Development and application of a catchment-based mass balance validation tool for land surface schemes

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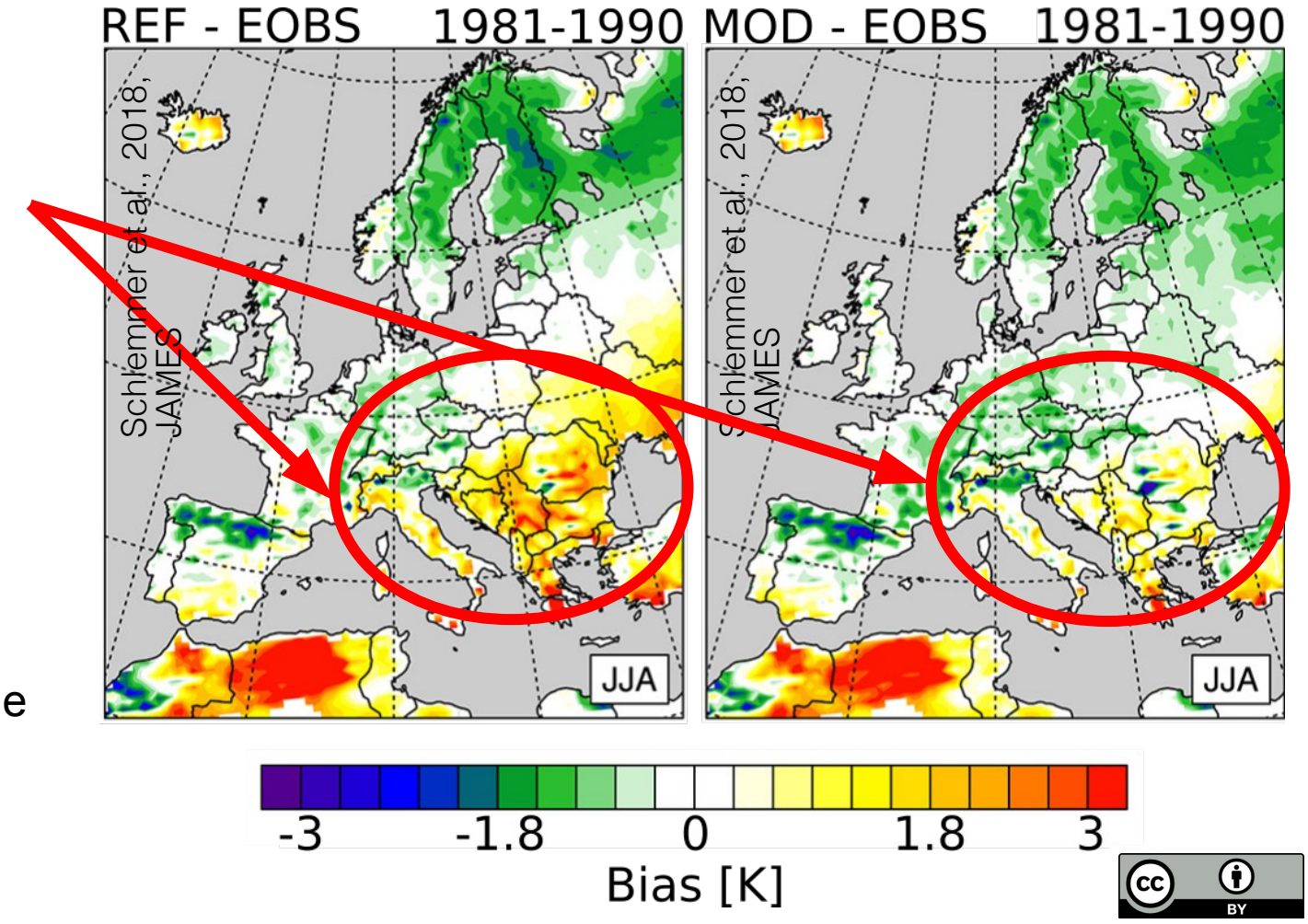
Is the new soil water treatment beneficial @ 1km?

New runoff and groundwater scheme for the COSMO NWP and Climate Model: Clear reduction of T-2m bias in coarse resolution (50 km) climate simulations!
See Schlemmer et al. (2018), JAMES!

BUT:
Behavior in kilometer-scale simulations?

How to validate a new scheme in a physically meaningful way?

Further improvements?



Natural approach: Comparing catchment water balances!

Mass conservation yields:

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

dS/dt: Terrestrial storage change (here predominantly change in soil moisture)

P: Precipitation

Q: Discharge (aggregated runoff in the model world)

E: Evapotranspiration

→ Aggregate to catchments and monthly timescales (no routing required).

Data to establish observation budgets

PRECIPITATION (P)

MeteoSwiss COSMO-1 (1km) Preoperational Analyses

Uncertainty estimation: Validation against gauge-based dataset (RhiresM).

EVAPOTRANSPIRATION (ET):

MODIS MOD16A02 (Running et al. 2016)

Uncertainty estimation: Validation against 10 Fluxnet stations in the alpine region.

