Towards a framework for the validation of kilometer-scale land surface models

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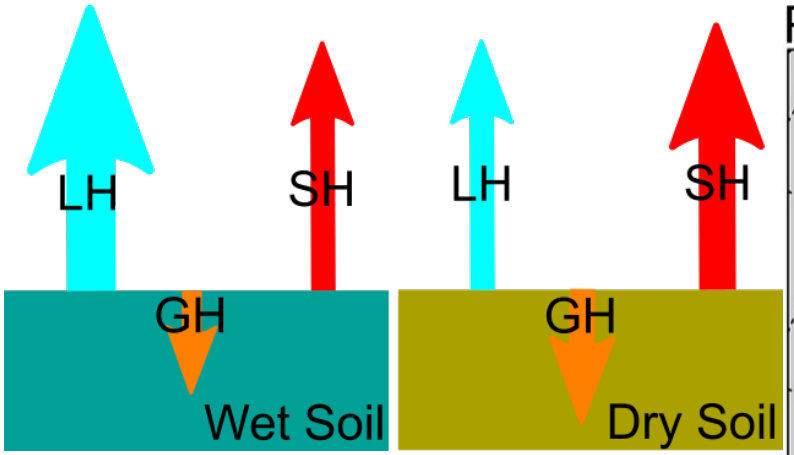
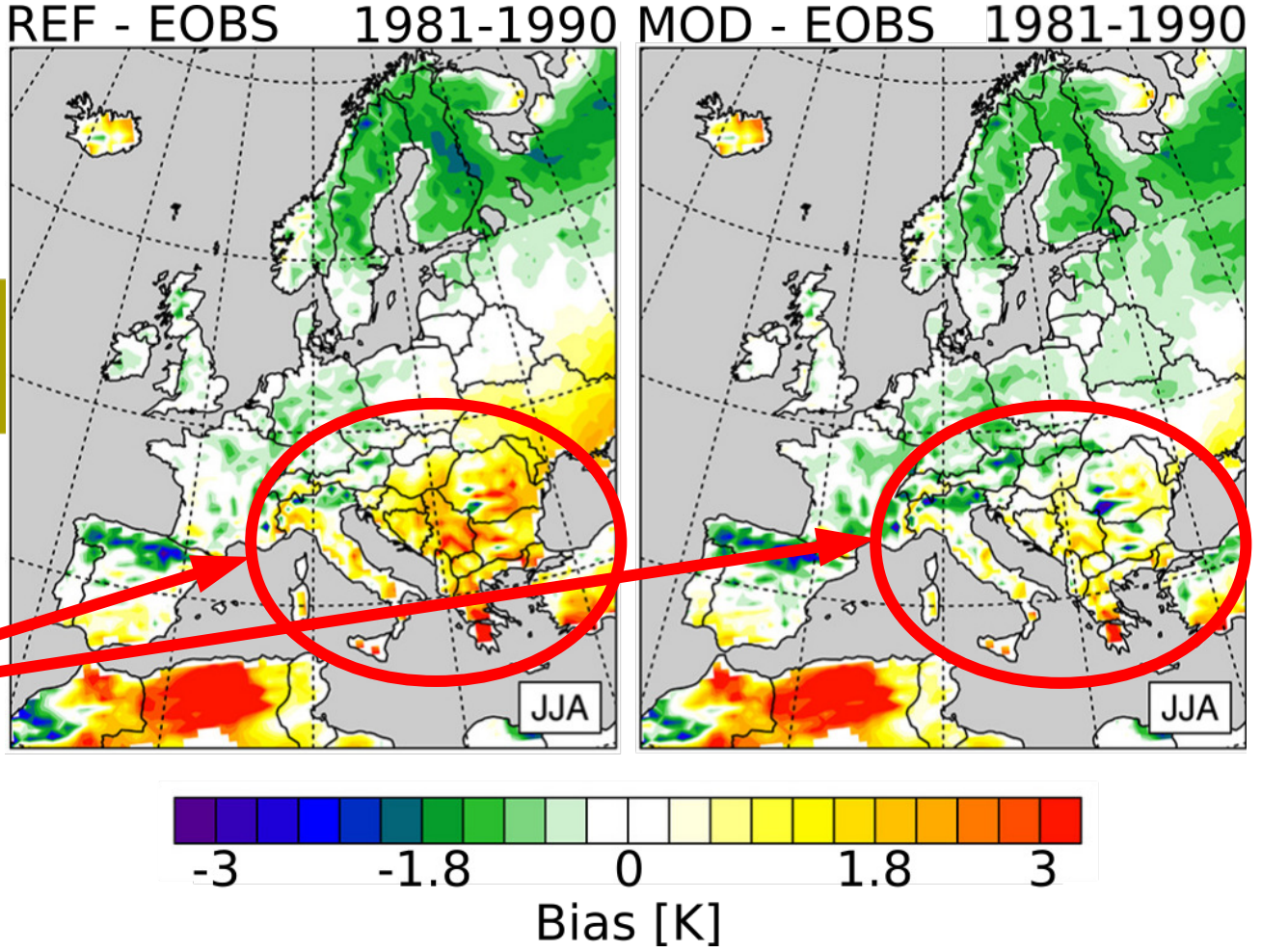
Hydrological state of the soil matters.

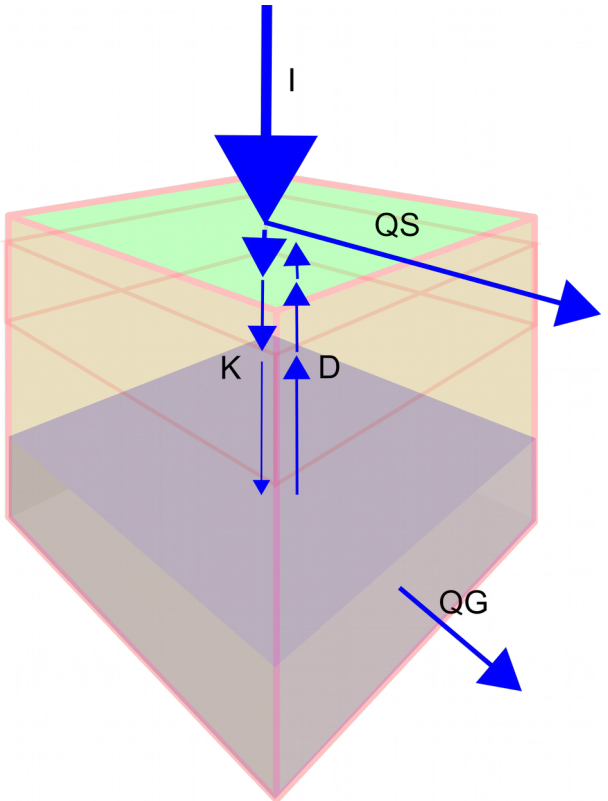




New runoff scheme:
Clear reduction of T-2m bias in coarse resolution (50 km) climate simulations!

