Increased snowpack ephemerality augments groundwater recharge in the Swiss Alps

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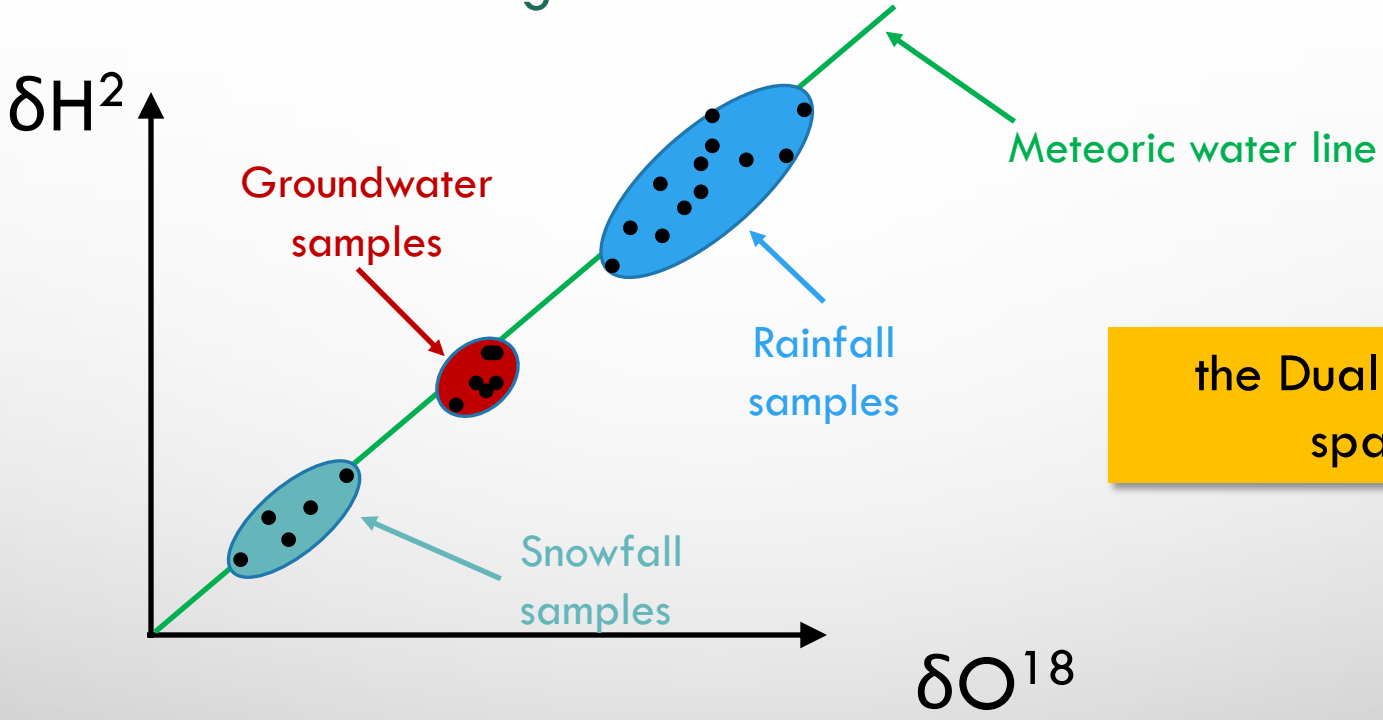
Vallon de Nant, Switzerland

What is likely to happen to snow in a warming climate?

- Warmer climate will lead to more precipitation as rain than snow (Choi et al., *J. Climate* 2010)
- More ephemeral snow (Petersky & Harpold, *HESS* 2018)
- Earlier snowmelt at lower melt rates due to lower solar radiation (Musselman et al., Nat. Clim. Chang. 2017)
- Impact on groundwater resources?

Stable isotopes can be used to separate groundwater recharged from rain vs snow



the Dual isotope space

Beria et al. 2018 (*WIRES Water*)

