Possibilities of Flood Forecasting in Small Headwater Catchments: Case Study Czech Republic

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Outline

Small Headwater Catchments

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Small Headwater Catchments

Small Headwater Basins

- Area < 500 km^2
- Fast runoff response LAG TIME $\rightarrow$ several hours
- There are basins, where it is impossible to perform runoff forecast.

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Flood Events and LWS

- Prevailing Flood Events $\rightarrow$ caused by extreme rainfalls
- Both **Thunderstorms** and **Frontal Rainfalls**
- **The Challenge** $\rightarrow$ improving and developing flood runoff forecast and incorporating it into the **Local Warning Systems**.

Flood Memory – Flood Event 1925

Figure: Flash Floods (Basta, 2011)

Extreme Precipitation →78[mm/hour], 132 [mm/3 hours]

Flood Memory – Flood Event 2009

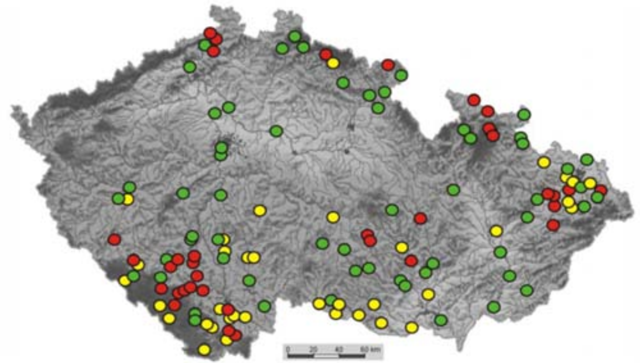


Figure: Warnings Issued by the CHMI (ME CR, 2010)

Red dots → HIGH EXTREME

Objectives

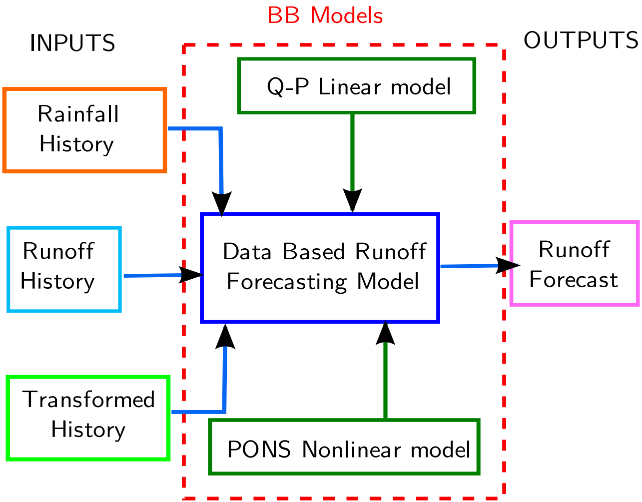
Aims

1. The analysis of local flood events in small catchments.
2. The preparation of Flood Event Set.
3. The development of SIMPLE forecasting tool used in LWS.
4. The test of flood forecast in different conditions

Flood forecast:

- Flood runoff forecast with different lead times.
- Flood runoff forecast in un-gauged catchments.
- The uncertainty assessment and ensemble forecast.

Data Based Modeling



Q–P Linear Model

Simple linear transfer function model

- Linear model

$$Q(t) = \sum b_i Q(t-i) + \sum p_i P(t-i) \qquad (1)$$

- Combined rainfall and runoff history
- Parameters $\rightarrow$ length of histories
- Parameter estimation $\rightarrow$ ordinary least square method
- Tested Extended versions of Q–P Linear model

