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Multidisciplinary expertise of historical information for the characterization of water levels during storm and coastal flooding events

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Multidisciplinary expertise of historical information for the characterization of water levels during storm and coastal flooding events

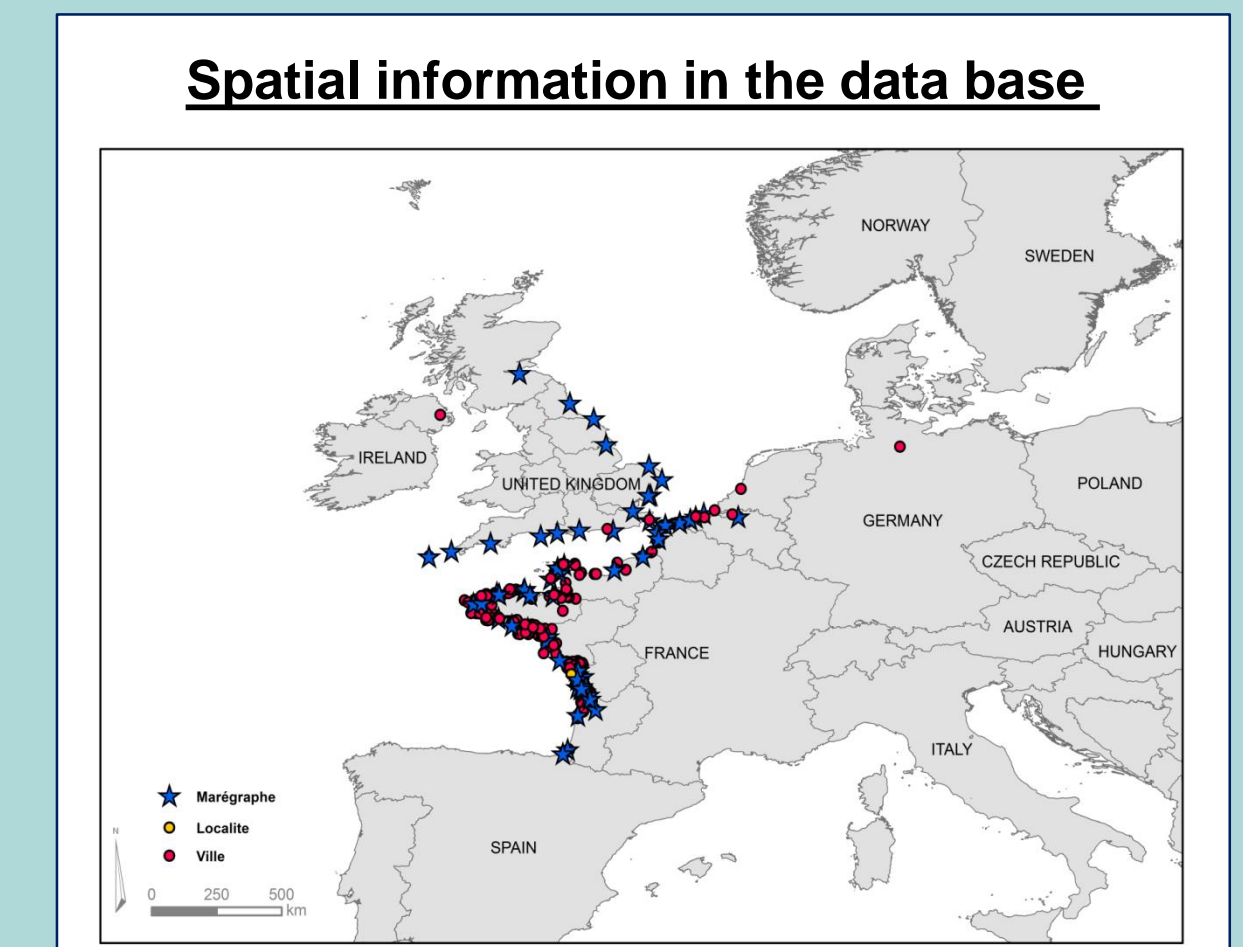
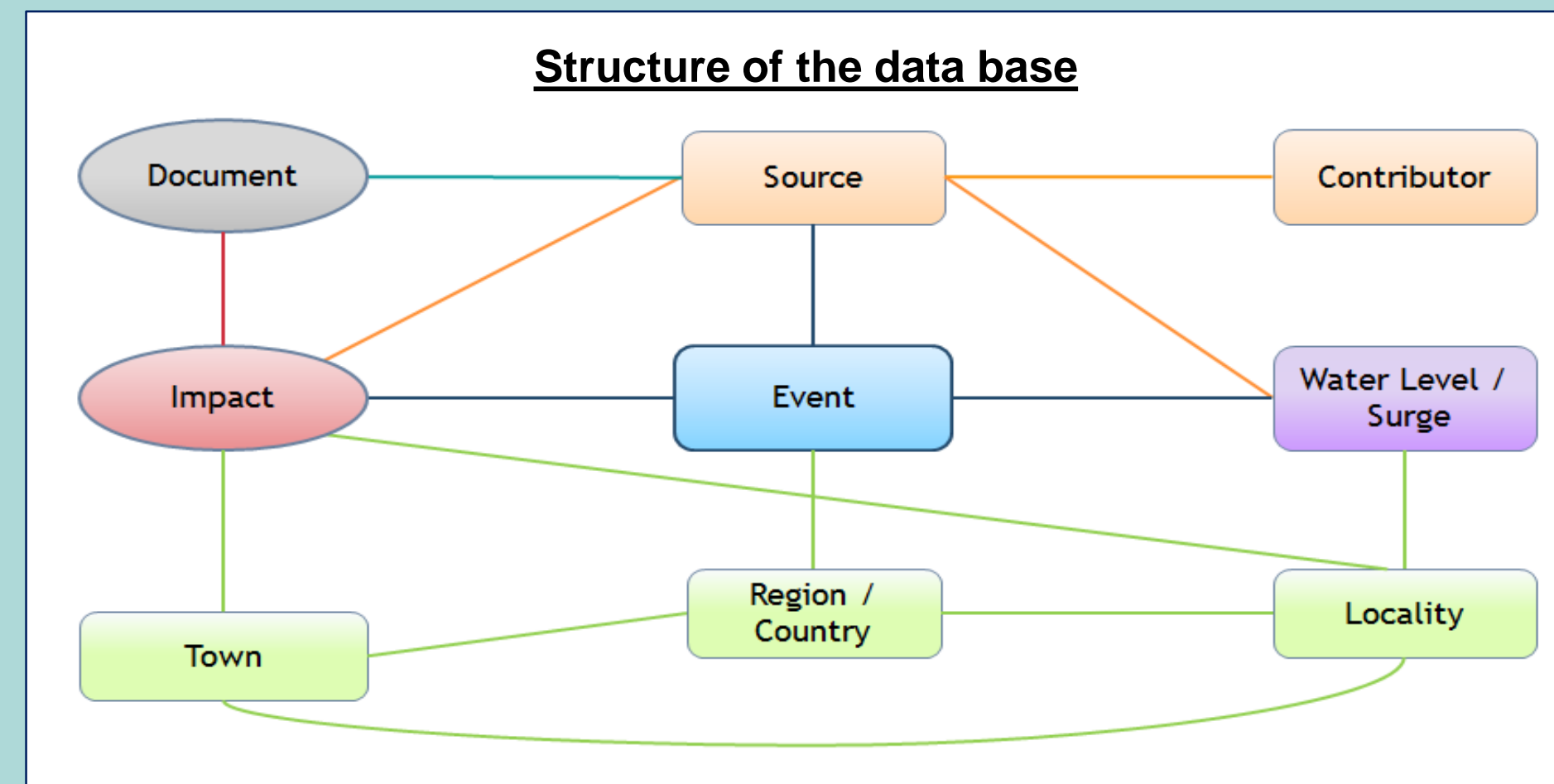
Characterization of coastal water level reached during extreme events is a strong societal concern for a better coastal risk management. Historical archives related to storms and floodings are still not often considered whereas they could be used to improve probabilities on extreme sea levels. In this context, the French national Working Group (WG) "Historical Storms and Coastal Floodings" has been created to perform a multidisciplinary expertise of historical information. This WG includes researchers, statisticians and historians from different entities (IRSN, ARTELIA, BRGM, Cerema, EDF, Shom and Université Populaire du Littoral Charentais).