STORAGE CHANGE (dS/dt)

Residual to close balance

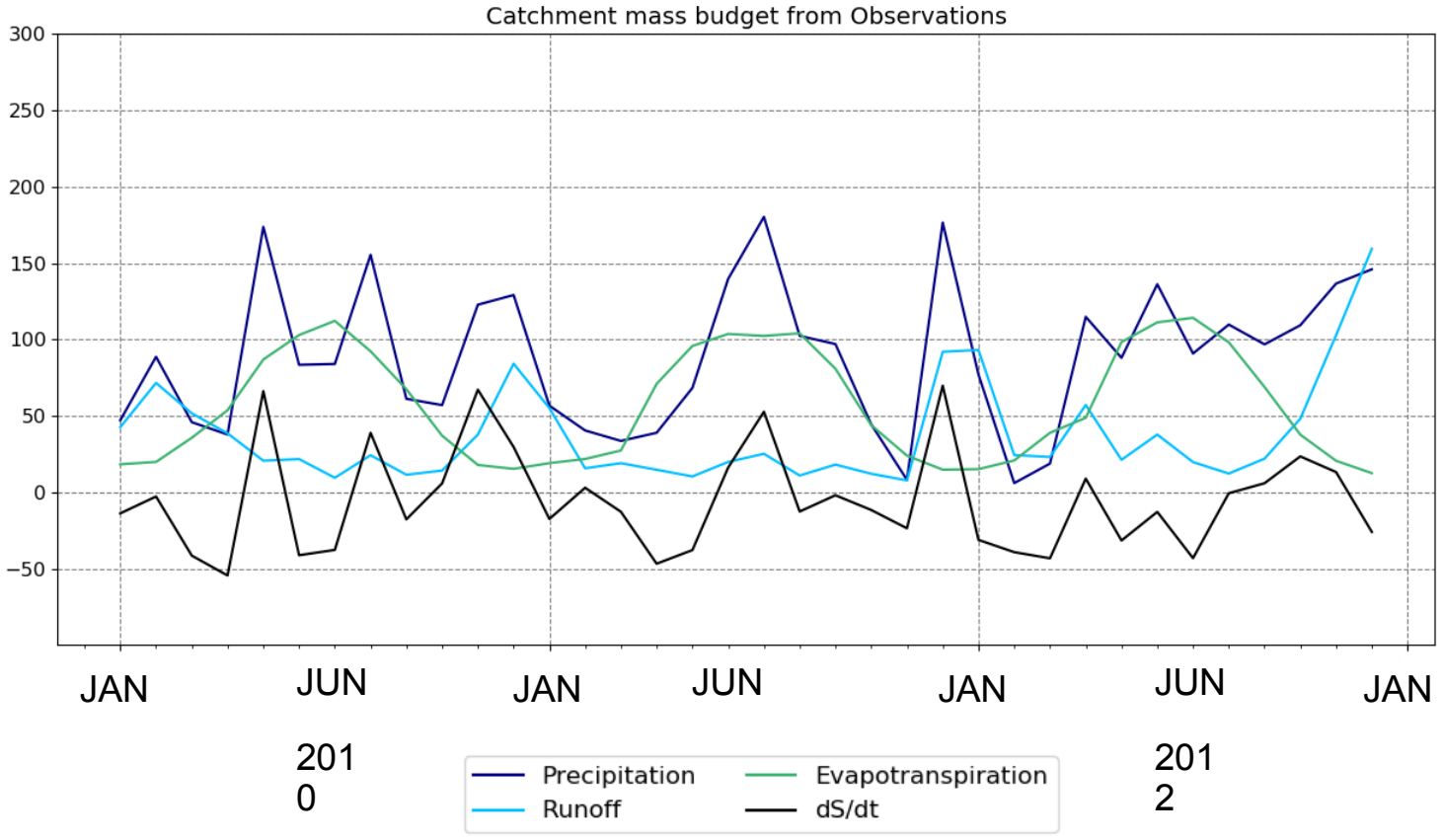
Uncertainty estimation: Error Propagation (P, ET)

RIVER DISCHARGE (Q):

Gauge measurements by the Federal Office for the Environment (FOEN)

Uncertainty estimation: Measurement error assumed negligible compared to P, ET. P Error considered.

Example: Established water balance for Broye (416km^2)

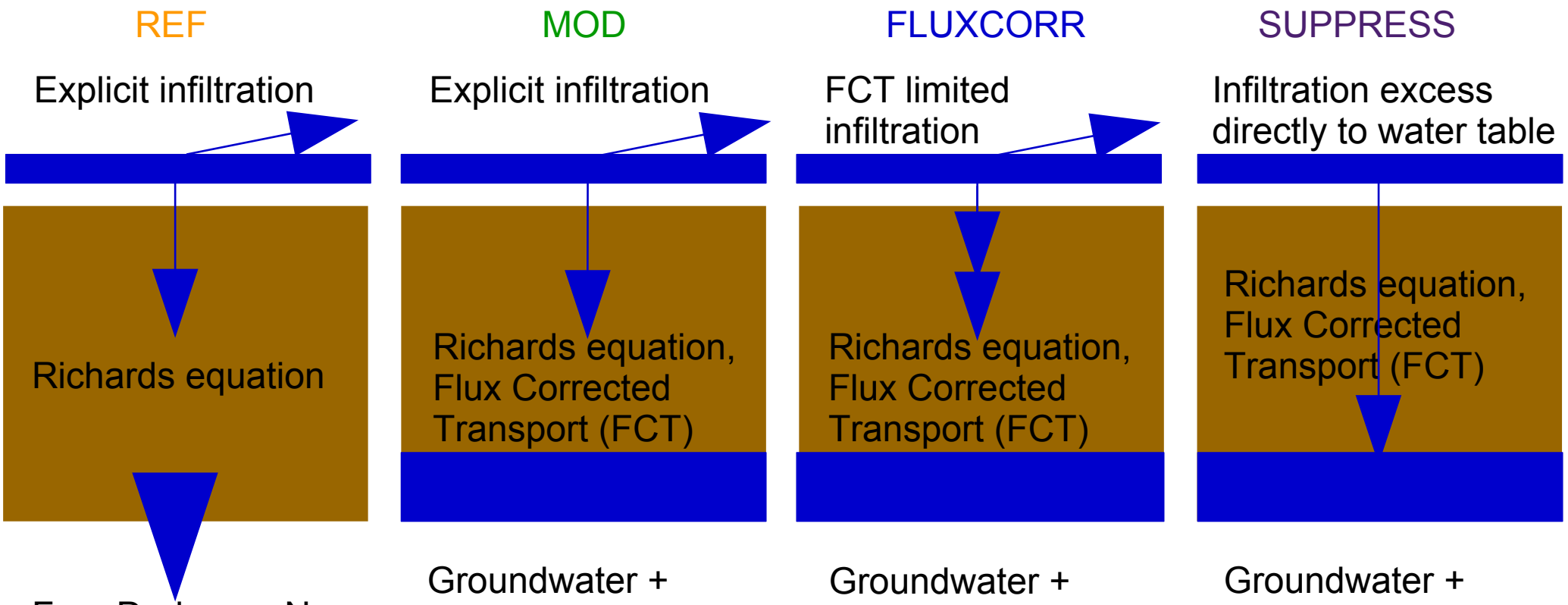


Compare established water budget to simulations of different model versions!

