

➤ Flood simulation errors show an unexpected seasonal trend

Results obtained on a set of 229 catchments and 11,054 flood events

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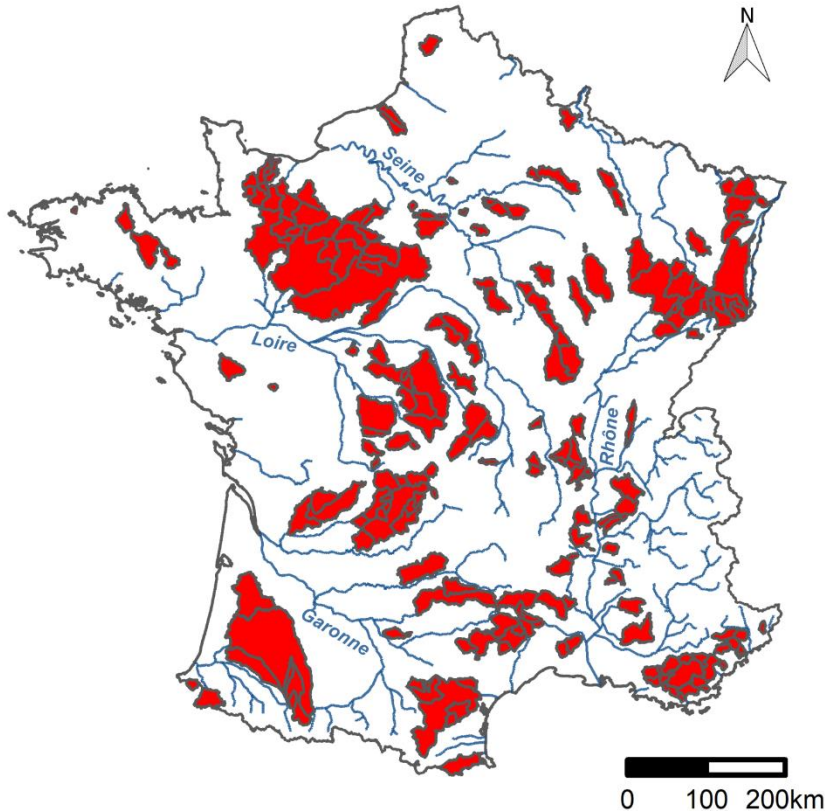
➤ Context

- A need for improving hydrological models
 - Reducing model structure uncertainty to improve process understanding, hydrological forecasting ...
- Model diagnostics to identify where to improve models
 - Using relevant signatures to link model performance with hydrological processes
 - On large data samples for more general analyses
 - At the event-scale to assess flood simulation performance
- Streamflow can have strong seasonal variations
 - This results in variable flood generating processes between catchments and events

➤ Objectives

- *Assess whether the seasonal variations of streamflow can be a good indicator of model performance in simulating floods*
- *Identify event-scale conditions for which a conceptual hydrological model yields lower performance*

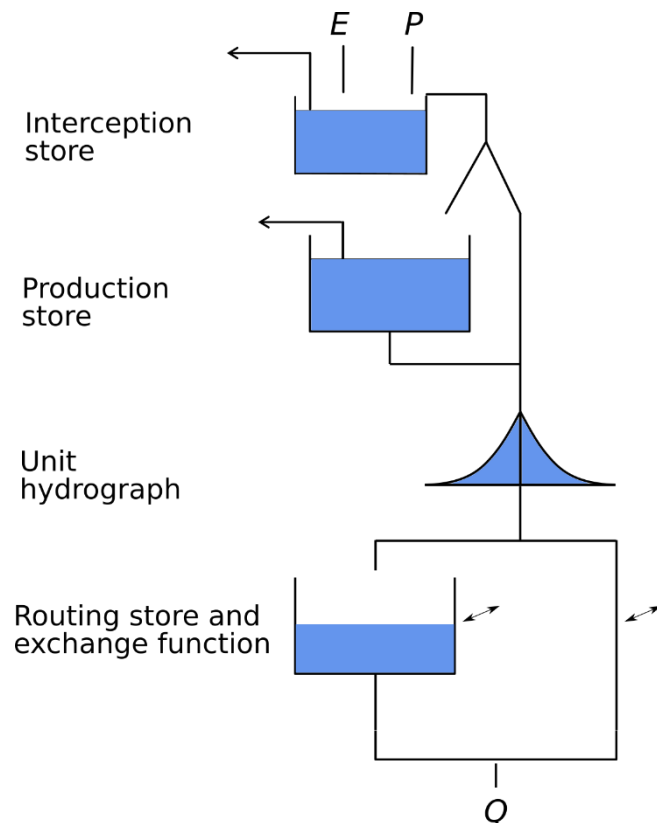
➤ A large sample of catchments and flood events



