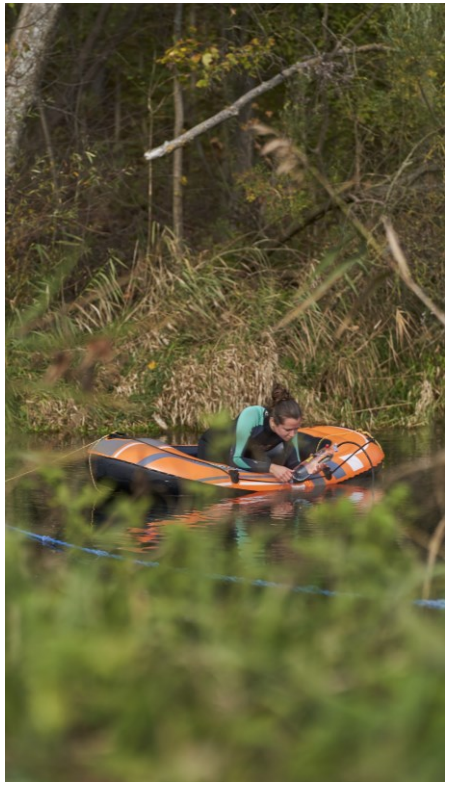
Chair of Hydrogeology
TUM School of Engineering and Design
Technical University of Munich

Understanding the hyporheic methane cycle based on field investigations in a small stream

Tamara Michaelis (tamara.michaelis@gmail.com)

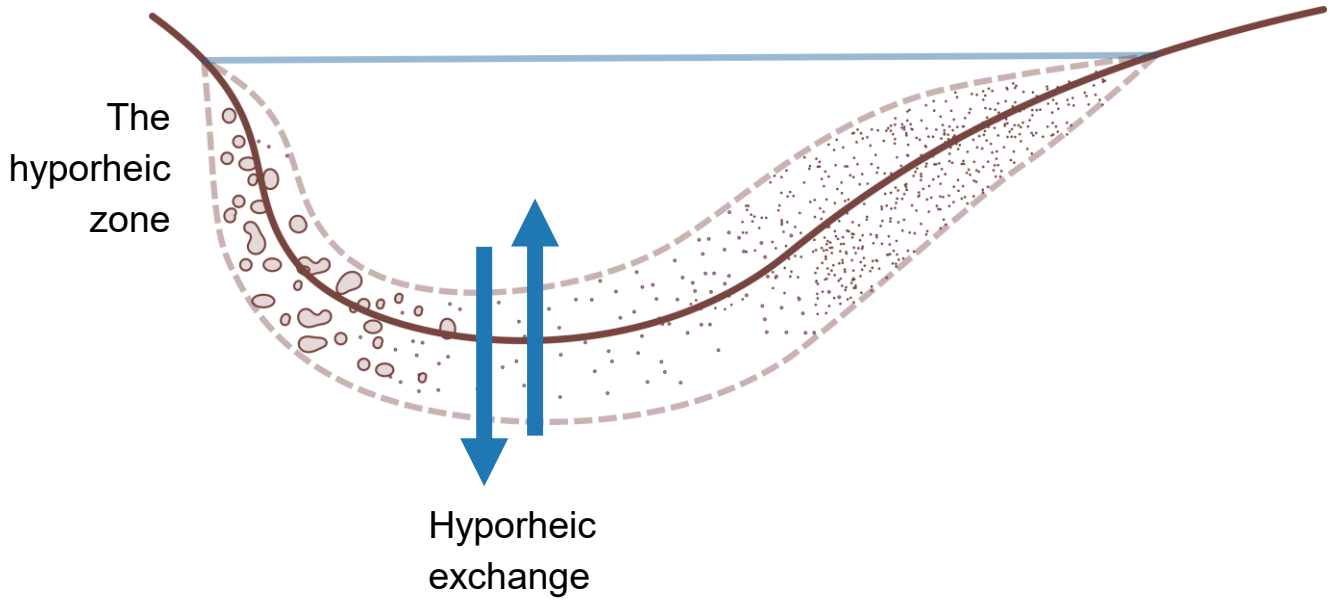
Anja Wunderlich, Thomas Baumann, Florian Einsiedl

