



**Barcelona  
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*Centro Nacional de Supercomputación*

# Comparative analysis of bottom-up and top-down estimates of agricultural $\text{NH}_3$ emissions in Spain

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# Background

## New Ambient Air Quality Directive Directive 2024/2881

NH<sub>3</sub>: pollutant of emerging concern

Human health

Ecosystems

PM<sub>2.5</sub>

Respiratory and cardiovascular diseases

Biodiversity loss

Premature mortality

Ecosystem eutrophication

(Ma et al., 2021)

(Stevens et al., 2010;  
Dirnböck et al., 2014)



## National Emission reduction Commitments Directive (NECD) Directive 2016/2284

The biggest challenge is reducing NH<sub>3</sub> emissions  
(EEA, 2025)

Agriculture

94% of total EU-27 NH<sub>3</sub> emissions in 2023  
(EEA, 2025)



Synthetic fertiliser application



Manure management and application



Livestock farming

Spain

Third largest EU-27 emitter of agricultural NH<sub>3</sub>  
(EMEP/CEIP, 2025)

# Overview of the comparative analysis

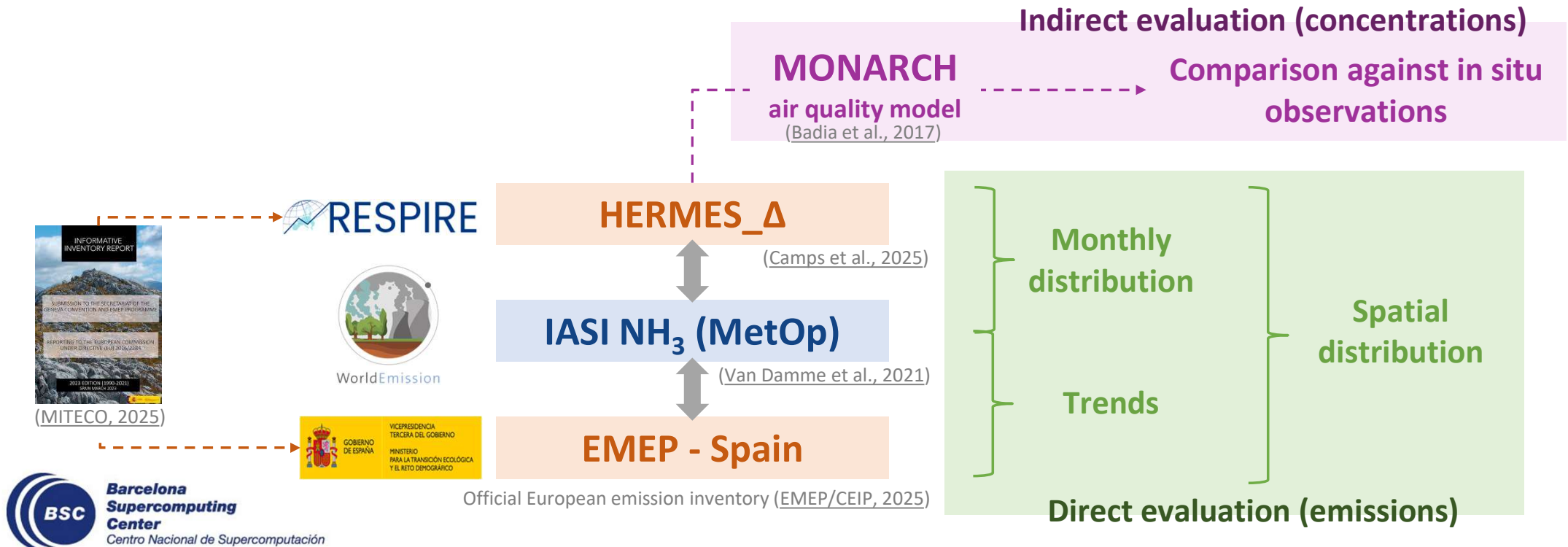
Bottom-up

Top-down

**Activity factors** (amount of fertiliser) and **emission factors** (mass of  $\text{NH}_3$  emitted per amount of fertiliser)  
Main uncertainties: limited knowledge of agricultural practices, non-consideration of meteorological conditions

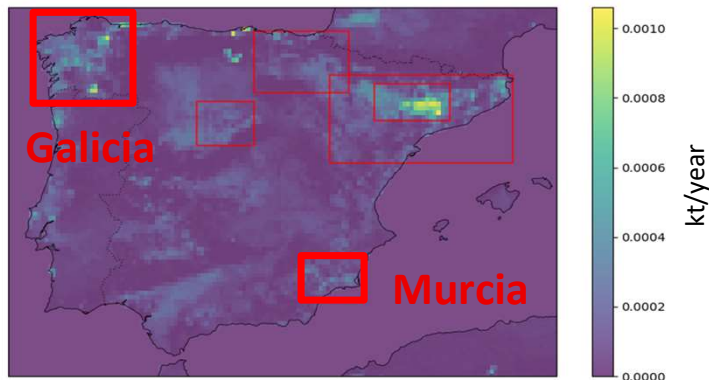
Application of an inversion algorithm to **satellite observations**

Main uncertainties: parametrisation and input information considered in the inversion algorithms, cloud coverage



# Spatial distribution

NH<sub>3</sub> bottom-up emissions (EMEP - 2023)



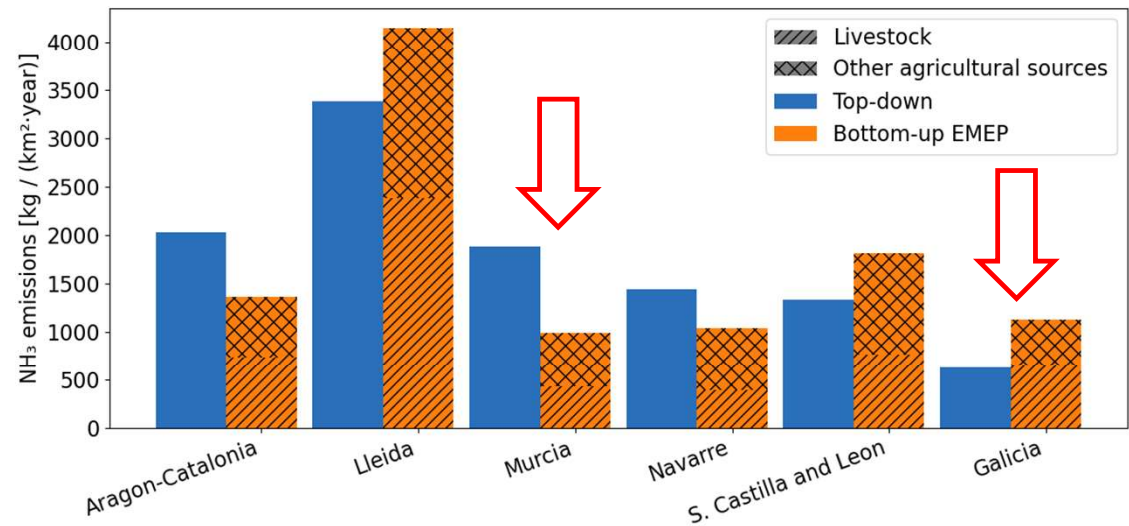
Regions with available top-down emissions (NH<sub>3</sub> hotspots)

