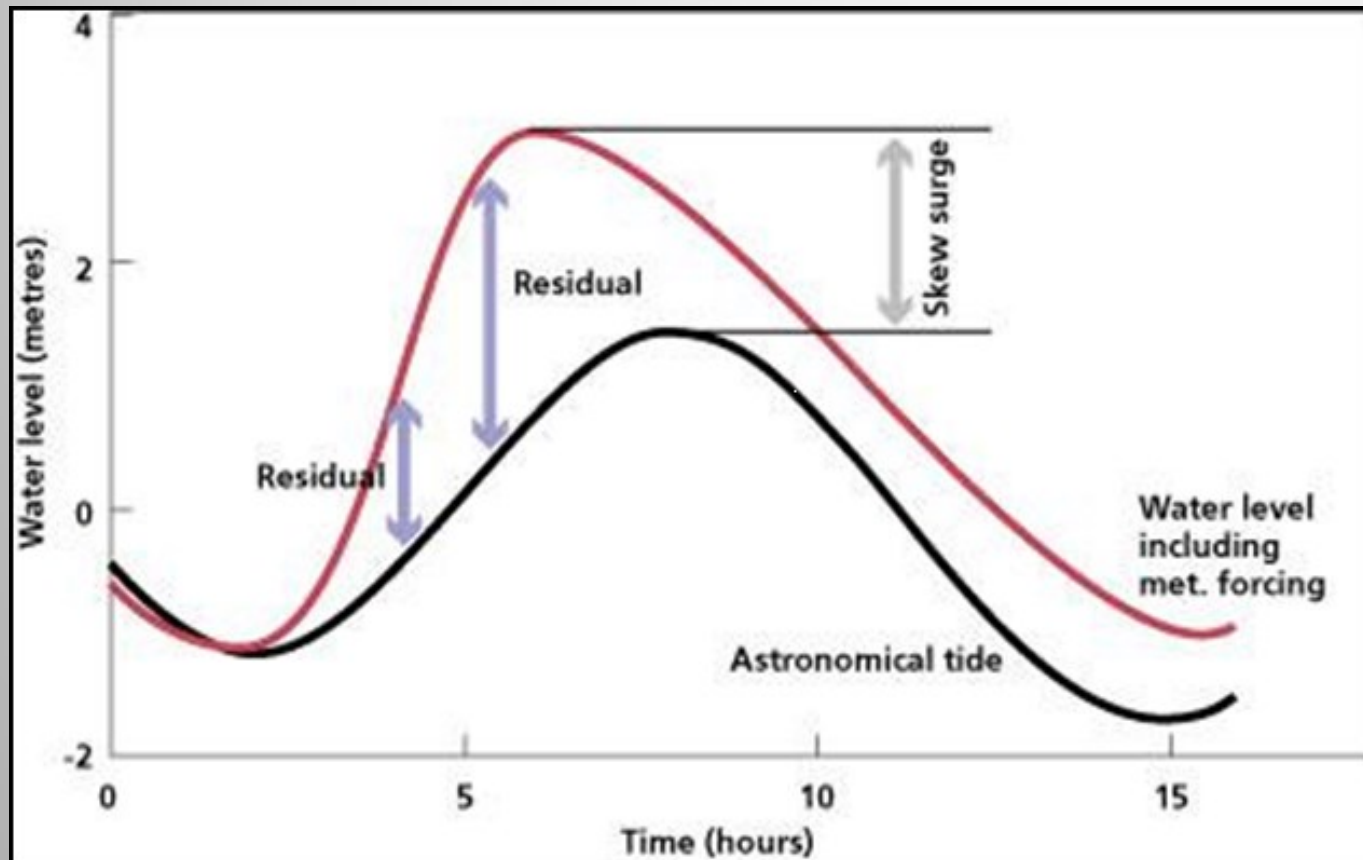


QUANTIFICATION OF HISTORICAL SKEW SURGES : CHALLENGES AND METHODS



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June, 16th 2021

- Over the past 20-25 years, several storms causing major impacts occurred on the french atlantic coast
- Necessity to implement an efficient historical reconstruction and analysis of past storms, coastal floodings and skew surges over a longer period to better assess the risk associated to these extreme events in France
- The use of historical sources and data to improve knowledge of past extremes is no longer to be demonstrated

