TERRA Incognita: Why we should care about the hydrological cycle in COSMO

APN Info
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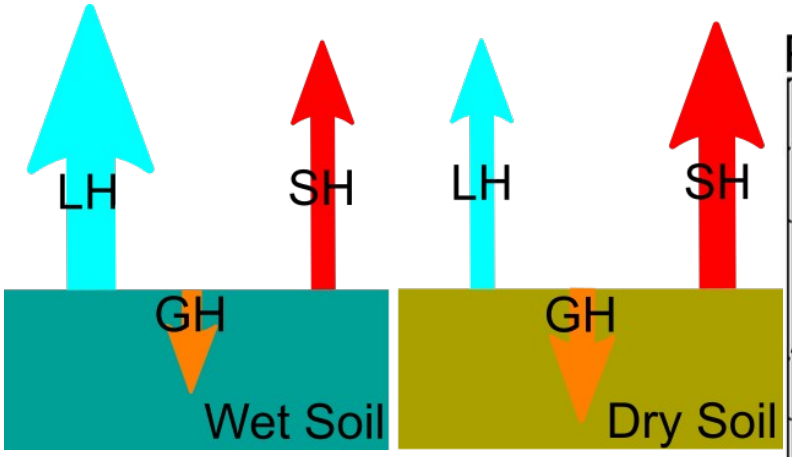
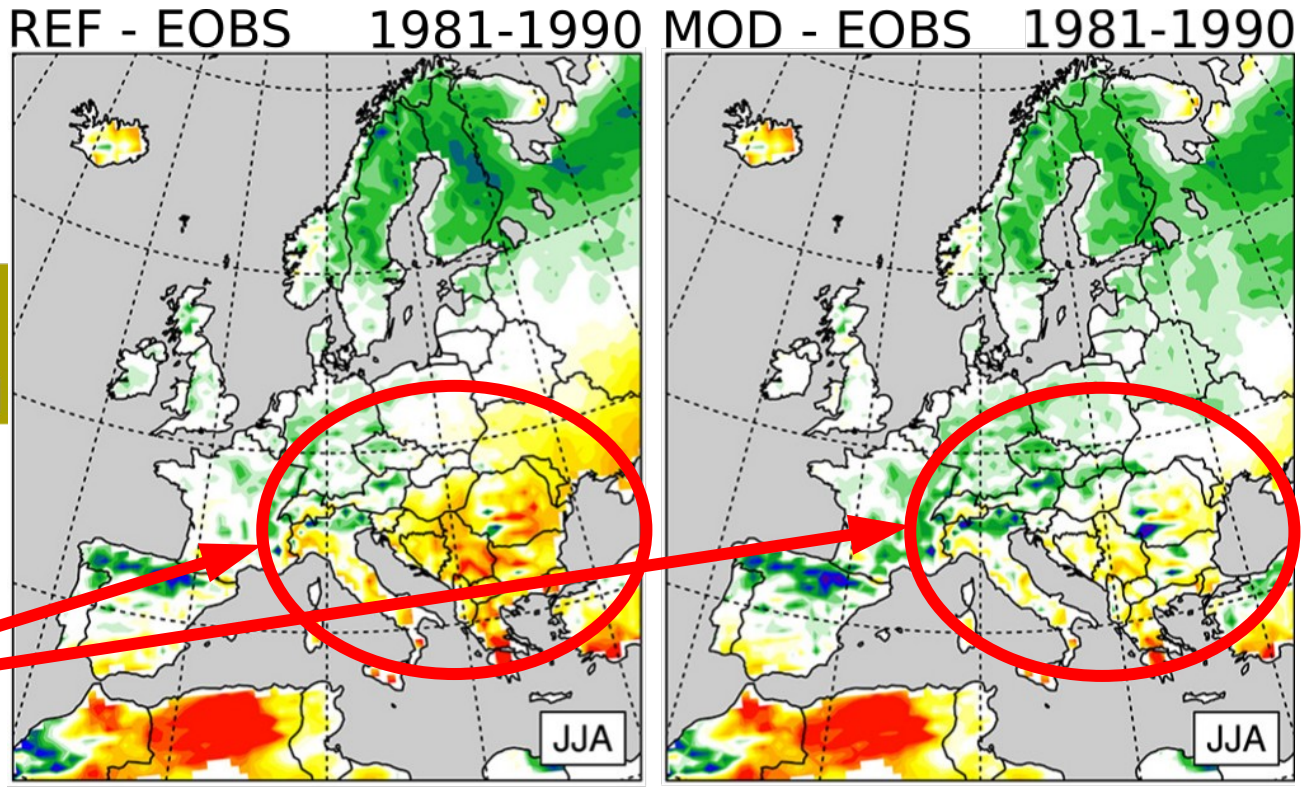
Hydrological state of the soil matters.

