Representing multicompartment stream transport utilising exposure time

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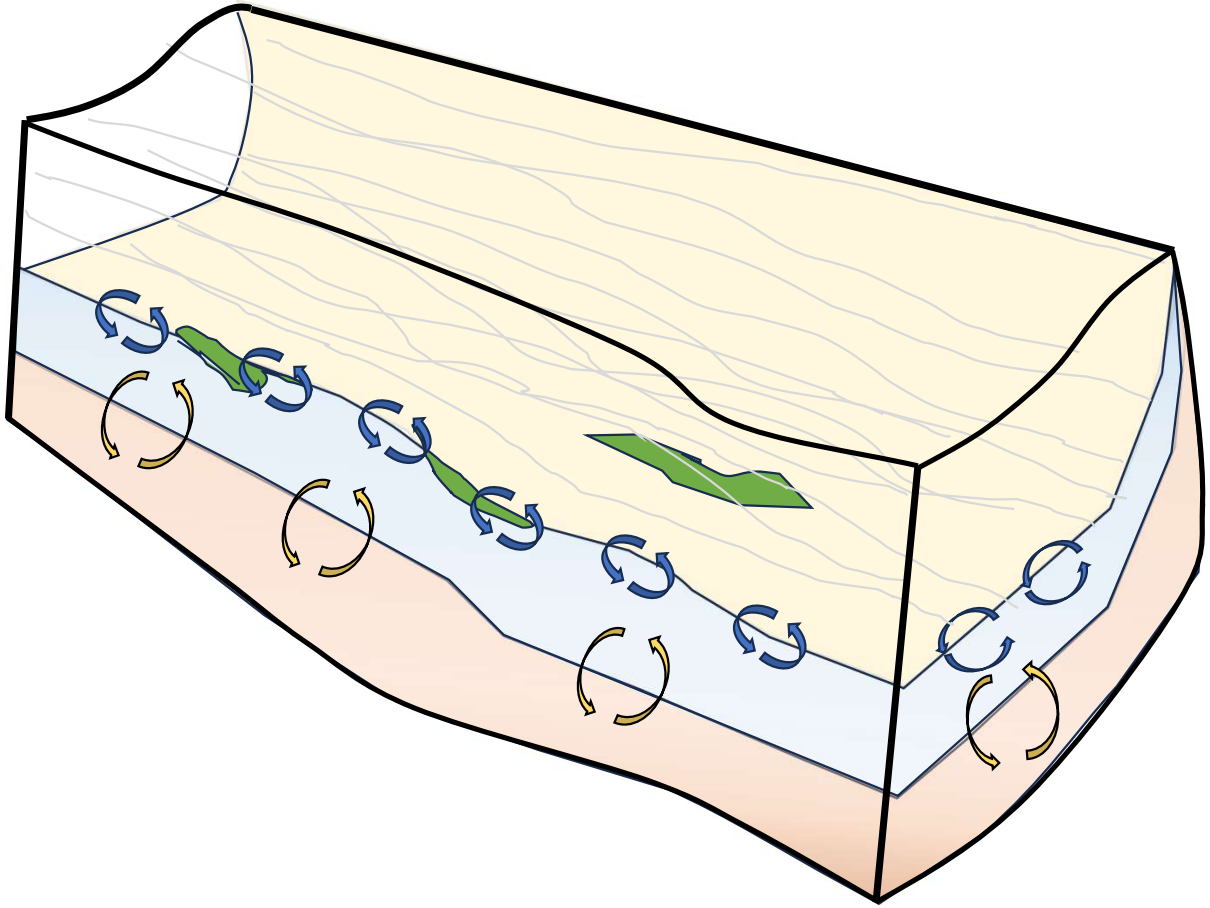
Background

Stream sediment environments:

- Flowing stream
- Exchanges with sediments
- Redox gradients
- Biofilms



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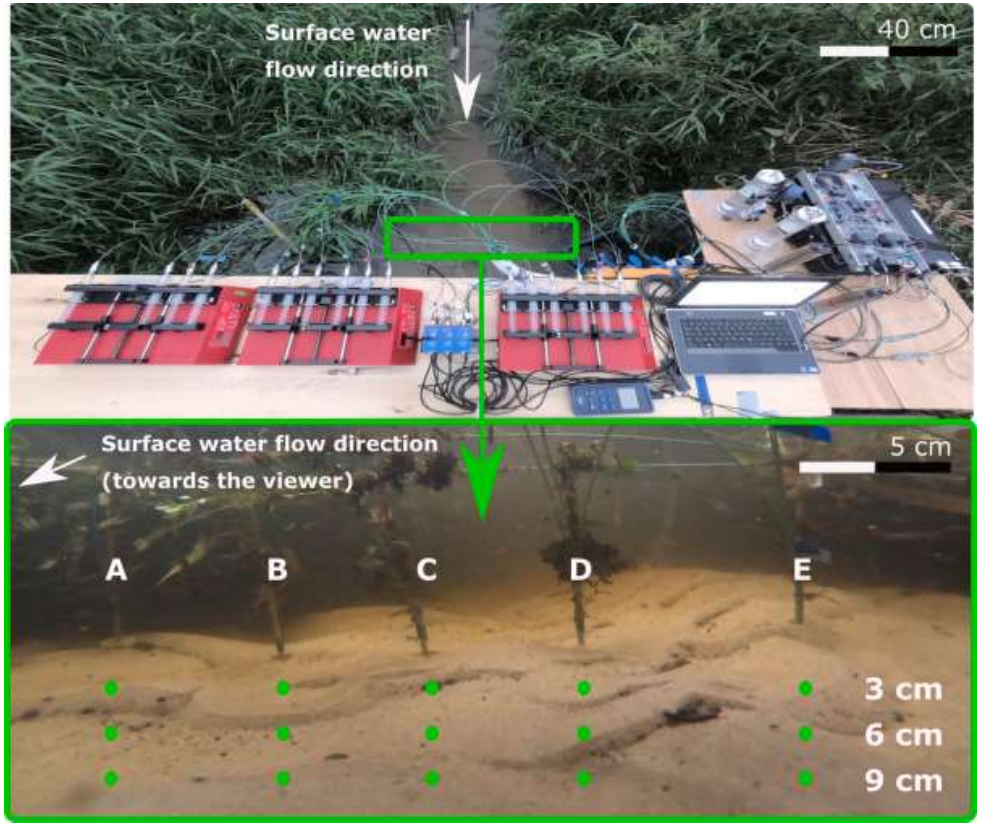
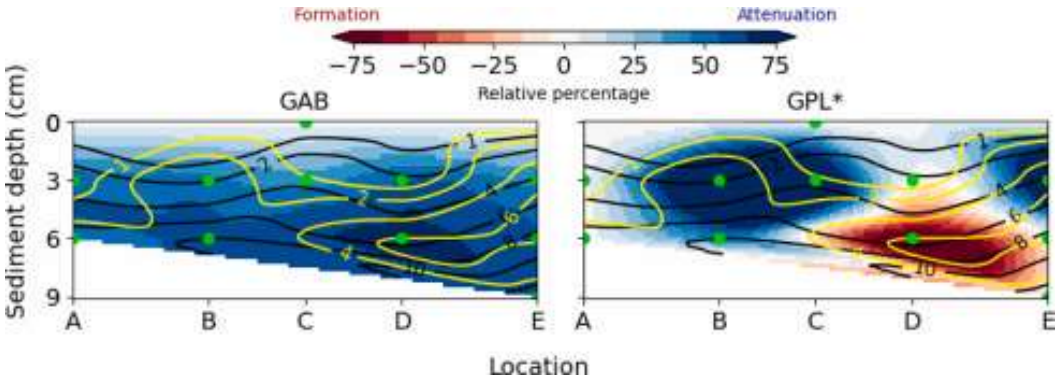
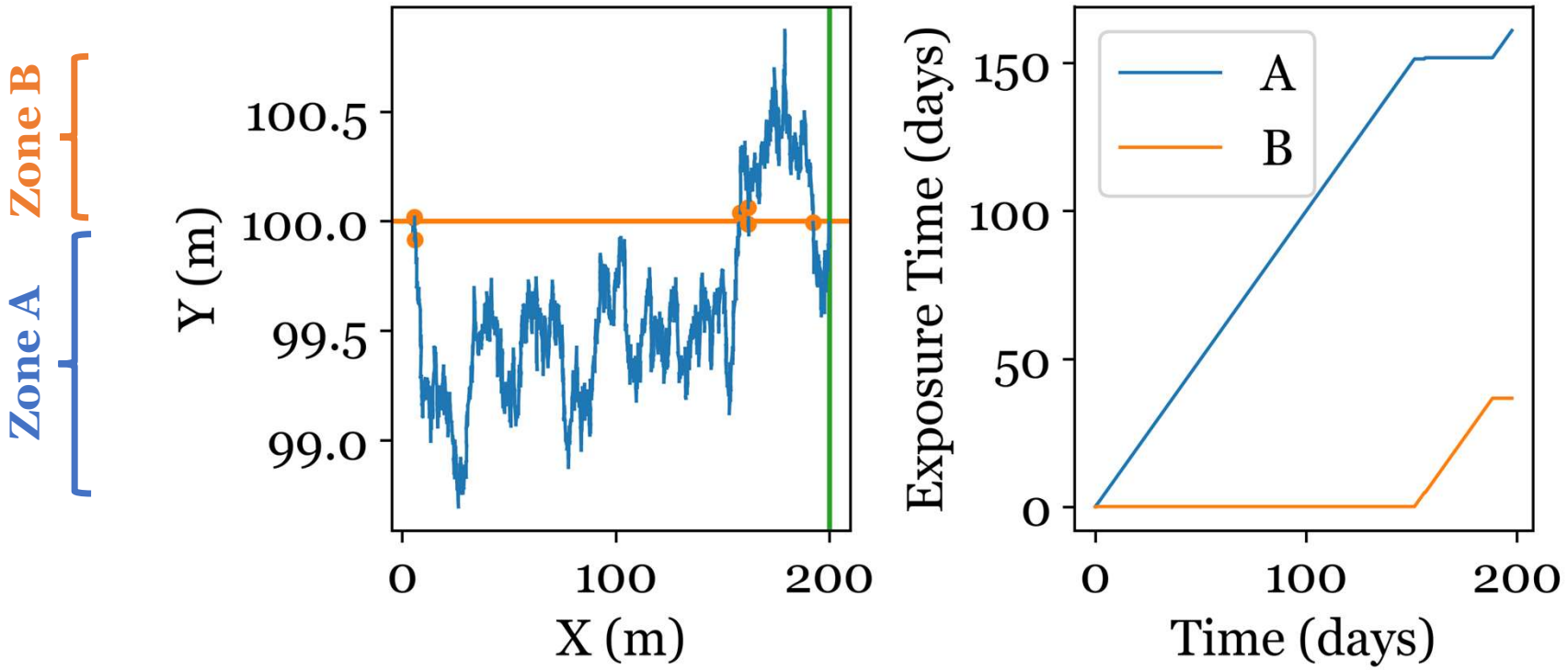


Höhne et al. 2022, Water Research, 224



Can we characterise the times water spends in different compartments of streams at the reach scale?