- 229 French catchments with varying hydro-climatic conditions¹
- 18 years of hourly time series
- COMEPHORE reanalysis²
 - Hourly precipitation time series
- Hourly streamflow time series^{3,4}
- 11,054 flood events selected with an automated procedure
 - Events with peak flow higher than the 95th streamflow quantile

¹Ficchì et al. (2016); ²Tabary et al. (2012); ³Leleu et al. (2014); ⁴Delaigue et al. (2020)

➤ Rainfall-runoff model and parameter estimation



- GR5H-I lumped hourly rainfall-runoff model^{5,6}
- Five parameters calibrated on two independent sub-periods (P1 and P2) of 9 years
 - Local gradient-based optimization procedure preceded by a gross screening of the parameter space⁷
 - KGE index objective function⁸

⁵Le Moine (2008); ⁶Ficchi et al. (2019); ⁷Perrin et al. (2008); ⁸Gupta et al. (2009)

➤ A progressive increase in model evaluation focus

Overall model performance
in simulating the whole
streamflow time series



Seasonality of model bias in
simulating floods

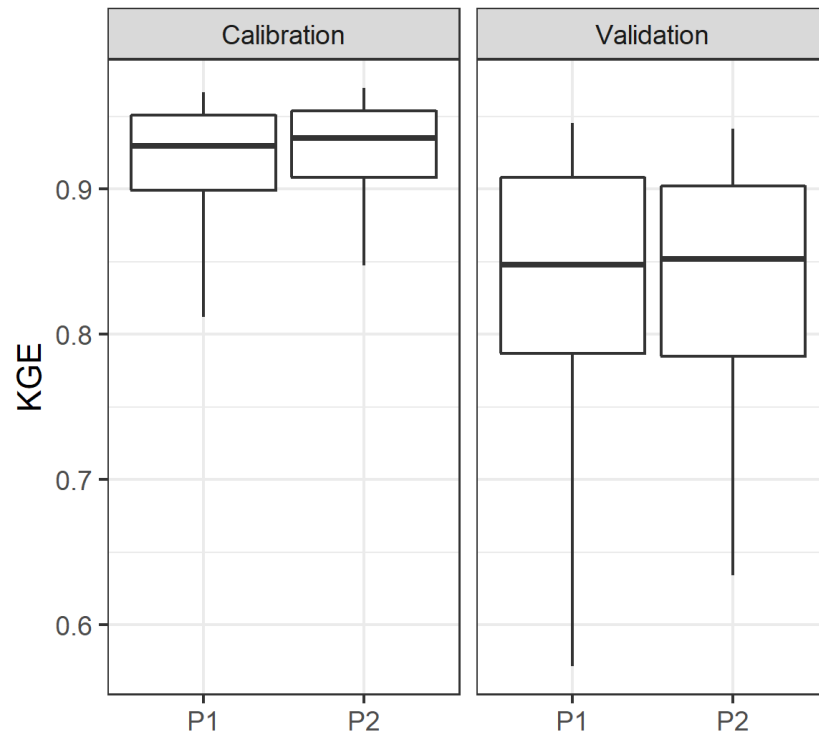


Event bias vs. several event
characteristics

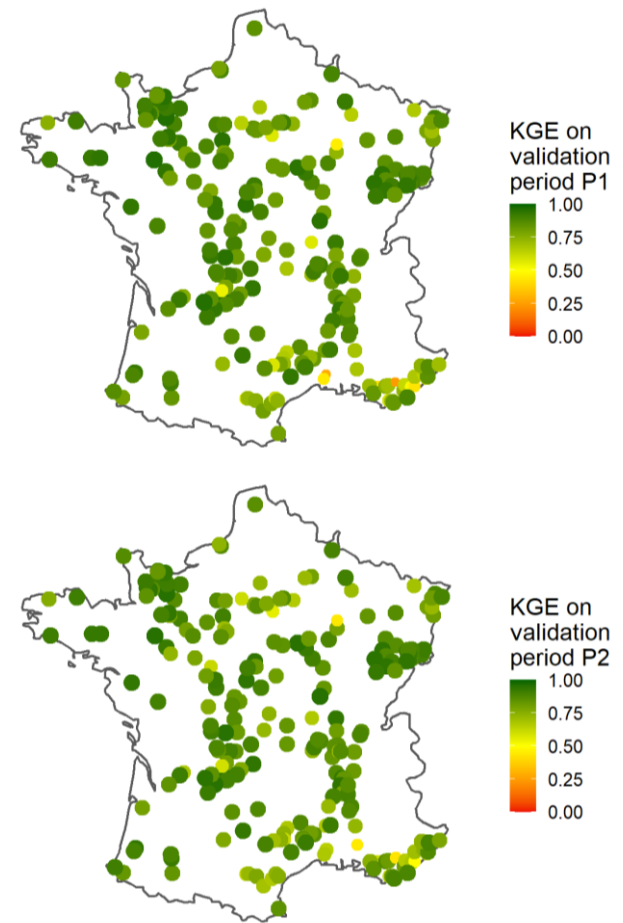
- KGE index for calibration and validation sub-periods
- Bias for each flood (cross-validation values):
$$\beta = \frac{\sum Q_{sim}}{\sum Q_{obs}} - 1$$
- Bounded between -1 and 1: $\beta^b = \frac{\beta}{\beta + 2}$
- Seasonality = month of flood peak
- Rainfall event maximum hourly precipitation
- Smith index of rainfall spatial variability⁹
- Antecedent catchment wetness condition: SWI index calculated by the ISBA surface model¹⁰

⁹Smith et al. (2004); ¹⁰Coustau et al. (2015)

