Interreg
Danube Region

Co-funded by
the European Union

Tethys

Model Development

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Tethys Final Conference

Vienna, 02.06.2026

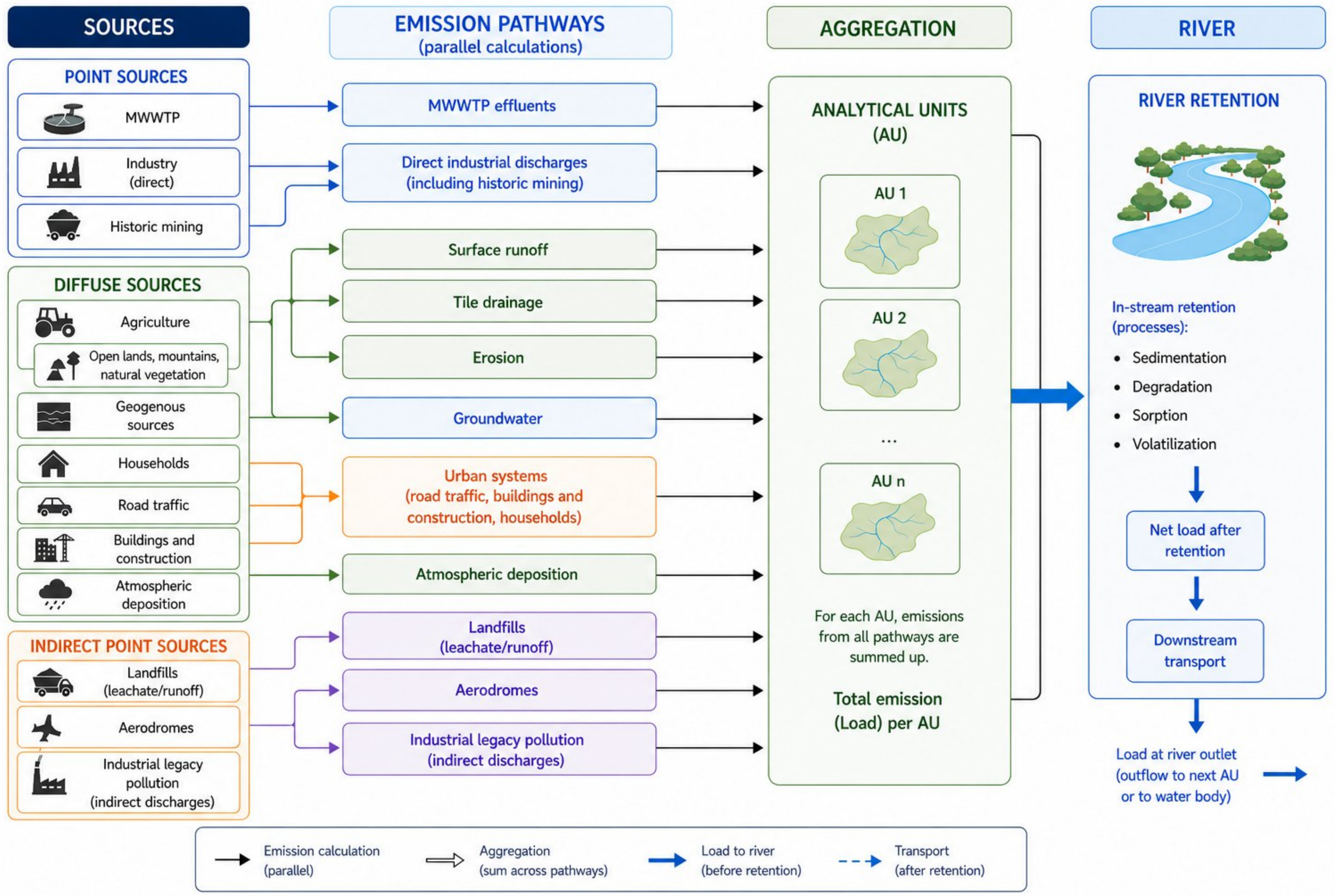
MŰEGYETEM 1782

Objective of the emission modelling

- Understand emission patterns of priority substances in the Danube River Basin
- Understand the significance of specific emission hot spots/pathways
- Create an inventory of specific priority pollutants in the DRB to support river basin management planning
- Highlight information/data gaps
- Identify research needs
- Support risk assessment and mitigation evaluation

Method – emission modelling with MoRE modell

- Pathway-oriented, conceptual model (Modelling of Regionalized Emissions) (Fuchs et al, Karlsruhe Institute of Technology)
- Algorithms based on MONERIS 2.01
- Mainly used to model heavy metals and organic pollutants
- Is built on a PostgreSQL database in order to store the large datasets required for modelling
- Has a flexible structure, enabling adaptations (pathways or pathway modifications) and the implementation of new substances
- Newly developed retention estimate is used for heavy metals

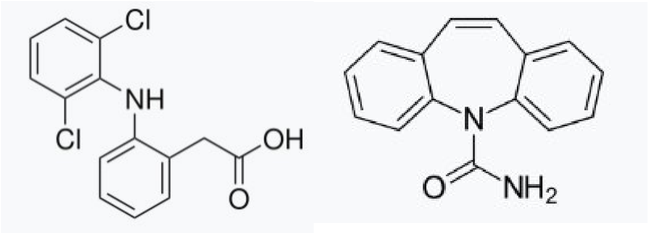


SOURCES
EMISSION PATHWAYS
(parallel calculations)
AGGREGATION
RIVER
POINT SOURCES
MWWTP
Industry (direct)
Historic mining
DIFFUSE SOURCES
Agriculture
Open lands, mountains, natural vegetation
Geogenous sources
Households
Road traffic
Buildings and construction
Atmospheric deposition
INDIRECT POINT SOURCES
Landfills (leachate/runoff)
Aerodromes
Industrial legacy pollution (indirect discharges)
MWWTP effluents
Direct industrial discharges (including historic mining)
Surface runoff
Tile drainage
Erosion
Groundwater
Urban systems (road traffic, buildings and construction, households)
Atmospheric deposition
Landfills (leachate/runoff)
Aerodromes
Industrial legacy pollution (indirect discharges)
ANALYTICAL UNITS (AU)
AU 1
AU 2
...
AU n
For each AU, emissions from all pathways are summed up.
Total emission (Load) per AU
RIVER RETENTION
In-stream retention (processes):
Sedimentation
Degradation
Sorption
Volatilization
Net load after retention
Downstream transport
Load at river outlet (outflow to next AU or to water body)
Emission calculation (parallel)
Aggregation (sum across pathways)
Load to river (before retention)
Transport (after retention)

Overview of the modelled substance groups/ substances

- **Heavy metals and metalloids:**

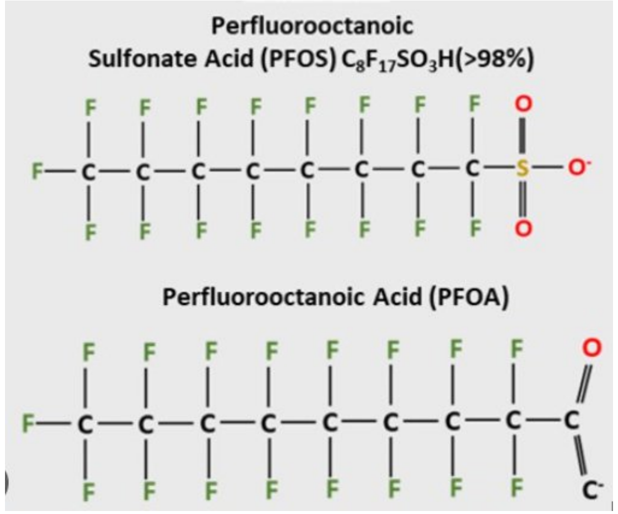
  As, Cd, Cr, Cu, Ni, Pb and Zn



- **Pharmaceuicals:**

  Dicplophenac (DCF) and Carbamazepine

(CBZ)



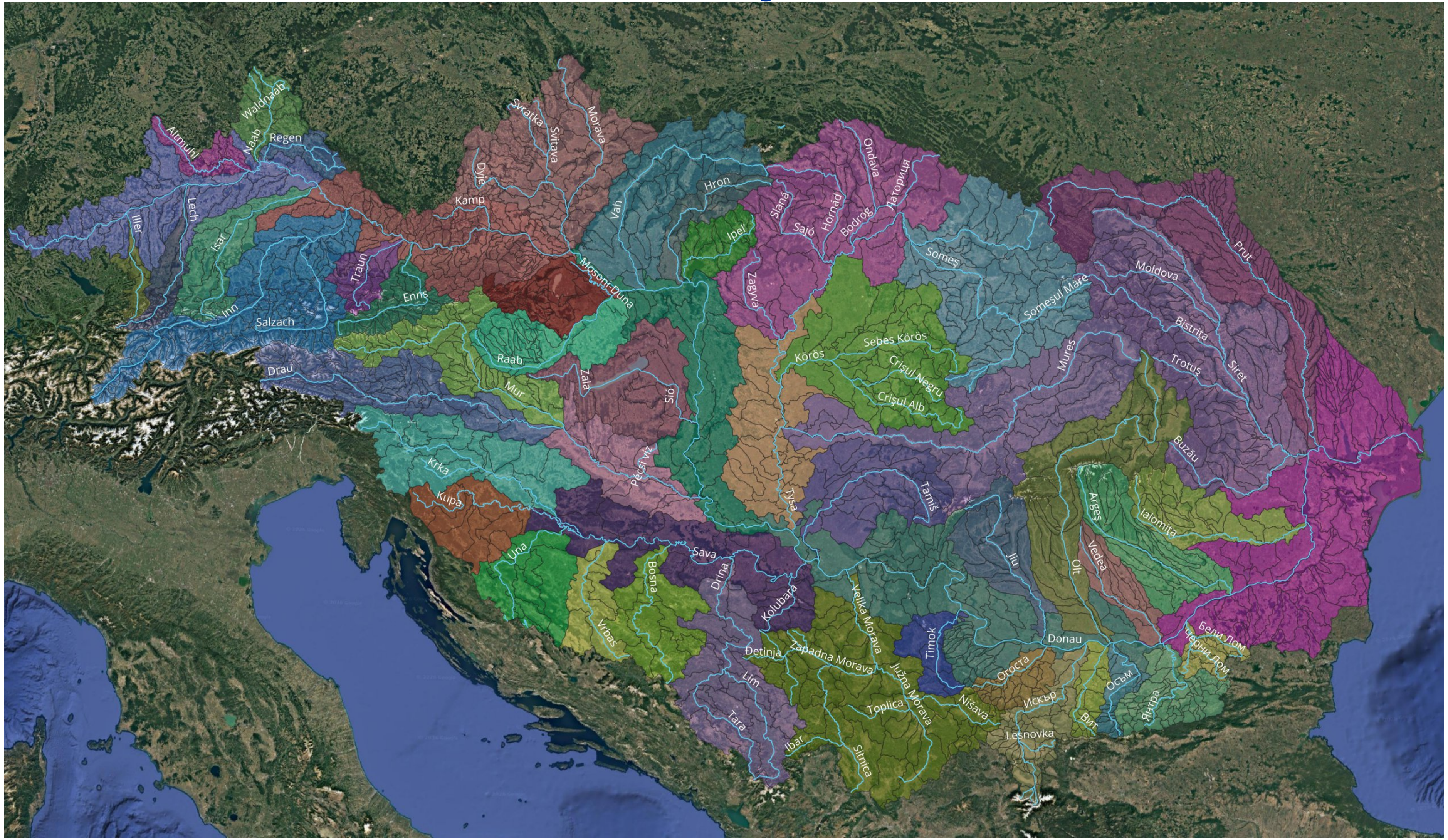
- **Per- and polyfluoroalkyl substances (PFAS):**

  - PFOS and PFOA

■ Literature data (outside DRB) ■ Pilot measurements within DRB ■ Regional dataset ■ Country dataset ■ Modelled data

Process	Heavy metals	Pharmaceuticals	PFAS
Erosion	Regional dataset 🌍	🗺	Pilot measurements within DRB 🌍
Surface Runoff	Literature data (outside DRB) 🌍	🗺	Literature data (outside DRB) 🌍
Tile drainage	Literature data (outside DRB) 🌍	🗺	Literature data (outside DRB) 🌍
Urban emission	Literature data (outside DRB) 🌍	Literature data (outside DRB) 🌍	Literature data (outside DRB) 🌍
Groundwater	Regional dataset, Country dataset 🌍	🗺	Country dataset, Literature data (outside DRB) 🌍
Atmospheric dep.	Modelled data, Pilot measurements within DRB 🌍	🗺	Pilot measurements within DRB 🌍
Atmospheric dep. - hot spot	Literature data (outside DRB), Regional dataset 🌍	🗺	Literature data (outside DRB), Regional dataset 🌍
Point source - communal	Pilot measurements within DRB, Country dataset 🌍	Pilot measurements within DRB 🌍	Pilot measurements within DRB, Country dataset 🌍
Point source - industrial	Literature data (outside DRB), Regional dataset, Country dataset 🌍	Literature data (outside DRB) 🌍	Literature data (outside DRB), Regional dataset 🌍
Industrial diffuse hot-spots	Literature data (outside DRB) 🌍	🗺	Literature data (outside DRB) 🌍
Landfills	Literature data (outside DRB) 🌍	Literature data (outside DRB) 🌍	Literature data (outside DRB) 🌍
Aerodomes and other fire fighting centres	🗺	🗺	Literature data (outside DRB) 🌍

Model domain – 1727 analytical units



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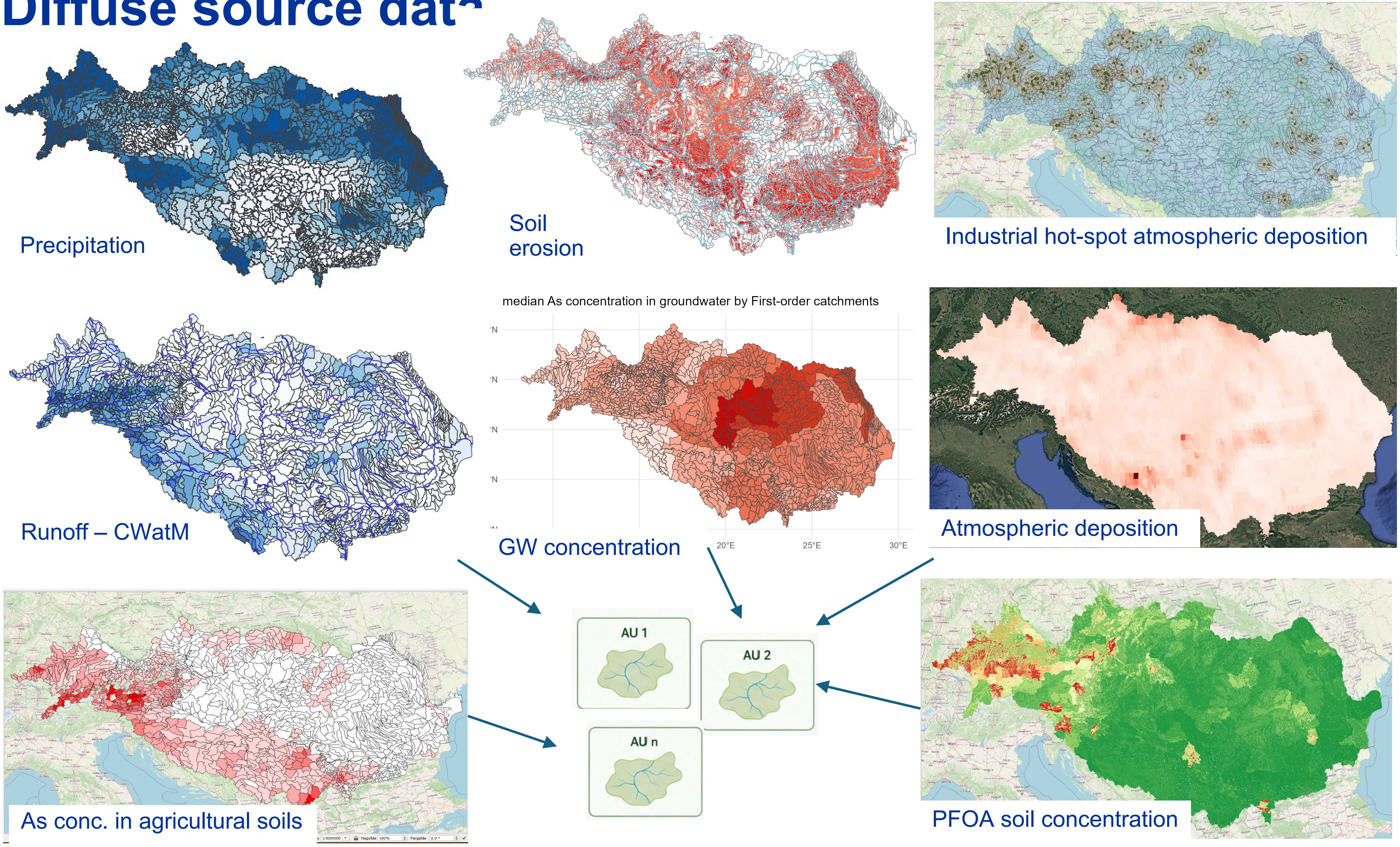
Temporal coverage

2015-2020

Diffuse source dat



Point source data

Industrial emissions

I-EPR database (2007-2023)

-10.445 facilities

Municipal sewage emissions

ICPDR – WWTP database

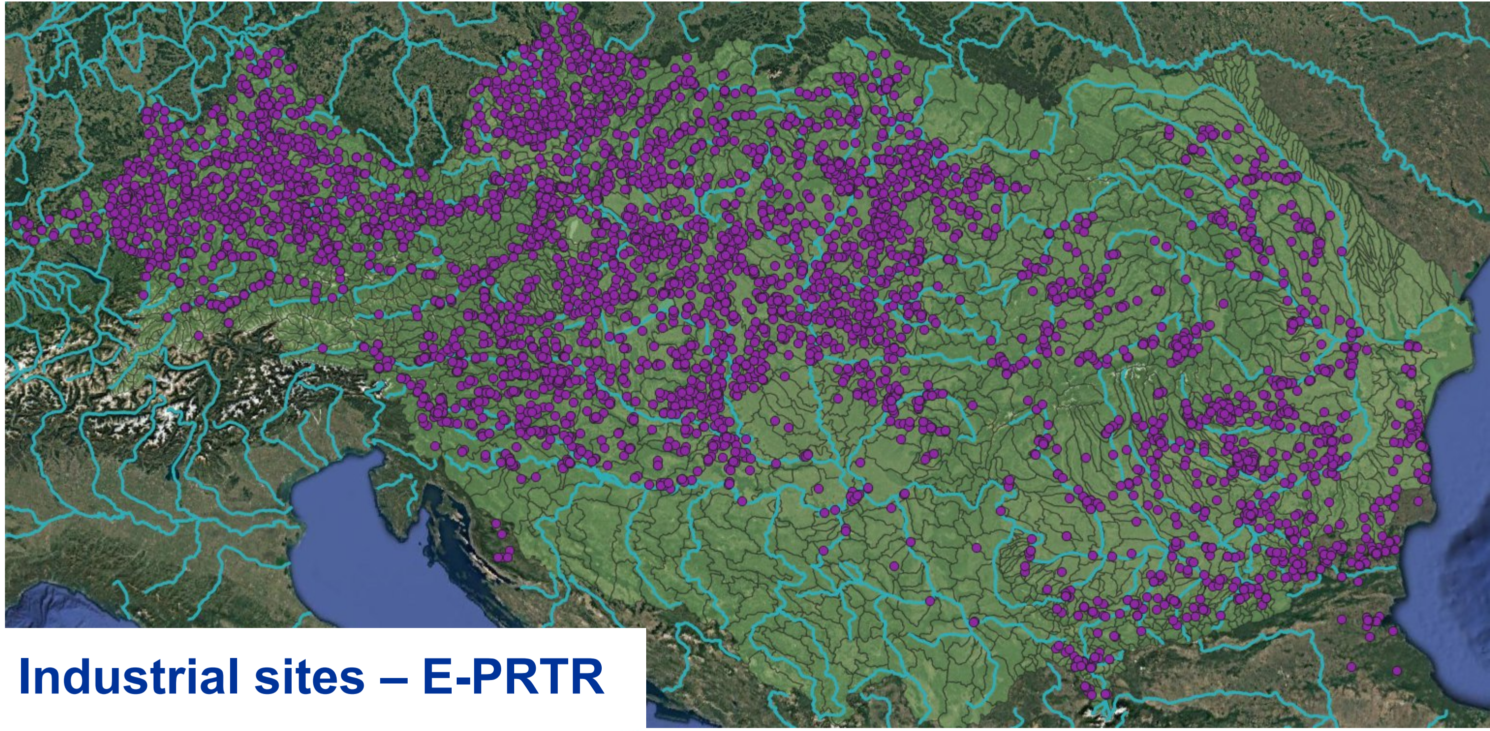
-5636 agglomeration

-3867 discharge point

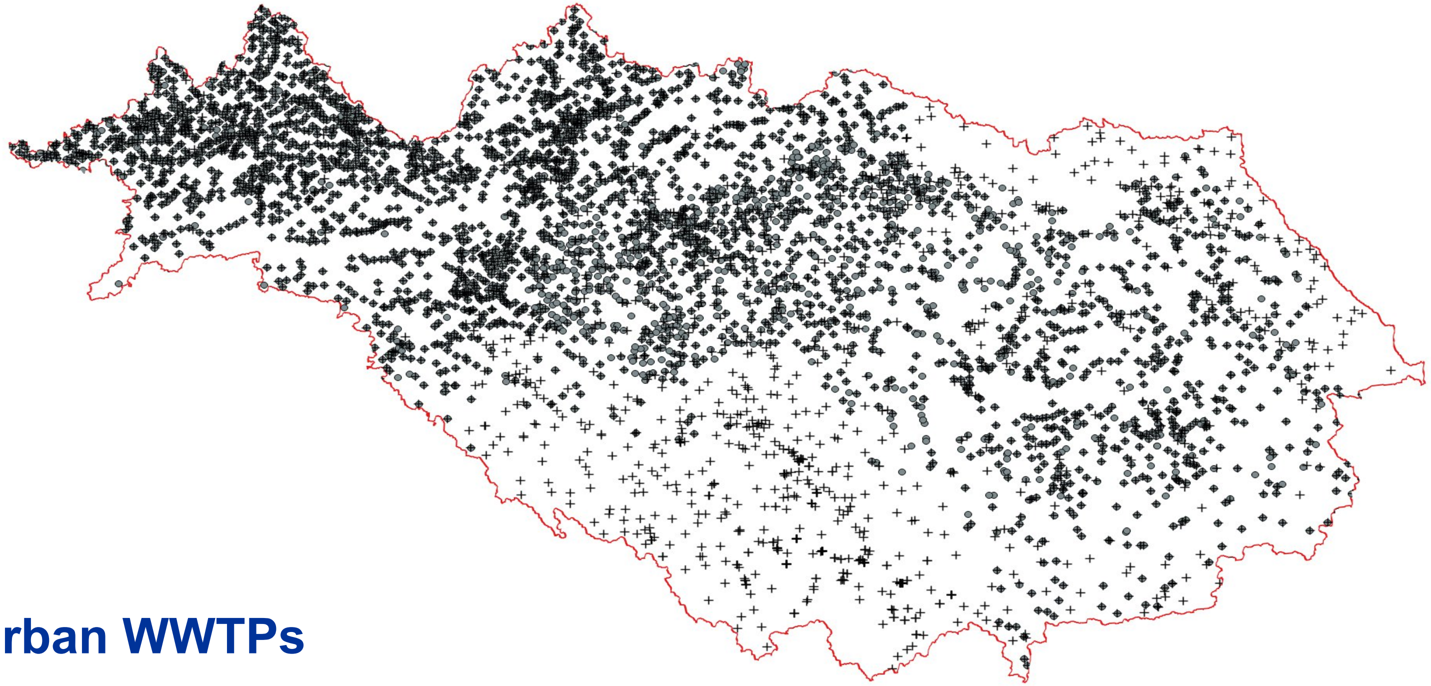
-Total capacity: 85 million PE

-Total discharge:

