Model Assessment Strategy in a Karst Hydrological Model Using a Process-based Diagnostic Tool

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Research Outline

Model reliability is an important aspect of model assessment, entailing the detailed investigation of model performance, parameter identifiability, model structure suitability and prediction uncertainty (Wagener, Boyle et al. 2001).

Research Motivation: *extract different hydrological process from the model output space.*

Pragmatic Question: *What could be the proper model assessment approach while considering the simultaneous effectiveness of hydrological model in conveying different hydrological information?*

Research Target : *to explore the model output space which is simultaneously informative on system hydrological behaviour and hydrological functioning ?*

Data and Models

Available Data

- Daily climate data from Central Institution for Meteorology and Geodynamics in Austria (ZAMG) covering the period of 1994-2016.
- Discharge data (1995-2015) https://ehyd.gv.at/#
- Spring and precipitation $d^{18}O$ isotope data digitized from the work Maloszewski, Stichler et al. 2002

Models

- **Varkarst:** Karst-dedicated well-known hydrological model by Hartmann, Barberá et al. 2013
- **StorAge Selection Function Approach:** a new generation of theoretical catchment transport model by Benettin and Bertuzzo 2018.

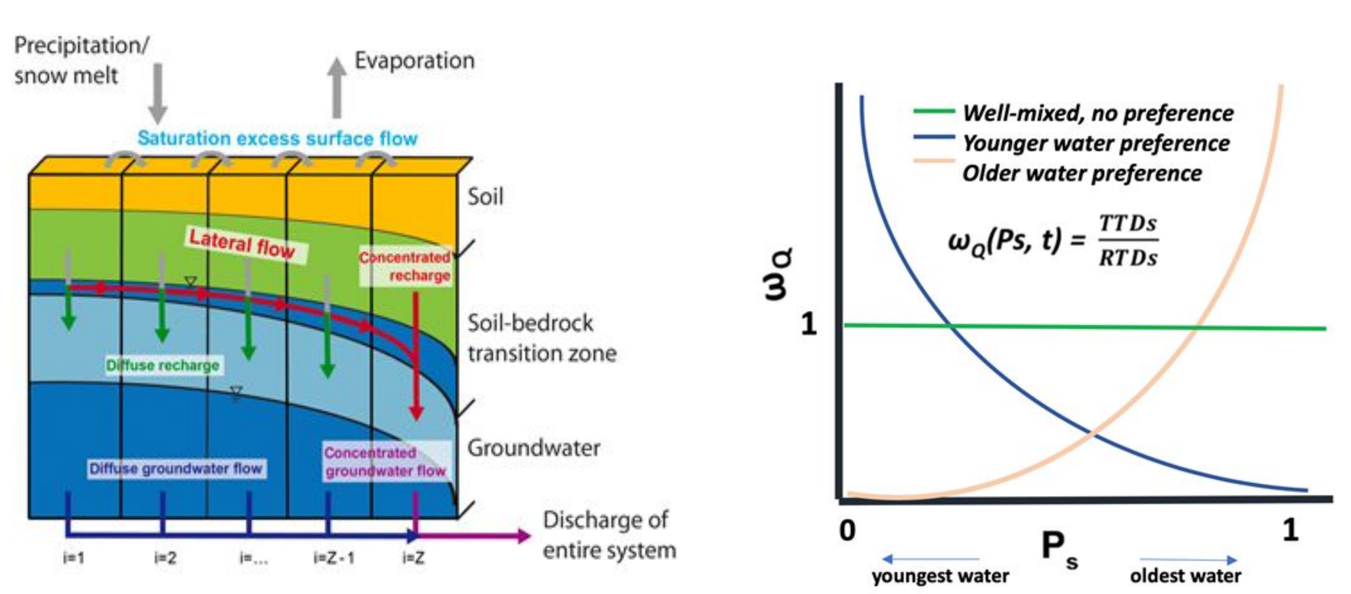


Fig 1. Left: Varkarst model, Right: StorAge Selection Function Approach (Kaandorp, De Louw et al. 2018), and (Hrachowitz, Benettin et al. 2016)

The age structure of the karst aquifer:

Age distribution of karstic aquifer is solved by the age master equation (ME). To do that, SAS function approach was performed by tran-SAS package.

In the study, we used $\delta^{18}O$ simulations and young water fractions (F_{yw}) of spring discharge as being two process-diagnostic metrics while characterizing karst aquifer system hydrological functioning based on the storage-mixing process information.

