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.

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.

**BASEFLOW RECOVERY**

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

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

**STRESS TEST MODELLING TO ASSESS CATCHMENT DROUGHT RESISTANCE AND RECOVERY**

Michael Stoeblé¹, Jost Hellwig¹, Kerstin Stahl¹, Markus Weiler², Erik Tijdeman³, Lucas Menzel³

(¹) Environmental Hydrological Systems, University of Freiburg, Germany. (²) Hydrology, University of Freiburg, Germany (³) Institute of Geography, Heidelberg University, Germany

michael.stoeble@hydro.uni-freiburg.de
https://www.researchgate.net/profile/Michael_Stoeble
twitter.com/michistoeble

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

**TAKING HOME**

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

Classification of catchments into flashy and stable regimes uncover different in drought resistance and baseflow recovery from stress tests.
Stress test modelling to assess catchment drought resistance and recovery

Michael Stoelzle et al.

STRESS TESTS

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

The last period with medium 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 km², mean area is 100km². 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_p/Qo2.

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 computation time.

MODEL STRUCTURES: DETAILS (6 of 9 boxes)

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

LL1: Extension of L1 with a parameter (%). Leaked water from storage is not translated into the water balance.

LBY1: Extension of L1 with a parameter (%). Leaked water from storage is not translated into the water balance. LL1: Extension of L1 with a parameter (%). Leaked water from storage is not translated into the water balance. LBY1: Extension of L1 with a parameter (%). Leaked water from storage is not translated into the water balance.

The MAT-structure (from now on) has a mobile and immobile compartment, where the gradient (storage coefficient k) has an influence on the mobile compartment (p1) and a river acts as boundary condition (p2).

For this layered structure LAY (LBY1 is a storage threshold in the mobile segment) the gradient (storage coefficient k) influences the mobile compartment (p1) and the river acts as boundary condition (p2).

Best model structures are linked to catchments’ hydrogeology, e.g. LBY1 is often best model for mainly porous aquifers, L1 for karstic etc. LAY is more versatile structure, PA2 is compared to LAY better if hydrogeology is more homogenous.

BEST MODEL STRUCTURE?

PA2 and LAY are the best performing model structures (77%). Some catchments (23%) both 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.

LINK BETWEEN HYDROGEOLOGY AND MODEL STRUCTURE

Benchmark performance (%) of the only best model calibrations with all other calibrations.

BENCHMARK

For each catchment the performance of the eight model structures is compared against a simple linear model (L1). Depending on the objective function (OF) as minimized (OF is a ratio of the correlation coefficient R² and the sum of squares of errors S²). For this study, the OF is a ratio of the correlation coefficient R² and the sum of squares of errors S².

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 1 km resolution. Recharge rates from TRAIN included percolation water but also faster components (i.e. interflow). 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-parametar 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 logGGE (-). 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

