# The additional value of using proxy data besides runoff for calibrating a conceptual hydrological model in a small agricultural catchment

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## Objectives

The objective of this study was to investigate the **additional value of using proxy data besides runoff**, such as snow cover measurements, eddy covariance measurements of evapotranspiration, soil moisture from spatially distributed network, groundwater level measurements, time lapse photography of overland flow, **for calibrating a conceptual hydrological model** in a small agricultural catchment (Széles et al. 2020).

**Science question:** How to link **observations** with **hydrologic model** simulations?

**(I) Observations, field measurements, different data sources.** ? **(II) Hydrological model simulations with the lumped conceptual TUWmodel (Parajka et al. 2007)**

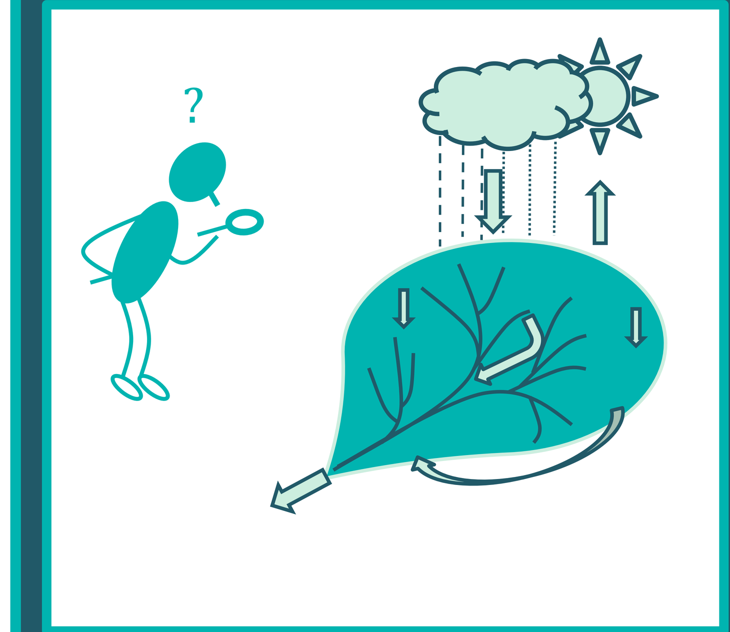


**Fig 1. Observations in the field.**

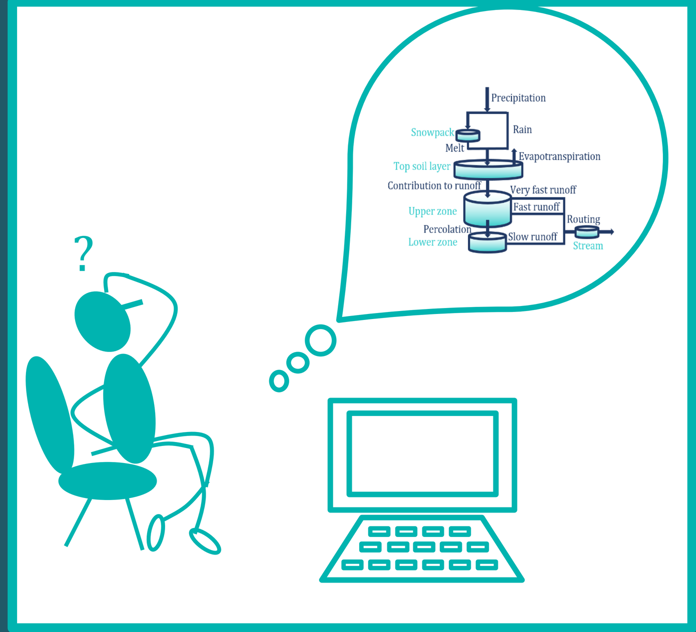


**Fig 2. Hydrological model simulations.**

## Methodology: New Stepwise Model Calibration Approach

**Step 1.** Snow

### Observations / Simulations

Fig 5. Precipitation gauges (4).

Fig 6. Present weather sensor (1).

Fig 7. Humidity and temperature probe (1).

Fig 8. Snow depth sensor (1).

Fig 9. Time lapse photography (1).

Fig 10. MODIS Snow cover. (Source: svs.gsfc.nasa.gov).