(without completeness : Athimon, 2021 ; Pouzet et Maanan, 2020 ; Lageat et al., 2020 ; Sarrazin et Athimon, 2019 ; Frau et al., 2018; Frau, 2018; Giloy et al., 2018 ; Hamdi et al., 2018 ; Garnier et al., 2018 ; Chaumillon et al., 2017 ; Athimon et al., 2016 ; Haigh et al., 2016 ; Breilh et al., 2014 ; Péret and Sauzeau, 2014 ; Baart et al. 2011 ; Garnier and Surville, 2010 ; Testut et al., 2010 ; Soens, 2009 ; Pouvreau, 2008 ; De Kraker, 2006 ; Hickey, 1997 ; Camuffo, 1993 ; Lamb and Frydendahl, 1991 ; Gottschalk, 1971-1977)



Two variables commonly used to compare extreme floodings :

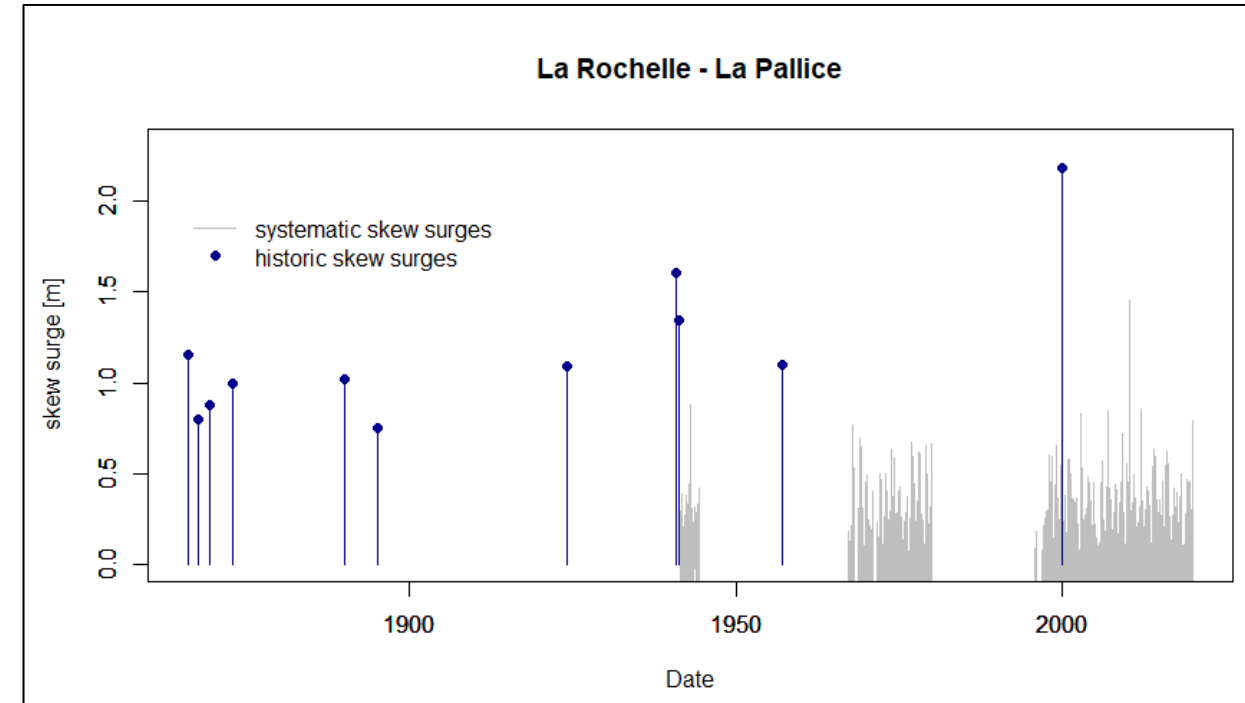
- Maximum water level reached
- Skew surge