- 4.96E+09 m^3/year
- 157 m^3/s



Industrial sites – E-PRTR



Urban WWTPs

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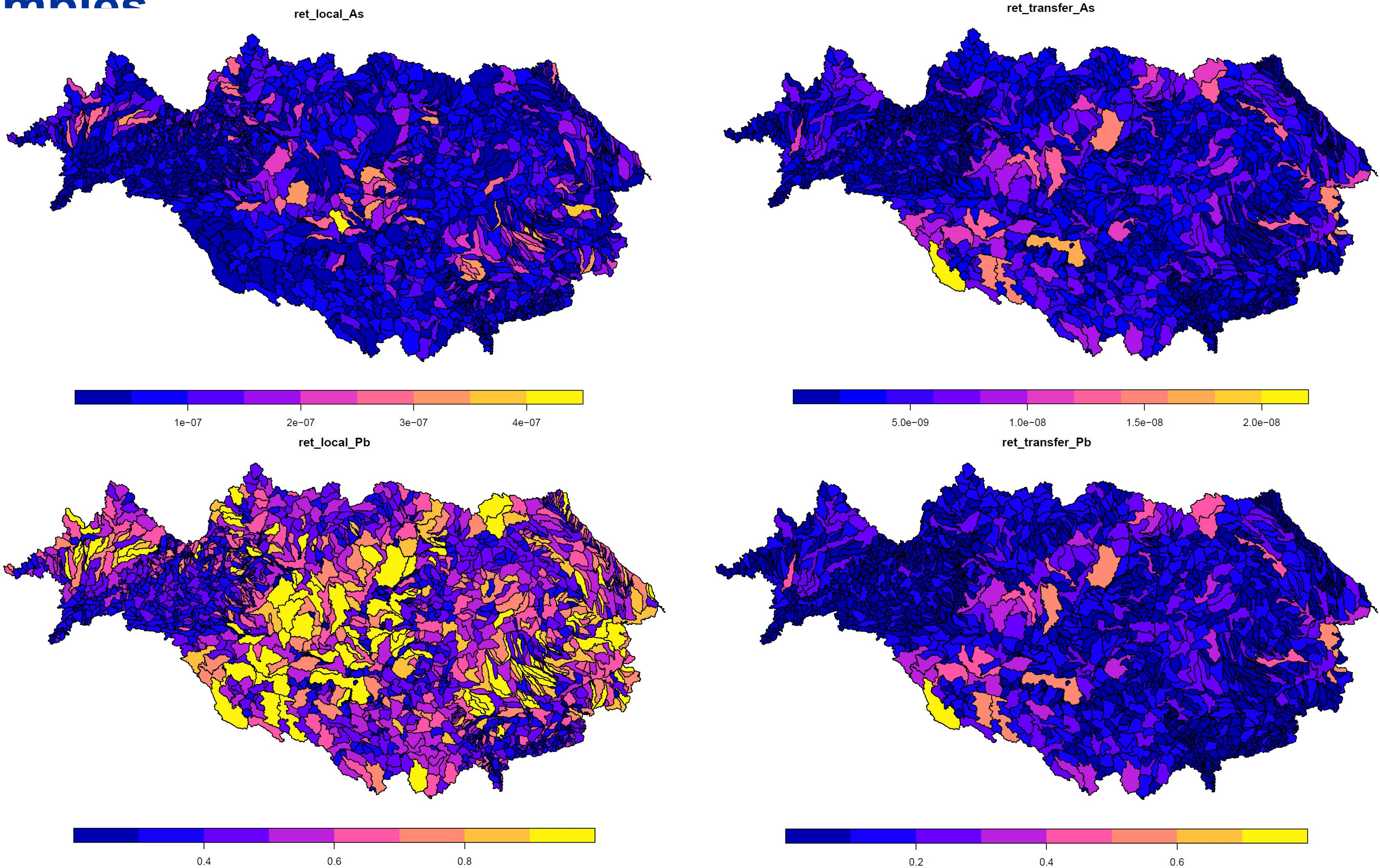
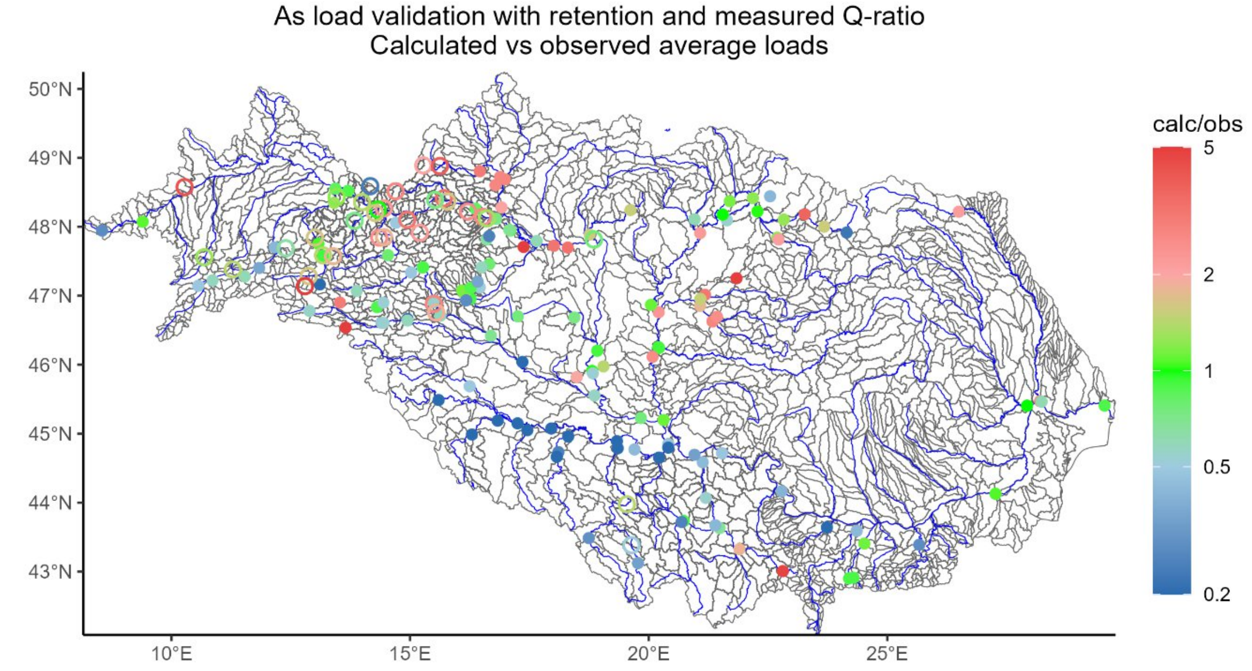
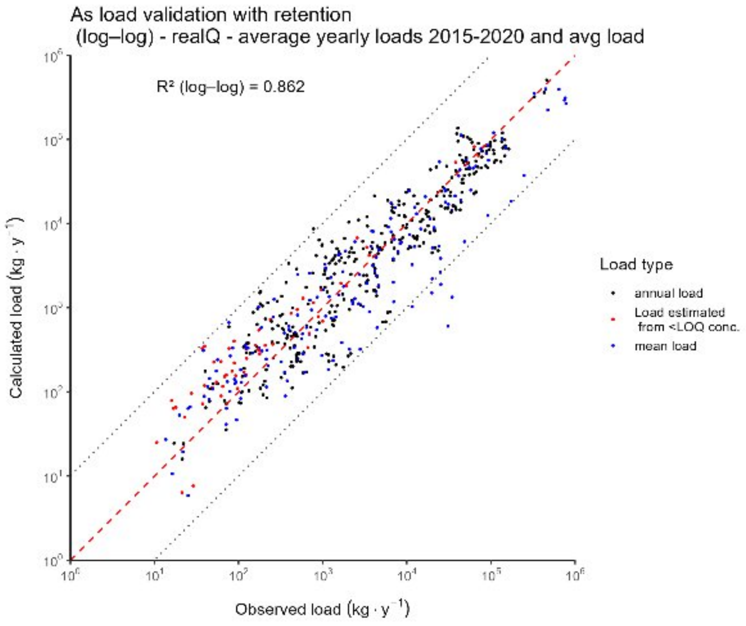
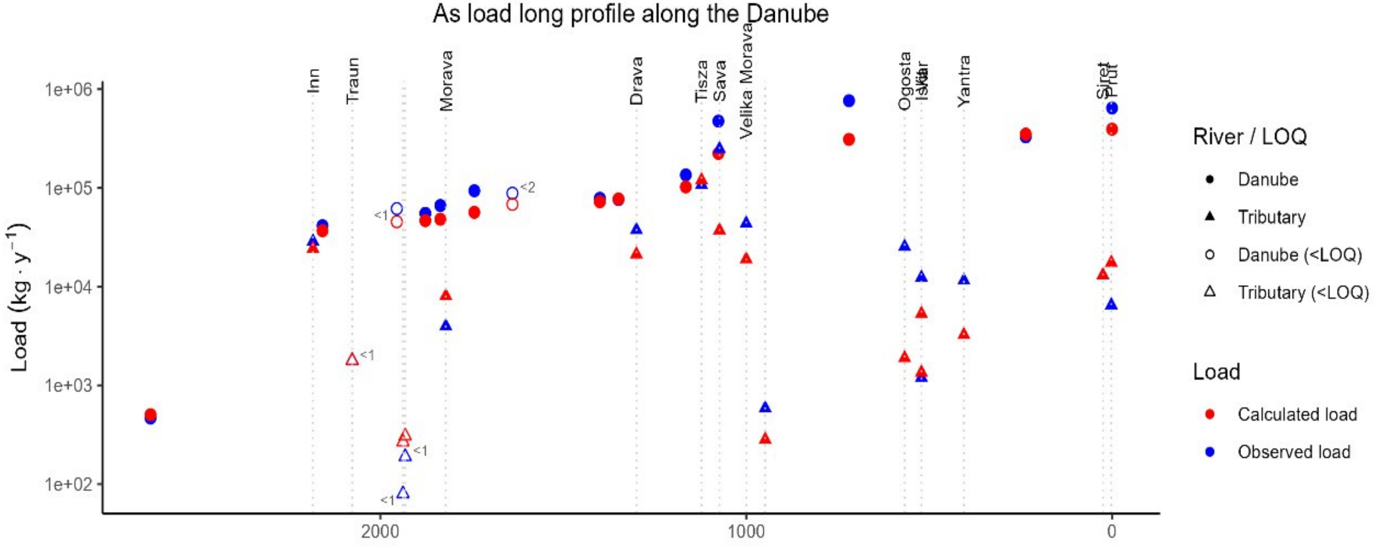
Retention of HM in the model - examples



Validation map for metalloids – arsenic, a „well” validated example



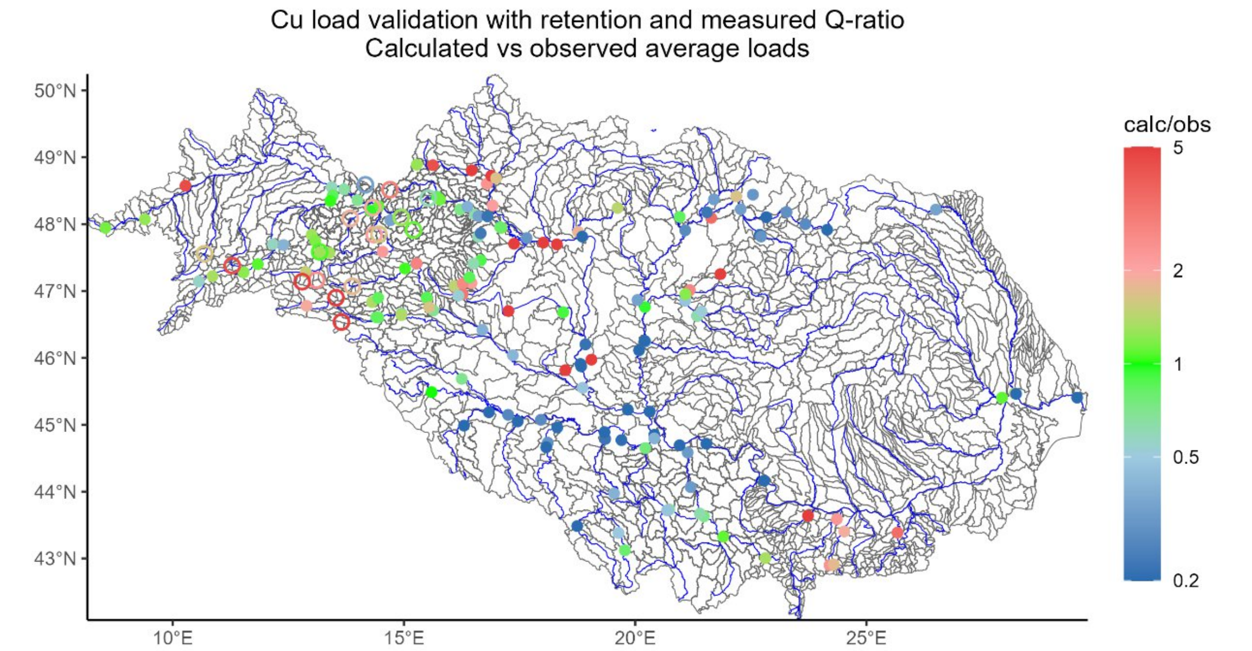


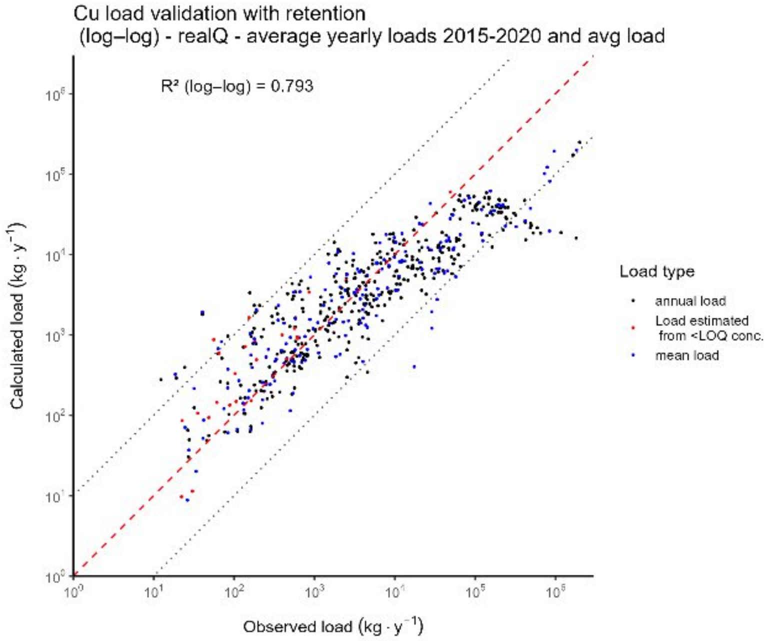


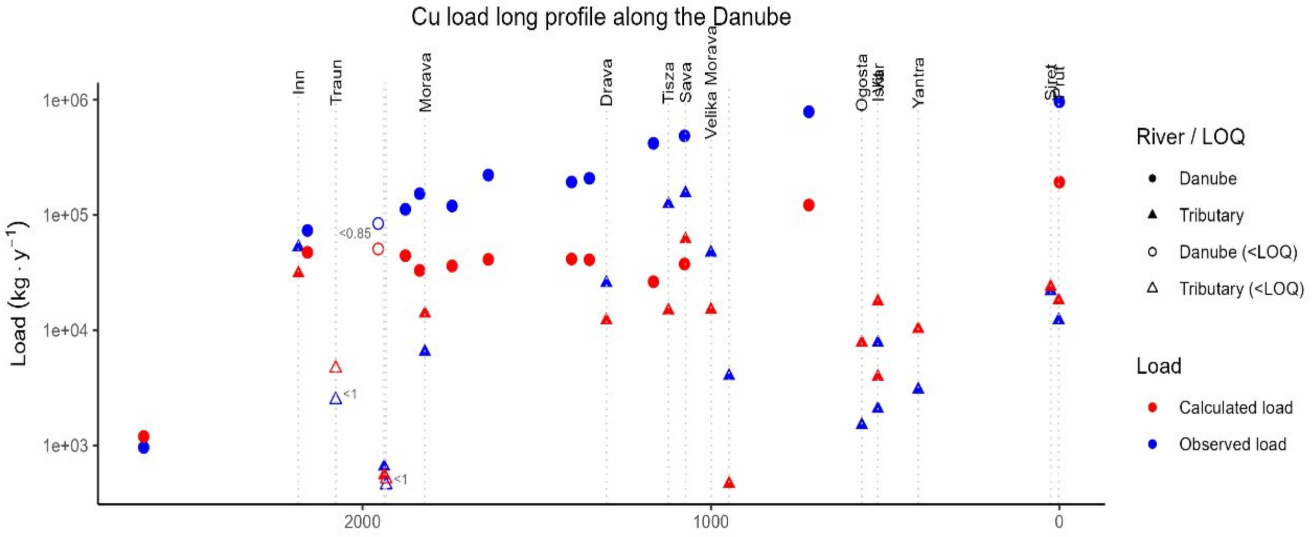
Main observations

- Clear underestimation of loads in the Sava basin
- Generally good agreement of Danube loads
- Low number of groundwater wells behind derived gw. concentrations are main suspect for the underestimation of loads at Sava and lower Danube tributaries
- Lack of industry data

Validation map for metalloids – copper, the worst validated example



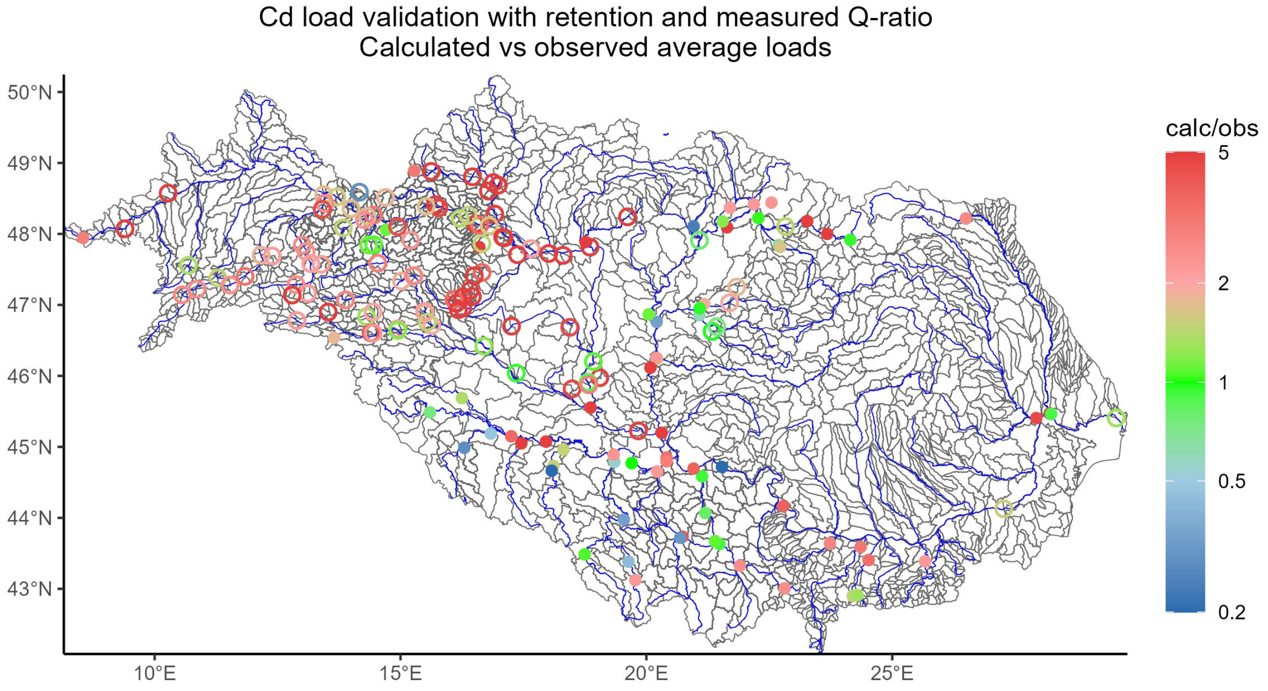


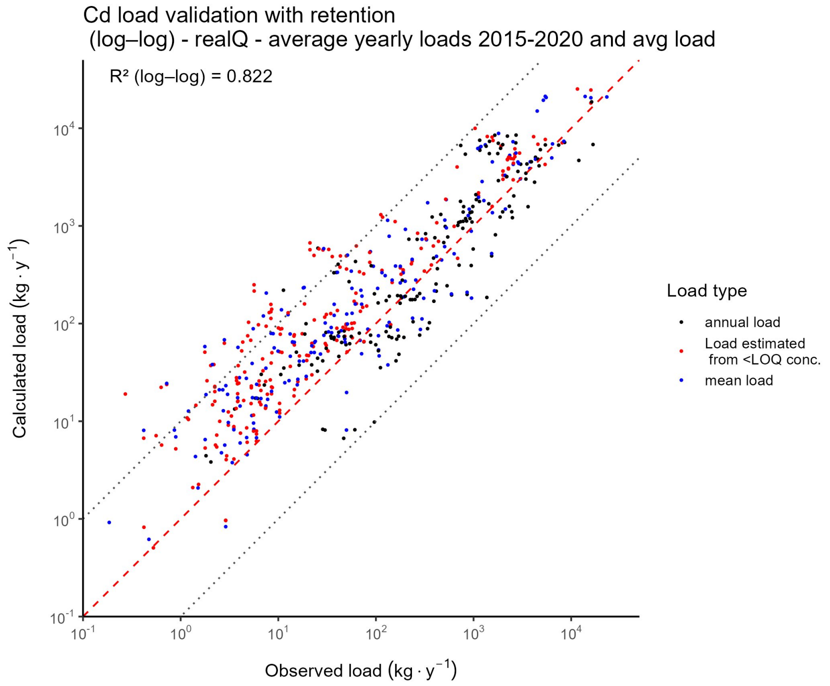


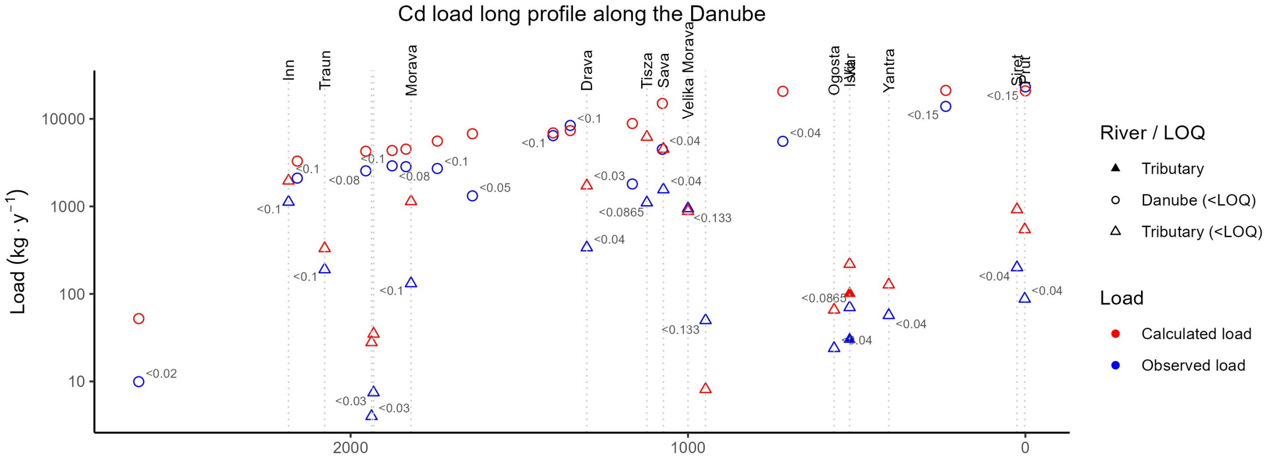
Main observations

- Clear underestimation of loads in the Sava and Tisza basins
- Strong underestimation of Danube loads
- Loads at Tisza and Sava are comparable to the upper Danube loads
- Lack of industry data/industrial underestimation?
- Orchards/Vinyard soils as hot-spots?

