Spatial vs. temporal variability in German river water quality

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Motivation

Problem

- Worldwide degradation of river water quality
- Lacking process understanding of landscape-scale spatiotemporal variability

Analysis

- Characterization of solute concentration probability over time
- Locate dominant solute source zones in space

Goal

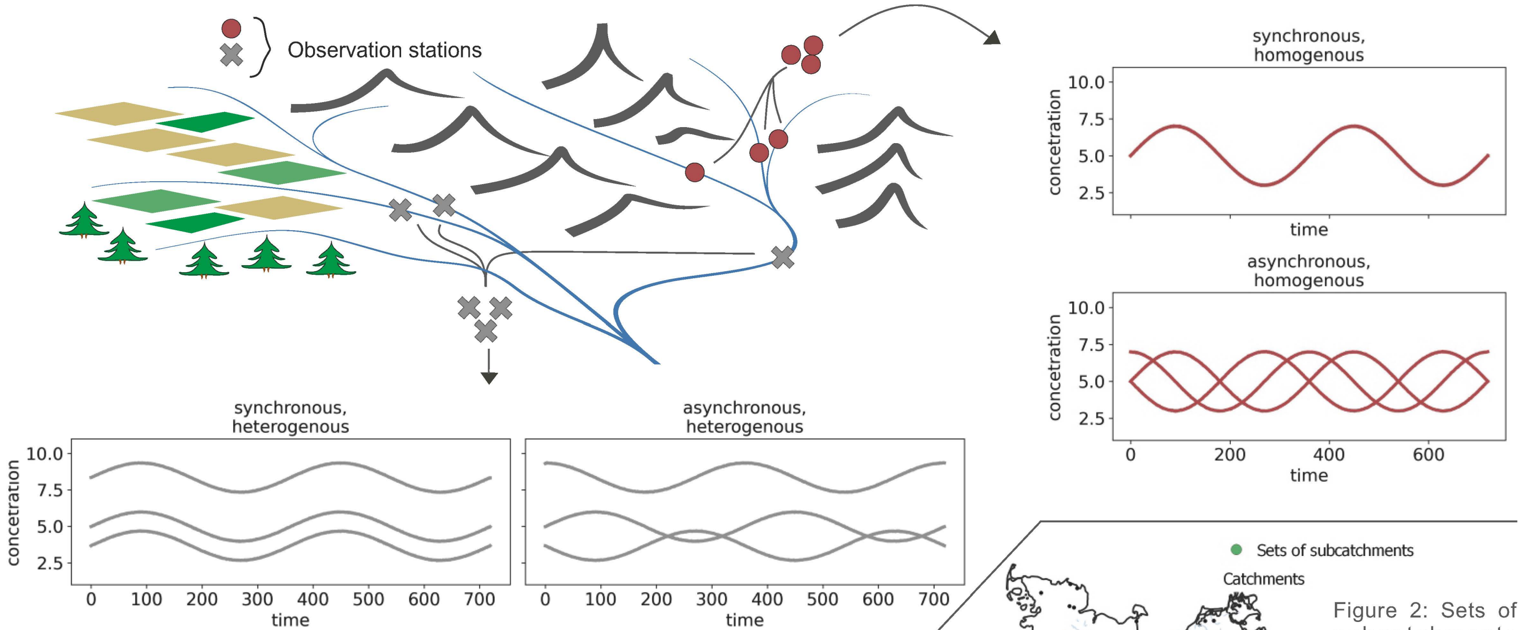
- Optimization of water quality monitoring programs
- Effective and targeted water quality management strategies

In order to characterize archetypal spatiotemporal patterns of solute concentrations in rivers and streams, we aim to answer the following questions:

- What is the relative importance of spatial vs. temporal variability of German catchments?
- How do synchrony and persistence of spatial patterns play into the relation of spatial vs. temporal variability?

