Project 3-4 (CAFFEWS)

Uncertainty Estimation through Bayesian Forecasting System (BFS)

An Application to Humber River Watershed in Southern Ontario

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Outline

1. Introduction
2. What is BFS?
3. BFS method
4. Preliminary Application Results
5. Future Plans

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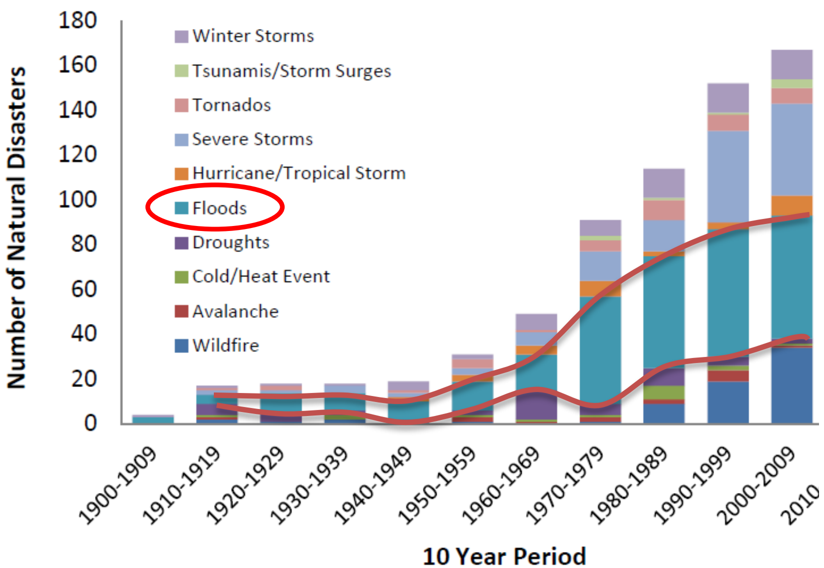
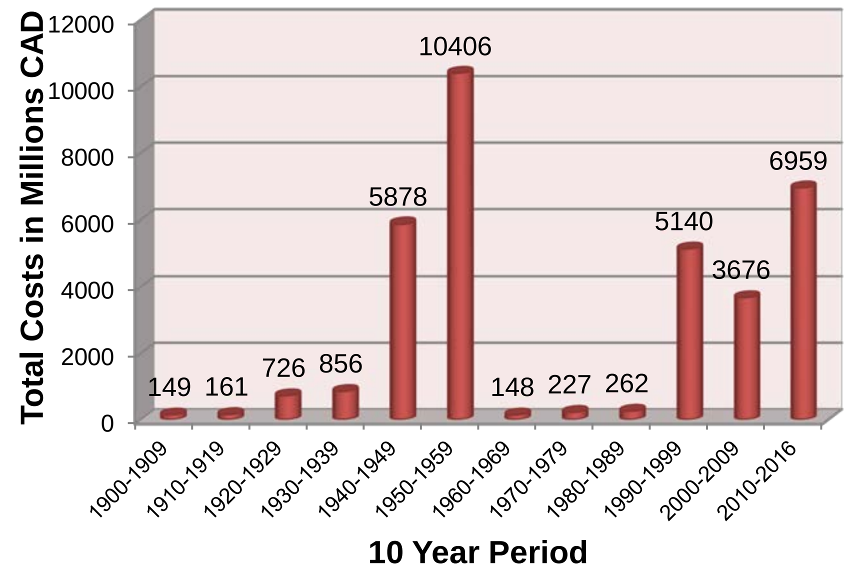
Introduction





Frequency of Natural Disasters in Canada (1900-2011)

Source: Climate Change Adaptation Plan 2012

Estimated Total Costs of Large Floods in Canada

Data Source: Public Safety Canada

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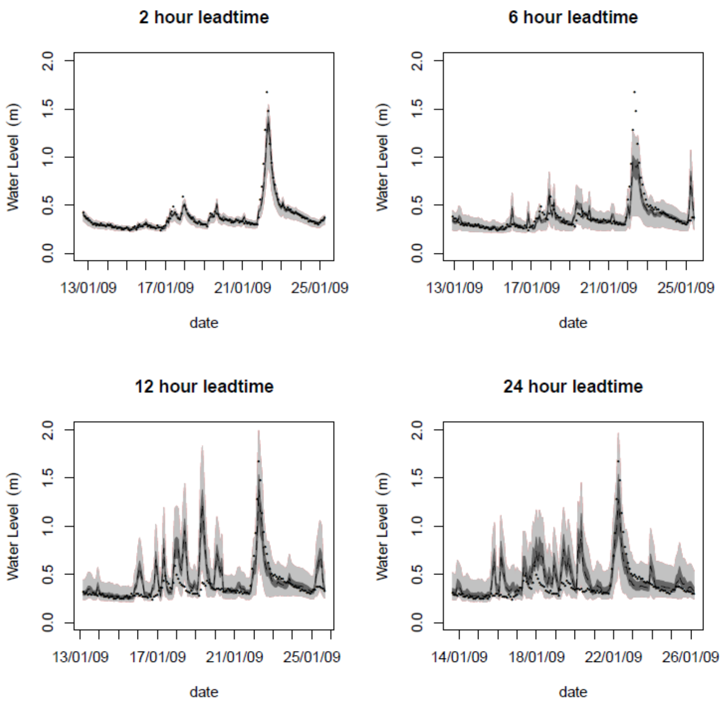
Introduction…

Deterministic forecast VS Probabilistic forecast …

- Deterministic forecast: point forecast
- Probabilistic forecast: degree of confidence associated with point forecast

- This work presents a preliminary application of BFS to Humber river watershed to assess and reduce the flood forecast uncertainty.



