Should we use seasonal meteorological ensemble forecasts for hydrological forecasting?

A case study for Nordic watersheds in Canada.

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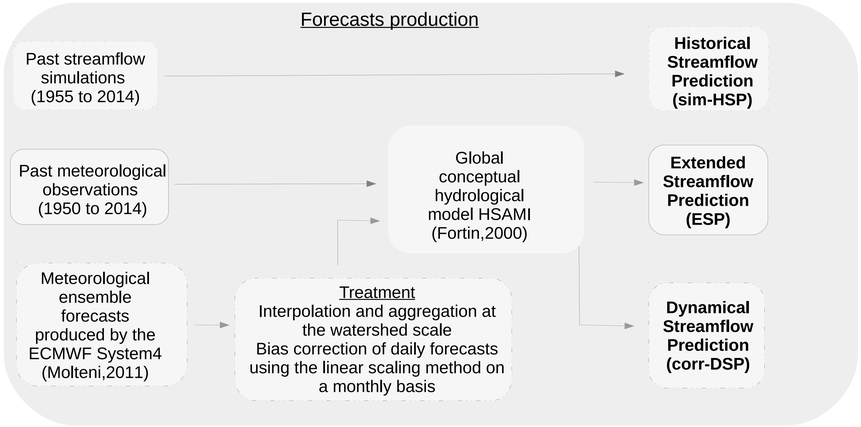
1 - Context and methodology

Electricity in the province of Québec is mainly produced by hydropower. Long-term hydrological forecasts assist managers in developing production strategy over several months. Most well known methods for long-term forecasting are based on past observations. However, meteorological and hydrological conditions are expected to change due to climate change (Guay et al.,2015). Therefore, past observations might not provide good indications about the future. An alternative is to use seasonal ensemble meteorological forecasts produced by dynamical models.

Objective → **Compare the performance of long-term ensemble meteorological forecasts to classical forecasting techniques**



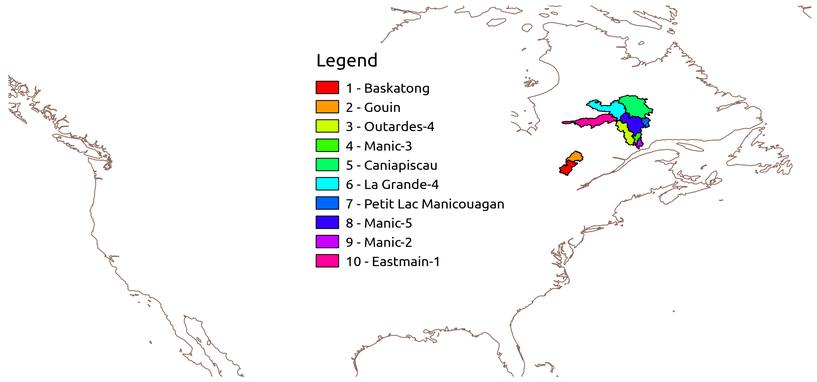


Figure 1 : Geographical location of the watersheds

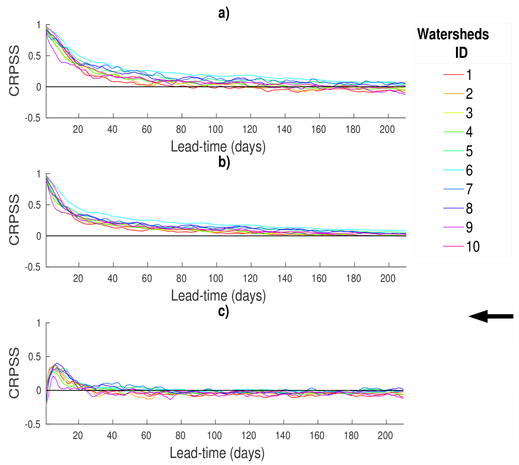
1 ensemble forecast issued on the 1st of each month for the next 210 days between 1981 and 2014.
15 or 51 members for corr-DSP, 64 members for ESP and 59 members for sim-HSP.

