Event based uncertainty assessment in urban drainage modelling applying the GLUE methodology

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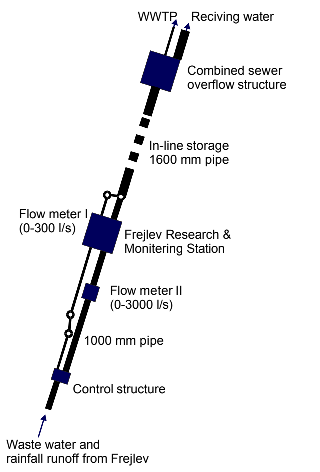
ABSTRACT

Prediction of flooding, surcharge, and combined sewer overflow (CSO) in urban drainage systems using drainage models are highly uncertain due to uncertainties in boundary conditions (primarily the rainfall input) as well as parameter uncertainty. Using flow measurements and CSO registration an uncertainty analysis based on ten rainfall-runoff events is carried out using a six parameter global setup of the commercial urban drainage model MOUSE. The uncertainty analysis is conducted applying Generalized Likelihood Uncertainty Estimation methodology (GLUE), where probability distributions are chosen a priori for each parameter, and based on approx. 10000 crude Monte Carlo simulations posterior distributions for each parameter is derived based on an empirical best fit likelihood measure.

OBSERVATION DATA

Frejlev is a small town covering an area of approx. 90 ha and with 2000 inhabitants. Since 1997 flow has been measured continuously every 20 seconds both during dry weather and rain with two electro magnetic flow meters. Since 2004 a binary registration of combined sewer overflow has been conducted. Using these observation data 10 rainfall-runoff events are selected for this analysis.

The urban catchment: Frejlev. In the blue areas the sewer system is separated and the rest is a combined sewer system.



Concept of flow meters and overflow registration downstream the drainage system

THE MOUSE MODEL

In the present analysis the urban drainage model MOUSE from DHI Water & Environment is applied with the following setup:

- A time-area surface runoff submodel and a dynamic wave pipe flow submodel
- Model input: Rainfall time series from a single local rain gauge (20456)
- 6 selected globalmodel parameters:
    1. Surface runoff concentration time on subcatchments, t_c (min), U(1,20)
    2. Hydrological reduction factor, φ(-), U(0.2,0.9)
    3. Initial loss, s (m), U(0,0.0008)
    4. Dry weather flow, DWF (l/(PE·d)), U(90,150)
    5. Manning number in pipes, M ($m^{1/3}$/s), N(85,5), for plastic pipes fully correlated values are drawn for other pipematerials
    6. Head loss factor in manholes, K_m (-), U(0,0.5)

$U(x_1,x_2)$ is a uniform distribution with lower x_1 and upper bounds x_2 and $N(\mu,\sigma)$ is a normal distribution withmeanμandstandarddeviation σ.

GENERALIZED LIKELIHOOD UNCERTAINTY ESTIMATION

Using Crude Monte Carlo simulations the MOUSE model is evaluated 10000 times with random parameter sets (**Θ**) with the same input (**I**). For every simulation an informal likelihood measure, determining the best fit, for each of the three observations points (flow meter I, flow meter II, and the CSO registration) is calculated:

$$L_j(\mathbf{O}_j|\mathbf{M}_j(\Theta,\mathbf{I})) = exp\left(\frac{-\sigma^2_{\mathbf{M}_j-\mathbf{O}_j}}{\sigma^2_{\mathbf{O}_j}}\right)$$

$\sigma^2_{M\text{-}O}$ is variance of the residuals between model (**M**) and observations (**O**) and σ^2_O is the variance of the observations. These three individual likelihoods are waited equally to a total likelihood of each simulation:

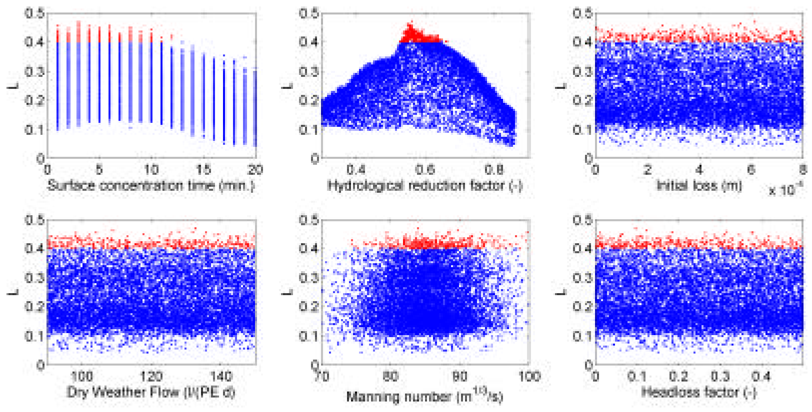
$$L(\mathbf{M}(\Theta,\mathbf{I})|\mathbf{O}) = \prod_{j=1}^{J} L_j(\mathbf{O}_j|\mathbf{M}_j(\Theta,\mathbf{I}))$$