Comparison of observed & predicted water level (Weerts, A. H., et al, 2011)

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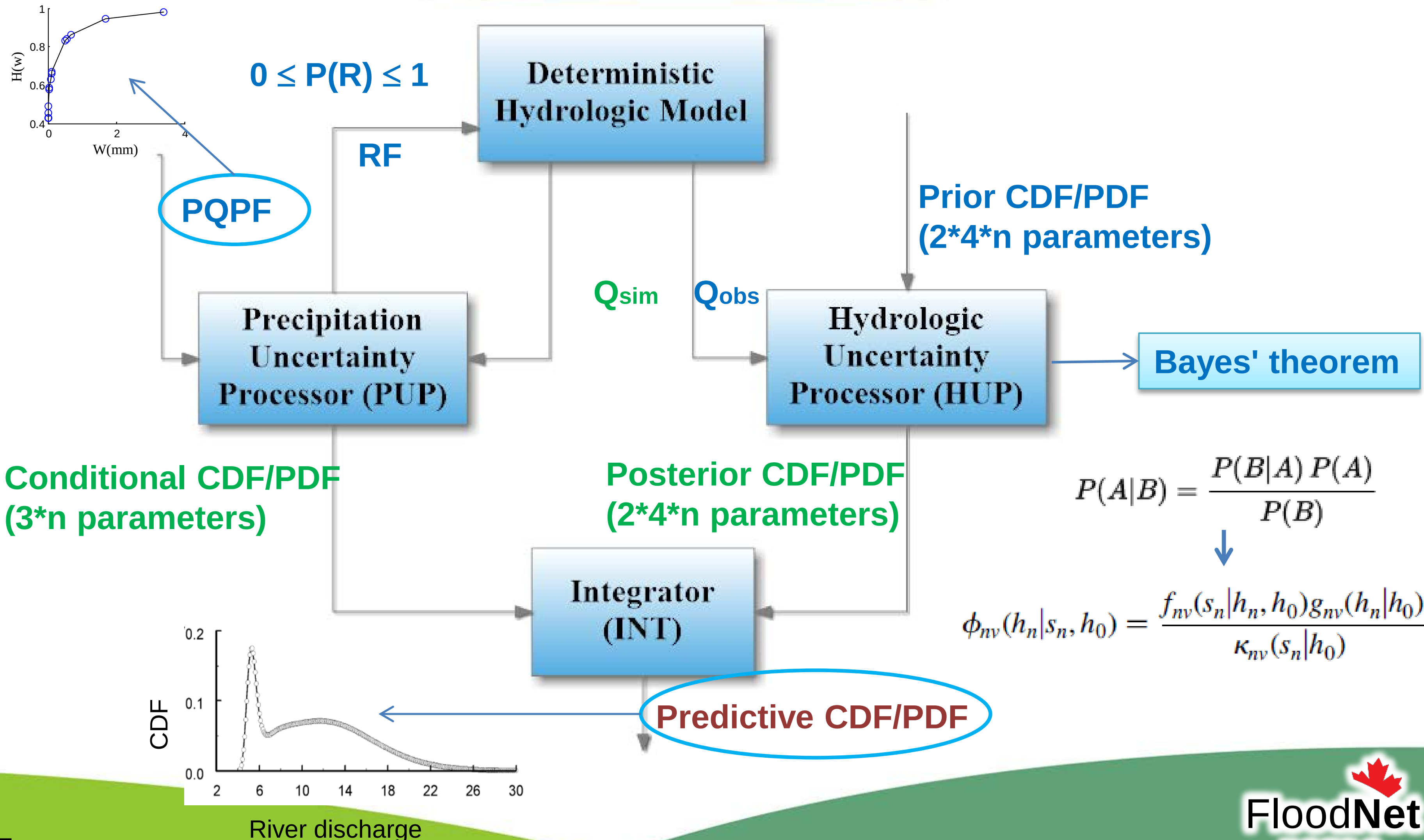
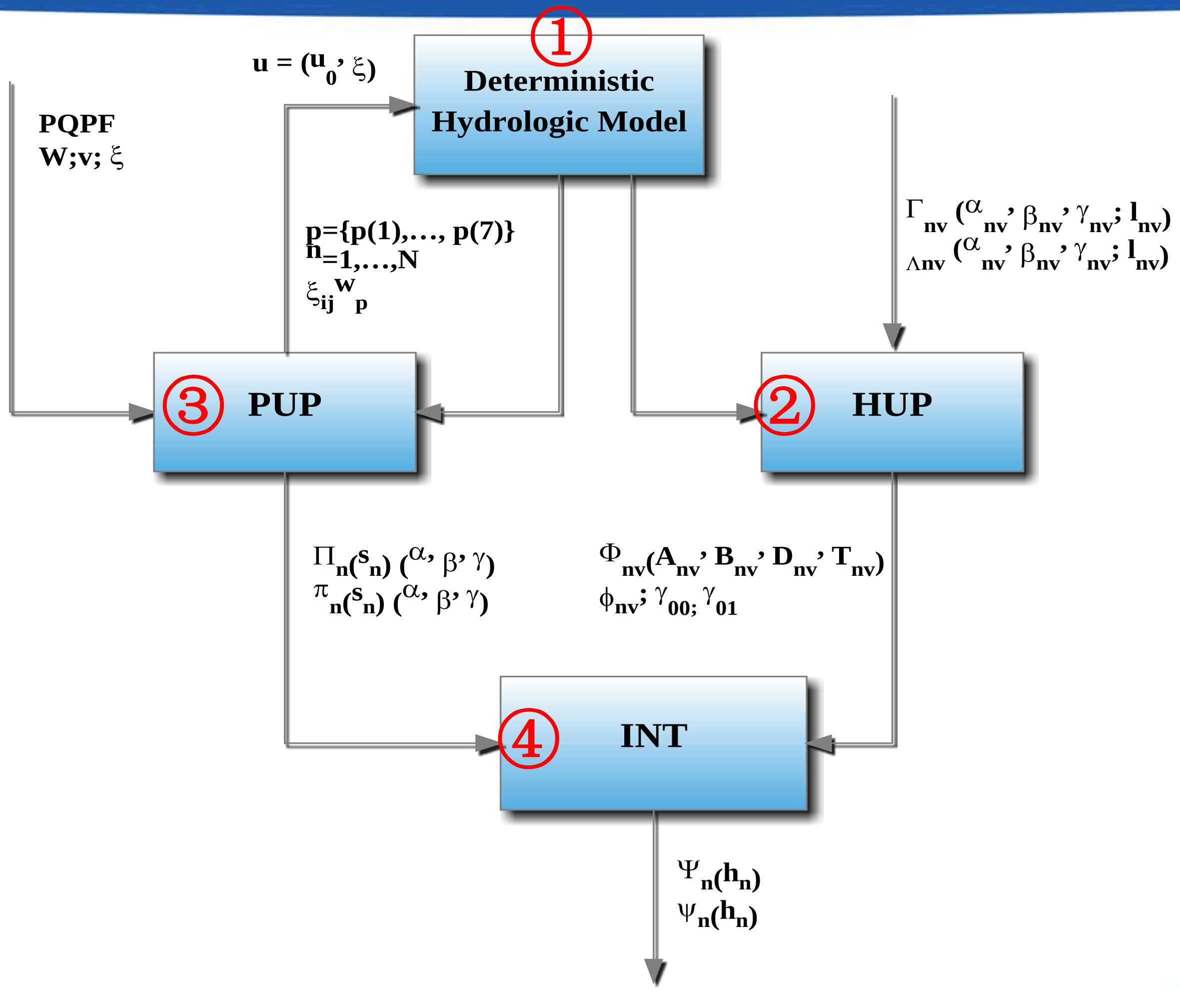
What is BFS?



