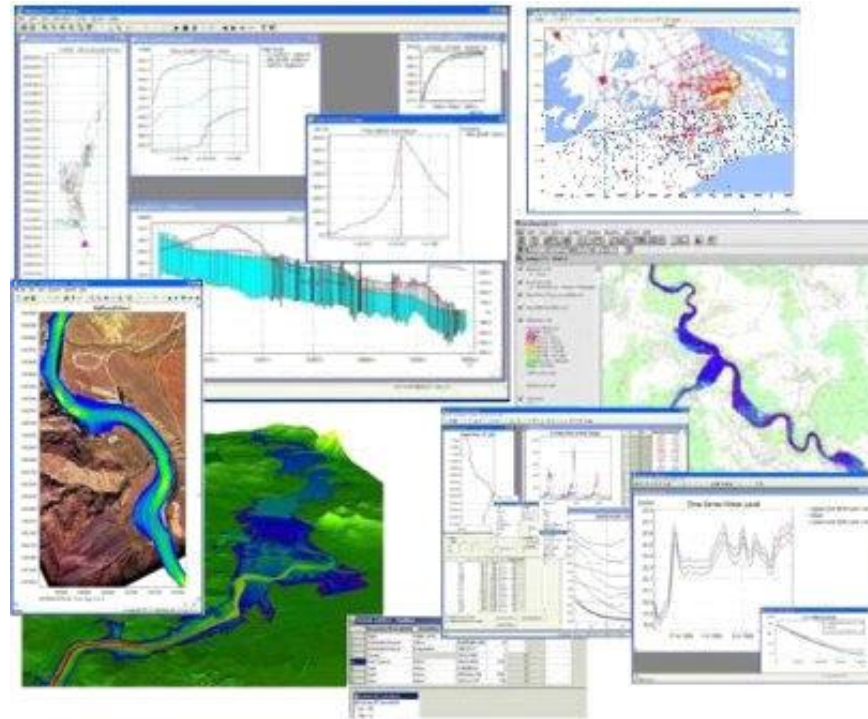


River Modelling



Assignment1: Calibration / Validation Unsteady Model



Modelling Process

Typical Modelling Steps

- data collection and pre-analysis and -processing
- model set-up (unsteady model)
- **model calibration**
- model validation
- model application
- data post-processing
-



Model Calibration and Verification

Work Steps

- **calibration**: model optimization by changing parameters for a specific simulation scenario
- specification of calibration parameters and their ranges
- specification of the target function to be optimized
-> **model evaluation**
- specification of an optimization strategy
- model **verification** with calibrated model for a simulation scenario not used for calibration
-> **model evaluation**



Model Calibration

Specific Simulation Scenario

different flood scenarios (examples)

- HQ10 -> 9470 m³/s -> ~ Nov 1998
- HQ50 -> 11500 m³/s -> ~ Jan 1995

different models (options)

- Mike11
- HEC-RAS

different geometry resolution (options)

- e.g. 100 m, 500 m, 2500 m, selected cross-sections

different roughness coefficients (main parameter)

- one Manning/Strickler value for the river section -> range: ~25-40
- different values for river bed and flood plains -> several values



Model Evaluation

Quantitative Evaluation of a Model

- specification of an objective function
- reference model/data:
 - measurements
 - (other) model results
 - target values
 - ...
- quantifying with mathematical coefficients
relationship simulation model \leftrightarrow reference



Model Evaluation

Examples of Evaluation Coefficients

- error index
 - Root Mean Square Error (RMSE)
 - Percent bias (PBIAS)
- standard regression
 - Pearson's correlation coefficient (r)
 - Coefficient of determination (R^2)
- dimensionless evaluation
 - Nash-Sutcliffe efficiency (NSE)

Model Evaluation Coefficients

Root Mean Square Error (RMSE)

standard deviation of the residuals/errors

- $$RMSE = \sqrt{\frac{\sum_{i=1}^n (V_i^{obs} - V_i^{sim})^2}{n}}$$
 coefficient ≥ 0

Percent Bias (PBIAS)

average tendency of the simulated data to be larger or smaller than their observed counterparts

- $$PBIAS = \frac{100 \times \sum_{i=1}^n (V_i^{obs} - V_i^{sim})}{\sum_{i=1}^n V_i^{obs}}$$

