Flash Flood Warnings: Recent Achievements in France With The National Vigicrues Flash System

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Abstract

Flash floods events are difficult to forecast because of their small temporal and spatial scale. Furthermore, they often occur on un-monitored small rivers, where no real-time data is available to warn people. To better anticipate these events and mitigate their impacts, the French Ministry in charge of Ecology has launched a national FF warning system: Vigicrues Flash. This system takes real-time radar-gauge rainfall products at a 1-km² resolution from Météo-France and issues automatic flood warnings based on the AIGA method at small un-gauged catchments (greater than 10-km²). AIGA aims to characterize flood hazard at any point along the river network by comparing discharges in real-time produced by a simplified distributed rainfall-runoff model (GRD) to reference flood quantiles obtained using the same model and a continuous radar-gauge rainfall re-analysis. Vigicrues Flash was launched in March 2017. The aim of this paper is to briefly present the new system and a first analysis of its performance during one exceptional large event that occurred in June 2018.

1. Introduction

According to the United Nations Office for Disaster Risk Reduction, between 1995 and 2015, floods have caused damage worth around US $662 billion and affected more than 2.3 billion people worldwide (Wallemacq et al., 2015). Predictions for the future are also pessimistic, since they forecast that flood-related impact will more than triple by the end of the century (Alfieri et al., 2015; Pigeon, 2002; Munich RE, 2017). In France, the risk of flooding is the main risk that stakeholders have to deal with. More than 20 people die each year because of floods in France (Vinet et al., 2016). The cost of floods in terms of insurance damages calculated by the CCR (the French re-insurance company) is about €1–1.4 billion each year (Bourguignon, 2014) and it is estimated that one third of French local authorities are affected by the risk of flooding (source : French ministry in charge of the environment).

In 2015, the Sendai Framework adopted by UN Member States defined seven global targets to reduce risk disaster in the world (UNISDR, 2015). One of these targets is described as: “Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to the people by 2030”. In France, two devastating events in 1999 (flooding in November and a storm in December) highlighted the limits of the available warning system, especially the lack of understanding by the public. To answer the issue, a multi-hazard, comprehensive warning procedure was set up in 2001 by Meteo-France (vigilance.meteofrance.com). To date, this weather warning system known as “Vigilance météorologique” only shows risks per French “département” (County) but not at a smaller scale. Concerning flood warning, this can be a limitation, since the hazard is typically in and around river, and not necessarily throughout the whole administrative area. For this reason, in 2003, the French Ministry in charge of the environment launched a complementary vigilance service specifically dedicated to floods: “Vigicrues”, which covers 22,000 km of monitored rivers (www.vigicrues.gouv.fr). Both meteorological and flood vigilance systems are closely connected.

In this context, the aim of this paper is to review the progress that has been made with respect to flood warnings during these past few years, especially on unmonitored rivers that are not covered by the Vigicrues system.

First, we present how flood warning is organised in France and how un-monitored rivers have recently been included in a national flash flood warning (FF) system: Vigicrues Flash. Then, FF warnings emitted by this new system are analysed,

with a special focus on the summer of 2018 which had an abundance of thunderstorm activity. Finally, the last paragraph discusses the usefulness of the new system and possible areas for further improvement.

2. Flood warning in France: from “Vigicrues” to “Vigicrues Flash”

Gauged river monitoring: the Vigicrues service

In France, 22,000 km of rivers are monitored in real time by the Ministry in charge of the Environment. This task is carried out by the SCHAPI (the Central Service of Hydrometeorology and Flood Forecasting) which supervises 19 regional flood forecasting centres (FFCs). FFCs collect data at river gauges in real-time (around 3,000 automated stations) and produce flood forecasts using hydrodynamic models. This process is conducted in a close cooperation with Météo-France, the national weather office, which provides meteorological data, mainly through observed and predicted precipitations. All this information is synthesized into the so called national flood “vigilance” maps, produced by the SCHAPI and updated twice a day or more if necessary. Their aim is to inform the public, in a understandable way, about a required vigilance level. The flood vigilance maps are freely accessible on-line (at the website www.vigicrues.gouv.fr). As mentioned in the introduction, this flood vigilance is also incorporated into the multi-hazard weather warnings issued by Météo-France, which includes other hazards such as high winds, thunderstorms, snow, avalanches, heatwaves, cold snaps and marine flooding. In a similar manner, four coloured levels are defined for the “Vigicrues” flood vigilance:

- **Red**: risk of a major flood with direct impact on goods and life,
- **Orange**: risk of flood with potential impact,
- **Yellow:** risk of flood with no significant damages, but requiring a particular vigilance,
- **Green:** no particular vigilance required.