Forecasts verification :

- Verification set
  - 408 pairs ensemble forecasts-observations for daily streamflows
  - 34 pairs of ensemble forecasts-observations for monthly volumes and Snow Water Equivalent (SWE)
- Observations : **Simulated observations (daily streamflows, monthly volumes and SWE)**
- Continuous Ranked Probability Skill Score (CRPSS)

$$CRPSS = 1 - \frac{CRPS_{forecasts}}{CRPS_{benchmark}}$$

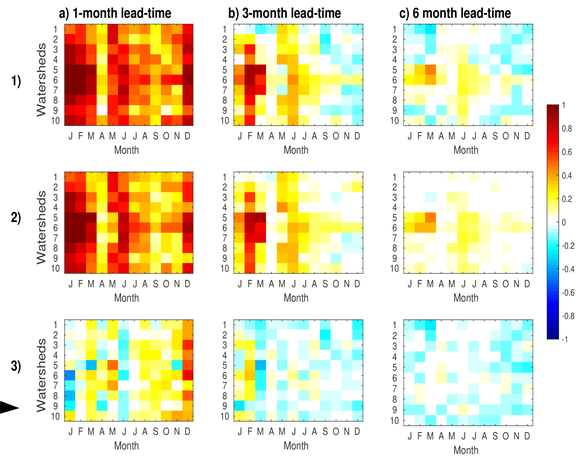
2 - Performance of daily streamflow and monthly volume forecasts



- Both ESP and corr-DSP outperform HSP for the 1-month lead-time. The CRPSS of daily streamflow and volume forecasts are unanimous. This advantage remains until the 3-month lead-time for some watersheds. According to Figure 3-1b and 2b, the difference of information in volume forecasts between sim-HSP and ESP or corr-DSP is higher during the winter and late spring.
- The performance of corr-DSP compared to ESP depend on the watershed and on the month for the 1-month lead-time. For longer lead-times, ESP are slightly better, according to daily streamflow and monthly volume forecasts.

Figure 2 (left) : CRPSS of daily streamflow forecasts (408 ensemble forecasts-observations pairs) as a function of lead-time for a) corr-DSP compared to sim-HSP (benchmark), b) ESP compared to sim-HSP (benchmark), and c) corr-DSP compared to ESP (benchmark).

Figure 3 (right) : CRPSS of monthly volume forecasts (34 ensemble forecasts-observations pairs) for 1) corr-DSP compared to sim-HSP (benchmark), 2) ESP compared to sim-HSP (benchmark) and 1) corr-DSP compared to ESP (benchmark) for a) 1- month lead-time, b) 3-month lead-time and c) 6-month lead-time.



3 - Performance of SWE forecasts

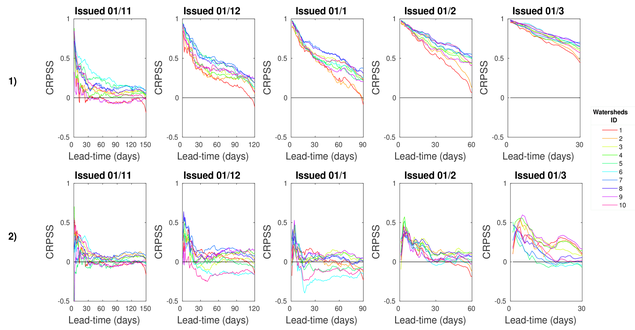


Figure 4 : CRPSS of Snow water equivalent (SWE) forecasts (34 ensemble forecasts-observations pairs) for various dates of emission for 1) corr-DSP compared to sim-HSP (benchmark) and 2) corr-DSP compared to ESP (benchmark).

- Forecasts issued after the 1st of December produced by corr-DSP provide more information about the SWE at the end of winter than SWE forecasts produced by sim-HSP.
- The best performing system varies from one watershed to another: either ESP or corr-DSP SWE forecasts.

4 - Conclusion

- A simple method such as linear scaling leads to good results for hydrological forecasting, as shown by Crochemore (2016). Corr-DSP and ESP have similar overall behavior. This is particularly true for lead-times longer than one month. They both outperform sim-HSP for all watersheds and for almost all lead-times.
- Corr-DSP is at least an alternative to climatology and a complement to ESP in the face of climate change.
- More sophisticated bias correction methods could be investigated, as well as seasonal ensemble forecasts produced by different models. Verification assessment with others scores are in progress to consolidate the analysis.

References

Crochemore, L., Ramos, M.-H., and Pappenberger, F.: Bias correcting precipitation forecasts to improve the skill of seasonal streamflow forecasts, Hydrology and Earth System Sciences, 20, 3601–3618, 2016.

Fortin, V.: Le modèle météo-apport HSAMI: historique, théorie et application, Institut de recherche d'Hydro-Québec, Varennes, 2000.

Guay, C., Minville, M., and Braun, M.: A global portrait of hydrological changes at the 2050 horizon for the province of Québec, Canadian
Water Resources Journal/Revue canadienne des ressources hydriques, 40, 285–302, 2015.

Molteni, F., Stockdale, T., Balmaseda, M., Balsamo, G., Buizza, R., Ferranti, L., Magnusson, L., Mogensen, K., Palmer, T., and Vitart, F.: The new ECMWF seasonal forecast system (System 4), European Centre for Medium-Range Weather Forecasts, 2011.

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