Model Evaluation Coefficients

Pearson's correlation coefficient (r)

linear correlation between observed values and simulated values

- $$r = \frac{\sum_{i=1}^n (V_i^{obs} - V_{mean}^{obs})(V_i^{sim} - V_{mean}^{sim})}{\sqrt{\sum_{i=1}^n (V_i^{obs} - V_{mean}^{obs})^2} \sqrt{\sum_{i=1}^n (V_i^{sim} - V_{mean}^{sim})^2}}$$
 coefficient: $-1 \leq r \leq 1$

$\pm 0.5 < r \leq \pm 1.0$ high correlation

$\pm 0.3 < r \leq \pm 0.5$ medium correlation

$\pm 0.1 < r \leq \pm 0.3$ low correlation

$r = 0.0$ no correlation

$r = \pm 1.0$ perfect linear relationship

Coefficient of determination $R^2 = r^2$

Model Evaluation Coefficients

Nash-Sutcliffe efficiency (NSE)

relative magnitude of the residual variance compared to the measured data variance

- $$NSE = 1 - \frac{\sum_{i=1}^n (V_i^{obs} - V_i^{sim})^2}{\sum_{i=1}^n (V_i^{obs} - V_{mean}^{obs})^2}$$
 coefficient: $0 \leq NSE \leq 1$

$$0.75 < NSE \leq 1.00$$

very good

$$0.65 < NSE \leq 0.75$$

good

$$0.50 < NSE \leq 0.65$$

satisfactory

$$NSE \leq 0.5$$

unsatisfactory

Model Calibration

Strategy Model Calibration

Calibration Parameter: roughness coefficient (Manning/Strickler Value)

1. unsteady simulation model setup
2. choice of roughness coefficient
3. simulation run -> simulation result file
4. model evaluation (R Script -> result file -> evaluation criteria)
5. model calibration sufficient -> yes -> stop
6. iteration to 2. by updating the roughness coefficient
 - > bisection method / interval halving method
 - > other searching functions

Model Calibration

Example Mike11 – Batch Simulation

BatchSimulation

Base simulation file: ... Number of simulations:

Available parameters:

- + Models
- + Simulation mode
- + Input files
- + Simulation period
- + Initial conditions
- + Result file

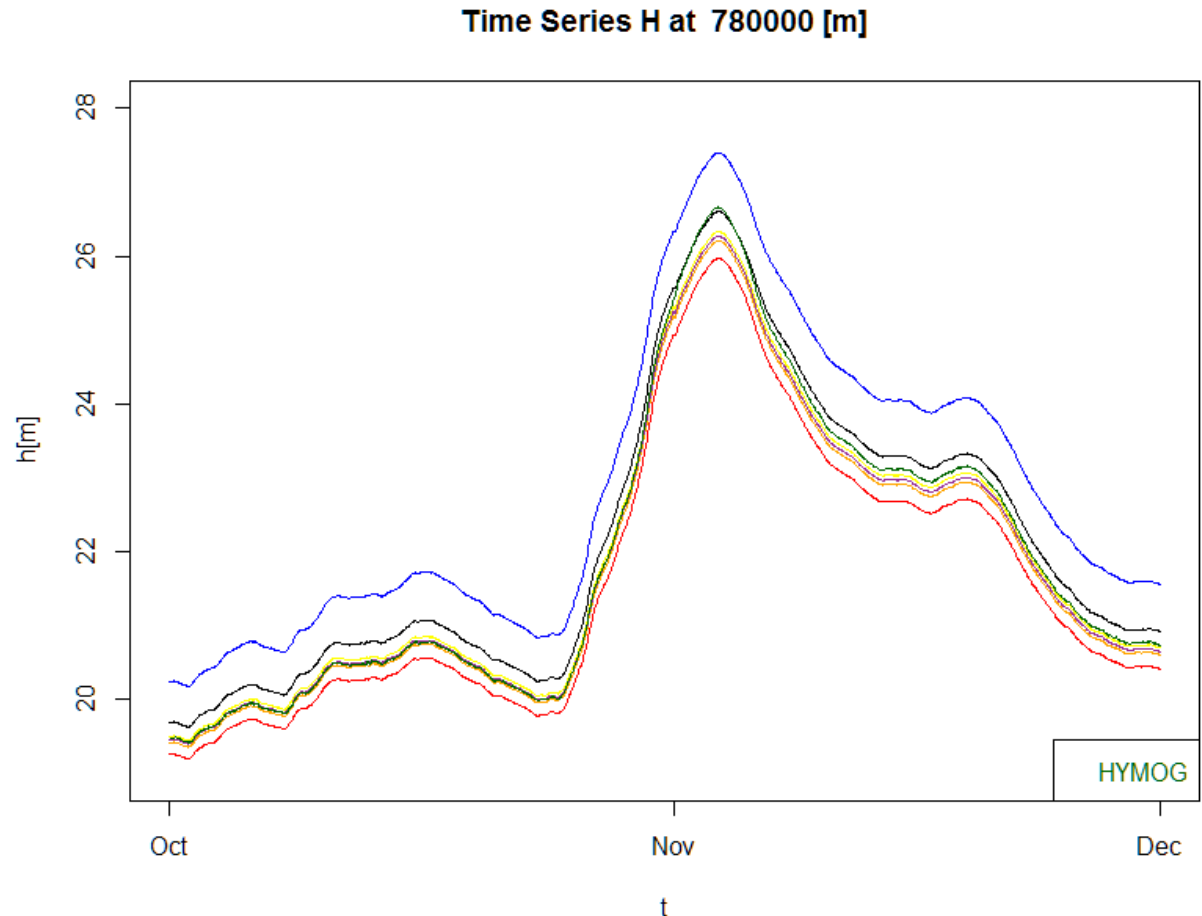
Selected parameters:

Nb.	HD result file	HD parameter
1	Result/1_HW98_S25.res11	Rhine_HDParameter_25.hd11
2	Result/2_HW98_S35.res11	Rhine_HDParameter_35.hd11
3	Result/3_HW98_S30.res11	Rhine_HDParameter_30.hd11
4	Result/4_HW98_S32.res11	Rhine_HDParameter_32.hd11
5	Result/5_HW98_S33.res11	Rhine_HDParameter_33.hd11
6	Result/6_HW98_S32_5.res11	Rhine_HDParameter_32_5.hd11

Model Calibration

Example Mike11

Ruhrort water level
for different
Strickler values



Model Calibration

Example Mike11 - Autocorrelation

Rhine_Calibration - Modified

- Auto Calibration
 - ✓ Simulation Specifications
 - ✓ Model Parameters
 - ✓ Objective Functions
 - ✓ Parameter Optimisation
 - ✓ Save Output Files
 - ✓ Office Grid

Simulation Specifications

	Model simulation sequence	Optional arguments
1	C:\Users\...2Month_ModelRhine_Simulation.sim11	

	Model parameter file	Template file
1	C:\Users\...2Month_ModelRhine_HDParame	C:\Users\...2Month_ModelRhine_HDParame Edit

Setup Output

AUTOCAL simulation: Rhine_Calibration

Simulation option: Parameter optimisation

Algorithm: Shuffled Complex Evolution

Evaluation of parameter set No. 1 initiated
 C:\Program Files (x86)\DHI\2009\bin\Mikell.exe -s "C:\Users\molkenthin\Desktop\River_Rhine\Rhein_Mikell_Frank\2Month_Model\Rhine_Simulation.sim11": OK

Evaluation of parameter set No. 2 initiated
 C:\Program Files (x86)\DHI\2009\bin\Mikell.exe -s "C:\Users\molkenthin\Desktop\River_Rhine\Rhein_Mikell_Frank\2Month_Model\Rhine_Simulation.sim11": OK

Evaluation of parameter set No. 3 initiated
 C:\Program Files (x86)\DHI\2009\bin\Mikell.exe -s "C:\Users\molkenthin\Desktop\River_Rhine\Rhein_Mikell_Frank\2Month_Model\Rhine_Simulation.sim11": OK

Evaluation of parameter set No. 4 initiated
 C:\Program Files (x86)\DHI\2009\bin\Mikell.exe -s "C:\Users\molkenthin\Desktop\River_Rhine\Rhein_Mikell_Frank\2Month_Model\Rhine_Simulation.sim11": OK

100 % 0 seconds

Validation Simulation

Model Calibration

Example Mike11 - Autocorrelation

Rhine_Calibration - Modified

- Auto Calibration
 - Simulation Specifications
 - Model Parameters**
 - Objective Functions
 - Parameter Optimisation
 - Save Output Files
 - Office Grid

Setup Output

Model Parameters

	ID value	Name	Parameter type	Initial value	Lower bound	Upper bound	Transformation	Equation	Keyword / Line no	Comment
1	1.01e-035	Strickler	Variable	25	10	40	Real		Rhine_HDPar	

