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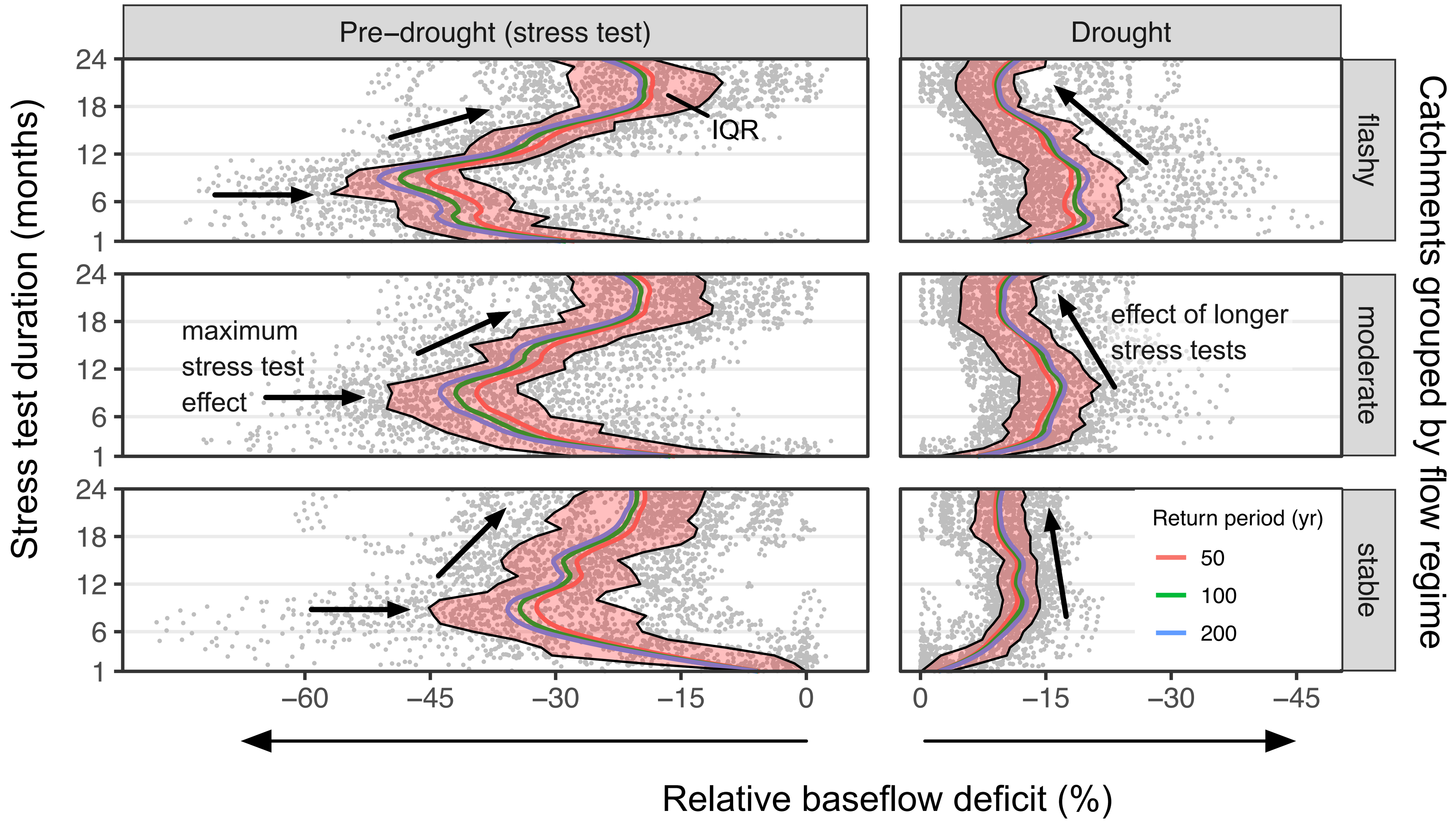
Hydrogeology-specific groundwater model boxes could improve low flow modelling by 30% (compared to a simple linear storage box).