All these levels are associated with an expected level of damage, which is often derived from past experience with similar events. In their communication to the public, FFCs also indicate for each river and each level some dates of corresponding floods that the people may remember (for instance in Paris: the flood of 1910 for the red level).

Figure 1 presents a flood vigilance map issued on 2nd November 2008 at 4pm. The map shows an exceptional flood that happened on the upstream part of the Loire River (coloured in red). Around this hot spot, other rivers were also flooding but in a less exceptional way (coloured in orange and yellow).

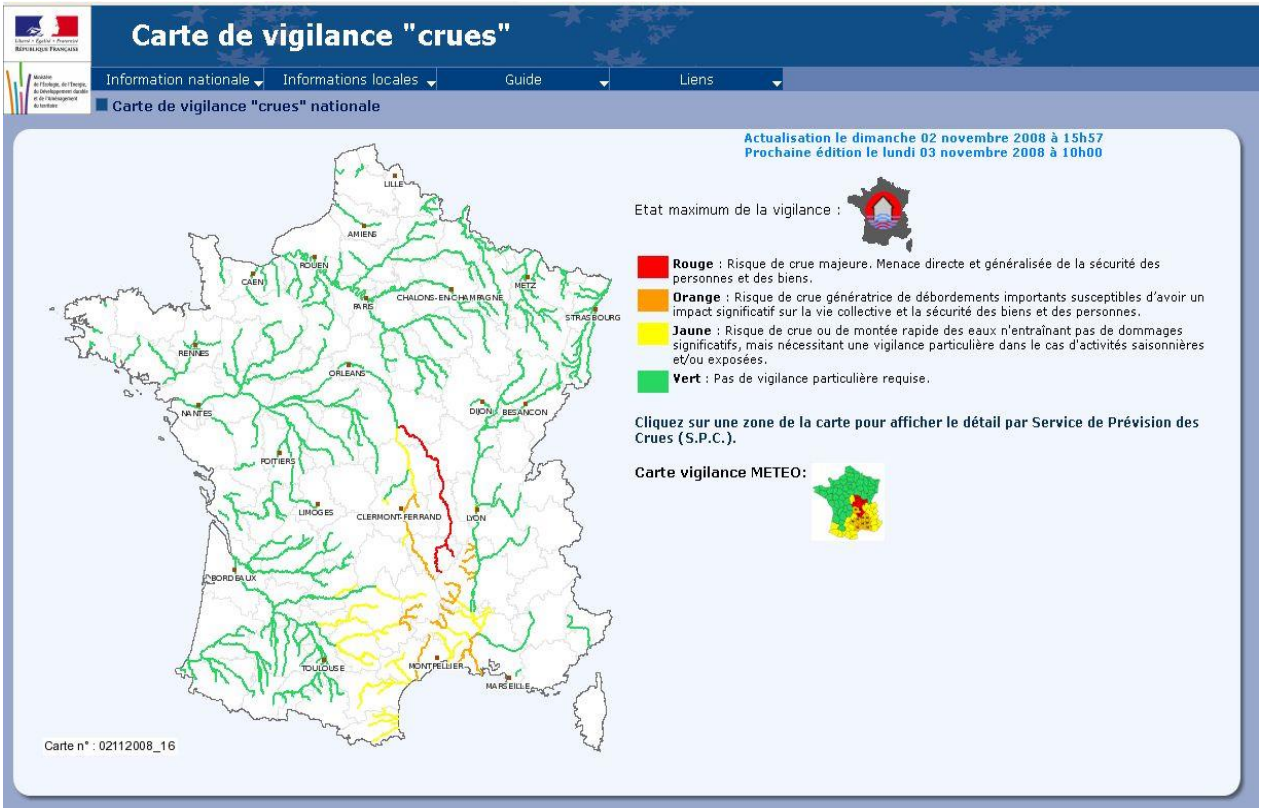

Figure 1: Vigicrues Flood vigilance map: example for 2nd November 2008 at 4pm.

It should be mentioned that flood warnings are not a forecast bulletin with expected values at different gauges and lead times. They are neither an alert issue, dedicated to emergency services and mayors (since this decision is taken by authorities in collaboration with the FFC). They simply inform the public about the flood situation, and what would be

the appropriate behaviour for the next 24-hours. For instance: “Cancel an outdoor activity”, if the probability of flood is estimated too high, or “no specific vigilance required” if the same probability is very weak. It does not necessarily mean that a flood will happen (or not).

