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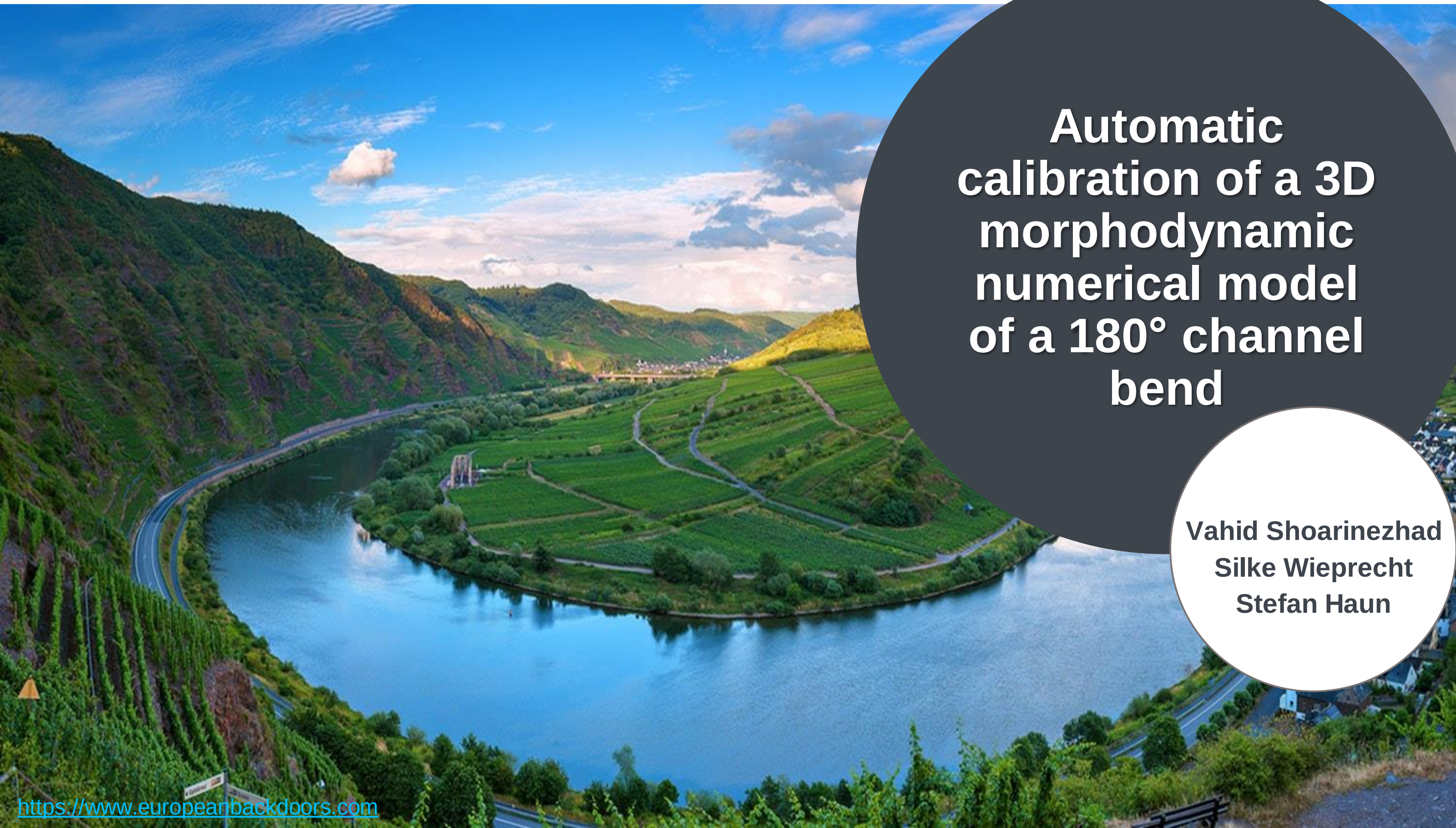

Automatic calibration of a 3D morphodynamic numerical model of a 180° channel bend

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https://www.europeanbackdoors.com

Introduction & Background

- The quality of numerical modelling outputs depends on how well the physical processes can be mathematically described through
  - governing equations
  - discretization schemes
  - boundary conditions
  - empirical formulas
  - input parameters (numerical & physical)
- The relationship between data, such as direct observations and recorded measurements, and numerical models is very complicated in the 'water domain'.

