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Bayesian merging of large scale and local hydrological forecasts

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Context and objective

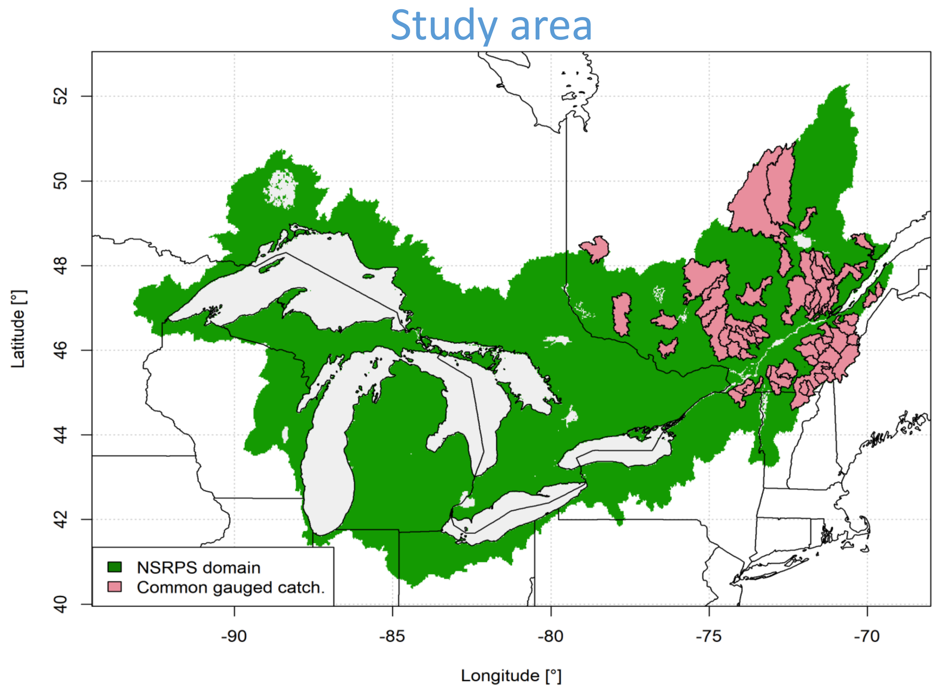
In Quebec (eastern Canada), two hydrological forecasting systems from the federal and provincial governments can be compared over a time period starting in 2019. The purpose of this study is to propose and test a framework that would merge those forecasts while considering the skill and uncertainty of each system.

Hydrological forecasting systems

	H-exp	NSRPS‡
Producer	MELCC (Québec)	ECCC (Canada)
Meteo	ECCC regional forecasting system	
Model	HYDROTEL	SVS + WATROUTE
Model type	Conceptual	Physically based
Lead time	3h, 6h, 9h,…, 5d	1h, 2h, 3h,…, 6d
Nature	Deterministic dressed	Deterministic†
Assimilation	Expert judgement [3]	None†
Spatial resolution	28,035 river reaches	1km*1km grid

‡ *Not fully operational yet*
† *Ensemble version and assimilation under development*