Exposure time



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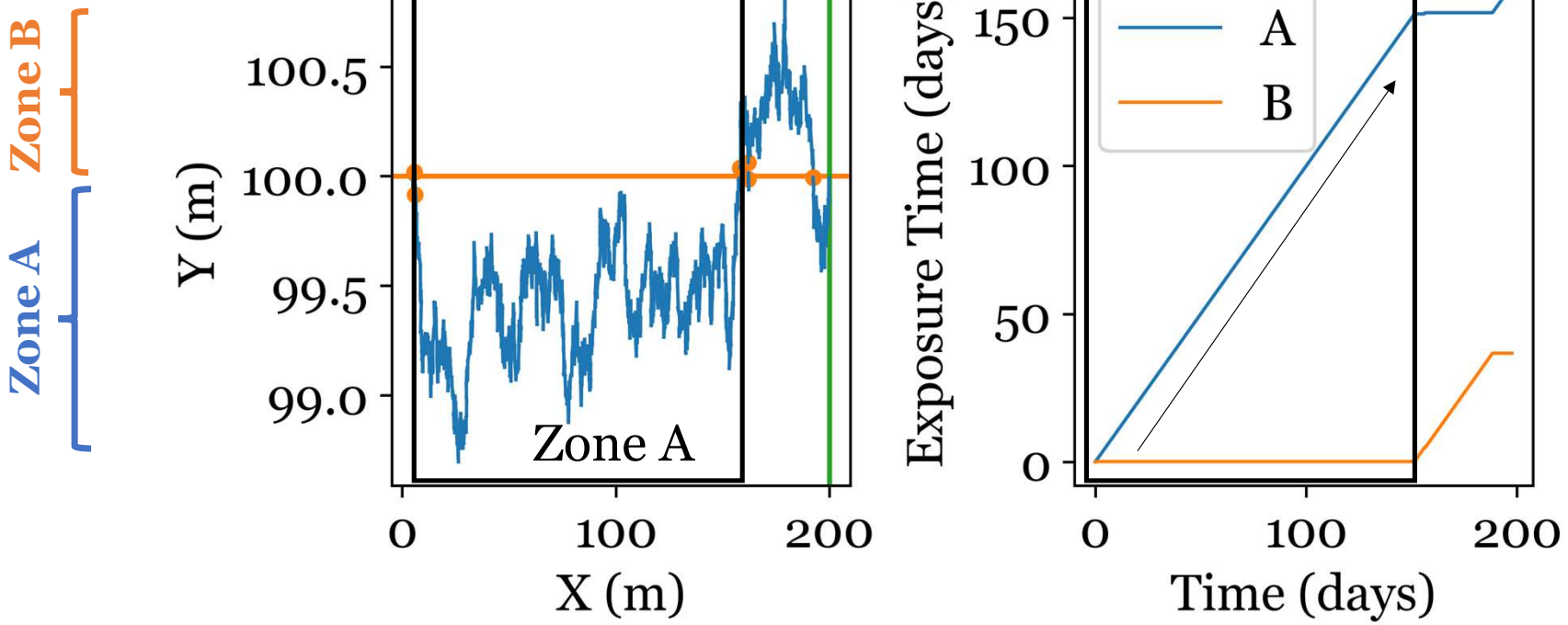
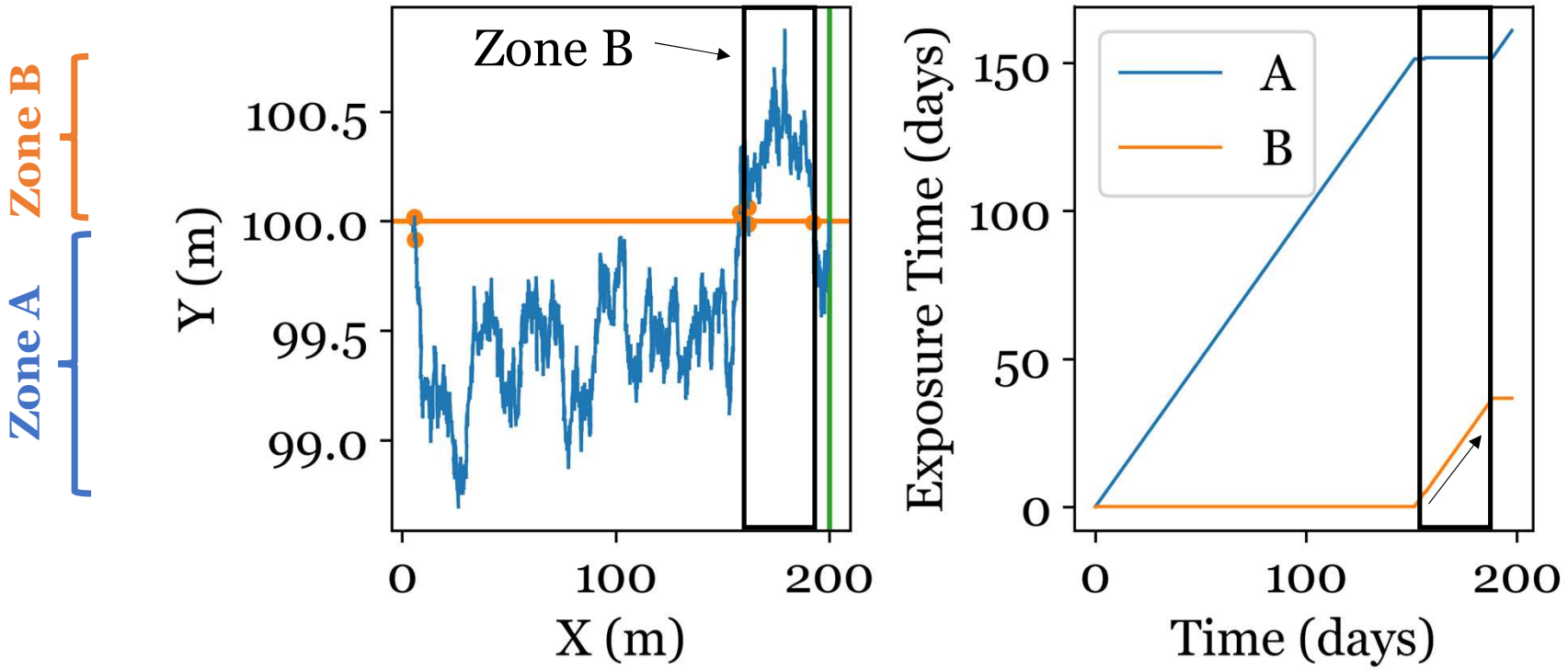


Exposure time



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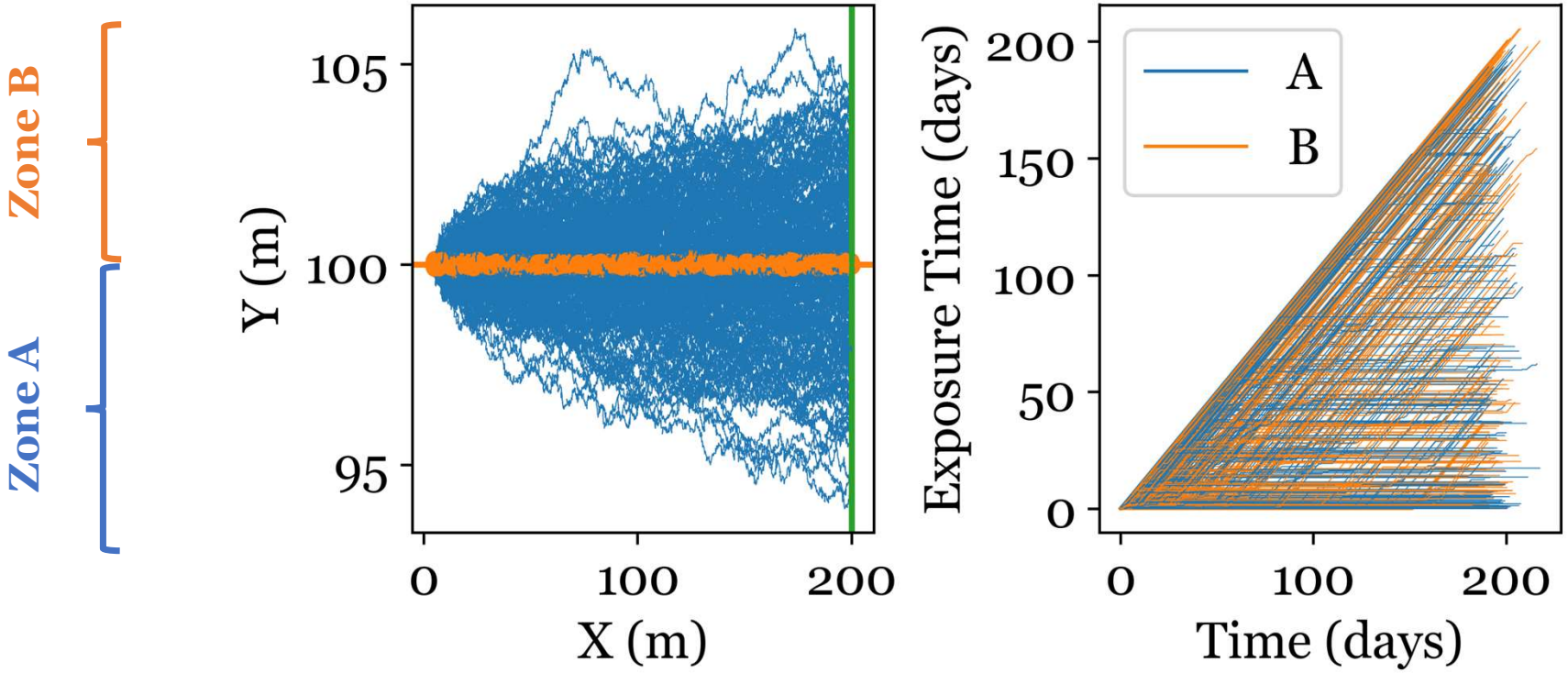
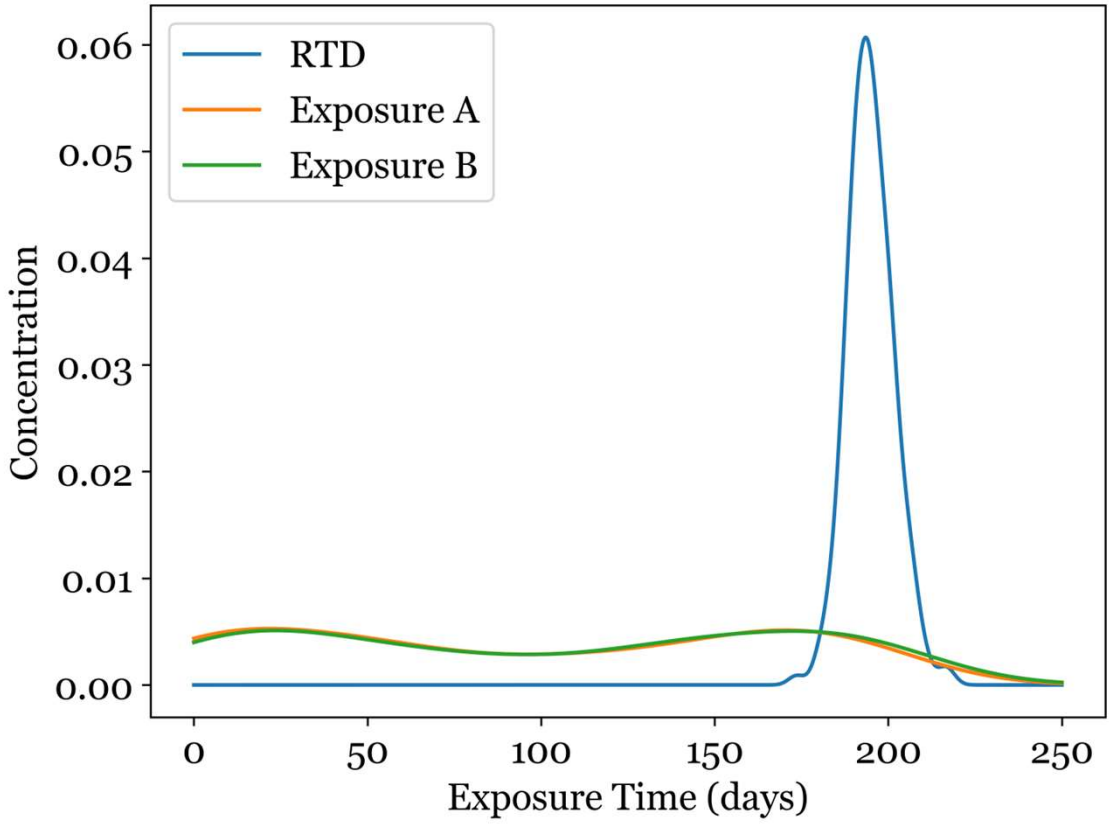


