Vulnerability, resilience and adaptation of societies during major extreme storms during the Little Ice Age

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Abstract. This manuscript reviews more than 19691 French historical documents from 14 French archive centers. To assess data from historical documents, a method has been applied that leads to a record of 101 extreme storms with damage, including 38 coastal floods. Thus, the results show periods of increasing and decreasing storminess frequency. These periods are questioned. Furthermore, coastal hazards have forced societies to adapt and develop some specific skills, lifestyles and coping strategies. This paper analyses some responses of past societies to these hazards. By doing so, useful ideas may be (re)discovered by today's communities in order to enhance the ability to adapt and develop resilience. Similarly, a thorough knowledge of past meteorological hazards may allow our societies to recreate a link with territory, particularly through the (re)construction of an effective memory of these phenomena.

Keywords: Coastal hazard; Human vulnerability; Society's reactions; Little Ice Age.

1 Introduction

Climate change alters the occurrence and severity of extreme events. The frequency of these extremes events and their impacts on humans calls for better integrated risk management. Recent IPCC reports (IPCC, 2014) have shown that climate change would lead to increased risks and intensity of natural hazards, particularly droughts, heavy rains and river floods – for the moment, there is no consensus regarding the increase in storm frequency due to climate change. Over the past fifteen years, at least three extreme storms causing marine flooding, major impacts and deaths: Lothar and Martin (1999), Klaus (2009) and Xynthia (2010) occurred on the French Atlantic coast. These events have exposed the necessity to create an efficient historical reconstruction and analysis of past storms over a long period in France (Garnier E., Surville F., 2011; Sarrazin, 2012; Athimon et al, 2016).

In the XIVth-XVIIIth centuries, a storm is mentioned in historical documents if its impacts are major, meaning if they disrupt the manorial levy, induce extraordinary expenses, compromise the salt or agricultural productions, put a population in a dramatic situation that could allow them a tax exemption for example. Although very precise and detailed damage descriptions are rare for the

period, texts usually focus on consequences of extreme climatic hazards on the environment, societies and their activities (Barriendos and Martin-Vide, 1998; Athimon et al, 2016). This studies the human, material, agricultural, environmental and economic impacts of storms and apprehending the vulnerability of past societies. In fact, while studying the socioeconomic parameters of impacts in a quantitative way, it is possible to measure a societies vulnerability (Bradzil et al, 2005 ; Pfister, Bradzil, 2006 ; Bradzil et al, 2010), albeit for the early Little Ice Age (XIVth-XVIth c.), this is difficult to achieve. Furthermore, through cultural history, many researchers in historical climatology have recently focused on climate and extreme meteorological hazard representations, including people's attitudes and reactions (Pfister, 2010; Gerrard and Petley, 2013). As defining vulnerability of late medieval and modern societies is not the point of this paper, we will not discuss it. We will only admit the concept of vulnerability induced indicates both the impacts of meteorological hazards on populations and the societies' ability to anticipate, mitigate and adapt (Fussel, Klein, 2006).

The Little Ice Age (LIA) starts at the very beginning of the XIVth (around 1300) and ends in the middle of the XIXth century (around 1850) (Le Roy Ladurie, 1967; Lamb and Frydendahl, 1991; Pfister, 1996). Due to the rupture of the French Revolution in terms of environmental perceptions, societies' adaptation and mentalities (Richefort, 1999 ; Corbin, 1999), this study ends at the end of the XVIIIth century (around 1790-1800). The LIA is known as a cooler period that has resulted in a glacial thrust (especially in the Alps), colder summers, regular floods and poor harvests causing famine episodes (Le Roy Ladurie, 2004, 2006). A wide body of research has proved that during the LIA, there was an increased frequency in the number of storms (Brooks, 1949; Gottschalk, 1971-1977; Lamb, 1980 and 1985; Hickey, 1997; Galloway, 2009) and, more recently, based on the number of proxies, Trouet et al (2009) provide new evidence for enhanced storminess in NW Europe during the LIA. Similarly, Vide J.M. and Cantos J.O. (2001) in *Clima y Tiempos de España* note four periods of catastrophic events (mid-15th century, 1570-1610, 1769-1800 and 1820-1860) marked by heavy rains, snowfalls and sea storms. Moreover, in Western Europe, extreme storms can be devastating. In the North Sea, the sea floods of the Danish, English, Dutch and German coasts in 1421 and 1446 killed more than 100,000 each in England and the Netherlands, while those of 1570 caused over 400,000 deaths (Lamb, 1991, p. 174).

This paper is aimed at helping communities adapt to climate change by outlining a set of lessons derived from coastal hazard experience together with insights from contemporary and modern scholarship. These lessons are framed in the context of building resilient and sustainable communities in this era of climate change. This step will be followed by the development of a

database on extreme events over the past thousand years, to assess the impact of past climate changes on changes in the frequencies and intensities of these events.

From historical examples of storms during the LIA, this research will:

1) Identify, as accurately as possible, the storms and the coastal floods on the French Atlantic coast,

2) Discuss the impacts of these phenomena on populations,

3) Define the vulnerability, resilience and adaptation of French medieval and modern societies by presenting their perceptions and their reactions.