→ uncertain input variables which cannot be measured directly

→ limitation in measured data for model calibration (certain locations over a finite duration)

Introduction & Background

- The model accuracy and its prediction reliability strongly depend on the calibration procedure by adjustment of the uncertain input parameters.

Model Calibration

- Manual → trial-and-error adjustment of input values
  - complex, subjective, time-consuming
- Automated → using optimization algorithms

gradient-based (Local) algorithms

- \+ computationally efficient
- − can be trapped in a local minimum

population-evolution-based (Global) algorithms

- − computationally demanding
- \+ robust in finding the global minimum

Methods

➢ Experimental Data (Yen & Lee 1995)

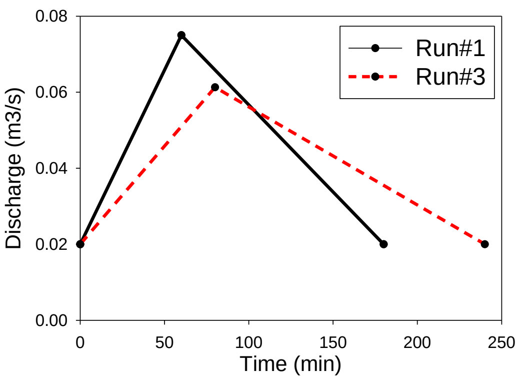
- 20 cm non-uniform sand $d_{50} = 1.0$ mm
- standard deviation of the particle size distribution $\sigma = 2.5$
- initial bed slope $S_0 = 0.002$
- base flow discharge $Q_0 = 0.02$ m^3/s and depth $h_0 = 5.44$ cm
- unsteady inflow with two different hydrographs

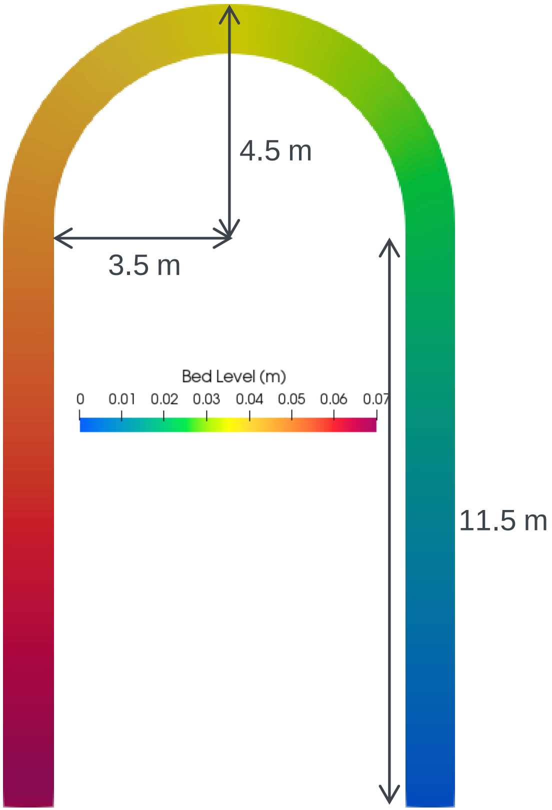
▪ *Run#1*: T= 180 min

$Q_{peak} = 0.0750$ m^3/s

▪ *Run#3*: T= 240 min

$Q_{peak} = 0.0613$ m^3/s





Methods

➤ Numerical Model (SSIM2)

Grid

- adaptive 3-D, non-orthogonal grid
- wetting and drying algorithm
- finite-volume approach for the spatial discretization
- grid size: 225 × 20 × 5 cells

Hydrodynamics

- RANS equations
  - Reynolds stress term → k-ε turbulence model
  - pressure term → semi-implicit method (SIMPLE)
  - convective term → second-order upwind (SOU) scheme
  - implicit scheme for the temporal discretization

Sediment Transport

- 8 grain size classes
- bedload transport calculation by using the formulas of
  - van Rijn
  - Engelund/Hansen
  - Einstein
  - Wu