Space-Time Variance Framework

- Assessment of specific discharge and three contrasting groups of solutes (geogenic, biogenic, anthropogenic) by comparing sets of neighboring catchments through combinatorics (figure 1)
- Large scale analysis of time series data across 1386 catchments in Germany (Ebeling et al. 2022, figure 2)



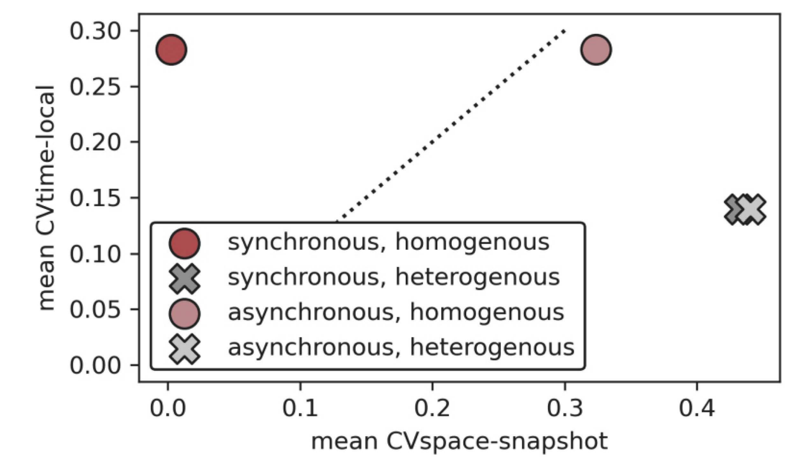


Figure 1: Spatial and temporal CV of four different scenarios are dependent on landscape heterogeneity and temporal dynamics of subcatchments.

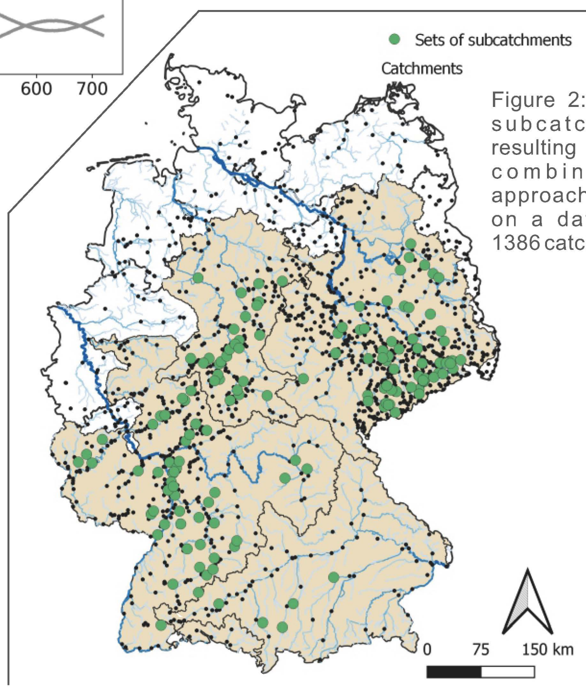


Figure 2: Sets of subcatchments resulting from the combinatorial approach (based on a dataset of 1386 catchments).

Results

- Apart from specific discharge, Calcium (Ca), Nitrate (NO_3) and dissolved organic carbon (DOC) exhibited overall higher spatial than temporal variability (figure 3 and table 1)
- Independent dynamics (near identity line) were observed for all three solutes and specific discharge
- Ca had the highest ratio of spatial to temporal variability followed by NO_3 and DOC

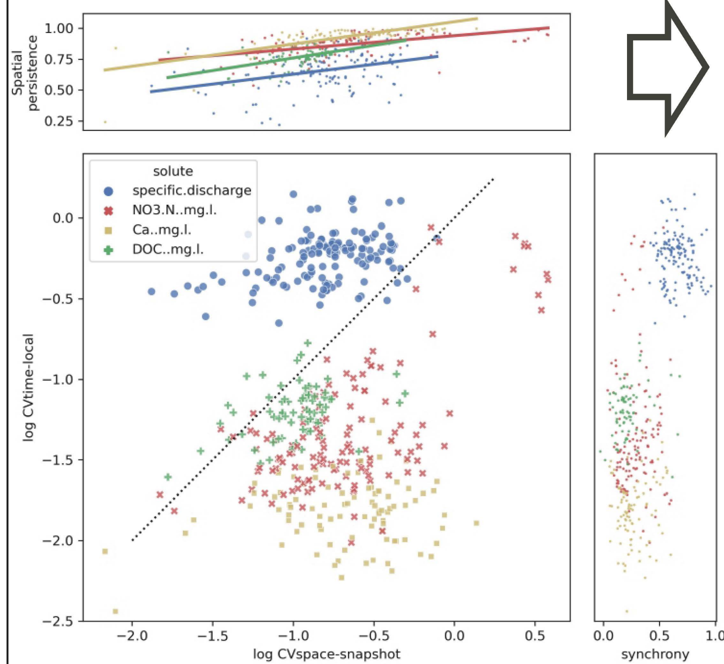


Figure 3: Spatial vs. temporal variability of all derived sets of subcatchments for specific discharge, Nitrate (anthropogenic), DOC (biogenic) and Calcium (geogenic). Additional scatter plots of spatial persistence (SP) and synchrony.

