Learning non-linearities from flow simulators

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IAHR AIRH International Association for Hydro-Environment Engineering and Research

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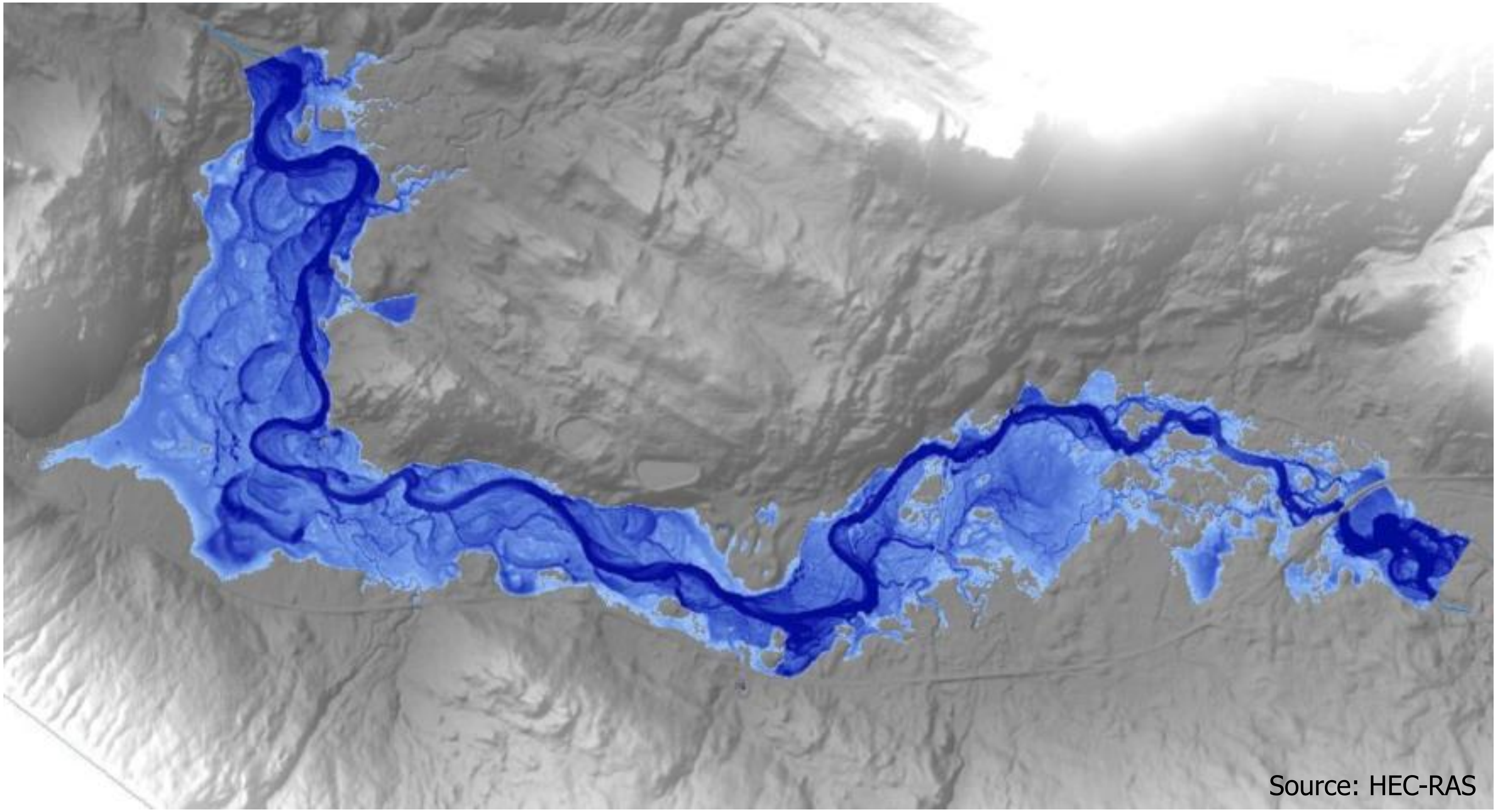
QUICS