Study area

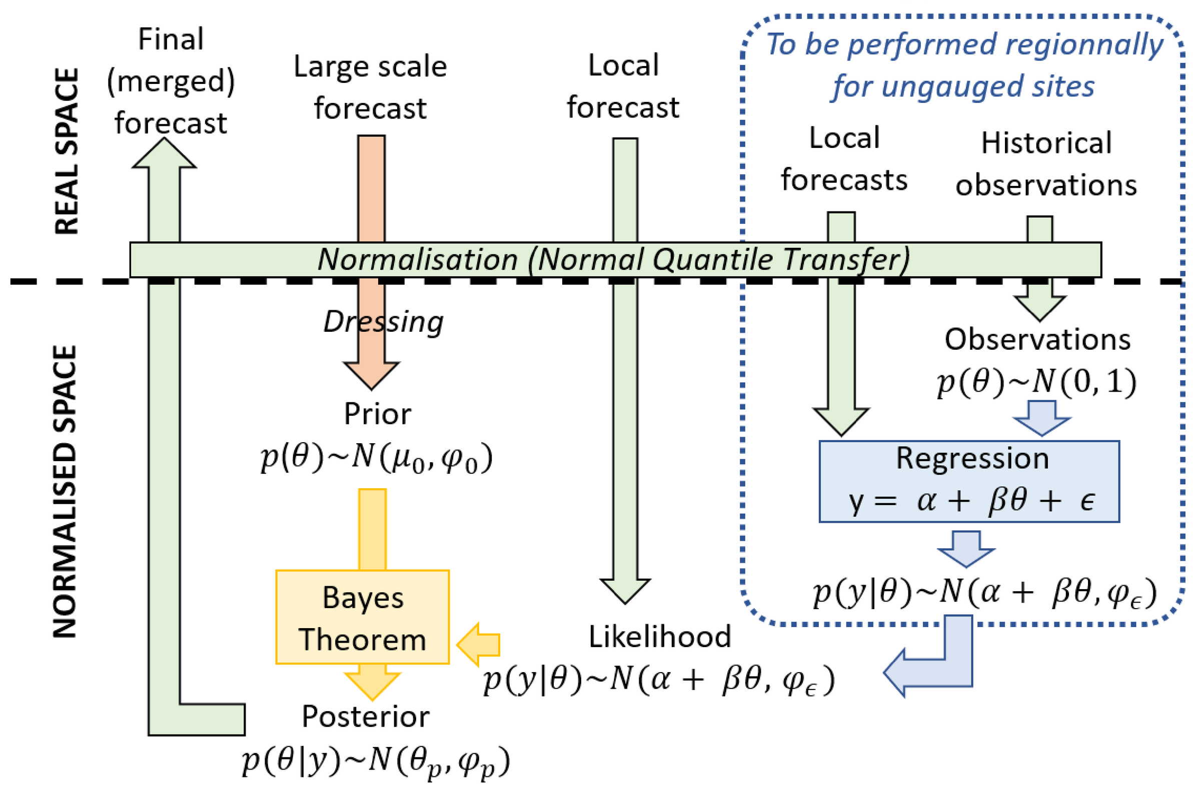


- 57 common gauged catchments are identified in the St Lawrence river basin.
- Those catchments are unregulated with drainage areas ranging from 188 to 15,515 km^2.
- Forecasts for the spring period are tested, as it is the most flood-prone season.

Methodology

The approach is adapted from the Hydrological Uncertainty Processor [1] and Bayesian Updating [2]. In those Bayesian frameworks a forecast posterior distribution is derived from a prior distribution and a likelihood function associated with the forecast. Here, after normalisation, the large scale forecasting system (NSRPS) is used as a prior distribution while the locally expertised system (H-exp) is used as the actual forecast. The likelihood is obtained by fitting a regression on past forecast and observation couples.

