AUTOMATIC ESTIMATION OF PARAMETER TRANSFER FUNCTIONS FOR DISTRIBUTED HYDROLOGICAL MODELS

FUNCTION SPACE OPTIMIZATION APPLIED TO THE mHM MODEL

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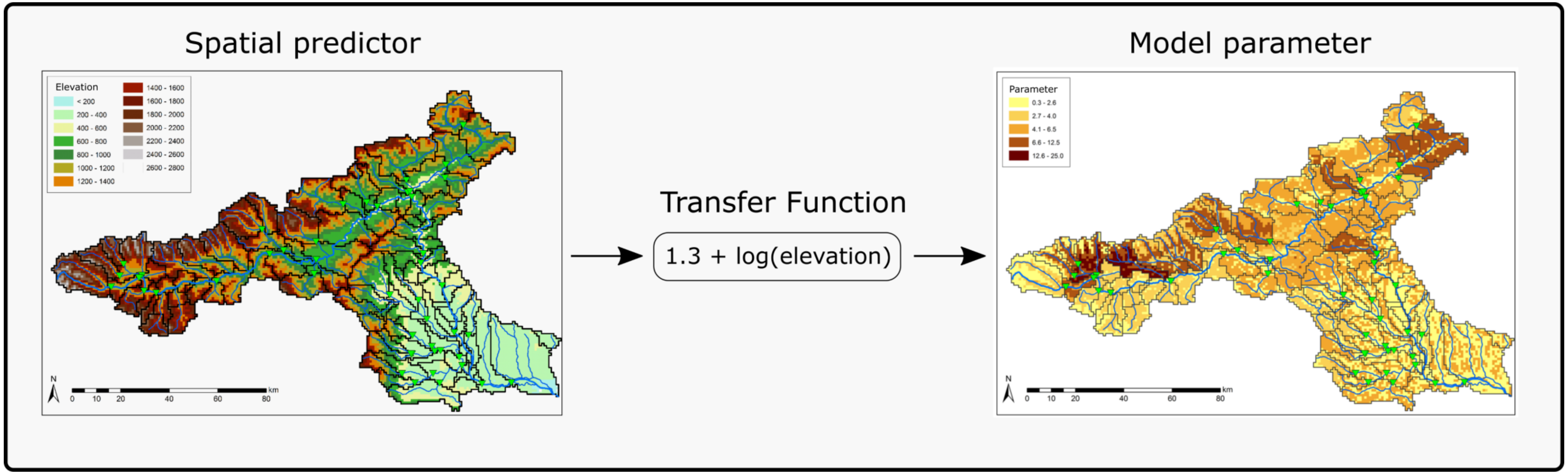
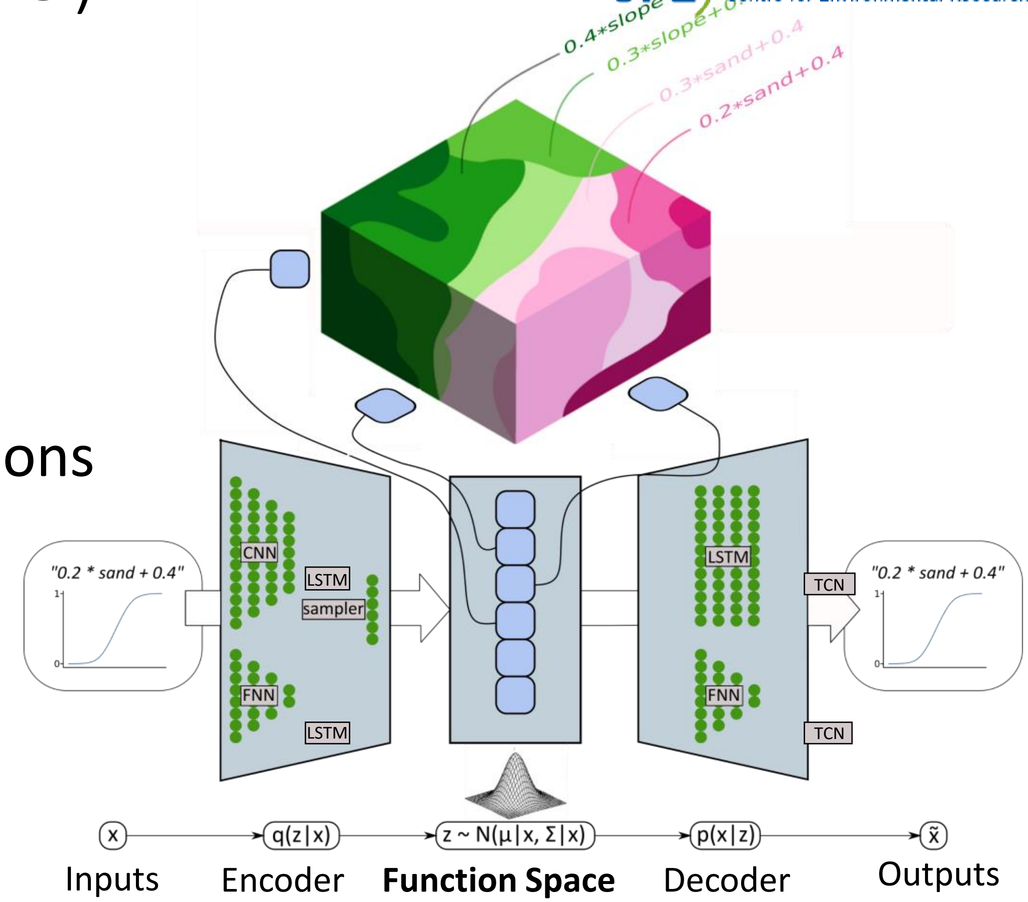
Transfer Functions



Transfer functions map geophysical catchment properties to distributed model parameters

