Vallon de Nant – experimental catchment

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The Vallon de Nant is a narrow and steep north-facing valley in the Vaudois Alps in Switzerland (Figure 1). The catchment has an area of 13,4 km² ranging from 1200 to 3051 m asl., including the peaks of the Grand Muveran and Petit Muveran, the Dent Favre, the Dent de Morcles, the Pointe des Martinets and Pointe des Savolaires. Due to shading from some of these mountain peaks, a small glacier continues to exist a relatively low elevation (2200 – 2600 m asl.) (GLAMOS, 1881-2019).

The area has been protected (Natural Reserve of the Muveran) since 1969 (Université de Lausanne, 2021). Ongoing research in this catchment spans the fields of hydrology, hydrogeology, pedology, biogeochemical cycling, stream ecology, plant ecology, permafrost and geomorphology. Overall, 10 research groups from the University of Lausanne, the Ecole Polytechnique Fédérale of Lausanne and the University of Neuchâtel are active in this catchment (Boix Canadell, Escoffier, Ulseth, Lane, & Battin, 2019; Buri et al., 2020; Cianfrani et al., 2019; Fallot, 2016; Giaccone et al., 2019; Grand, Rubin, Verrecchia, & Vittoz, 2016; Horgby, Boix Canadell, Ulseth, Vennemann, & Battin, 2019; Kneib et al., 2020; Lambiel, Bardou, Delaloye, & Schuetz, 2009; Lane, Vittoz, & Verrecchia, 2011; Mächler et al., 2020; Rowley, Grand, Adatte, & Verrecchia, 2020; Schoeneich & Reynard, 2021; Vittoz et al., 2010; Vittoz & Dessimoz, 2009; Vittoz, Randin, Dutoit, Bonnet, & Hegg, 2009). Hydrological monitoring started in November 2015.

The hydrological equipment from 2016 – 2020 included (see maps in Figure 1 and appendix 1 and table in appendix 2):

- 1 gauging station with geophone (Figure 2)
- 2 streamflow isotope auto-sampling sites + 15 grab sampling sites (Ceperley et al., 2019)
- 4 meteo stations (real-time transmission, Figure 3 and appendix 1 (Michelon, Schaefli, Ceperley, & Beria, 2017))

The climatic data are transmitted real-time via www.climaps.ch.

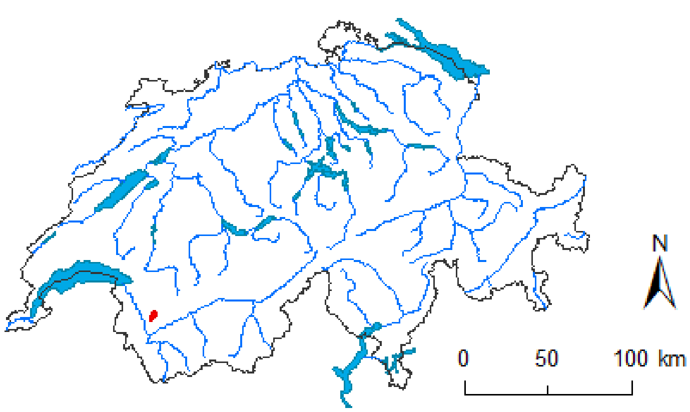

Figure 1. Location of the Vallon de Nant catchment in Switzerland.

Figure 2. The discharge station in A) summer (July 2016) and B) winter (January 2017).