Mean annual temperature



(AEMET, 2026)

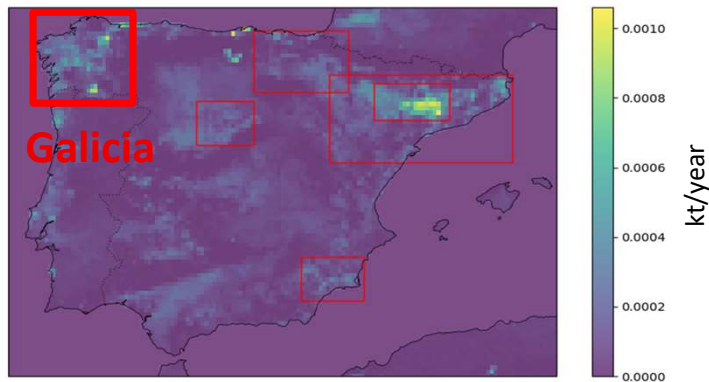
Top-down versus bottom-up NH<sub>3</sub> emissions by hotspot (2023)




↑ temperature    ↑ NH<sub>3</sub> volatilisation    ↑ NH<sub>3</sub> emissions  
 The agricultural EF considered in the EMEP/EEA guidelines (Tier 2) do not account for the impact of temperature on NH<sub>3</sub> emissions  
 Bottom-up NH<sub>3</sub> emissions: **potentially underestimated in Murcia, overestimated in Galicia**

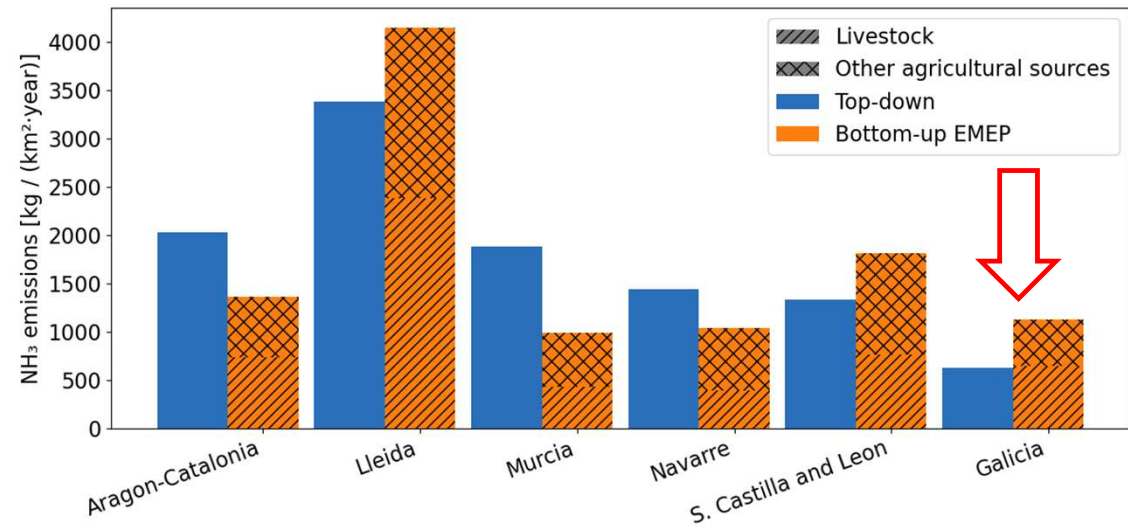
# Spatial distribution

NH<sub>3</sub> bottom-up emissions  
(EMEP - 2023)



 Regions with available top-down emissions (NH<sub>3</sub> hotspots)

Top-down versus bottom-up NH<sub>3</sub> emissions by hotspot (2023)



**No consideration of Best Available Techniques in cattle emission factors**

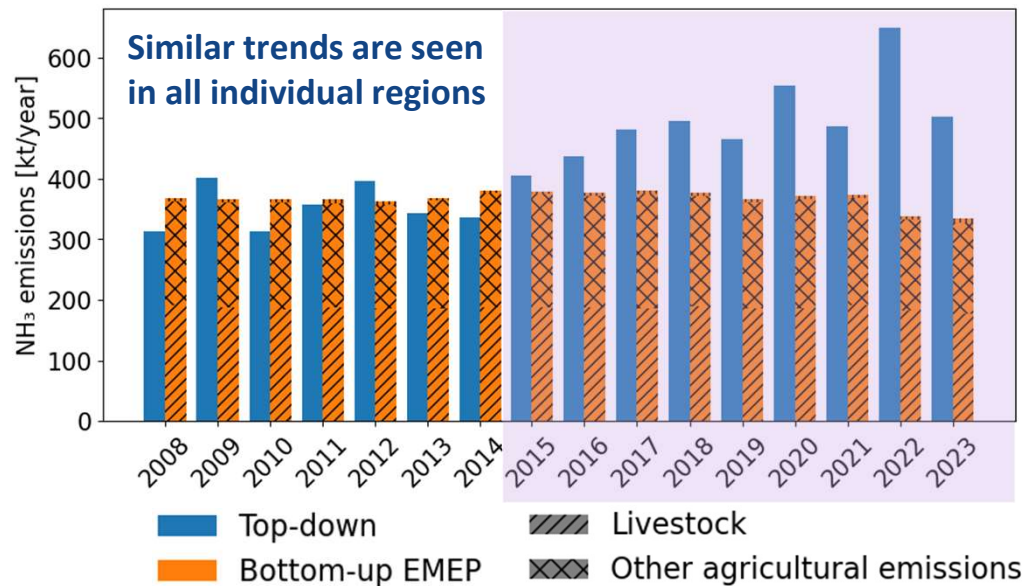
60% of NH<sub>3</sub> emissions in **Galicia** come from **cattle** farms

