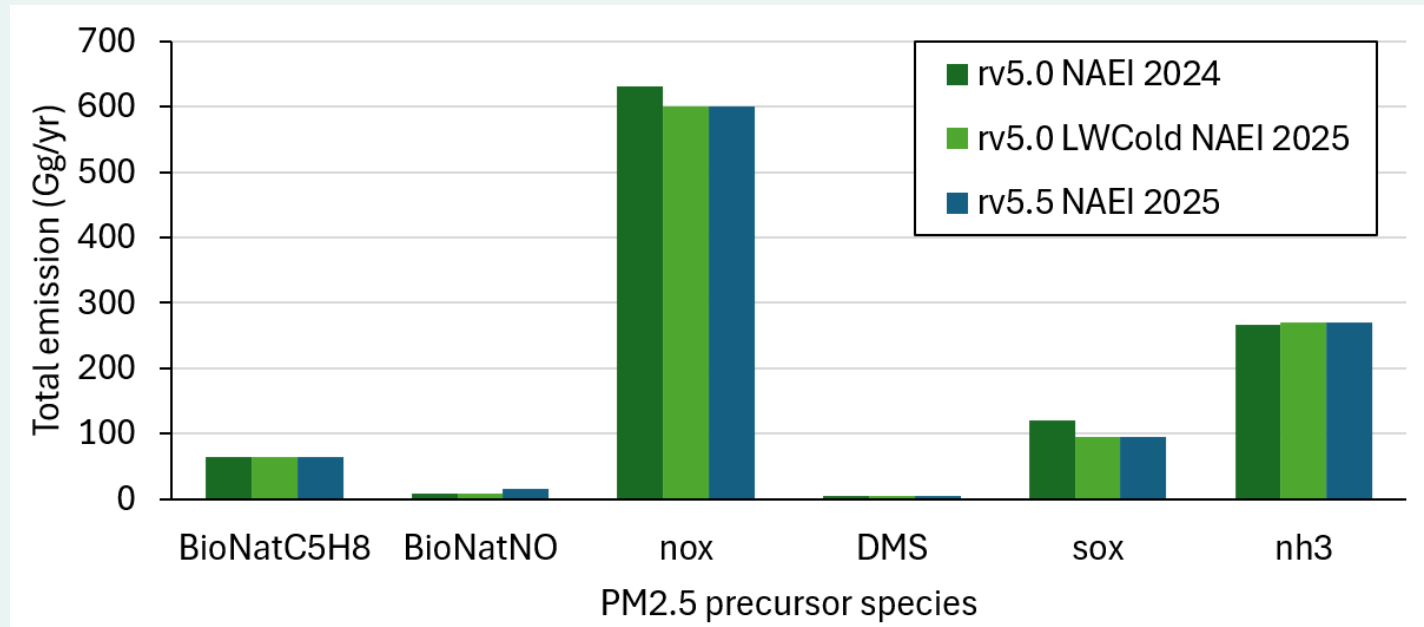
EU domain comparisons

UK emissions comparison

Anthropogenic emissions identical for both model versions

Soil NO emissions increase in EMEP rv5.5 but still small compared to anthropogenic NO_x

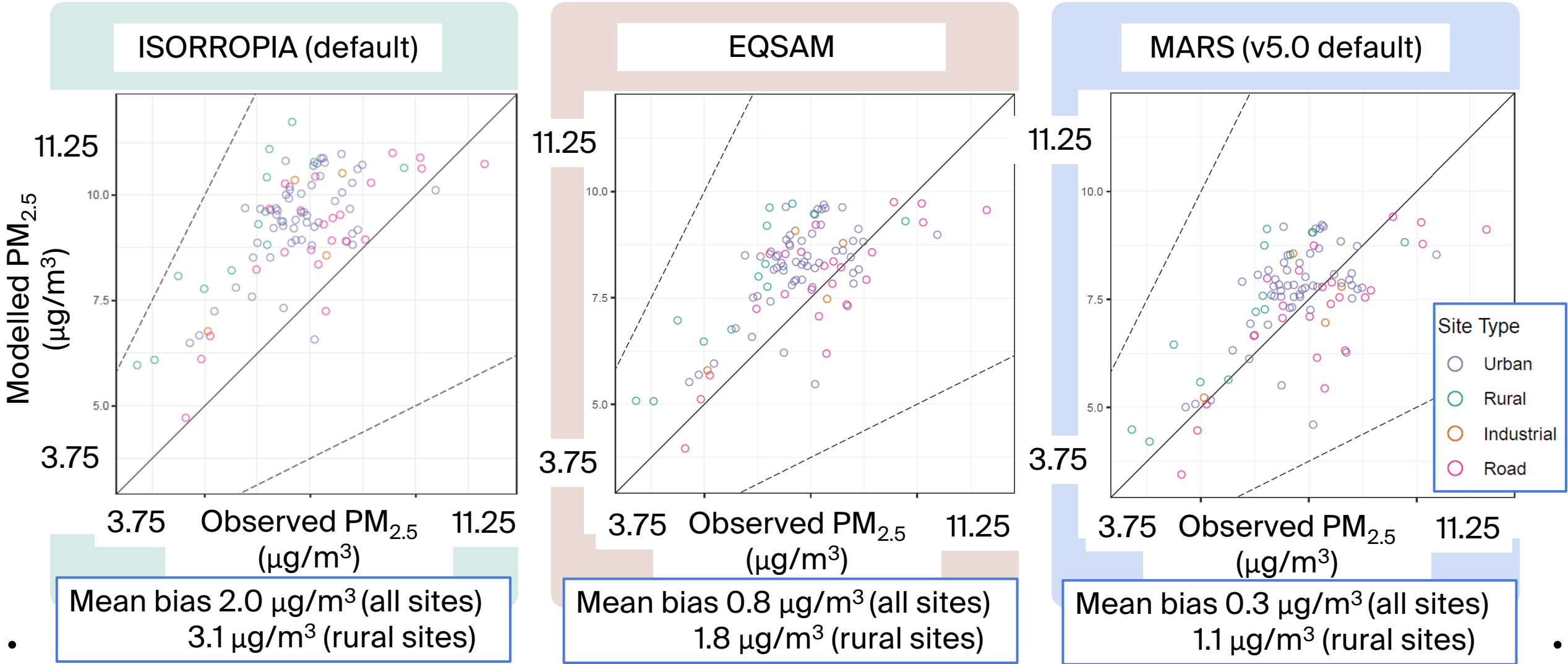
EMEP total emissions within UK land mass



