Multi-objective calibration of a hydrologic model using multi-objective screening

J. Mai [1,2], M. Cuntz [3], S. Thober [2], L. Samaniego [2], and B. Tolson [1]

[1] University of Waterloo, Waterloo, Canada [2] Helmholtz Centre for Environmental Research - UFZ, Leipzig, Germany
[3] INRA-Université de Lorraine, UMR Ecologie et Ecophysiologie Forestières, UMR1137, Champenoux-Vandoeuvre Les Nancy, France Contact: (juliane.mai@uwaterloo.ca)

1. Introduction

Hydrologic models are traditionally calibrated against discharge. Recent studies have shown however, that only a few global model parameters are constrained using the integral discharge measurements. It is therefore advisable to focus only on this **informative subset of parameters** during calibration. To constrain a larger subset of parameters, **multiple objectives** might be considered and a multi-objective calibration algorithm should be applied. The questions are (1) which subset of parameters can be constrained using these multiple objectives and (2) do multi-objective calibration algorithms benefit from only using this subset of parameters during calibration.

2. Model & Study Area

The study is performed using the **distributed hydrologic model at the mesoscale** (mHM) with 53 parameters. The model uses grid cells as a primary hydrologic unit, and accounts for processes like snow accumulation and melting, soil moisture dynamics, infiltration, surface runoff, evapotransp., subsurface storage and discharge generation. The model is applied in **three distinct catchments** of different hydrological characteristics over Europe.

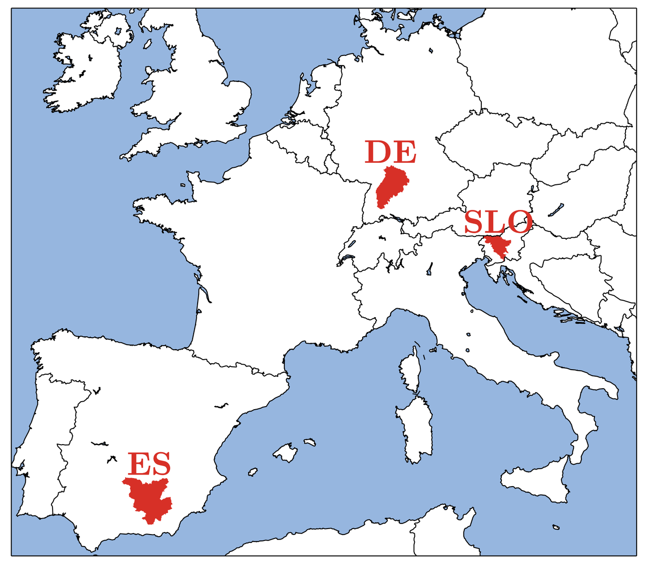

Fig. 1: Neckar (DE), Sava (SLO), and Guadalquivir (ES)