Bottom-up NH<sub>3</sub> emissions: **potentially overestimated in Galicia**

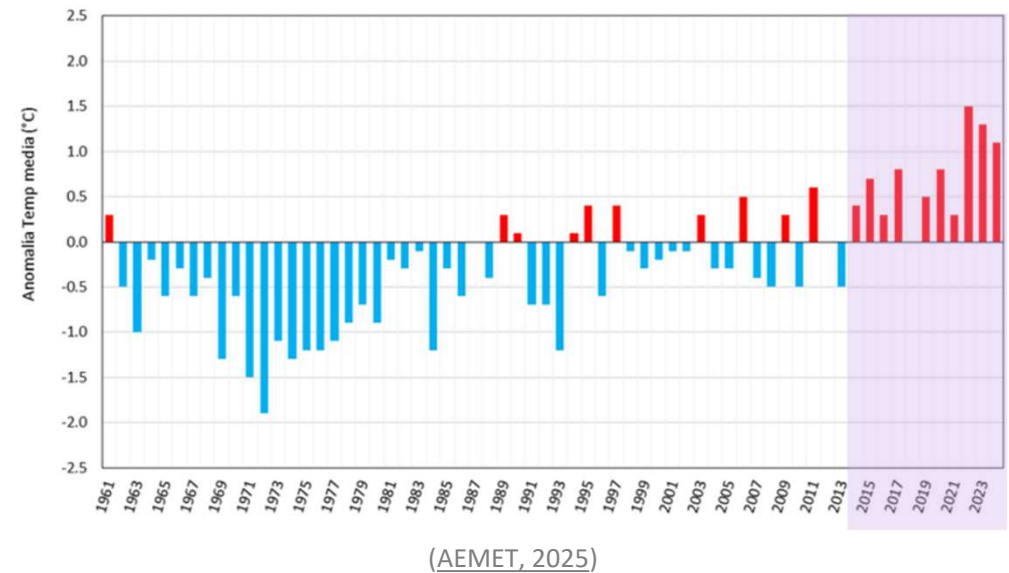
# Trends

↑ temperature    ↑ NH<sub>3</sub> emissions

## NH<sub>3</sub> emissions (2008-2023, SUM of all regions)



## Annual temperature anomalies in Spain (reference period: 1990-2020)

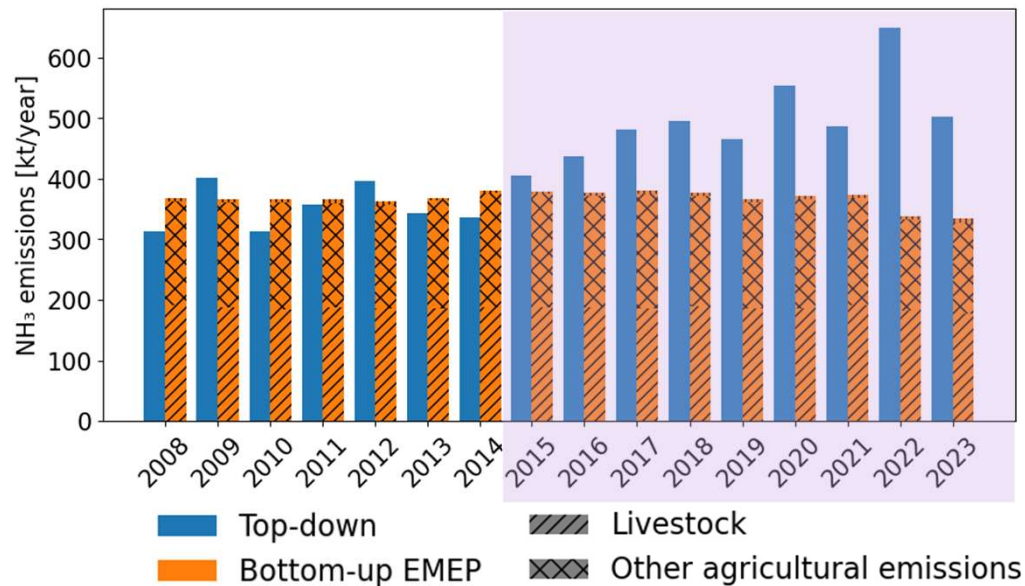


The potential NH<sub>3</sub> emissions increase linked to climate warming is not reflected in official bottom-up inventories

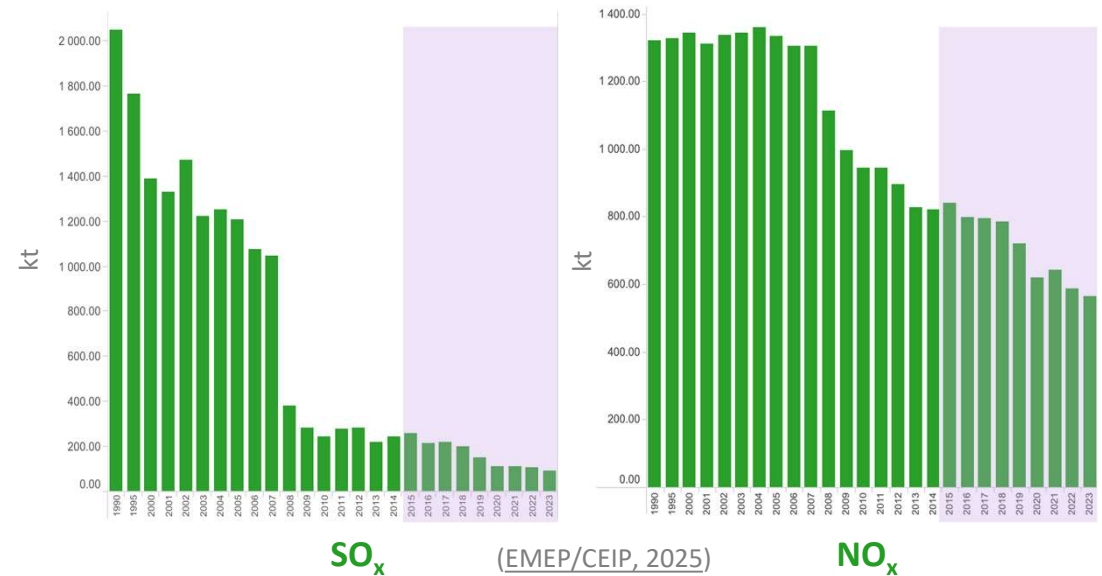
The agricultural EF considered in the EMEP/EEA guidelines (Tier 2) do not account for the impact of temperature on NH<sub>3</sub> emissions