The geographic framework of this study is located in France, from Brittany to Gascony (figure 1), while the period of study stretches from the XIVth into the XVIIIth century. The study area includes rocky and sandy coasts, lowlands and marshes, and islands. This area is regularly affected by violent winds and episodic coastal flooding (Feuillet et al., 2012; Sarrazin, 2012; Garnier et al., 2018; Pouzet et al., 2018a; 2018b).

2 Materials and Methods

This research is based on French historical published and unpublished documents including narrative sources (chronicles, diaries and memoirs), archives (records of city repairs, books of accounts, parish registers, and surveys conducted after a disaster, etc.) and ancient maps. In all, 19691 documents were consulted within the archive centers of the 14 French cities of: Nantes, Angers, Saumur, Le Mans, Laval, Rennes, Vannes, Brest, Quimper, Saint-Brieuc, La Roche-sur-Yon, La Rochelle, Bordeaux and Paris. These historical documents contain observational and descriptive data on past storms, their impacts on societies and the reactions and adaptation to them, allowing the study of past societies' vulnerability. Every historical source used for the redaction of this paper, including those already studied and published by other scientists, have been consulted. They have all been analysed and criticised.

The critical approach of sources is crucial. The redaction conditions of a document are essential to consider, as is the author and the institutional framework. No descriptive meteorological data are objective. Depending on the writer's age, his social environment, his life experiences, memories, perception of phenomenon, his propensity to exaggerate etc, the event's description will change. It is also necessary to define if the document is contemporary and if the author witnessed the events related (Hickey, 1997). If not, it needs to be determining whether the events occurred during the life-time of the author or if he copied it from other documents. In the case of a copy, the original

manuscript (if it still exists) needs to be consulted to make comparisons and eventually correct any errors, mostly of date, in the transcription. Particular attention should be paid to dates (Bràzdil et al., 2005). In the West of France during the XIVth-XVIth centuries, Easter style dates predominated.

100   Therefore, the New Year started at Easter. Here, dates have been homogenized in order to appear in the « new style (n.st.) ». In other words, the « new » year is meant, even when the event happens in February. Moreover, in 1582, Pope Gregory XIII created the Gregorian calendar. This replaced the Julian calendar, which was then counting 10 days less (of late on the sun). In this present paper, before 1582, dates will be given both in the Julian and Gregorian calendars, the Gregorian dates

105   being in parentheses. The correction of Julian dates is possible by adding 8 days to the XIVth century dates, 9 days to those of the XVth century and 10 to the XVIth century's dates. The possibility of improper understanding and interpretation of sources and data by the researcher should finally be admitted (Bràzdil et al., 2005).

According to Le Roy Ladurie (1967), to reduce the risk of improper interpretation and to use data

110   contained in historical records for the study of climatic events and effects, four conditions must be satisfied: 1) the series must be annual; 2) they must be continuous, so without documentary gaps, 3) homogenous and 4) quantifiable. In matters of historical reconstruction of storms in the LIA, this methodology cannot exactly be followed. However, the important difference of the quality of documentary sources necessitates making a selection of data. This research is based on a strict

115   critical approach of sources as discussed earlier and on precise criteria to generate data that is as reliable, coherent and relevant as possible (Barriendos and Martin-Vide, 1998). For this research, the identification and authentication of a storm relies on four criteria:

1) The information comes from an eyewitness or a contemporary of the event[1]. However, the data are taken into account only if other first-hand sources and/or bibliographical documents confirm

120   the reliability of the information.

2) The event is presented in the historical records as a storm and not, for example, as strong winds or a thunderstorm with high winds.

3) The date, as accurate as possible, is recorded, either because it is specified on the original document or it is possible to estimate it.

125   4) There is a description of the damage caused.

Once these four criteria are fulfilled, information is scrupulously analysed, criticized and included in databases to produce crosschecking. The crosschecking and comparison of data from different

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1 Intellectuals, clergymen, people with municipal responsibilities, etc., with a good level of education and culture, produced the original documents. So, the information tends to be reliable, though sometimes exaggerated.

documentary sources allows the historical reconstruction of storms within a defined temporal and spatial frame.

130 Fundamentally, the process of reconstruction is nevertheless difficult: some limits to the storm reconstruction work must be taken into account and discussed. First, as explained in the results section below, storms recorded in historical documents are ones with major impacts, even if climatologically speaking these are not necessarily the most violent events. It is therefore obvious that for many of these hazards, the historical climatologist has no information and even no clue

135 they happened. In these circumstances, the reconstruction is somewhat biased. Secondly, the series of storms recorded in the West of France are discontinuous owing both to an oral tradition (Sarrazin, 2012) and many documentary gaps (Athimon, 2017). They are due to historical contingencies such as archival disasters[2], the French Revolution[3], wars such as the Hundred Year War against England in the XIVth-XVth centuries, the religious wars between Protestants and

140 Catholics in the XVIth century; the Second World War etc. The loss of these documents certainly deprives the searcher of precious censuses of wind hazards. These first two limitations make any reliable appreciation of the recurrence of storms difficult. Moreover, today's satellite images allow precise delineation of the wind direction, the trajectory of a storm and the flooded areas, during medieval times a precise spatial demarcation is impossible to establish, mainly due to a lack of

145 information, documentations and instruments. Finally, the descriptions are often either exaggerated or undervalued, which makes the characterization and the intensity estimations of a phenomenon difficult to undertake for the XIVth-XVIIIth centuries.

