Enhancing Model Development & Predictions with the Dynamically Dimensioned Search (DDS) Algorithm

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IP3 Workshop #1

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What is DDS?

- A new tool tailored to help environmental modellers more effectively & efficiently calibrate their models
- Simple and fast approximate global optimization algorithm for automatic calibration
- Designed specifically for automatic calibration:
  - Must be simple to implement
  - Must generate good results in modeller's time frame
  - Find good calibration solutions rather than globally optimal
- Tolson & Shoemaker (accepted) in WRR

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Main Limitation of Current Calibration Schemes

- They require too many model evaluations given our models take too long to run!
  - 10,000 or more model evaluations (e.g. using SCE or GLUE) simply infeasible for distributed models
- Many recent advancements in automatic calibration were not developed with computationally expensive distributed hydrologic/land surface models in mind

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Keys to DDS

- Algorithm scales to user-specified computational limits
- DDS mimics the manual calibration process:
  - Start at an initial solution & try to improve it
  - Always search around best known solution
  - Early in search, change MANY model parameters at a time
  - Later, change FEWER model parameters at a time
  - Near end of search, change only 1 or 2 model parameters at a time
- DDS vs Manual calibration difference
  - Manual uses knowledge to choose next parameters to modify
  - DDS picks the parameters randomly

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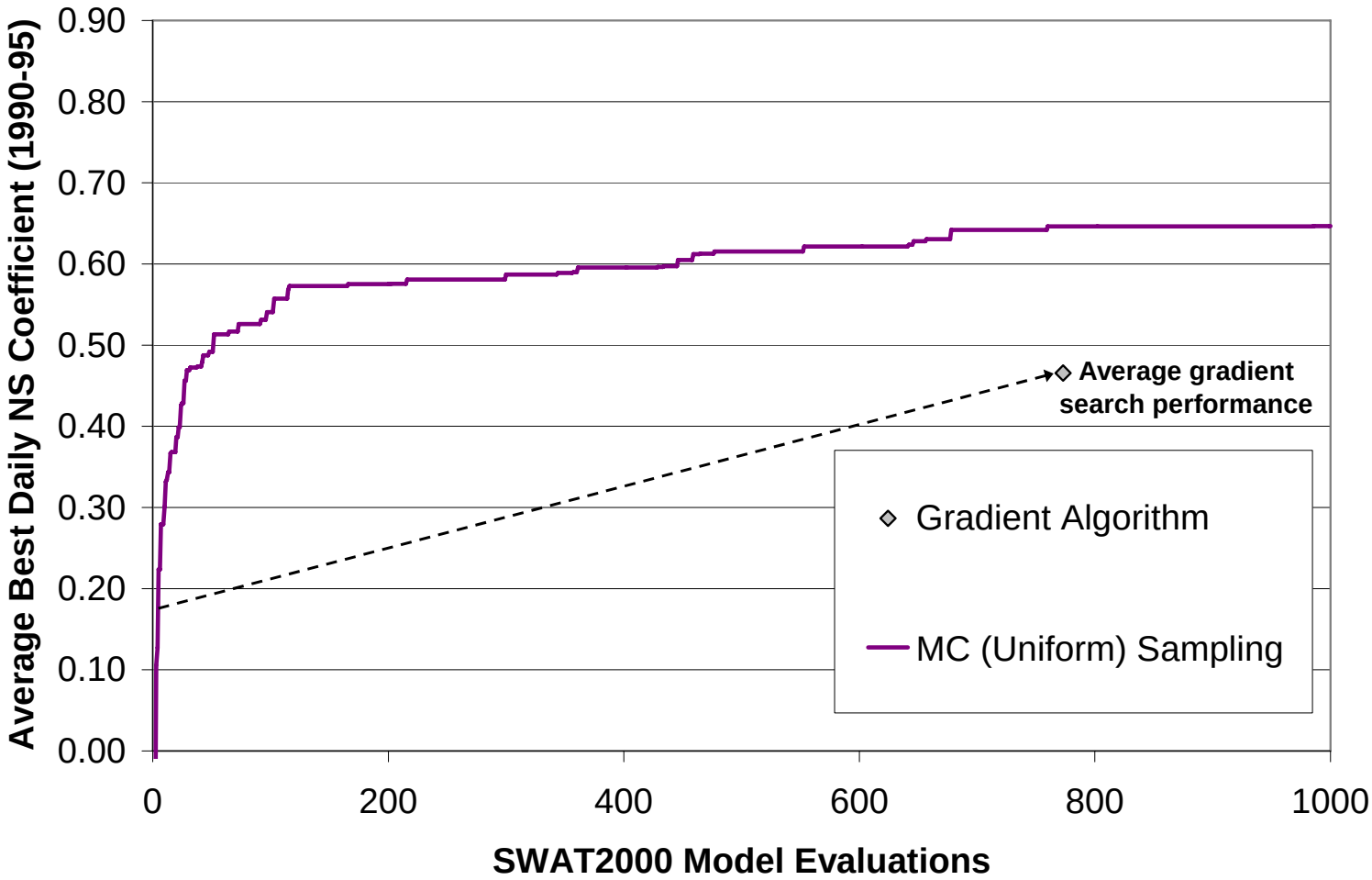
DDS Performance Comparison 1 – 10 optimization trials