# Trends

## NH<sub>3</sub> emissions (2008-2023, SUM of all regions)



## SO<sub>x</sub> and NO<sub>x</sub> emissions in Spain (1990-2023)

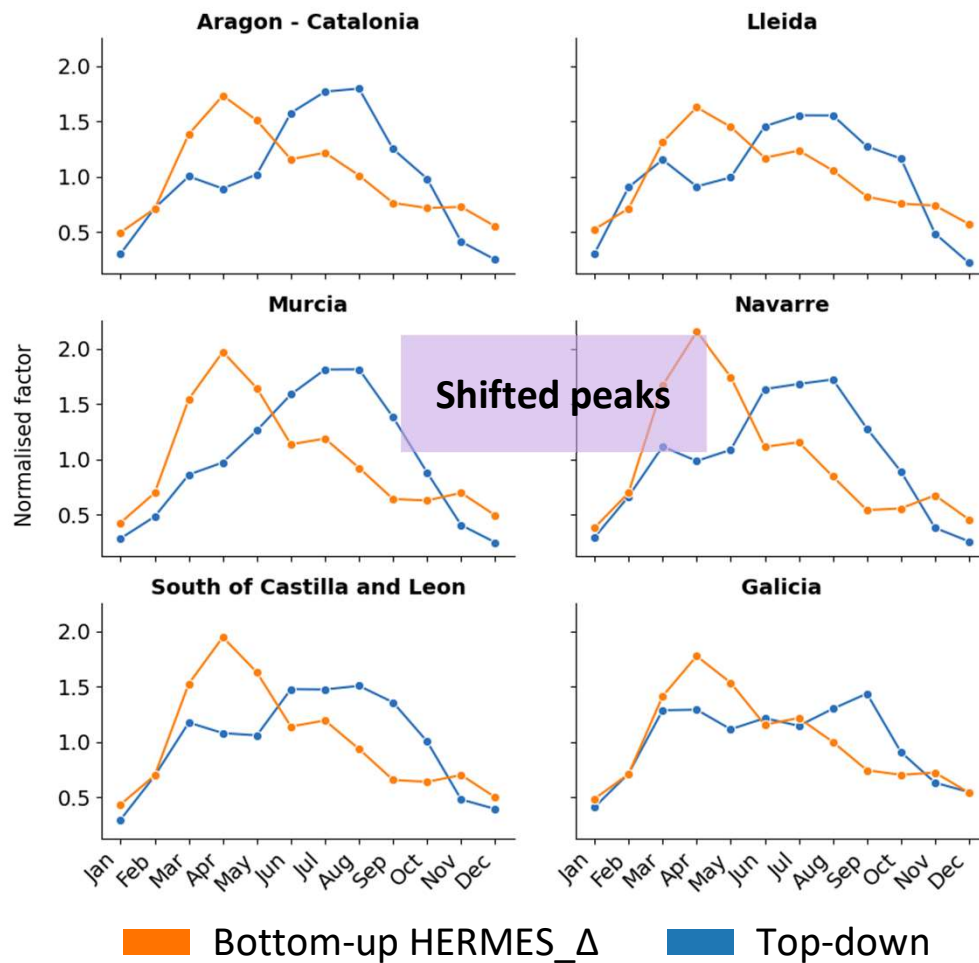


The top-down approach uses a **constant NH<sub>3</sub> lifetime** across time and space and this may not properly reflect **changes in atmospheric composition** on observed NH<sub>3</sub> columns

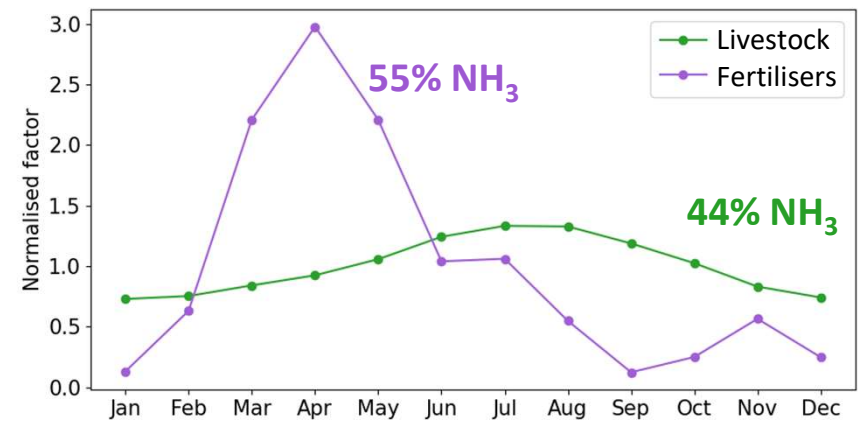
↓ SO<sub>2</sub>/NO<sub>2</sub> levels, ↓ sulphate/nitrate, ↓ NH<sub>3</sub> uptake, ↑ NH<sub>3</sub> concentrations ↗ ↑ NH<sub>3</sub> emissions

