Uncertainty Estimation through Bayesian Forecasting System (BFS)

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Research Objectives

- Significantly enhance flood forecasting system
- Better understand predictive uncertainty associated with flood forecast

Methodology

Among the predictive uncertainty quantification methods, BFS provide an ideal theoretic framework that could be used for probabilistic flood forecast through any deterministic hydrologic model. It considers all sources of uncertainties and produce predictive distribution. BFS consists of three parts (Fig. 1): PUP, HUP and INT.

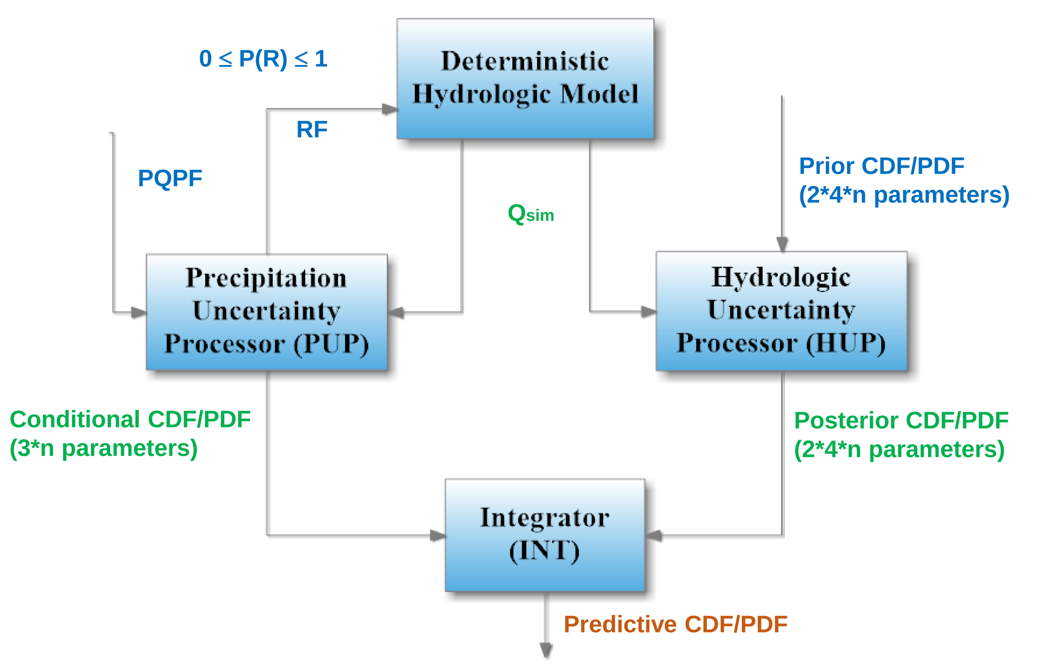

Fig. 1. Structure of BFS

Main content of this work:

- Application of a Precipitation-Dependent HUP to a semi-urban watershed in Canada for hydrologic uncertainty quantification
- Comparison between the predictability of this HUP combined with different hydrologic models

