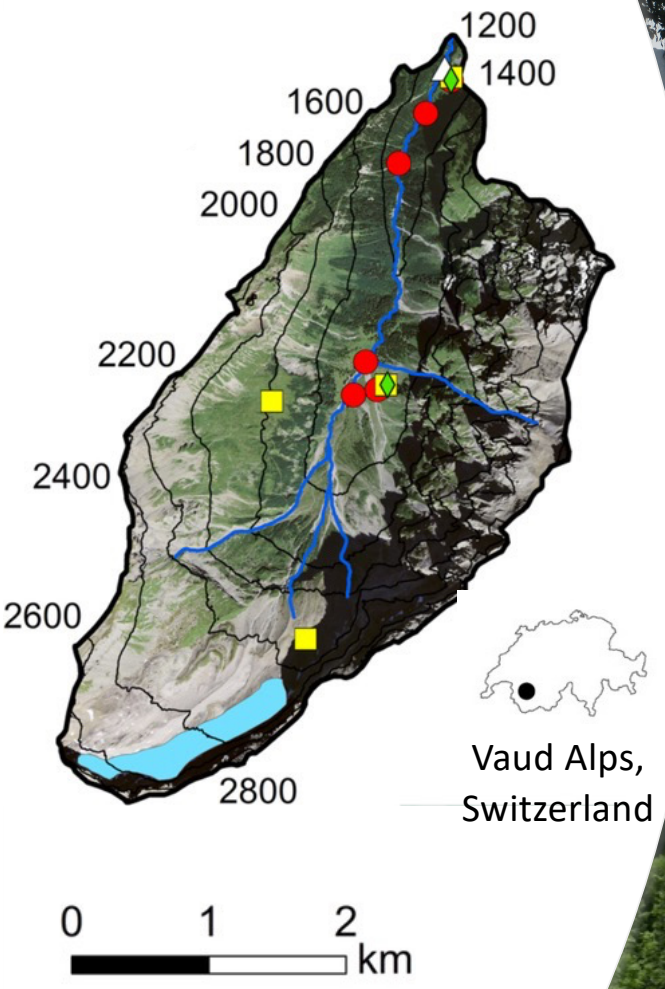
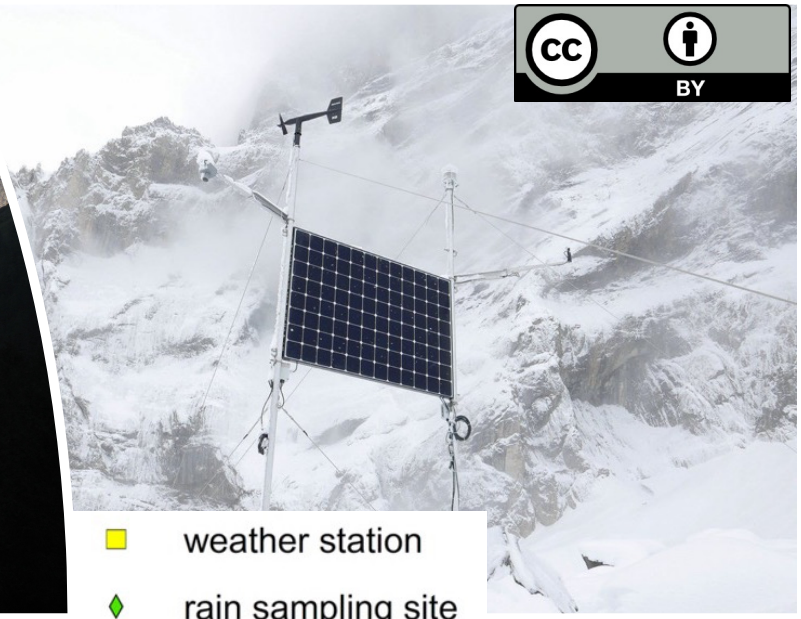
Exposing Seasonal and Spatial Variability in Storage and Release Upstream of the Outlet

Natalie Ceperley, Sabina Kurmann, Anna Meier, Martine Helfer, and Bettina Schaefli

