

A generic land to sea modelling chain for fighting coastal eutrophication in France

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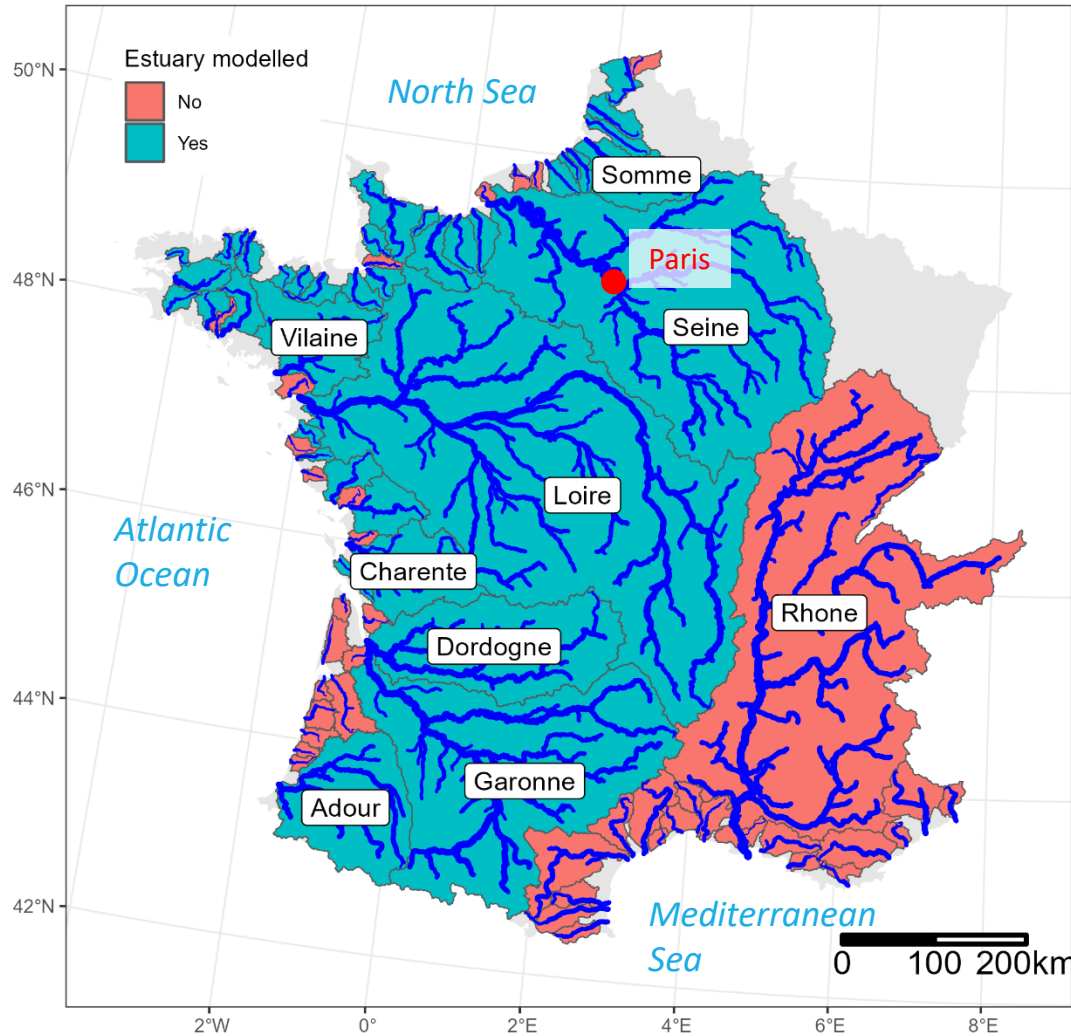


Problematic:

To reach good ecological status in coastal areas, there is a need to consider the land-to-sea continuum

Here we propose to tackle this problematic deploying a biogeochemical modelling chain (C, N, P & Si) from land to sea for the main French rivers & estuaries.

Study area: Modelling domain



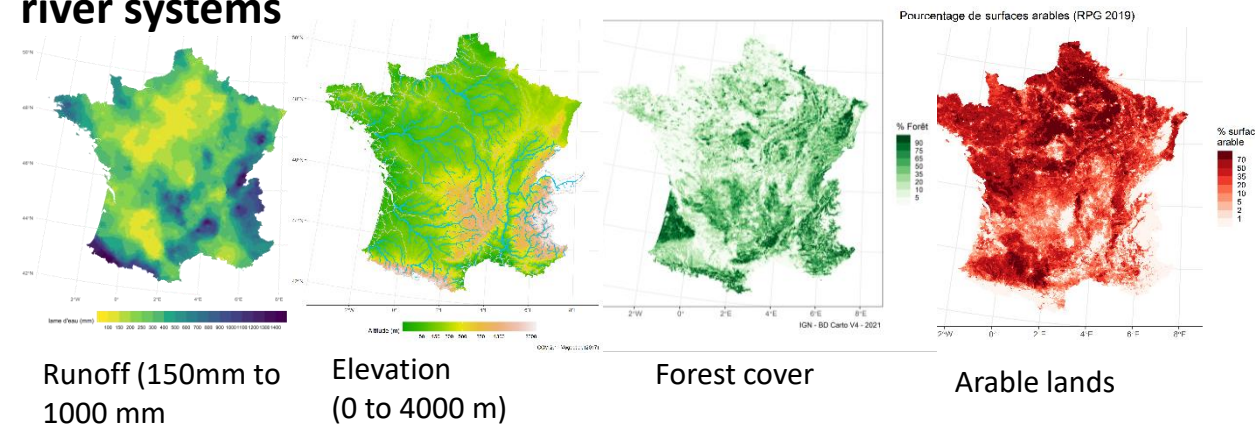
80 river networks (pyNuts-Riverstrahler)

- Size: 300 km² to 117 000 km²
- Total drained area: 486 000 km²
- River network length (CCM 2.1, Vogt et. al 2007) : 174 181 km

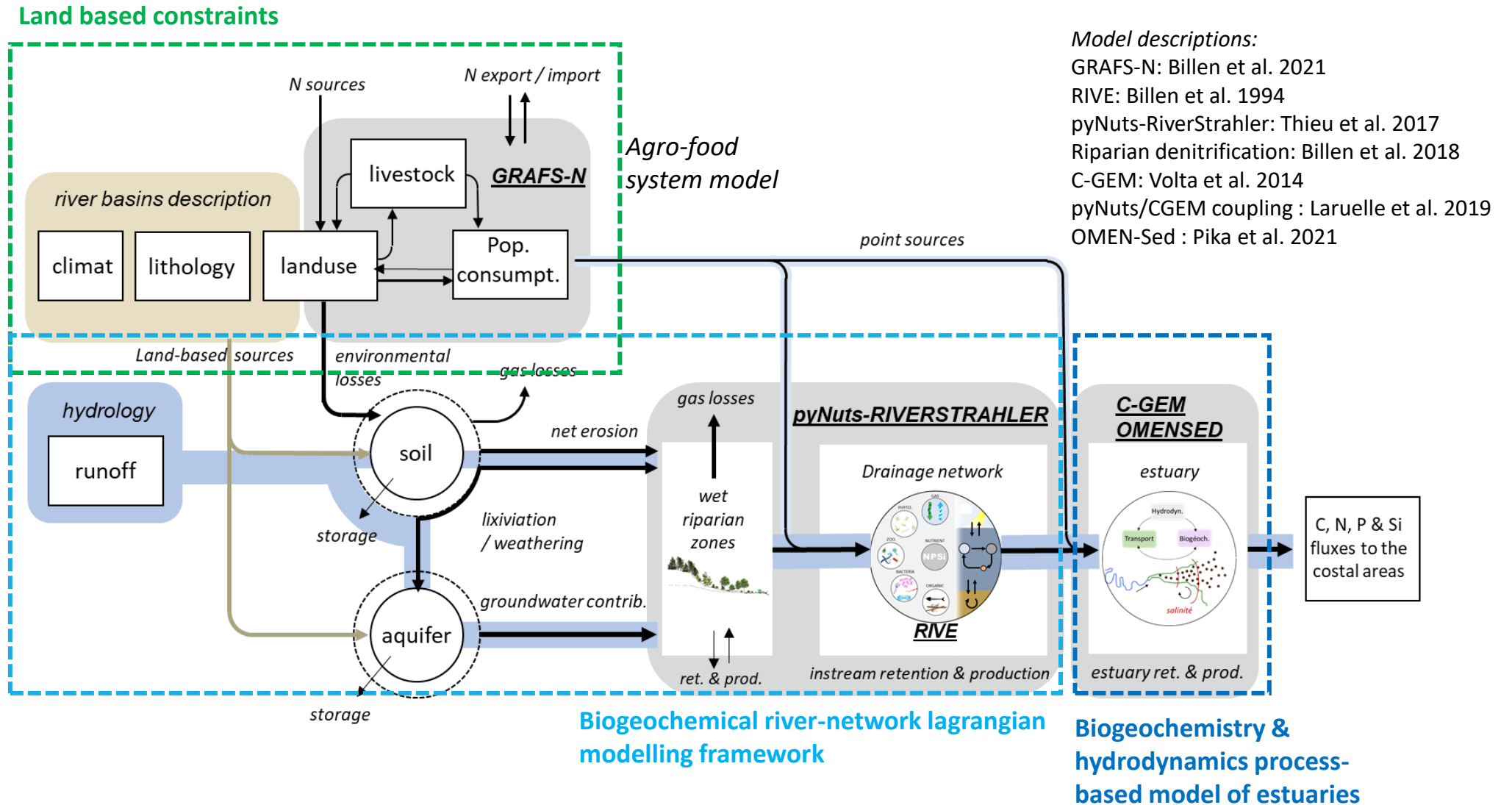
40 estuaries (CGEM-OMENSED)

