# Spatial consistency of automatically calibrated SWAT simulations in the Dill catchment and three of its sub-catchments

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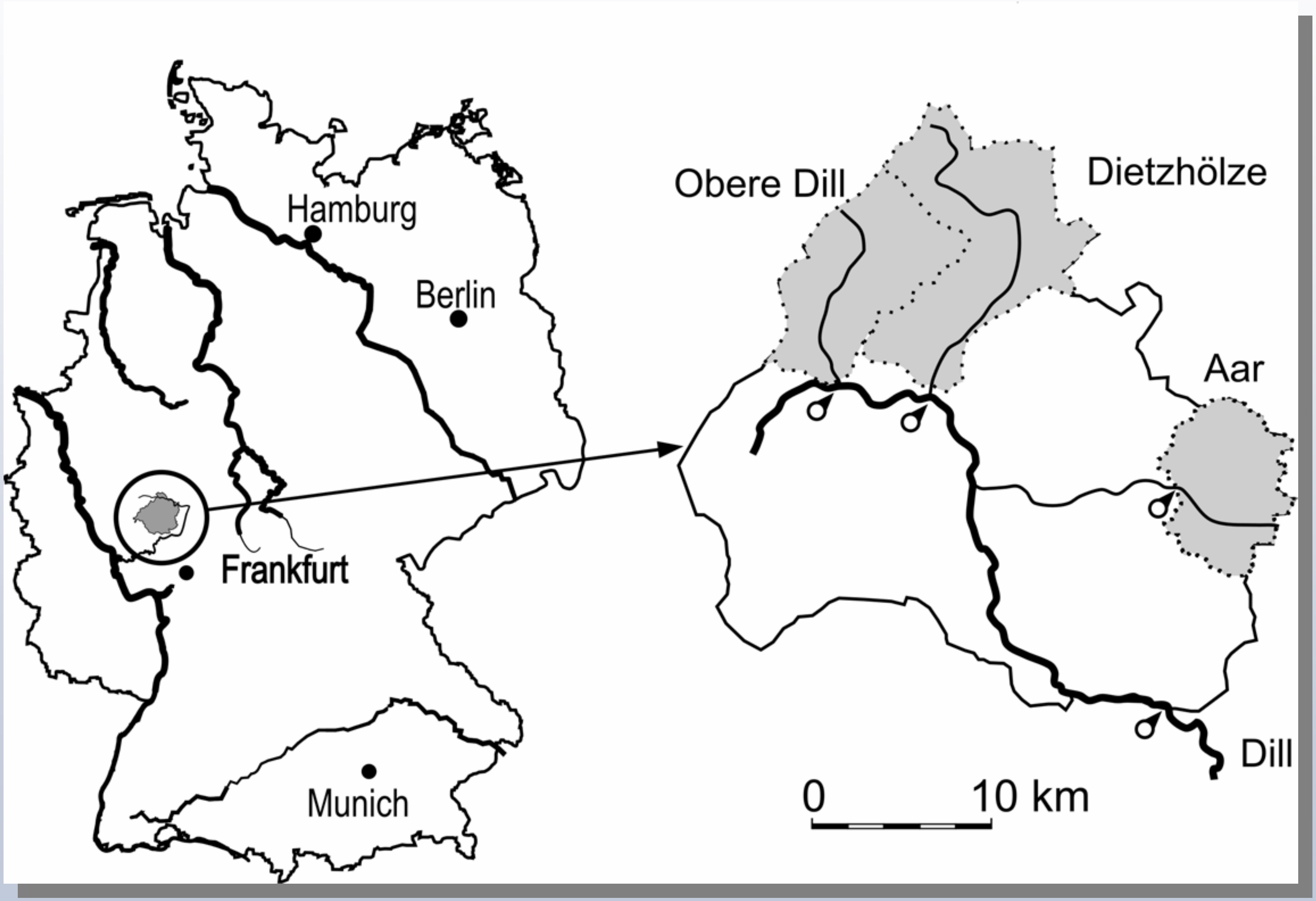
# Introduction & Aim