EU domain comparisons: UK PM_{2.5}

EMEP rv5.5 aerosol modules

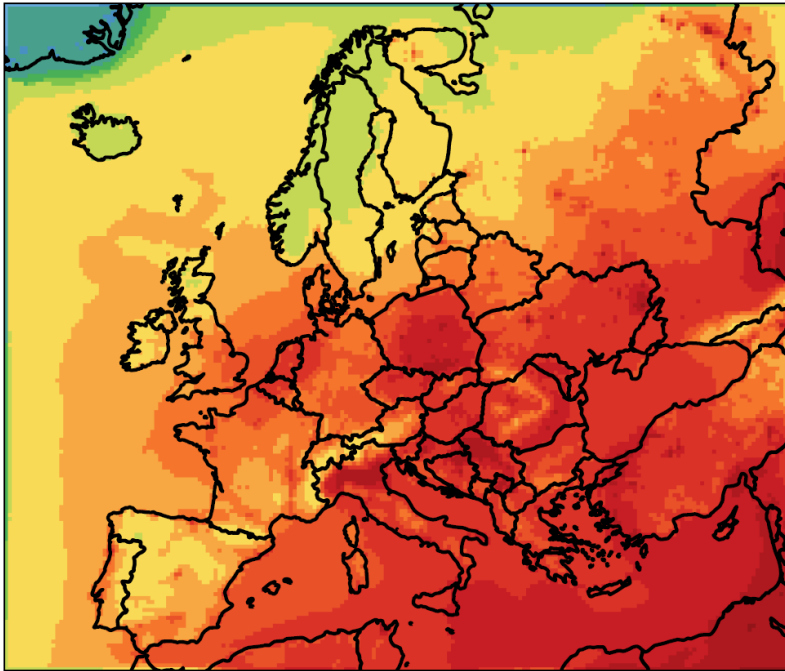
Observed PM_{2.5} from UK Automatic Urban & Rural Network via R openair package