Schlemmer et al., 2018

Testing a new groundwater and runoff formulation

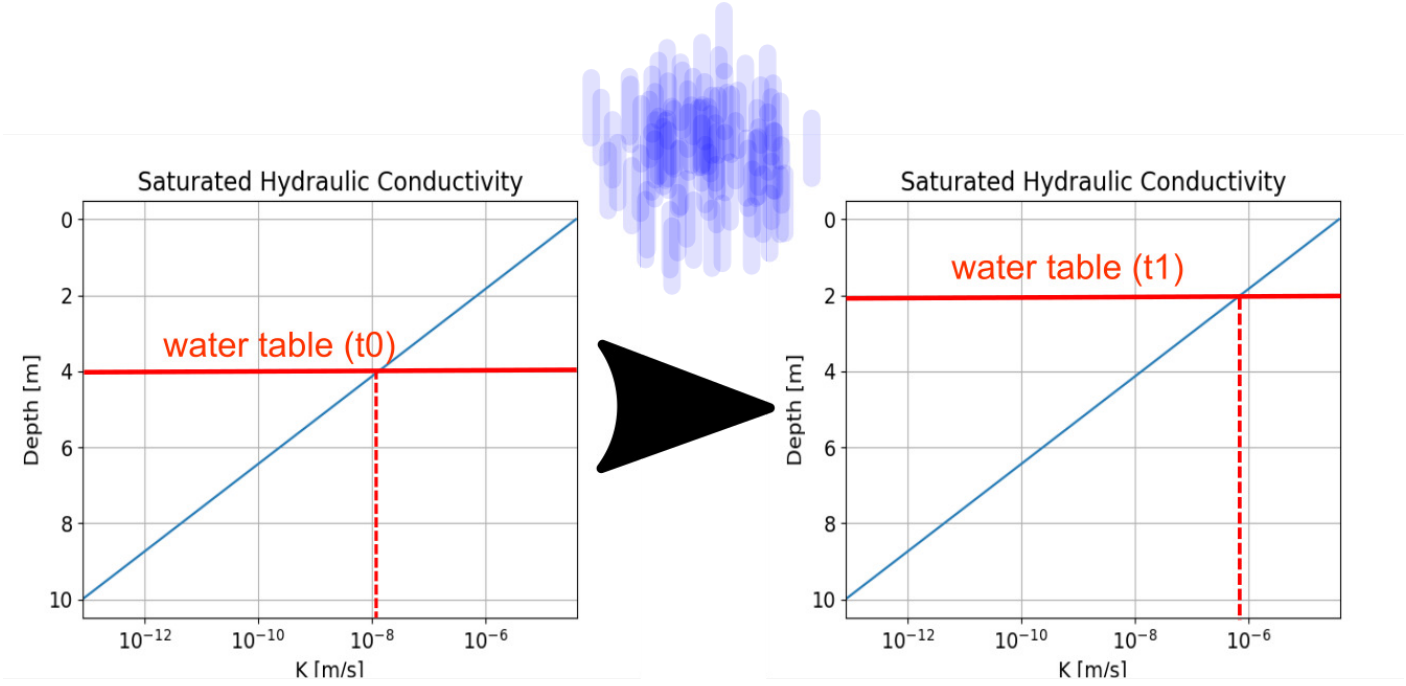


- 1D **Richard's equation** (K, D)
- **Zero flux bottom boundary condition**
- **Mass conserving flux corrections** (move water excess upward and limit outgoing fluxes)
- **Exponential decrease of hydraulic conductivity** with depth (Decharme, 2006)
- **Diagnostic runoff** from water table, proportional to K_{sat} and gradient of orography.

(Schlemmer et al., 2018)

→ **Testing** within **TERRA ML – standalone**, forcing with **1 km** MeteoSwiss analyses (2010-2012, 2x to ensure equilibration)

Tuning: The dark side of modeling



Q increases by two orders of magnitude

$Q \sim K_{sat} exp\ (-f_D\ (z_{wt} - z_{root})$

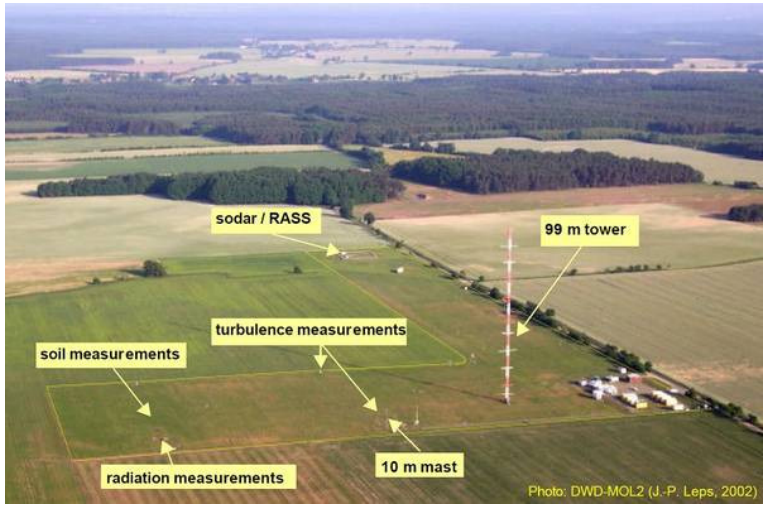
$Q \sim L_g^{-1}\ S_{ORO}$

Q increases linearly with terrain gradient.

L_g^{-1}, f_D: Inhomogeneity length scale, Decharme parameter (tuning parameter)

S_{ORO}, z_{root}: External parameter (or derived), heavily method dependend!

“Scale Gap” in common validation approaches.



