Estimating groundwater recharge from summer and winter precipitation in Switzerland – a combination of hydrological recession analysis and stable water isotope

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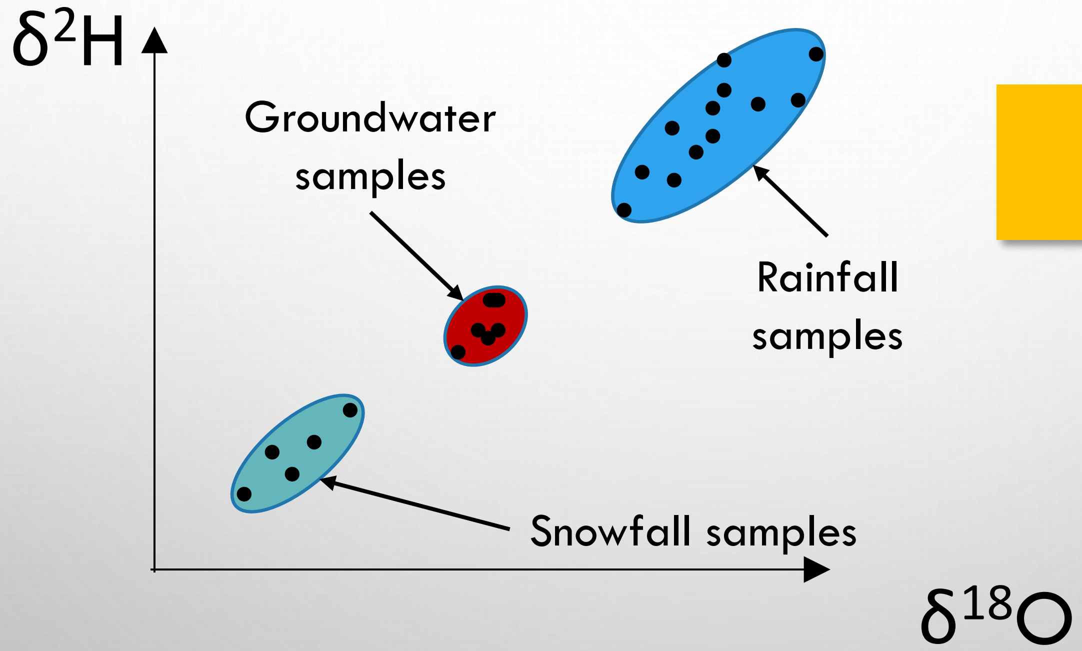
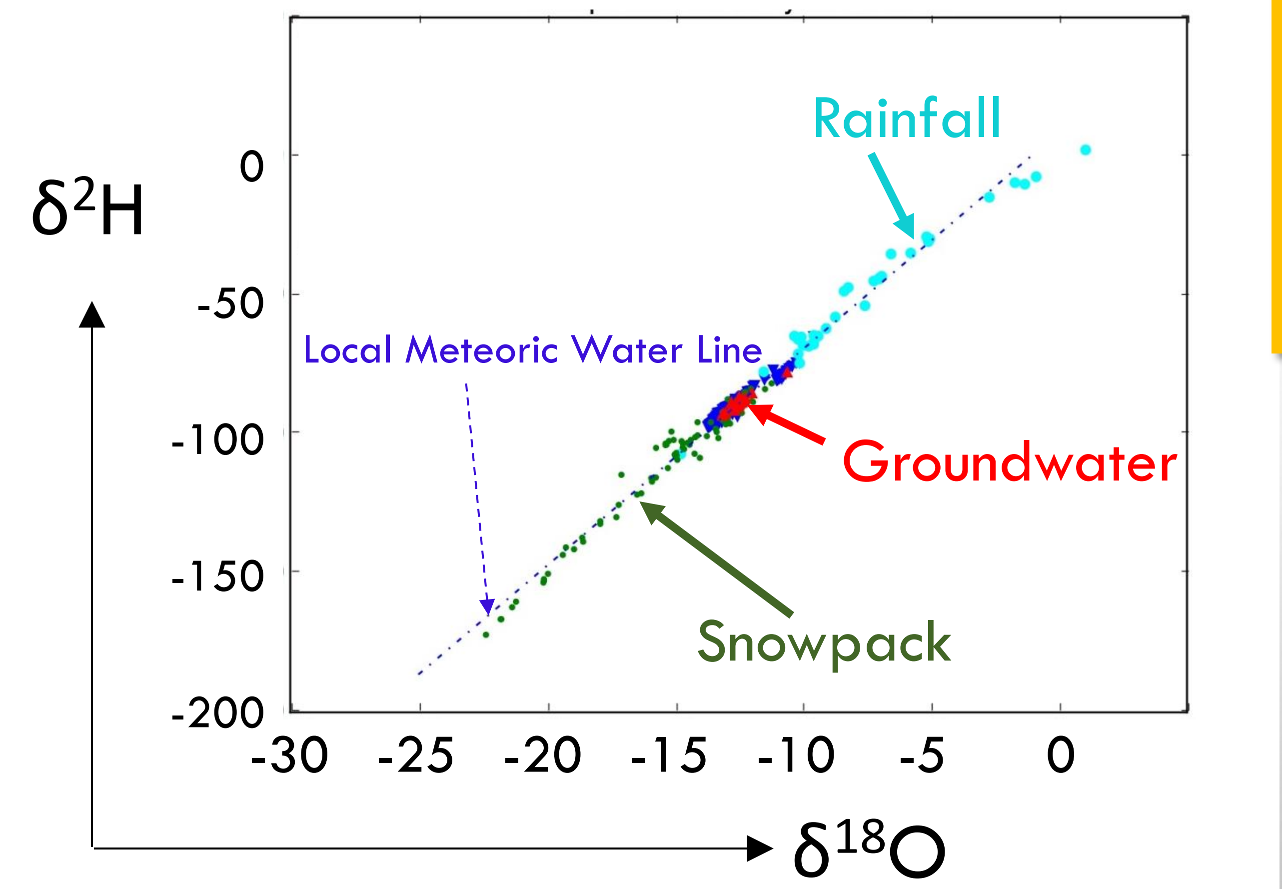
How to quantify the importance of snow for high Alpine water resources ?