# Monthly distribution

## Monthly climatologies: top-down vs bottom-up



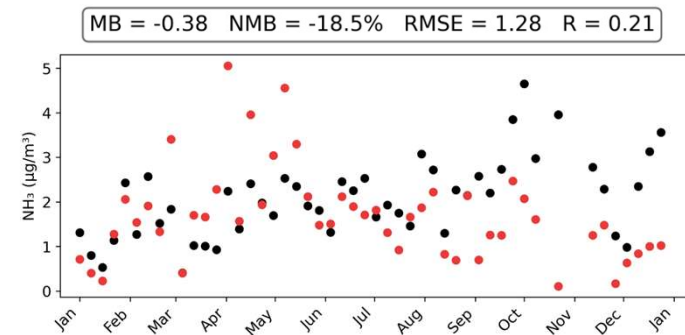
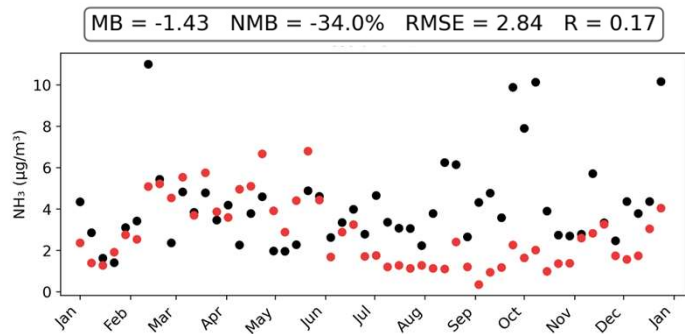
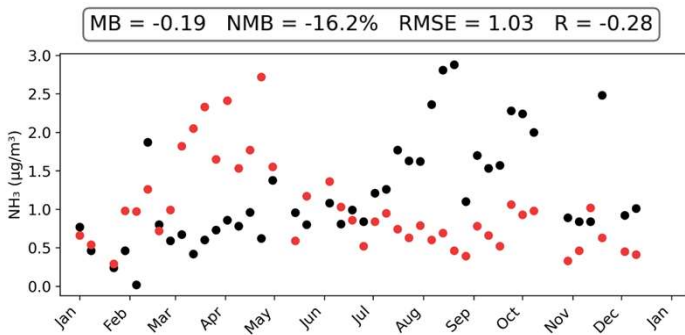
## HERMES\_Δ monthly profiles for NH<sub>3</sub>



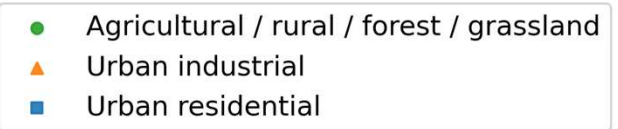
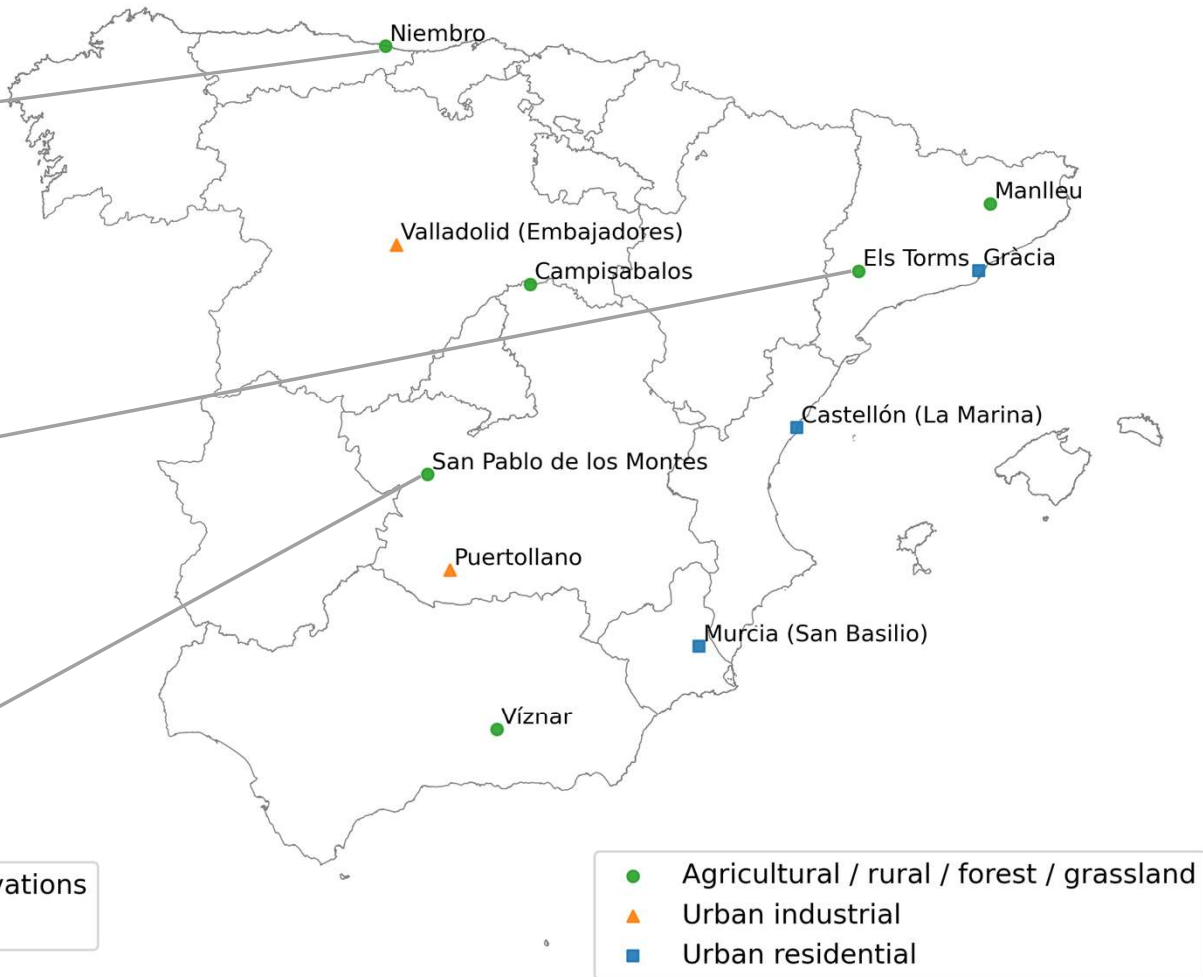
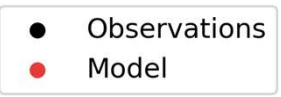
Based on CAMS-REG-TEMPOv4.1

HERMES\_Δ: need to implement crop-specific profiles that account for crop calendar, temperature, wind speed