Computation of skew surge thanks to :

- Systematic tide gauge records (short period covered by the data)
- Historical sources and data (long period covered by the data, but historical critical method required)

The historical sources and data used to quantify historical skew surges can be :

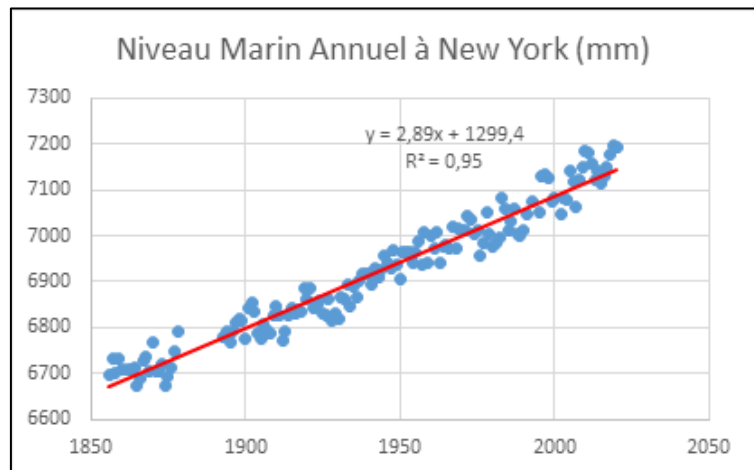
- quantitative (observations of water levels through tidal scale, non-digitized tide gauge records, etc.)
- qualitative / **description of water levels reached regarding to constructions** (newspapers, chronicles, city council registers, engineers' reports...) – Giloy et al., 2019



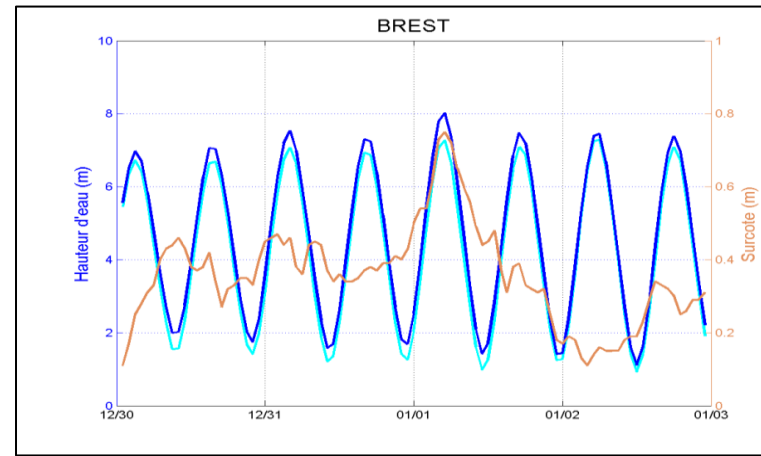
Nine variables leading to uncertainties on the quantification of historical skew surges have been identified :

- 1) Vertical land movements
- 2) Tidal predictions
 - Two methods:
 - a) contemporary tide gauge data **is** available (best method, but dependent on the data; the more we go back in time, the less we can implement it)
 - b) No contemporary tide gauge data **is** available (method more often used due to the availability of data)