Despite these limitations, through an acute critical study of documents, selection criteria of data and cross-checking, the historical climatologist can identify and characterize noteworthy storms

150 and sea floods of the past.

3. Results and discussion

3.1 Reconstruction of past storms

With 19691 documents studied from XIVth to XVIIIth c., this research is the most exhaustive work done on storms and storms causing coastal flooding during the LIA on the French Atlantic coast.

155 138 storms were identified from the beginning of the XIVth century to the end of the XVIIIth century.

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2 For instance, the Chamber of Accounts fire in Paris in 1737 and the fire at the Municipals Archives in Bordeaux in 1862 have caused the destruction of entire sets of registers, bundles and acts.
3 Almost all of the documents relating to the life, history and possessions of some noble families, such as the Rohan and the La Trémoïlle families in Brittany, disappeared during the revolutionary episodes.

However, due to the application of the strict criteria presented above, the final list of these phenomena is not as high in number and only 101 occurrences could be selected.

Figure 2 establishes a trend of increased and decreases storm activity. As can be seen, for instance, the late XVIth century shows an intense stormy period. This period of cooling between 1560/70-1630/40 is well-known by historical climatologists and has been named the "Second Hyper LIA" (Lamb, 1980; Le Roy Ladurie E., 2004). Similarly, the first twenty years and the end of the XVIIIth century seem to stand out (Lamb and Frydendahl, 1991). These periods of increased frequency of storms also exist in the North Sea (Gottschalk, 1971, 1975, 1977; Lamb, 1980; Lamb and Frydendahl, 1991; De Kraker, 2013). However, the question of whether or not and of the reasons why some periods experienced more storms than other is still discussed (Soens, 2018) : is it due to temperature variations ? the NAO ? inter-annual to multi-decadal variability ? an increase in human stakes leading to more and more damage, so more and more historical records ? a larger number of historical documents for some centuries ?... In fact, owing to the absence of documents this figure is not exactly representative of the reality of the storms studied in the space-time frame, especially for the earlier periods. Furthermore, Aunis, particularly Ré island, as same as the area on the border of Brittany and Poitou, called "Marches" (Bouin, Bourgneuf and Noirmoutier island) are well represented (figure 3). This can be explained by extensive research on this spatial framework (Sarrazin, 2012; Athimon et al, 2016; Garnier et al, 2018), a natural vulnerability since these coastal areas are low lying, sandy and/or marshy (Pouzet et al, 2018a ; 2018b), the presence of important human activities, economic, salicultural and agricultural stakes that can be damaged by the winds and sea. Moreover, "Marches" are located at the junction of two storm lanes : one with West-East winds coming from Ireland and UK, the second with South-West winds coming from Bay of Biscay. Conversely, Brittany, which is subject to violent winds and located on the West-East wind trajectory, seems not to have been badly affected by past storms. This is mainly explained by the loss of a large number of archives during the wars and French Revolution mentioned previously.

Once they are identified, analysis of the storm descriptions allows the study and definition of the impacts of storms on societies and their activities.

3.2 Impacts, damage caused by storms

Most of the damage was caused to monuments and buildings. Damage to infrastructures is globally demonstrated in a precise hierarchical structure. First are the religious monuments, whose alteration by wind disrupts populations. Second, the constructions where repair costs affect local

finances are mentioned. The final cluster shows, noble houses while modest homes are often ignored (Garnier, 2010). For instance, a violent storm hit the French Atlantic coast on June 24th (3rd July) 1452. It knocked down the bell towers of two churches in Angers (De Bourdigné, *Chronique* written in 1529) and washed away part of the roof of the La Tremoille family's castle on Noirmoutier island (AN[4] Paris, 1 AP 1976, n°176).

Storms can also lead to major damage on agriculture: damaged crops, seed dispersal etc. On July 2nd (12th) 1507 a storm occurred. One of the effects of the violent winds was the destruction of many wheat fields in Ancenis, Nantes and the surrounding areas (AD Loire-Atlantique, E 269, second book, f°8). In cases of significant agricultural damage the manorial levy could be disrupted. For instance, in 1346, the sacristan of Bourg conducted an investigation in the parishes of Bayon and Gauriac in Gascogny. Farmers had difficulty paying taxes due to storm damage (AD Gironde, GG 236-II). Agriculture damage aside, a violent wind can also spoil the fauna and the flora: stranded fish, damaged trees and so on. From December the 29th 1705 to January the 1st 1706, there was a severe storm on the north-west French Atlantic coast. Brittany, and the countryside of Mayenne, Sarthe and Normandy, suffered extensively. During this storm, on the property owned by Saint-Melaine Abbey in Rennes more than 120 trees were uprooted (Bordeaux, *Journal d'un bourgeois de Rennes*, 1598-1800 , written by 5 eyewitnesses, 1992 edition), while in the parish of Montjean and that of Courbeveille for example, more than two thousand fruit trees, chestnut and oak trees were uprooted (AD Mayenne, E dépôt 60/E13, view 6-7 ; E dépôt 116/E9, view 103).

