Shifting nitrate seasonality along decades of anthropogenic impact in western European catchments

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Motivation & Concept

- Nitrate (NO_3^-) pollution from agricultural sources persists in aquatic ecosystems
- NO_3^- and discharge (Q) seasonality varies and affects eutrophication

Changes in NO_3^- source strength and distribution + **Seasonally variable hydrologic activation** → **Trajectories of NO_3^--Q seasonality**

Study area

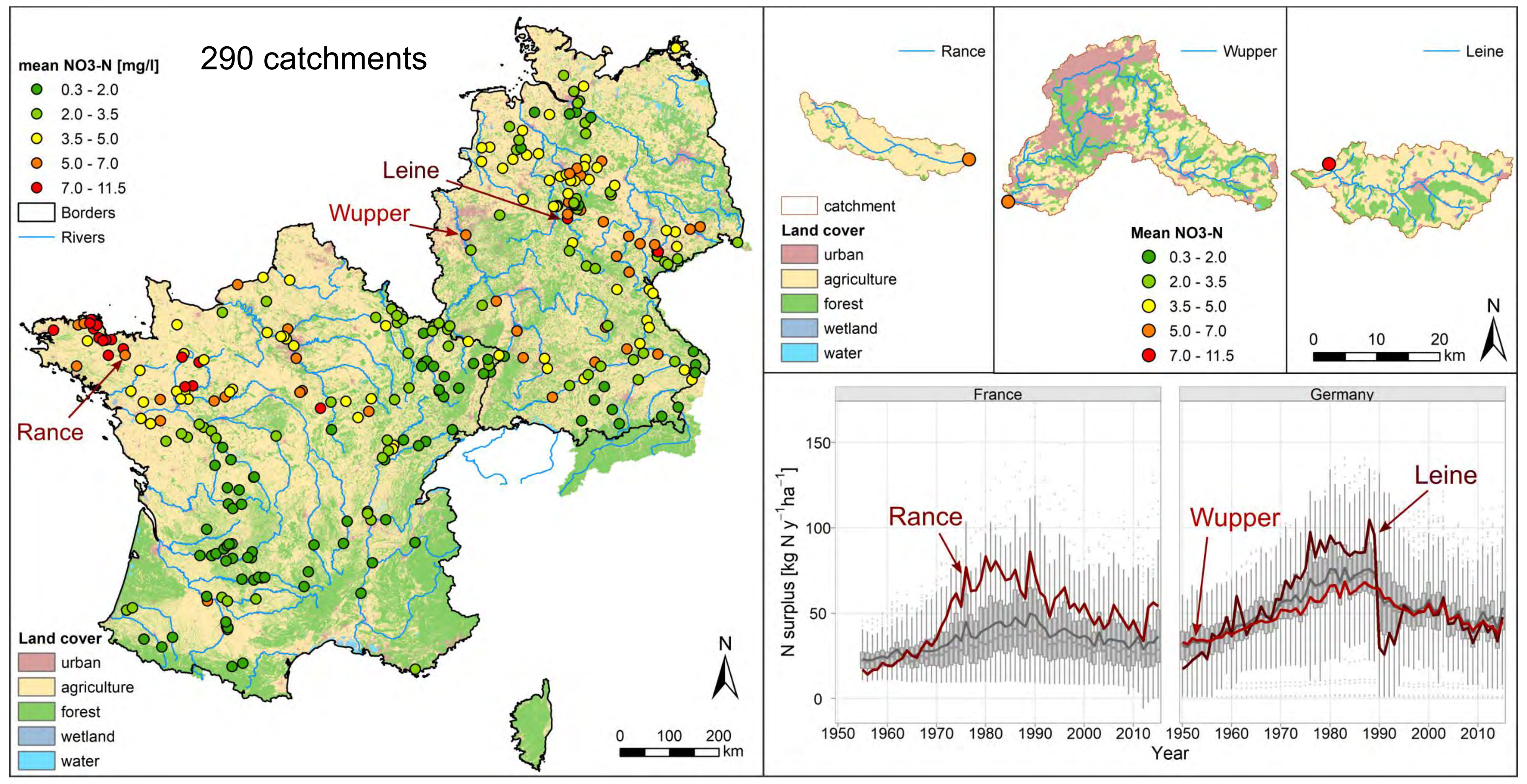

Fig. 1: Study area (n=290 catchments) with mean NO_3^--N and N input time series

Concept: Hysteresis

- Trajectories of NO_3^- concentrations (C) during low- (LF) & high-flow (HF) season