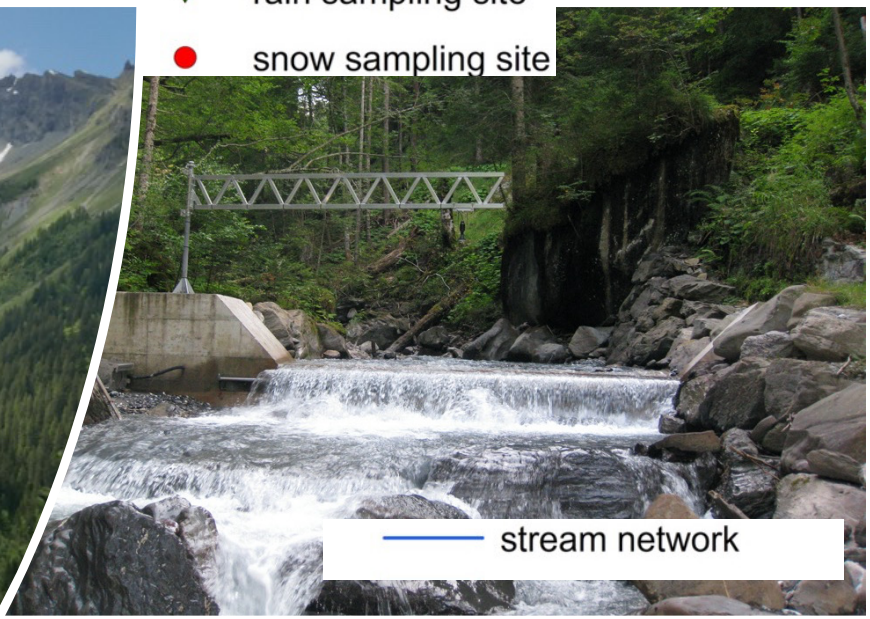
Vallon de Nant



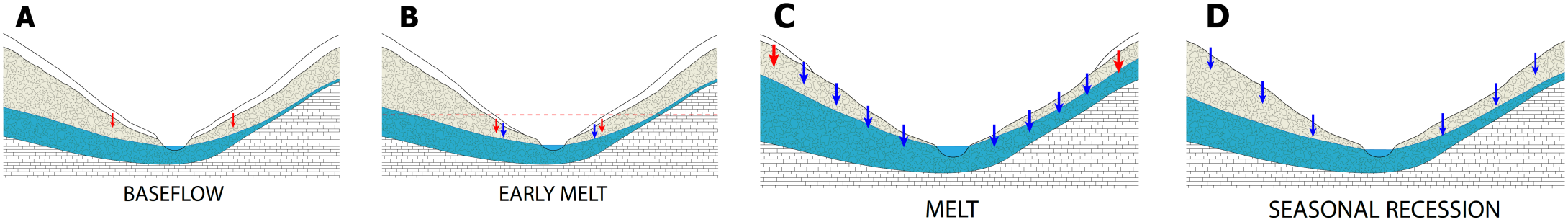
Vaud Alps, Switzerland



- 1200 – 3051 m
- Protected Area
- ~14 km^2



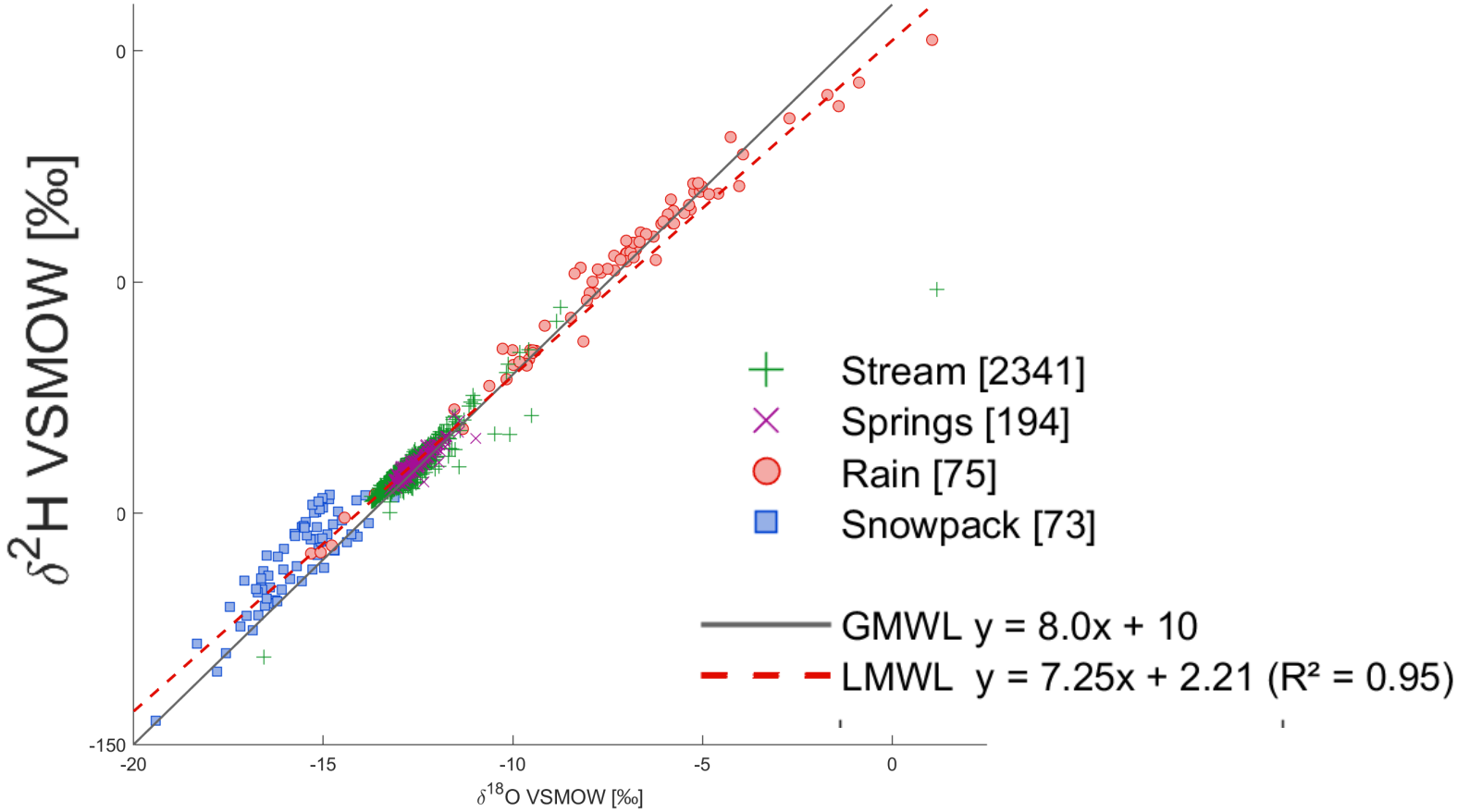
Emerging Image of an interplay of different processes over 4 periods



- Changing saturated area and snow cover
- Snowmelt contributes even to baseflow and early melt
- Rain is important for the seasonal “reset” / MELT
- Snow recedes at low elevation first, contributing snow melt from bottom up.
- Asymmetry in hillslopes, reservoirs, conductivities drive varying **(spring)** responses

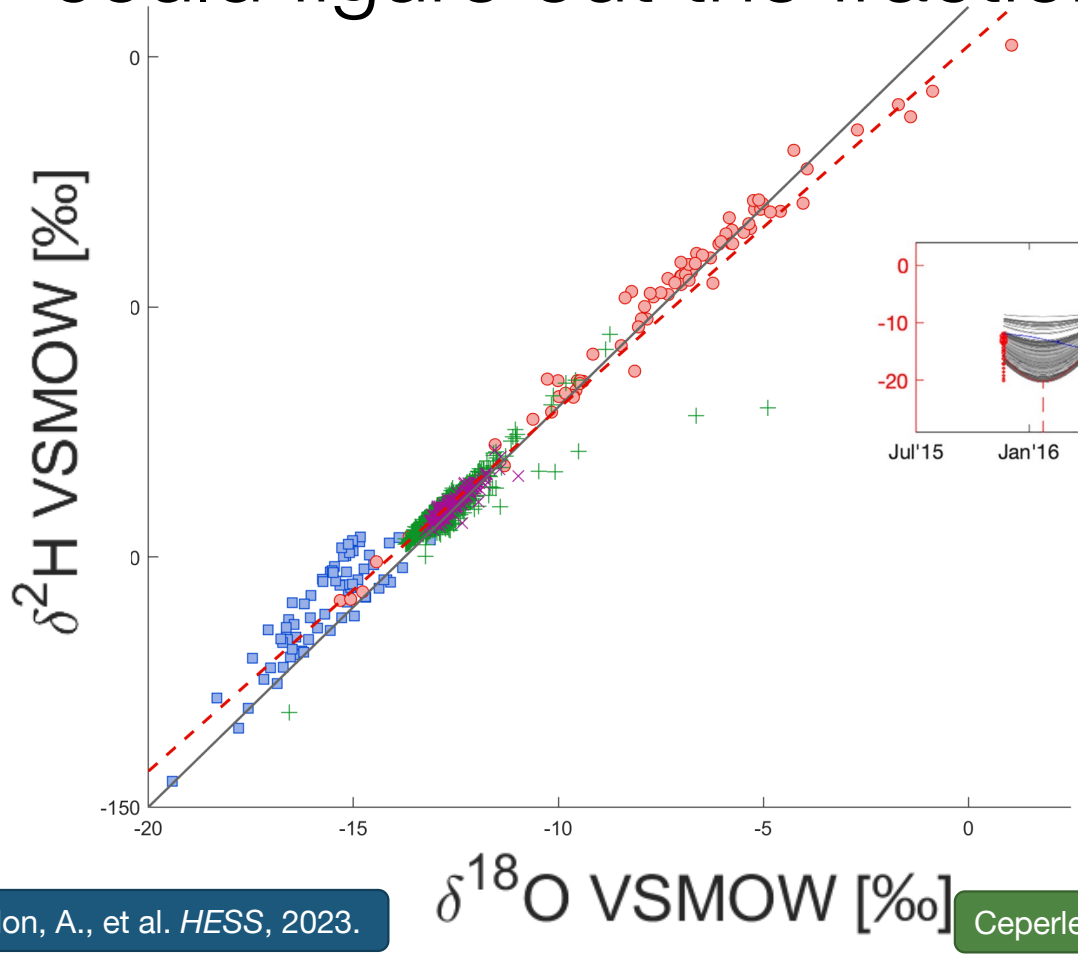
Michelon, A., et al. *HESS*, 2023.

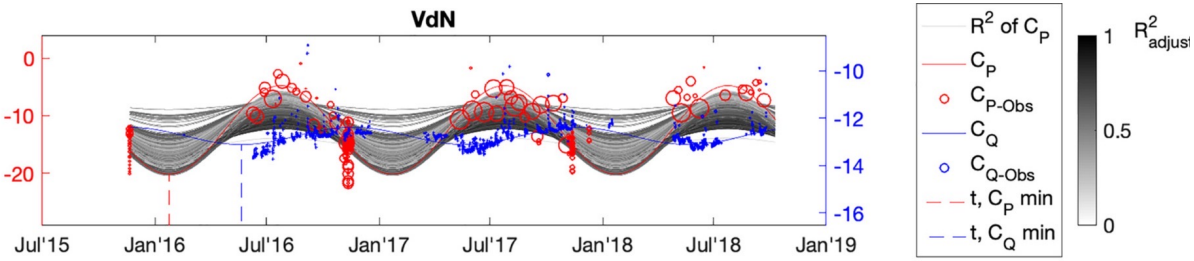
So we looked towards isotopes



Michelon, A., et al. *HESS*, 2023.

Through time, (thanks to snow samples) we could figure out the fraction of young water…