This kind of extreme meteorological hazard can also endanger people's lives. Sources registering the number of dead as a result of a storm or a storm with sea flooding are rare. Descriptions mostly remain using words such as "several", "many" and "countless". From time to time, a source stands out and gives a number. It should nevertheless not be considered as the total number of deaths during the event since information is always much localized. According to Etienne De Cruseau, at the end of March 1591 (end of February in reality), a west-south-west storm hit the French Atlantic coast. In Bordeaux structural damage was so significant that at least 4 people died in their homes, while several were injured by falling roof tiles (De Cruseau, *Chronique*, written between 1587 and 1616, 1879-1881). Similarly, on November the 3rd 1656, during a violent storm which caused widespread damage on the Poitou, Brittany and the "Marches" coast, at least 184 people died in shipwrecks, such as the Marshal of Meilleraye warship (AM Nantes, GG 485, f° 87).

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4   AN: National Archives; AD: Departmental archives; AM: Municipal archives.

During the medieval and modern periods, no overall or itemized records on the economic or human toll were provided after a climate event by the different institutions (urban, seigniorial, and royal). This can be explained as much by the thinking of the day – the very notion of a human toll was unknown, as by the authorities' lack of organisation, the poor administrative procedures, and other means available. A general estimation of the economic and human cost of storms is therefore unrealizable. For a limited spatial framework such as property, salt marshes, a fifedom, a town district, etc. accurate and reliable information on the amount of human (cf. supra), material or economic losses or on the cost of repairs can nevertheless be made available. Thus, in 1469 or 1470[5], owing to flooding, the Blanchet family, modest notables, lost eight heaps of salt in the salt marshes of Bourgneuf and Prigny (AD Loire-Atlantique, 2 E 382), which is equivalent to the annual income of an average seigniory (Athimon et al, 2016). Sometimes information is not quantified, but the hazard is so extreme that several years of cleaning, restoration and repair are required. This kind of data thus gives interesting estimations of the loss generated by the event. During the winter of 1351-1352(n.st.), a storm with coastal flooding overwhelmed some areas, in particular Noirmoutier island, for nearly half a century (AN Pierrefitte-sur-Seine, 1 AP 1974, n°50) and destroyed salt marshes in Olonne (*Cartulaire de l'abbaye de Saint-Jean d'Orbestier*, 1877). Damage was so severe that almost 15 years later, in the middle of the 1360's, salt production had still not been re-established (Mollat, 1983).

Where possible – depending on the data stored in historical documents –, the study of past storms and their impacts must be followed by an analysis of societies' reactions and responses to these kinds of extreme meteorological hazards. The question of past societies' vulnerability, their adaptation and resilience is of huge importance. This appears to be the new focus of interest for historical climatologists (Pfister, 2010).

3.3 Societies' reactions and responses

Constantly living with the risk of storms and sea floods, coastal societies have developed significant risk awareness, an effective memory of these extreme meteorological hazards, a specific way of life, a particular perception of natural hazards and risks. These elements are part of a mental coping (fig. 4). They are of relevant importance in terms of societies' reactions to storms and sea flood as can be seen in figure 4. In fact, storms and sea floods were part of the culture and habits of past coastal societies, who were used to dealing with them and considered them a normal

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5 The destruction of these salt heaps is either due to the storm with sea floods on 27-28th of January (5th-6th February) 1469(n.st) or an unknown event which occurred between the end of the spring and the beginning of the summer of 1470.

part of life. This is precisely what enabled them to fix memory and develop some specific knowledge. The most destructive, traumatic or atypical storms and sea floods were preserved in their collective memory. The preservation and dissemination of these memories over a long period developed risk awareness among ancient societies. In 1627, inhabitants in Bouin sent a petition to king Louis XIII in which they certified having suffered from more than 15 storms and coastal floods since the year 1500 (Luneau et Gallet, 1874, n°XXXIII). Furthermore, they wrote another memorandum dated 18th November 1775 in order to defend and explain their privileges in which they mention the storms and sea flooding which affected Bouin on November the 13th (23th) 1509 (fig. 4), December the 31th 1598, September the 7th-8th 1599 (fig. 4), March the 14th-15th 1751 (AM Nantes, II 136, n°30 ; fig. 4). Memory is however not completely reliable since it is sometimes fragmentary and selective. This can result in exaggerations, anachronisms, mental reconstructions etc. It also relies on the author: his age, his discernment, understanding and interpretation of the events, etc. (Athimon et al, 2016). A meteorological event can also seem more violent than an earlier identical one. Despite these limitations, memory of extreme meteorological hazards can continue over several decades, which results in promoting risk awareness, develops adaptability and resilience and a better understanding of the elements. A better understanding and interpretation of the elements is of significant importance. Unlike today, ancient coastal societies considered the sea a constant and unpredictable threat. In 1451, a memorandum, sent to the court of King Charles VII, sets forth the feelings of coastal societies and its dangers (*Mémoires présentés au roi Charles VII par les délégués de la ville de Poitiers pour le détourner d'établir la gabelle en Poitou et en Saintonge*, 1873). This document rests on an ancient, but reliable, hazards observation practice and a perpetual struggle with limited resources against the sea and its risks. In the XIVth-XVIIIth centuries, risks and storm hazards were incorporated into memory, culture, habits and the lifestyle of coastal societies. This contributed to the development of specific knowledge, risk awareness and prevention measures.