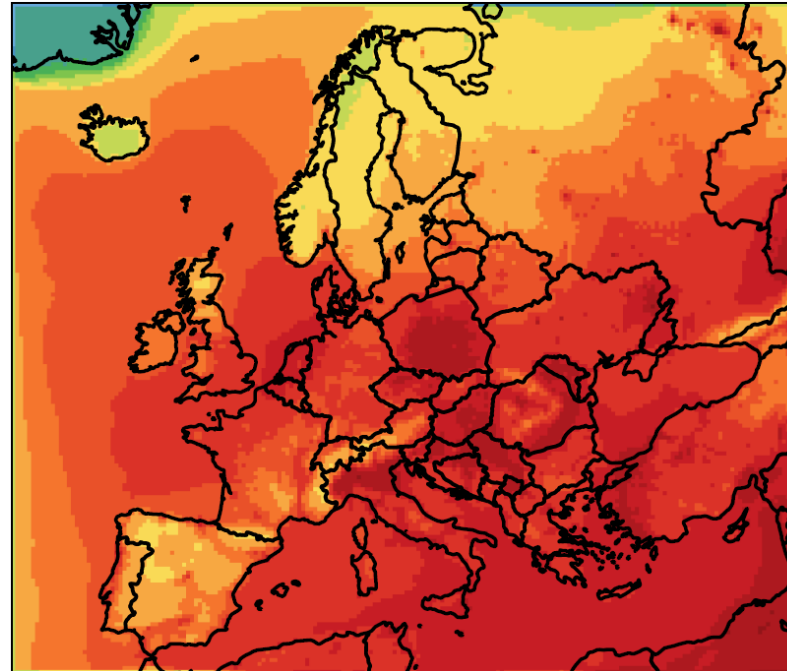
EU domain comparisons

PM_{2.5} spatial variation

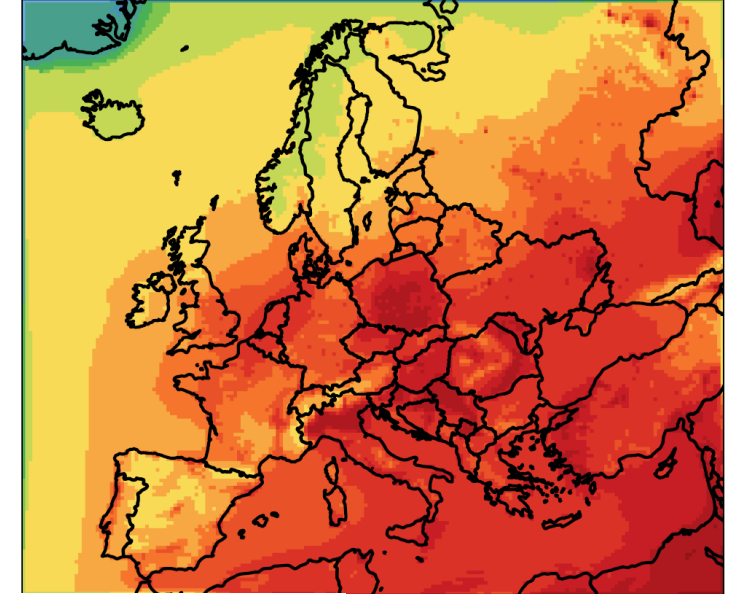
V5.0 (modified wet deposition)



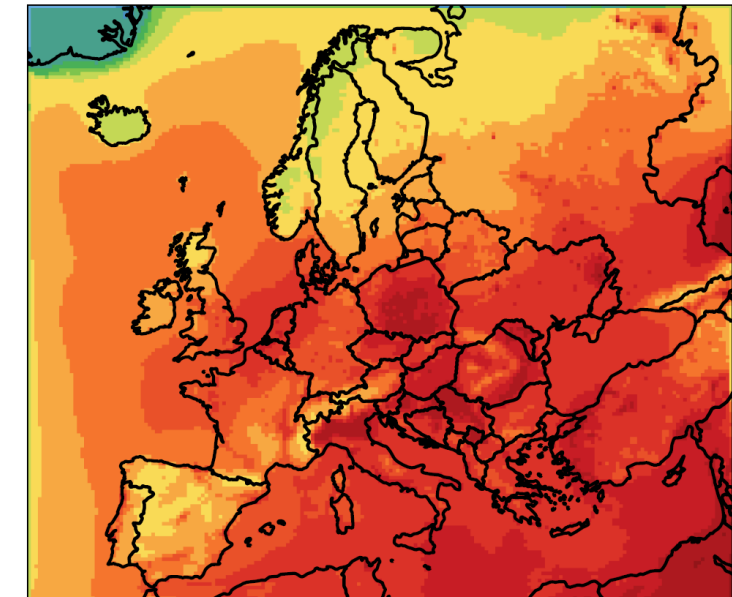
V5.5 ISORROPIA (default)



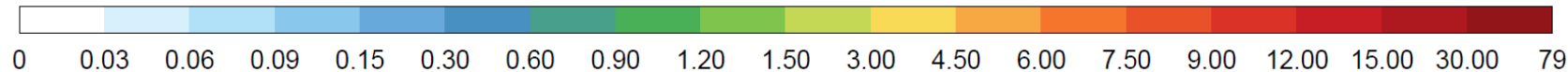
V5.5 MARS



V5.5 EQSAM



SURF_ug_PM25_rh50 (ug/m3)



2023 annual average, v5.5 ISORROPIA shows increases in N and W Europe compared to v5.0 (MARS)