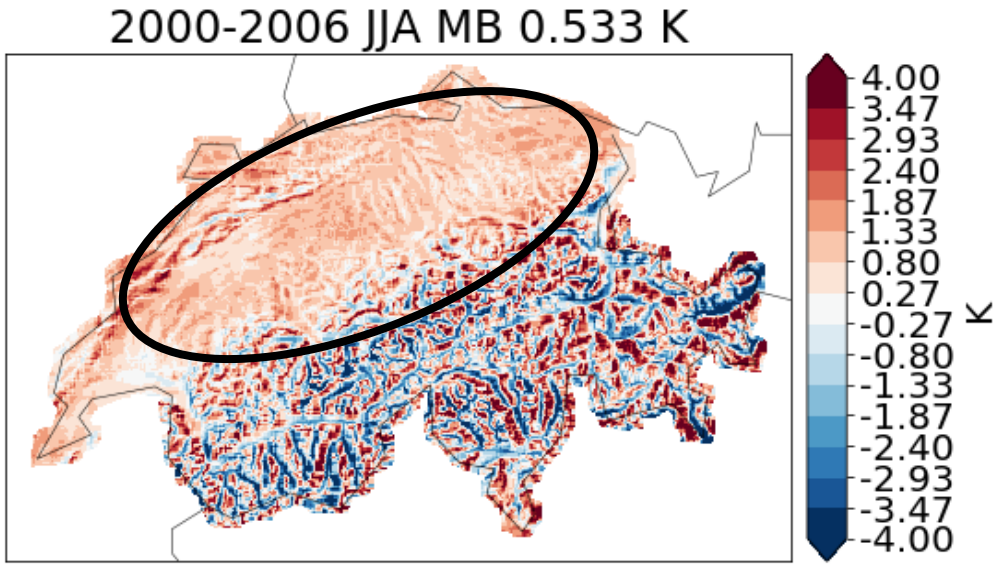




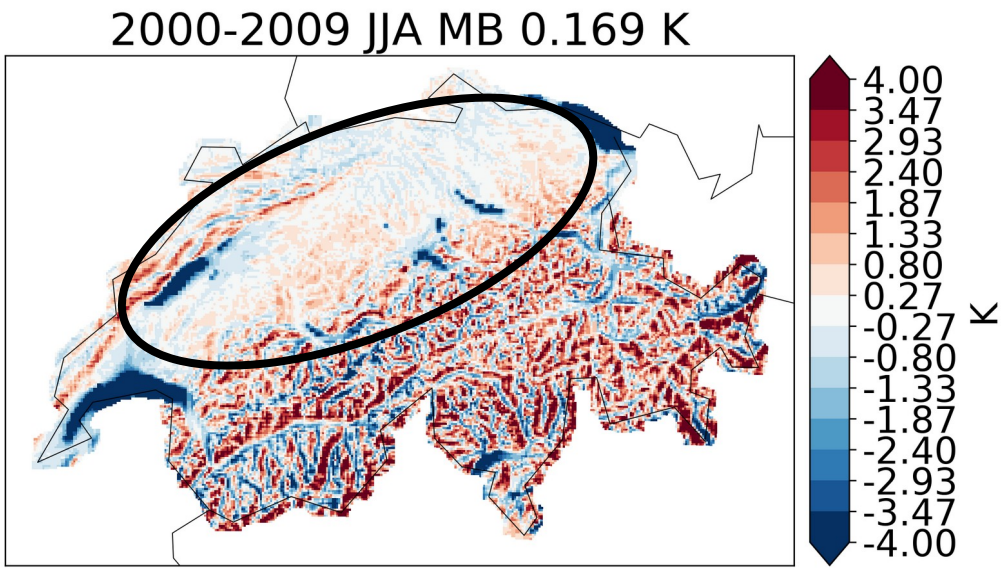
New runoff scheme: Clear reduction of T-2m bias in coarse resolution (50 km) climate simulations!

Schlemmer et al., 2018

Similar patterns in high resolution simulations



Leutwyler et al. 2017



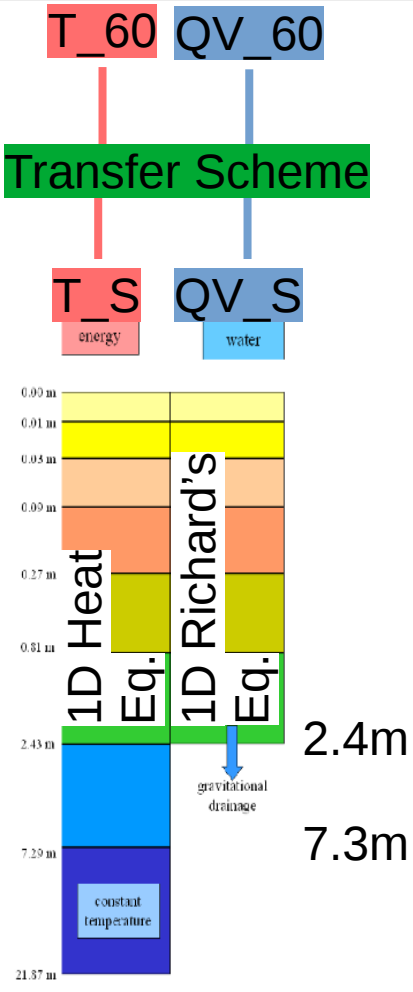
Vergara et al., in preparation

T_{2M} Bias Plots by Jesus Vergara

Outline

- Introduction
- Validation Approach and Data
- Results from TERRA Standalone Runs
- Evapotranspiration in Coupled Runs

TERRA Basics



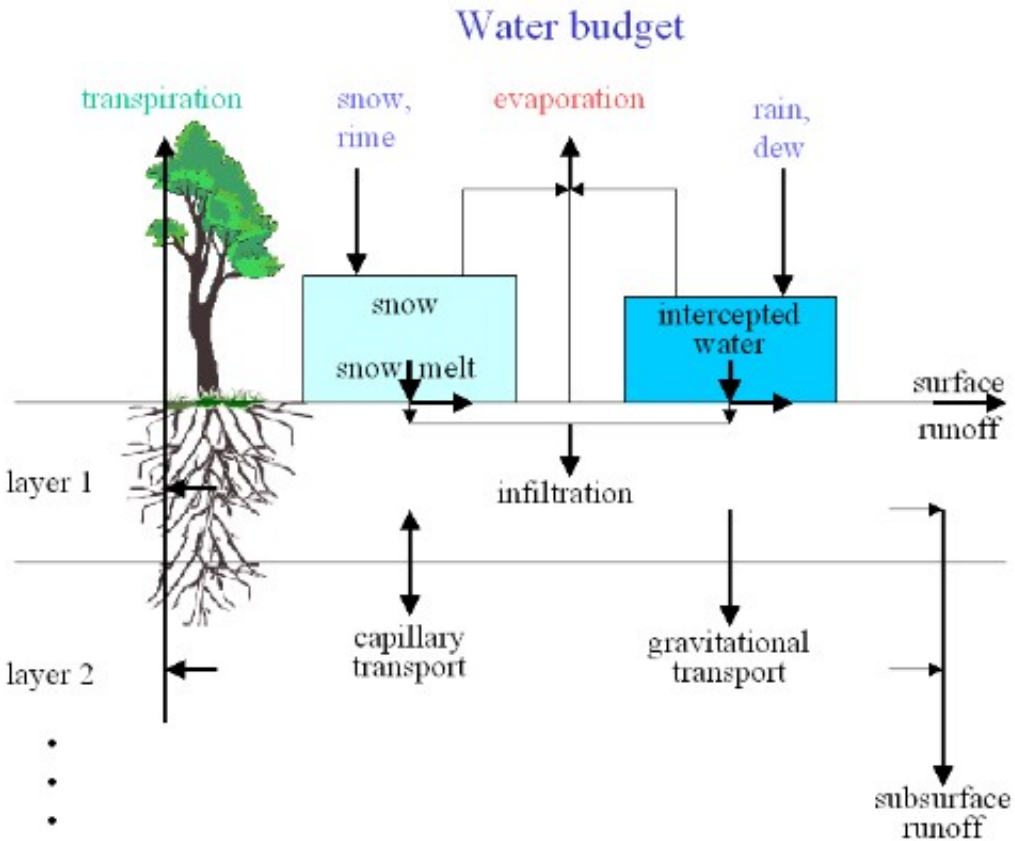
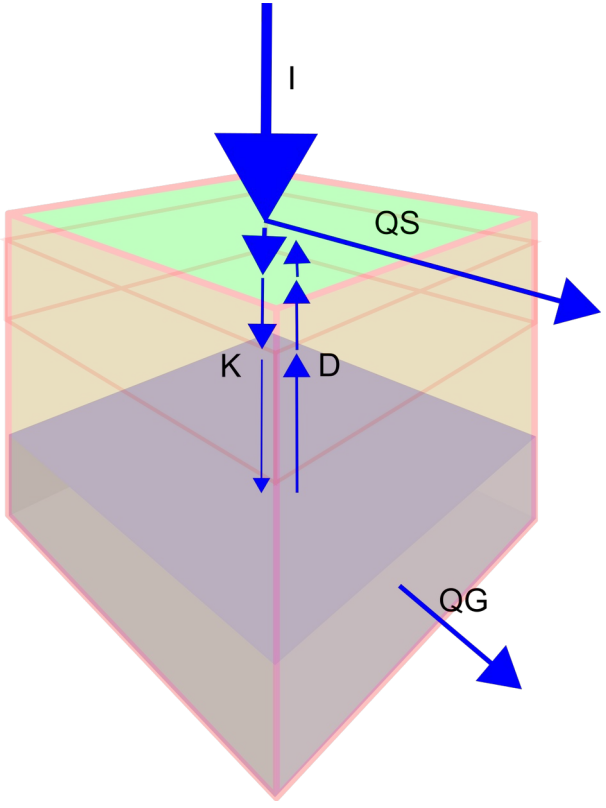


