Source apportionment studies in support of air quality plans and impact assessment

Oriol Jorba, Roger Garatachea, Elena Fernández, Hervé Petetin, Marc Guevara, Alba Badia, Patricia Tarín-Carrasco, Jordi Massagué, and Carlos Pérez García-Pando

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27th EMEP Task Force on Measurement and Modelling Meeting

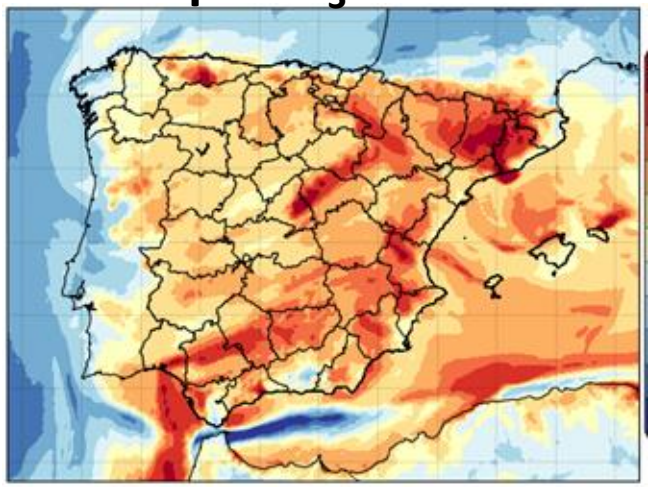
Outline

- Source contribution of O3 and the role of shipping emissions
- Biases in source contribution: example of PM2.5
- Supporting Air Quality plans