Methods

➢ Calibration

- PEST (Parameter ESTimation)→ a model-independent, non-linear inverse modeling code
  - optimization algorithm: Gauss-Marquardt-Levenberg (GML)
  - objective function: sum of the squared residuals $$\Phi = \sum_{i=1}^{m} (w_i(s_i - o_i))^2$$
  - inverse problem solver: singular value decomposition (SVD)

- Investigated parameters

Parameter	Initial value	Lower bound	Upper bound
Roughness height (k_s)	d_{90}	d_{50}	$10d_{90}$
Active layer thickness (ALT)	d_{max}	d_{50}	$5d_{max}$
Volume fraction of sediments/water content (VFS)	50%	40%	60%

d_{50} = 0.1 cm
d_{90} = 0.32 cm
d_{max} = 0.85 cm

Results

Calibrated Parameter	Sediment Transport Formula							
	van Rijn		Engelund-Hansen		Einstein		Wu	
	Run#1	Run#3	Run#1	Run#3	Run#1	Run#3	Run#1	Run#3
k_s (*cm*)	0.63	0.61	0.48	0.31	2.09	1.71	1.52	1.34
ALT (*cm*)	2.20	1.94	1.31	1.12	3.43	2.42	2.04	1.85
VFS (%)	60	60	52	51	51	53	49	51

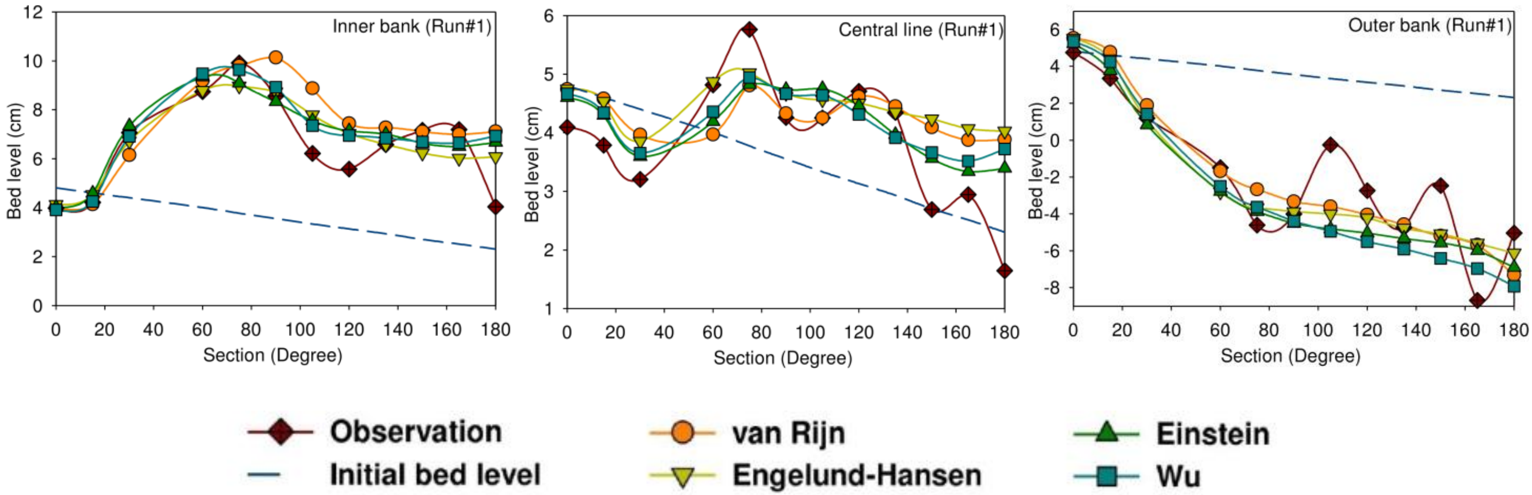
- The sediment packing volume in comparison to the water content remains almost constant around 50%, independent of the discharge alteration. → exception: van Rijn
- The thickness of the active layer and the roughness height rise by the increase of the flow discharge.

