TUBAF
Die Ressourcenuniversität.
Seit 1765.

TECHNISCHE UNIVERSITÄT DRESDEN

MOBILISIERUNG UND TRANSPORTPFADE VON WASSER UND DOC IM EINZUGSGEBIET DER TALSPERRE SOSA

MOBILISATION AND FLOW OF WATER AND DOC IN SOSA CATCHMENT

TU Freiberg: Jun. Prof. Dr. Conrad Jackisch und Jun. Prof. Dr. Maximilian Lau,

Universität Potsdam: Sophie Stephan

Supported by: Karsten Kalbitz, Tobias Hrouska, uvm.

Funded by DFG Deutsche Forschungsgemeinschaft German Research Foundation

Universität Potsdam

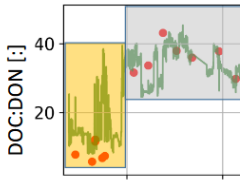
LANDESAMT FÜR UMWELT, LANDWIRTSCHAFT UND GEOLOGIE | Freistaat SACHSEN

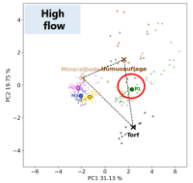
SOSA-DOC knowledge hitherto

(based on TUD project):

Mineral soils

Organic soils





1 identity of source

2 dynamic of source

3 activation of source

but unknown still:

interaction of source *and* event dynamics

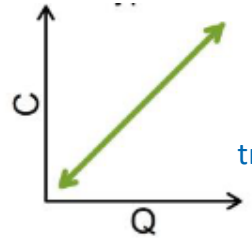
1-Year monitoring and experimental project to complement "Phase I" and prepare "Phase II"

Event flow is important for DOC dynamics

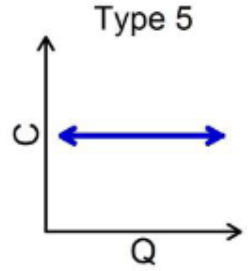
c-Q relationships characterise such events

3 different possibilities:

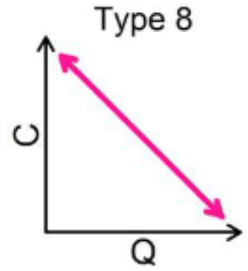
c: concentration (mg / L)
Q: flow (L / min)



Enrichment
transport-limited mobilisation



Neutral
homogenious distribution in surface and subsurface



Dilution
source-limited m.

Pohle et al., 2021 (WRR, amended)

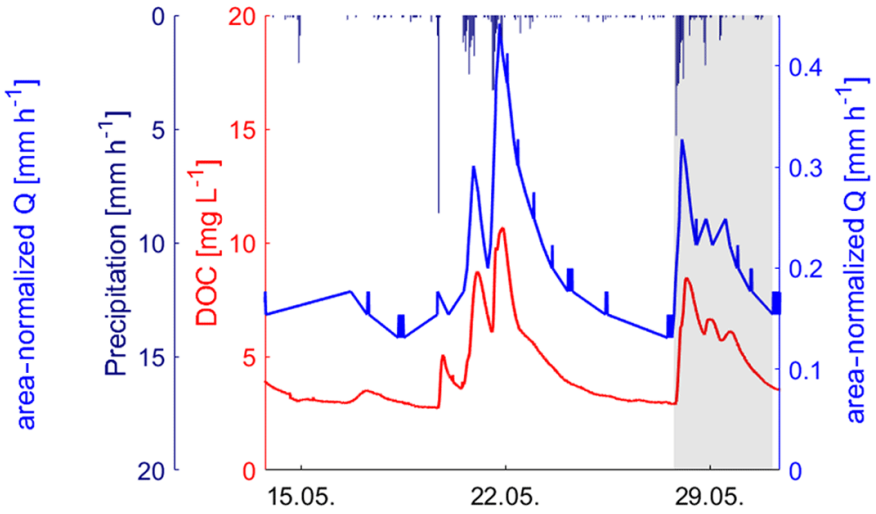
Event flow important for DOC dynamics

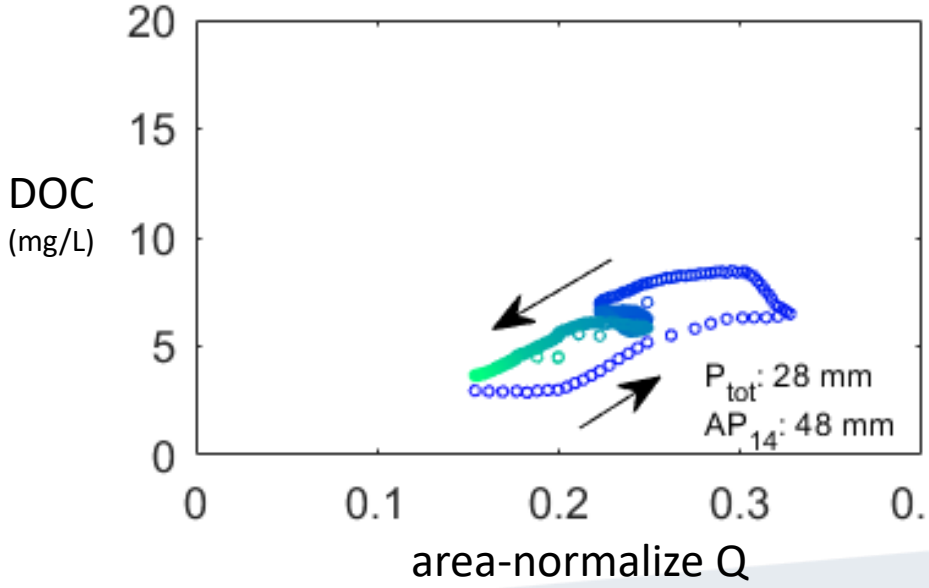
Hydrologische Events bringen wichtige DOC Frachten

DOC <u>enrichment</u> during event is often observed

peaks in flow and concetration

many examples in headwaters: e.g., in steep, forested catchment in Bavaria

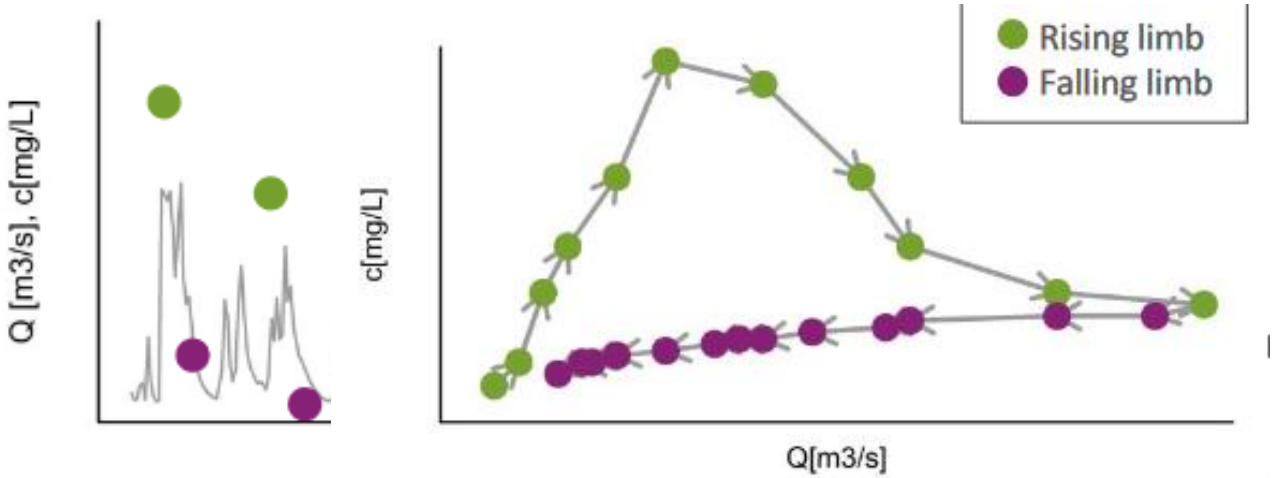


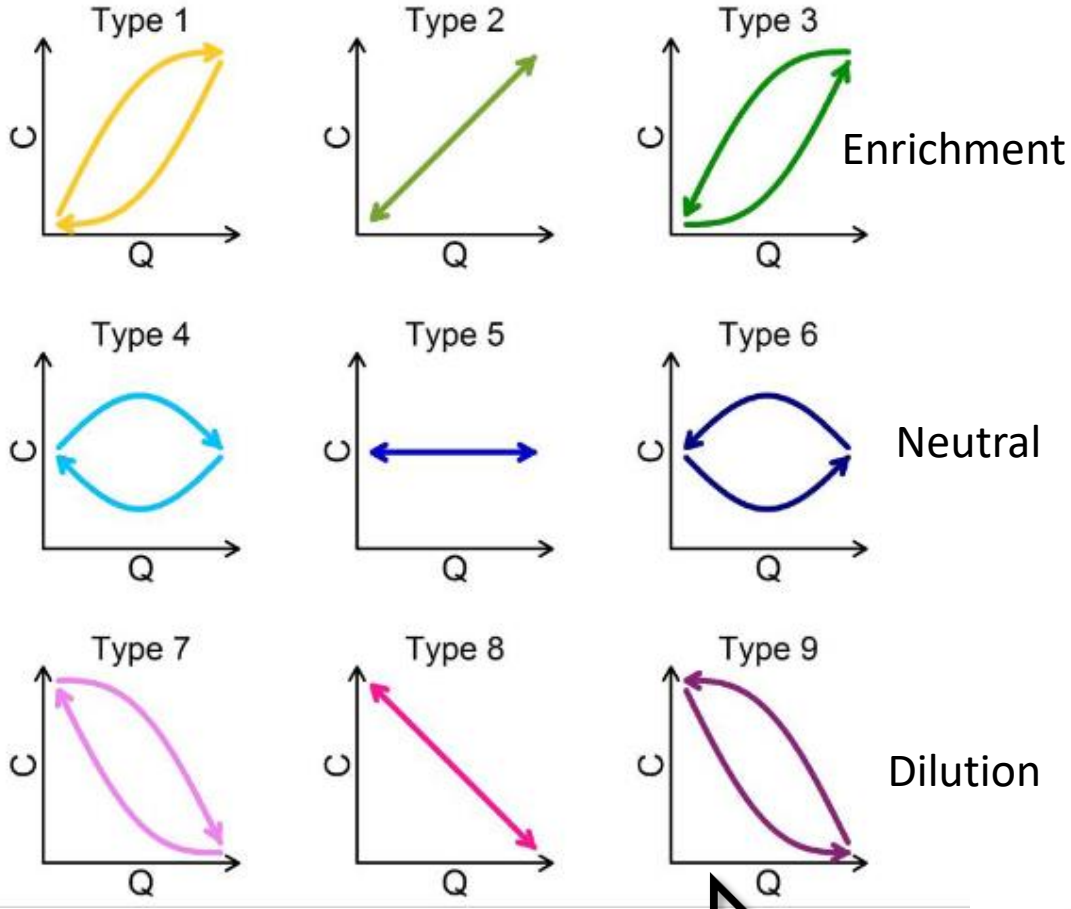


Katharina Blaurock et al., 2021, HESS (excerpt)

