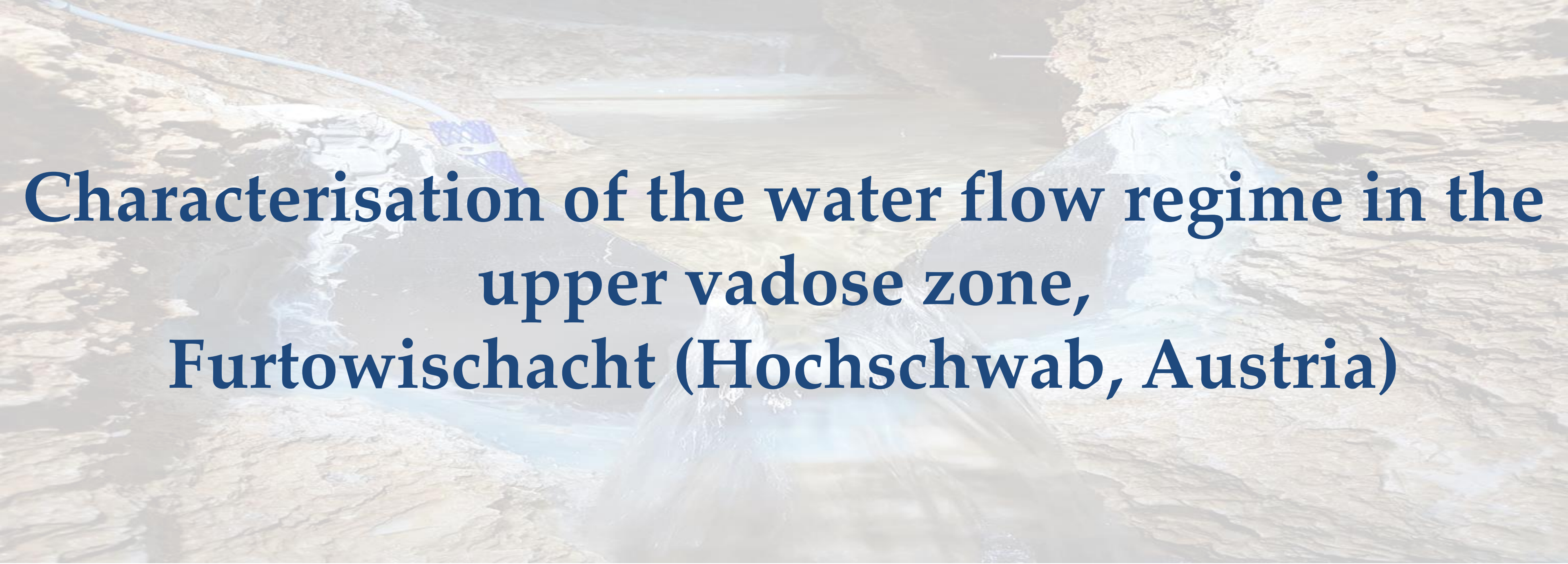

Characterisation of the water flow regime in the upper vadose zone, Furtowischacht (Hochschwab, Austria)

HS 8.2.3 – Fractured and karstified aquifers
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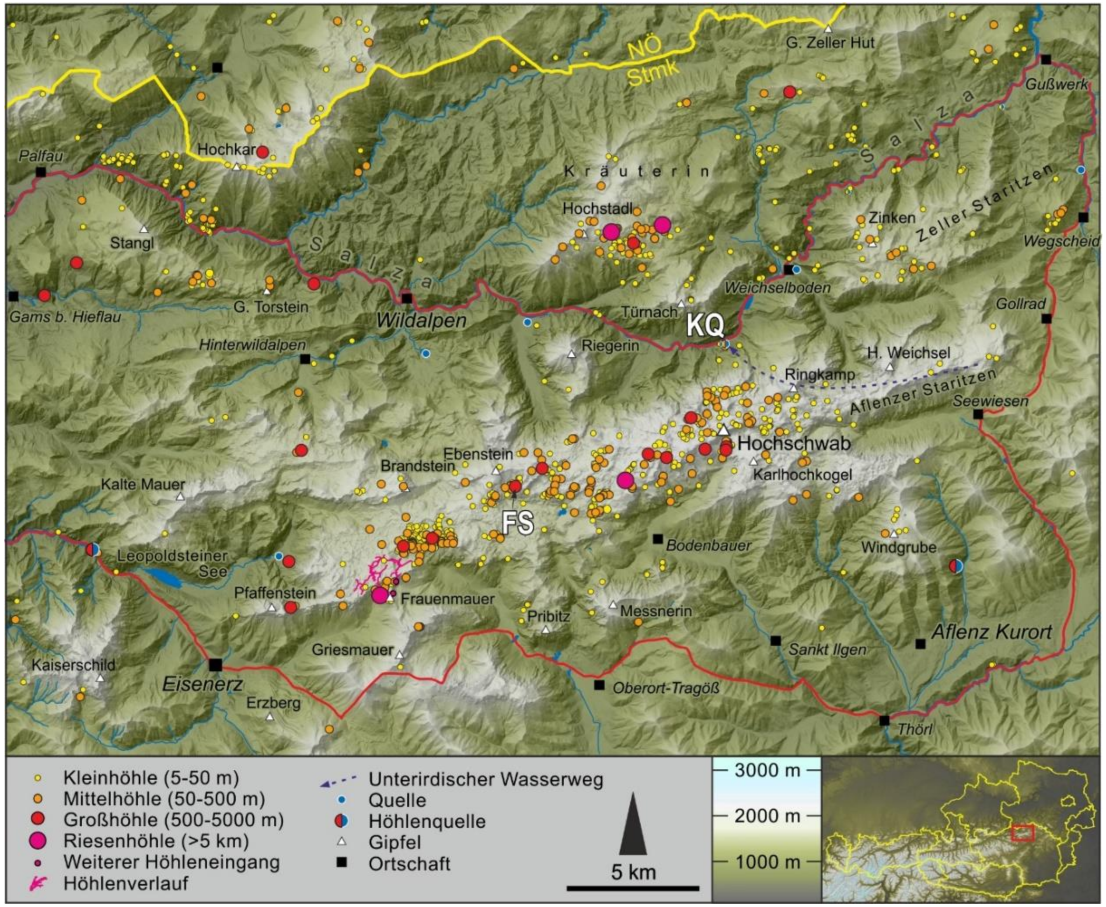
1.1 Research aim