Source contribution of O_3 and the role of shipping emissions

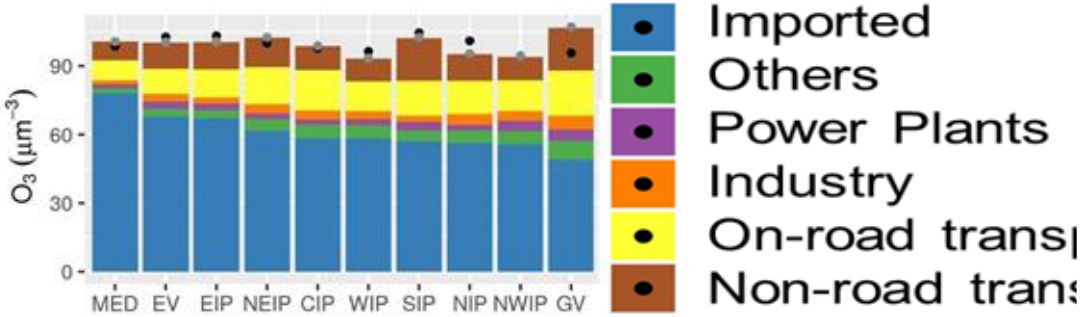
Sector contribution vs imported O_3

p90 O_3 for 31 Jul 2012



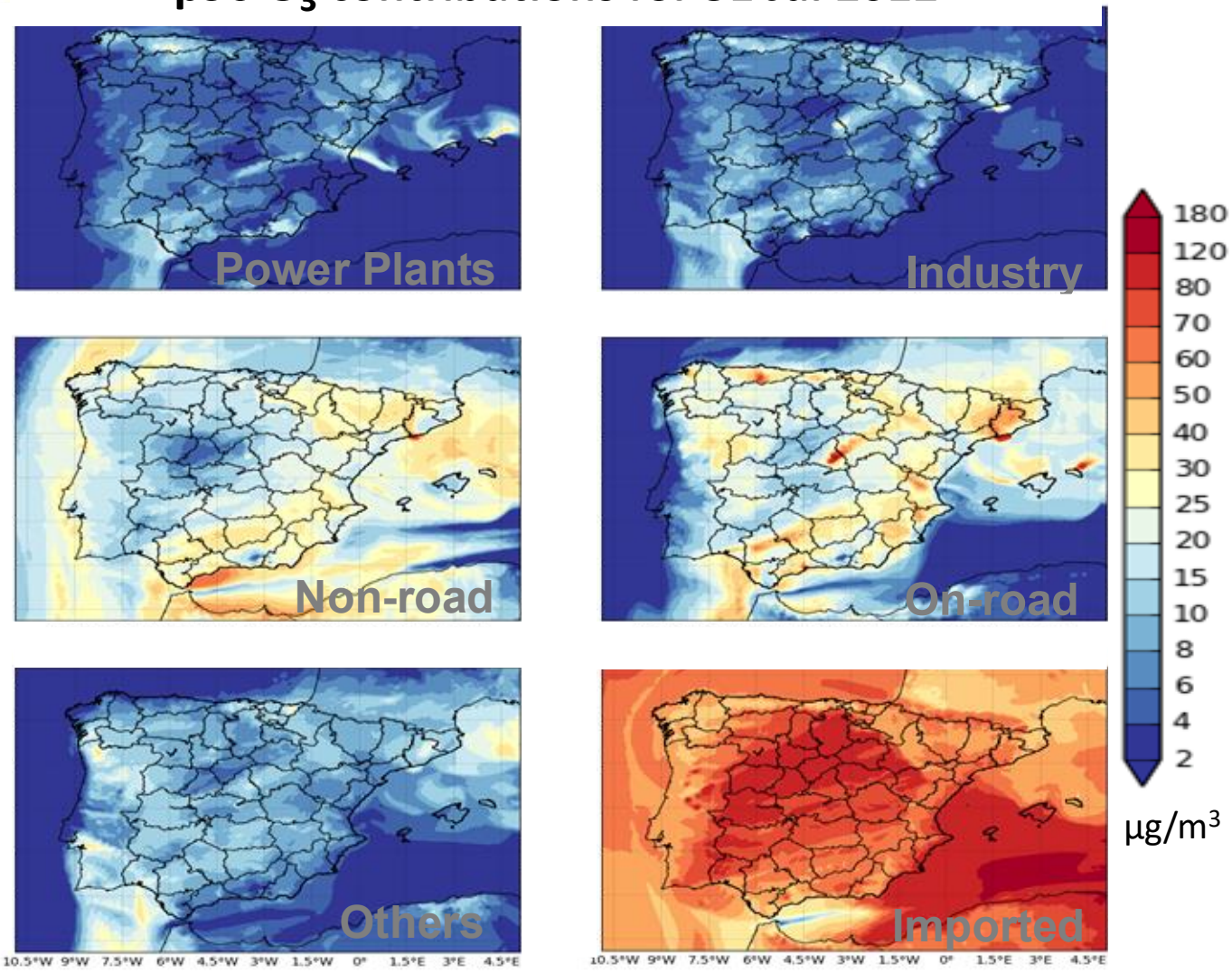
Total

µg/m^3



CMAQ-ISAM SA system

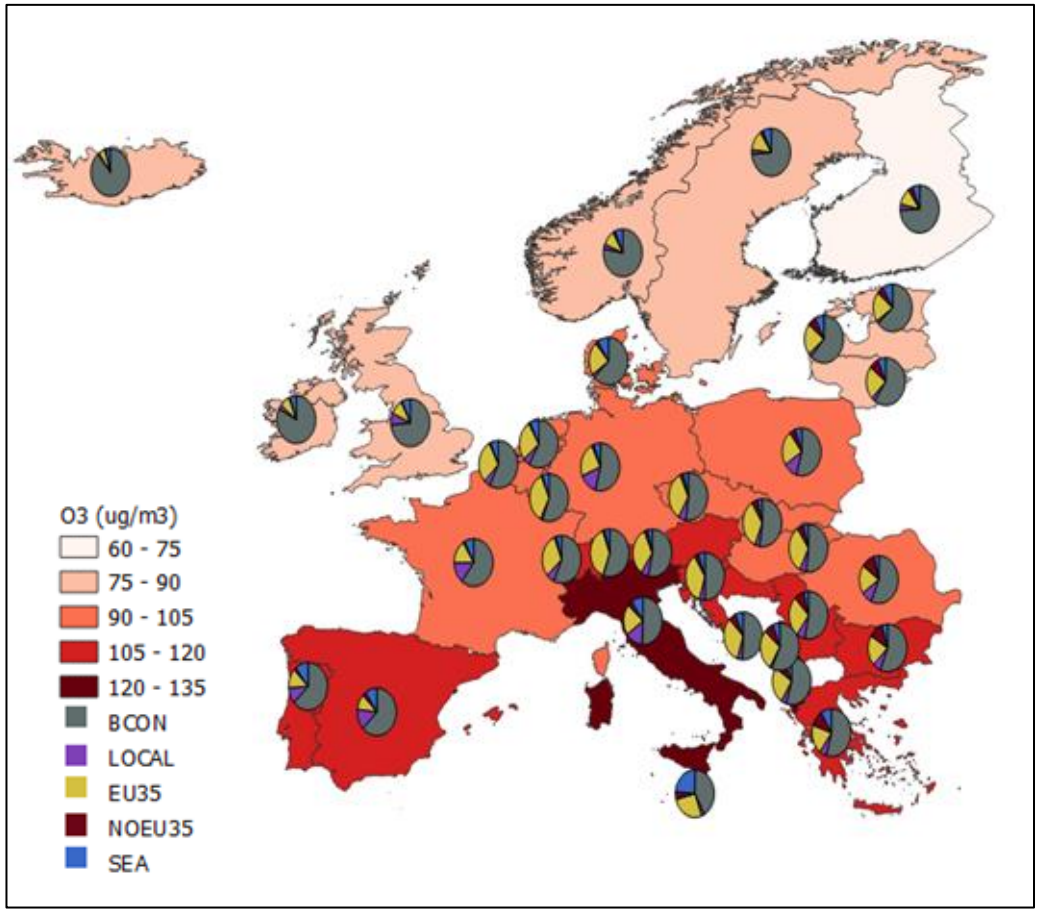
p90 O_3 contributions for 31 Jul 2012



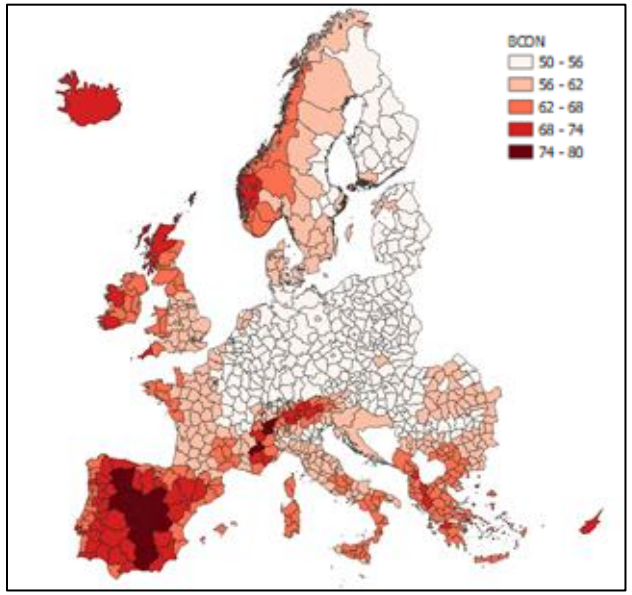
µg/m^3

Pay et al. (2019 ACP)