Vienna, 16th April 2024



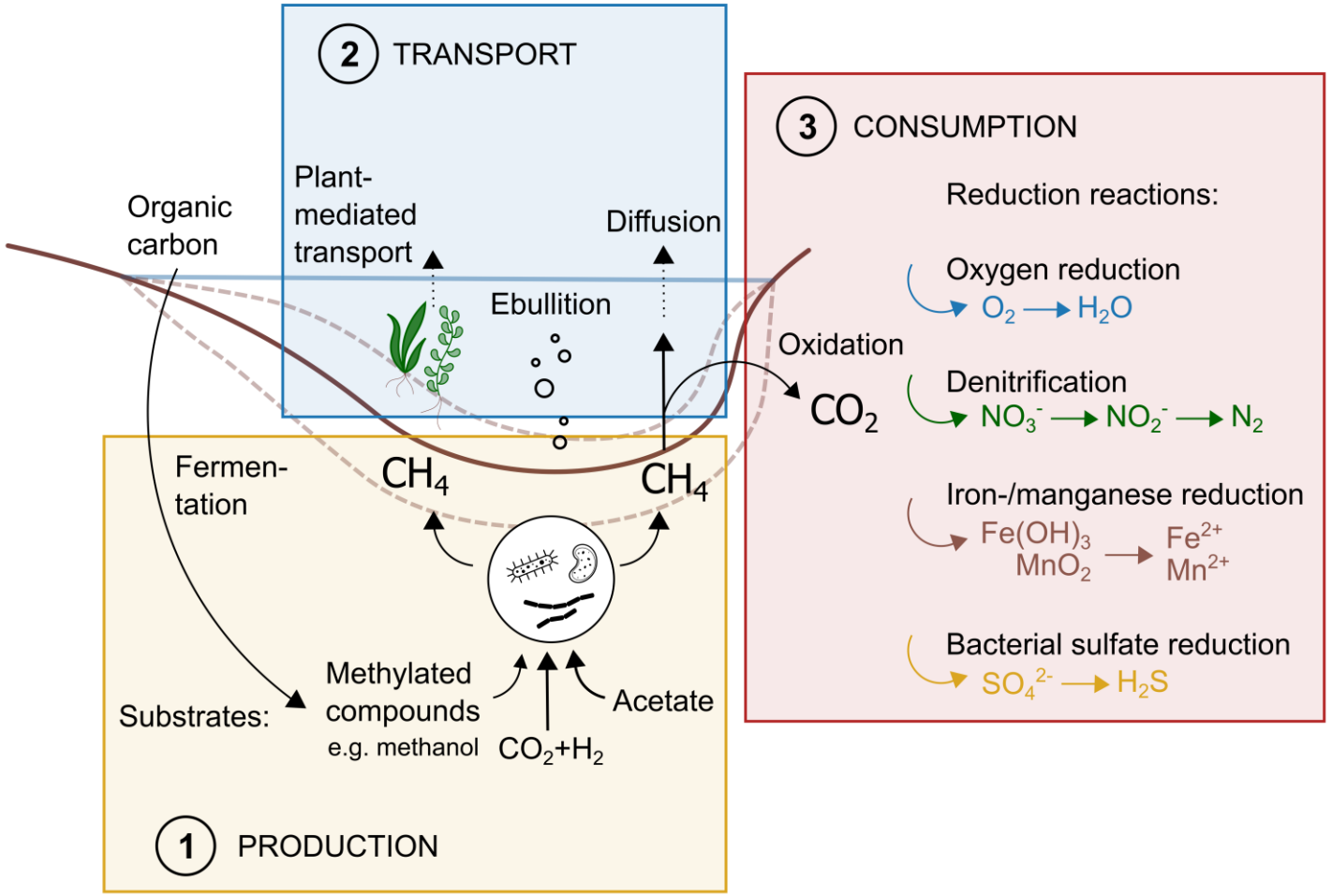
Why rivers?

Large **uncertainties** in global budgets due to high **spatial heterogeneity** and **temporal dynamics**

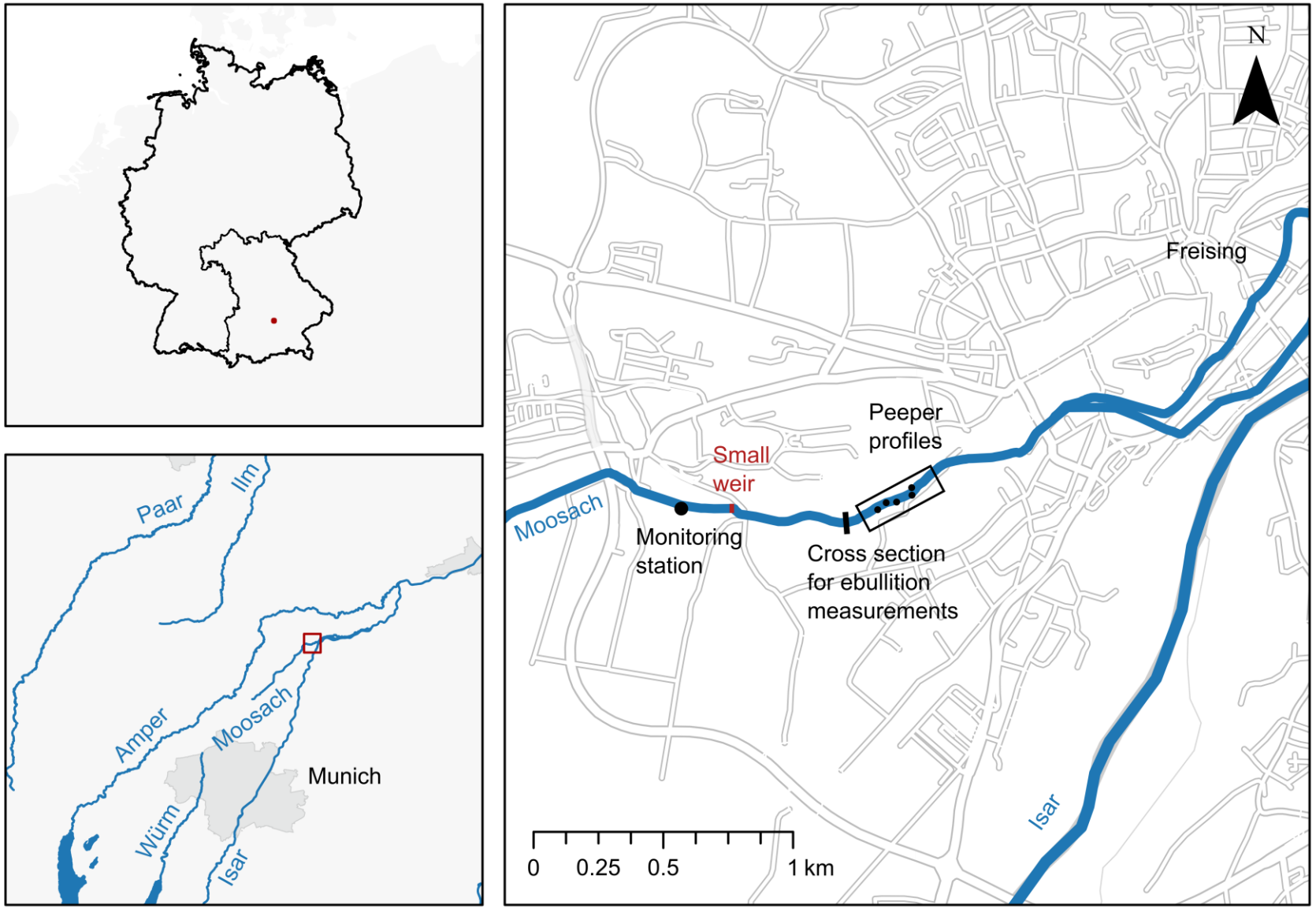


Chair of Hydrogeology
TUM School of Engineering and Design
Technical University of Munich

