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Como as deficiências das previsões podem ajudar a melhorar os modelos hidrológicos de previsão? Caso dos eventos de cheia de 2013 na França.

How can failures to forecast help to improve hydrological forecast models? The case of the 2013 flood events in France.

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1. INTRODUCTION

Giving greater prominence to the analysis of failures and errors would more fruitfully advance the hydrological sciences, as suggested by Andréassian et al (2010). The authors claim that “in-depth analysis of these observations and results that deviate from the expected norm blazes a trail that can only lead to progress.” Taking lessons from failure is at the very heart of the feedback scheme of the learning process. After failure we try hard to understand the source of problems, so that next time we are more likely to succeed. Even so, failures are still seldom communicated in scientific publications. Scientific articles focus mostly on case studies where hydrologists have been able to produce successful model runs. Failure stories, which can be just as instructive as successes, meet much more resistance in the world of scientific publishing. In operational forecasting, models are also expected to be successful in predicting events of interest. Evaluating the performance of models after a series of events can however point out model deficiencies and ultimately show that the model does not meet the expected level of performance shown during its calibration. Learning from these evaluations can help to understand the forecasting system and improve forecast performance.

The objective of this paper is to propose a simple analytical framework for guiding flood forecasters to identify causes for model failures. It is not only suited for post-event analyses following an unsatisfying forecast but also for pre-operational tests that precede model implementation. Specific tools to perform the different stages of the post-evaluation process within this framework, i.e. the quality assessment of precipitation and discharge flow data, the calibration of the model and the evaluation of adequacy between model structure and its underlying hypotheses, are introduced. Results on the use of different calibration approaches are shown through the investigation of some unsatisfying flow forecasts provided by the GRP hydrological model (Berthet, 2010), used in real-time forecasting in France (Furusho et al., 2013), during the flood events that occurred in May 2013 in the upstream sub-catchments of the Seine River Basin in France. The paper concludes with a short discussion of the benefits of the proposed framework.

2. STUDIED CATCHMENTS

Table 1 summarizes the main features of the catchments selected for this study (figure 1-a). The selection was performed according to their operational relevance, including particularly the catchments for which the local operational service (SPC SMYL- *Service de Prévision de Crues Seine Moyenne - Yonne - Loing*) wishes to enhance the forecast performance.

Catchment areas range from 99 km² to 43800 km² (river Seine at Paris), with a median value of approximately 640 km². The response time of each catchment was estimated by the unit hydrograph parameter of the hourly hydrological model GRP. It is a continuous, lumped storage-type model designed for food forecasting (see Berthet, 2009 for details about the model). The response time values vary from 6 to 48 hours, with a median value of 12 hours. A split-sample test (Klemes, 1986) has been performed to characterize the model performance for each catchment, considering forecasts for a 24h horizon. The relative average absolute error (EARM) obtained in validation for the period 1997-2013 is displayed in table 1. The average EARM is 11%, with maximum and minimum values of 14% and 6%, respectively.

Table 1: Main characteristics of the test catchments (EARM: Relative mean absolute error)

Catchment outlet	Area (km²)	Response time (h)	EARM (%)
Yonne at Dornecy	781	18	9.65
Beuvron at Ouagne	264	12	11.85
Serein at Dissangis	643	18	12.55
Armancon at Brianny	222	6	11.55
Brenne at Montbard	732	9	6.90
Armancon at Aisy	1350	12	9.25
Loing at Montbuy	409	18	14.05
Aveyron at La Chapelle	99	12	12.45
Ouanne at Toucy	153	6	12.50
Ouanne at Charny	562	18	13.40
Bezonde at Pannes	339	12	12.90
Orge at Morsang	922	6	11.00
Marne à La Ferté	8818	24	6.00
Grand Morin	770	9	11.15
Seine à Austerlitz	43800	48	9.20

3. REAL TIME FORECASTS OF THE 2013 FLOOD EVENTS

The flood warning system operated in the catchments studied here has been developed to provide alert levels according to the estimated flood risk in the main streams with 24h in advance. The main hydrological modelling tool implemented for flood forecasting in the local forecast service is the GRP hydrological model, which runs using as input hourly forecast scenarios of precipitation and evapotranspiration, as well as, when available, real-time discharge data for forecast updating (Berthet et al., 2009).

According to Météo-France[1], the year 2013 was a wet year in France, with, on average over the country, accumulated rainfalls greater than the average climatological value by 10%. The area studied here was particularly touched by high amounts of rainfall. We estimated the return period of the particular flood events of this post-evaluation exercise ranging from 2 to 77 years, according to the catchment within the study area (figure 1-b). The failures to forecast that occurred during this event may be due to erroneous precipitation estimates, poorly identified model parameters, inadequacy of the model structure or errors in the streamflow that were assimilated in real time by the model. The methodology proposed in the next section was applied to identify the potential main sources of forecast errors.