14 parameter daily flow calibration for SWAT2000 model



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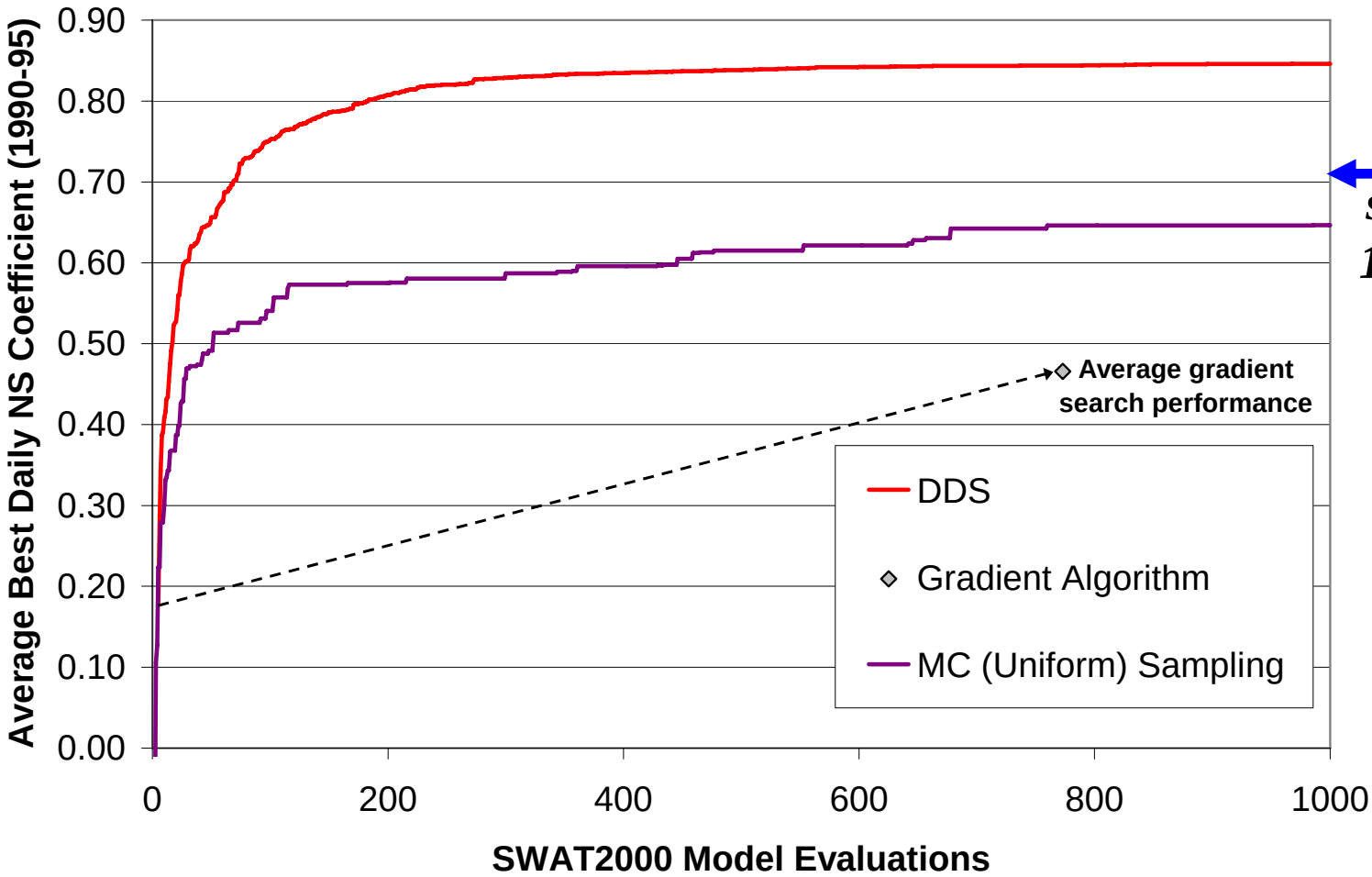