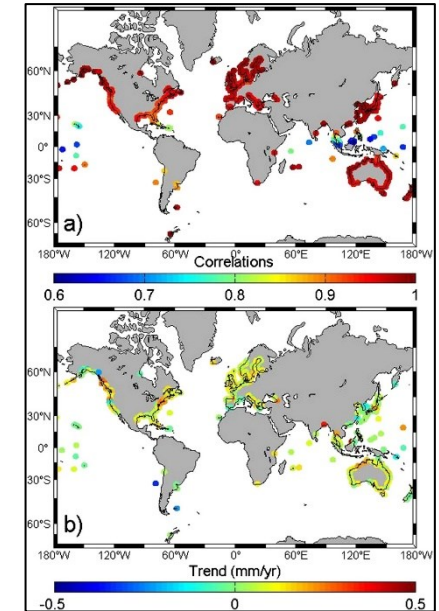
3) Changes in sea level



Reference : PSMSL



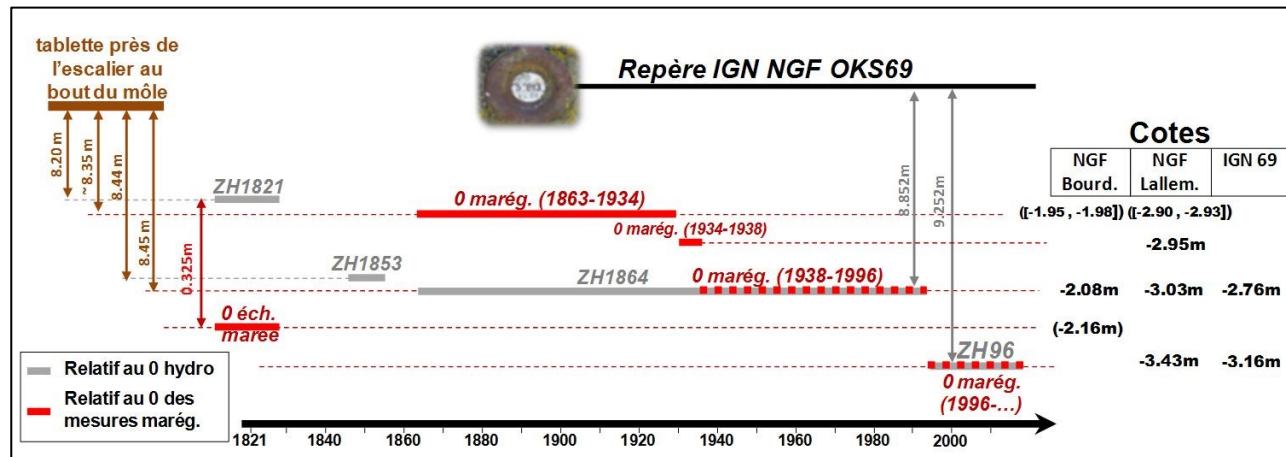
SimHydro



Woppelmann and Marcos, 2015

Nine variables leading to uncertainties on the quantification of historical skew surges have been identified :

- 1) Vertical land movements
- 2) Tidal predictions
- 3) Changes in sea level
- 4) Chart Datum References
- 5) Bathymetry changes
- 6) Local hydrodynamic phenomena



