Flood forecasting using sensor network and Support Vector Machine model

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Motivation

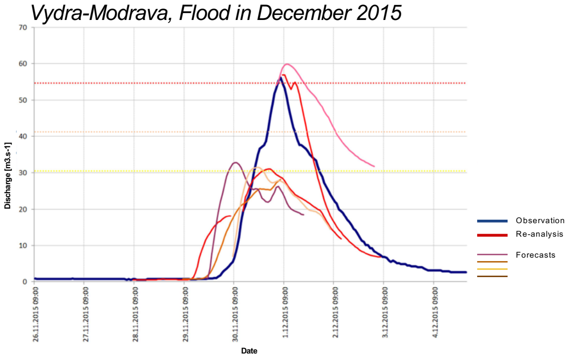
Hydrological modeling in mid-latitude montane basins

Specific conditions
- Decisive area for flood generation
- Complex physiography
- Rapid runoff response

Limitations
- Limited data sources
- Uncertainties in forecasting by process-based models

=> Potential for data-driven models

Example of the volatility of hydrological forecasts Vydra-Modrava, Flood in December 2015



Rain-on-snow flood - issued hydrological forecasts, reanalysis and discharge observations at Vydra-Modrava station (CHMI)

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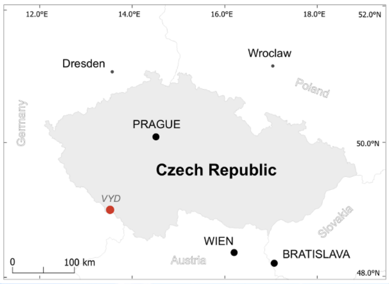
Study area



Vydra River basin, Sumava mts.

- Mid-latitude montane basin
- Source area of frequent flooding
- Irregular rainfall distribution
- Significant share of peatbogs
- Extensive forest disturbance by bark beetle

=> Rapid flood generation

Effects of climate change

= rise of air temperature
= changing runoff seasonality
=> rising frequency of high flows
=> prolonged low flow periods

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LANGHAMMER, J., BERNSTEINOVÁ, J., 2020. Which Aspects of Hydrological Regime in Mid-Latitude Montane Basins Are Affected by Climate Change?. Water, 12(8), 2279.

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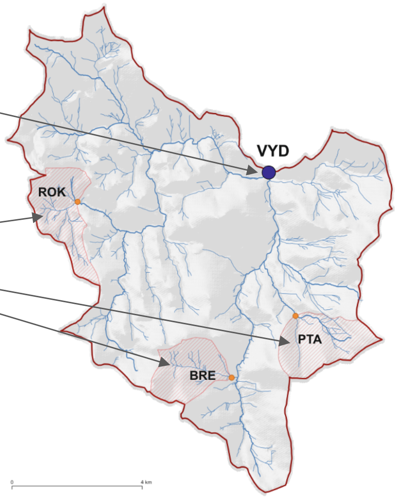
Monitoring and input data

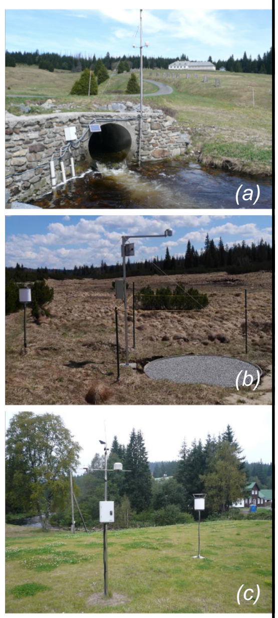
Long-term monitoring

- CHMI gauging station at outlet
- Precipitaiton, snow cover (Churáňov, Filipova huť) -> outside the catchment



Experimental catchments

- Experimental catchments
- Charles University, since 2006
- Basin headwaters
- Automated sensor network
  - gauging stations *(a)*
  - meteo stations *(b)*
  - snow pillow, snow scale *(c)*



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Input data and modeling scenarios