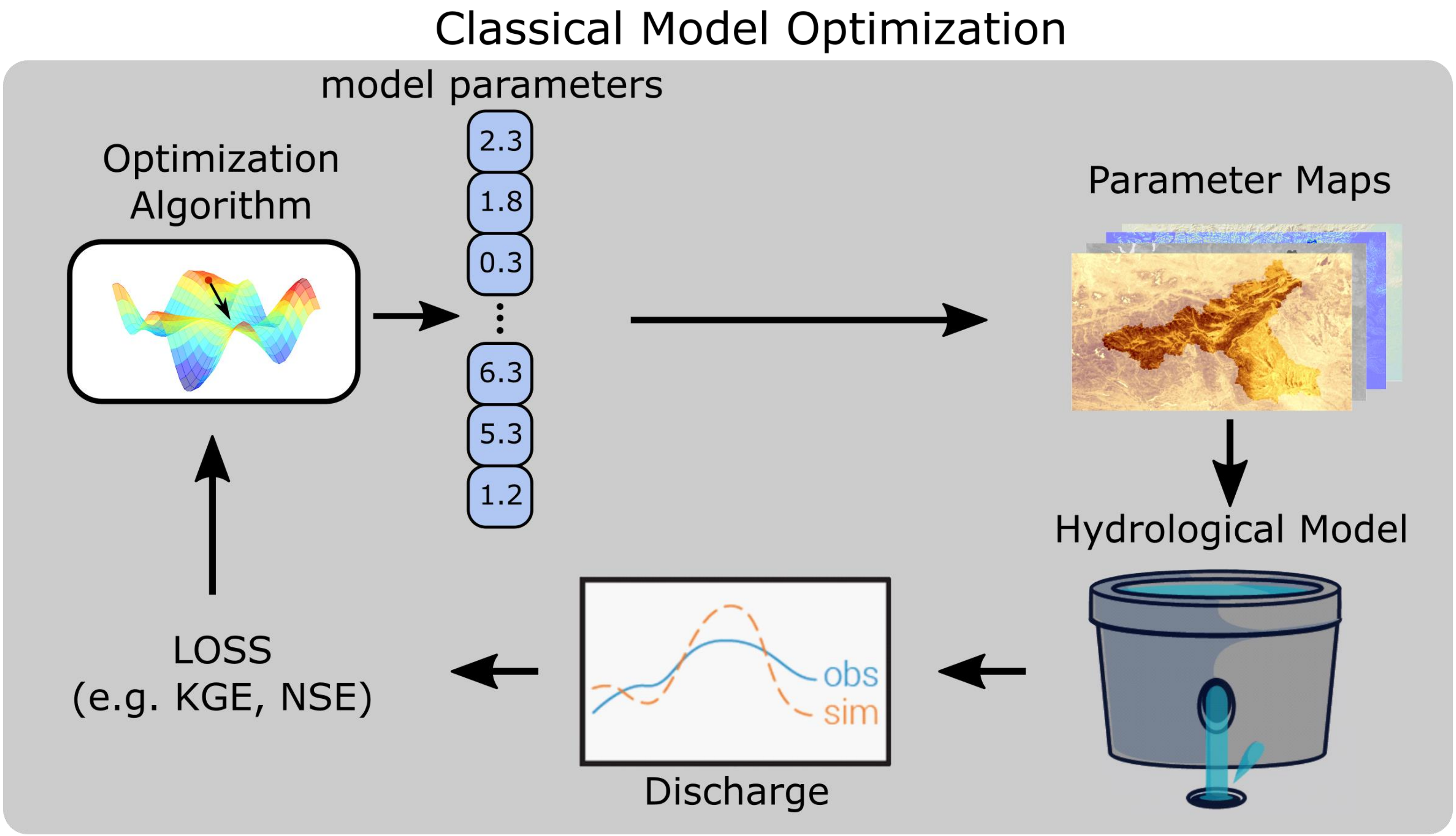
Function Space Optimization (FSO)
Feigl et al., 2020

- FSO: optimization method for transfer functions
- Uses a text generating Neural Network
- Transforms search into continuous problem
- Successfully tested on a single catchment

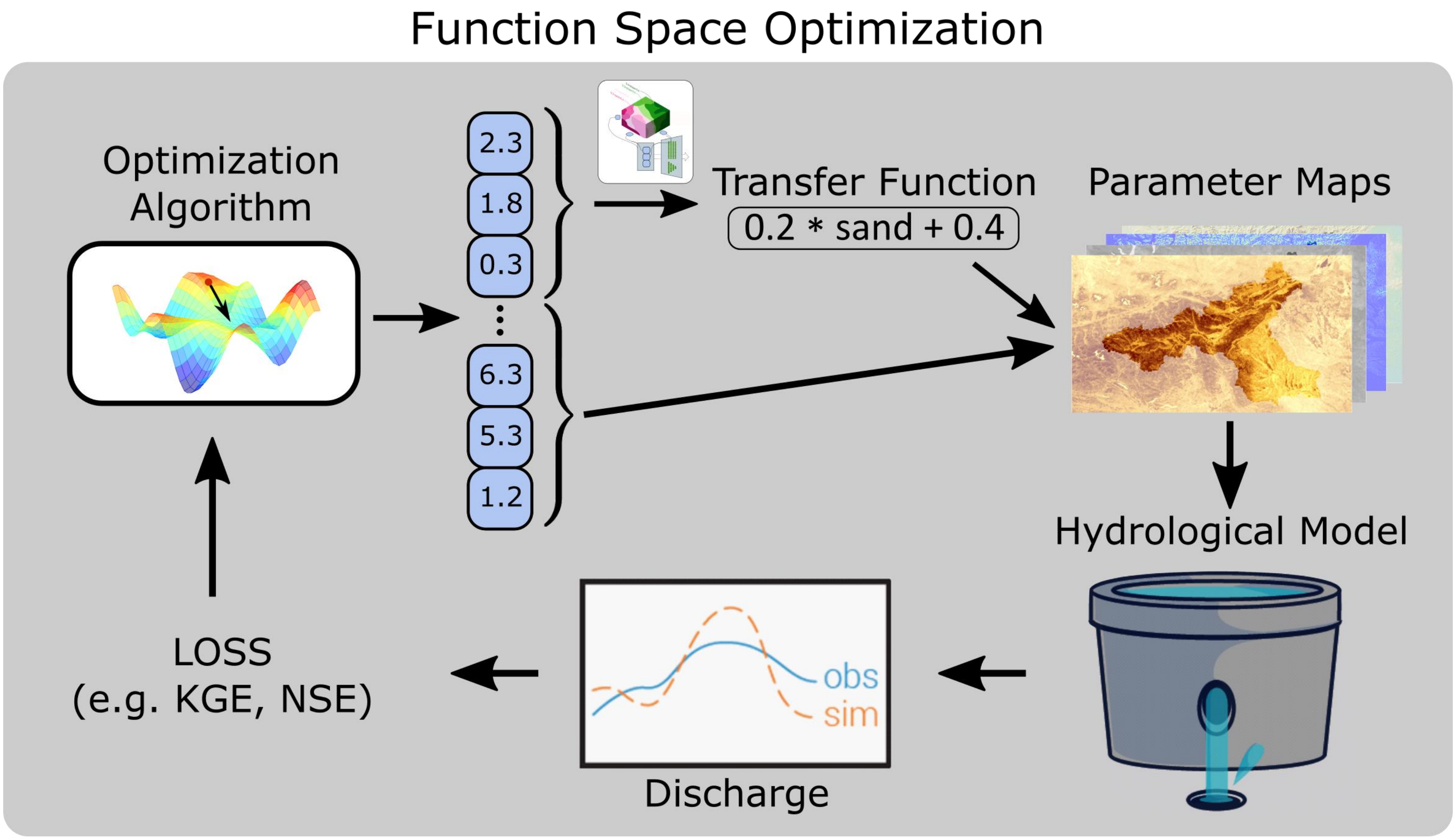


FSO variational autoencoder
Feigl et al. (2020)

