TEMPORAL GEOVISUALIZATION IN RISK AREA

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Abstract

Today, infinite possibilities exist to map different information's dimensions. However, it is necessary to reflect on new map shape possibilities with geovisualization process. This research focuses on the time representation that appears, when observing maps on the Internet, as a dimension with a high development potential.
Our goal is to develop a geovisualization method of different objects temporalities in order to improve knowledge and understanding of these for territory's actors. This work is based on temporalities describing natural risk events. Indeed, the risk is a very popular issue in problems visualization on territorial management.
The article describes existing temporalities through example of risk events, and shows the contributions and limits of mapping and geovisualization. Finally, our proposal on geovisualization method of object's temporalities is exposed.

Keywords: Temporalities - cartography - risk events

Introduction

The "risk cartography" is an expression that encompasses many concepts and methods. Indeed, if cartography is a tool to display objects by following some representation methods, the term "risk" contains differents elements that are more or less concrete. This may include probabilities (hazard and vulnerability), but also tangible material (damage and phenomena). These objects are described by many informations with various dimensions: spatial, temporal and thematic. Our focus of interest is on the temporal information from risk events mapping, for several reasons:

1. the map is a tool privileged by territory's actors;
2. information about risk events is very popular among scientists and decision makers through the risks prediction and risks prevention, such as risks memory enrichment;
3. if one or more knowledge about objects temporalities is essential to the understanding of some processes (eg. probability's laws), their representation lets identify global trends, but also extraordinary trends. The risk management actors are looking for this.

Our problem is to map the temporalities about risks events. The following questions apply to various areas:

- The mapping: how to represent time dimension on a map, a quantitative attribute, that is not obvious to evaluate given its passing and changing? Which temporalities can be taken into account with cartographic methods?
- The risks: what definition of risk allows us to consider events? What are temporalities of one or more events?

Our objectives are to identify the temporalities about risks events and build a geovisualization method. The first part defines what we consider as the " temporalities about risks events ", while the second part presents some cartographic methods to represent this concept and geovisualization contributions. They will enable us to build a proposal to improve mapping of temporalities about risks events.

1- Temporalities about risk events

The temporalities about risks events and more specifically the events-related on are still few studied. The term "temporality" has several meanings. In the field of risk sociology, Hewitt (1983) distinguishes the following parameters in a disaster: frequency, duration, rate of change, return period and chronological spacing. From the nineties, temporalities consideration focuses on the time step (as a small period of time characterized by a duration) and their rhythms. This vision is popular in the field of geography in particular through the *time-geography* thinking, but also in urbanism (eg “urban temporalities” of Lepetit et al, 1999). The study of these time steps entanglement according a new temporality: the synchronization.

The scientist Allen (1983) describes different time synchronizations, identifying thirteen relations between two time steps. In the geovisualization field and more specifically the study objects representation on maps, DiBiase (1992) and MacEachren (1994) identify dynamic variables that are, in addition to the duration, frequency, velocity and synchronization: the time of representation and chronological order.

Baudelle (2004) adds a distinction between probable elements temporalities (random and rhythmic temporalities, as a risk return period) as part of a cyclical time; and real elements temporalities (the acceleration and ideological temporality referring to the temporal thickness of history) within a linear time.

Firstly we study the event temporalities according to an analysis within the geography science, by analysis how synchronization of risk events time steps. In a second time, we apply the Allen (1983) relations to these synchronizations. Finally, we describe other temporalities qualifying risks events.

1.1- Time steps synchronisation

We study the temporalities about events through the detection of variable time step (objects lifetimes: exposed elements, physical space; or virtual: risk) with the aim of showing synchronizations where events born. These time steps are short or long compared to a timescale.

The risk temporalities are little studied, and related of event, barely considered.

The physical space (a cliff, a watershed, a mountain) has its own temporalities (time step related to phenomena kinetic or related to its execution speed, and traces time step) and its exposed elements (time step related to physical and human exposure). A combination of these temporalities brings bloom events. For example, an avalanche (a phenomenon with own temporality) with has a trajectory towards houses (exposed elements with have their own temporality) causes an event that need to take in account the damage caused.