During the studied period, dikes are built in order to provide sea defences against swell, chop and tidal movements, and reclaim land from the sea (Thoen et al., 2013). They also protect salt marshes, fields, infrastructures and local populations from coastal flooding. They are part of coastal management of societies in order to deal with storms and sea floods, as can be shown in fig. 4. They are small, around two meters high, and made up of clods of clay, sand, wood and pebble (Sarrazin, 2014). Leaky and fragile, they are easily destroyed but are useful coastal defences. Moreover, their structure makes them very easy and quick to repair. Unlike the Netherlands (Soens, 2009) or England (Galloway, 2009), on the French Atlantic coast no real

authority interferes in dike construction (Sarrazin, 2014). Dyke construction and maintenance relies either on owners of lands and salt marshes or, if they are public, on the community (Sarrazin, 2014). In 1492-1493(n.st.), some dykes broke under sea and wave pressure on the island of Noirmoutier. Their restoration cost was modest for lord La Trémoïlle, owner of these dikes (AN Pierrefitte-sur-Seine, 1 AP 1964). These low cost are mostly due to the abundance of cheap labor. However, sometimes the cost is exorbitant. For example, in a document dating from the 7th of December 1663, David Tessier and his wife, Janne Jumel inhabitants of Croisic, near Guérande, state that they had to restore their marsh dykes following a violent storm on January the 12th-13th 1663. These repairs cost more than 6000 livres (AD L-A., B 655, f°277)!

The vulnerability management of past coastal societies is mainly based on a precise social and work organization. Everyone (lords, farmers, fishermen, salt producers etc.) has a specific role to play. Everyone's involvement in the construction/repair of dikes and territory management develops risk awareness and ensures its dissemination within society (Sarrazin, 2014). The risks are then perfectly integrated into the coastal societies' conception and lifestyle (Galloway, Potts, 2007). Therefore, the vulnerability of coastal societies, in particular salt producing ones, is scaled down. Furthermore, during the late Middle Ages and modern period, dikes are built in a subdivision system. In other words, it is an intricate network of levees. Next to Anse de l'Aiguillon, a map of Champagné swamps drawn by André Chevreux in 1656 (AD Vendée, 1 E 442) presents this spatial subdivision. Dikes follow each other in a quasi « sequential » order: the newest are erected on the seafront, while the older ones are further back. This technique is part of a preventive approach (Athimon et al, 2016). When the sea floods, it encounters a multitude of small levees which absorb the wave energy and break the speed of waves, lessen the intensity of flooding and reduce the spread of the water. In fact, populations were aware of the importance in maintaining levees, including the older ones, as noted in a Champagné's seigniorial court document of the 7th of November 1560 (Médiathèque de Niort, fonds La Fontenelle de Vaudoré – Clouzot, 1904; Sarrazin, 2014). Finally, the construction, development, maintenance and repair of dikes are part of the lifestyle and the culture of coastal societies. They are also connected to a notion of anticipation of future damage and risk prevention (Athimon et al, 2016).

It was not until the late XVIIIth century that the royal authority becomes a systematic reference in the case of an extreme hazard (Favier, 2002). However, at the end of the Middle Ages and during the whole modern period, French kingdom authorities' interference gradually increases (Athimon et al., 2016). A range of societies' reactions and responses to meteorological disaster are seen in figures 4 and 5. Figure 5 shows that the first to react to a disaster is the local population followed

by the local authorities, either seigniorial or urban. Next, the counts, dukes and princes can offer their assistance. The king appears as the last resort. Each « player » offers different reactions which result in three main effects: adaptation, resilience and a reduction in vulnerability (figure 5). In the case of local authority intervention, actions were mainly practical: materials labor, funding and supervision in order to rebuild and repair. Through court proceedings, local authorities could also compel people to repair damaged sites. This is what happened after the violent storm with sea flooding on August 22nd (1st September) 1537 at Ré island : people who did not take part in the cleaning, restoration and repair of flooded areas or public levees could incur very heavy fines (AN Pierrefitte-sur-Seine, 1 AP 2002). In addition, ducal and royal institutions could also interfere. Their reactions are mostly financial: they provide tax assistance. In 1392, King Charles VI gives a tax exempts to the inhabitants of Noirmoutier island who fought to prevent the English from landing on the island and regularly experience storms and sea floods (*Recueil des documents concernant le Poitou contenus dans les registres de la Chancellerie de France*, 1893). Moreover, the royal authority gradually intermediates on the construction, maintenance and repair of dikes. For instance, on February 9th 1510 (n.st.), after the stormy winter of 1509-1510 (n.st.), and the sea flooding of November the 13th (23th) 1509, the duke of Brittany, also King of France, Louis XII sends a letter to his alderman in Nantes to coerce him to visit the disaster areas (AD Loire-Atlantique, B 20, view 34 numerisation). The aim is to keep abreast of the situation, have an idea of the amount of damage and see if repairs are needed. The damage is so significant that on the 23rd of June 1511, the duchess of Brittany, also Queen of France, Anne, orders a 5 year tax exemption to the disaster victims (Luneau S., Gallet E., 1874). Extreme meteorological hazards such as storms and sea floods have led the various authorities in the kingdom of France to take decisive action. Their point was somehow to provide post-disaster support and prevent future risks.