1- Physically based flow simulators

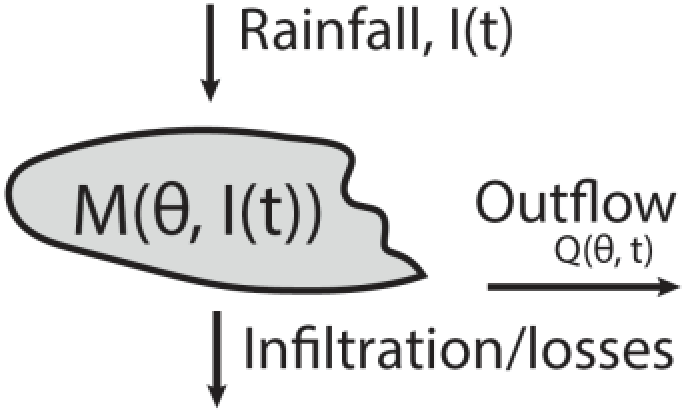
1.1 Context



1- Physically based flow simulators

1.2 Emulation of computationally expensive simulators

Simulator (e.g. 2D-SWE):



Interpolator:

$$Q(t, \theta) \approx \text{Emulator}(\theta)$$

- Gaussian Process (Carbajal et .al 2017)
- Polynomial expansion (Laloy et .al 2013)
- NN's

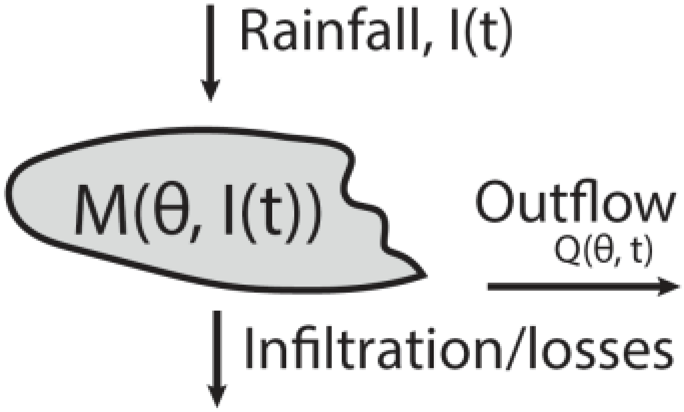
Carbajal, J. P., Leitão, J. P., Albert, C., & Rieckermann, J. (2017). Appraisal of data-driven and mechanistic emulators of nonlinear simulators: The case of hydrodynamic urban drainage models. *Environmental Modelling & Software, 92*, 17-27. doi: 10.1016/j.envsoft.2017.02.006

Laloy, E., Rogiers, B., Vrugt, J. A., Mallants, D., & Jacques, D. (2013). Efficient posterior exploration of a high-dimensional groundwater model from two-stage Markov chain Monte Carlo simulation and polynomial chaos expansion. *Water Resources Research, 49*(5), 2664-2682. doi: 10.1002/wrcr.20226

1- Physically based flow simulators

1.2 Emulation of computationally expensive simulators

Simulator (e.g. 2D-SWE):



Interpolator:

Only static parameters

$$Q(t, \theta) \approx \text{Emulator}(\theta)$$

- Gaussian Process (Carbajal et .al 2017)
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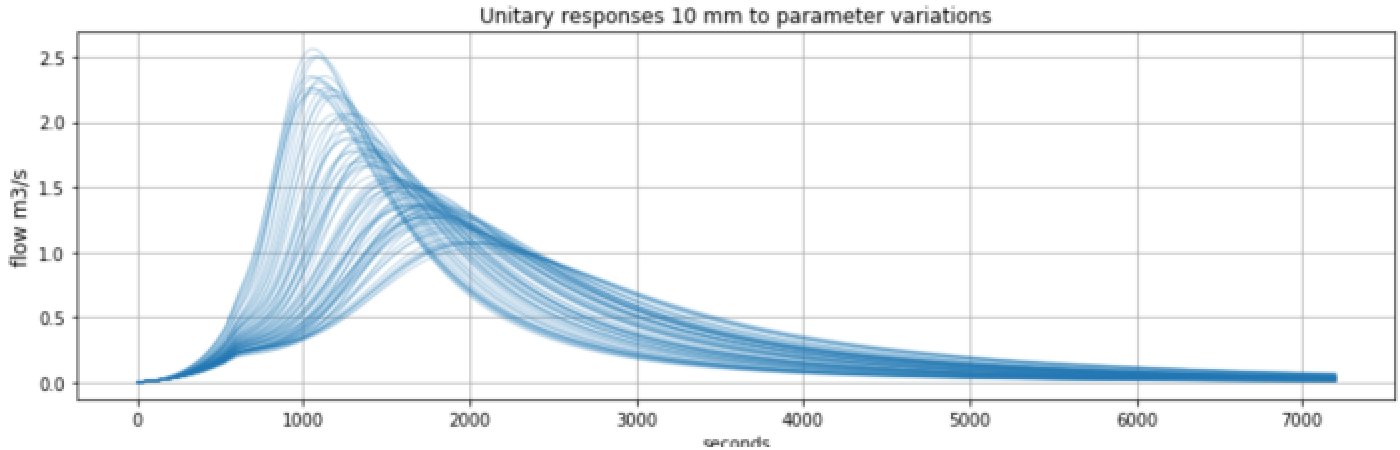
2- Emulator structure