Best MC solution out of 10,000 samples is 0.71 !

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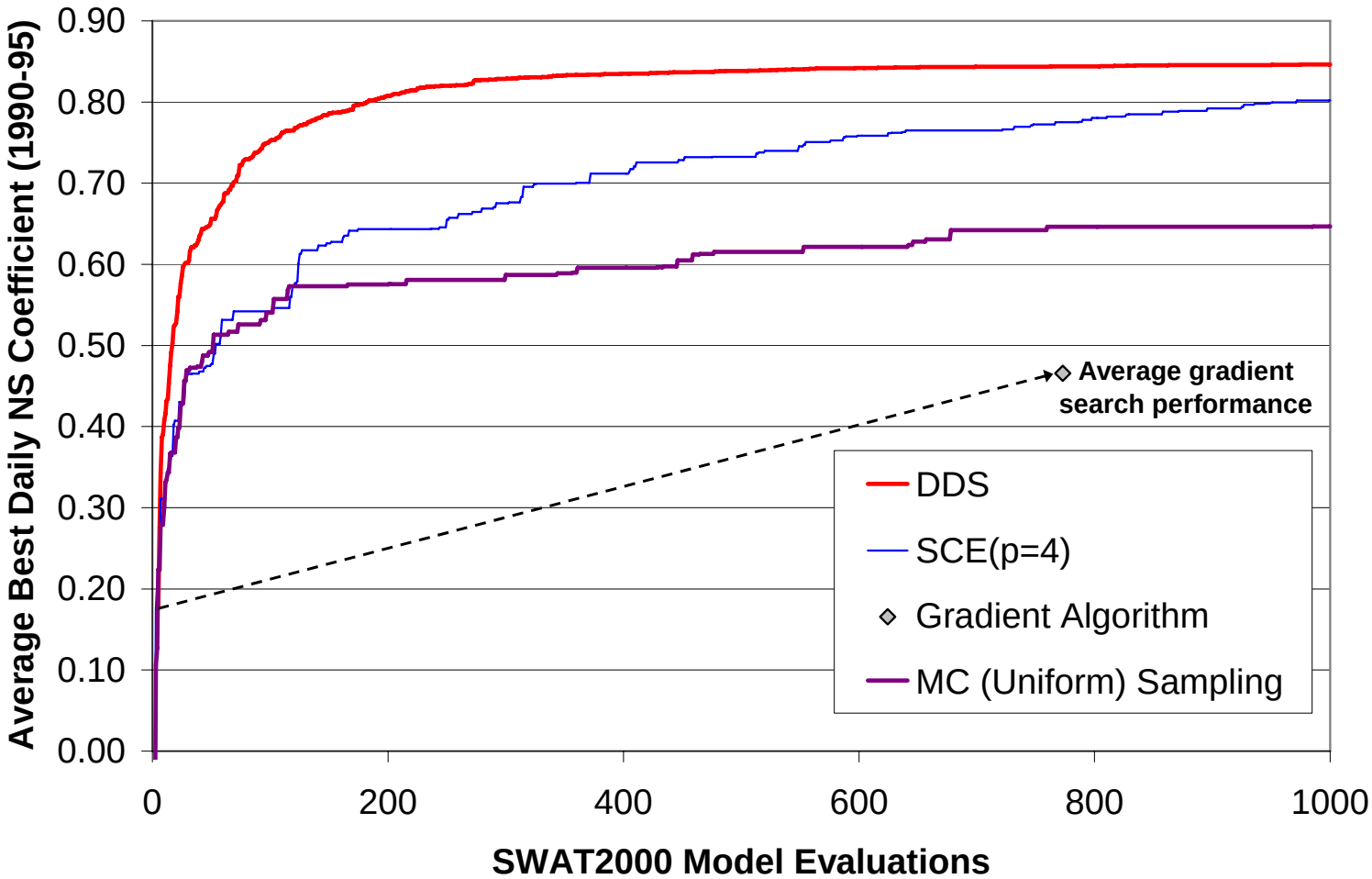