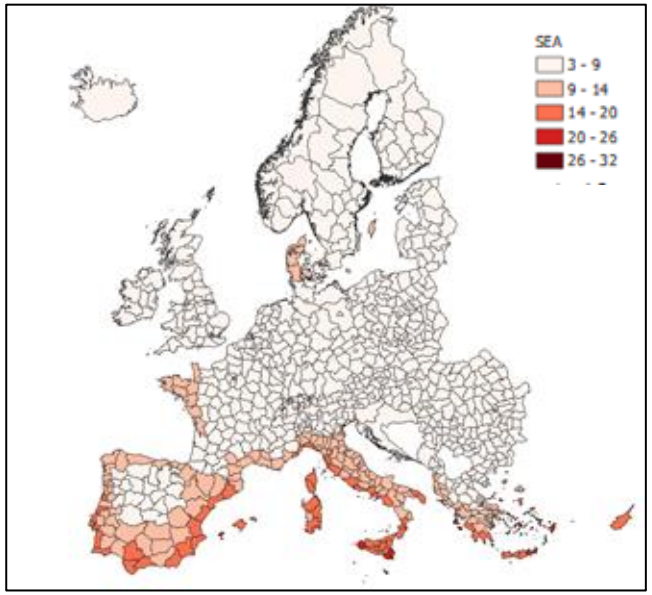
Country vs foreign O_3 contributions



Important hemispheric contribution - vertical mixing processes



Relevant role of shipping emissions

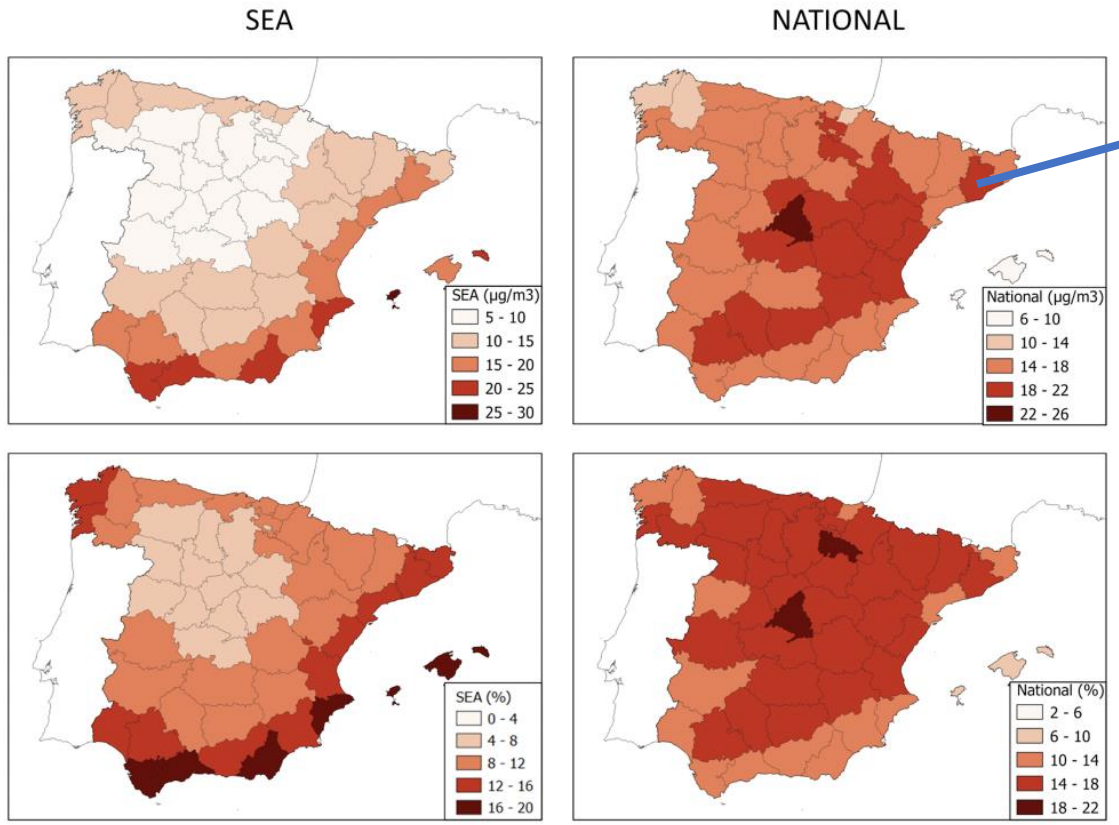


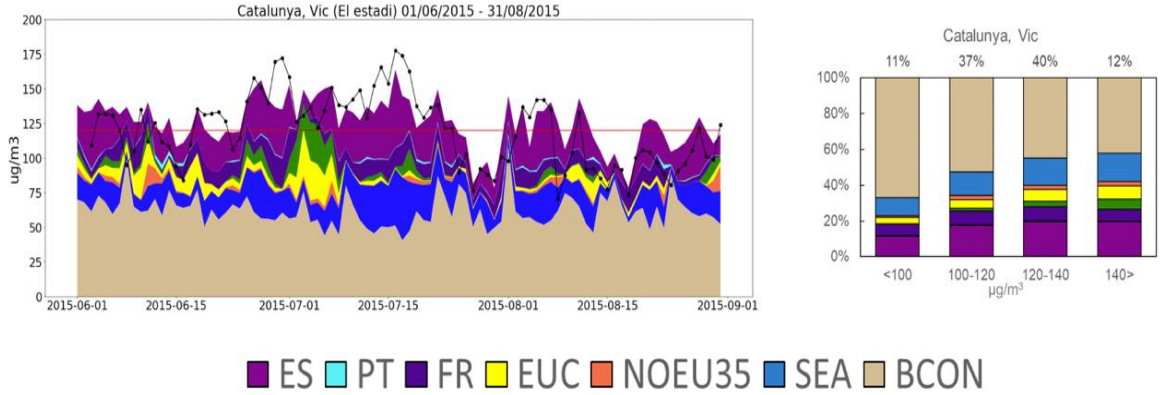
2015-2016-2017 MJJAS Mean MDA8 O_3

CMAQ-ISAM SA system

Garatachea et al. (2024 Comm. Earth & Env.)

Role of shipping emissions in O_3 exceedances in Spain





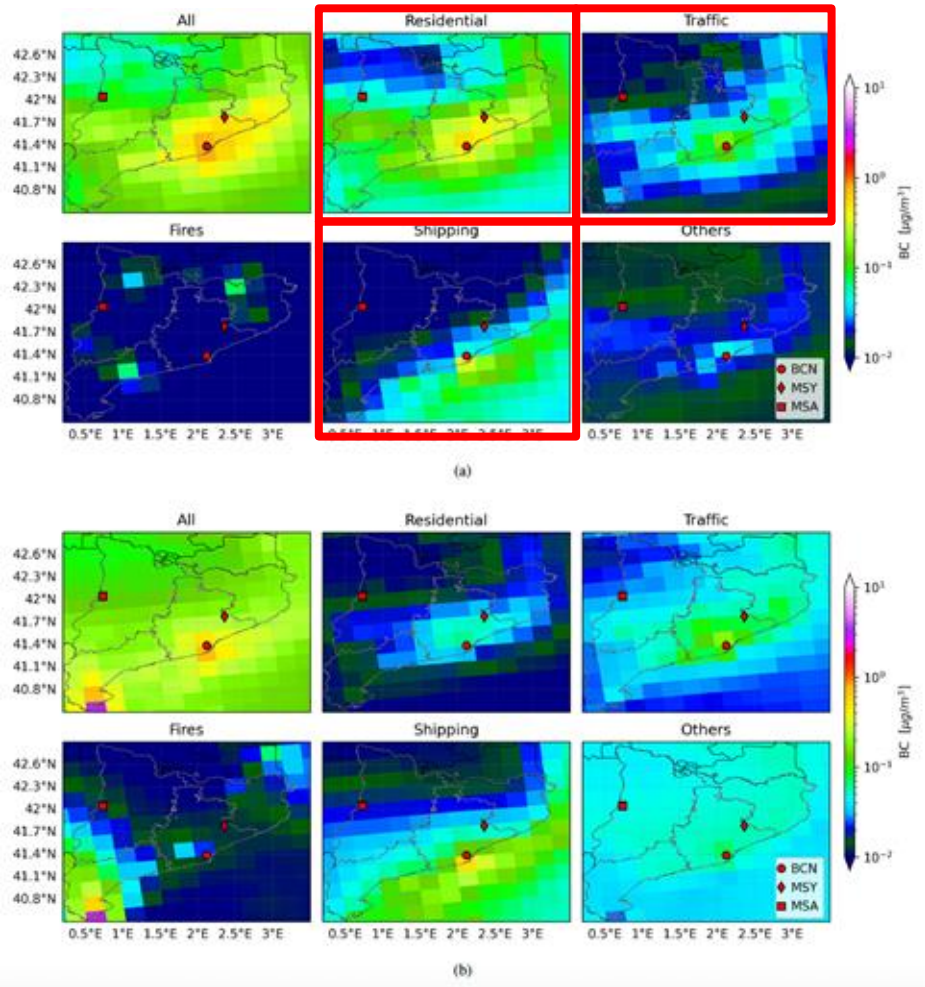
- Shipping emissions key contributor to O_3 pollution in Mediterranean coastal regions
- Notably during ozone season and specific episodes
- Implementation of a Mediterranean NOx ECA (Nitrogen emission control area) could significantly reduce O_3 leves in Southern Europe