Temporalities about events consist of temporalities related to its cause (phenomenon), its parade (warning and crisis), but also its consequences and traces (damage). Territory's actors need to visualize them to help in their search or their decisions.

If our goal is to represent the events temporality, these phenomena and damages that must be mapped. But beyond these time step representation, what relationships can we meet in their synchronisation?

1.2- Application of Allen's relation to risk events

Relations between two intervals, defined by Allen (1983), are as follows (Figure 2).

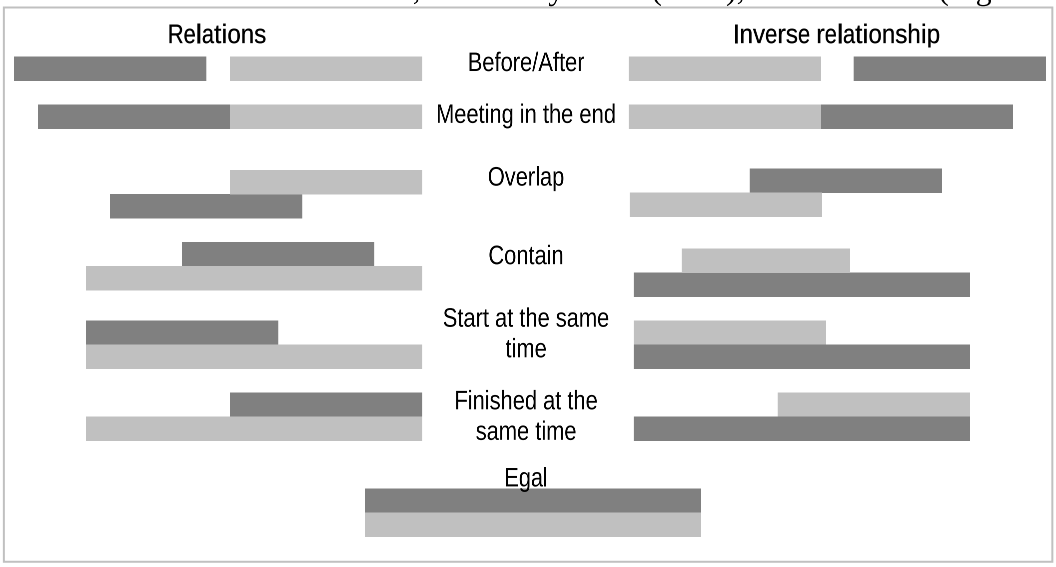


Figure 1 : Thirteen relations between two temporal intervals (Allen, 1983)

These relationships are suitable for events and exist only when one considers a single event. They are shown in chronological order (a flooding happened before another), and the relationship is then based on two events: for example, an event (n avalanche) ended when another occurred, a rock fall has achieved while a flash flood was prevented, two flash flood had the same duration. These relationships can be extended if we add a third event or more. These relationships correspond to the temporal elements that territory's actor want to know and visualize.

However, events contain other temporalities.

1.2- Other criteria of events

In addition to the events duration, we have to consider the time steps synchronization: display data, duration, frequency, chronological order and rate of change are other temporalities identified by Hewitt (1983), Dibiase (1992) and MacEachren (1994). We will define them according to our problem

- The occurrence highlights the time when the phenomenon occurs and indicates the beginning and the end of it; For example, the occurrence date of a snow avalanche;
- The duration is the time (or time step) interval in which an event occurred. For example, the flood duration or building life. The duration may also be a time when nothing changes, no event which is considered as "separation date" of Hewitt (1983);
- The frequency is the number of events that occur in a time unit (eg: in one year, or in one month, occurred five rick falls). The return period can be regarded likely frequency: for example, "once every hundred years occur flooding that this magnitude": the time required for the same physical characteristics flooding (or of same magnitude) to occur again;
- The chronological order displays phenomena ordered in a ascending or descending way;
- Rate of change: when a phenomenon changes, using a regular time interval, the animation highlights quiet or turbulent periods, or times of stagnation or of strong progression. For example, the velocity of flood propagation who depends on the roughness soil and topography.

