Multi-objective vs. single-objective calibration of a hydrologic model

HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ

J. Mai [1,2], M. Cuntz [1], M. Zink [1], D. Schaefer [1], S. Thober [1], L. Samaniego [1], M. Shafii [2], and B. Tolson [2]

[1] Helmholtz Centre for Environmental Research - UFZ, Leipzig, Germany [2] University of Waterloo, Waterloo, Canada Contact: (juliane.mai@ufz.de)

UNIVERSITY OF WATERLOO

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 use additional information to calibrate those models. Signatures focused on low flows, for example, could improve the parametrization of baseflow processes, which might be underrepresented when using only discharge. A common approach is to combine these multiple objectives into one single objective function and allow the use of a single-objective (SO) algorithm. Another strategy is to consider the different objectives separately and apply a multi-objective (MO) algorithm. Both methods are challenging in the choice of appropriate multiple objectives for calibration.

2. Model & Study Area

The study is performed using the **distributed hydrologic model at the mesoscale** (mHM) with 52 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.

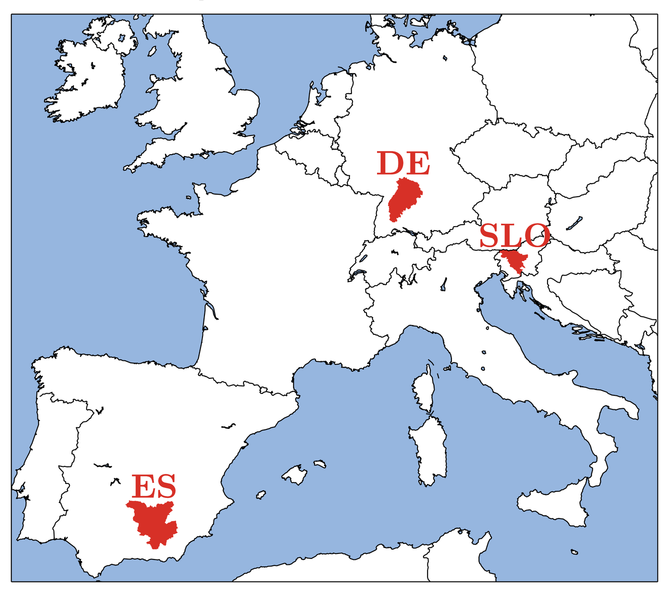


Fig. 1: Neckar (DE), Sava (SLO), and Guadalquivir (ES)

References

[1] Cuntz, M & Mai, J, et al. (2015). WRR, 51(8), 6417-6441.
[2] Shafii, M, & Tolson, BA (2015). WRR, 51(5), 3796-3814.
[3] Tolson, BA & Shoemaker, CA (2007). WRR, 43(1), W01413.
[4] Asadzadeh, M, & Tolson, BA (2013). Engin Optim, 45(12), 1489–1509.