Validation map for metalloids – cadm



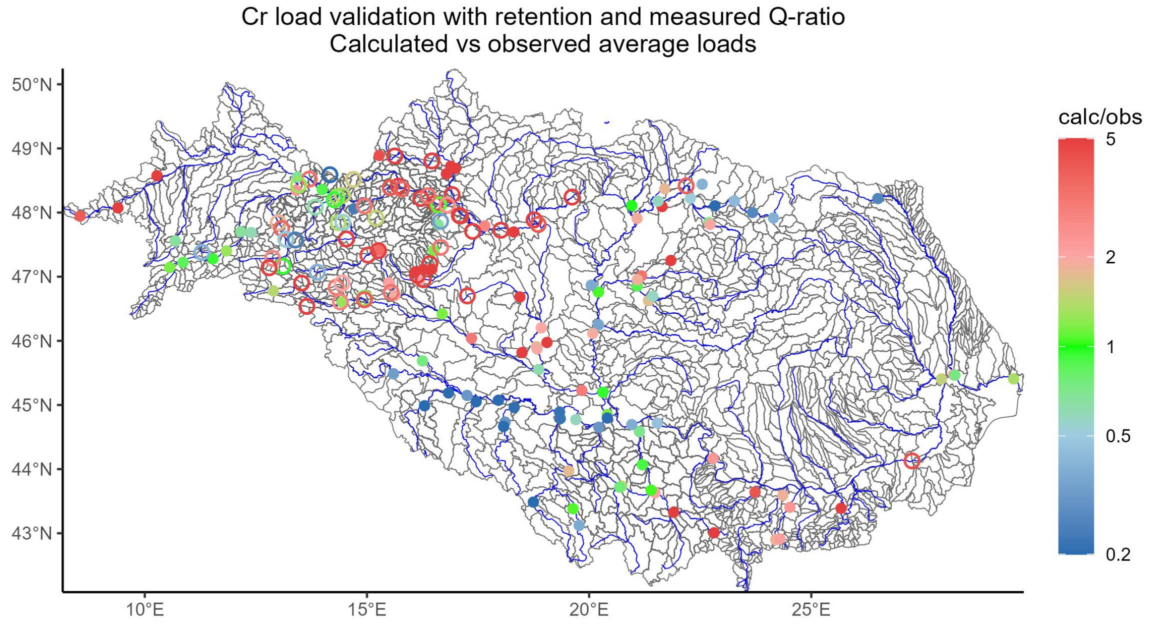


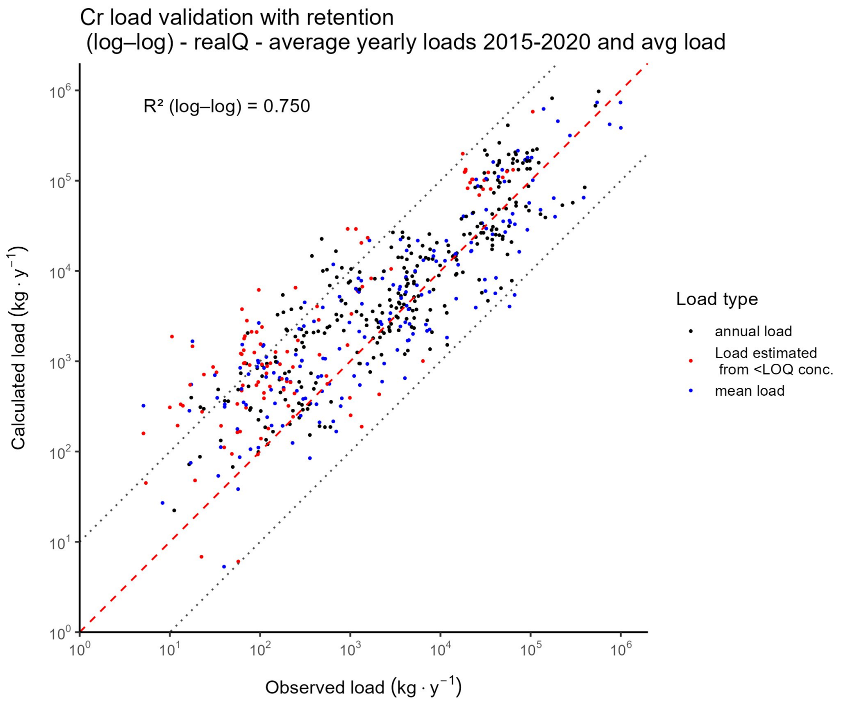


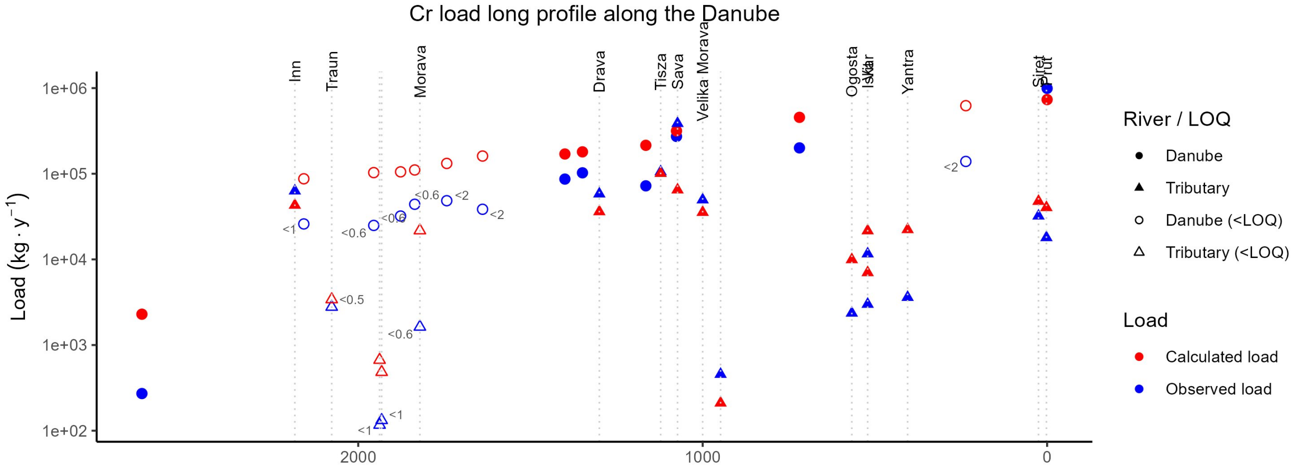
Main observations

- Most measurements are calculated from partly censored data
- Clear overestimation of Danube loads
- Generally overestimated in the upper Danube

Validation map for metalloids – ch



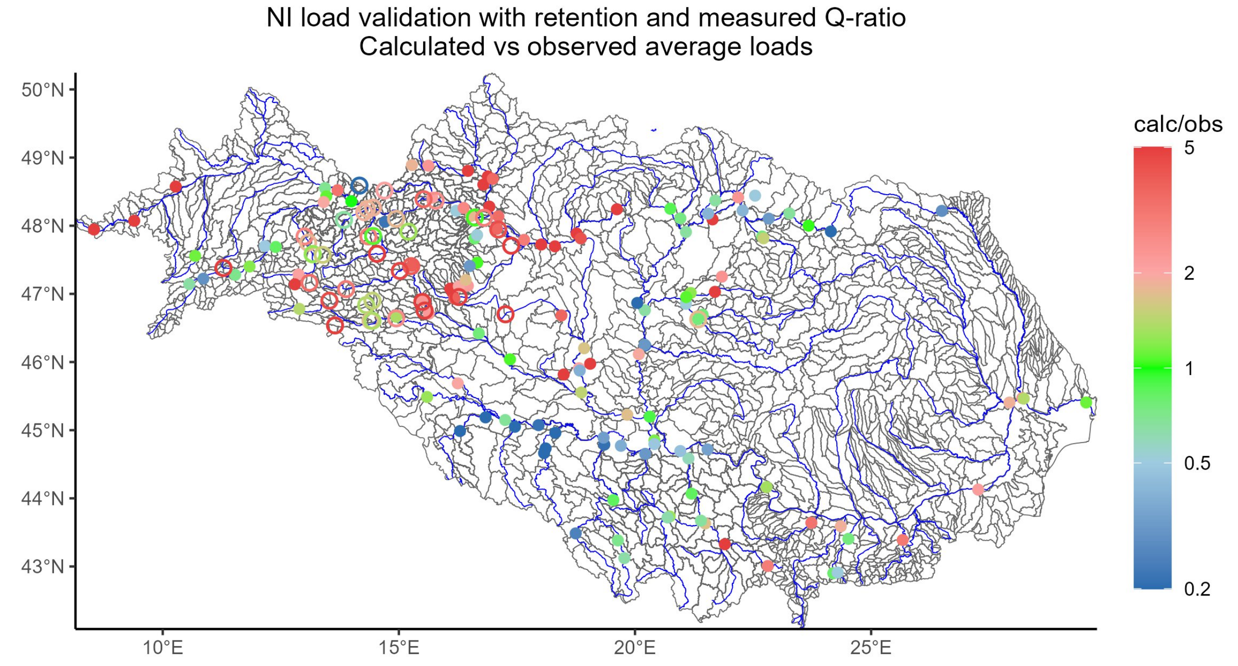


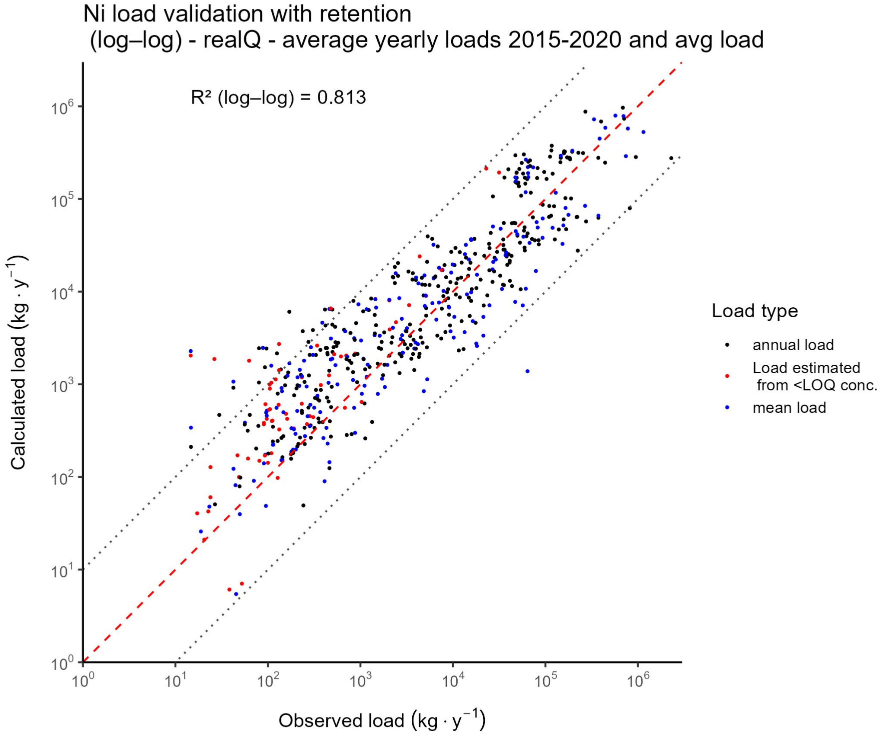


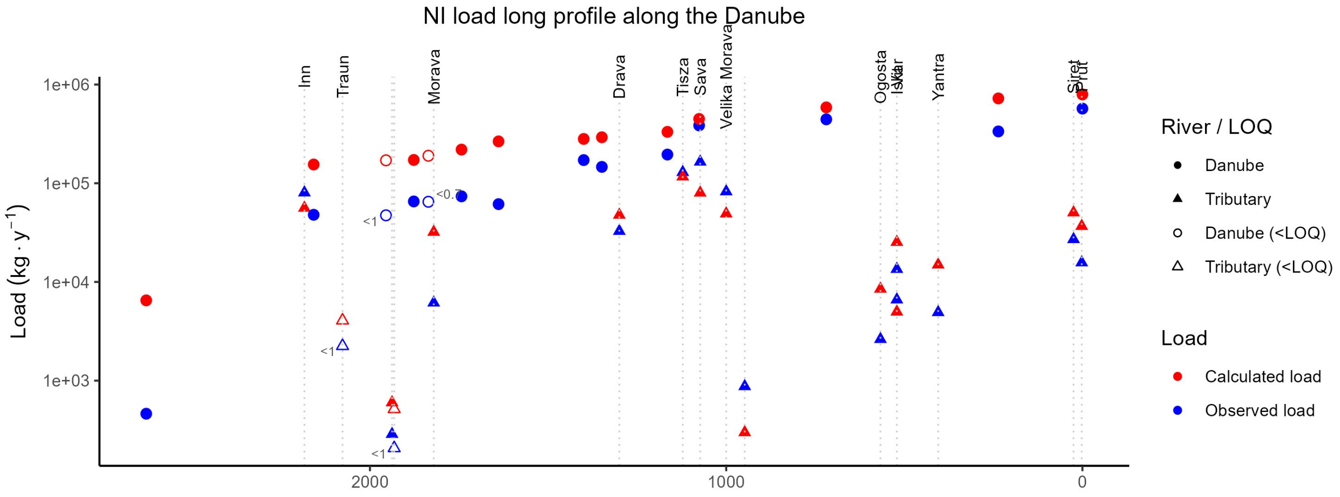
Main observations

- Clear underestimation of loads in the Sava and Tisza basins
- Strong underestimation of Danube loads
- Loads at Tisza and Sava are comparable to the upper Danube loads
- Lack of industry data/industrial underestimation?
- Orchards/Vinyard soils as hot-spots?

Validation map for metalloids – nic



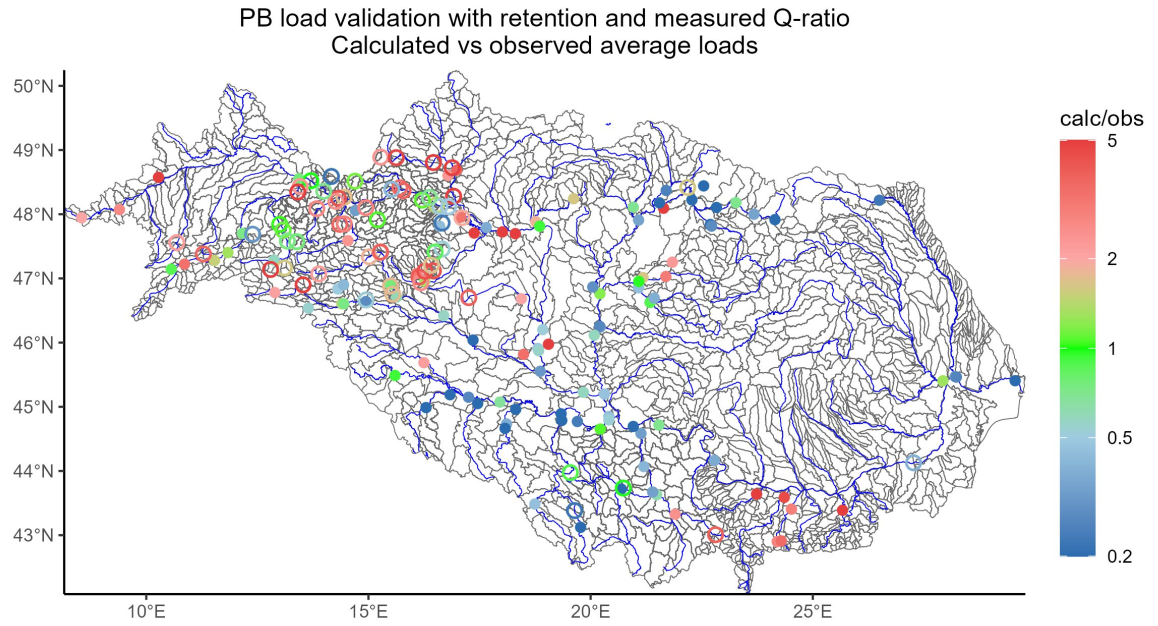


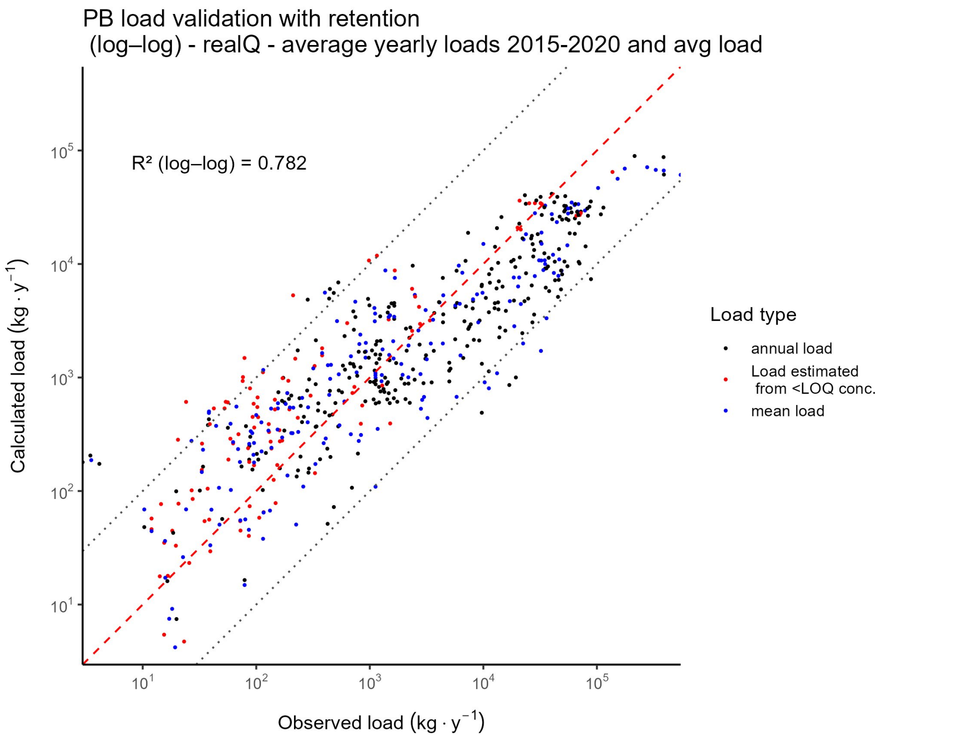


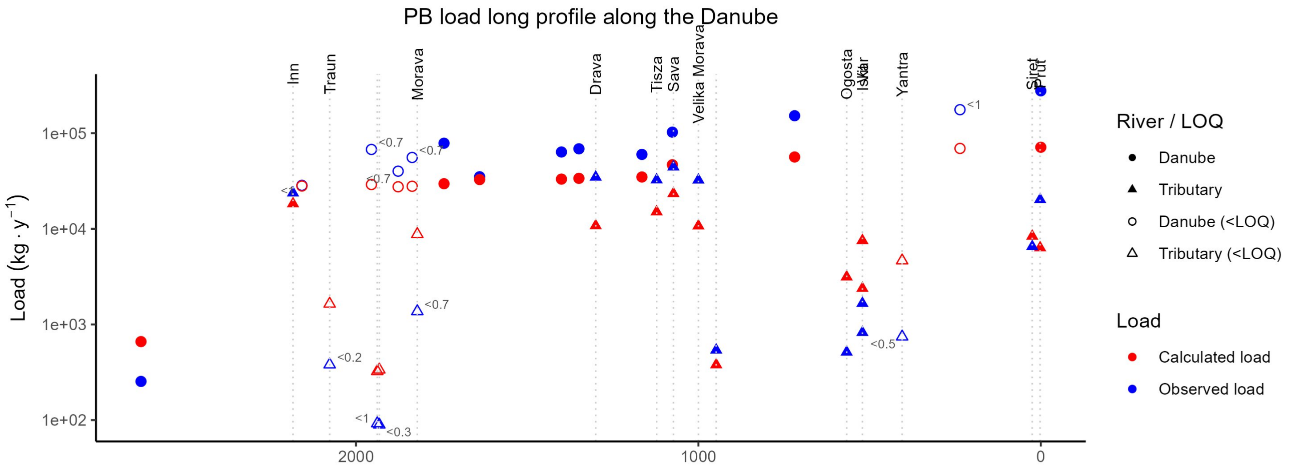
Main observations

- Clear underestimation of loads in the Sava basin
- Strong overestimation of Danube loads in the upper basin