A big challenge in such a multidisciplinary approach is the management of different types of information coming from various scientific contexts and practices. For each archive, the quality of the data depends also on the author's aim, which must be taken in account, so as to define its trustability. These issues, the way there are addressed and the tools created within this working group will be presented.

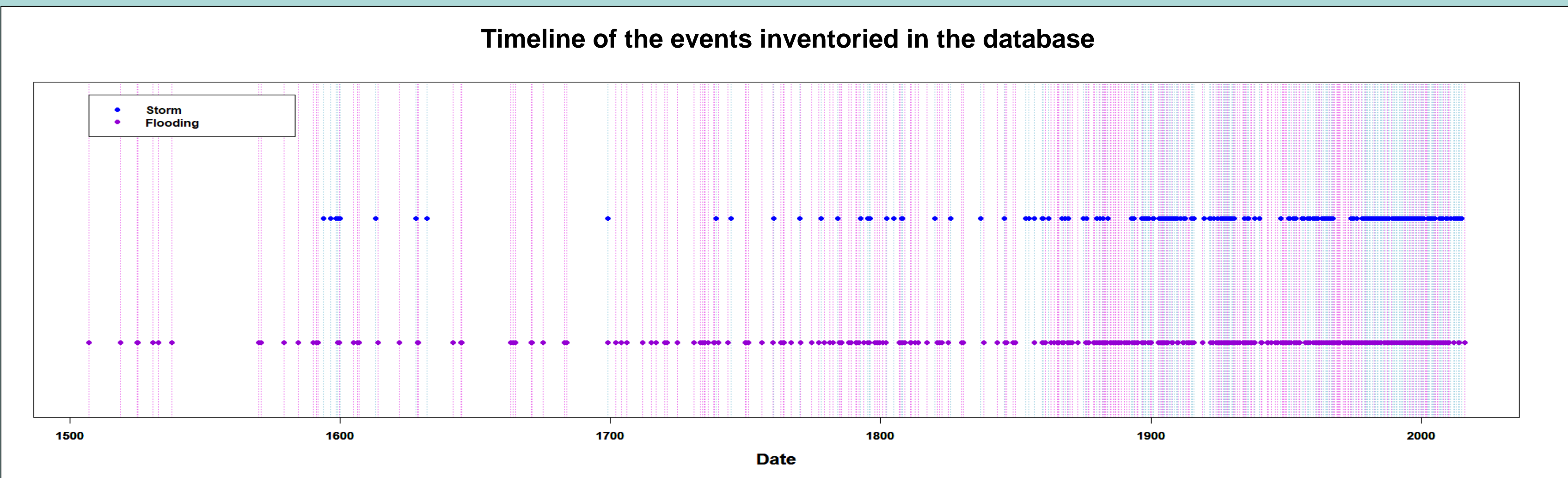
Database « historical Storms and coastal floodings »

As a starting point, the database was created by the IRSN and has been provided to the WG members. This database aims at inventorying qualitative and quantitative information on storms and/or floodings that occurred on the English Channel and Atlantic coastlines. This public database is under open access license and available on <https://gforge.irsn.fr/gf/project/bdts/>

FLOODING: event for which a marine flooding is mentioned
STORM: events where no indication of flooding is given, but which might have caused marine flooding so far not identified in the database



- Event** contains information about the date of an event
- Source** gives information about the author of a document relating a storm or flooding event
- Contributor** is connected to source, contains information about the provider of the document
- Water Level / Surge** extraction of the information for an exact localization given in a source, concerning a water level or flooding
- Impact** allows exact localization of an event and its consequences on sea and land
- Document** refers to the .pdf document of the source (if available) available on the shared workspace
- Region** spatial table (polygon shapefile), containing shapes of French and British regions and national Countries
- Locality** spatial table (point shapefile), containing exact localities affected by an event mentioned in the sources
- Town** spatial table (polygon shapefile), containing outlines of French towns



↑ In September 2019 the database contains 800 events from 1500 up to today, 543 floodings and 257 storms.