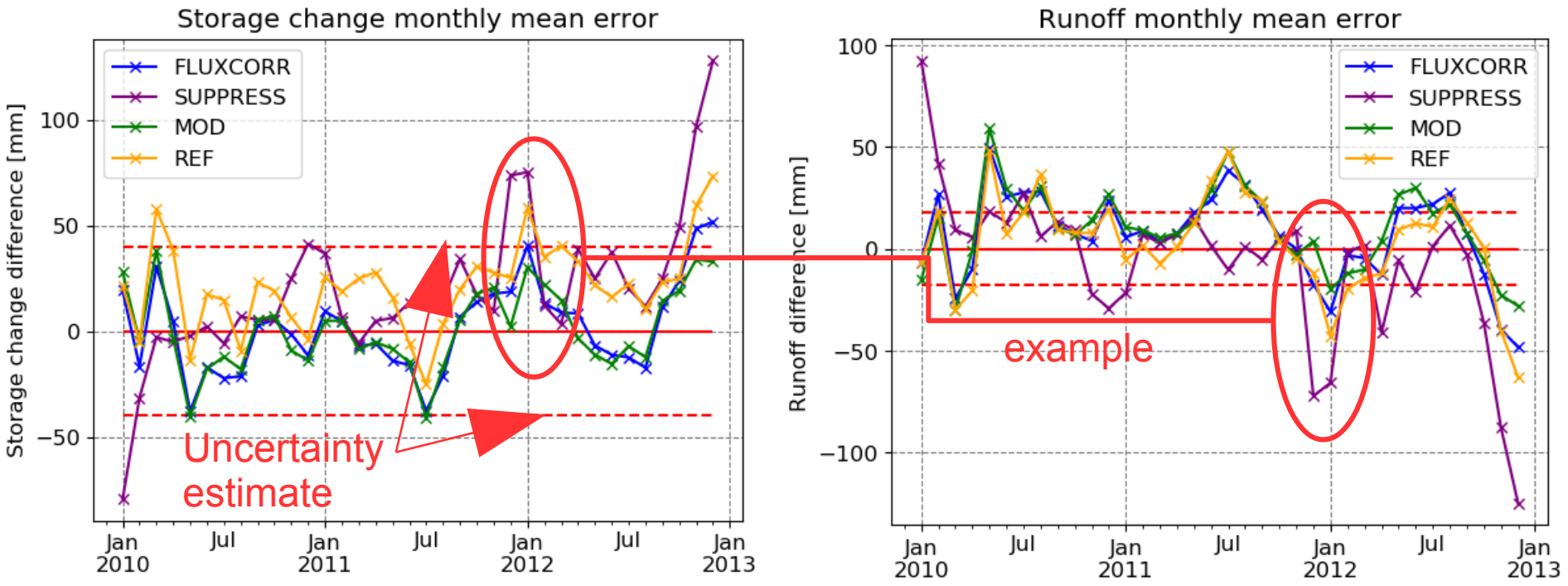
Simulation Setup

- Four different versions of TERRA ML 2nd generation land surface scheme (COSMO v. 5.03 based)
- Running in standalone mode (one-way coupling to atmosphere), resolution 0.01° (~1.1 km)
- Cycling 2x Years 2010-2012, first cycle is discarded as spin-up.
- Detailed description of TERRA ML and a new groundwater and runoff formulation can be found in Schlemmer et al. (2018)
- Apply validation framework over five mesoscale catchments in Switzerland (Broye, Ergolz, Mentue, Thur and Venoge)