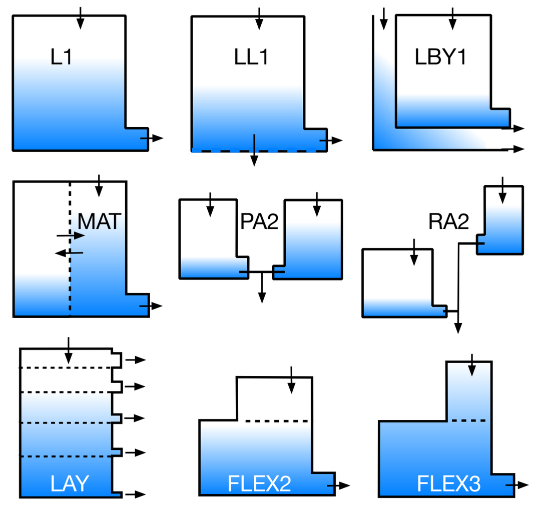
Recharge stress leads to different baseflow responses for both pre-drought and drought periods and different flow regimes.



BACKGROUND

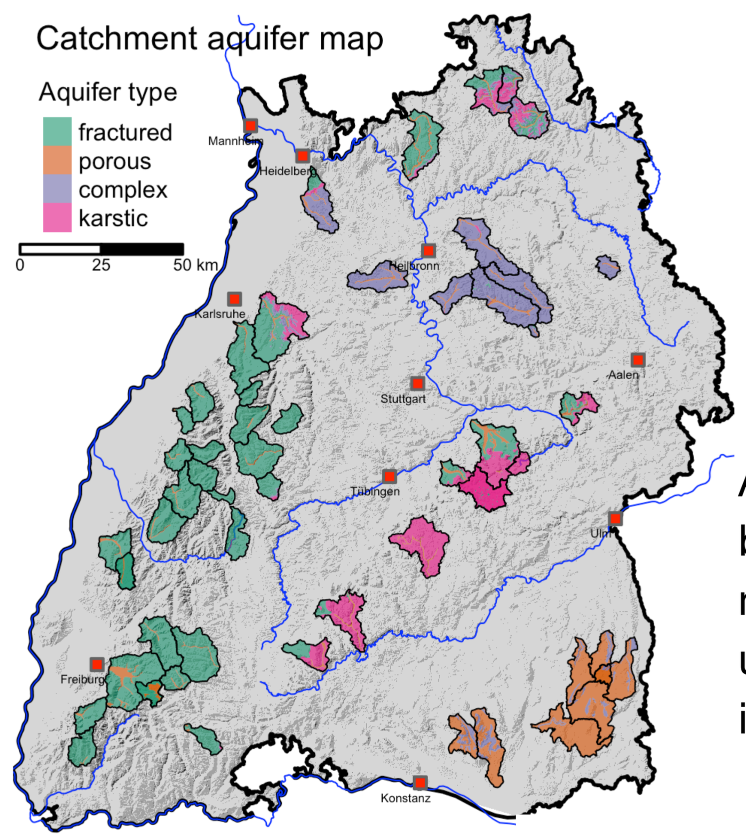
This study identifies the **drought resistance** based on **recharge stress tests**. Pre-drought recharge is systematically decreased and baseflow response is quantified for different drought events and flow regimes.

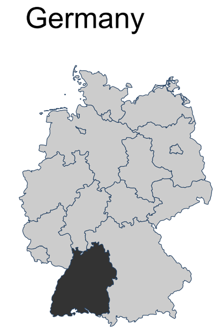
The **best of nine optional model structures** is assigned to each catchment to translate recharge into baseflow. This model then performs the stress test.