The description of these temporalities is also done using a linear time (event description: date, occurrence, duration, velocity), cyclical (seasonal events such as snow avalanches or having a flooding return period).
However, the time scales identified are inevitably linked to space and therefore linked to this dimension. The interest of temporal mapping is very large. What mapping methods and techniques used to valorise them? What are geovisualization input?

2- Temporal geovisualization: related works

Temporal mapping is accomplished through varied cartographic techniques and methods, written in geovisualization processes. Today, both "classic" maps (static maps

and maps collections), and new maps designed by geovisualization processes, have potential for time representation. But how?
To begin, this section presents the various static maps designs which are able to reflect time through graphic semiology rules. Secondly, other mapping forms, integrated into a geovisualization processes are described. Indeed, geovisualization uses animation and interactive environment, expanding opportunities to reflect time on maps.

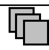
2.1- Temporalities cartography: basic concepts

Classic cartography can make single static map or maps collections. What bring these cartographic forms and graphic semiology? What are their limits?

A static map can represent durations, execution velocity and frequencies thanks to the size, value, value associated with the colour, transparency and granularity variables; but it can also uses the text variable (eg. a date). However, this graphic semiology can be applied only in the case of representations of several events that do not overlap (eg. aftershocks or volcano flow lava). Moreover, the chronological events evolution is not seen through application of this semiology.

The maps collection is a set of juxtaposed maps. Collection shows duration of one or more event, speed, frequency and ocurence. Their representation often uses movement variables proposed by many authors, which are based on Bertin (1967) graphic semiology : change of size, shape, texture, location, color, color value, angle, scenes, zoom, perspective and theme rate of change proposed by Ormeling (1995), l'Hostis (2003) and Peterson (1994). However, some temporalities can be represented with difficults (Table 1).

Indeed, as soon as event or events series raise many steps to be represented, maps collection is not sufficient: for example a fast event, on a long time step, requires many maps for the reader understand the temporal evolution.

Execution speed of one event or Event frequency / Time step duration	Fast High	Average Average	Slow Low
Short (second, minute, hour)			
Average (days, weeks, months)	Problem	Problem	
Long (year, decade…)	Problem	Problem	

 Mapping representation of time through maps collection

Table 1 : Temporalities static representation of one or more events

2.2- Contribution of geovisualization : new cartographic forms

The geovisualization is a set of methods and tools using an interactive, animated and multimedia environment to visualize geo-referenced data including through maps. They take many forms. Applied to temporal dimension visualization, we present animated maps and dynamic maps.

An animated map is created by running a maps series. This process represents a change in place (position), up (attributes) or in time (Kraak et al, 1997). This cartographic representation enables to reveal spatio-temporal phenomena and more generally the changes.

The animated map highlights the chronological order (eg: rock fall occurrences); event speed (some atmospheric phenomena in real time); and duration.
This cartographic methodology reduces graphic overload. However, a problem arises when the user want to visualize an animation sequence. Dynamic maps bring some solutions.

The dynamic map use an animated and interactive environment. It is then possible to control the animation of the map.
Authors show the great interest of animated maps to be interactive. It is mainly the evolution, duration, display data, the separation time and the chronological order dynamic variables that can be read through these maps (Perterson, 1999). The frequencies is hardly readable on this type of maps (but better than on static maps), while the return period is largely unexploited.
Mapping variables of size, value, granularity, hue, orientation and shape are visualizable through an adapted semiology. The following table propose a summary of cartographic variables application according to visualize time criteria using results of Kobben et al (1995) and Dukaczewski (2006), Table 2.

Temporal criterias / Cartography variables	Occurence	Duration	Frequency	Order	Rate of change
Size		+++	++	++	+++
Value colour		+++	++	++	+++
Granularity	+++	+++	++	++	+++
Colour hue	+		(+)	(+)	
Orientation	+++		++	++	
Shape	+++		++	++	

+++ Very suitable ++ Adapted + Moderately suitable

Table 2 : Representation of temporal criterias on dynamic maps

However, frequency and synchronisation appear poorly, while the return period is largely unexploited.