Test Site:

- As a part of the Northern Limestone Alps, the Schneealpe karst massif consists of Triassic limestones and dolomites, characterized as being highly karstified catchment was selected to test the model assessment approach.

Model Assessment Approach and Competing Criteria

Model performance assessment: refers to assessment of model structural adequacy in simulating dominant hydrological process.
Model functionality assessment: refers to model capability assessment in reflecting additional system knowledge from model output.

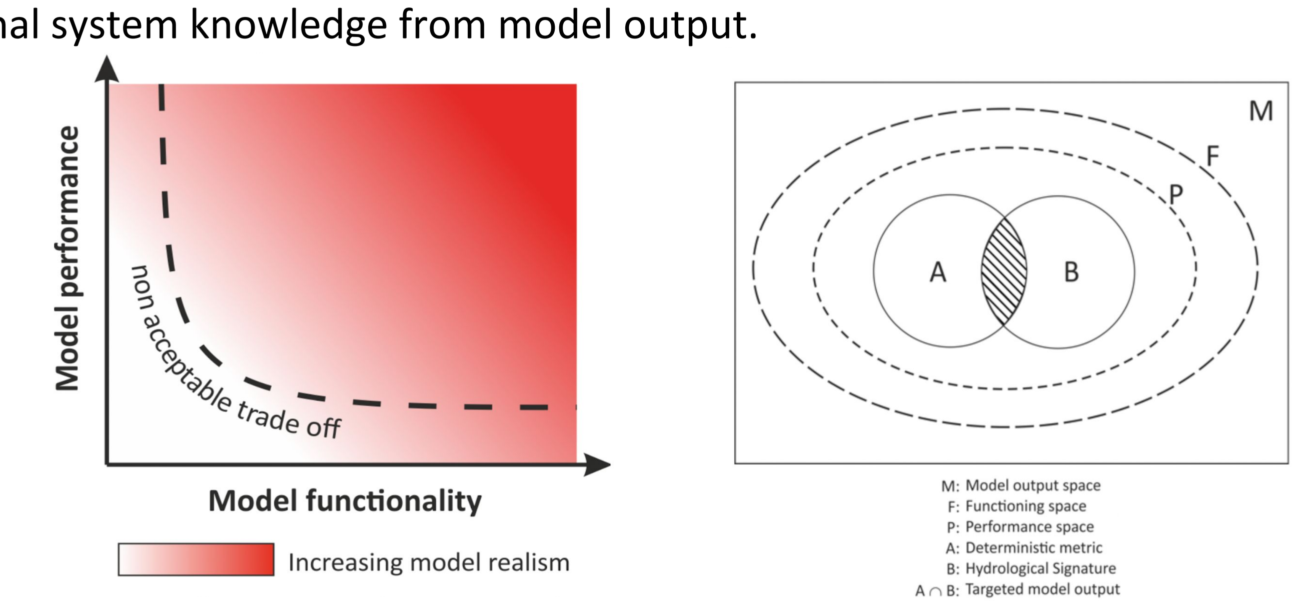


*Fig 2. Left Panel: Model assessment strategy: **Pareto-optimal model output space**. Right: Model ensemble confinement approach: target is the **"intersected model space".***

Model Conditioning Scheme : Multi-Criteria Performance Assessment

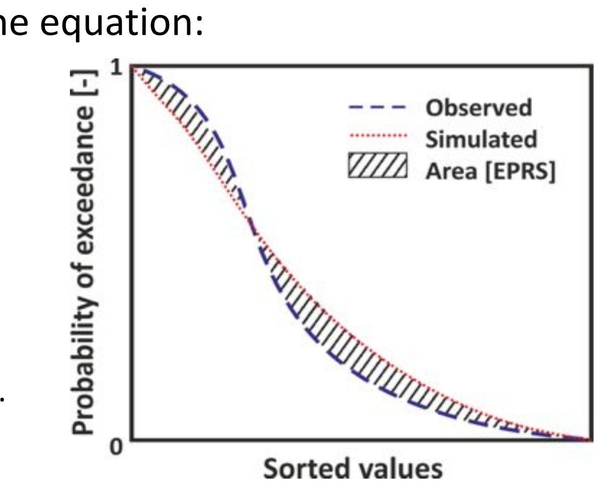
Model performance was assessed by Kling Gupta Efficiency (KGE) and Nash Suffice Efficiency (NSE), as well as karst system signatures: Autocorrelation (ACF), Cross Correlation (CCF), Spring Variability Index (SVI) , Flow Duration Curve (FDC).