- Length: 1.7 km to 202 km (mean = 30km)
- Reasons no modelled:
 - Not an estuary (lagoon, delta)
 - Too small

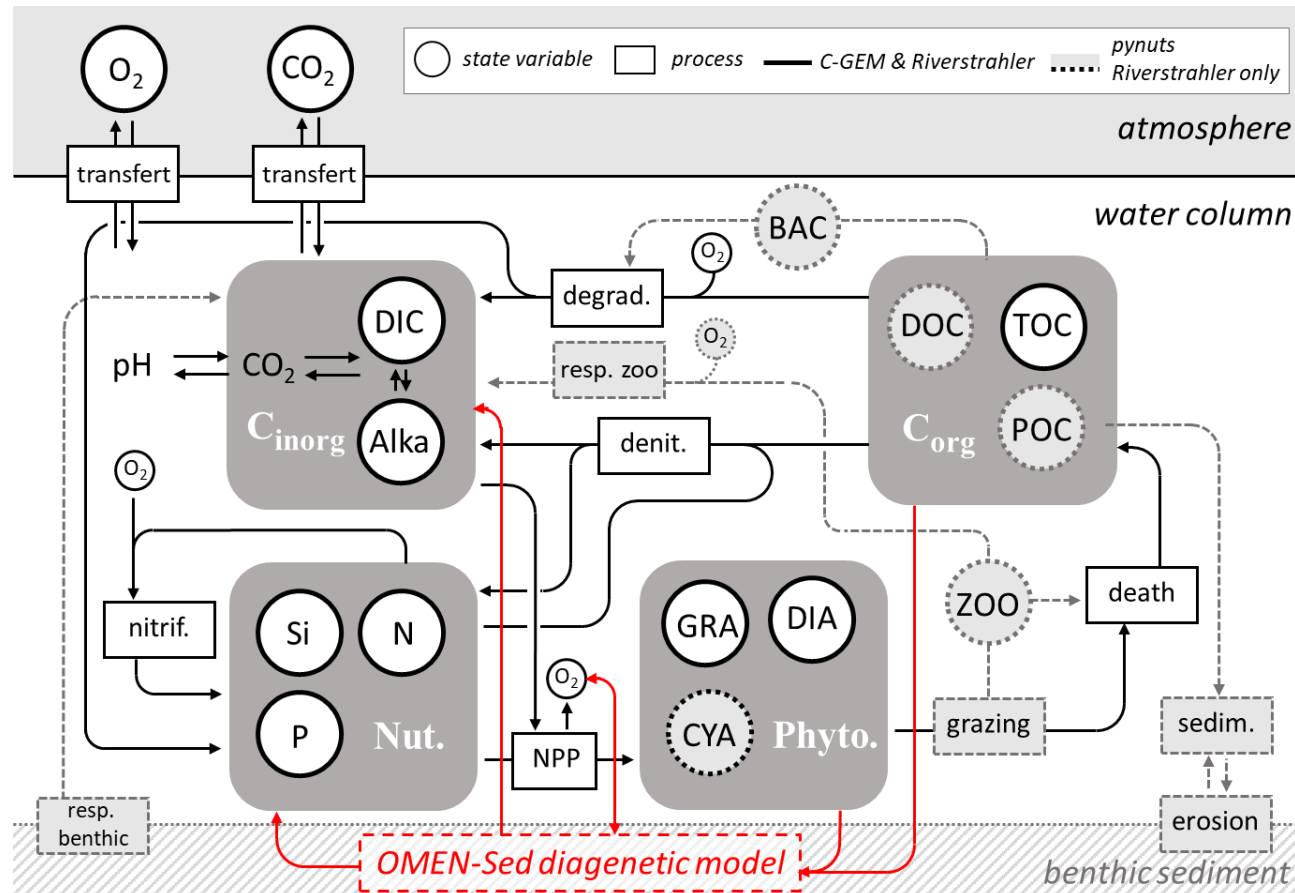
Diverse climates, lithology, land use/land cover among the river systems



Process based modelling chain deployed at the national scale



Strong coupling between the river-network and the estuary model



- **Two process based models sharing most of their states variables and processes**
- **Both models simulate nutrients as NO3, NH4, PO4, DSi (BSi, NO2, N2O pyNuts-RS only).**

Simplified conceptual scheme of the share of state variables and processes between C-GEM, *OMEN-Sed* and *pyNuts-RiverStrahler* model. (Laruelle et al. 2019, *novelty*)

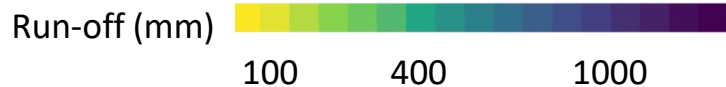
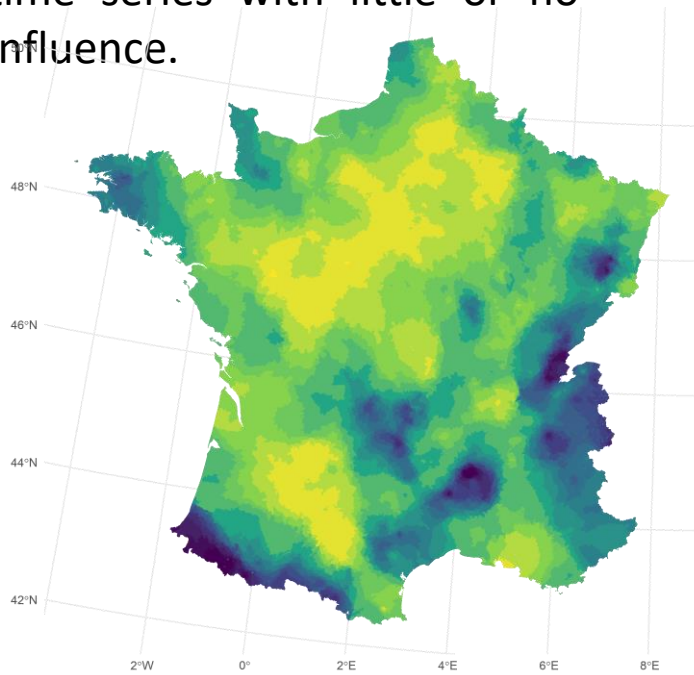
Objective: Modelling current (2014-2019) nutrient loads exported to the coastal zones

- Respective contribution of **point sources and diffuse sources**
- **Validate the results** of the modelling chain **spatially** and **temporally**
- Evaluate **nutrient removal in&near stream** and in **estuaries**