EU domain comparisons

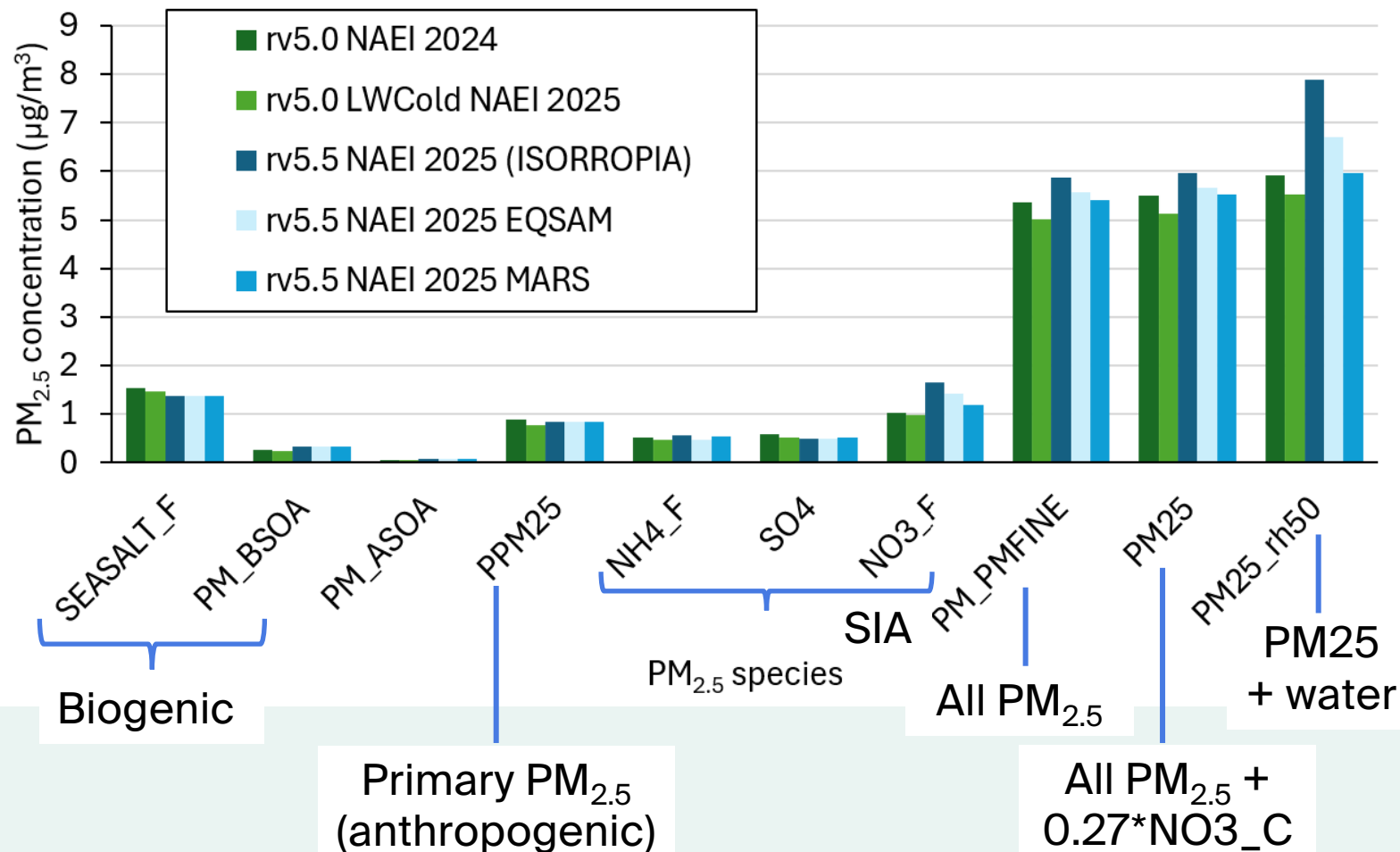
PM_{2.5} components

2023 annual average concentrations within UK land mass

Notable changes rv5.5 vs rv5.0:

- Increased fine NO₃
- Substantially increased particle-associated water

EMEP output PM2.5 components



EU domain comparisons

PM_{2.5} water

EMEP v5.3+ ISORROPIA aerosol water calculations by default include fine sea salt, dust and organic matter

Substantial increase in UK particulate water may be dominated by addition of sea salt to aerosol water calculations?

