A new French flash flood warning service

Céline de Saint-Aubin[1], Léa Garandeau[1], Bruno Janet[1] and Pierre Javelle[2]

[1]*SCHAPI, Ministry of Environnement, Energy and Sea, 42 avenue Gaspar Coriolis, 31057 TOULOUSE Cédex 1,France*

[2] *Irstea, RECOVER, CS 40061, 13182 Aix-en-Provence Cedex5, France*

Abstract. The French State services in charge of flood forecasting supervise about 22,000 km among the 120,000 km of the French rivers within a warning procedure called Vigilance Crues (*http://www.vigicrues.gouv.fr*). Some recent dramatic flood events on small watershed not covered by Vigilance Crues highlight the need for a new warning procedure to anticipate violent flash floods that regularly affect rapid river-basins. Thus the concept emerged of an automatic warning service specifically dedicated to local crisis managers. This service will be less elaborated than Vigilance Crues, probably with false alarms and missed events sometimes, but it will deliver a first information. The generation of the warning is based on a simple rainfall-runoff hydrological model developed by Irstea on all French rivers, fed with radar-gauge rainfall grids provided by Meteo-France. Every fifteen minutes, the hydrological model estimates the discharges on the rivers eligible to the service and determine if certain thresholds corresponding to a high or very high flood are likely to be exceeded. The last step of the real-time system is to determine which municipalities are concerned with flood risk and send them an automatic warning by voice call, optionally by sms or email. A specific web interface is available for users to monitor the evolution of the flood risk on maps that are updated every 15 minutes. This new flash flood warning service will be operational early 2017 as a free service for about 8,000 French municipalities.

[a] Corresponding author: celine.desaint-aubin@developpement-durable.gouv.fr

1 A new service complementary to Vigilance Crues

Since 2003, the Vigilance Crues [1] produced by the French State services aims at sending flood warnings to local authorities as well as general public over 22 000 km of the main French rivers. This procedure is applied to gauged watersheds usually bigger than 1000 km² and consists to produce warning maps and bulletins at least twice a day at 10 am et 4 pm disseminated on the www.vigicrues.gouv.fr website and sent to local authorities. On the vigilance map, the potential floodrisk for the next 24-h is declined in 4 levels resulting from flood-forecasters analyse.

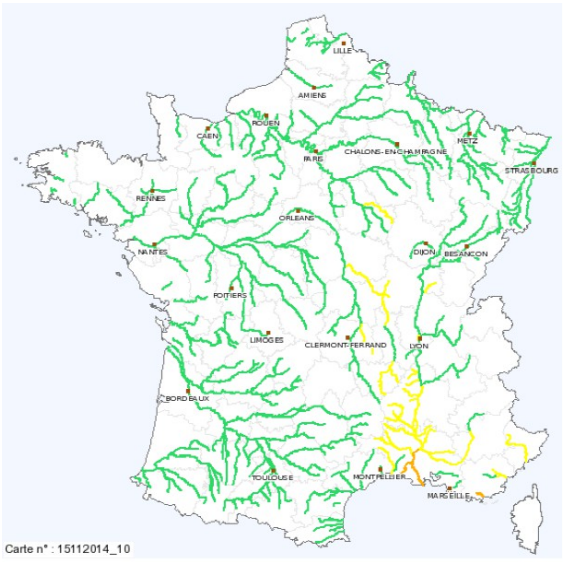

Figure 1. Example of Vigilance Crues map (2014/11/15 10h)

Sometimes, especially in the last decade, damaging flash floods leading to severe damage and casualties occur on smaller French rivers not covered by the Vigilance Crues. Mid-june 2010 a dramatic flood event caused 25 victims in the area of Draguignan in the Provence region. More recently, the 3rd october 2015, 20 people passed away in the area of Nice striken by some heavy steady precipitation that lead to severe floods.

Thus, the French State decided in 2011 to launch the project of a new warning nation-wide service devoted to small rapid river-basin exposed to flash floods [2]. The idea of this new flood warning service is to cover 24h a day most of the small river-basins. This service will be offered to local and regional authorities on the principle of a free voluntary subscription similarly to the APIC Service from Meteo-France dedicated to intense rainfall warning.