Reconstructing historical Water Levels and Surges

The identification of extreme historical water levels allows a better understanding of extreme events and may improve the risk prevention. When no measured data is available, historical sources such as local newspapers, diaries, accounts, parish or communal registers etc. can be used to reconstruct water levels. Critical analysis and cross-checking of facts has to be done, when using this kind of data. Additionally, complementary data such as historical maps, sketches, may be consulted to place the sources in their geo-historical context.

1. Event identification

The database was used to identify the impacts of three events:
2nd February 1791, 1st January 1877 and 9th January 1924.

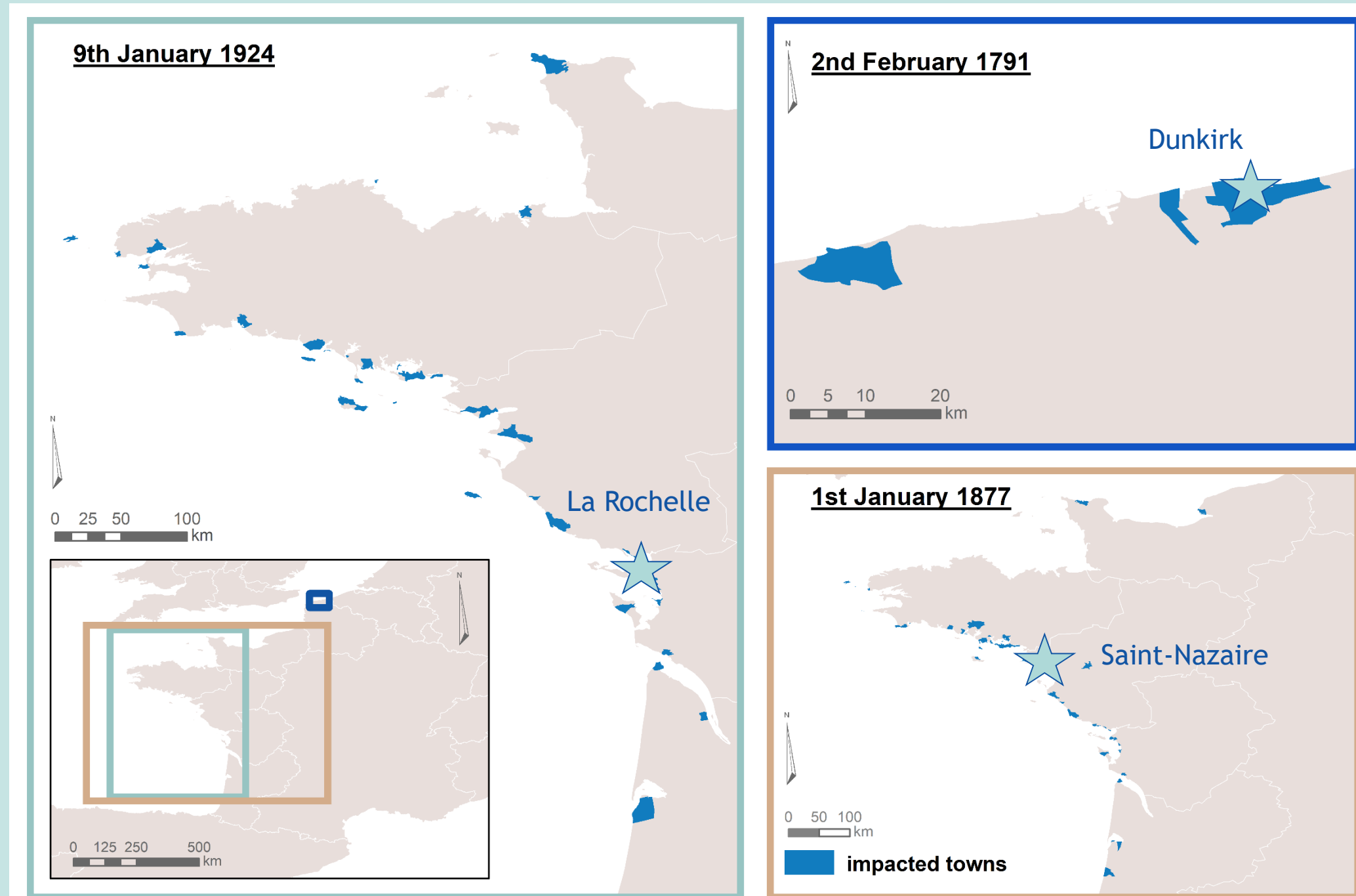
10 sources describe the 1791 event
32 sources describe the 1877 event.
42 sources describe the 1924 event.