$$Q(t+Lag) = \sum b_i Q(t-i-Lag) + \sum p_i P(t-i-Lag) \qquad (2)$$

- Applied for the runoff forecast in real time

PONS – Nonlinear Model

Prediction of **O**utflow via **N**eural network**S**

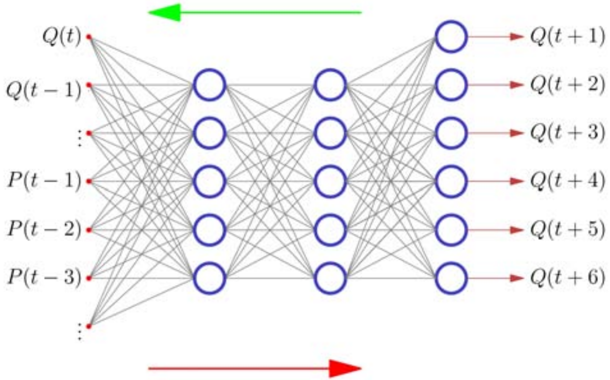
MLP

Hornik – MLP with 1 HL → approximation of bounded continuous integrable function

PONS core

- feed-forward neural network
- neurons with different nonlinear activations
- back-propagation with momentum
- on-line training
- nonlinear exponential data transformation
- MLP with 1HL and 2HD
- open-source written in c++ **http://kvhem.cz**

MLP example



Application Procedure

Data preparation

- calibration and validation sets of flood events
- chronological and non-chronological sorting
- nonlinear exponential transformations (PONS)

Runoff Forecast

- Q–P and PONS model parameters optimization
- preparing the real–time forecasting mode (Research Institute for Soil and Water Conservation)
- runoff forecast on ungauged catchment
- uncertainty tests