Table 1: Maximum, minimum spatial and temporal variability for specific discharge, Nitrate, Calcium and DOC.

	$Cv_{space\text{-}snapshot}$			$Cv_{time\text{-}local}$		
	Min	Max	Median	Min	Max	Median
Specific Q	0.15	0.90	0.45	0.52	1.16	0.8
NO3	0.16	1.79	0.49	0.13	0.94	0.24
DOC	0.17	0.74	0.39	0.2	0.46	0.3
Calcium	0.11	1.15	0.56	0.09	0.29	0.17

- Spatial vs. temporal variability varies across sets of subcatchments for all solutes
- Spatial persistence is correlated to spatial variability
- Synchrony of subcatchments shows a complex relation to temporal variability

Archetypal patterns can be derived for the three groups of solutes (figure 4):

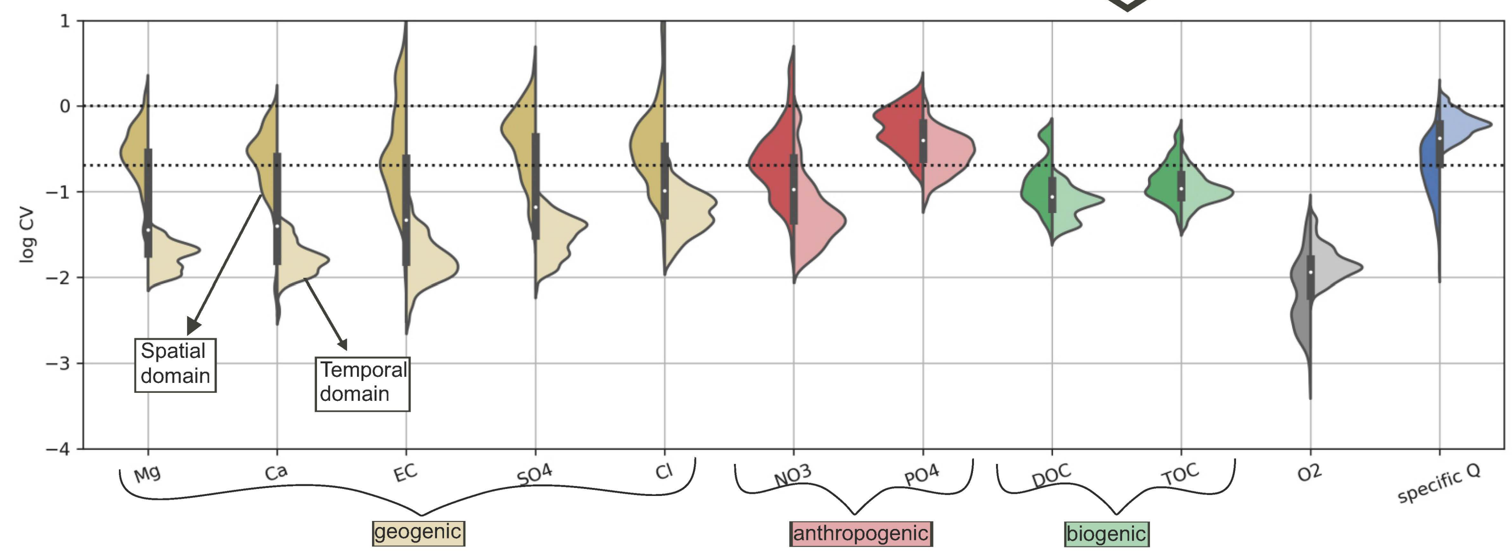


Figure 4: Distributions of spatial (left side) and temporal (right side) variability. Solutes are sorted by ratio of spatial to temporal variability from left (highest) to right (lowest).

Conclusion

- Spatial variability is high among all groups of solutes which has implications for water quality monitoring programs (more focus on spatially distributed than high frequency observations?)
- Spatial persistence and synchrony can aid disentangle temporal dynamics of neighboring catchments and advance process understanding of solute sources, mobilization and export across scales