Fig.: COSMO Documentation Part II

Testing a new groundwater and runoff formulation



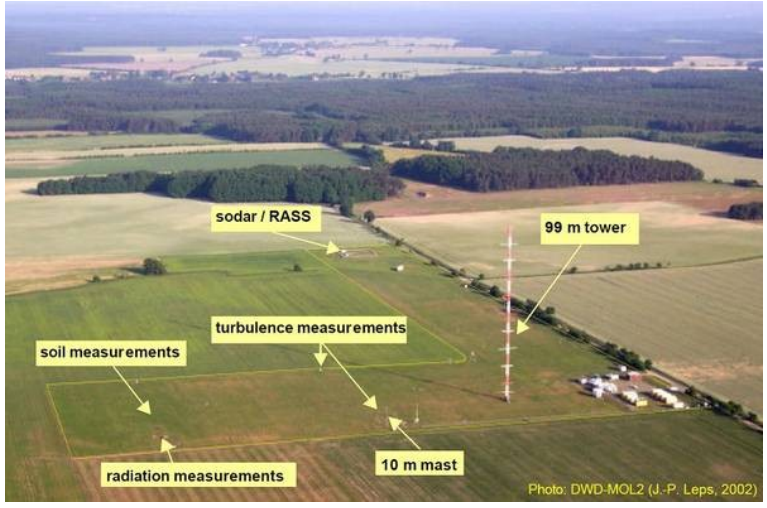
- 1D **Richard's equation (K, D)**
- **Zero flux bottom boundary condition**
- **Mass conserving flux corrections** (limit K and QG to avoid overflow and overdepletion)
- **Exponential decrease of hydraulic conductivity (K)** with depth, scaled with root depth (Decharme, 2006)
- **Surface Runoff (QS)** due to infiltration **(I)** excess or saturation excess
- **Diagnostic ground runoff (QG)** from water table, proportional to K_{sat} and gradient of orography.

(See Schlemmer et al., 2018 for implementation details)

→ **Testing** within **TERRA ML – standalone**, forcing with **1 km** MeteoSwiss analyses (2010-2012, run 3x to ensure equilibration)

Common validation approaches have a scale gap.

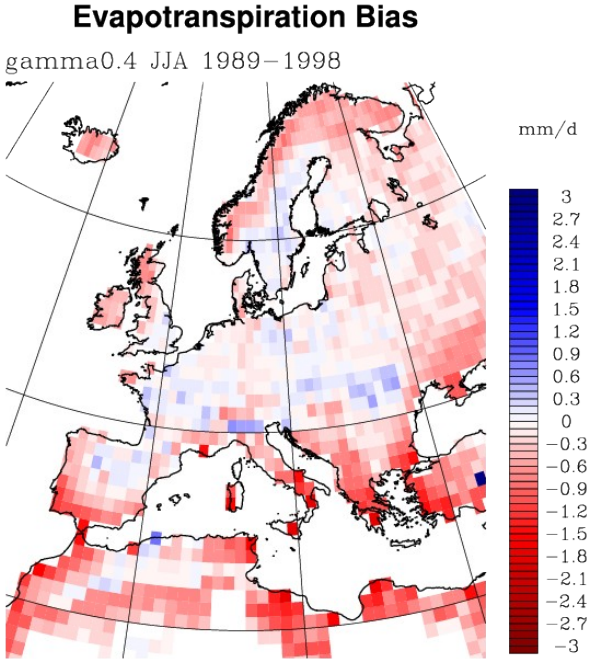
Point



https://icdc.cen.uni-hamburg.de

?

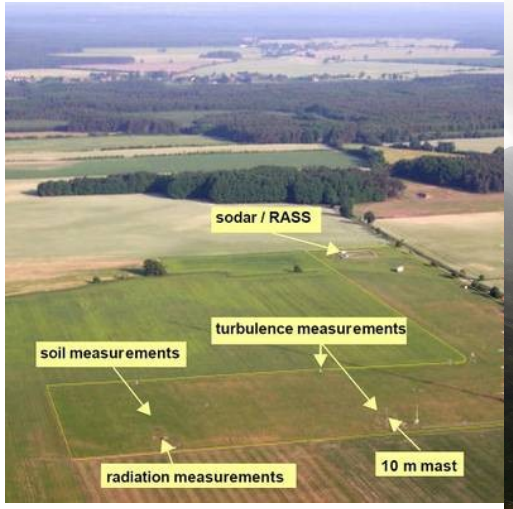
50 km



LandFlux-EVAL Dataset: Mueller et al., 2013

Bridge the gap with hydrological methods.

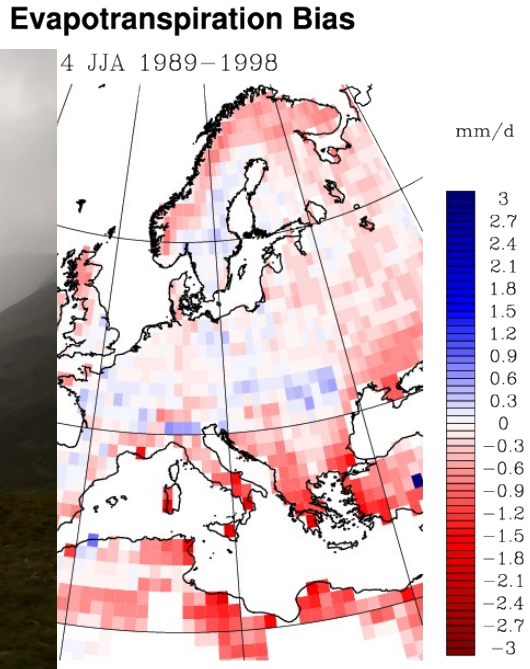
Point



https://icdc.cen.uni-hamburg.