Flood vigilance maps are valid for the following 24 hours. For this reason, all rivers cannot be incorporated into the so-called “Vigicrues” river network that can be seen on Figure 1. Small catchments, having short response time (less than 12 hours) and/or with no automatic river station cannot be included, the information available in real time being not sufficient to correctly appreciate the situation for the next 24 hours. But because flood and damages can also occur on small ungauged catchments, the Ministry in charge of the Environment decided to complement the Vigicrues service with a new service specifically dedicated to flash floods and called Vigicrues flash (Figure 2).

An automated flash flood warning system

The Vigicrues flash service was inaugurated in March 2017, after a 5-month pilot with end-users who helped to define the service. It sends automatic warnings directly to local authorities and covers around 30,000 km of river network (Figure 2). At the start, it was decided to exclude small rivers where warnings are not currently efficient enough for different reasons: basin area (<10-km2) and/or a response time (<1,5-hour) too small, radar-based rainfall measurements with too much uncertainty, or an unadapted hydrological model (too much influence of snow, dams, karst or ground water). The of the river already covered by Vigicrues were also excluded as they already benefitted from a better service, with real time discharge observations. As a result, Vigicrues flash is potentially available to 10,165 eligible local authorities (i.e. one third of the total). But this number will be re-evaluated each year, depending on the progress of radar rainfall estimates and hydrological modelling.

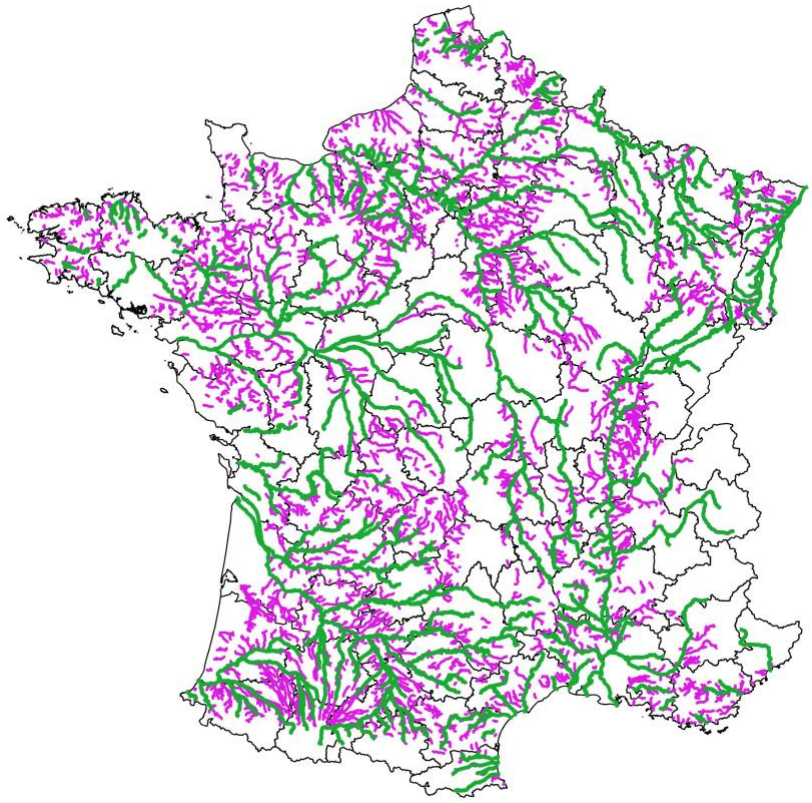

Figure 2: Comparison of the Vigicrues river network (green) with the “Vigicrues Flash” river network (pink), source SCHAPI March 2017

The hydrological modelling behind Vigicrues flash is based on the AIGA method that has been developed by the Irstea national research institute over the past 15 years. AIGA aims to characterize flood hazards at any point along the river network by comparing discharges in real-time produced by the GRD model, a simplified distributed rainfall-runoff model (Javelle et al., 2010, 2014) with reference flood quantiles obtained using the same model and a continuous radar-gauge rainfall re-analysis. The real-time time input data is radar-gauge rainfall products at a 1-km^2 resolution from Météo-France. The hydrological model runs at a hourly time step but is updated every fifteen minutes. Regional calibration was done by HYDRIS during different studies for the SCHAPI (Javelle et al., 2016).