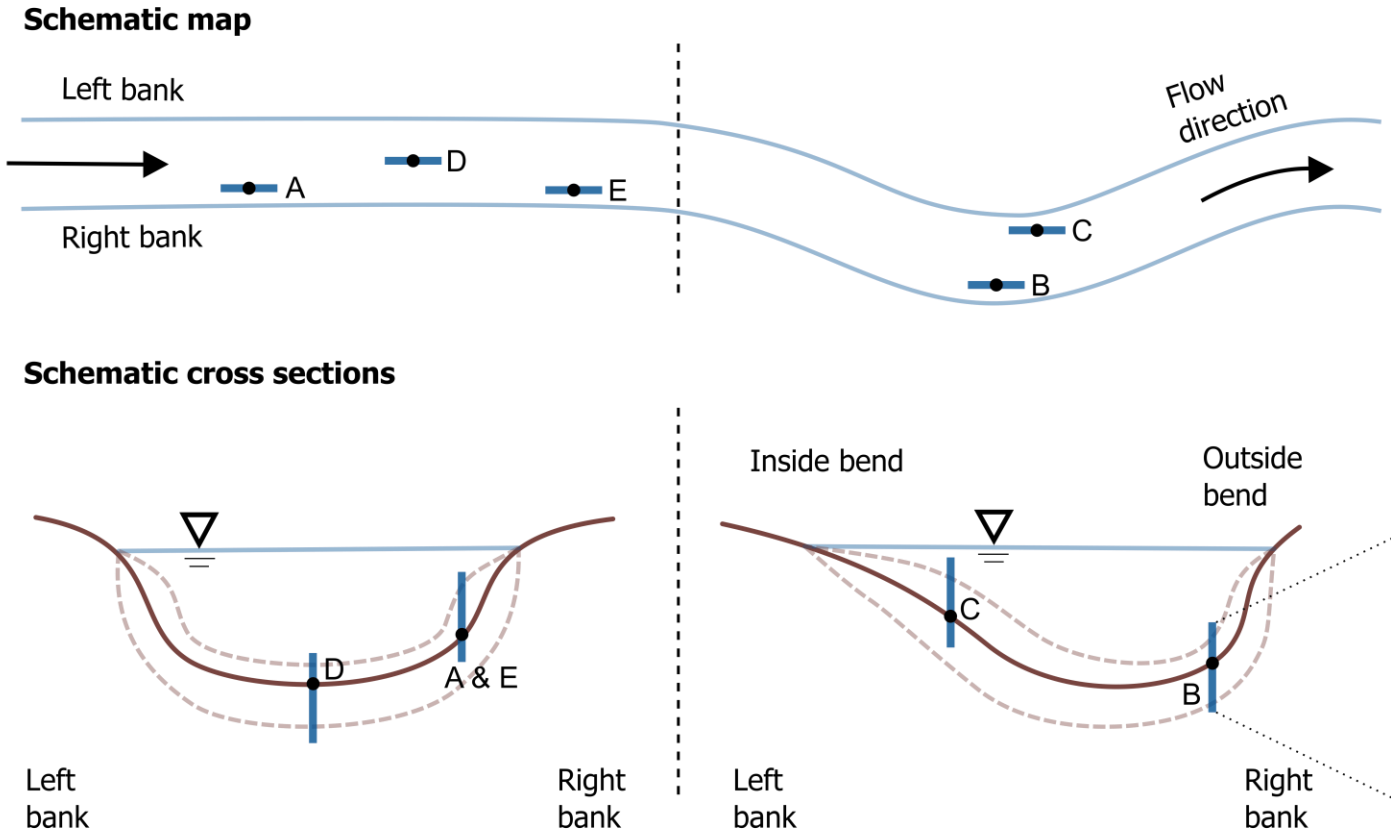
Methane cycling in the hyporheic zone

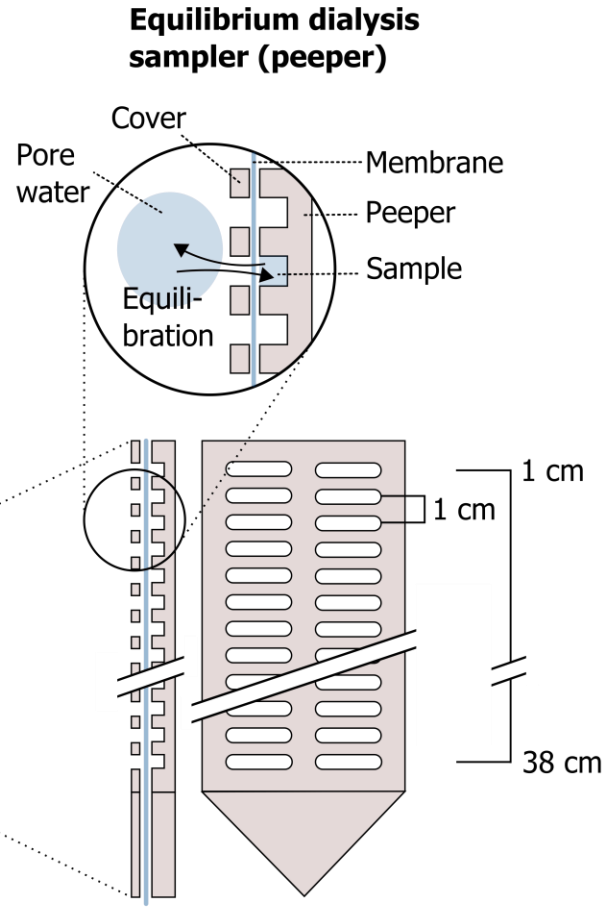


Study site


Paar
Ilm
Amper
Moosach
Würm
Isar
Munich
N
Freising
Peeper
profiles
Small
weir
Moosach
Monitoring
station
Cross section
for ebullition
measurements
Isar
0
0.25
0.5
1 km