Function Space Optimization (FSO)

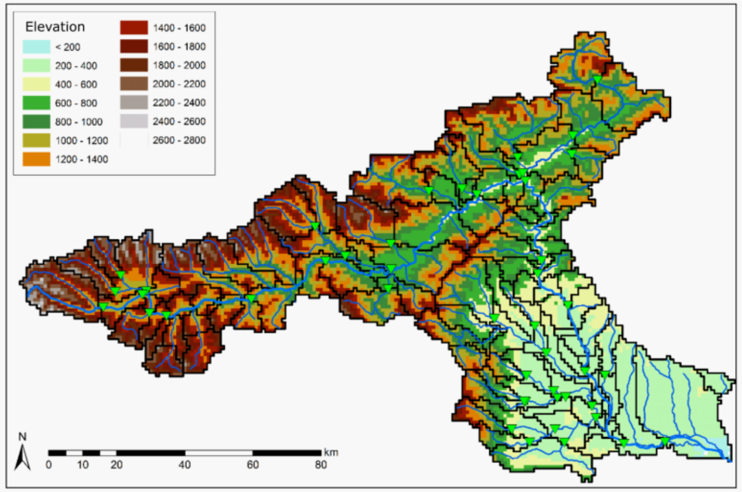


Function Space Optimization (FSO)



FSO parameter scaling

Spatial predictor

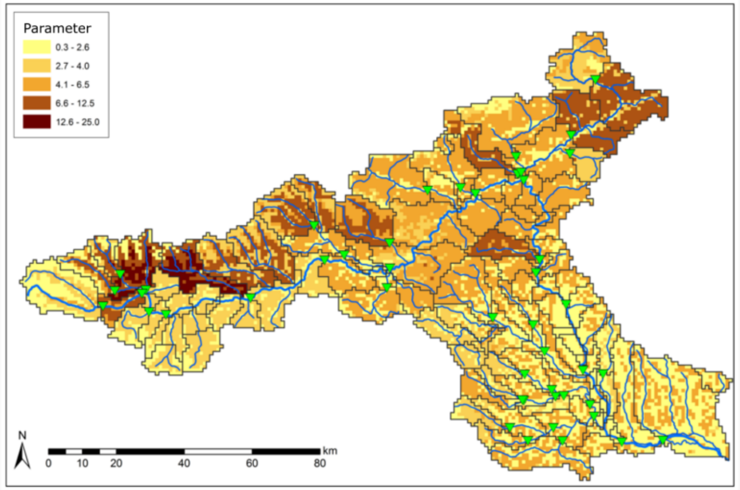


value range: e.g. elevation [0, 3000]

Transfer Function

1.3 + log(elevation) ?

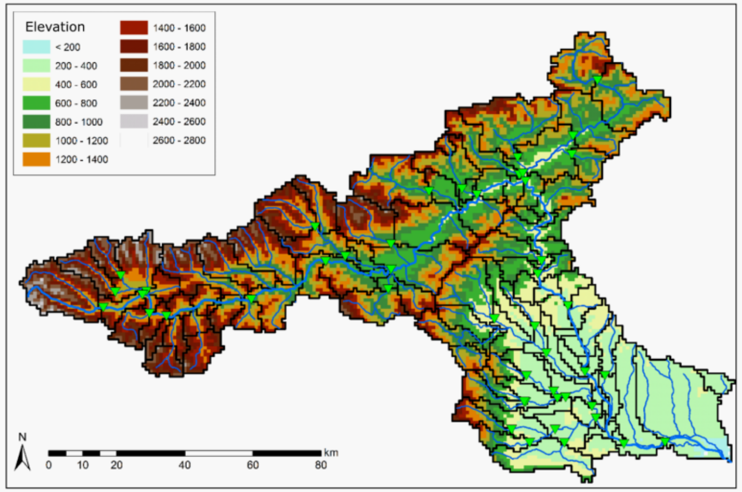
Model parameter



value range: e.g. [0, 25]

FSO parameter scaling

Spatial predictor



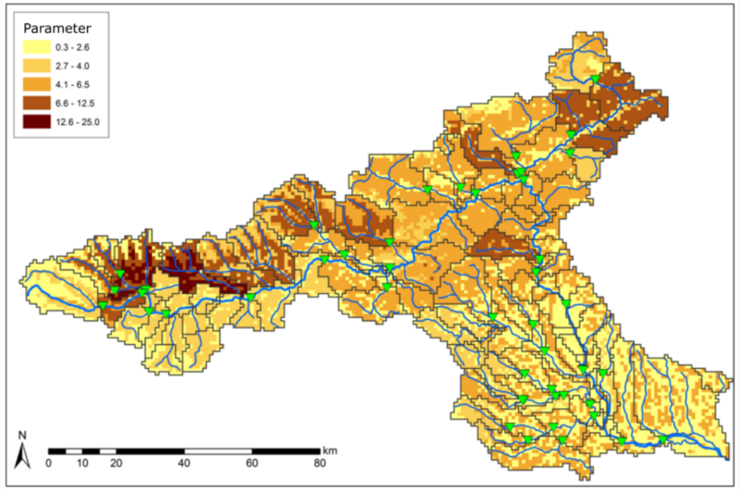
value range: e.g. elevation [0, 3000]

scale to range: [0,1]

Transfer Function

1.3 + log(elevation)