3. Parameter Screening

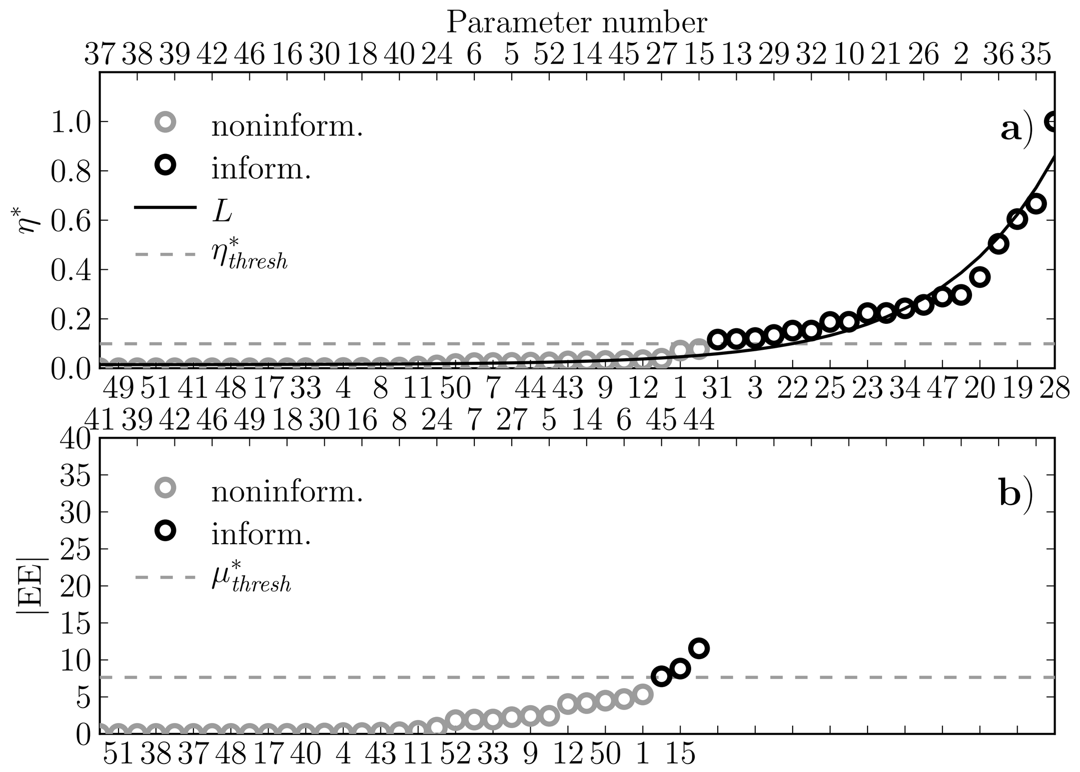


Fig. 2: **Single-objective parameter screening** based on Elementary effects following the procedure described by Cuntz et al. (2015) [1].