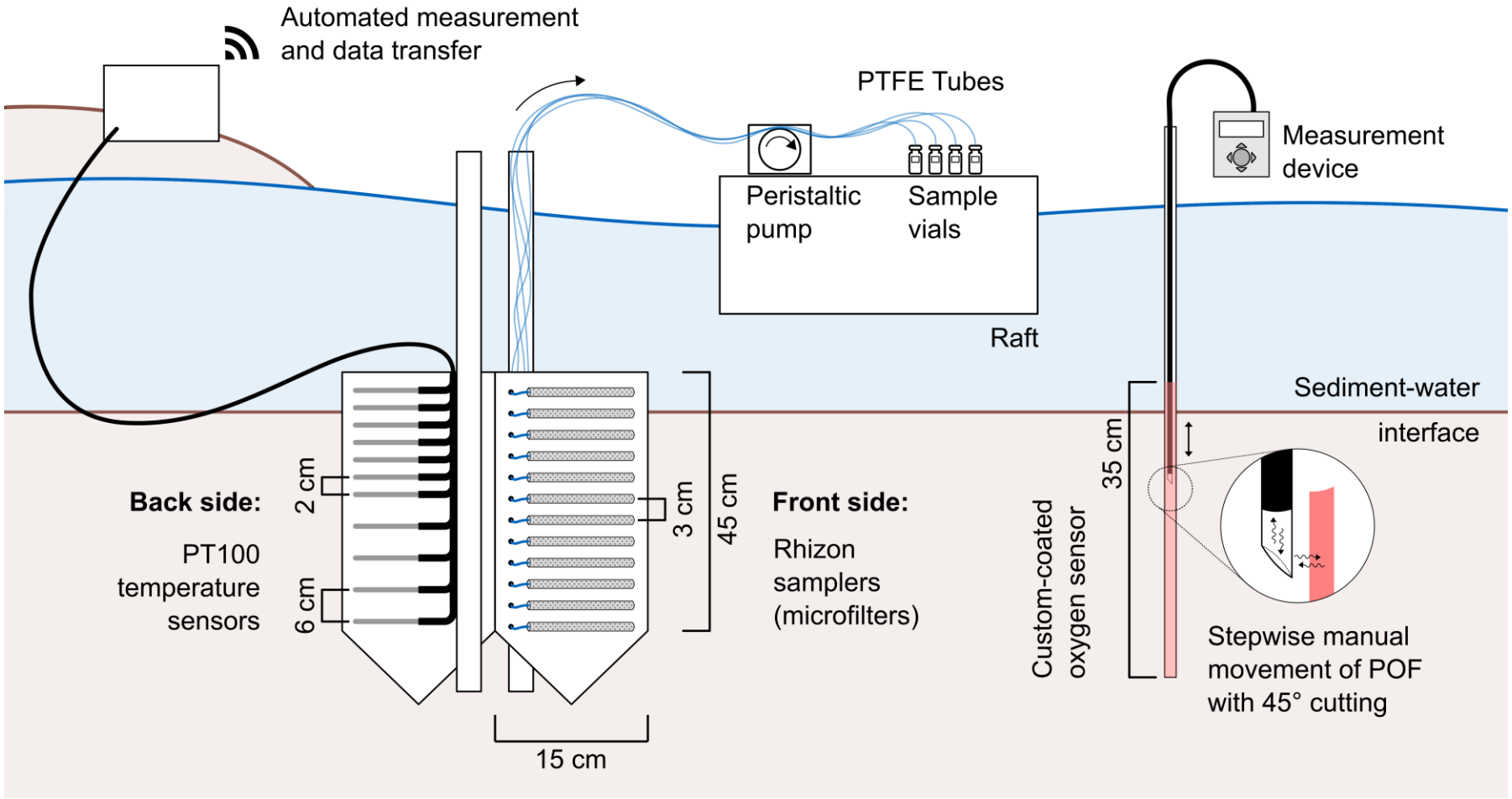
Pore-water sampling with sediment peepers





Michaelis et al., *BG* (2022)

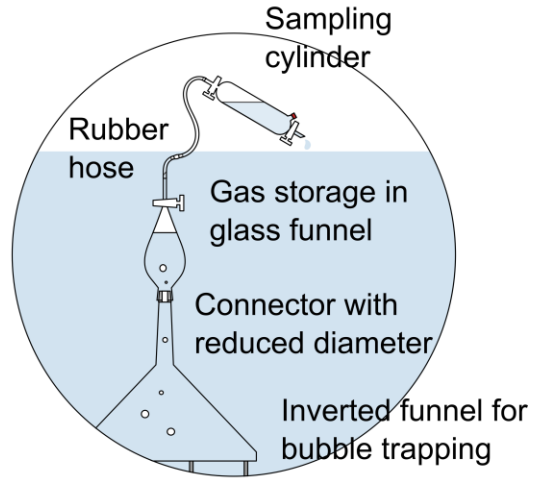
A new monitoring station for pore-water extraction

