Imaging flow dynamics and resulting reactivity in the transition zone between streams and riparian aquifers

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ITN Enigma

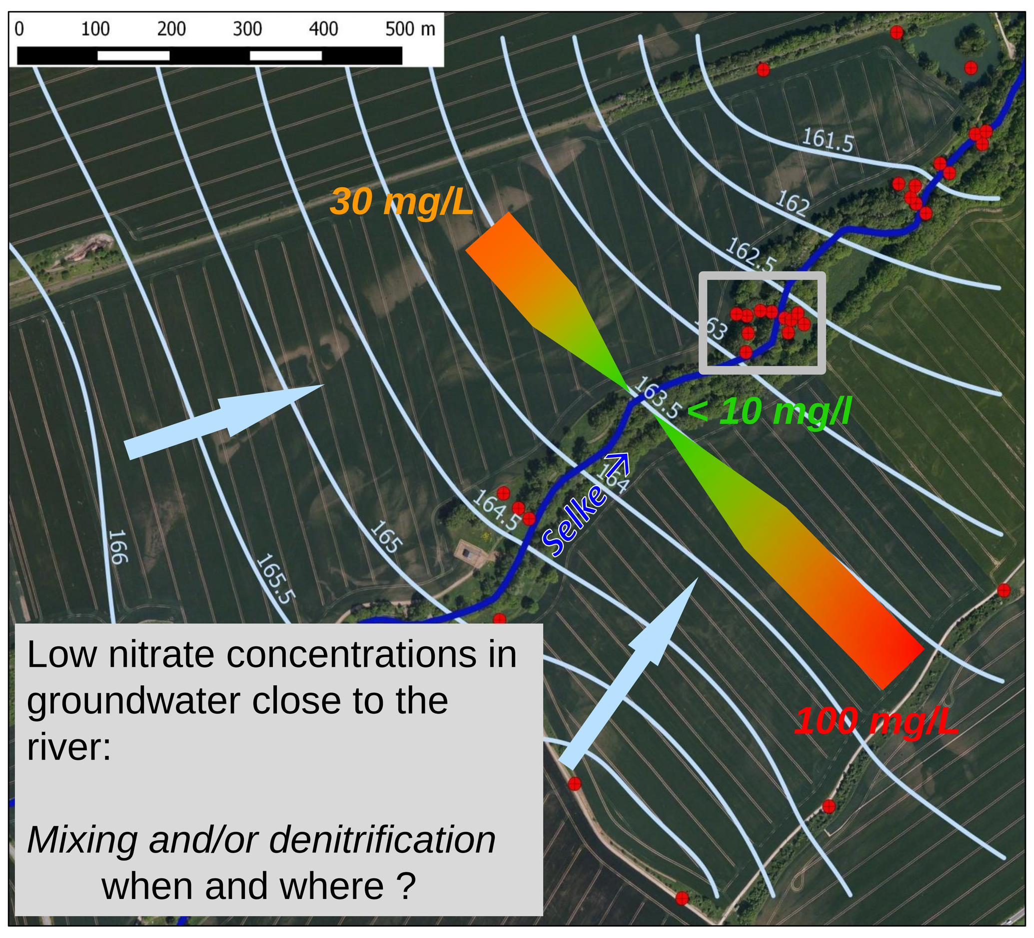
Introduction

Numerous studies have demonstrated that temperature plays a major role on solutes turnover rates in riparian aquifers. However, hydraulic controls on resulting reactivity are not well comprehended, leading to an overall simplification of the turnover capacity on transition zones.

We aim to close this gap through a detailed understanding of river-groundwater exchange dynamics by delineating controls of turnover capacity of redox-sensitive compounds (oxygen, carbon, nitrogen) by using integrative data driven and modelling approaches.