The Kläfferquellen as the largest springs in the north of the Hochschwab karst massif are an important source of drinking water for the city of Vienna. Due to the vulnerability of karst waters, major parts of the Hochschwab (80 km southwest of Vienna) are a spring water protection zone. The upper part of a karst aquifer is the vadose or unsaturated zone, that also includes the epikarst on the top. The epikarst plays an important role for the recharge, potential storage, and the regulation of water flow to the vadose zone below. A better understanding of the karst aquifer recharge is important for karst water protection management. To ensure the quality of drinking water, research is being conducted to understand the processes within the underground aquifers.

The aim of this research is to quantify the water flow characteristics and its storage in the upper vadose zone. Hydrological monitoring in an Alpine vadose shaft, the Furtowischacht, is the basis of these analyses. The Furtowischacht is located in the western part of the Hochschwab and opens at 1785 m a.s.l. A Thomson-weir and data logger were installed in a small and water-bearing canyon 100 m below the entrance. Since 2016, water level, electrical conductivity (EC), and temperature (T) have been measured at the weir at least every 10 minutes.

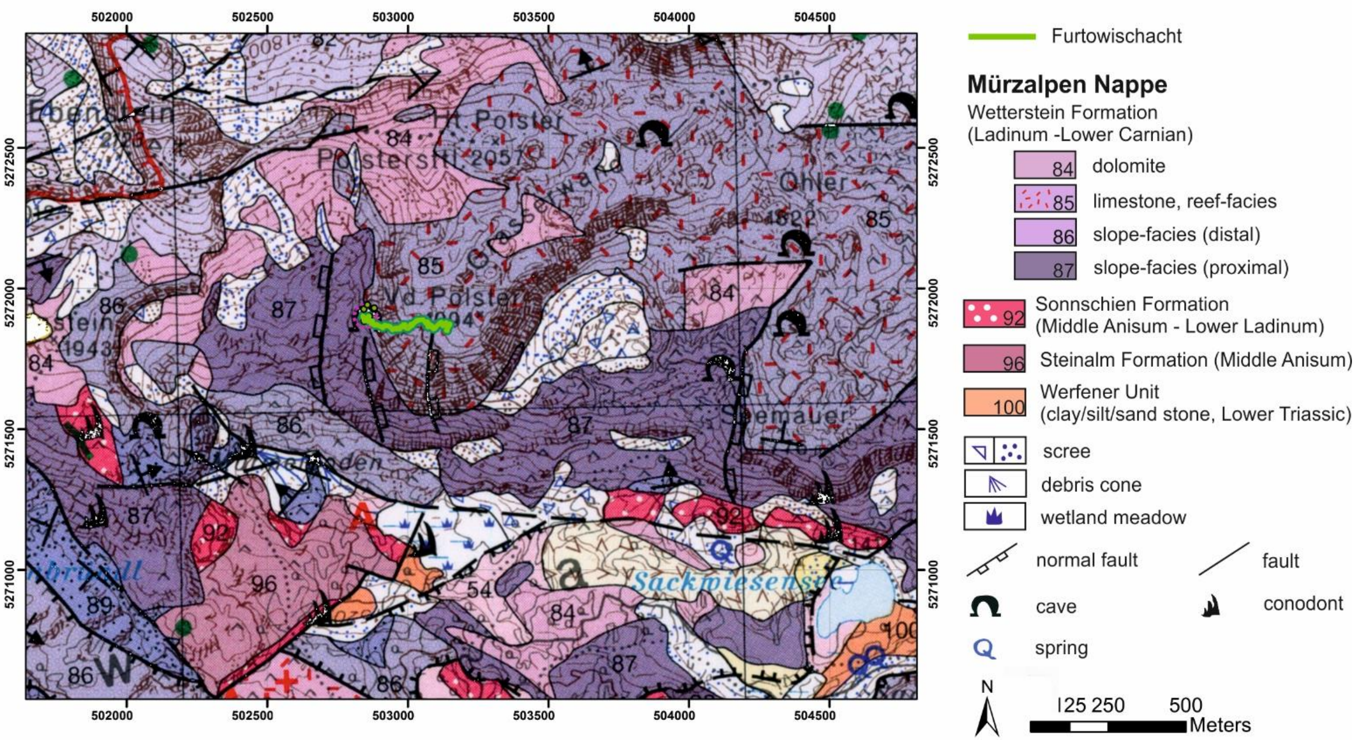
1.2 Study area

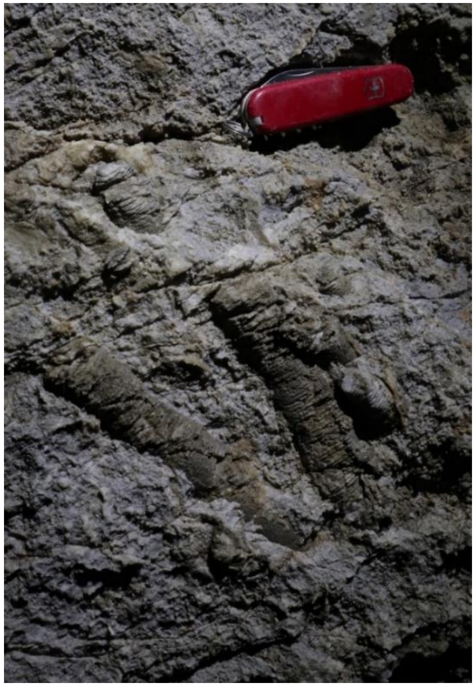


Caves at Hochschwab (Austria) and location of Furtowischacht (FS; UTM 33N: 5271884 N / 502845 E).