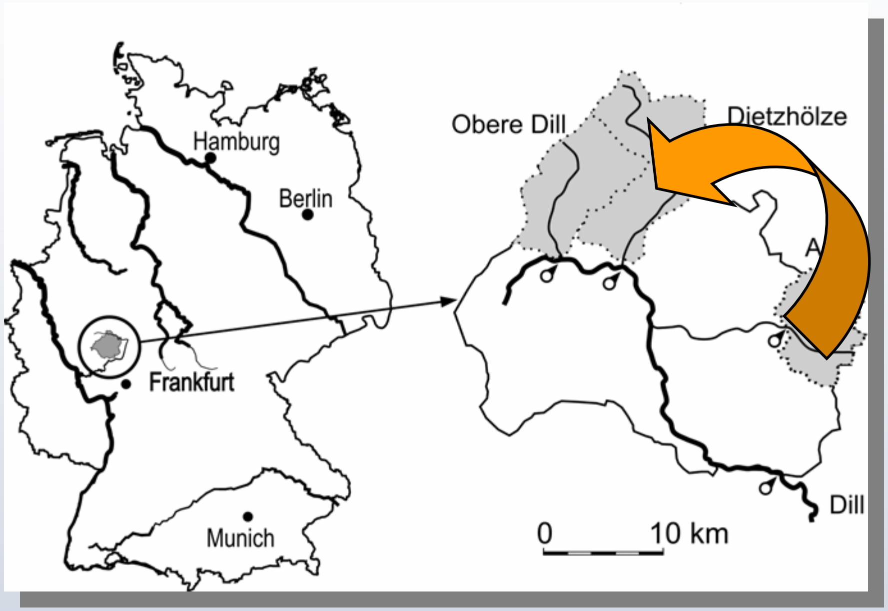
→ Model validation is often limited to applying the calibrated parameters in an independent validation period for the same catchment (simple split-sample test)

→ Aim of this study: Higher-order validation by applying calibration results in different catchments (simple proxy-catchment test)

# Research Area



# Research Questions




→ How well does a calibrated subcatchment parameterization characterize another subcatchment?

→ Is there one parameterization that provides good simulations for the Dill catchment and its three subcatchments simultaneously?

# SWAT-G Calibration & Validation

→ SWAT-G is an adaption of SWAT for low mountaineous regions

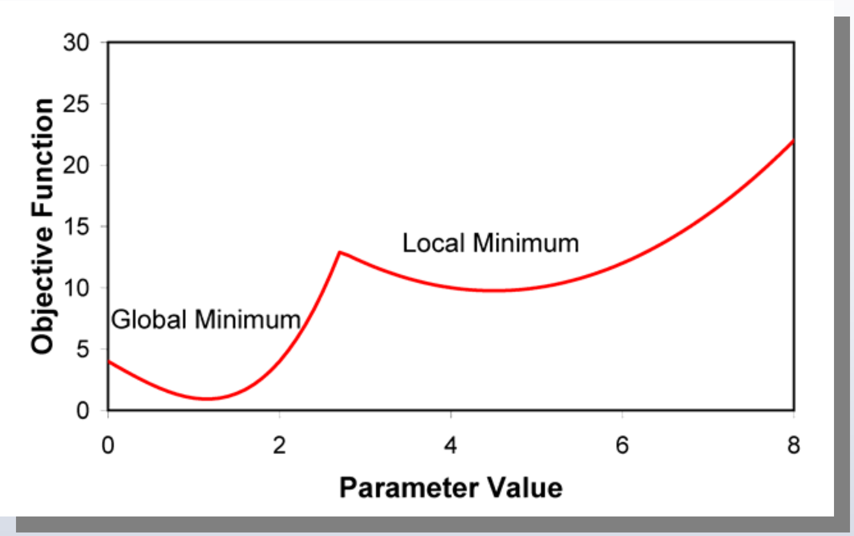
- Enhanced lateral flow through anisotropy between vertical and horizontal hydraulic conductivity

→ SWAT-G calibrated to three hydrological years (1986-1988) for Dill catchment and each subcatchment

→ SWAT-G validated for three hydrological years (1989-1991) and by cross-application of parameterizations in different subcatchments

# SCE-UA for Optimization

→ Shuffled Complex Evolution (SCE-UA) is a well-established algorithm to find the global minimum of an objective function within user-defined bounds.