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Analyzed Flood Events

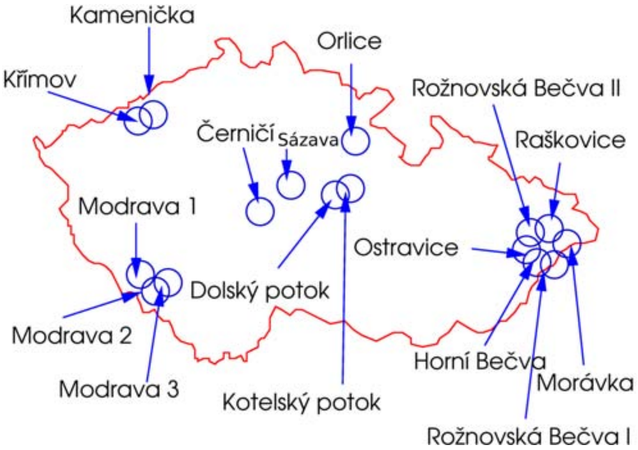

Figure: 16 Analyzed Watersheds

Micro Catchments

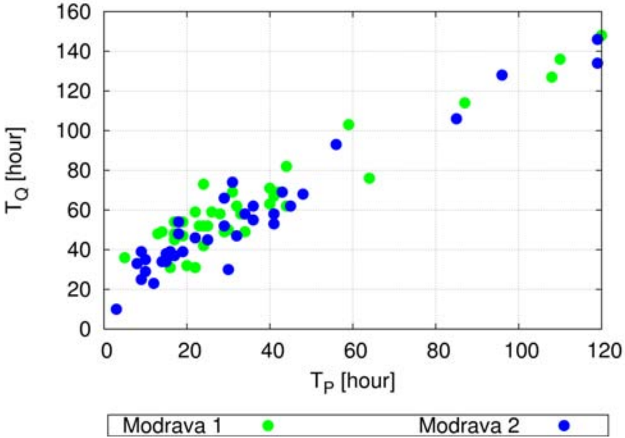

Figure: Temporal Flood Event Characteristics

Large Catchments

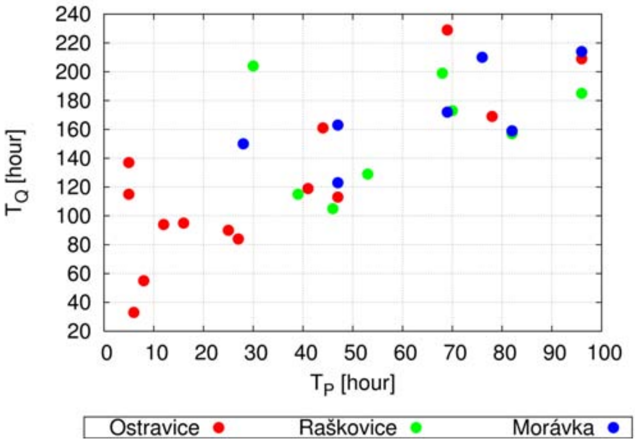

Figure: Temporal Flood Event Characteristics

Runoff Forecast

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Runoff Forecast

Results – Weak points

1. Time shift in peak discharge prediction
2. High influence of correlation between $Q(t)$ and $Q(t-1)$
3. Key Parameter $\rightarrow$ Temporal resolution of Flood Event

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Results – Strong points

1. Functional real-time mode forecast of Q–P Linear model
2. Very good results in runoff forecast during testing computations on 1997 and 2002 floods
3. Developed good Application procedure