Hochschwab is part of the water protection zone for the Second Vienna Water Main with the Kläfferquellen (KQ) as a main source. (Plan (2016))

1.2 Study area (geology)



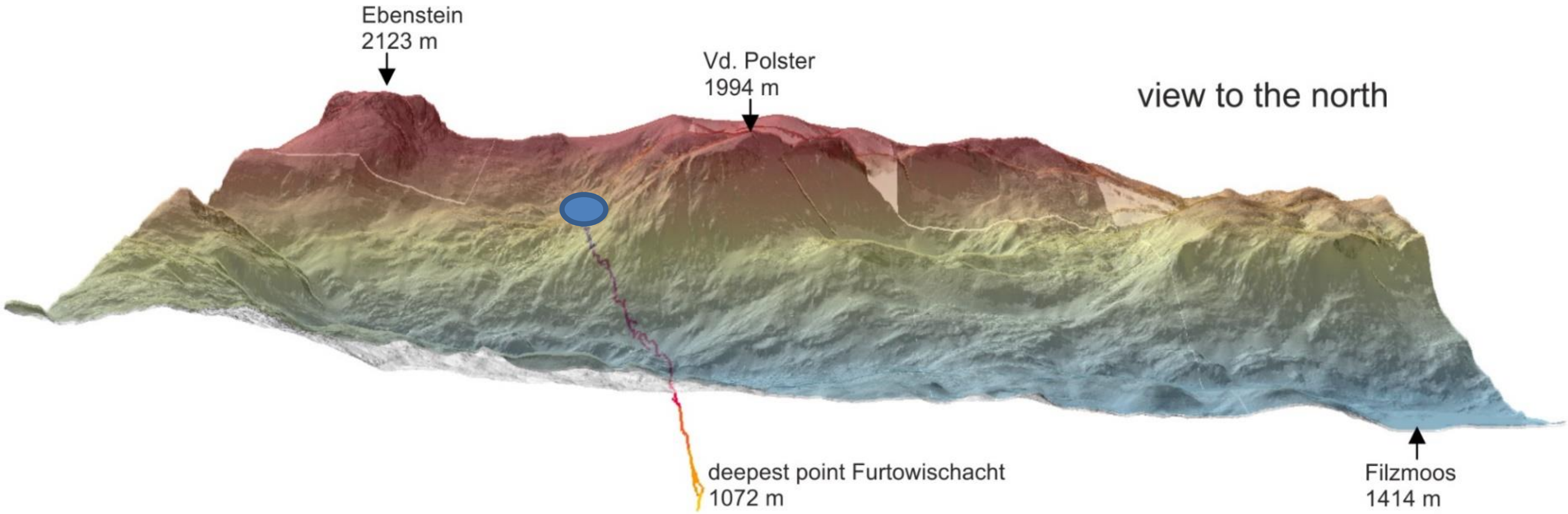


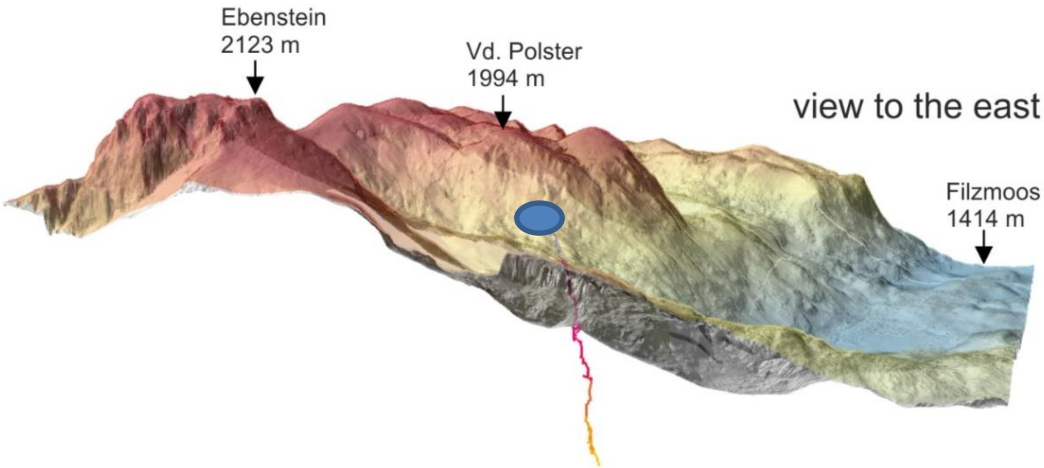
Geological Map of the Vorderer Polster (modified after Bryda, 2010; coordinates UTM 33N) and a picture of the Wetterstein limestone with a crinoid stalk in Furtowischacht at Crinoidenschacht. The crinoid stalk is exposed as – 40 m in the shaft wall.

1.3 Methods

1. Catchment characteristics and tectonics
2. Approaches for the data at the weir
    1. Data generation and analysis to identify and assess the water dynamic at and above the weir
        → Threshold analysis
        → Hydrograph recession analysis
    2. Numerical conceptual model that is being used to simulate the discharge behavior of the stream at the weir
3. Tracer experiments

2.1 Catchment area and tectonics



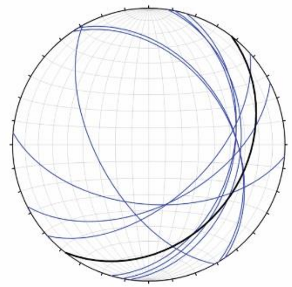


Oblique downward view on the surface of Ebenstein, Polsterkar and Polster to the north (top) and east (bottom) (ALS © GIS Land Steiermark).