Snowmelt dominant in groundwater

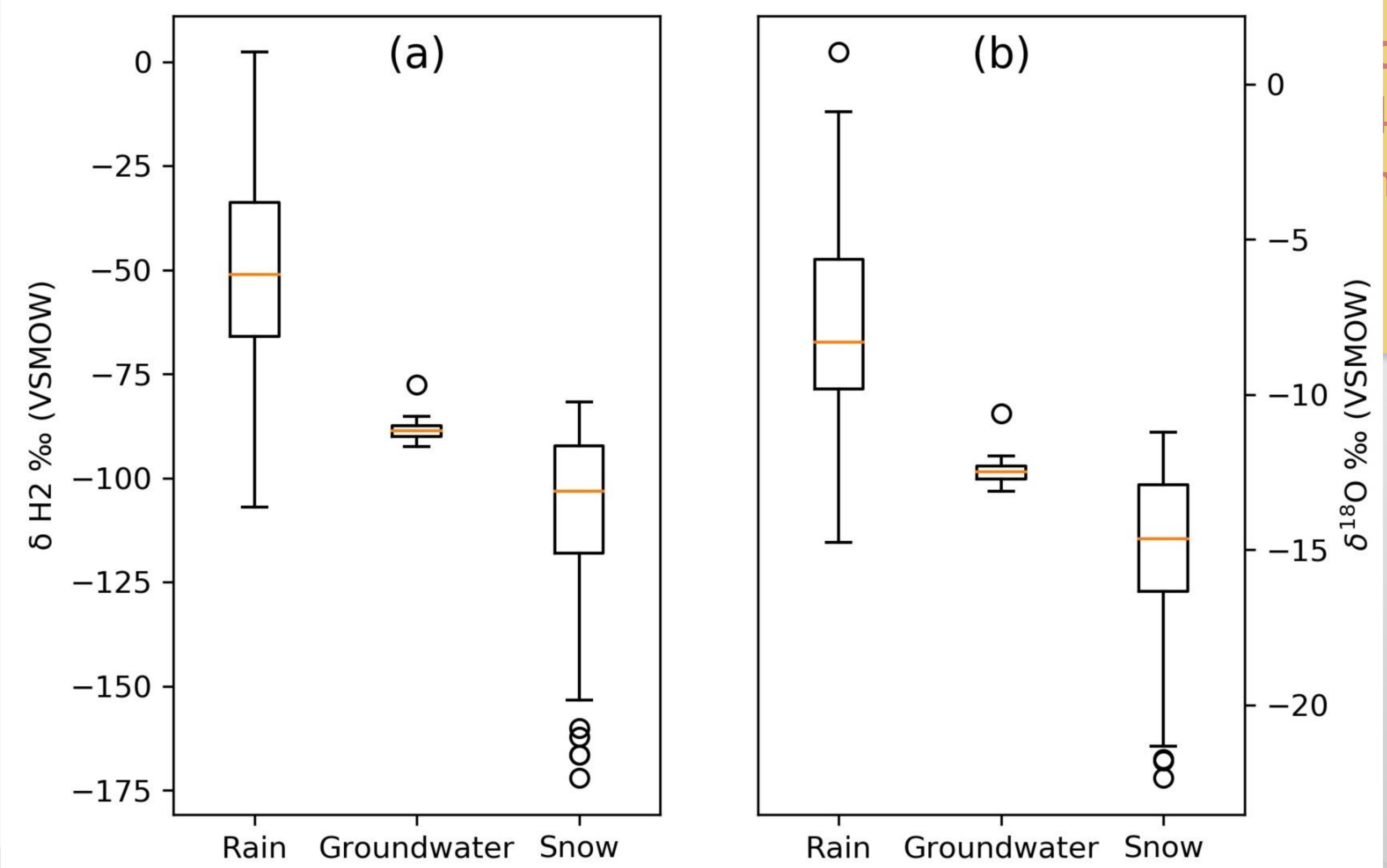
Why stable water isotopes ?



the Dual isotope space



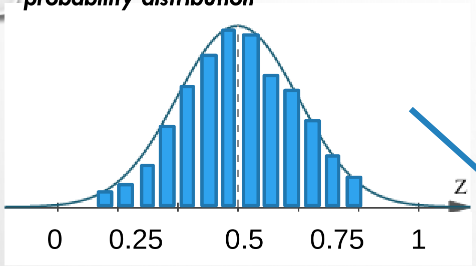
Vallon de Nant
(13.4 km^2,
1253 m asl. –
3051 m asl.,
> 2700 samples)



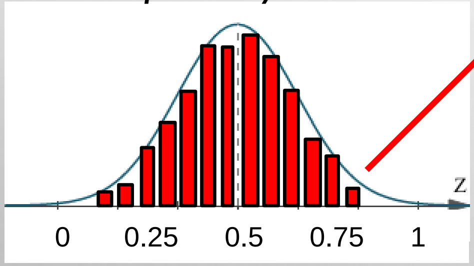
de Nant
4 km²,
m asl. –
m asl.,
samples)