Event flow conceptualisation

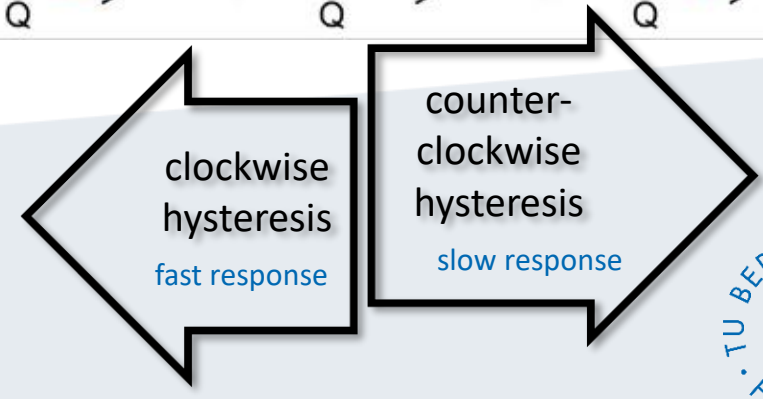
Klassifizierung hydrologischer Events





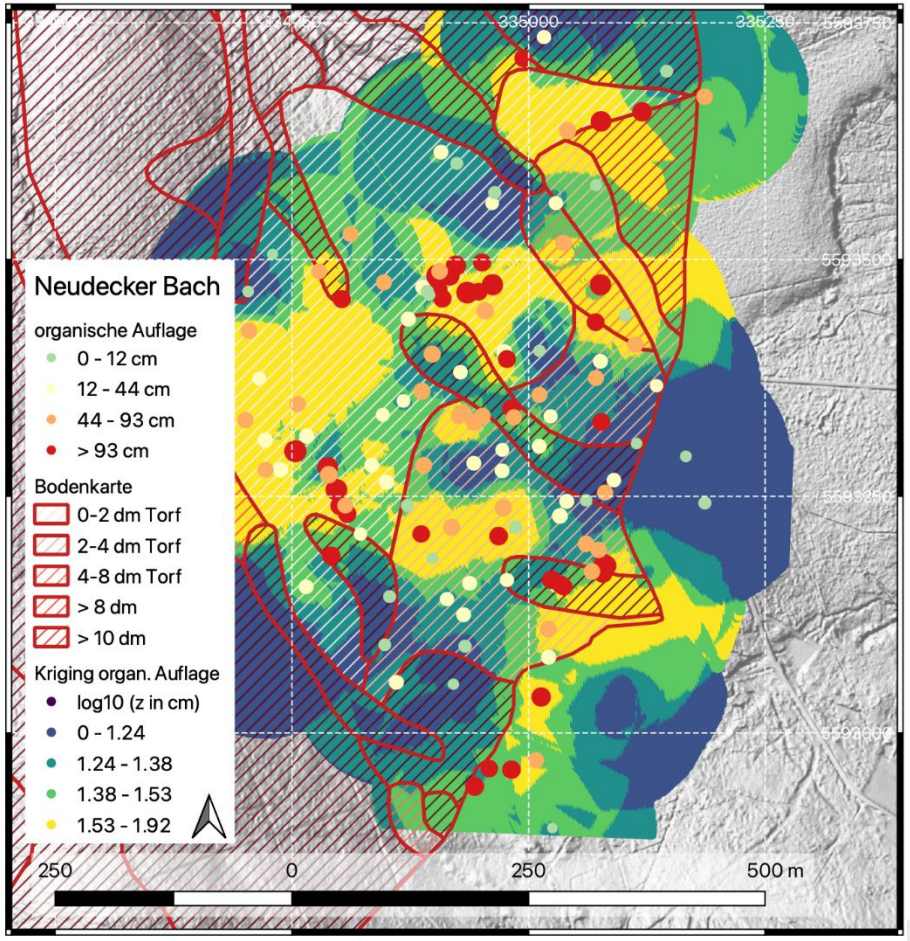
c-Q relationships

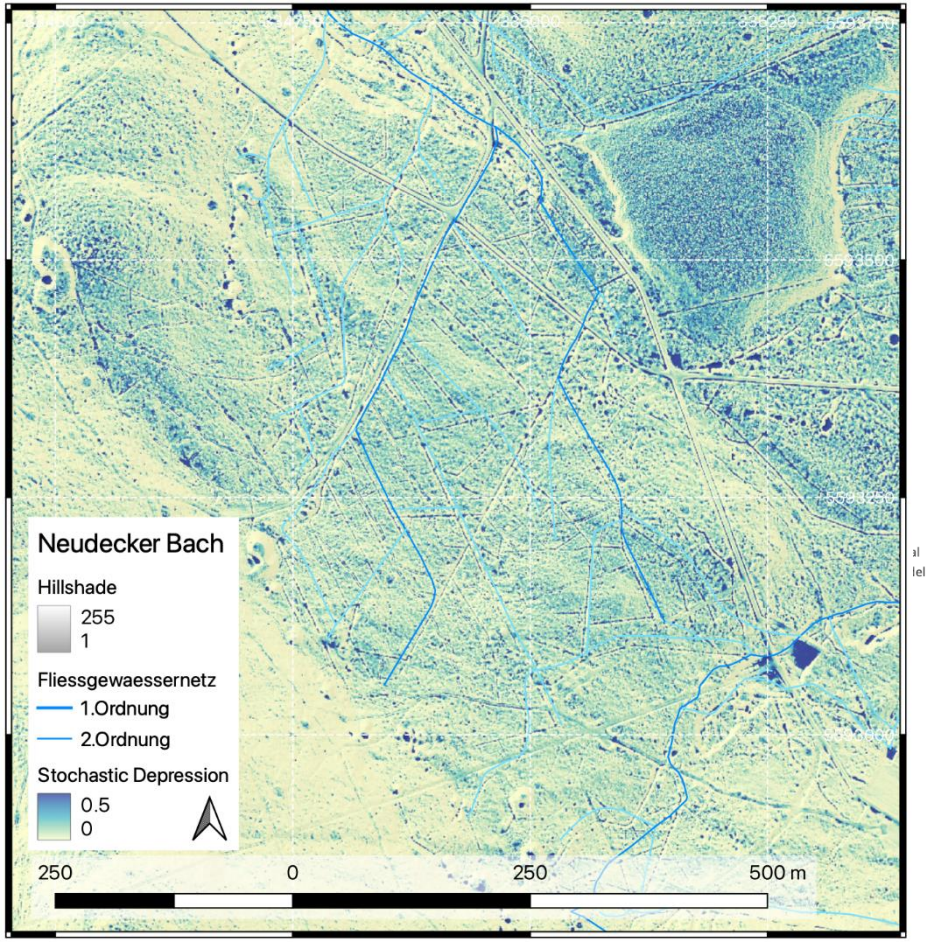
- sophisticated theoretical concept in stream hydrology
- help interpret observations across multiple scales
- sufficient to understand interplay of source *and* event?



Pohle et al., 2021 (WRR, amended)

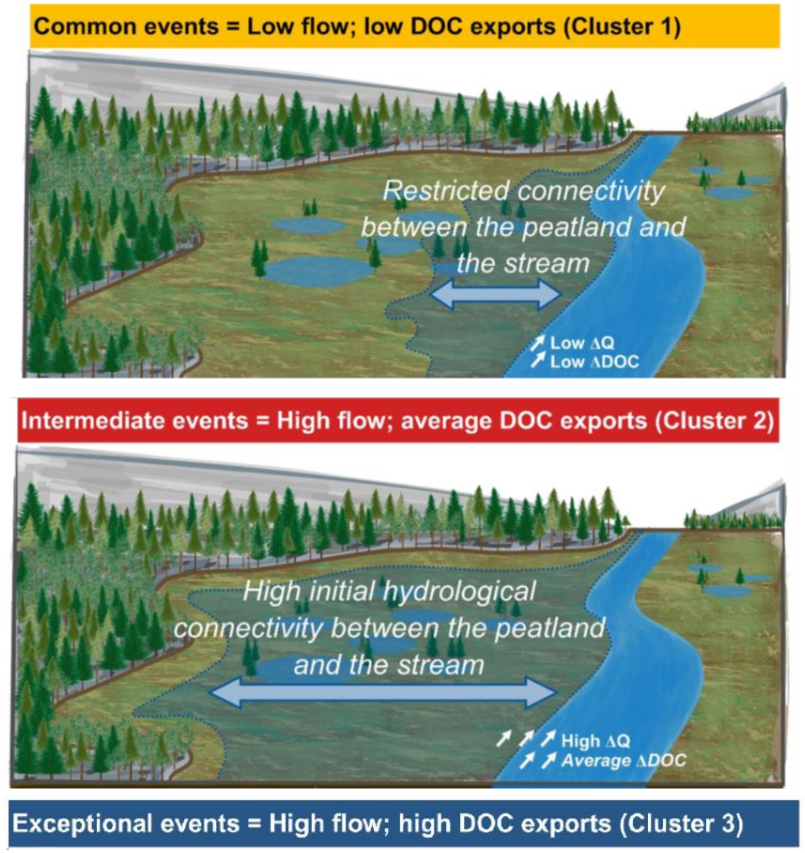
Sources, patchiness and connectivity
Quellen, Mosaikartigkeit und Konnektivität





- abundant depressions (potential wet spots)
- Again variable with no clear connectivity patter

Lateral Connectivity
Laterale Konnektivität



lateral (horizontal) connectivity can help to understand event character

- shown intuitivly in peatlands: water availability before event determines DOC export severity
- limitation: peat is relatively homogenious and porouse
- Sosa: more complicated matrix, but similar mechanisms at play ?

https://hess.copernicus.org/preprints/hess-2022-426/
Prijac et al. 2023 (HESS, preprint)

Project 'soil hydrology': Addressing missing processes on the critical scale

Teilprojekt 'Bodenhydrologie' schließt Lücken in Prozessverständnis auf der entscheidenden "plot"-Skale

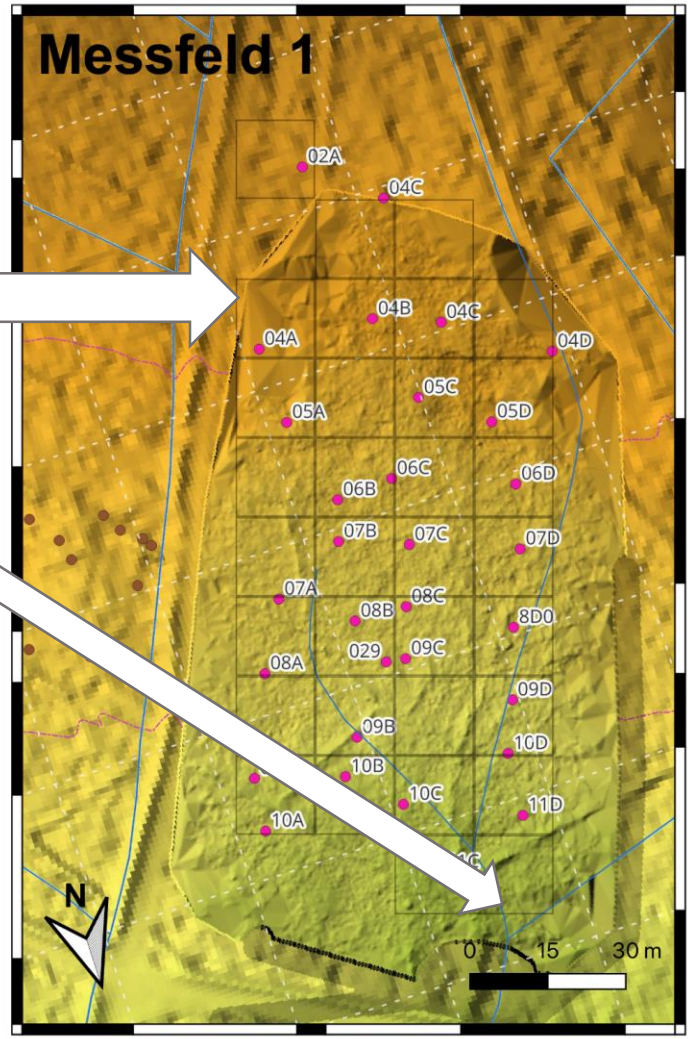
- Our approach to measure event and source activity: plots ("Messfelder")
- Because both mineral and organic soils are important: two of them
- Closes the gab in current concept:

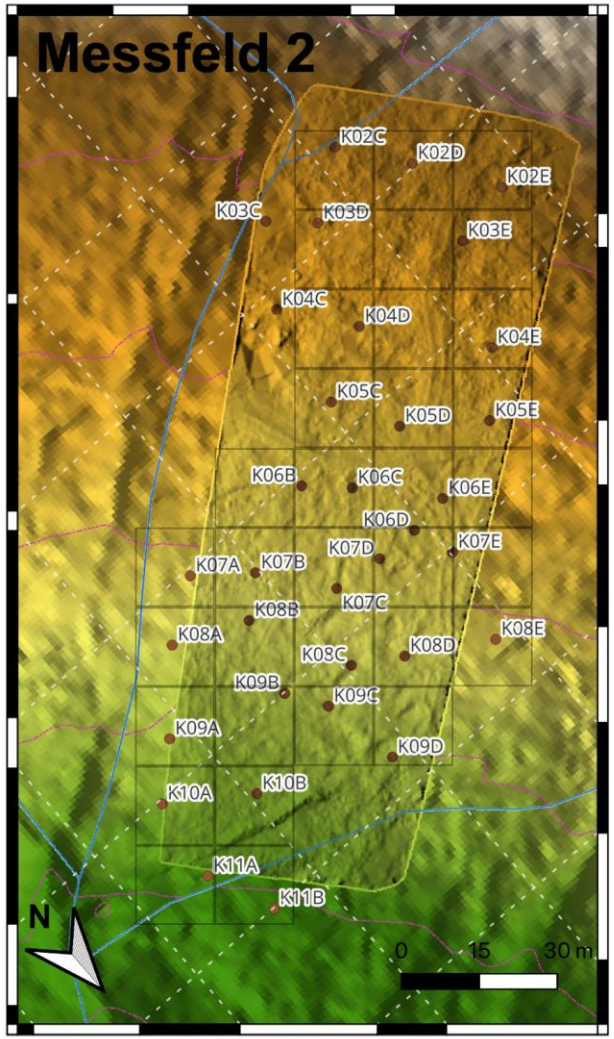
source (soils, meter-scale)
<<
"plots" (hectar-scale)
<<
outlet (reservoir, catchment scale)

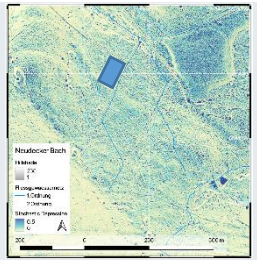
Instrumented grit points

Gauged headwater catchments

Contrasting locations





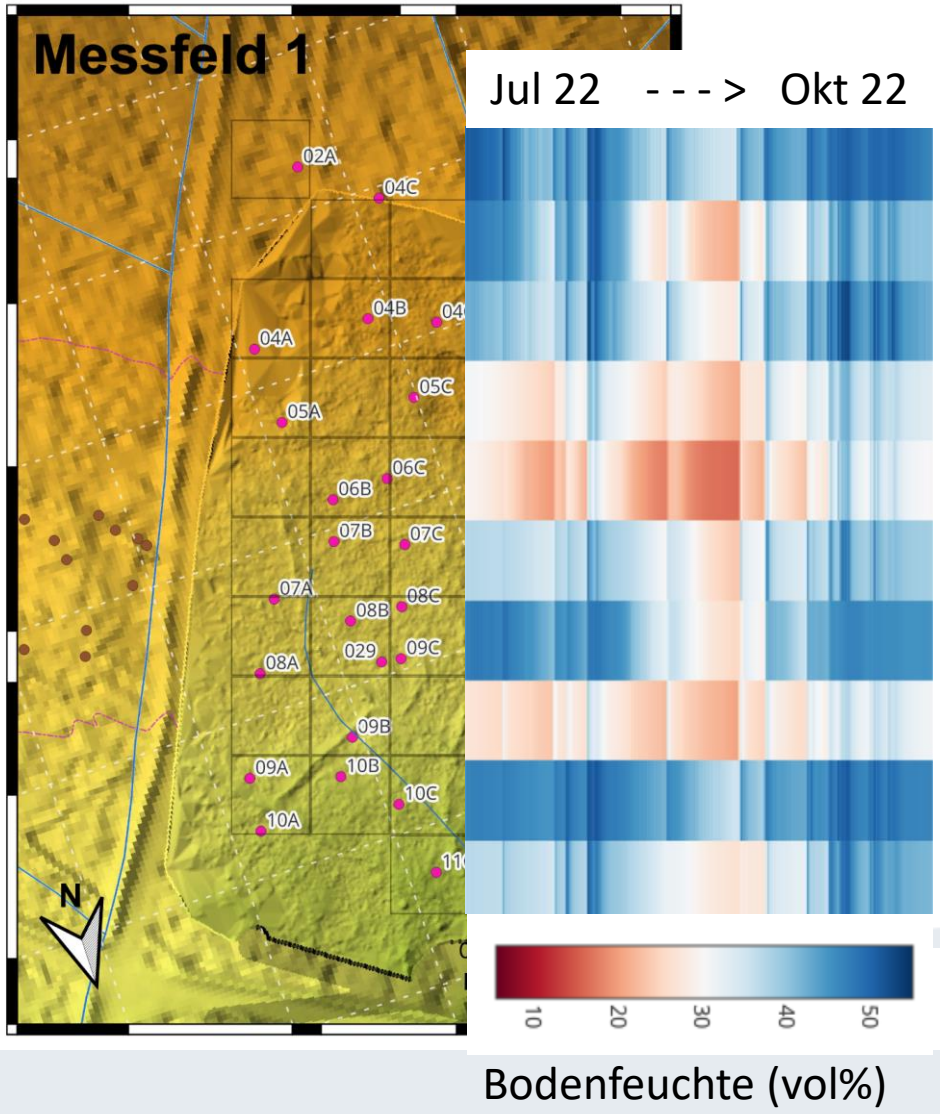


Monitoring along central transect

Monitoring entlang der zentralen Transekte

- Simple soil moisture, radiation and temperature sensors
- Time-series for each variable
- Substantial heterogeneity within one site