4 Conclusion

Historical documents can contain data on weather disasters, so research in historical climatology can identify past storms over time, the impact of these phenomena on populations and responses, adaptability and resilience of ancient societies. This paper shows periods of increasing and declining storminess frequency during the LIA in French Atlantic Coast. These periods, such as that of 1560/70-1630/40, can be cross-checked with those of the North Sea, but also other hazards as heavy rains and river floods in Europe (Vide and Cantos, 2001; Macdonald N., 2014). Future researches will deeply question relations between these periods and temperatures, NAO, multi-decadal variability... In addition, this paper shows evidences of the storm impact on population and of the seniority of societal' reactions to mitigate storms and sea floods. As nowadays, in the past,

storms have had material, structural and functional impacts on the economy, activities (agricultural, salicultural…) and living beings. Used to cope with storms, XIVth-XVIIIth century populations had developed specific practices that allowed them to adapt, stay aware of risks and incorporate them into their lifestyle, such as a long-term memory of past events, a good understanding of the danger of natural elements or a « sequential » order of dikes. These practices led to the reduction of their vulnerability.

By providing information about past extreme meteorological hazards, this field and paper are of the utmost importance for the current concerns and discussions about climate change, increasing vulnerability and risks, and greater severity of hazards. Indeed, by providing a thorough knowledge of past storms and coastal flooding, this paper allows today's societies to: 1) recreate a link with their territory, 2) develop an effective memory of these events, and 3) develop new strategies based on the experiences of ancient societies. This paper (historical research in general) can make a relevant contribution to prevention and management of natural risks and hazards.

Future works will take into account a greater quantity and a wider range of sources in order to improve the knowledge and reconstruction of past storms. They will be extended over a longer historical period in order to try to calculate the frequency of storms and coastal floods. Another objective is to identify the periods of increased and decreased storm activity over the last seven hundred years and correlate them with climatic fluctuations (Lamb, 1980). This may also enable us to identify modifications in attitudes and lifestyles, some changes in risk perception, loss of habits, technical development and their connections to adaptability, resilience and vulnerability. By analysing the responses of past societies to extreme weather hazards, useful strategies may be (re)discovered in order to enhance the ability to innovate, adapt and develop resilience in today's societies. In collaboration with French researchers, some correlations will also be made with coastal sediment. Finally, with the aim of identifying trajectories, storm corridors etc., international collaboration will be required ; including co-operation with sociologists, psychologists, anthropologists, etc., which will be of great interest to investigate and better understand the social perceptions and representations of past extreme climate and meteorological hazards (Brazdil et al, 2005).

Competing interests

The authors declare that they have no conflict of interest.

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535   Figure 1. Location Map