$$F_{yw} \approx \frac{A_Q}{A_p} = \frac{0.36}{7.71} = 5\ \%$$

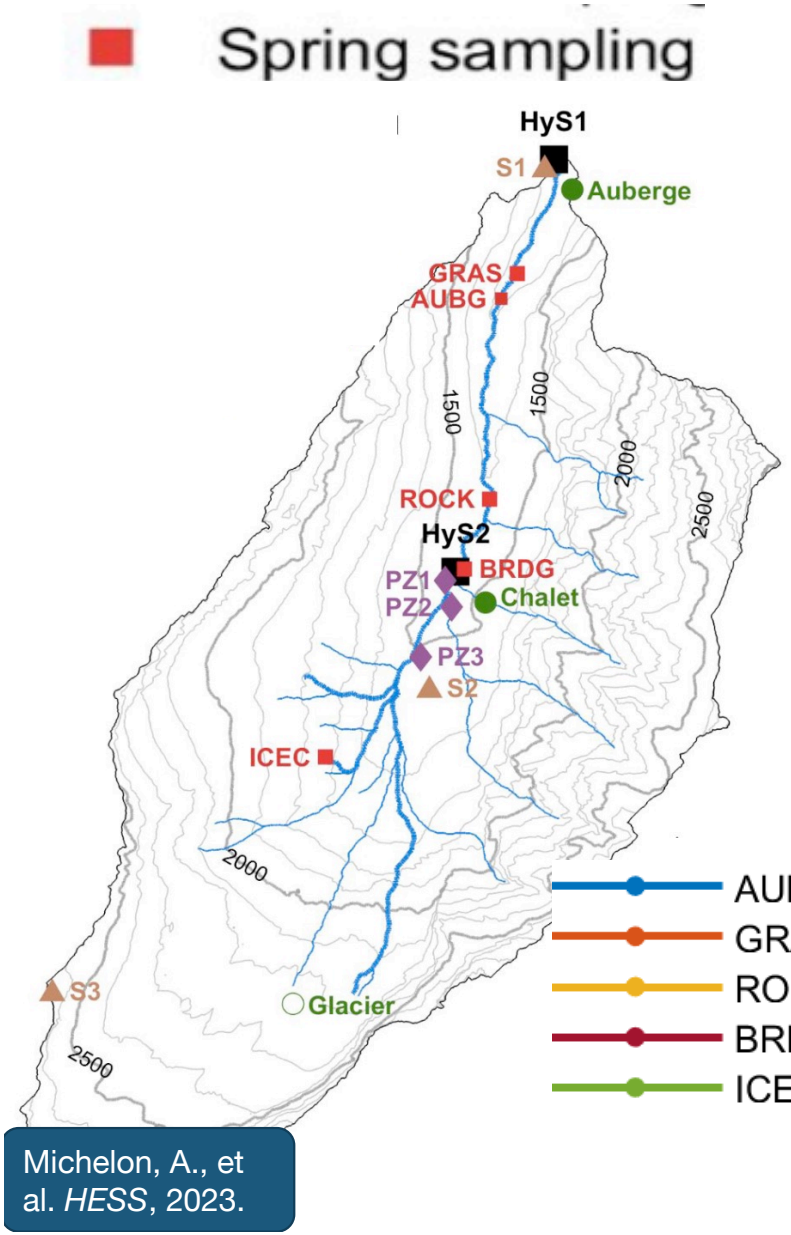
Amplitude of $\delta^{18}O$ in:

- **Q**- discharge
- **P**recipitation

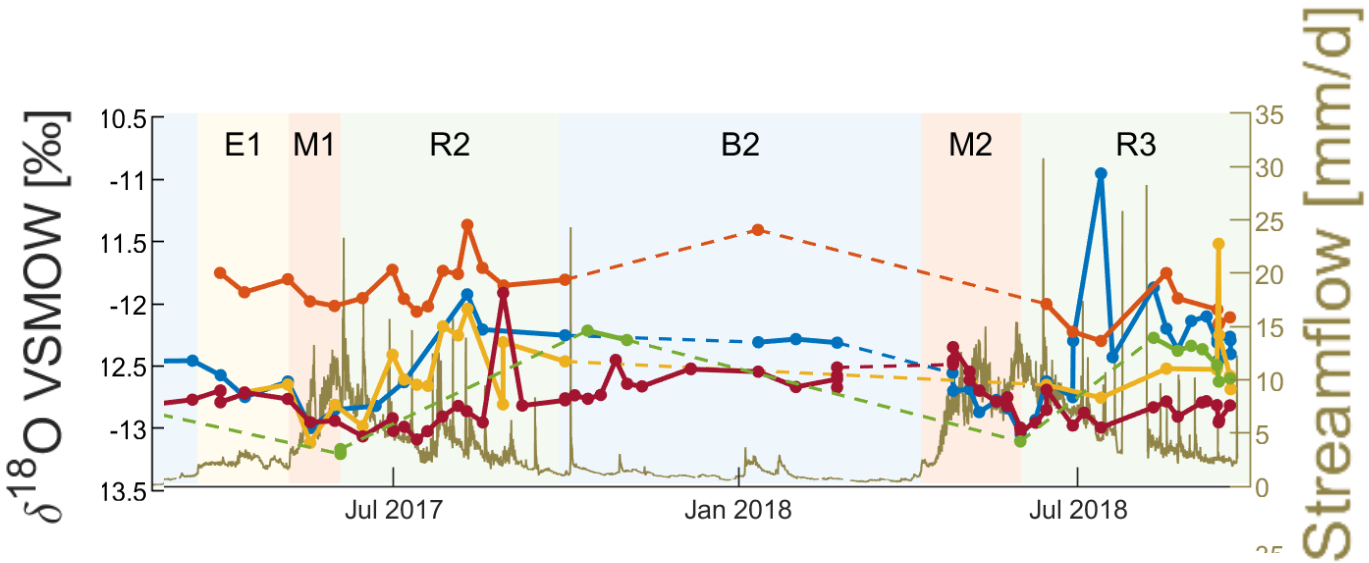
Michelon, A., et al. *HESS*, 2023.

Ceperley, N.C., et al. *HP*, 2020.

Springs in particular

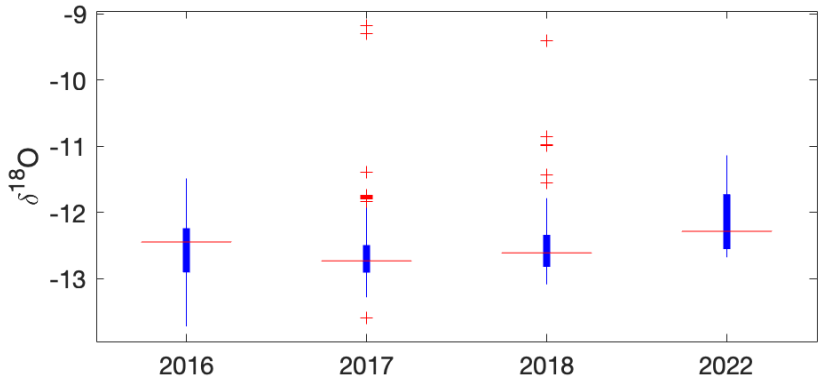


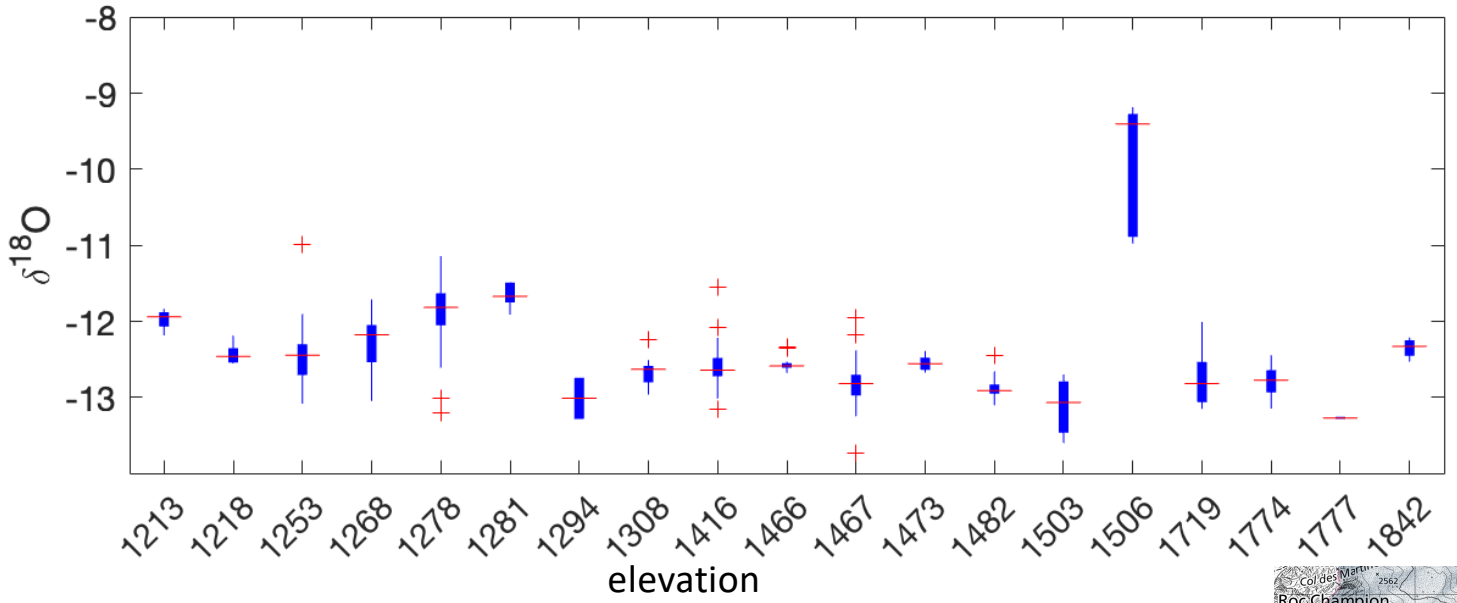
Michelon, A., et al. *HESS*, 2023.