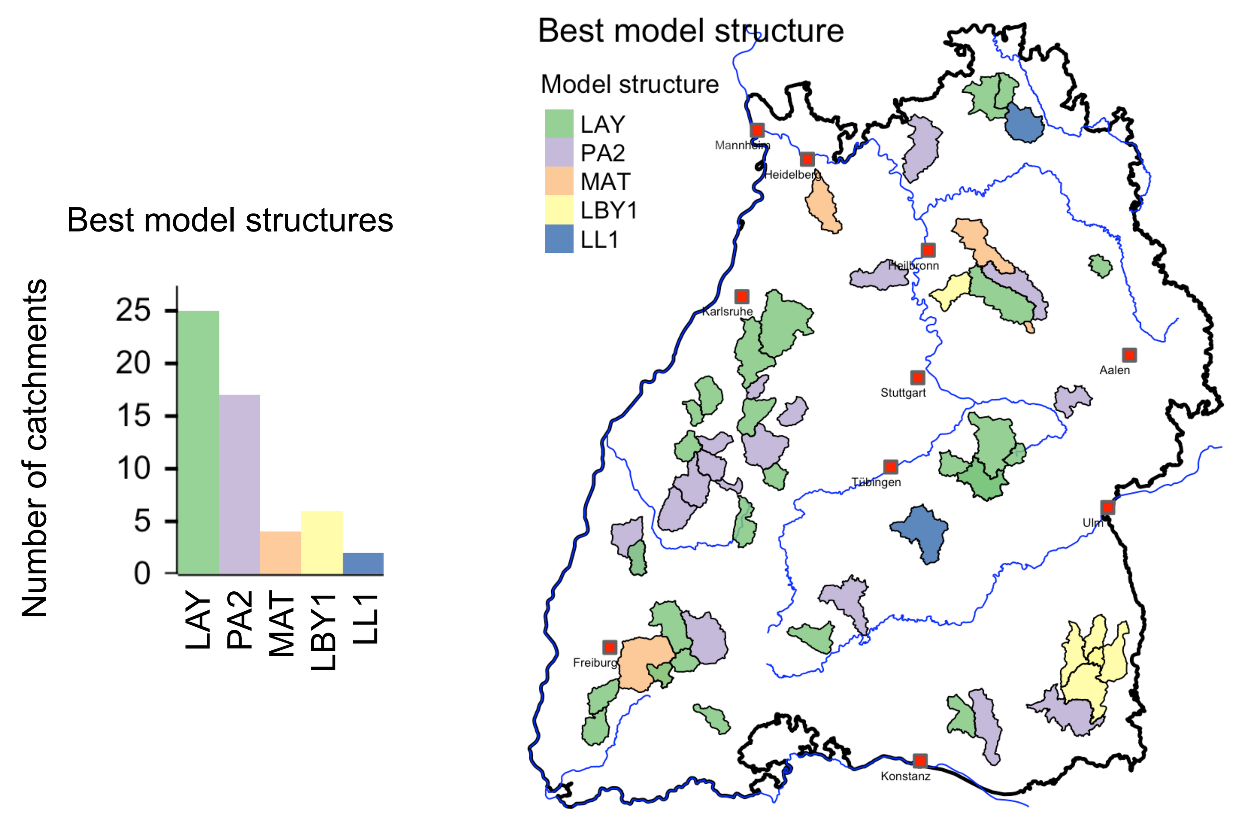
BEST MODEL STRUCTURES

5 of 9 model structures stick out in terms of model performance (details on page 2). We found a strong **relationship** between **hydrogeology** and **best performing model structures**.