Four different groundwater formulations for COSMO

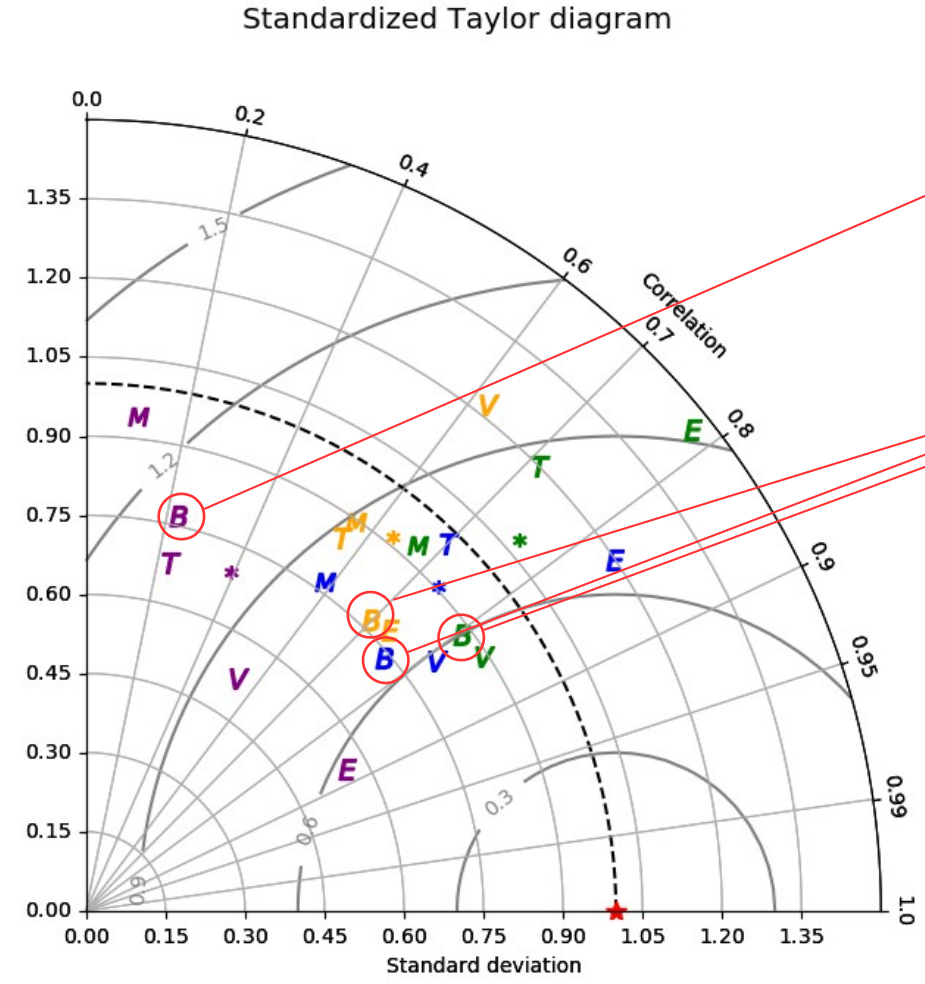


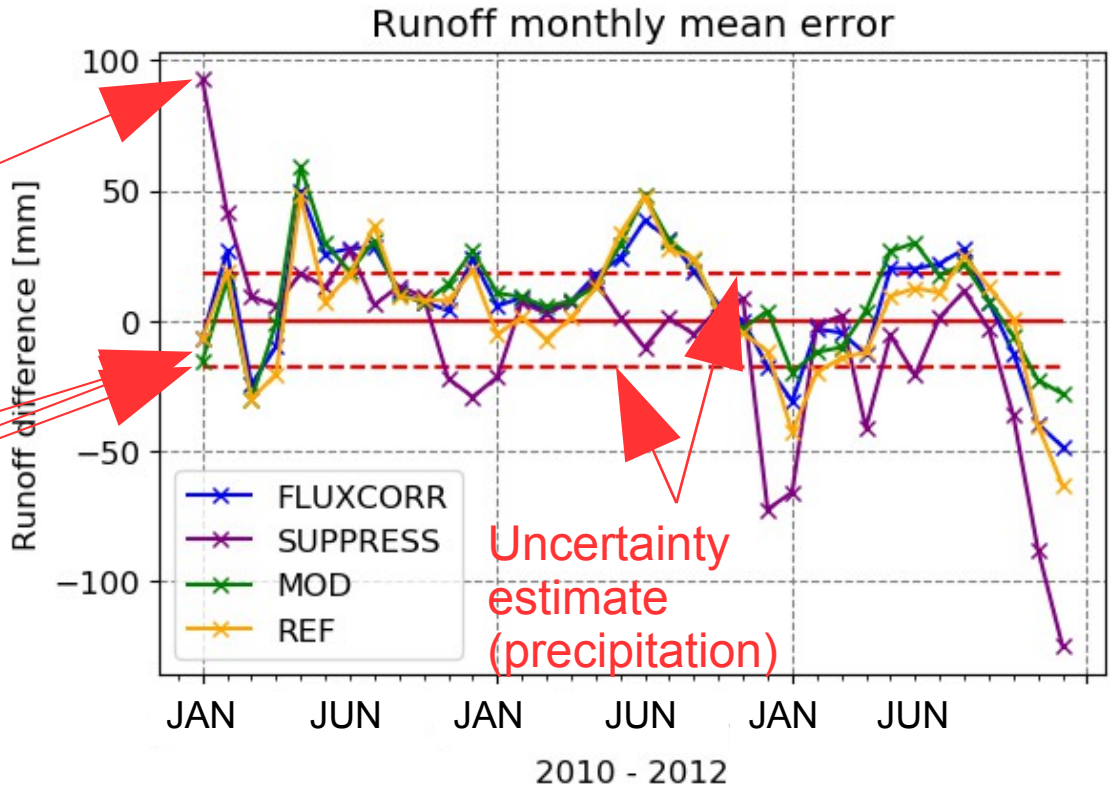
Storage change errors driven by runoff Errors



Example for Broye (416 km^2), but the same is true for all five investigated catchments.
A positive error in runoff corresponds to a negative error in storage change.

In depth: Comparing runoff





Different Model Versions can be clearly distinguished by catchment (here e.g. B for Broye) and in the mean behaviour (asterixes).

Conclusions

- Development of a catchment mass balance validation framework for high resolution land surface models, which is scalable in space and time (Regenass et al., in preparation).
- Applied validation framework to four different groundwater formulations.
- Different model versions clearly distinguishable in the validation framework.
- In our case: Storage change error driven by runoff.
- Runoff score strongly dependent on treatment of infiltration! No satisfactory formulation yet.

Questions?

Thank you!