2.1 Mapping dynamic rainfall and parameters spaces

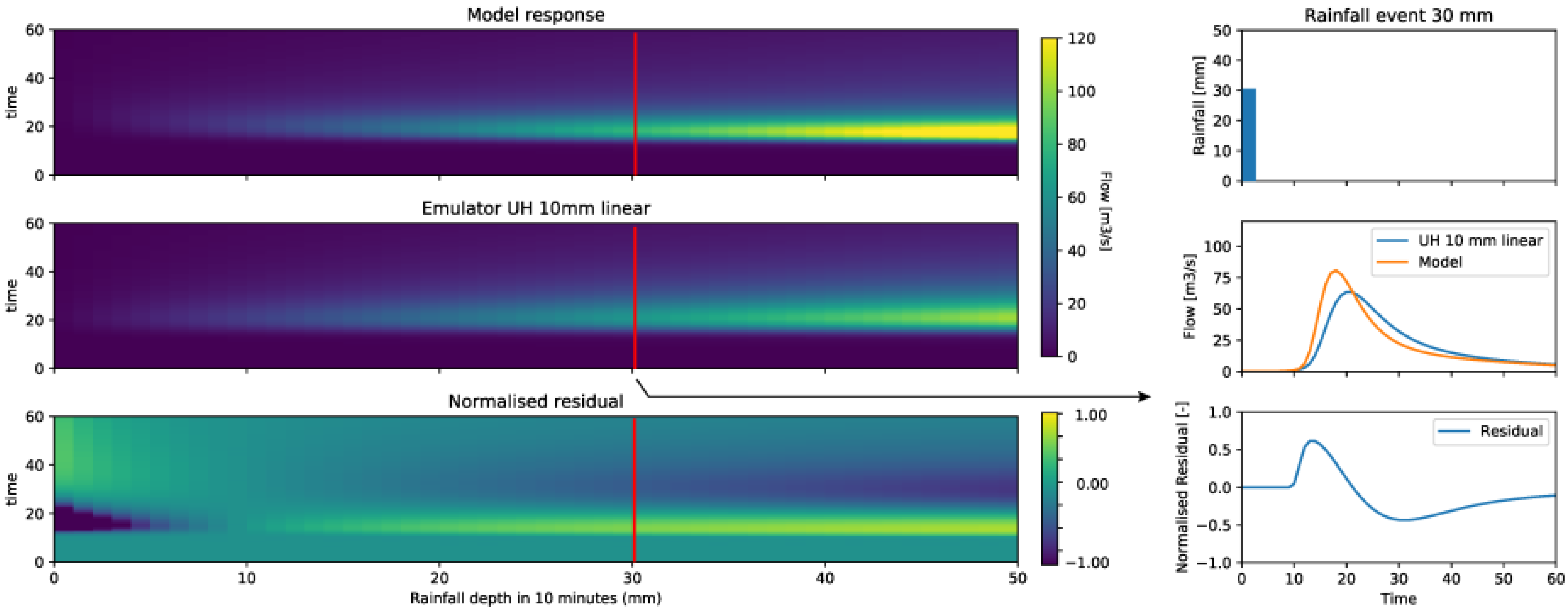
1- **UH_linear**:
Unit hydrograph responses [10 mm unitary rainfall]
(proportionality + superposition)



$$UH_{10mm}(t,\theta) \approx \boldsymbol{c}_{10mm}(t)^T \cdot \boldsymbol{\phi}_{10mm}(\theta)$$