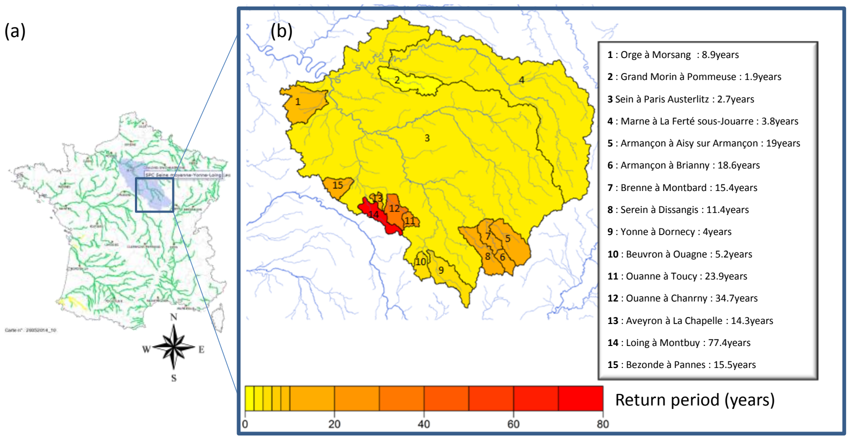

Figure 1. (a) Localization of the studied catchments within the zone attributed to the local service SPC SMYL (gray area, at the northern of France). (b) To the right, a zoomed view of upstream sub-catchments of the Seine River Basin, and corresponding return periods of the flood events in each catchment in May 1st, 2013.

4. METHODOLOGY TO DIAGNOSE FAILURES TO FORECAST

The approach for model diagnosis has basically two main steps. The first one consists on evaluating the quality of the data used for the calibration period and also for feeding the model in real time. The time series used for calibration is analysed and the gaps are filled using data from neighbouring stations. In real time, it is essential to evaluate the quality of rainfall scenarios but also the quality of assimilated discharge flow data, caring for the existence of upstream dams and the quality of rating curves, especially for higher flows. The second step is to test different calibration strategies to choose the configuration that provides the best results for each basin concerning: data assimilation method, optimum calibration threshold, optimum forecast horizon according to the forecast purpose and, finally, forecast timing and accuracy of flood peak predictions.

5. RESULTS

Figure 3 shows an example of results obtained for the diagnosis of failures to forecast by testing different calibration strategies. It shows two different calibration approaches tested on the

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[1] http://www.meteofrance.fr/climat-passe-et-futur/bilans-climatiques/bilan-2013/bilan-climatique-de-l-annee-2013

Serein at Dissangis catchment. In this example, the choice was to calibrate model parameters using different objective functions, including a focus on flow data over a threshold and only on rising limbs. The results show that we can enhance the accuracy of flood peaks and reduce the delay of the forecasts comparing to the observed peak flows for 48 hours forecast horizon. Quadratic objective functions have also shown to be more adapted to capture flow peaks (figure 3).

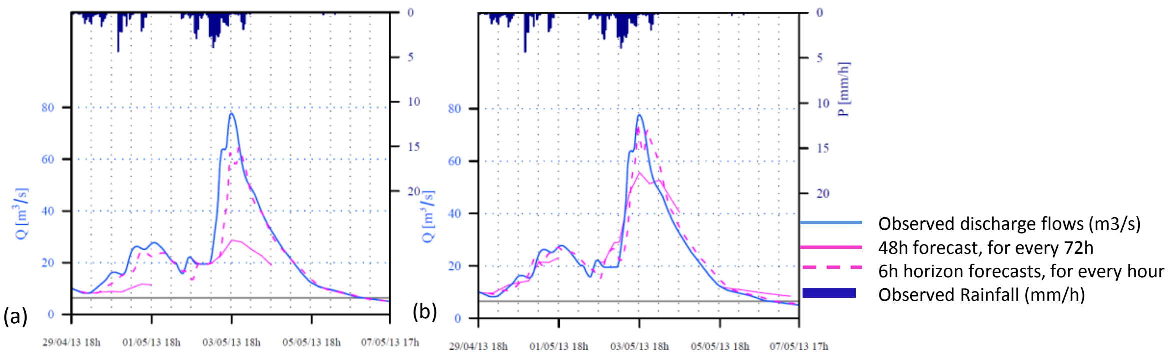

Figure 2. Calibration approaches tested on the Serein à Dissangis catchment: (a) Objective function = Mean absolute error calculated over the entire time-series; (b) Objective function= Root-mean-square error for positive flow rates above the threshold of 12.8m^3s^{-1} (exceeding the 95% quantile). Total observed rainfall over the basin: 69.98mm.

5. CONCLUSIONS

The methodology used to investigate failures to forecast flood events has been tested in a set of 15 French catchments ranging from approximately 100 to 43000 km². It proved to be a suitable framework to answer to questions about poor model performance during post-event analyses. It is particularly useful in operational forecasting, following unsatisfying forecast events as it shows that significant improvements can be made without necessarily changing the model structure, but improving model calibration strategies. The methodology is also advised for pre-operational tests that precede model implementation within a flood forecasting systems. Further investigations will focus on studying the importance of data quality check on real-time forecast performance and on considering probabilistic predictions to enhance predictability.

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