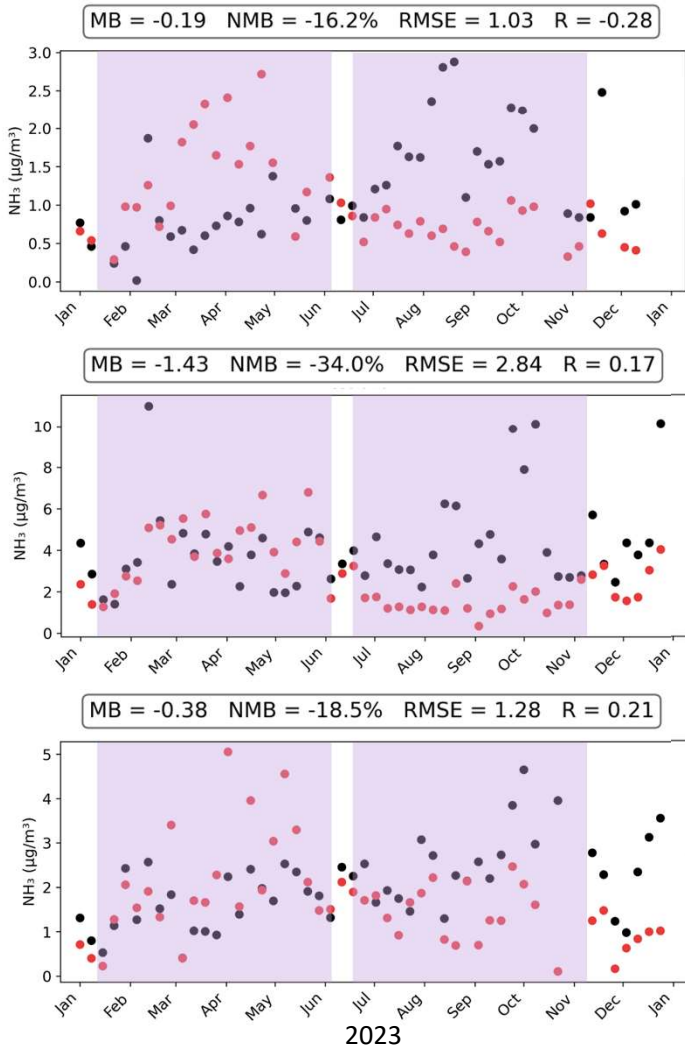
# Agricultural / rural / forest / grassland observations