However, the time and space scales concerned by these rapid local flood events require a totally new warning procedure compared to Vigilance Crues, in terms of warning production and dissemination, to be able to inform civil security and municipalities as effectively as necessary for crisis management.

2 The warning production and dissemination

Contrary to Vigilance Crues that is based upon forecasters expertise of various hydro-dynamic or empirical models, the idea is here to build an automatic warning system efficient enough to produce warnings upon a large number of basins within a very short time to be able to anticipate the potential field-disorders.

The new flash flood warning system is based on a simple rainfall-runoff semi-distributed model called AIGA [3]. This model was first set up in the South-East of France, validated on past events and experimented in real time by local authorities. Since its satisfactory results, it was extended to the entire French territory: first calibrated on the gauged catchments and then regionalized to be used on ungauged rivers as well.

The AIGA hydro-model running, every 15 minutes, is the first step of the flash flood warning generation process. The model ingests the last quantitative radar precipitation estimation from Meteo-France at 1-km² resolution and simulates the discharges upon a large number of river-basins.

The next step is to determine which rivers could be prone to flash floods, by comparing the simulated hydrograms to relevant thresholds calibrated on a long term model-simulation. Thus, two thresholds are used representing a high or very high flood.

Then, given the list of the rivers with high or very high flood risk, the system identifies which municipalities are concerned with these potential flash floods and sends automatically warnings to the subscribers.

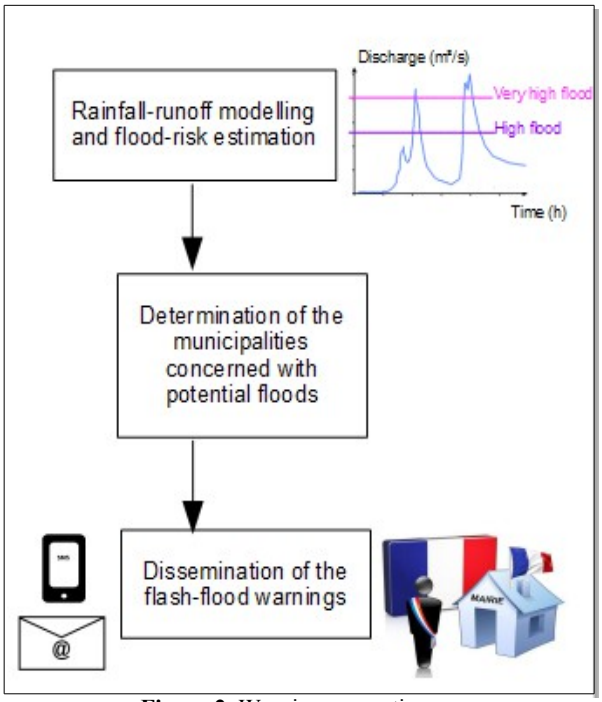

Figure 2. Warning generation process

The warning messages encourage the subscribers to visit the flash flood warning website to visualise the warning maps and to monitor the evolution of the situation. Two maps are available online and updated every 15 minutes: one that represents the river network with a colour chart indicating the estimated range of the potential flood-event, and a second one that shows the towns concerned with a warning.