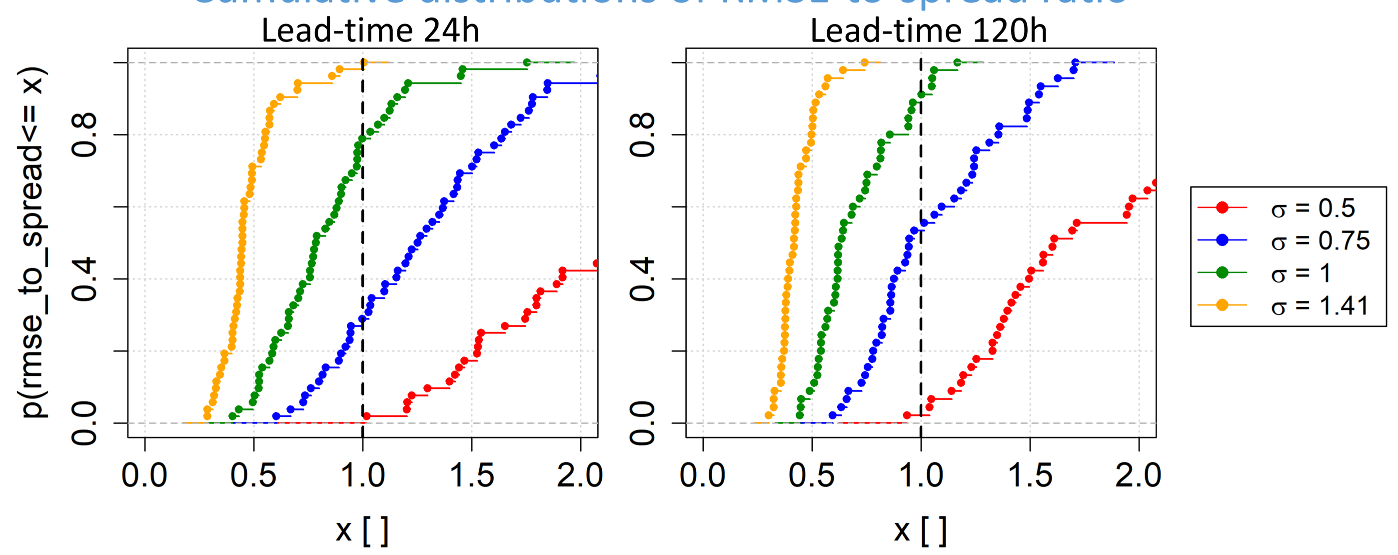
Schematic view of the methodology



NSRPS dressing

As NSRPS is used as a prior, a simple dressing with constant variance is used. A variance of 1 seems to offer the best compromise between skill and spread for NSRPS forecasts.

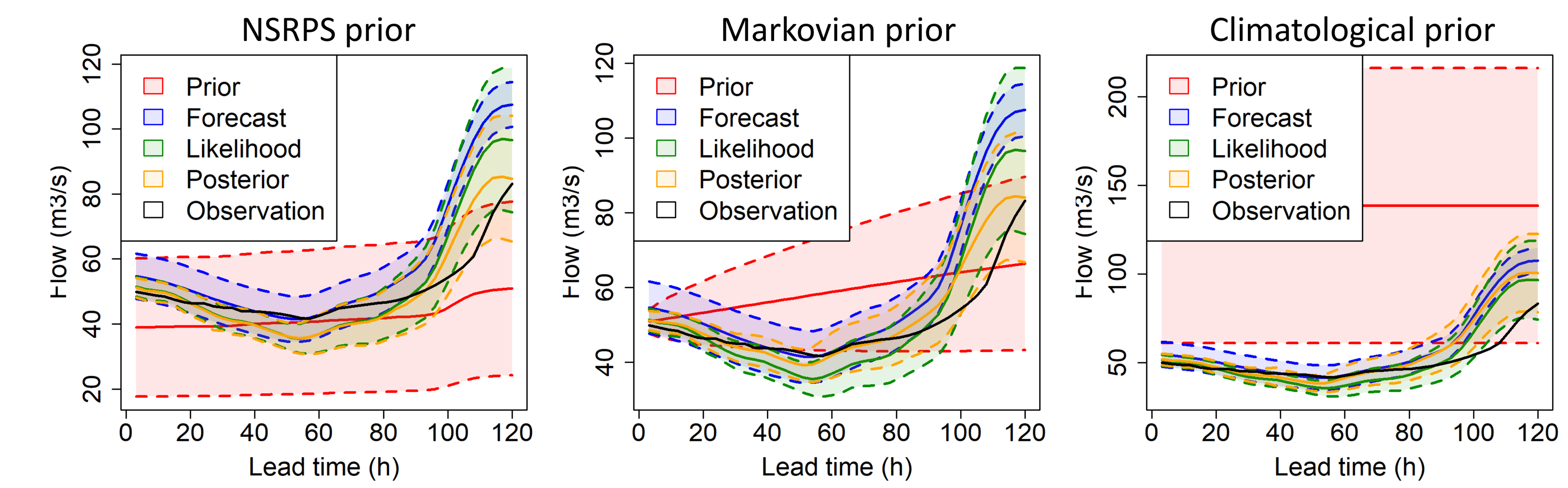
Cumulative distributions of RMSE-to-spread ratio