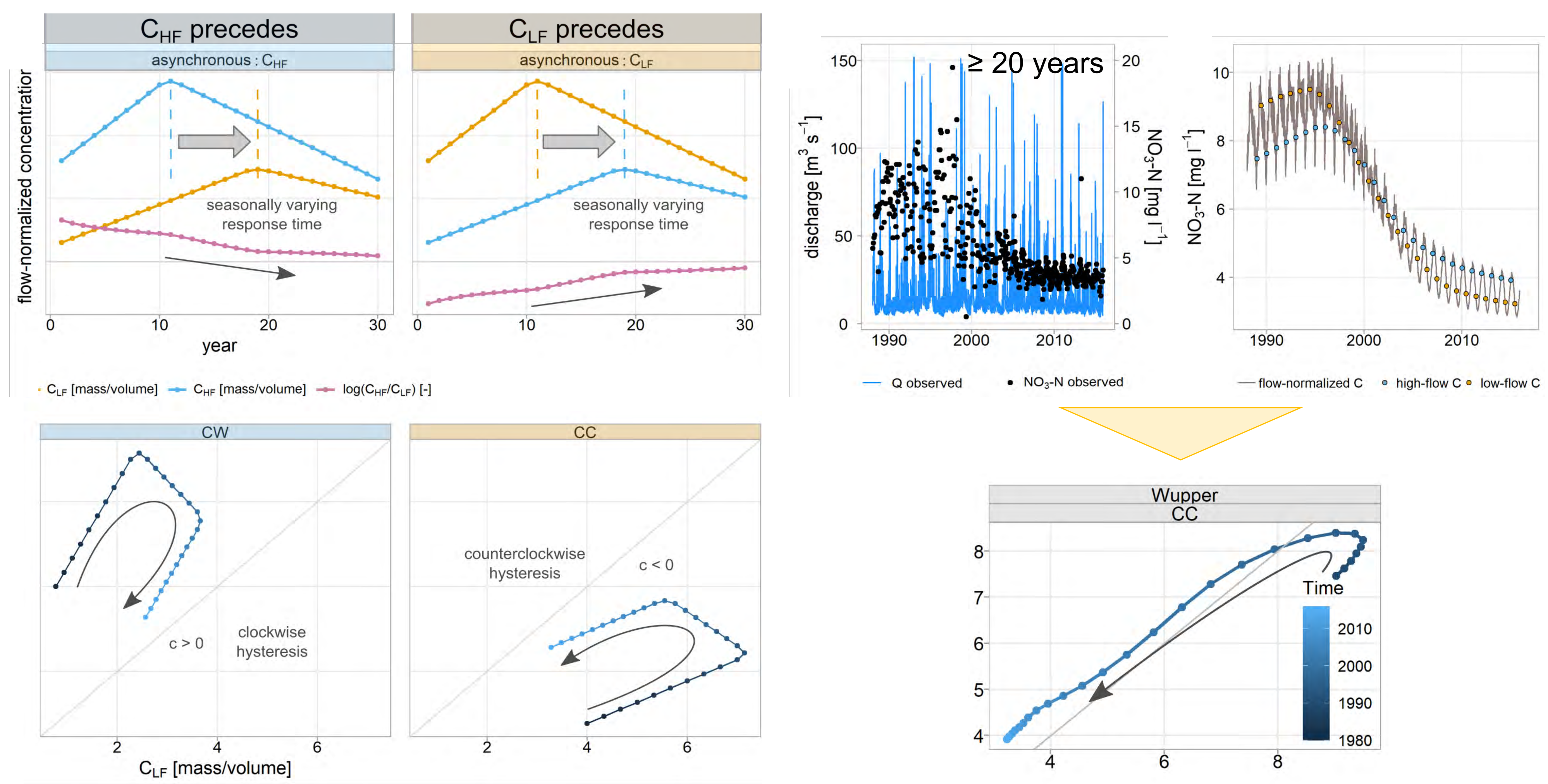

Fig. 2: Concept of hysteresis and NO_3^- and Q time series in Wupper as exam. of counterclockwise (CC) hysteresis (preceding C_{LF})

Hypotheses

1 **Synchronous NO3-N and Q seasonality** dominates as shallow diffuse sources get hydrologically mobilized