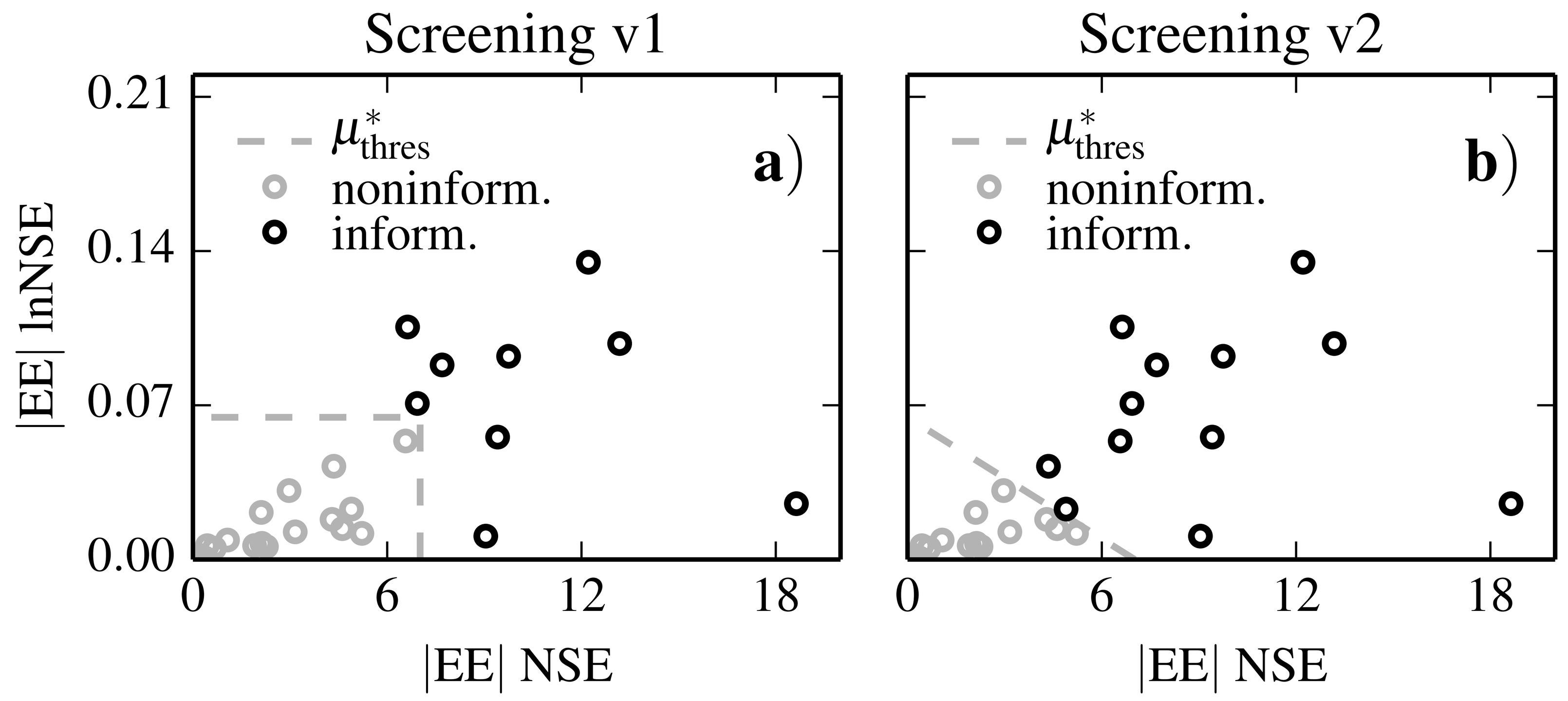


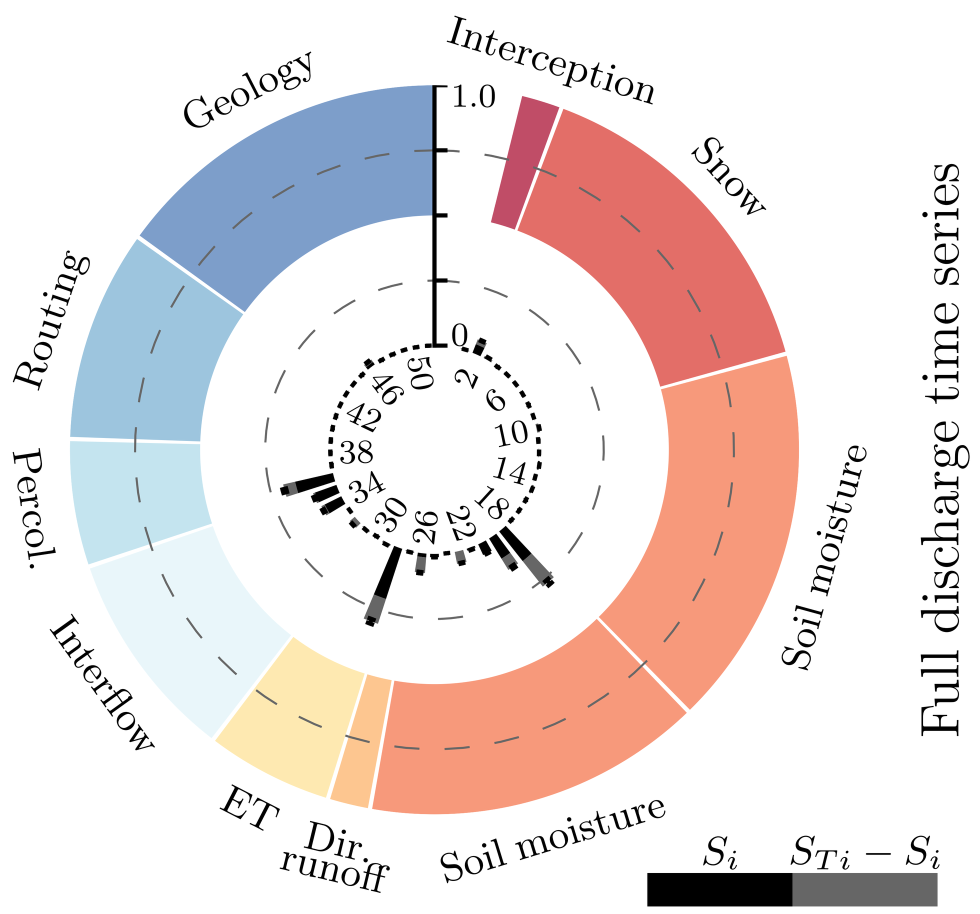
Fig. 3: Different versions of **multi-objective parameter screening**. The thresholds are determined for each objective individually and then either (a) parameters have to be in rectangular region of (b) triangular region to be marked as noninformative.