Validation map for metalloids – le



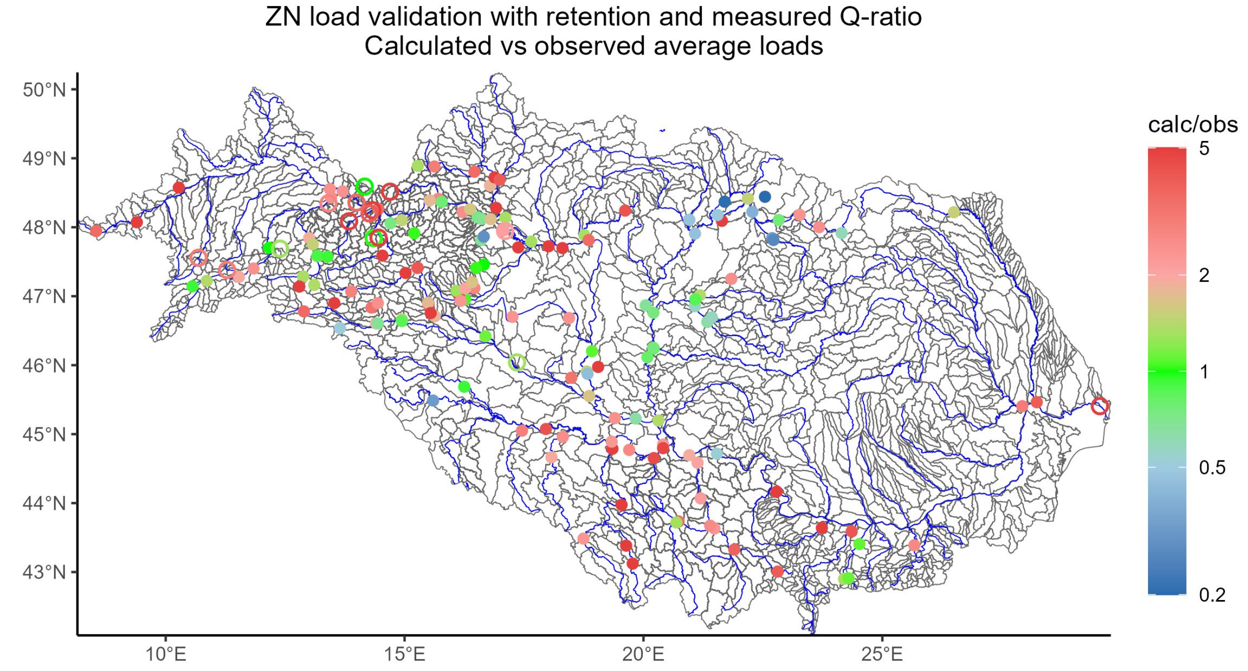


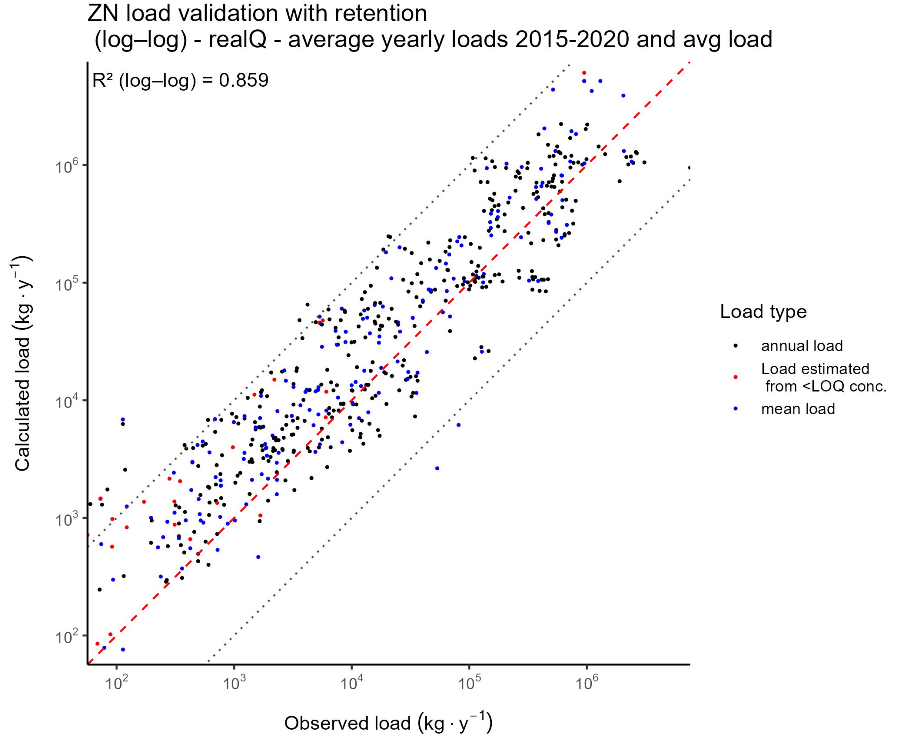


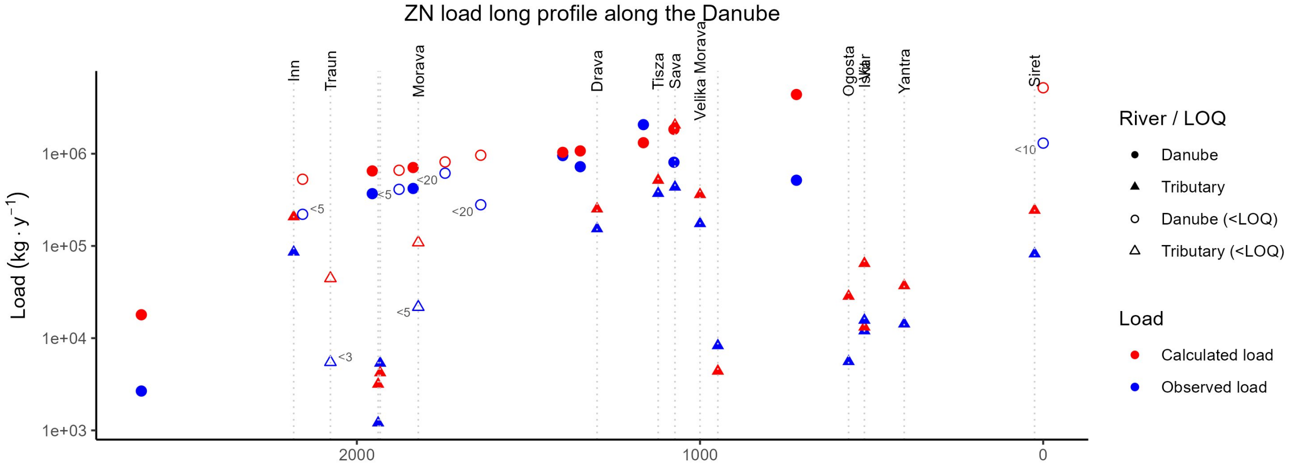
Main observations

- Clear underestimation of loads in the Sava and Tisza basins
- Strong underestimation of Danube loads
- Too high loads in the south-east DRB

Validation map for metalloids – zi



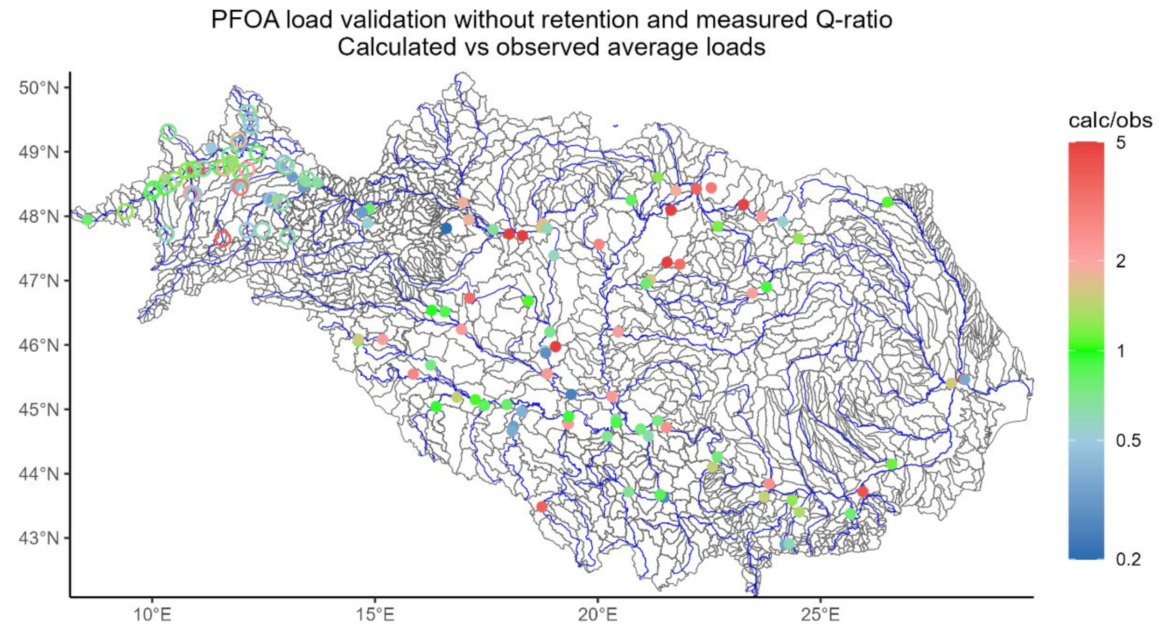


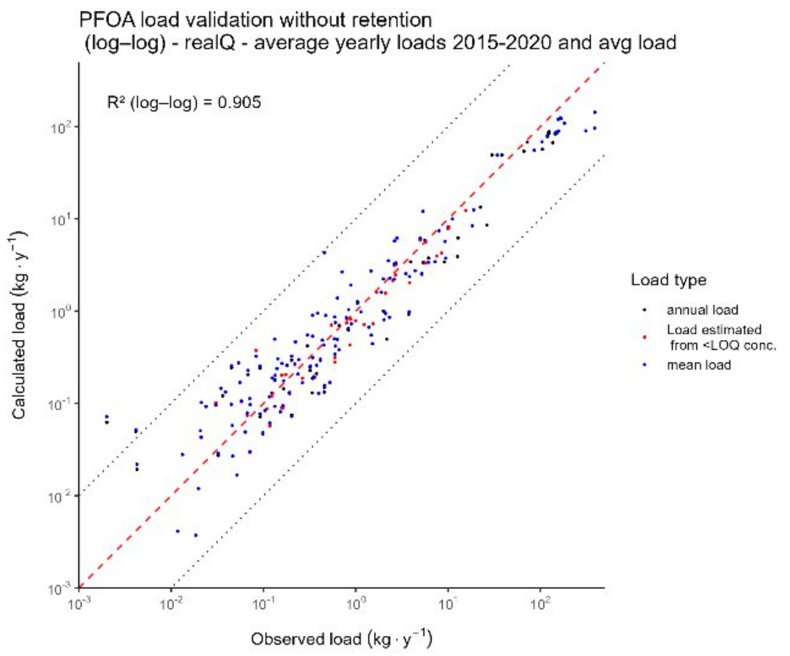


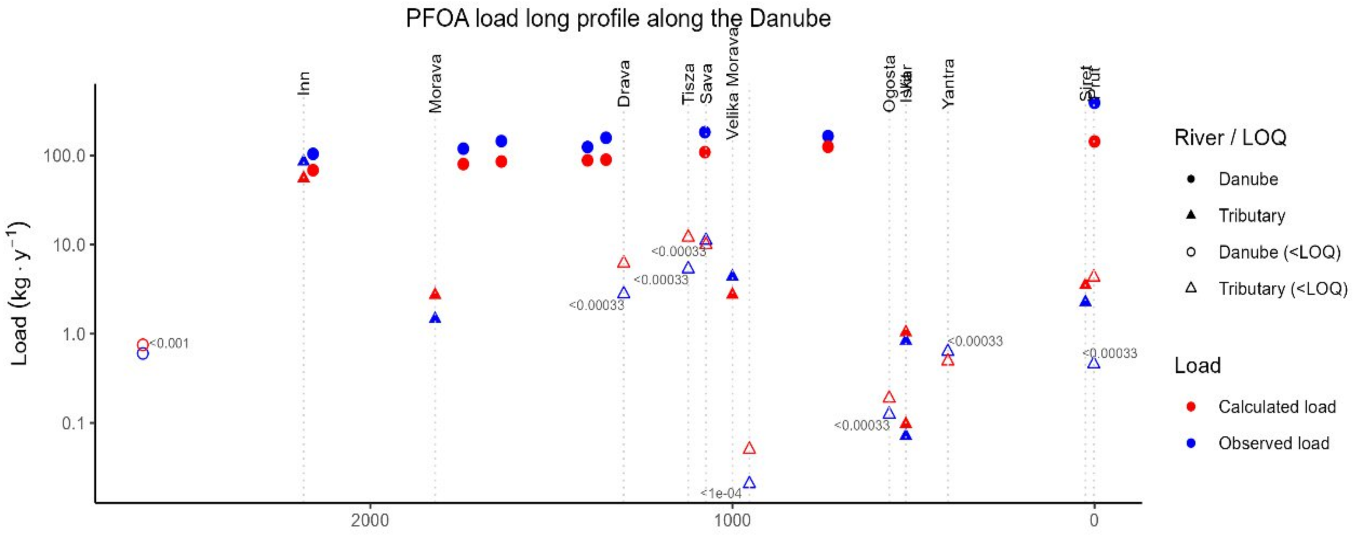
Main observations

- Fairly stable model performace across the basin
- Strong drop of loads in the lower Danube section
- Highly overestimated in the Sava basin

Validation map for PFAS – PFOA



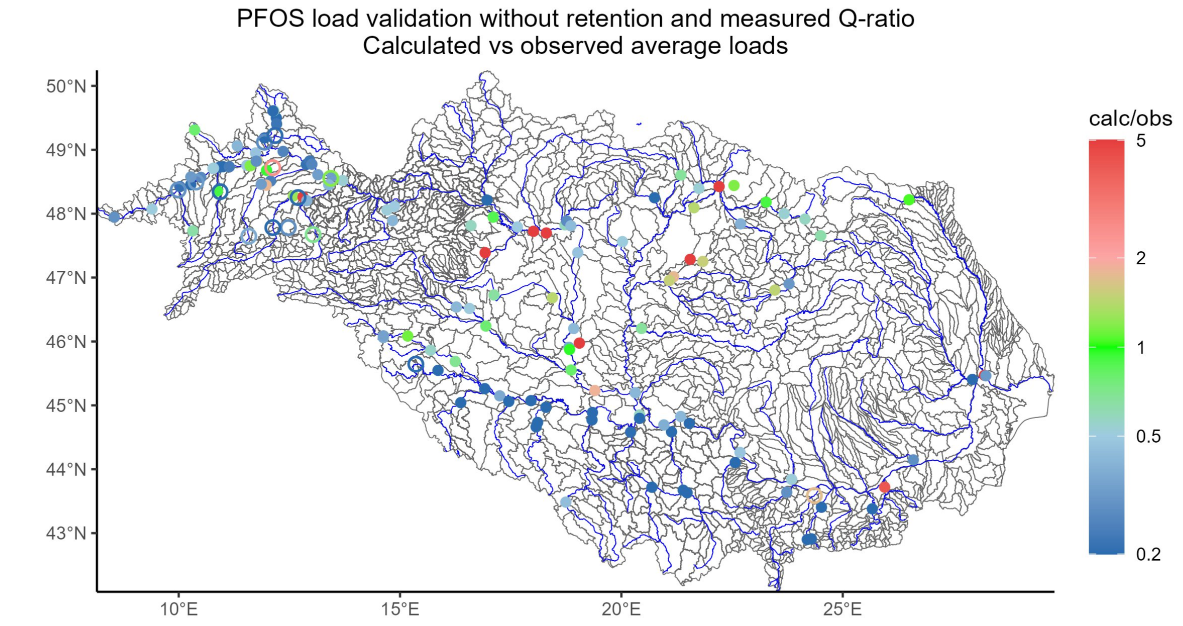


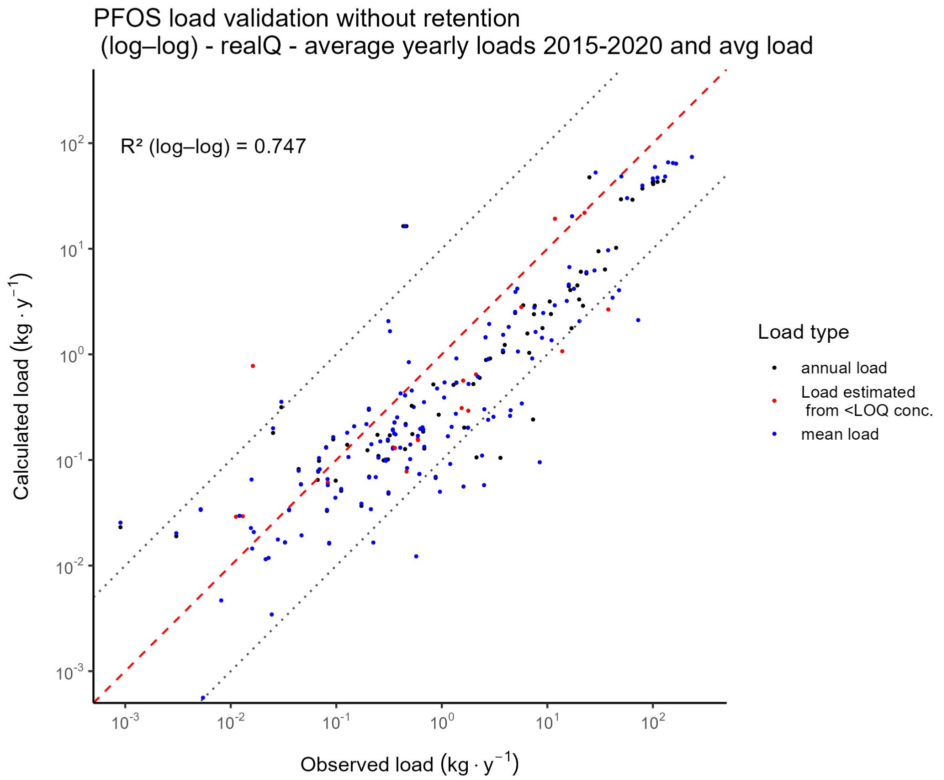


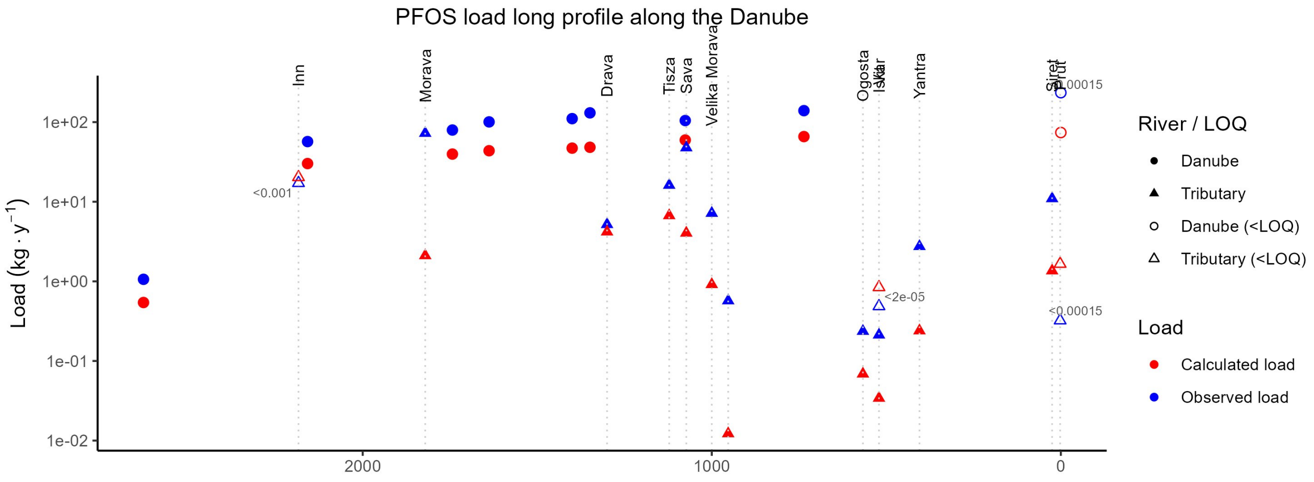
Main observations

- Less reliable validation datasets (1,2 measurements per year in some cases)
- Strong overestimation at some smaller rivers
- Clear underestimation along the Danube
- Most loads come from upper Danube region
- No significant retention in rivers