Biases in source contributions: exemple of PM2.5

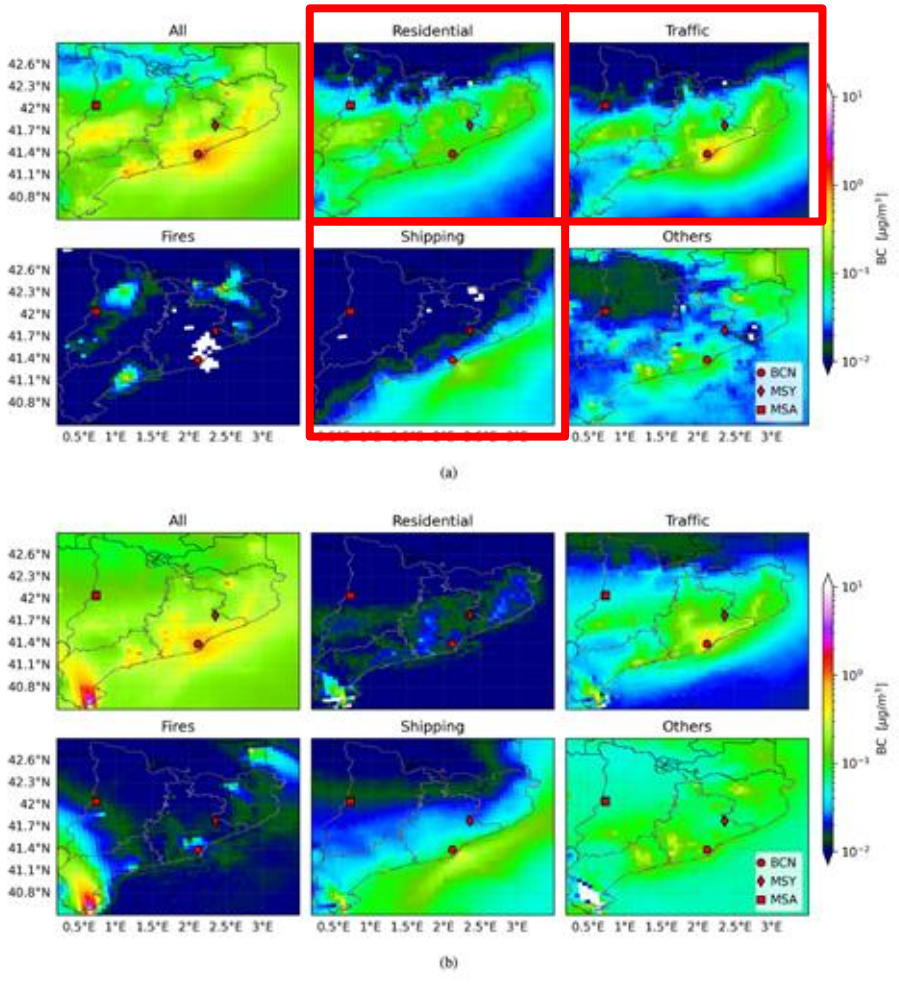
Modeling source contribution of Black carbon