Model Functionality was assessed by a newly described area-based performance metric: **Exceedance Probability Ranked Score (EPRS)** followed by the equation:

$$\text{Area} = \int_{-\infty}^{\infty} |F(x) - S_n(x)|dx$$

$$\text{EPRS} = \frac{Area - Area_{min}}{Area_{max} - Area_{min}}$$

where $F_i(x)$ is the area of the distribution function of the simulated model output, and $S_n(x)$ is the distribution function of the observed input variable.



Results and Discussion

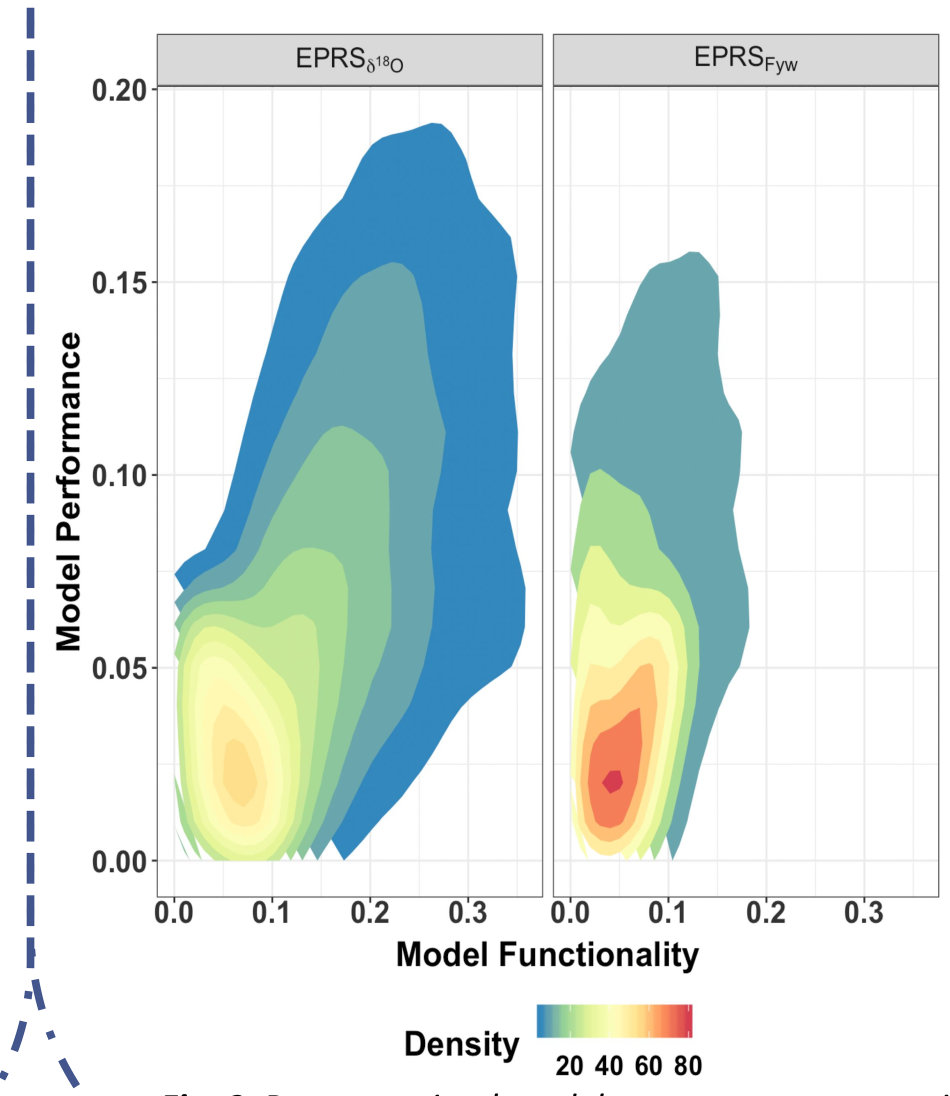


Fig. 3 Pareto-optimal model output space constrained by the model performance and functionality using EPRS.

Here, spring young water fraction, F_{yw} indicates a narrow "bump" characterized by a more condense output space in comparison to $d^{18}O$, which demonstrates a relatively wider "bump" with a dispersive output space.