2 **NO_3^- during high-flow season responds faster (CW)** because of greater connectivity of shallow diffuse sources to rivers

Outcome

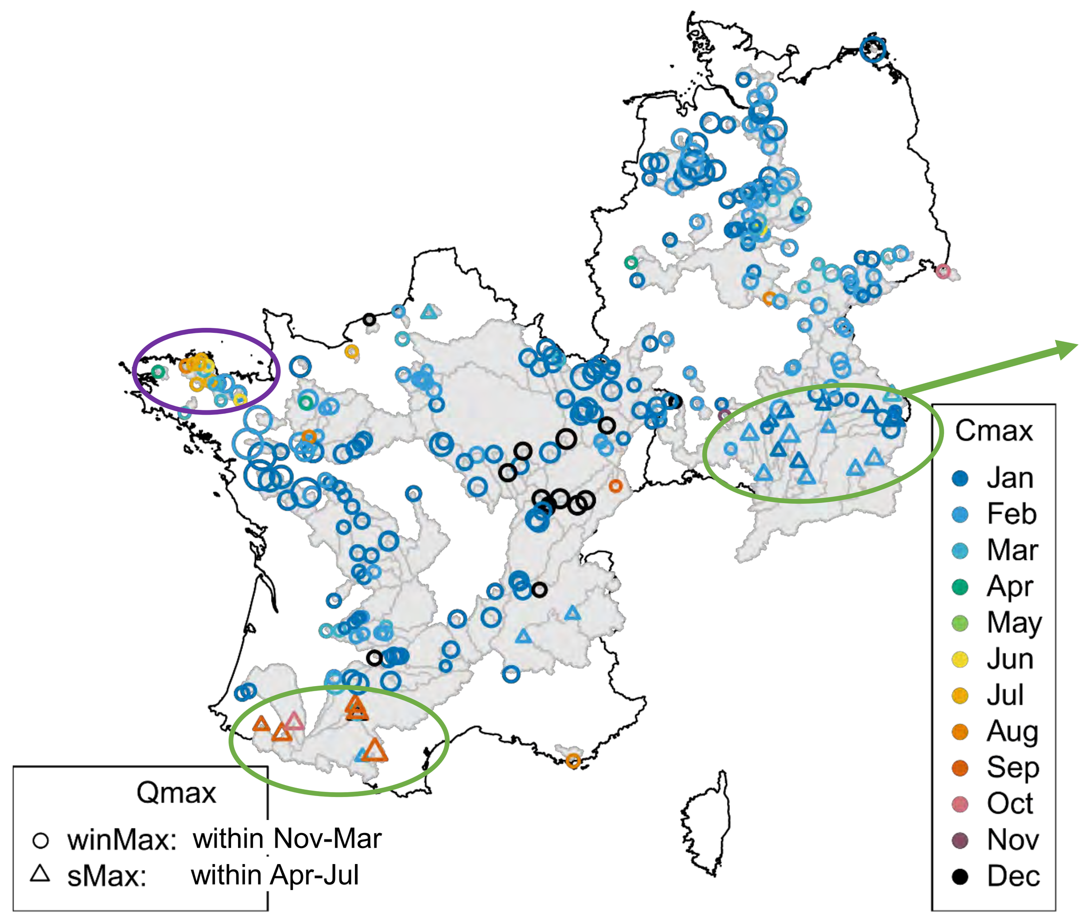

Fig. 3: Timing of Q and NO_3 maxima from long-term average

NO_3-Q archetypes

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- Synchronous NO_3-Q with winter max (i.e. enrichment) dominates (84%) ✓
- Asynchronous NO_3-Q with large seasonal variations (i.e. dilution) (10%)

→ Spatial separation between Q generating and N source zones

- Asynchronous NO_3-Q with high mean NO_3, summer peaks and small seasonal NO_3 variations (7% of catchments)