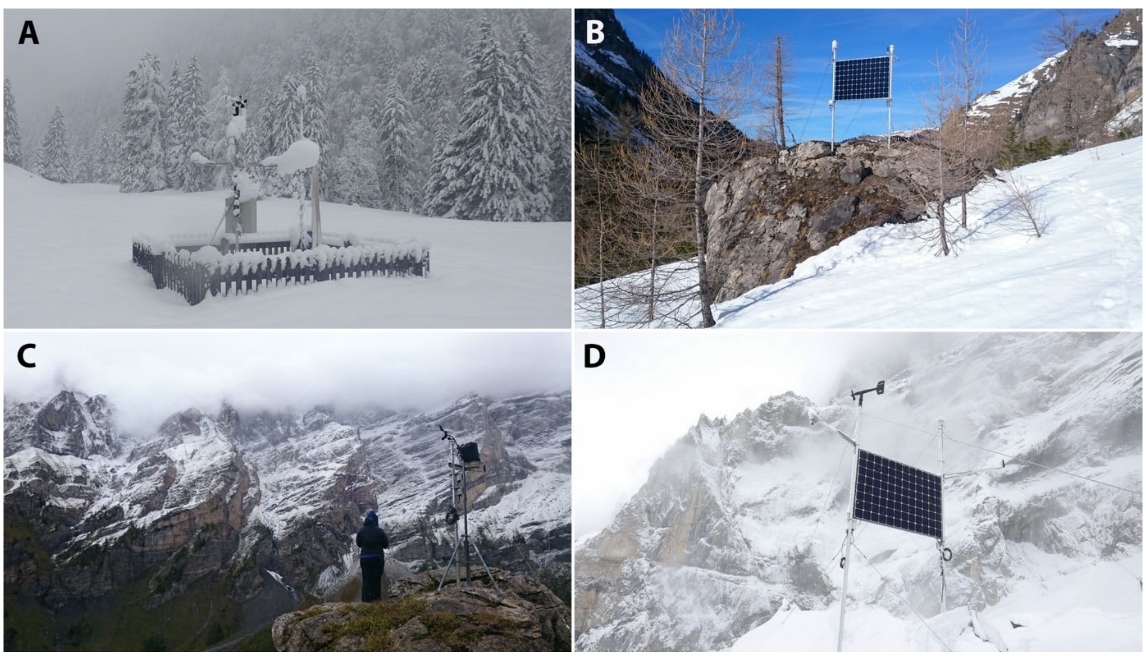

Figure 3. The 4 weather stations of the Vallon de Nant at the so-called places of A) the Auberge, B) the Chalet, C) La Chaux, and D) the Glacier.

Geology and surface formations

The Vallon de Nant belongs to the reverse side of the nappe of Morcles (Figure 4). The old cretaceous and tertiary layers are recognizable as a succession of thick, rocky bars which overlook and surround the valley. They lie on a substratum of flysches, soft rocks (schistose marls and sandstone benches), which explains the digging and fast expansion of the valley at its southern part (Badoux, 1991). At the foot of the cliffs, large alluvial cones and scree extent up to the river. In the upper part of the valley lies the Glacier des Martinets, which is now confined to the shade area of the Dents de Morcles, but the complex shape of moraine reveals its past progressions and withdrawals. The actual extent of the glacier is hard to define as it is partially covered by rocks, which erase its boundary with the moraine.

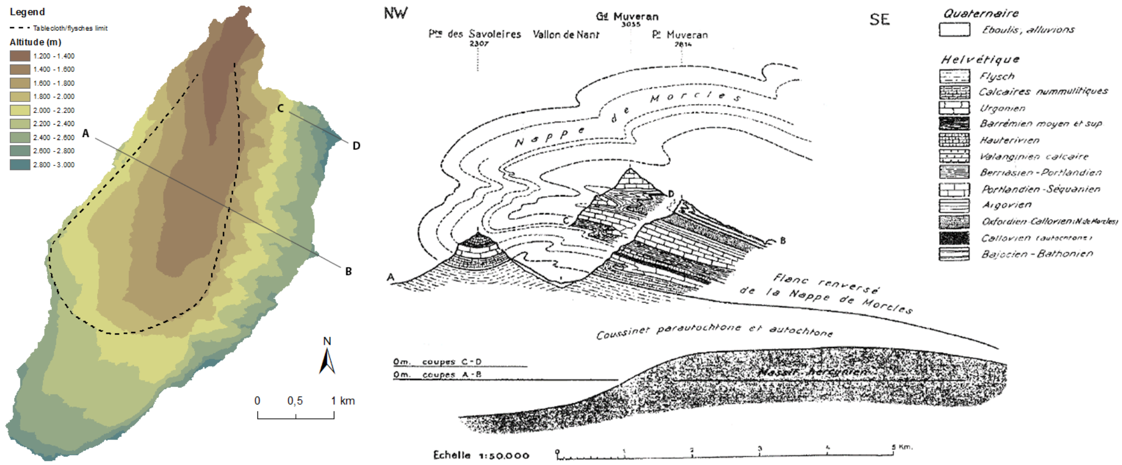

Figure 4. Location (on the left) of the simplified geological cross-sections of the Vallon de Nant (Badoux, 1991). The A-B cross-section is going through the Pointe des Savolaires and the Petit Muveran (north-west/south-east). The C-D cross-section follows the same orientation, going through the Grand Muveran 1,5 km further north. The dashed line represents the limit between the tablecloth and the flysches.