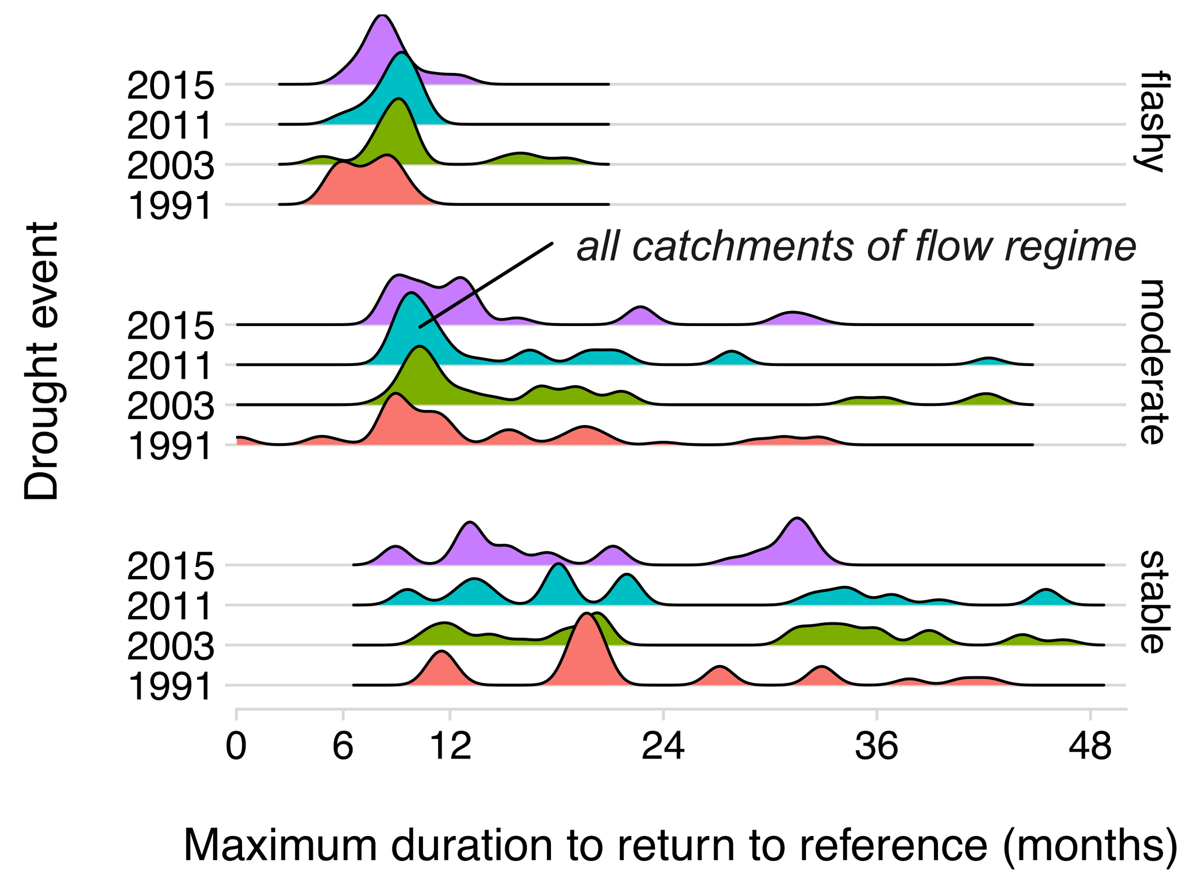




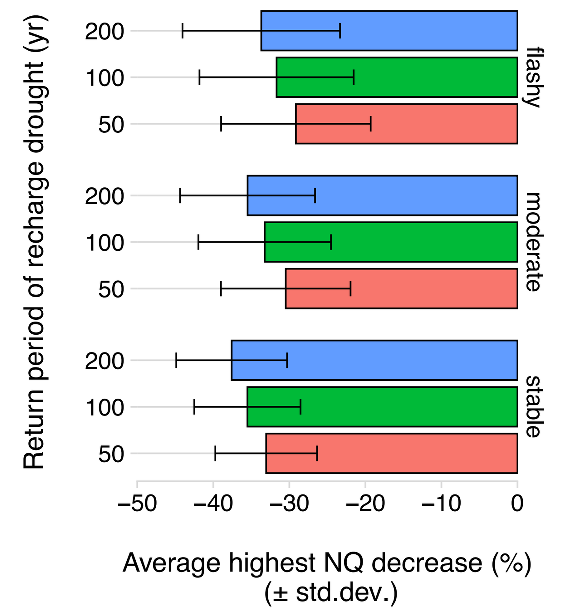
Aquifer classification is based on a lithology map. We also plan to use transmissivity data in the future.



BASEFLOW RECOVERY



We found that catchments **return** to the reference baseflow **on different timescales** , i.e. for flashy regimes after 6-12 months. The variation of return durations between drought events is smaller than the variation of return durations between flow regimes.



Decrease in low flows is slightly higher for stable flow regimes. With drier pre-conditions (i.e. longer return periods) NQ decreases by several percent.

TAKE HOME

We found clear relationships between catchments' hydrogeology and appropriate groundwater model structures.

Classification of catchments into flashy and stable regimes uncover differences in drought resistance and baseflow recovery from stress tests.

Detailed methods and more results on page 2.