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Robustness of DDS

- DDS has been applied to a number of case studies, for example:
  - 6, 9, 10, 14, 20, 26, 30, 34 & 50 calibration parameters
  - And anywhere from 100 to 100,000 model evaluations
- In each case, DDS was applied with the *same optimization algorithm parameters* and generated good results

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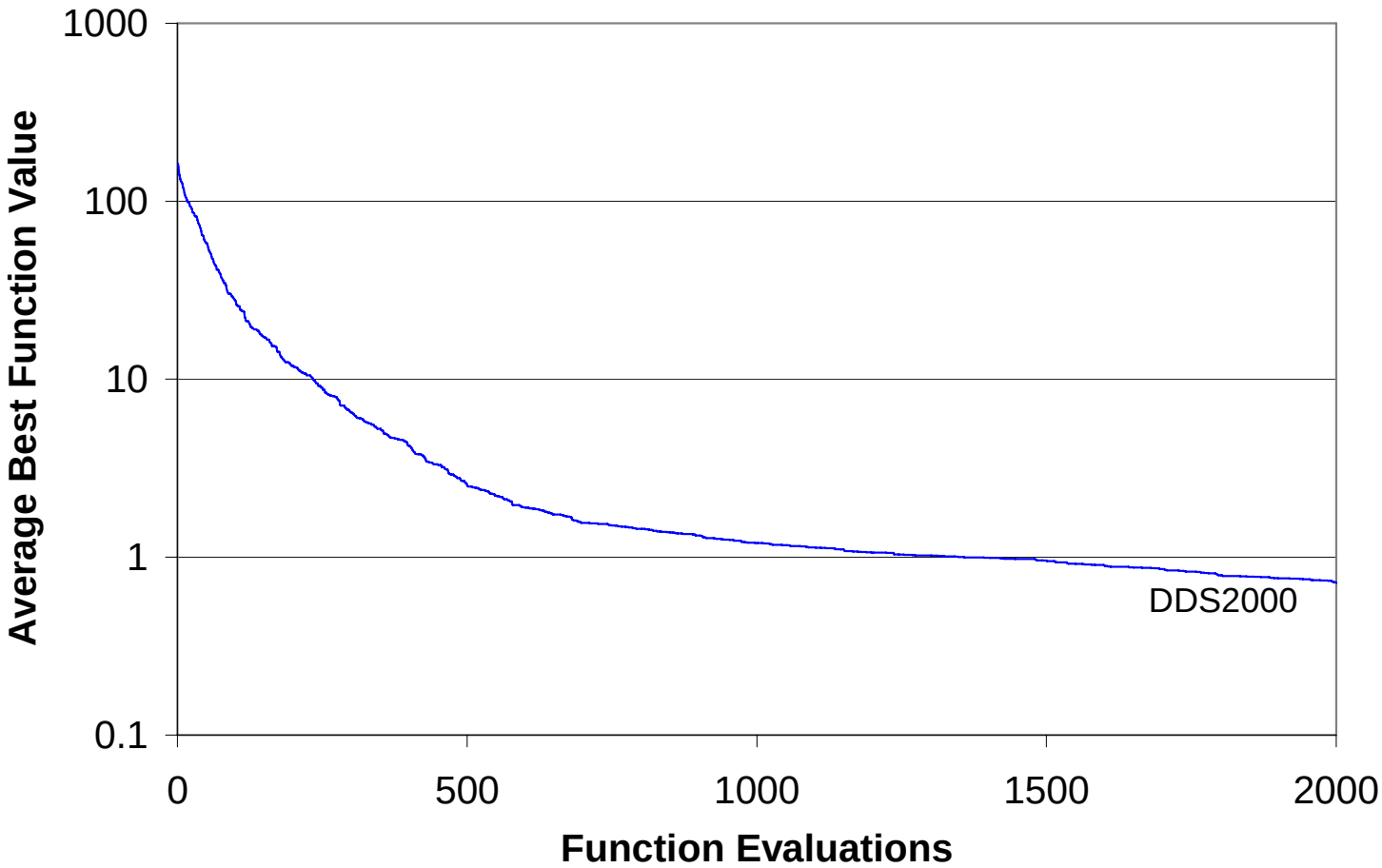
Observed DDS Algorithm Behaviour as User Computational Limits Change