Results

- Bed levels of the bend along 3 longitudinal-sections

➢Run#1

10 cm from the inner wall | central radius | 10 cm from the outer wall

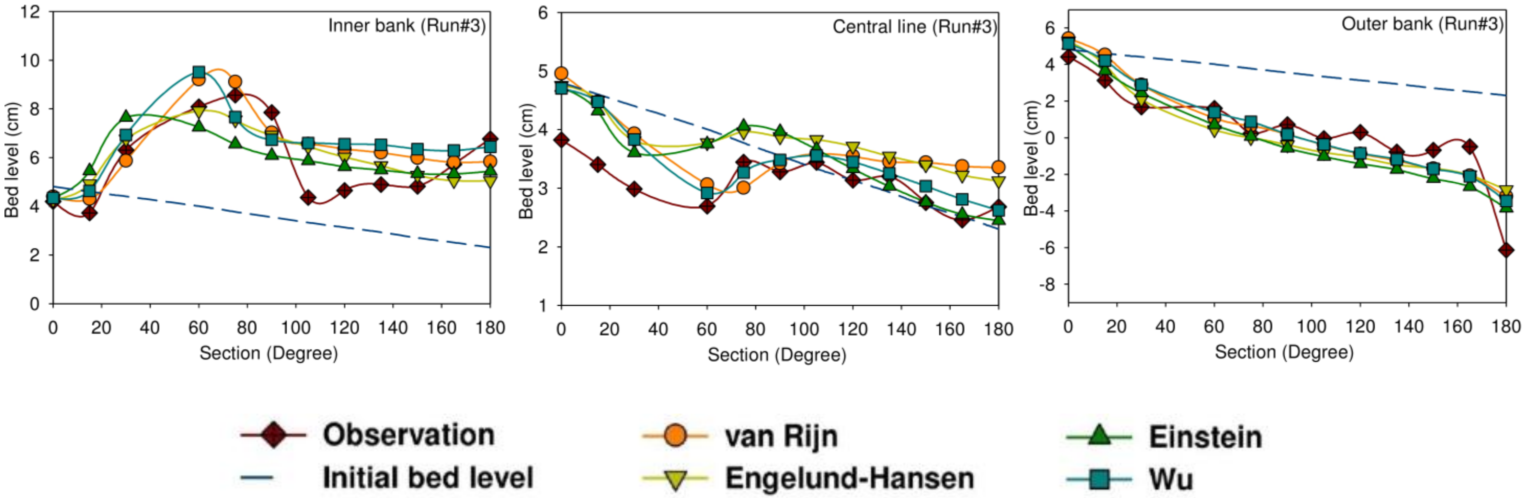


Results

- Bed levels of the bend along 3 longitudinal-sections

➢ Run#3

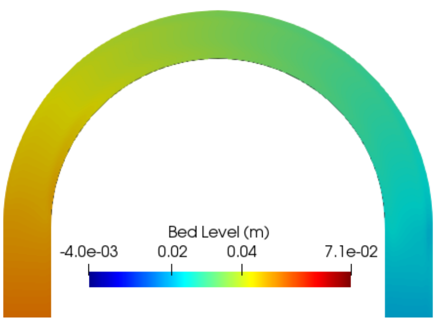
10 cm from the inner wall | central radius | 10 cm from the outer wall



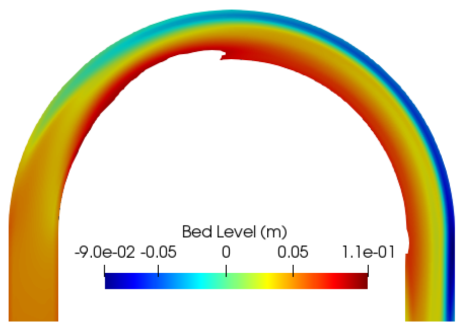
Results

- Statistical performance of the calibrated models

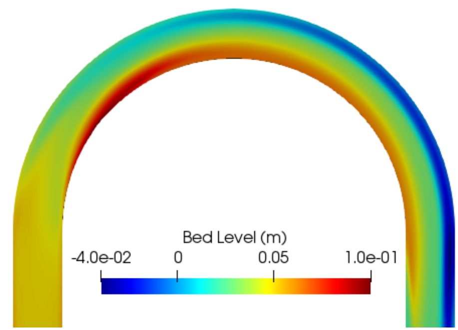
Goodness of Fit	Sediment Transport Formula							
	van Rijn		Engelund-Hansen		Einstein		Wu	
	Run#1	Run#3	Run#1	Run#3	Run#1	Run#3	Run#1	Run#3
R^2(-)	0.90	0.89	0.88	0.83	0.89	0.84	0.90	0.89
RMSE (cm)	1.57	1.08	1.63	1.33	1.61	1.25	1.49	1.04