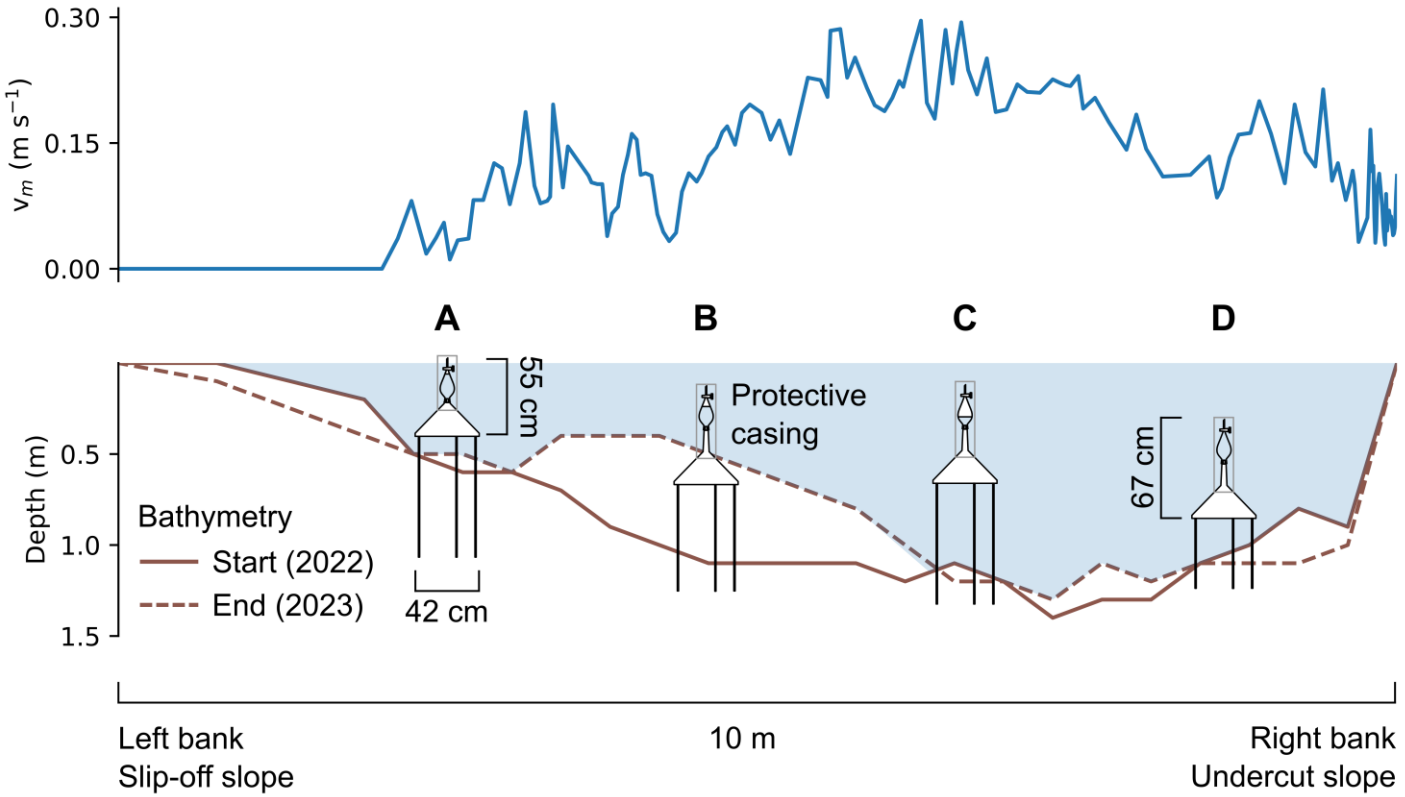


Michaelis et al., *HESS* (2023)

Chair of Hydrogeology
TUM School of Engineering and Design
Technical University of Munich

Ebullition monitoring

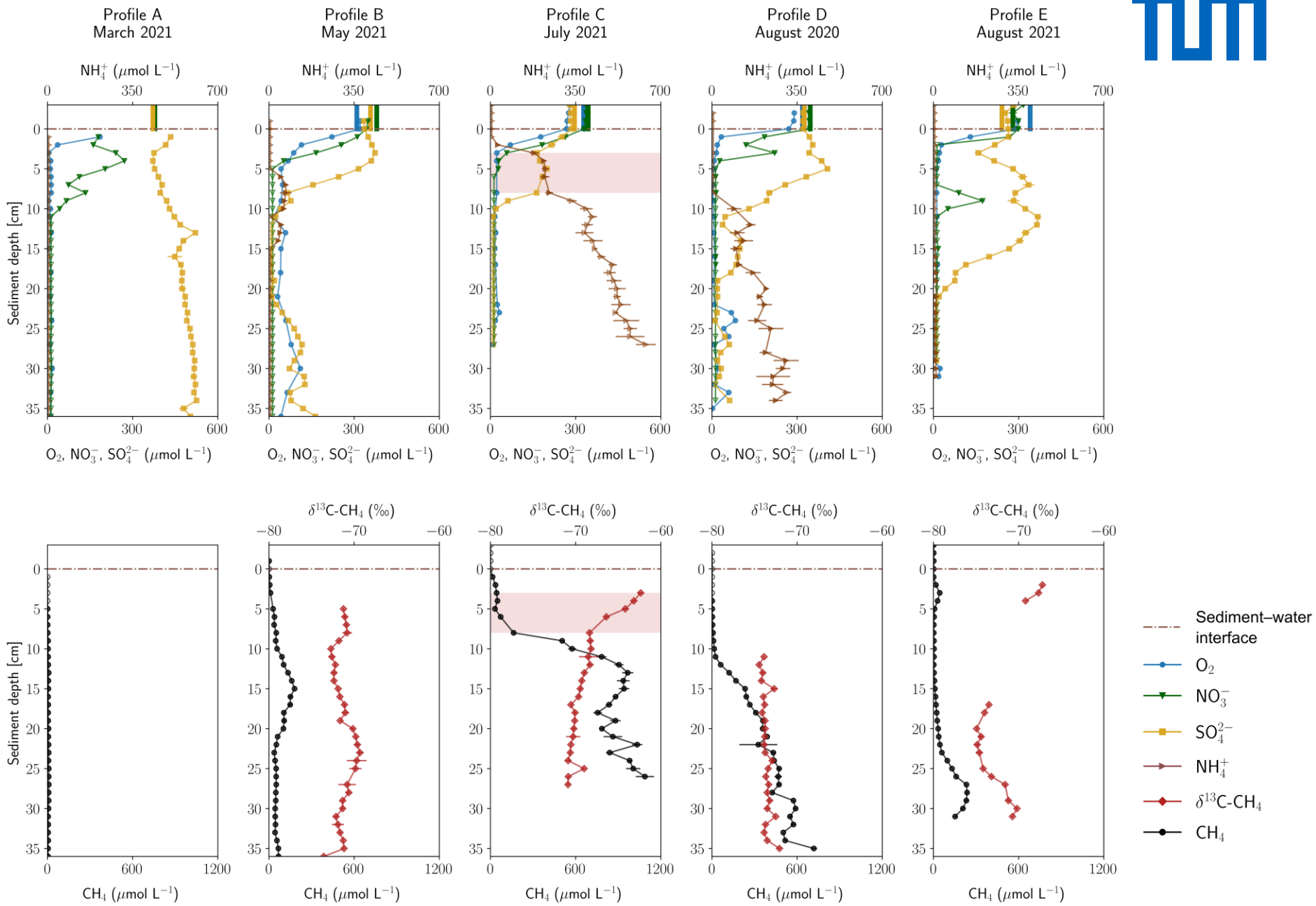




Michaelis et al., *ScR* (2024)