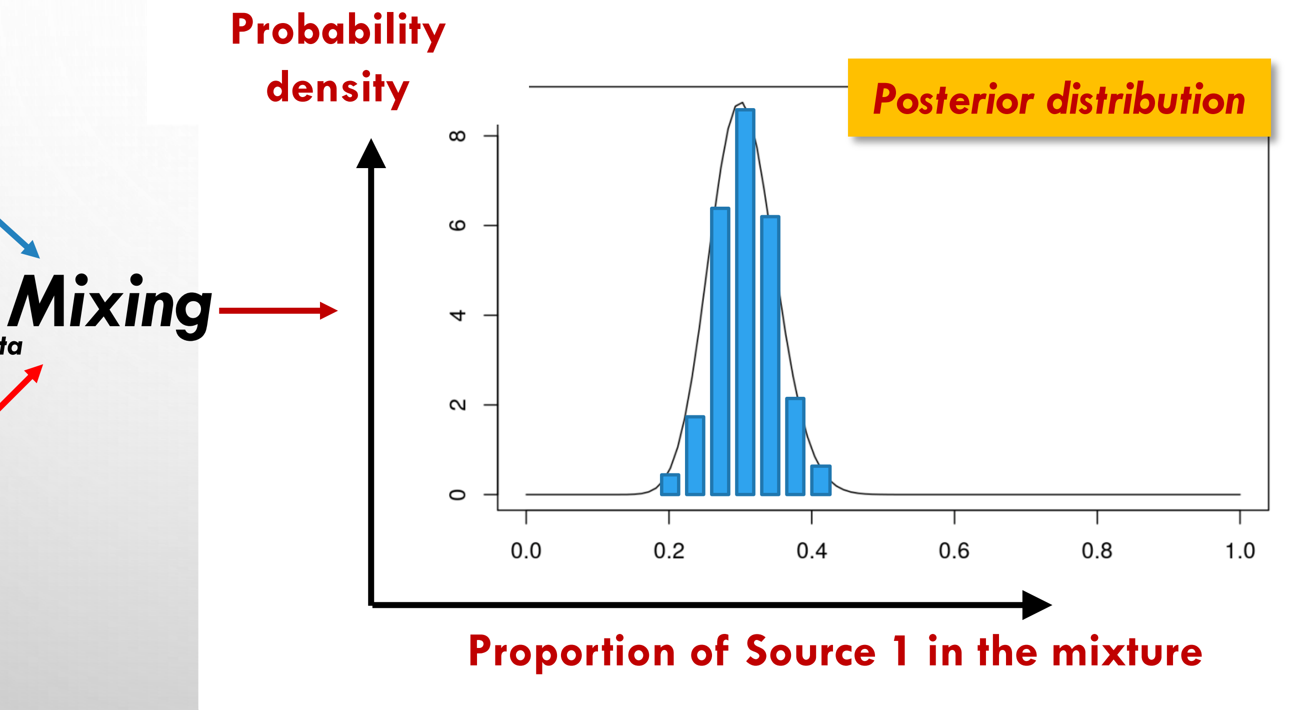
State of the art: Bayesian Mixing

Source 1, *histograms of observed data and fitted probability distribution*



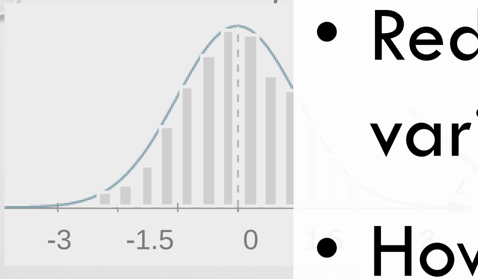
Source 2, *histograms of observed data and fitted probability distribution*