A linear mixing equation with 2 sources

Snow

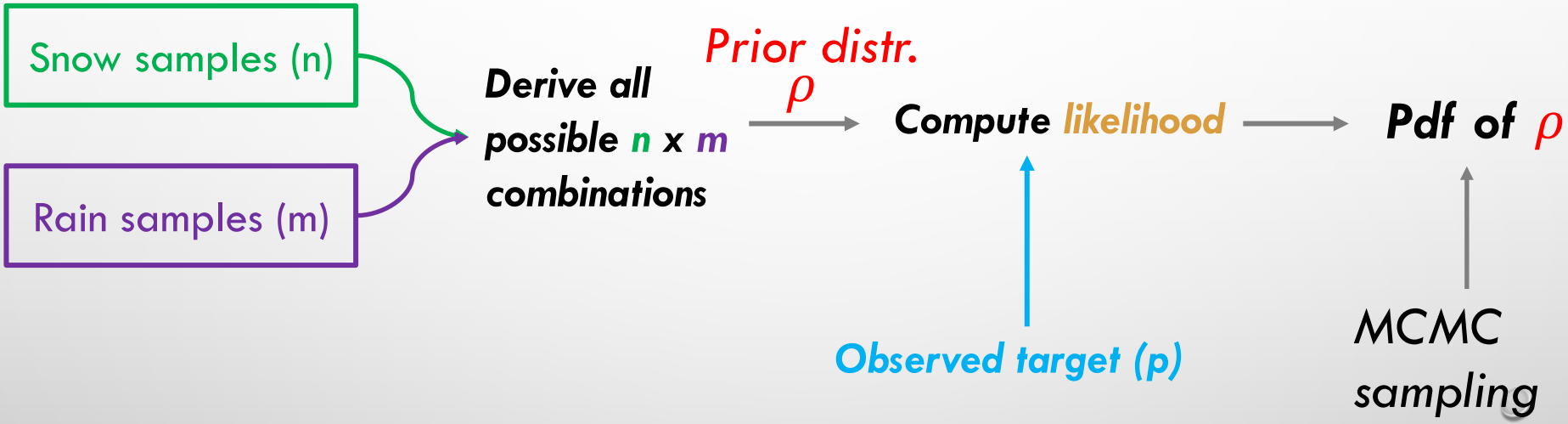
Rain

Mixing ratio → $\rho S + (1 - \rho) R = G$ Groundwater

Replacing S, R and G with their means

Bayesian inversion

HydroMix



$$\rho S + (1 - \rho) R = G$$

HydroMix

$$L_j(\tilde{Y}_{obs}|S,R,\boldsymbol{\rho}) = \prod_{k=1}^{p}\prod_{j=1}^{m}\prod_{i=1}^{n}(2\pi\sigma^2)^{-0.5}\exp\left(-\frac{1}{2}\frac{\left(\tilde{Y}_{obs}^{k}-\hat{Y}_{ij}\right)^2}{\sigma^2}\right)$$

Snow samples (n)

Rain samples (m)

Derive all possible *n* x *m* combinations

Prior distr. ρ

Compute *likelihood*

Pdf of ρ

Observed target (p)

MCMC *sampling*

$$\rho S + (1-\rho)R = G \longrightarrow \varepsilon \sim N(0,\sigma)$$

HydroMix

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Discussion papers

Abstract | Discussion | Metrics

Model description paper

28 Mar 2019

HydroMix v1.0: a new Bayesian mixing framework for attributing uncertain hydrological sources

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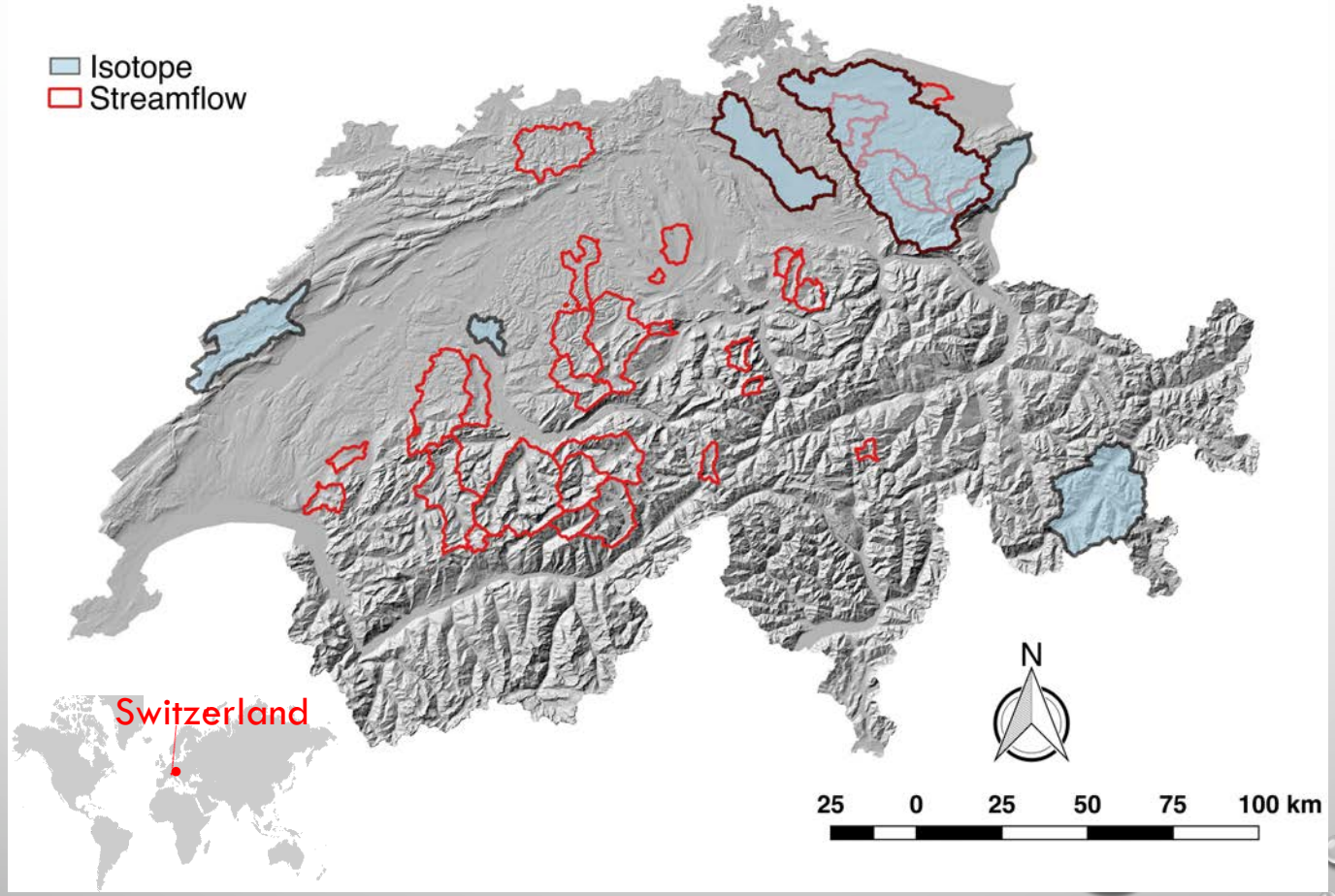
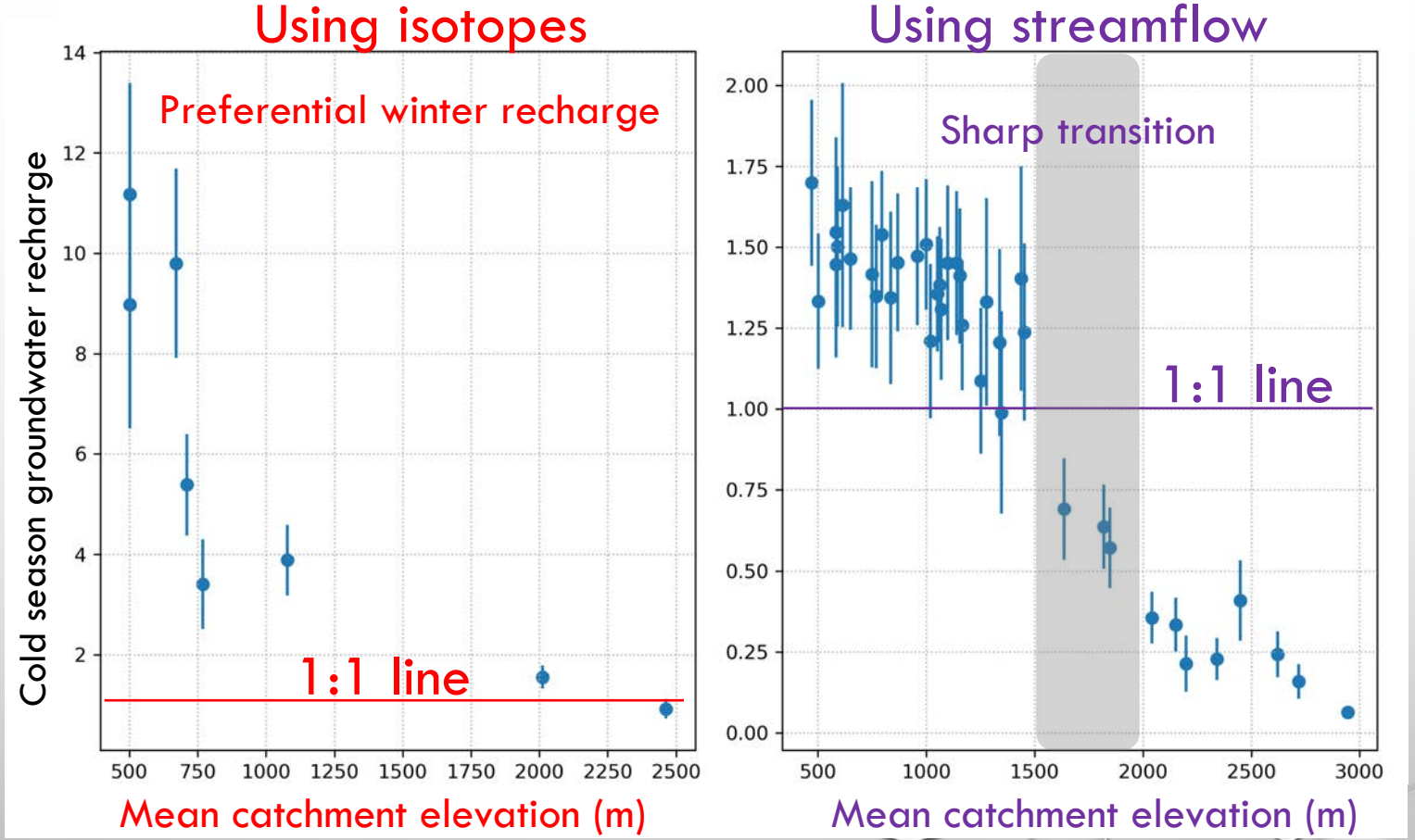
https://www.geosci-model-dev-discuss.net/gmd-2019-69/