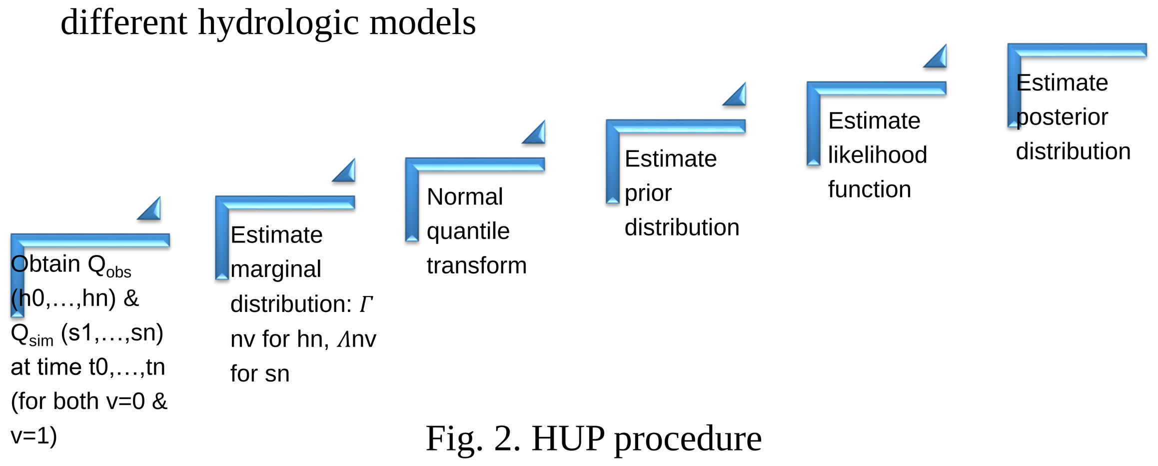

Fig. 2. HUP procedure

Study Area and Data

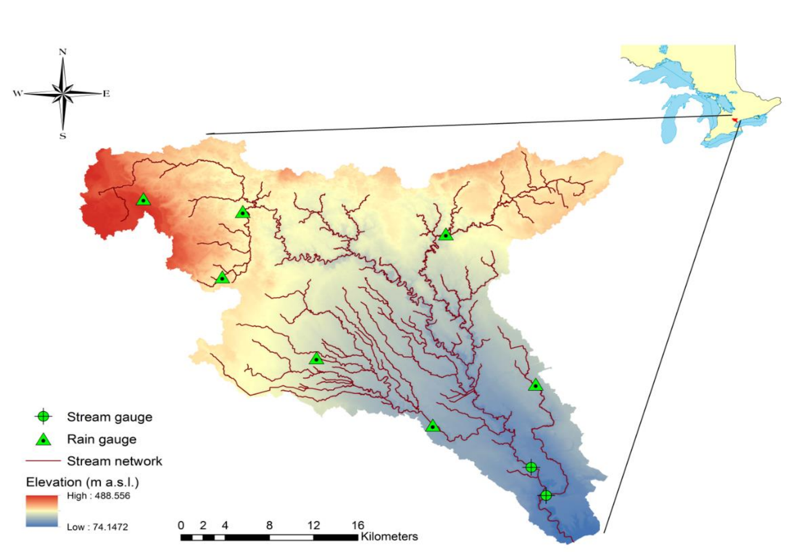

Fig. 3. Humber River Watershed

Data:

- Precipitation
- Discharge
- Temperature

Event-based:

- 24 events

Hydrologic Model

Hydrologic model (hourly):

- HYMOD
- GR4H

Parameter optimization: Particle Swarm Optimization (PSO)

Multi-objective function:

- NVE (combined Nash Sutcliffe efficiency and volume error)
- KGE (Kling-Gupta efficiency, decomposition of the mean squared error and NSE)