Real time mode – Q–P linear model

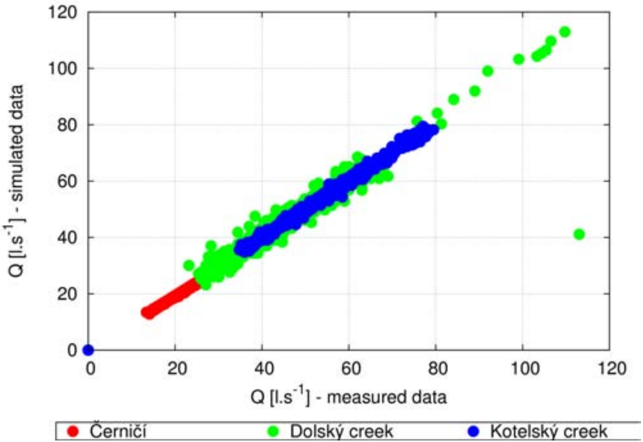

Figure: Agricultural watersheds

Mohelnice 33 km^2

MLP Architecture

- 4 – 6 – 6

Q–P history

- $P(t-4)$
- $Q(t-1)$, $Q(t-2)$, $Q(t-3)$

MLP Training

- $\alpha = 0.009$
- $\eta = 0.01$
- $\mu = 0.3$
- number epochs 250

Calibration

- 4 extreme Floods
- 1985, 1996, 1999 and 2000

Validation Results NS

LT.	1996	1997
1	0.98	0.95
2	0.98	0.96
3	0.96	0.95
4	0.92	0.92
5	0.85	0.90
6	0.78	0.88
AVE.	0.91	0.92

3-Hour Lead Time Forecast

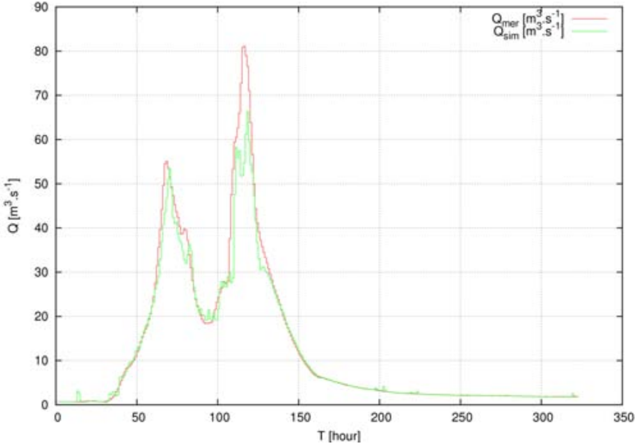

Figure: Mohelnice-Raškovice – validation

6-Hour Lead Time Forecast

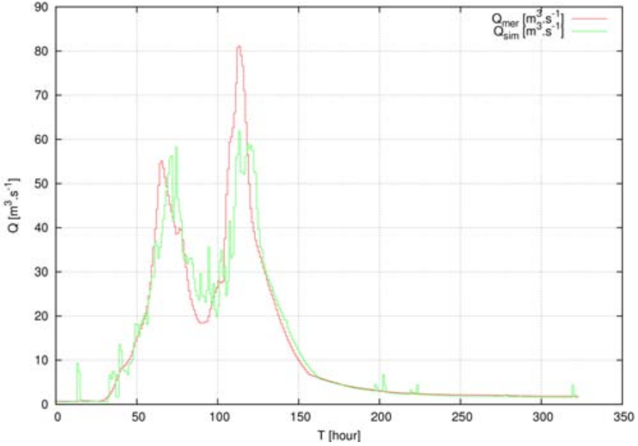

Figure: Mohelnice-Raškovice – validation

Raškovice vs Morávka

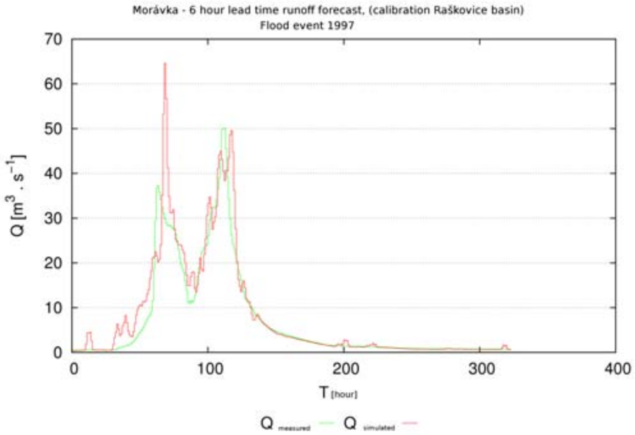

Figure: Mohelnice 33 km^2 – Morávka 22 km^2

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Lead time test

- Nash Sutcliffe efficiency

$$NS = 1 - \frac{\sum (Q_{obs}(i) - Q_{sim}(i))^2}{\sum (Q_{obs}(i) - \bar{Q})^2} \quad (3)$$

- Persistence Index

$$PI = 1 - \frac{\sum (Q_{obs}(i) - Q_{sim}(i))^2}{\sum (Q_{obs}(i) - Q_{obs}(i - lag))^2} \quad (4)$$

- Combined Precip and Runoff history

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Generalization test

- 35 MLPs Ensemble
- **Only the Runoff history**

Morávka – Flood Event 1997 – 22.2 km^2

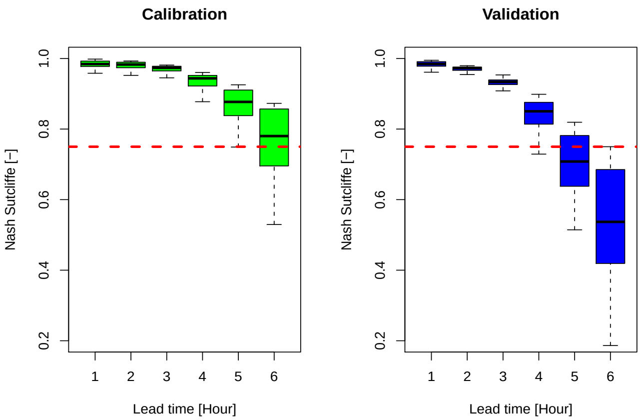

Figure: Nash-Sutcliffe Efficiency (Nash et Sutcliffe, 1970)

