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To cite this version:

Cécile Saint-Marc, Paule-Annick Davoine, Michel Lang, Denis Coeur, Marlène Villanova-Oliver. Cartographical Approaches to Visualize Overlapped Locations of Major Historical Floods on Territories. ICC 2015, Aug 2015, Rio de Janeiro, Brazil. hal-01383614

HAL Id: hal-01383614

https://inria.hal.science/hal-01383614v1

Submitted on 19 Oct 2016

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Cartographical Approaches to Visualize Overlapped Locations of Major Historical Floods on Territories

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Abstract. In the field of natural risks, it is necessary to study spatio-temporal extents of historical events, which impacted a given territory. Dynamic maps are a good mean to perform spatio-temporal analyses. However, in some contexts, the printing of maps remains mandatory. Our aim was to make maps showing the locations of several major historical floods, which were described for the European Flood Directive. This article deals with a method to reconstruct impacted areas from uncertain textual descriptions and to make static maps of dated successive floods, their extent, their type and the territorial elements, namely watercourses and cities, that were impacted during the events. The main issue concerned the amount of data to be read in a same map. Our approach consisted in associating different cartographical visual variables: hollow geometric shapes (rectangle, ellipses) for representing floods extents with a colored border; labels for indicating the temporal dimension and iconic symbols for specifying the type of flood. This map design may be used in other natural risk contexts, for kinds of risks that impacted areas.

Keywords: temporal map, historical floods, static display

1. Introduction

In the field of natural risks, the anticipation and the prevention of future events involve studying in details past events. A map is an interesting tool to work over past natural risk events in their spatial context. Phenomeno-

logical maps enable people to better understand past events via the visualization of their locations, their features, their spatial context and some potential related phenomena. This contributes to identify threatened areas.

Floods are cyclic hydrological events, each characterized by a return period (e.g. 1 in 100 year flood) that indicates the probability of occurrence of a similar event. Decision makers are particularly interested in the study of major historical floods, which are relatively rare on a human-life scale (1 in 50 year flood and more) but which have big impacts, often on large territories.

Historical information about past floods mainly comes from archives and testimonies, that only described overflowed watercourses and some damaged places. So, the spatial extent of historical floods is often imprecise, which makes it difficult to draw it on maps.

The succession of numerous floods or flood's phenomena on the same territory leads to three design issues that endanger the legibility of a phenomenological map. First, the number of events that should figure on the map may be high, leading to dense information. Second, it is essential for the analysis with the map to show several features of the events (e.g. dating, type of flood, climatic causes). Finally, several phenomena may occur at the same place through time and may be spatially overlaid.

Dynamic maps (interactive and animated displays) have been developed over the last decades and have contributed to overcome the limitations of classical maps to show big and dense data. Nevertheless, static maps remain mandatory in specific cases, such as the publication on a paper medium or the comparison of several locations of events at different dates. For illustration purpose of a book dealing with an inventory of major historical floods in France (Lang et Coeur 2014), which results from the national preliminary flood risk assessment (PFRA) (European Commission's Floods Directive 2007/60/EC), we made maps of major flood events in France by PRFA units of management[1]. Our maps concerned eleven PFRA regions and forty-three sub-regions, each including from three to eleven flood events.

The main challenge was to enable the visualization of 5 dimensions of the information on the map, whereas the classical semiological variables (Bertin, 1967) only address 3 or sometimes 4 (e.g. 2D for the space, color and grain of the surface). The request was to show the area that was impacted by a flood (2D), the dating of events (1D), types of flood (1D) and their meteorological causes (1D). Impacted places of the territories had also

1 See http://www.eea.europa.eu/themes/water/interactive/floods-directive-pfra-apsfr for more information about units of management and the PFRA in Europe

to be shown: watercourses, major cities and sometimes names of remarkable places.

This article deals at first with the datasets and the method used to locate historical floods on a map. Then, based on a state of the art, it focuses on proposals for making a single cartographical view (or static map) of the succession of floods that occurred on a given territory at a large time-scale. Finally, the advantages and limits of the proposals are discussed and outlooks for future work are presented.