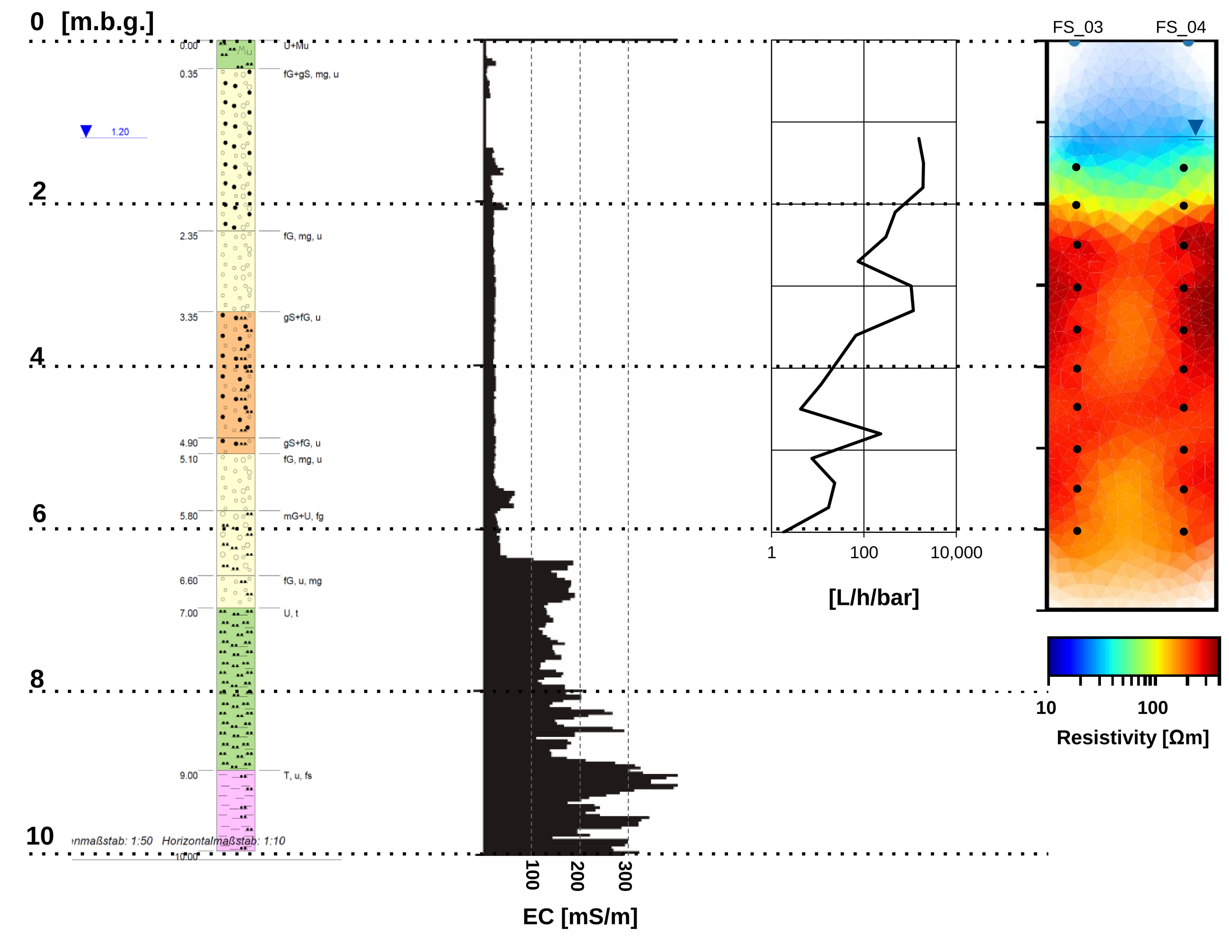
Study area

The Selke site – part of TERENO observatories

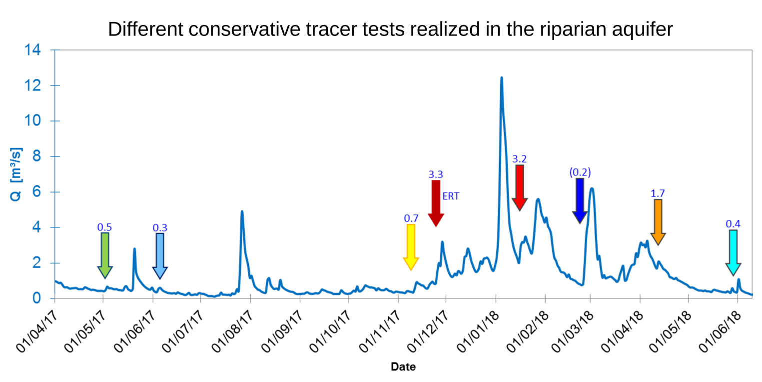


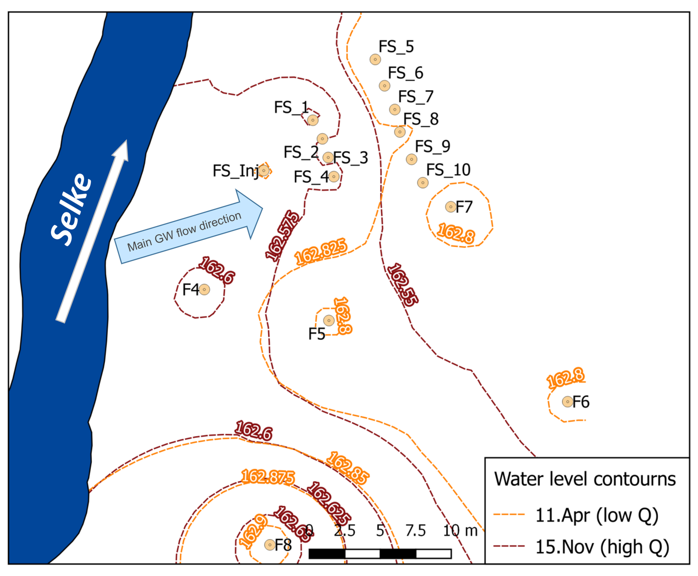
Aquifer characterization