Exposure time



Exposure time applied to hyporheic zones

Define the time spent in different components of the stream – sediment system.

Has been demonstrated with Lagrangian (particle) approaches:

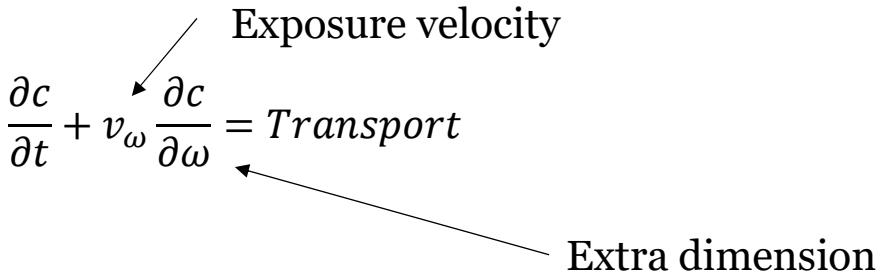
- Roche et al. (2019) Water Resources Research – developing memory functions
- Li et al. (2020) Water Resources Research – tracked time in bioreactive layers

Consideration of multi-zone models:

- Roche and Dentz (2022) Geophysical Research Letters – layered multi-zoned models
- Aubeneau et al. (2015) Freshwater Science – parallel multi-zoned model

Model approach

Exposure time (Ginn, 1999; Seeboonruang and Ginn, 2006a; 2006b)



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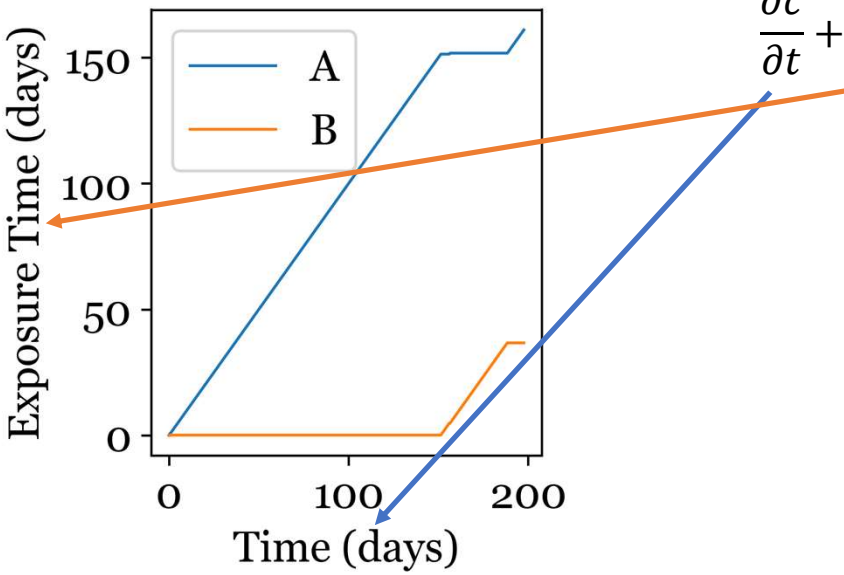
Exposure time (Ginn, 1999; Seeboonruang and Ginn, 2006 a,b)



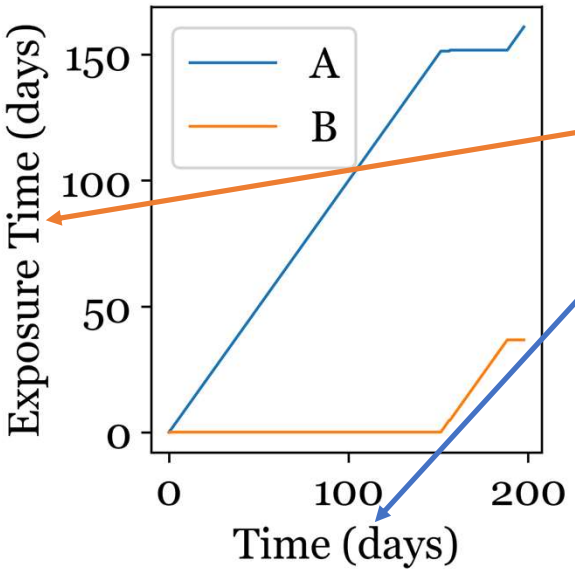
Exposure velocity

$$\frac{\partial c}{\partial t} + v_\omega \frac{\partial c}{\partial \omega} = Transport$$

Extra dimension

Model approach

Exposure time (Ginn, 1999 ; Seeboonruang and Ginn, 2006 a,b)