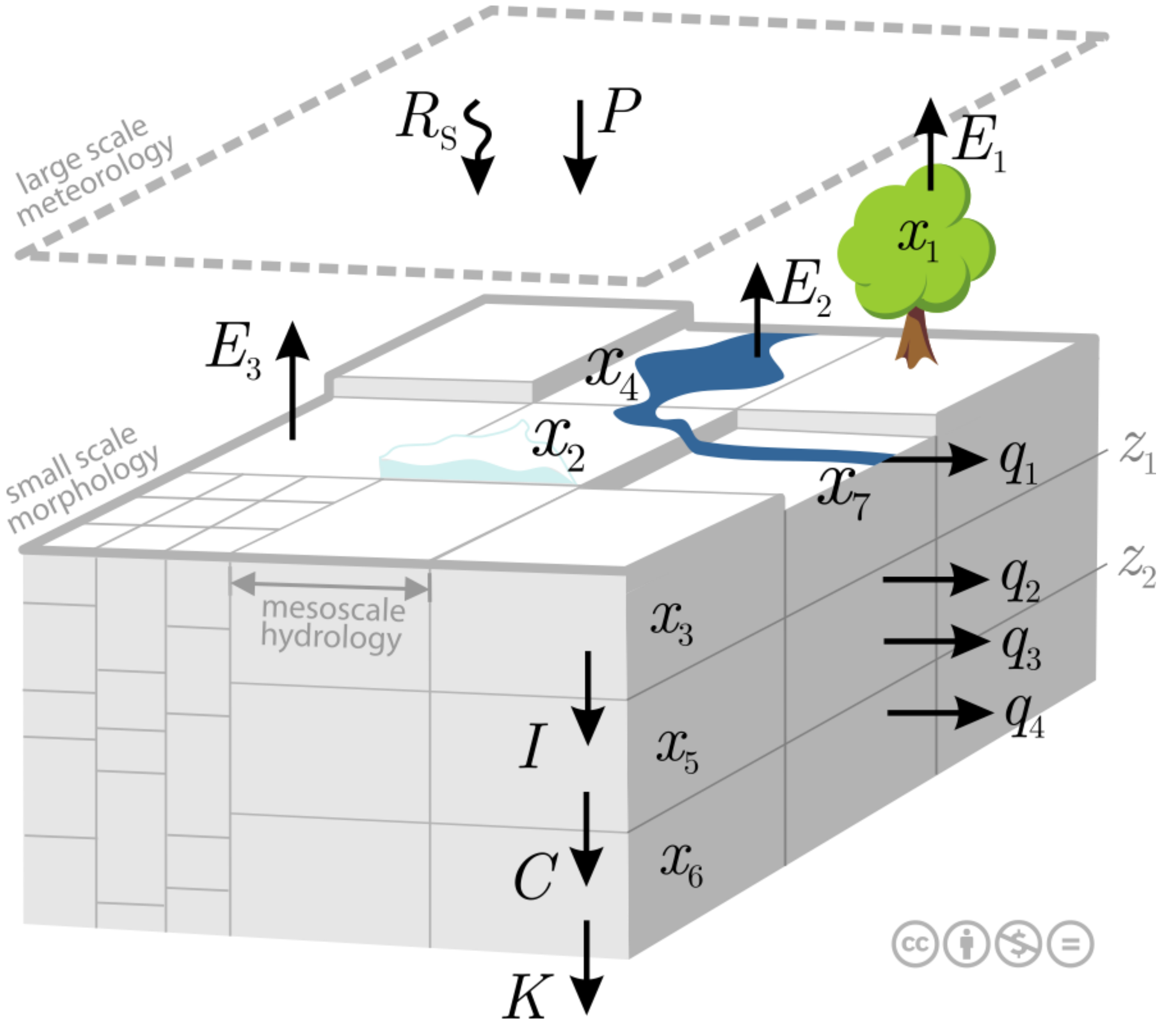
Model parameter



value range: e.g. [0, 25]

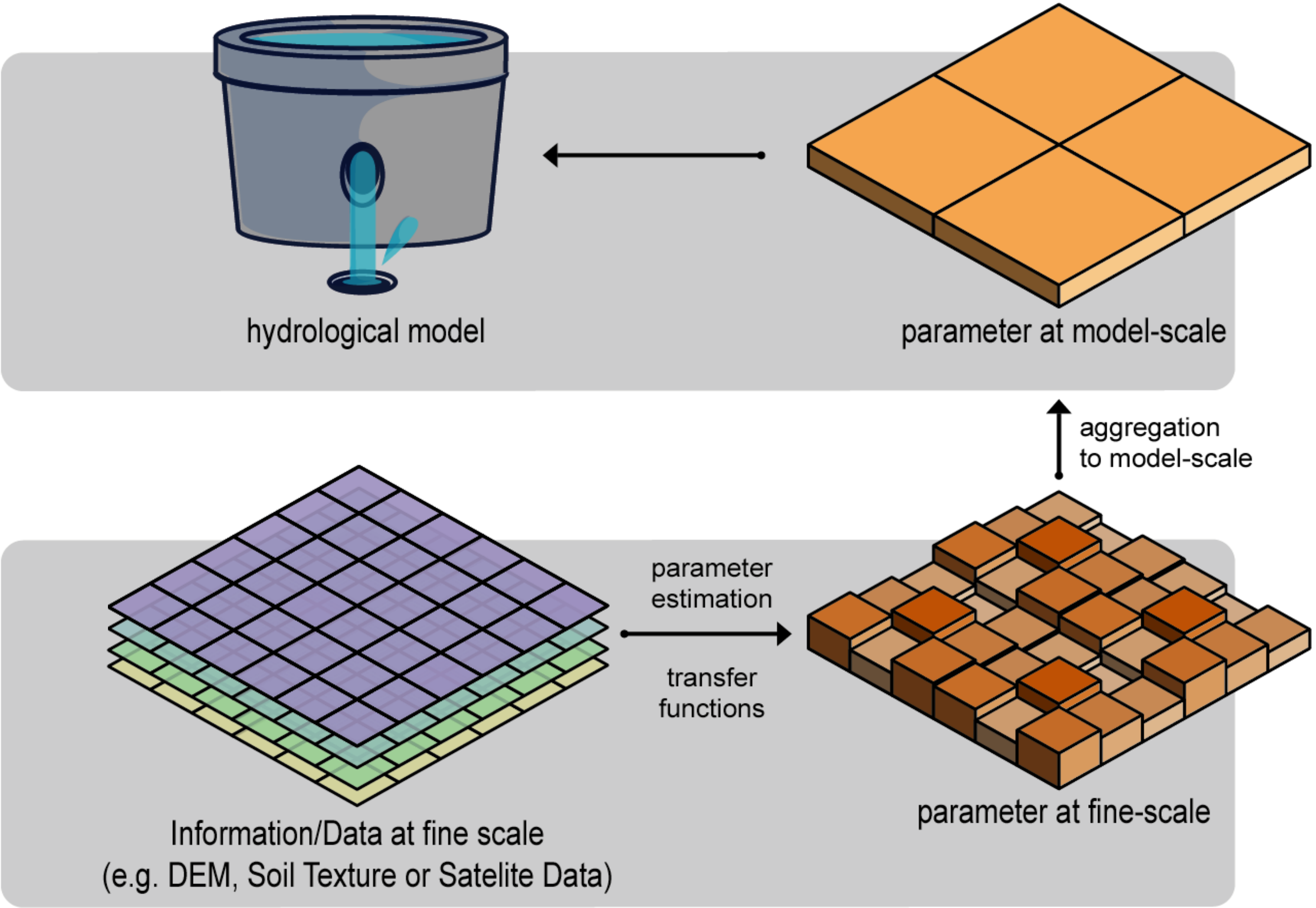
scale to parameter range: [0,25]