$$P(A|B) = \frac{P(B|A)\,P(A)}{P(B)}$$

$$\phi_{nv}(h_n|s_n,h_0) = \frac{f_{nv}(s_n|h_n,h_0)g_{nv}(h_n|h_0)}{\kappa_{nv}(s_n|h_0)}$$

BFS Method Structure



Structure of Bayesian Forecasting System (BFS)

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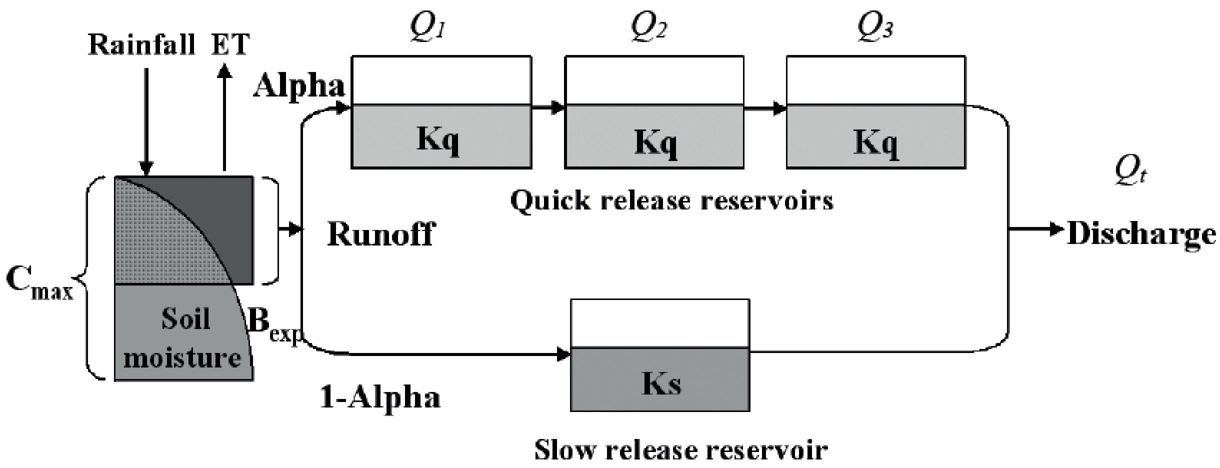
Deterministic Hydrologic Model

- Hydrologic model: HYMOD
- Parameter optimization : Monte Carlo method



Schematic description of HYMOD (Quan et al., 2015)

Further improvement:

- ET: another ET calculation method instead of Hargreaves-Samani 1985
- Data: use most recent data

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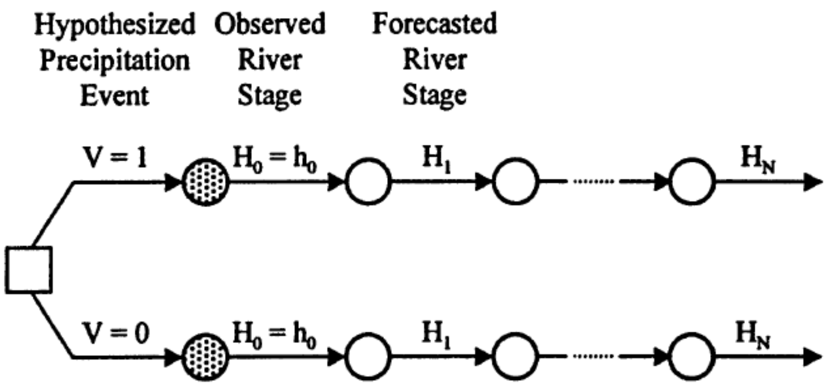
HUP (Hydrologic Uncertainty Processor)

HUP

- **Precipitation-independent HUP (PI-HUP)** — One-branch processor
- **Precipitation-dependent HUP (PD-HUP)** — Two-branch processor: each conditional on the occurrence or nonoccurrence of precipitation



Rainfall > 0 (v=1)

Rainfall = 0 (v=0)

PD-HUP (Krzysztofowicz & Herr, 2001)