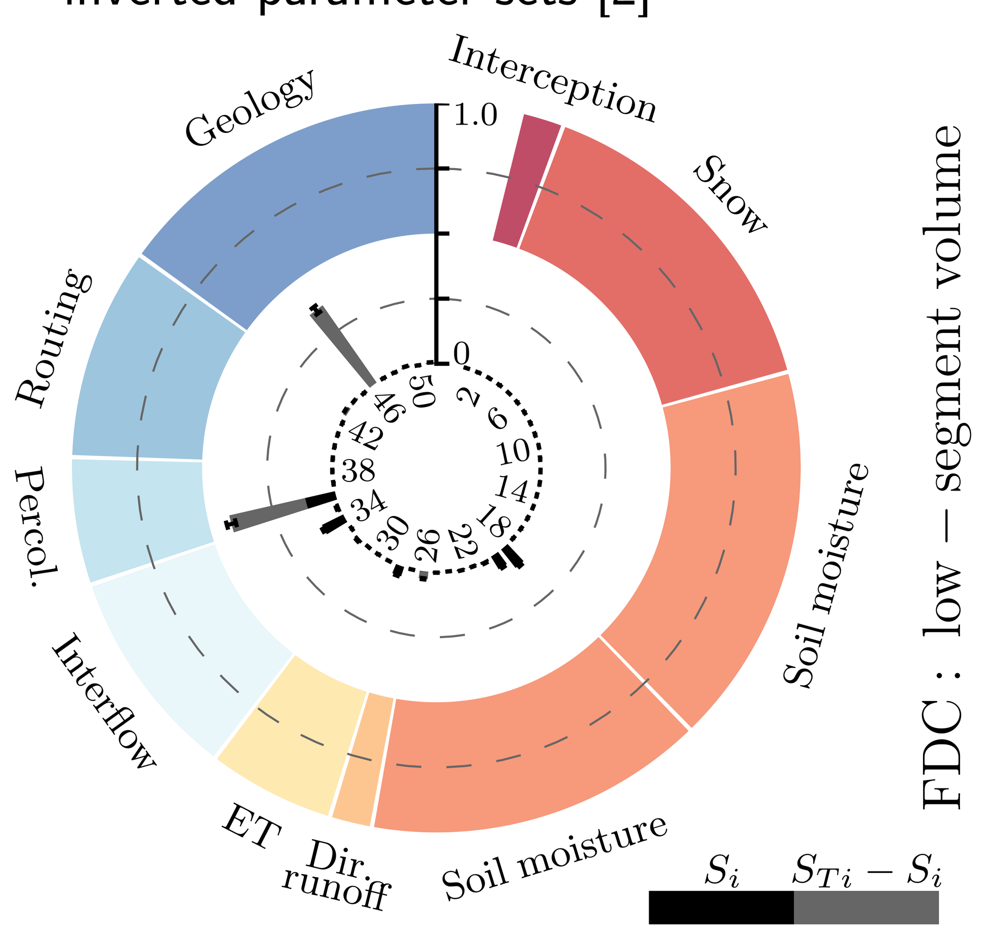
	SO		MO	
	NSE	lnNSE	v1	v2
DE	24 (550)	22 (533)	26 (1083)	27 (551)
SLO	18 (563)	20 (520)	20 (1083)	26 (477)
ES	21 (509)	23 (490)	24 (999)	26 (469)