The approximal catchment area is 4000 m² (blue).

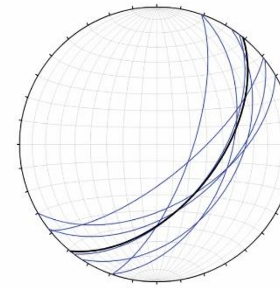
2.1 Catchment area and tectonics

E-directed faults at Vorderer Polster



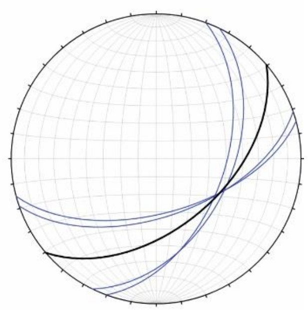
Schmidt Net
n = 9
mean =128/30

Faults in Furtowischacht



Schmidt Net
n = 8
mean =129/52

Fault controlled entrance of Furtowischacht



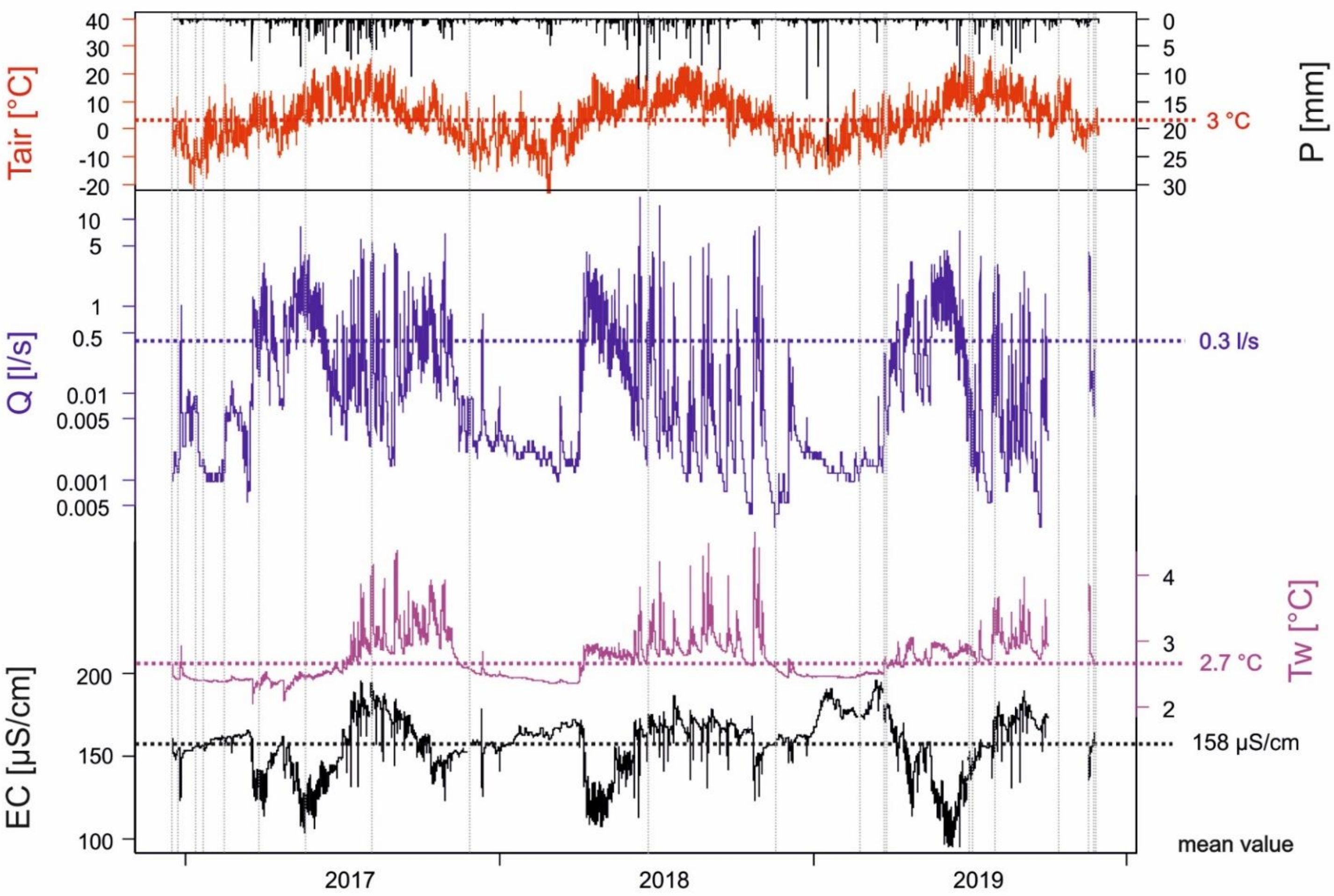
Schmidt Net
n = 4
mean =140/51

The fault depended Furtowischacht, glacial overprint, doline-dominated landscape, and thin soil cover was observed during the field work.

Different faults at the Vorderer Polster and in the Furtowischacht were located and measured. The fault – most probably a normal fault – at the Vorderer Polster dip to the ESE with some oblique faults to the NE and SW.