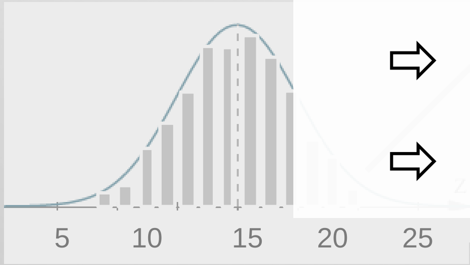


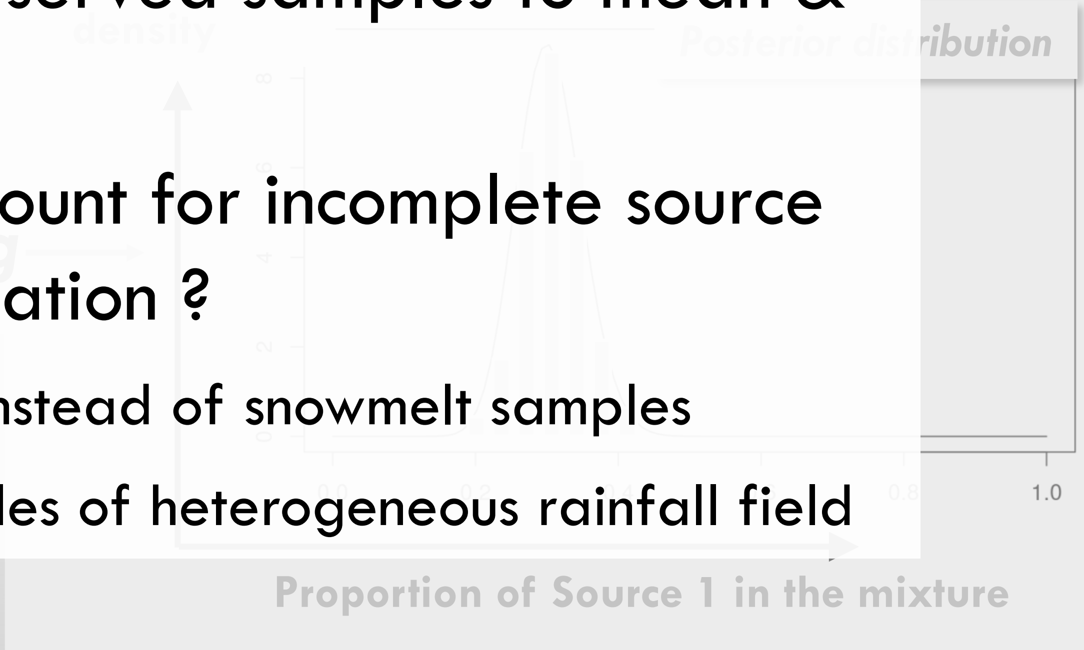
State of the art: Bayesian Mixing

Source 1 samples, fitted distribution



Source 2, samples fitted distribution

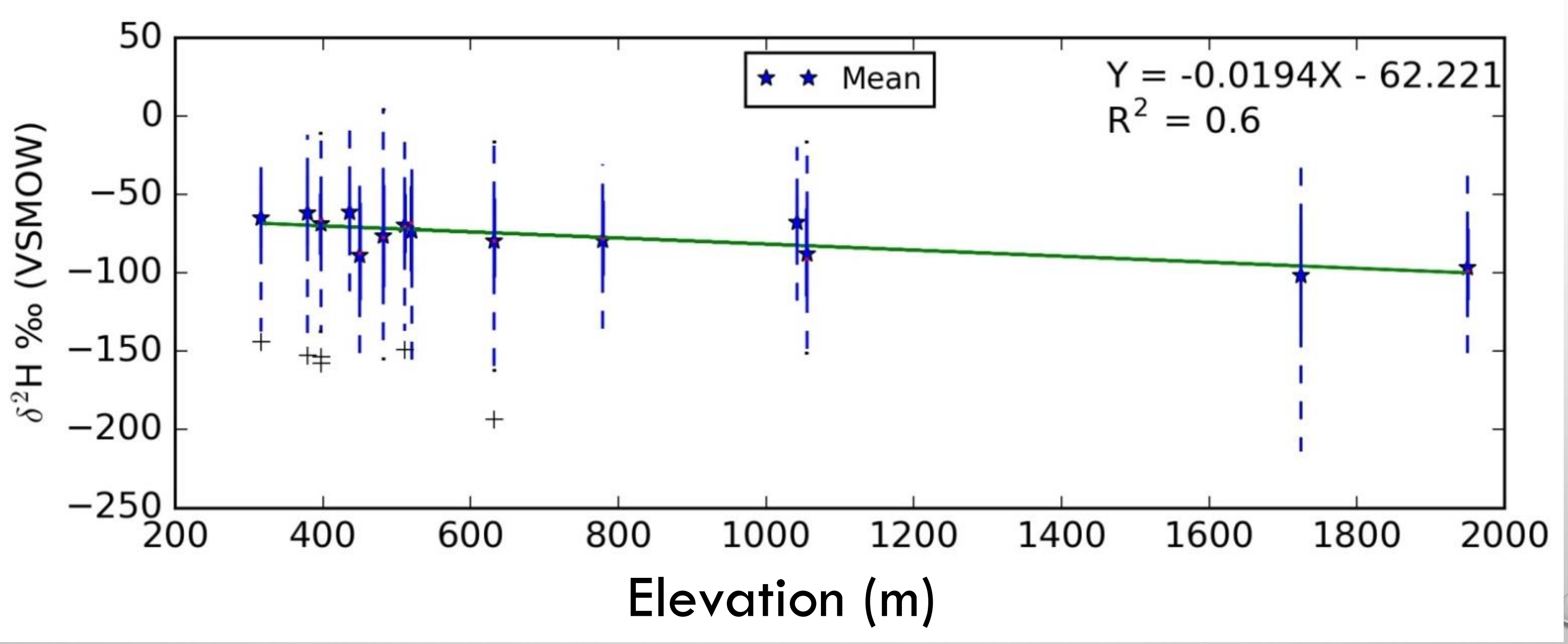




Limitations:

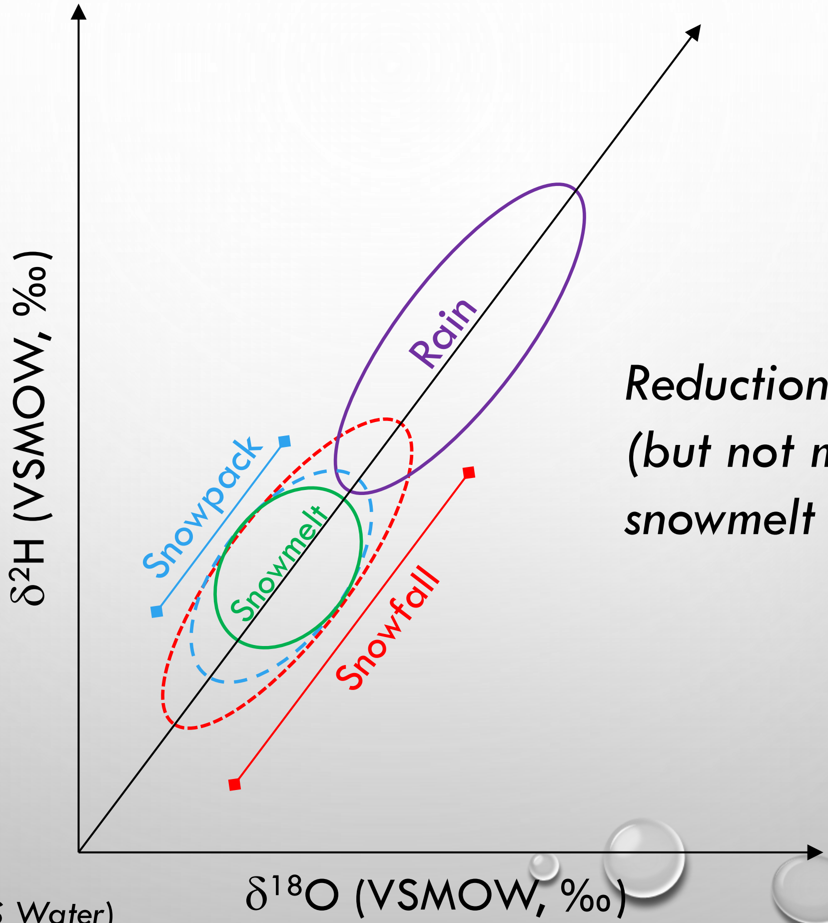
- Reduces observed samples to mean & variance
- How to account for incomplete source characterization ?
  - ⇨ snowfall instead of snowmelt samples
  - ⇨ few samples of heterogeneous rainfall field

Isotopic lapse rate in rain and snow



~1.94 ‰ / 100m (δ^2H) enrichment based on Swiss precipitation isotope data

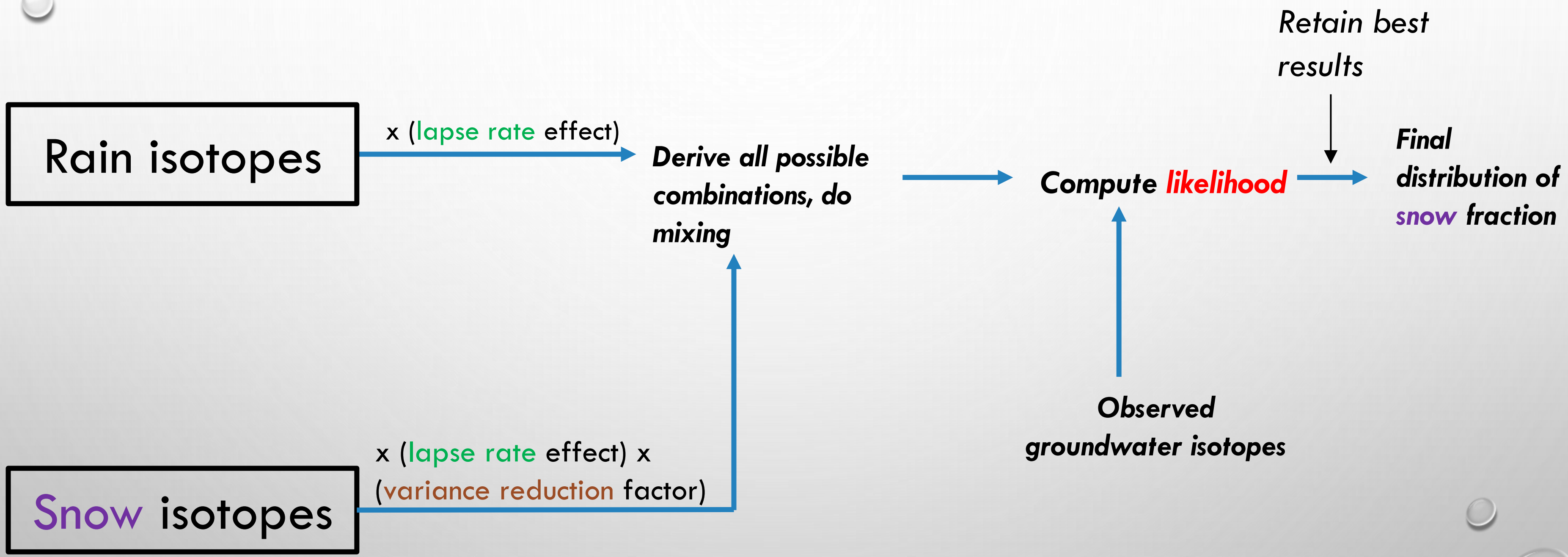
Effect of melt on snow isotopic ratio



Reduction in isotope variance (but not mean) from snowfall to snowmelt

Beria et al. 2018 (under review *WIRES Water*)