Instrumented grid points

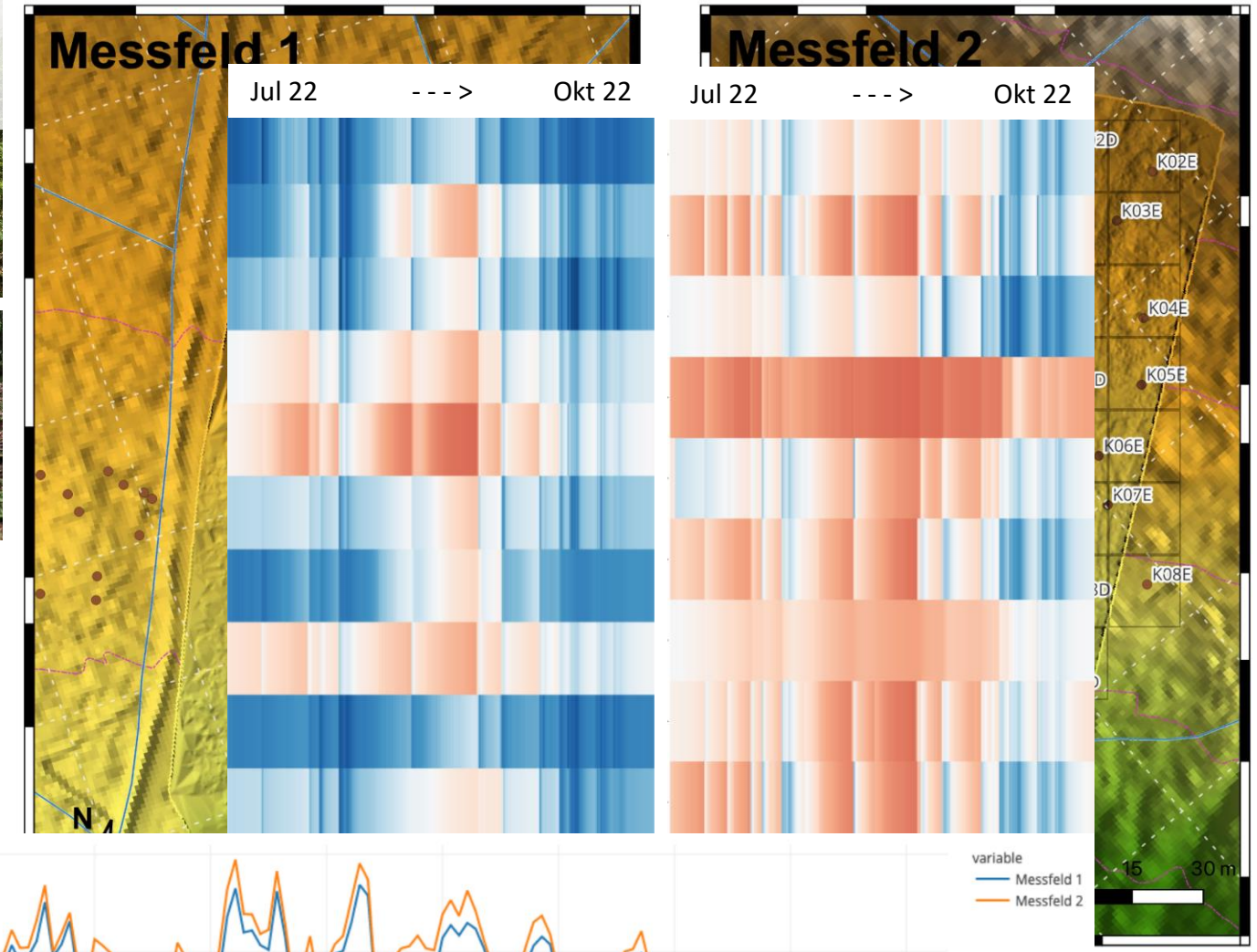


Project 'soil hydrology'

Monitoring along central transect

Monitoring entlang der zentralen Transekte

Instrumented grit points



However, clear difference between the two sites:

- Organic site ► less steep, more moist, cooler
- Mineral site ► steeper, dryer, warmer

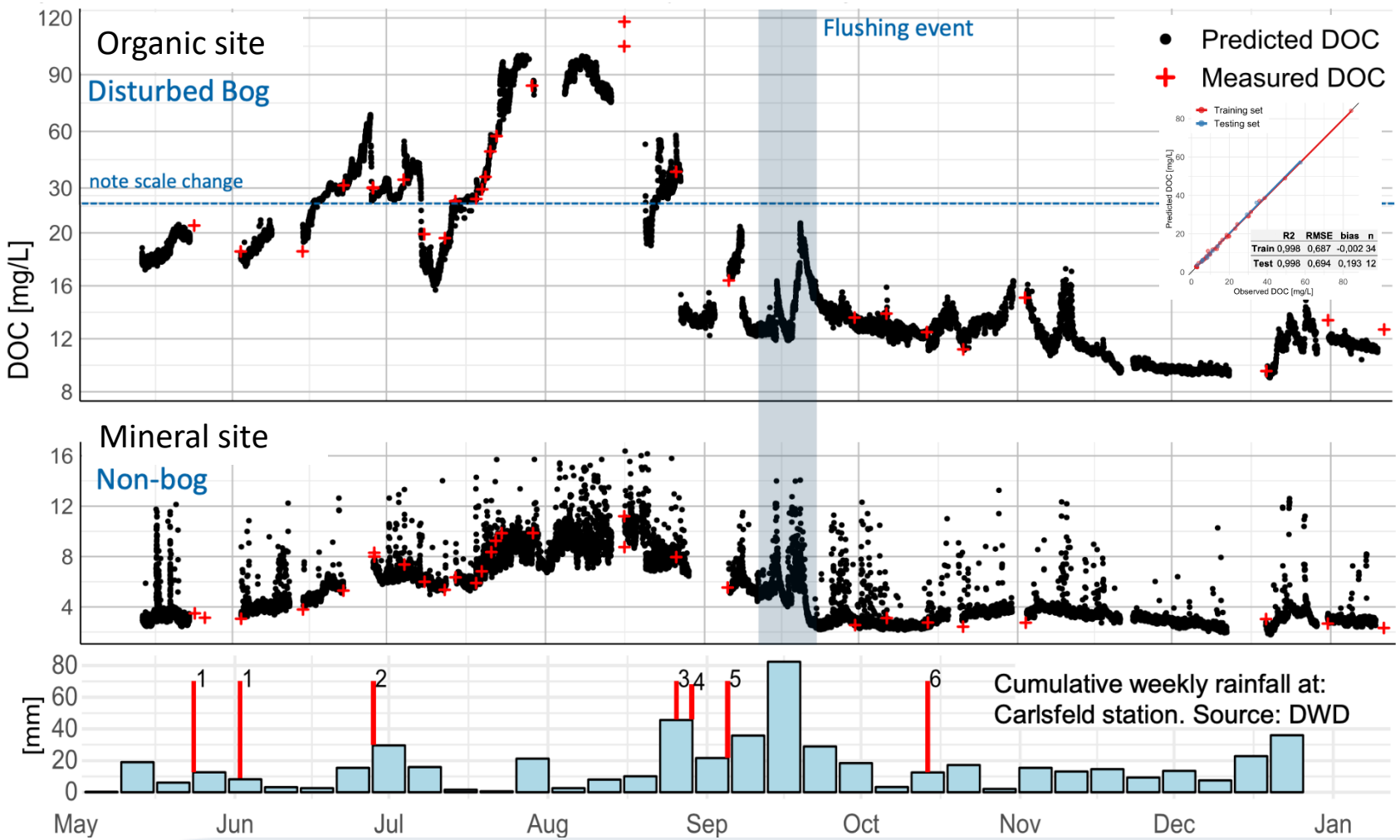
Project 'soil hydrology'

Outlet DOC dynamics

DOC Dynamik am Auslass

Spectro:lyser

- Organic site: higher overall DOC concentration, higher peaks
- Mineral site: lower overall DOC concentration, more scatter (at low level)



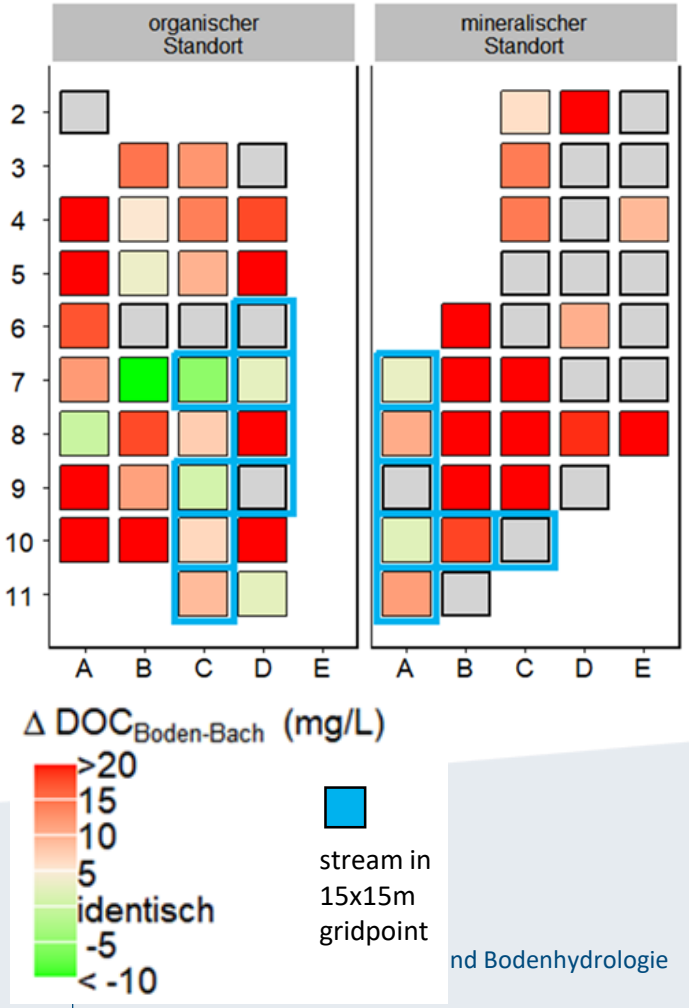
"Messfelder" show limited spatial coupling between soil and stream

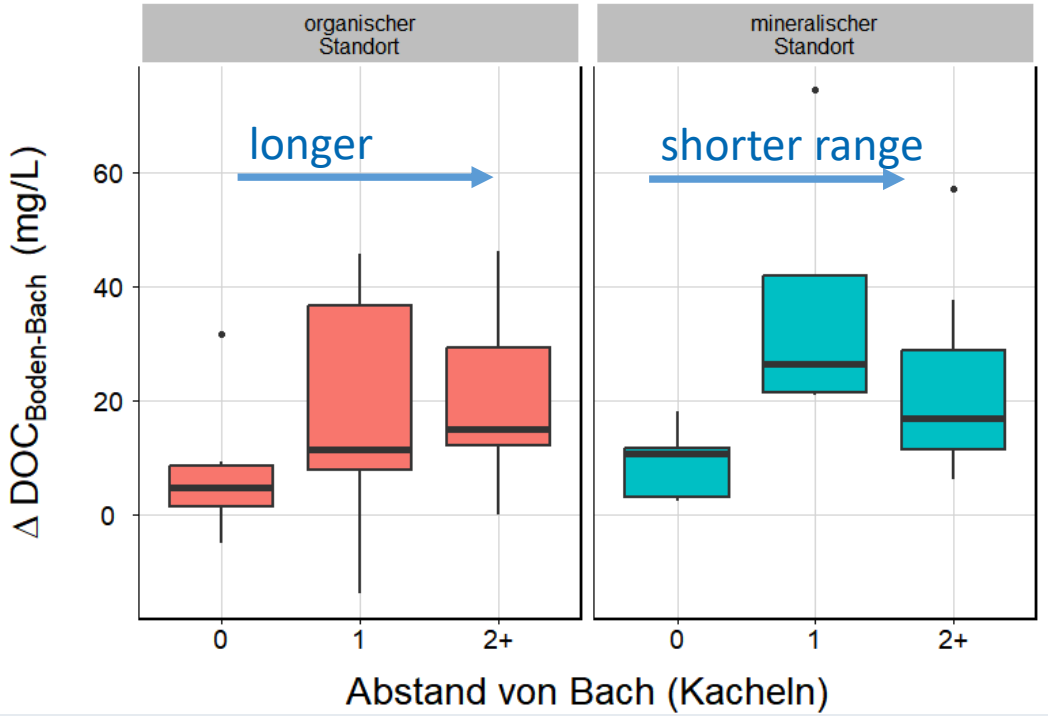
aquatisch-terrestrische Kopplung nur über kurze Distanz

source-event-dynamics
1

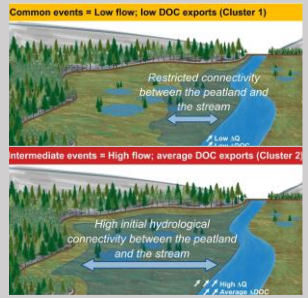
Coupling between soil and stream water:

- more often are concentration differences smaller close to the stream
- otherwise is soil DOC usually higher: source