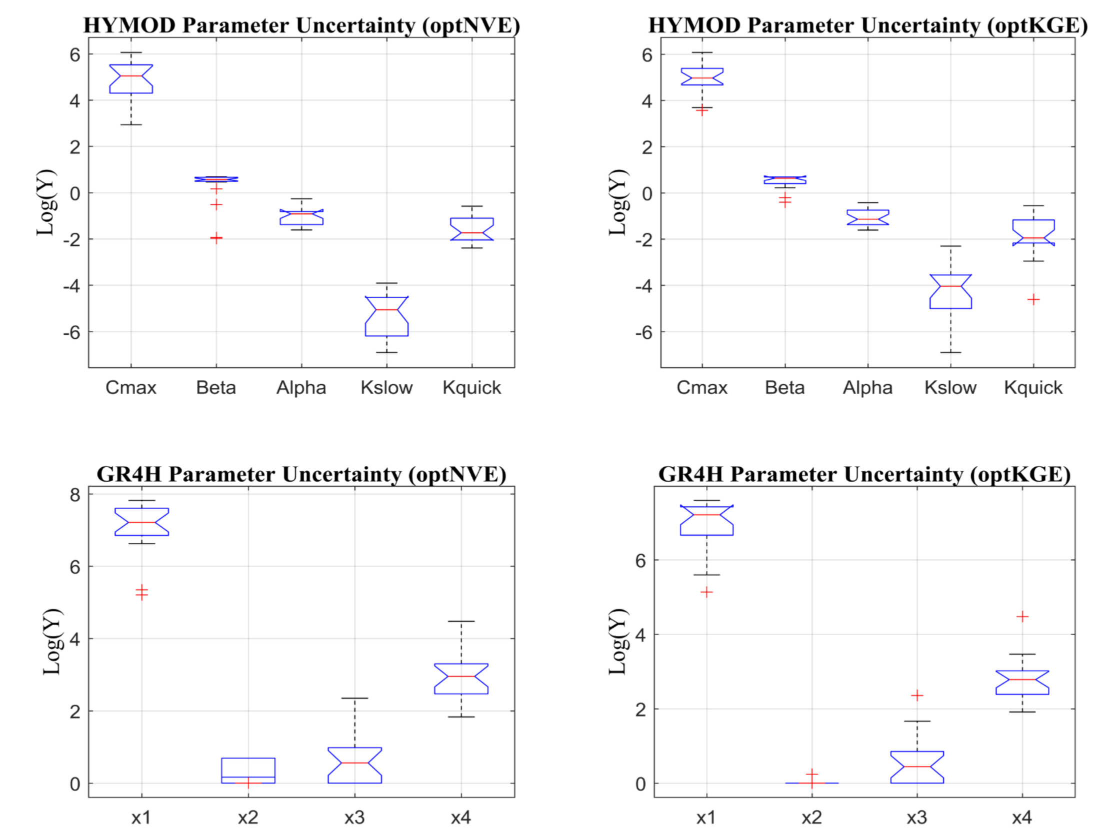

Fig. 4. Parameter uncertainty for calibration events

- Optimal parameter values for different events could be very different
- Parameter uncertainty is a large contributor to hydrologic uncertainty