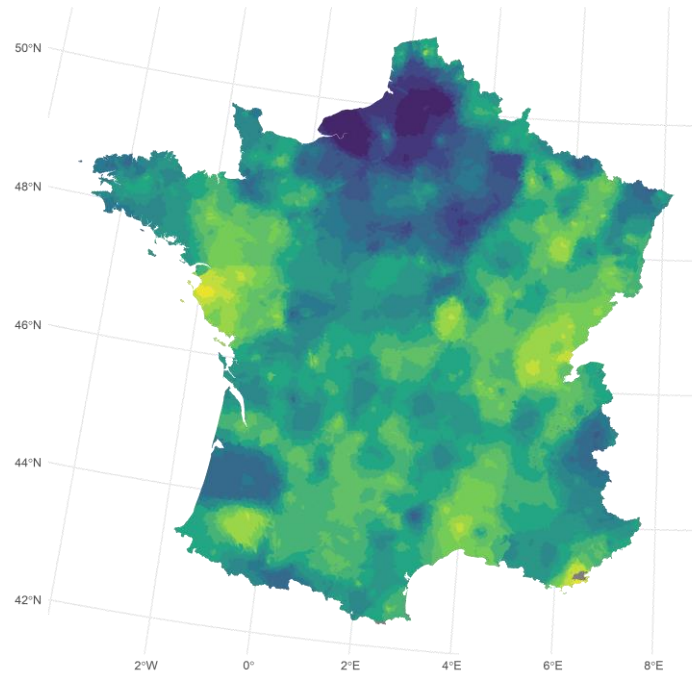
pyNuts-RS: hydrological forcing

Two components of discharge

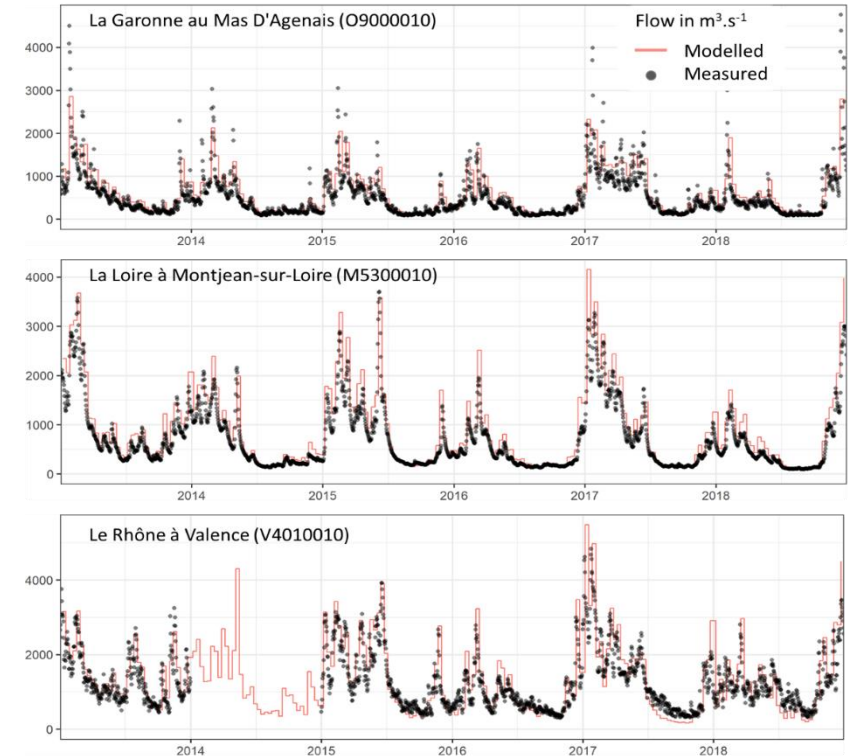
Interpolation of discharge (Delavenne et al. 2023) on 1664 completed discharge time series with little or no influence.



Flow separation with BFLOW algorithm (Arnold et al. 1995)



Validation



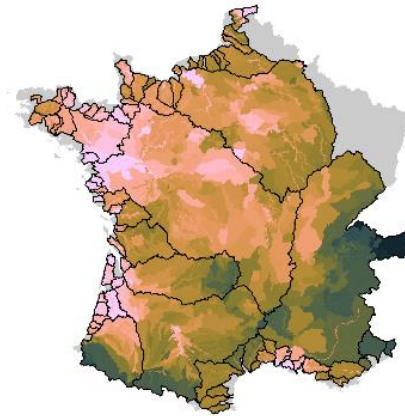
- Very good consistency with discharge measurements !
- Good consistency of flow separation results with subsoils properties & other similar maps

pyNuts-RS: diffuse sources of nutrients

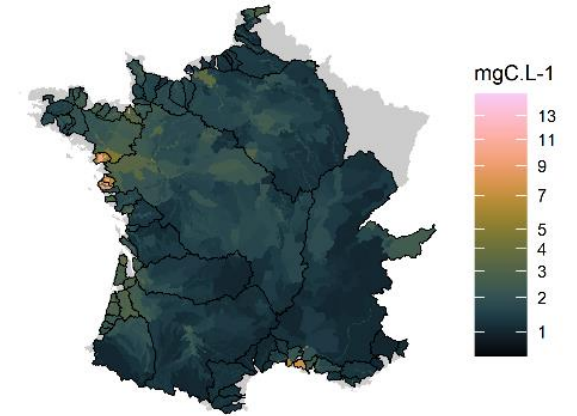
Different methods:

- Agro food model GRAFS-N (Billen et al. 2021) and land use
 - NO₃ – Nitrate
- Net erosion (Borrelli et al. 2018) and national or european database on soil content (Orgiazzi et al. 2018; Delmas et al., 2015)
 - POC – Particulate Organic Carbon
 - PON – Particulate Organic Nitrogen
 - TIP – Total Inorganic Phosphorus
- Regression on obs. in headwaters
 - DOC – Dissolved Organic Carbon (wetlands + other factors)
 - DSi – Dissolved Silica (lithology + other factors)
- Land used based (EEA, 2018)
 - NH₄ – Ammonium

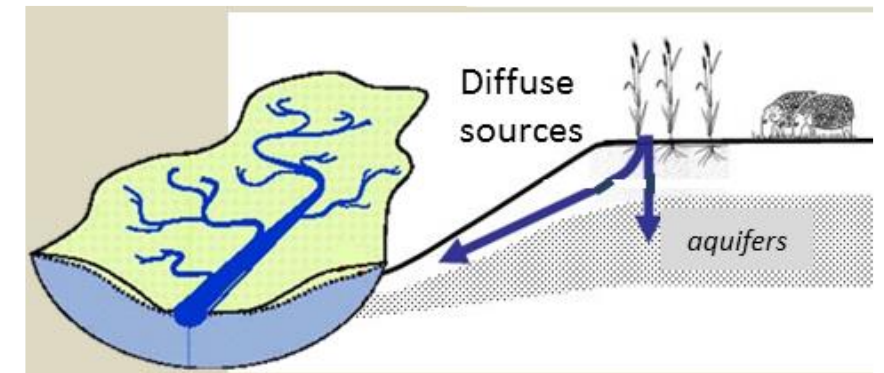
DOC - subroot/fastflow



DOC - groundwater



DOC diffuse inputs at the scale of modelling objects for subroot and groundwater flow