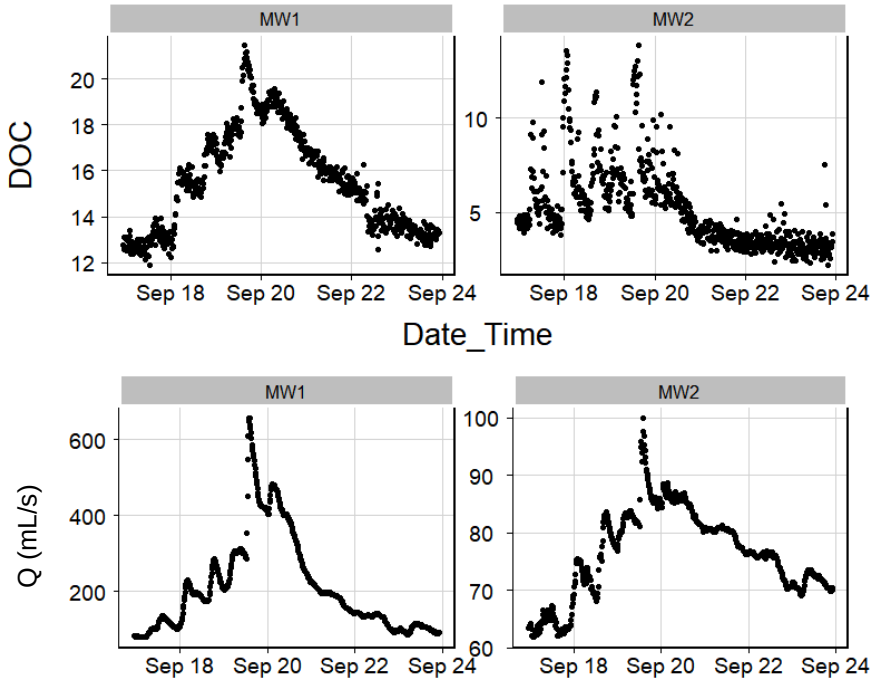
compare to pattern of peat study



Streams show dissimilar enrichment responses

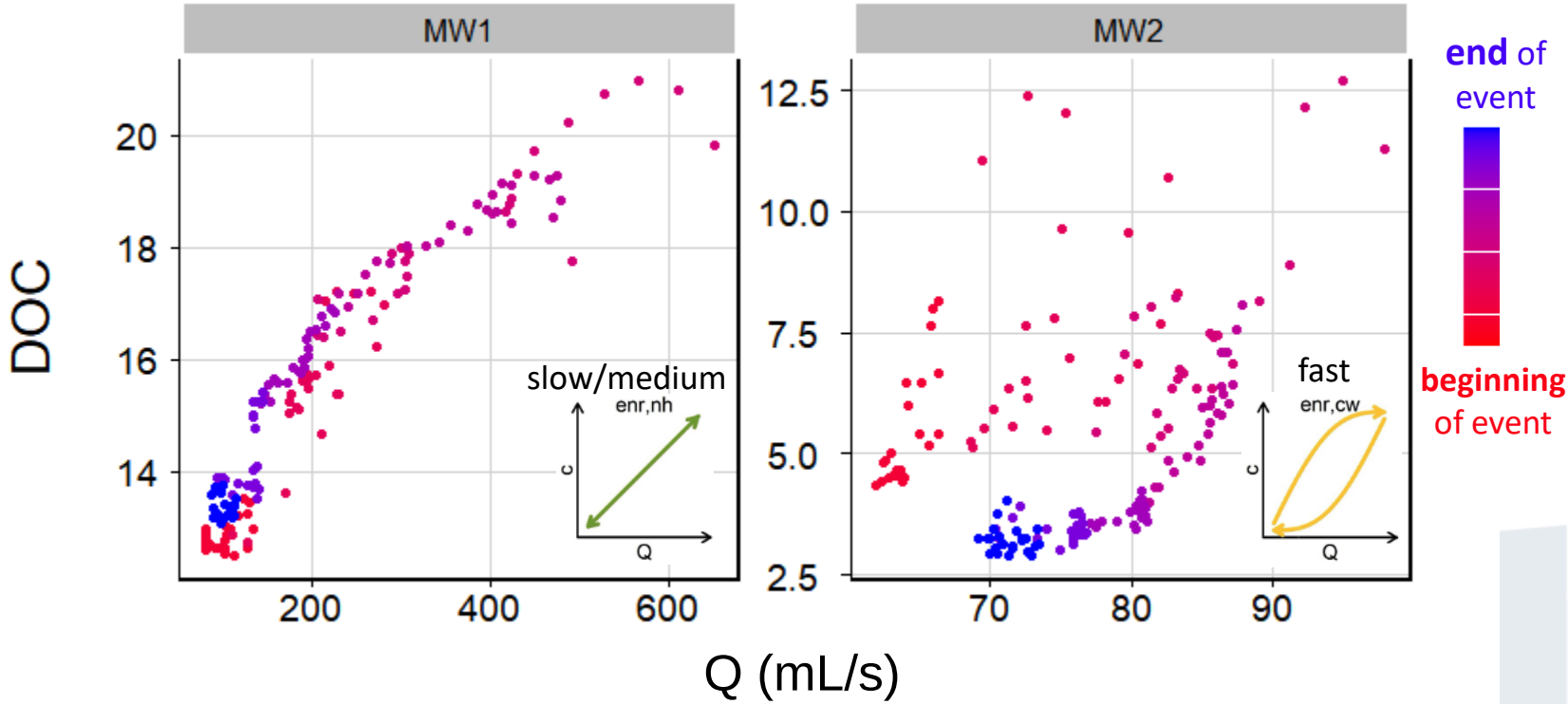
Abfluss zeigt unterschiedliches Anreicherungsverhalten

source-event-dynamics **2**



Difference in responses between sites

- both with enrichtment but c-difference and different speed of response
- Hydrological situation patch-dependent and important
- 1-yr monitoring not sufficient for adequate insights ▶ irrigation experiments

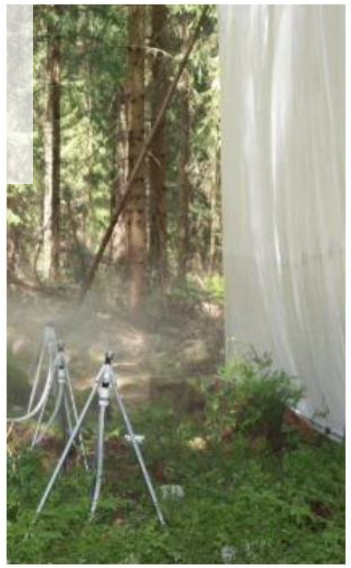


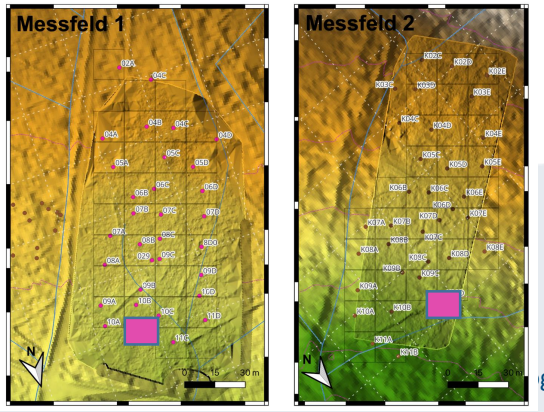
Irrigation experiments at two contrasting sites

Beregnungsexperimente an zwei kontrastierenden Standorten

- 2 irrigation events, 1.5 days break
- lateral passage between irrigation shield and observation trench
- trench in sections and 2 layers (topsoil and expected drainage base layer)

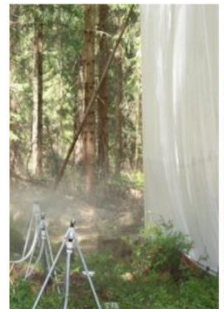
- Full water recovery
- analysis for stable isotopes & DOC
- mobilisation dynamics



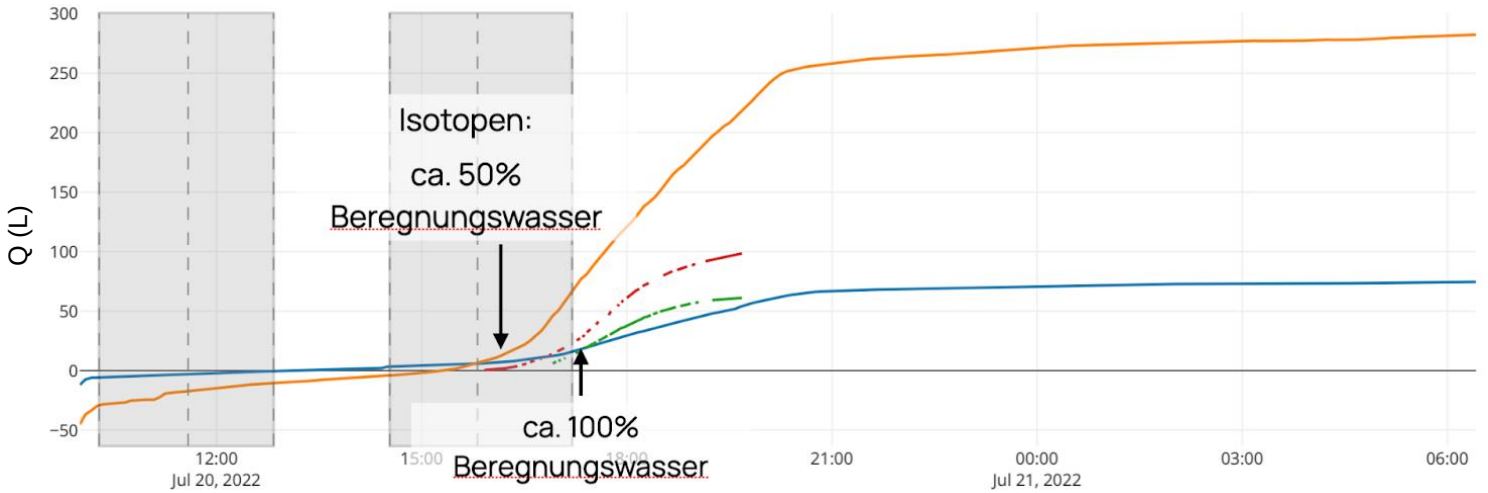


Irrigation experiments: organic site

Beregnungsexperimente: organischer Standort



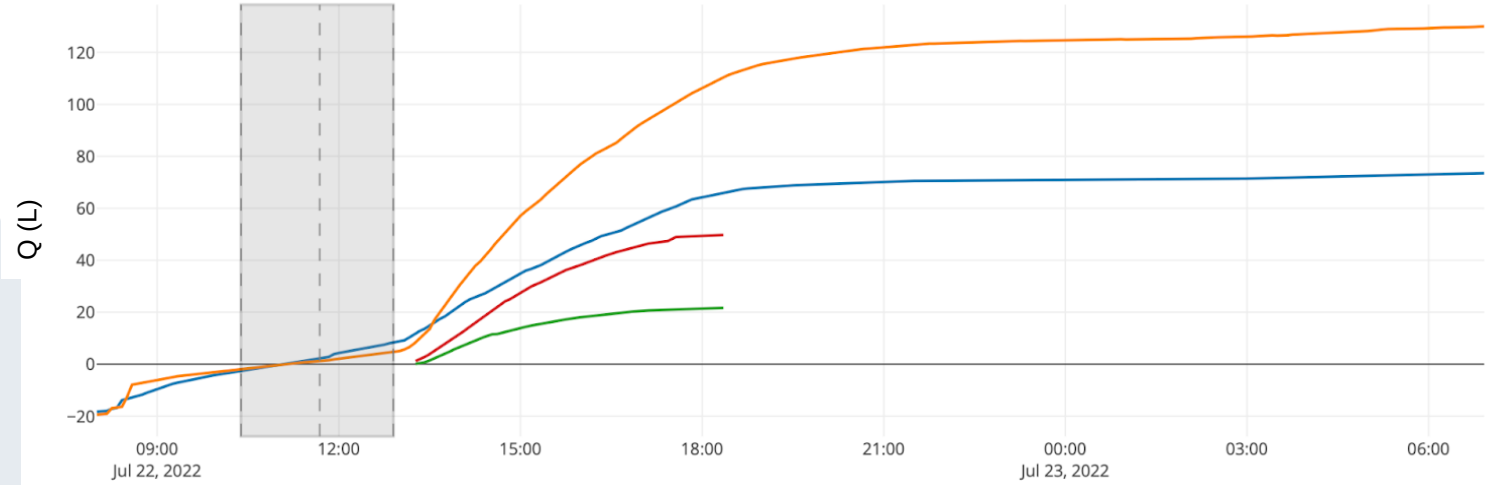
1st irrigation (4m³ in 5h)



- very similar reaction despite different intensities

Experiment	MF1 Ex1	MF1 Ex2
Irrigation	4 m^3, 5 h	2 m^3, 2 h
Recovery	470 L (12%)	265 L (13%)
Reaction after	3 m^3, 4 h	2 m^3, 2 h

2nd irrigation (2m³ in 2h)