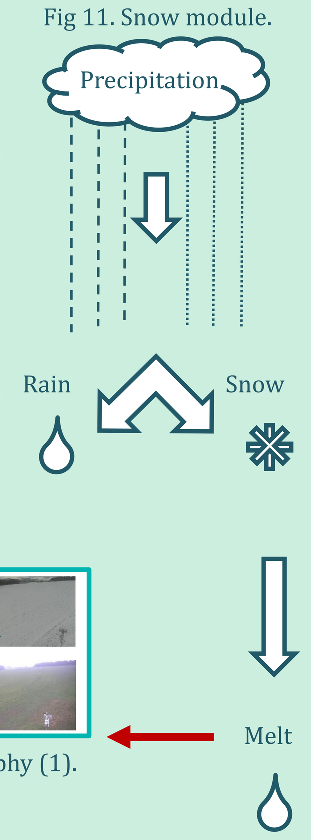



Fig 11. Snow module.

**Step 2.** Evapotranspiration (*ET*) and soil moisture (*SM*)

### Observations / Simulations

Fig 12. Eddy covariance systems (3).

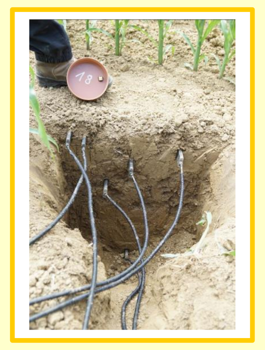


Fig 13. Soil moisture sensors (19 permanent, 10 temporary stations).

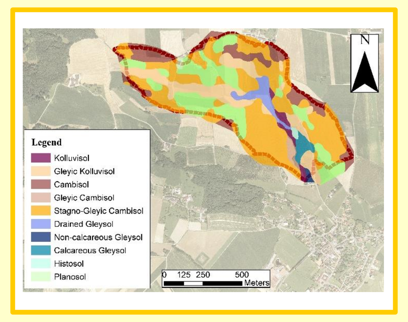


Fig 14. Soil survey.

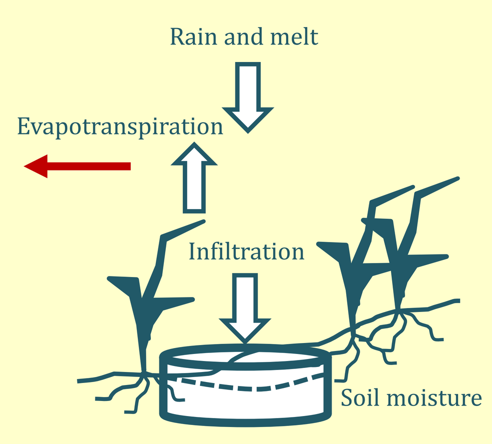



Fig 15. Soil moisture module.

**Step 3.** Overland flow and storage change

### Observations / Simulations


Fig 16. Time lapse photography.

Fig 17. Piezometers (17).

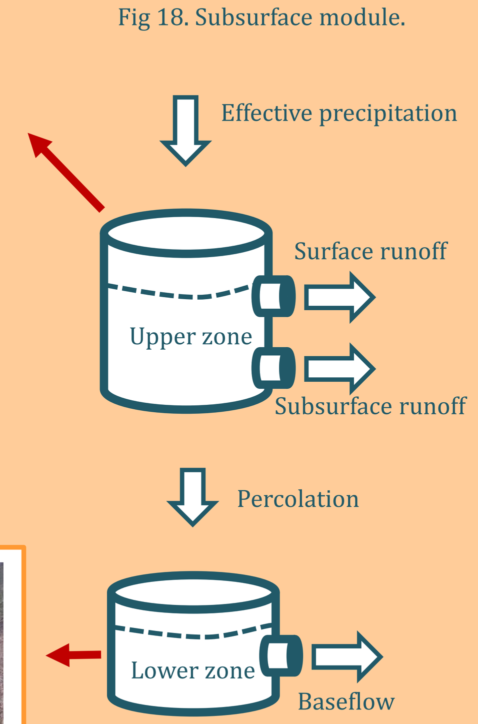



Fig 18. Subsurface module.

**Model calibration**

Model calibration **with only runoff** data:

- All 14 free parameters were calibrated in one step, using only runoff in the objective function (Scenario R).