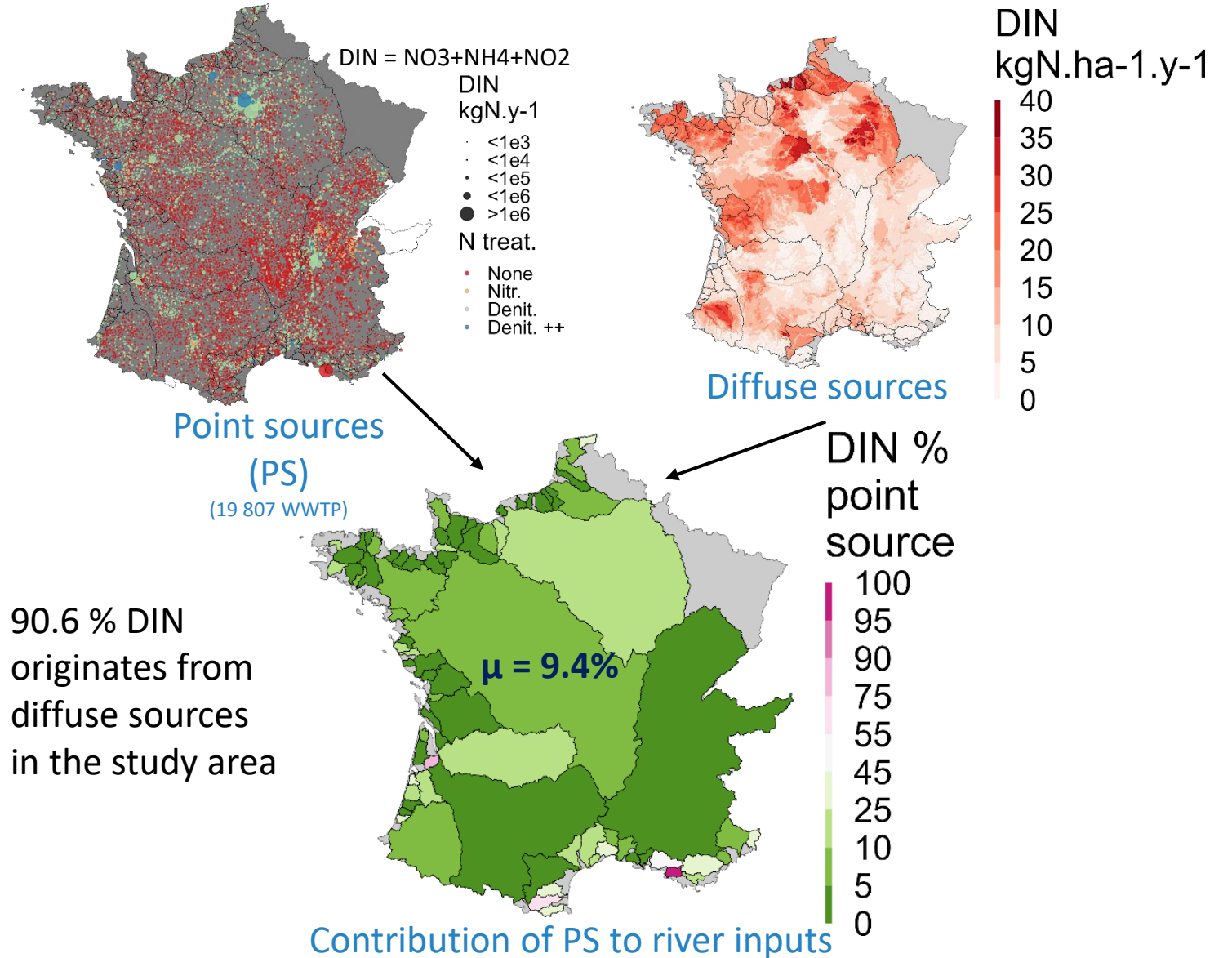


Particle-bound nutrients and DOC have differing concentrations in subroot and groundwater

Source apportionment for DIN : mean 2014-2019

Point sources:

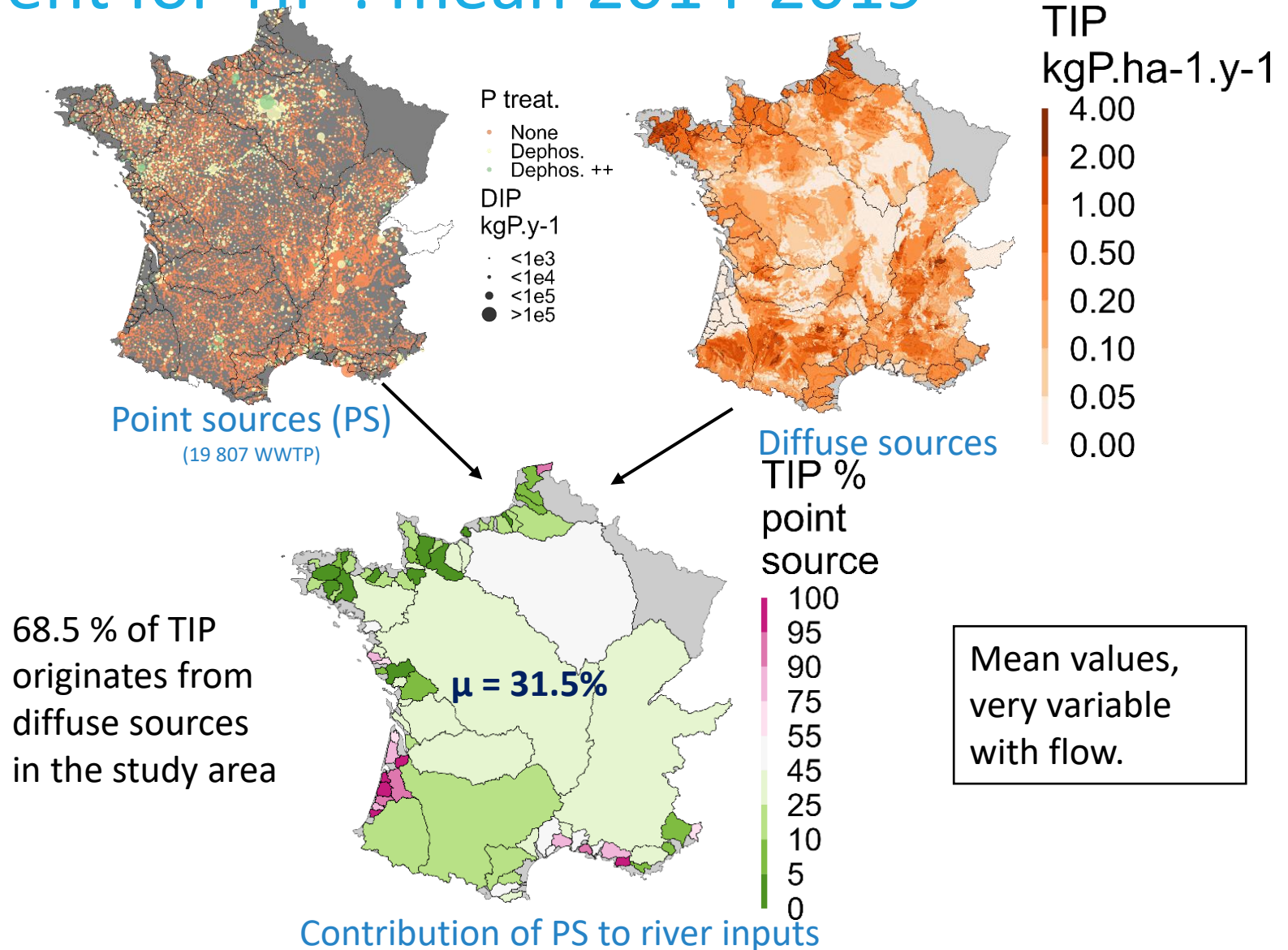
- Wastewater treatment plants: DBO, DCO, NH₄, NO₃ and TP/PO₄ data in kg/j from water agencies for most big WWTPs and numerous small ones.
- N° of eq. habitants and water treatment (incl. info on N & P specific treatments) **available for all stations** → stats to fill missing data



Source apportionment for TIP : mean 2014-2019

Point sources:

- **Wastewater treatment plants: DBO, DCO, NH₄, NO₃ and TP/PO₄ data in kg/j from water agencies for most big WWTPs and numerous small ones.**
- **N° of eq. habitants and water treatment (incl. info on N & P specific treatments) available for all stations → stats to fill missing data**



pyNuts-RIVERSTRAHLER modelling results

Period: 2014-2019

Time step: 10 days (decade)

Spatial resolution: kilometric along main rivers (n= 90, 15 468 km)

n of objects: > 5000

Spatial Validation of flow weighted concentration

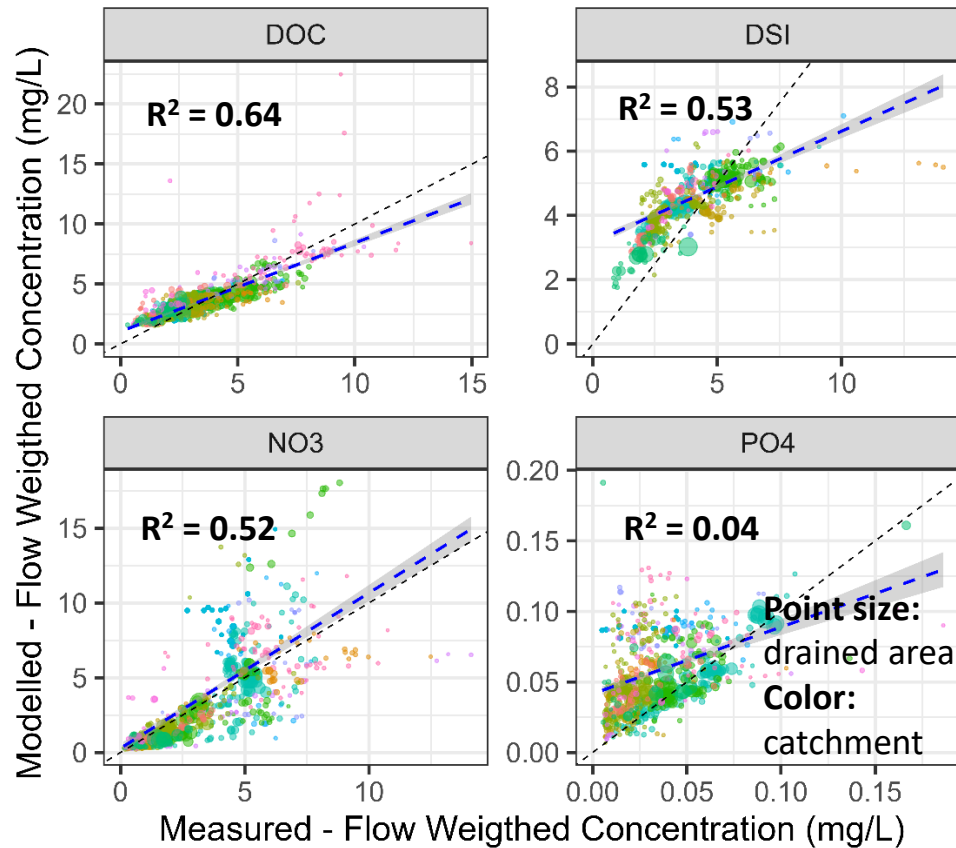
Focus on loads at the outlets (before estuaries)