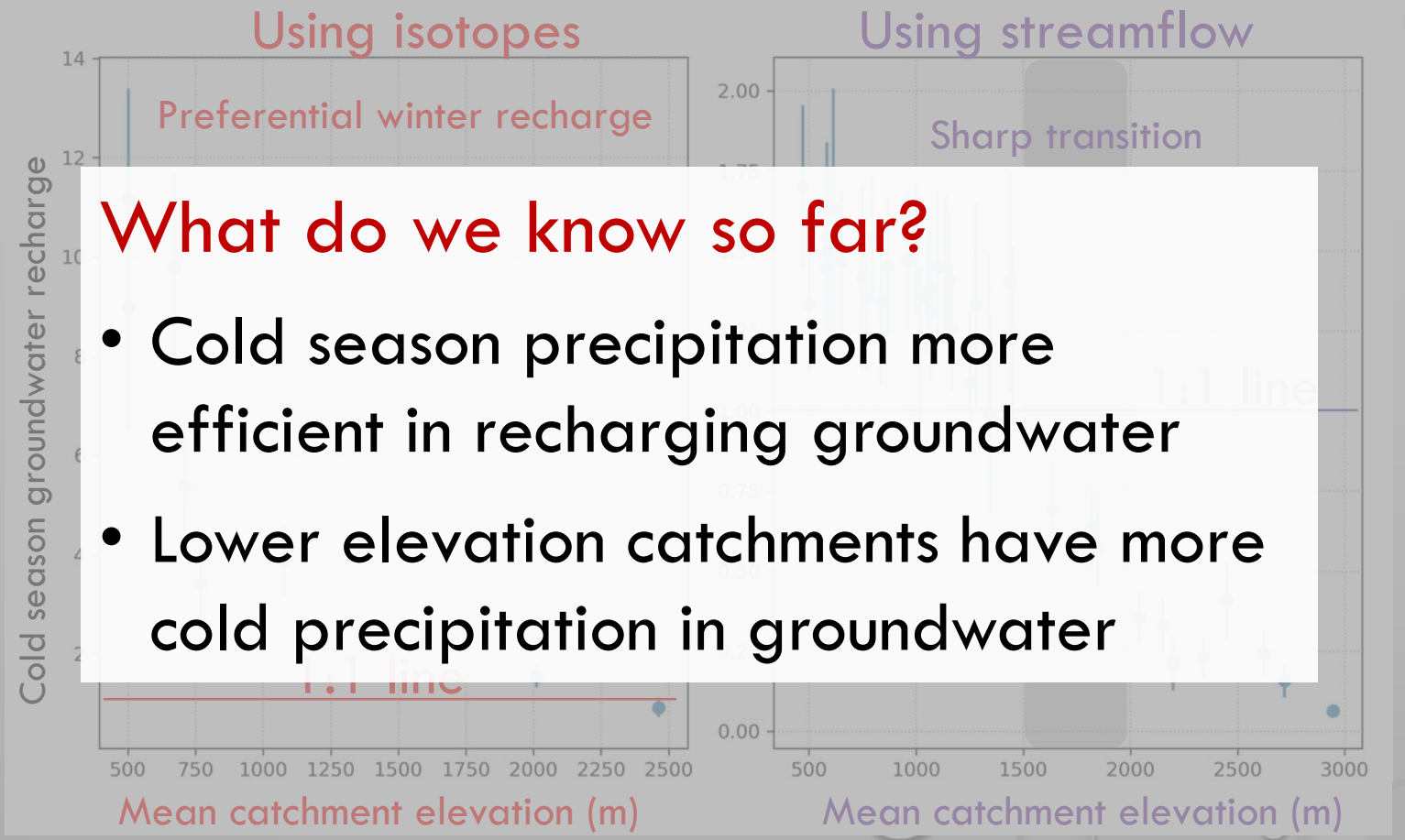
Isotope collection network in Switzerland