- Each different
- Shallow flow depth of **SOME** springs
- Contrasting storage release according to elevation over the winter

Further observation of subsurface, reveals annual & site variability

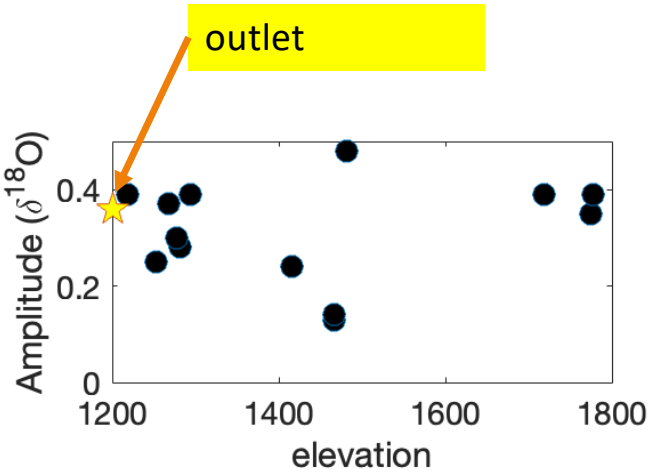




Kurmann, S. (2023).
https://doi.org/10.5281/zenodo.1154798

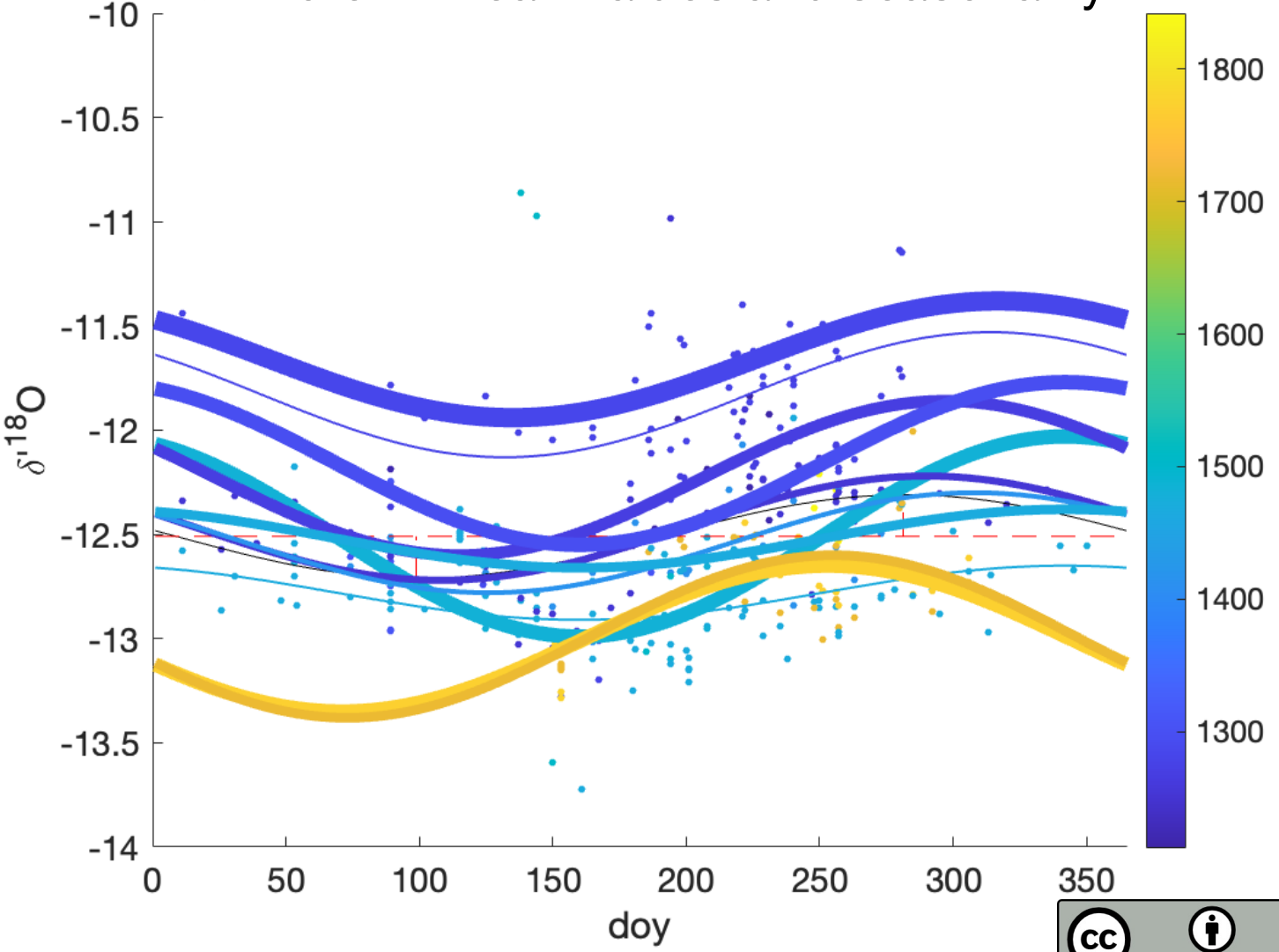
Sine waves

- Do we see a dampening of the isotope signal as it moves through the catchment ?



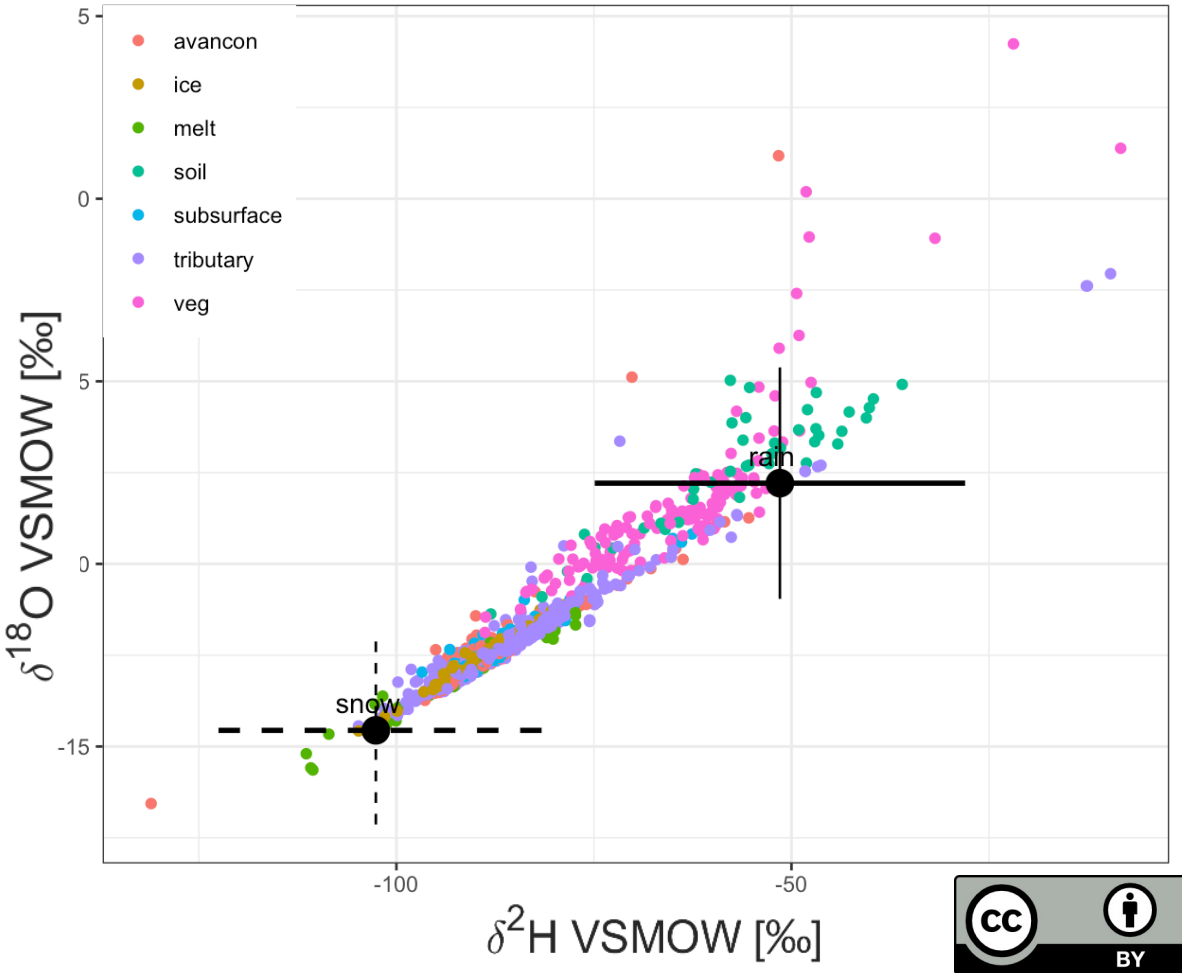
> Not systematically

> More in mean values and seasonality



Mixing model - MixSIAR

- Continuous effect of **elevation**
- Random effect of **year**
- Fixed effects of **type** and **month**
- **2-components, constrain**