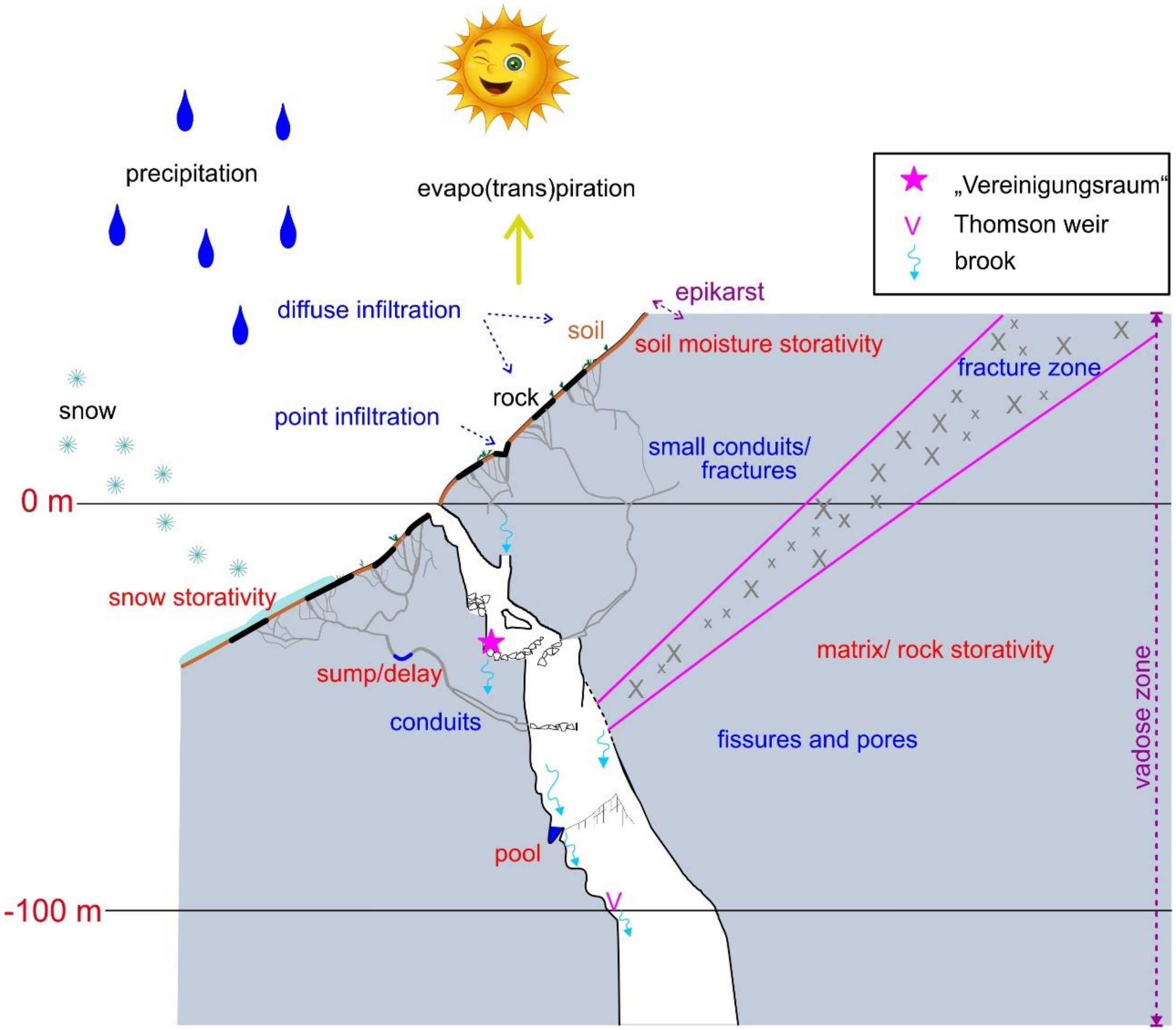
It can be concluded that the karst network in the catchment area of the Furtowischacht is particularly shaped by tectonics.

2.2 Data overview



Air temperature (Tair) and precipitation (P) measured at Sonnschienalm compared to discharge (Q), water temperature (Tw) and electrical conductivity (EC) at the weir in Furtowischacht between 12/2016 and 11/2019. Dashed lines mark the days of field work.

2.2 How can we interpret the data?



2.2 Data analysis (dual porosity model)

The discharge behavior after a recharge event is classified using the hydrograph recession analysis. The following components can be separated:

(1) slow flow ($\alpha 3$) through "rock matrix" (e.g. small fissures in the Wetterstein limestone)

(2) quick flow ($\alpha 1$) through canyons, tubes and large fissures (e.g. tube at -55 m in the cave)

(3) intermediate flow ($\alpha 2$) which is composed of (1) and (2).

Snowmelt events only produces intermediate and slow flow.

2.2 Data analysis (summer conditions)

Summer:

Event analysis e.g. R11:

Recession over 19 days

- $\alpha 3 = 0.25$ 1/d
- Q(min) = 0.003 l/s

→ Storage capacity at the event's end: 1 m³

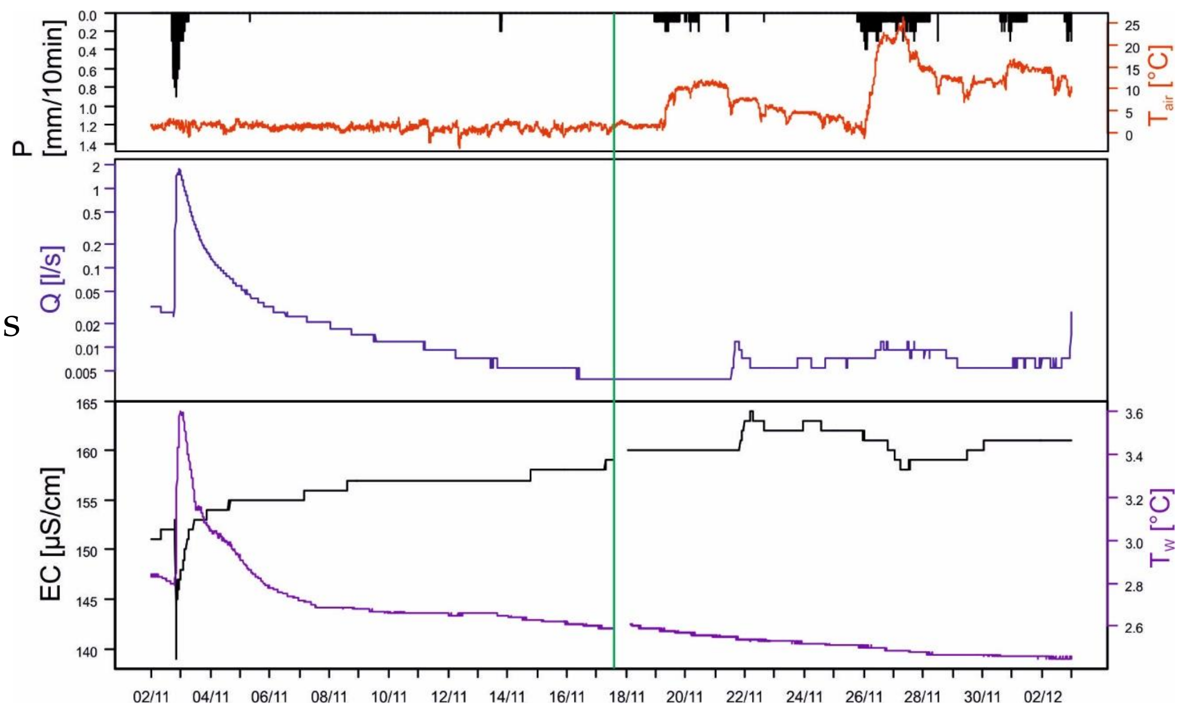
Time series analysis:

$\alpha 1 = 4$ 1/d

$\alpha 2 = 1.4$ 1/d

$\alpha 3 = 0.4$ 1/d

Delay between Q increase and EC decrease: up to 6 h, Ø 50 min



R11 as the longest observed recession start 03/11/2018. Field work was carried out on 17/11/2018 (green).

2.2 Data analysis (winter conditions)

Snow melt:

Time series analysis:

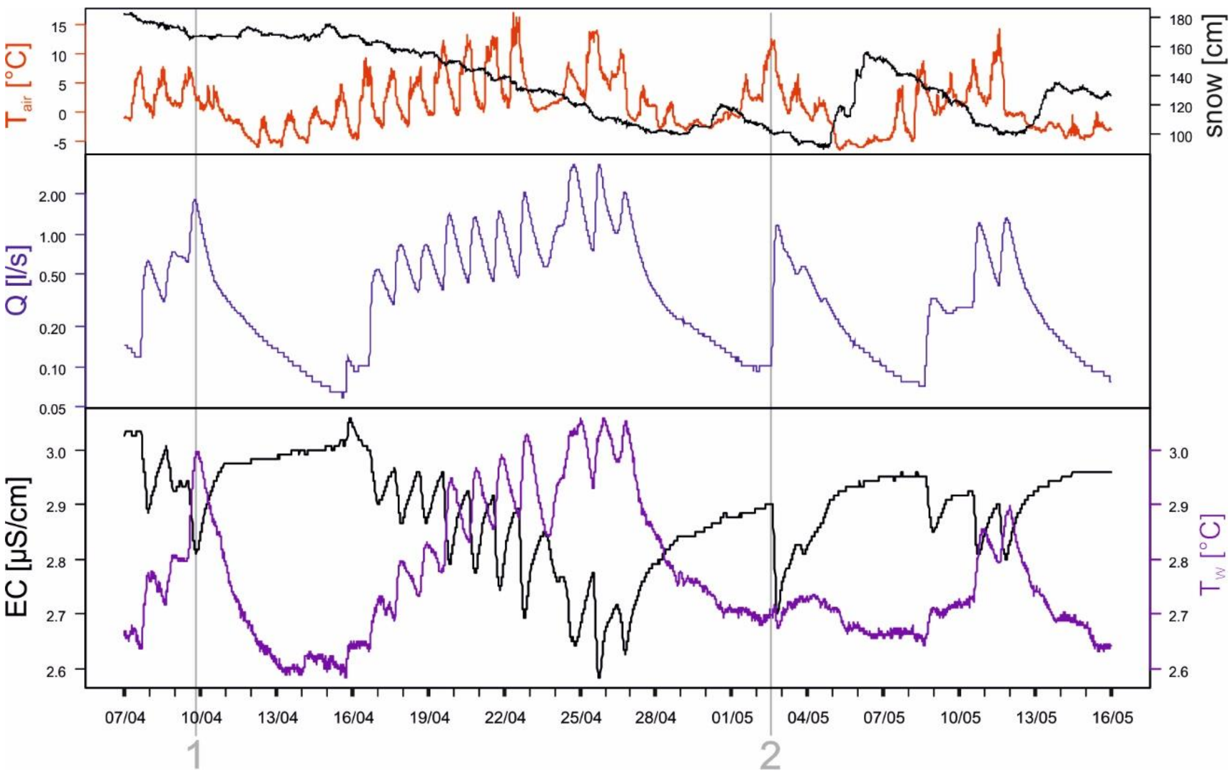
$\alpha 2 = 1.4$ 1/d

$\alpha 3 = 0.4$ 1/d

Delay between Q increase and EC decrease: up to 5:40 h, Ø 53 min

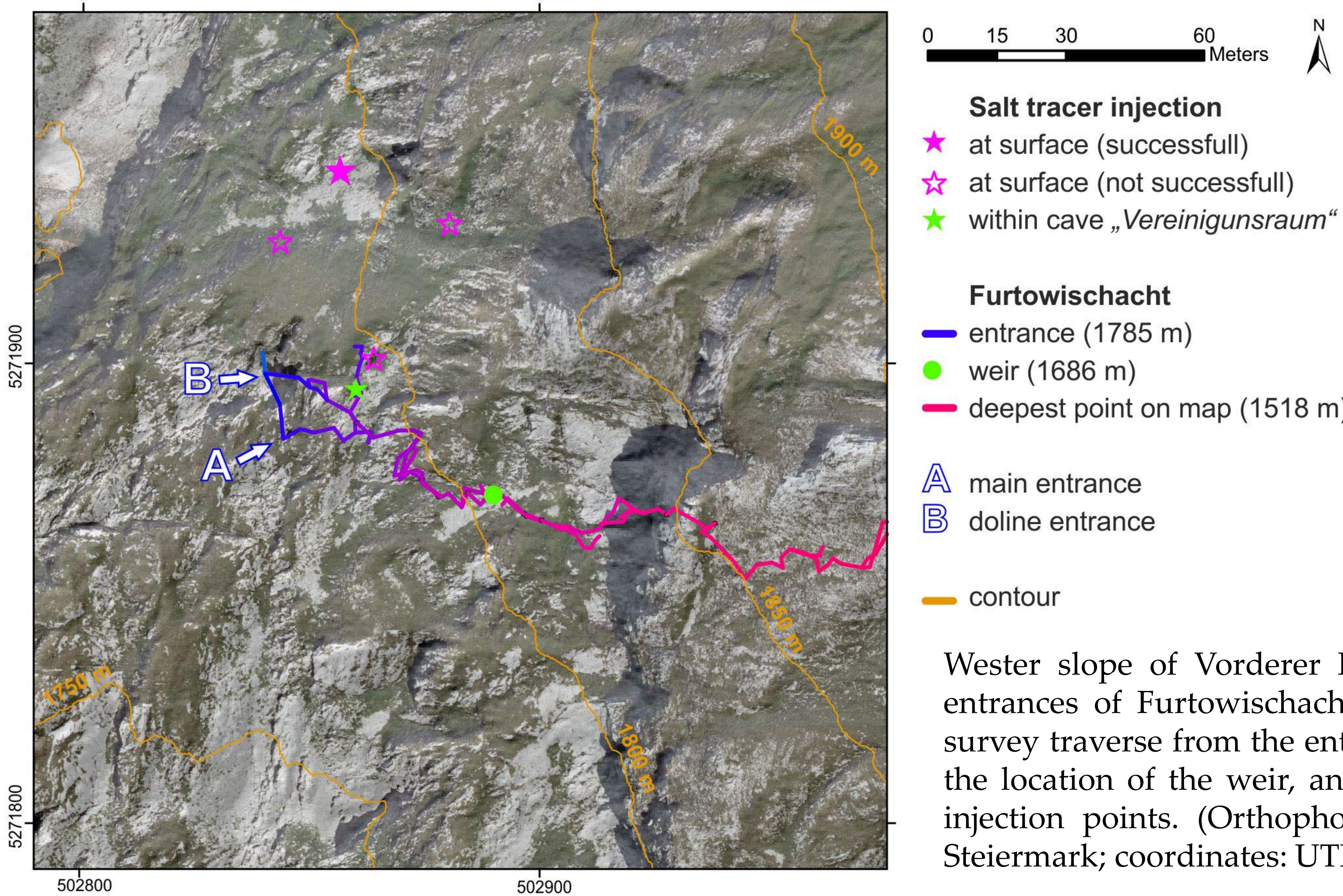
Winter:

- Longest period without any event: 89 days (2017/2018)



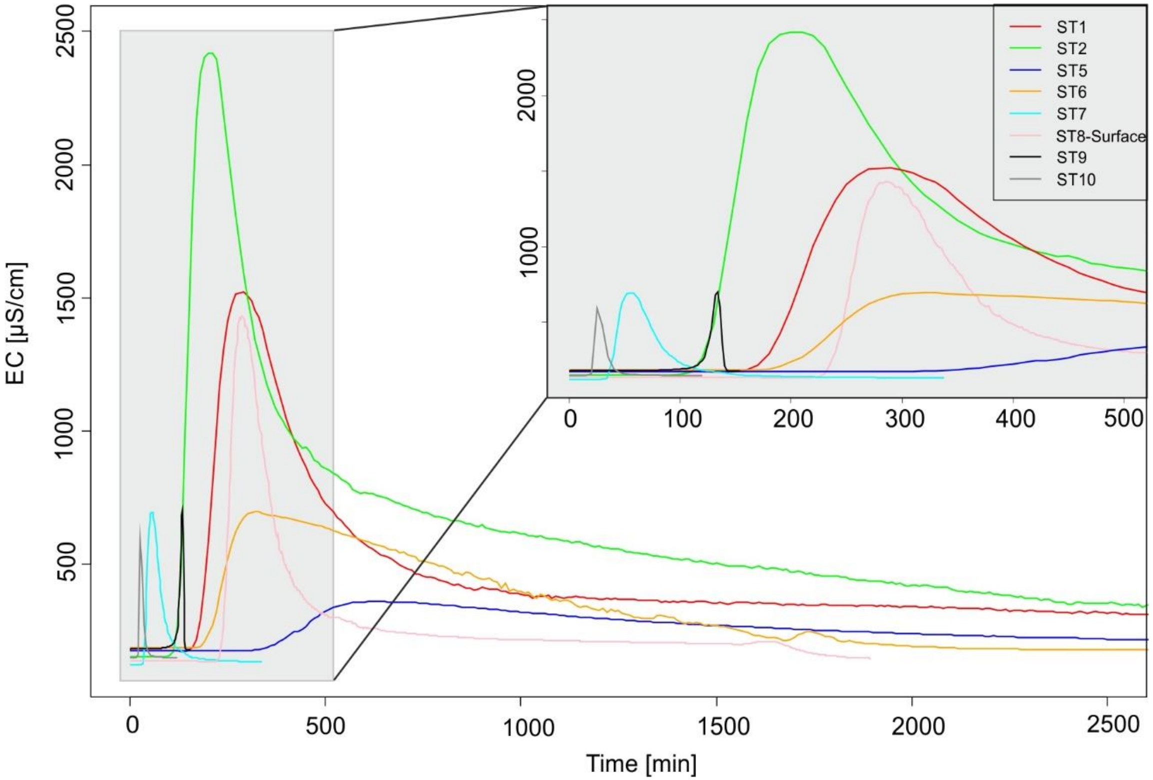
Time series from 07.04. to 16.05.2019. In the long run, during the daily oscillations, the curves of Q and Tw are parallel while the ones of Q and EC are divergent (“1”). Daily Tair fluctuations are also reflected in the fluctuations in Q, EC and TW. “2” indicates the Tair maximum while Q, EC, and TW start to react.