Cold season groundwater recharge (Nov-April)



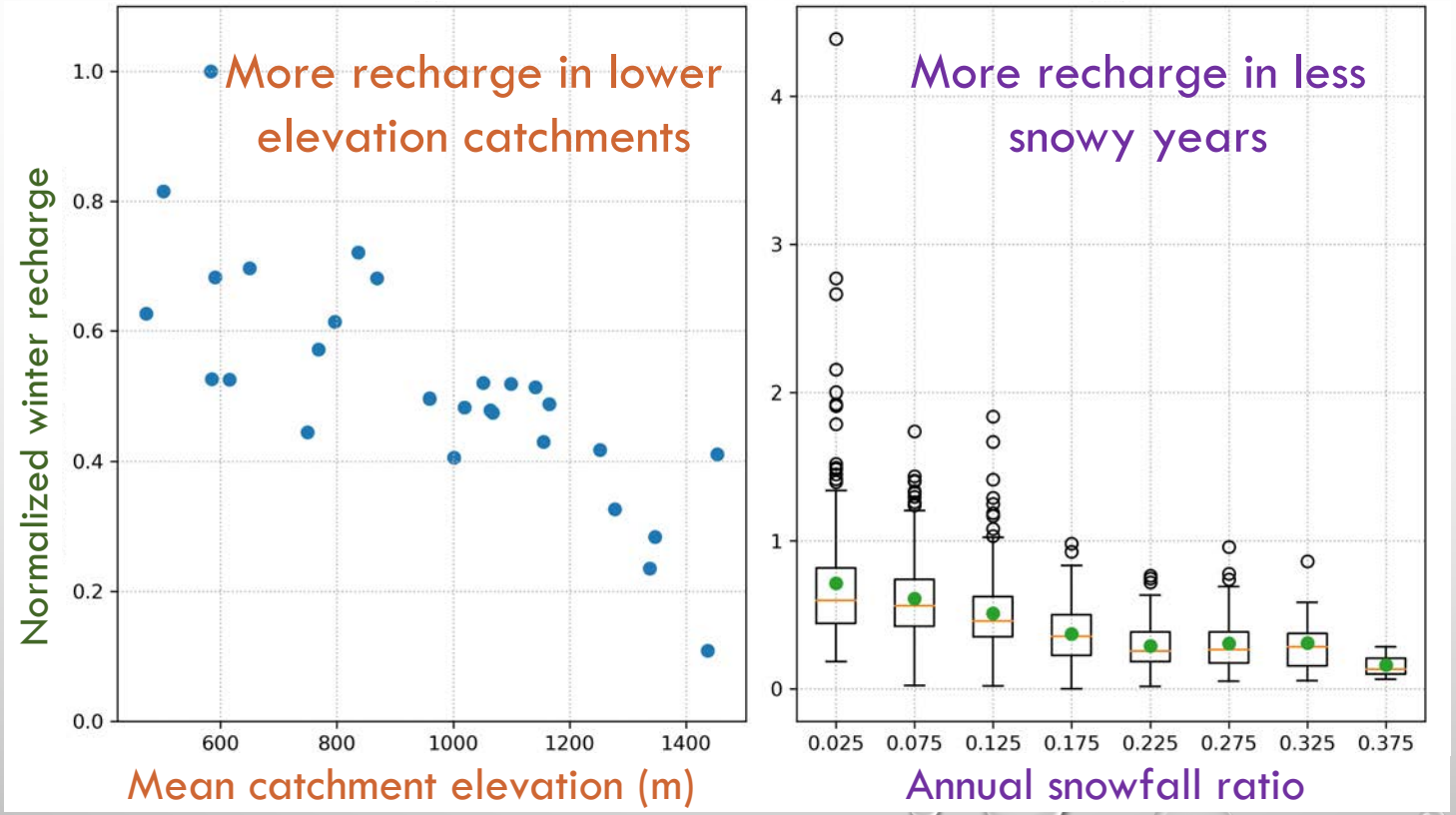
Cold season groundwater recharge (Nov-April)