|Sediment cores | EC-logs | Inj.-logs | ERT |

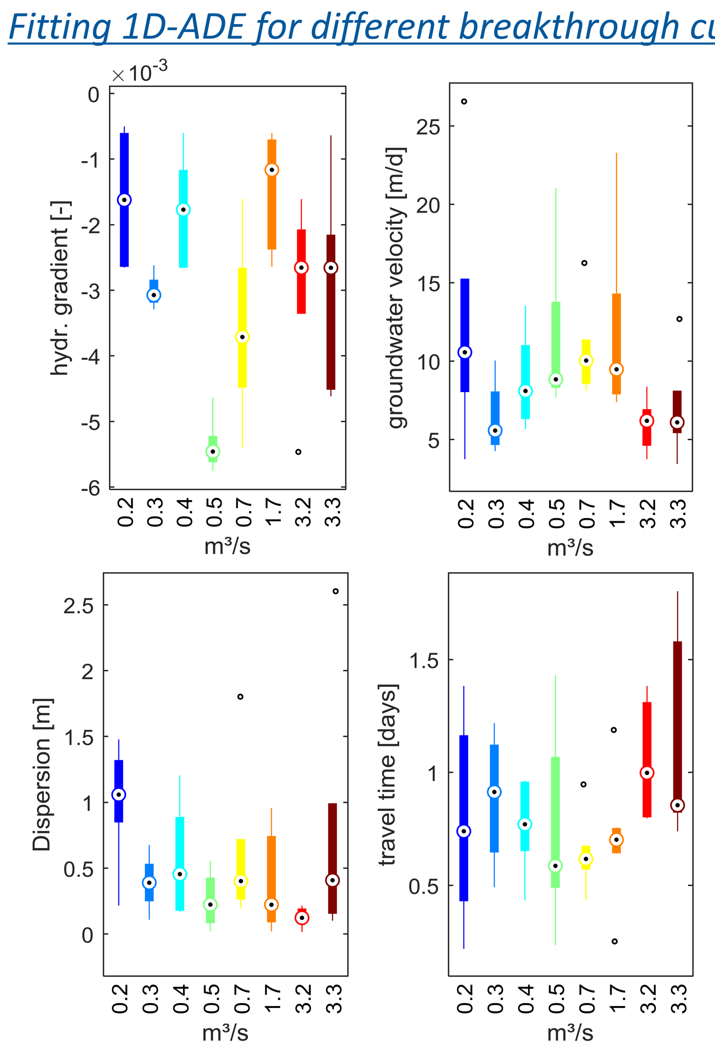


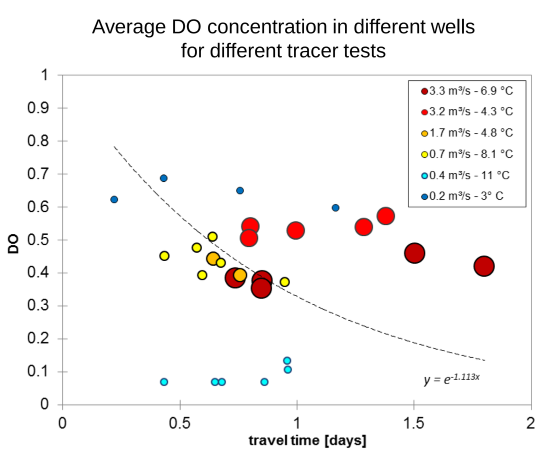
Natural gradient salt tracer tests under different Q's