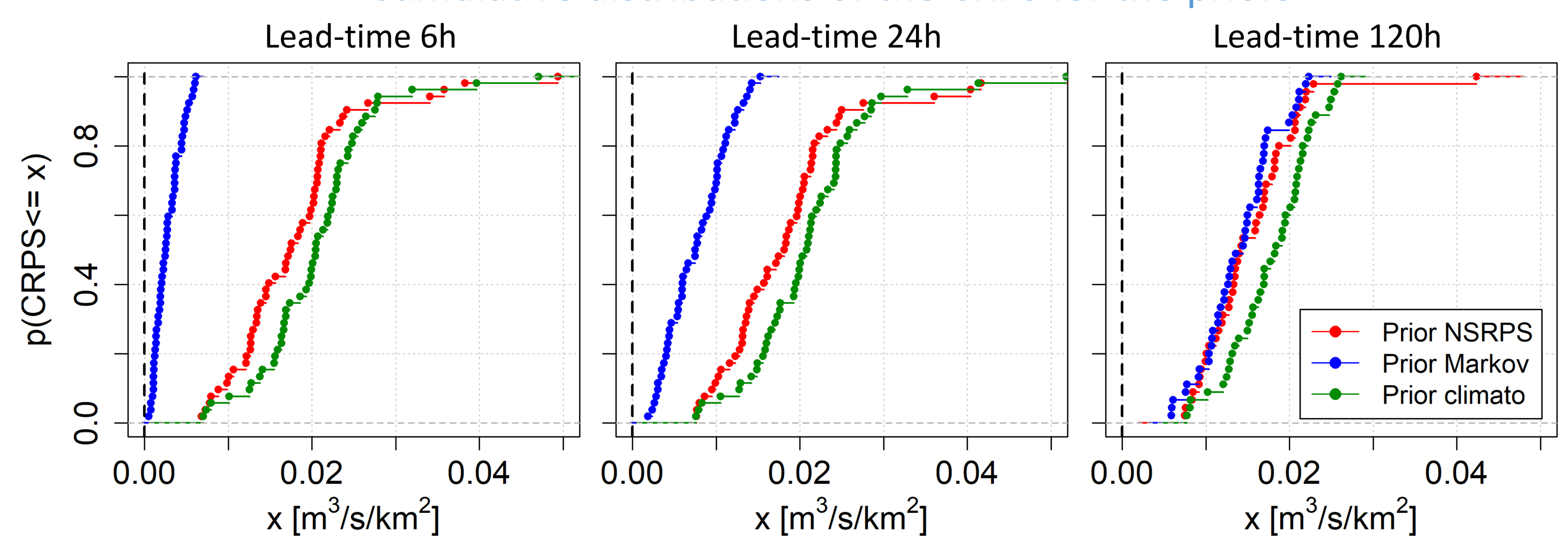
Building the prior

The NSRPS prior is compared to a climatological prior [2] and a Markovian one [1]. In gauged sites the markovian prior performs better than NSRPS, but it relies strongly on the latest available observation, which is not available for ungauged catchments.