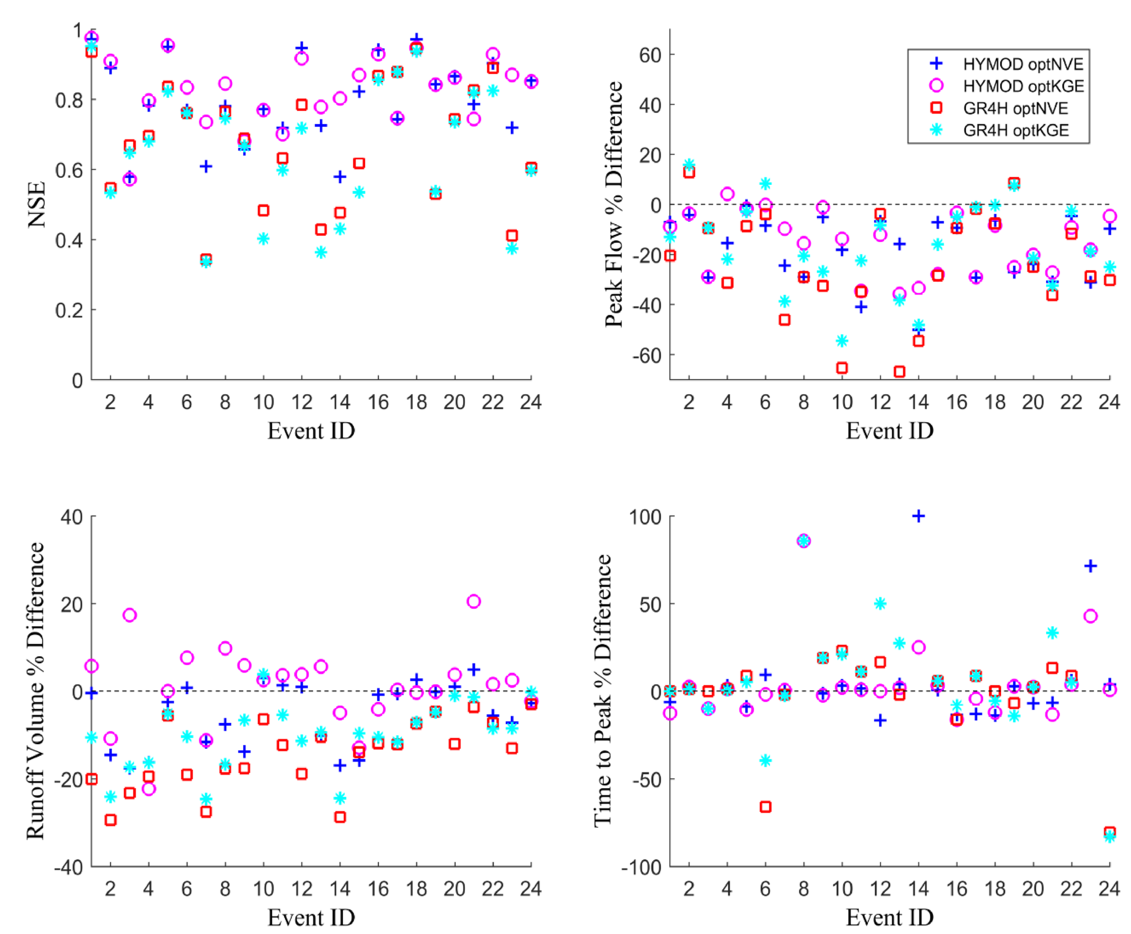

Fig. 5. Model performance evaluation

- HYMOD performed much better than GR4H
- Using optKGE gave slightly better performance than optNVE

Hydrologic Uncertainty Processor Results

The deterministic hydrologic model outputs were further analyzed in HUP to assess the hydrologic uncertainty.