The region satisfies the targeted model space condition in which the model clusters are more prone to convey hydrologically relevant information, considering the system hydrological response and functioning concurrently.

Results and Discussion

Model Parameter and Prediction Uncertainty

The best ensemble members of $EPRS_{Fyw}$, KGE, and NSE lead to different parameter combinations. In particular, recharge contributing area, *A* and groundwater variability constant, a_{GW} have notably different ranges depending on the applied constraints.

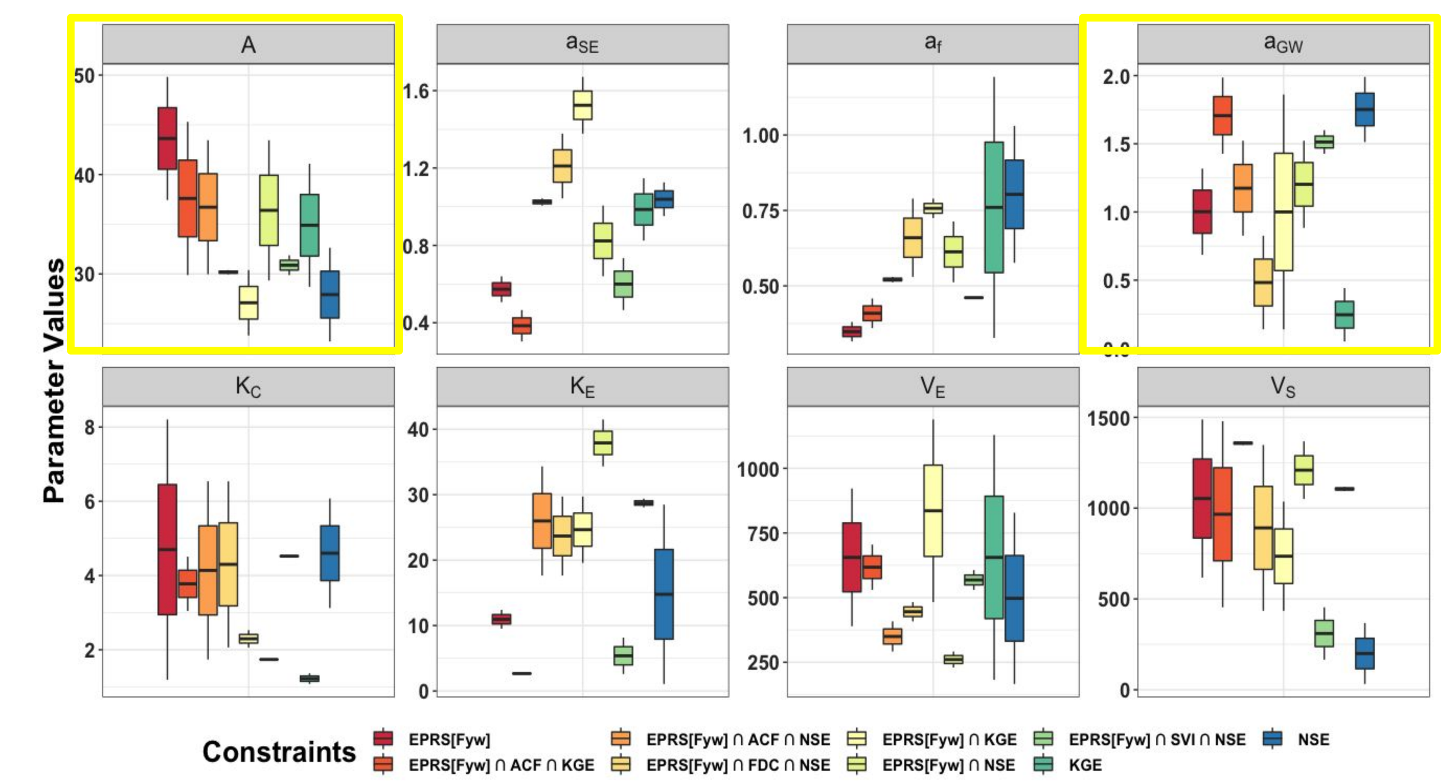


Fig 4. The parameter ranges from the model confinement stage considering P1 and P2 sub-periods.

The **differential split-sampling test results** are presented in Fig 5. The validation over the P1 (wet period) is much better than the P2 (dry period). The figure examines to what extent the proposed model confinement approach have influences on the strength of the model calibration.