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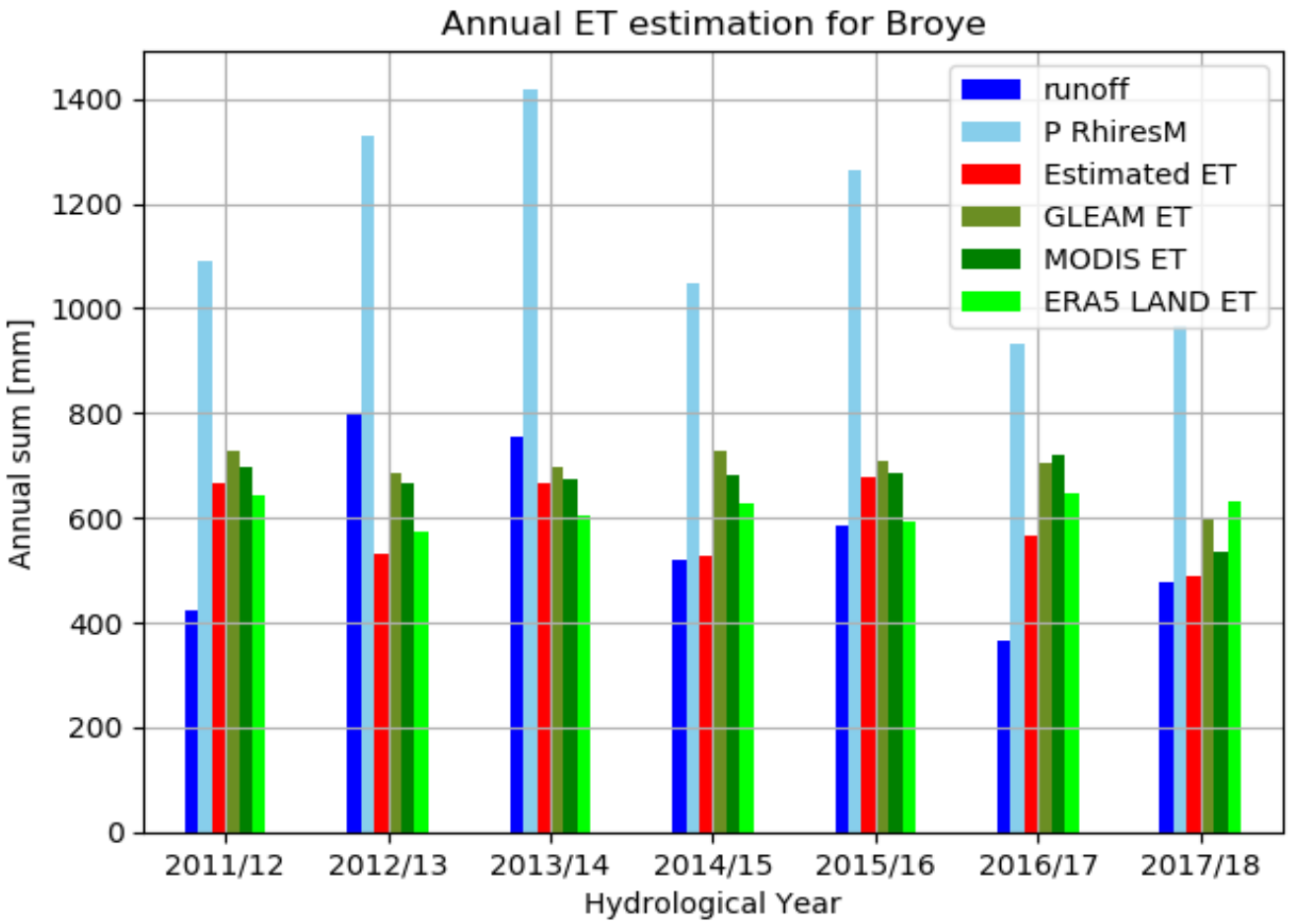
Additional Material

- From here onward, you can find additional material
- i.e. we show results from uncertainty estimation

Long term water balances justify use of MODIS ET



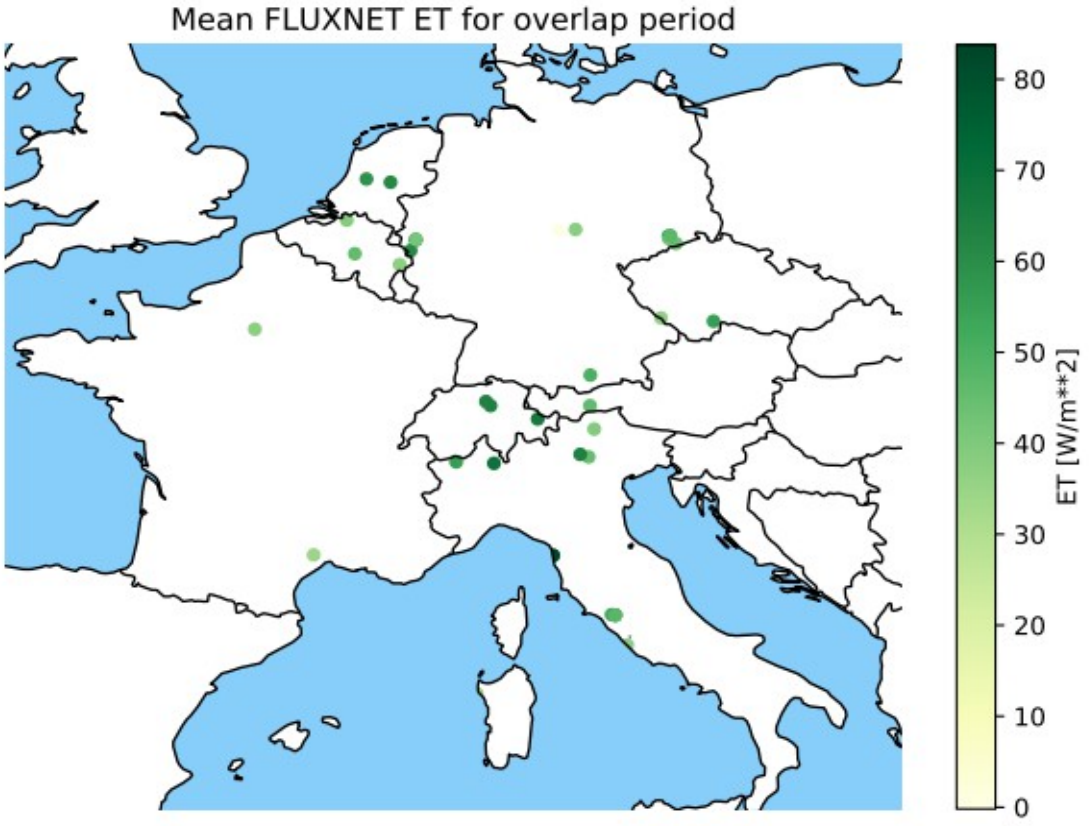
We compare three different evapotranspiration products: MODIS MOD16A02, GLEAM and ERA5 LAND