Forecast emitted on May, 12th 2020 at 6am for the Malbaie River



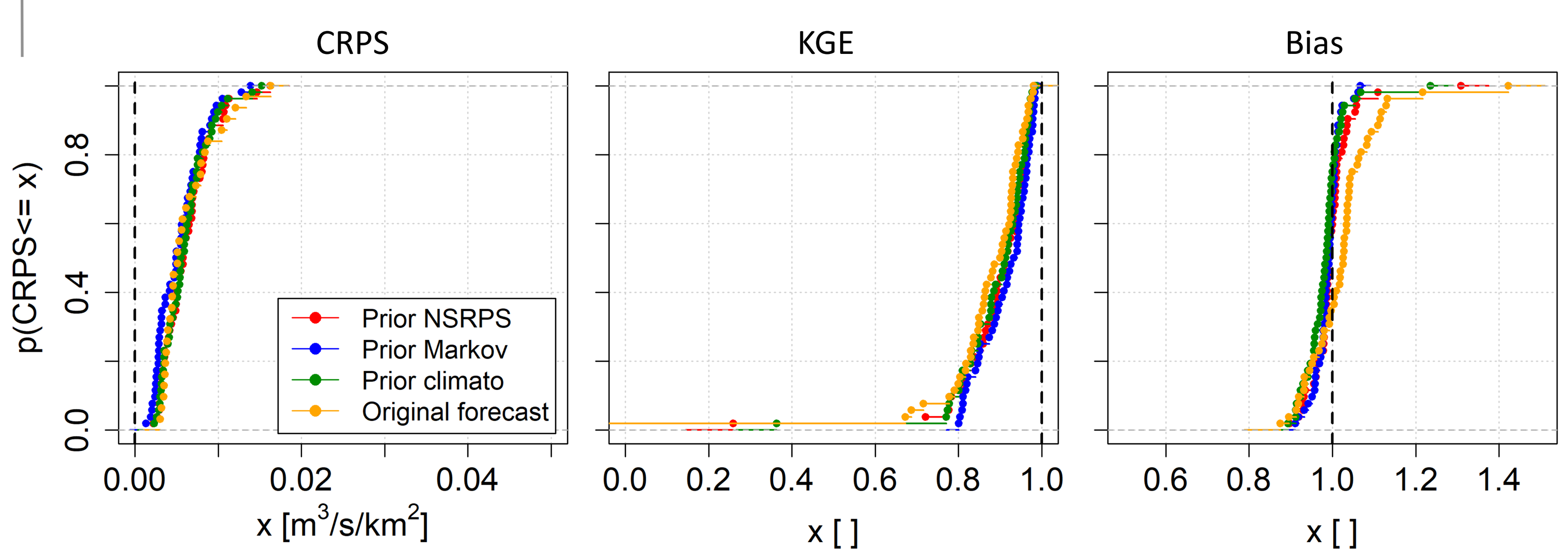
Cumulative distributions of the CRPS for the priors