Depending on real-time AIGA simulations, the Vigicrues flash system takes two warning levels into account, “high flood” and “very high flood”, associated with two different return periods. A warning is then issued for a given local authority if at least one of its rivers crosses a higher warning level (i.e. from no warning level to “high flood” level or from “high flood” level to “very high flood” level). A “recall” warning is also issued if over the 6 hours following the previous warning, the situation has not evolved (ie the warning level stayed the same).

The warning messages are sent by SMS, voice mails and emails to local authorities who have subscribed to the service. The content is specific to each local authority and indicates which warning level has been exceeded (high or very high). It also provides a non-permanent internet link (valid for 48 hours) to a web site where the user can see a national map indicating all the local authorities where a warning has been issued in the last few hours, at 15 minute intervals. On the site you can zoom in to each local authority, in order to see which river is concerned by the warnings. Warning messages are also sent to the prefecture (the county council) to inform county services about the situation of all the eligible local authorities within its administrative area. This web site and the messages are not available to the public (contrary for Vigicrues). A screen shot of the live web site is presented in Figure 3.

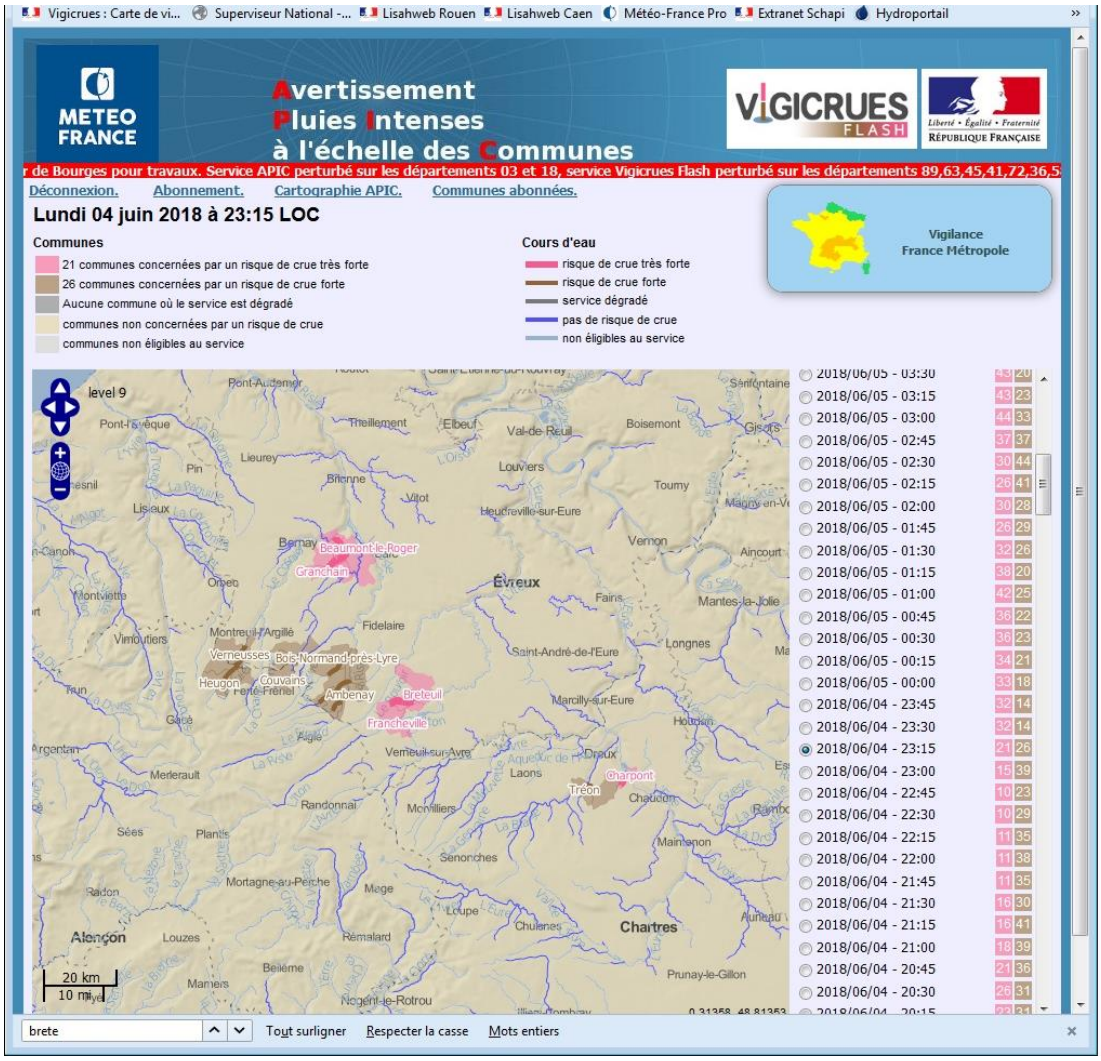

Figure 3: Example of real-time maps produced by the Vigicrues Flash system (4th June 2018 at 11.15pm local time)