HydroMix

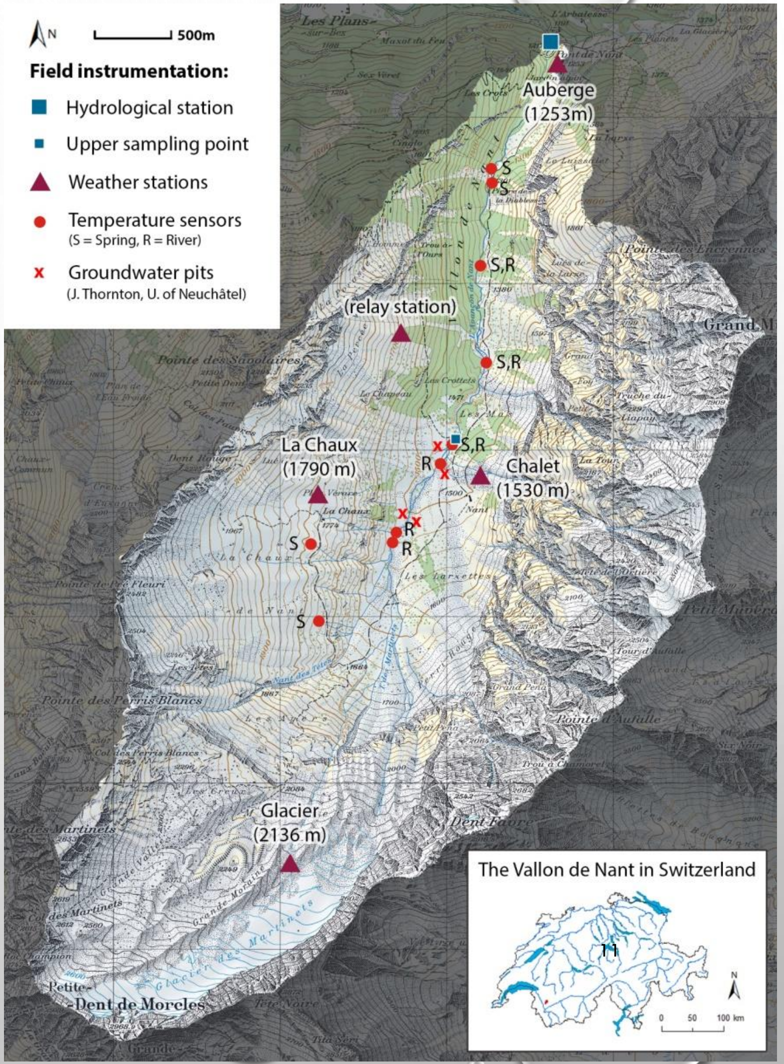


Rain isotopes
x (lapse rate effect)
Snow isotopes
x (lapse rate effect) x (variance reduction factor)
Derive all possible combinations, do mixing
Compute likelihood
Observed groundwater isotopes
Retain best results
Final distribution of snow fraction

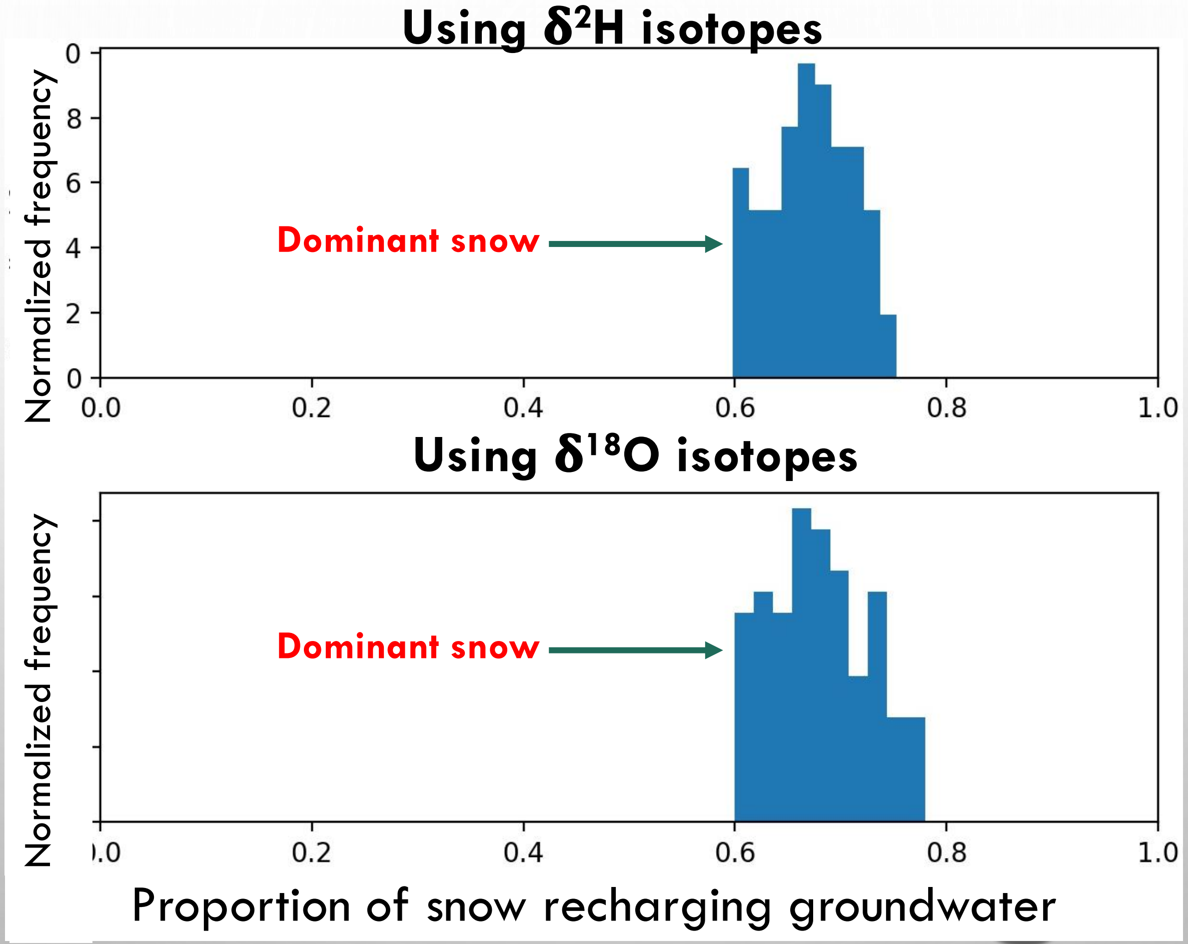
Vallon de Nant (Swiss Alps)