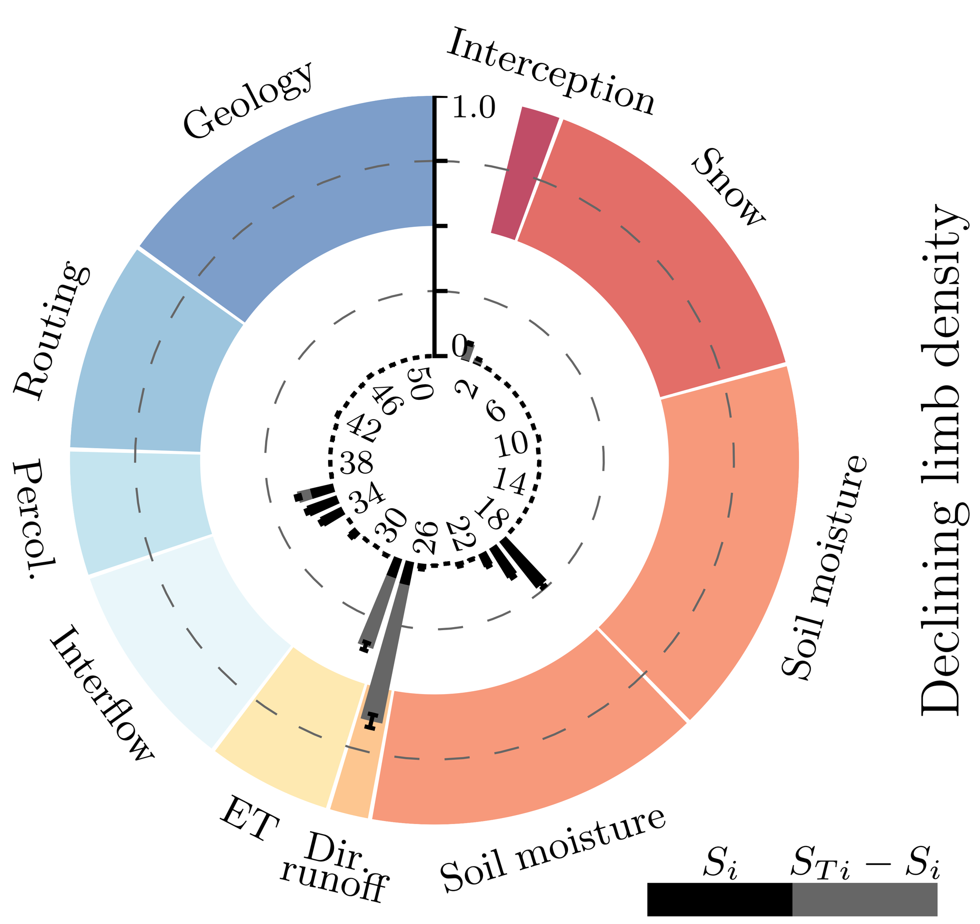
Tab.: Number of informative parameters and number of model evaluations required using sequential screening for different objectives. Version 1 of multi-objective parameter screening required more model evaluations due to independent handling of objectives and less parameters are selected.

4. Sensitivities Regarding Signatures

- Sobol' sensitivity analysis regarding 64 hydrologic signatures such as features of FDC and limb densities [2]
- Identification of informative parameters, i.e. parameters contributing to 90% of total variability per signature
- 10 (DE), 9 (SLO) and 12 (ES) parameters are informative using only discharge
- 17 (DE), 16 (SLO) and 21 (ES) parameters are informative using 10 (DE), 9 (SLO) and 12 (ES) signatures
- Identified signatures later used for calibration to assure hydrologic consistency of inverted parameter sets [2]