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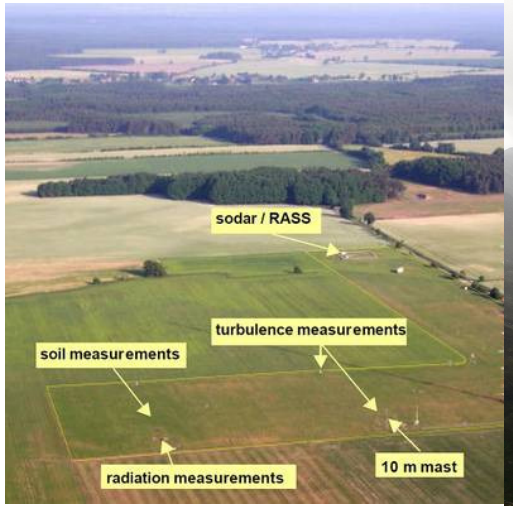
Trying to bridge the gap with hydrological methods.

Point



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Catchment

x-EVAL Dataset: Mueller et al., 2013

50 km

Catchment water balance

Mass conservation yields:

$$dS/dt = P - Q - E$$

dS/dt: Terrestrial storage change (soil moisture, lakes, deep groundwater reservoirs)

P: Precipitation

Q: Runoff

E: Evapotranspiration

→ Aggregate everything to monthly timescales (no routing)

Data to close the water balance

Mass conservation yields:

$$dS/dt = P - Q - E$$

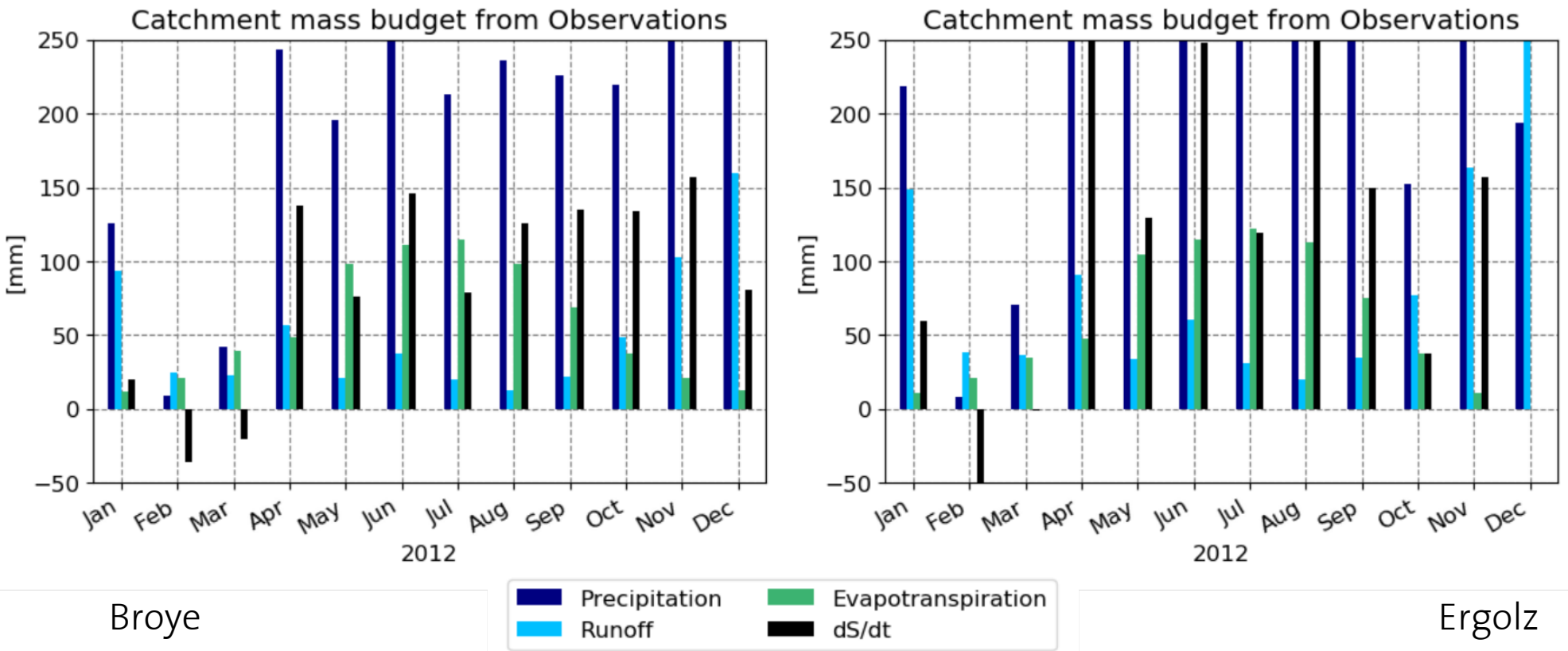
dS/dt: Terrestrial storage change (soil moisture, lakes, deep groundwater reservoirs) Residual

P: Precipitation MeteoSwiss Analyses

Q: Runoff Measurements by the FOEN

E: Evapotranspiration MODIS (Running et al., 2017)