2. Reconstruction of Historical Flood Extents

Our dataset about past flood events was a set of synthesis of archive documents about major historical floods, written for the French PFRA. It contains literary descriptions of historical events, their hydro-climatic causes and their main impacts. Descriptions had the form shown below:

"An oceanic weather system coming from west to south-west impacted Isère watershed on September 14th and 15th, 1940 … The cumulated rainfall over a period of about thirty hours was about 140 mm in Combe de Savoie and 147 mm in Bourg-d'Oisans … The highest levels of watercourses occurred in some watershed impacted by the thundershower activity. Eau d'Olle river flooded at Le Verney, after the water passed over the four-meters-high dike, and a two-meters-high layer built up near the factory … 80 m³/s were measured at the bridge of Rigaud … Bout-du-Monde dam, at the beginning of Allevard gorges, was destroyed and the main square of Pontcharra was submerged." (Lang et Coeur 2014)

The method used for reconstructing the extents of floods is illustrated on *Figure 1*. Place names were manually extracted from descriptions in order to reconstruct the corresponding flood extent.

We used baseline geographical data sources (Geofla® DB for administrative units, Carthage® DB for watercourses) in a GIS software, to point out rivers, cities and remarkable places that were impacted by a given flood event.

Then, an extent including all these areas was digitalized. Spatial extents were represented by simple geometric features (rectangles and squares, ellipses and circles). Geometrics forms helped to visually separate the extents from natural elements of the background, which are mostly represented by curved lines. Moreover, this visual opposition with natural shapes intended to suggest that the drawn extents are imprecise because of the historical nature of data sources, i.e. they do not fit with the morphology of the landscape. Rectangles and ellipses were alternated to distinguish nearby events. The meaning of the selected spatial extent is therefore very general as it is

issued of a crossing of both hydro-meteorological data and damage descriptions. This spatial extent should not be confused for example with the area of heavy rainfall, or with the real flooded area.

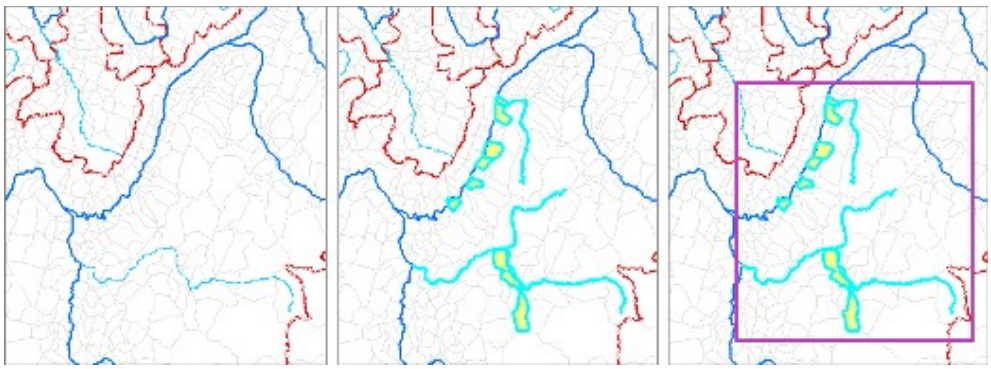

Figure 1. Steps followed to digitalize extents of past floods. From a GIS software including rivers and administrative boundaries (left), cities and rivers quoted for having been impacted by a specific flood were selected (middle) and a global geometric extent, suggesting data imprecisions, was drawn in the floods layer (right).

We produced one geographical information layer of spatial extents of historical floods per PFRA region and sub-region. At last, tables of attribute were filled in with temporal and descriptive attributes about the flood. Then, we produced the corresponding maps.

3. Approaches to Make Maps of a Collection of Major Historical Floods

Research about the cartography of temporal data is not new. We began with a review of existing techniques to make temporal maps. Mapping specifications that we received oriented the design of the maps, which aimed to show collections of flood events. Our mapmaking process included several successive map versions. It seemed interesting to us to inform the reader about the narrative of mapmaking, with a focus on a first version of the map that satisfies map specifications, but that finally evolved to a simpler and more legible one.

3.1. Related work about temporal maps

A common approach to make maps of natural phenomena consists in drawing the maximal possible extent of the studied phenomena, while indicating

their occurrence dates thanks to labels (Borrel 1994, Vasilev in Cauvin et al. 2008). Two issues arise when dealing with historical data: first, several phenomena may occur in the same place and overlay on the map, what decreases its legibility; second, dating labels may add to other textual labels which are already on the map, what may overload the content of the map. Visual variables are another possible way to represent time. In the classical rules of graphical semiology (Bertin 1967), time is considered to be a qualitative ordered variable. So it can be represented by color hues or color values (saturation plus intensity of color) applied to features.