Exposure velocity → One when in tracked zone, zero otherwise

$$\frac{\partial c}{\partial t} + v_\omega \frac{\partial c}{\partial \omega} = Transport$$

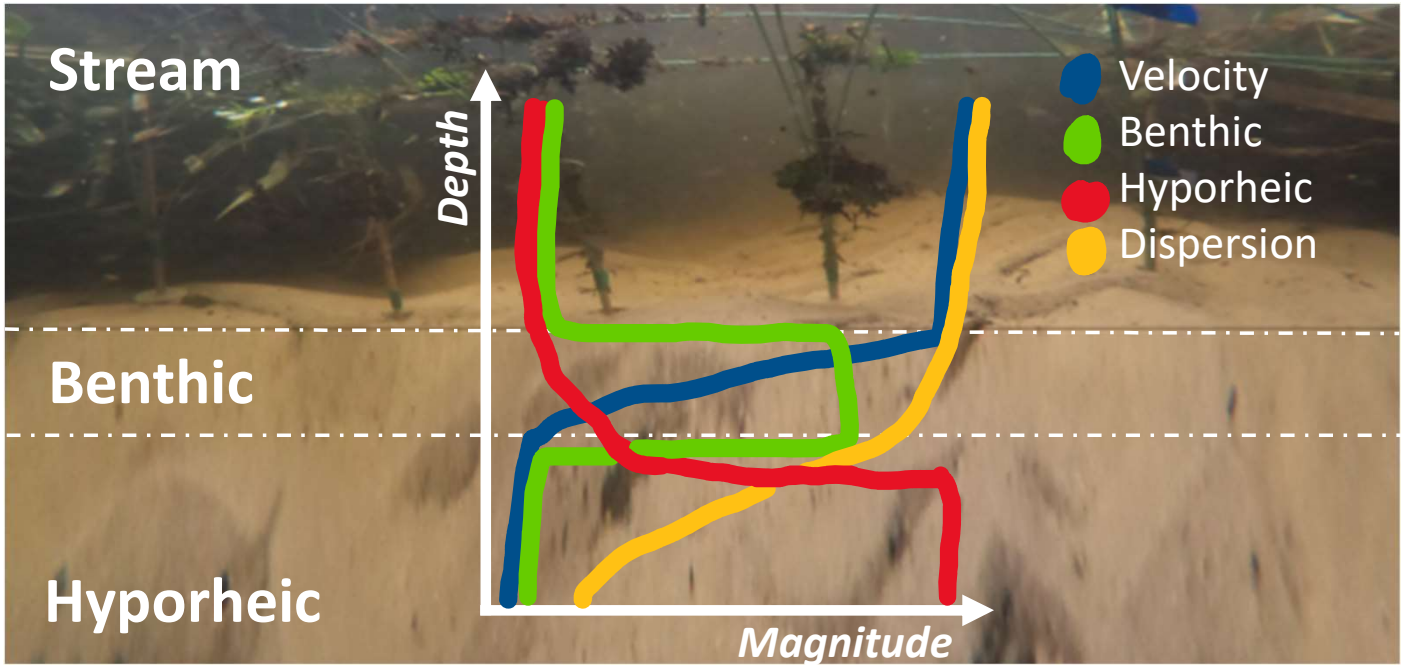
Extra dimension

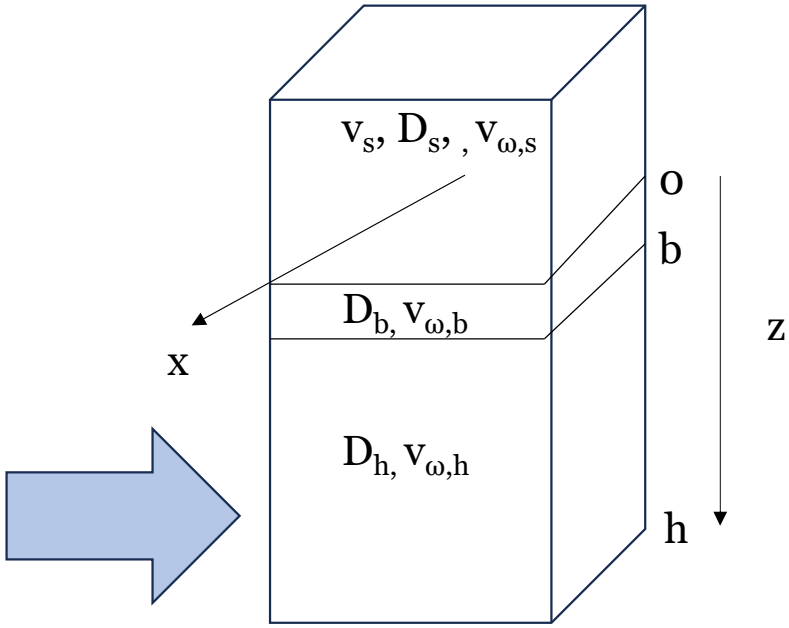
Extend to assume dc/dt = 0:

Tracked – transient state transport equation

Not tracked – steady state transport equation

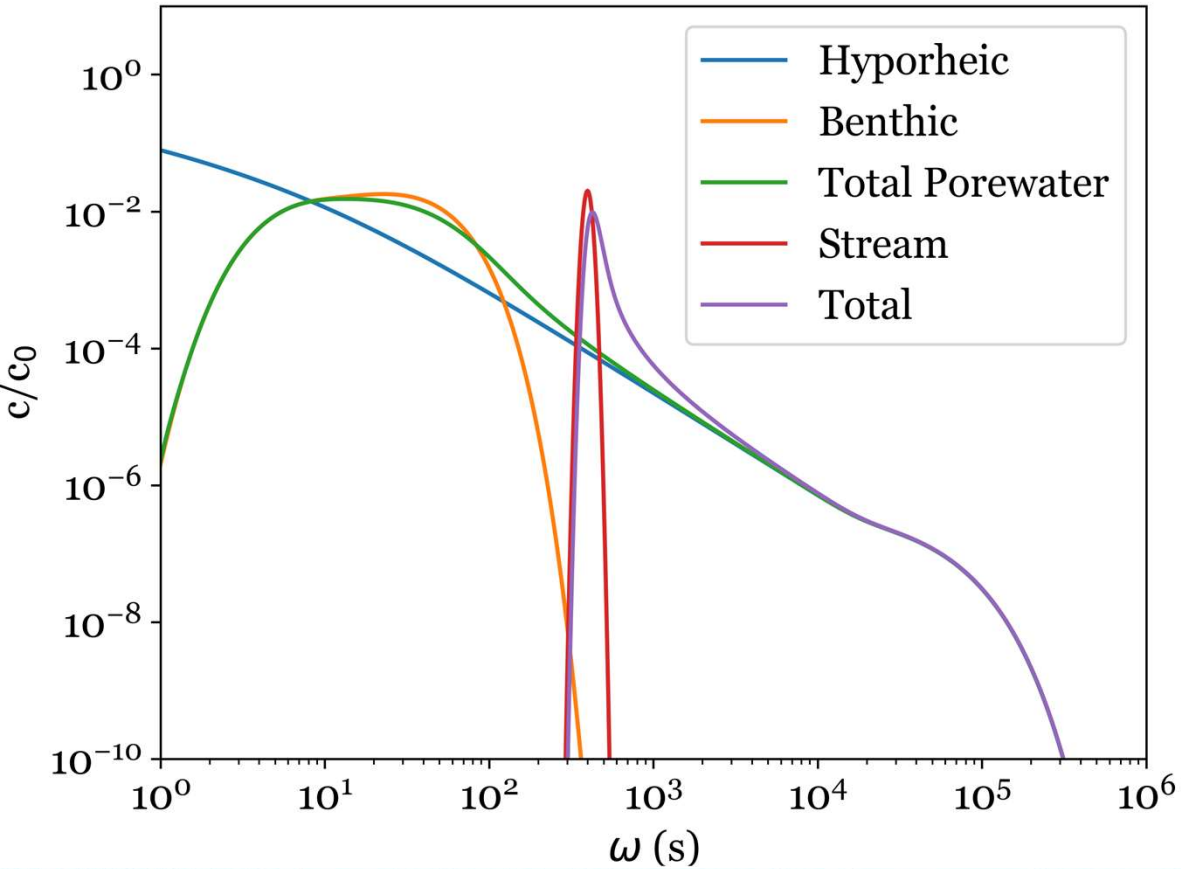
Model approach





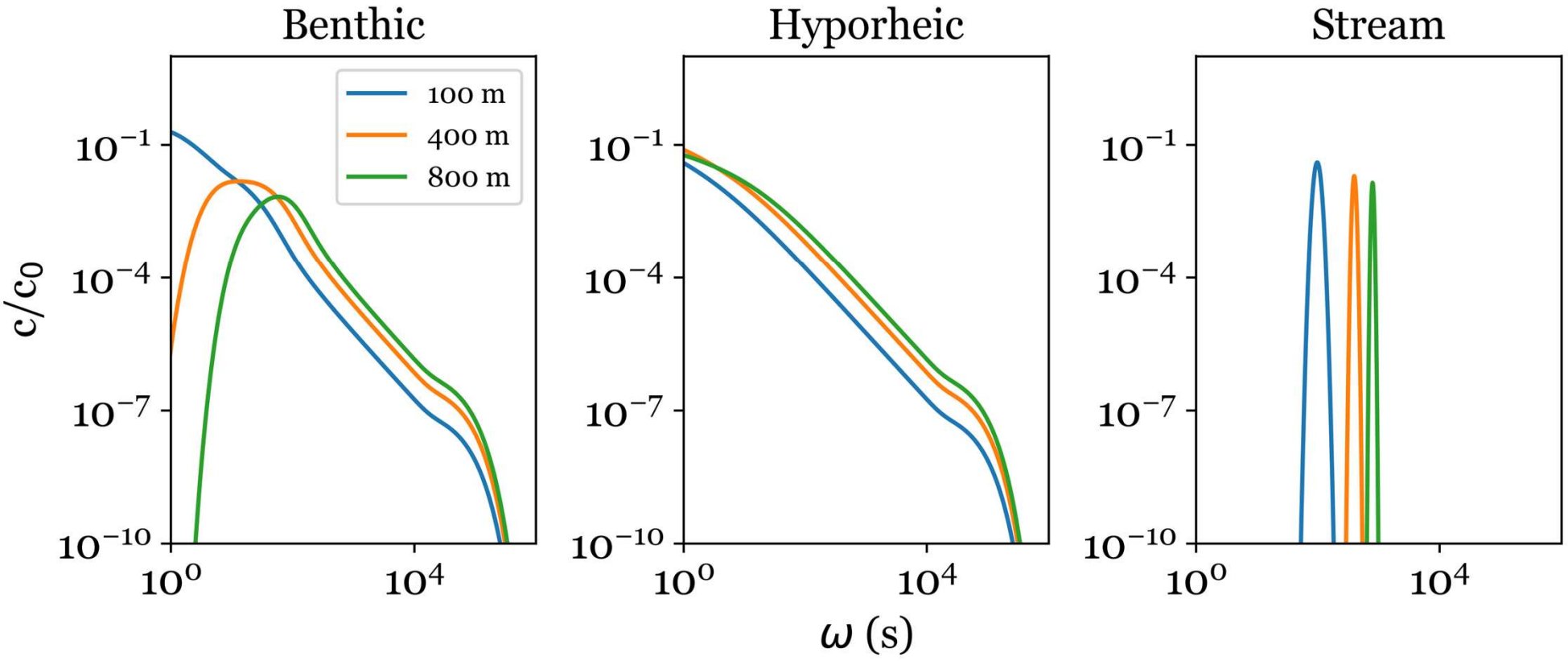
Solve analytically for different combinations of exposure velocity

Conceptual results



v_s = 1.0 m/s
D = 0.5 m^2/s
$D_b = 1 \times 10^{-4}$ m^2/s
$D_h = 1 \times 10^{-5}$ m^2/s
b = 0.05 m
h = 1.0 m
x = 400 m
Coupling term = 2 m

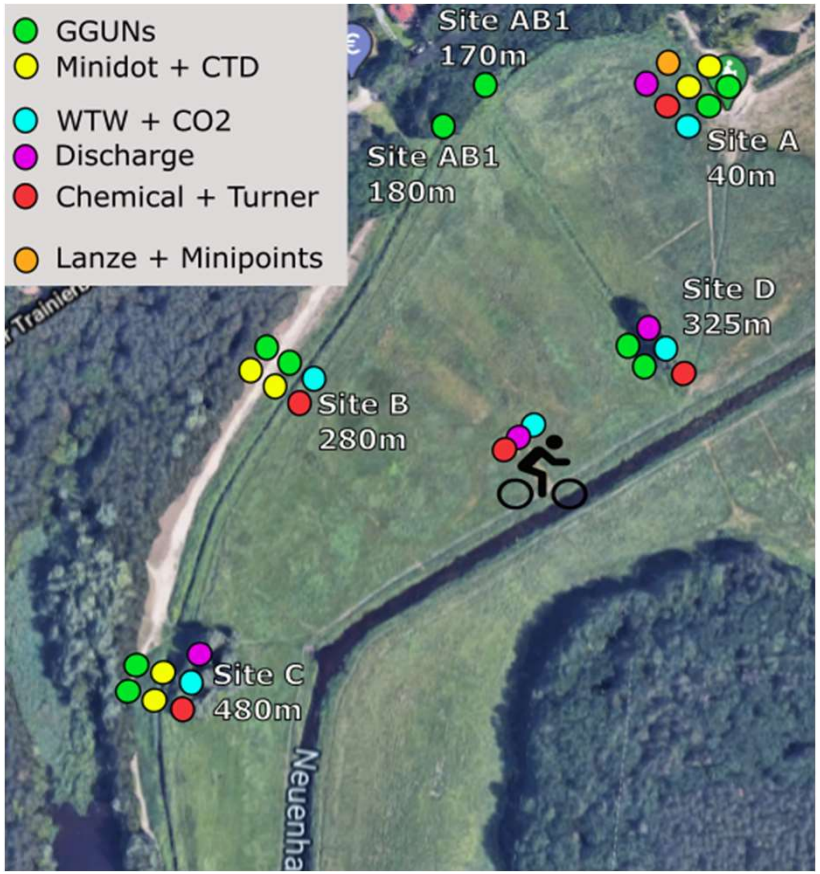
Conceptual results



Field application – Erpe River (side channel)