Model calibration **with runoff and additional** data (**step-by-step**):

- 3 main steps (see panels on the left),
- Steps associated with the processes represented by the 3 modules of the model,
- Steps were linked to in-situ field observations,
- 1st step: all 14 free parameters calibrated using runoff+snow data (Scenarios R+Snowacc, R+Snowmelt) – Snow parameters fixed,
- 2nd step: 10 free parameters calibrated using runoff, actual evapotranspiration and/or soil moisture data (Scenarios R+ET+SM) – Soil moisture parameters fixed,
- 3rd step: 7 free parameters calibrated using runoff, overland flow and storage change data (Scenarios R+ET+SM+G).

Fig 19. Runoff measurement at outlet.

## Study Area and Data

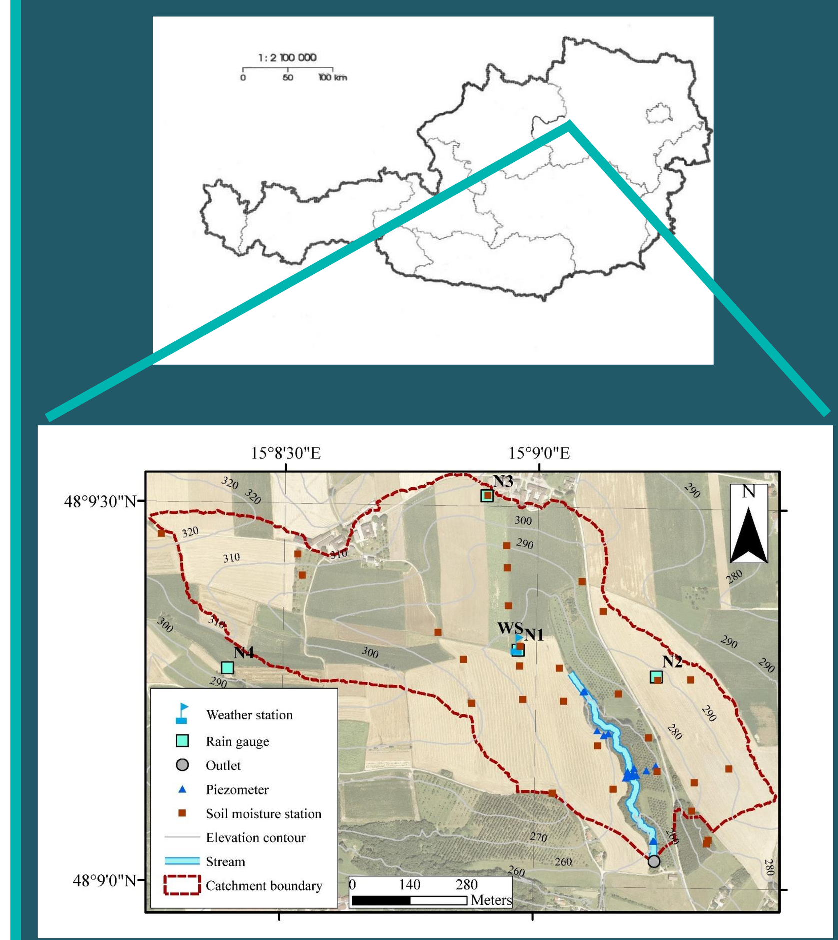


**Fig 3. Study area: the Hydrological Open Air Laboratory (HOAL), Austria.**

Table 1. Study area.

| | | |
|---|---|---|
| Location | | Lower Austria |
| Drainage area | | 66 ha |
| Stream length | | 590 m |
| Elevation | | 268÷323 m a.s.l |
| Mean slope | | 8% |
| Geological designation | | Tertiary sediment, fractured siltstone |
| Pedology | | Cambisols, Kolluvisol and Planosols |
| Land use | | Agricultural, Riparian forest along the stream |
| Average annual (1991-2017) | Precipitation | 782 mm/year |
| | Runoff | 184 mm/year |
| | Evapotranspiration | 598 mm/year |
| For details see | | Blöschl et al., 2016<br>Széles et al., 2018 |