- Catchment area: 13.4 km^2
- Elevation gradient: 1253m – 3051m (m.s.l)
- Protected since 1969 (Natural Reserve of the Muveran)
- Data availability: February 2016 – present

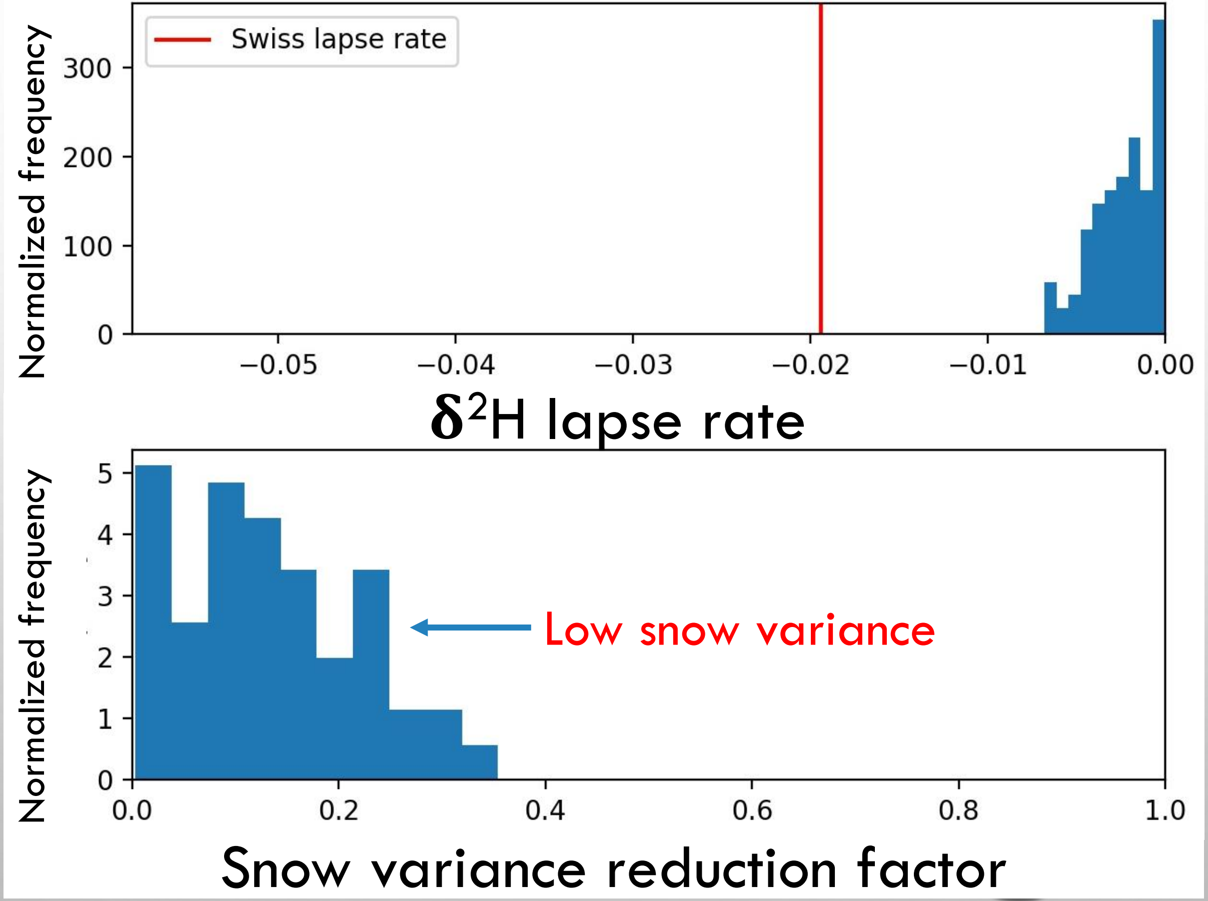
Isotope samples	# samples
Rain	75
Snowpack	144
Groundwater	49
Stream	> 2000 (~ 6 hourly)
Spring	153