The mesoscale Hydrological Model (mHM)



- Developed by Samaniego et al. (2010)
- Spatially explicit distributed model
- Uses grid cells as primary units
- Defines parameter fields with the Multiscale Parameter Regionalzation method (MPR)

Multiscale Parameter Regionalization (MPR)



Regionalization method by Samaniego et al. (2010)

Benchmark Study – Zink et al. (2017)

Hydrol. Earth Syst. Sci., 21, 1769–1790, 2017
www.hydrol-earth-syst-sci.net/21/1769/2017/
doi:10.5194/hess-21-1769-2017

Hydrology and Earth System Sciences
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A high-resolution dataset of water fluxes and states for Germany accounting for parametric uncertainty

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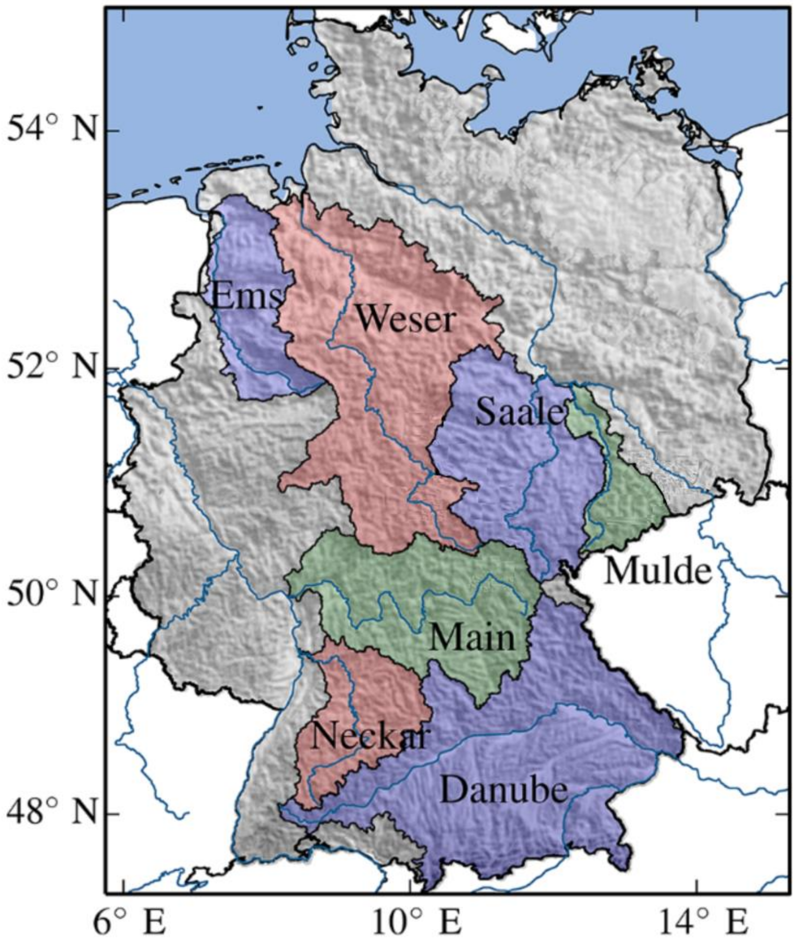
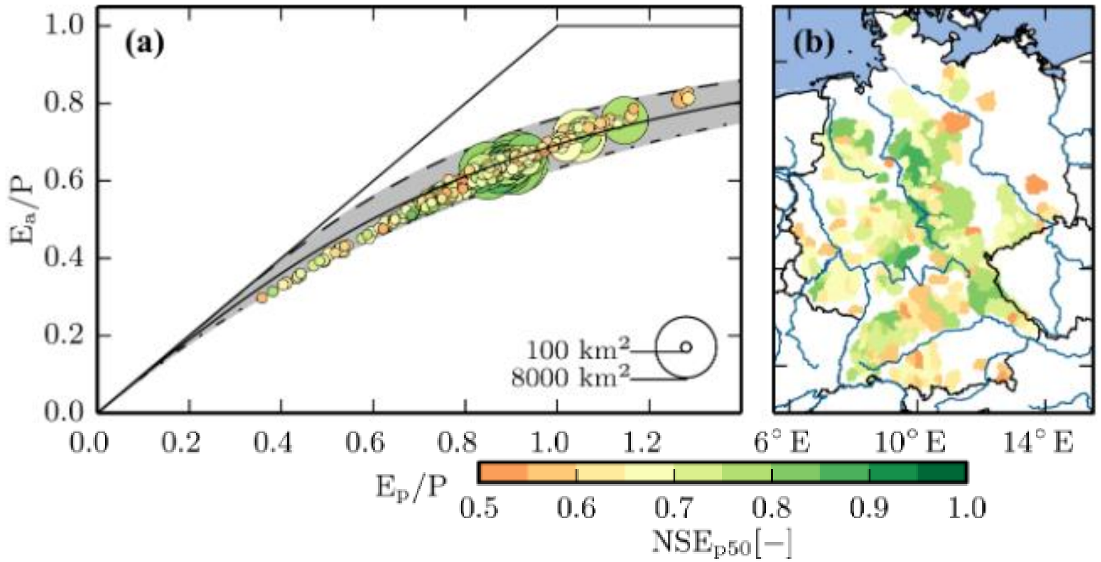
Benchmark Study – Zink et al. (2017)



Training basins

(Zink et al., 2017)

- Optimizing mHM 100 times with 2000 iterations
- Using 7 gauging stations
- Validate 100 parameter sets on 220 Basins



Validation basins

(Zink et al., 2017)

Study Objectives

1. Apply FSO using a wide range of catchments
2. Simultaneously optimize 2 transfer functions and all other numerical parameters
3. Optimize: Saturated Hydraulic Conductivity, Field Capacity
4. Analyze performance and transferability in a prediction in ungauged basins (PUB) setting
5. Compare original mHM tranfer functions with FSO estimates