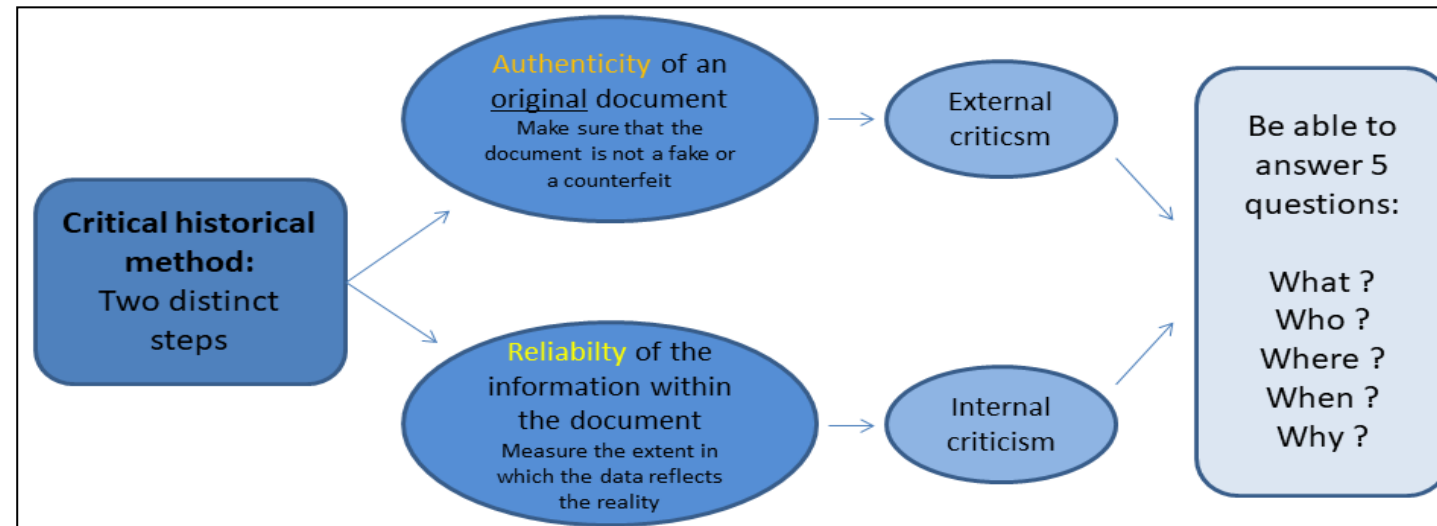
Position of the tide gauge vertical reference and the chart datum in Saint-Nazaire (1821 to nowadays) – Ferret, 2016, p. 57



Map of the Pertuis Breton and the Anse de l'Aiguillon, 1703-1704
 BnF, GE SH 18PF43 DV1 P8 BIS

Nine variables leading to uncertainties on the quantification of historical skew surges have been identified :

- 1) Vertical land movements
- 2) Tidal predictions
- 3) Changes in sea level
- 4) Chart Datum References
- 5) Bathymetry changes
- 6) Local hydrodynamic phenomena
- 7) The use of anachronistic documents
- 8) Data analysis control
- 9) Reliability of the data