Validation map for PFAS – PFC



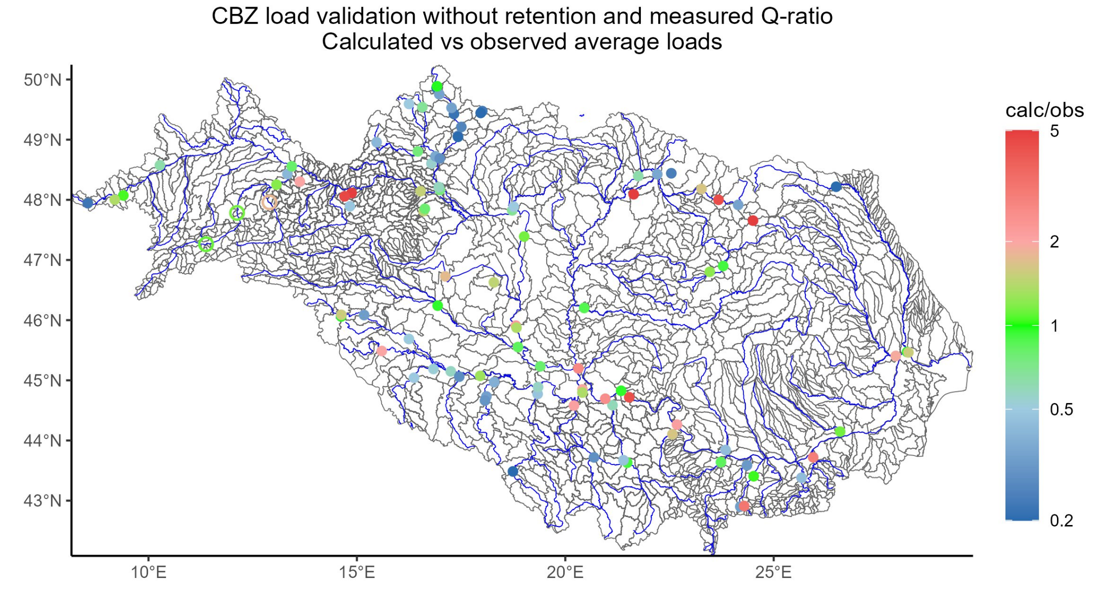


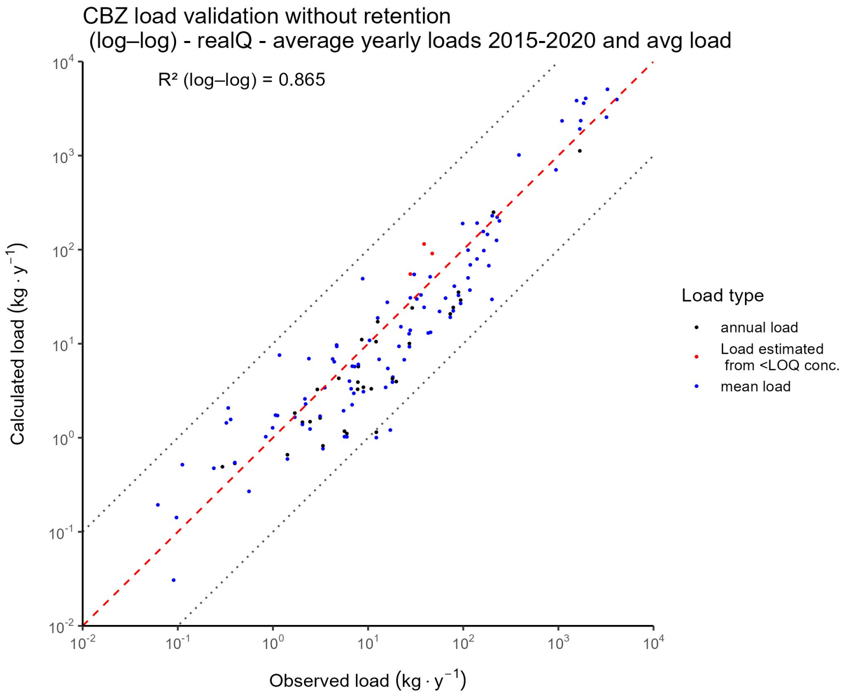


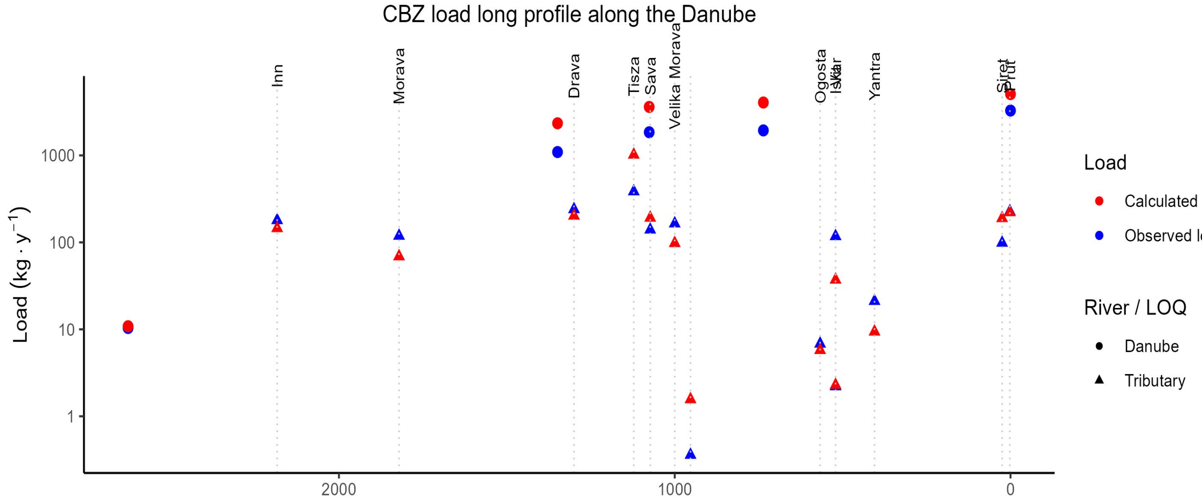
Main observations

- Less reliable validation datasets (1,2 measurements per year in some cases)
- Strong regional differences in model performance
- Heavy underestimation in the Danube and in most tibutaries

Validation map for pharmaceuticals - carbamazepine



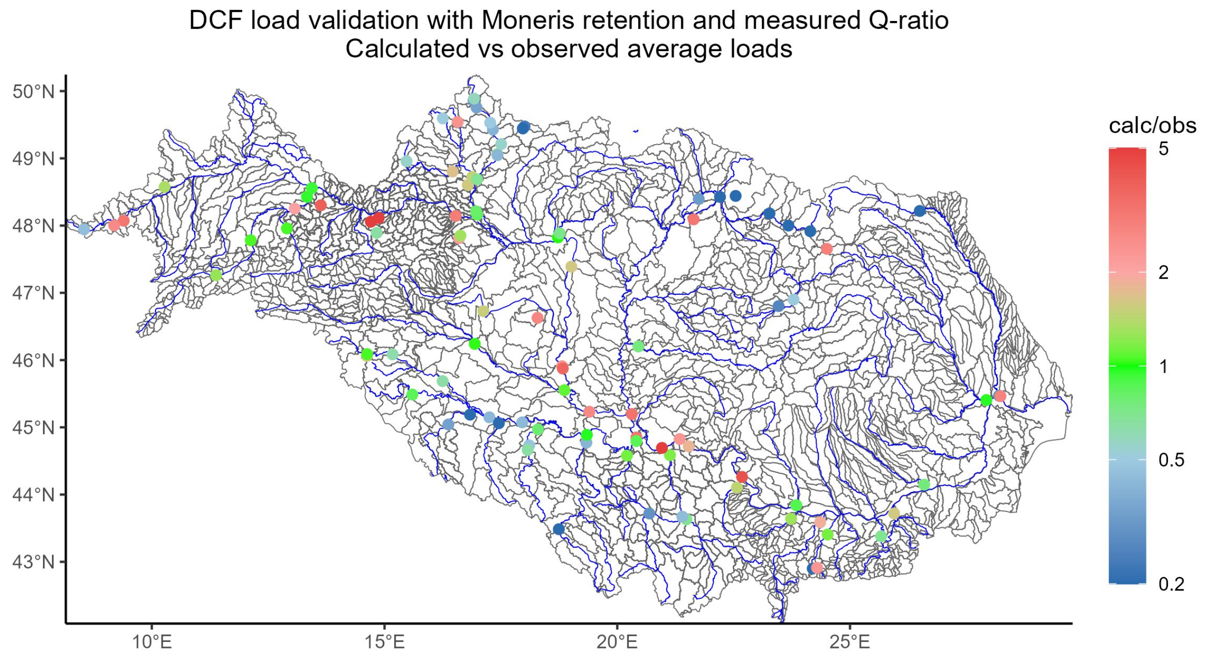


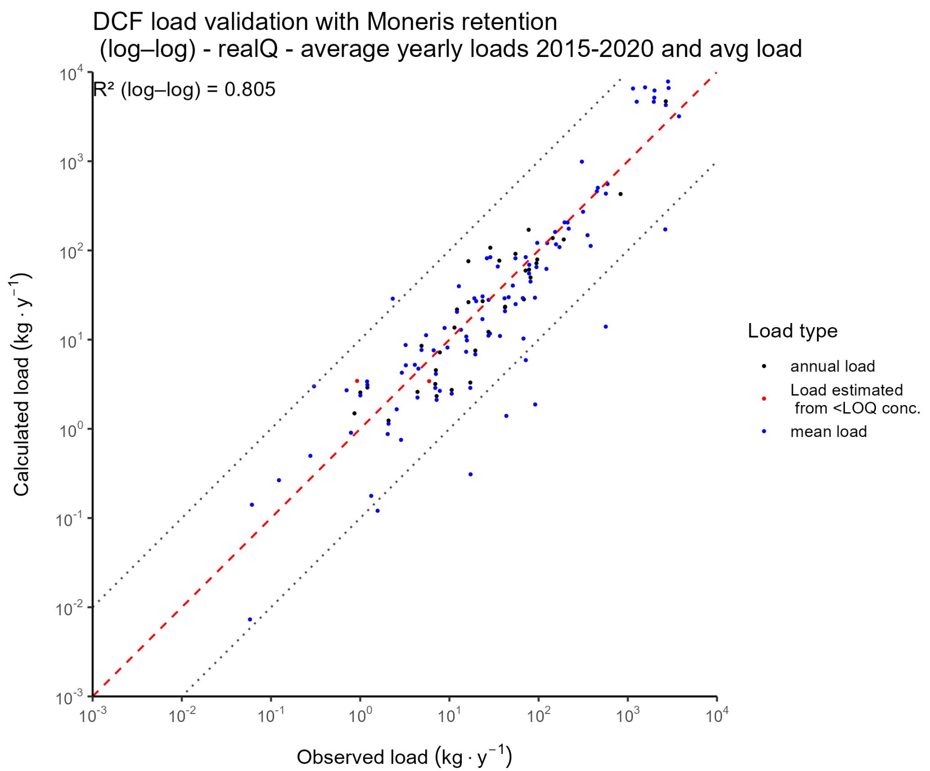


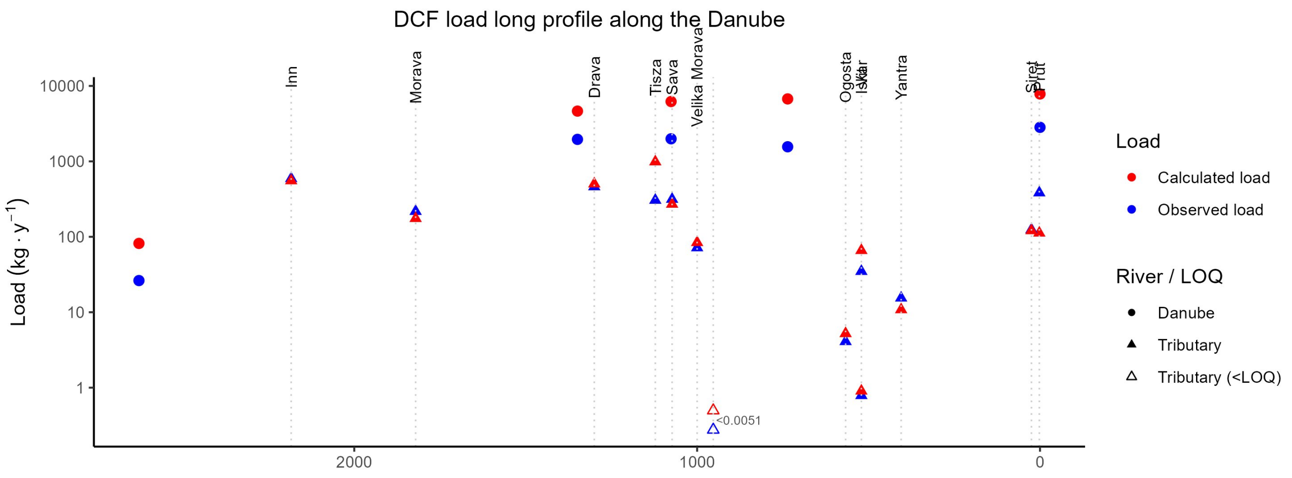
Main observations

- Less reliable validation datasets (1,2 measurements per year in some cases)
- Overestimation of loads in the Danube river
- Obvious underestimation in major tributaries (Morava, Sava)
- No significant retention in rivers

Validation map for pharmaceuticals - diclophenac



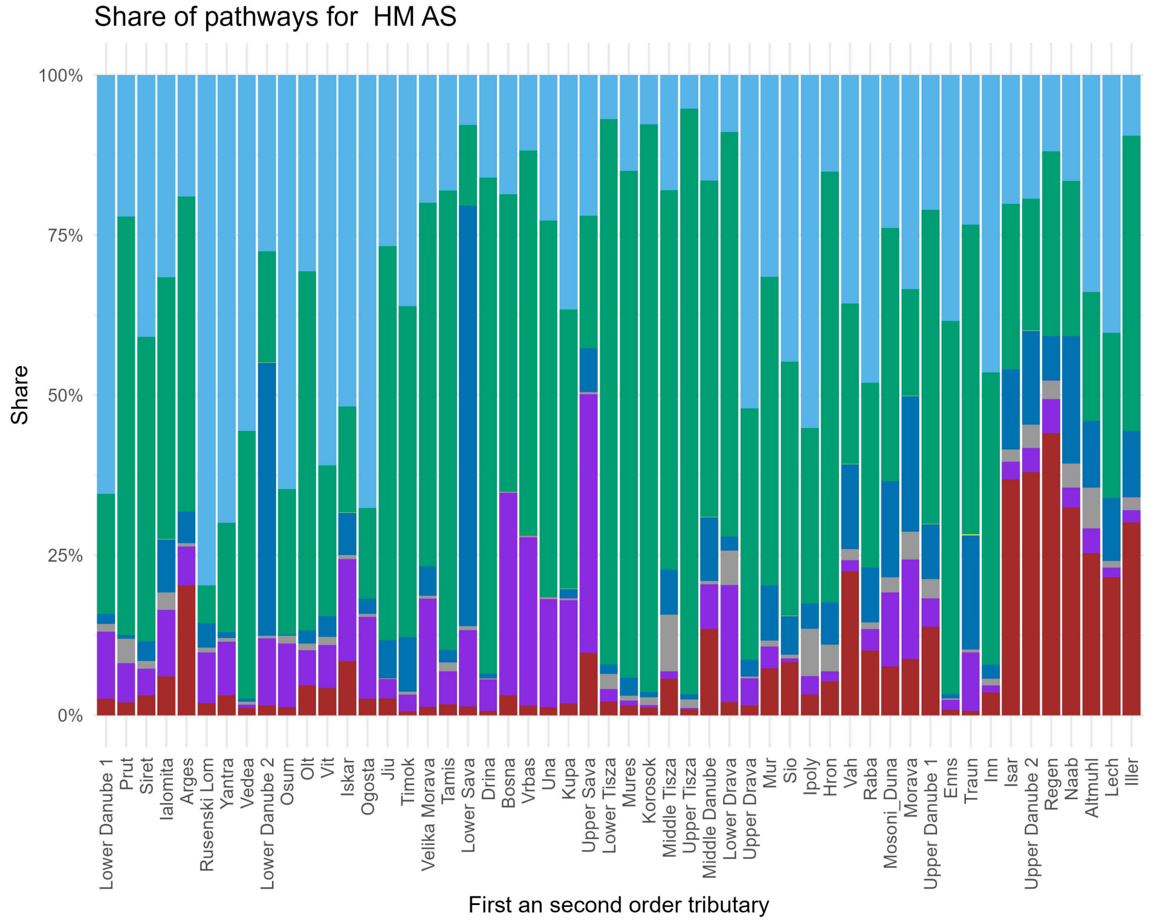


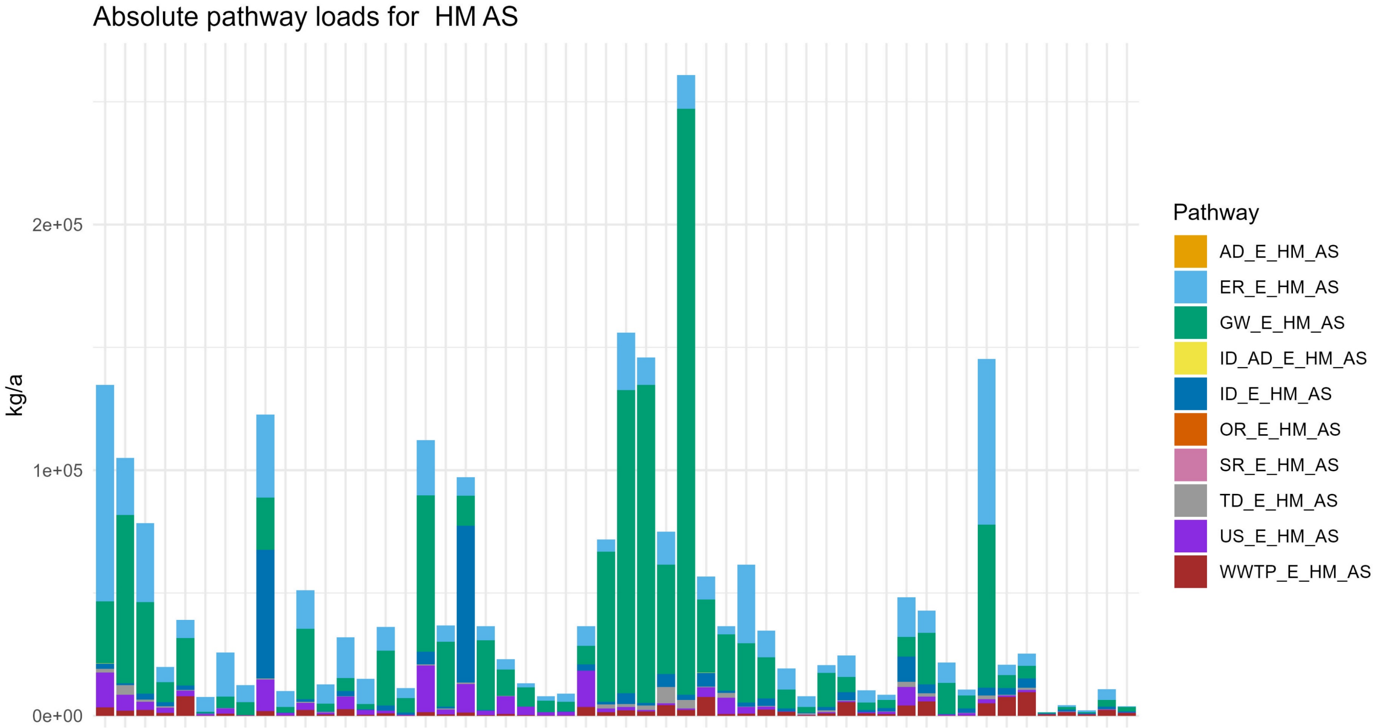


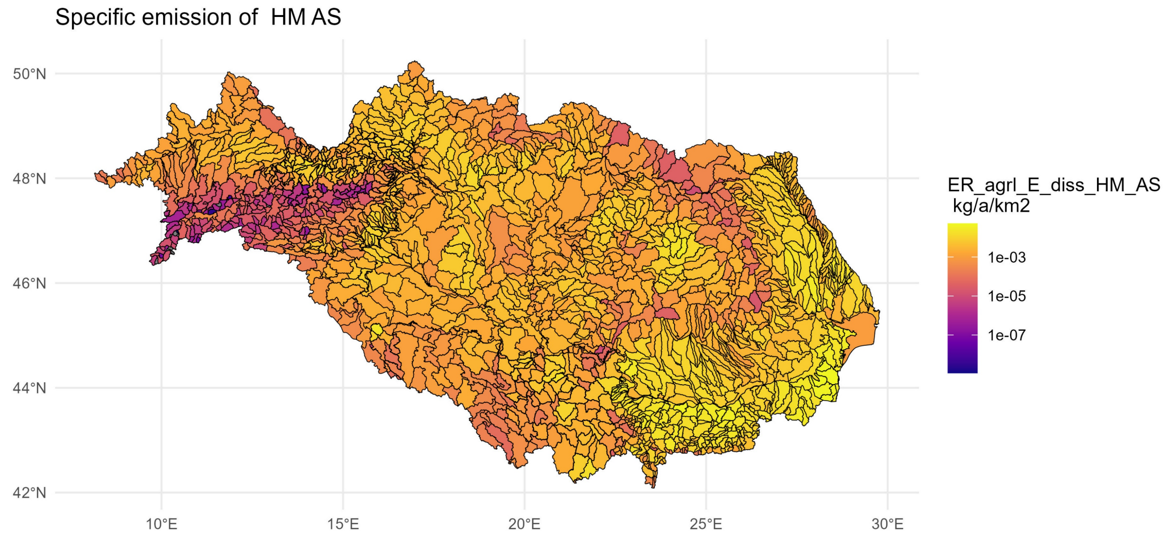
Main observations

- Less reliable validation datasets (1,2 measurements per year in some cases)
- Strong overestimation of loads in the Danube river
- Riverine retention for Danube is very likely, not yet in the model!!