2- Emulator structure

2.2 Unit hydrograph response from a non-linear flow model (UH_linear)



2- Emulator structure

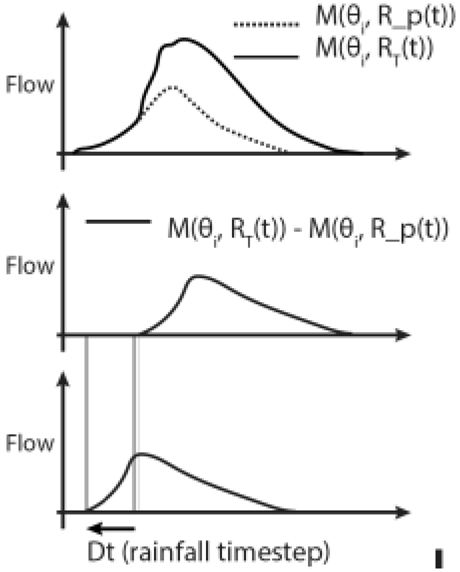
2.3 Sampling from the internal model state:

- UH_p (proportionally correction):

$$UH_P(t,\theta,R) \approx \boldsymbol{c}_P(t)^T \cdot \boldsymbol{\phi}_P(\theta,R)$$

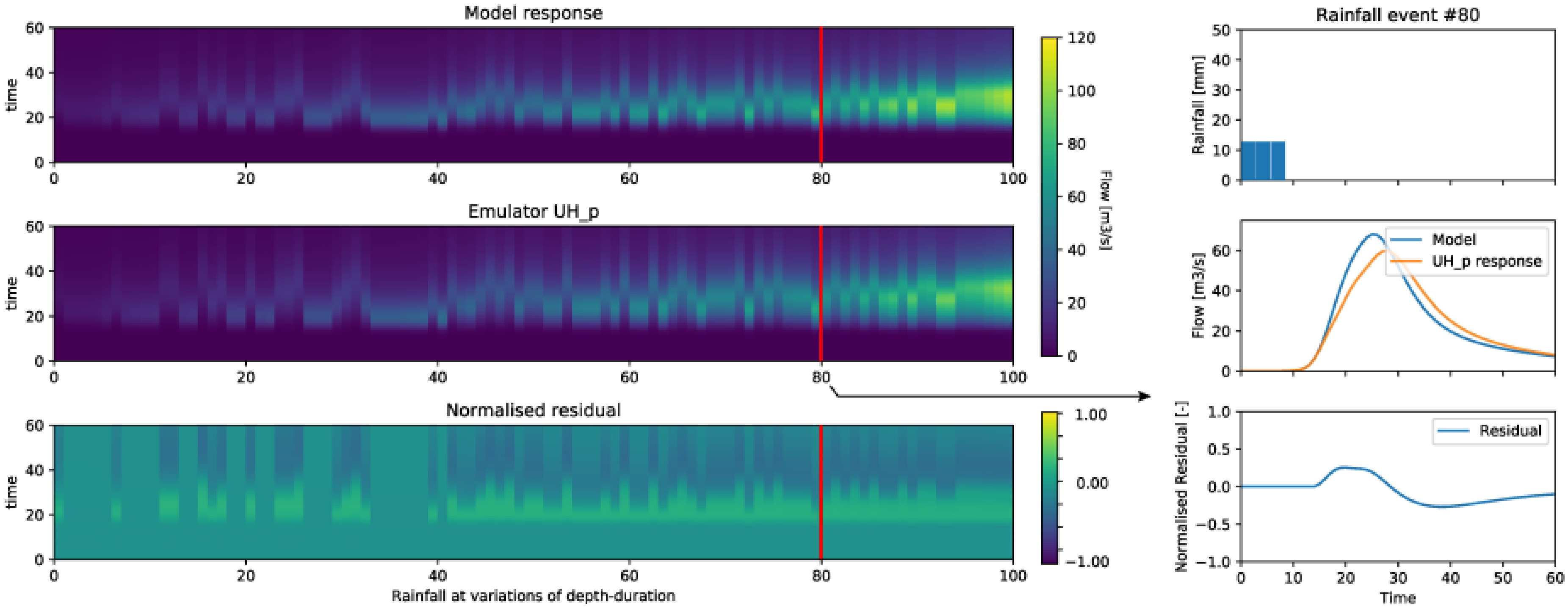
- UH_ps (proportionality and superposition)

$$UH_{PS}(t,\theta,R,R_p) \approx \boldsymbol{c}_{ps}(t)^T \cdot \boldsymbol{\phi}_{ps}(\theta,R,R_p)$$