Products are compared to ET estimates from annual balances (hydrological year in Switzerland Nov.-Oct.), assumption is that ET = P-Q

In all five investigated catchments, differences between different products are relatively small (example Broye)

We choose MODIS, because the vegetation resolution is best comparable to footprint of FLUXNET sites (important for uncertainty estimation)

FLUXNET Site-Level ET validation

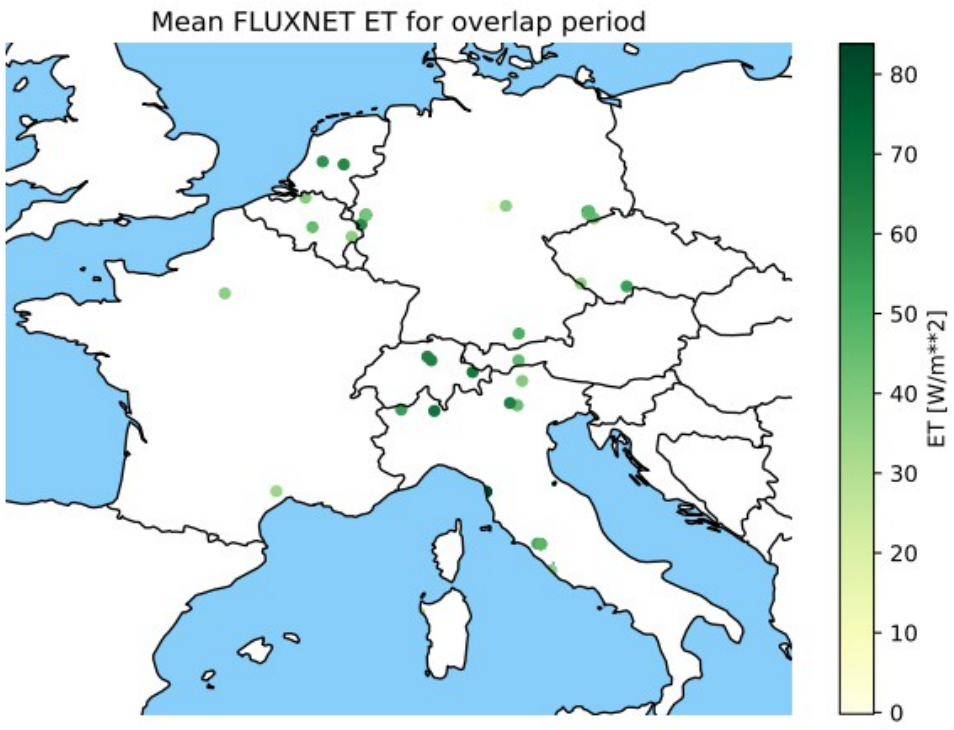


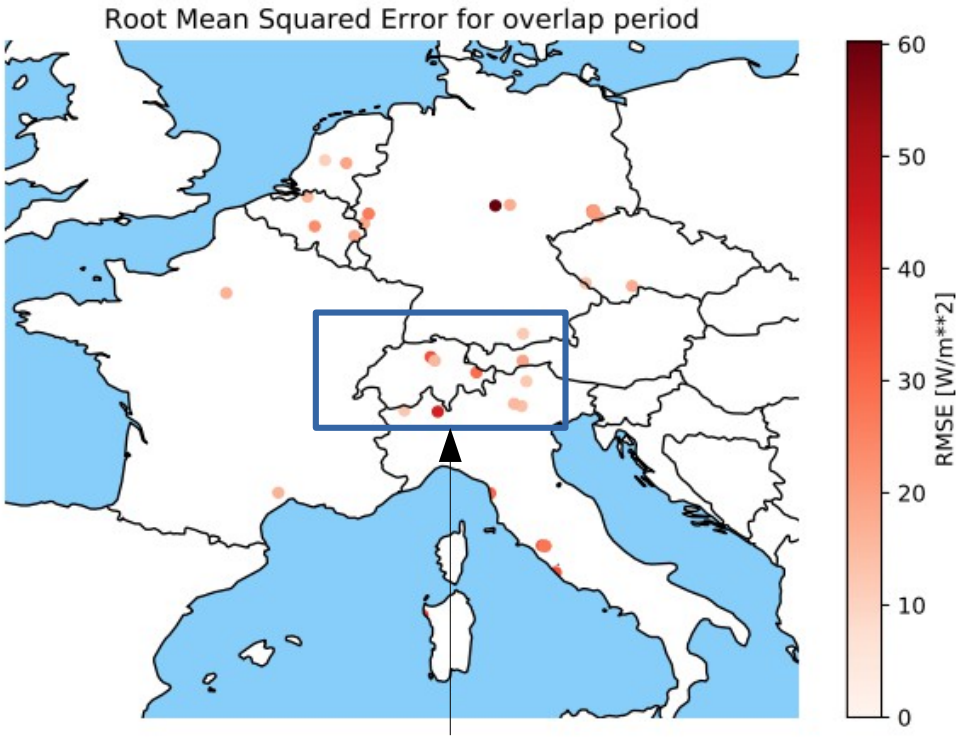
Aggregate MODIS ET to monthly timescale and convert to energy units (Latent Heat Flux).

Select nearest neighbor to site.