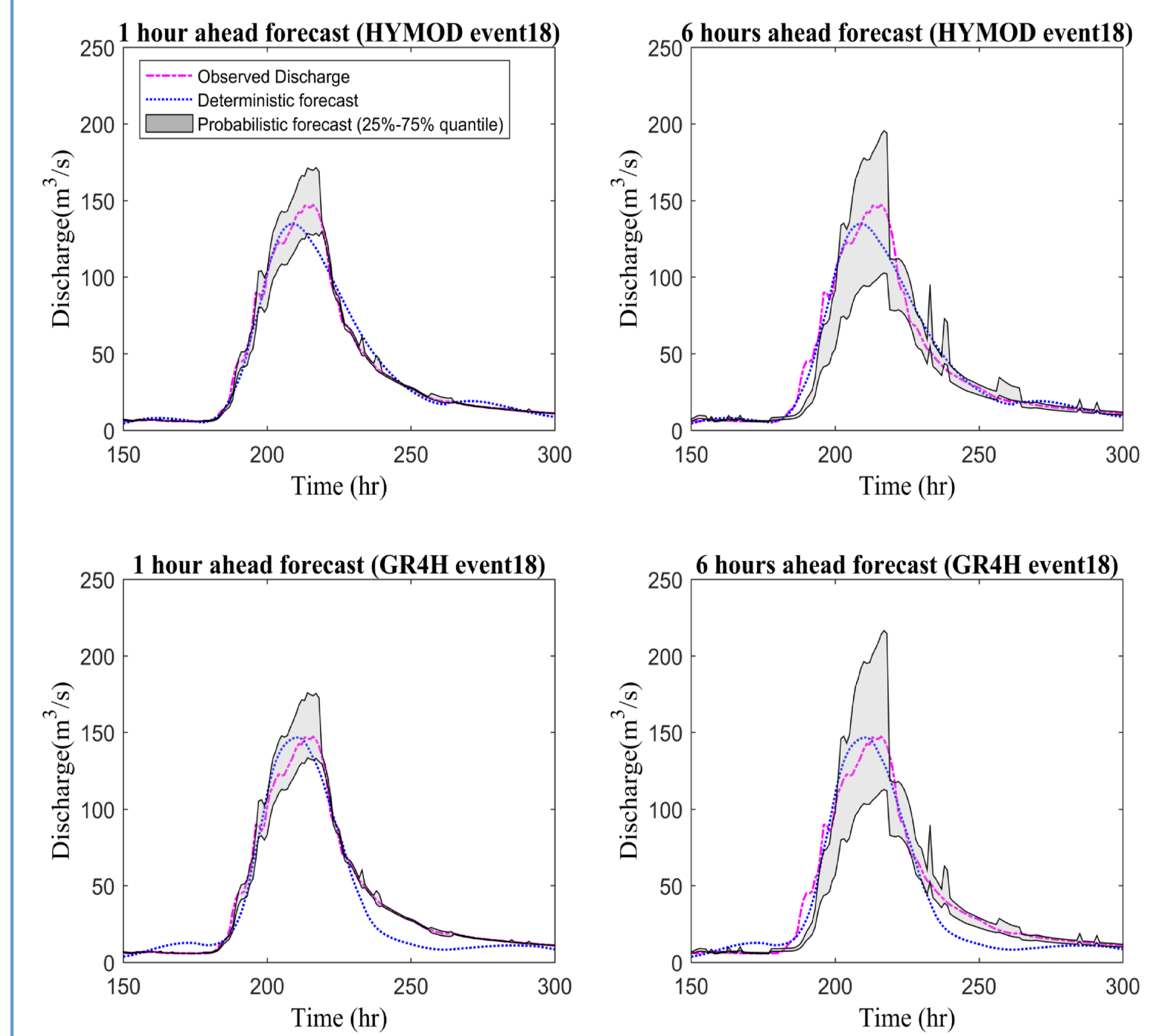

Fig. 6. Hydrologic uncertainty bound generated by HUP for one event

- Hydrologic uncertainty grows with increasing lead time
- Hydrologic uncertainty increases as the discharge increases
- Uncertainty bound can well capture the actual value
- As lead time increases, a deteriorative probabilistic forecast can be seen