5. How does MO calibration compare to SO calibration?

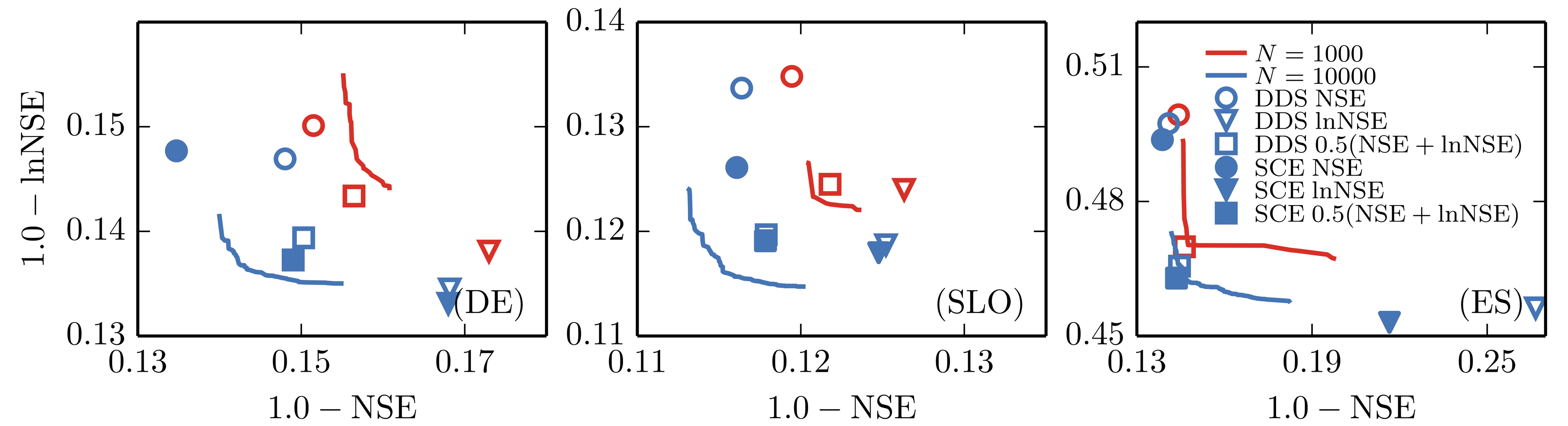


Fig. 4: MO calibration using PA-DDS (lines) [4] compared to SO calibration with DDS (open markers) [3] both using the same budget N of either 1000 (red) or 10 000 (blue) iterations. **For large budget MO is superior to SO.** SO results using SCE (filled markers) required about 20 000 iterations until convergence and are shown for reference.

6. Is a parameter screening prior to a MO calibration helpful?

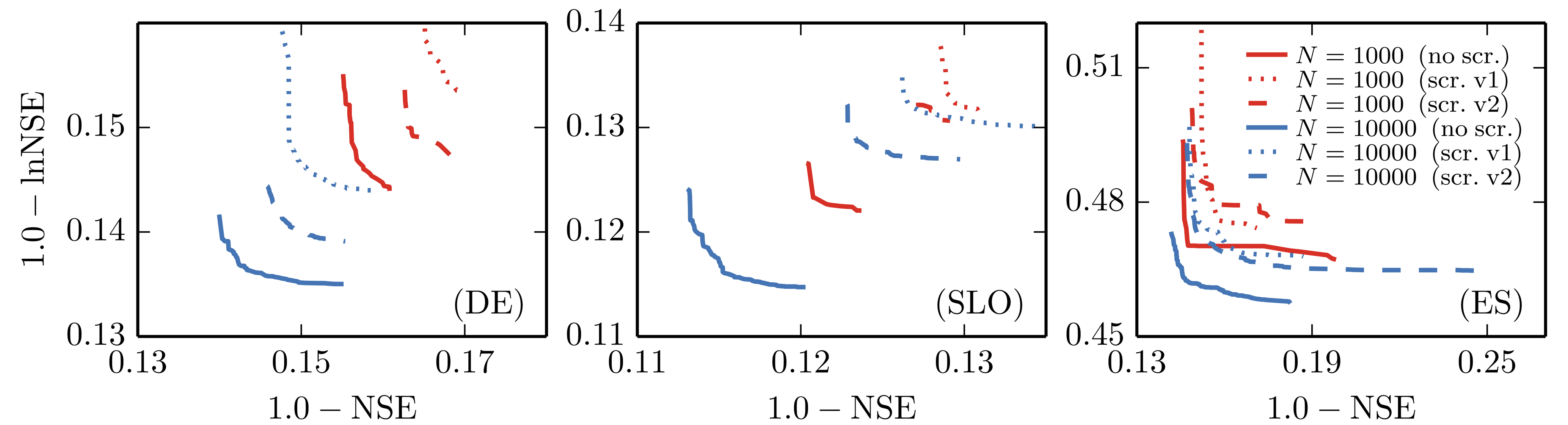


Fig. 5: MO calibration with either no prior parameter reduction (solid line) or state-of-the-art screening (v1, dotted line) or improved screening (v2, dashed line). **PA-DDS can not benefit from reduced sets of parameters** (neither v1 nor v2). Hence, multi-objective screening methods have to be improved.