Catchment

50 km



ix-EVAL Dataset: Mueller et al., 2013

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:

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

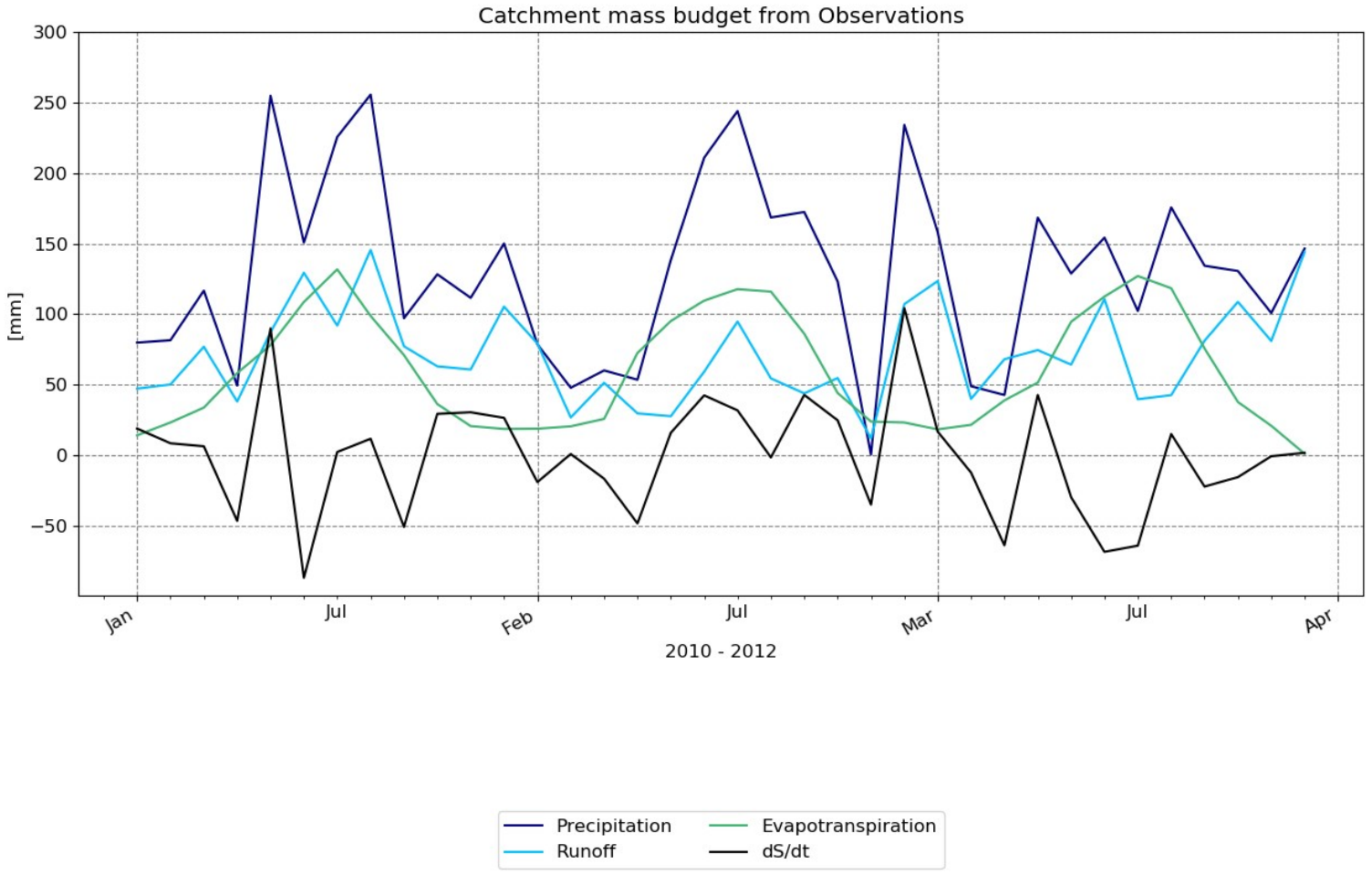
P: Precipitation MeteoSwiss Analyses

Q: Runoff Measurements by the FOEN

E: Evapotranspiration MODIS MOD16A2 (Running et al., 2017)

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

Water balance example (Thur 1713 km^2)