2. Water Levels (WL) reconstructing

Water levels reached during historical events are often not provided in the historical sources. During the reconstruction process, different documents may be used and hypotheses have to be made which need to be traced with following flags [1]

Hypotheses

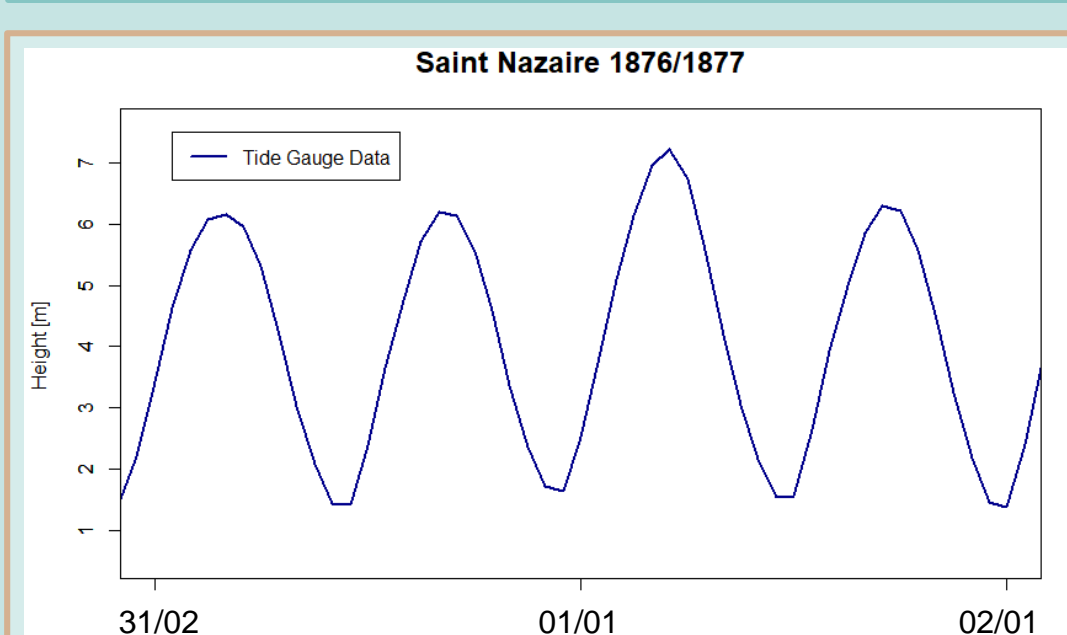
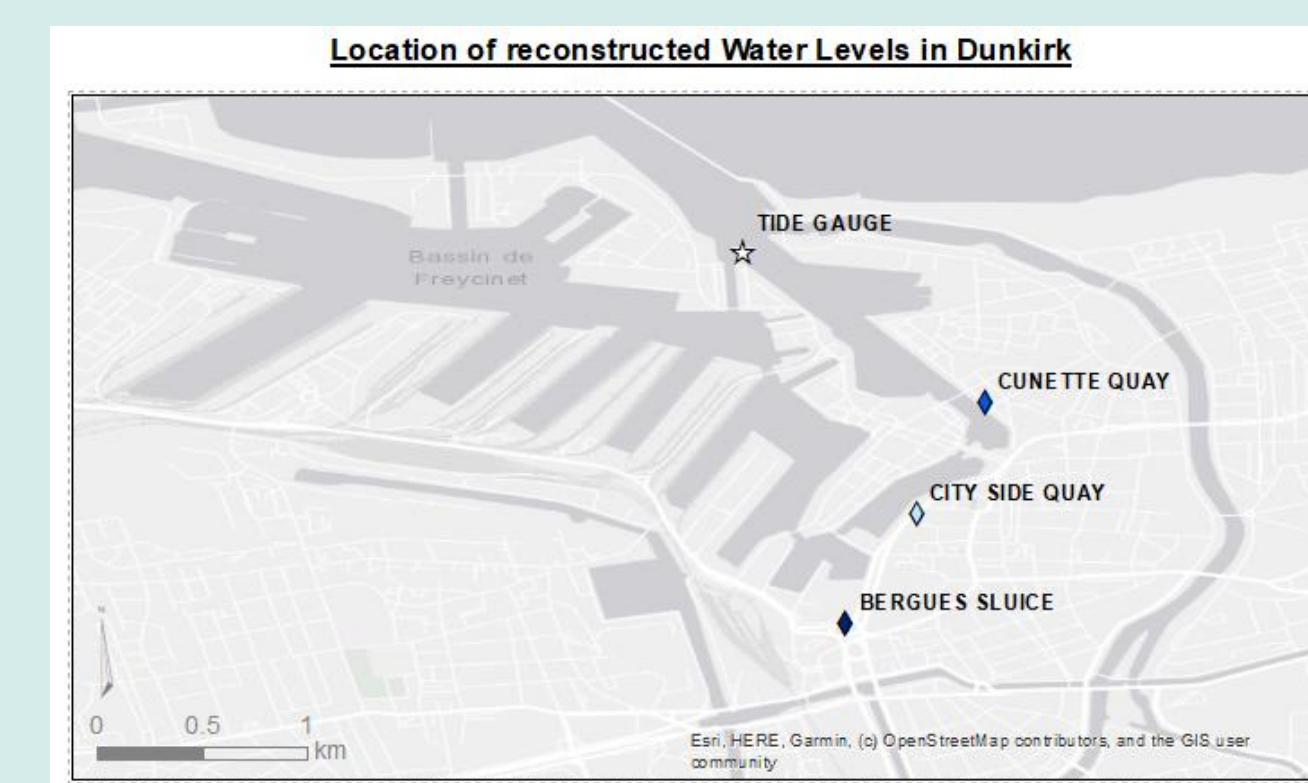
- Δ interpretation hypothesis
- T temporal hypothesis
- S spatial hypothesis
- M when no verification between tide gauge chart datum and actual chart datum has been done