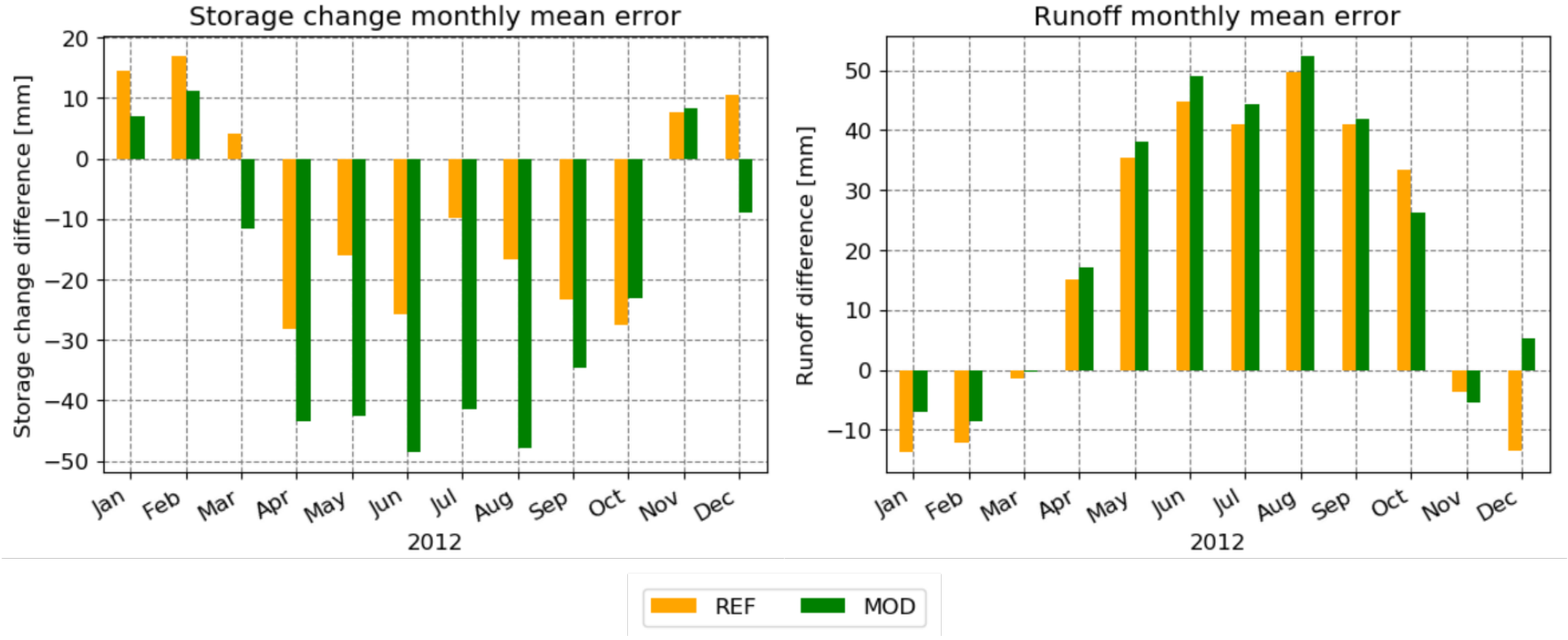
Budgets for prototype catchments: Broye (416 km ²), Ergolz (261 km²)



Broye

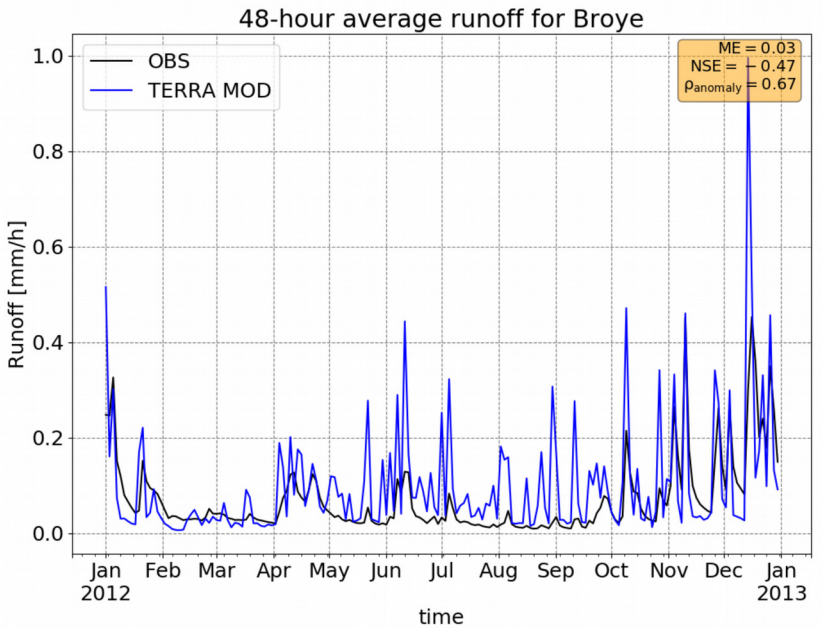
Ergolz

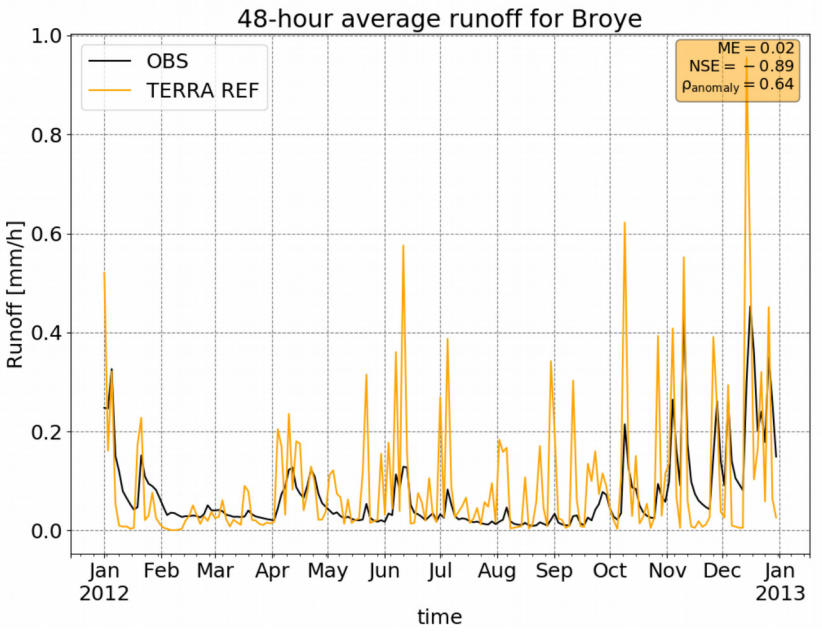
Storage change biases driven by runoff biases.