Stock, B. C., & Semmens, B. X. (2016). *MixSIAR GUI user manual. Version 3.1*. doi:10.5281/zenodo.47719

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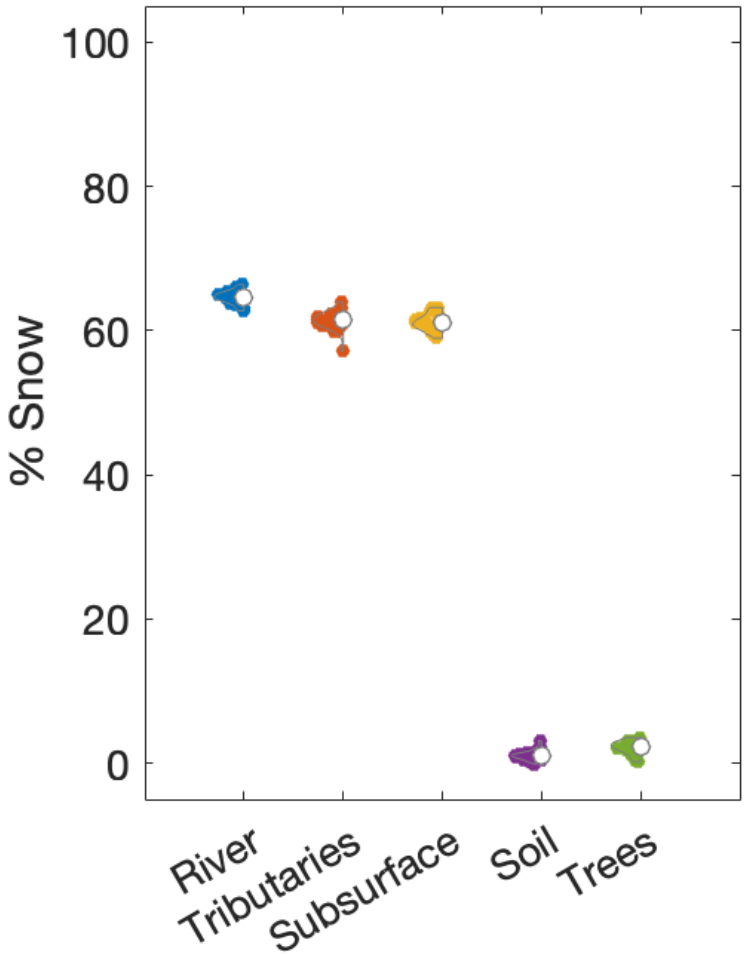

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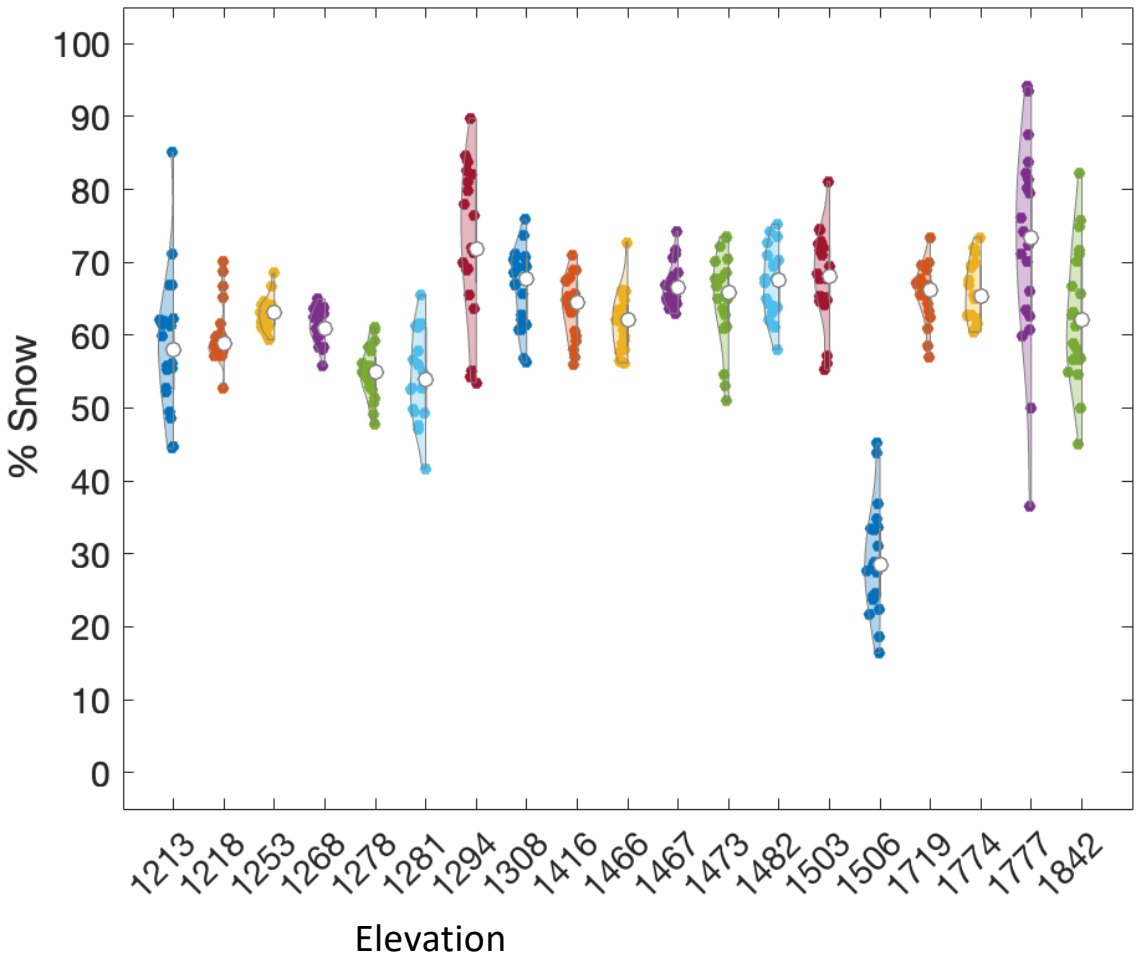
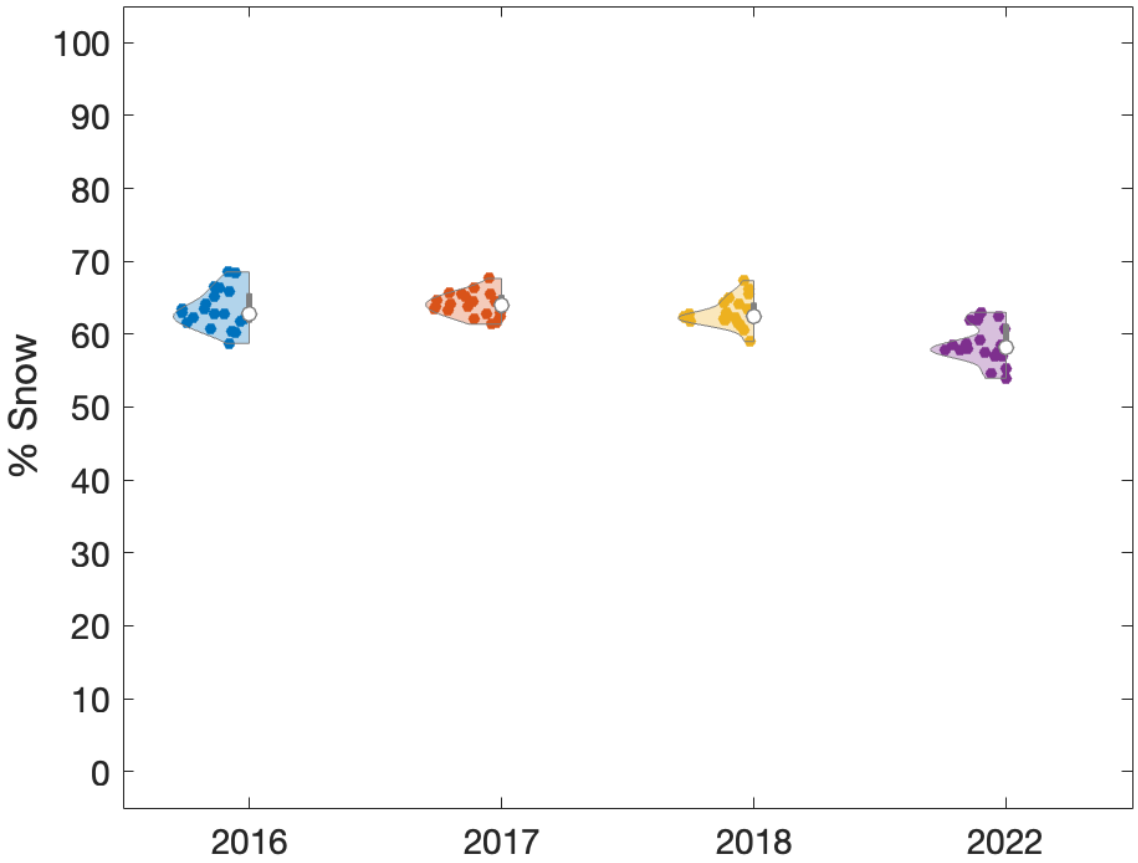
Springs, Wells