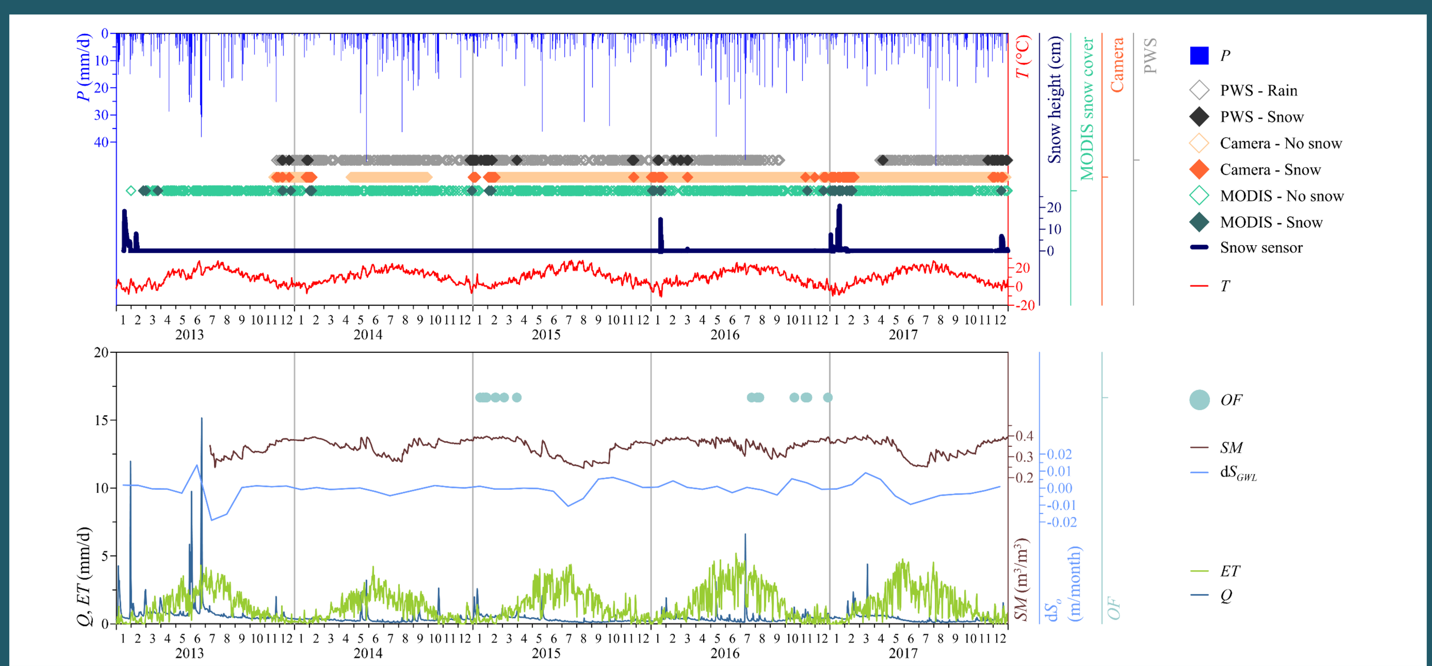
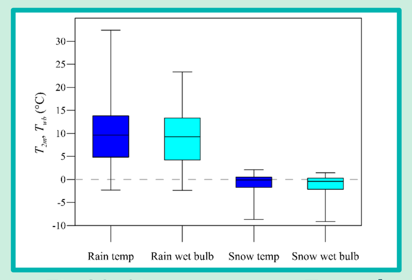


**Fig 4. Data: 3 years for model calibration (2013-15), 2 years for model validation (2016-17).**

## Results

**Step 1.** Simulation of Snow



- Comparing half hourly wet bulb temperature with air temperature measured at 2m height, the **variability** of temperature, when rain or snow was observed, **decreased** (Fig 19),
- Using different forms of **snow observations**, the snow simulations improved (Fig 20 and Table 2).

Fig 20. Air temperature $T_{2m}$ and wet bulb temperature $T_{wb}$ conditions during periods with precipitation. Precipitation was separated into rain and snow based on measurements from the present weather sensor.

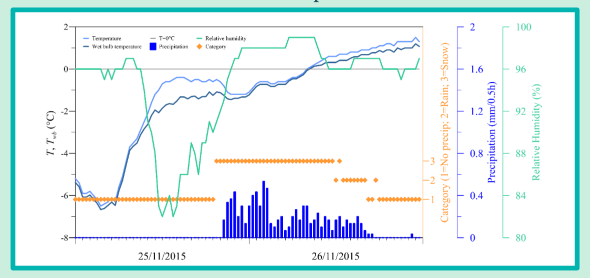
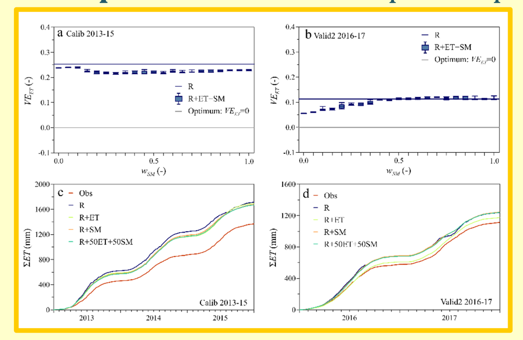