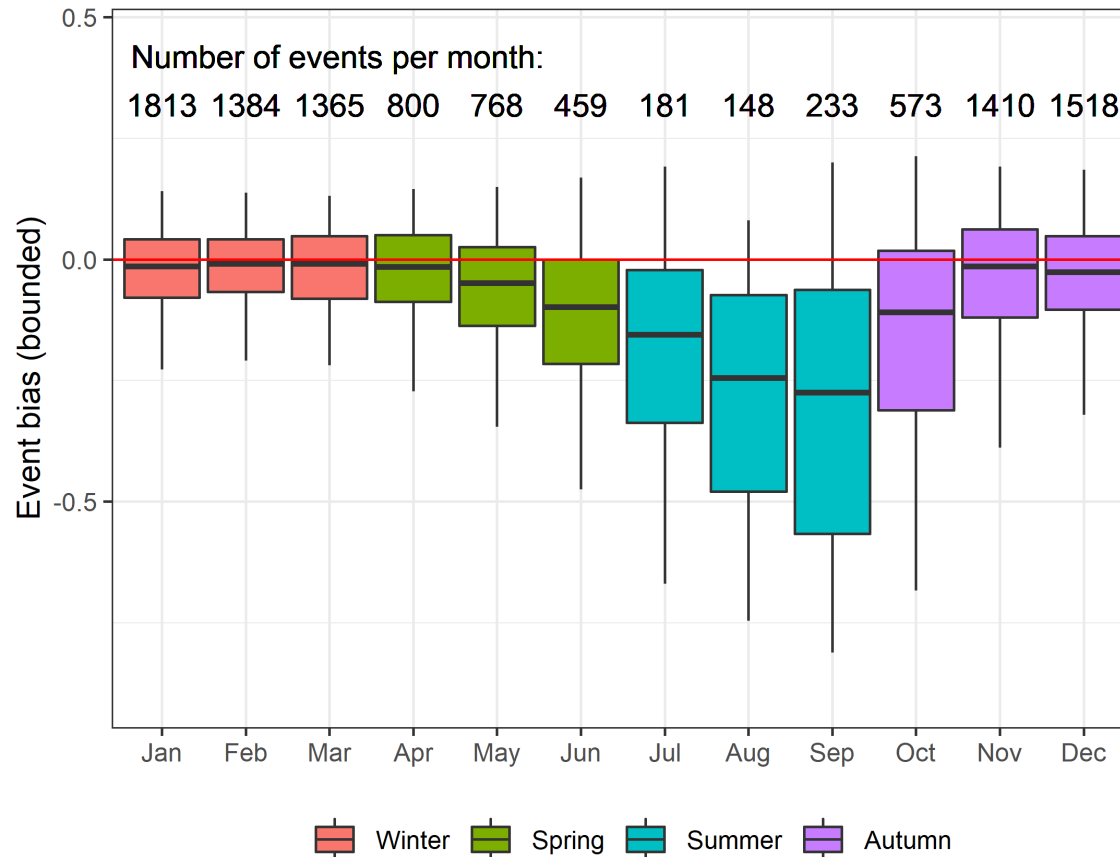
➤ Overall model performance



Good overall performance for most catchments of the dataset

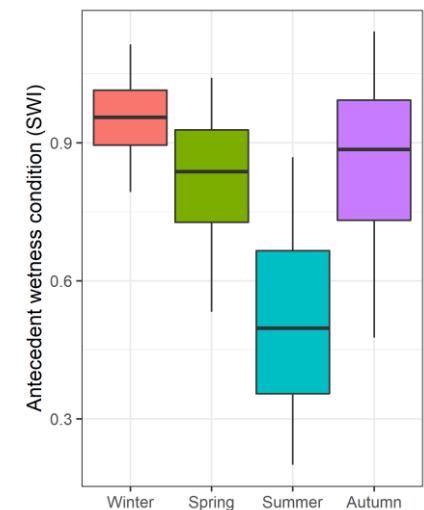
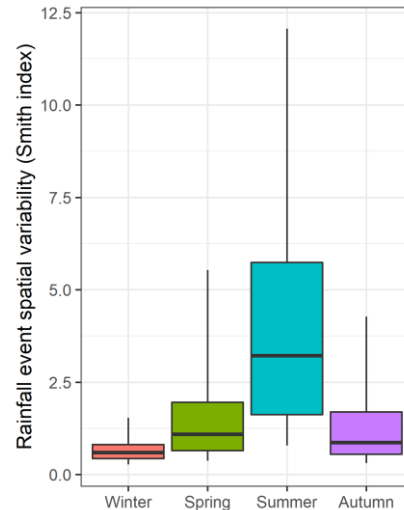
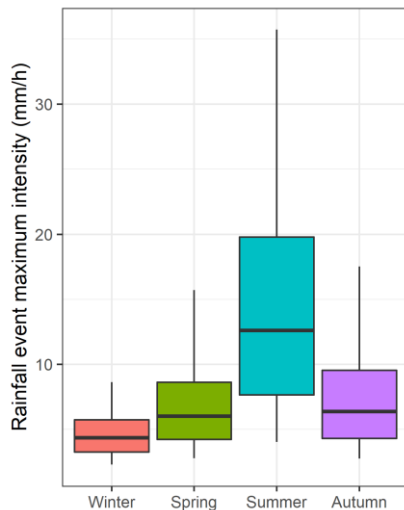
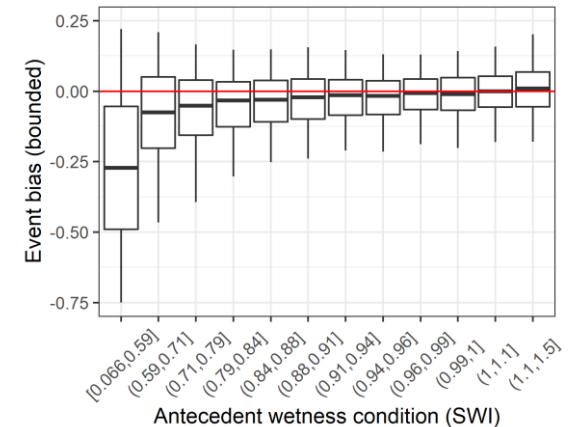
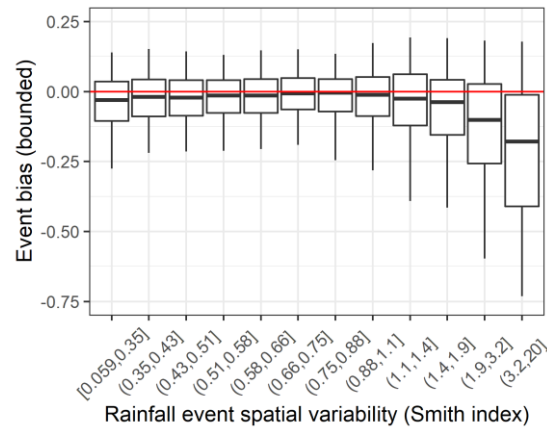
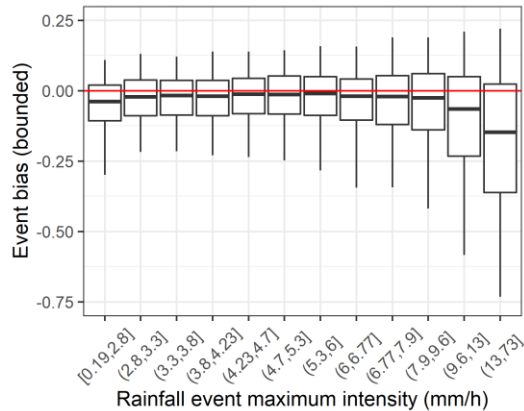


➤ Seasonality of model bias in simulating floods



The model underestimates most of the summer floods while it is unbiased in other seasons

➤ Event bias vs. event characteristics



Underestimation for: high intensity rainfall events — highly spatially variable rainfall fields — dry antecedent wetness conditions

➤ What are the first-order factors leading to the model's deficiencies ?