The use of dynamic legend, both interactive and animated (Peterson, 1999; Kraak *et al*, 1997), has expanded the possibilities of visualization of temporalities objects such as linear time (past, present, future) and the cyclic time (eg. seasons, day / night, return period, frequency).

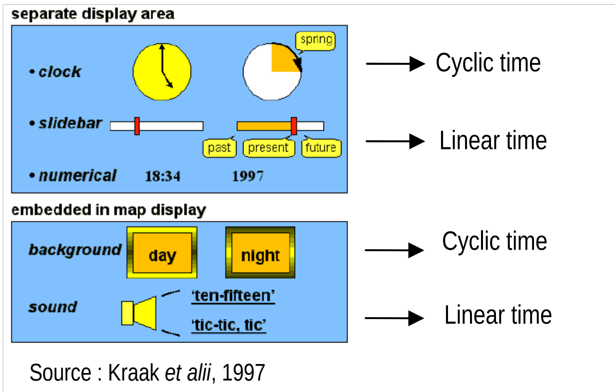


Figure 2: Dynamic legend to control animated maps

Dynamics chronologies are also popular tools for interacting on animated maps (Davoine *et alii*, 2001 and 2004). They have advantage of showing in addition to the chronological order, other attributes through graphics (eg. histograms, scatter plots), Moisuc (2007).

Contribution of dynamic maps is required for the representation of temporal objects on map. However, a problem persists in automated use of these qualities when we want to create maps with tools (eg. a Geographic Information System – GIS). Another problem arises in the temporal criteria representation in which a semiological vacuum adapted for animates map form, persists. It is difficult to find appropriate variables to construct temporary maps.

What kind of temporalities the cartographer can use, can display in function of this problems? How to combine the contributions of graphic semiology and new maps form to represent the whole of temporality?

To answer these questions, a geovisualization method is proposed, always relying on risk events.

3- Time geovisualization method proposal for mapping temporalities about risk events

The geovisualization method proposed aim to assist the map designer, from chosen objects (related to events), to the final map. For this, we create "temporal pictograms" to understand temporalities to represent each object. Then, we propose specific cartographic rules extensions to translate these symbols into "geovisual variables”. Finally, a global geovisualization model of time is created.

3.1- Temporal pictograms in order to specify the temporal dimension

Temporal pictograms are directly applied on the objects model of representation (eg. risk events) to be mapped. We have use the pictogram concept come from MADS (Modeling Language for Spatial and Temporal Information: Vangenot et al, 2002; Spaccapietra et al, 2007). We have choose to use the pictogram concept to map temporalities about risk events. We applied the basic pictogram as occurrence, duration, frequency (occurrence set , duration set ).
We propose new symbols to represent other temporalities (Table 3).

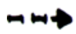
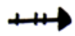
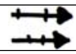
Temporalities	Pictograms
Return period	
Velocity	
Temporal spacing	
Chronological order	
Synchronisation	

Table 3. Pictograms modeling some temporalities

Pictogram creation of return period is based on the cycle sign on which we add points representing the phenomena potential return.
The next step is to enable the map designer to move from pictograms reading and application, to the temporalities cartographic representation.

3.2. Use pictograms to map temporalities

The related works showed a graphic semiology is applicable to temporal criteria to be mapped. However, it does not take into account the geovisualization processes. We therefore propose new variables named "geovisual variables” (Figure 3).

Five geovisual variables are defined:

- Appearance: it allows to reflect occurrence visualizing objects display. This geovisual variable can also represent order visualizing objects successive appearance, frequency by visualizing an occurrences number or duration number, and return period by visualizing time between two objects.
- The object display duration permit to cartography an apparition period or absence duration.

- Moving permits mapping an object that moves in time. This variable may be associated with object speed.
- The velocity, it allows to visualize the rate of change.
- The flashing can view the objects synchronization.