To receive their warnings messages, eligible local authorities have to fill a subscription form, indicating a list of phone numbers and email addresses to be used to send the warning. This service is free, but by the end of 2018, only 1,117 local authorities had subscribed, i.e. 10% of the eligible local authorities. This low number can be explained by the fact that a lot of small local authorities are not aware of Vigicrues flash, despite a communication campaign was made. The reason is that local authorities often delegate the flood risk management to other entities, that regroup several local

authorities (communauté de communes, syndicat de rivière,…). For this reason, the French Ministry in charge of Environment decided to make Vigicrues flash available not only for local authorities, but also for all public entities who are potentially interested. This improvement will be operational in 2019. More details on the operational set-up of Vigicrues flash can be found in De Saint-Aubin et al. (2016).

3. **Case study**

The summer of 2018 gives us a very good opportunity to make a first operational analysis of the Vigicrues Flash system. Indeed, there was exceptional thunderstorm activity in France in 2018. The number of observed lightning strikes was the highest since a real-time lightning detection network was established by Météo-France, 30 years ago. Thunderstorms produced many flash flood events that caused considerable damage, specifically during the summer.

With respect to Vigicrues Flash, June 2018 was the month in which the highest number of warnings was issued since the service launched: 2,629 “High flood” warnings, and 1,679 “Very high flood” warnings. As seen in Figure 4, all the messages were issued during the first half of the month. It should be mentioned here that the study considers all eligible local authorities, and not only those who have subscribed and then really received the messages.

In June 2018, the most intense event was observed during the night from 11th to 12th June. Over 24 hours (between 12:00 and 12:00), 1,000 “High flood” messages and 782 “Very high flood” messages were sent.