DDS2000 means DDS with 2000 maximum function evaluations

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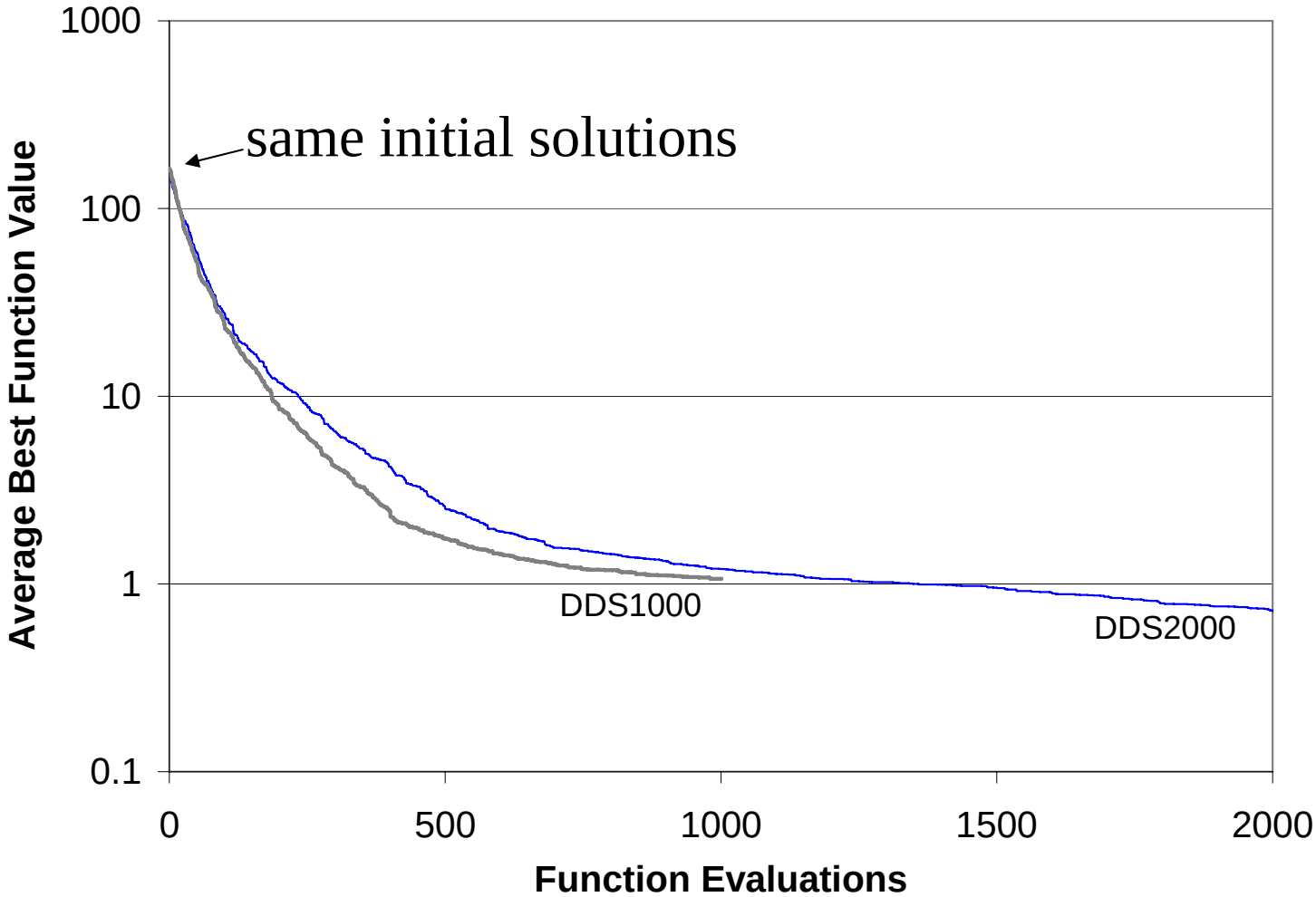