Dominant hydrological landscape units

The hydrological behavior of the catchment is driven by a number of dominant hydrological landscape units (Figure 5, Figure 6), the functioning of which is the subject of current hydrological research in this catchment.

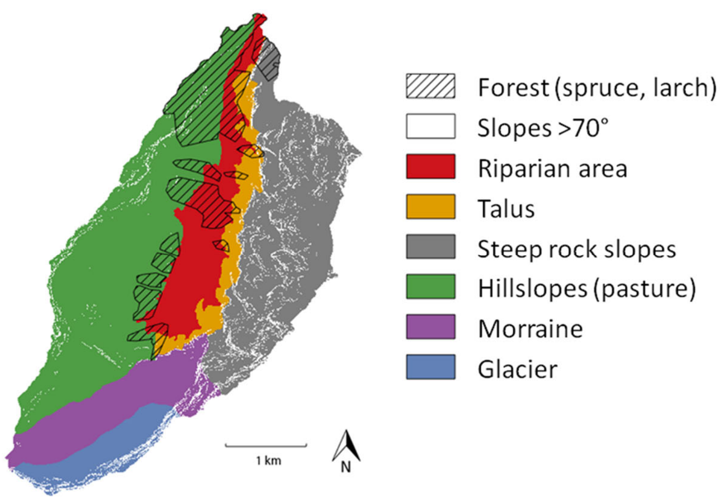

Figure 5. Dominant hydrological landscape units, from the work of (Michelon, Benoit, Beria, Ceperley, & Schaefli, 2020), [link]

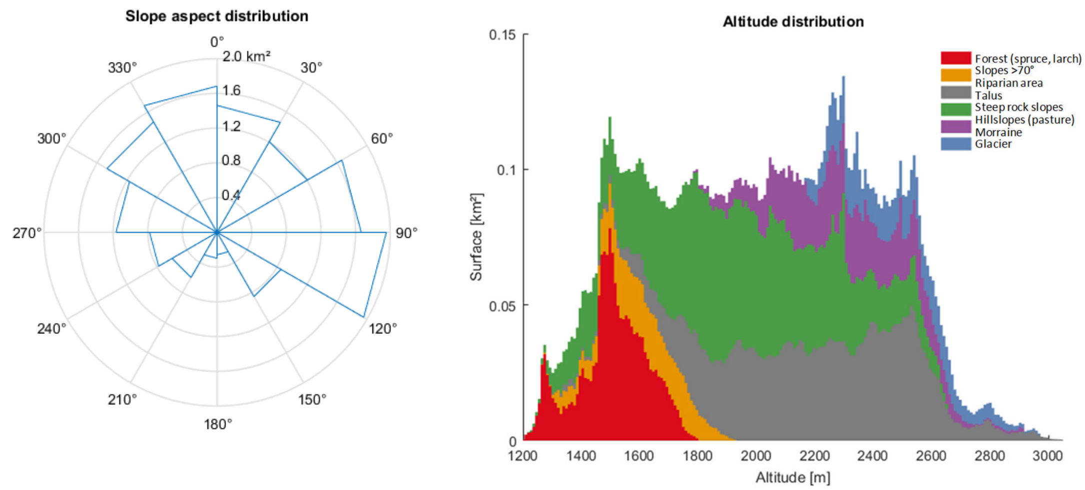

Figure 6. Slope aspect distribution of the entire catchment (left); elevation distribution of the dominant landscape units (right)

Hydrological regime

The catchment is strongly snow-influenced. Our current estimates based on stable isotopes of water (Beria et al., 2017) indicate that around 60% of groundwater and streamflow originates from streamflow. Accordingly, the streamflow shows a typical nival regime (Figure 7, appendix 3), with very low flow during winter and high flows during summer.