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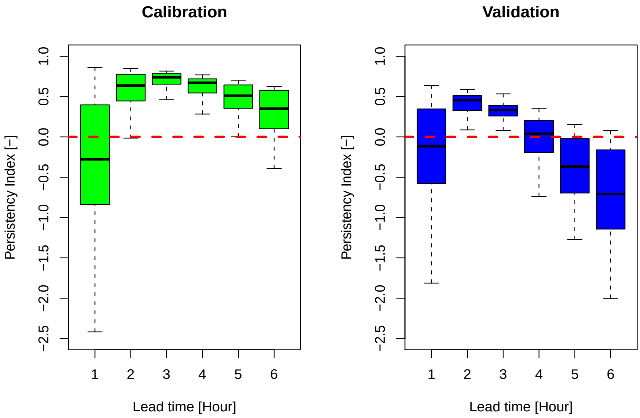
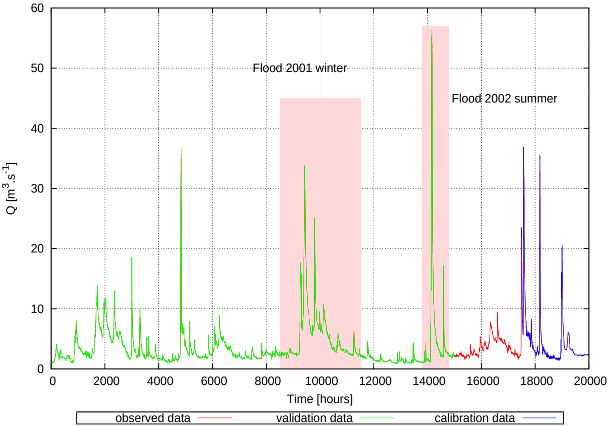
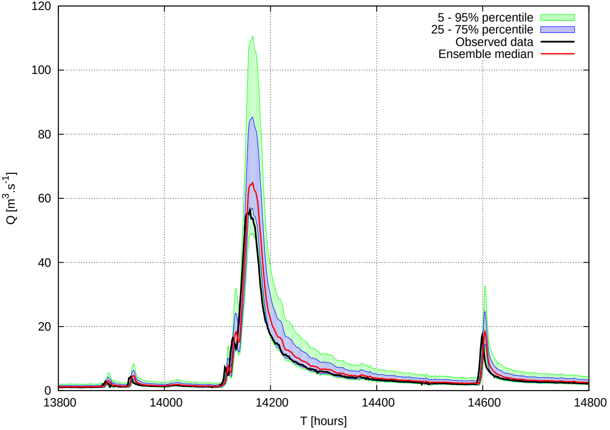


Figure: Persistence Index (Kitanidis et Bras, 1980)

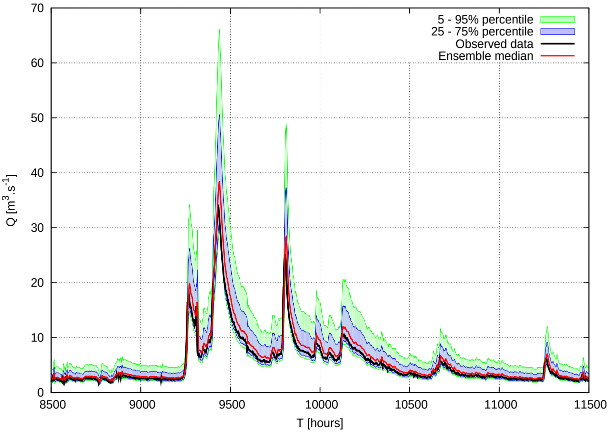
Sázava Basin – 381 km^2



Sázava Basin - 29.6.–10.8. 2002



Sázava Basin - 21.11–2.12 2002



Conclusions

1. Runoff forecast in small headwater catchment still is a **Challenge**.
2. Proposed tested techniques may help to extend the runoff forecast within currently operating **Local Warning Systems**.
3. Runoff forecast based on runoff history is capable to capture development of **selected floods**, when wrong rainfall data are available.
4. **Dataset of flood events** across the different spatial scale was built up.
5. **Uncertainty tests** should be included within similar computations.

Thank you for your attention.