January

July



MONARCH - CAMS-REGv4.2_Ref2 emissions



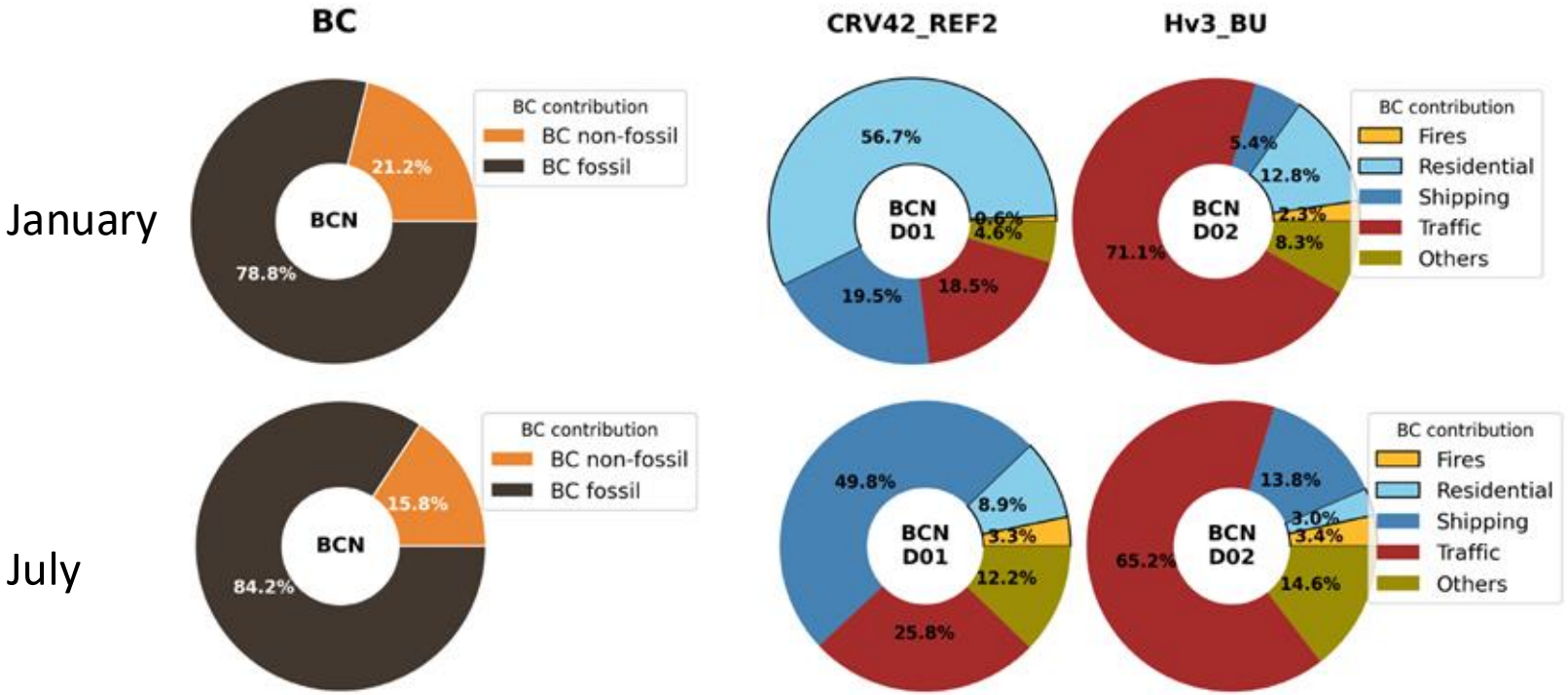
MONARCH - HERMESv3 emissions

Very different representation of Traffic/Residential/Shipping contributions

Navarro et al. (2024 Env. Int.)

Black carbon in urban background: source contribution using observations-based methodologies and modelling

- Tagged sectors: traffic, shipping, residential, biomass, others



WP1 obs. Aethalometer model (Sandradewi et al., 2008)

MONARCH - perturbation method D01(20km), D02(5km)

CAMS-REG emissions:

- Mismatch between fossil and non-fossil
- More weight in the residential/shipping compared with traffic in January/July

HERMESv3 bottom-up:

- Traffic is the dominant sector
- Good match with source contribution derived from observations

Navarro et al. (2024 Env. Int.)

Observation-constrained PM2.5 methodology in SA

1 — $PM_{2.5}$ Source Attribution

20% emission perturbation per sector & country (301 simulations). Sector-country contributions derived from CALIOPE/CMAQ v5.4 at 18 km resolution.

2 — Regulatory Adjustment (Water Content)

Aerosol water uptake computed at 50% RH & 20°C using ISORROPIA-II, aligning modelled dry $PM_{2.5}$ with gravimetric observations.

3 — BLUE Data Assimilation

Best Linear Unbiased Estimator minimises model–observation discrepancy at EEA background stations. Monthly optimal scaling factors α(c,s,m) applied per country & sector. Prior uncertainty: 20% (model); 10% (obs).

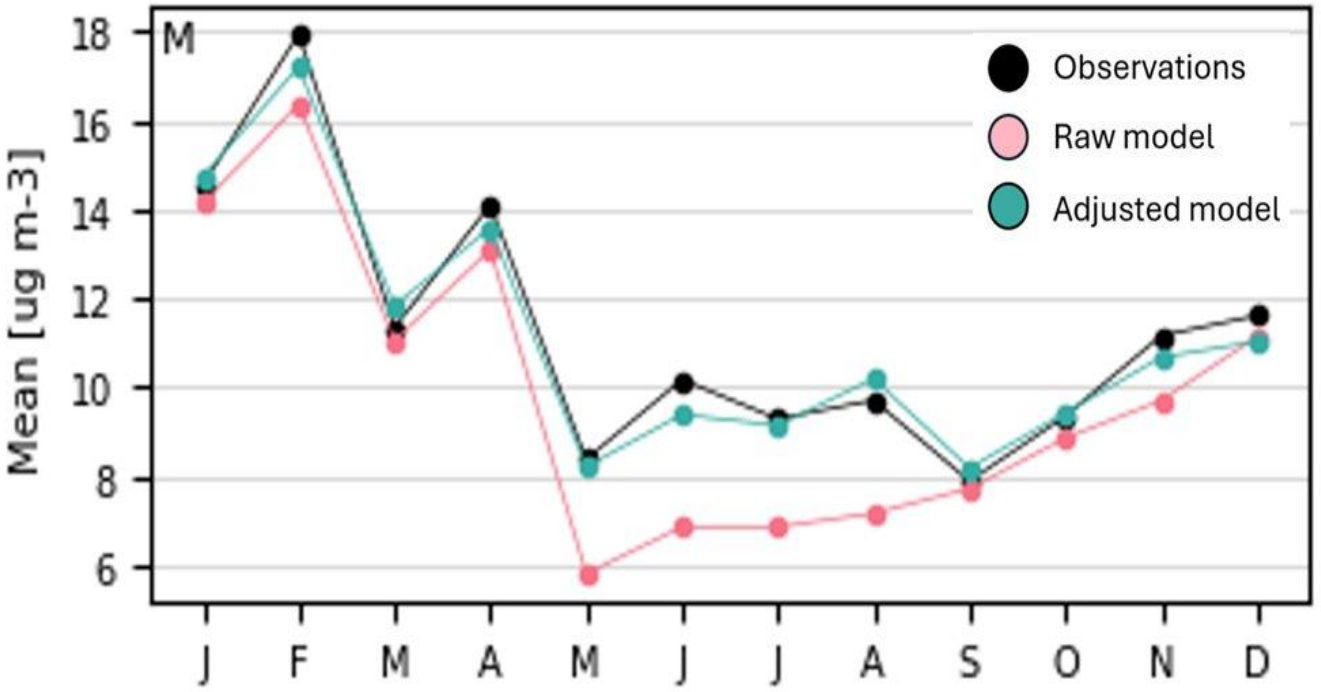
4 — Global Multiplicative Correction (γ = 1.184)

Residual systematic underestimation removed via a single domain-wide factor γ, preserving spatial patterns and relative sectoral fractions.

Model Performance After Correction

PCC	RMSE	Bias	MQI
0.71 → 0.76	6.24 → 5.37 µg/m³	−1.28 → −0.04 µg/m³	≤1 (all stations)

Monthly Mean $PM_{2.5}$: Observations vs. Raw & Adjusted Model



Key finding: The raw CALIOPE model systematically underestimates $PM_{2.5}$, where the adjusted model closely tracks observations year-round. The BLUE assimilation corrects sector- and country-specific scaling factors α(c,s,m) monthly, while the global factor γ = 1.184 removes the residual domain bias — ensuring mortality burden estimates are consistent with observations .