EMEP v5.3 MARS vs ISORROPIA aerosol water comparisons

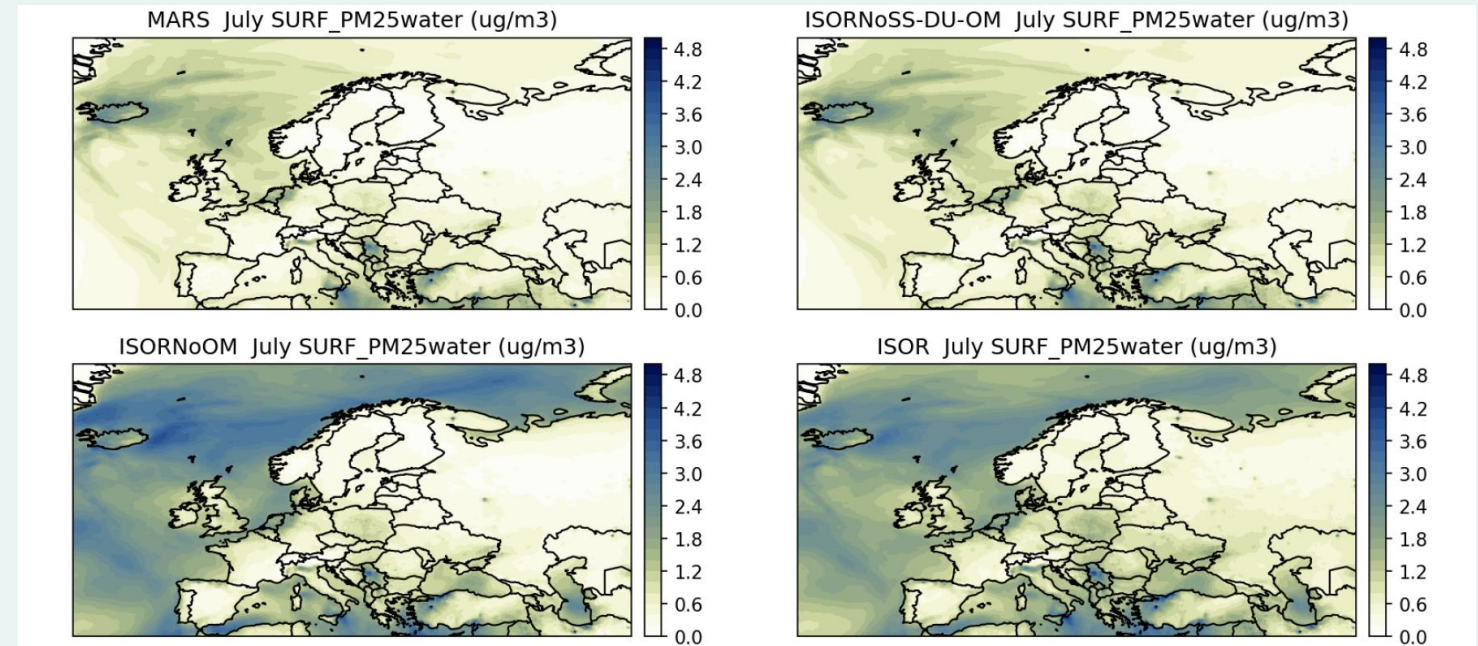
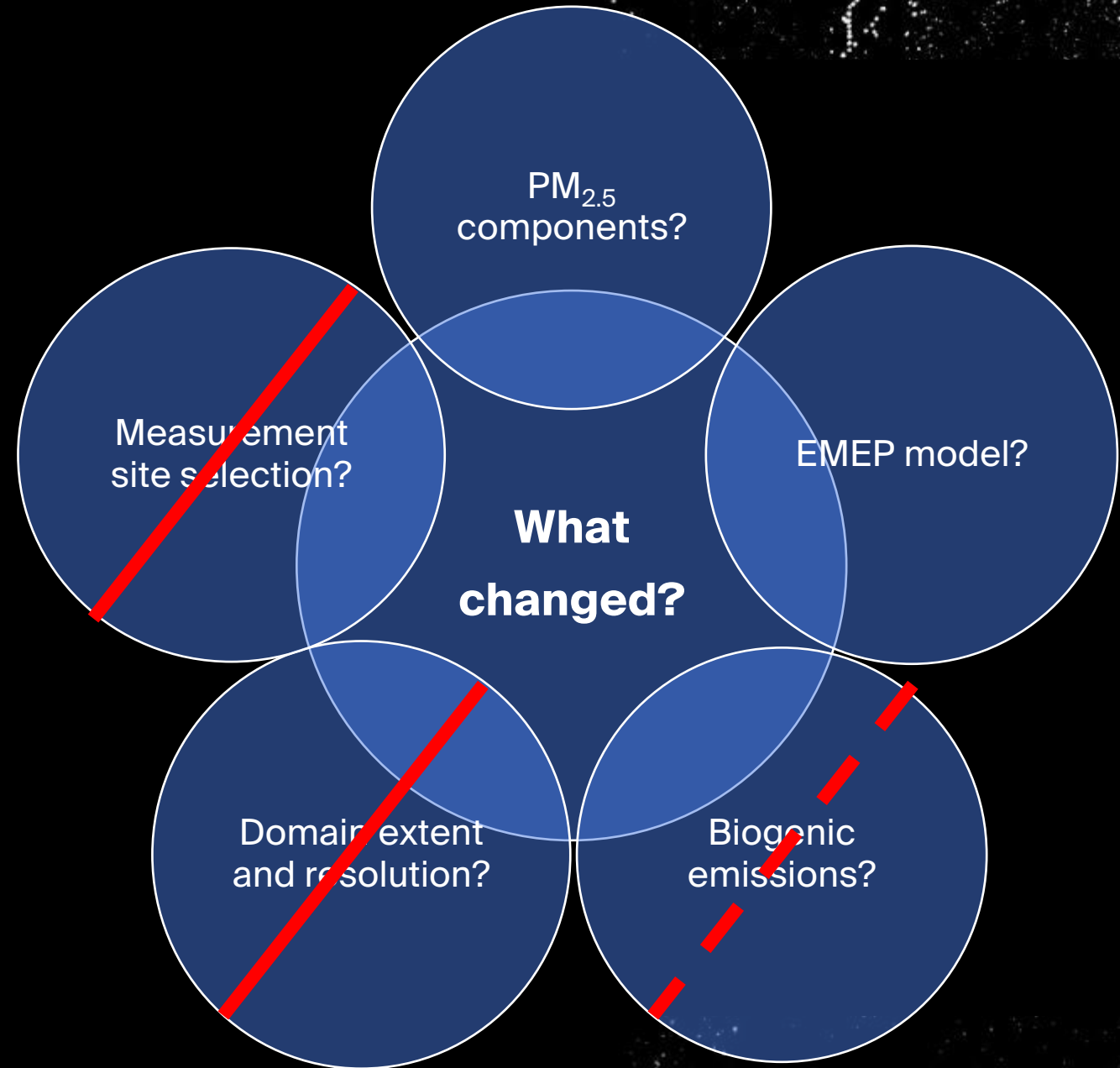