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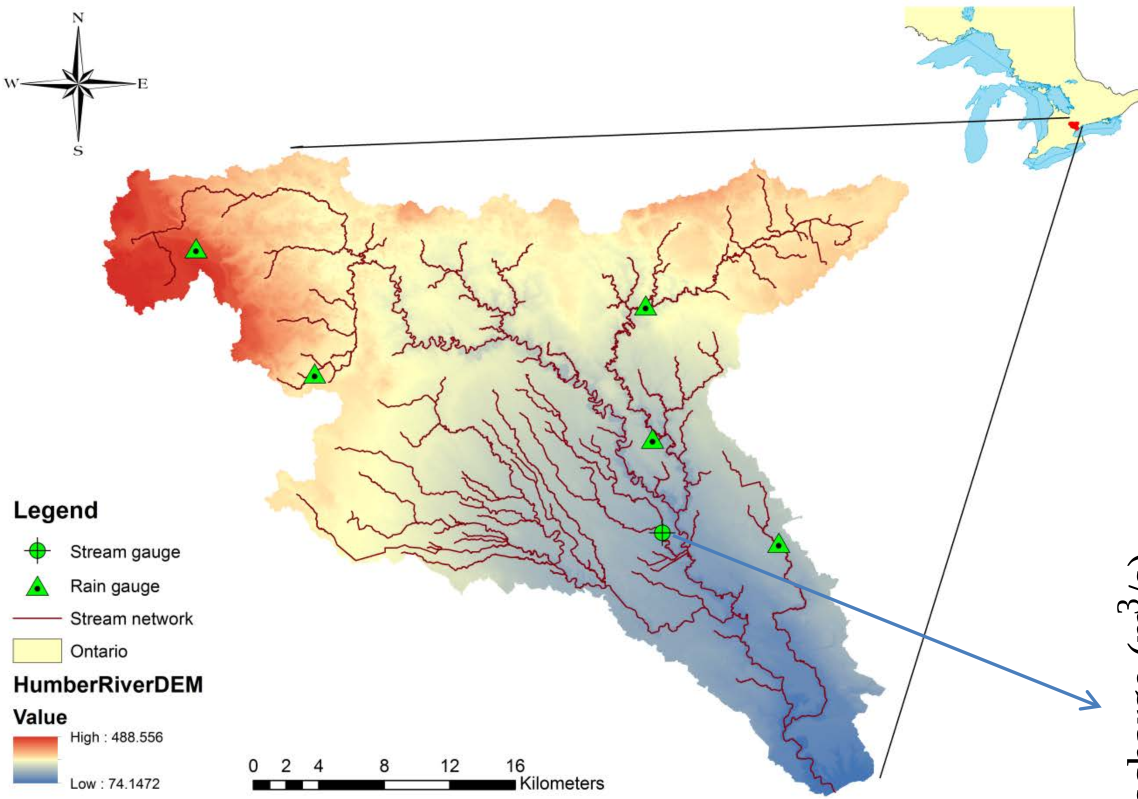
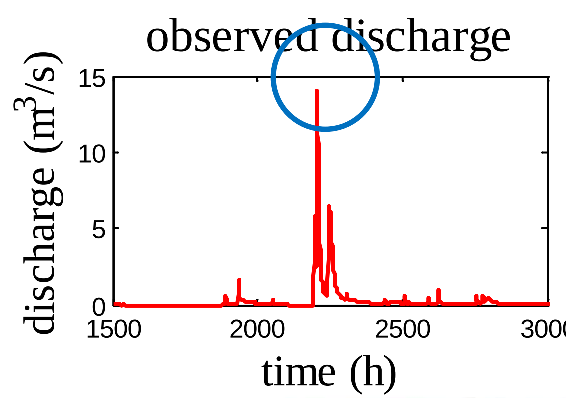
Study Area and Data



Humber River Watershed

- Northwest of Toronto
- Drainage area=911 km^2
- Hourly precipitation, discharge & temperature



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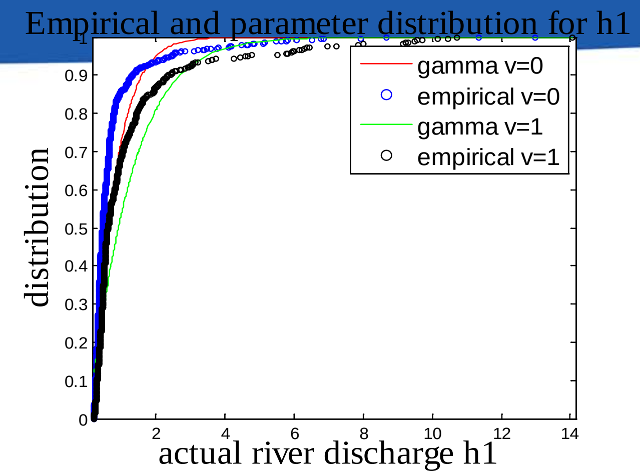
Data Pre-processing

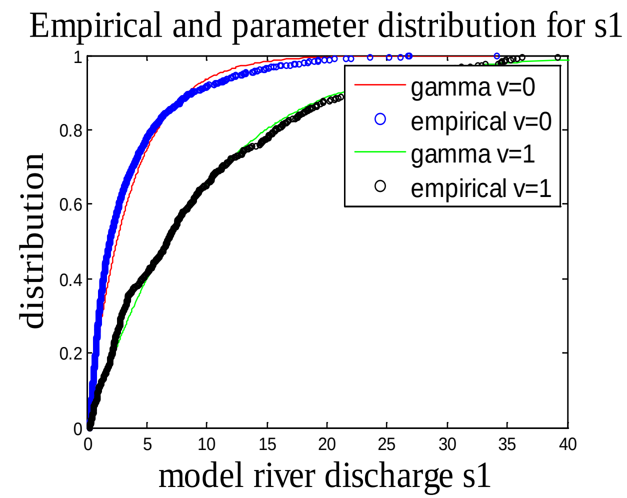
Step 1: Define lead time n

n=lead time of precipitation + concentration time of basin

Step 2: Obtain Q_{obs} (h0, h1,...,hn) & Q_{sim} (s0, s1,...,sn) at time t0, t1,...,tn (for both v=0 & v=1)