D112 | EGU2020-5046 | Session HS 2.4.5: Catchment Organisation, Similarity & Memory

Stress test modelling to assess catchment drought resistance and recovery

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Stress test modelling to assess catchment drought resistance and recovery

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Detailed methods and additional results

STRESS TESTS

Baseflow stress testing uses historical extreme events and simulate their progress under drier preconditions. The catchments' drought restistance is then assessed by the degree of response on stress testing, e.g. baseflow recovery from stress tests.

The last period with median streamflow before major drought events (1991, 2003, 2011, 2015, 2018) is identified as starting point for stress testing. From this point recharge stress tests with durations between 1 and 24 months reduced the pre-drought recharge to quantities with a return period of 50, 100 and 200 years. The calibrated model structures then simulate stress test series (i.e. baseflow) with the decreased recharge input.

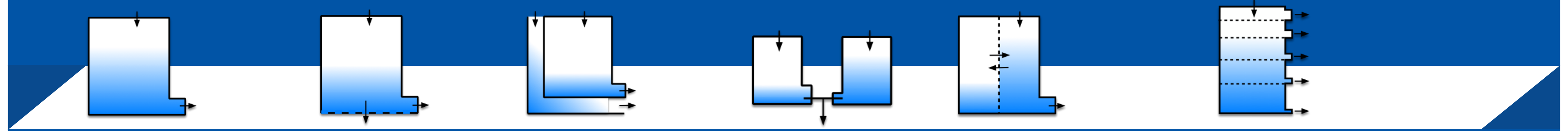
CATCHMENTS

54 study catchments located in Southwestern Germany. Catchment areas are 10-250 km^2, mean area is 100km^2. Catchments are all rainfall-dominated and have variations in precipitation, evapotranspiration, geology, land use etc. Urban areas are negligible. Flow regimes (flashy, moderate and stable) are classified with low flow stability index Q_{95}/Q_{50}.

DATA

We use data from the last 35 years (1984-2018) including five major drought events in Germany (1991, 2003, 2011, 2015, 2018). Observed streamflow and recharge series are converted to pentads (five day blocks) to ensure that recharge dynamic is not overestimated and to improve coumputation time.

MODEL STRUCTURES: DETAILS (6 of 9 boxes)



L1 benchmark: Simple linear storage (L1) as benchmark model with recharge as input and baseflow as output. Storage coefficient k controls drainage.

LL1: LL1: Extension of L1 with leakage parameter (%). Leaked water from storage is not considered for the water balance.

LBY1: LBY1: Extension of L1 with a by-pass. By-passed water fraction (%) is recharge that directly becomes baseflow (without being delayed in the storage).

PA2: Two parallel storages (PA2), both gain 50% of recharge each timestep and each compartment has n individual storage coefficient (*k1* and *k2*).

MAT: The MAT-structure (from matrix) has a mobile and immobile segment. Only the mobile segment (here on the right side) drains and sustain baseflow. A parameter controls the flux between the gradient (storage filling) of both segments.

LAY: For this layered structure (**LAY**) a storage threshold *h* is calibrated. Storage volume below *h* is divided in five compartments with the ratio 16:8:4:2:1 (from bottom to top), the largest compartment drains with 1*k*, the smallest with 5*k*. Stored water above *h* is also drained with 5*k*.

Detailed description of the model structures in Stoelzle et al. (2015)