Another approach, that prevents overlaying of map features over time, is to use a collection of maps, i.e. several maps each representing one date or duration (Bertin 1967). The advantages of collection of maps over a single map is that it decreases the amount of information in each map, making them more legible, and that it better allows comparing patterns of phenomena between dates. Its main limit is that the number of years to show is limited, because it is difficult to memorize and compare too numerous maps to each other.

Animation and interactivity provided by dynamic maps are an efficient way of depicting time (Griffin et al. 2006; Fabrikant et al. 2008) and overcome some limits of classic maps to represent spatio-temporal data. However this kind of map is not compatible with the printing of maps on paper, which is a required parameter in our context.

3.2. Required elements about floods and territories

The request was to make maps that summarized and display the knowledge about major historical floods that happened on given regions. This knowledge consisted in the extent of the flood, the dating of events, types of flood and their hydro-climatic causes. Five types of floods were identified: overflowing of a watercourse, debris flood, water table rise, surface runoff or sea submersion. The described hydro-climatic causes of floods were large scale weather systems (Oceanic or Mediterranean regimes), storms, hurricanes, quick snow melt associated with precipitation and failure of a dam.

Main cities had to figure on the map as reference elements for location purpose. Watercourses, smaller cities and remarkable places impacted by the historical floods also needed to be displayed, in order to illustrate the spatial organization of the territory which is referred to in the text describing the events.

As the reporting of rivers and cities should have an optimum accuracy and resolution in relation with the edited format of the map, an editorial work allowed restricting needed information to the minimum. The river network

was restricted to the main rivers plus secondary rivers (first rank tributaries). The cities were restricted to the main administrative places plus some hydrographic nodes which were referred to within the textual description of the historical flood.

3.3. Map design proposals

We couldn't represent easily all the attributes of floods with visual variables, as it implies to make a '5-Dimension' map. As a consequence, we chose to use the hue of color to represent the date of the events. The color was applied to the borders of flood extent features while their content was left transparent in order to see the objects they contain and impacted. We completed the date information by labels next to the surfaces, which described the two other characteristics of floods. The solution of labels was chosen because floods were not too numerous (up to eleven floods per map), but their placement was an important point.

Some specifications for names placement were produced by Imhof (1975). We follow them to place watercourses names, which were linear features, and cities names, which were punctual features. But for surface features, Imhof only considered the possibility to place names inside surfaces. In the flood map case, it was problematic because several surfaces overlaid, which reduced the placement possibilities, and because a lot of other labels (every primary watercourses names) were already inside the extents. In the first version of the map, presented in *Figure 2*, we chose to consider surfaces as if they were points to place floods labels, while paying attention to avoid overlaying between them and others contents of the map.

As mentioned before, an other issue was that lots of labels were already on the map without placing flood events descriptions. To add these descriptions as labels led to a visual overload of the map. That's why we reduced the part of text by representing the type of flood with iconic symbols instead of textual descriptions. In addition, we indicated the hydro-climatic cause of the flood in a table next to the map. The map and the table were related by the color of the date of the events. We chose to repeat the date of the events both in the map and in the table in order to allow reading them independently.