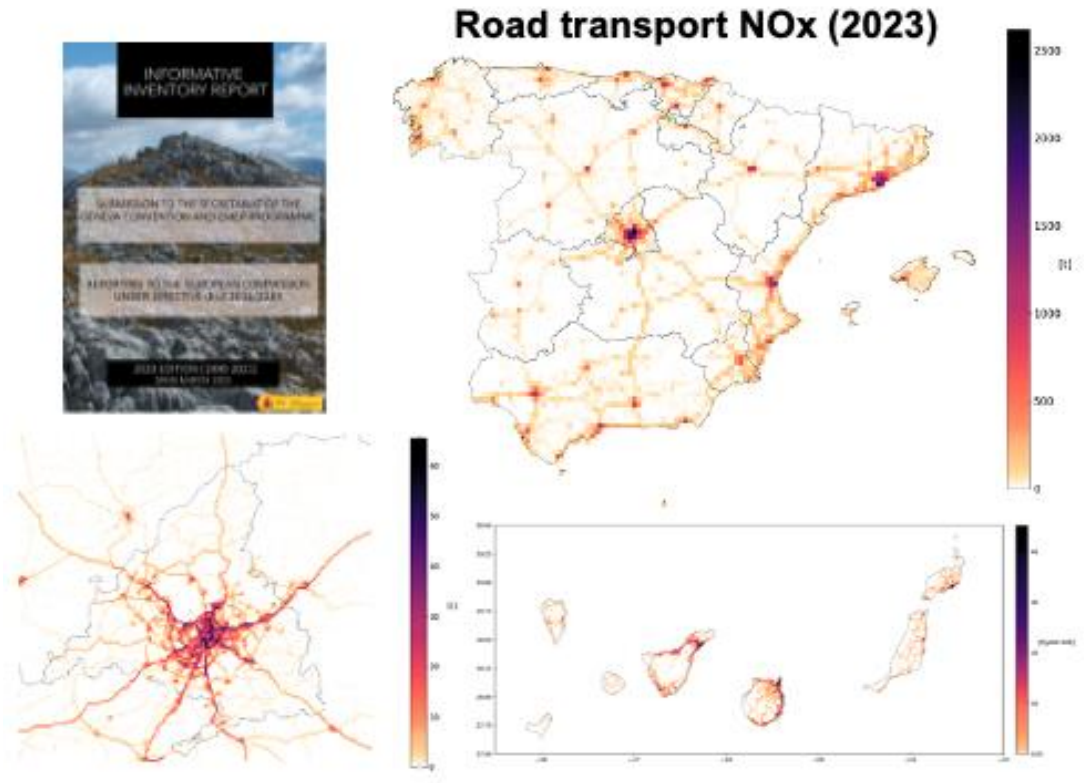
Data assimilation preserves **spatial & sectoral coherence** of the CTM source attribution — only the magnitude is adjusted, not the relative contribution pattern.

Garatachea et al. (2026 in preparation)

Supporting Air Quality Plans

Activities on support of Spanish AQ plans

- Spain is currently assessing which regions will have to submit 2028 roadmaps (if pollutant concentrations are projected to exceed the AAQD 2030 limits)
- Preparation of emissions for the different scenarios with HERMES_delta:
  - **EB: base case (2023)**
  - **EP: planned scenarios (2030 with national plans)**
    - WeM 2030 (With Existing Measures)
    - WaM 2030 (With Additional Measures)
    - WaM 2030 + CAO3
  - **EXs: extreme scenarios over Spain:**
    - EX_TRA0: No road traffic emissions (SNAP07)
    - EX_RES0: No residential emissions
    - EX_AGR0: No agricultural emissions (SNAP10)
    - ...
    - EX_ANTH0: No anthropogenic emissions
    - EX_BIO0: No biogenic emissions
- Ongoing evaluation and assessment of 2030 future scenario on NO_2 , O_3 , $PM_{2.5}$ and PM_{10} pollution across Spain using state-of-the-art modelling tools.



HERMES_DELTA: Emission model for the pre-processing of the Spanish official inventory to support modelling efforts (Castesana et al., 2025; Tena, 2026)

Activities on support of Spanish AQ plans – Trans./Residential/Agric./biogenic contribution

NO2:

The removal of **anthropogenic** emissions reduces the annual concentrations of NO_2 by 0.5 µg/m³ (-85%)

Key contribution of road transport *(-1.6 µg/m, -42 %).*

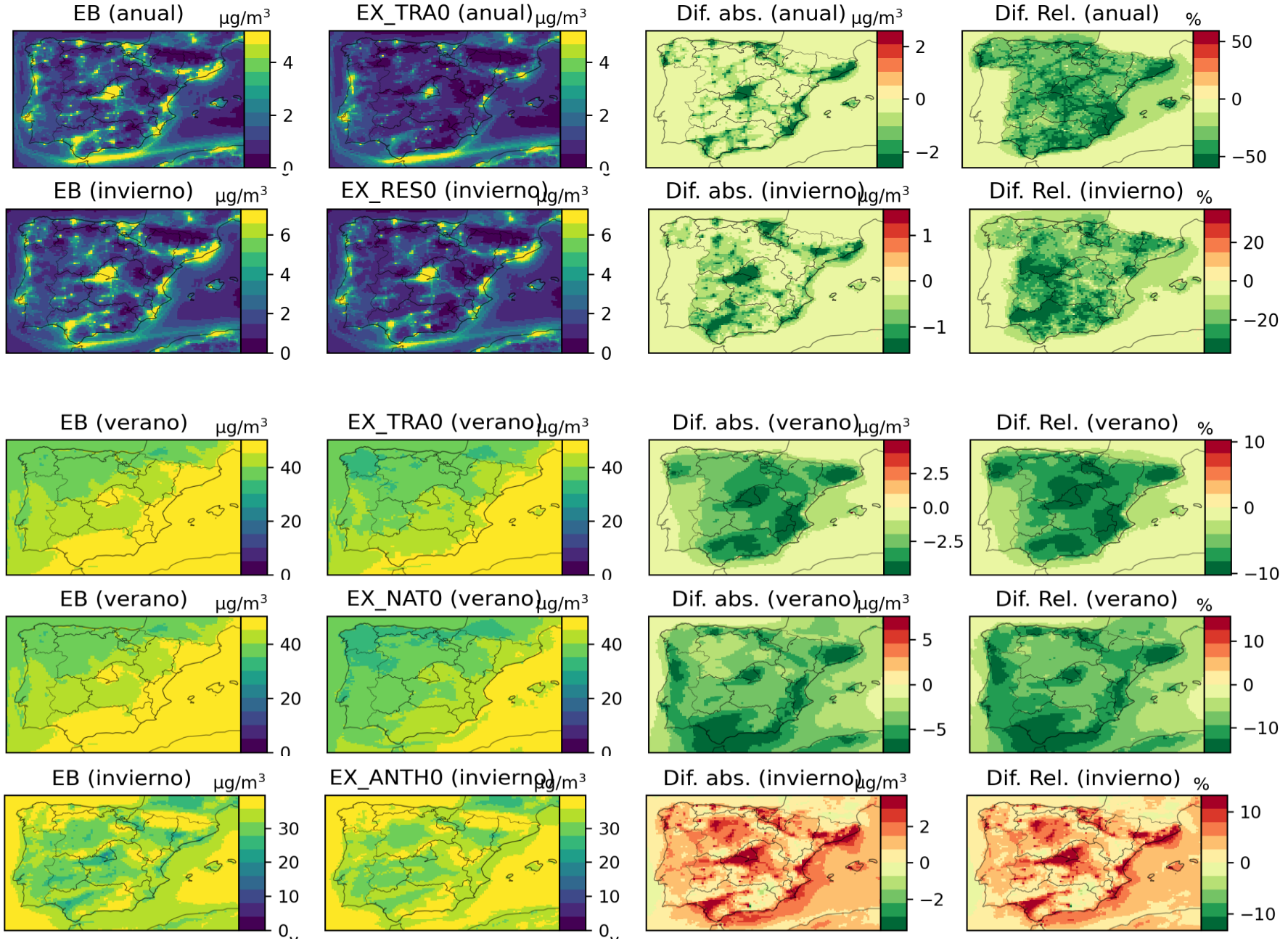
The impact on the residential sector in winter is significant *(-1.1 µg/m³, -21 %)*