Fig 21. Phase shift in the form of precipitation (rain or snow) observed by the present weather sensor: as the temperature gradually increased, snow became rain.

| Scenario | Relative number of time steps with poor snow accumulation simulations (%) | | Scenario | Relative number of time steps with poor snowmelt simulations (%) | |
|---|---|---|---|---|---|
| | Calibration period 2013-15 | Validation period 2 2016-17 | | Calibration period 2013-15 | Validation period 2 2016-17 |
| R | 0.45 | 0.52 | R | 4.66 | 7.25 |
| R+Snowacc | 0.31 | 0.40 | R+Snowmelt | 4.38 | 6.29 |
| Number of half hourly time steps | 35626 | 23972 | Number of daily time steps | 1095 | 731 |

Table 2. Performance of snow accumulation and snowmelt simulations.

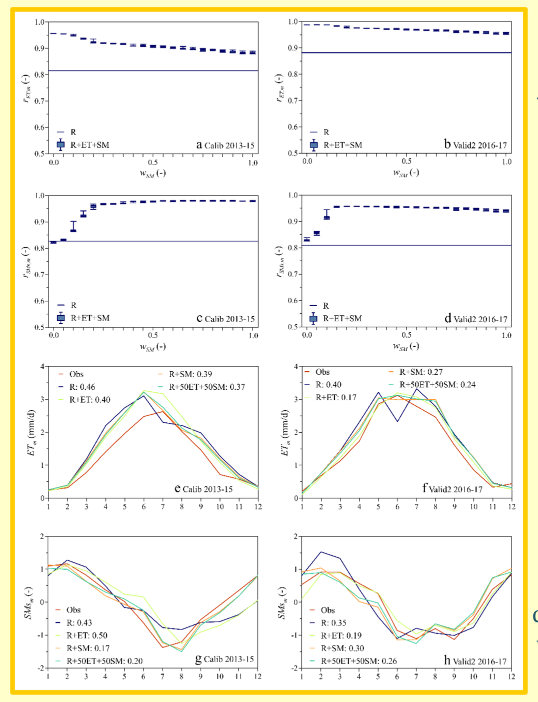
**Step 2.** Simulation of evapotranspiration and soil moisture



### Annual Performance

- Smallest volume error for *ET* achieved by either using a **combination of *ET+SM*** in the multi-objective function or **only *ET***,
- Generally, model tended to **overestimate *ET*** - possibly consequence of using Nash Sutcliffe efficiency.

Fig 22. $VE_{ET}$ volume error for *ET*, when the *ET+SM* module of the model was calibrated for different combinations of observed *ET* and *SM* ($w_{sm}$ weight on *SM*).

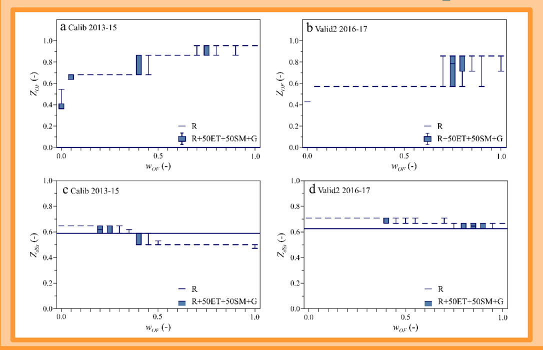


### Seasonal Performance

- Using only *ET* or only *SM* in the multi-objective function to calibrate the *ET+SM* module: decreased efficiency of simulation of seasonality of *ET* and standardized *SM* (*SMs*) -> best choice to **combine *ET* and *SM***.

Fig 23. Monthly Pearson correlation coefficient $r_m$ and seasonal performance for *ET* and standardized *SM* simulations, when the *ET+SM* module of the model was calibrated for different combinations of *ET* and *SM* (a-d: $w_{sm}$ weight on *SM*, e-h: numbers in legend indicate RMSE).

**Step 3.** Simulation of overland flow and storage change



- Using a **combination** of overland flow *OF* and monthly average standardized storage change *dSs* in the saturated zone in the multi-objective function improved the modelling efficiency in simulating overland flow and change in groundwater storage compared to the scenario when only runoff was used for model calibration.