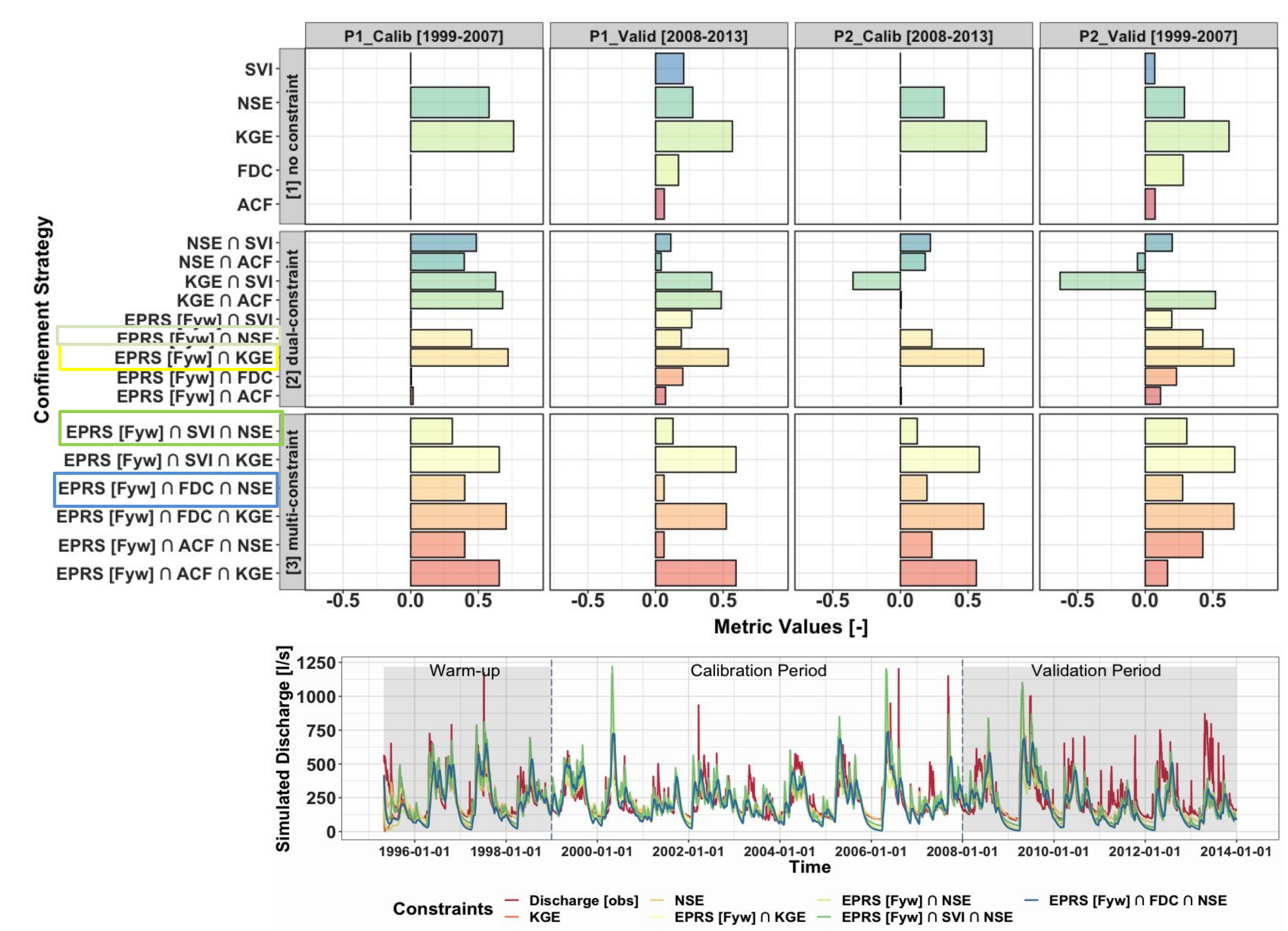


Fig 5. Upper Panel: The differential split-sampling test result for sub-period P1, Lower Panel: The uncertainty ranges of the selected model realizations.

Conclusion

- Young water fractions (F_{yw}) is a useful functional metric in identifying model ensemble clusters in which system underlying processes information is conveyed throughout model output.
- The proposed model assessment strategy could improve model realism by increasing physical realism of parameters due to capturing hydrologically more informative model realizations.

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