3. Multi-objective Parameter Screening

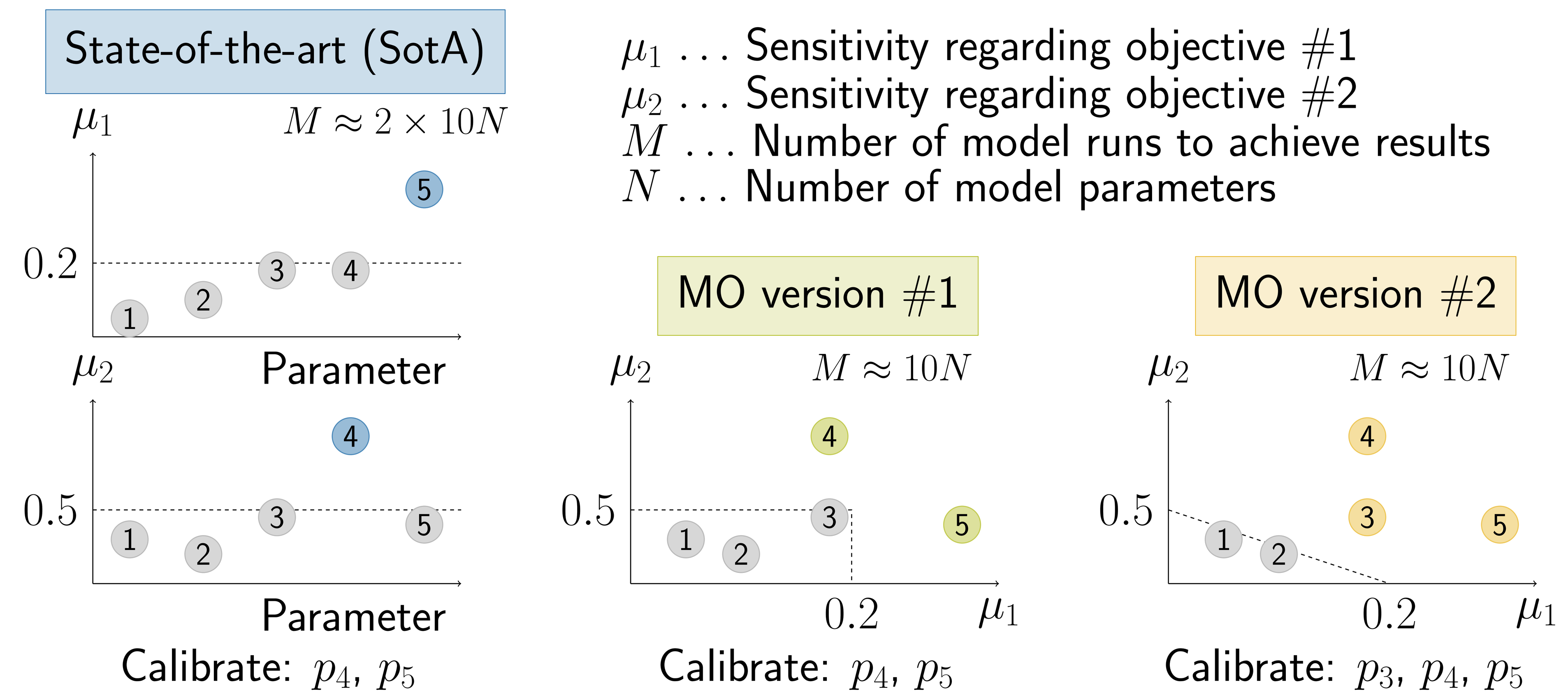

Fig. 2: Different methods of multi-objective screening

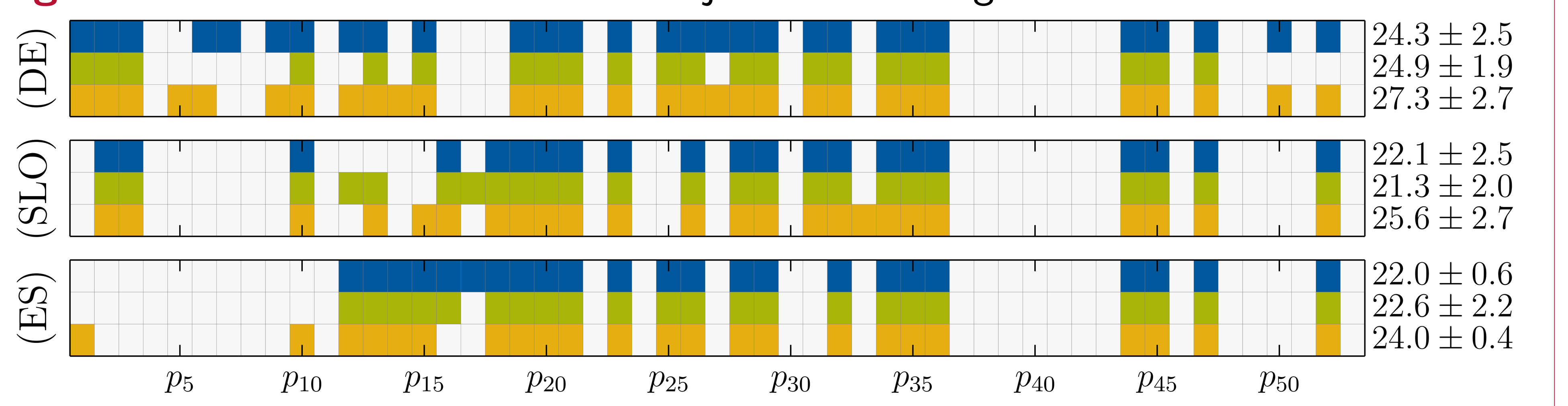

Fig. 3: Informative parameters (colored boxes) for all three catchments. μ and σ for total number of parameters identified in all 10 screenings can be seen to the right.