Snow proportion in groundwater

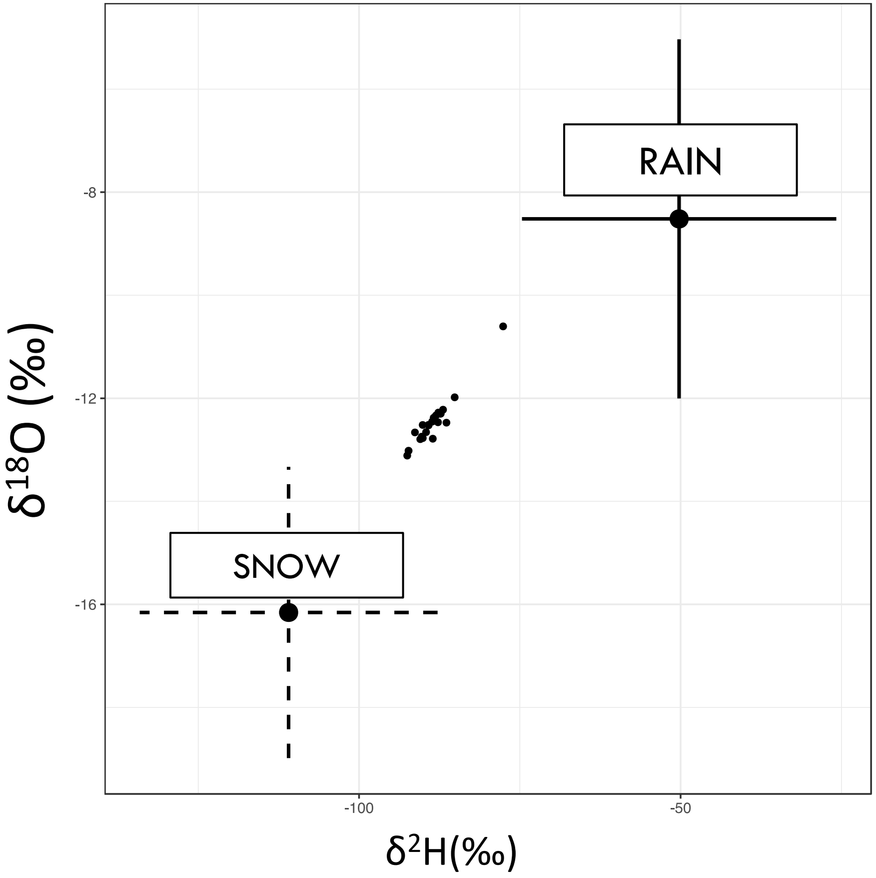


Posterior distributions of *HydroMix*

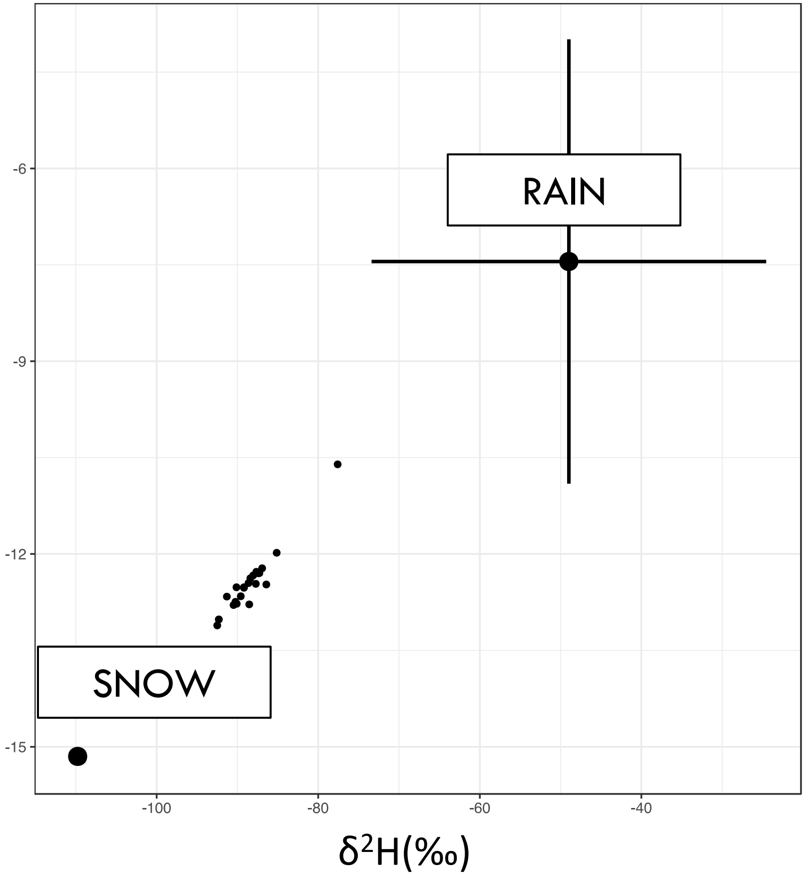


Snow reduction effect

No snow variance reduction



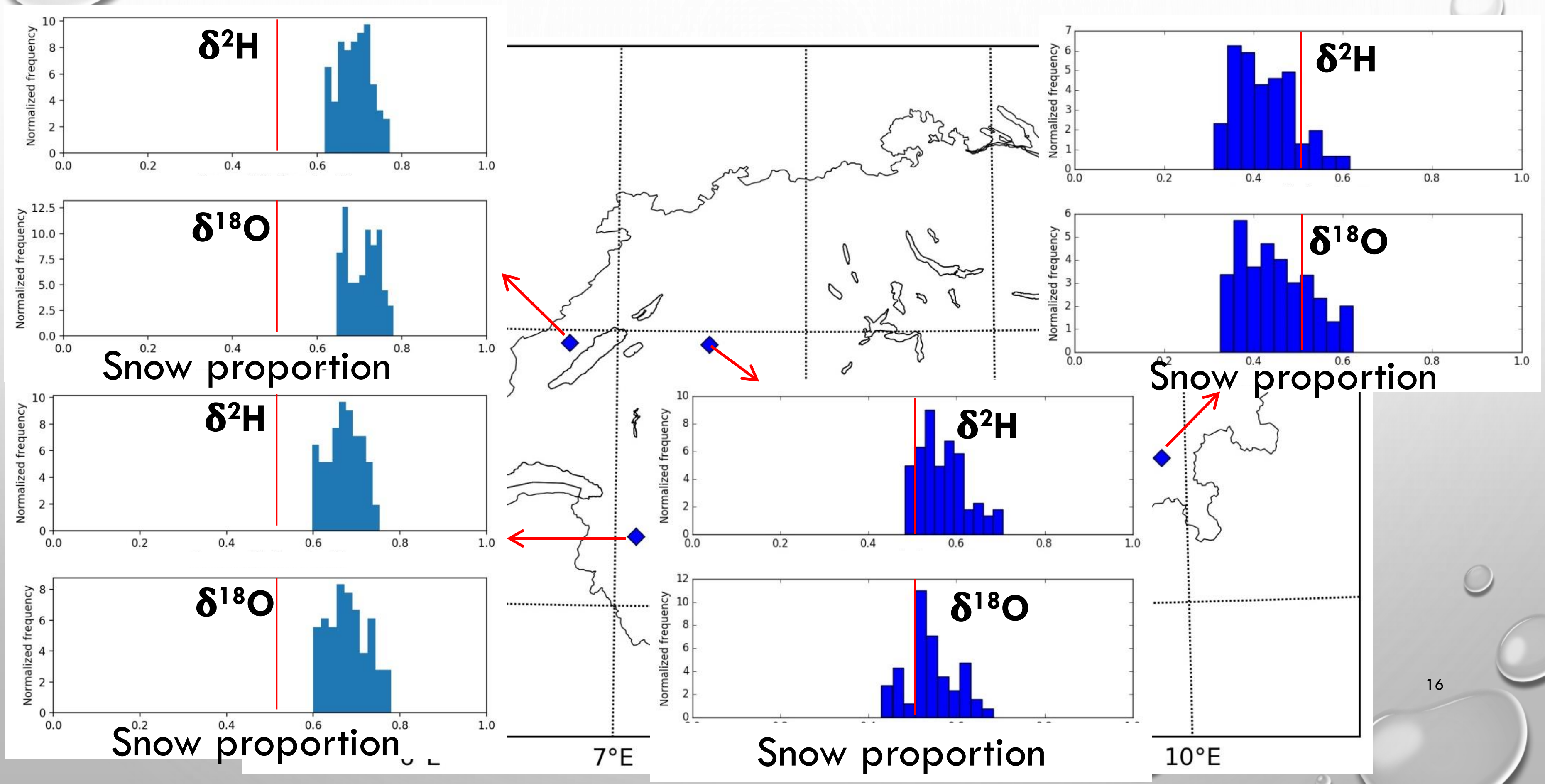
Snow variance reduction



What do we learn?

- Isotope lapse rates important to account for spatial heterogeneity
- Snow variability reduces from snowfall -> snowpack -> snowmelt
- How much does variability in snow isotope matter?