As emissions in the DRB



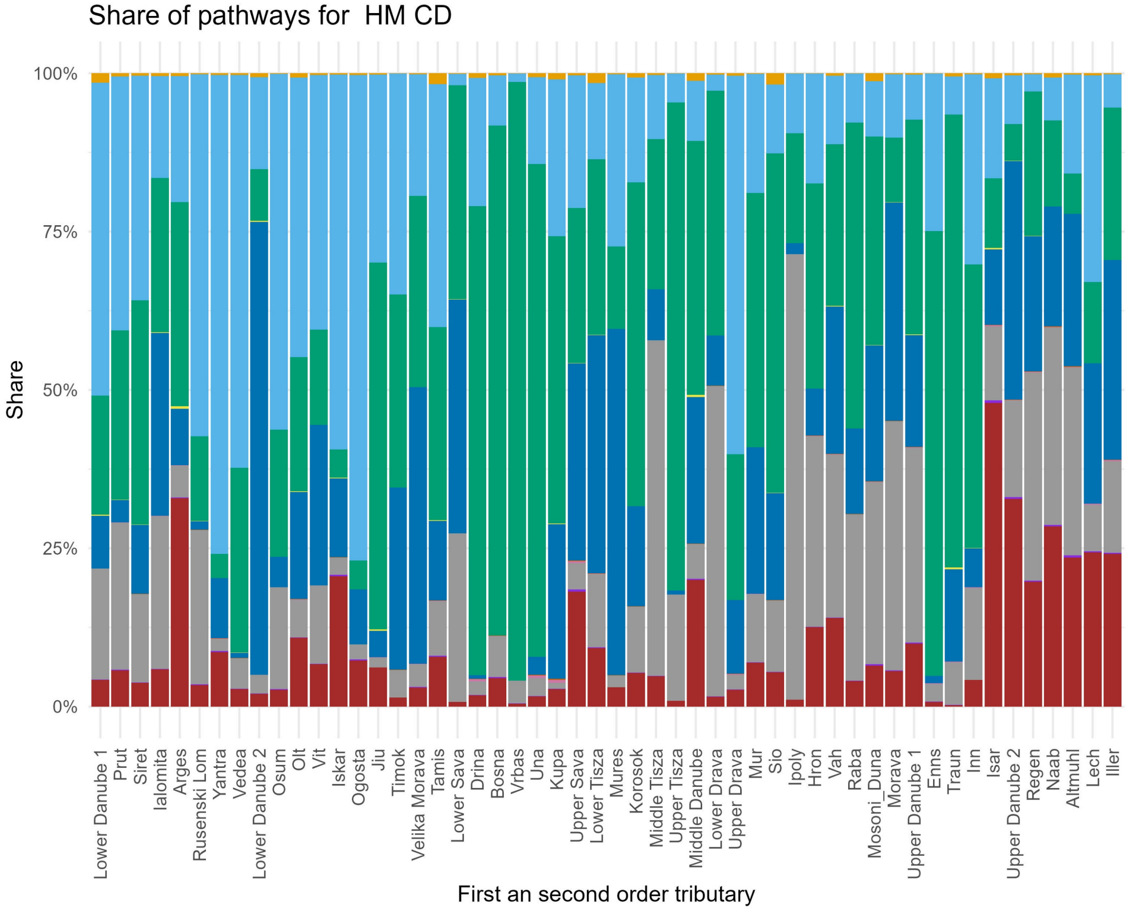


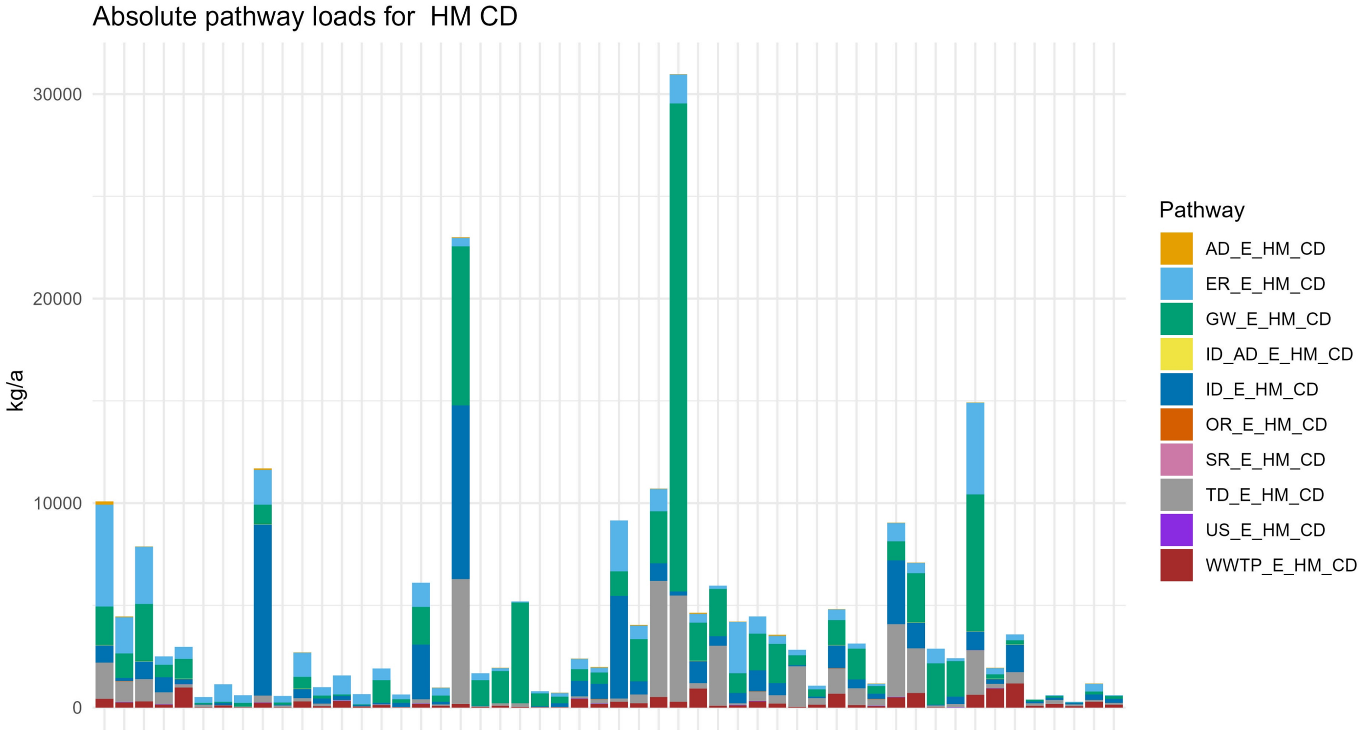


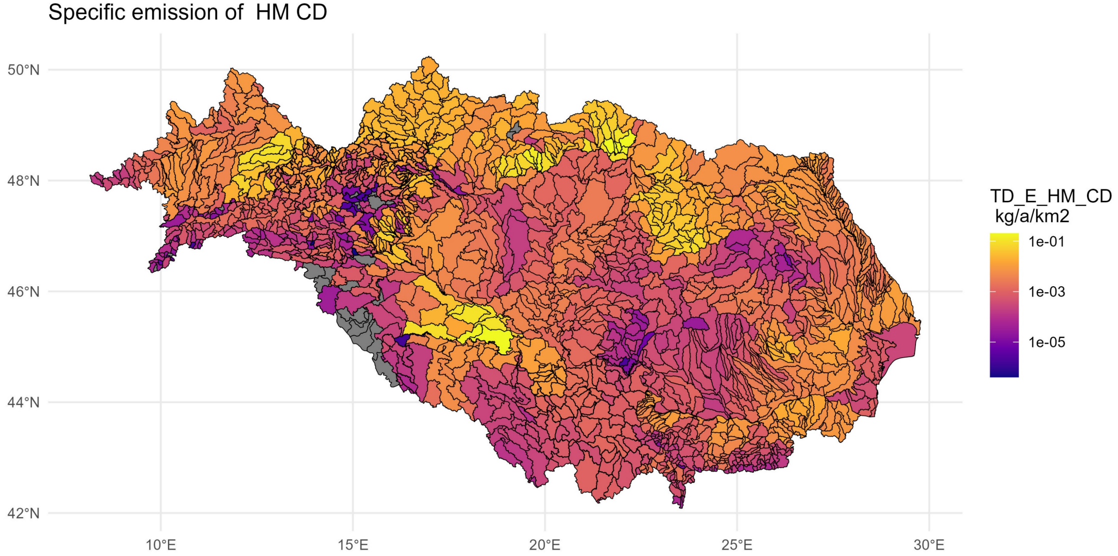
Main observations

- Strong regional patterns in total loads
- Groundwater is the main overall source, especially in the middle Danube
- Erosion is significant, especially in the lower Danube
- WWTP load is a small share in total terms

Cd emissions in the DRB



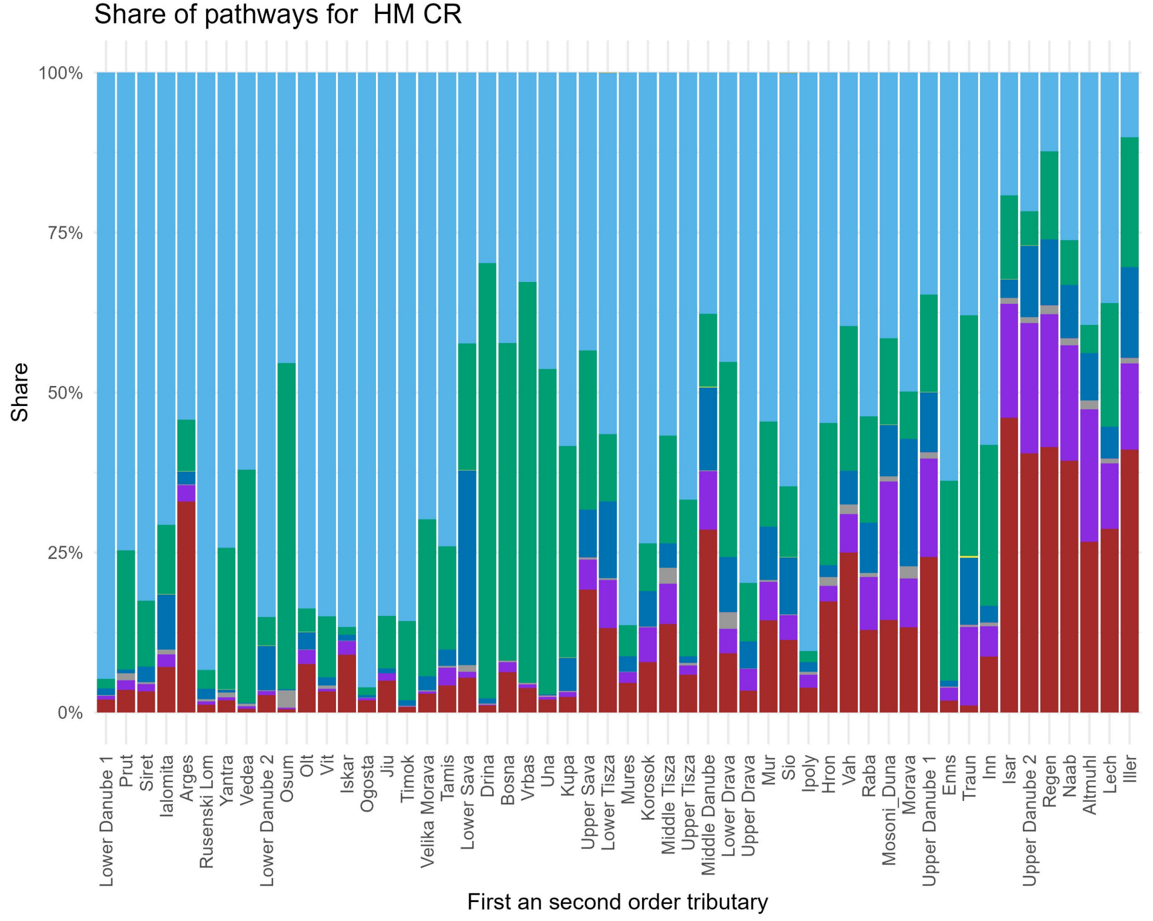


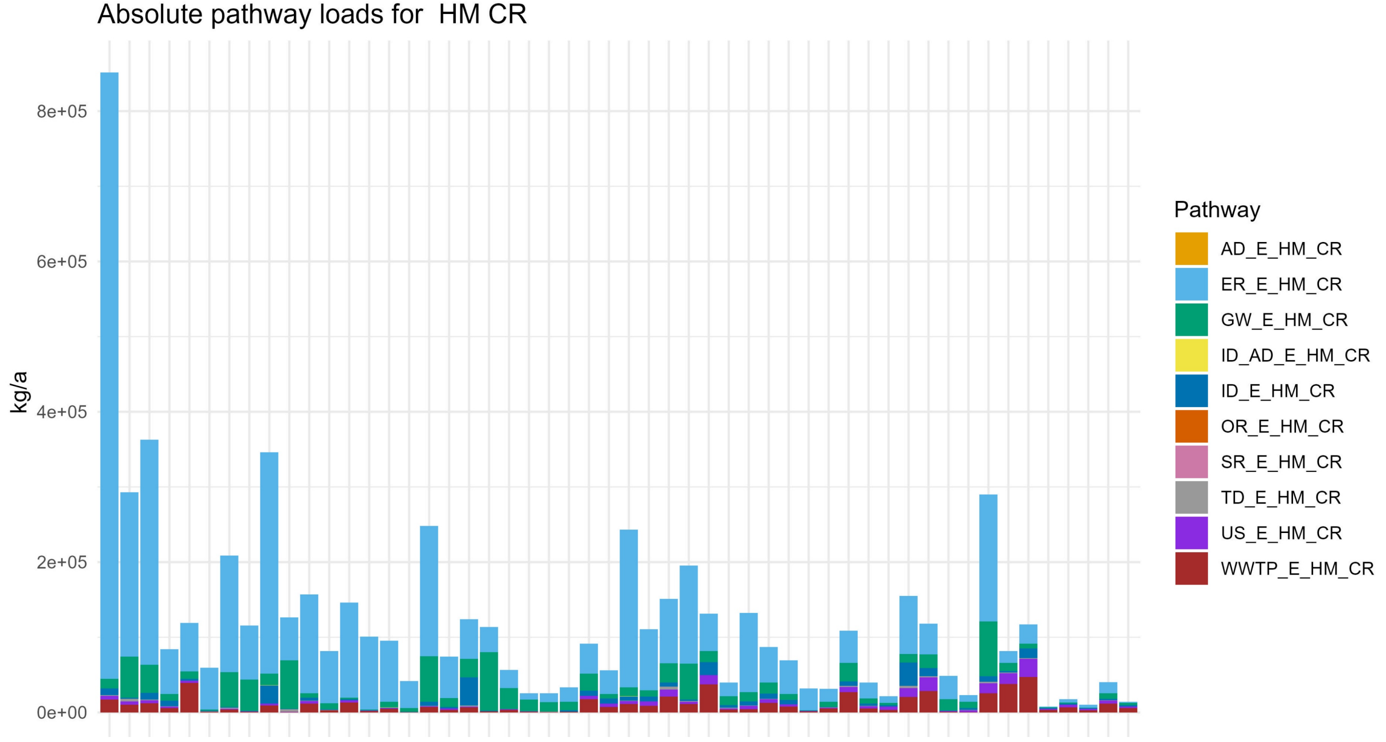


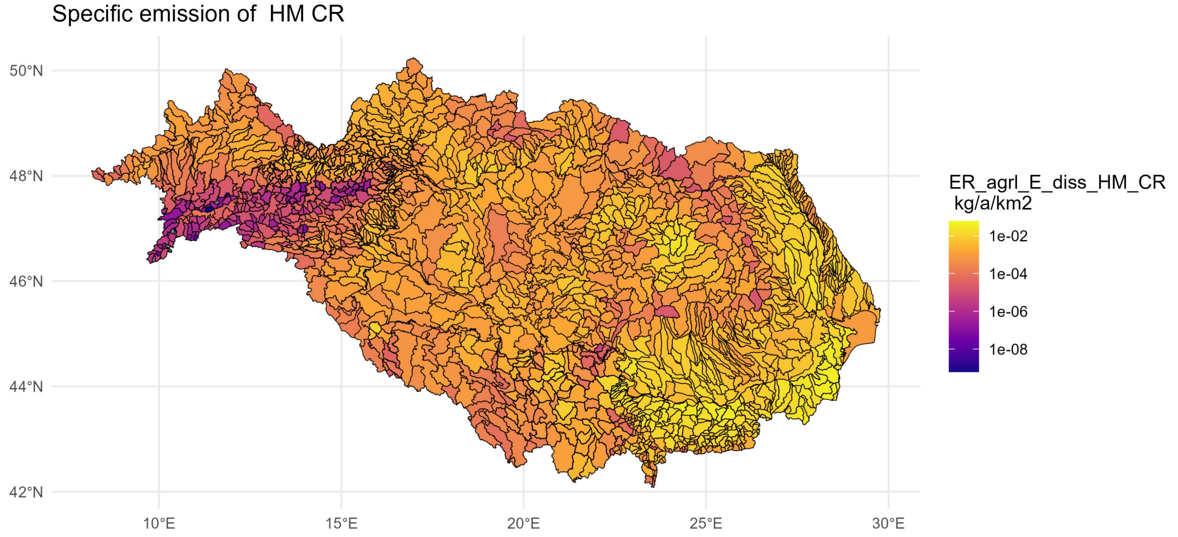
Main observations

- Industry, erosion and groundwater are the main pathways
- Some hot spot catchments are present (lower Sava, middle and upper-Tisza, Inn)
- Tile drain loads is shown high, but high uncertainty

Cr emissions in the DRB



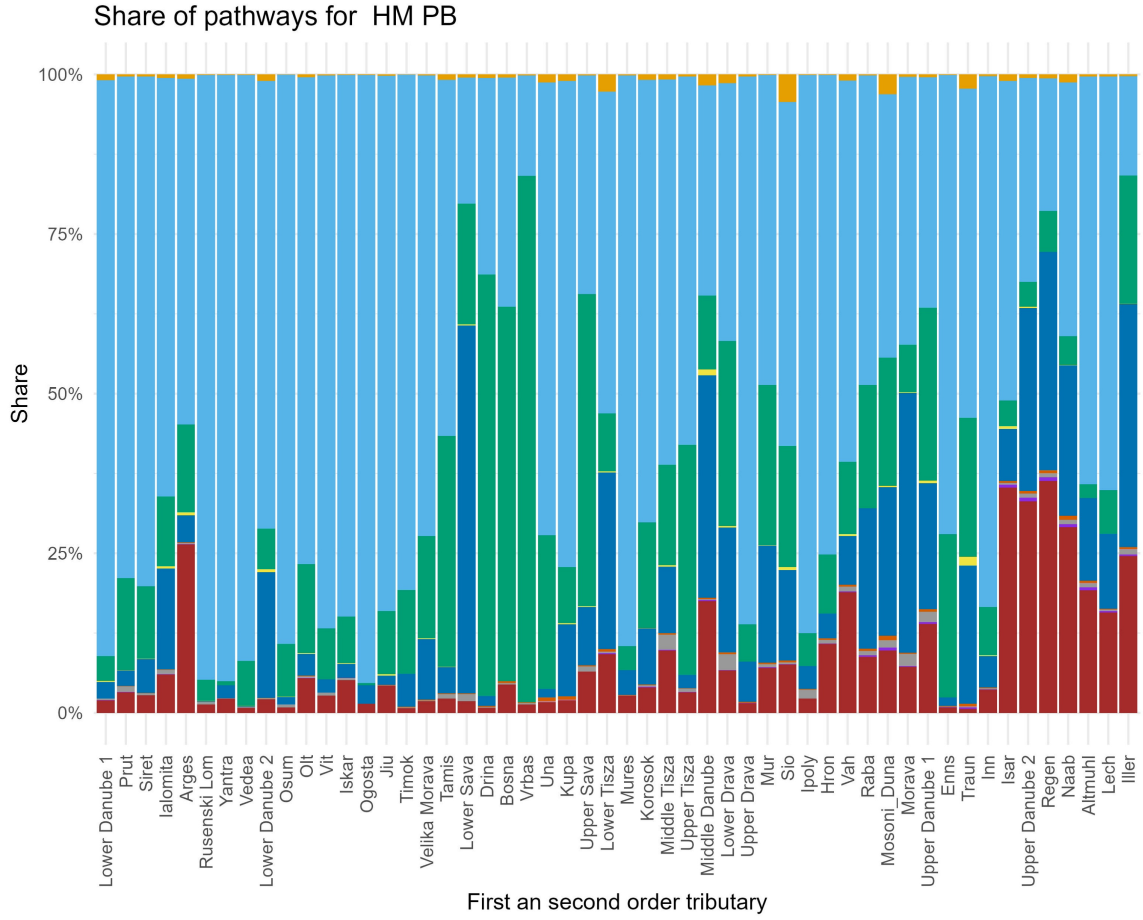


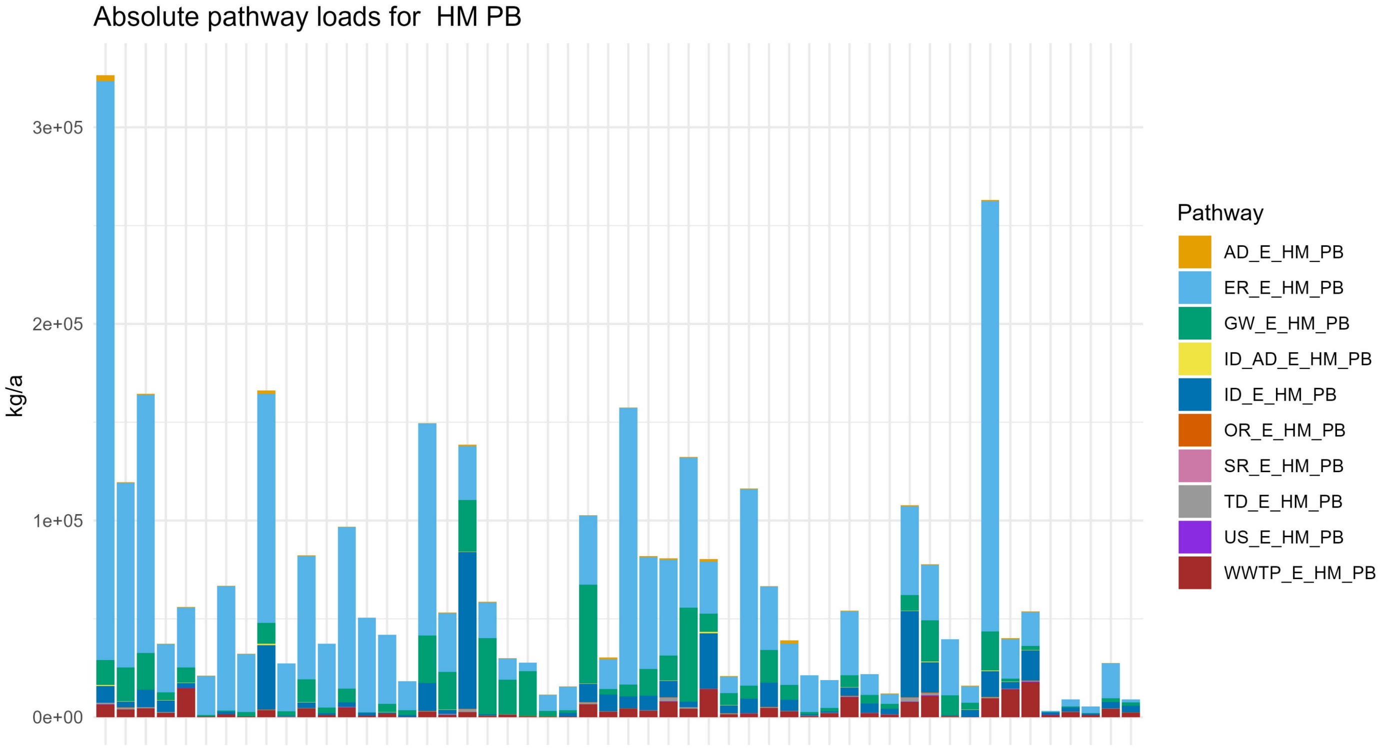


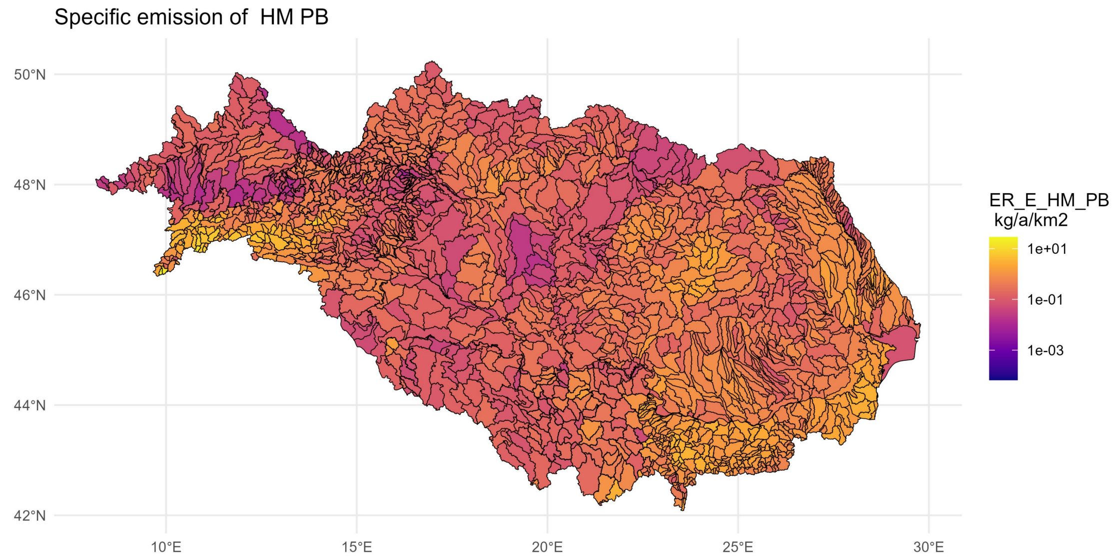
Main observations

- Strong regional patterns in total loads, highest loads in the lower Danube
- Erosion is the most significant pathway, especially in the lower Danube
- WWTP load is a small share in total terms