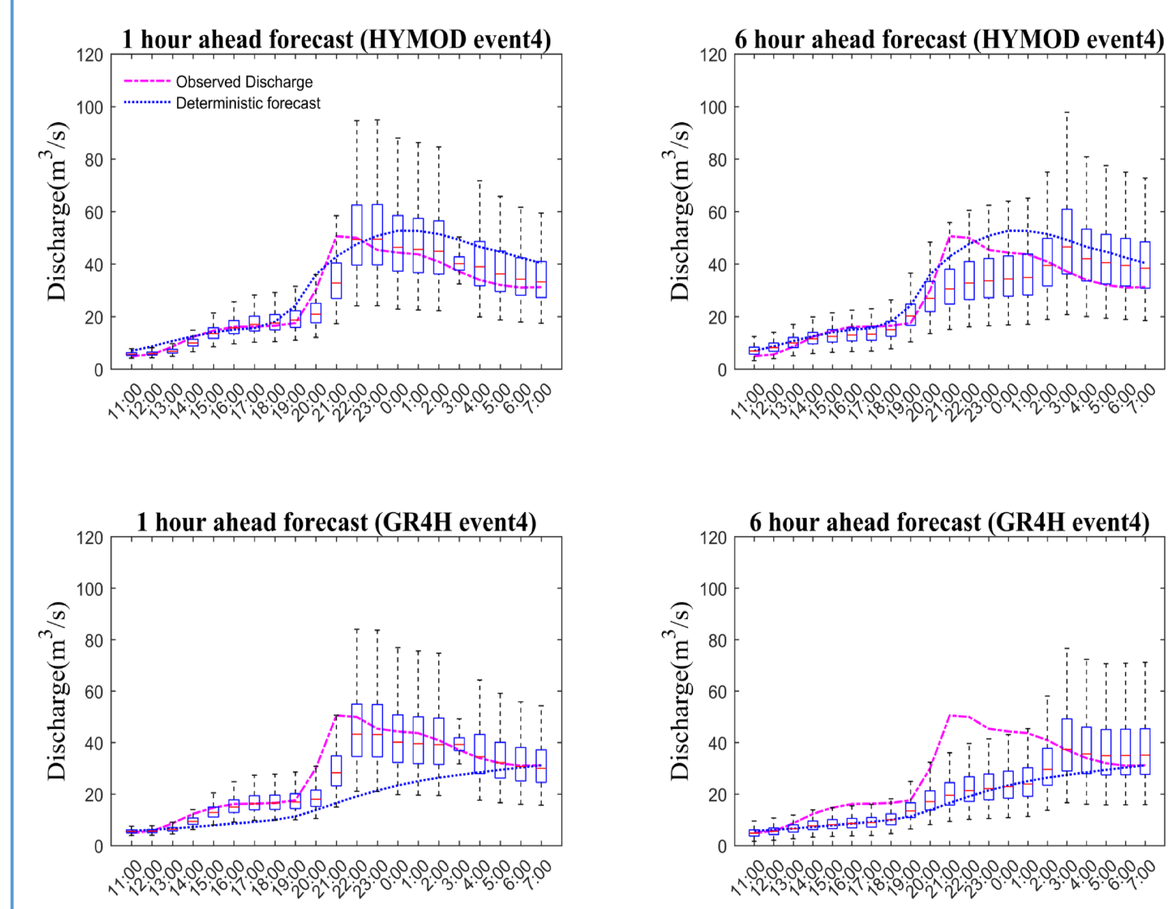

Fig. 7. Hydrologic uncertainty boxplot generated by HUP for peak flow

- HUP can improve deterministic forecast from HYMOD or GR4H, and gives more reliable probabilistic forecast
- For small lead times, no significant difference is presented between HUP-HYMOD and HUP-GR4H

HUP Performance Assessment

Continuous ranked probability score (CRPS) measures how good the predictive distributions are in matching the observed values by considering both the location and spread of the distribution

Table 1. Comparison of CRPS under different conditions

Mean CRPS	Lead Time	Calibration Events	Validation Events	High Flow Events	Peak Flow
HUP-HYMOD	n = 1	1.02	0.76	2.74	3.38
	n = 2	1.28	0.94	3.34	3.96
	n = 3	1.52	1.13	3.70	4.52
	n = 4	1.67	1.30	3.78	5.10
	n = 5	1.78	1.35	3.90	5.23
	n = 6	1.91	1.39	3.98	5.27
HUP-GR4H	n = 1	1.07	0.75	3.03	3.44
	n = 2	1.35	0.97	3.79	4.23
	n = 3	1.62	1.19	4.31	4.95
	n = 4	1.78	1.41	4.49	5.74
	n = 5	1.96	1.52	5.04	6.11
	n = 6	2.16	1.62	5.41	6.31

- For general event, HUP-GR4H presents comparable performance to HUP-HYMOD
- While for extreme high flow, HUP-HYMOD has better performance than HUP-GR4H

Main Conclusions and Future Work

Main conclusions:

- Precipitation-dependent HUP is proved as a robust method for hydrologic uncertainty quantification
- HUP has the ability to correct the deterministic forecast and produce reliable predictive distribution
- Under extreme high flow condition, a better performed model is needed to work with HUP in order to obtain an improve probabilistic forecast

Future work:

- Apply and develop PUP to assess precipitation uncertainty
- Combine all the uncertainties together in INT to assess total predictive uncertainty

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