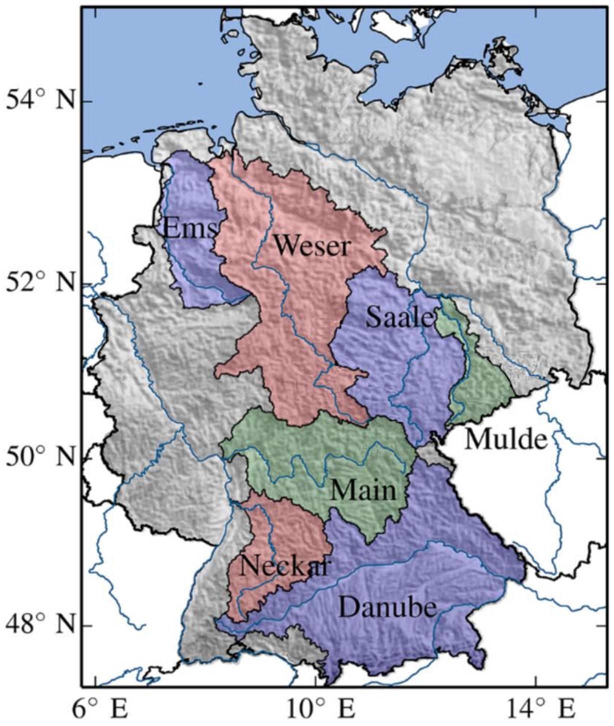
Case study – study basins

7 Training basins, 220 Validation Basins

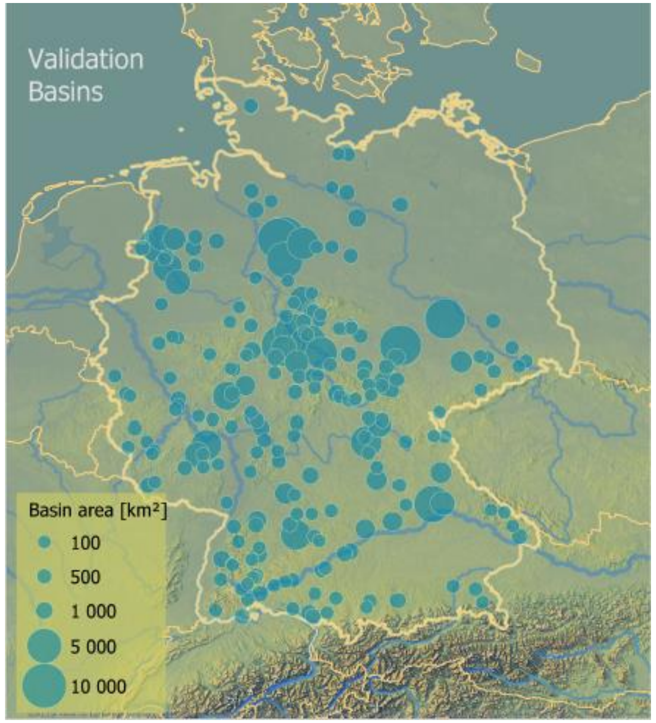
Resolution:
Spatial predictors: 100 x 100 m
Model grid: 4 x 4 km

Spatial predictors:
Mean sand percentage (sand)
Mean clay percentage (clay)
Mineral bulk density
Aspect
Terrain slope
Elevation

Time series:
7 & 220 gauging stations
Calibration: 2000-2004
Validation: 1965-1999
Spin-up: 5 years

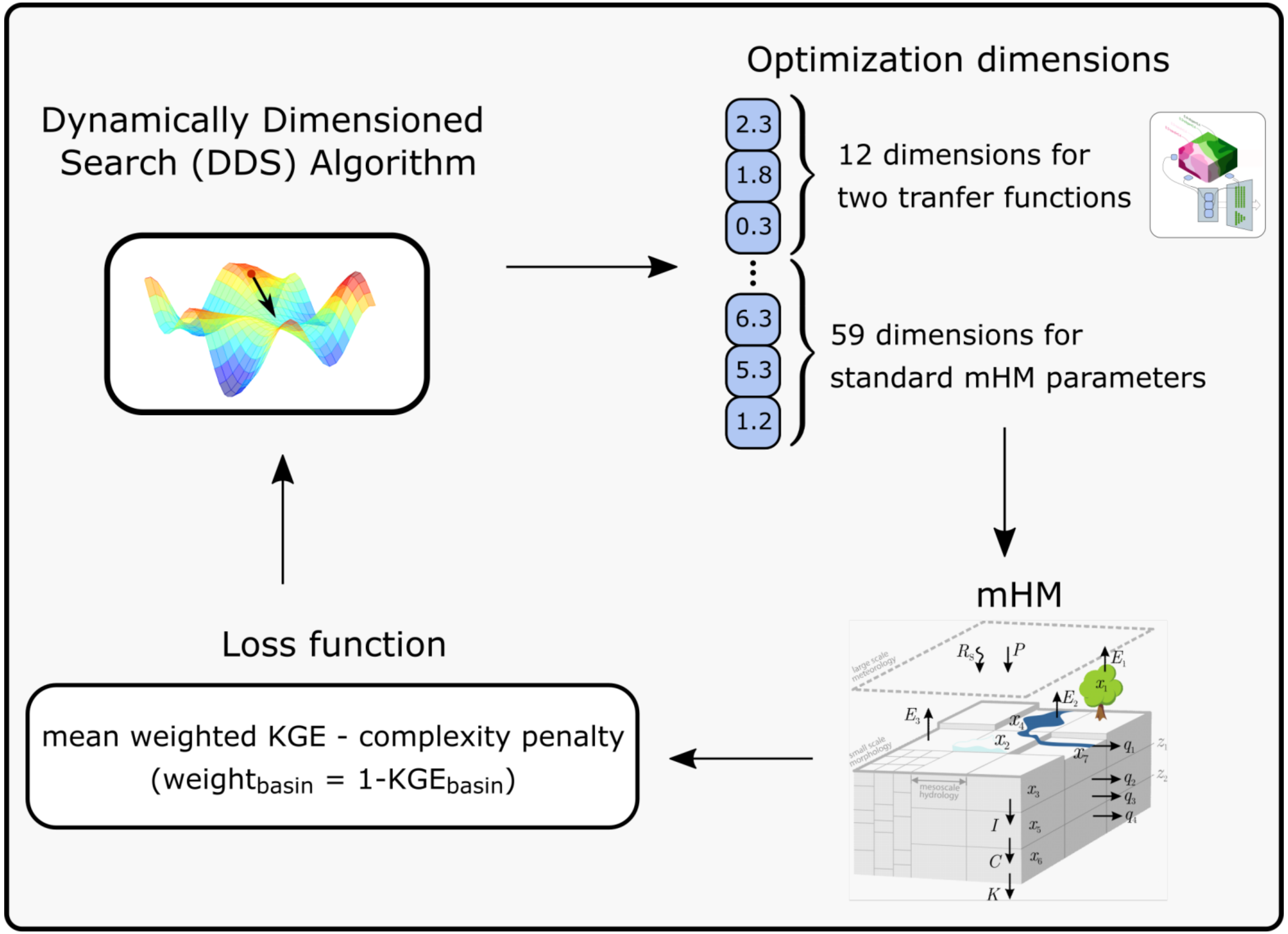


7 Training basins
(Zink et al., 2017)



220 Validation basins

Case study – Optimization



FSO optimization using the DDS algorithm (Tolson & Shoemaker, 2007)