Compare to FLUXNET site data (shown left)

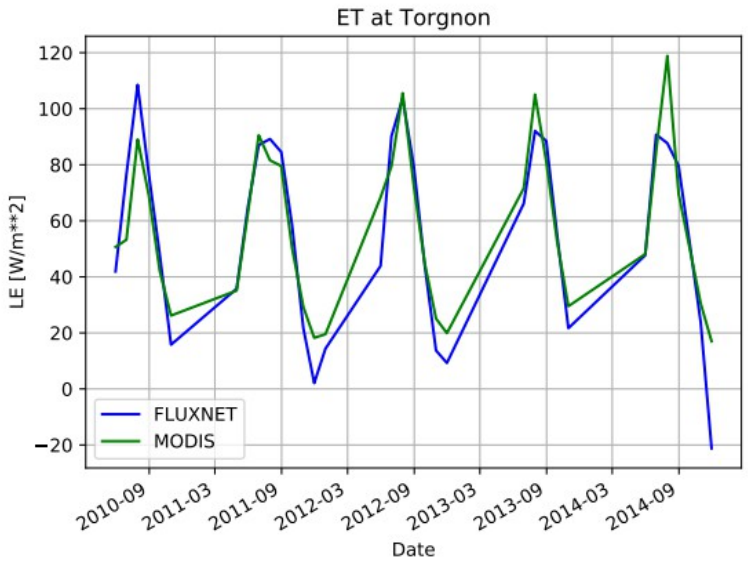
Data selection for estimating MODIS ET error