Finally posterior probability density functions are calculated based on the simulations with the highest likelihood, L(**O**|**M**(**Θ**,**I**)) > 0.4, using Bayes equation:

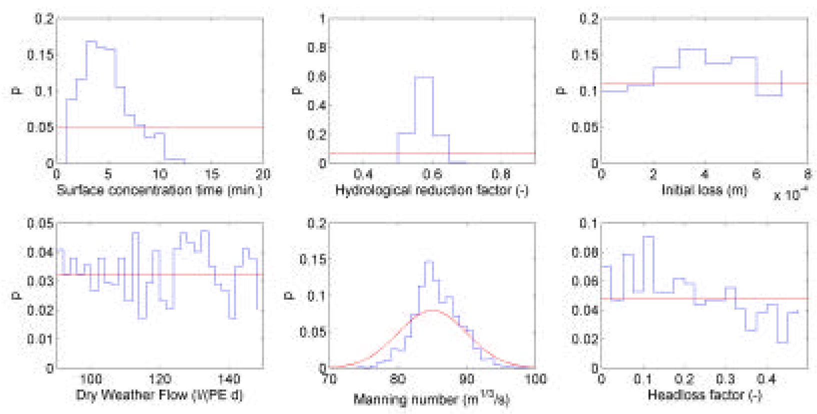
$$L(\mathbf{M}(\Theta,\mathbf{I})|\mathbf{O}) = L(\mathbf{M}) \cdot L(\mathbf{O}|\mathbf{M}(\Theta,\mathbf{I}))$$

RESULTS

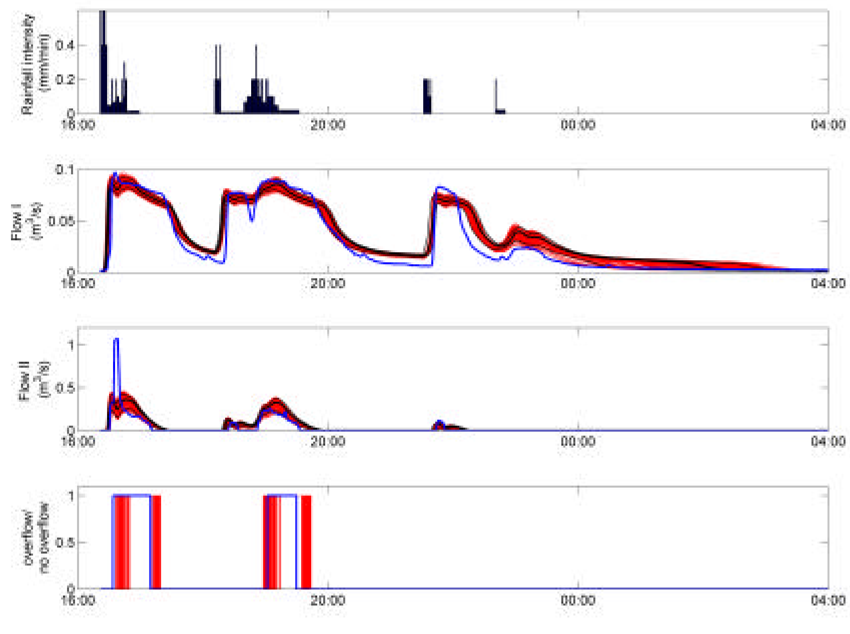
One simulation takes approx. 20. min, so using a cluster of 10-15 computers it has been possible to conduct 10000 simulations within two weeks. Comparing the first 5000 simulations and all 10000 the results are very similar indicating a sufficient number of simulations. 350 of the simulations are accepted.



The empirical likelihood measure for each of the 10000 simulations and corresponding parameter values. Red dots are the accepted simulations and blue dots are the non-accepted.



Prior (red) and posterior (blue) probability density functions for each of the 6 parameters.



One of the ten events in the three observation points and the rainfall input. The blue line is the measured, the red lines is each of the accepted simulations, and the black is 5 %, 50 % and 95 % prediction intervals of the accepted simulations.

DISCUSSION

Exploring the flow time series it is clear that the model observations could not be bracketed by the 5 and 95 % prediction intervals. Furthermore there are no consistent over or under prediction of the observation peaks. This is an obvious result of input uncertainties (uncertainties on the rainfall time series). In order to investigate the input uncertainties new simulations with an area weighted input of two rain gauges will be conducted.

The tails of the modeled hydrographs are unsatisfactorily over predicted. This is most likely a result of a simplified surface runoff submodel (the time-area model); therefore a more complex kinematic wave approach will be implemented in order to transfer model uncertainty to parameter uncertainty.

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