→ Finding the global minimum requires many simulations

# Parameter Reduction

→ Optimization algorithms cannot be used to calibrate all SWAT parameters

→ Define parameter ratios (Eckhardt and Arnold, 2001)

| Bulk Density | **Soil-A** | **Soil-B** |
|---|---|---|
| **Layer 1** | 1.55 | 1.55 |
| **Layer 2** | 1.55 | 1.35 |
| **Layer 3** | 1.75 | 1.60 |

0.86

0.91

# Bounds of Automatic Calibration

| | Lower Bound | Upper Bound |
|---|---|---|
| Surface runoff lag time (d) | 1.000 | 5.000 |
| Manning N surface runoff ($m^{1/3}s$) | 0.200 | 0.500 |
| Groundwater recession coefficient ($d^{-1}$) | 0.030 | 0.060 |
| Delay of groundwater recharge (d) | 1.000 | 20.000 |
| Deep aquifer percolation factor (-) | 0.000 | 0.800 |
| Bulk density soil ($gcm^{-3}$) | 1.500 | 1.600 |
| Bulk density bedrock ($gcm^{-3}$) | 2.510 | 2.650 |
| Available water content ($m^3m^{-3}$) | 0.160 | 0.200 |
| Saturated hydraulic conductivity Soil I ($mmh^{-1}$) | 1.000 | 45.000 |
| Saturated hydraulic conductivity Soil II ($mmh^{-1}$) | 10.000 | 85.000 |
| Anisitropy factor (-) | 2.000 | 8.000 |