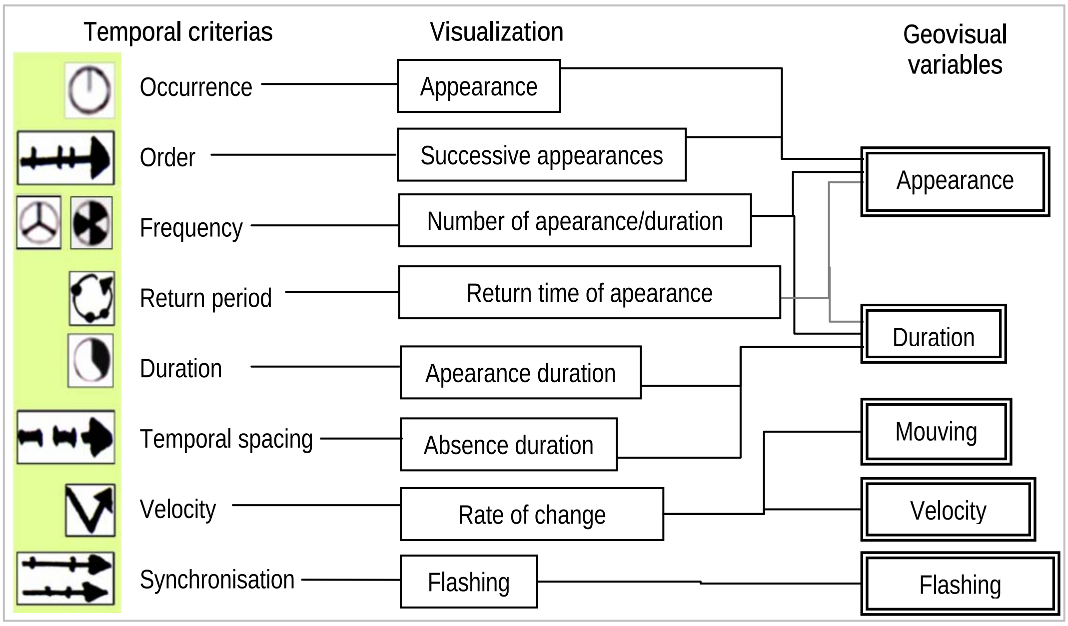


Figure 3: Geovisual variables

The designer can then associate to each pictogram one of these geovisual variables when representing an object. That's why we propose in this paper a model for these rules, in order to include them in a GIS (it's a next works).

3.3. Model for semiologic rules and geovisualization

The goal of the modeling of the graphical semiologic rules (using the variables already presented in the state of the art) and the previously identifed geovisualization rules, is to make their use easy when designing dynamic maps. At the end, the computer scientists should be able to integrate these rules in existing geovisualization tool using this model in order to be able to use them automatically.

The choice in semiology and geovisualization are then used against the rules of semiology establised by Ormeling (1995), Hostis (2003) or Peterson (1994).