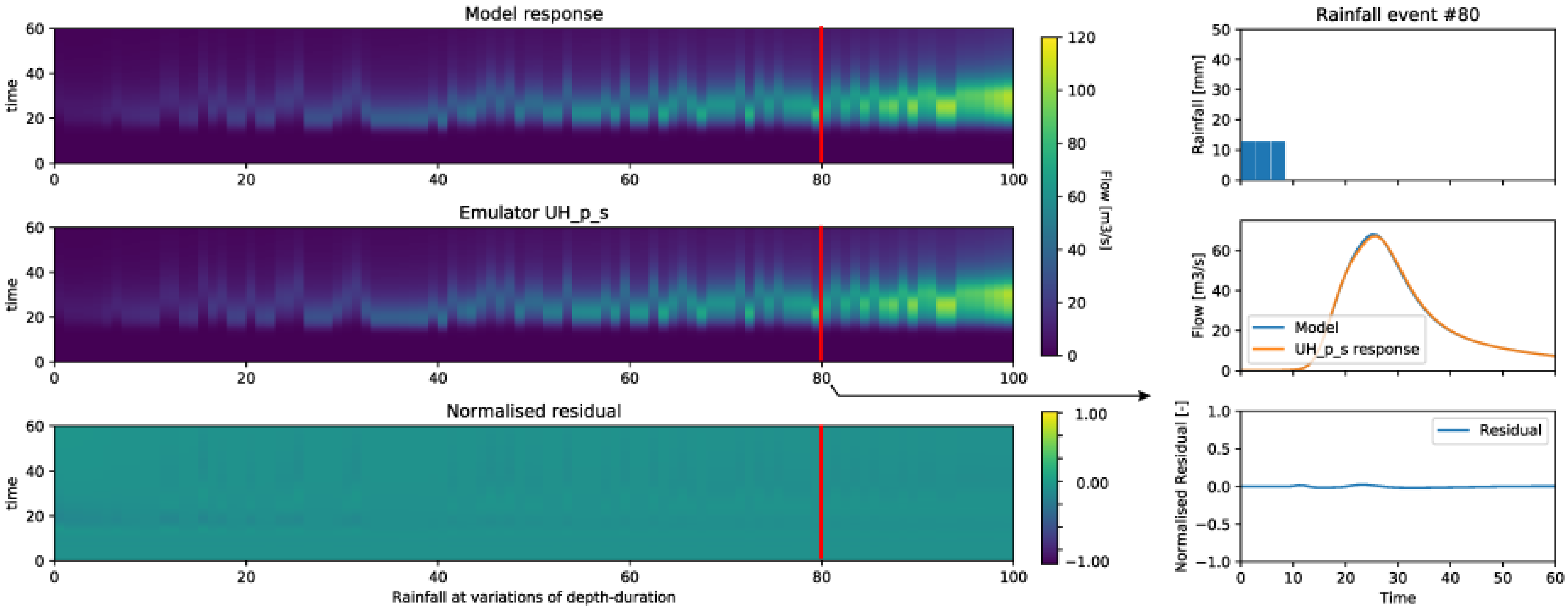
3- Learning non-linear responses

3.1 UH error superposition (UH_p)



3- Learning non-linear responses

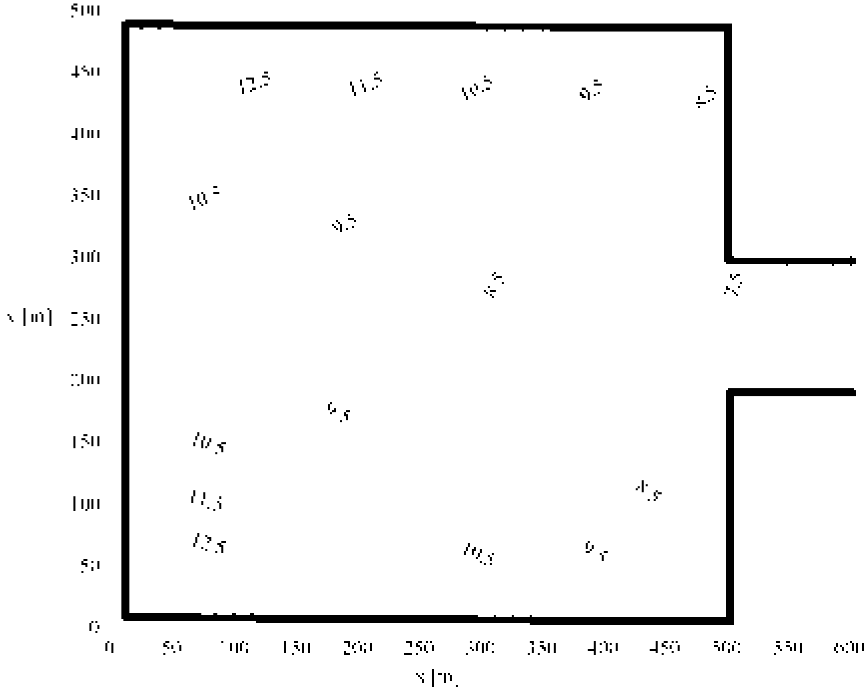
3.1 UH error corrected (UH_ps)