- High-intensity precipitation events can be subject to large data uncertainties
- The choice of objective function and the parametrization method could lead to inconsistent streamflow simulation
- The parsimonious structure of the model could limit its ability to account for specific processes occurring in summer
- The model does not explicitly take rainfall spatial variability into account

➤ Concluding remarks

- Seasonal variations of floods appear to be a good proxy for several event-scale characteristics
- The GR5H-I yields lower performance for summer events characterized by:
 - High-intensity precipitation events
 - Highly spatially variable precipitation fields
 - Low catchment antecedent wetness conditions
- Improvements of the GR5H-I structure could be to explicitly account for these processes mainly occurring in summer

For more information, please refer to *Astagneau et al., 2021: When does a parsimonious model fail to simulate floods? Learning from the seasonality of model bias, Hydrological Sciences Journal, in press.*

References

- [1] Ficchi, A., Perrin, C., Andréassian, V., 2016. *Impact of temporal resolution of inputs on hydrological model performance: An analysis based on 2400 flood events*. Journal of Hydrology 538, 454 – 470. <https://doi.org/10.1016/j.jhydrol.2016.04.016>.
- [2] Tabary, P., Dupuy, P., L'Henaff, G., Gueguen, C., Moulin, L., Laurantin, O., Merlier, C., Soubeyroux, J.M., 2012. *A 10-year (1997–2006) reanalysis of Quantitative Precipitation Estimation over France: methodology and first results*. IAHS Publication 351, 255–260
- [3] Leleu, I., Tonnelier, I., Puechberty, R., Gouin, P., Viquendi, I., Cobos, L., Foray, A., Baillon, M., Ndimba, P.O., 2014. *La refonte du système d'information national pour la gestion et la mise à disposition des données hydrométriques*. La Houille Blanche, 25–32. <http://hydro.eaufrance.fr/>.
- [4] Delaigue, O., Génot, B., Lebecherel, L., Brigode, P., Bourgin, P., 2020. *Database of watershed-scale hydroclimatic observations in France*. INRAE, HYCAR Research Unit, Hydrology group, Antony, France. <https://webgr.inrae.fr/base-de-donnees>.
- [5] Le Moine, N., 2008. *Le bassin versant de surface vu par le souterrain : une voie d'amélioration des performances et du réalisme des modèles pluie-débit ?* Ph.D. thesis. UPMC, Cemagref.
- [6] Ficchi, A., Perrin, C., Andréassian, V., 2019. *Hydrological modelling at multiple sub-daily timesteps: Model improvement via flux-matching*. Journal of Hydrology 575, 1308–1327 <https://doi.org/10.1016/j.jhydrol.2019.05.084>.
- [7] Perrin, C., Andréassian, V., Rojas Serna, C., Mathevet, T., Le Moine, N., 2008. Discrete parameterization of hydrological models: *Evaluating the use of parameter sets libraries over 900 catchments*. Water Resources Research 44. <https://doi.org/10.1029/2007WR006579>.
- [8] Gupta, H.V., Kling, H., Yilmaz, K.K., Martinez, G.F., 2009. *Decomposition of the mean squared error and NSE performance criteria: Implications for improving hydrological modelling*. Journal of Hydrology 377, 80–91. <https://doi.org/10.1016/j.jhydrol.2009.08.003>.
- [9] Smith, M. B., Koren, V., Zhang, Z., Reed, S., Pan, J., Moreda, F., 2004: *Runoff response to spatial variability in precipitation: an analysis of observed data*. Journal of Hydrology 298, 267–286. <https://doi.org/10.1016/j.jhydrol.2004.03.039>.
- [10] Coustau, M., Rousset-Regimbeau, F., Thirel, G., Habets, F., Janet, B., Martin, E., de Saint-Aubin, C., Soubeyroux, J.M., 2015. *Impact of improved meteorological forcing, profile of soil hydraulic conductivity and data assimilation on an operational Hydrological Ensemble Forecast System over France*. Journal of Hydrology 525, 781–792. <https://doi.org/10.1016/j.jhydrol.2015.04.022>.