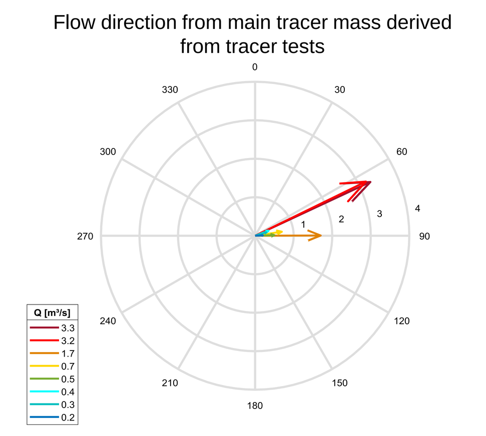




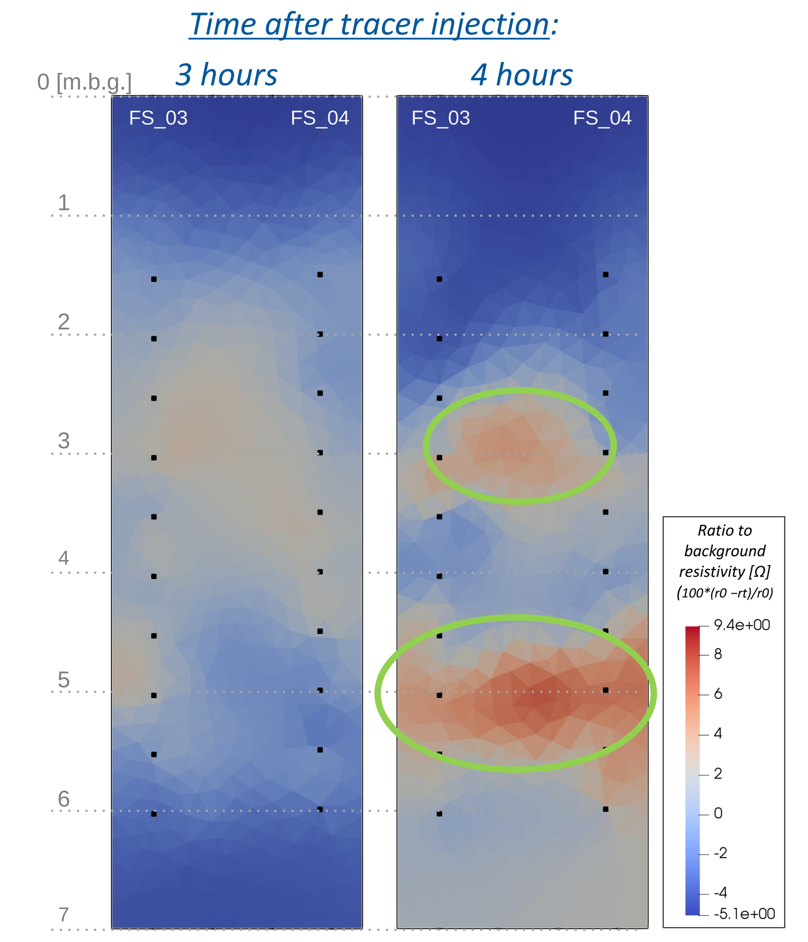
Fitting 1D-ADE for different breakthrough curves