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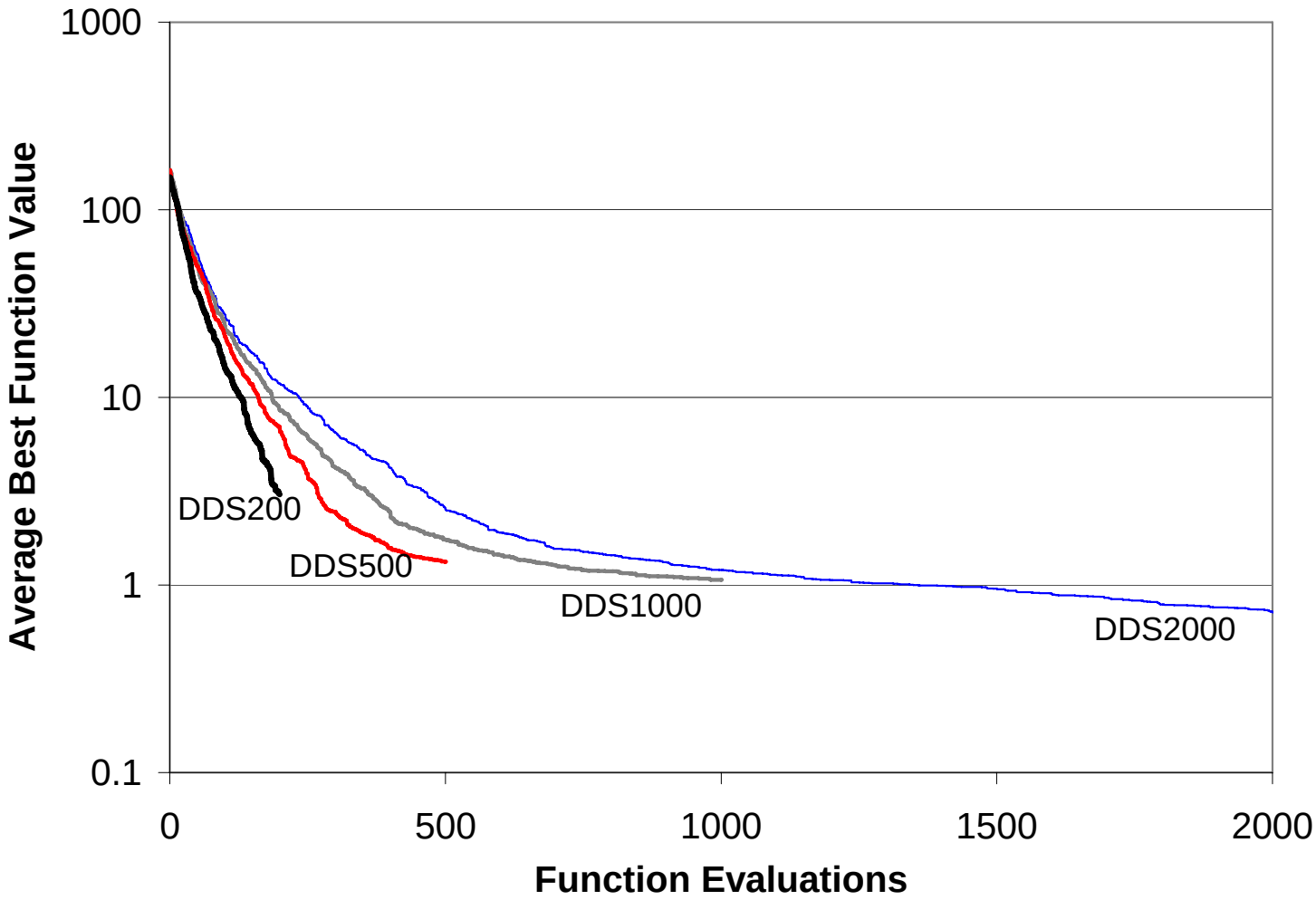