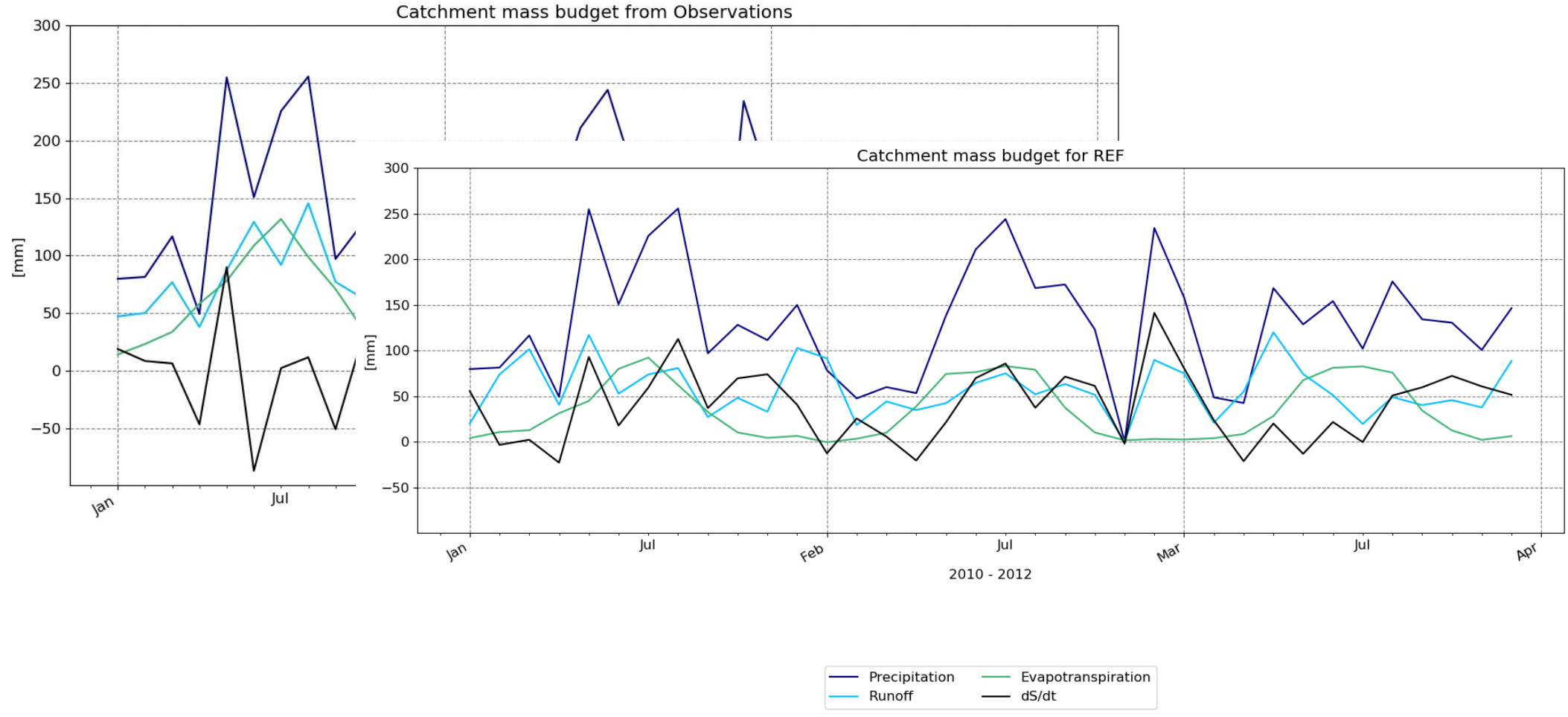


Apply mass balance validation to 3 model versions.

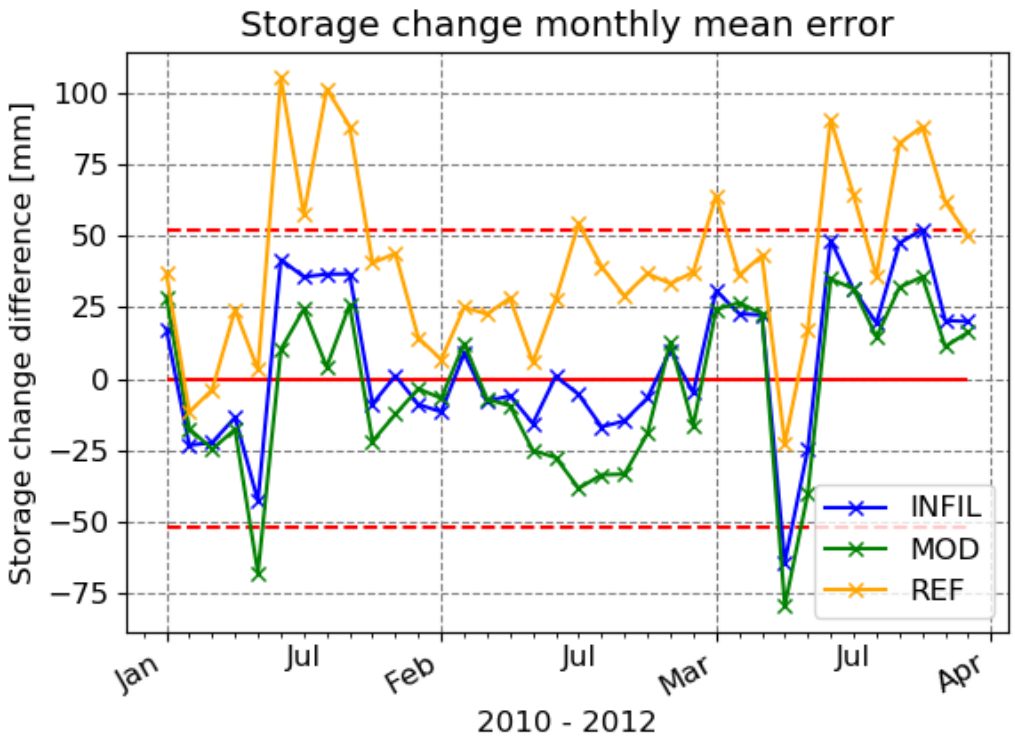
Parameterization	REF	MOD	INFIL
Hydrology (inner layers)	Standard TERRA, Free Drainage, No dependence of runoff on orography	Schlemmer et al. (2018), Groundwater, Slope dependent runoff generation	Schlemmer et al. (2018), Groundwater, Slope dependent runoff generation
Infiltration	Standard TERRA, available pore space calculated at beginning of timestep.	Standard TERRA, available pore space calculated at beginning of timestep.	Infiltration treated as flux to first layer, included to FCT implementation

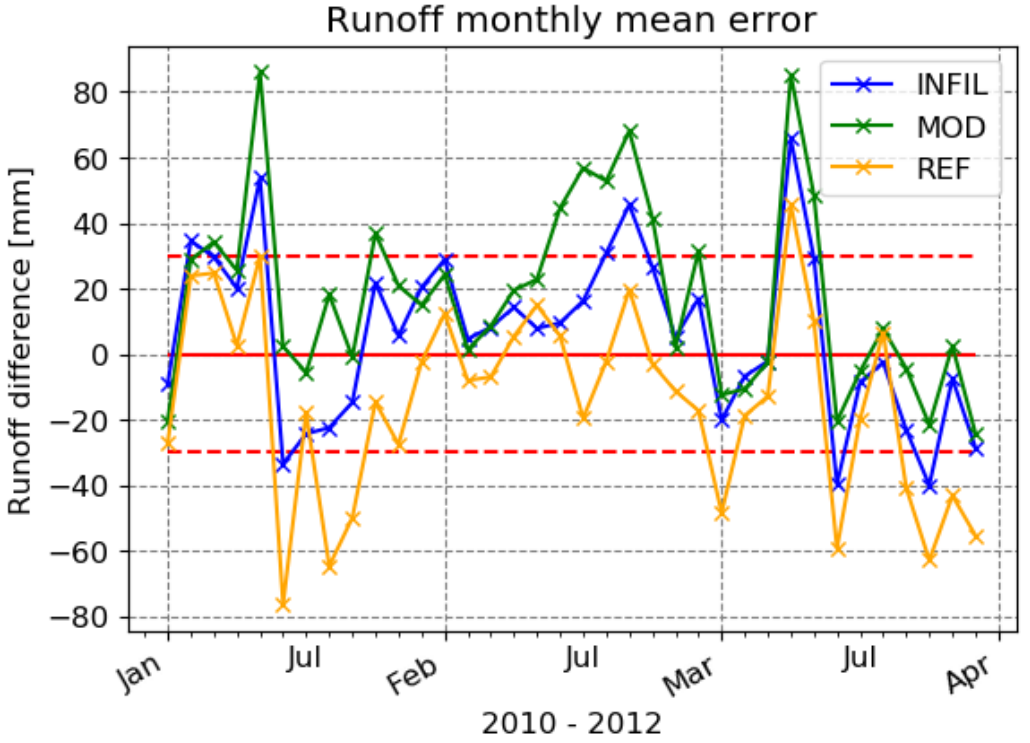
NOTE: In all versions hydraulic conductivity decreases exponentially with depth!