2.3 Salt tracer (injection map)



Wester slope of Vorderer Polster with the entrances of Furtowischacht (A, B) and its survey traverse from the entrance to -267 m, the location of the weir, and the salt tracer injection points. (Orthophoto © GIS Land Steiermark; coordinates: UTM 33).

2.3 Salt tracer (break through curve)

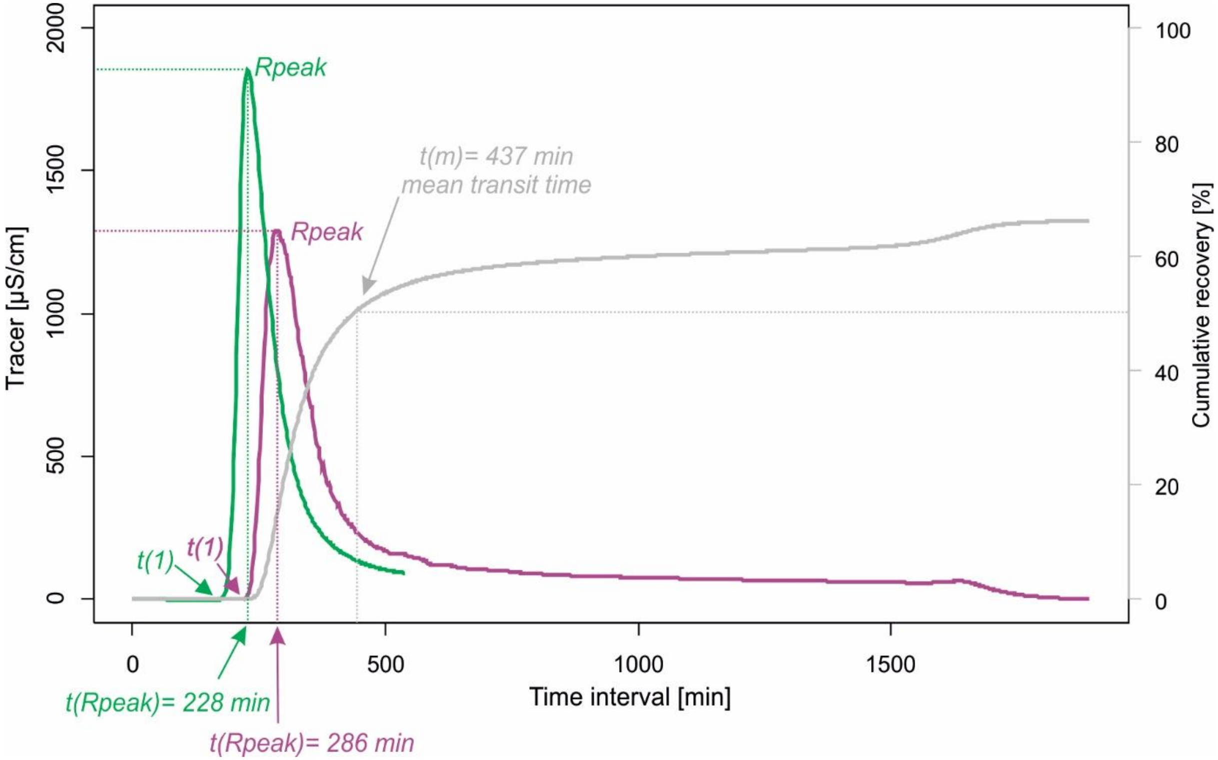


Break through curve (ST = Salt tracer) at the weir. ST1 to ST10 injection in the cave ("Vereinigunsraum" -25 m) except ST8 with injection at the surface.

Salt tracer injection (18/11/2019) at "Vereinigungsraum" - 25 m.

Transport velocity:
V_t(meas.) = 0.98 m/s (Q = 0.6 L)
V_t (interpol.) = 1.7 m/s (Q = 19.1 L)

2.3 Salt tracer (injection at the surface)



Salt tracer (ST8) injection at the surface (28/06/2019).

ST8 also indicates a fast flow component with little storage due to the meant tracer transit time (tm), recession coefficient (α = 3.1 1/d), and the calculate system volume (4 m³).

3. Conclusion

A high Alpine catchment with its upper vadose zone until – 100 m is characterised as followed:

- Extreme unstable discharge at the cave weir ranges from 0.003 to 19.1 l/s which gives a variability degree (IV) of 6367.

- Time lags between a discharge and physiochemical parameter response on a precipitation event varies between 0 and 6 h, depending on the event type.

- Hydrograph separation supports the assumption that precipitation and snow melt events behave differently. Due to single event- and time series analysis, flow characteristics for rain events are described with three flow components. The hydrograph analysis of the time series gives an average recession coefficient for the quick flow ($\alpha 1$) of 4 1/d, for the intermediate flow ($\alpha 2$) of 1.4 1/d, and for the baseflow ($\alpha 3$) 0.4 1/d. Snowmelt events are described with the flow components: $\alpha 2$ and $\alpha 3$ only. At average, they are the same as for rain events.

- No drying up of the weir, low recessions and their extrapolations indicates a storage capacity in the upper vadose zone.

- The fastest tracer response could be observed with a tracer transport velocity of 0.09 m/s.

Literature

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