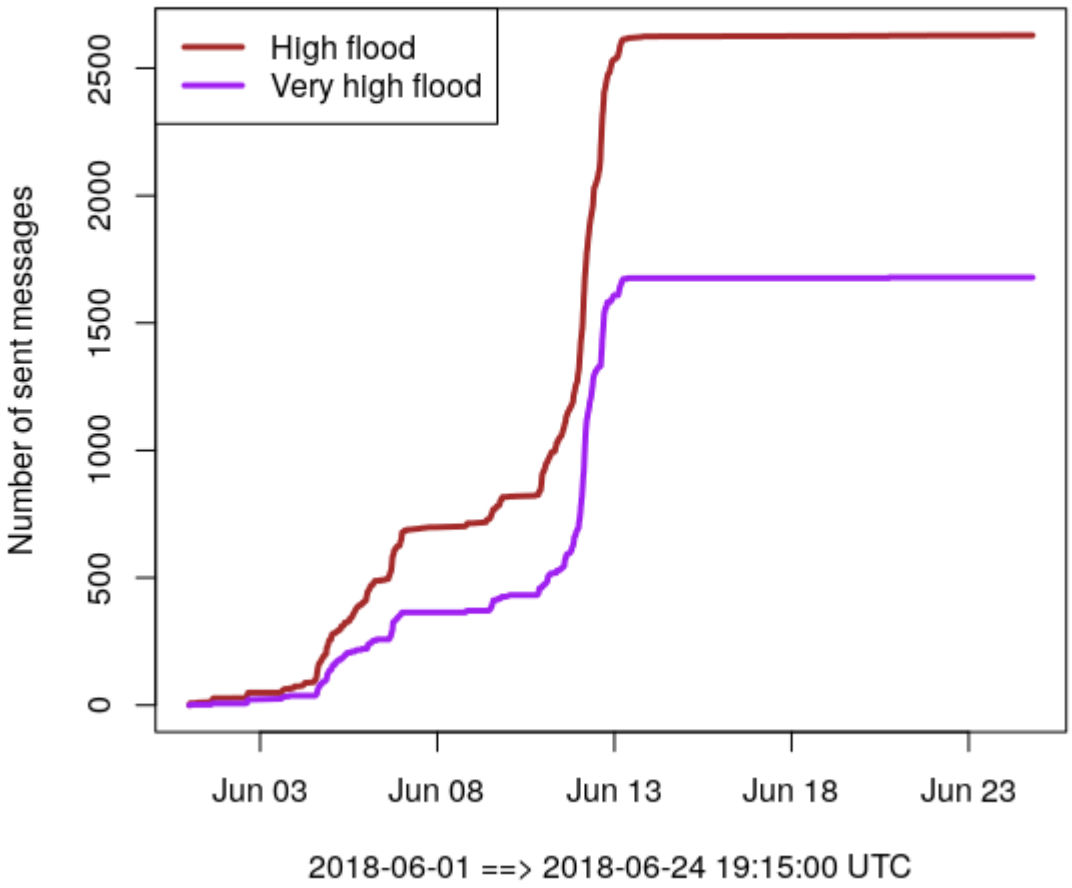

Figure 4: Number of messages potentially sent by Vigicrues Flash during June 2018

The map showing cumulative rainfall measured over 24 hours from Monday 11th June 2018 at 6am CET to Tuesday 12th June 2018 at 6am CET explains this exceptional situation (Figure 5). A low-pressure system was positioned in the South-West of France, generating very intense precipitations moving slowly over the regions of Pays de Loire, Normandie, Île de France, Centre, and Champagne-Ardennes. 24-hour historical records were exceeded at many rain gauges, especially in the region around Paris. For example, 108mm was registered at Torcy, 79mm at Achères, 75mm at Orly. These values seen over 24 hours are what is usually recorded in 1.5 month (source: Météo-France).