Höhne et al (2022):

- Stream tracer test accompanied sediment stream bed test
- Injection of Fluorescein and Resazurin for 75 Minutes
  - BTC's collected at 170m, 180m, 280m and 480m
  - BTC collected 325m on return channel



Tracer test interpretation

Exposure time distributions:

- Modified exposure times after Höhne et al. (2021)

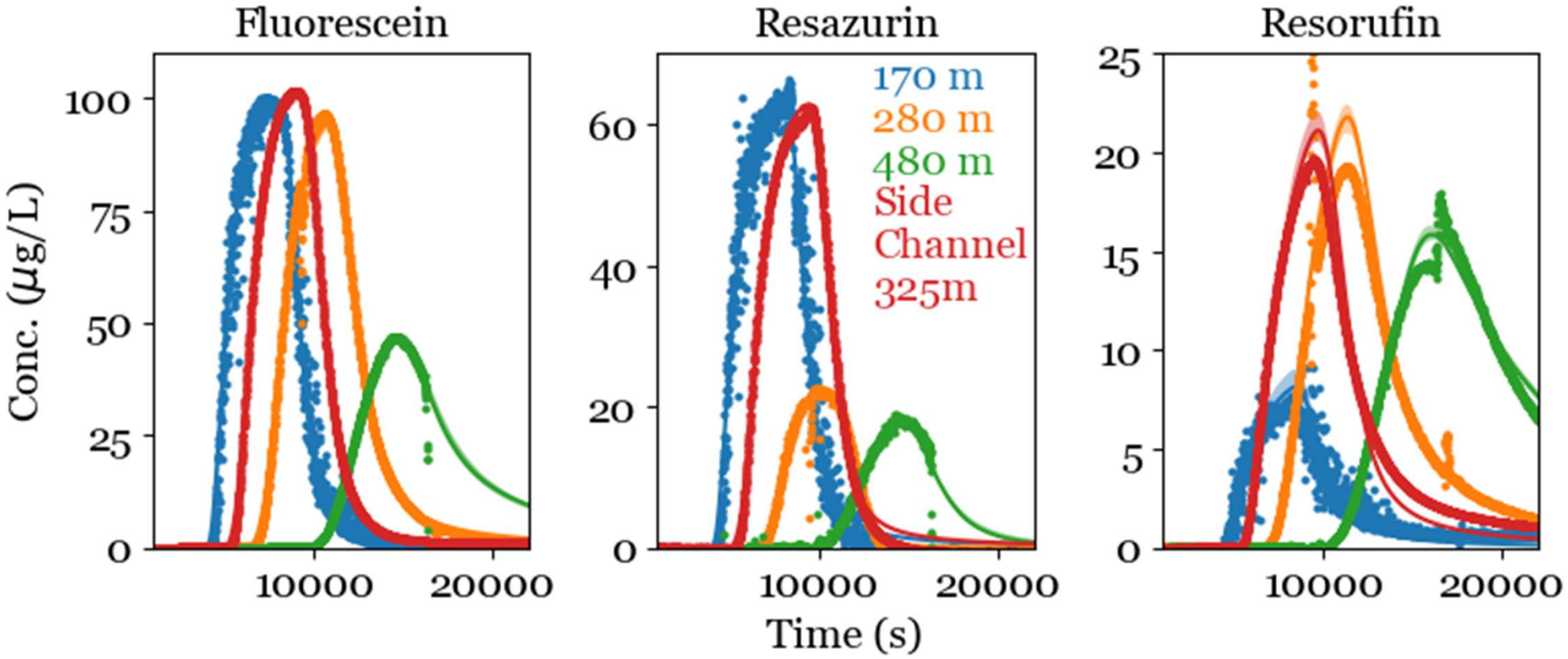
Convolve modified exposure times to develop transfer function

Perform convolution with stream tracer pulse

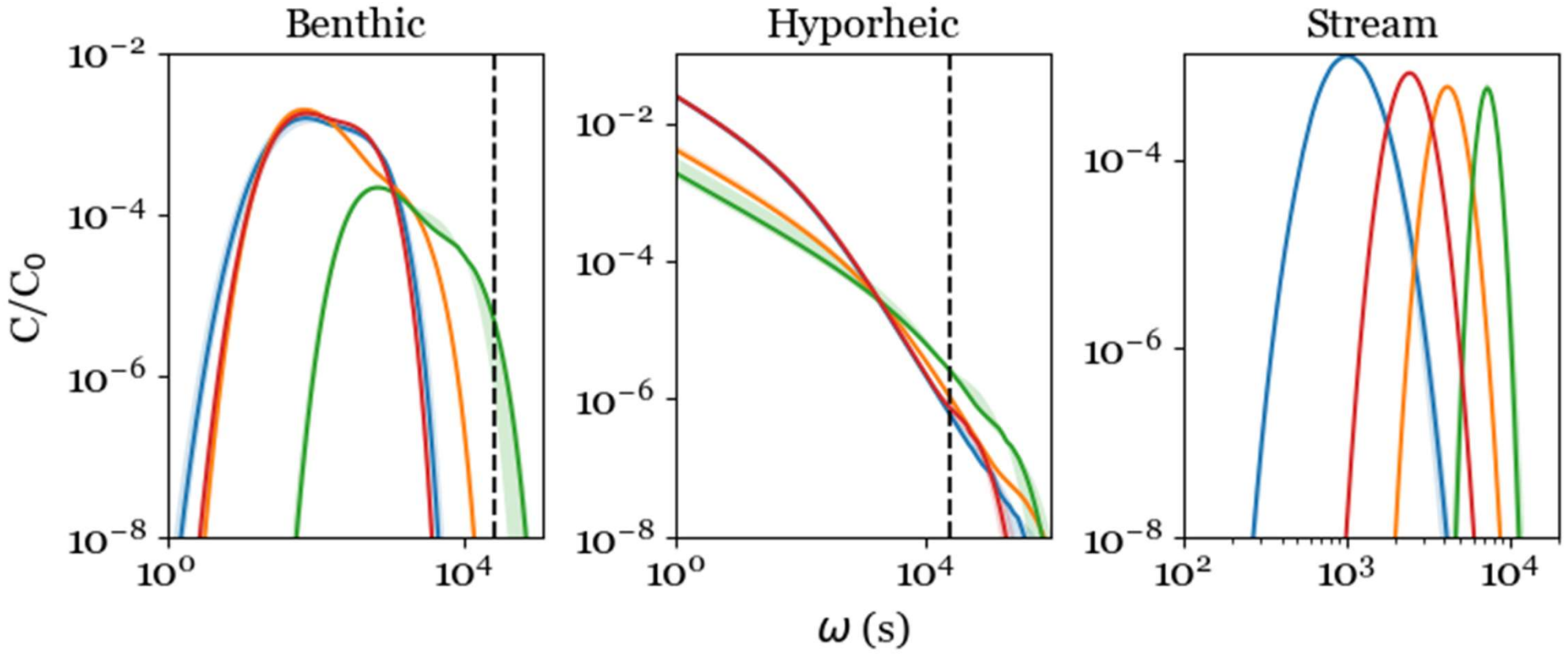
Consider first order reactions and parent-daughter relationships (RAZ/RRU)