Observations
- Gauging station at basin outlet
  - daily discharge
- Sensor network in headwaters PTA, BRE, ROK
  - water stage
  - precipitation
  - snow cover

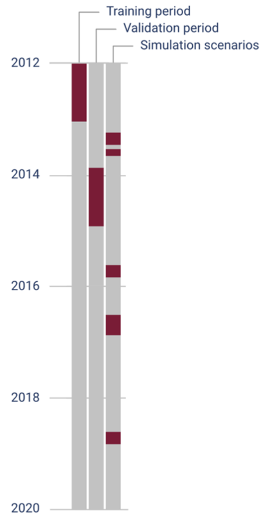
Calculated indices
- Sensor network data
  - API30, API 7
  - baseflow index (Digital recursive filter)
  - Potential Evapotranspiration (Oudin method)

Data processing
- Time span 2011 - 20
- Filling the gaps in time series
- Unified to daily values

Training period
- Complex period covering all types of events
- Hydrological year 2012

Validation period
- Hydrological year 2015

Simulation scenarios
- Spring snowmelt (April 2016)
- Rain on snow event (December 2015)
- Flood from regional rain (Spring 2013)
- Summer storm flood (June 2013)
- Repeated storms (August 2018)



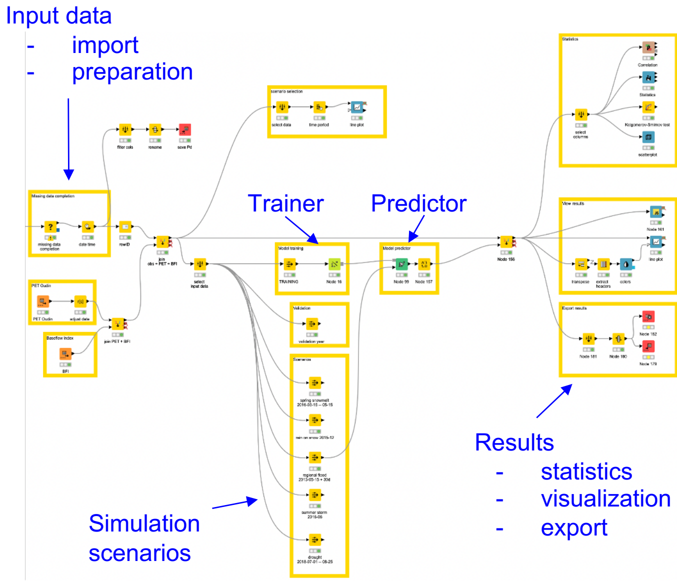
Model setup

Data driven model
Support Vector Machine

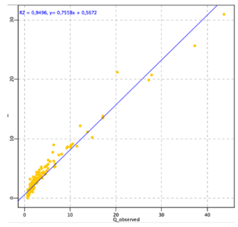
Non-probabilistic classifier, based on the augmentation of dimensionality for classification

Network design
- Target
  - CHMI gauging station (Qd)
- Source
  - sensor network (H, P, SNW)
  - calculated indices (API, BFI, PET)

Computing environment
- **KNIME 4.5**
- LibSVM library, nu-SVR algorithm
- Python



Results – Validaton period



Complex hydrological year

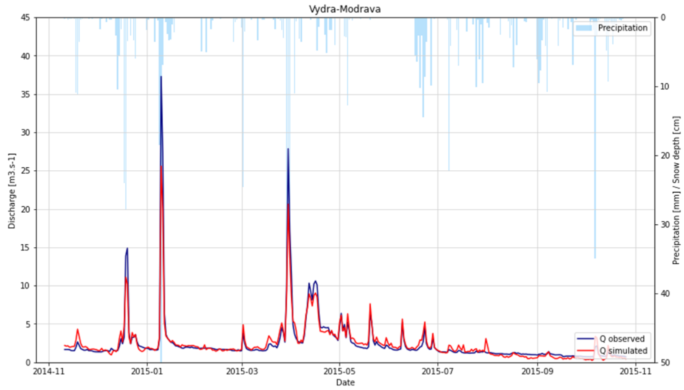
2014-11-01 -> 2015-12-01

Hydrological year covering key types of events

- spring snowmelt
- recurrent flooding from rainfall
- single storm floods
- multiple-peak storms
- low flow period