4. Multi-objective Model Calibration

Pareto-archived dynamically dimensioned search (PA-DDS) algorithm introduced by Asadzadeh and Tolson (2013) using hyper-volume contribution metric and 10 replicates for each of the scenarios

Comput. budget: 1000, 2000, 5000, $10\,000$, $15\,000$ model evaluations

Reference front: $100\,000$ model evaluations

Objective functions used:

Objective #1: $1 - \mathrm{NSE}(\ln(Q_{\mathrm{high}})) \rightarrow$ Min!

Objective #2: $1 - \mathrm{NSE}(\ln(Q_{\mathrm{low}})) \rightarrow$ Min!

where Q_{high} and Q_{low} are the high and low flow discharge values resp. using $Q_{\mathrm{thres}} = Q_{\mathrm{min}} + (Q_{\mathrm{max}} + Q_{\mathrm{min}}) \cdot 0.05$ to categorize discharge values

5. Results

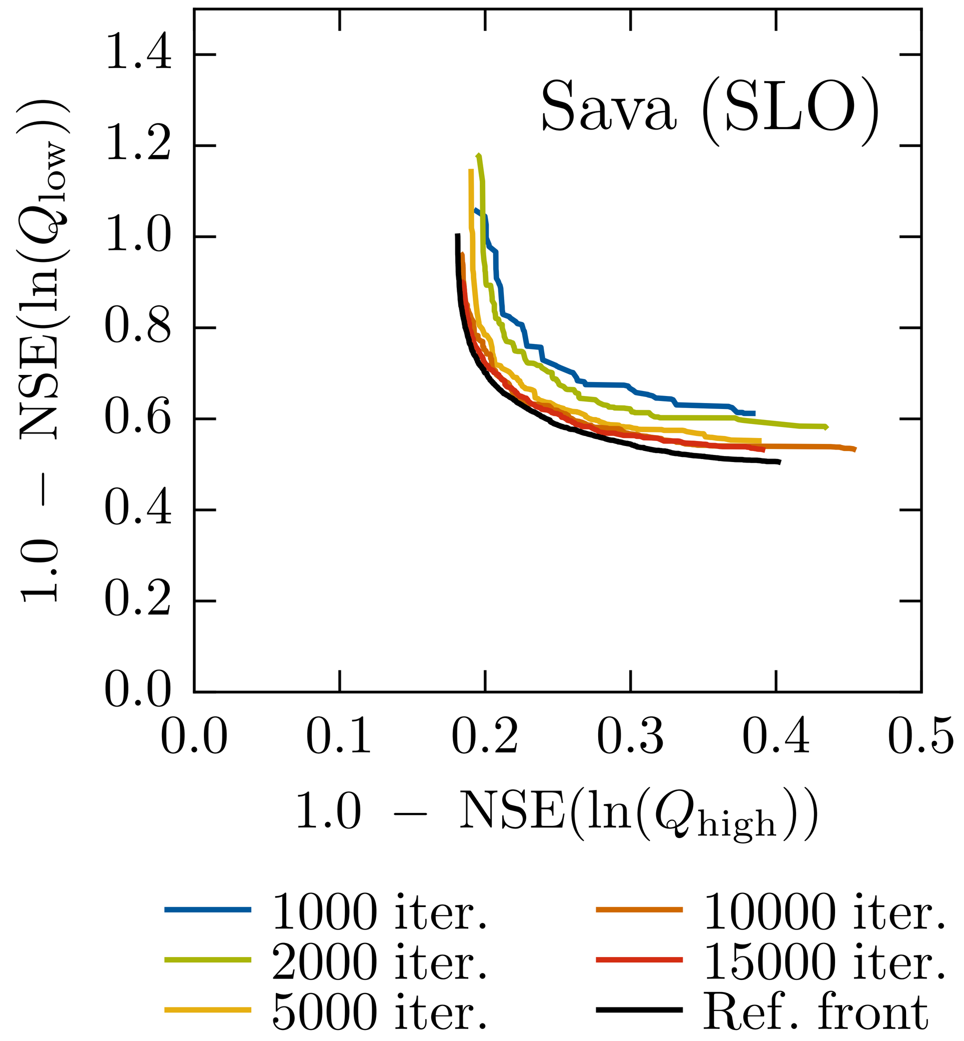

Fig. 4: MO calibration results without screening (all 53 parameters are calibrated) using different budgets for PA-DDS

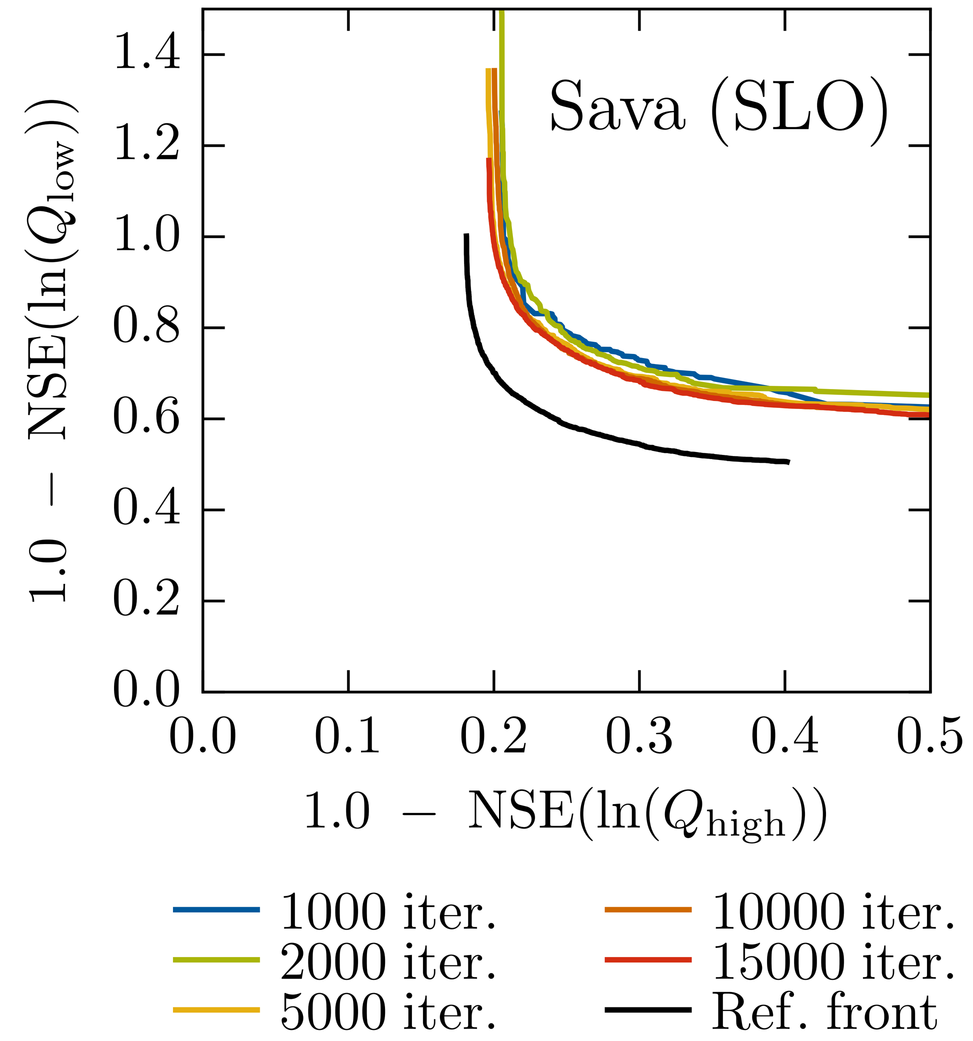

Fig. 5: MO calibration results using MO screening #2 (only screened param. are calibrated) using different budgets for PA-DDS