- By point, elevation
- Mix of springs and wells
- Anomaly = piezo that only reached near surface, and was often dry



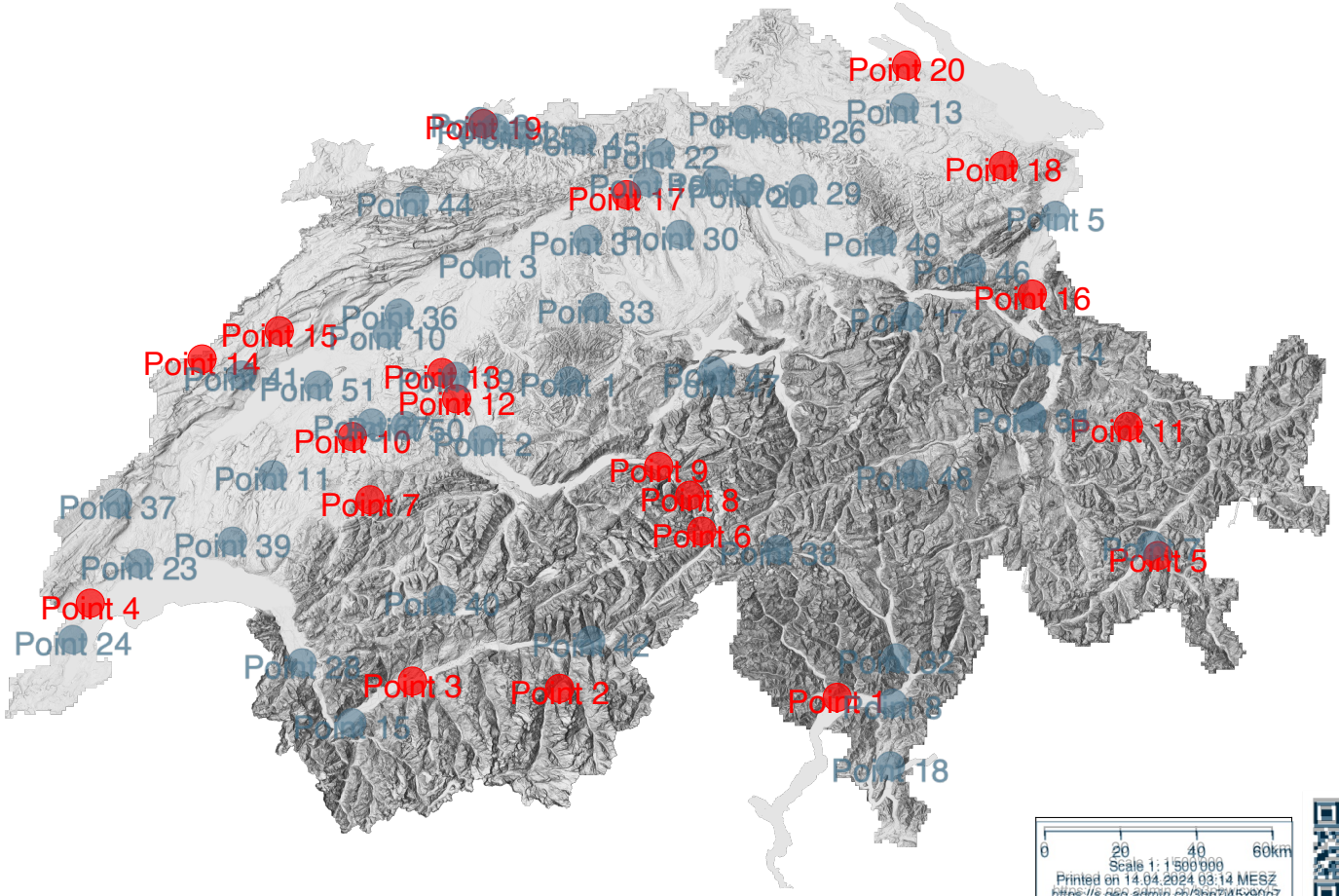
Springs, Wells

- By point, elevation
- Mix of springs and wells
- Anomaly = piezo that only reached near surface, and was often dry
- By year => the effect of low snow year (2022) drought starts to be visible



Upscale to Swiss Scale

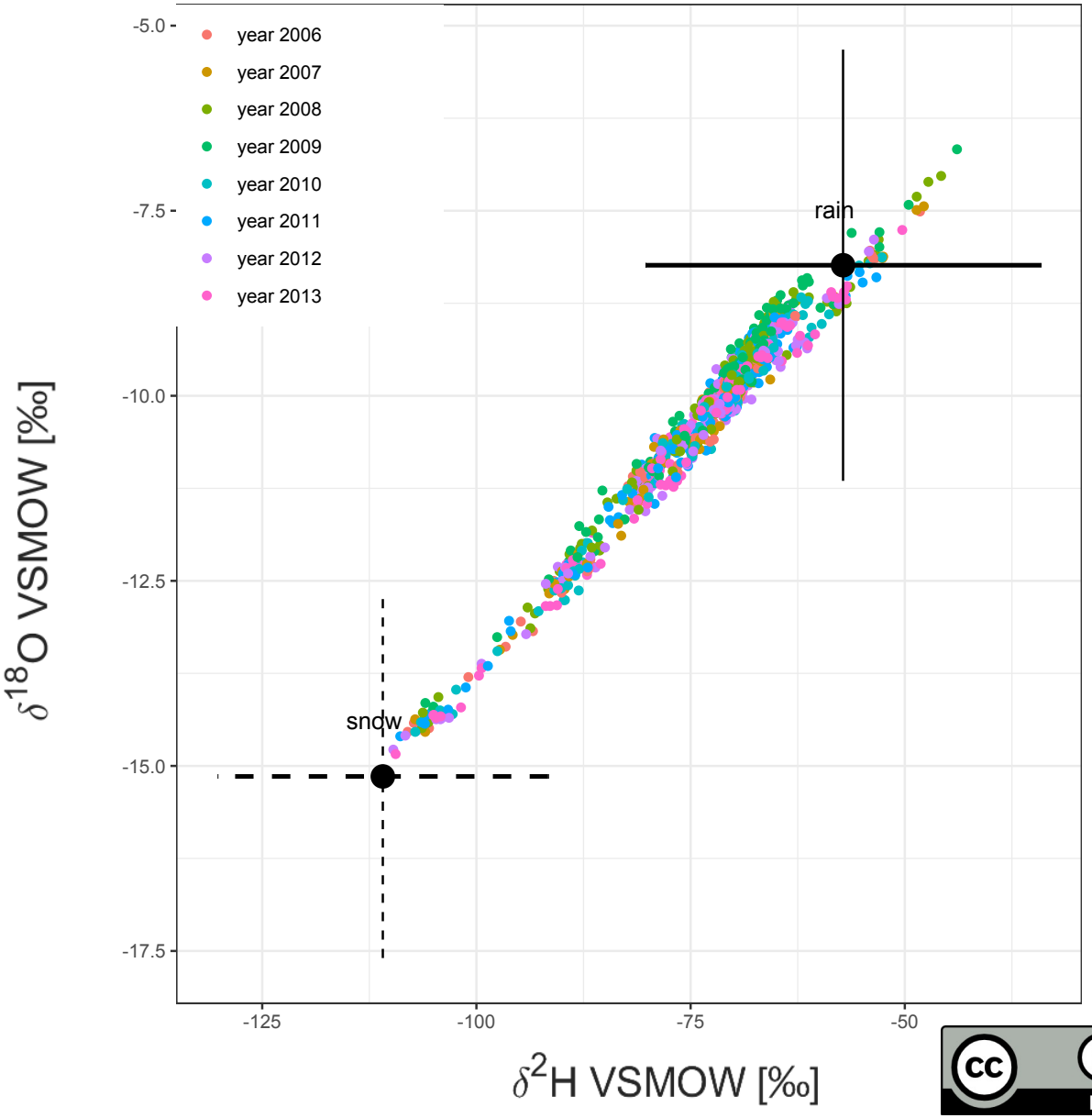
- 50 TREND groundwater stations from 2006-2013 (NAQUA-FOEN, blue, 50)
- Global Network of Isotopes in Precipitation (IAEA, red, 20)