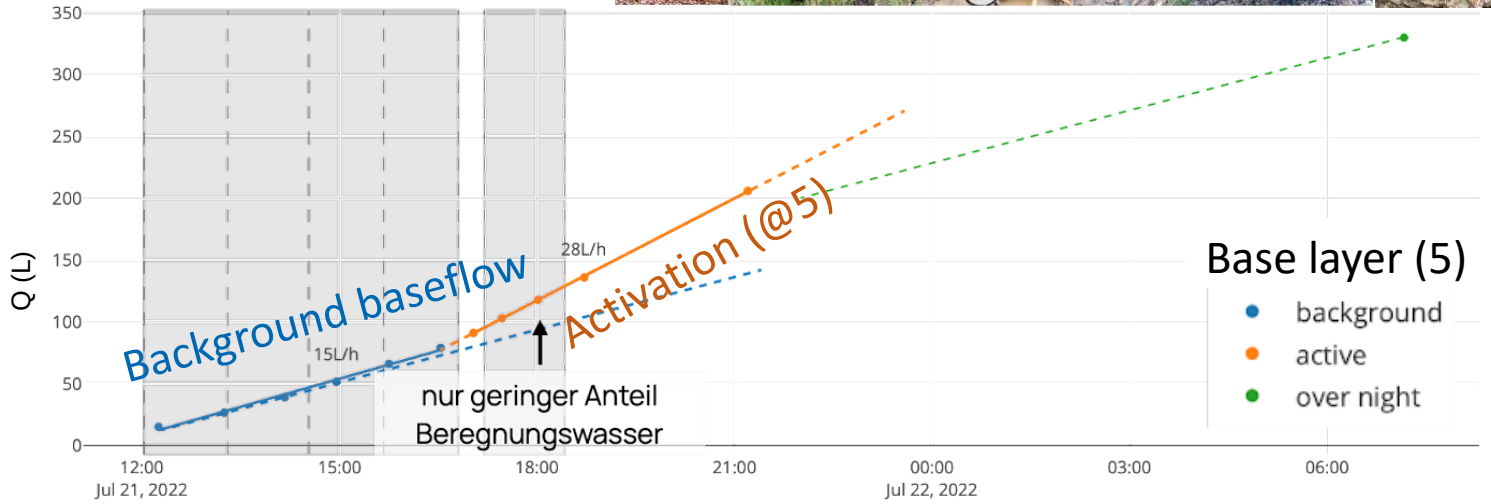
Irrigation experiments: mineral site

Beregnungsexperimente: mineralischer Standort

- very similar reaction despite different intensities
- only very little recovery of irrigation water

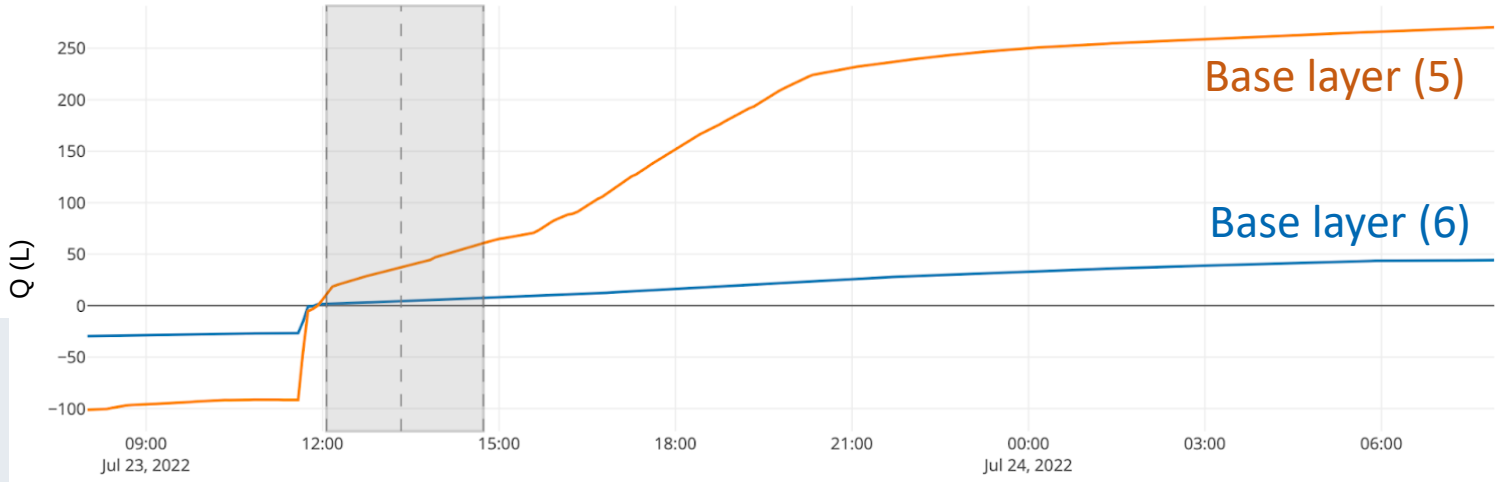
Experiment	MF2 Ex1	MF2 Ex2
Irrigation	5 m^3, 5 h	2 m^3, 2 h
Recovery	78 L (1.6%)	80 L (4%)
Reaction after	4 m^3, 4 h	2 m^3, 2.5 h

1st irrigation (5m^3 in 5h)



Exp.2, MF2, B5

2nd irrigation (2m^3 in 2h)

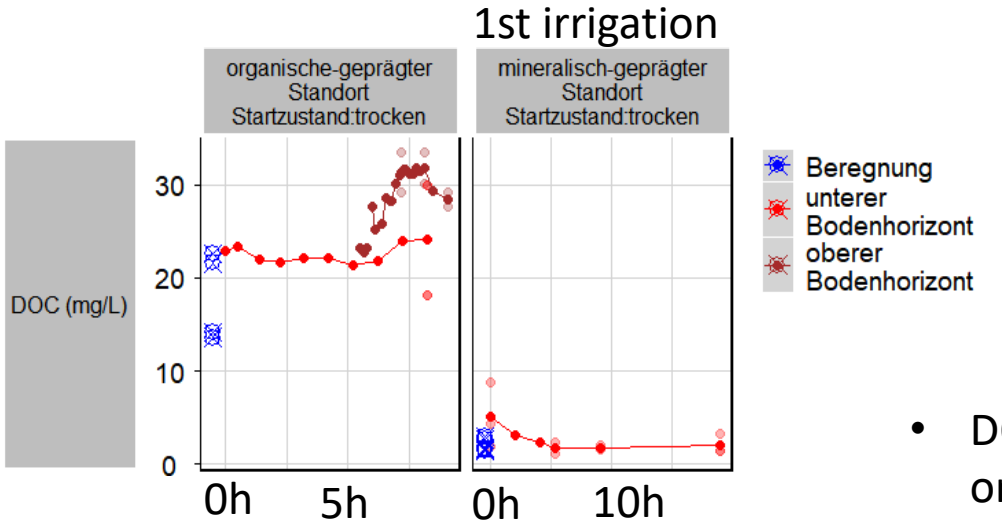


Irrigation experiment show reactive DOC transport

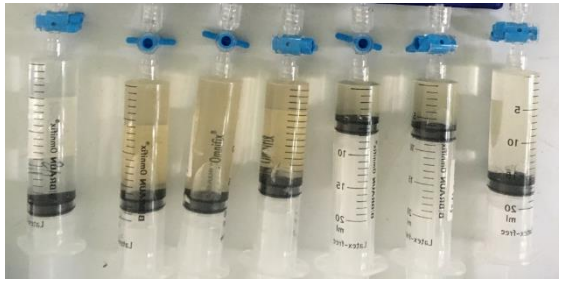
Beregnungsexperimente zeigen DOC Reaktionstransport

artificial rain

d^2H-enriched stream water



⊗ artificial drain →



- DOC measurements above and below the organic/mineral horizon interface
- experiment not optimized for reactive transport: artifical rain = local stream
- organic site: DOC mobilisation
- mineral site: drainage, passage of absorbant layer

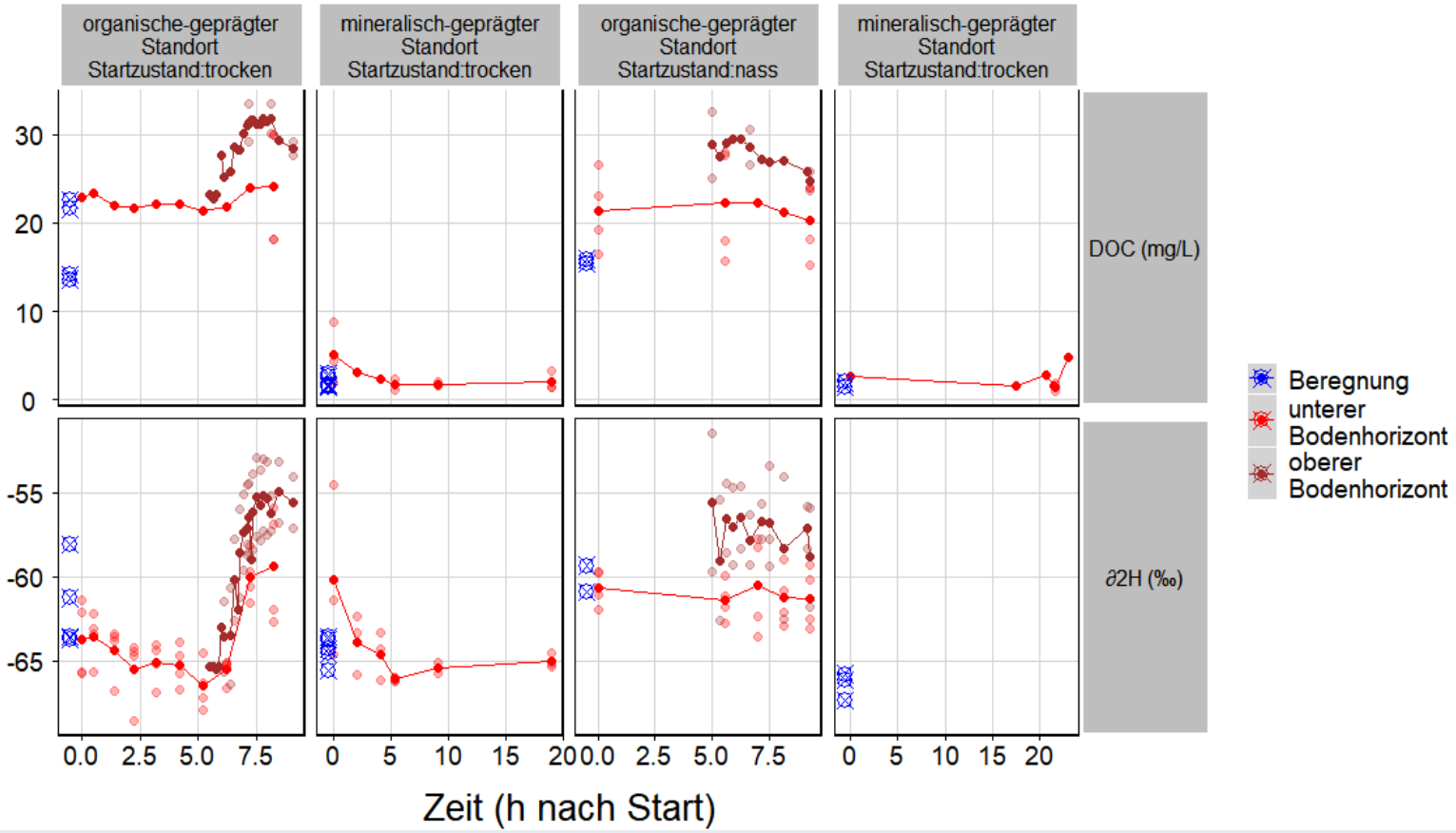
Irrigation experiment show reactive DOC transport

Beregnungsexperimente zeigen DOC Reaktionstransport

Tracking of irrigation water DOC via isotopic label
Precondition determines DOC peak

organic site // wet (more) **DOC mobilisation**
slow top passage ► high loads

mineral site // wet **DOC mobilisation only after intense rain**
slow passage through large volume ► low load