Chair of Hydrogeology
TUM School of Engineering and Design
Technical University of Munich

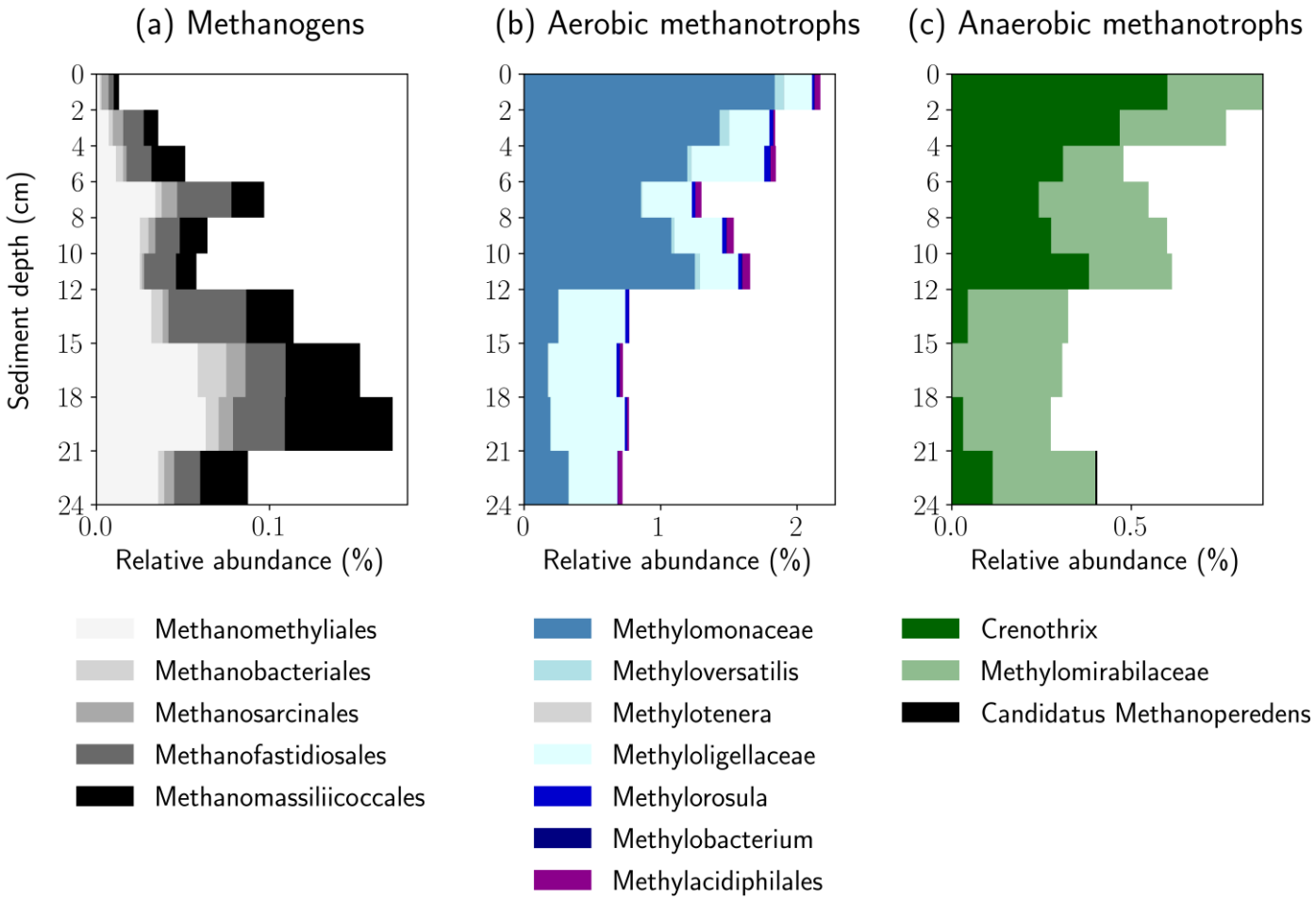
High variability in pore-water profiles



Michaelis et al., *BG* (2022)

Chair of Hydrogeology
TUM School of Engineering and Design
Technical University of Munich

The microbial community distribution



Methanogens

- *Candidatus* “Methanomethyliales” and Methanomassiliicoccales encode pathway for **H_2-dependent methylotrophic methanogenesis**