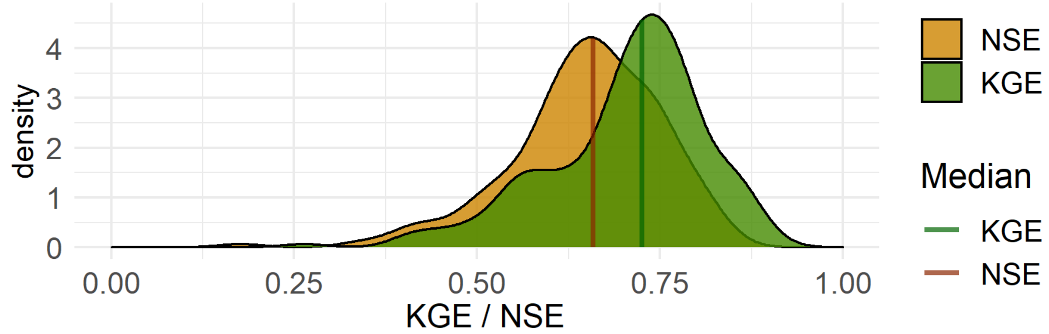
Preliminary results – 7 Training Basins

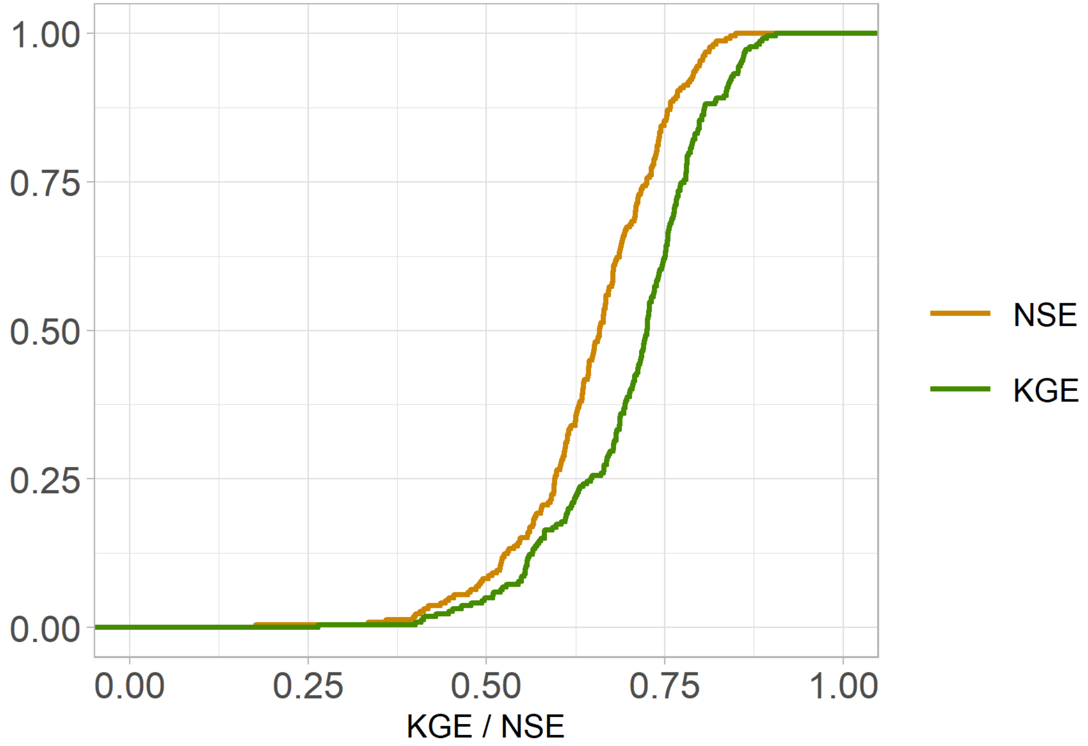
Training Basins KGE Results

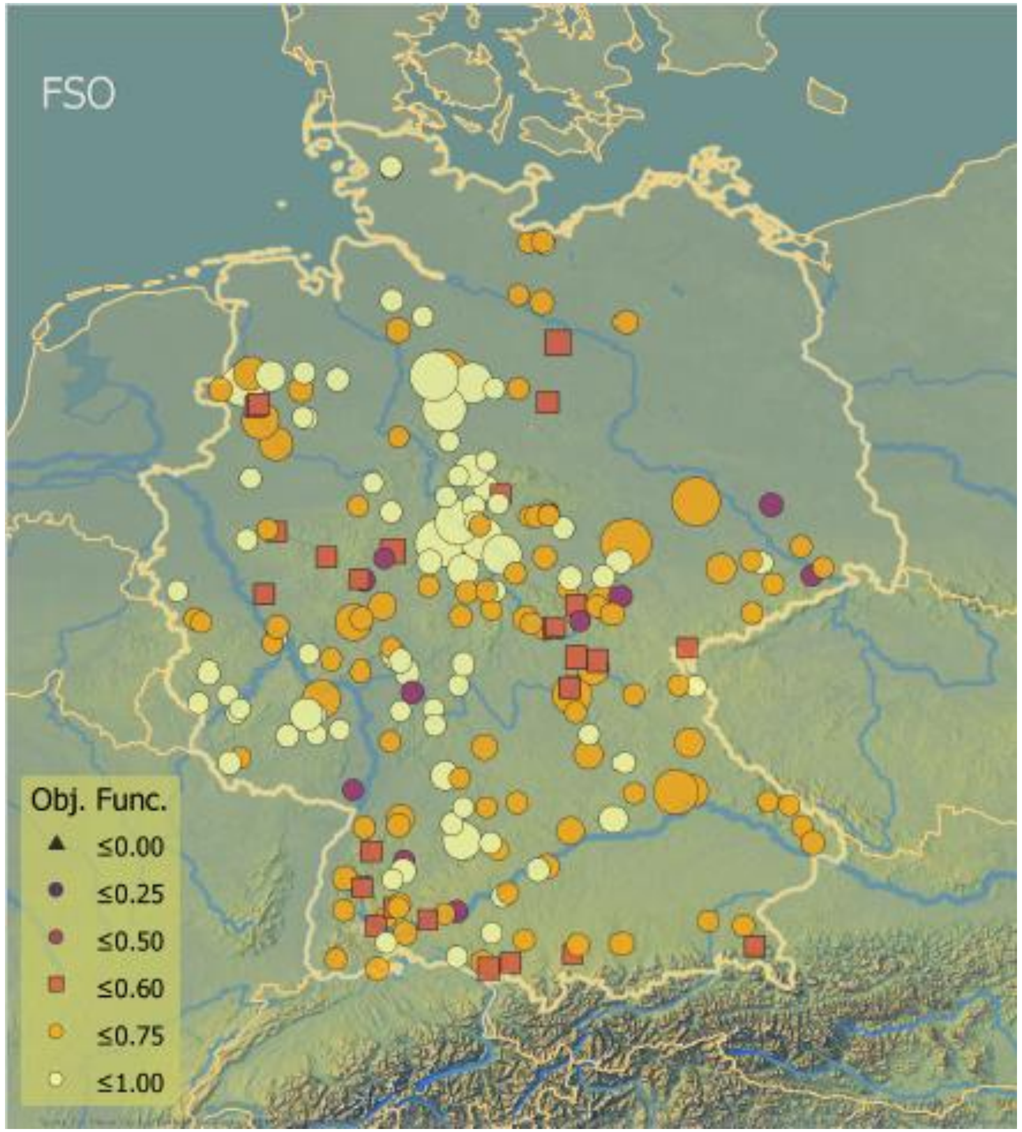
	Period	median KGE	Main	Neckar	Weser	Ems	Saale	Mulde	Donau
FSO-mHM	Calibration	0.83	0.90	0.85	0.90	0.82	0.81	0.77	0.82
	Validation	**0.80**	**0.85**	**0.83**	**0.89**	**0.80**	**0.77**	**0.65**	**0.71**