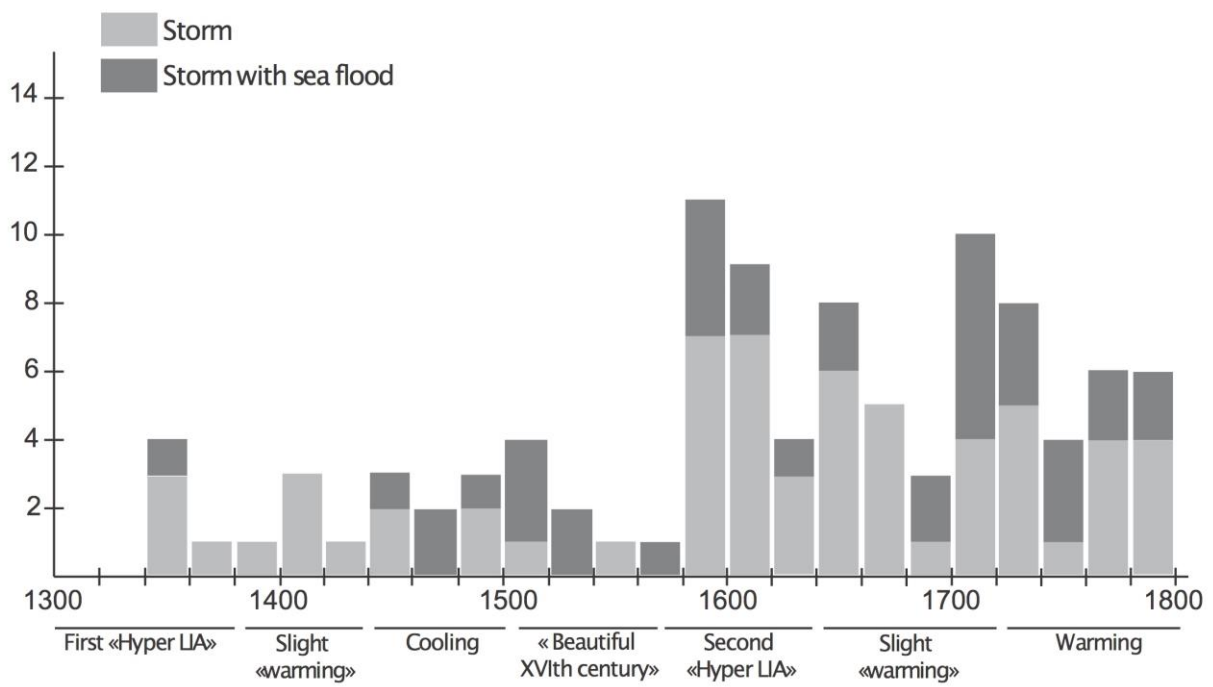



Fig. 2: Storms and storms with sea flood in the study area

540

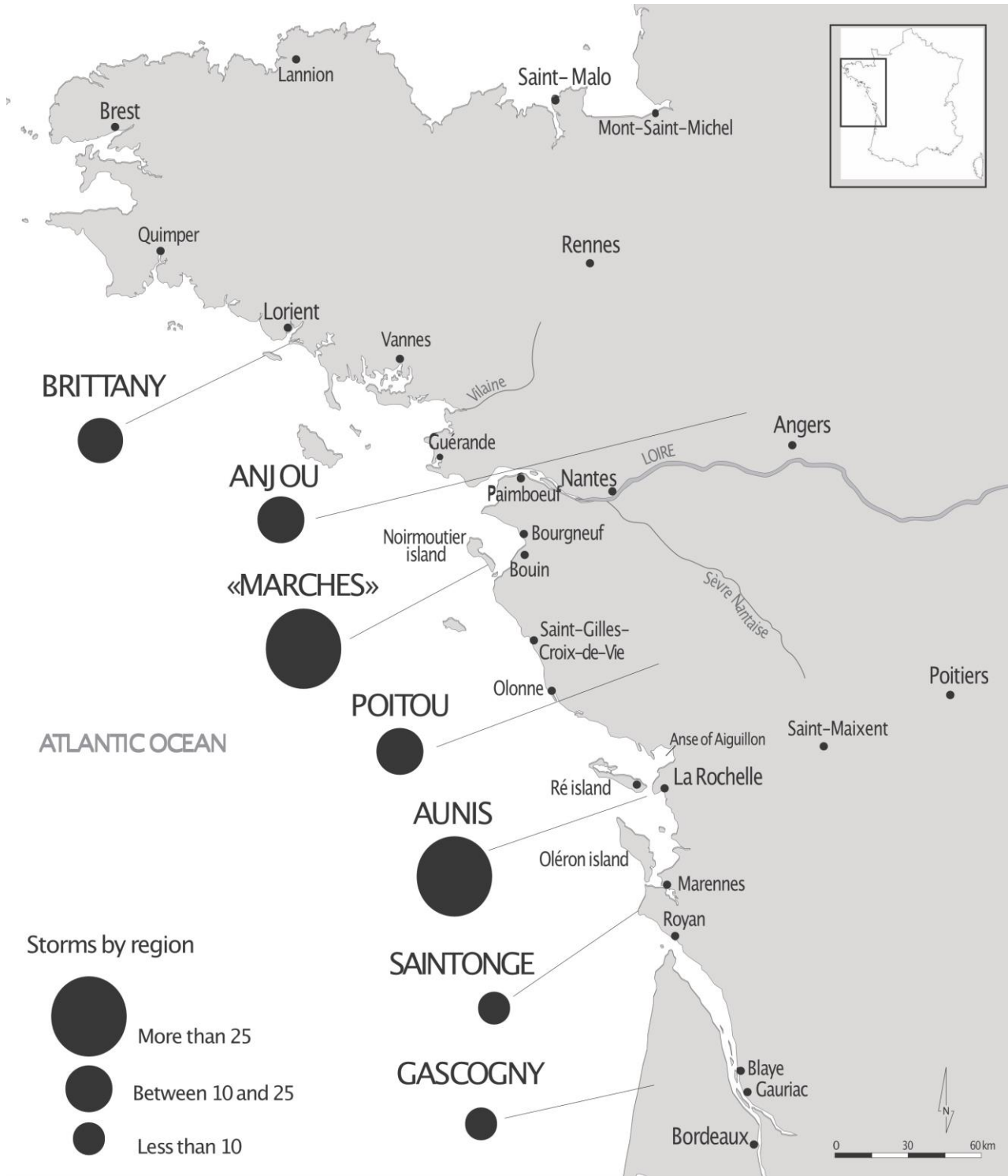



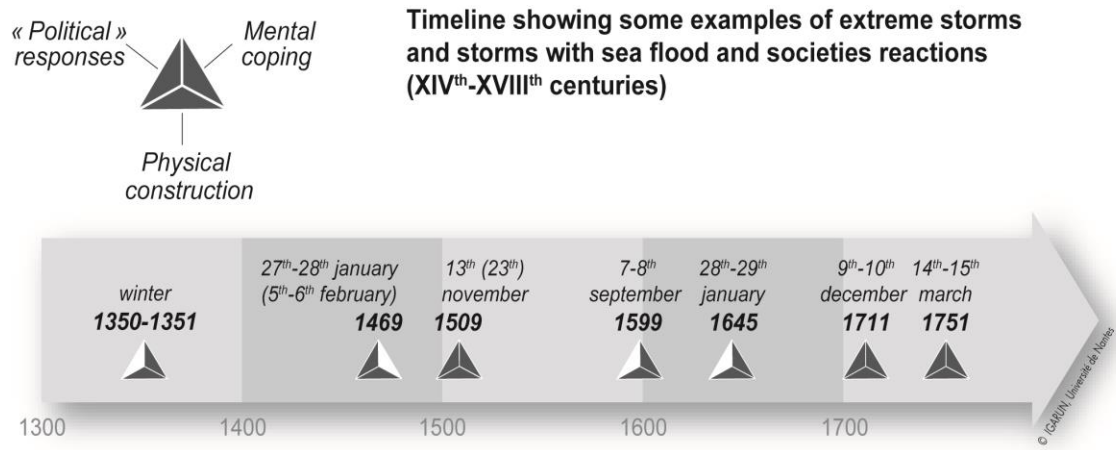
Fig. 3: Map of areas subject to the risk of storms from 1300 to 1800