Anaerobic methanotrophs

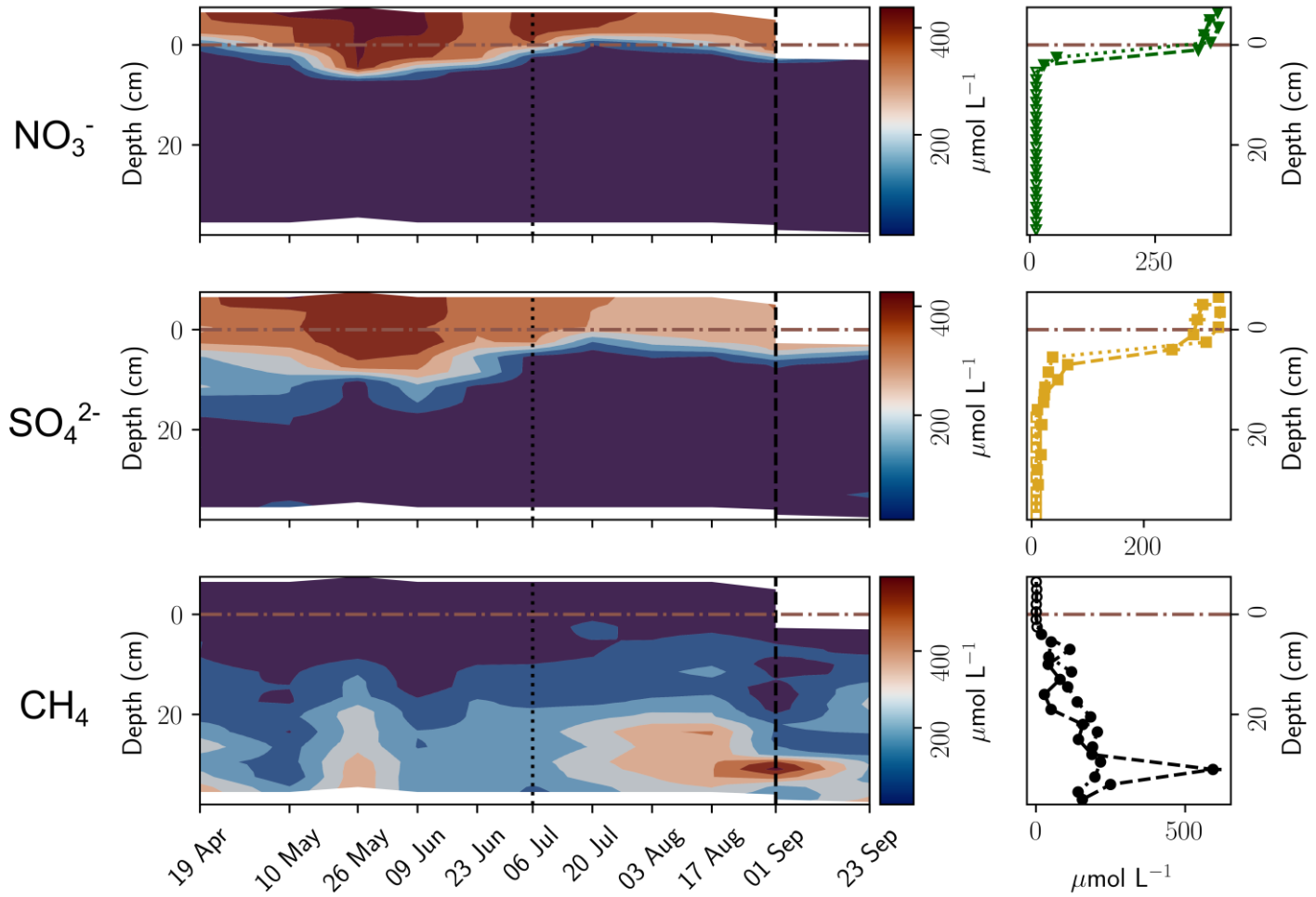
- *Crenothrix* are facultative anaerobes that reduce NO_3^-
- *Candidatus* “Methylomirabilis” are oxygen intolerant and reduce NO_2^-
- Absence of ANME archaea

Michaelis et al., *BG* (2022)

Chair of Hydrogeology
TUM School of Engineering and Design
Technical University of Munich

Stable geochemical conditions in the hyporheic zone

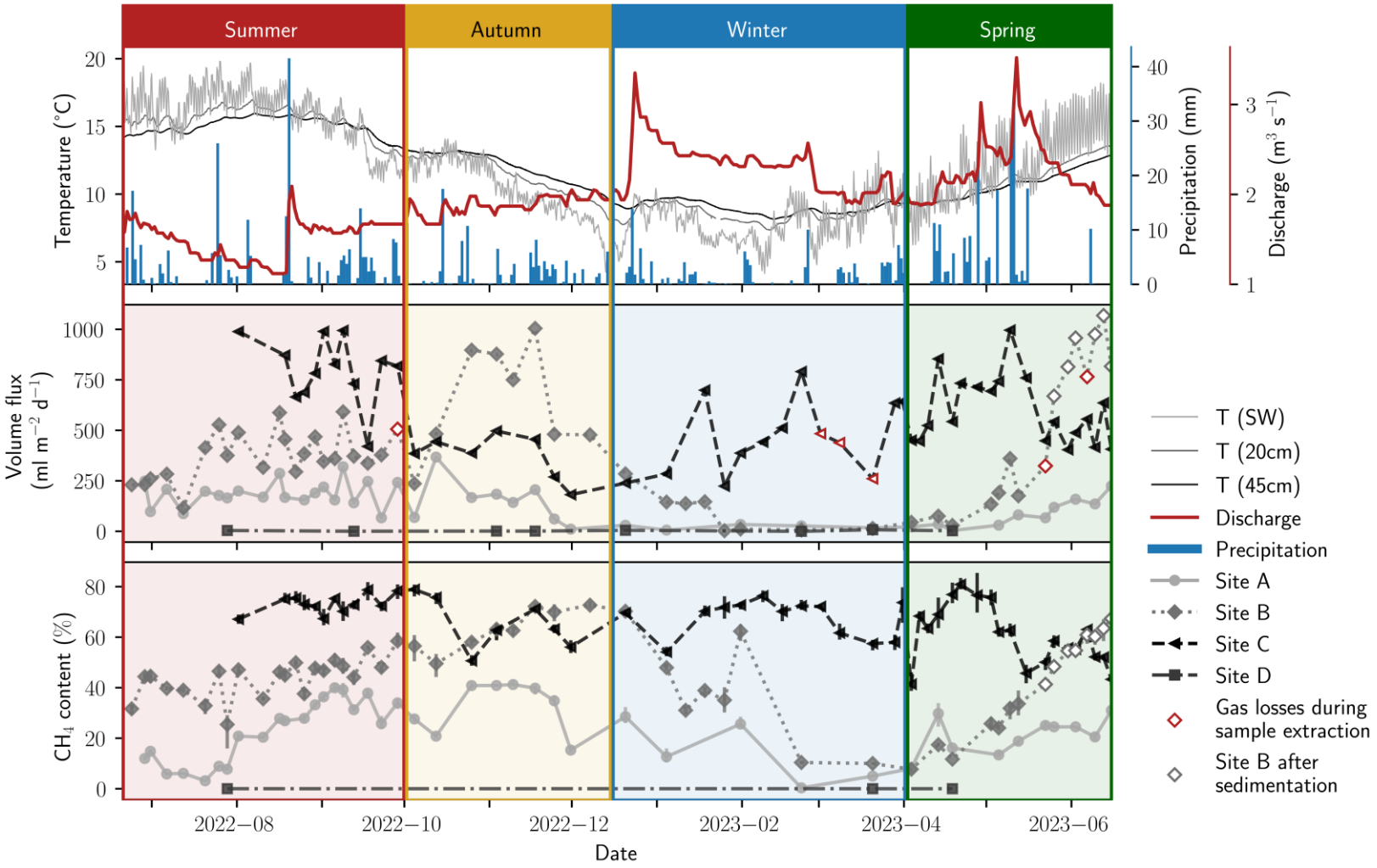
Repeated sampling at the monitoring station