REF: TERRA 5.03, old hydrology, MOD: Schlemmer et al. 2018 Runoff formulation

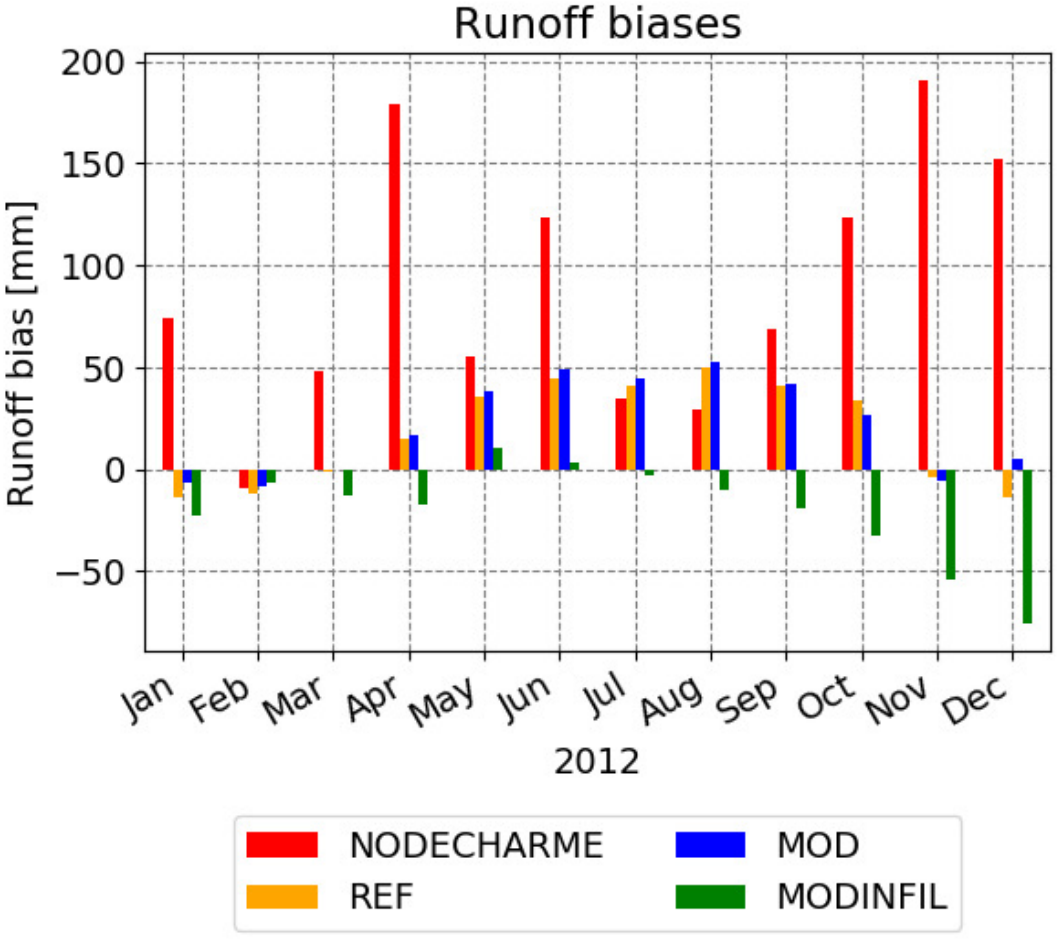
Runoff bias attributable to surface runoff.





REF: TERRA 5.03, old hydrology, MOD: Schlemmer et al. 2018 Runoff formulation

(Surface) Runoff heavily dependent on infiltration.



REF: TERRA 5.03, old hydrology

MOD: Schlemmer et al. 2018 Runoff formulation

NODECHARME: No exponential decrease with depth for hydraulic conductivity (→ more infiltration excess!)

MODINFIL: Infiltration from v. 5.05 (Fix by G. Zängl), remove excess water at infiltration after timestep instead of before.

Assessing uncertainties in precipitation forcing and ET validation datasets

dS/dt: Terrestrial storage change (soil moisture, lakes, deep groundwater reservoirs) Residual

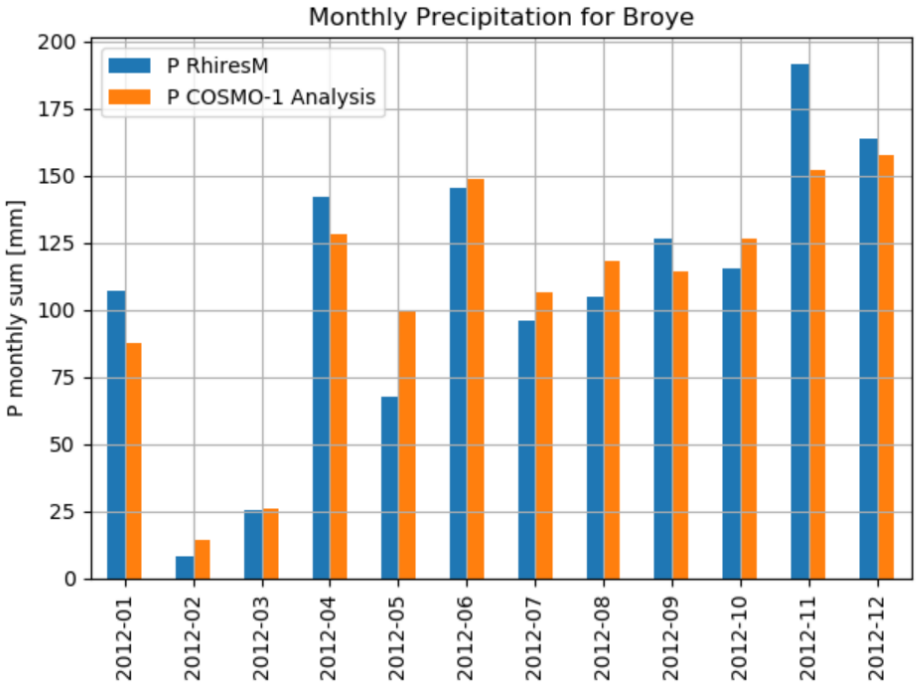
P: Precipitation MeteoSwiss Analyses MeteoSwiss RhiresM monthly gridded (2km) precipitation (rain gauges)

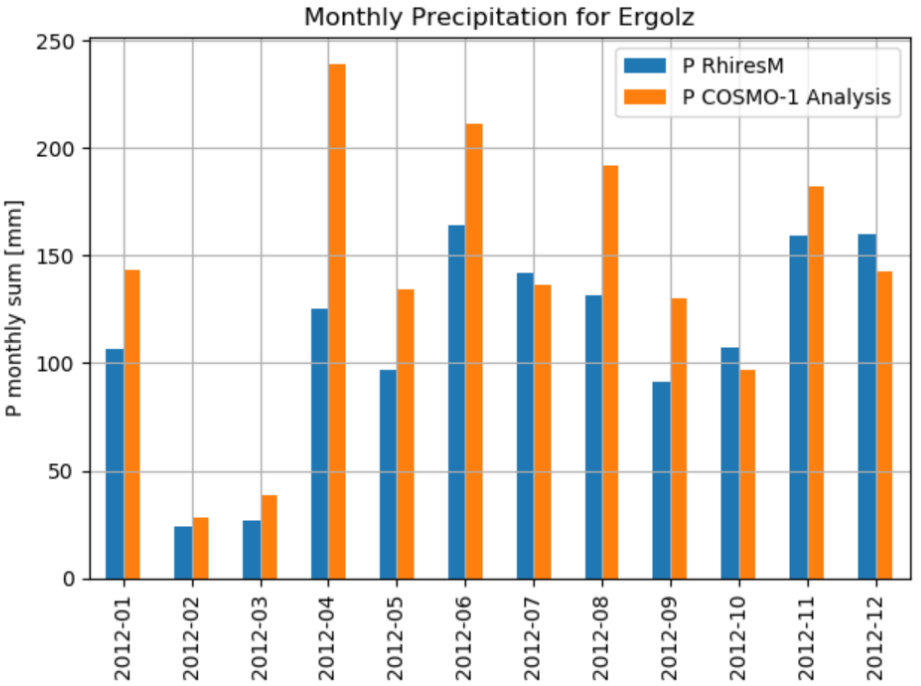
Q: Runoff Measurements by the FOEN Error negligible