Initial bed level



Final bed level Run#1, Wu



Final bed level Run#3, Wu

Conclusion

- PEST can considerably expedite and facilitate the model calibration procedure by reducing the user-intervention.
- PEST is a gradient-based method; consequently its prediction credibility is dependent on the parameter starting value. Therefore, the calibration routine can be reassessed using different criteria for parameters.
- Based on the coefficient of determination, and the root mean squared error the calibrated model outputs obtained by Wu's formula have the best agreement with the experimental data.
- The formula by van Rijn using the hiding-exposure approach of Wu also provides reasonably acceptable results.

"*No man ever steps in the same river twice, for it is not the same river and he is not the same man*"

Heraclitus

Thank you

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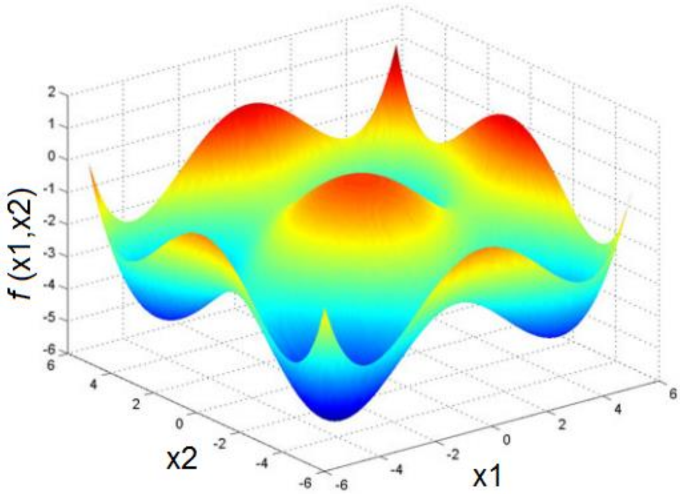

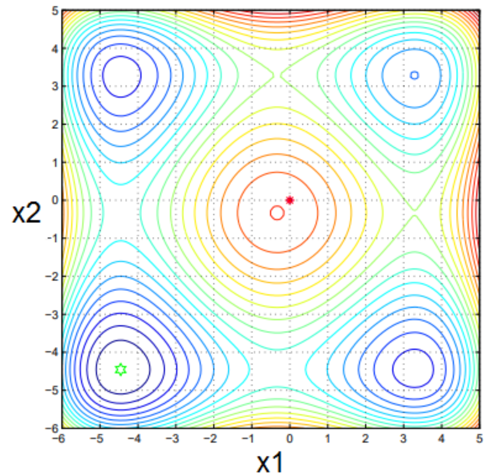

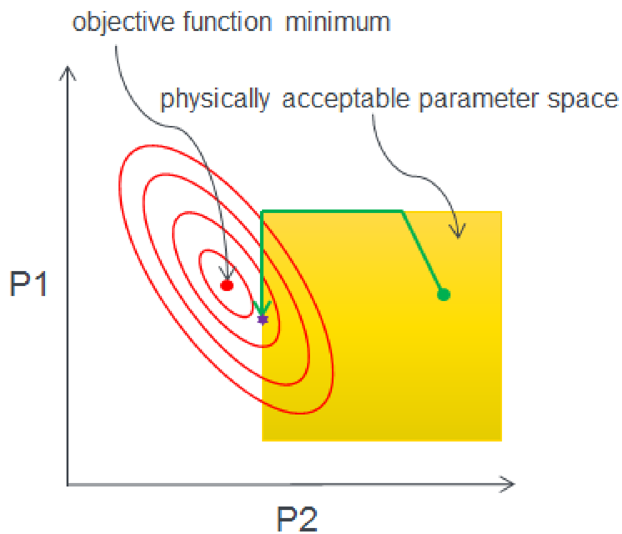

The reliability of results depends on

- initial guess of parameters
- meaningful upgrade boundaries