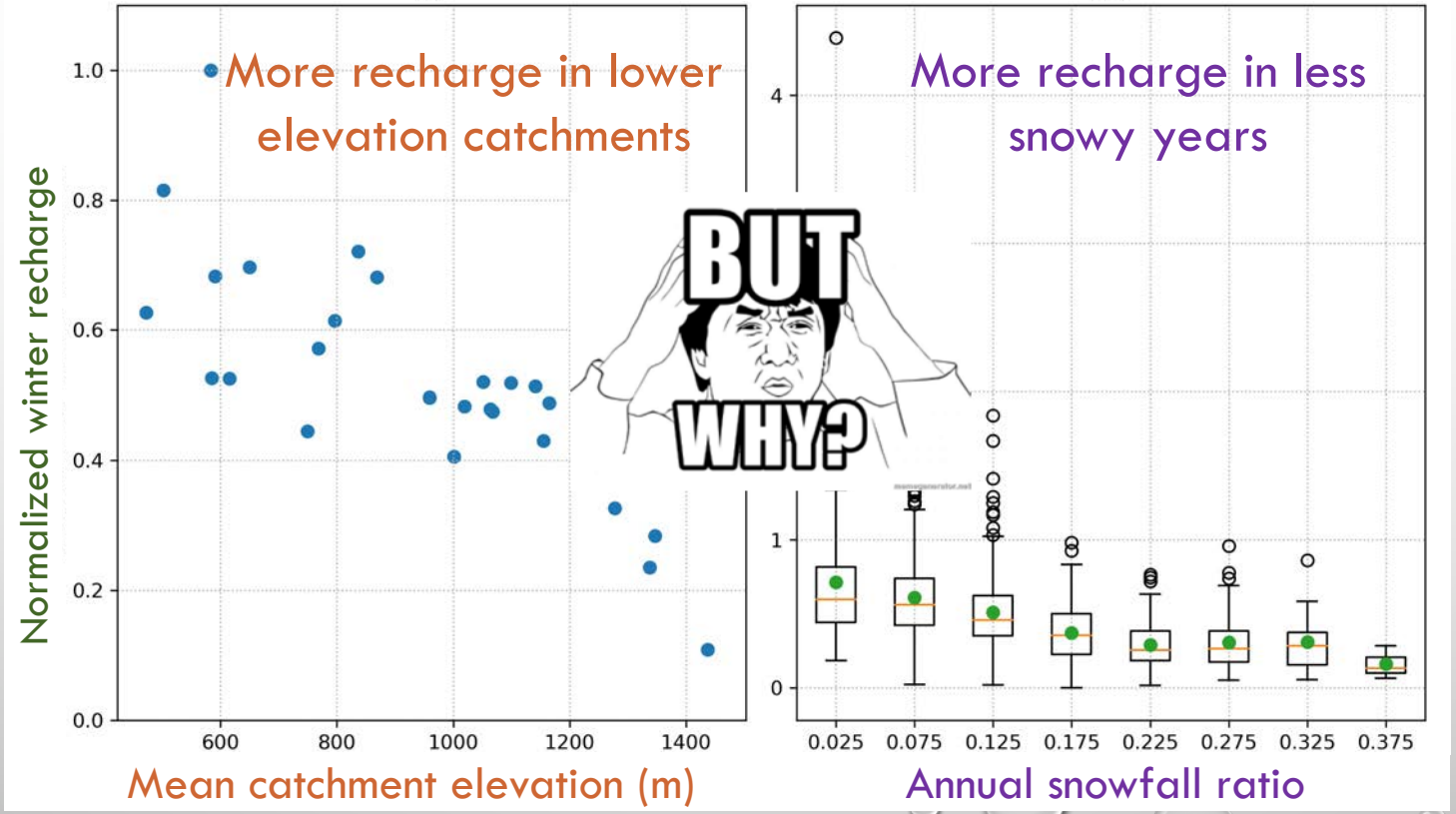
What do we know so far?

- Cold season precipitation more efficient in recharging groundwater
- Lower elevation catchments have more cold precipitation in groundwater