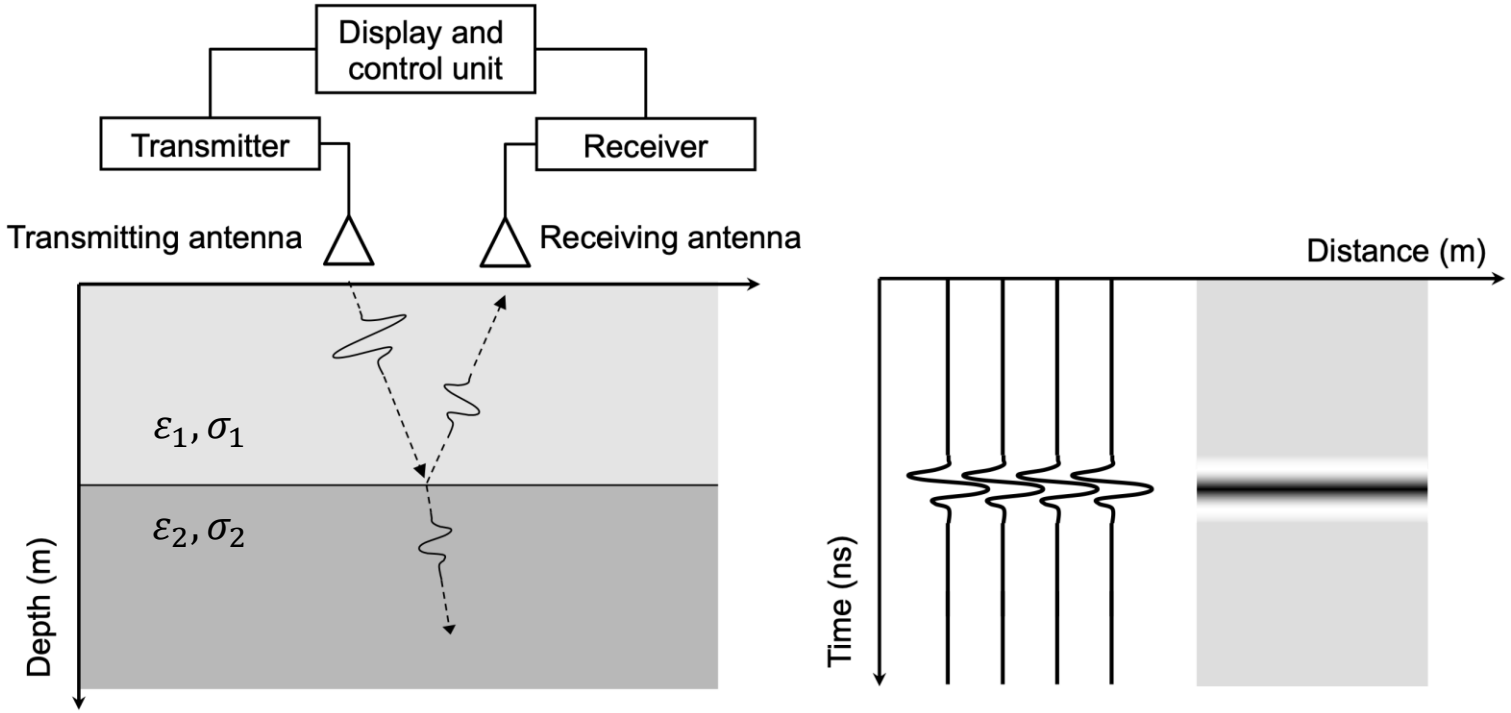
Setup time-lapse GPR: organic site

Aufbau zeitabhängige Bodenradar-Messung: organischer Standort

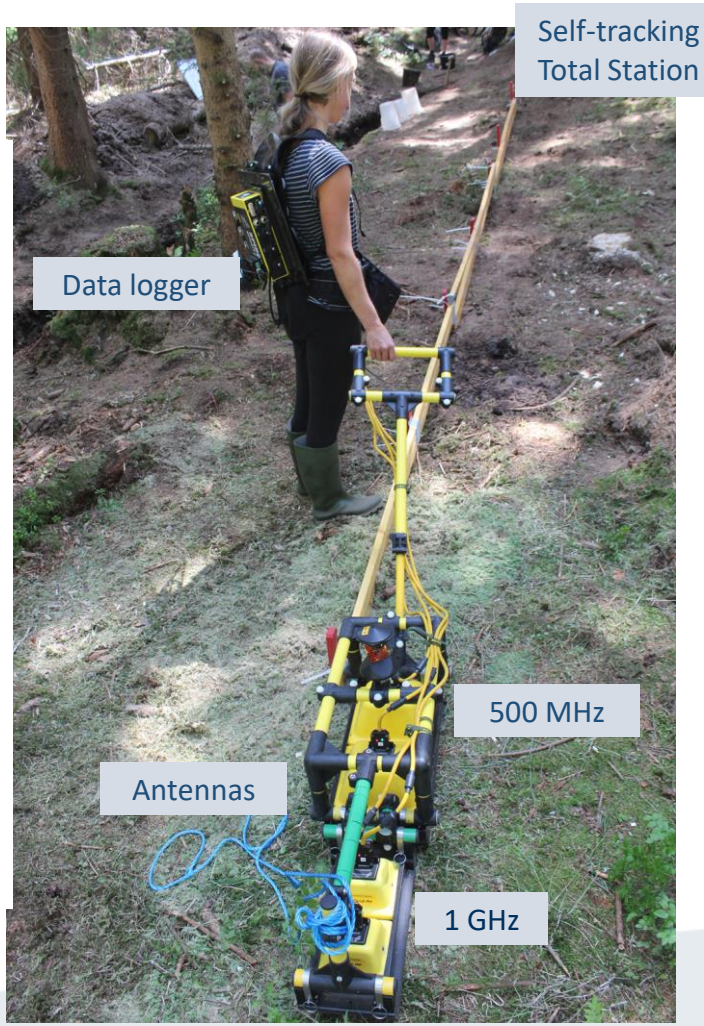
- Repeatable, non-invasive, high-resolution monitoring of soil conditions
- 2 profiles across transfer zone
- Interpolated resolution: 1 cm and 5 min

- Complicated measurement conditions due to dense root network in upper soil and shallow subsurface

Time-lapse GPR: general features
Zeitabhängige Bodenradar Messung: Generelle Eigenschaften

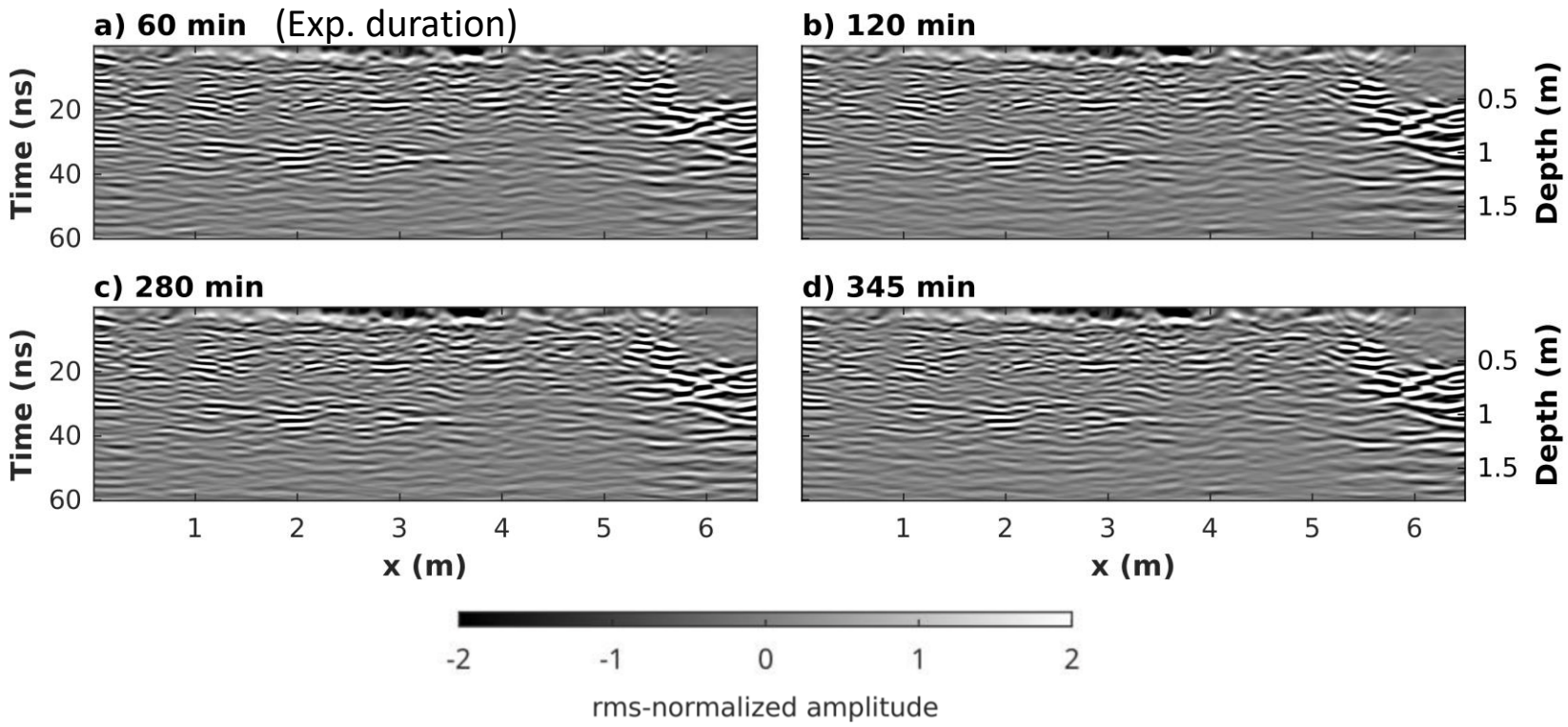


ε - Dielectrical Permittivity
σ - Electrical conductivity



- GPR propagation velocity depends on ε and hence, water content
  → detection of soil water changes

Visual comparison of time-lapse GPR profiles
Visueller Vergleich von GPR-Profilen einzelner Zeitschritte



Problem:

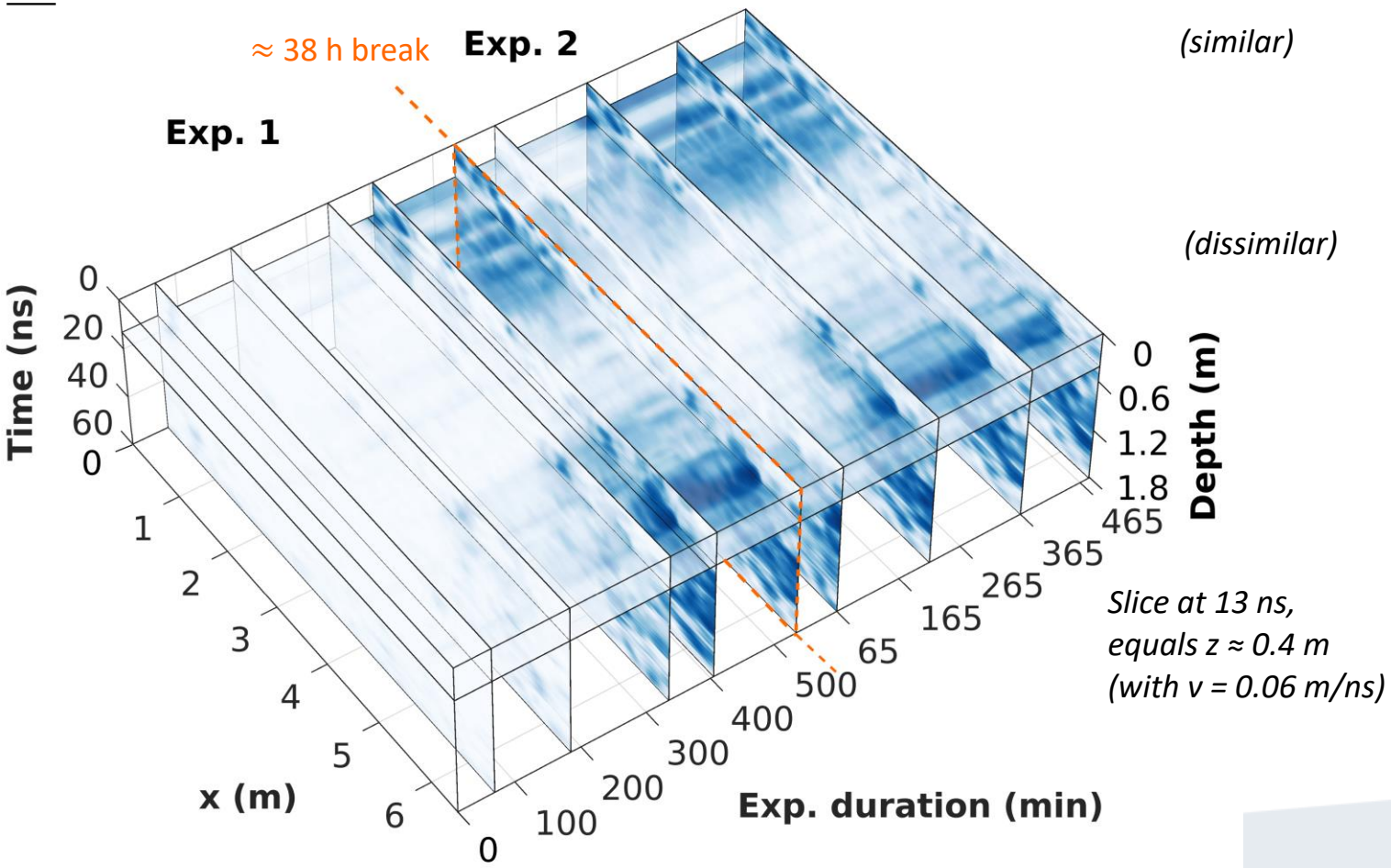
- Difficult to detect changes between GPR profiles related to subsurface processes

Solution:

- Attribute analysis: similarity between two profiles (statistical difference measure)
- **Structural similarity attribute** (SSA) → highlighting traveltime changes induced by subsurface processes (Allroggen and Tronicke, 2016)

3D cube of similarity attribute: organic site, Profile 1 (close to trench)

3D Würfel des Ähnlichkeits-Attributs: Organischer Standort, Profil 1 (nahe Trench)



(similar)

(dissimilar)

Slice at 13 ns, equals z ≈ 0.4 m (with v = 0.06 m/ns)

1st irrigation (Exp. 1):

- ≤60 min: few spots with slightly decreased SSA, especially close to surface
- 180 - 300 min: few spots with decreased SSA also in greater depth
- >300 min: larger areas with strongly decreased SSA

2nd irrigation (Exp. 2):

- soon after start of experiment locally decreasing SSA
- ≈180 min: similar patterns of strongly decreasing SSA (as in Exp. 1 >300 min)

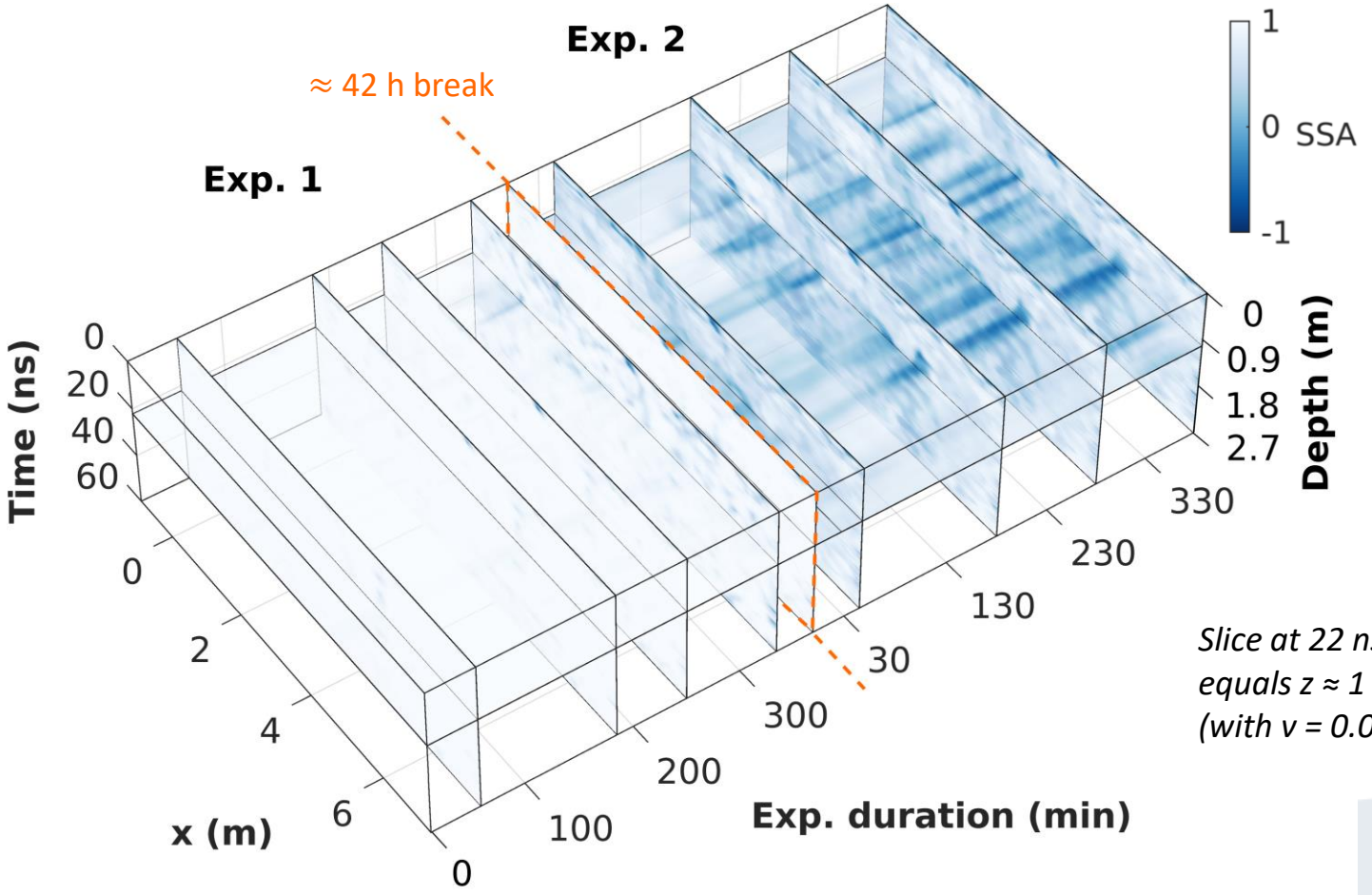
Setup time-lapse GPR: organic site

Aufbau zeitabhängige Bodenradar Messung: organischer Standort

- Easier measurement conditions compared to organic site
- Same setup with 2 profiles across transfer zone and high-resolution measurements