Mixing over Switzerland



Nice things about *HydroMix*

- Generic and provides a more flexible approach
- Leverages all available input data and accounts for spatial heterogeneity
- Can potentially account for different snow processes
- Can be separately used on different tracers

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Questions?

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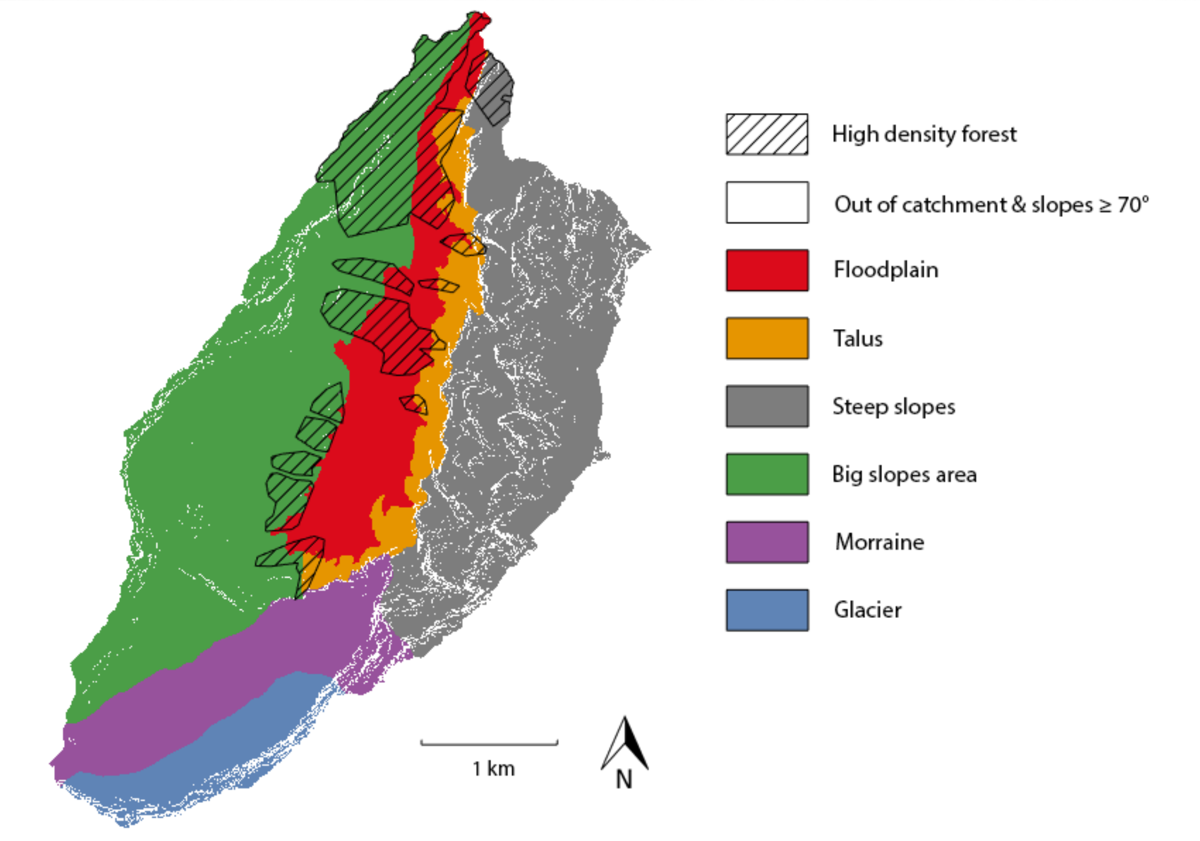
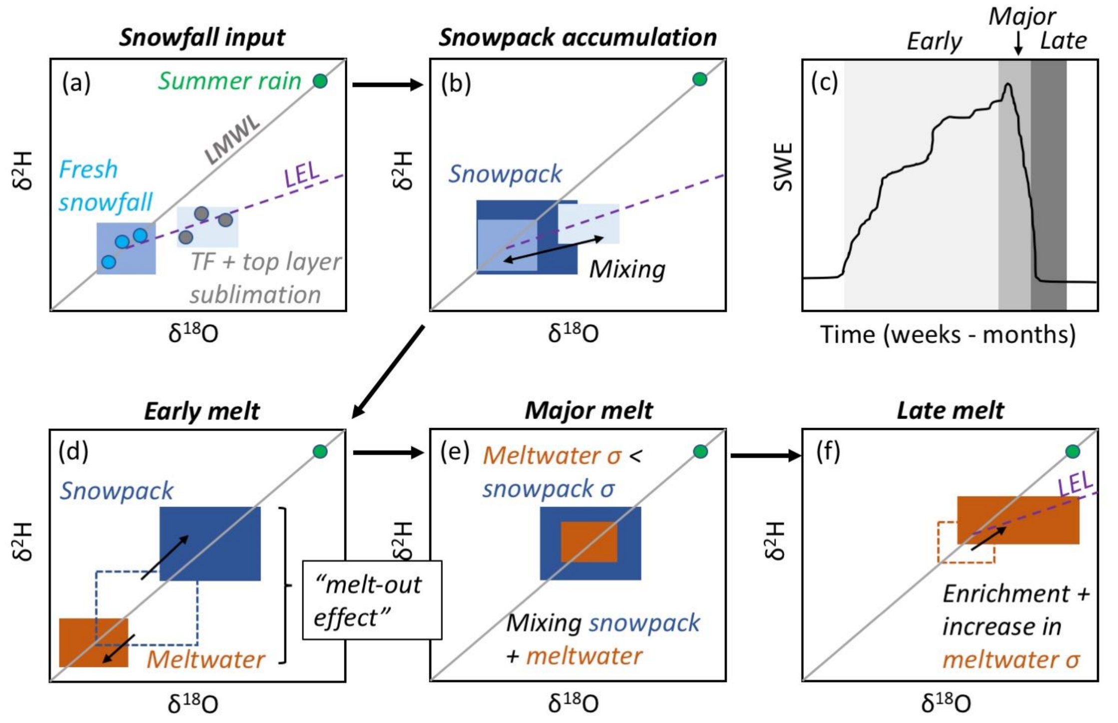
Major land units



- Dense forest at lower elevations
- Large slopes on both sides of the valley
- Floodplains and talus at low-to-mid elevations
- Small glacier

Literature review (extra slide)



Temporal evolution in stable isotopes of snow

GEOLOGY

- ✓ Nappes Helvétiques
- ✓ Superpositions of >1000 m of sediment rock layers, limestone and marls; the sediment rocks are strongly folded;
- ✓ Underlain mostly by impervious flysch, which is a typical alpine sedimentary rock
- ✓ Karst on the mountain ridges