Step 3: Estimate the marginal distribution: Γnv for hn, Λnv for sn





Step 4: Normal quantile transform

$$W_n = Q^{-1}(\Gamma_{nv}(H_n)), \qquad n = 0, 1, \ldots, N,$$

$$X_n = Q^{-1}(\bar{\Lambda}_{nv}(S_n)), \qquad n = 1, \ldots, N.$$

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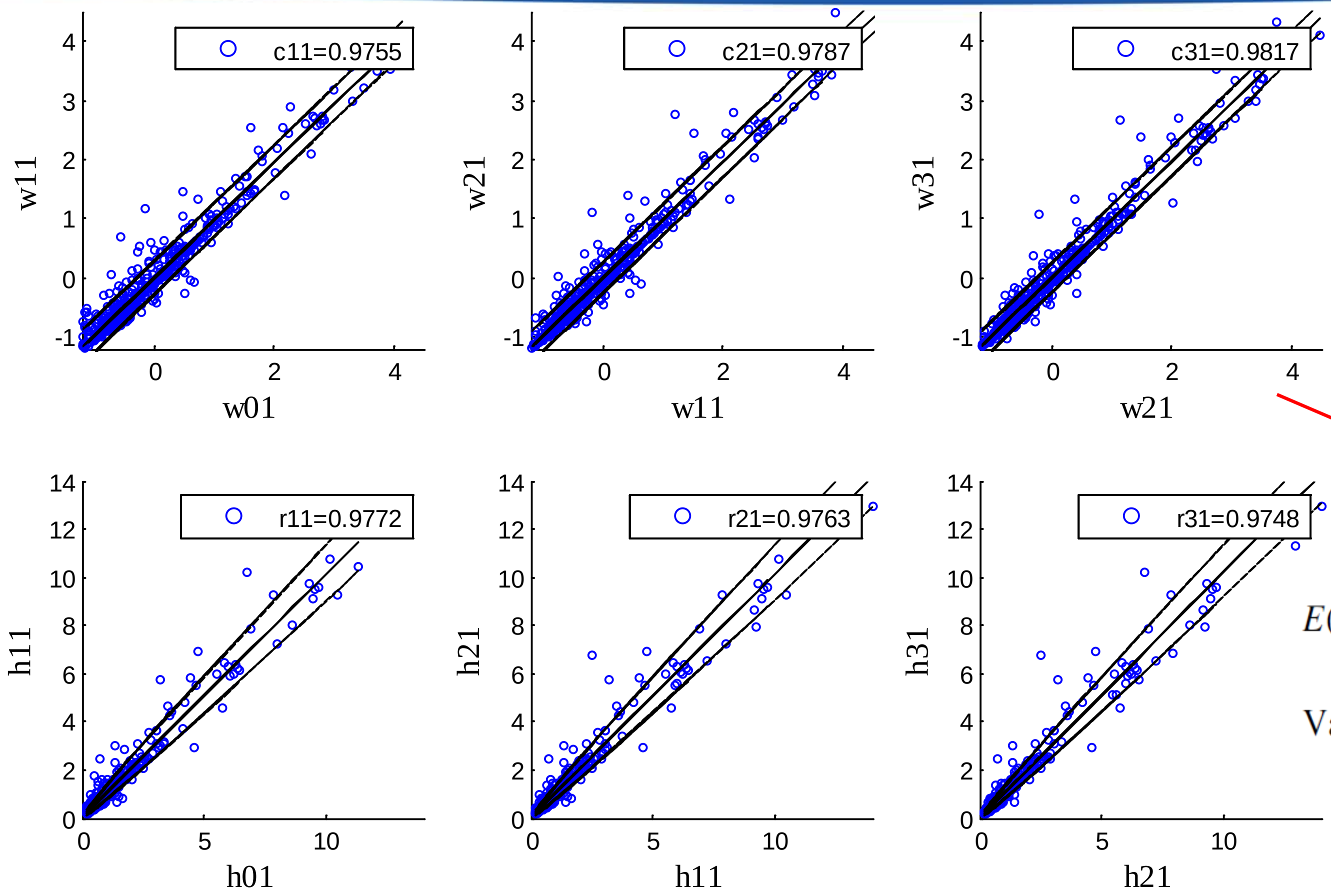
Preliminary Regression Results



Dependence parameters of the transition densities:

$$E(W_n | W_{n-1} = w_{n-1}, V = v) = c_{nv} w_{n-1},$$

$$\mathrm{Var}(W_n | W_{n-1} = w_{n-1}, V = v) = 1 - c_{nv}^2.$$

Dependence structure of transition densities (linear regression and 80% central credible interval. Upper: in transformed space; Lower: in original space)

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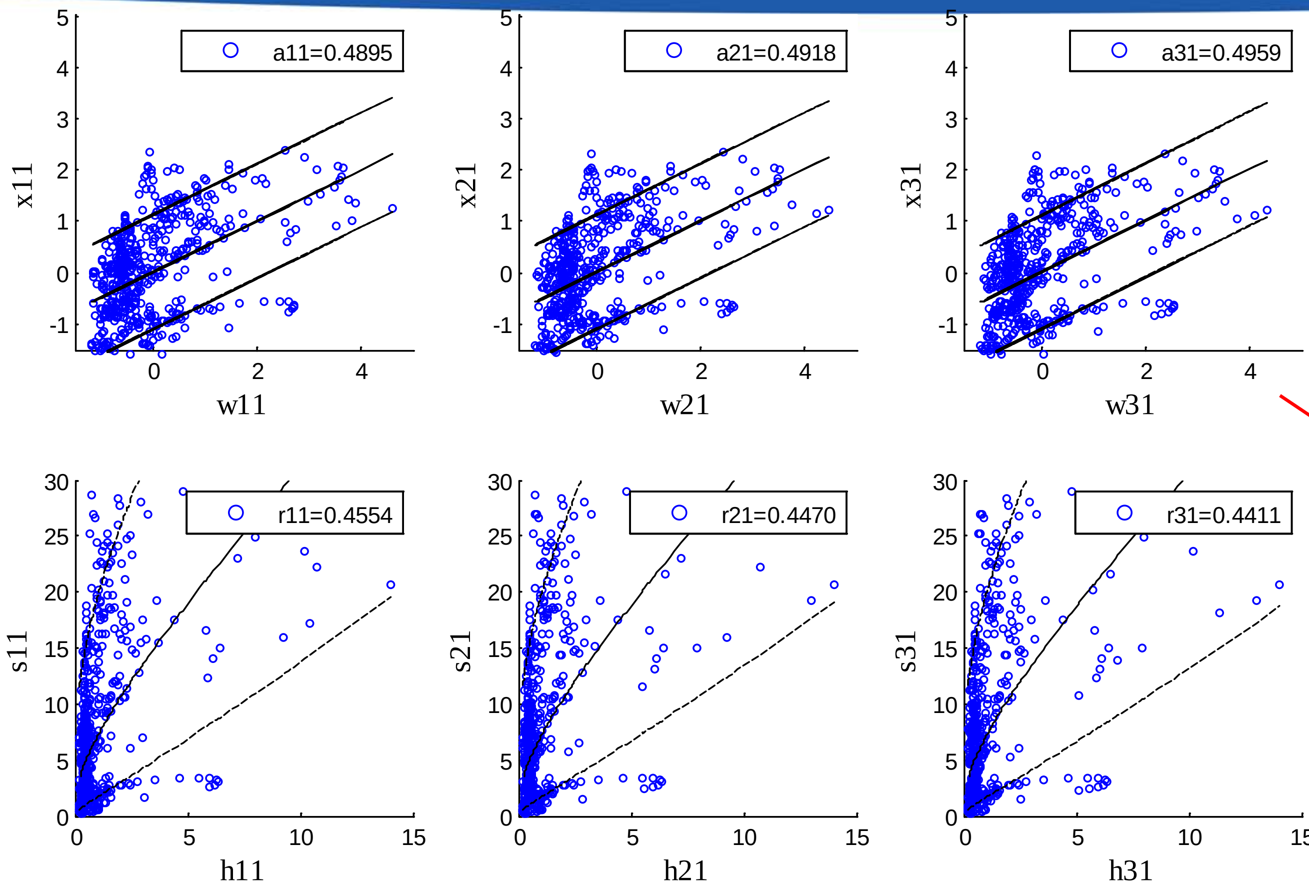
Preliminary Regression Results