Water balance examples



Error time series





Validation Summary: Runoff

Runoff Bias [mm/month]

Catchment	REF	MOD	INFIL
Broye (417 km^2)	3.27	9.92	7.06
Ergolz (261 km^2)	-8.61	28.4	16.0
Mentue (105 km^2)	12.3	14.6	13.3
Thur (1713 km^2)	-14.1	18.3	5.89
Venoge (228 km^2)	-5.38	-6.03	-6.51

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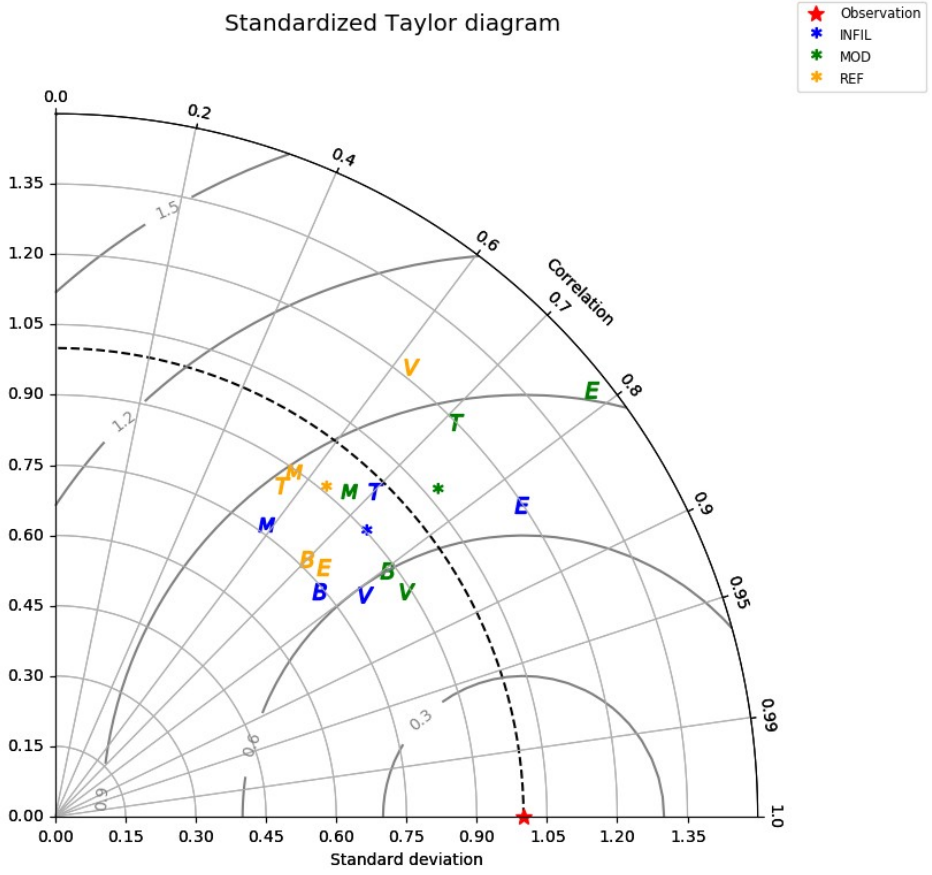
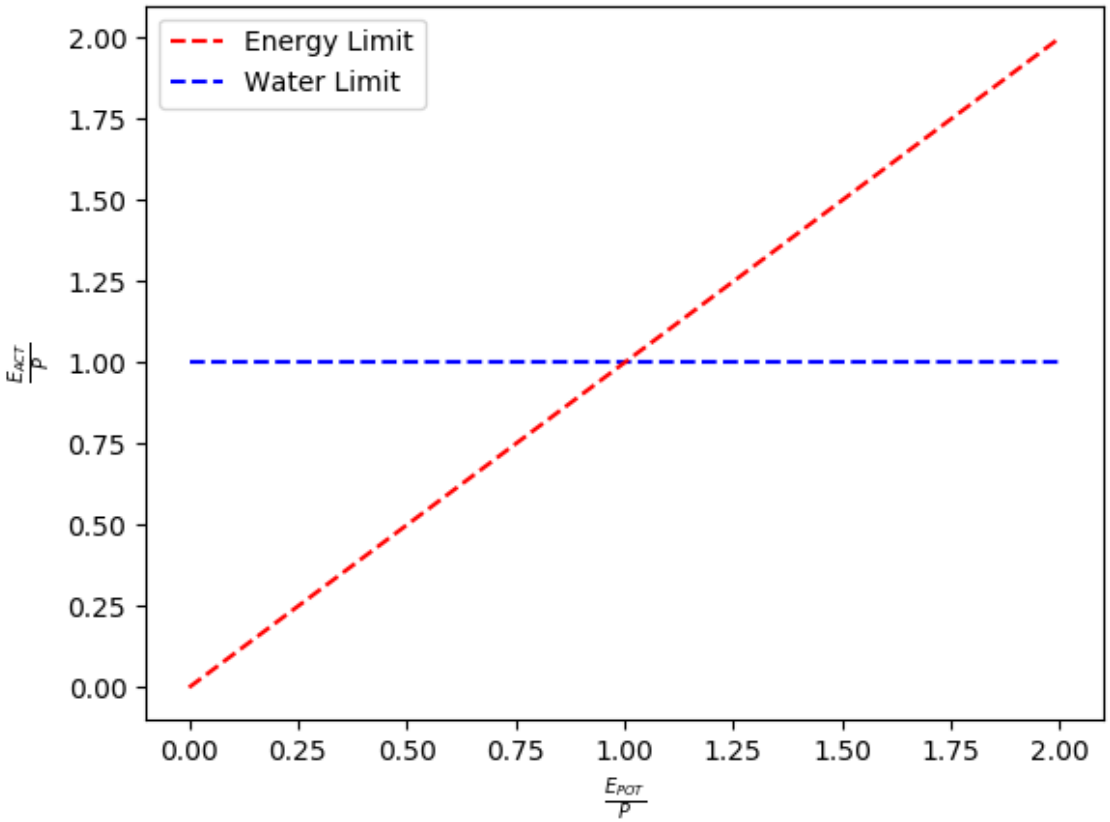


Preliminary Results from Coupled Runs

MOD	REF
Schlemmer et al. (2018) soil hydrology	Standard soil hydrology
itype_evsl = 4 (Resistance)	itype_evsl = 3 (Noilhan & Planton 1989)
Bottom layer of soil hydrology @8m	Bottom layer of soil hydrology @ 4m
tkhmin = 0.35	tkhmin = 0.4
tkmmin = 1.0	tkmmin = 0.4