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Should We Calibrate More or Less Model Parameters?

- Increasing decision variables (calibrated parameters):
  - increases search space size → increases problem difficulty
  - more flexibility to fit data → improve objective function
- Does opt. algorithm find better solution for *same amount of computational time* given more flexibility?

OR

- How important is it to pick only the most sensitive parameters (sensitivity analysis) prior to calibration?

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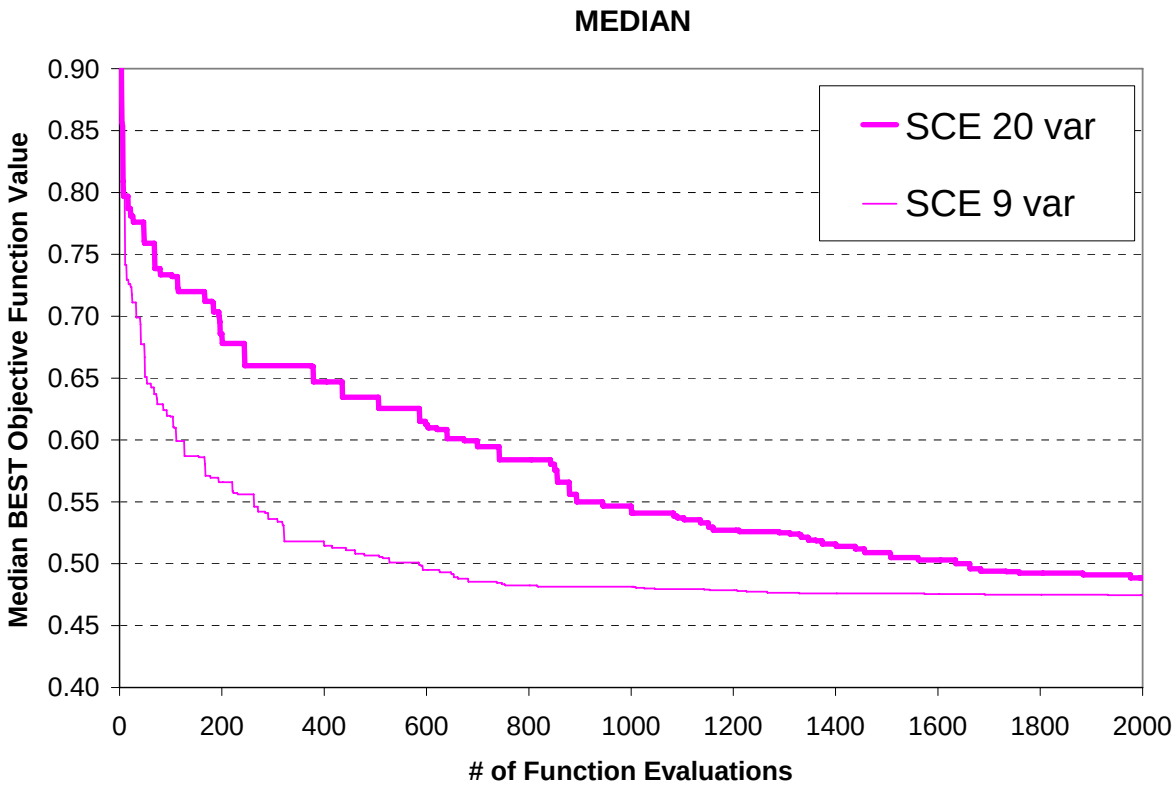
Objective Functions Problems 1 & 2