Step 1: Historical critical analysis

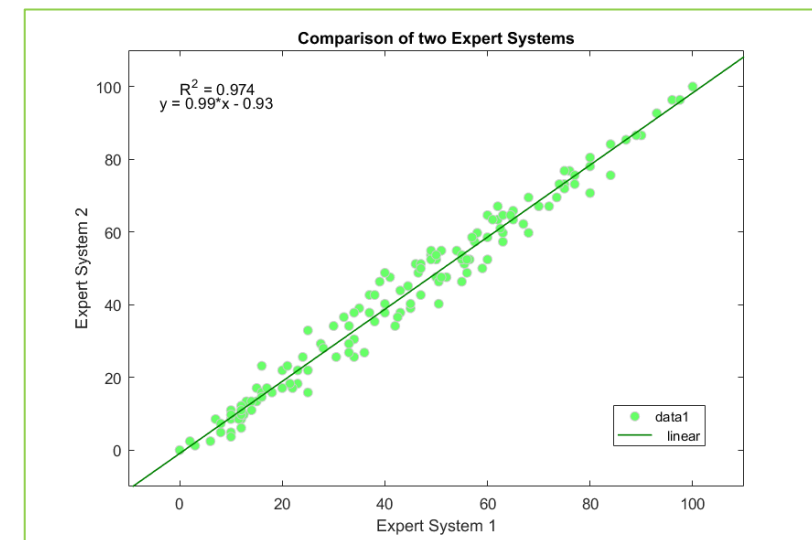
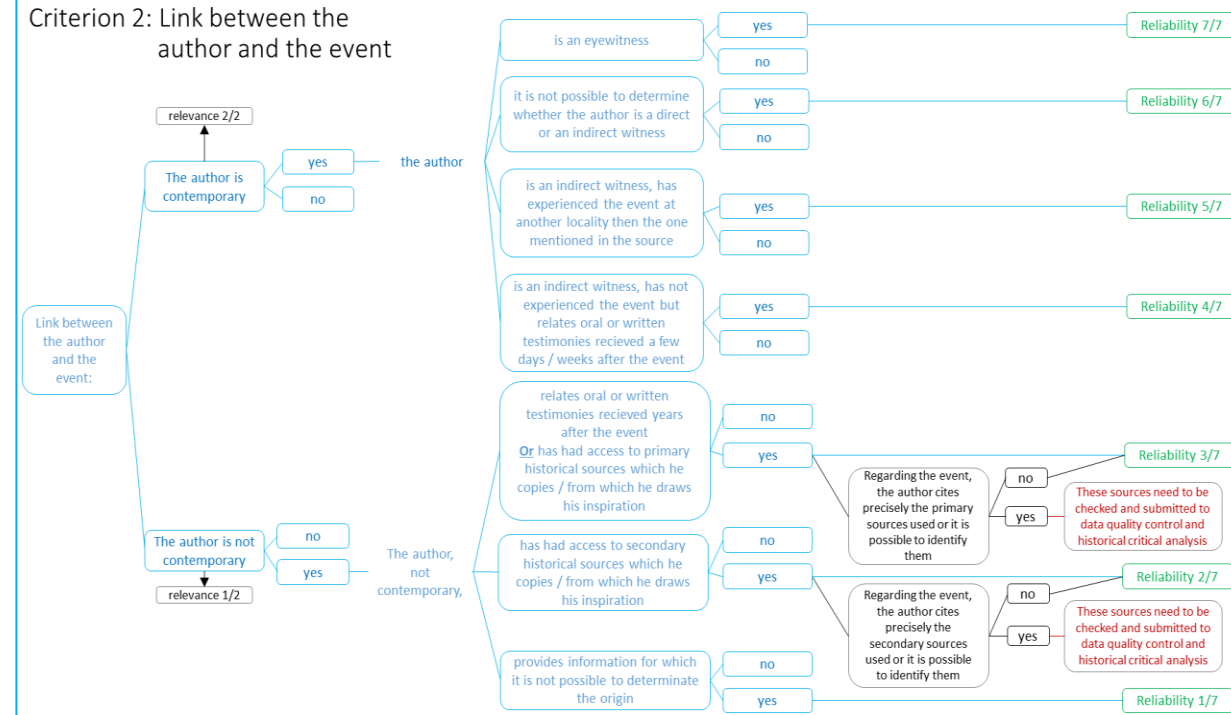
Step 2: Rating of four criteria

Step 3: Final Assessment

Step 1: A complete and precise critical analysis for each historical source studied must be written by a historian

Step 2: Based on the step 1, 4 standardized criteria are rated through a decision tree with closed questions (yes/no): 1) the type of the document, 2) the author's link to the testimony of an event, 3) the cross-checking, 4) the consistency of the source contents

Step 3: From the scores assigned to the 4 criteria (step 2), a final score is given to the source evaluated by an expert system (several hypotheses developed and 4 systems tested)



pendant les hivers 1940-41 et 1941-42; elles ont ravagé tout le littoral vendéen et n'ont pas épargné celui de la Loire -Inférieure. On a enregistré à Saint-Nazaire la cote (6,44) le 16 février 1941 et la cote (6,60) le 16 Novembre 1940 correspondant à de véritables raz de marée.

Extract from a dike repair report, written by the Nantes Ponts et Chaussées engineer Mr Desbazeille and dated 10.20.1943.

AD 44, 365 W 124

Translation : “[...] during the winter 1940-41 and 1941-42 ; they completely devastated the Vendée coast and did not spare the Loire-Atlantique coast. The sea levels rates (6.44) on February 16, 1941 and (6.60) on November 16, 1940 were recorded at Saint-Nazaire, corresponding to real tidal waves”.