The Budyko Framework



E_{ACT}: Actual Evapotranspiration

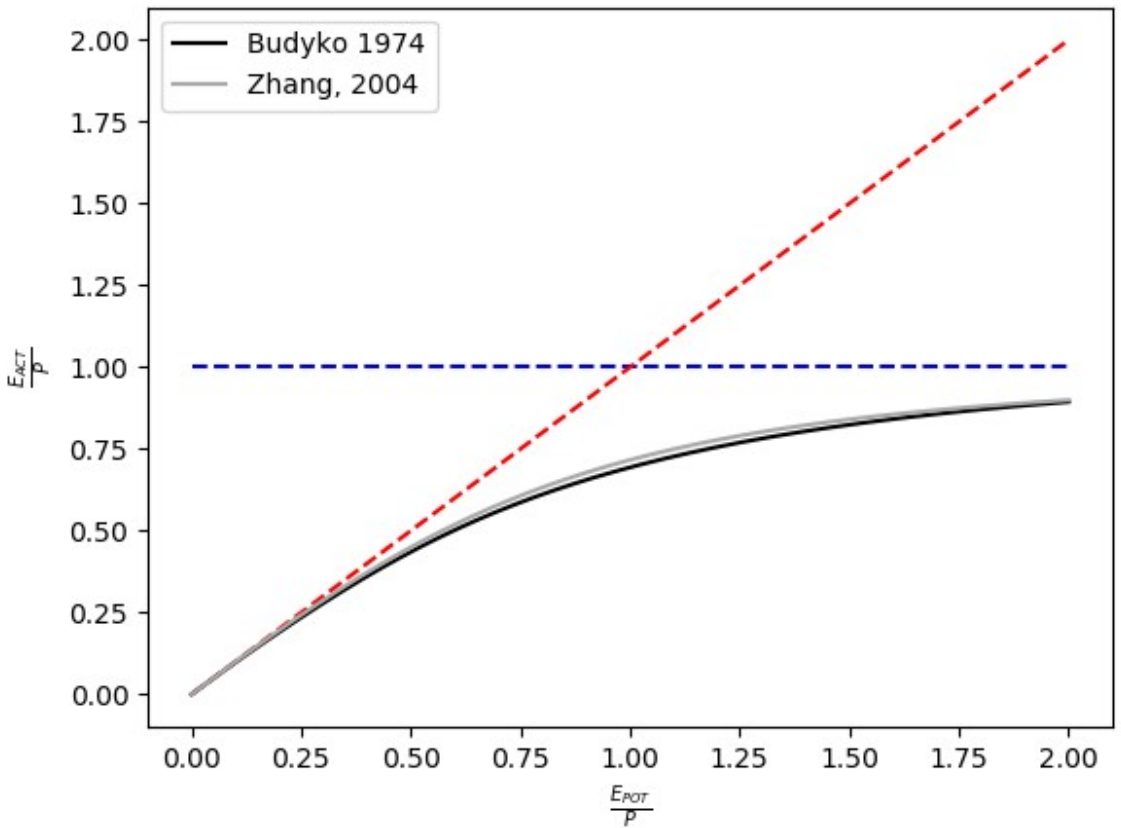
E_{POT}: Potential Evapotranspiration (Energy Equivalent R_{NET})

P: Preciptiation

Not more evapotranspiration than precipitation!

Not more latent heat release than available energy (by net radiation)

The Budyko Framework



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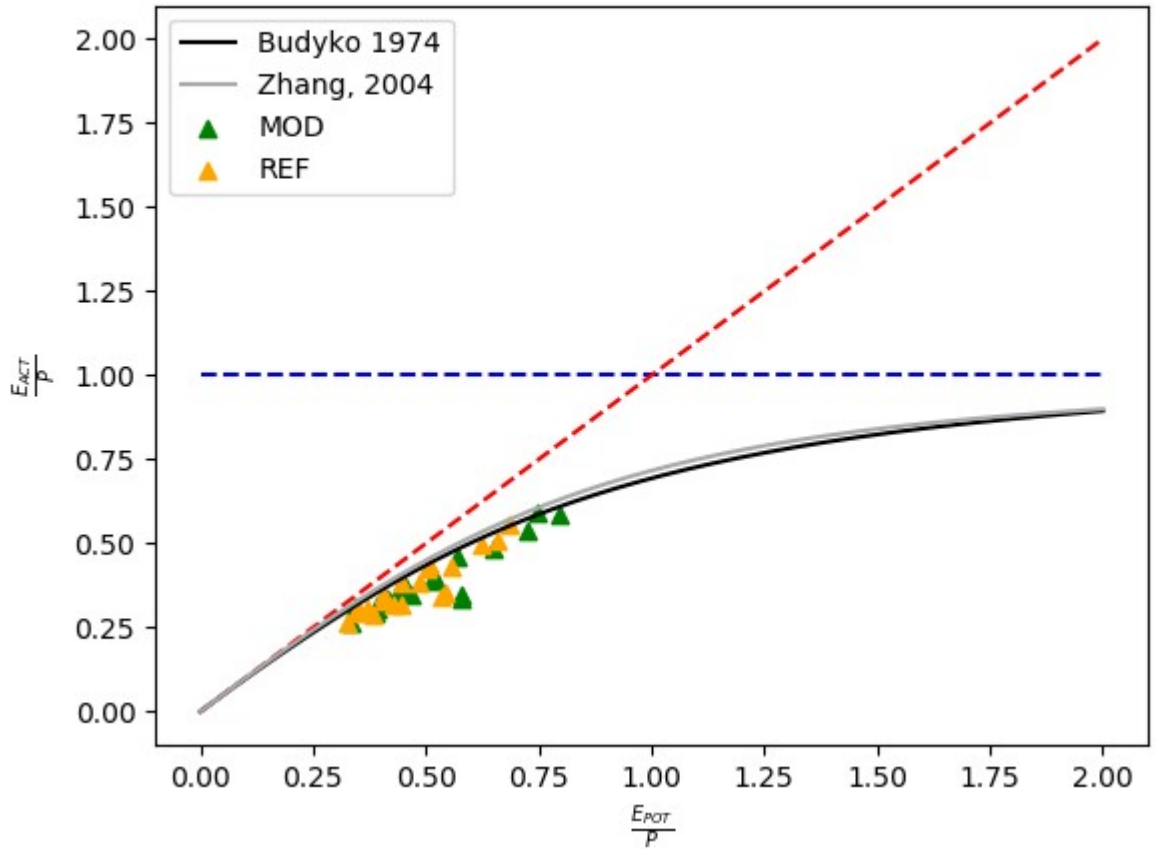
Not more evapotranspiration than precipitation!