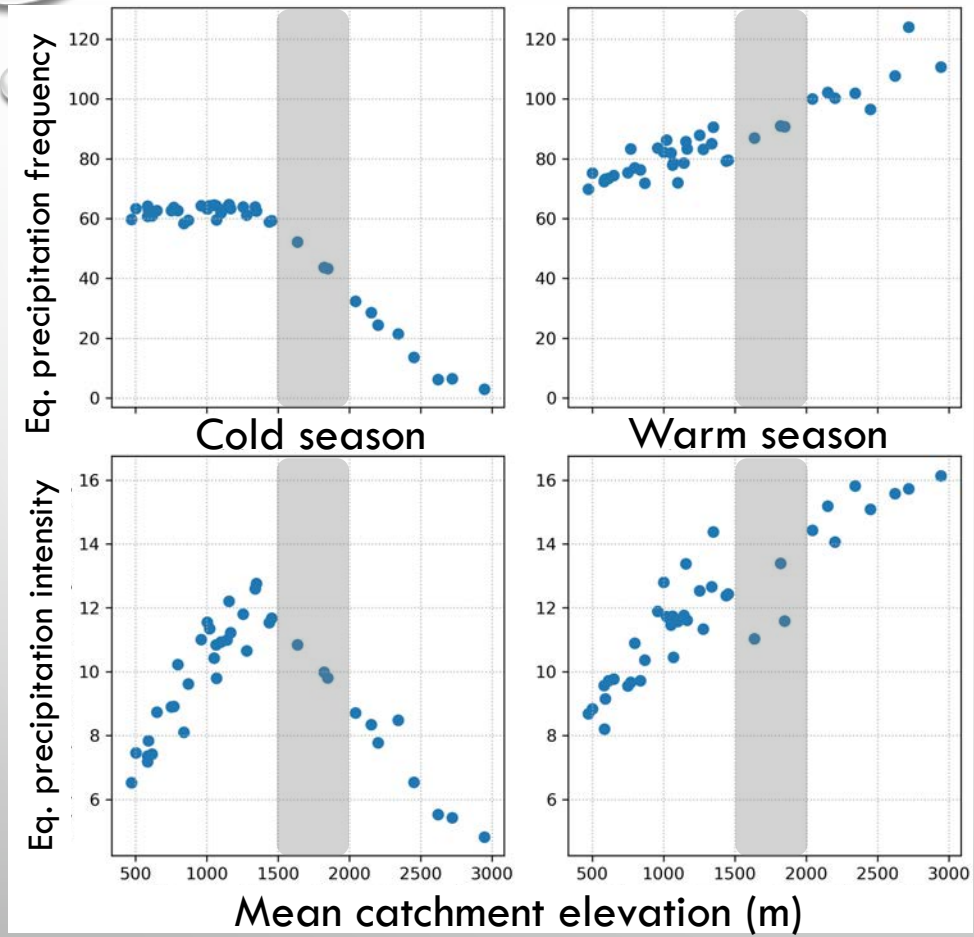
Winter groundwater recharge (Dec-Feb)



Winter groundwater recharge (Dec-Feb)

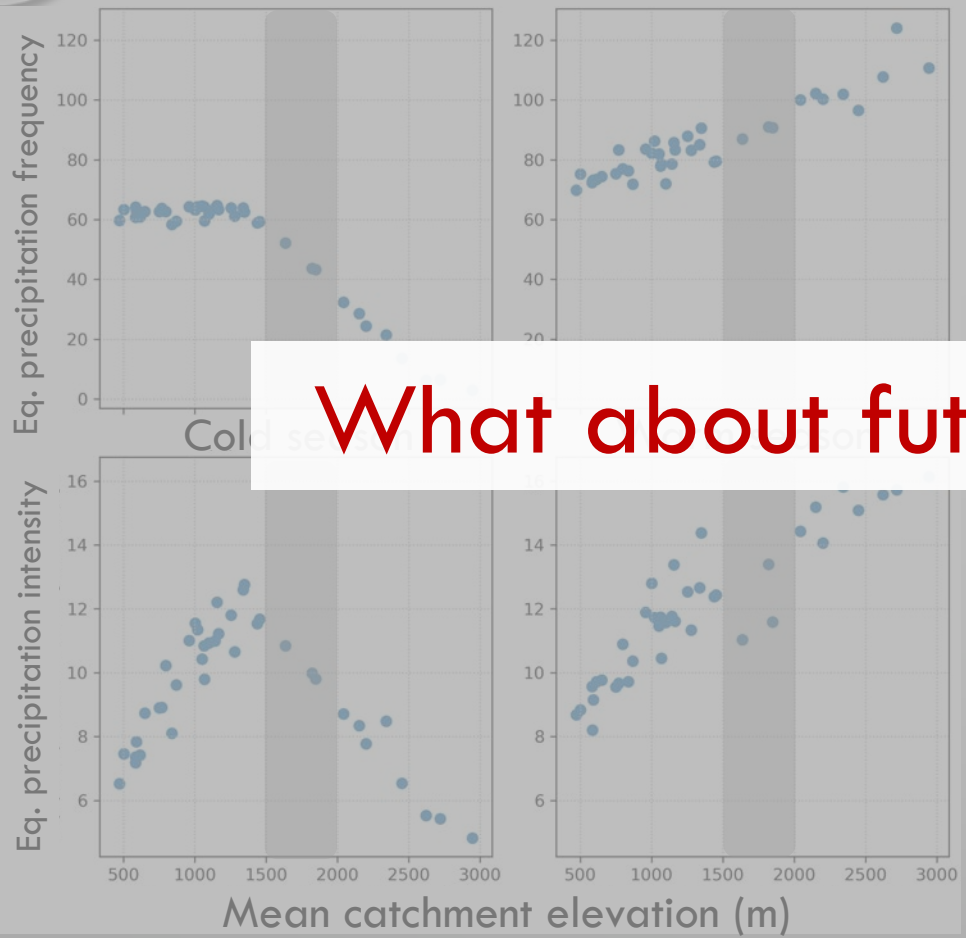


Cold vs warm season liquid water input



- At lower elevations:
  - More # cold season melt events
  - Higher melt intensity
- Vegetation inactive during winters
- Most melt recharges groundwater