Red: Parameter ratios

Blue: Assumed constant in research area

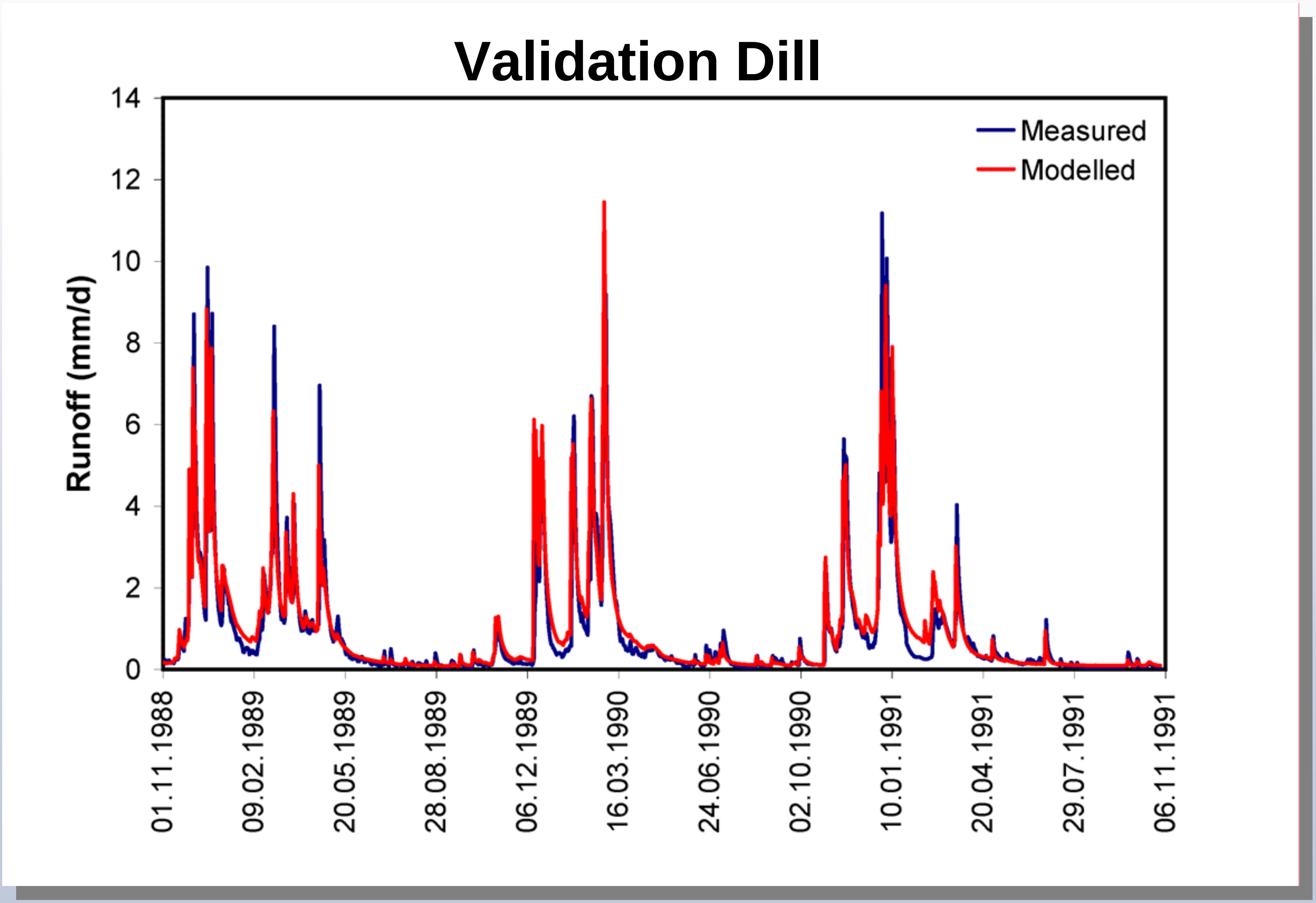
# Model Efficiency Results

| | Calibration | Validation |
|---|---|---|
| **Dill** | 0.85 | 0.80 |
| **Aar** | 0.83 | 0.83 |
| **Dietzhölze** | 0.83 | 0.78 |
| **Obere Dill** | 0.80 | 0.61 |

→ High model efficiency for daily simulations

→ Acceptable drop in efficiency from calibration to validation except for Obere Dill (impact of wet versus dry years?)

# Model Efficiency



# Comparison Parameterizations

| | Dill | Aar | Dtz | Obd |
|---|---|---|---|---|
| Surface runoff lag time (d) | 1.000 | 1.000 | 1.000 | 1.030 |
| Manning N surface runoff ($m^{1/3}s$) | 0.497 | 0.480 | 0.495 | 0.477 |
| Groundwater recession coefficient ($d^{-1}$) | 0.030 | 0.038 | 0.035 | 0.044 |
| Delay of groundwater recharge (d) | 19.500 | 1.090 | 9.060 | 9.060 |
| Deep aquifer percolation factor (-) | 0.351 | 0.024 | 0.010 | 0.045 |
| Bulk density soil ($gcm^{-3}$) | 1.600 | 1.600 | 1.600 | 1.580 |
| Bulk density bedrock ($gcm^{-3}$) | 2.620 | 2.630 | 2.640 | 2.630 |
| Available water content ($m^3m^{-3}$) | 0.200 | 0.200 | 0.200 | 0.194 |
| Saturated hydraulic conductivity Soil I ($mmh^{-1}$) | 44.800 | 44.500 | 44.900 | 1.150 |
| Saturated hydraulic conductivity Soil II ($mmh^{-1}$) | 84.800 | 84.900 | 84.600 | 84.700 |
| Anisitropy factor (-) | 7.990 | 8.000 | 7.960 | 7.800 |