NO3 Retention near & in stream

Spatial Validation on flow weighted concentrations

Validation dataset

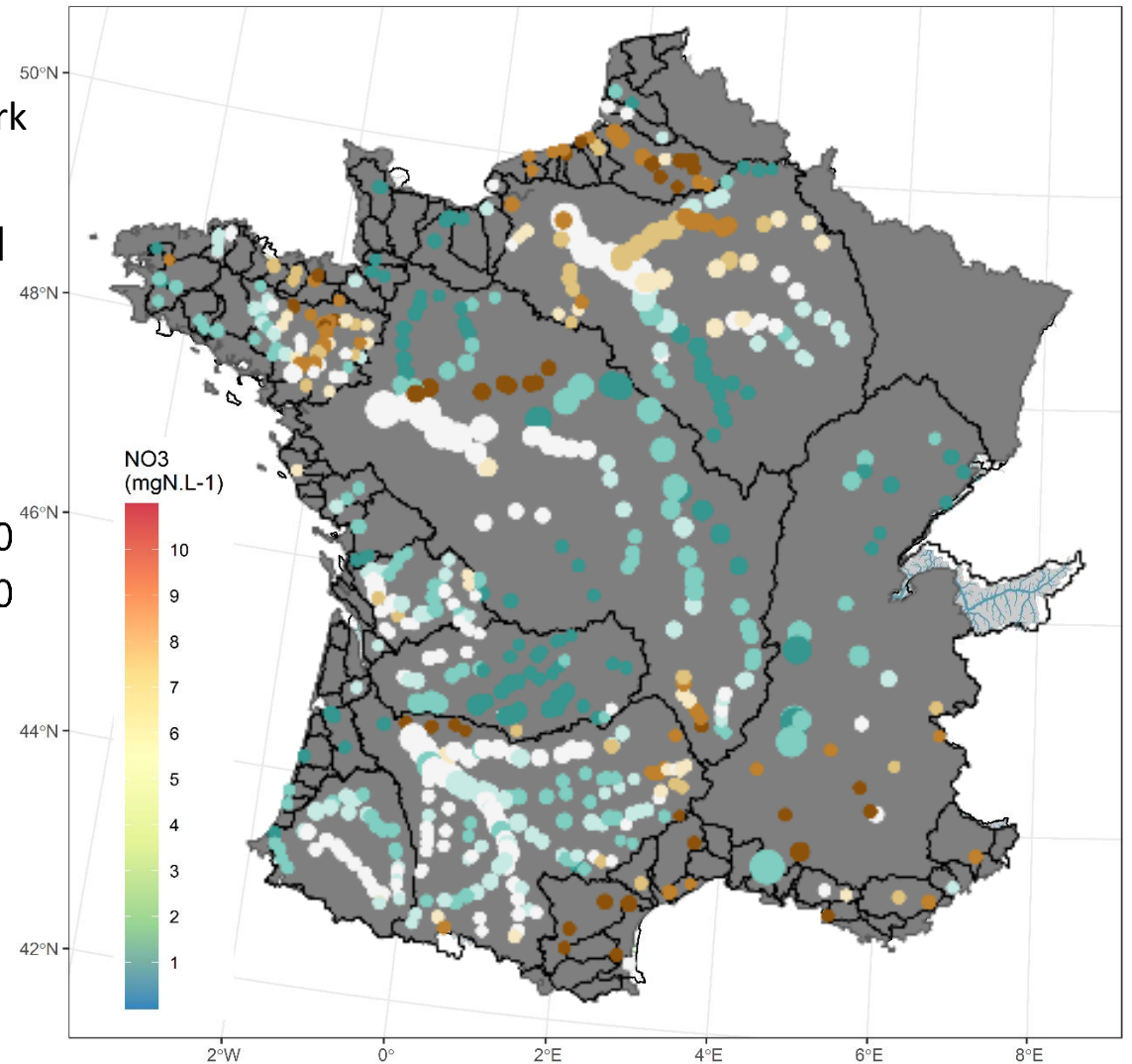
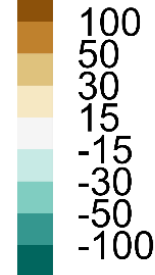
- 929 stations upstream estuaries influence
- Curated dataset of public data snapped on idealized river-network
- At least 40 meas. 2014-2019



Drained area (km²)

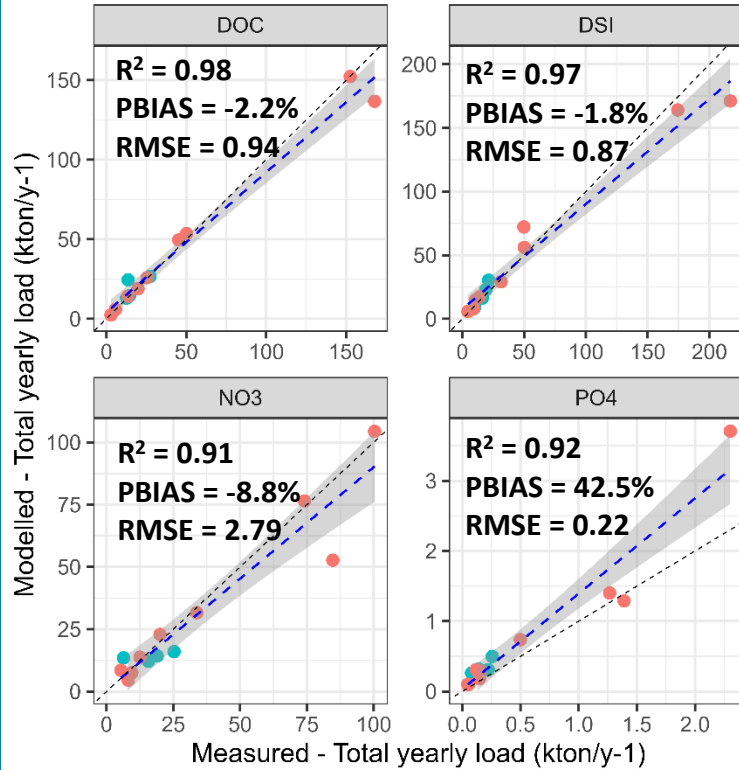
- 1 000
- 5 000
- 25 000
- 50 000

PBIAS (%)