Cold vs warm season liquid water input



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  - More # cold season melt events
  - [illegible]ity
- Vegetation inactive during winters
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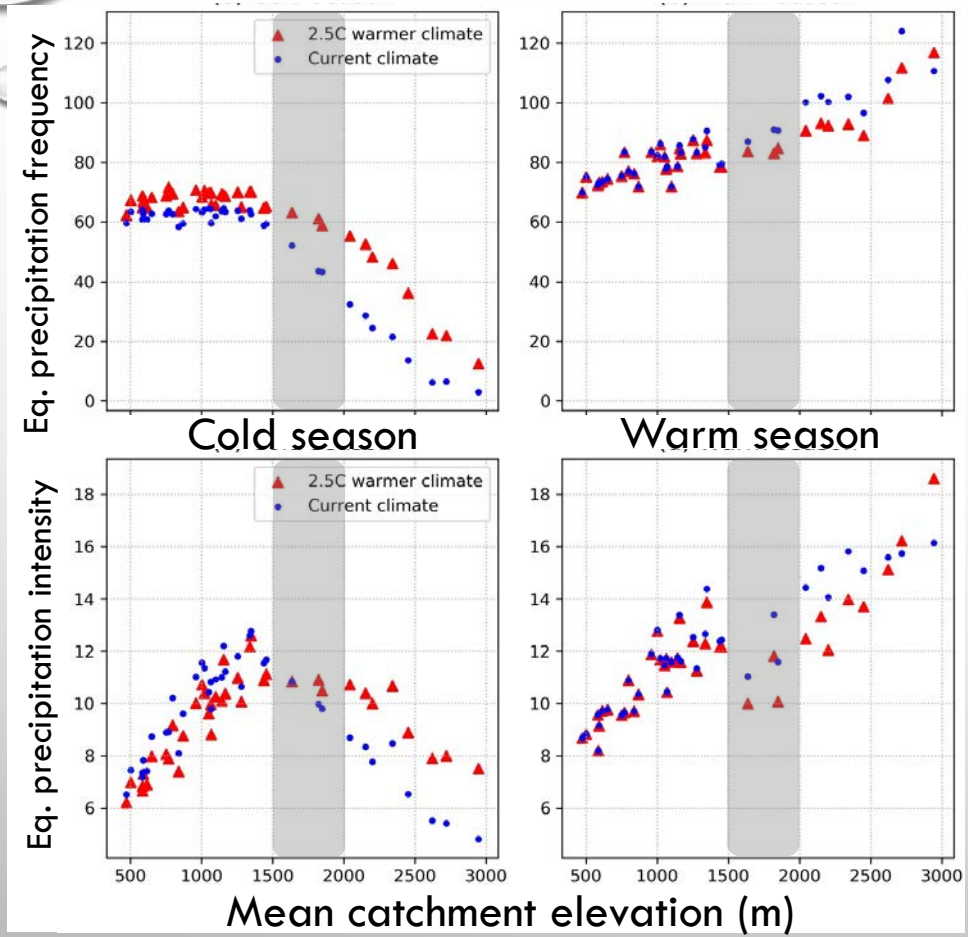
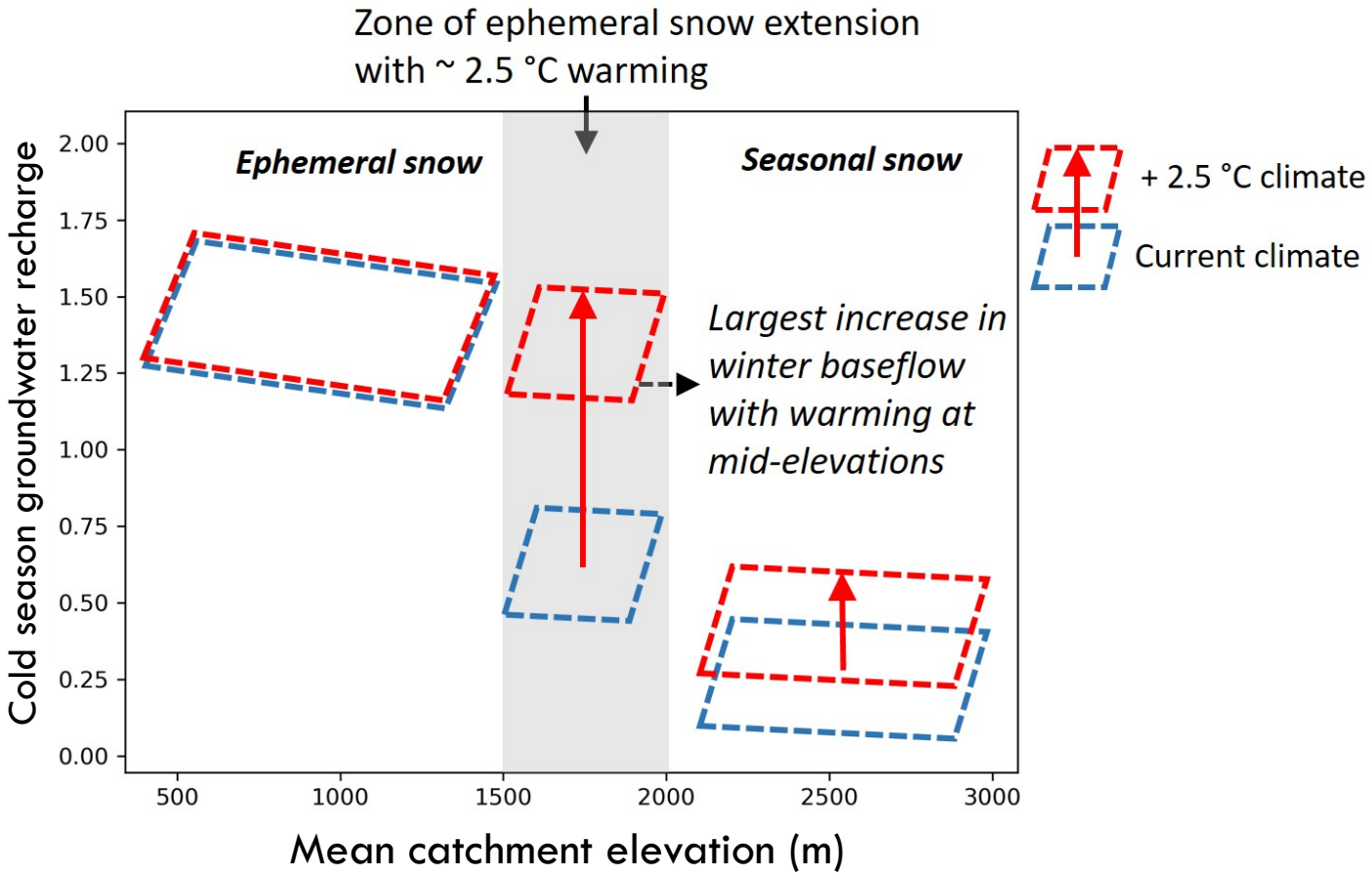
What about future warming?