O3:

Removing all **anthropogenic** emissions reduce the O_3MDA8 by -6.3 µg/m³ (-8%), with a -14 µg/m³ (-16%) reduction during the summer.

In summer, road transport (-6.1 µg/m³ , -7 %), **energy and industry** (-2.6 µg/m³, -3%) and **biogenic** (-8.9 µg/m3, 10 %) emissions.

In winter, the **titration** of NO by O_3, leading to increases in O_3 in major cities and surrounding rural areas.



Activities on support of Spanish AQ plans – Trans./Residential/Agric./biogenic contribution

PM2.5:

The removal of **anthropogenic** emissions reduces the annual $PM_{2.5}$ by up to 4.1 µg/m³ (-25%), with greater reductions during the winter (2.3 µg/m³, -45%).

Key contribution of agricultural and residential sectors reaching significant reductions in winter (> 20%)

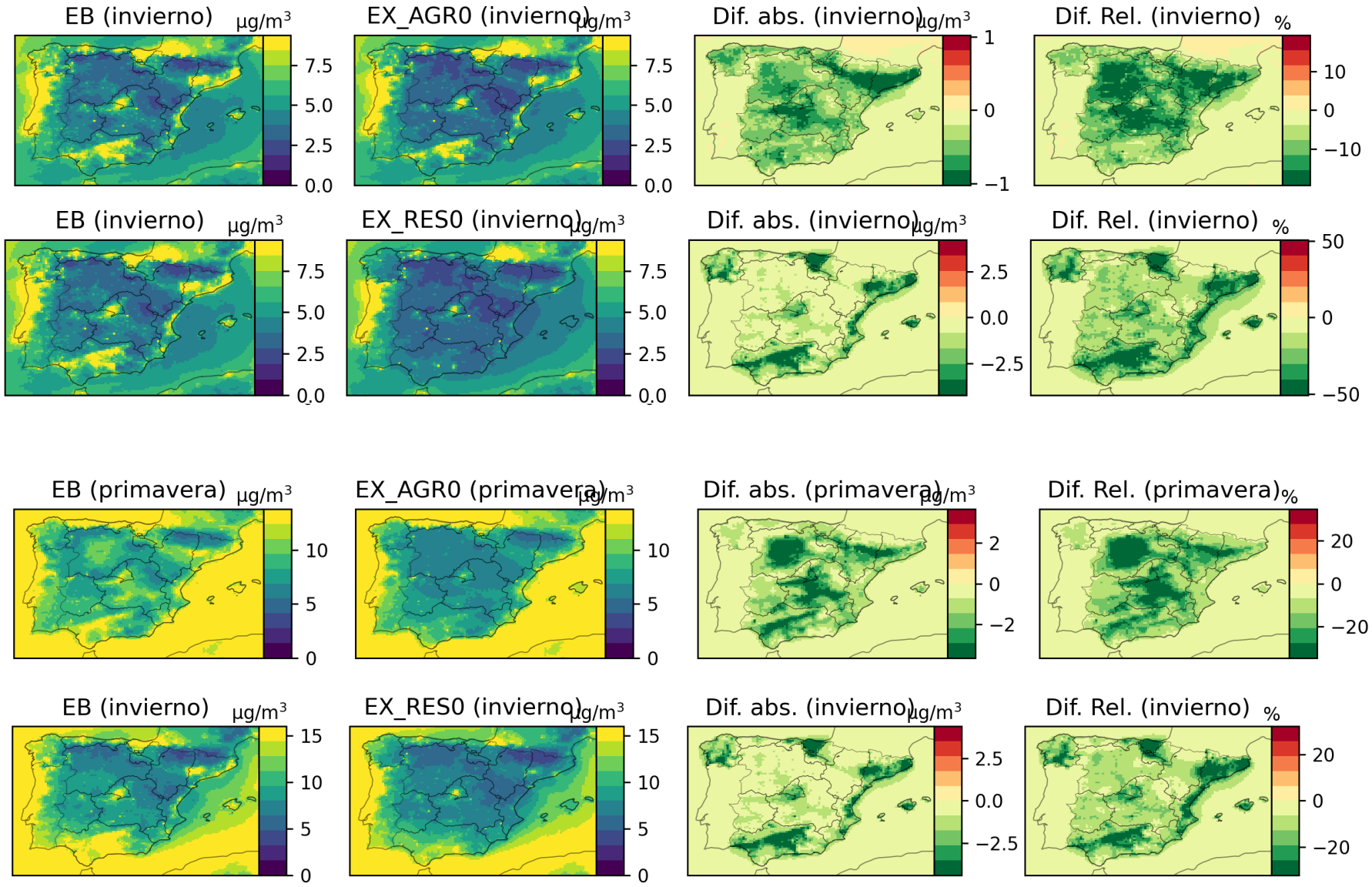
Agricultural emission reductions are primarily due to the **exclusion of ammonia** (NH_3) from fertilizer use.