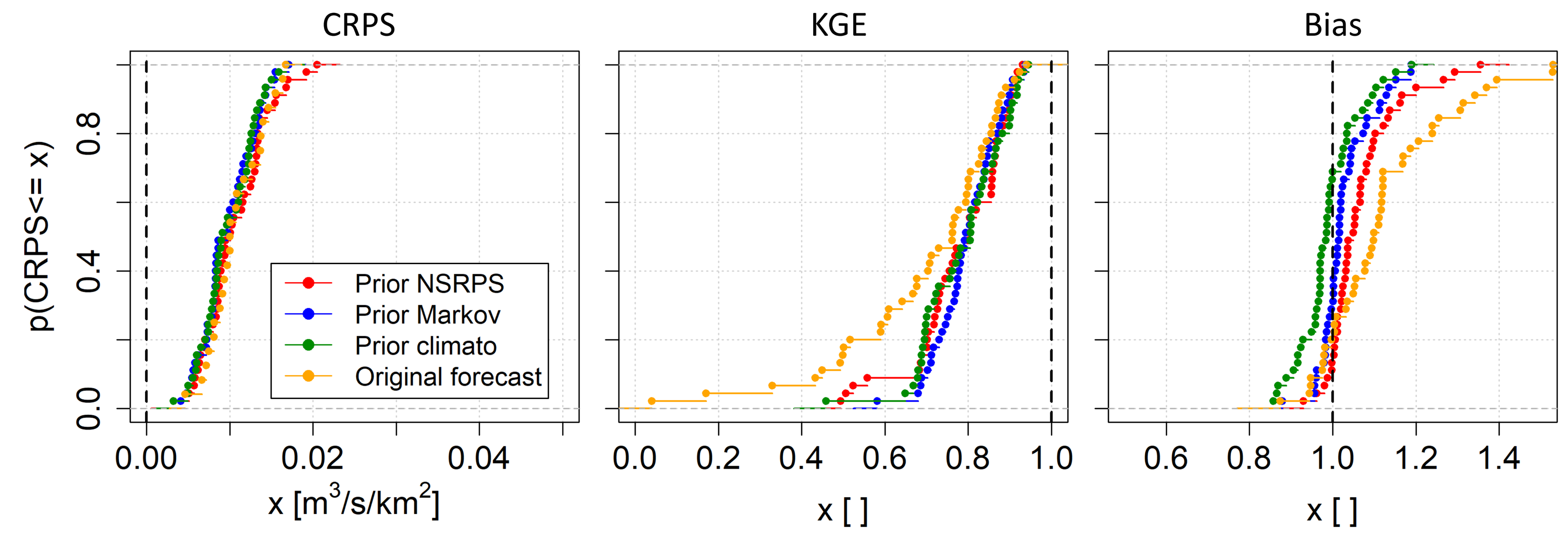
Performances at gauged sites

Bayesian post-processing improves forecasts for longer lead-times especially regarding bias reduction. There is not a large difference in using the different priors.

Cumulative distributions of the scores at lead-time 24h



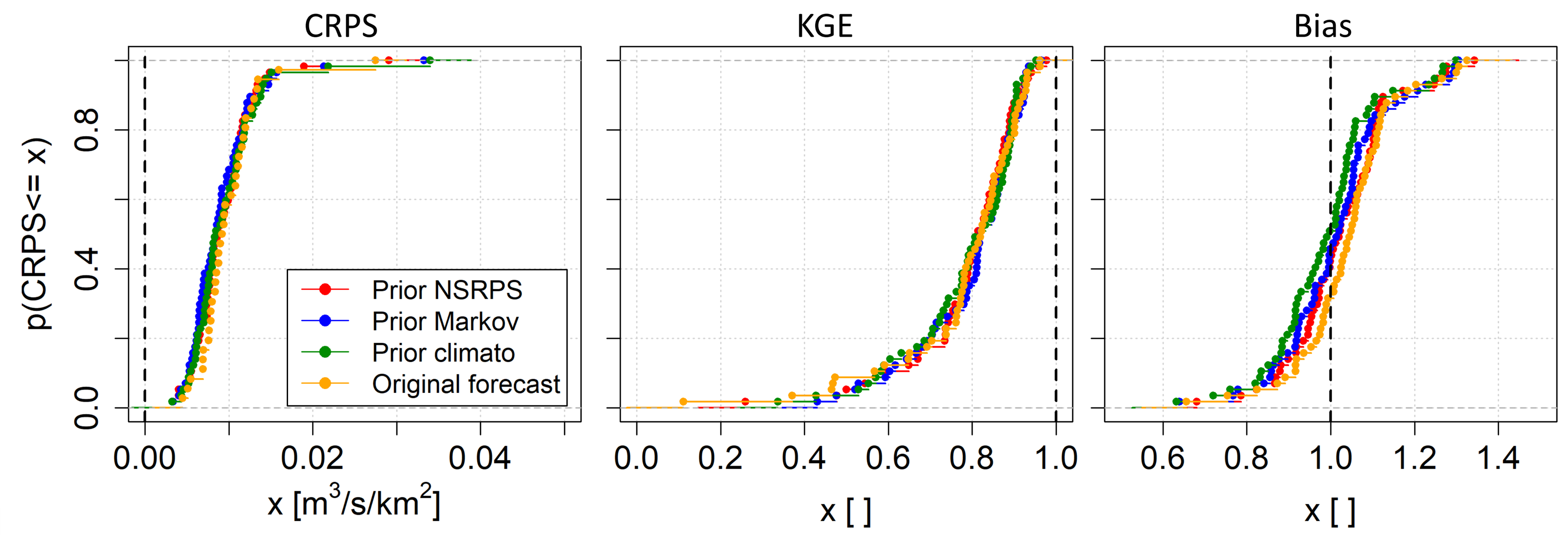
Cumulative distributions of the scores at lead-time 120h