| Crosshole ERT measurement within tracer test |

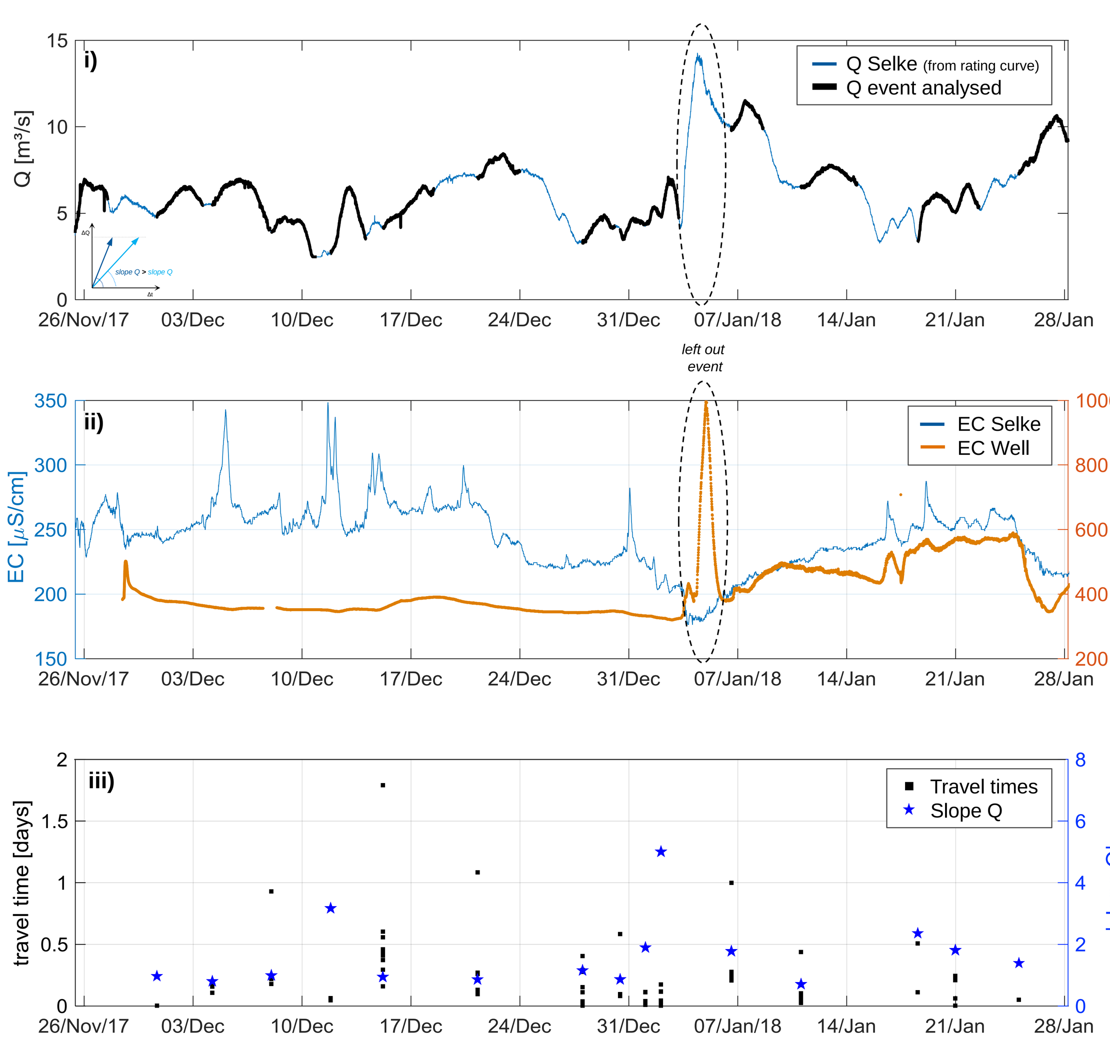


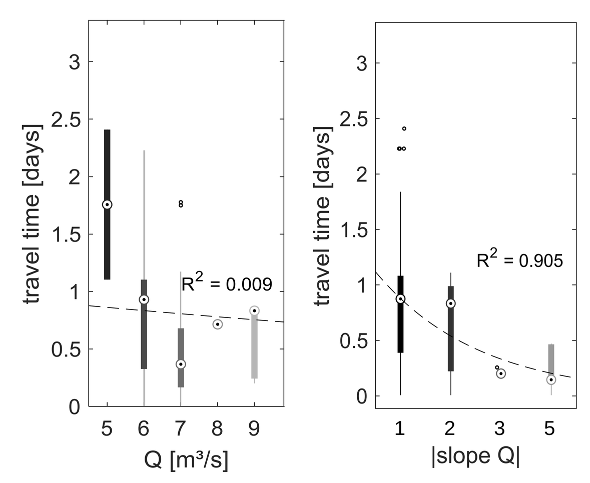
- Change in main groundwater flow direction with discharge
- Travel times slightly increase with river discharge
- Mean O_2 consumption: appx. 5 mg/L/d
- Moments of oxygen enrichment under long travel times
- Preferential flow paths towards wells FS_03 and FS_04, and around 3 and 5 *mbg*. No significant differences in first arrival times in different depths