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Fig. 4: Major storms and the societies' reactions
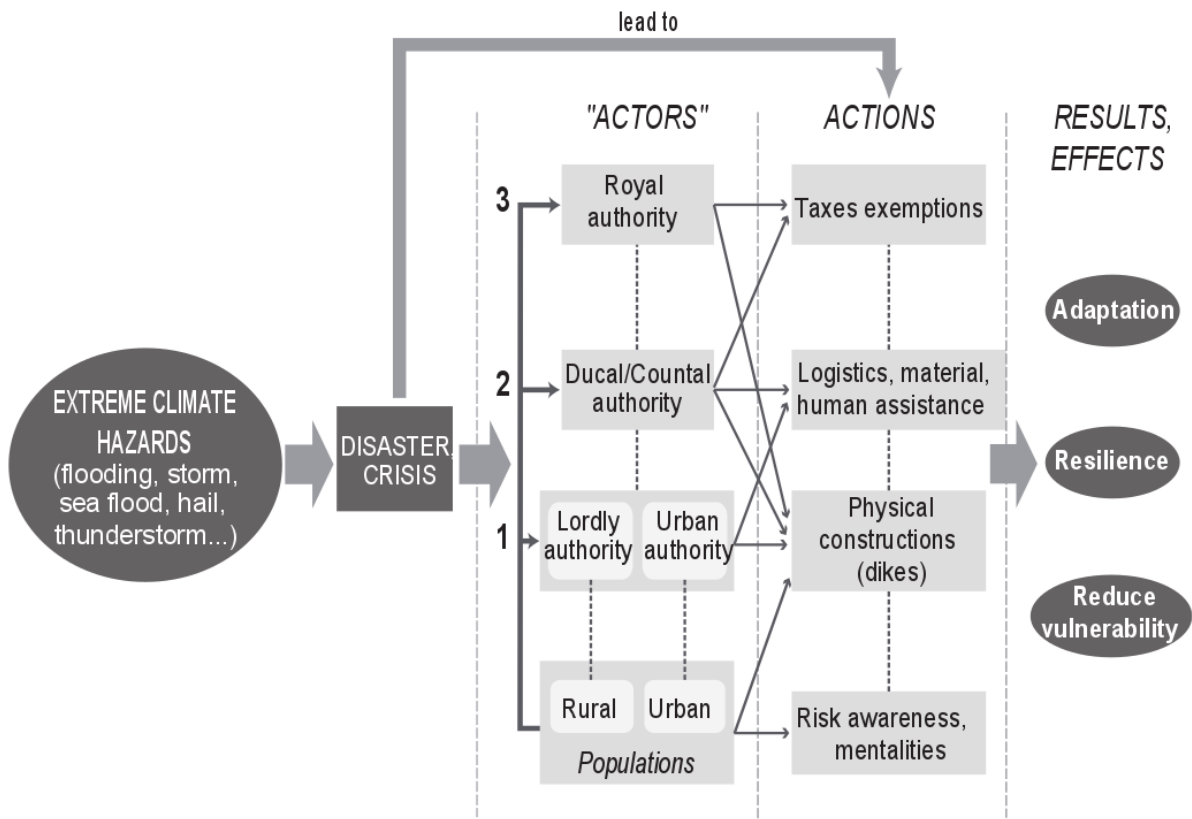
Fig. 5: Simplified representation of governance and disaster management