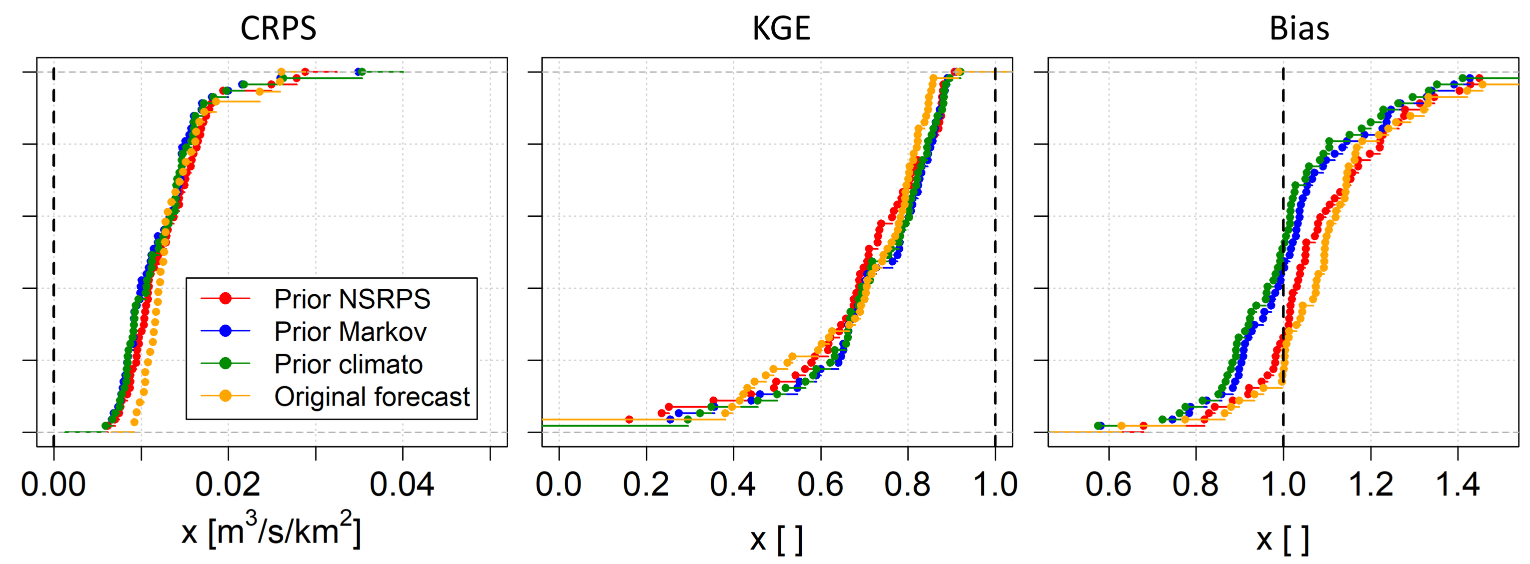
Performances at ungauged sites

For ungauged sites, the prior, likelihood function and normalisation are obtained using observations from the 5 nearest neighbors in a leave-one-out framework.

Cumulative distributions of the scores in ungauged sites at lead-time 24h



Cumulative distributions of the scores in ungauged sites at lead-time 120h



Conclusions and future work

- The proposed merging technique is efficient: merged forecasts remain at least as good as the raw local forecasts.
- At ungauged sites, the use of regional laws seems to be acceptable to estimate the likelihood functions and to perform the normalisation.
- Limitations:
  - The study period is very short.
  - One forecasting system is individually much more skillfull than the other.
  - Both systems are fed by approximately the same meteorological forecasts, so the information brought by the second forecasting system is not entirely new.

REFERENCES

(1) **Krzysztofowicz, R. and K. S. Kelly (2000).** Hydrologic uncertainty processor for probabilistic river stage forecasting. *Water Resour. Res.*, 36(11).

(2) **Luo, L., E. F. Wood, and M. Pan (2007).** Bayesian merging of multiple climate model forecasts for seasonal hydrological predictions. *J. Geophys. Res.*, 112(D10).

(3) **Lachance-Cloutier S, Turcotte R. et Cyr J-F (2017).** Combining streamflow observations and hydrologic simulations for the retrospective estimation of daily streamflow for ungauged rivers in southern Quebec (Canada), *Journal of Hydrology*, 550, 294-306

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