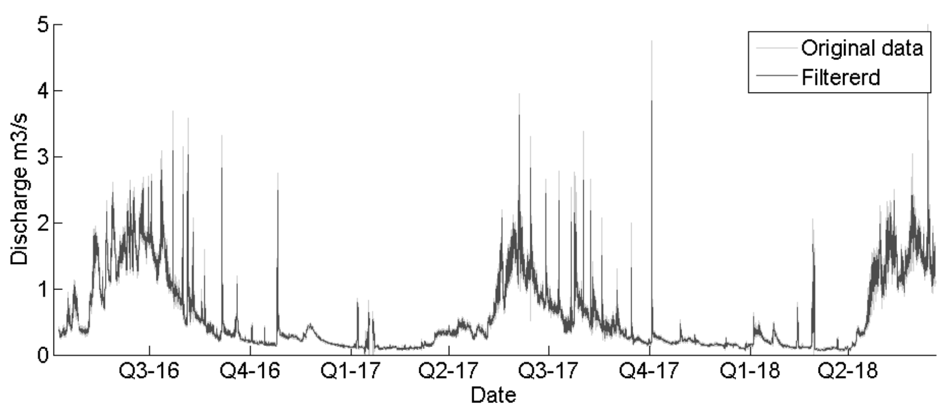

Figure 7. Discharge observed at the catchment outlet; the stage-discharge curve is obtained with salt gauging (Ceperley et al., 2018)

Climate

There is currently no reliable data from MeteoSwiss for this catchment. Available gridded data products (MeteoSwiss, 2011; Sideris, Gabella, Sassi, & Germann, 2014) all give less precipitation than observed discharge. Detailed climatology based on our own observations will be available in the near future. The mean daily discharge over the period Jan 2016 to Jan 2018 corresponds to an annual discharge of around 1200 mm/year. The annual evapotranspiration at this elevation can be assumed to be between 300 mm/year and 400 mm/year.

Publications about the Vallon de Nant that include further details

Published or currently under peer-reviewed papers include:

Beria, H., Larsen, J. R., Michelon, A., Ceperley, N. C., and Schaefli, B.: HydroMix v1.0: a new Bayesian mixing framework for attributing uncertain hydrological sources, Geosci. Model Dev., 13, 2433-2450, 10.5194/gmd-13-2433-2020, 2020.

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Kneib, M., Cauvy-Fraunié, S., Escoffier, N., Boix Canadell, M., Horgby, Å., and Battin, T. J.: Glacier retreat changes diurnal variation intensity and frequency of hydrologic variables in Alpine and Andean streams, Journal of Hydrology, 583, 124578, https://doi.org/10.1016/j.jhydrol.2020.124578, 2020.

Lane, S. N., Borgeaud, L., and Vittoz, P.: Emergent geomorphic–vegetation interactions on a subalpine alluvial fan, Earth Surface Processes and Landforms, 41, 72-86, https://doi.org/10.1002/esp.3833, 2016.

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PhD theses

Beria, H.: Improving hydrologic model realism using stable water isotopes in the Swiss alps, University of Lausanne, 2020.

Horgby, A.: Spatiotemporal Drivers of CO2 Dynamics and Evasion Fluxes from Mountain Streams, EPFL, Lausanne, 2019.

Giaccone, E. The influence of geomorphological parameters on vegetation in the Alpine periglacial environment, University of Lausanne, 2019.

Rowley, M. Investigating calcium mediated accumulation of soil organic carbon at the Nant Valley alpage, Vaud Alps, Switzerland, University of Lausanne, 2020.

Thornton, J.M. Fully-integrated surface-subsurface hydrological modelling in steep, snow-dominated, geologically complex Alpine terrain, University of Neuchâtel, 2020.

Studies that use data from Vallon de Nant include

Etter, S., Strobl, B., van Meerveld, I., and Seibert, J.: Quality and timing of crowd-based water level class observations, Hydrological Processes, 34, 4365-4378, https://doi.org/10.1002/hyp.13864, 2020.

Horgby, A., Gómez-Gener, L., Escoffier, N., and Battin, T. J.: Dynamics and potential drivers of CO2 concentration and evasion across temporal scales in high-alpine streams, Environmental Research Letters, 14, 124082 2019.