Invert/uncertainty analysis with MCMC approach

Results: Model fits

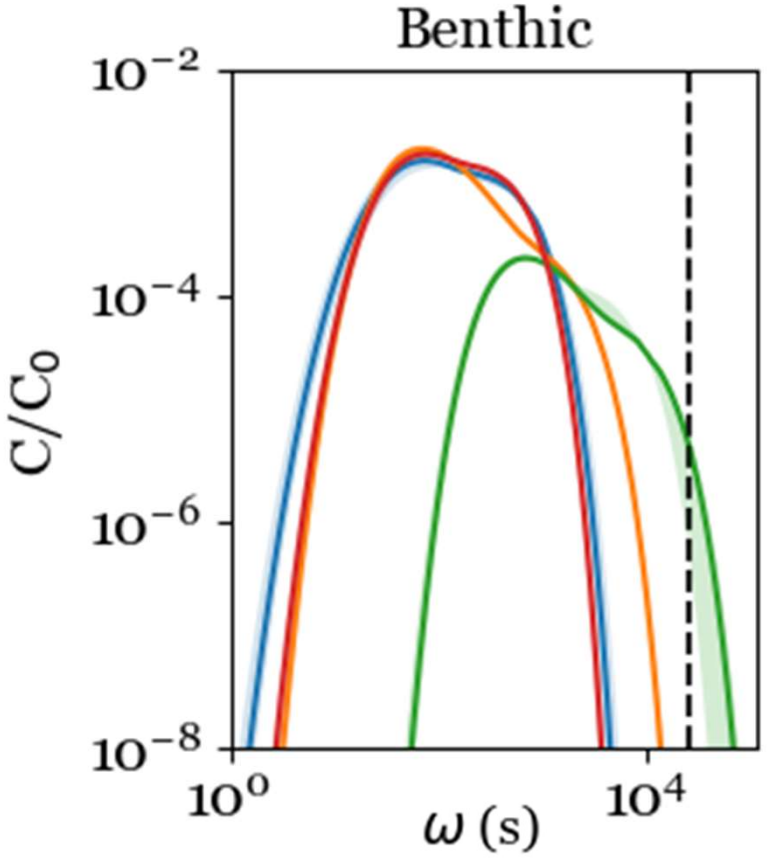


Results: Exposure time



Relationship to point observations

	Gabapentin (µg/L)	Gabapentin-Lactam (µg/L)
Site A - 170 m	1.15	0
Site B - 280 m	0.98	0
Site C - 480 m	0.78	0.11
Site D -side channel	1.22	0.12



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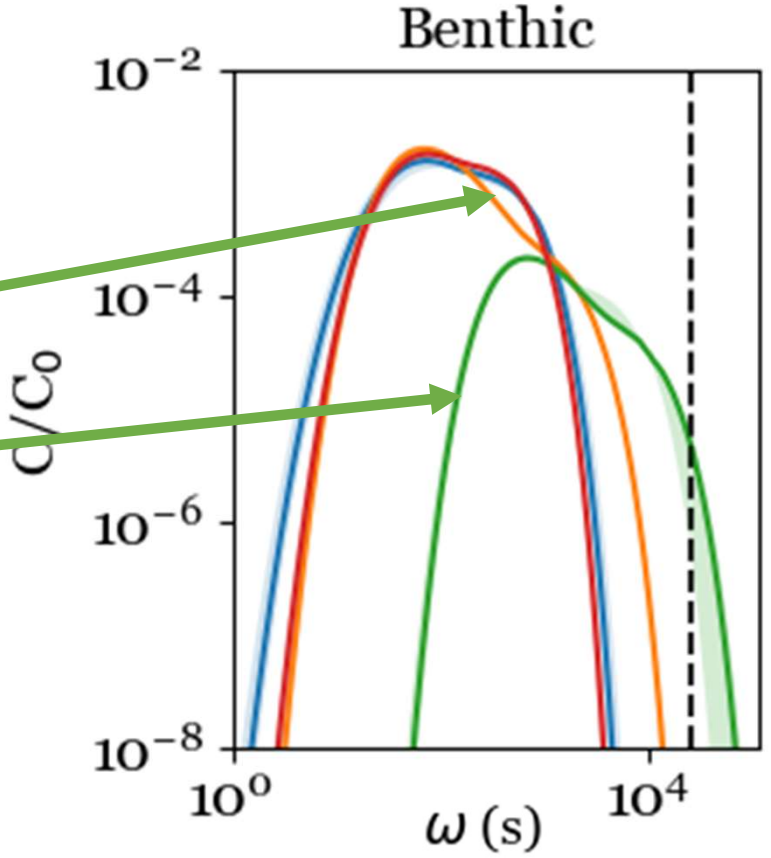

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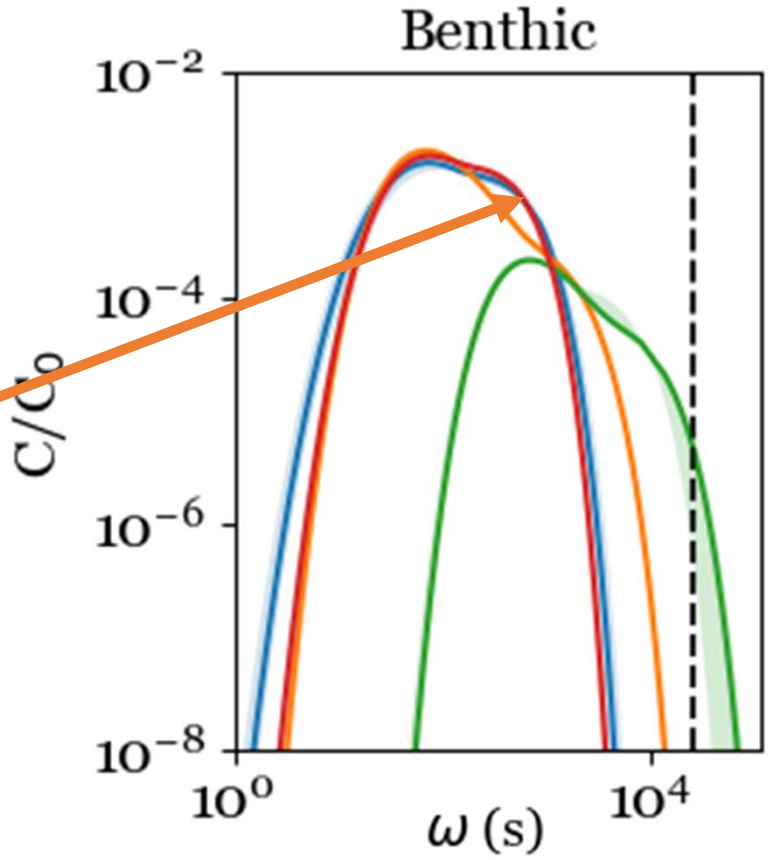

Summary

Exposure time model:

- Allows us to track time spent in different components of the stream

Can interpret multi-tracer tests utilising underlying exposure times

Inverted tracer tests quantify the exposure to benthic zone (microbial metabolism)

Transformation of Gabapentin to Gabapentin-Lactum consistent with sediment studies of Höhne et al. (2022)

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