3D cube of similarity attribute: mineral site, Profile 1 (close to trench)

3D Würfel des Ähnlichkeits-Attributs: Mineralischer Standort, Profil 1 (nahe Trench)



Slice at 22 ns,
equals z ≈ 1 m
(with v = 0.09 m/ns)

1st irrigation (Exp. 1):

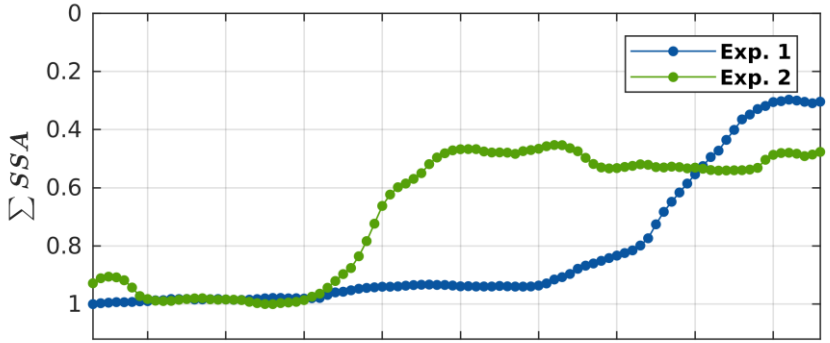
- very few and late spots
- no significant decrease in SSA

2nd irrigation (Exp. 2):

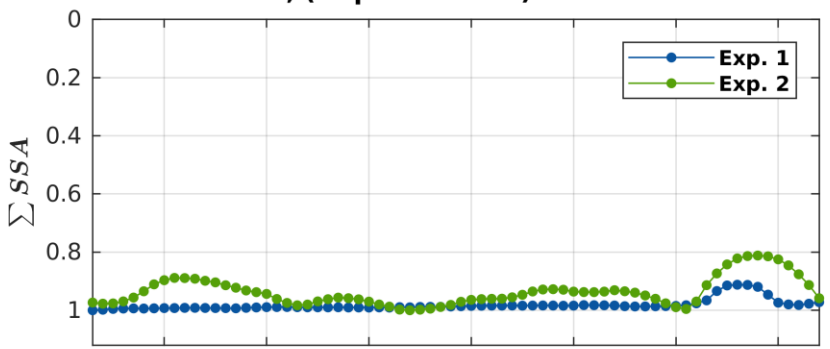
- only few spots close to surface
- in greater depth (z > 0.8 m) few distinct flow paths
- dispersed wetting across profile

Temporal development of similarity attribute: Sum over profile axis
Zeitliche Entwicklung des Ähnlichkeits-Attributs: Summe über Profil

Organic site
Time = 7 ns, (Depth ≈ 0.2 m)



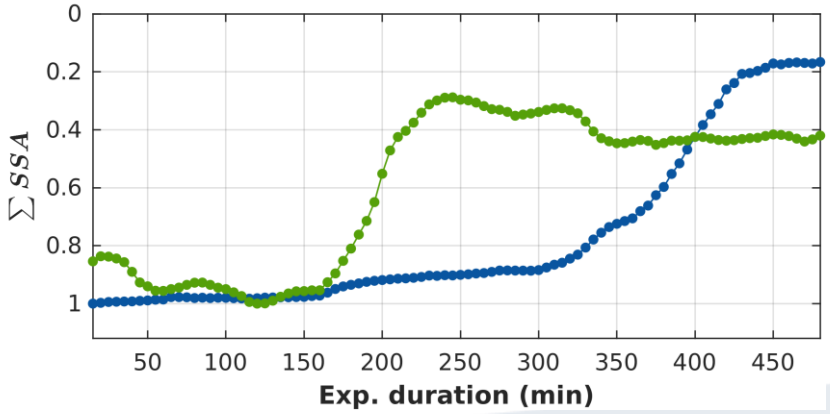
Mineral site
Time = 11 ns, (Depth ≈ 0.5 m)



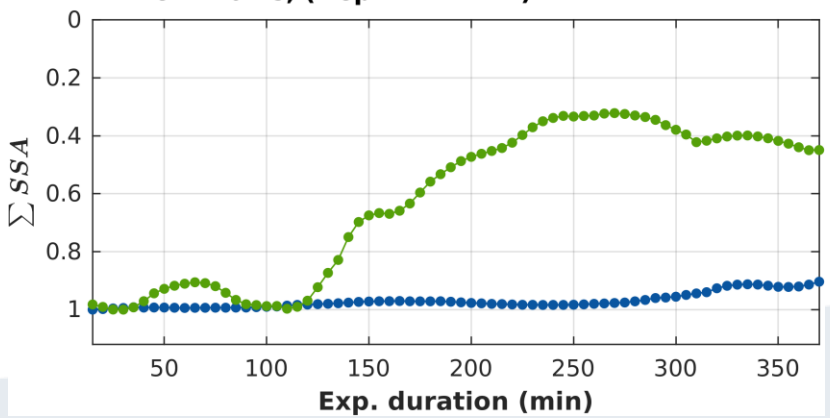
(dissimilar)

(similar)

Organic site
Time = 13 ns, (Depth ≈ 0.4 m)

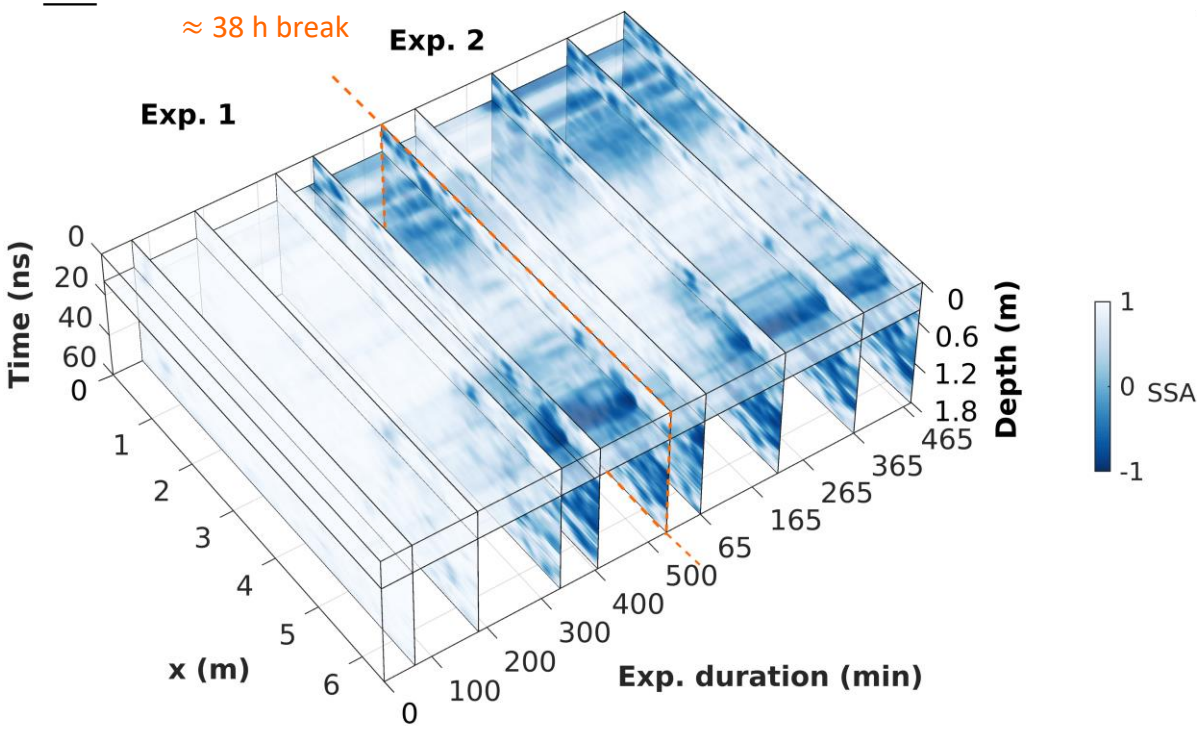


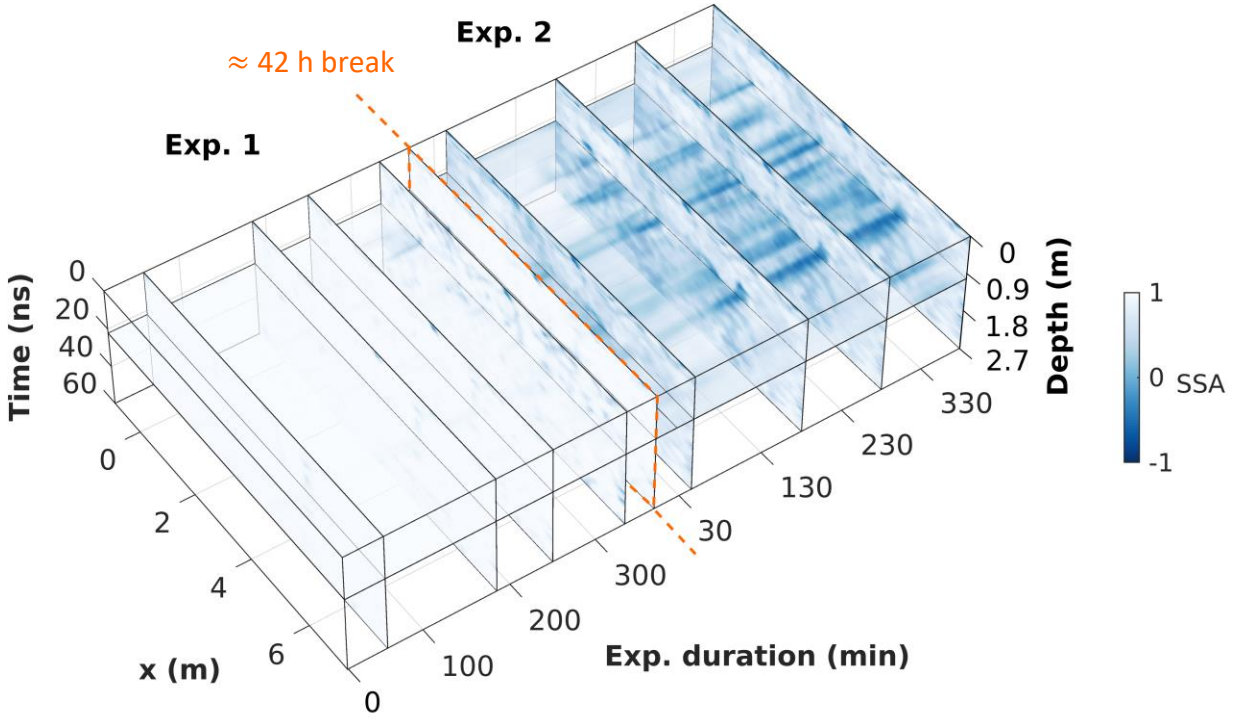
Mineral site
Time = 26 ns, (Depth ≈ 1.1 m)



- Reactivation of subsurface process ≈2 h earlier during 2nd irrigation
- Activation of subsurface process mainly during 2nd irrigation and z < 1 m

Summary of time-lapse GPR measurements
Zusammenfassung der zeitabhängigen Bodenradar-Messungen





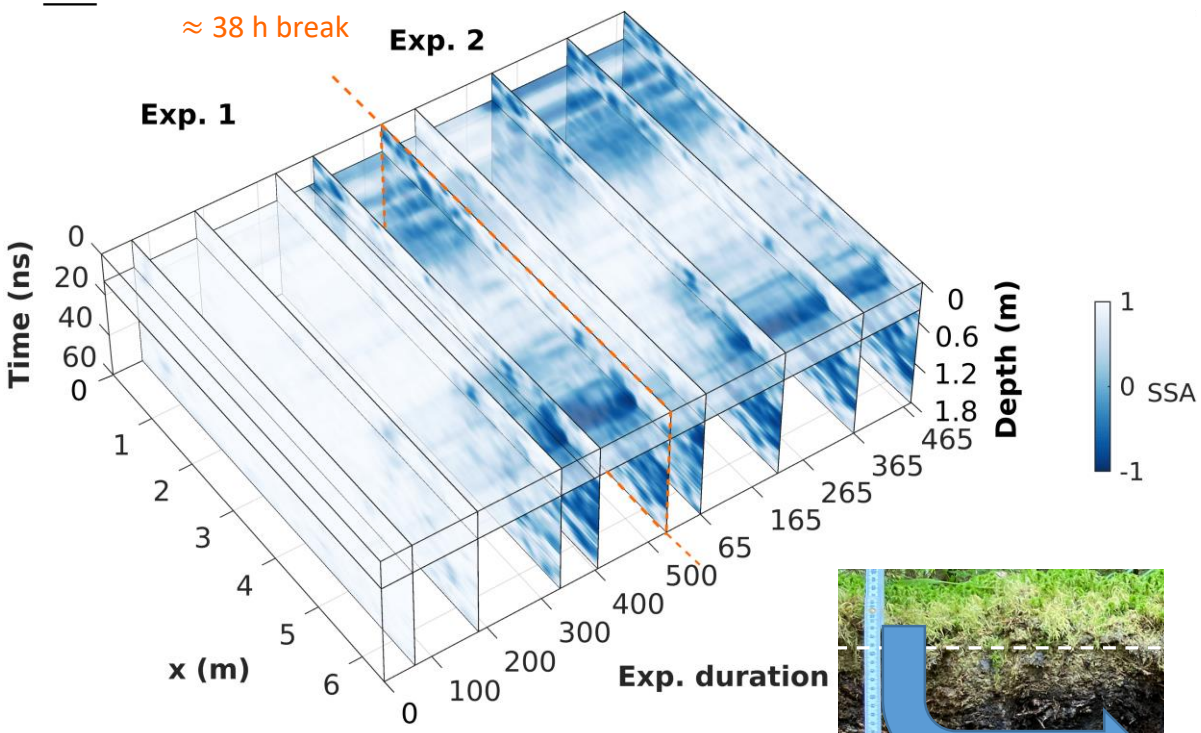
Organic site:

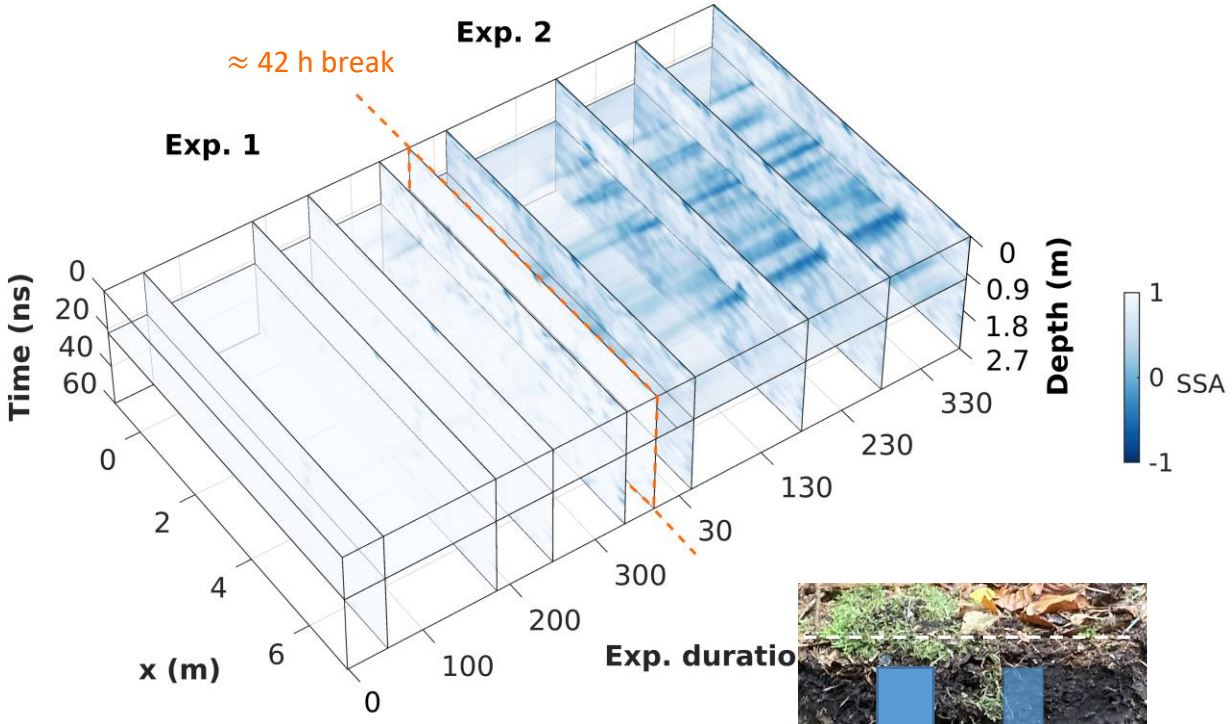
- two-stage subsurface processes
- fast, localized wetting; followed by later, distinct connection of subsurface flow paths
- same flow paths activated earlier during 2nd irrigation

Mineral site:

- few low wetting spots; local flow paths only activated during 2nd irrigation
- activated flow paths mainly in depth > 0.8 m, overall wetting of the profile

Summary of apparent drainage processes
Zusammenfassung der scheinbaren Abflussbildungsprozesse





Organic site:

- Fill, connection and spill of structures near interface between soil layers

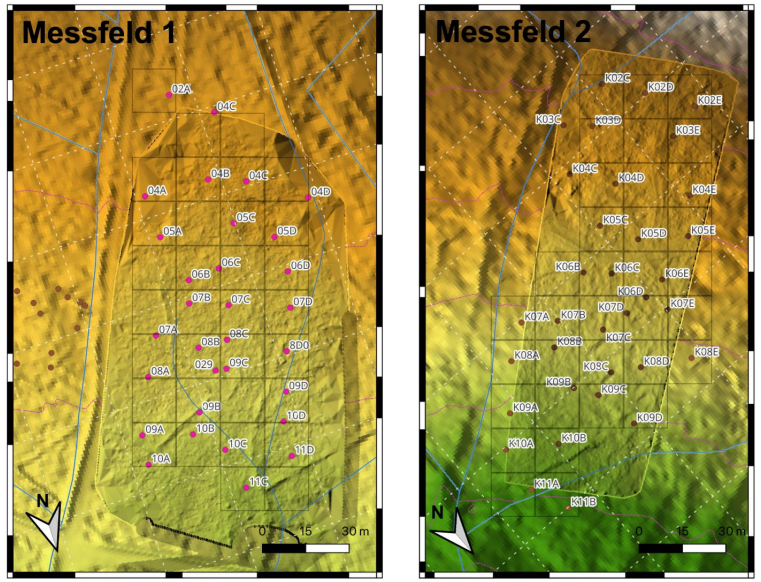
Mineral site:

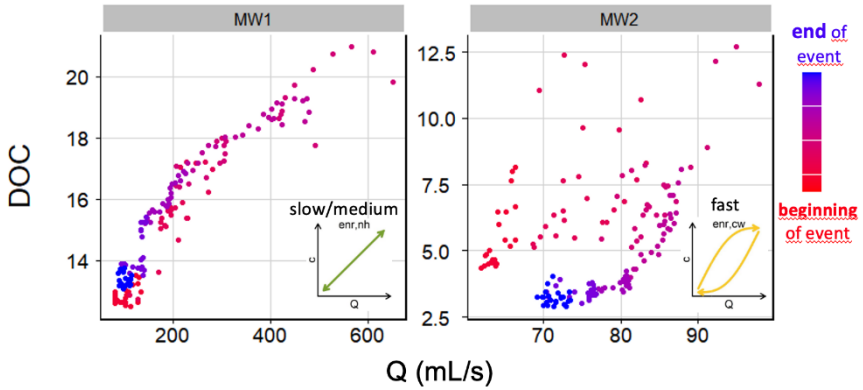
- Access to larger macropore network, dispersive flow
- eventual drainage at gravel layer (z ≈ 80 cm)

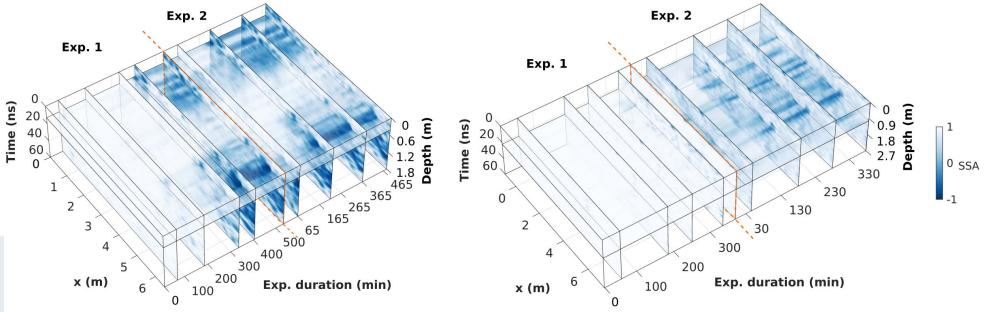
Water drives DOC production and controls export connectivity
Wasser treibt DOC Produktion und steuert Konnektivität für Austrag

Organic site
fill, connection and spill at soil layer interface meets high enrichment w/out hysteresis

Mineral site
Derspersive drainage in mineral macropores meets moderate enrichment w/ fast response hysteresis







Conclusions
Schlussfolgerungen

From Sosa to Saxony freshwater reservoirs
Von Sosa zu den Sächsischen Trinkwasser-talsperren allgemein

Sosa catchment features similar-looking forest patches with vastly different DOC source-transport properties
Sites show hydro-climatic drivers of sources, and hydro-dynamic drivers of coupling
-> conditions for potential DOC loading and export

Conclusions
Schlussfolgerungen

From Sosa to Saxony freshwater reservoirs
Von Sosa zu den Sächsischen Trinkwasser-talsperren allgemein

Sosa catchment features similar-looking forest patches with vastly different DOC source-transport properties
Sites show hydro-climatic drivers of sources, and hydro-dynamic drivers of coupling
-> conditions for potential DOC loading and export

Soils drain differently – Availability and transport of DOC moderated accordingly

- organic top soil is source – but diverse in magnitude
- Soil water storage and DOC loading differ: high load at organic site, flush at strong events after loading
- Disperser flow and reduced load at mineral site
- Rain pattern matters for DOC export

-> future research (monitor & experiments)

Conclusions
Schlussfolgerungen

From Sosa to Saxony freshwater reservoirs
Von Sosa zu den Sächsischen Trinkwasser-talsperren allgemein

Sosa catchment features similar-looking forest patches with vastly different DOC source-transport properties
Sites show hydro-climatic drivers of sources, and hydro-dynamic drivers of coupling
-> conditions for potential DOC loading and export

Soils drain differently – Availability and transport of DOC moderated accordingly

- organic top soil is source – but diverse in magnitude
- Soil water storage and DOC loading differ: high load at organic site, flush at strong events after loading
- Disperser flow and reduced load at mineral site
- Rain pattern matters for DOC export

-> future research (monitor & experiments)

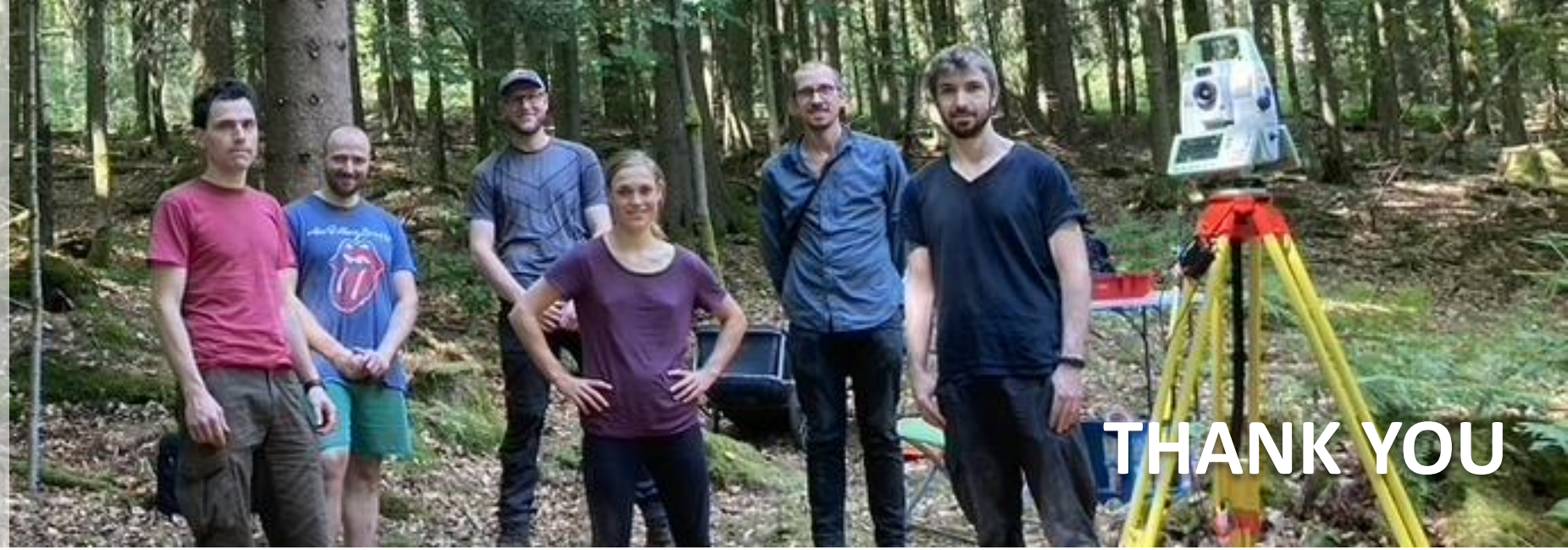
DOC load and export depend on:

- hydroclimatic conditions
- small-scale soil processes
- emergent properties

-> short-term forecast possible
-> process models complex
-> mitigation difficult

Conclusions
Schlussfolgerungen

From Sosa to Saxony freshwater reservoirs
Von Sosa zu den Sächsischen Trinkwasser-talsperren allgemein



Sosa catchment features similar-looking forest patches with vastly different DOC source-transport properties
Sites show hydro-climatic drivers of sources, and hydro-dynamic drivers of coupling
-> conditions for potential DOC loading and export

Soils drain differently – Availability and transport of DOC moderated accordingly

- organic top soil is source – but diverse in magnitude
- Soil water storage and DOC loading differ: high load at organic site, flush at strong events after loading
- Disperser flow and reduced load at mineral site
- Rain pattern matters for DOC export

-> future research (monitor & experiments)

DOC load and export depend on:

- hydroclimatic conditions
- small-scale soil processes
- emergent properties

-> short-term forecast possible
-> process models complex
-> mitigation difficult