Dependence parameters of the likelihood function:

$$E(X_n|W_n = w_n, W_0 = w_0, V = v) = a_{nv}w_n + d_{nv}w_0 + b_{nv},$$

$$\mathrm{Var}(X_n|W_n = w_n, W_0 = w_0, V = v) = \sigma^2_{nv}$$

Dependence structure of likelihood function (linear regression and 80% central credible interval. Upper: in transformed space; Lower: in original space)

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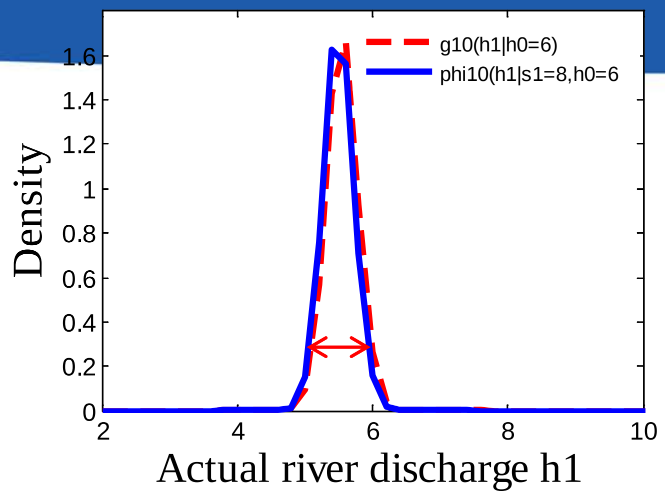
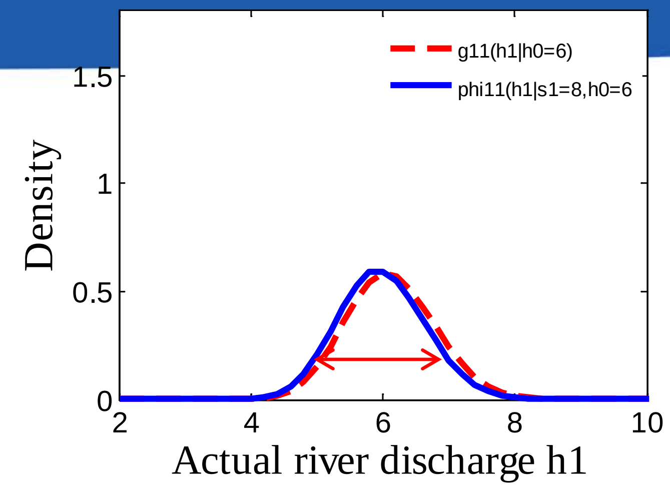
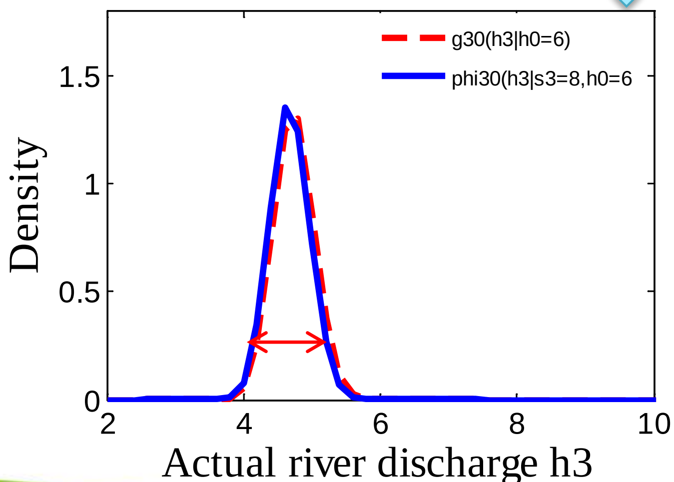
HUP Result: Prior density vs Posterior Density



Lead time n=1 (v=0)



Lead time n=1 (v=1)



Lead time n=3 (v=0)

- Hydrologic uncertainty grows when precipitation occurs
- Hydrologic uncertainty increase with increasing lead time