E: Evapotranspiration MODIS (Running et al., 2017)

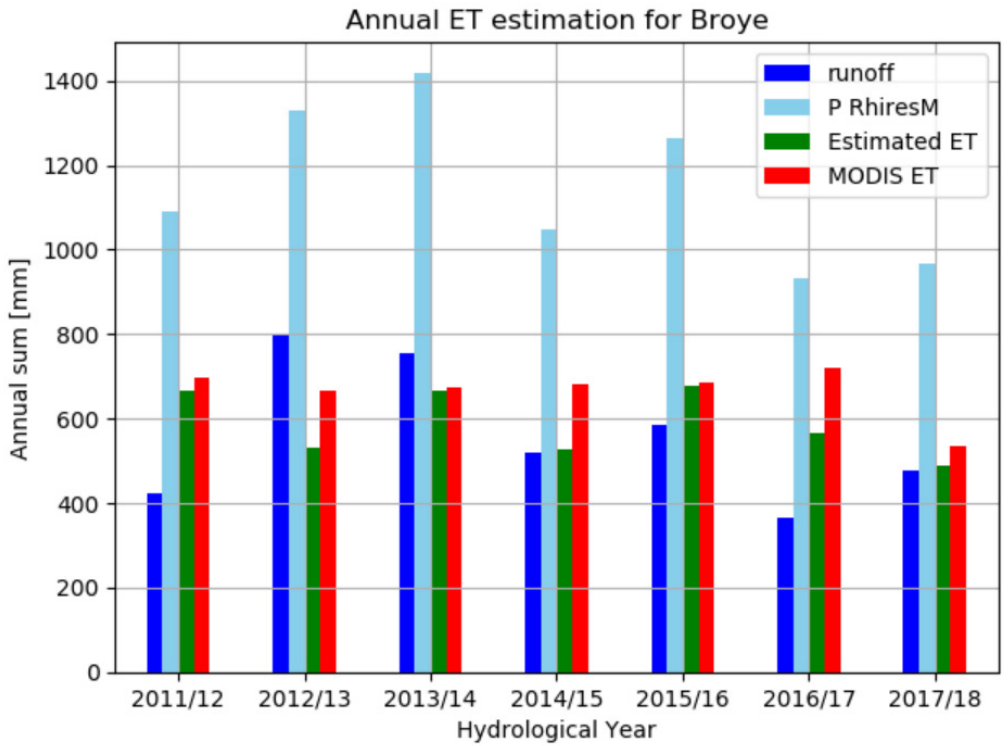
$dS/dt = o = P - Q - E \rightarrow E = P - Q$ (annual balance estimates)

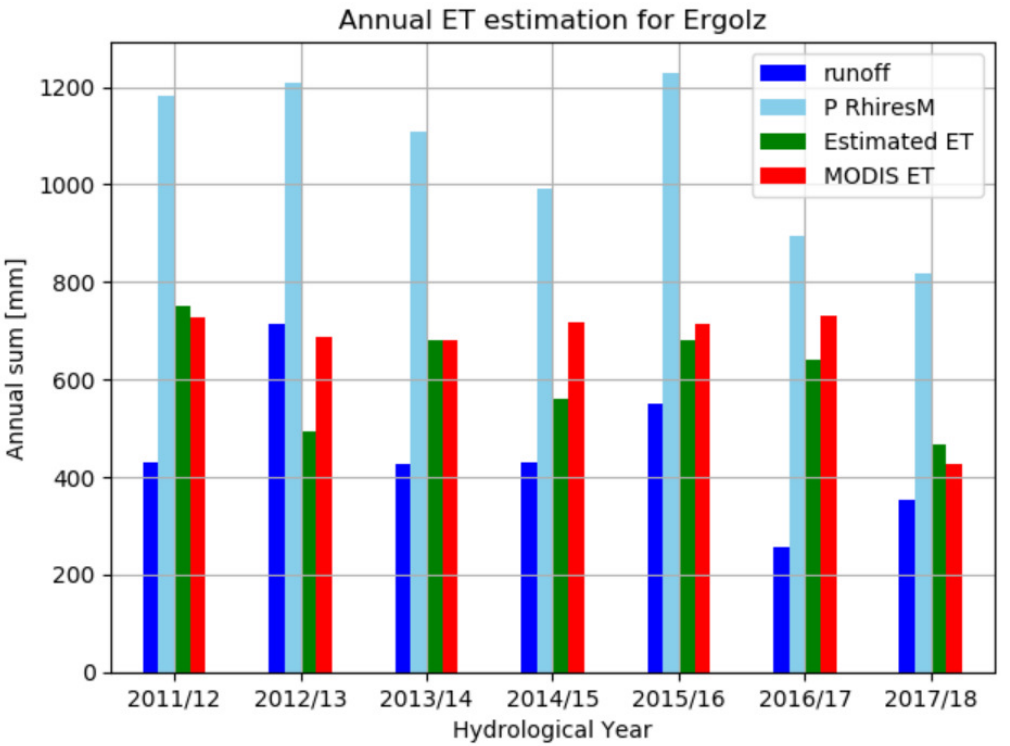
Precipitation data reliable for chosen catchments