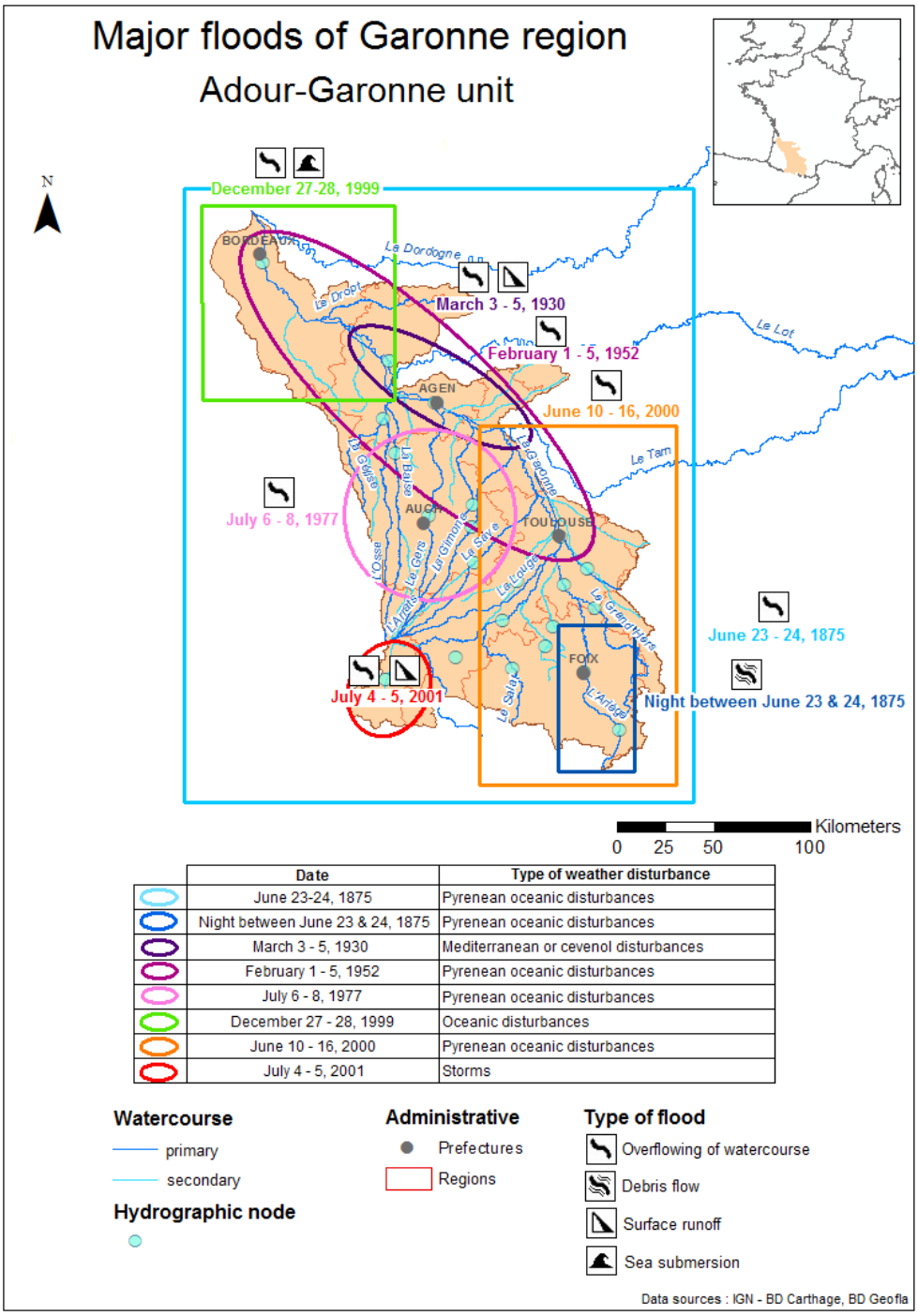

Figure 2. First version of the map of major historical floods in Garonne sub-region

Even if this first map was legible and satisfied the content requirements, its design was still dense. After some trials, we produced the second and final version of the map, which is presented on *Figure 3*. The table of hydro-climatic causes was added in the text description instead of being in the map frame. It left more place to draw the map itself. The background became a neutral grey and the white halo around letters could be removed. The borders of flood extents were slimed down. Floods labels were pushed on either sides of the map and vertically aligned. It resulted in an increased feeling of order and a globally lighter map, which is more pleasant to read.

In both versions, a small icon was added at the top right side of the figure, with a display of PFRA unit within France.

4. Conclusions

The aim of this work was to make maps of locations of major historical floods. These maps must be drawn from incomplete textual descriptions and should show hydro-climatic properties of past floods, major cities as reference points and impacted watercourses and places.

Geometric shapes (rectangles and ellipses) seemed to be suitable for representing floods extents. They showed that extents were uncertain and they enabled to visually distinguish them from territorial features. The borders of flood extent shapes were colored according to their dating and were placed on a neutral grey background. Flood extent shapes were hollowed, in order to see the temporal overlaying between events and to see elements of the covered territory. In the final version of the map, labels about floods were aligned on either side of the map and types of floods were represented by iconic symbols in order to decrease the amount of text.

This approach could be generalized to inventories of other natural phenomena that impacted areas (e.g. landslides, forest fires, avalanches, volcanic eruptions), with one event property and impacted elements of the territory. It appears to be more efficient and more synthetic to communicate knowledge than a textual description.