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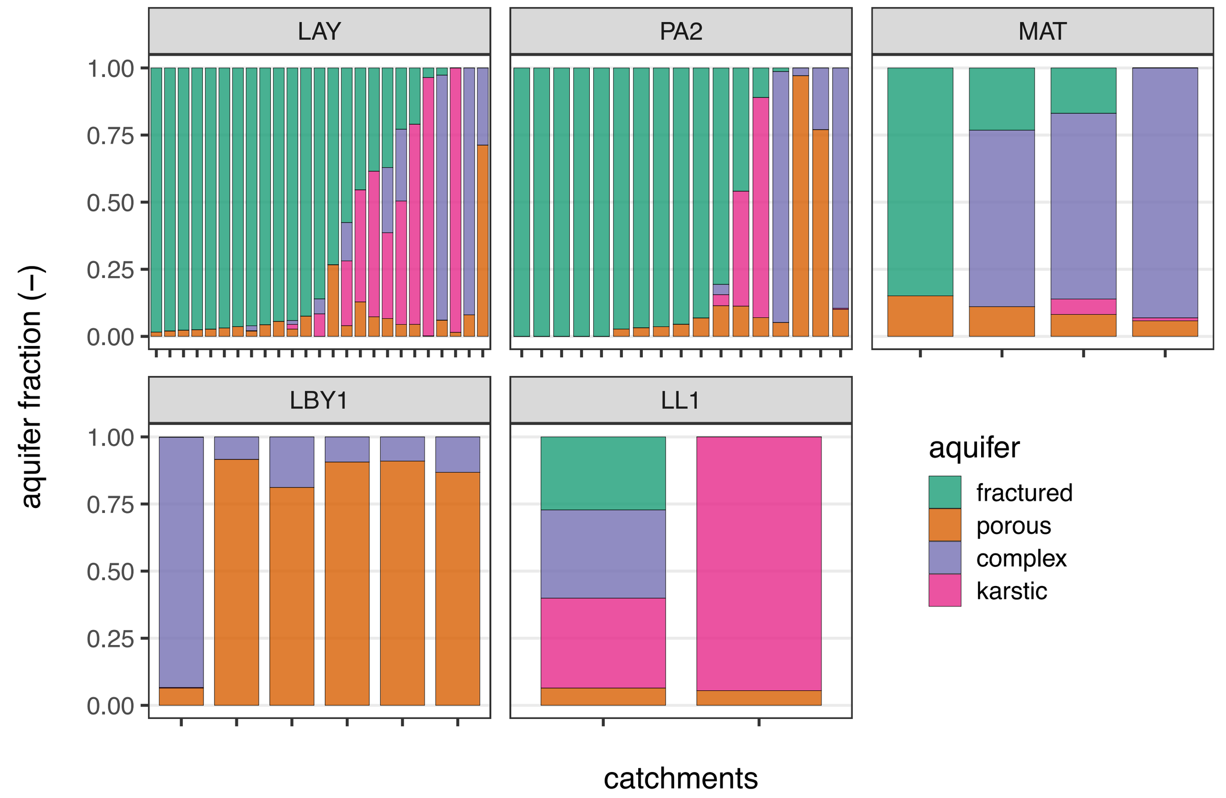
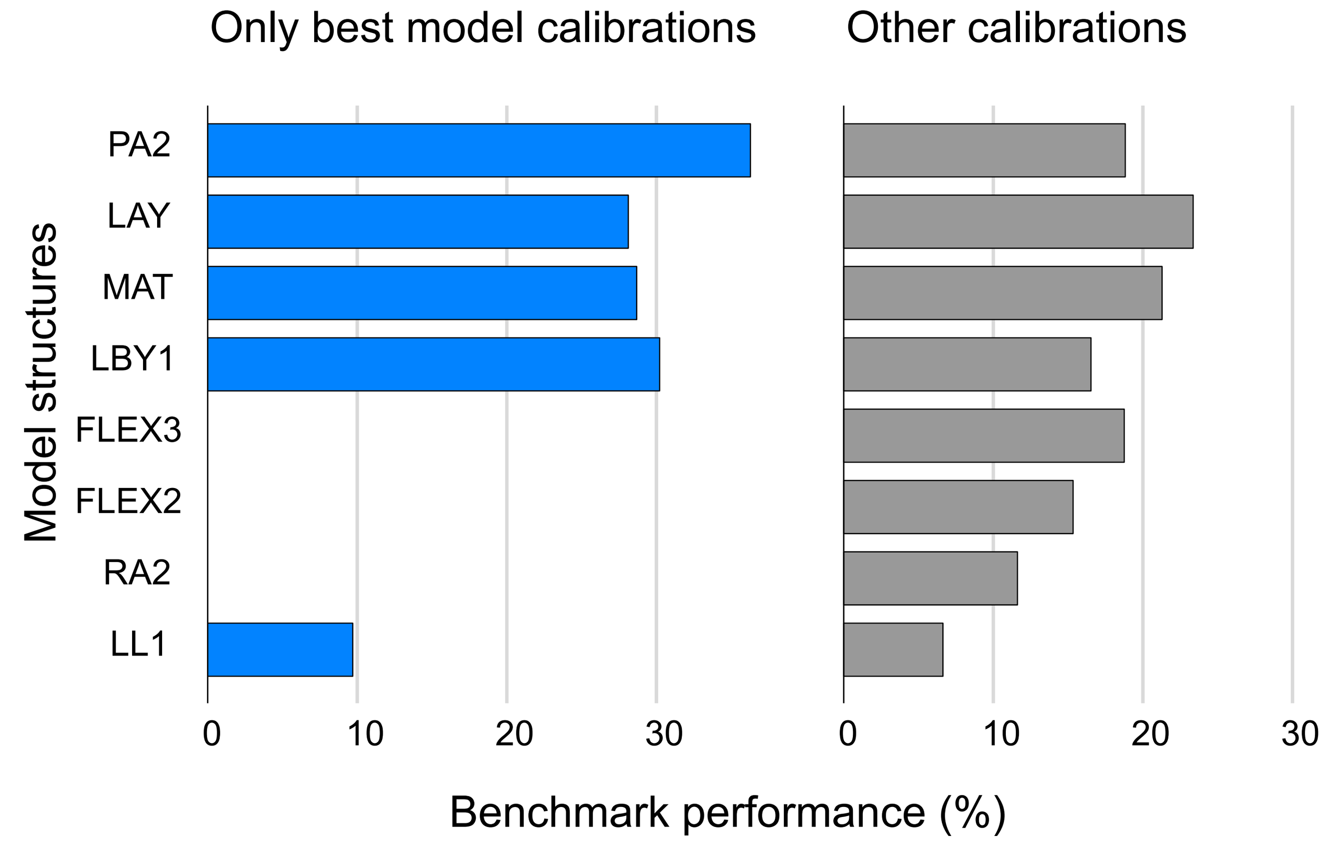
LINK BETWEEN HYDROGEOLOGY AND MODEL STRUCTURE