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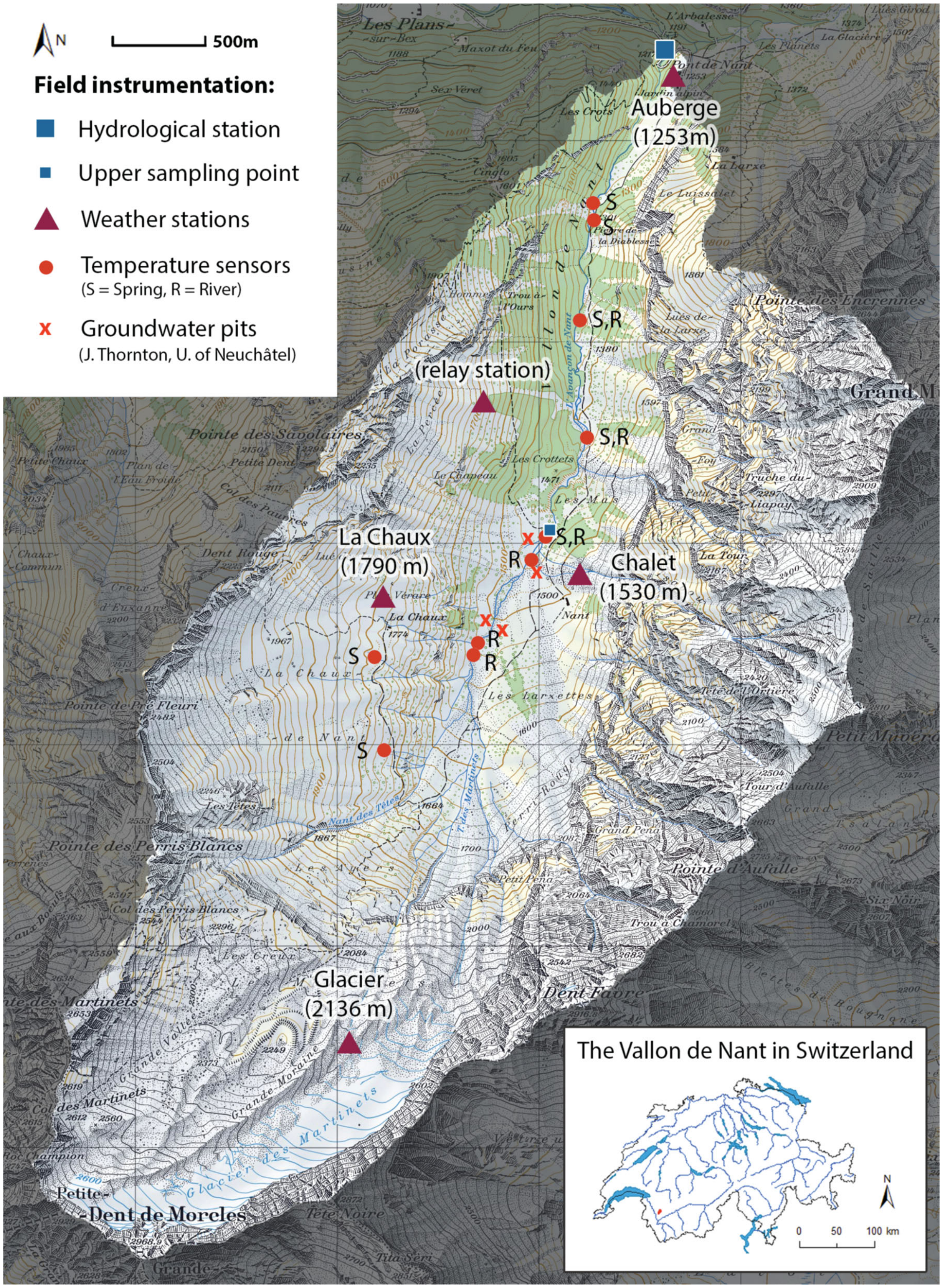
Vittoz, P., Randin, C., Dutoit, A., Bonnet, F., & Hegg, O. (2009). Low impact of climate change on subalpine grasslands in the Swiss Northern Alps. *Global Change Biology, 15*(1), 209-220. doi:10.1111/j.1365-2486.2008.01707.x

Appendix 1: Map, extracted from a poster presented at EGU2017 (Michelon, Ceperley, Beria, Larsen, & Schaefli, 2017)



Appendix 2: List of known stations, sensors, and measurements (updated: December 2020)