A limit of this map design could be that it remains a ‘map to be read’ rather than a ‘map to be seen’. Thus, it would be suitable to communicate knowledge but not to conduct spatio-temporal analyses.

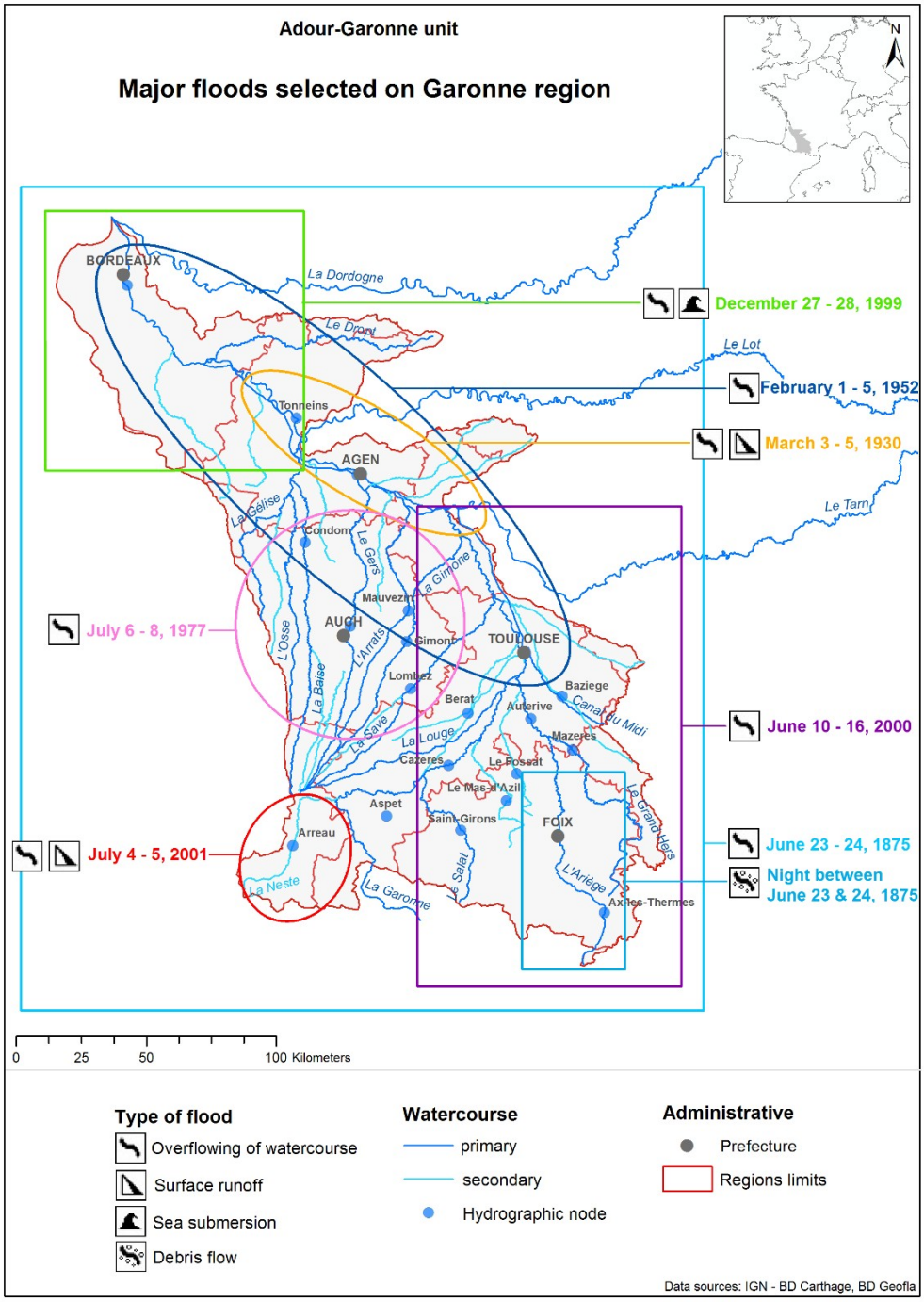

Figure 3. Final version of the map of major historical floods in Garonne sub-region

In future work, we plan to enrich the proposed design by adding interactivity and animation, in an analysis purpose. These evolutions will need to be tested, in order to assess their efficiency according to different types of users and different tasks.

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