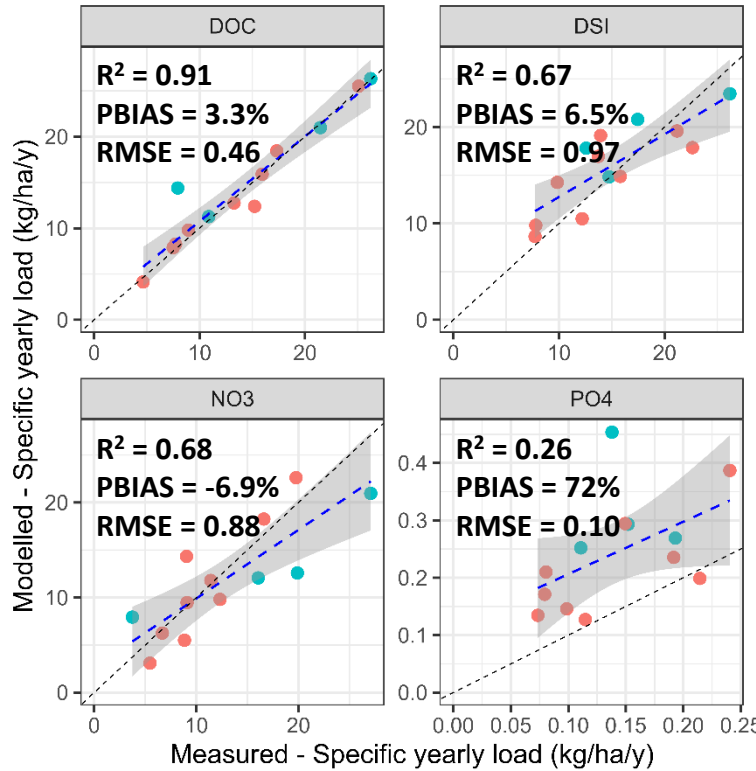
Total & specific loads at outlet

Total loads (kton.y⁻¹)



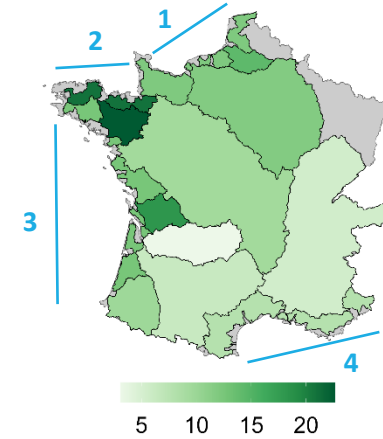
type ● big systems
● small systems (grouped)

Specific loads loads (kg.y⁻¹.ha⁻¹)

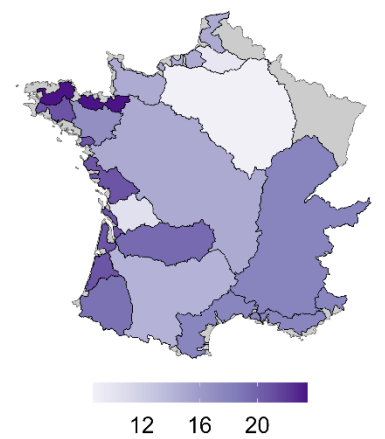


type ● big systems
● small systems (grouped)

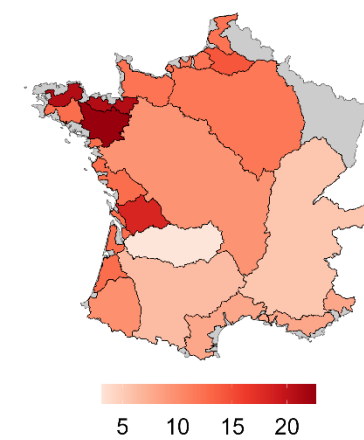
DOC (kgC.ha⁻¹.y⁻¹)



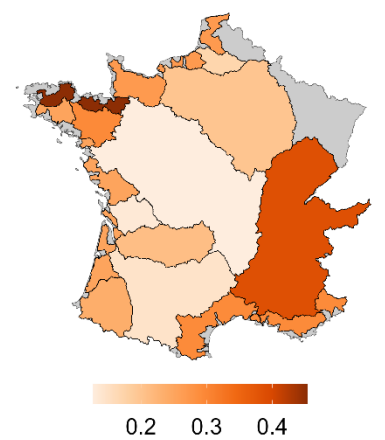
DSi (kgSi.ha⁻¹.y⁻¹)



NO3 (kgN.ha⁻¹.y⁻¹)

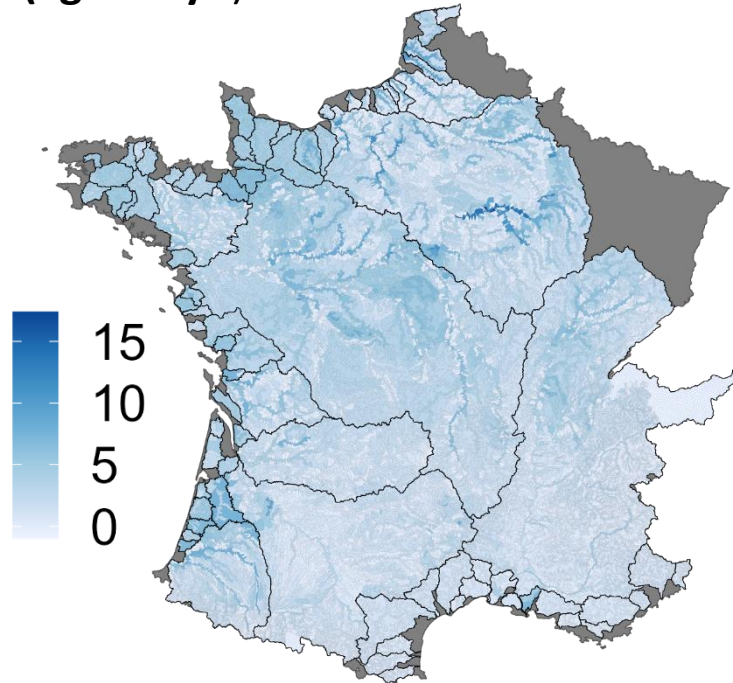


PO4 (kgP.ha⁻¹.y⁻¹)



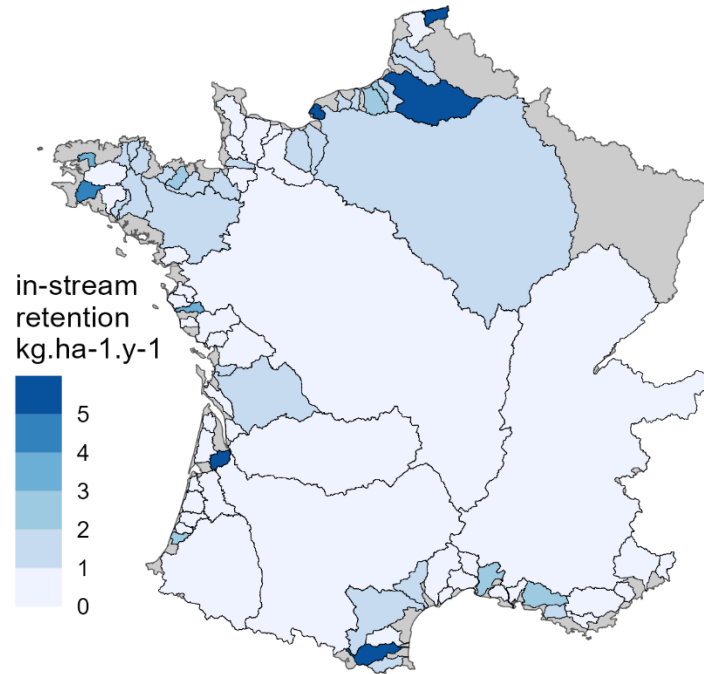
NO3 Retention near & in stream

Removal of NO3 by riparian wetlands (kg.ha⁻¹.y⁻¹)



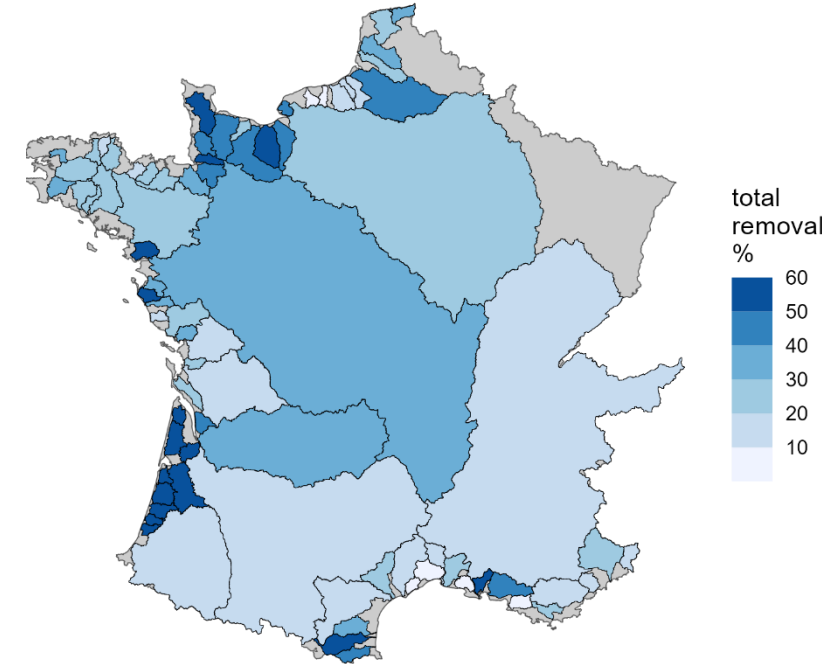
Only “active” riparian wetlands are considered i.e. not tile-drained and not on arable lands.
Possibility to increase this removal by targeting drained / cultivated wetlands.