Statistics

R2 = 0,9496



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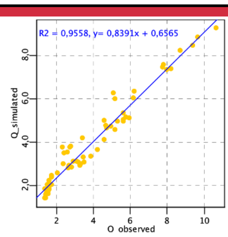
Results - Spring snowmelt



Spring snowmelt in April, 2016

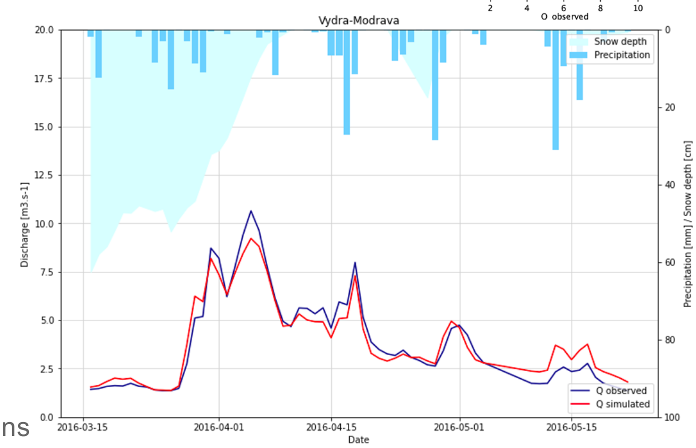
- 25 days of high flows
- Continuous snowmelt
- Recurrent but weak precipitation
- One wave, four peaks

Fit of simulation to observations

- Good fit of shape
- Good timing of peaks
- Slight underestimation of flows

Statistics

- NSE = 0,9405
- R2 = 0,9558
- Kolgomorov-Smirnov test
  p-value 0,21 > 0,05 = fit of distributions



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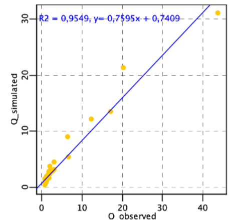
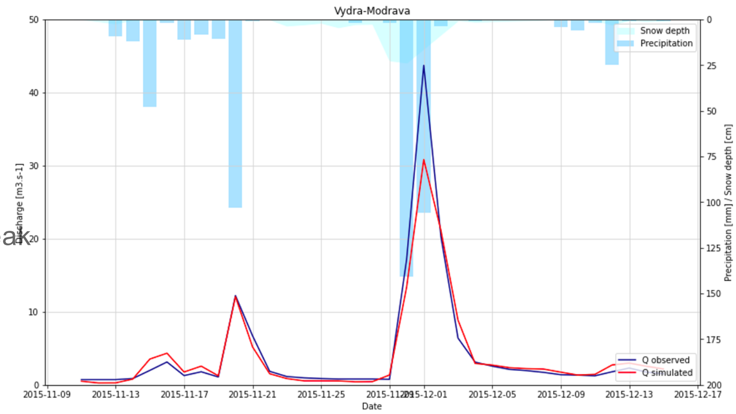
Results - Rain on snow flood



Flood in December, 2015
- Beginning of winter
- Fresh snowpack + heavy rainfall
- Rapid snowmelt
- 5-10-years flood

Fit of simulation to observations
- Good fit of shape
- Good timing of peaks
- Slight underestimation of major peak

Statistics
- NSE = 0,9103
- R2 = 0,9549
- Kolgomorov-Smirnov test
  p-value 0,21 = fit of distributions