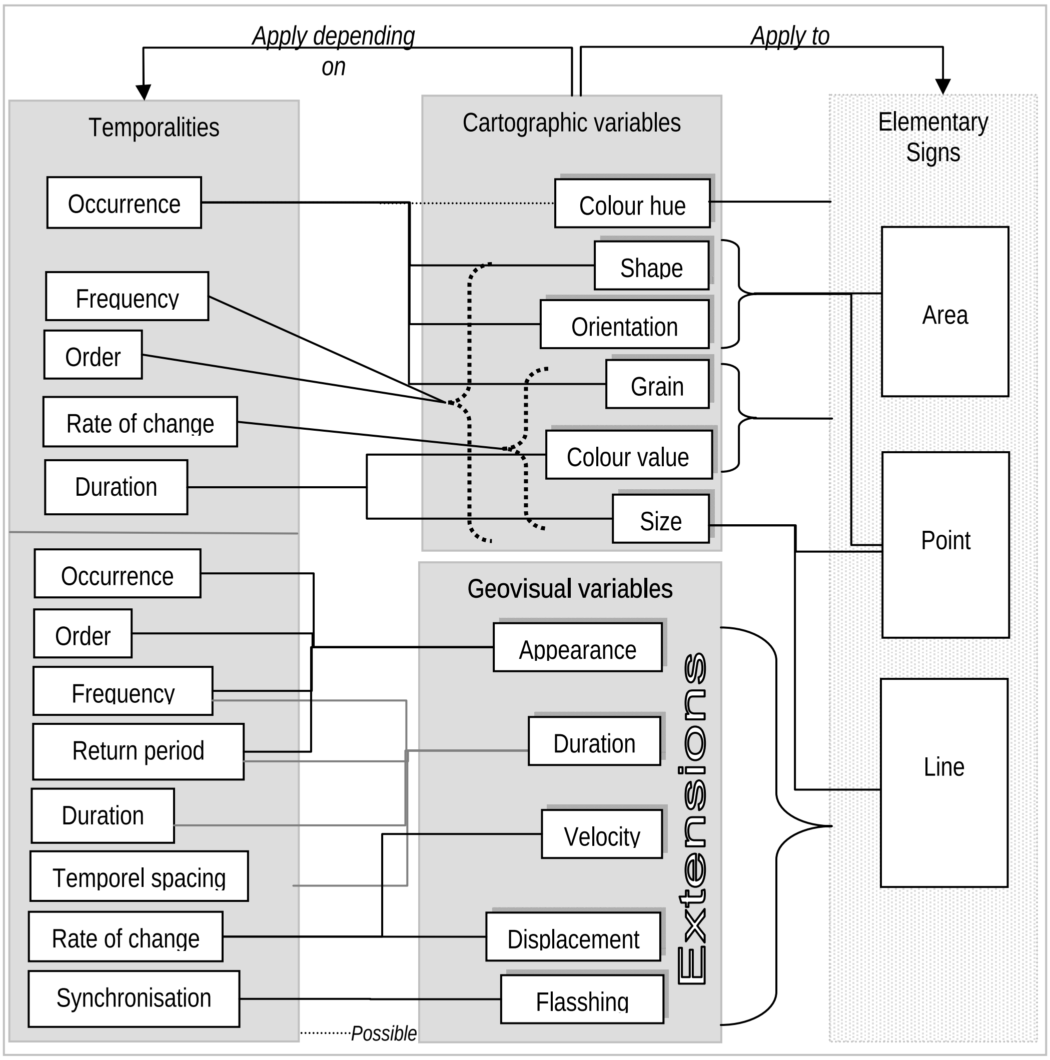


Figure 4: Model used for rules in geography and geovisualization

The figure 4 shows the use of the geovisual and cartographic variables using the temporal criterias. Moreover, it indicates the elementary signs available according the variable considered.

Nevertheless, the visualization of the thirteen rules of Allen (1983) and the synchronisation can be improved by using other techniques of geovisualization: one example is the association of a plot to the animated map. In this case, the display of events extracted from a risk on a point plot shows, when animated, the synchronization between different elements, but all the links established by Allen. The visualization of this solution need to rely on geovisualization.

4- Use of this method on risk events

The temporal pictograms can be applied to a conceptual diagram modeling the event (Arnaud, 2009).