2023



# Agricultural / rural / forest / grassland observations



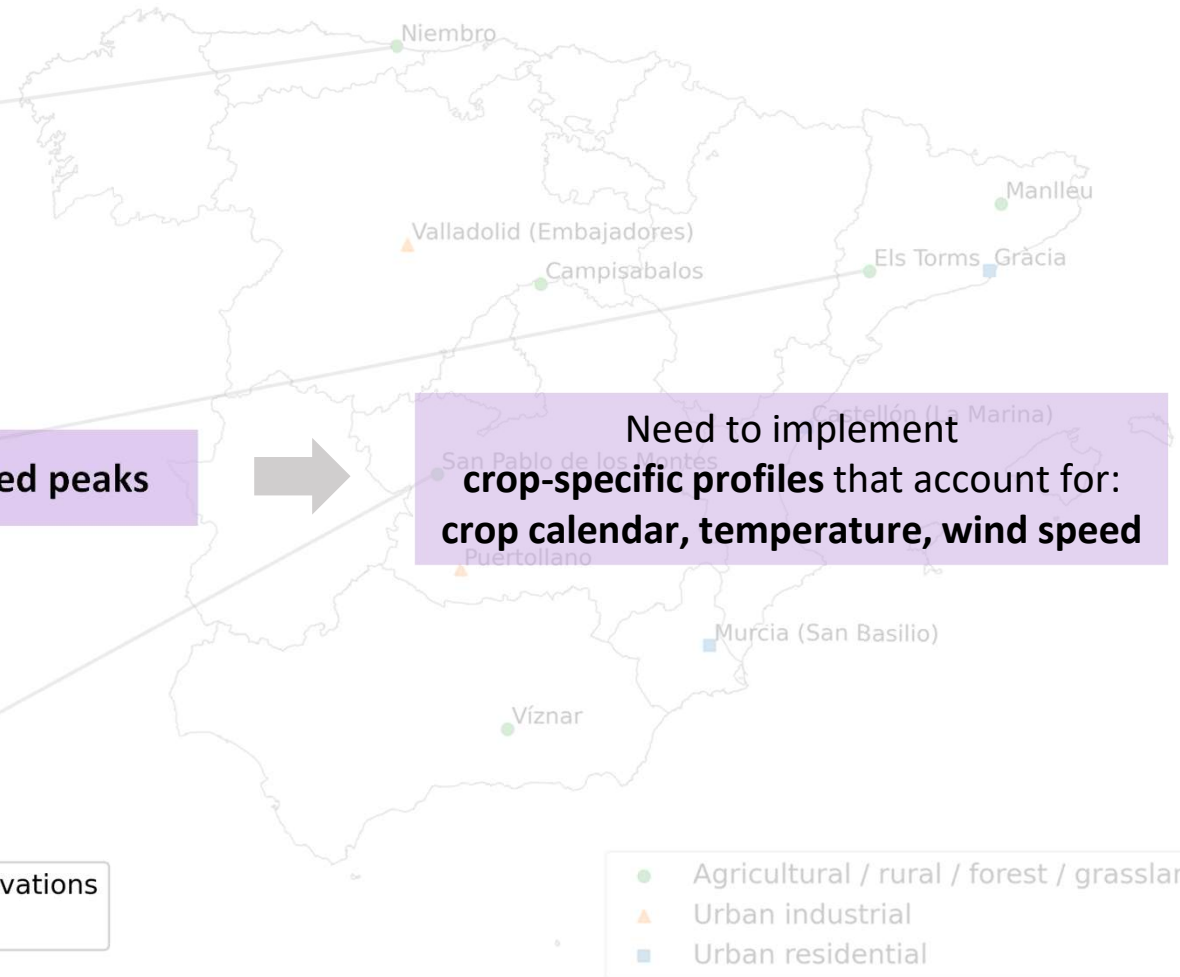
Shifted peaks



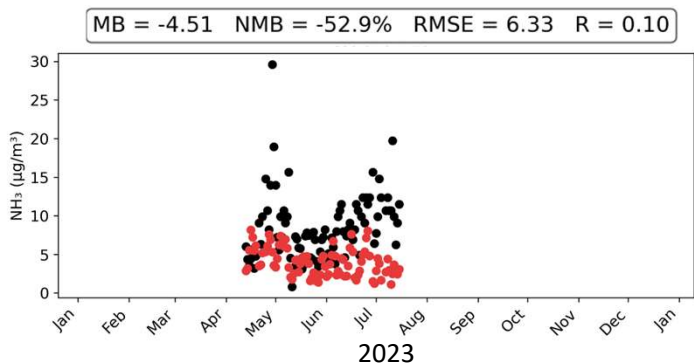
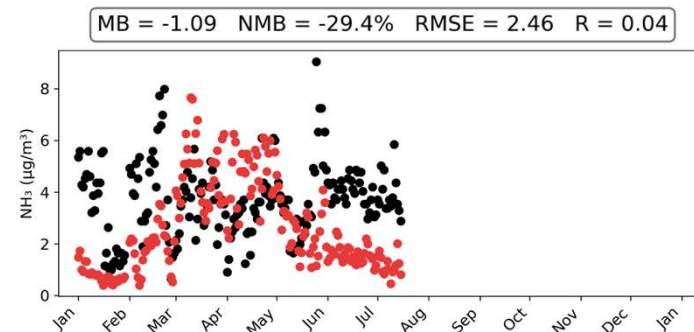
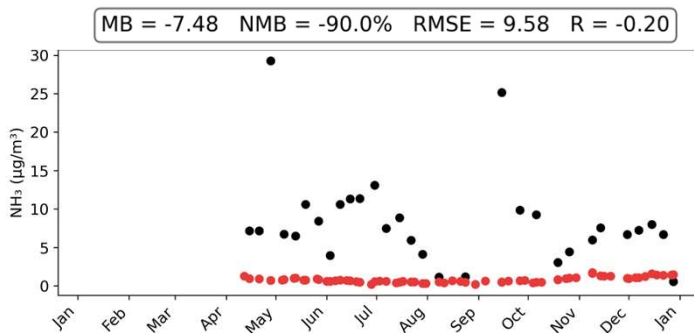
Need to implement crop-specific profiles that account for: crop calendar, temperature, wind speed

- Observations
- Model

- Agricultural / rural / forest / grassland
- ▲ Urban industrial
- Urban residential



# Urban residential observations

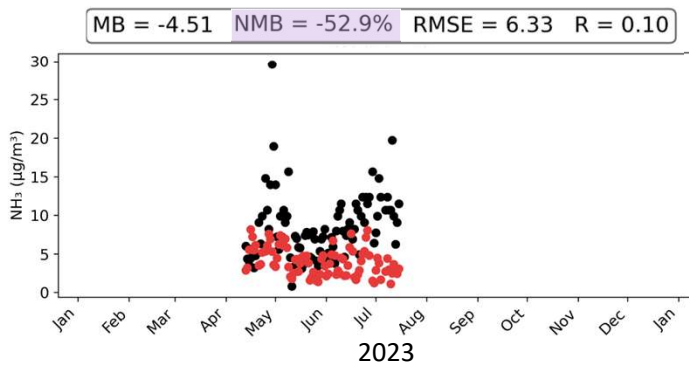
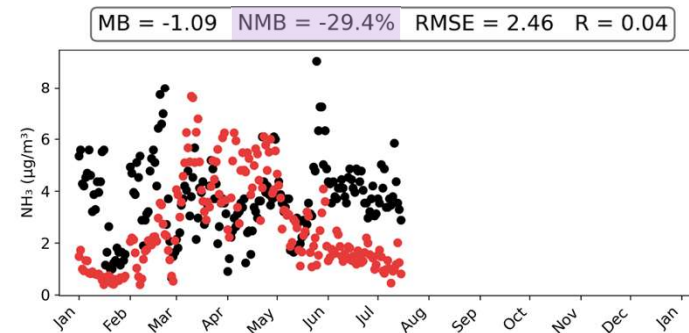
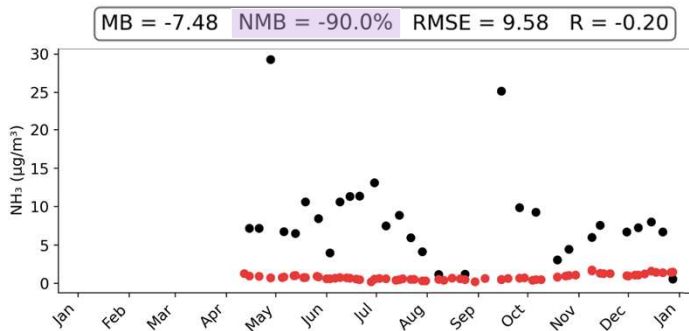


● Observations  
● Model

● Agricultural / rural / forest / grassland  
▲ Urban industrial  
■ Urban residential



# Urban residential observations



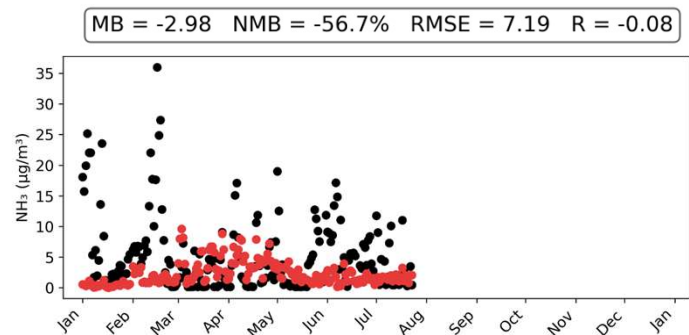
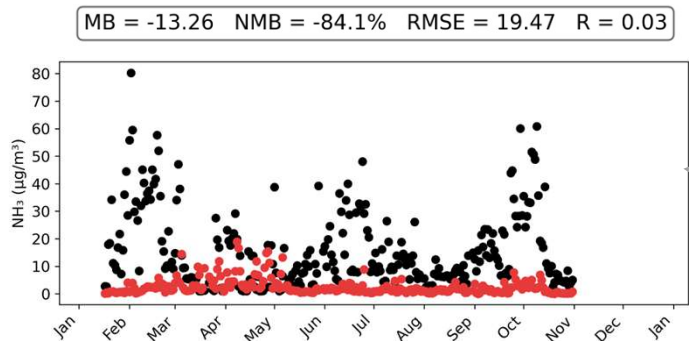
● Observations  
● Model

**Underestimation of gasoline vehicle emission factors**  
(Farren et al., 2020)

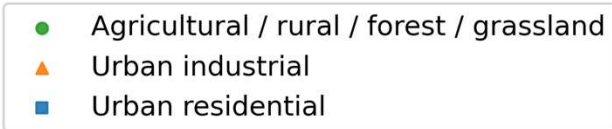
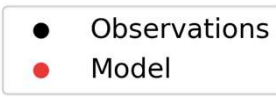
**Missing sources in national emission inventories:**  
Sewage systems and garbage containers (Reche et al., 2012)  
Human breath and sweat (Li et al., 2020)

● Agricultural / rural / forest / grassland  
▲ Urban industrial  
■ Urban residential