Fig 24. Relative number of days with good overland flow simulation $Z_{OF}$, and relative number of months with correctly simulated sign of the standardized monthly average storage change $Z_{dSs}$ ($w_{GWL}$ weight on *GWL*).

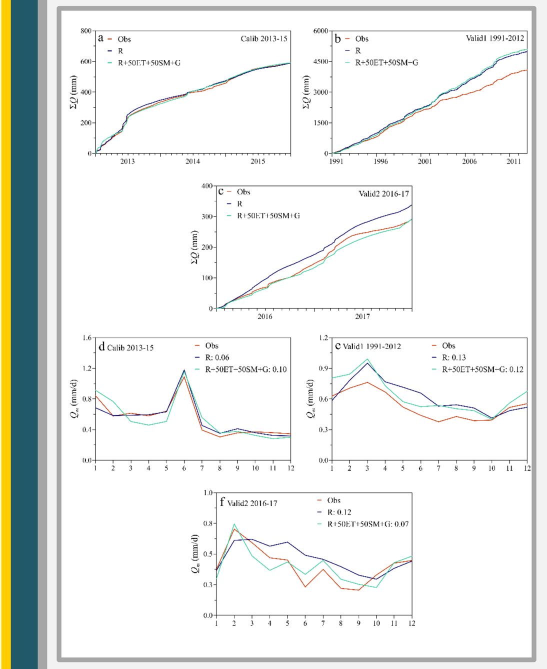


Fig 25. Annual and seasonal efficiency of runoff simulations (d-f: numbers in legend indicate RMSE).

**Runoff simulation**

- **Annual performance**: proposed step-by-step approach similar performance to only runoff R scenario.
- **Seasonal performance**: during validation periods proposed step-by-step approach outperformed only runoff R scenario.
- **Daily performance**: step-by-step approach worse performance compared to only runoff R scenario.
- Using additional data besides runoff for calibration improved runoff simulation efficiencies on 3 time scales (volume error $VE_Q$, monthly average Pearson correlation coefficient $r_{m,Q}$, daily logarithmic Nash Sutcliffe efficiency $lNash_Q$) for the 2nd validation period (Fig 27).

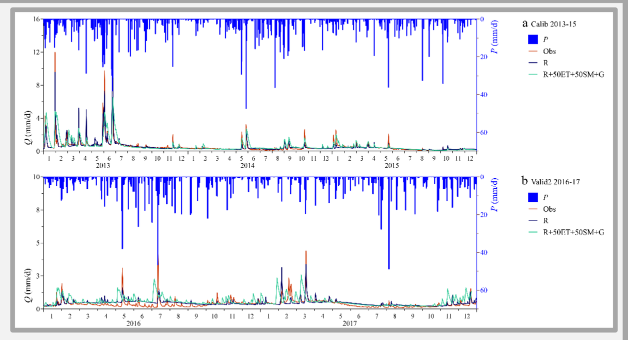


Fig 26. Daily efficiency of runoff simulations.

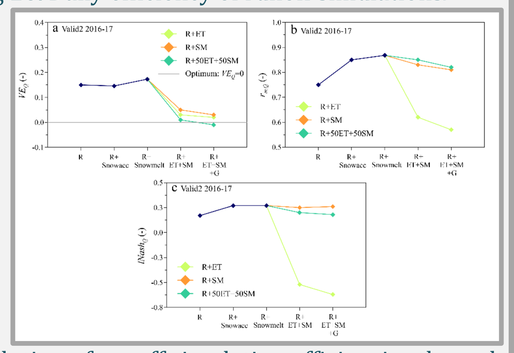


Fig 27. Evolution of runoff simulation efficiencies through the scenarios for the second validation period.

## Conclusions

**New framework** for estimating the parameters of a conceptual hydrological model in a stepwise fashion from proxy data :

- By using the proposed step-by-step model calibration approach with different sources of data besides runoff for parameter estimation, we were able to **efficiently simulate not only runoff but other state variables as well** on the annual and seasonal time scales.
- For the study catchment, correlation coefficient of monthly runoff in the second validation period was 0.82 and the volume error was -1%.
- For this catchment, **field observations of soil moisture and evapotranspiration** played the **most important** role in predicting runoff.

## References and Acknowledgments

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