Figure 10.1: Top-left: Aerosol water (AW) in the old default MARS module. Top-right: AW from ISORROPIA with a 'MARS' setup (no contributions from sea-salt, dust, or OM). Bottom-left: AW from ISORROPIA with sea-salt and dust included. Bottom-right: AW from ISORROPIA with sea-salt, dust, and OM water uptake.

Testing aerosol modules

Evaluation with EU measurements

More than a UK problem?

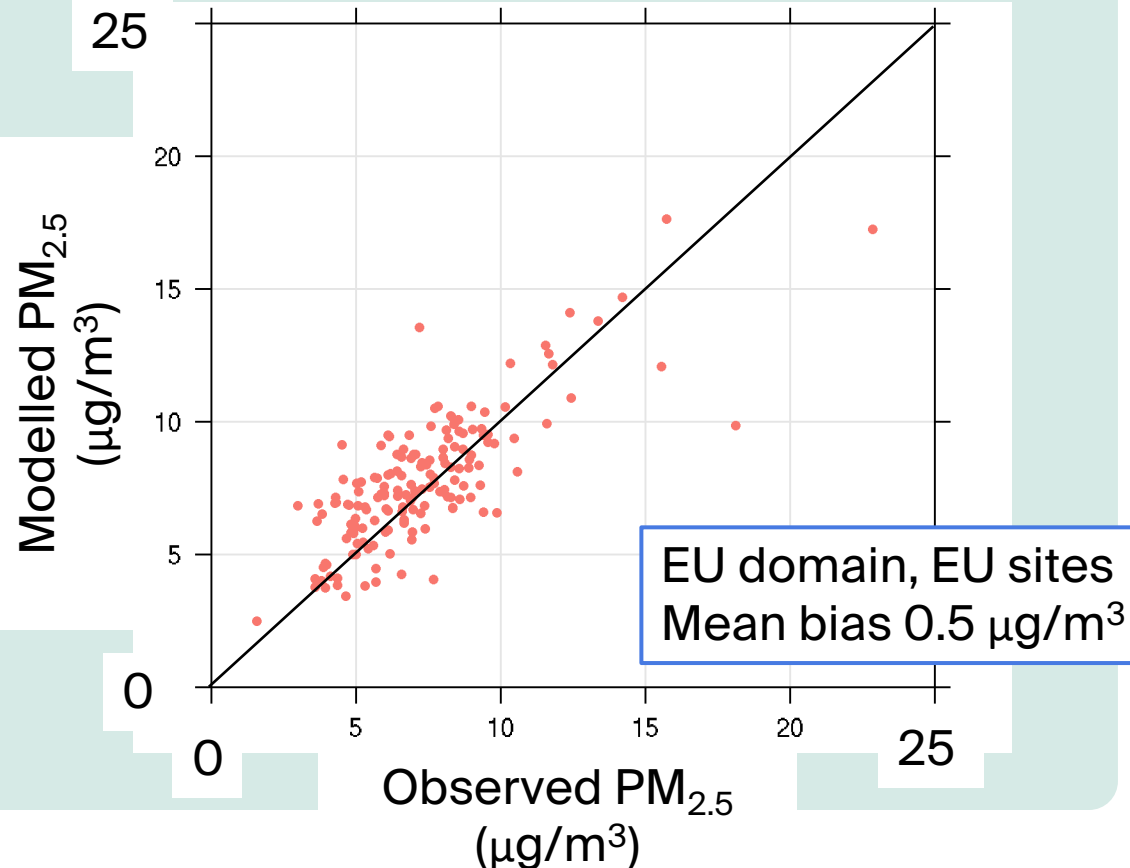


EU domain comparisons

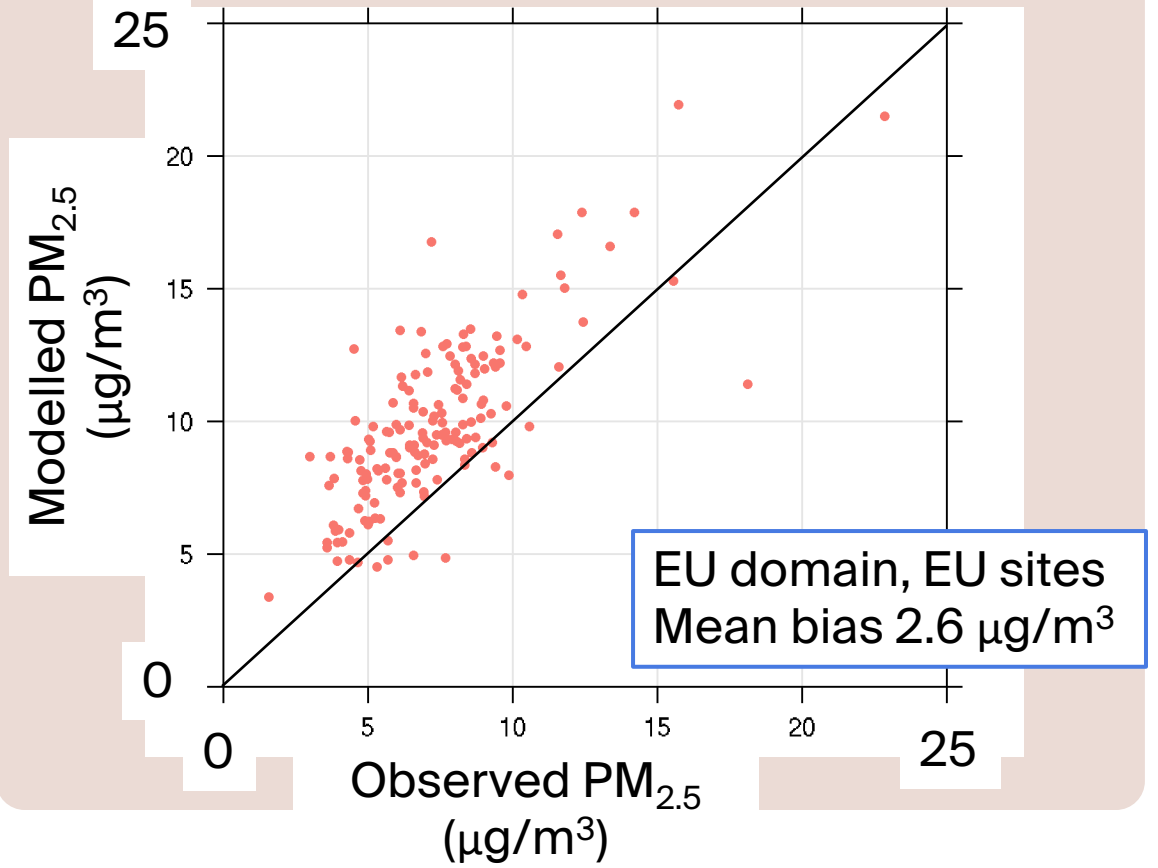
Observed PM_{2.5} from EU rural sites via R openair package

EU PM_{2.5}: 2023 annual averages

EMEP v5.0 (modified wet deposition)