Removal of NO3 by phyto, bacteria and sediment (kg.ha⁻¹.y⁻¹)



Lower typical values than removal by wetlands.

Total removal of NO3 in %



Varies from less than 10% to more than 60%.
Size of the river basin is less important than %wetlands.

Results of the CGEM-OMEN- SED modelling

CGEM: 1D transport & biogeochemical estuary model

coupled with

OMEN-SED: sediment model

Forcings: **pyNuts-RS simulation** (discharge & nutrients-phyto concentrations),
estuaries geometry (simplified depth & geometry), **tidal influences** (water height)

Period: 2014-2016 for big estuaries, 2014 for others

Time step: 90s to 180s depending on estuary size

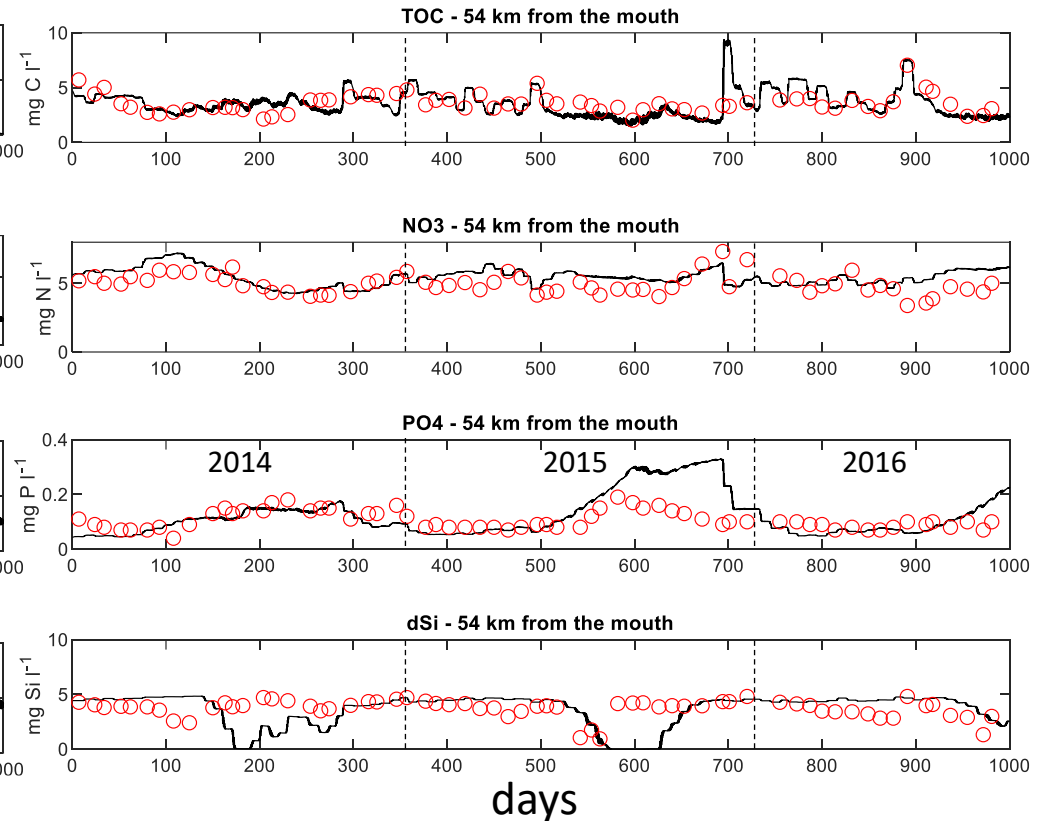
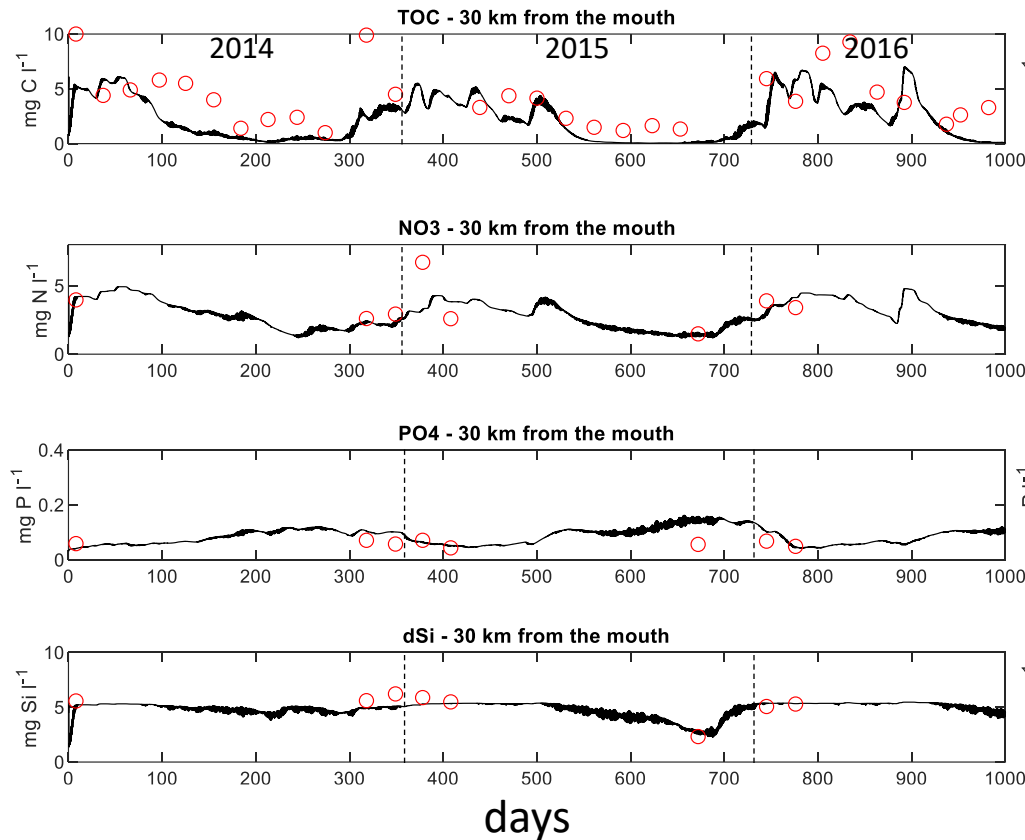
Spatial resolution: 0.25km to 2km depending on estuary size

n = 40

Validation on the Loire and Seine estuaries

Comparison between model outputs and **observations** for the **Loire** over the **2014-2016** period 30 km upstream of the estuarine mouth (92 km downstream the river outlet)

Comparison between model outputs and **observations** for the **Seine** over the **2014-2016** period 54 km upstream of the estuarine mouth (112 km downstream the river outlet)