Data belong to:
Swiss Federal Office for the Environment FOEN
Swiss National Groundwater Monitoring NAQUA
International Atomic Energy Agency (IAEA)
https://www.iaea.org/services/networks/gnip

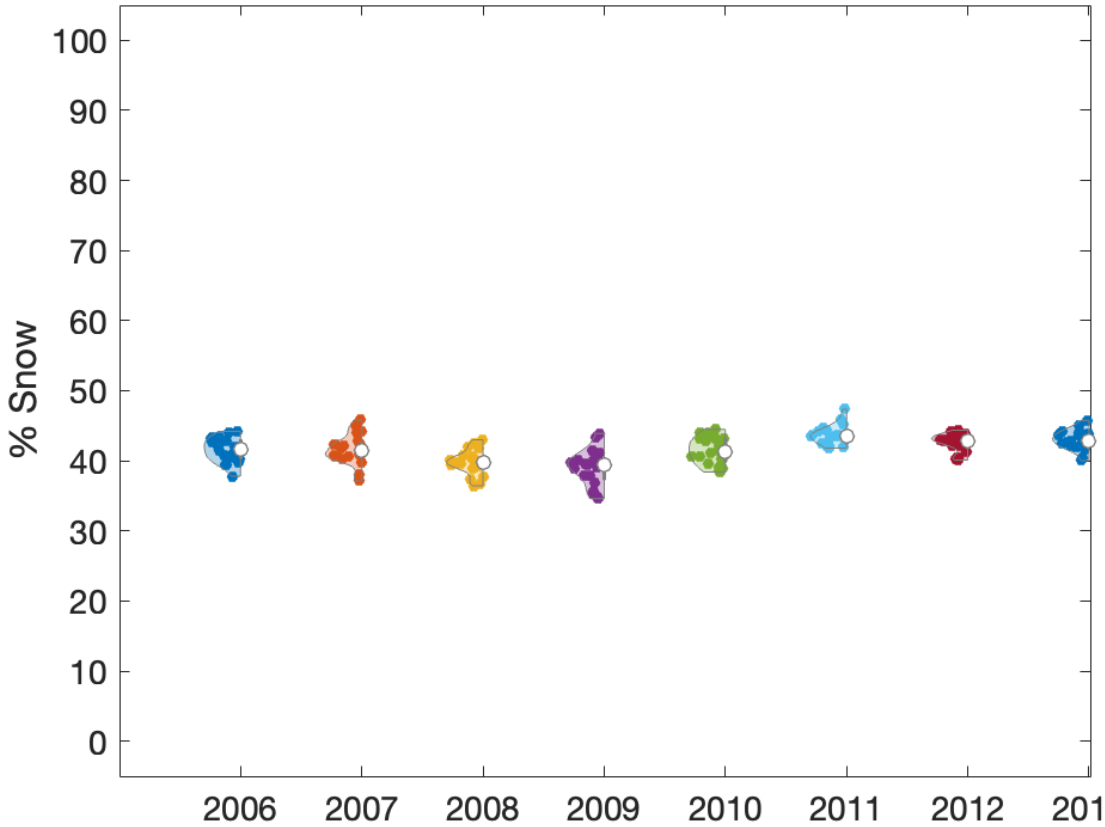
GNIP constrains NAQUA – groundwater points

GNIP – rain vs. snow discrimination. Swiss wide, use all that were labeled “rain” or “snow” or with strong temperature indications (<0ºC, >10ºC), 644 points between 1971 and 2018



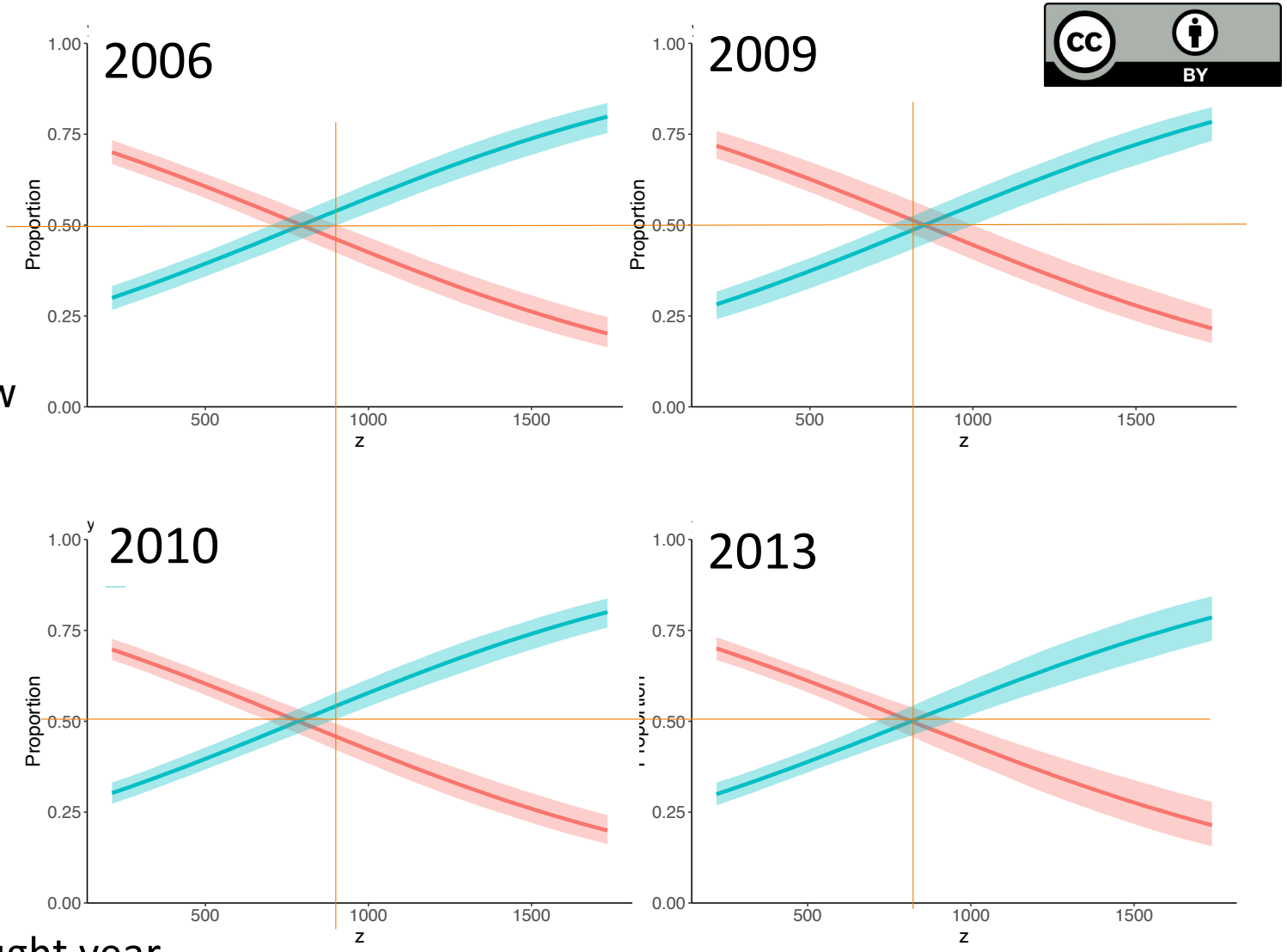
NAQUA available for 7 years

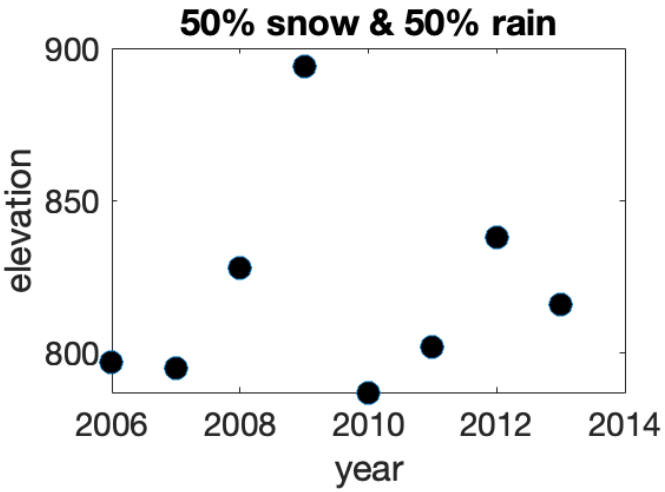
Interannual Variation is present, but subtle



Unfortunately, no major drought year included (2003, 2015, 2018, 2022)

NAQUA contributions by year elevation





Unfortunately, no major drought year included (2003, 2015, 2018, 2022)

Continuous effects described by: Francis et al. (2011). Ecology letters, 14(4), 364-372.