A 2.5° warmer world

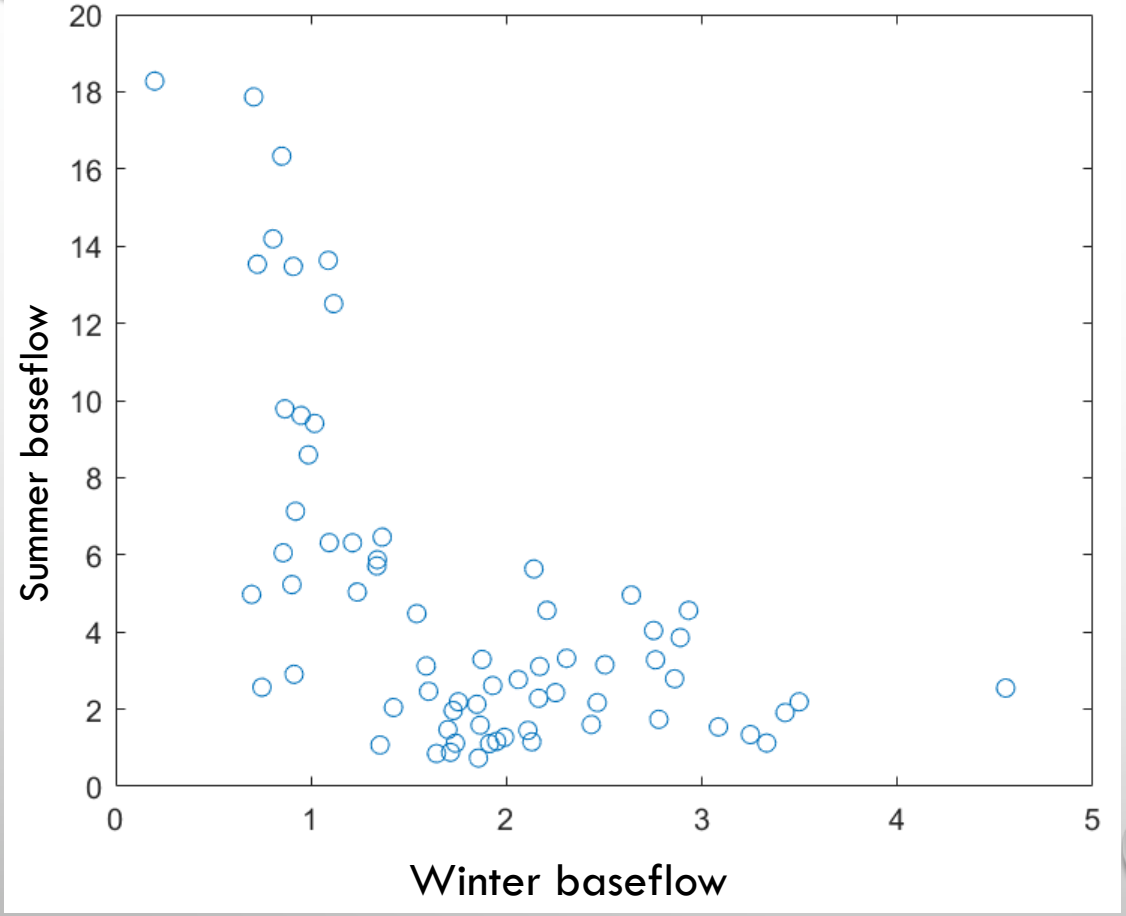


- At mid to high elevations
  - More # cold season melt events
  - Higher melt intensity
- What will happen to winter baseflow?

Future winter flows



Why is higher winter baseflow important?



- Higher winter baseflow leads to lower summer baseflow
- Increased risk of summer droughts

Key takeaways!

- Snowmelt/winter precipitation more efficient at recharging groundwater than rainfall
- Ephemeral snowpack > Seasonal snowpack in terms of groundwater recharge
- Shift from a seasonal to an ephemeral snow regime in a warmer world may increase groundwater recharge

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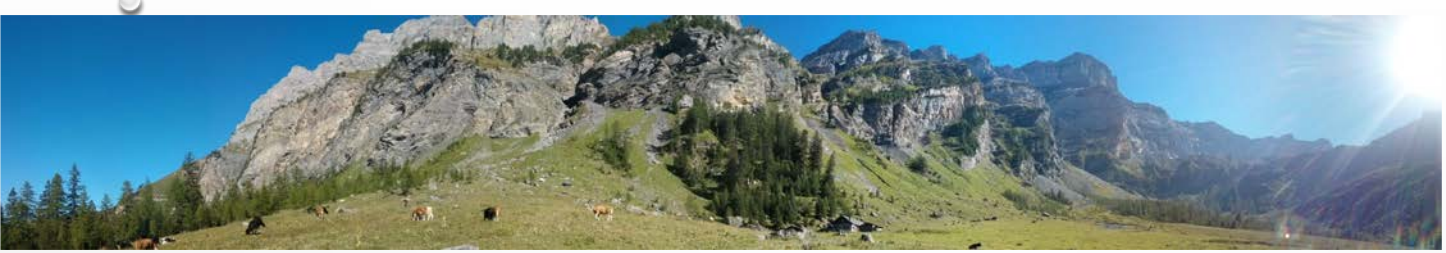

Questions?

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