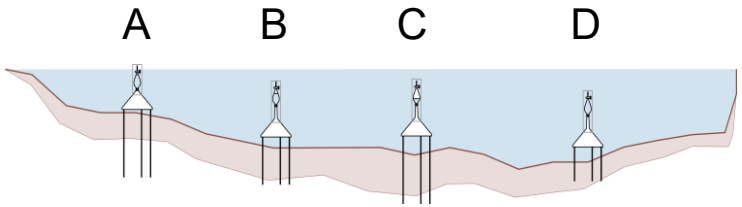


Michaelis et al., *HESS* (2023)

Chair of Hydrogeology
TUM School of Engineering and Design
Technical University of Munich

Large volume fluxes and high methane contents in bubbles

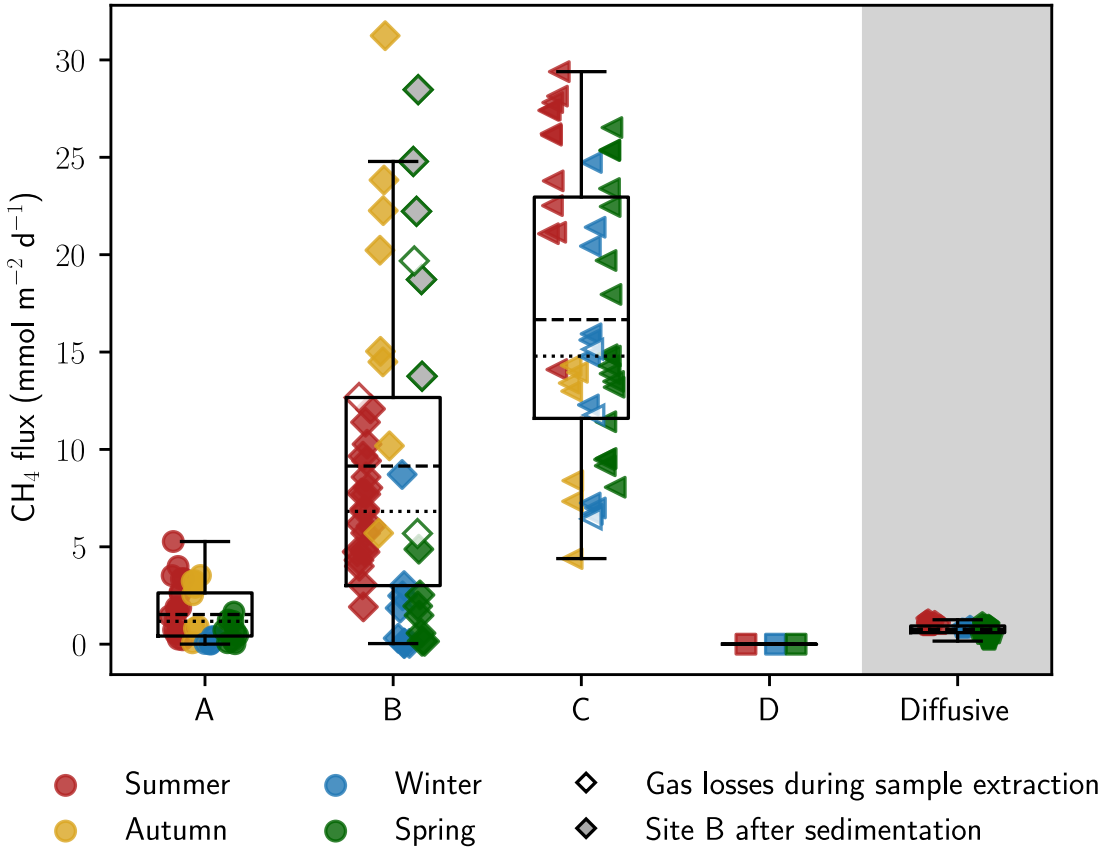




Michaelis et al., *ScR* (2024)

Chair of Hydrogeology
TUM School of Engineering and Design
Technical University of Munich

Ebullition fluxes up to 30 times higher methane than diffusion



Michaelis et al., *ScR* (2024)

Main findings

- The hyporheic zone was a **hotspot of methane production and emissions**.
- Relevant **substrates for CH_4 production** according to stable isotope signature, abundance of microorganisms, and due to methanogenesis at cold temperatures: H_2, CO_2, and methanol.
- There was a potential for **methane oxidation** coupled to O_2 reduction and denitrification.
- CH_4 oxidation could **only marginally reduce GHG emissions** from the HZ.
- **Ebullition** was the **main transport pathway** of CH_4 to the atmosphere.
- **Spatial heterogeneity** was larger than temporal variation. The temperature dependence was less clear than expected.
- Factors favoring methane emissions were higher **temperatures**, high **organic carbon contents** in the hyporheic zone, and a **fine-grained but permeable bed substrate**

References

Michaelis, T., Wunderlich, A., Coskun, Ö. K., Orsi, W., Baumann, T., & Einsiedl, F. (2022). High-resolution vertical biogeochemical profiles in the hyporheic zone reveal insights into microbial methane cycling. *Biogeosciences*, 19(18), 4551-4569. https://doi.org/10.5194/bg-19-4551-2022

Michaelis, T., Wunderlich, A., Baumann, T., Geist, J., & Einsiedl, F. (2023). Technical note: Testing the effect of different pumping rates on pore-water sampling for ions, stable isotopes, and gas concentrations in the hyporheic zone. *Hydrology and Earth System Sciences*, 27(20), 3769-3782. https://doi.org/10.5194/hess-27-3769-2023

Michaelis, T., Kaplar, F., Baumann, T., Wunderlich, A., Einsiedl, F. (2024). High methane ebullition throughout one year in a regulated central European stream. *Scientific Reports*, 14(1), 5359. https://doi.org/10.1038/s41598-024-54760-z