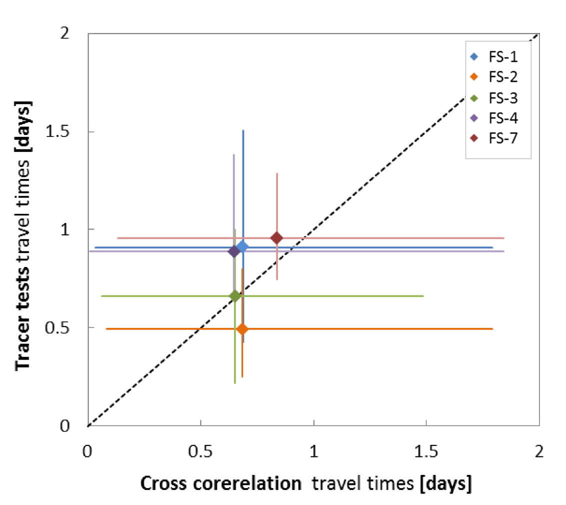
Travel times – natural EC variations

Time series analysis of different peak discharge events

Windowed cross correlation of EC signal *vs.* rising limb slope of river discharge events



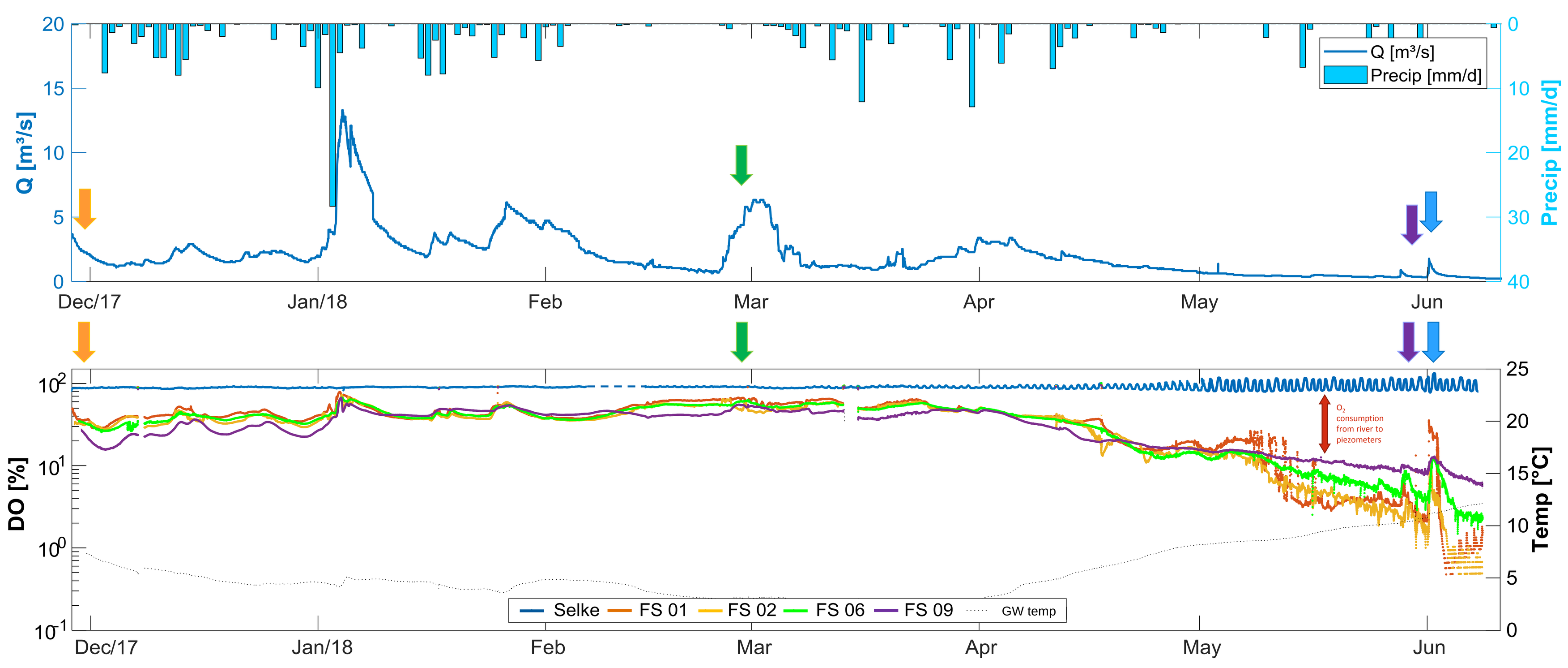


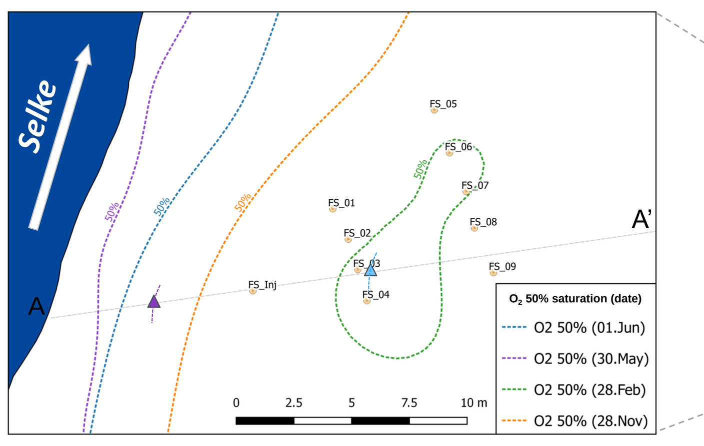


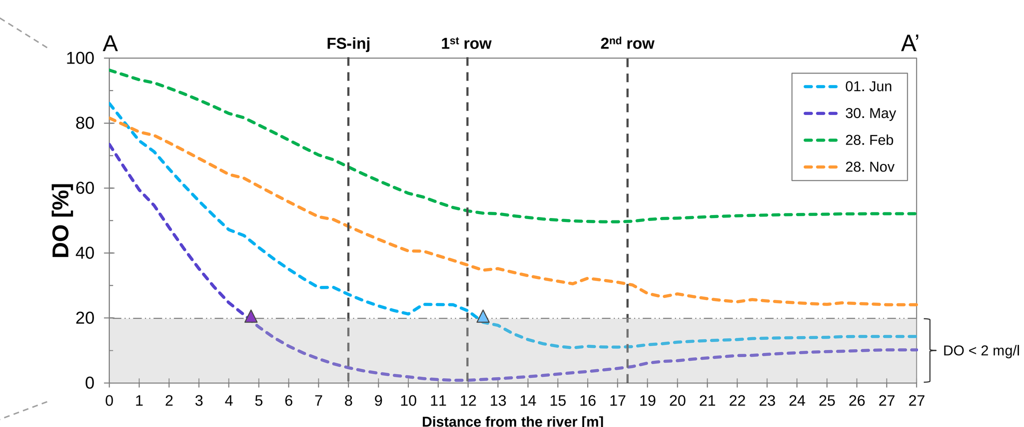
- Travel times greatly change during discharge events, decreasing with the increase of event slope, and with a stronger correlation with it than with the absolute discharge values (p_{slope}<< $p_{discharge}$)
- No significant difference in travel times between different depths for a same piezometer (*p*> 0.05)
- Similar mean travel times derived from tracer tests

DO dynamics in the vicinity of the river

High resolution DO time series – temperature and discharge effects







- Rapid O_2 consumption within first few meters from the river (up to 50%), especially high during warm season and low river discharges (up to 80%)
- Higher O_2 supply from river during discharge events increases oxic zone in its vicinity areas
- O_2 enrichment in piezometers far from the river

Synthesis and Outlook

Main findings

- Highly conductive riparian aquifer built up of fluvial sediments (K=1·10^{-2} m/s)
- Travel times decreases under discharge events due to rapid increase in hydraulic gradients
- Highest reactivity of the riparian zone in the vicinity of the river, due to bioavailable carbon and heat supply of infiltrating river water.
- Higher O_2 supply during discharge events increases the width of oxic zone near the river, decreasing the potential for anaerobic reactions
- Strong seasonal effects on aerobic and anaerobic reactions (temperature control of reaction rates)

Next steps

- Model O_2 dynamics through EC and DO time series analysis employing time-variable travel times and temperature-standardized respiration rate coefficients;
- Installation of multilevel piezometers in the vicinity of river infiltration area;
- Reactive tracer tests (C or N) for solute turnover rates;
- Implement high frequency DOC measurement (quantity and quality) in the riparian aquifer.

Simulation of exchange flows and biogeochemical reactions in the riparian zone

- **Riparian corridor surface-subsurface flows - *HGS***: parametrization using PEST and calibration with groundwater levels and salt tracer breakthrough curves from field tests;
- **Biogeochemical reactions - *MIN3P***: multicomponent transient 3D reactive transport model, implementing aquifer texture derived from geophysics.

References

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