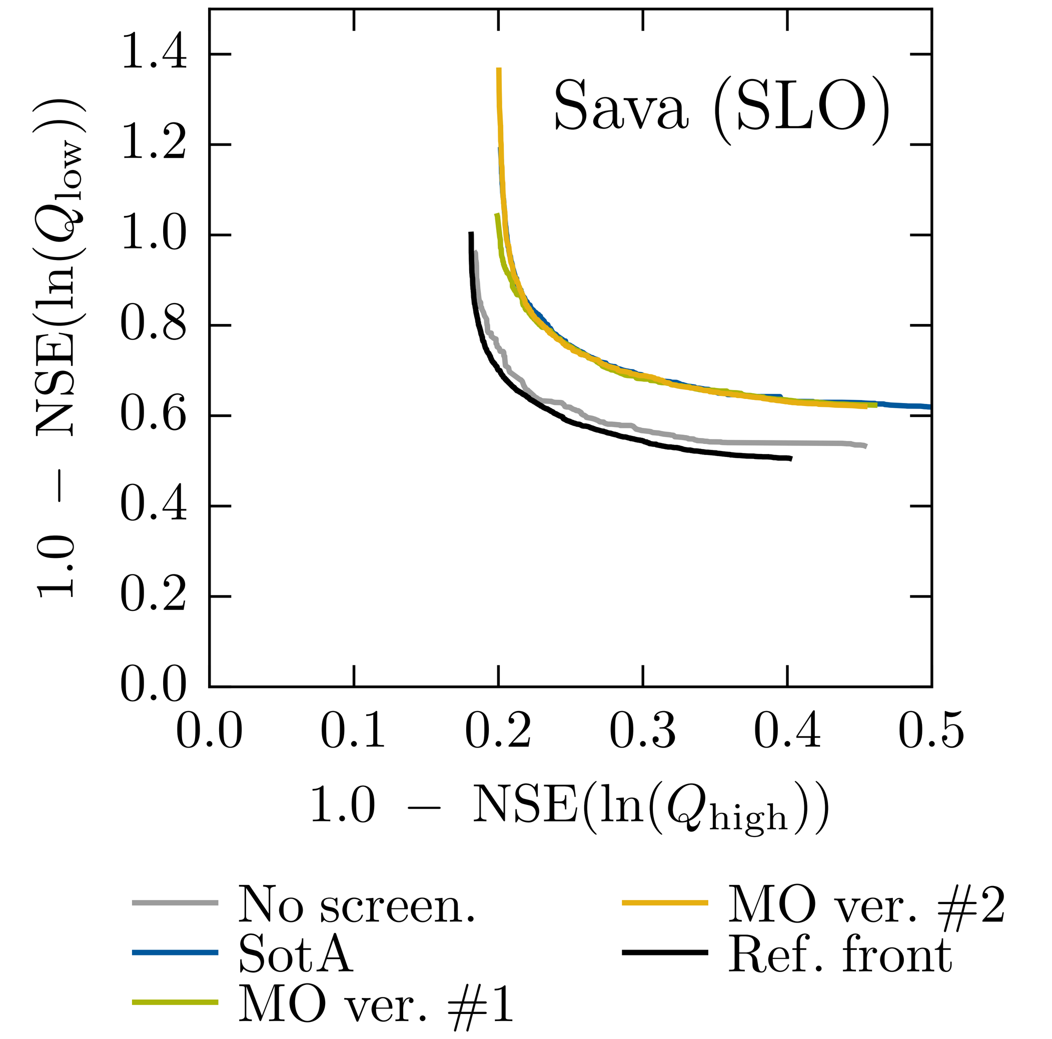

Fig. 6: MO calibration results using different versions of screening (only screened parameters are calibrated) using budget of 10 000 model evaluations for PA-DDS