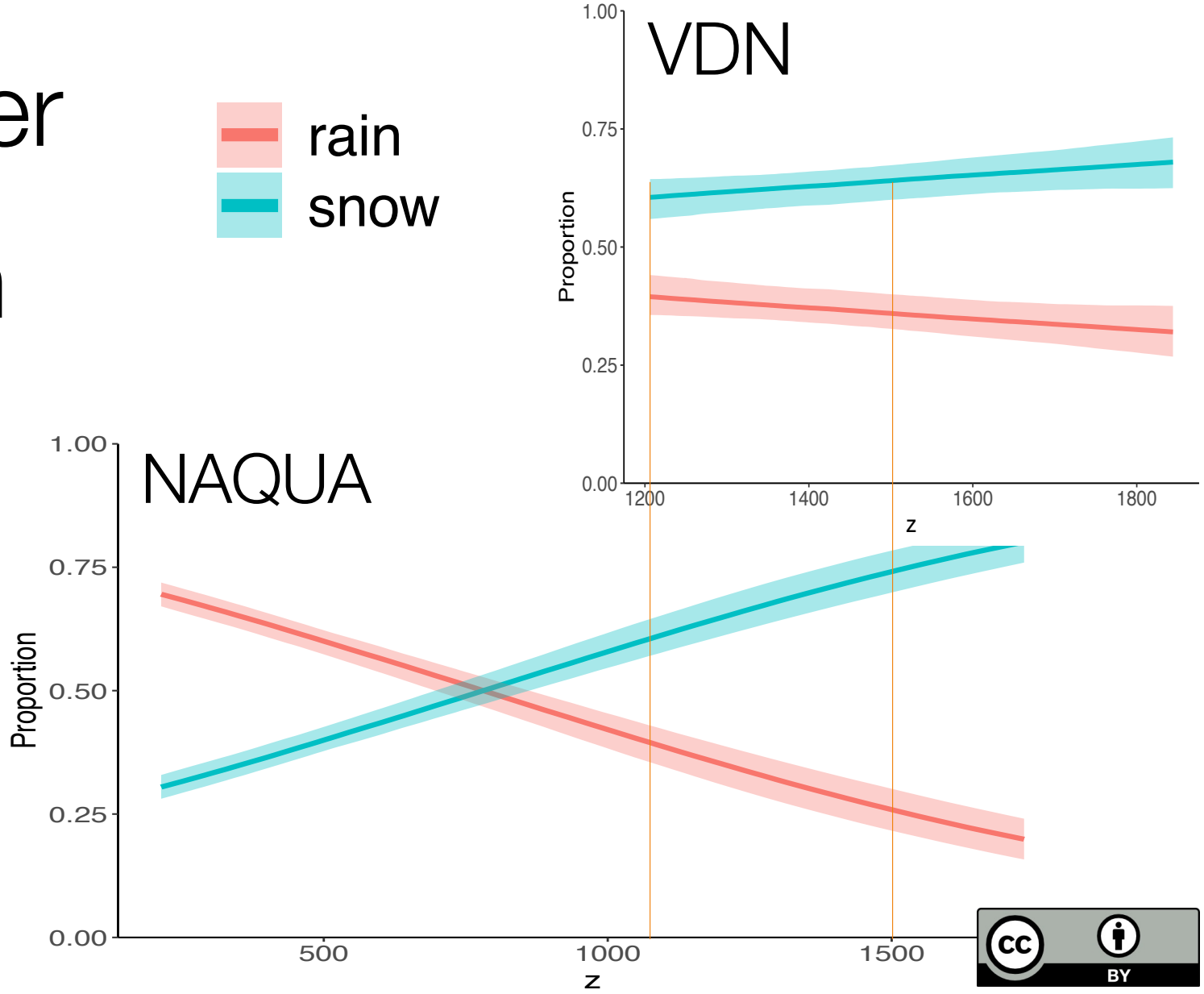
Groundwater – snow contribution

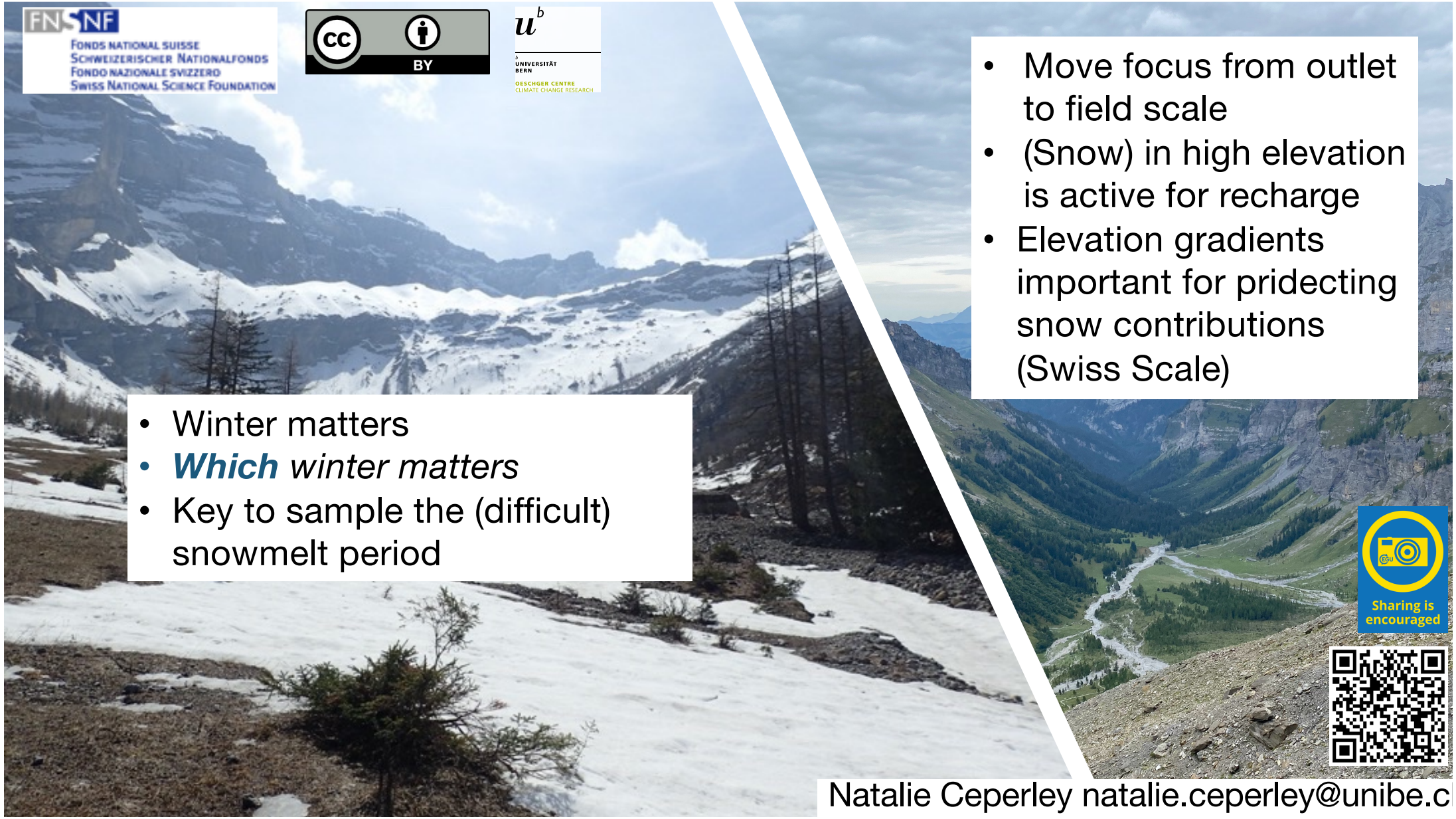
by elevation, continuous factor

- VDN cross would be at 350
- (NAQUA at 784)

> Variability by site vs. sampling

> VDN significant snow importance





- Winter matters
- ***Which*** *winter matters*
- Key to sample the (difficult) snowmelt period

- Move focus from outlet to field scale
- (Snow) in high elevation is active for recharge
- Elevation gradients important for pridecting snow contributions (Swiss Scale)

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