# Cross-Validation

| | Dill | Aar | Dietzhölze | Obere Dill |
|---|---|---|---|---|
| | CALIBRATION | | | |
| **Dill** | 0.85 | 0.82 | 0.82 | 0.79 |
| **Aar** | 0.84 | 0.83 | 0.83 | 0.80 |
| **Dietzhölze** | 0.84 | 0.83 | 0.83 | 0.80 |
| **Obere Dill** | 0.83 | 0.75 | 0.83 | 0.80 |
| | VALIDATION | | | |
| **Dill** | 0.80 | 0.82 | 0.77 | 0.65 |
| **Aar** | 0.78 | 0.83 | 0.78 | 0.65 |
| **Dietzhölze** | 0.77 | 0.82 | 0.78 | 0.65 |
| **Obere Dill** | 0.67 | 0.69 | 0.71 | 0.61 |

→ Cross-validation succesful for Dill and 2 subcatchments

→ Results for Obere Dill also unsatisfactory in cross-validation

# One Parameterization for All?

→ Multi-objective calibration by weigthed summing of residuals:

$$SSR_{tot} = \sum w_i SSR_i$$

with

$$w_i = \frac{1}{\sigma^2_{meas,i}}$$

→ Weigthing with variance ensures that decrease in residuals has similar value for all catchments

# Multi-Objective Calibration I

| | Dill | Aar | Dietzhölze | Obere Dill |
|---|---|---|---|---|
| | CALIBRATION | | | |
| **Dill** | 0.85 | 0.82 | 0.82 | 0.79 |
| **Aar** | 0.84 | 0.83 | 0.83 | 0.80 |
| **Dietzhölze** | 0.84 | 0.83 | 0.83 | 0.80 |
| **Obere Dill** | 0.83 | 0.75 | 0.83 | 0.80 |
| **'Multi-objective'** | 0.85 | 0.83 | 0.83 | 0.80 |
| | VALIDATION | | | |
| **Dill** | 0.80 | 0.82 | 0.77 | 0.65 |
| **Aar** | 0.78 | 0.83 | 0.78 | 0.65 |
| **Dietzhölze** | 0.77 | 0.82 | 0.78 | 0.65 |
| **Obere Dill** | 0.67 | 0.69 | 0.71 | 0.61 |
| **'Multi-objective'** | 0.79 | 0.82 | 0.78 | 0.65 |

There is a set of parameters adequately describing all catchments!

# Multi-Objective Calibration II

| | Dill | Aar | Dtz | Obd | MO |
|---|---|---|---|---|---|
| Surface runoff lag time (d) | 1.000 | 1.000 | 1.000 | 1.030 | 1.000 |
| Manning N surface runoff ($m^{1/3}s$) | 0.497 | 0.480 | 0.495 | 0.477 | 0.499 |
| Groundwater recession coefficient ($d^{-1}$) | 0.030 | 0.038 | 0.035 | 0.044 | 0.031 |
| Delay of groundwater recharge (d) | 19.500 | 1.090 | 9.060 | 9.060 | 19.200 |
| Deep aquifer percolation factor (-) | 0.351 | 0.024 | 0.010 | 0.045 | 0.344 |
| Bulk density soil ($gcm^{-3}$) | 1.600 | 1.600 | 1.600 | 1.580 | 1.600 |
| Bulk density bedrock ($gcm^{-3}$) | 2.620 | 2.630 | 2.640 | 2.630 | 2.640 |
| Available water content ($m^3m^{-3}$) | 0.200 | 0.200 | 0.200 | 0.194 | 0.200 |
| Saturated hydraulic conductivity Soil I ($mmh^{-1}$) | 44.800 | 44.500 | 44.900 | 1.150 | 45.000 |
| Saturated hydraulic conductivity Soil II ($mmh^{-1}$) | 84.800 | 84.900 | 84.600 | 84.700 | 84.900 |
| Anisitropy factor (-) | 7.990 | 8.000 | 7.960 | 7.800 | 7.990 |

→ The multi-objective parameterization is a mix of the individual sets, but most resembles the Dill parameterization

# Conclusions

→ Higher-order validation at least partly successful

→ Despite different optimized parameter sets for each subcatchment, there is one parameter set that adequately describes all subcatchments.

- Confidence intervals for optimized parameters?
- Impact of prior parameter ranges?

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