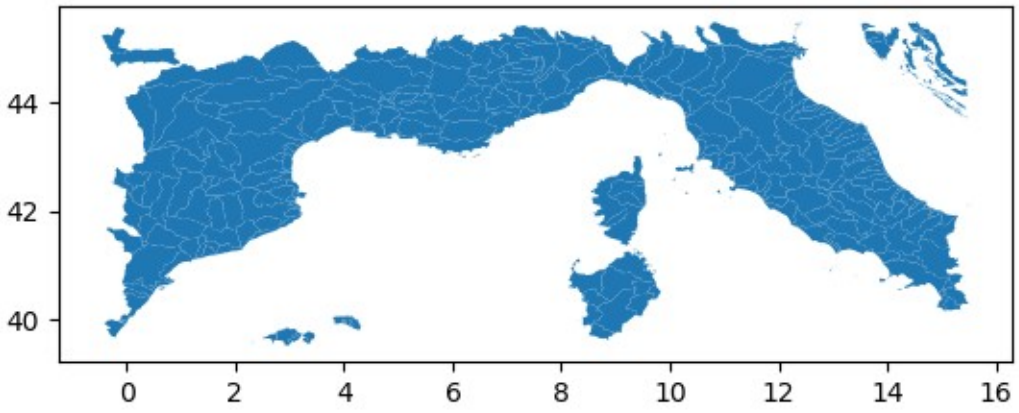
Not more latent heat release than available energy (by net radiation)

Approximate limiting cases with nonparametric (Budyko) or parametric (many others) functions

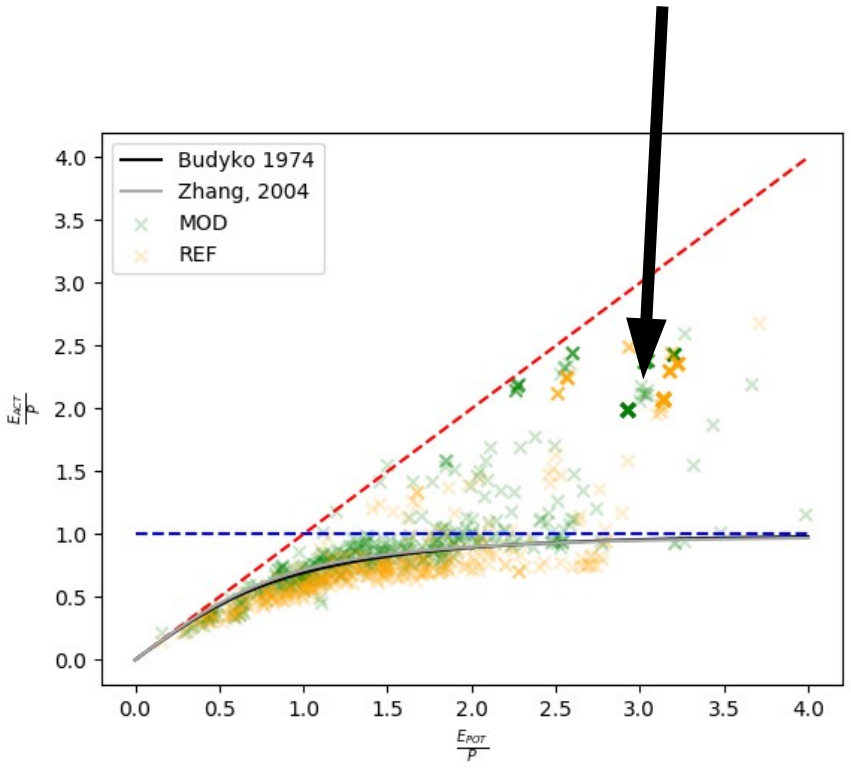
COSMO consistent with Budyko curve for CH



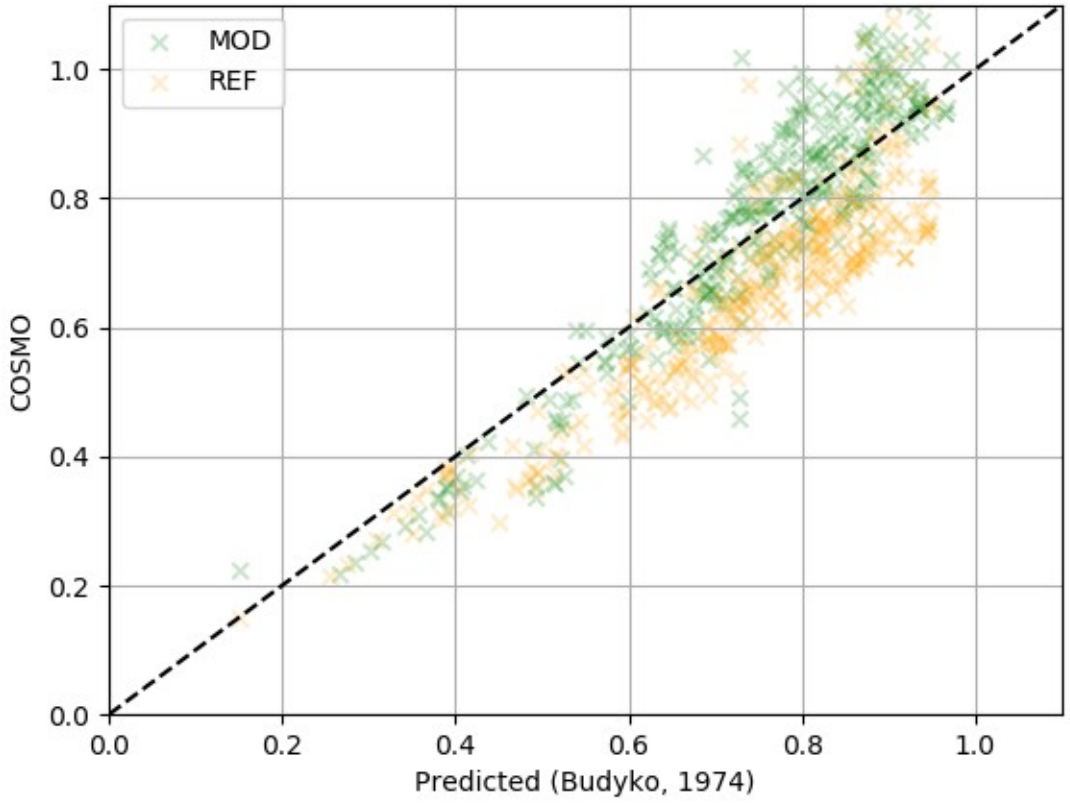
Differences visible for Mediterranean.



Landmask Mismatches
(not considered in analysis)



MOD in better agreement with Budyko curve.



Score	REF	MOD
R^2	0.91	0.93
Bias	-0.09	0.01

MOD outperforms REF in dry(er) regions.

Evidence for exaggerated water stress in REF.

To be continued …

- Water balance validation shows some improvement i.e. for INFIL
- INFIL available for COSMO 6.0 (implementation in ICON by LINDA(?))
- Still room for improvement ...
- Coupled simulations show benefit of Schlemmer et al. (2018) hydrology for dry(er) regions.

  → What is the exact impact on the atmosphere (PBL growth, convection, wind systems)? Link to NWP!

Questions?

Thank you!

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