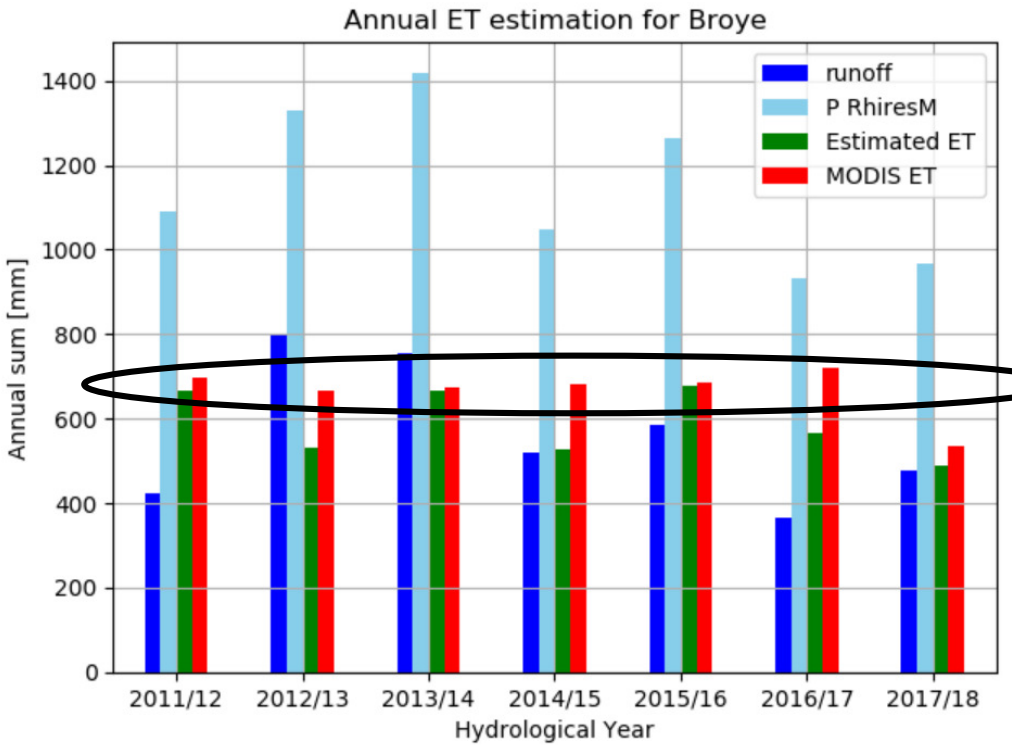


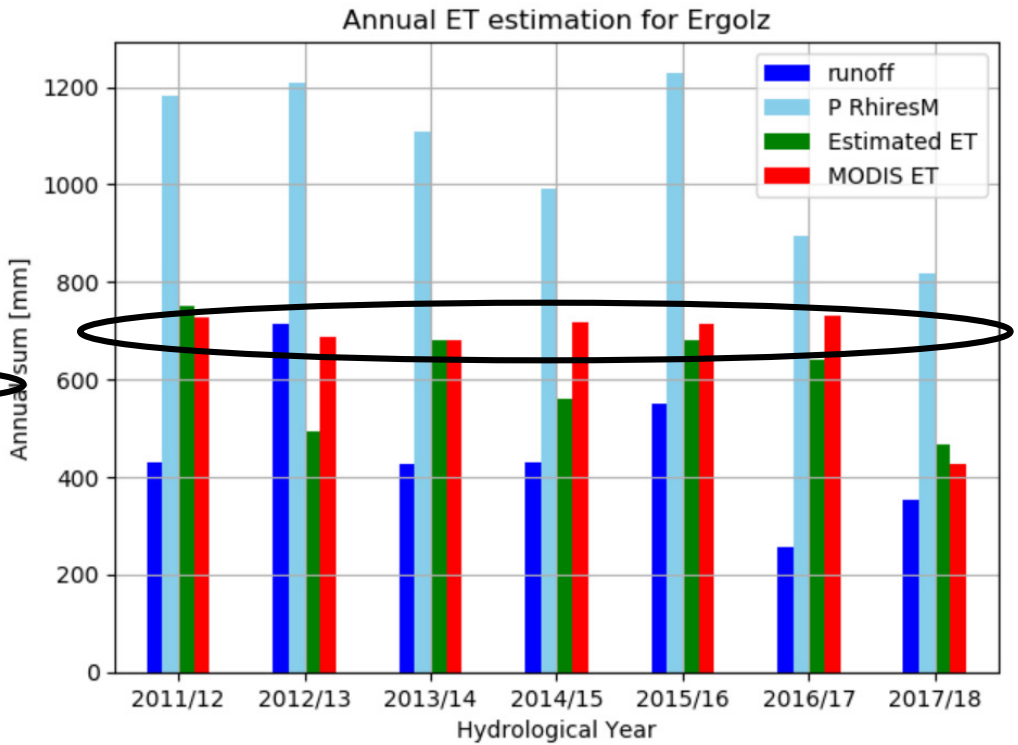
ET validation data: Magnitude seems right