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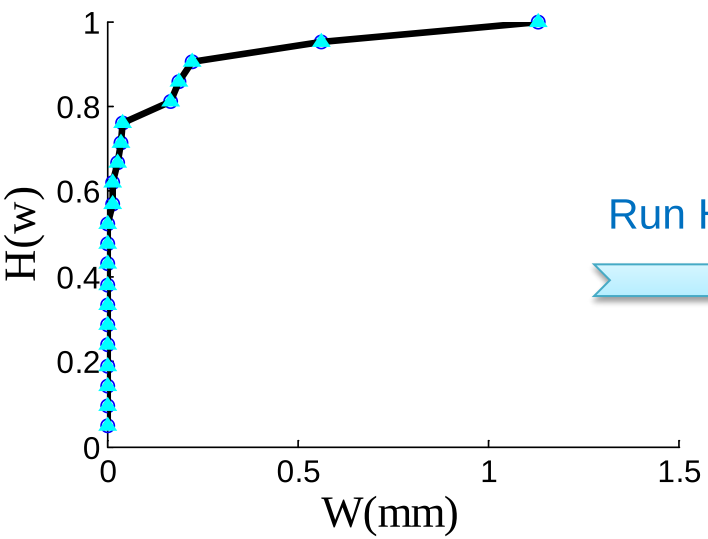
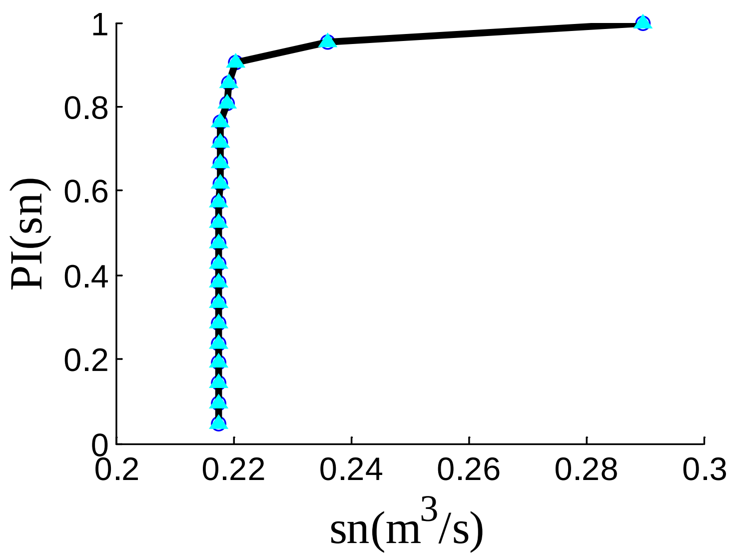
PUP (Precipitation Uncertainty Processor)

Input data: EC GEPS

- H(w): probability distribution of precipitation amount
- v: probability of precipitation occurrence



Run HYMOD



Forecast distribution H(w) of the basin average precipitation amount W at 0600 on June 4, 2015

Distribution Πn of model river discharge sn for W on June 4, 2015

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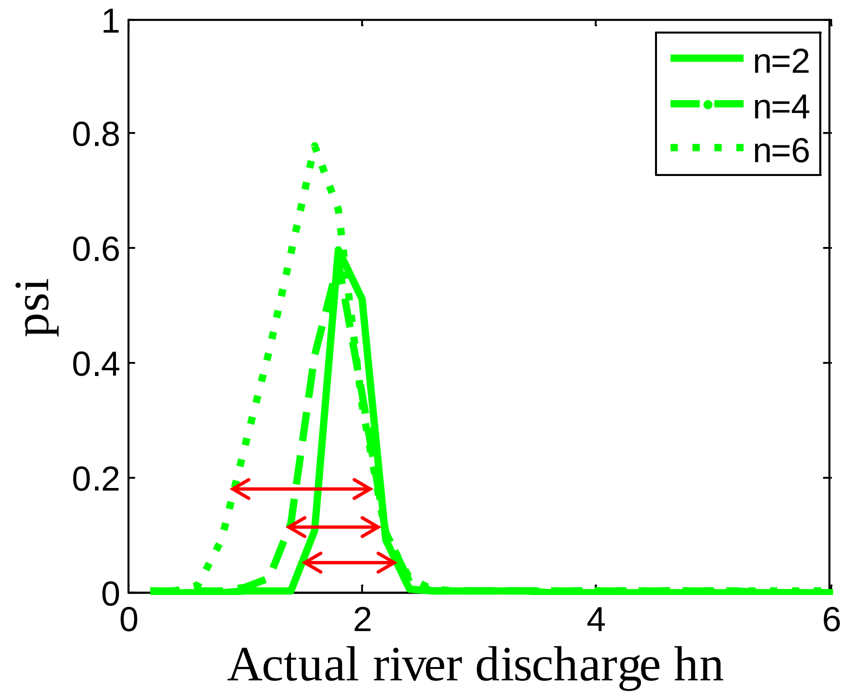
INT (Integrator)

Predictive distribution

$$\Psi_n(h_n) = \frac{\gamma_{00}(h_0)(1-\nu)}{\gamma_0(h_0)}\Phi_{n0}(h_n|s_{n0},h_0) + \frac{\gamma_{01}(h_0)\nu}{\gamma_0(h_0)}\int_{s_{n0}}^{\infty}\Phi_{n1}(h_n|s_n,h_0)\pi_{n1}(s_n)\mathrm{d}s_n$$

From PUP (blue box) From HUP (red box)

- Total uncertainty grows with increasing lead time



Comparison of predictive density at different lead time (2, 4, 6 hr)