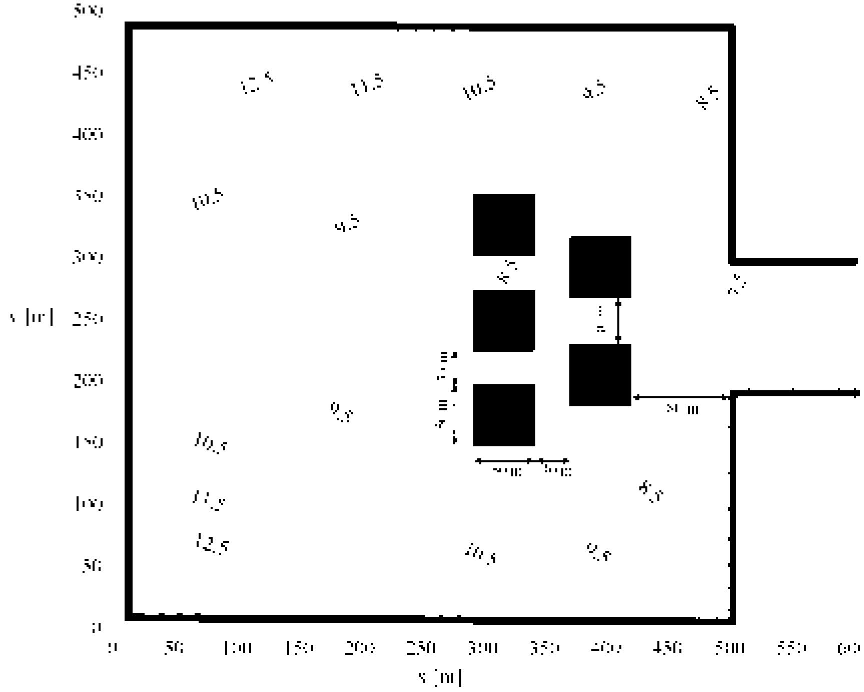
4- Application

4.1 – Emulation of 2D-Shallow Water Equations (FLOWR2D, NTUA). Rainfall(t) and manning roughness.