Station	Station Type	Latitude	Longitude	Elevation	Installed	Retired	Sensors, Equipment	Automatic Data Transmission	Responsible Person
Chaux	Meteo - Sensorscope	46.228660	7.092230	1780	2016	present	Atmospheric Pressure, Air temperature, relative humidity, wind speed, solar radiation incoming, surface temperature, soil moisture	1	Schaefli
Chaux	Meteo - Weatherlink	46.228660	7.092230	1780	2010	present	soil moisture, wind speed and direction, unheated rain gauge, air temperature, relative humidity (not all currently maintained)	0	Fallot
Chalet	Meteo - MADD	46.228660	7.092230	1780	2010	2016	Air Temperature	0	Hicox
Chalet	Meteo - Sensorscope	46.229869	7.103968	1529	2016	present	Precipitation (doppler radar), snow depth, atmospheric pressure, air temperature, relative humidity, wind speed and direction, incoming radiation, surface temperature, soil moisture	1	Schaefli
Glacier	Meteo - Sensorscope	46.211696	7.095800	2100	2016	2019	precipitation (doppler radar), snow depth, atmospheric pressure, air temperature, relative humidity, wind speed and direction, incoming radiation, surface temperature	1	Schaefli
Auberge	Meteo - MADD	46.211696	7.095800	2100	2007	present (reduced)	radiation, previously: wind speed and direction, heated rain gauge measurements, air temperature and humidity	0	Hicox
Auberge	Meteo - Sensorscope	46.251880	7.110560	1253	2016	present	Precipitation (doppler radar), snow depth, atmospheric pressure, air temperature, relative humidity, wind speed and direction, surface temperature, soil moisture; nearby:	1	Schaefli

							SONAR snow depth (non-transmitting)		
Relay	Meteo - Sensorscope	46.237183	7.097318	1720	2016	present	none	1	Schaefli
Hys2	Hydrologic	46.231520	7.101980	1466	2016	2018 (?)	Water temperature, conductivity, CO2, depth, dissolved oxygen	0	Battin
Hys1	Hydrologic - WSL	46.252600	7.109690	1207	2015	present	Water conductivity, depth, temperature, opacity; when in function: isotope sample collection for d17O, d2H, and d17O	1	Lane
Pointe des Savolaires	Meteo - MADD	46.235390	7.087650	2250	2008	present	Air Temperature	0	Hicox
Piezometer 1	Hydrologic	46.227590	7.098370	1502	2017	present	Depth to water, temperature	0	Brunner
Piezometer 2	Hydrologic	46.227050	7.099300	1505	2017	present	Depth to water, temperature	0	Brunner
Piezometer 3	Hydrologic	46.231050	7.101080	1472	2017	present	Depth to water, temperature	0	Brunner
Piezometer 4	Hydrologic	46.229630	7.101580	1482	2017	present	Depth to water, temperature	0	Brunner
Dendrometer 1	Meteo - Sensorscope	46.230090	7.104280	1520	2017	2017	Tree diameter, VWC	1	Schaefli
Dendrometer 2	Meteo - Sensorscope	46.221220	7.096940	1596	2017	2018	Tree diameter, VWC (in 2018, two sensors)	1	Schaefli
Additional soil moisture	Decagon / Meter*				2017	2017	Soil moisture	0	Brunner
Additional soil temperature	Isolated Sensors*				2009	present	Soil temperature	0	Vittoz
Hobo Temperature	Hydrologic*				2017	2019	Water temperature, light (not calibrated)	0	Schaefli
HyS1	Hydrologic - Hobo*	46.252600	7.109690	1207	2016	2019	Water temperature, conductivity, CO2, depth, dissolved oxygen	0	Battin
Snow Lysimeters	Hydrologic*	near met stations			2017	2018	Snow melt, soil moisture	0	Schaefli
Bridge Pilon	Hydrologic	46.242820	7.104610	1324	2017	2018	Water Temperature, Depth, Dissolved Oxygen	0	Battin
Near Big Hill	Hydrologic	46.235127	7.104665	1445	2017	2018	Water temperature, conductivity, CO2, depth, dissolved oxygen	0	Battin

* in multiple or additional locations

Appendix 3: First results on discharge, snow cover and isotope dynamics, extracted from the work of (Michelon, Ceperley, et al., 2017)

This first year of record shows:

- the hydrological response to snow/glacier melting and precipitation events through the melt season and a dry fall/winter period
- the streamflow δ¹⁸O monitoring at the outlet, starting at the end of the melt season
- the streamflow δ¹⁸O monitoring at the upper sampling point in the catchment, starting in fall
- the rain δ¹⁸O signal over a varying integration period