2 February 1791

West to northwesterly winds caused "extraordinary high waters" in the northern part of France and Belgium [2]. The harbor surroundings of Calais, Dunkirk were flooded as well as newly gained polders. In Dunkirk, it is reported that during the high spring tide, the water level rose above the city quays and floodgates of Bergues and Kesteloot sluices in the inner parts of the harbor [3, 4]. Using historical sketches of dykes, old city maps and information about historical mean tidal water levels, following heights were reconstructed. As quays were exceeded during this events, the reconstructed water levels are minimum water levels reached during the storm [1].

Bergues Sluice: + 7.30 m CD S T
City Side Quay: + 7.00 m CD Δ S T
Cunette Quay: + 7.25 m CD S T



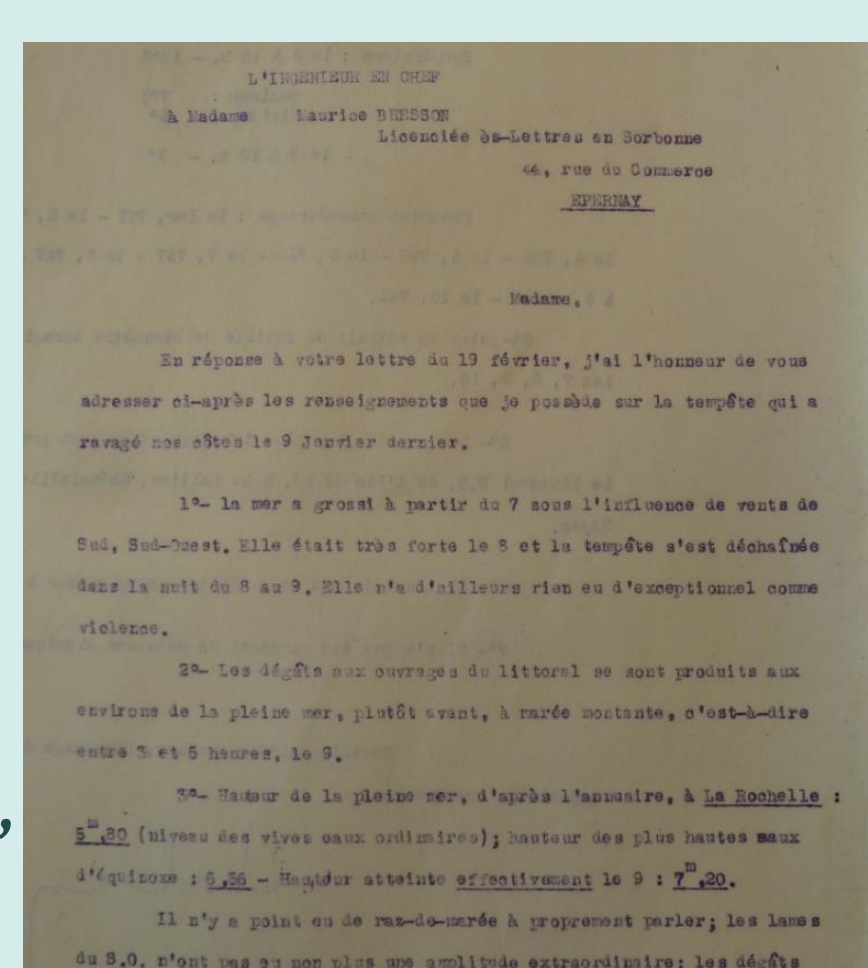
1 January 1877
At New Years Eve 1876/1877 a low pressure system which has formed over the North East Atlantic Ocean crossed Ireland, Southern England and the Channel, accompanied by gale force southerly and westerly winds. The storm was felt in the western and northern parts of France [5].
Tide gauge data Saint-Nazaire:
Maximum reached level: **+ 7.23 m CD**

9 January 1924

In the night from 8 to 9 January, a furious storm hit the French Atlantic coast from Brittany almost up to Corunna in Spain. The storm made landfall along with a high spring tide. A local newspaper from La Rochelle relates a surge flooding the coastline accompanied by "huge waves reaching the height of houses" [6].

A letter from an Engineer of Ponts-et-Chaussées relating [7] facts from the storm of 9th January in La Rochelle gives some details about the water level:

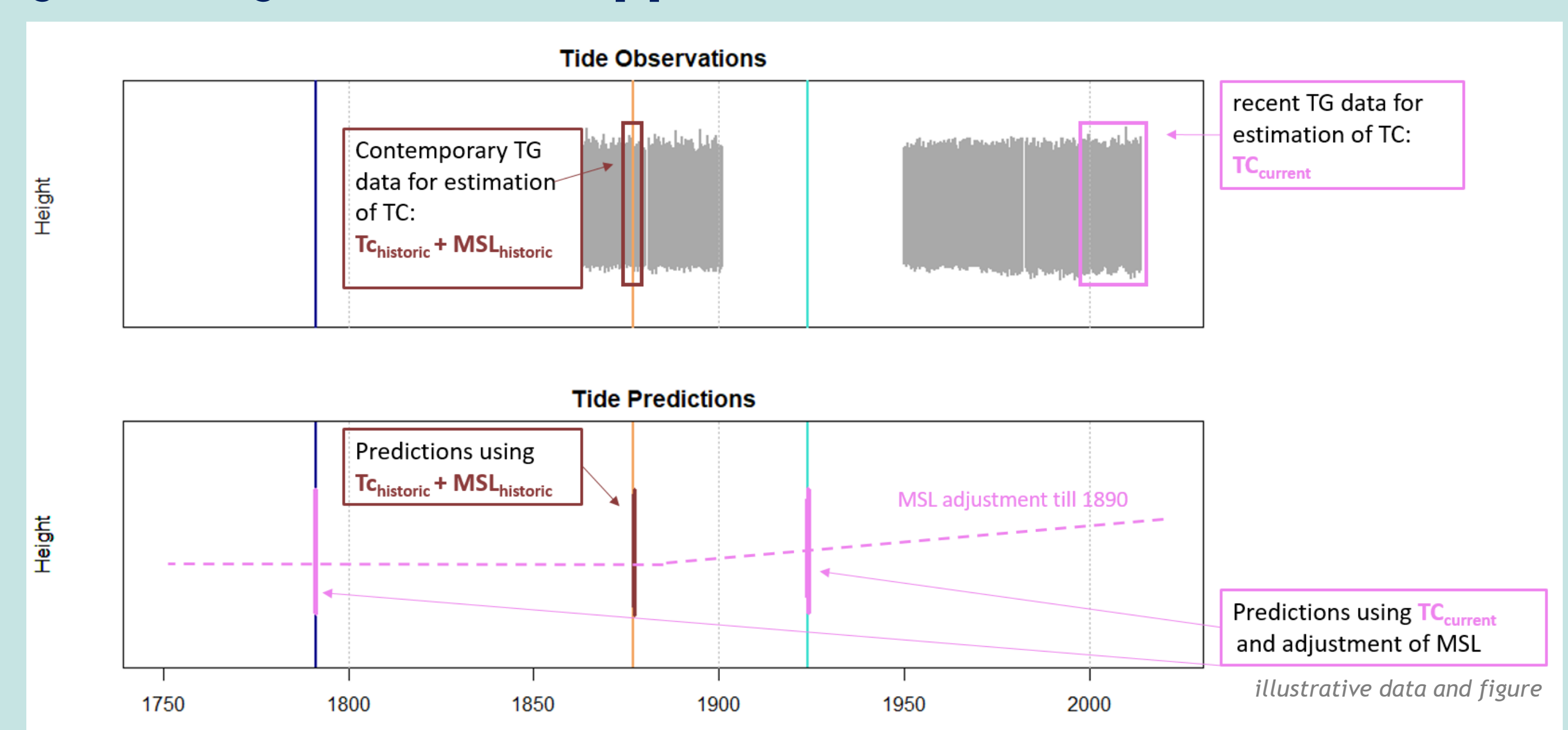
"sea grew big from 7th on [...] the storm wasn't exceptional"
"damages occurred around high tide, a bit before, between 3 and 5 o'clock."
"High tide according to tidal charts 5.80 m effective height reached on 9th : 7.20 m"
Reached water level: **+ 7.20 m CD**



3. Tidal Predictions

Depending on the existence of tide gauge measurements, different methods can be applied for the calculation of tidal predictions (TP) for historical events. By order of priority:

- Use available historical Tide Gauge Data for the estimation of Tidal Constituents ($TC_{historic}$)
- Use current Tidal Constituents ($TC_{current}$) and adjust the mean sea level (stable before 1890 and using a linear regression after 1890 [8])



4. Estimation of Surges

When maximum observed WL are reconstructed and TP are estimated, hourly and skew surges can be assessed. Water levels at the tide gauge station are considered to be comparable to the water levels at the different reconstruction point.

1791	1877	1924
Skew surges:	Skew Surge: 1.19 m	Skew Surges:
Berges Sluice 1.55 m S T City Side Quay 1.25 m Δ S T Cunette Quay 1.50 m S T	Max hourly surge: 1.19 m	Using TG data 1.15 m Using source data 1.40 m
→ Different reconstructed WL lead to different skew surges. No estimation of hourly surge possible.	→ Tide Gauge Data available for the event was used to estimate skew and maximum hourly surge.	→ Historical prediction differs significantly from prediction made with TC_{actual} and adjustment of MSL. No estimation of hourly surge possible.

The aim of this work is to show the diversity of WL that can be estimated using historical data and the different methods of estimation of tidal predictions, leading to varying skew surges. The first challenge consists in finding quality data relating about an event which also gives sufficient details about a water level reached or an exact location flooded. The next step is the reconstruction of historical WL in absence of measured data - this step comes often with strong hypotheses, that need to be traced for future users. The estimation of tide predictions is depending on the historical data available and may add uncertainties.

Still these reconstructed values, with all their uncertainties, are primordial when using them in an extreme value analysis. It has been shown that extreme return levels are more reliable when adding an high value even uncertain than ignoring it.

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