a) Model SWE_parabola

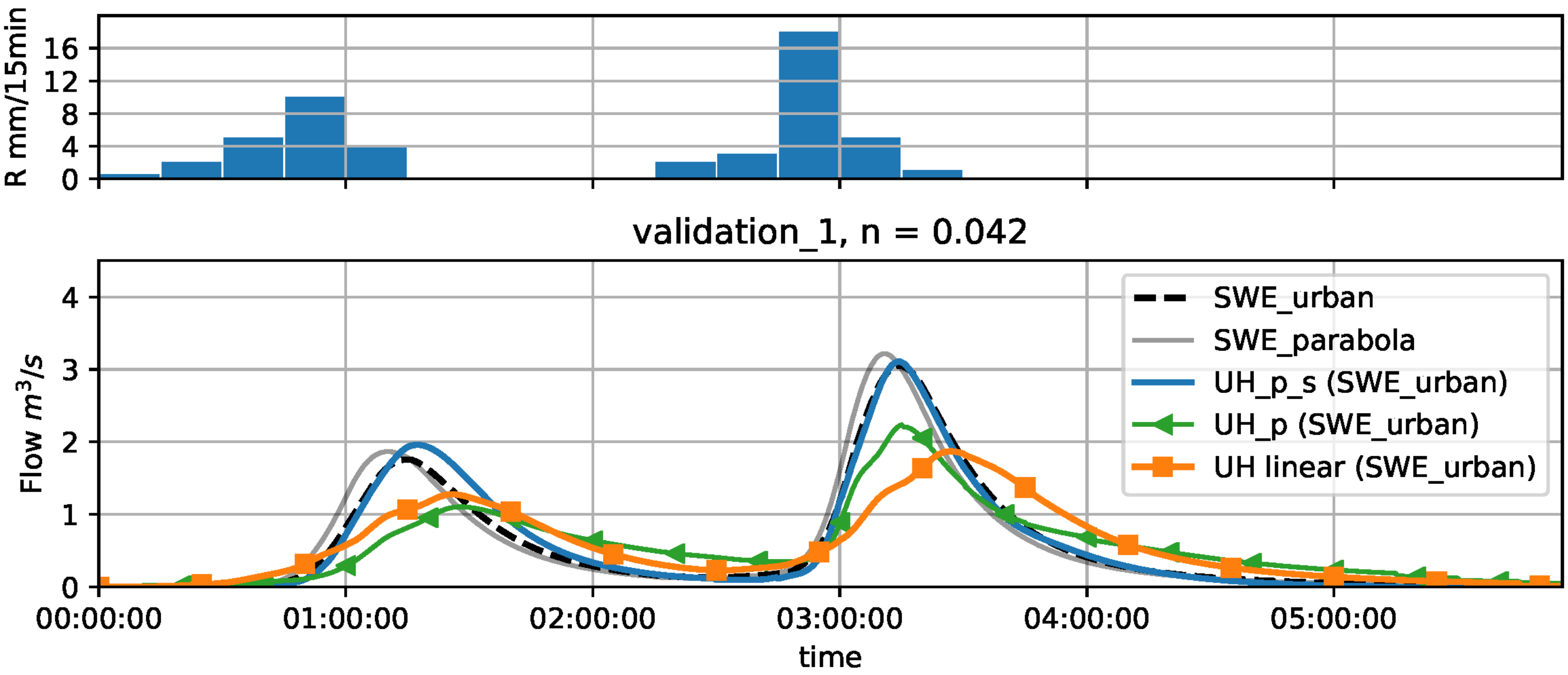


b) Model SWE_urban



4- Application

4.2 – Validation of the emulator



4- Application

4.2 – Validation of the emulator

	NSE						PRE					
	UH_{LINEAR}		UH_{P}		UH_{PS}		UH_{LINEAR}		UH_{P}		UH_{PS}	
Validation_0 (n=0.035)	0.64	0.53	0.74	0.65	0.988	0.987	0.46	0.51	0.18	0.23	-0.04	-0.03
Validation_1 (n=0.042)	0.53	0.36	0.65	0.54	0.989	0.983	0.48	0.53	0.24	0.27	-0.043	-0.01
Validation_2 (n=0.037)	0.46	0.48	0.59	0.61	0.985	0.988	0.51	0.52	0.28	0.24	0.055	-0.02
Validation_3 (n=0.043)	0.39	0.34	0.52	0.53	0.987	0.981	0.52	0.54	0.3	0.28	0.032	0.007
Validation_4 (n=0.036)	0.62	0.6	0.48	0.37	0.996	0.988	0.42	0.44	0.43	0.49	0.026	-0.049
Validation_5 (n=0.040)	0.6	0.55	0.41	0.25	0.996	0.986	0.42	0.45	0.45	0.51	0.012	-0.03
Validation_6 (n=0.038)	0.57	0.52	0.49	0.38	0.996	0.996	0.46	0.45	0.45	0.45	0.02	-0.04
Validation_7 (n=0.041)	0.53	0.45	0.43	0.28	0.997	0.996	0.48	0.47	0.47	0.48	0.016	-0.03

5- Conclusions

- Limitations and gaps for further research:
  - Only valid for spatially homogeneous rainfall series
  - Still constrained by curse of dimensionality
  - Untested on highly dynamic systems (Urban drainage)
- Highlights
  - Strategy to encode rainfall temporal variability and parameters
  - Range of applicability of physically based simulations for rainfall-runoff processes greatly extended.

Thanks for your attention

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More information at:

Moreno-Rodenas A.M., Bellos, V., Langeveld, J., Clemens, F., 2018. A dynamic emulator for physically based flow simulators under varying rainfall and parametric conditions. Water Research.

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