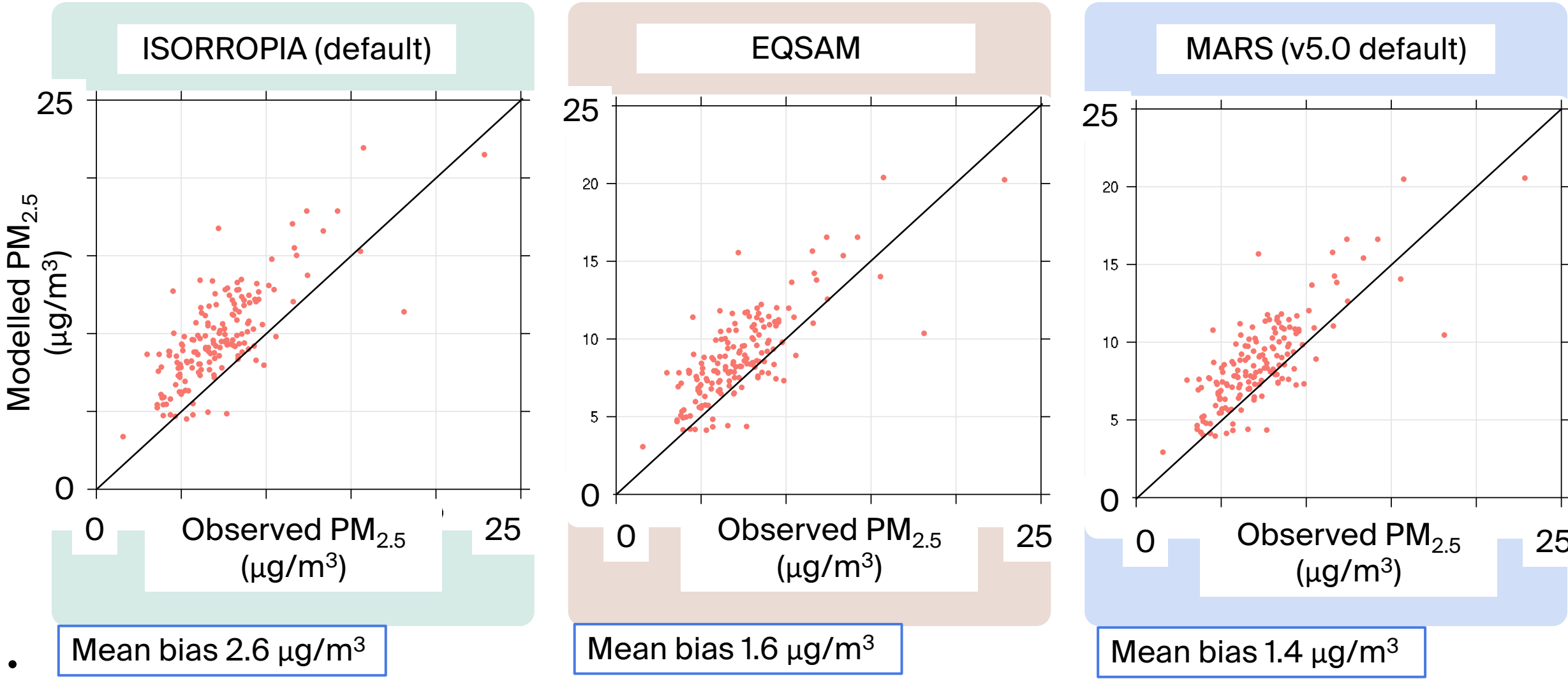
EMEP v5.5



EU domain comparisons: EU PM_{2.5}

EMEP rv5.5 aerosol modules

Observed PM_{2.5} from EU **rural** sites via R openair package



Testing aerosol modules

Summary and remaining questions



Summary

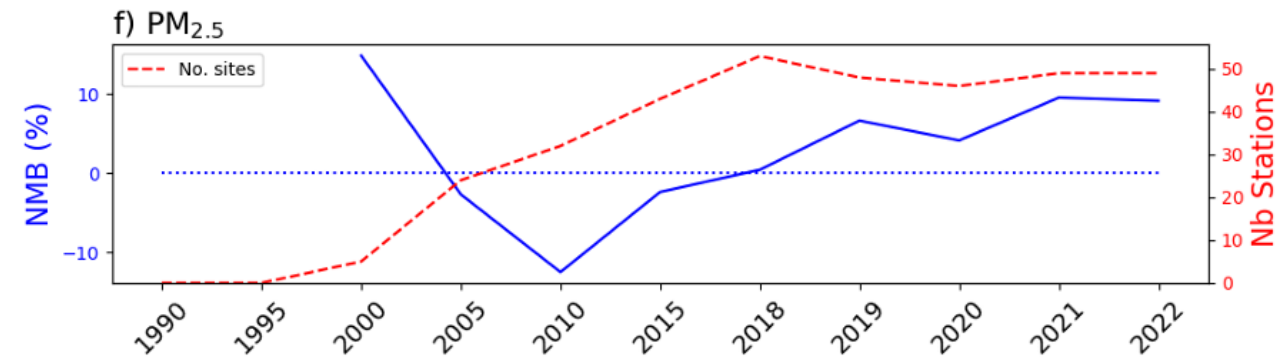
Overview of PM_{2.5} changes

EMEP rv5.3+ default aerosol module ISORROPIA causes substantially increased particle-associated water compared to EMEP rv5.0 default MARS

Bigger differences in PM_{2.5} mean bias between different aerosol modules for sites in UK compared to EU

Relative bias higher for low absolute concentrations

EMEP 5.3 change in PM_{2.5} normalised mean bias over time: how did measured values change?



Summary

Remaining questions

Increasing PM_{2.5} measurement uncertainty at low concentrations?

Link between reducing ambient PM_{2.5} concentrations and increasing normalised mean bias?

Experiences from other model users?

Any further development plans for EMEP aerosol modules?

Use of EMEP PM25_rh50 variable with ISORROPIA?

Internal mixing of sea salt with SIA in ISORROPIA? AERO%INTERNALMIXED setting, switching off increases PM_{2.5} mean bias at UK sites with ISORROPIA through shift from coarse to fine nitrate, also switching off AERO%CATIONS returns to MARS-like results

AERO%ORGANIC_WATER setting? Switching off gives small reduction in PM_{2.5} mean bias at UK sites with ISORROPIA

Thank you.

For more information
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