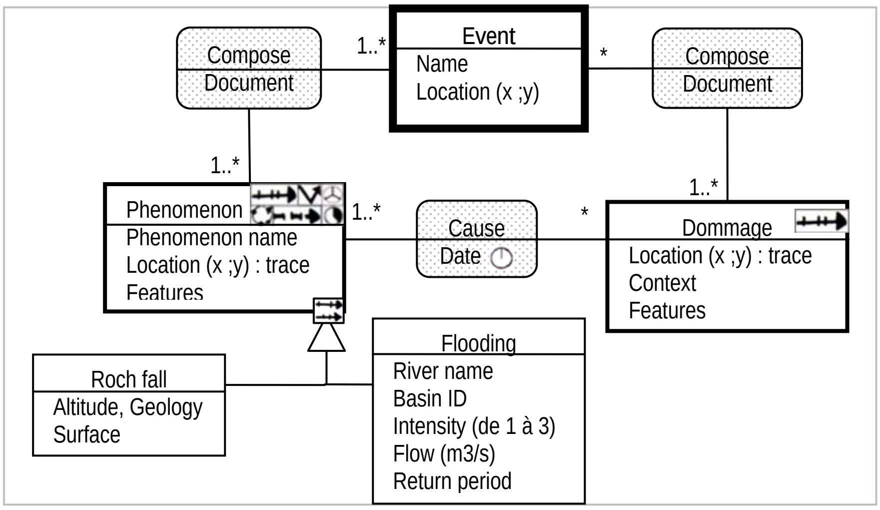


Figure 5: Use of temporal pictograms to a conceptual diagram

This figure shows the necessity to display the synchronisation of the cartographic representation of the timing occurrences of rock fall events and water flood events. Besides, classes used in the model shows that the timing of the damages to be displayed on the map is based on a chronological display. For the phenomenon itself, the order, the velocity, the frequency as well as the return period and the duration must be displayed.

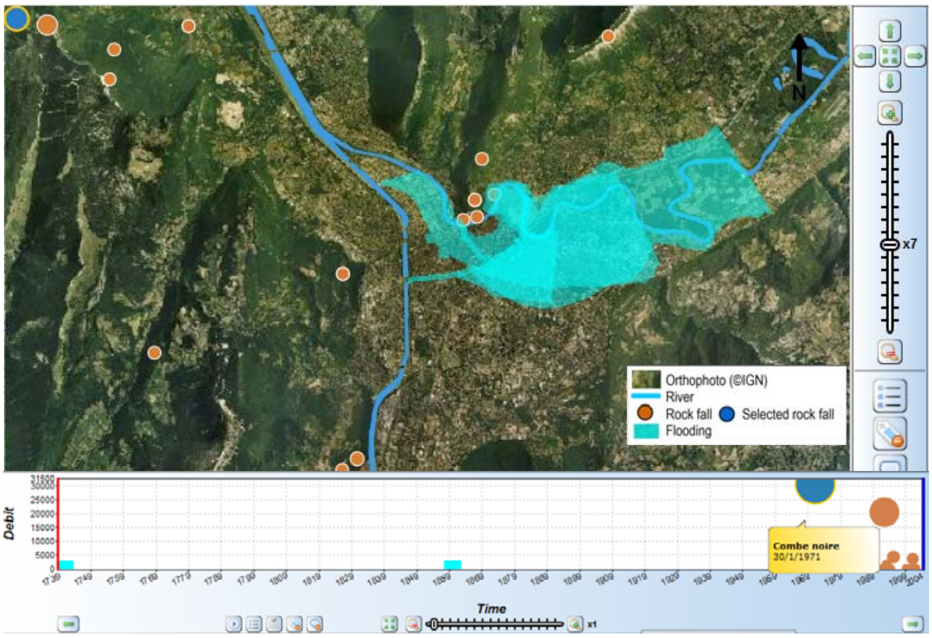


Figure 6. Exemple of events geovisualization

The figure 6 shows the temporal relation between multiple events: a flood envent has occurred between the events group. It enables too, using its animated function, to visualize the rock fall synchronisation. The map is then used to localize the rock falling events and water flooding, with the indication of the occurrence frequency when they are focused.

Conclusions

The diversity of the temporality of the objects is a dimension of the information, which needs to be displayed on maps in order to help actors and scientists to understand the time continum. Indeed, the geovisualization of temporalities helps to develop knowledge and analysis of time-space phenomena. We have identified that the static cartographic shapes can only represent limited time-related information despite of the use of an adapted semiology. On the contrary, the dynamic maps and plots offer new opportunities to visualize the temporalities of objects to be mapped. The limits identified when using a graphical semiology and the use of limited cartographic variables can be overridden with three proposals:

- the creation of temporal pictograms ;
- the creation of animated variables related to these pictograms ;
- the creation of models for using these geographic and geovisual variables .

In order to assert these proposals, we have implemented them in a geovisualization tool, generated by the GenGHIS platform (Moisuc, 2007; Arnaud, 2009). The next step will be the testing of our proposition against end-users of the generated geovisualization tool.

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