Rhine_Calibration - Modified

- Auto Calibration
 - Simulation Specifications
 - Model Parameters
 - Objective Functions**
 - Parameter Optimisation
 - Save Output Files
 - Office Grid

Setup Output

Objective Functions

Evaluation period

Start date: 10/1/1998 12:00:00 AM

End date: 11/30/1998 12:00:00 PM

Aggregation of objective functions

No transformation

Objective functions

	Name	Function type	Weight
1	rsme	Weighted sum of squares	1

Output measures

	Name	Output file	Item name	Target file	Item name	Statistic type	Weight below	Weight above	Function name
1	rmse	C:\Users\...\2Month_Mode	RHEIN; 8144	C:\Users\...\2Month_Mode	H_Ruhrort	RMSE	1	1	rsme

Model Calibration

Example Mike11 – Auto Calibration

Run #	Strickler	rmse	rsme
1	0.1155E+02	0.4226E+01	0.1786E+02
2	0.3503E+02	0.3579E+00	0.1281E+00
3	0.3400E+02	0.2584E+00	0.6678E-01
4	0.3461E+02	0.3179E+00	0.1010E+00
5	0.2478E+02	0.9373E+00	0.8786E+00
6	0.2447E+02	0.9855E+00	0.9713E+00
7	0.3297E+02	0.1618E+00	0.2619E-01
8	0.3194E+02	0.9546E-01	0.9112E-02
9	0.3091E+02	0.1372E+00	0.1882E-01
...			
63	0.3184E+02	0.9397E-01	0.8830E-02
64	0.3177E+02	0.9367E-01	0.8773E-02
65	0.3006E+02	0.2227E+00	0.4959E-01
66	0.3263E+02	0.1334E+00	0.1780E-01
67	0.3177E+02	0.9366E-01	0.8773E-02

Model Calibration

Example Mike11 – Auto Calibration

...

Evaluation of parameter set No. 66 initiated

```
C:\Program Files (x86)\DHI\2009\bin\Mike11.exe -s
"C:\Users\molkenthin\Desktop\River_Rhine\Rhein_Mike11_Frank\2Month_Model\Rhine_Simulation.sim1
1": OK
```

```
*** LOOP NO  6 **No. of trials      =          66
Best obj. func.  =  0.877E-02
Worst obj. func. =  0.178E-01
```

Best parameter estimate:

Strickler = 0.318E+02

SCE optimisation terminated: Objective function convergence criterion met

Evaluation of parameter set No. 67 initiated

```
C:\Program Files (x86)\DHI\2009\bin\Mike11.exe -s
"C:\Users\molkenthin\Desktop\River_Rhine\Rhein_Mike11_Frank\2Month_Model\Rhine_Simulation.sim1
1": OK
```

Normal termination

Model Calibration

Example Mike11

Calibration Parameter: roughness coefficient (Manning/Strickler Value)

[1]	"Mike11	M	RMSE	PBIAS	r	NSE"
[1]	"	1_HW98_S25_1.txt	0.89219	4.00000	0.99945996	0.80037 "
[1]	"	2_HW98_S35_1.txt	0.36421	-1.50000	0.99982832	0.96673 "
[1]	"	3_HW98_S30_1.txt	0.21911	0.90000	0.99972930	0.98796 "
[1]	"	4_HW98_S32_1.txt	0.09895	-0.10000	0.99978583	0.99754 "
[1]	"	5_HW98_S33_1.txt	0.17224	-0.60000	0.99980549	0.99256 "
[1]	"	6_HW98_S32_5_1.txt	0.12967	-0.40000	0.99979634	0.99578 "
[1]	"	7_HW98_S31_8_1.txt	0.09327	-0.00000	0.99978127	0.99782 "



Modelling Process

Typical Modelling Steps

- data collection and pre-analysis and -processing
- model set-up
- model calibration
- **model validation**
- model application
- data post-processing
-

Model Evaluation

Strategy Model Evaluation

Application of Calibrated Model

1. analysis of available data for similar flood event
(e.g. ~HQ10 -> Jan 2003: 9482 m³/s)
2. choice of evaluation scenario
3. simulation run -> simulation result file
4. model evaluation (R Script -> result file -> evaluation criteria)
5. evaluation criteria satisfying
-> yes evaluation okay
-> no deeper analysis required

```
[1] "7_HW98_S31_8_1.txt 0.09327 -0.00000 0.99978127 0.99782 "  
[1] "      HD_2003_1.txt 0.07176 -0.10000 0.99961643 0.99838 "
```