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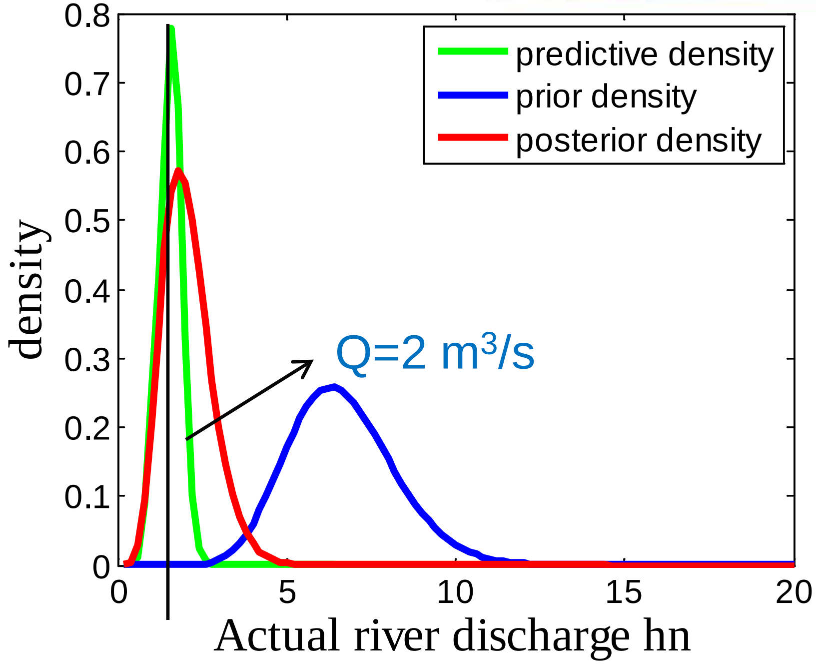
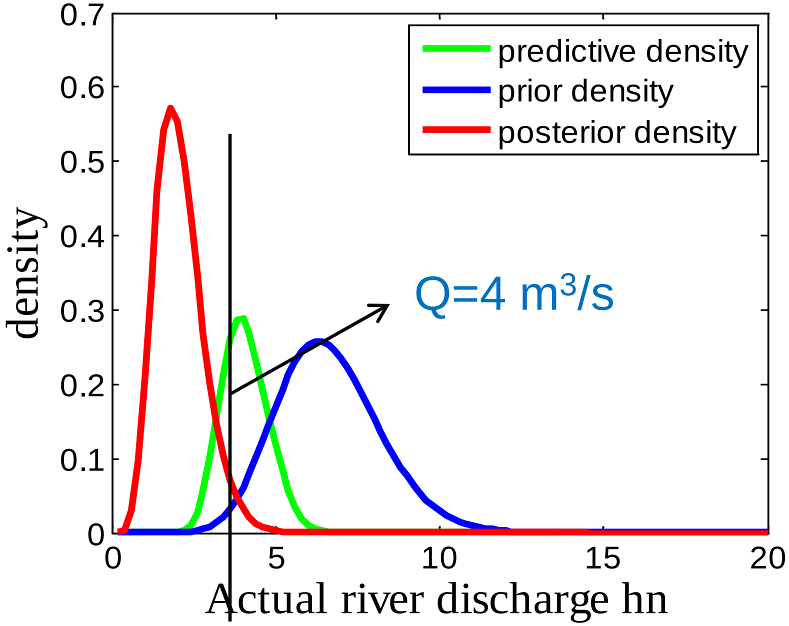
INT Preliminary Results



Comparison of prior density, posterior density & predictive density conditional on h0=6 & sn=2



Comparison of prior density, posterior density & predictive density conditional on h0=6 & sn=4

- The predictive density can reduce uncertainty and give a more accurate estimation compared with prior density

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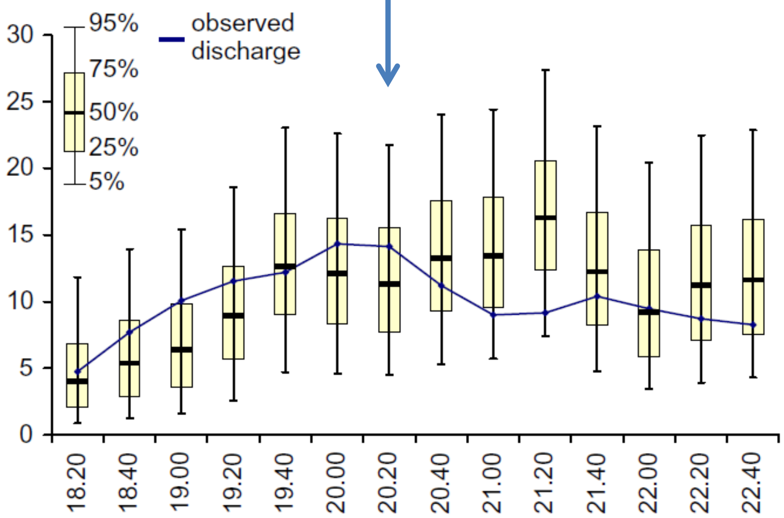
Future plans

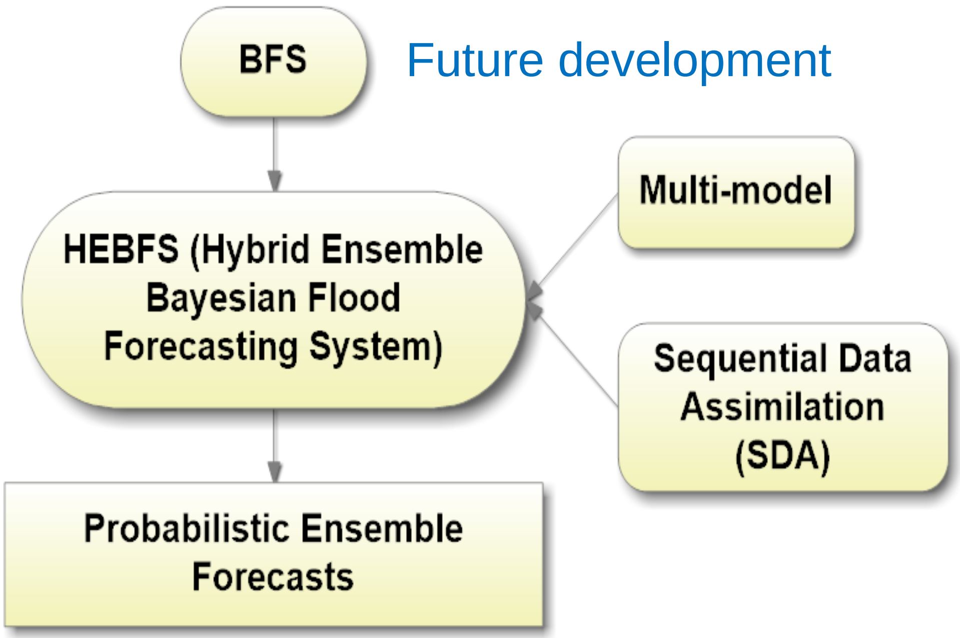
Present work…

- Optimize HYMOD and BFS method



BFS uncertainty bounds (Biondi, D., & De Luca, D. L., 2012)

Future work…



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THANK YOU!

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