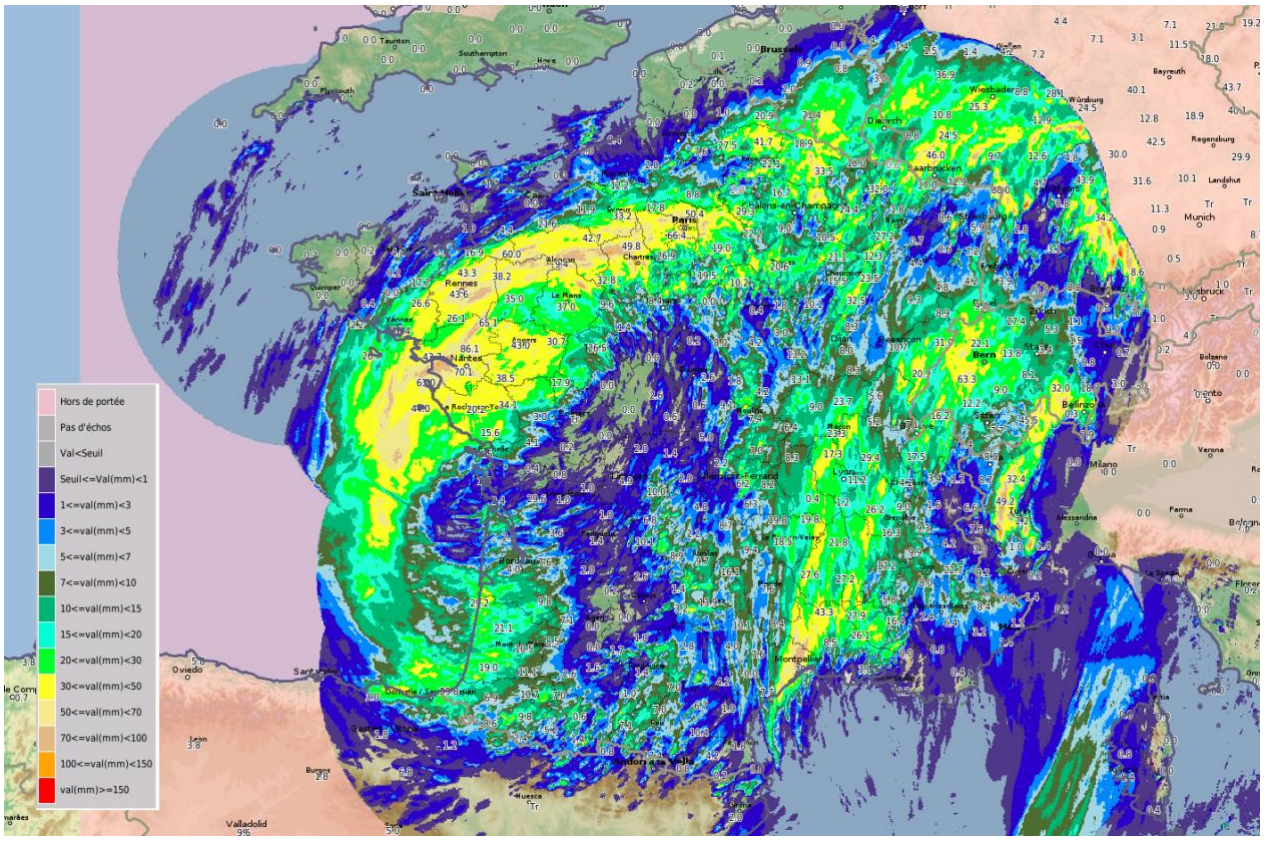

Figure 5: Cumulative rainfall measured by weather radar over 24 hours from Monday 11th June 2018 at 6am CET to Tuesday 12th June 2018 at 6am CET (source Météo-France)

By chance, the event didn't cause fatalities, but many residential areas were partly flooded as illustrated by Figure 6. Infrastructure was also impacted, for example the road or railway network which caused huge traffic disturbances, especially around Paris. For instance, an important station of the regional express train line RER A (Torcy, east of Paris) had to be closed due to flooding. On another regional line (RER B, south west of Paris), intense rainfalls damaged the railway ballast and caused the train to derail (Figure 7).

Figure 6: Flooded area at Palaiseau, Léon Bourgeois street (photo: Guillaume Thirel, Irstea, 12th June 2018)

Figure 7: Derailed train (RER B) between Saint-Rémi-lès-Chevreuse et Courcelle-sur-Yvette, 12th June 2018 (photo: Guillaume Thirel, Irstea, 12th June 2018)

In order to have a first assessment of the quality of the Vigicrues flash warnings, we collected the damage reported in the press or social networks just after the event. The methodology is described by Saint-Martin (2018) who carried out similar work for the 2011-2018 period in the South of France. Results are presented in Figure 8. The beige and pink colours indicate the maximum levels of warning reached during this event (high or very high flood) for each local authority. Dark gray indicates that the local authority didn't reach the first warning level. Light gray indicates that the local authority is not eligible to the Vigicrues flash service. The red triangles show were actual damage was reported and in general, the locations were were consistent with warnings.