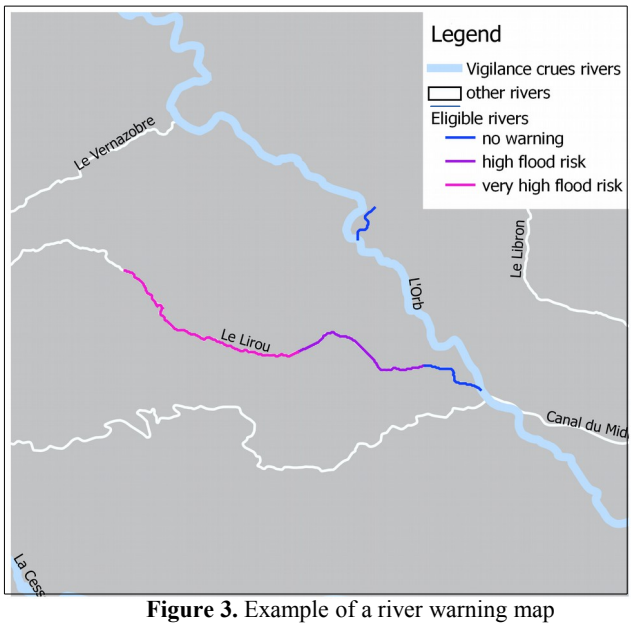

Figure 3. Example of a river warning map

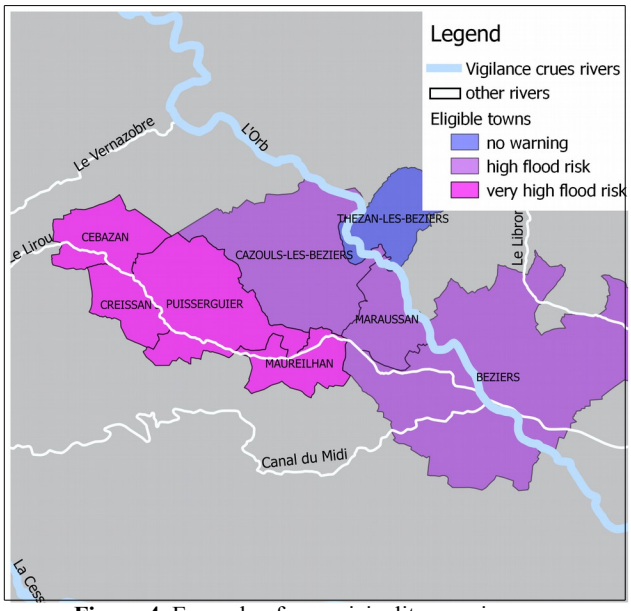

Figure 4. Example of a municipality warning map

The map of the towns with warning can be monitored at large scale for regional authorities survey whereas the river maps are dedicated to municipalities or local services as they show more details about which rivers have the highest risk to cause a major flood-event.

3 The selection of the rivers eligible to the service

The flash flood warning service cannot be applied to all small catchments. Several conditions are required for a river basin to be integrated to the warning service:

- the river shall not be covered by the Vigilance Crues,
- the river-basin shall benefit from a sufficient radar precipitation estimation quality (it is a condition for a realistic flood estimation by the hydrological model),
- the response-time of the river-basin has to be longer than 2 hours. Two reasons support that criteria: the hydrological model skill is not satisfactory on very small catchment due to its 1 km²-resolution inputs and one considers that 2 hours is a minimum duration to organise crisis management).

Moreover, catchments with certain specific characteristics that are not handled by the simple hydro-model such as karst, tide, nival or dam influences cannot be covered by the flash flood warning service.

The selection of the eligible catchments was carried out upon several theoretical criteria derived from these characteristics [4] that led to eliminate certain particular river basins. For example, the level of karst influence was determined over the basins by calculating the percentage of the catchment area covered by karsts.

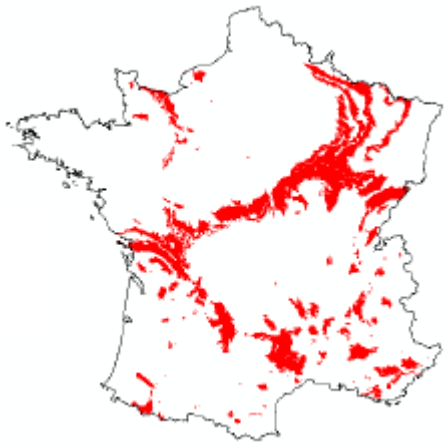

Figure 5. French areas with karstic influence (source IRSTEA [4])

A similar technique was used to eliminate catchments under strong dam influence.

Regarding the nival aspects, the annual ratio of solid precipitation against the total precipitation amount was used to reject river-basins with strong snowmelt influence.

Finally, a recent study about rivers under tidal influence was exploited to identify the coastal catchments that couldn't be relevantly surveyed by the flash-flood warning system.

4 The limits of the flash flood warning service

The sources of uncertainty are numerous all along the warning process. Among the most important ones, the uncertainty due to the hydrological model turns to be essential but is not dealt by the system for the moment.

Thus, by considering the selected catchments, the evaluation of the warning system over past events show variable performances, depending on the catchment and on the flood-event [3]. The system was voluntary tuned to limit the number of missed warnings, at the expense of a significant rate of false alarms.