Pb emissions in the DRB



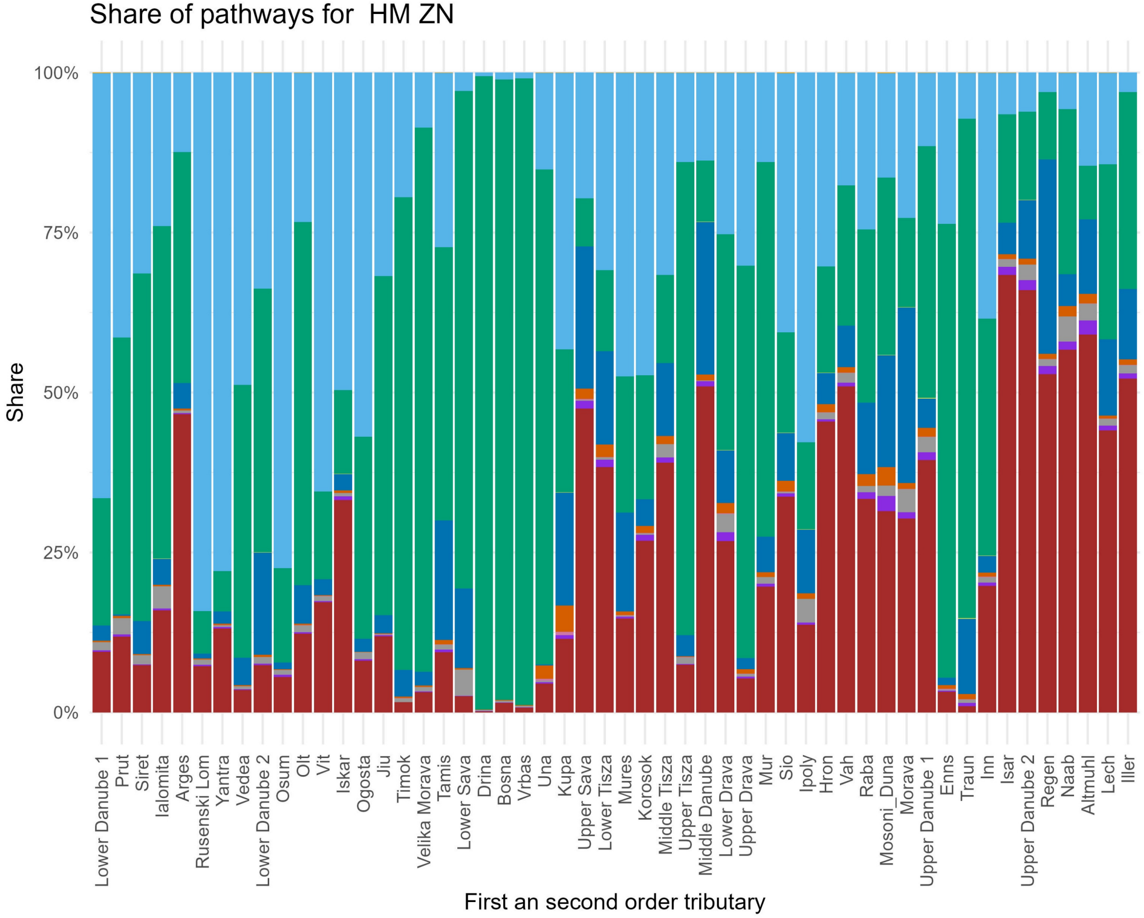


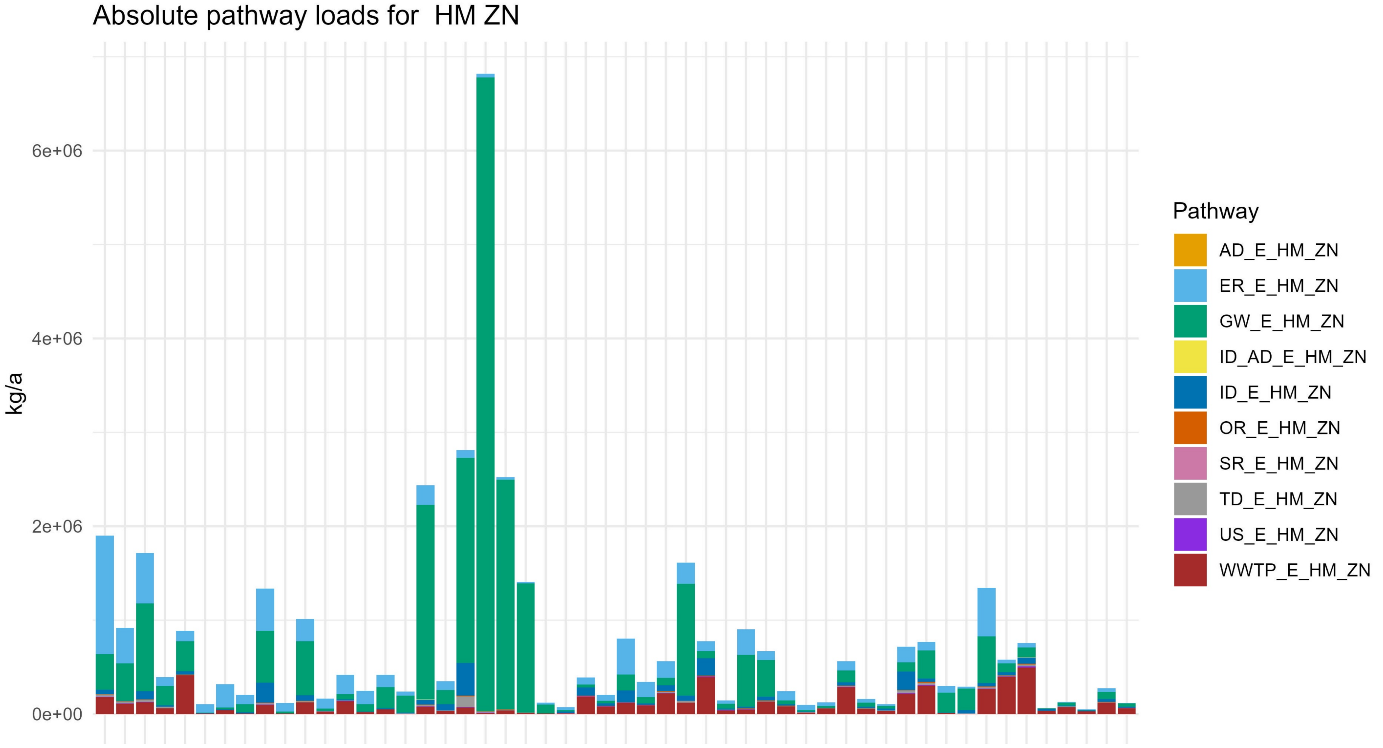


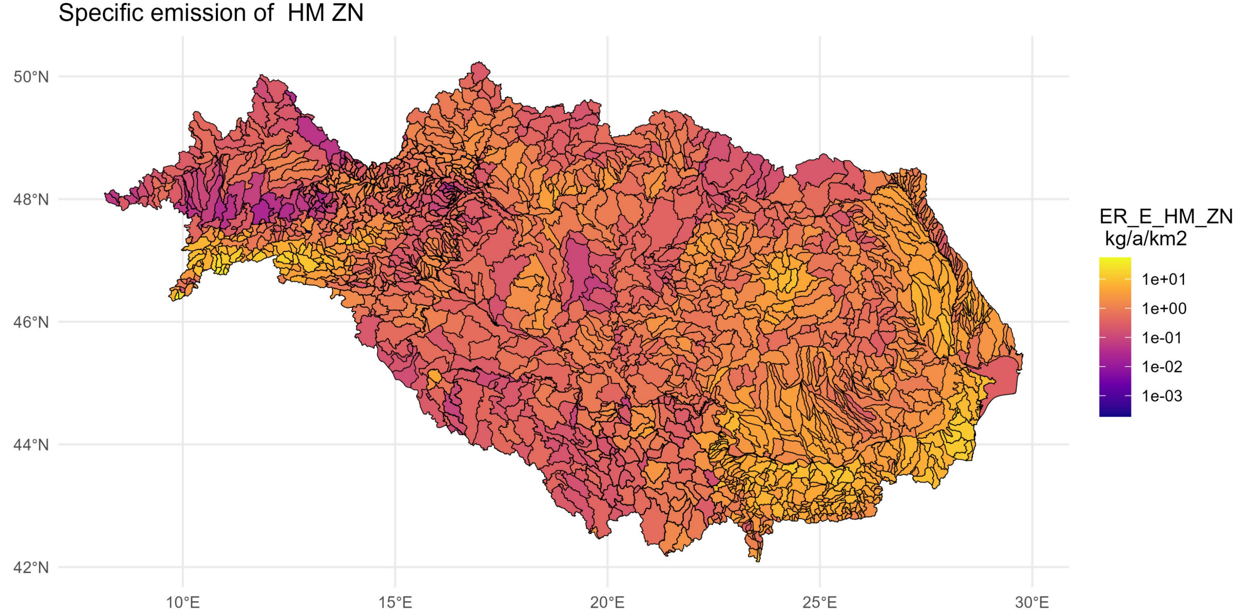
Main observations

- Uneven distribution of total loads (hot-spot catchments)
- Erosion is the most significant pathway, especially in the lower Danube

Zn emissions in the DRI



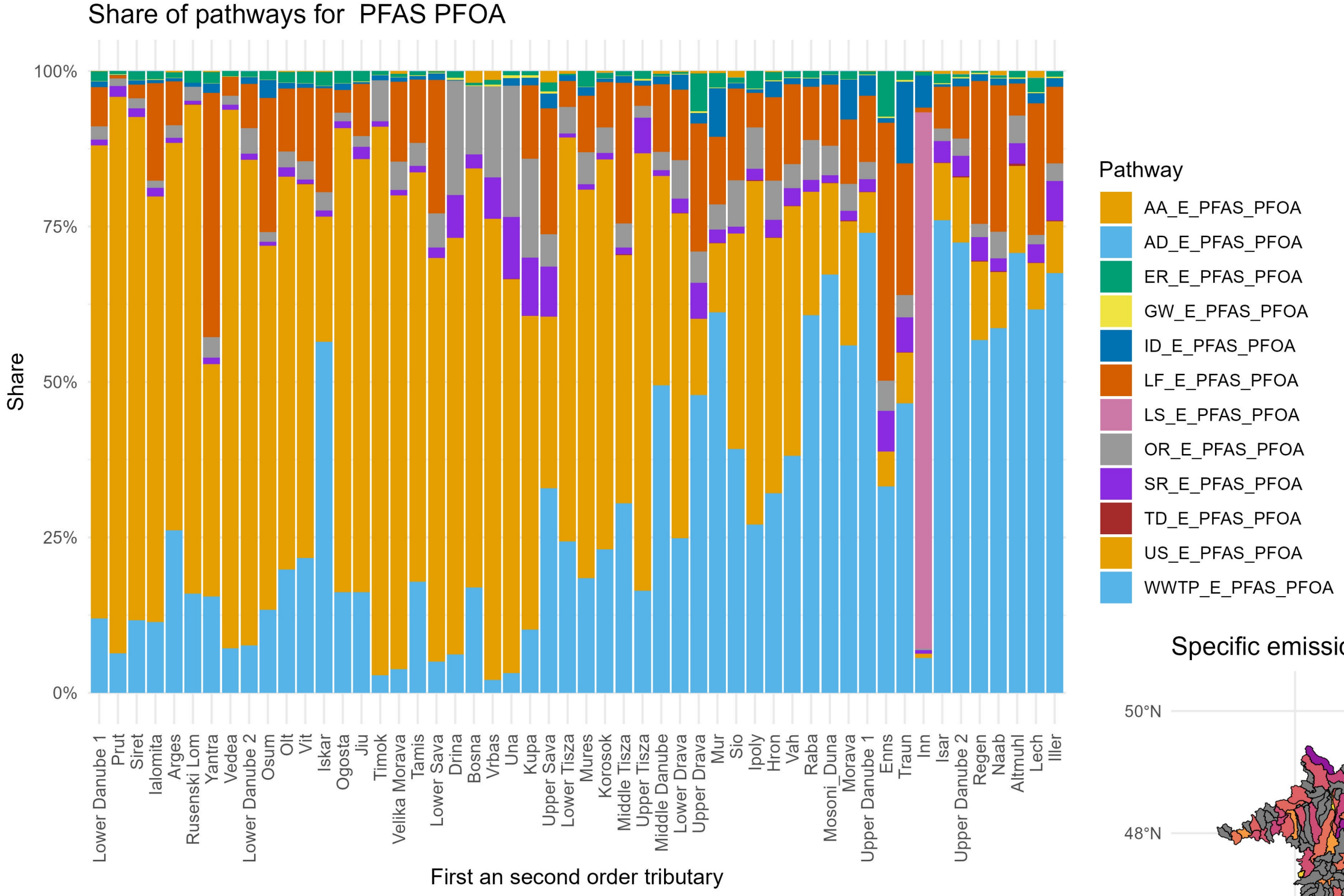


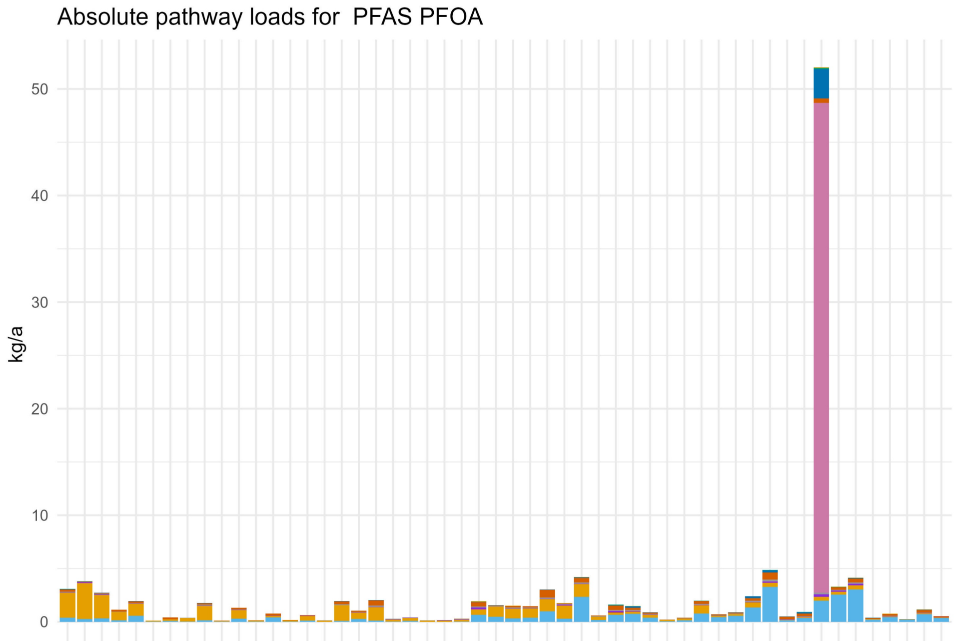


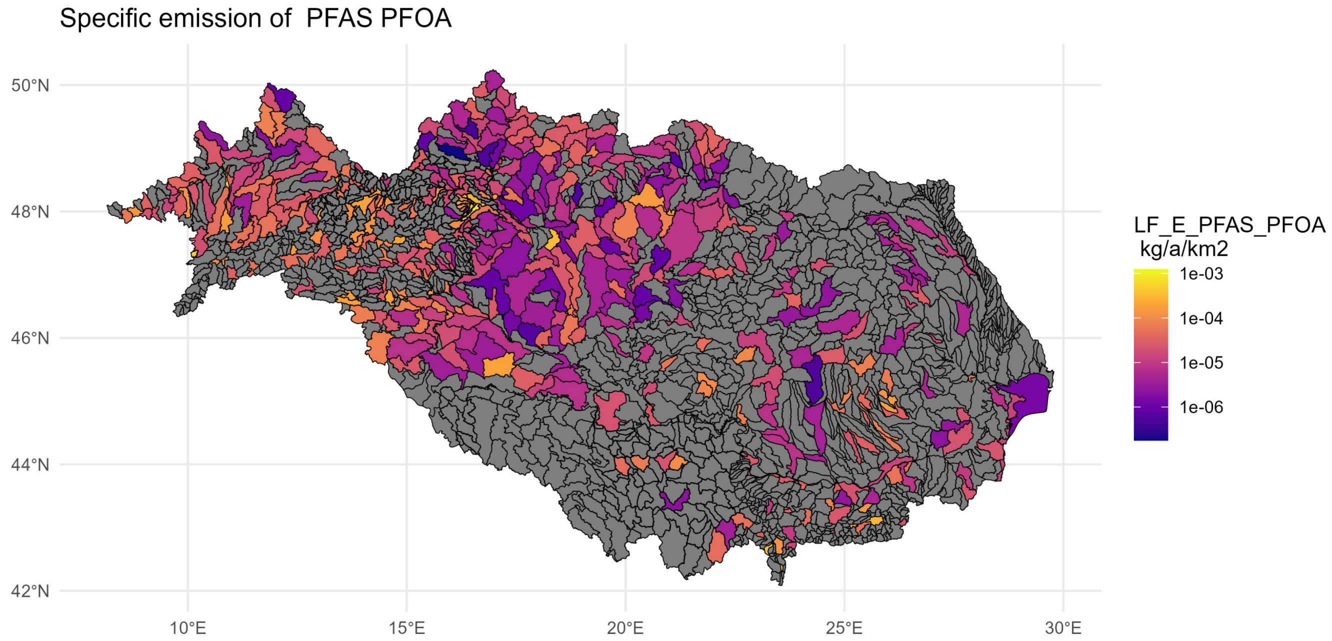
Main observations

- Overestimation of GW loads in the Bosnian rivers
- Erosion and waste water loads are the most significant
- Groundwater is locally significant.