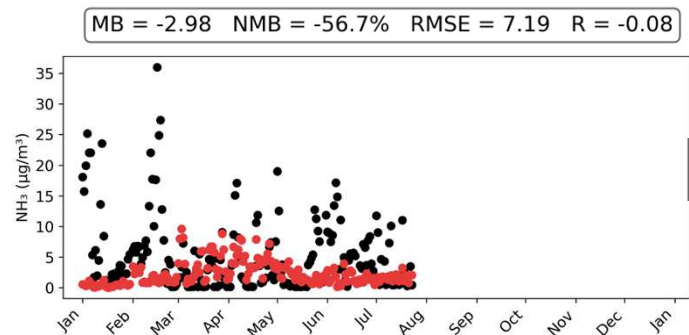
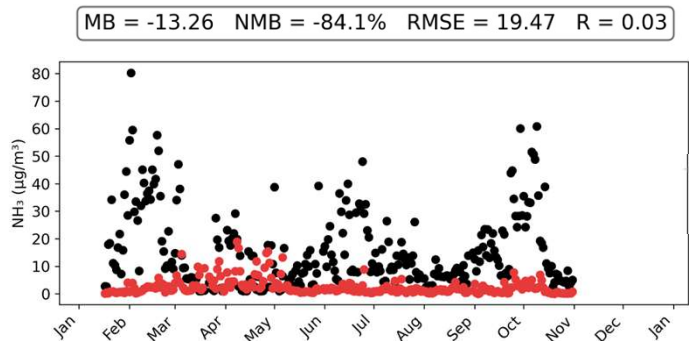
# Urban industrial observations



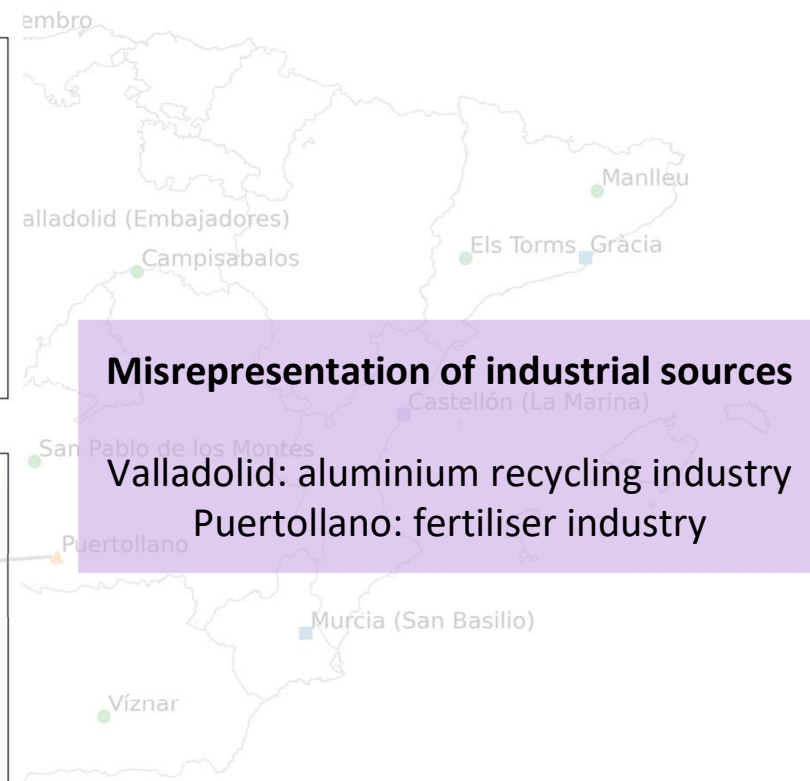
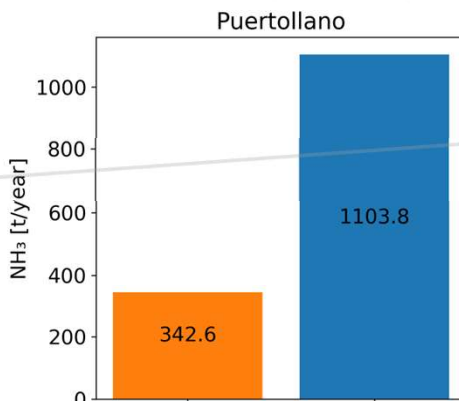
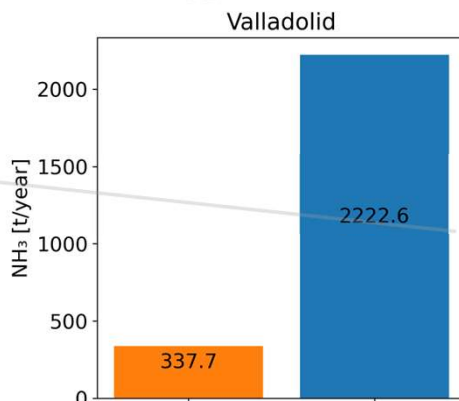
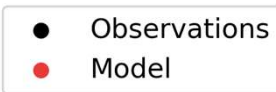
2023



# Urban industrial observations



2023



**Misrepresentation of industrial sources**

Valladolid: aluminium recycling industry

Puertollano: fertiliser industry

# Take home messages

- Demonstration of the **added value of integrating bottom-up and top-down** emission estimates to **enhance the spatiotemporal representation of NH<sub>3</sub> emissions**
- **Converging evidence** from direct (with satellite-based emissions) and indirect (with modelling + in situ observations) evaluations **reveals key gaps in bottom-up NH<sub>3</sub> emission inventories**:
  - **Influence of agricultural practices** (crop calendars) and **meteorological conditions** on the **spatiotemporal characterisation**
  - **Missing or underestimated urban NH<sub>3</sub> sources**
  - **Uncertainties in industrial point sources**
- **Large discrepancies** between bottom-up and top-down **NH<sub>3</sub> emission trends** –potential implications for the **NECD**– but further research needed to better understand the role of:
  - **Non-inclusion of temperature-dependent NH<sub>3</sub> emission factors** in bottom-up inventories
  - Use of **fixed lifetime NH<sub>3</sub> values** in inverse modelling techniques

# Future work

- **Improve bottom-up NH<sub>3</sub> emissions** based on lessons learned
- **Assess the impact** of improved NH<sub>3</sub> emissions on the **modelling of PM<sub>2.5</sub> levels**
- **Use AQ models and observations to evaluate** bottom-up versus top-down NH<sub>3</sub> emission trends

# Acknowledgements



WorldEmission

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# Thanks for your attention!

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