On the other hand, since the hydro-model only ingests radar precipitation estimations (and no precipitation forecasts), the anticipation of the warning system is limited to the response-time of the basin.

Finally, the warnings give an information on the rarity of the simulated flood-event and not about the potential damage. Since the thresholds used to trigger the warning are only based on return periods, they don't take into account the local vulnerability. For instance, a river with a high flood risk can turn to cause more damage than another concerned with a very high flood risk. The users have to be aware of these important issues.

5 What is offered to the end-users

The flash flood warning service will be offered freely to municipalities, local and regional authorities responsible for civil security.

Every municipality concerned with at least one eligible river will have the opportunity to subscribe online.

On the dedicated website, the future user chooses its favourite warning-media and gives its contact details. A local map is provided to inform of the rivers that may be concerned with real-time warnings. The limits of the service in terms of modelling performances and warning uncertainty are also available in a note that the subscriber has the obligation to read.

Then, in real time, when the warning system detects a possibility of flash flood on one or more river(s) linked with the town of interest, at any time, the user will be warned by an automatic phone-call (the only media that is assured even during crises periods), and possibly by e-mail or sms.

An end-users committee was created to help to set up the warning system and to make it as relevant as possible for the users. It deals with some practical questions such as ergonomics of the website, warning statements and more generally communication issues. Another crucial point that is discussed is the user-coaching with the redaction of simple files that gives guidelines to follow before or after receiving a warning message.

Finally, to be able to criticize the warnings and eventually improve the service, a satisfaction questionnaire is prepared to be sent to each user recently concerned with a warning.

6 Conclusions and perspectives

Thanks to a solid cooperation between IRSTEA, Météo-France and Vigicrues (the State services in charge of flood warning), a new warning service devoted to flash flood is about to be opened. This service will be first launched over approximately 10 000 French catchments early 2017, and progressively extended the next years.

The choice to limit at first the number of eligible rivers and towns has been made to ensure a certain degree of performance of the system. The first end-user impression about this new service will be crucial and will help for further developments.

The areas of improvements are numerous for the next years is terms of the ergonomics of the website as well as in the field of the system warning performances. Considering this last point, several studies are carried out to enhance the anticipation and the performance of the hydro-model.

Promising research studies are currently carried out to test precipitation forecasts as model inputs: experimental nowcast products from Météo-France are ingested by the model in a probabilistic way to take into account the inherent uncertainty of this high resolution rainfall forecasts.

On the other hand, different types of hydro-modelling approaches will be tested including some with real-time discharge assimilation where it is available.

Another idea would be to tune the hourly hydrological model to a shorter time step (10 minutes for instance) to simulate more reactive hydrograms.

More generally, these new modelling strategies will help to reduce the uncertainty linked with the hydrological model.

Besides those technical matters, a key-issue for the success of this new service will be the end-user support. In France, several State services are provided to warn regional and local authorities about upcoming danger linked with rainfall or floods: Vigilance Crues, Vigilance fortes précipitations (heavy rainfall) and APIC from Météo-France. A communication effort has to be made to explain the complementarity between these different warning systems, especially in terms of time and space scales, to insure an efficient crisis anticipation and management for the benefit of the citizens.

7 References

1. Tanguy, J.-M., Carrière, J.-M., Le Trionnaire, Y., Schoen, R. (2005). Réorganisation de l'annonce des crues en France, *Houille Blanche-Revue Internationale De L Eau*, **2**, 44-48
2. Environment, F.m.o., Plan submersions rapides : submersions marines, crues soudaines et ruptures de digues, *http://www.developpement-durable.gouv.fr/Le-Plan-Submersions-Rapides,41212.html*, 2011.
3. Javelle P., Organde D., Demargne J., Saint-Martin C., de Saint-Aubin C., Garandeau L., Janet B., (2016). Setting up a French national flash flood warning system for ungauged catchments based on the AIGA method, *FLOODrisk2016, 3rd European Conference on Flood Risk Management.*
4. Caruso A., Guillot A., Arnaud P. (2013). Notice sur les indices de confiance de la méthode Shyreg-Débit – Définitions et Calculs. IRSTEA