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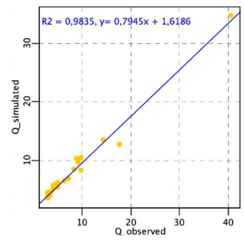
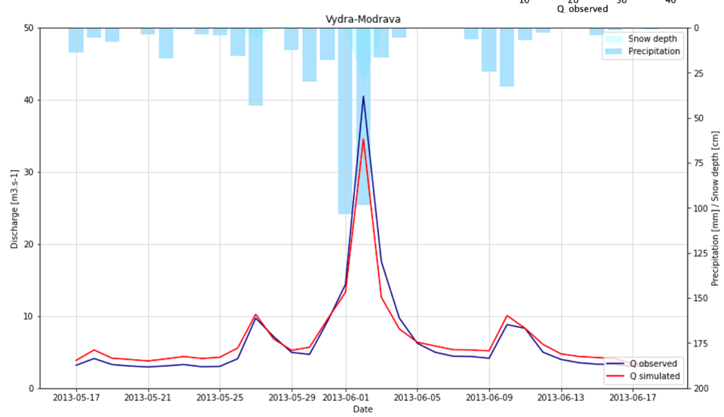
Results - Regional-scale flood



Spring flood in June, 2013
- Beginning of summer
- Long-lasting precipitation
- 5-10-year flood in headwater
- 50-year flood in lowland

Fit of simulation to observations
- Good fit of shape
- Good timing of peaks
- Good fit of peak flows
- Slight overestimation of low flows

Statistics
- NSE = 0,94524
- R2 = 0,9835
- Kolgomorov-Smirnov test
  p-value 0,13 = fit of distributions



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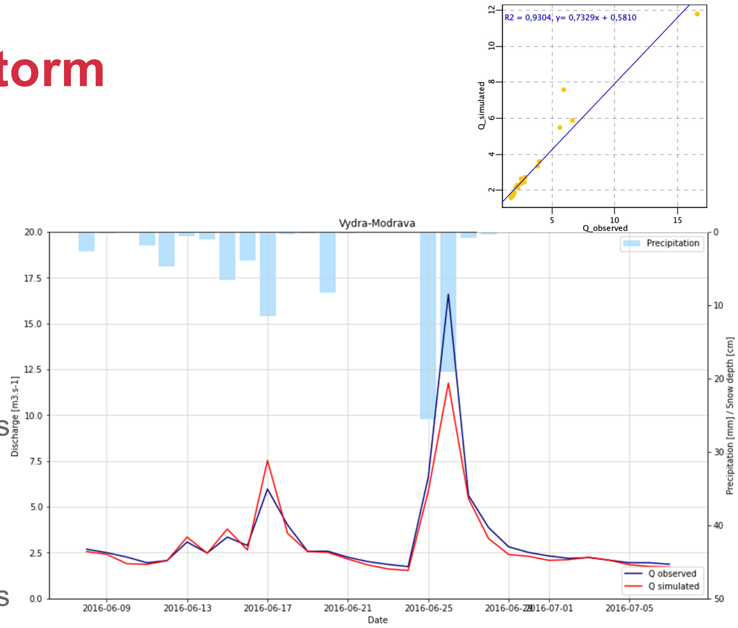
Results - Summer storm

Summer, 2016
- 5-10-year flood in headwater
- Summer storm

Fit of simulation to observations
- Good fit of shape
- Good timing of peaks
- Good fit of peak flows
- Slight overestimation of low flows

Statistics
- NSE = 0,9161
- R2 = 0,9304
- Kolgomorov-Smirnov test
  p-value 0,67 = fit of distributions



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Conclusions

Potential of SVM for flood forecasting
- Good fit of simulations to observations even in basins with complex physiography
- Ability to include heterogeneous data sources (i.e. sensor networks)
- Improvements of fit by use of calculated indices of basin status (API, BFI, PET)
- High computational efficiency
- Instant delivery of the predictions

Limitations
Black-box approach

Sensitivity to responsible model setup and training
- Even data-driven model needs hydrologists
- Avoiding models based on statistically correlated elements with no physical correspondence
- Hydrologically valid design of model network selection of variables
- Complexity of training period

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Thank you for your attention!

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LANGHAMMER, J., ČESÁK, J., 2016. Applicability of a Nu-Support Vector Regression Model for the Completion of Missing Data in Hydrological Time Series. Water 2016, 8(12), 560

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