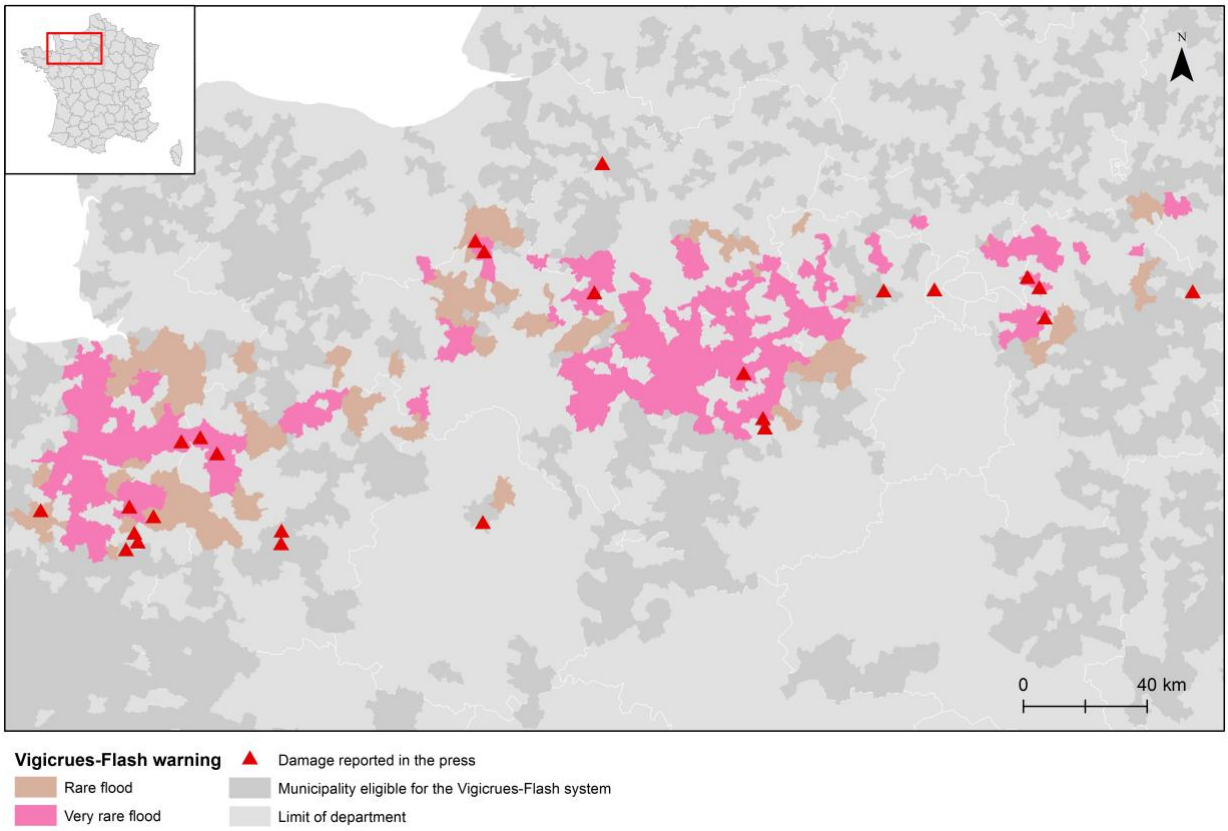

Figure 8: Vigicrues Flash map issued at 5.30am CET, 12th June 2018, comparared with damage reports (source : Clotilde Saint-Martin)

4. Discussion and conclusion

As presented in this paper, the new Vigicrues Flash service launched in March 2017 demonstrates real progress, as it is now possible to warn local authorities who were not covered by the traditional Vigicrues system. The case study of the events of 12th June 2018 showed that the system apparently works well. However, some points need to be further investigated.

The question of the evaluation

In order to improve the Vigicrues Flash system, the question of the evaluation is of great importance, but is also a very difficult one. Indeed, this paper did not present a real evaluation, but rather provided first elements of analysis. The difficulty stems from the fact that events tend to occur on ungauged rivers, without validating discharge data. Impact damage data is very useful, and will be more and more used. However, only a few adapted databases exist for this issue. For this reason, we also developed a database (called DamaGis) in order to collect data on flood-related damage for validation purposes. These data points are geo-referenced, and when possible offer information about the date and time of the event. Until now, this database has only been developed for the South of France, and for events that occurred from 2011 onwards (Saint-Martin et al., 2018). To go further, a national database should be developed allowing information to be collected from and shared with end-users, via social networks or the media, as it is already done in the US (Gourley et al., 2013).

From hazard to risk warning

A second point to be mentioned is that the method presented here is only based on a hazard estimation. This is a first step, but this is not sufficient to issue useful warnings. End-users also need to know the potential impacts to which their local authority are prone. To deal with this issue, Saint-Martin (2018) developed a risk index based on the combination of hazard forecasting provided by the AIGA method and an estimation of assets at risk and their vulnerability at elementary catchment level. This risk index could easily be applied at the national level, to integrate the Vigicrues Flash service.

Extending lead time and coverage domain

As showed in Figure 2, Vigicrues Flash does not uniformly cover all areas. Small rivers with short time responses (less than 1,5-hour), poor radar-based rainfall measurements and specific hydrological conditions are not covered by the service. This point needs to be improved. Indeed, because the method uses only observed and not forecasted rainfall information, the lead time is short (equal to the reaction time of the catchment). Using ensemble outputs of numerical weather models and/or radar-based nowcasting allow warnings to be made with more lead time and probabilistic estimations, as shown by Caseri et al., (2016) or Demargne et al., (2017). Furthermore, other research currently aims to extend the validity domain of the GRD hydrological model and to assimilate observed discharges to spatially correct forecasts. Concerning radar rainfall estimates, Meteo-France is continuously improving its operational product. All this work should increase the number of eligible local authorities.

To conclude, even if some improvements need to be made, the Vigicrues Flash service appears demonstrate real progress. Thanks to the system, it is now possible to warn local authorities that were not covered by the traditional Vigicrues system. Both of the services (Vigicrues and Vigicrues Flash) work together and complement each other for flood and flash floods respectively as part of the national multi-hazard meteorological warning system. This is an example of what could be done in order to improve people's access to early warning systems and disaster risk information. Since the Vigicrues Flash is relatively easy to set up, it could potentially be applied to border areas and also to developing countries which are often faced with this issue of "non-monitored" rivers for their early warning systems.

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