Best model structures are linked to catchments' hydrogeology, e.g. LBY1 is often best model for mainly porous aquifers, LL1 for karstic etc., LAY is more versitle structure, PA2 is comapred to LAY better if hydrogeology is more homogenous.

BEST MODEL STRUCTURE?



PA2 and LAY are the best performing model structures (77%). Some catchments (23%) have MAT, LBY1 and LL1 as best structures. All structures are superior to a simple linear storage box (L1) which is still often implemented in hydrological models to simulate low flow.

BENCHMARK

For each catchment the performance of the eight model structures is compared against a simple linear model (L1). With this benchmark a general ranking of the different structures and a catchment-specific ranking is possible. With the benchmark variations in model efficiency across catchments are adjusted.

RECHARGE

We use recharge time series from the physically based TRAIN model. The water balance model TRAIN simulates different fluxes and state variables at the soil-water-atmosphere interface and was set up to generate daily discharge time series over a 1km resolution. Recharge rates from TRAIN included percolation water but also faster components (i.e. interflow). As the study aims to translate recharge into baseflow the long-term recharge sum for each catchment is adjusted to match the long-term baseflow sum.

BASEFLOW = DELAYED FLOW

Baseflow is separated from observed streamflow series with the DFI method (Delayed Flow Index, **Stoelzle et al., 2020**). The DFI method is an advancement of two-component baseflow separation to quantify multiple delayed streamflow components. For each catchment four components with different delays were identified. The fastest (short-delayed) component was removed from observed streamflow to derive a continuous baseflow series.

CALIBRATION and OF

Calibration of the two-parameters box models is done with evolutionary global optimization via the Differential Evolution algorithm (R package *DEoptim*).
The objective function (OF) minimizes a equally-weighted combination of MARE (Mean Absolute Relative Error, %) and logKGE (-). Both parts are calculated split-wise for each year. For MARE calculation more weights are given to periods with low flows and periods with higher proportion of baseflow.
Model warmup are the first 5 data years, calibration period is between 20-26 years, validation period is 4 years (the years 1995 - 1998 included for all catchments dry, wet and average years).

REFERENCES

Stoelzle et al. (2020): Beyond binary baseflow separation: a delayed-flow index for multiple streamflow contributions. Hydrology and Earth System Sciences, 24(2), 849-867.

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