Biogenic emissions reduce $PM_{2.5}$ levels, especially in summer (up to -0.4 µg/m³) in forested and agricultural areas (not shown).

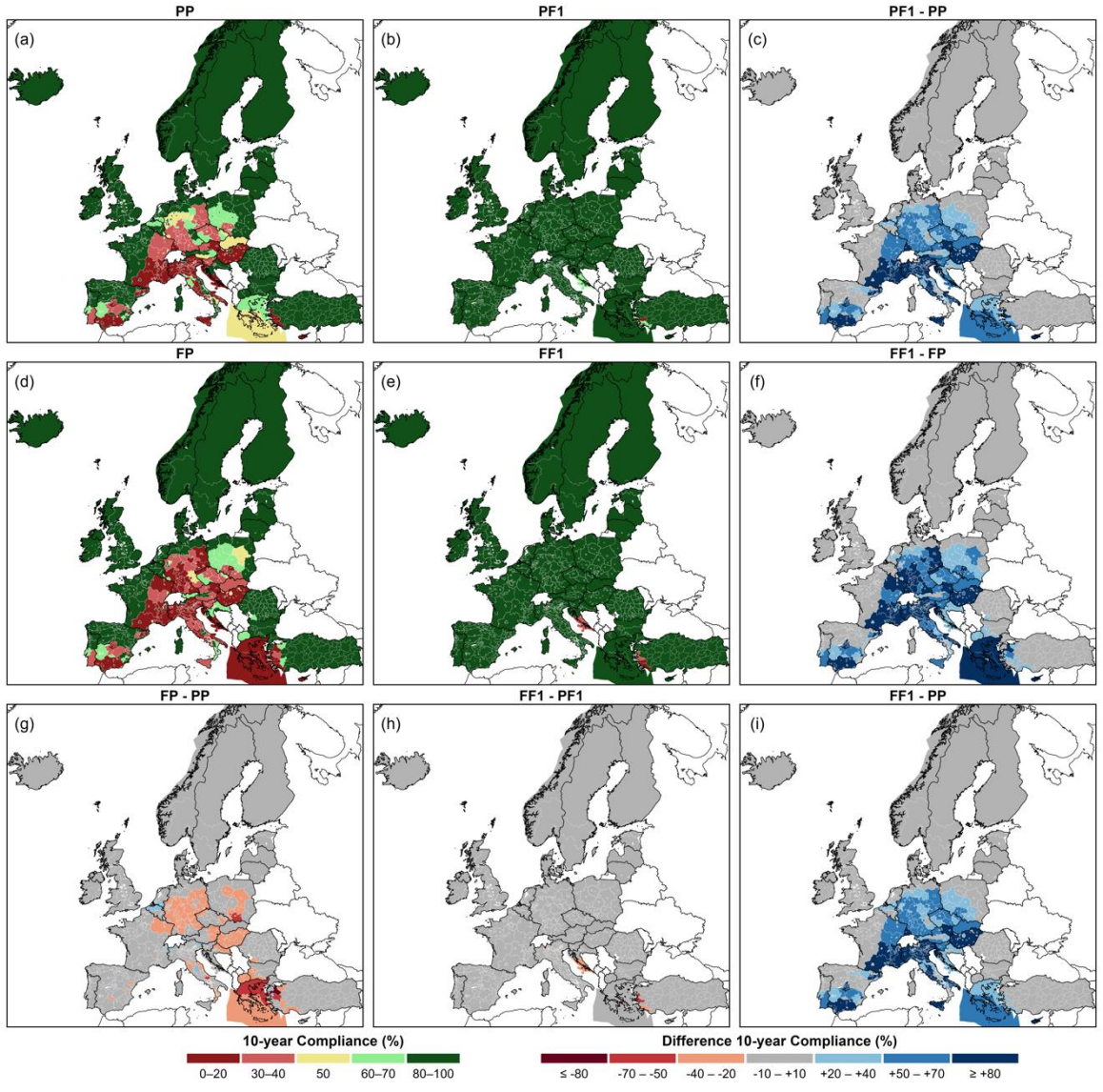
PM10:

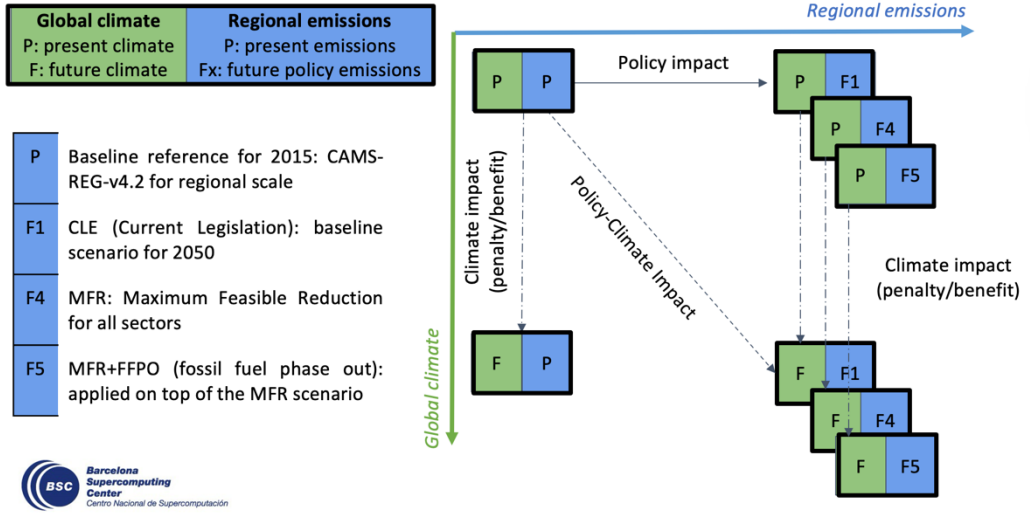
Eliminating all anthropogenic emissions reduces the annual average to 9.7 µg/m³, with the largest decrease in winter (up to -3.1 µg/m³).

Agricultural sector (farming activities and the use of machinery") and **residential sector** explain reductions of -1.5 µg/m³ (-15%) in spring and winter (respectively)



Quantifying the climate impact on air quality





- Downscaling EC-Earth3 climate runs using regional CTM MONARCH
- Assess the air pollution climate impact in Europe and Spain
- Quantify the effect on policy-related metrics and health

Tarín-Carrasco et al. (2026 in preparation)
Massagué et al. (2026 in preparation)

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oriol.jorba@bsc.es