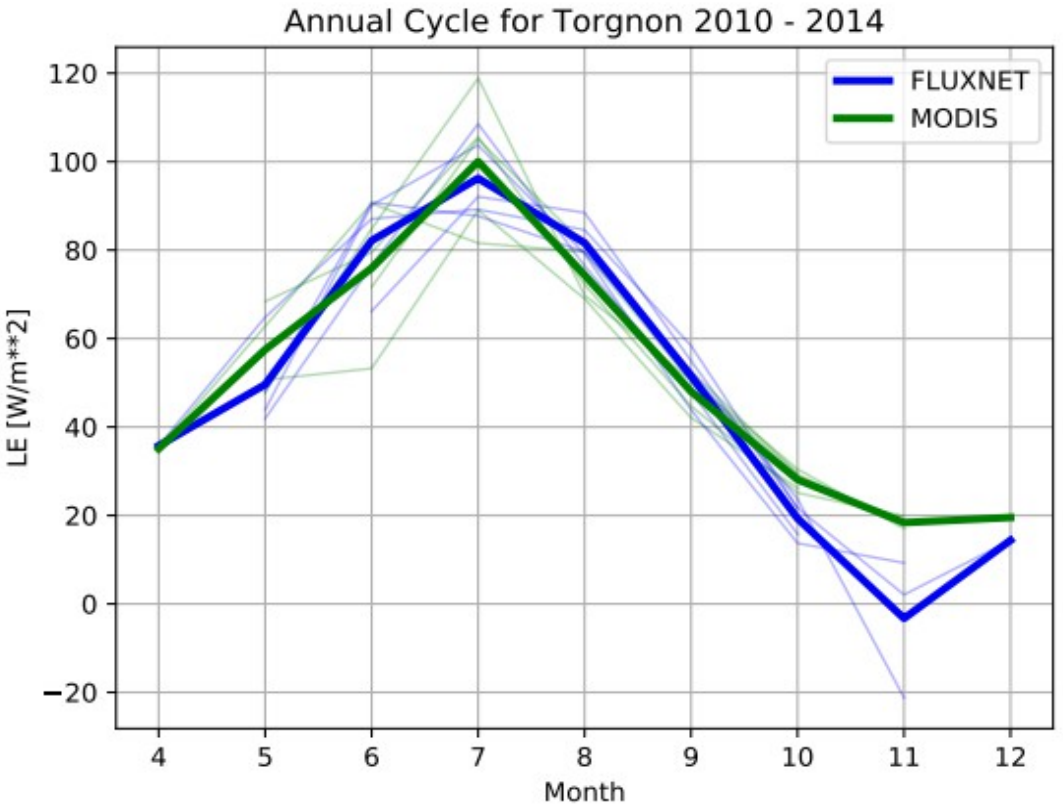




Region for Error Estimation. 10 Sites, 1-4 years per site

Calculating an estimation for MODIS ET error

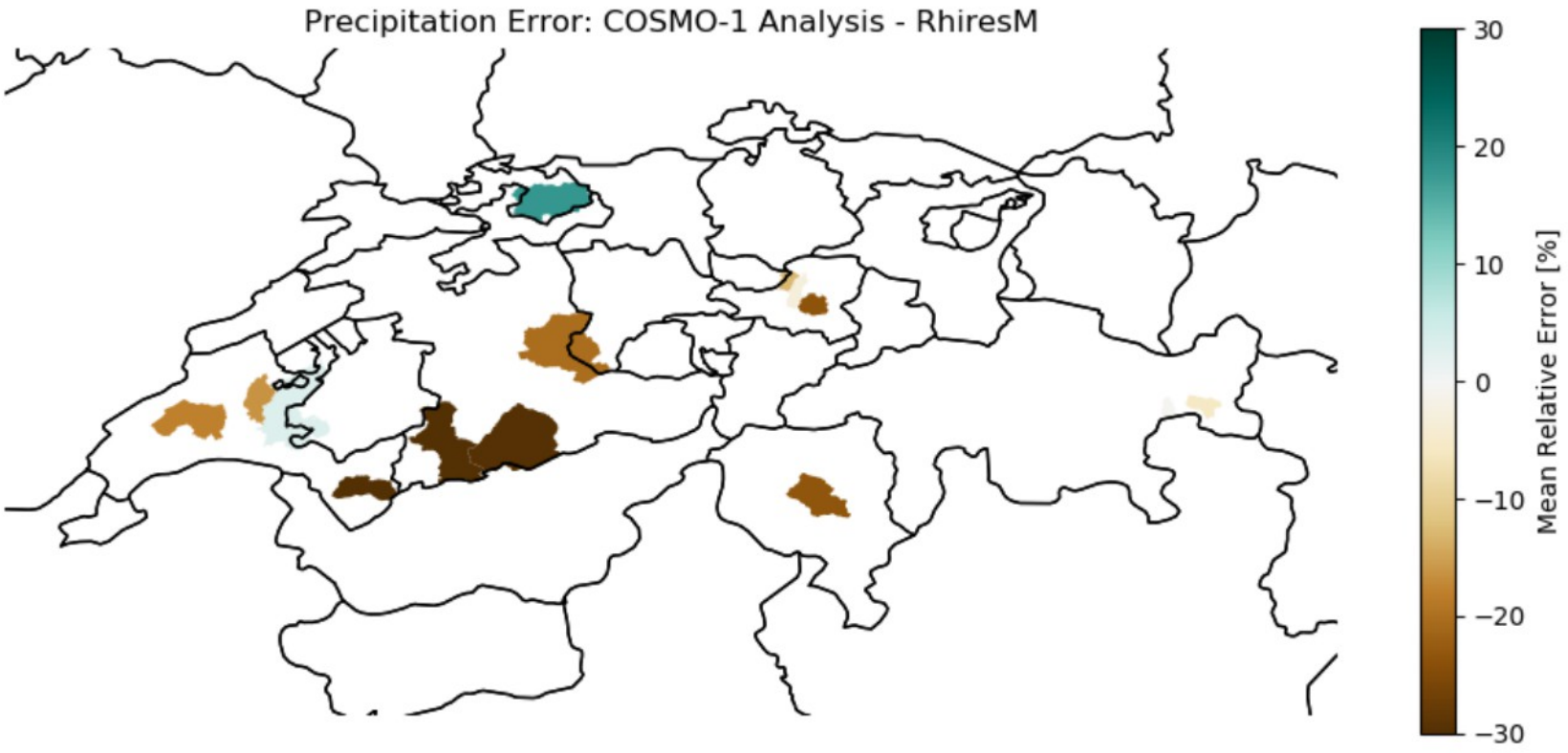




Ø RMSE over all 10 stations:
$\Delta LHF = 21.5\ W/m^2$

corresponding to ~22 mm water per month

Results from precipitation uncertainty estimation



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

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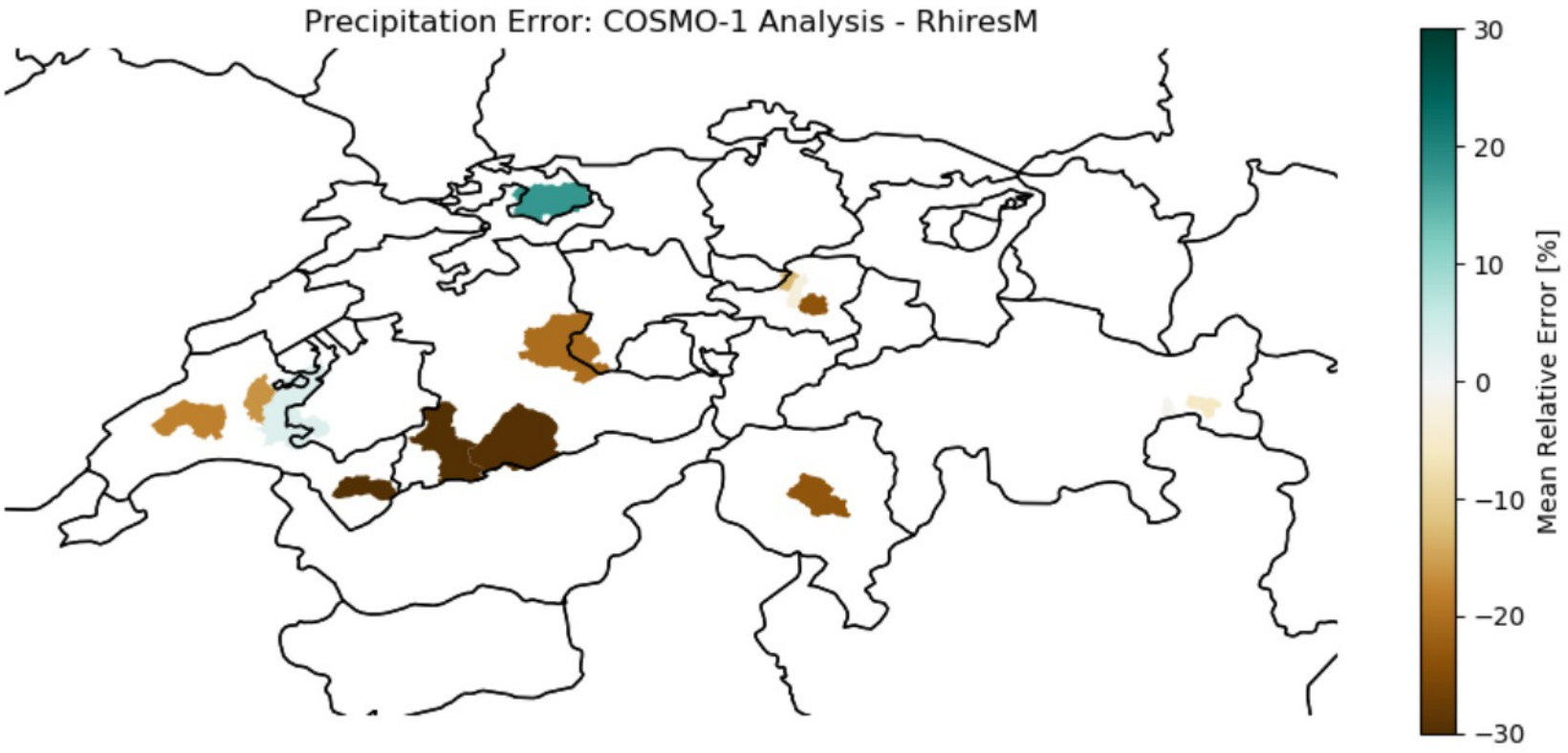

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