PFOA emissions in the DRB



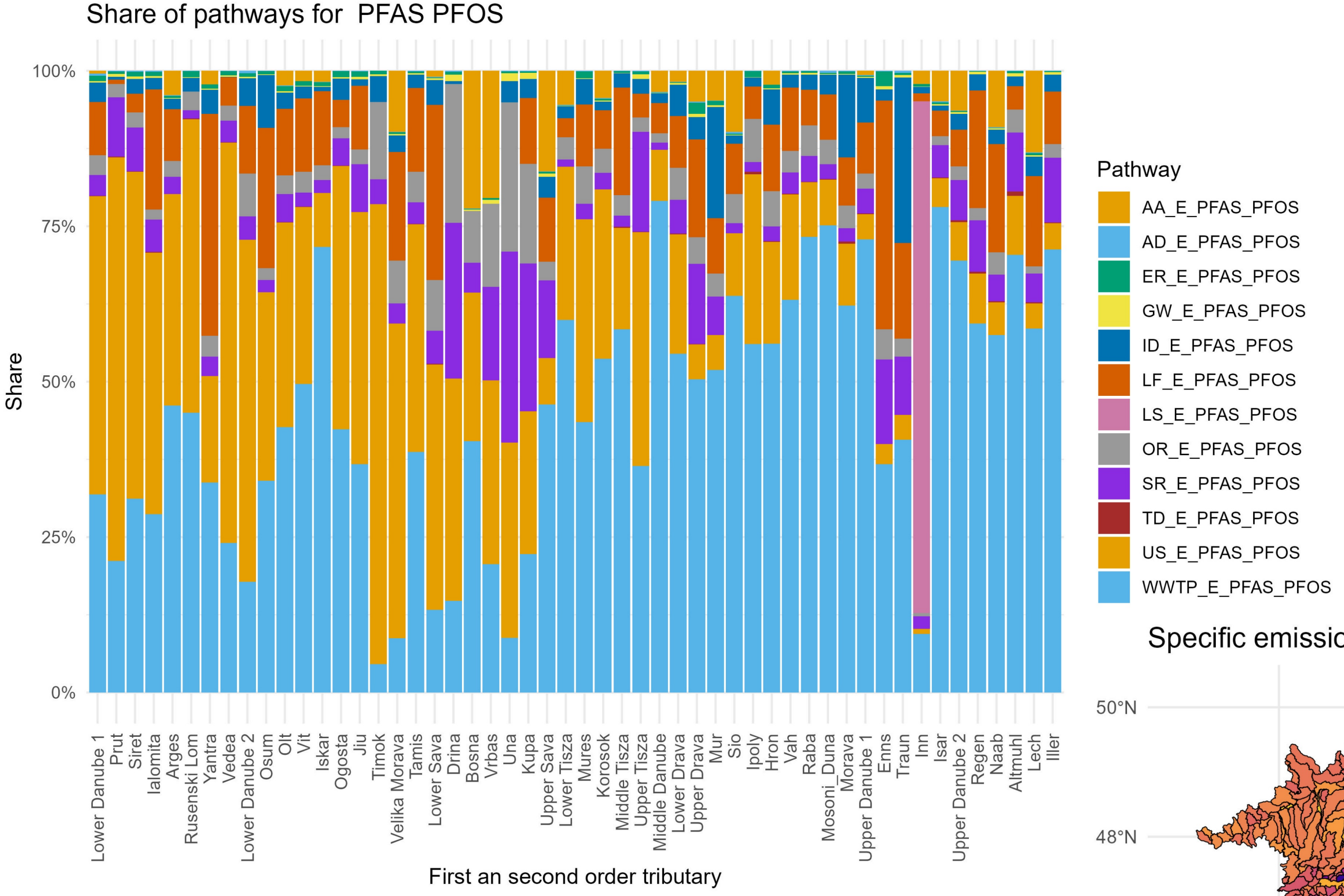


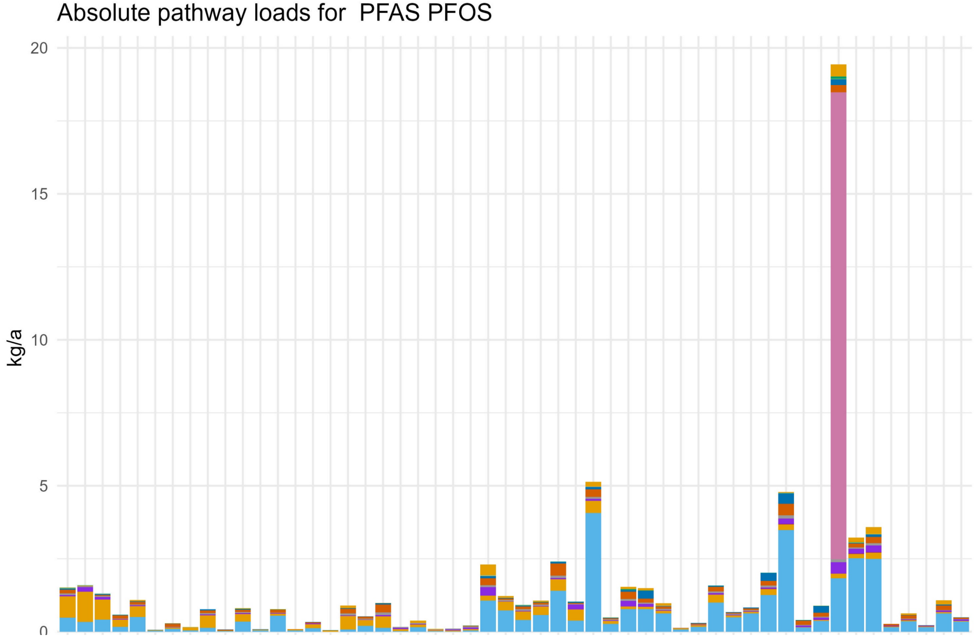


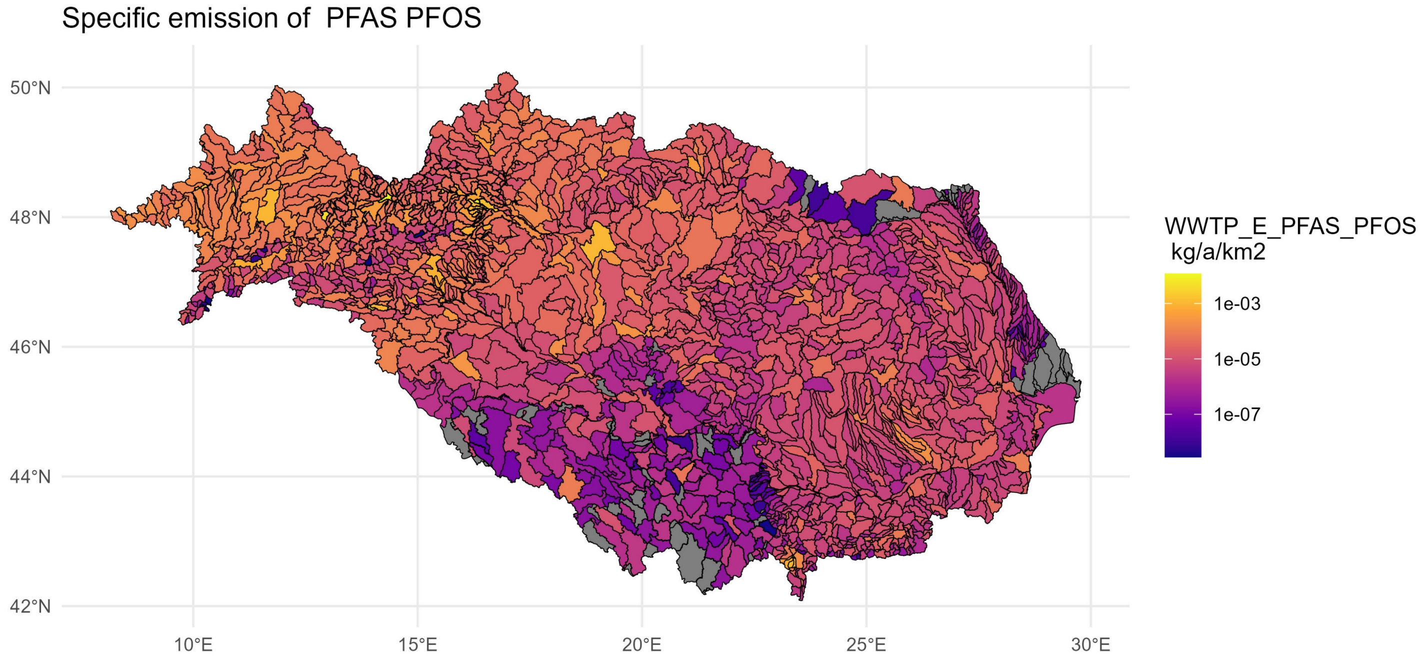
Main observations

- Gendorf legacy hot spot is a dominant source
- WWTP loads dominate river loads in the upper Danube
- Urban systems related emissions dominate river loads in the middle and lower Danube
- Landfill hot-spots give a significant share (high uncertainty)

PFOS emissions in the DRB - strongly underestimated!!!!



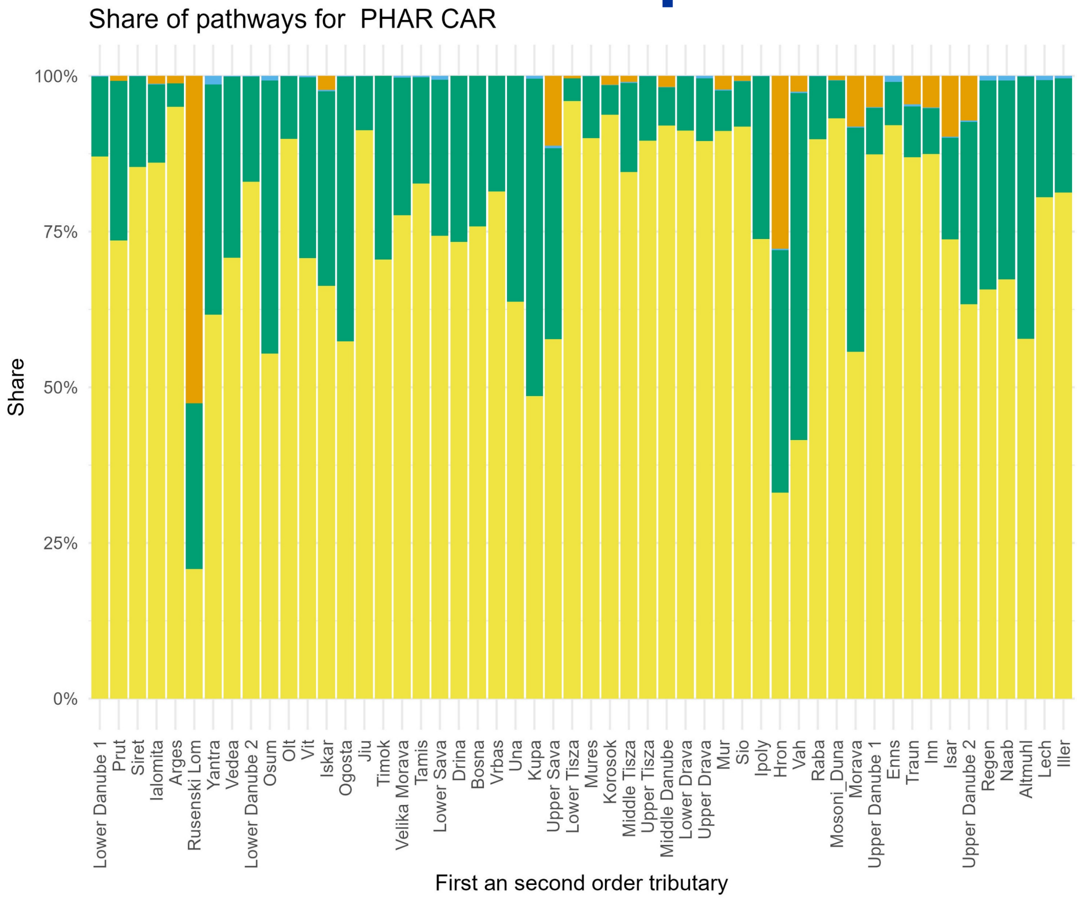


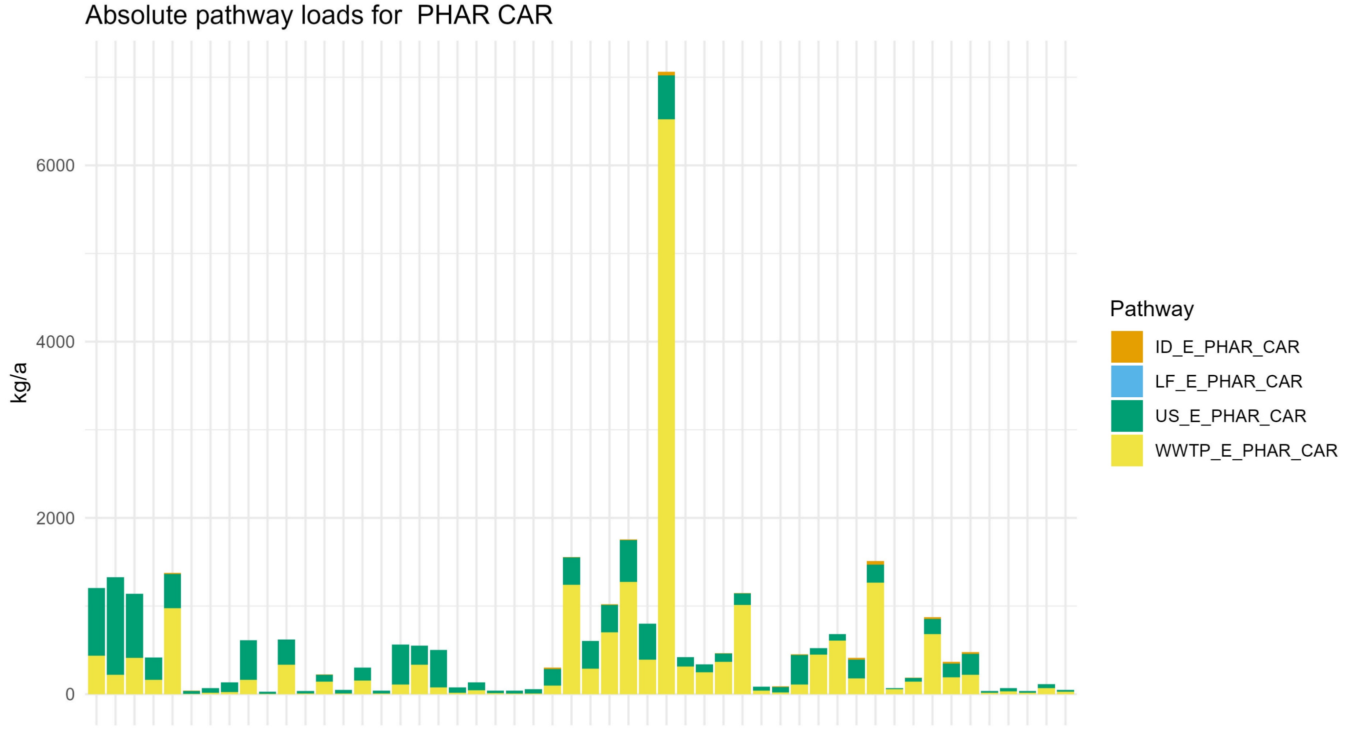


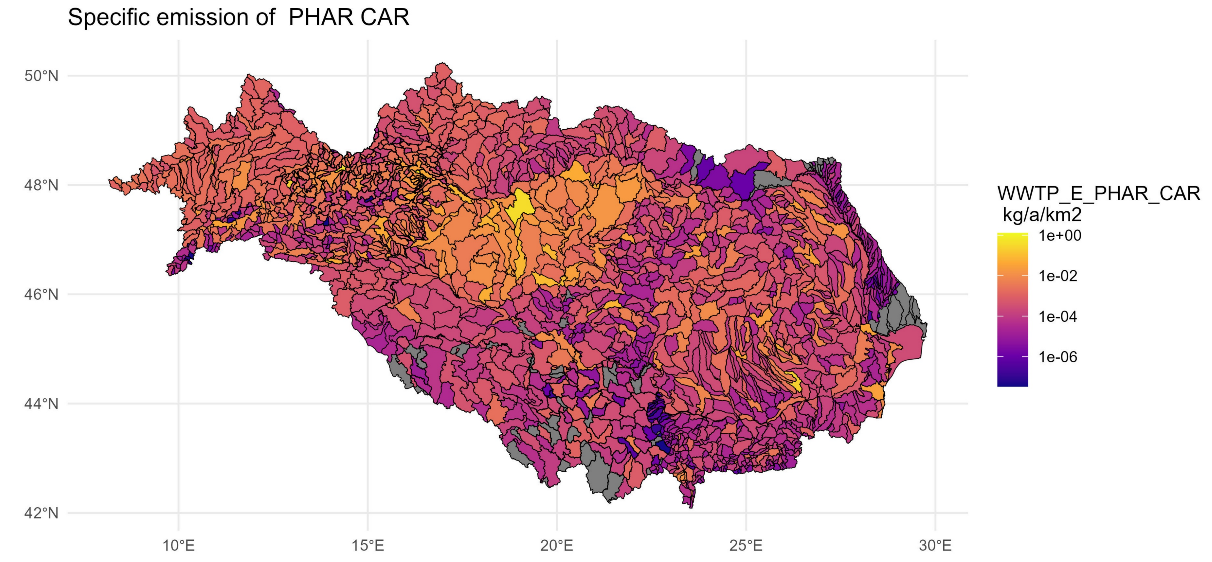
Main observations

- WWTP loads dominate river loads in the upper Danube
- Loads from urban systems are very relevant in the lower Danube region
- Landfill/Aerodrome hot-spots give a significant share (high uncertainty)

Carbamazepine emissions in the DRB





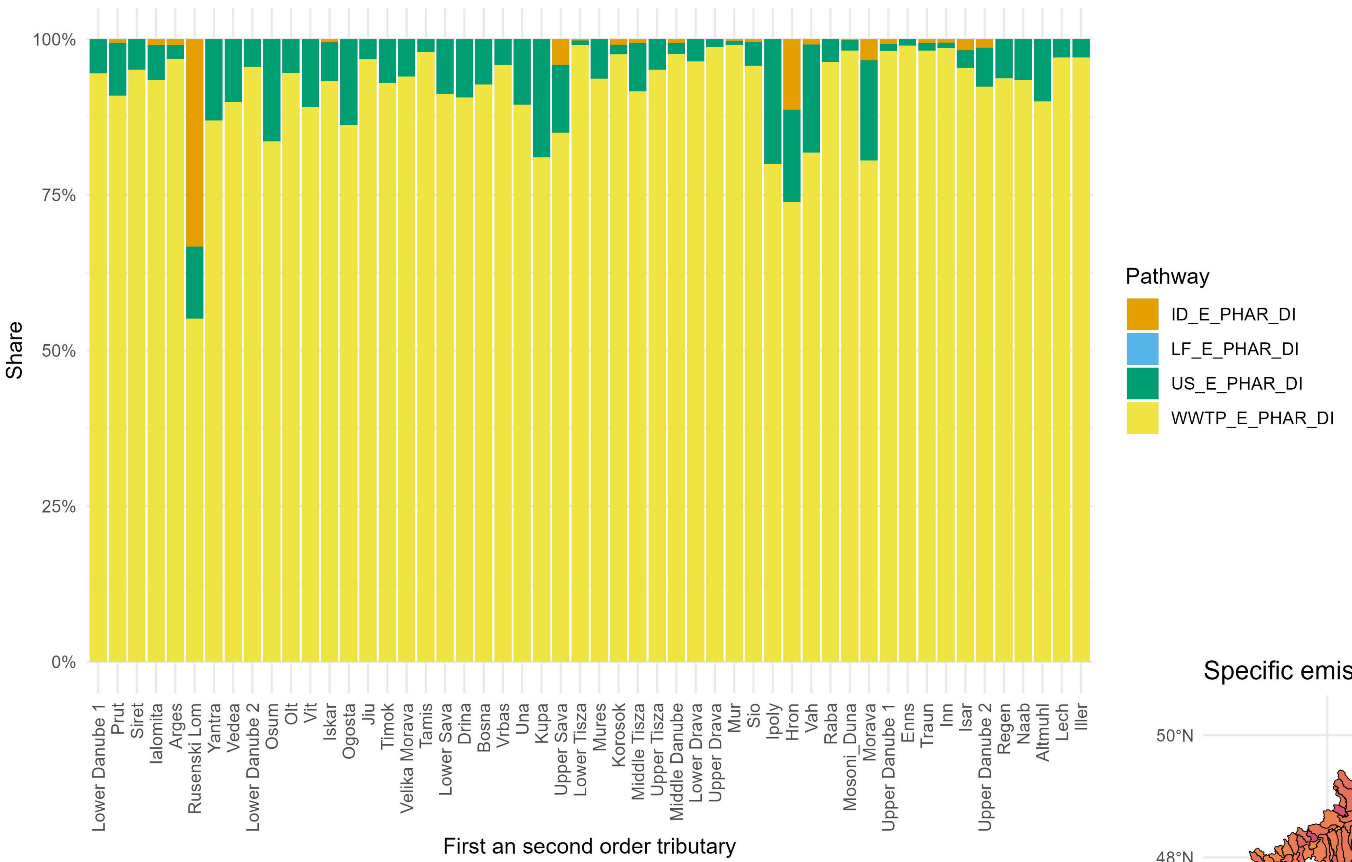


Main observations

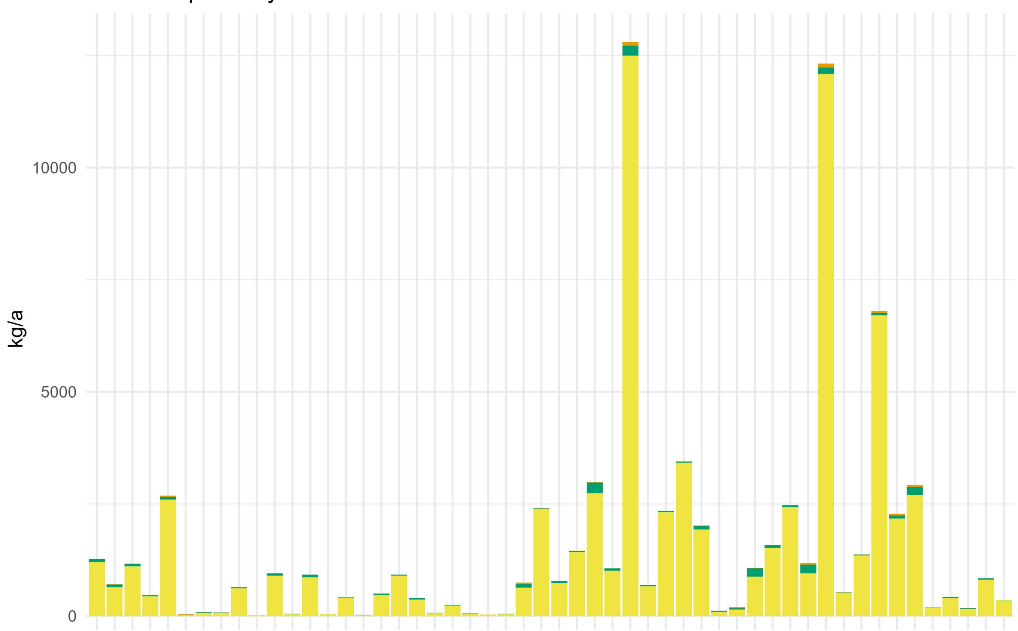
- Beside WWTPs, urban systems play an important part in total loads
- Due to lower share of sewege treatment, share of urban systems related diffuse load might be important in the lower Danube
- Industrial discharges show strong hot-spot loads in a few catchments (only estimated loads!)

Diclophenac emissions in the DRB

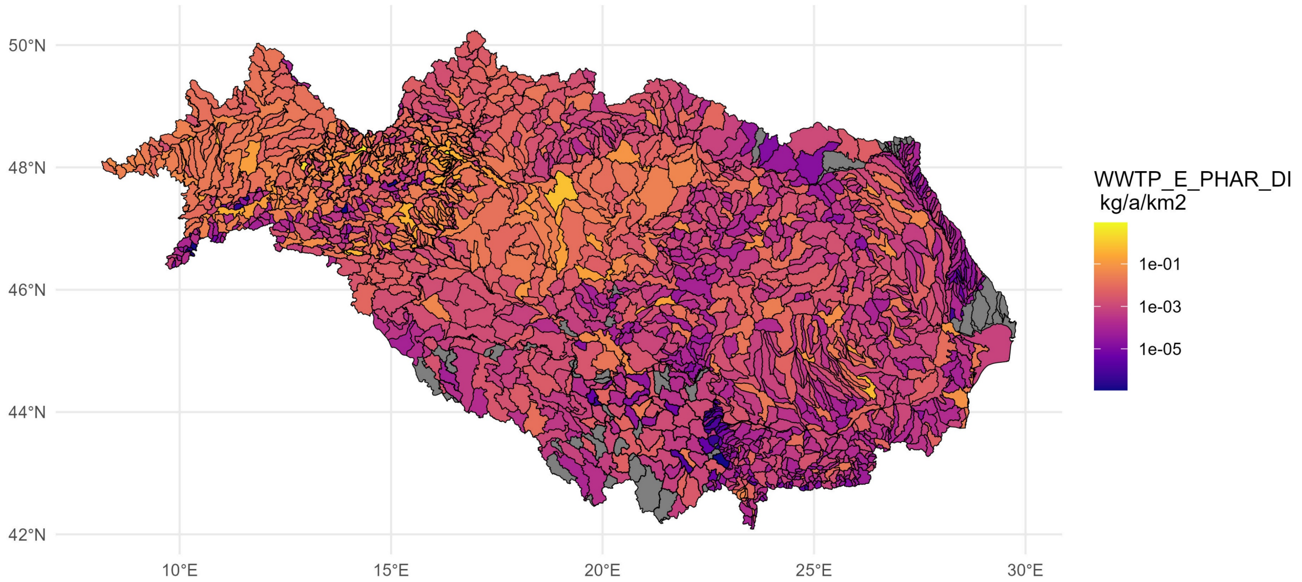
Share of pathways for PHAR DI



Absolute pathway loads for PHAR DI



Specific emission of PHAR DI



Main observations

- Beside WWTPs, urban systems may play an important part in total loads
- Due to lower share of sewege treatment, share of urban systems related diffuse load might be important in the lower Danube
- Industrial discharges show strong hot-spot loads in a few catchments

Conclusions

Model input data: some regions lack suficcient input data on groundwater concentrations and industrial emissions. Landfills and fire-fighting centre dataset is needed for PFAS substances.

Validation data: data frequency needs to be increased for emerging substances to improve validation load estimation.

Model validation: Validation performance vary between substances. Strong regional pattern is shown in validation performance for metalloids.

Emission patterns:

- ***PFAS*** loads are strongly dominated by the upper Danube (linked to GDP in soil and WWTP concentrations);
- ***Pharma*** emissions levels from WWTP are strongly country specific; urban diffuse loads might be important.
- For ***metalloids***, groundwater and agricultural erosion are dominating the overall loads, but regional differences are significant.

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Thank you for your attention!

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