FSO results after approx. 900 iterations

Preliminary results –220 validation basins







Imhof-Like Background Topography by @John_M_Nelson

Preliminary results – estimated transfer functions

Saturated hydraulic conductivity (cm/d):

mHM: $\mathrm{KSat} = \gamma_1 * \exp(\gamma_2 + \gamma_3 * \mathrm{sand} - \gamma_4 * \mathrm{clay}) * \log(10)$

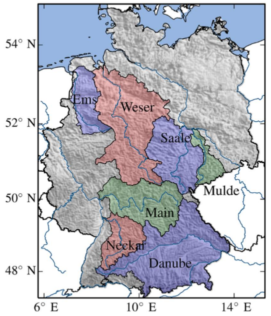
FSO-mHM: $\mathrm{KSat} = \mathrm{elevation} + \exp(\mathrm{bulk\ density}) - 3.14$

Field Capacity (-):

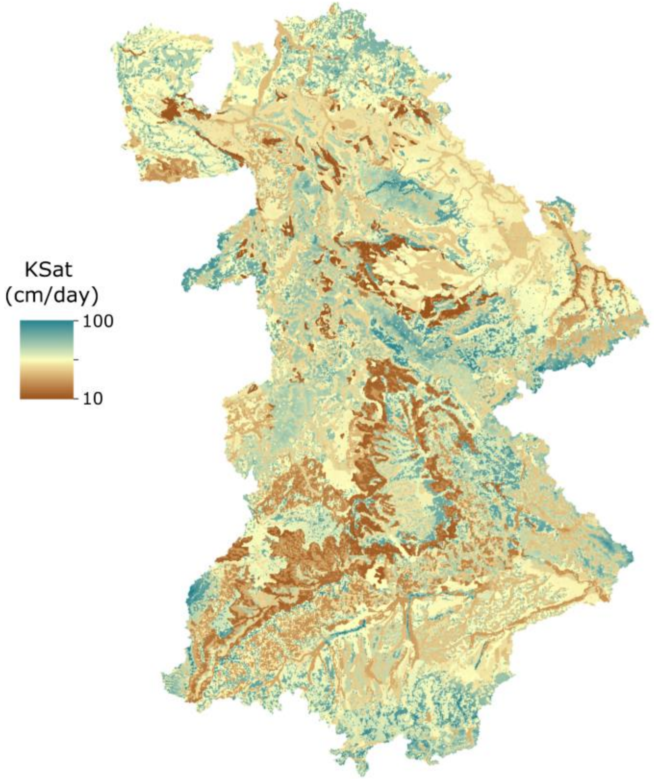
mHM: $\mathrm{FieldCap} = \mathrm{ThetaS} * \exp(\gamma_5 * (\gamma_6 + \mathrm{log10(KSat)}) * \log(\mathrm{vGenu\_n})$

FSO-mHM: $\mathrm{FieldCap} = -0.336^{\sqrt{0.333/\sqrt{\mathrm{bulk\ density}}}}$

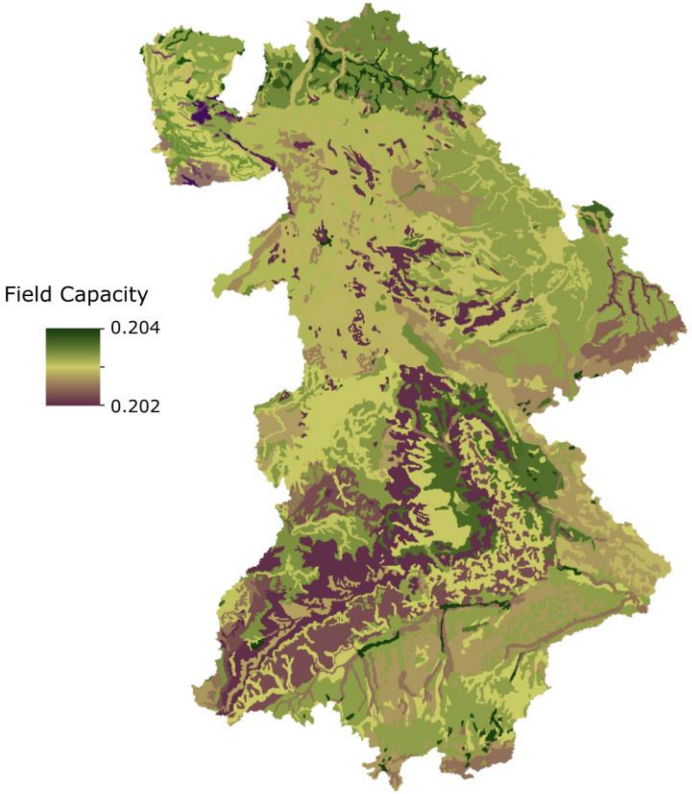
Preliminary results – estimated parameter fields



Saturated Hydraulic Conductivity (cm/day)



Field Capacity (-)



Resulting parameter fields on the 100 x 100 m grid for the top layer of the model (tillage layer, first 20 cm)

Summary, Discussion & Outlook

- FSO **trained with 5 years data of 7 gauging stations**:

  training median KGE = 0.80

  PUB median KGE = 0.73

- Preliminary results look promising →only 900 iterations
- Field Capacity is constant → most likely local minimum → continue optimization
- Multiple longer optimization runs needed for robust performance evaluation
- Compare validation basins results with performance of Zink et al. (2017)
- Comparison of final FSO parameter fields to geophysical properties

References

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