→ Bottom-loaded subsurface profiles

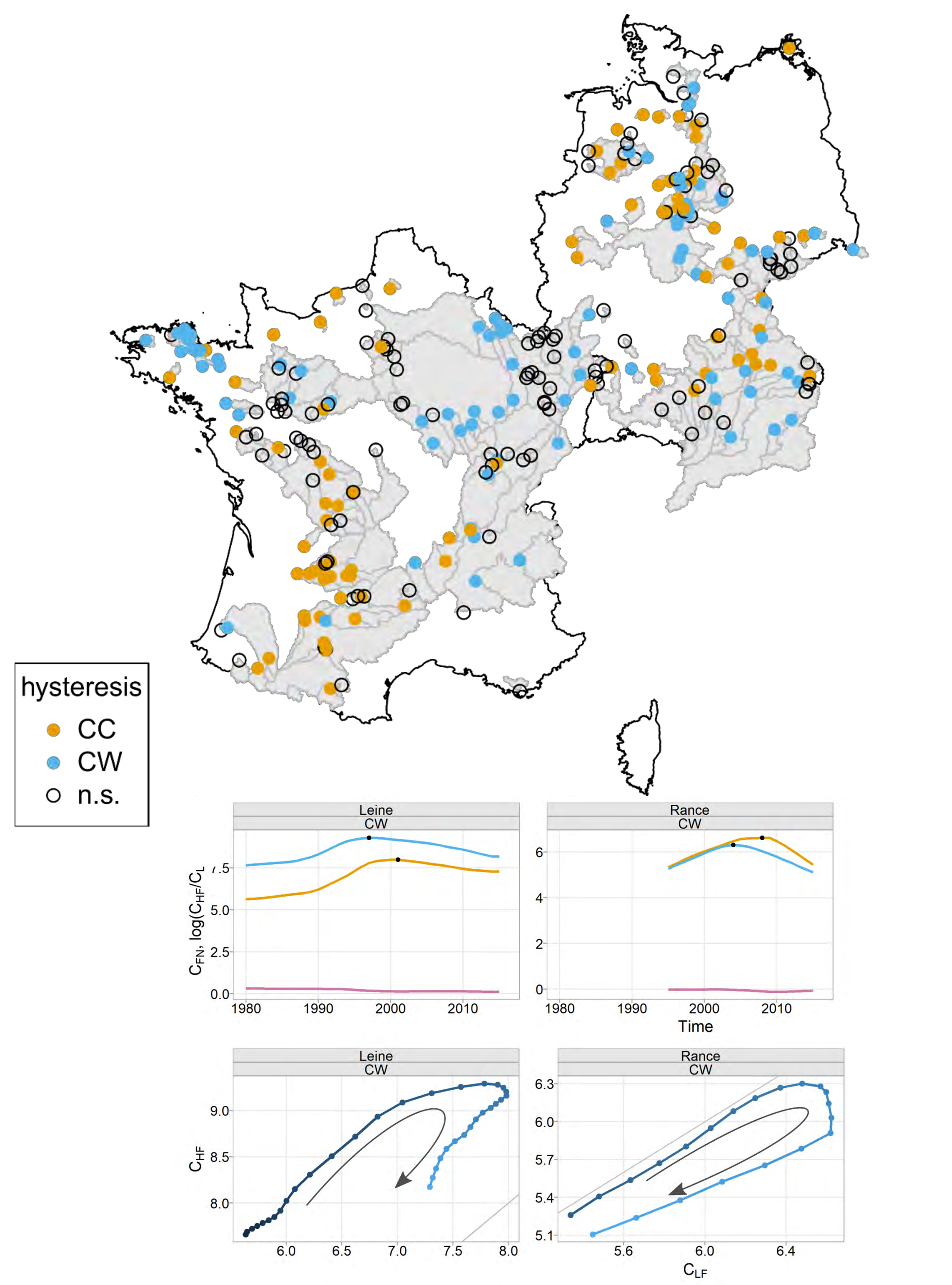

Fig. 4: Hysteresis between low- and high-flow NO_3 trajectories

Trajectories

- Significant shifts in NO_3-Q seasonality (60% hysteresis; 76% trends in seasonal ratio $\log(C_{HF}/C_{LF})$)
- Both hysteresis types in similar proportion

2 ✗

→ Delayed C_{LF} resulting from vertical movement of N (CW hysteresis) not dominant in study area

→ CW catchments had higher N export rates [2]

- Trajectories underlie complex controls
- Variability of seasonality across catchments larger than within catchments

Ongoing next step

N and phosphorus (P) seasonalities and their decadal trajectories

References:

[1] Ebeling, P., et al. (2021). "Long-Term Nitrate Trajectories Vary by Season in Western European Catchments." Global Biogeochemical Cycles **35(9): e2021GB007050.**

[2] Ehrhardt, S., et al. (2021). "Nitrate Transport and Retention in Western European Catchments Are Shaped by Hydroclimate and Subsurface Properties." Water Resources Research **57(10): e2020WR029469.**

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