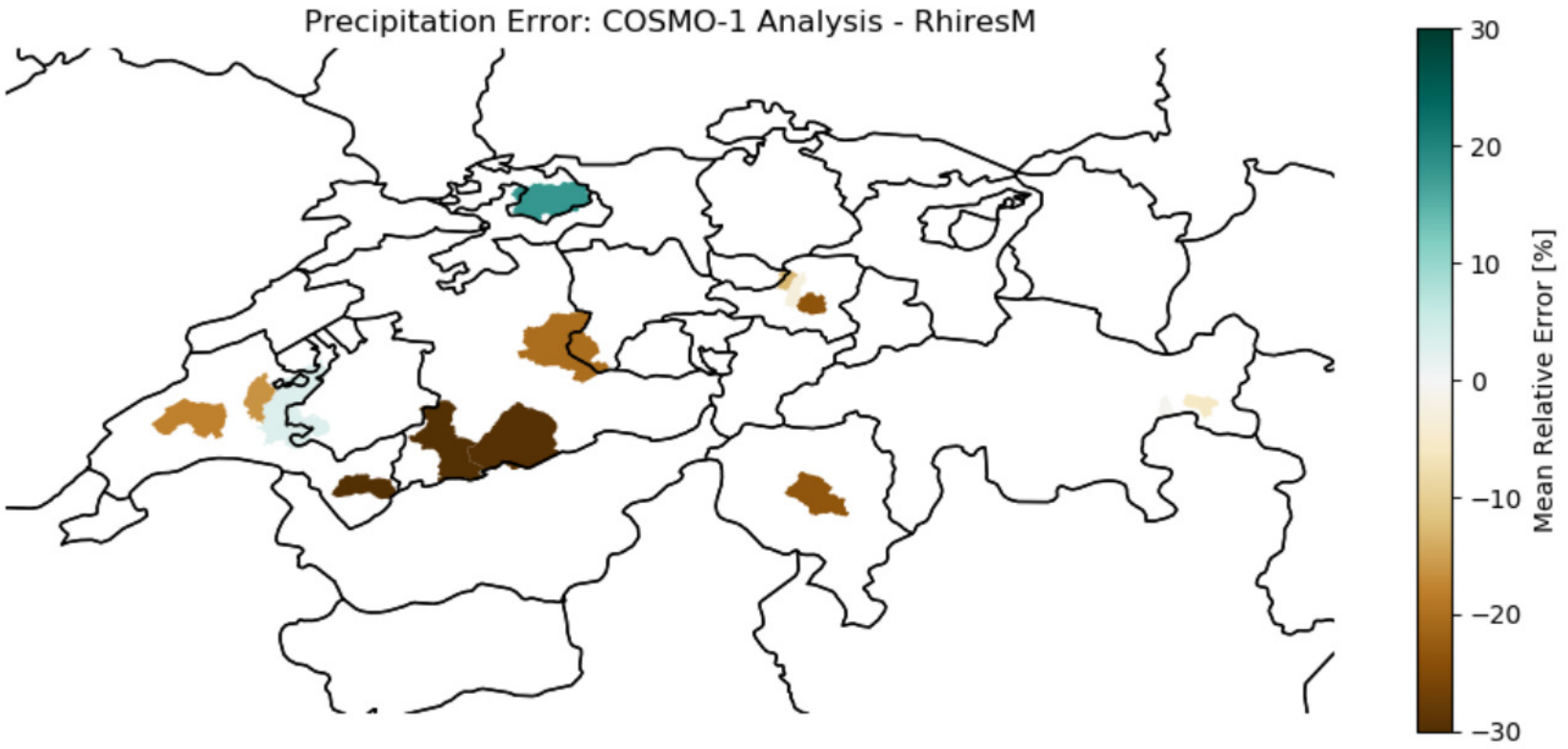
But: What about inter-annual variability?





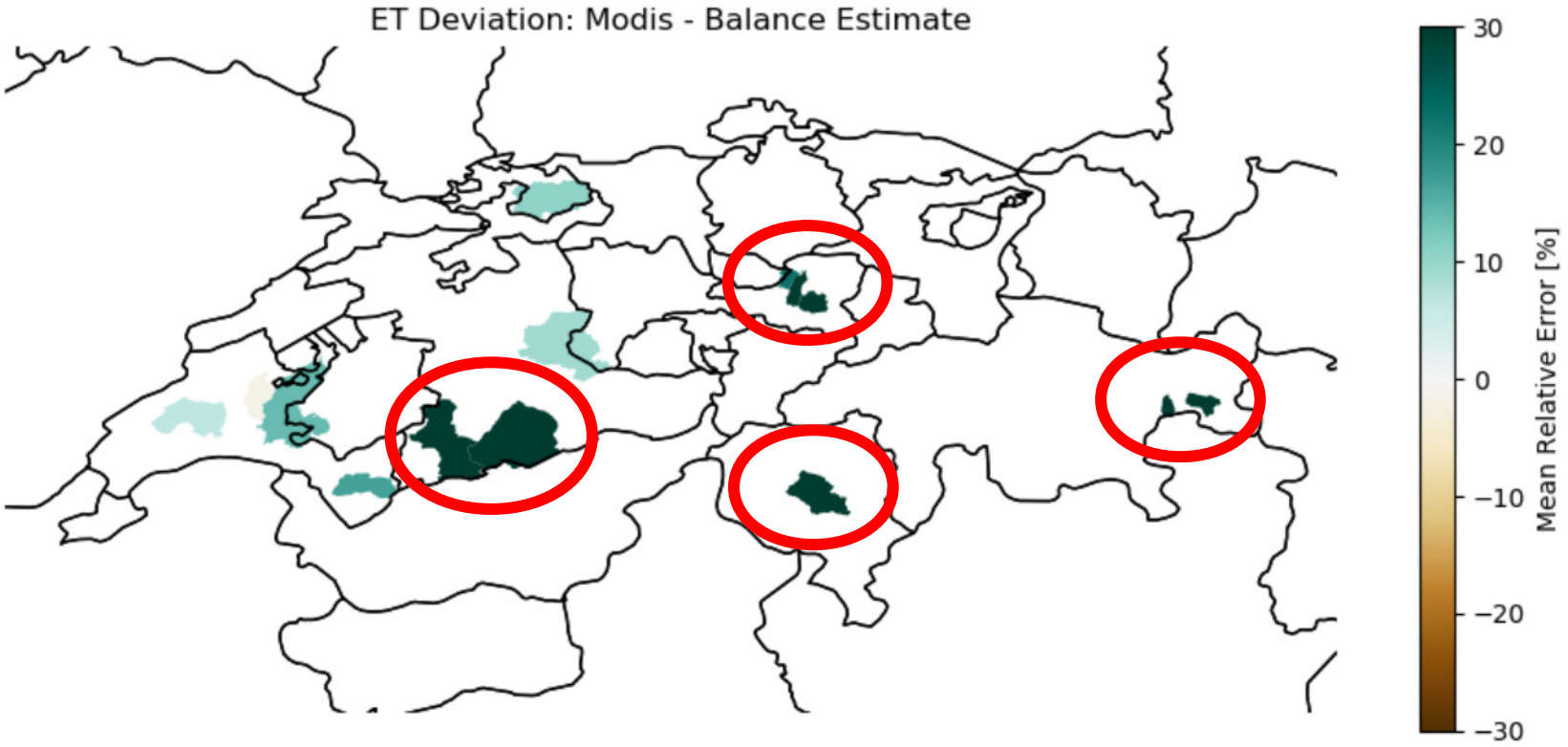
Estimated ET has substantially more inter-annual variability!

Overall: Substantial dry bias of MeteoSwiss analyses (precipitation forcing dataset)



Might be even worse, RhiresM is likely subject to rain gauge undercatch.

Overall: Large discrepancies in alpine catchments between estimated ET and MODIS ET



Likely: Rain gauge undercatch in RhiresM + coarse meteorological forcing for MODIS

Conclusions and outlook

- Validation and tuning of a new groundwater and runoff formulation (Schlemmer et al. 2018) still ongoing.
- Validation framework follows catchment water balances → Flexible in scales
- Overall remaining uncertainties about forcing and validation datasets.
- But: Infiltration is crucial! Urge for a better parameterization.

Questions?

Thank you!

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