TOC

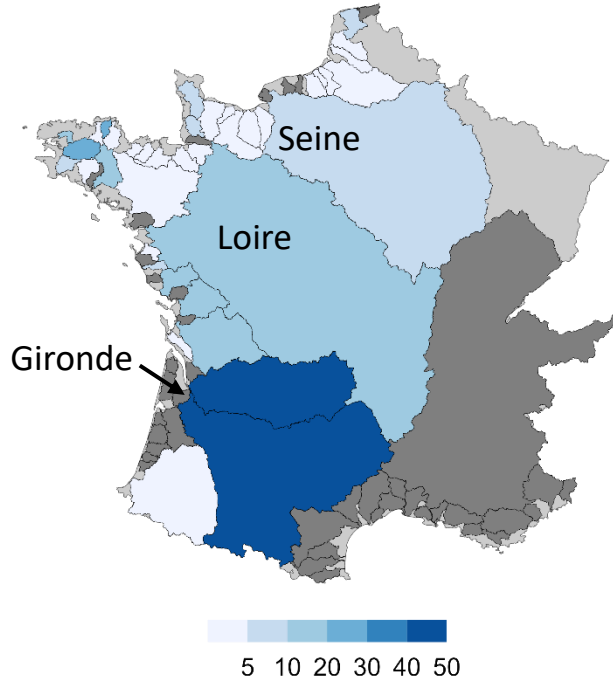
NO3

PO4

DSi

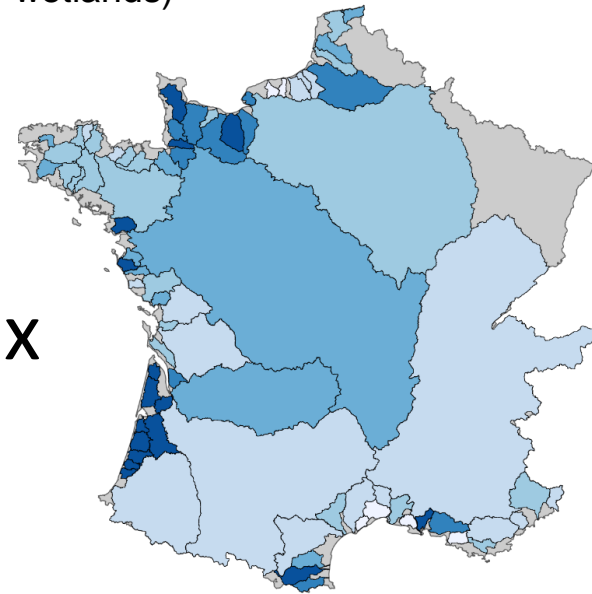
N removal on the land to sea continuum

TN removal % in estuaries (2014)



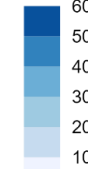
Except for the Gironde estuary
TN removal is low across
 estuaries (median = 4.1%)

NO₃ in&near stream removal % (incl. wetlands)

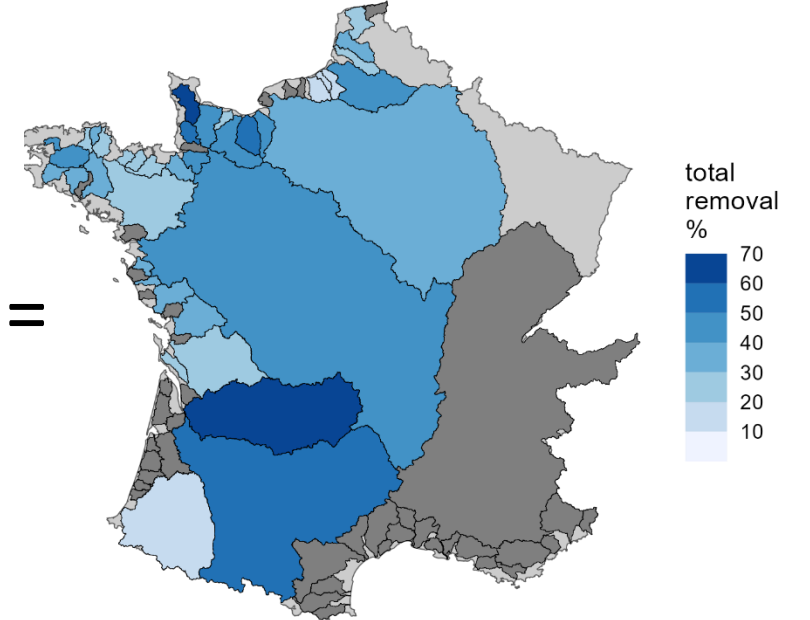


X

total removal %



=



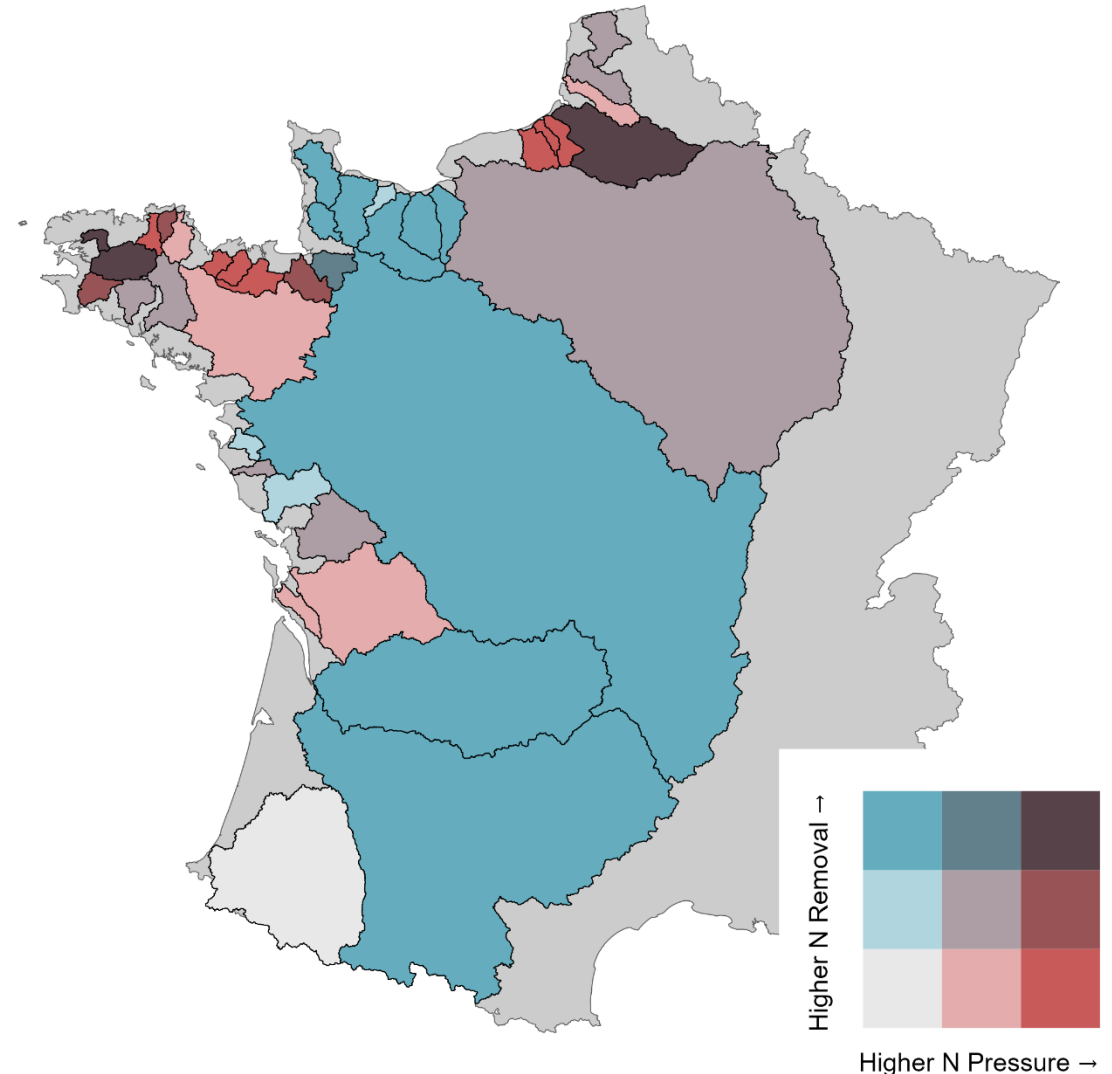
Total NO₃ removal from land to sea is obtained

TOC, TP, TSi also available

Typology of main French rivers regarding N exports & removal on the land to sea continuum

Bi variate map representing both:

- **N pressure** (diffuse + point source load) on the **red scale**
 - **N removal** (riparian + in&near stream + estuary) on **the blue scale**
- **Of least concern:** Low N pressure and **medium** or **high** removal
 - **Sensible:** Low N pressure & low N removal
 - **To monitor:** **median** N Pressure and N removal
 - **Resilient:** **median** and **high** N pressure and high N removal
 - **Of most concern:** High N pressure and **median** or **low** N removal



Conclusion:

- First deployment of a processed based land to sea modelling chain at this scale
- First fine scale spatio-temporal validation of GRAFS-pyNuts-RiverStrahler chain
- First results of coupling C-GEM & OMEN-SED
- A typology of catchments taking into account N pressure and N removal from land to sea

• Perspectives

- Compare resulting scenarios with recommended concentrations levels in coastal areas
- Propose localized wetland restauration
- Impact of nutrients processing from land to sea on nutrients imbalance

Questions ?

Thank you for your attention

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