- Problem 1 & 2 are same except for # parameters calibrated



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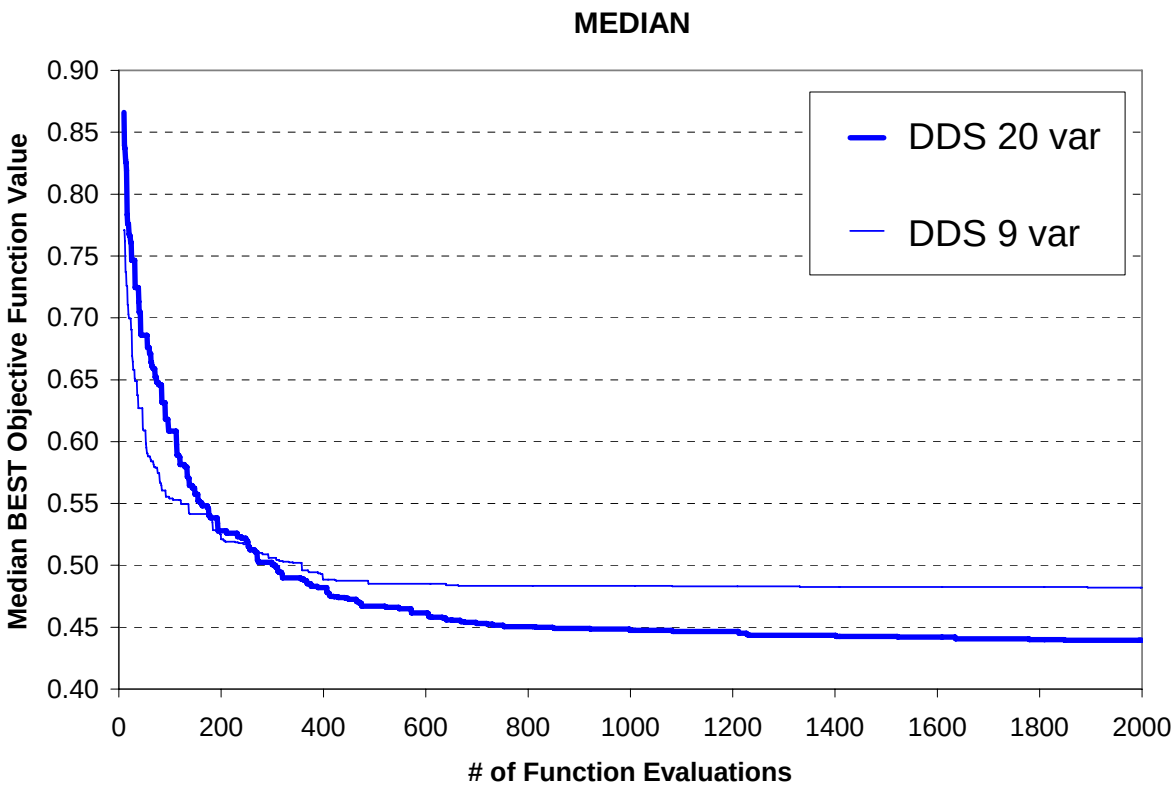

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My Research Plans for IP3

- Make DDS available to IP3 modellers
  - Matlab & Fortran 90, MESH/MEC
- Develop DDS into an effective multi-objective optimization tool
  - Modellers can more effectively match multiple sets of field data (streamflow, soil moisture & snowpack etc.)
- Help modellers find transferable land cover parameter sets to use with more confidence in ungauged basins
- Develop an objective methodology for evaluating improvements in model predictions due to changes in model physics, scaling etc.

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THANKS