Observations:

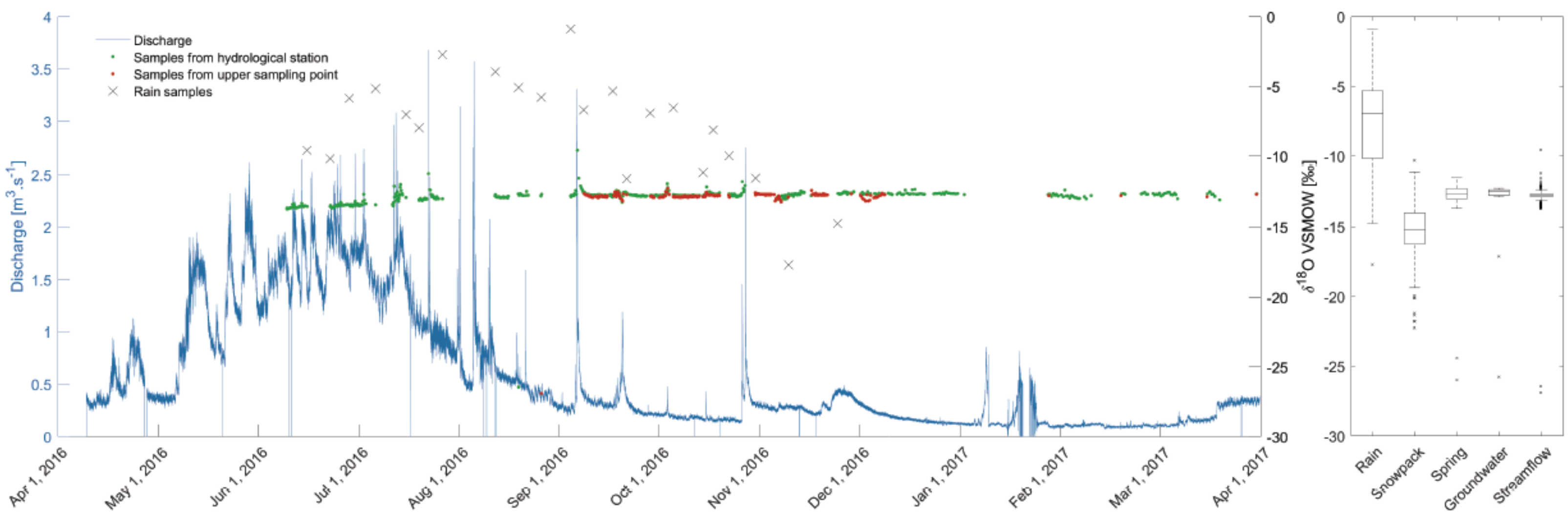
=> The analysis of 1300+ water samples (rain, streamflow, spring, groundwater, snowpack) started in June when snowpack almost disappeared (only small melt contributions left)

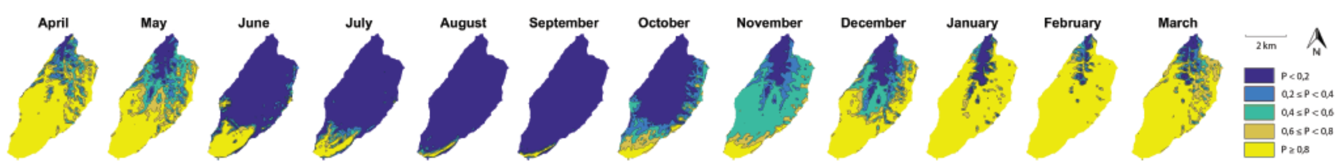
=> High variation in rain and snowpack isotopic composition but very low variability in the stream

=> The streamflow δ¹⁸O and δD seasonal variabilities are both about 2‰
The streamflow δ¹⁸O and δD daily variabilities are about 0.1 and 0.4‰, respectively

=> Around 0.1 and 0.3‰ depletion respectively in δ¹⁸O and δD between the two streamflow sampling points

=> Both sampling points show almost the same reaction to rainfall events





Snow cover probability computed using NDSI (Normalized Difference Snow Index) on 73 Landsat 8/Sentinel-2 satellite images over 2 years (3/2015 to 3/2017)