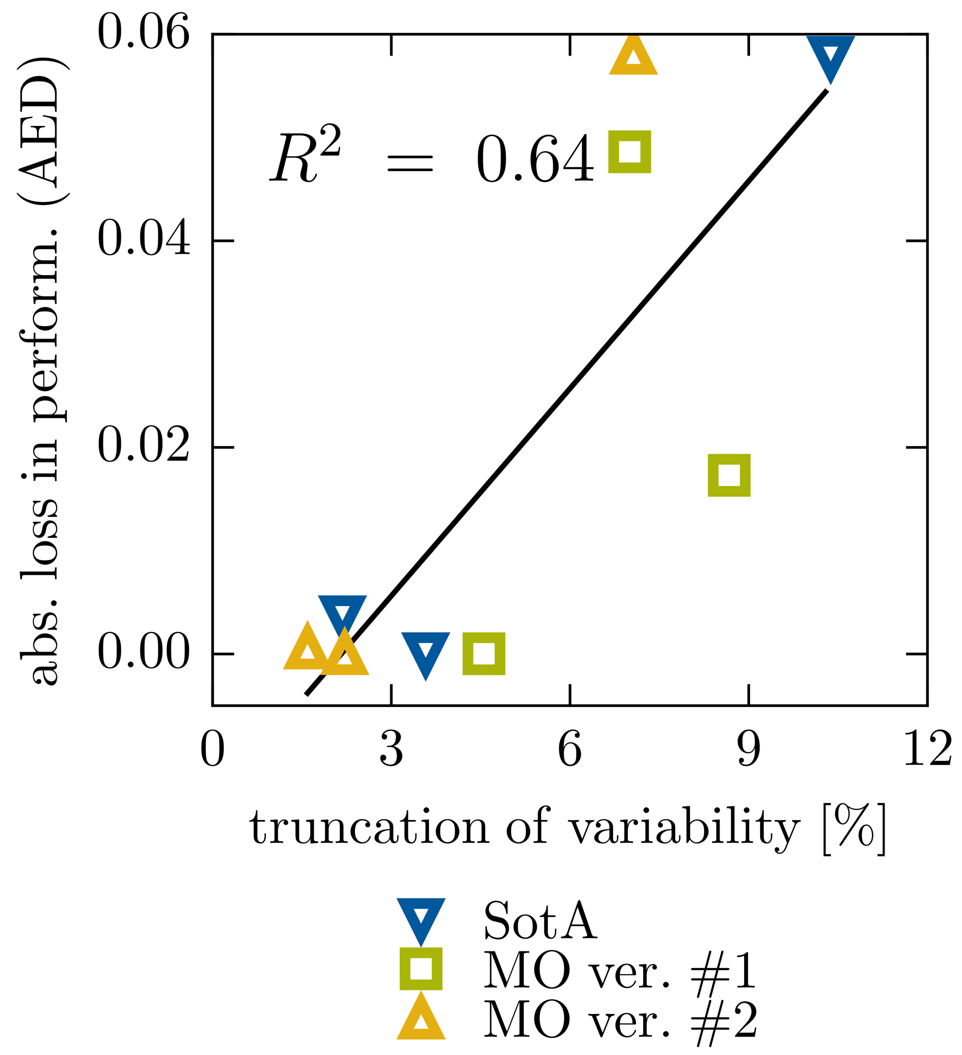

Fig. 7: Loss in performance vs. truncation error induced by neglecting screened parameters during PA-DDS calibration

6. Conclusions

- The parameter screening **degrades multi-objective calibration quality** relative to non-screening approach (compare Fig. 4 & 5).
- It is not clear yet whether this **performance reduction is specific** to the chosen calibration algorithm or holds also for other MO algorithms.
- The **loss in performance correlates** well with truncation of model variability during parameter screening (Fig. 7).
- The different parameter screening methods tested show **no real difference** from each other in terms of calibration results (Fig. 6).
- The number of **model evaluations** required for screening are **reduced** by a factor of 2 using a multi-objective screening approach instead of the state-of-the-art single objective approach (Fig. 2).

References

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[3] Asadzadeh, M, & Tolson, B (2013). Engin Optim, 45(12), 1489–1509.

HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ

UNIVERSITY OF WATERLOO