Quand survinrent les tempêtes de l'hiver 1940-41 où les eaux sont montées jusqu'à + 6,60 le 16 Novembre 1940 et à + 6,44 le 15 Février 1941, ces digues mal protégées ont été attaquées par les flots ; les brèches n'ont pu être réparées en raison des circonstances. Des affaissements s'en suivirent. Il importe

Extract from a dike repair report, written by the Nantes Ponts et Chaussées engineer Mr Ballade and dated 06.20.1947.

AD 44, 365 W 124

Translation : “When the winter storms of 1940-41 occurred, waters rose to +6.60 on November 16, 1940 and to + 6.44 on February 15, 1941, these poorly protected dikes were attacked by waves ; the breaches could not be repaired due to the circumstances (N.B : Second World War period) [...]”.

The storms with coastal floodings of November 16th 1940 and February 15th-16th 1941

Historical primary source	Criterion 1: Type of the document	Criterion 2: Link between author and event	Criterion 3: Cross-checking	Criterion 4: Consistency	Final score in % (expert system 1)	Final score in % (expert system 2)
AD 44, 365 W 124, report of 10.20.1943	7/7	6/7	7/7	4/4	98	96
AD 44, 365 W 124, report of 06.20.1947	7/7	4/7	7/7	4/4	84	84

→ The uncertainties number 5 (bathymetry changes), 6 (local hydrodynamic phenomena), 7 (use of anachronistic documents), 8 (data analysis control) and 9 (reliability of the data) are handled

Date	OHD (m, historic chart datum 1938-1996)	MLTGh (m, historic chart datum 1938-1996)	MPh (m, historic chart datum 1938-1996)	S (m)
11.16.1940	6.60	6.61	5.19 (evening high tide)	1.41-1.42
02.16.1941	6.44	6.42	5.52 (morning high tide)	0.92-0.90

Date	OHD40 (m, current chart datum)	MLTG (m, current chart datum)	MP (m, current chart datum)	MPmsl (m, current chart datum)	S 1 (m)	S 2 (m)
11.16.1940	7.00	7.01	5.75 (evening high tide)	5.67 (evening high tide)	1.25-1.26	1.33-1.34
16.02.1941	6.84	6.82	6.01 (morning high tide)	5.93 (morning high tide)	0.83-0.81	0.91-0.89

OHD : Observed sea level from Historical Documents (AD 44, 365 W 124), in historic chart datum (1938-1996)

OHD40 : Observed sea level from Historical Documents (AD 44, 365 W 124) + 40 cm to correct change in chart datum (1996-...)

MLTGh: Maximum sea Level measured by the Tide gauge in Historic chart datum (1938-1996)

MLTG: Maximum sea Level measured by the Tide Gauge corrected to current chart datum (1996-...)

MPh: Maximum Predicted tide (harmonic analysis on contemporary tide gauge observations to estimate harmonic components), in Historic chart datum (1938-1996)

MP: Maximum Predicted tide without correction of mean sea level (use of current tidal components and current mean sea level), in current chart datum (1996-...)

MPmsl: Maximum Predicted tide with correction of Mean Sea Level (use of current tidal components, correction of mean sea level applying a linear trend of 1.02 mm.y^{-1}), in current chart datum (1996-...)

S: Resulting skew surge of OHD/MLTGh - MPh

S1: Resulting skew surge of OHD40/MLTG - MP

S2: Resulting skew surge of OHD40/MLTG - MPmsl

- Variables 2 (tidal prediction), 3 (changes in sea level) et 4 (changes in chart datum) taken into account
- Uncertainties related to vertical land movements remain
- **!/** Failure to consider the variable 4 (change in chart datum) leads to significant errors :
Skew surge of 0,93-0,94 m in 1940
Skew surge of 0,51-0,49 m in 1941

This interdisciplinary study shows that:

- by paying attention to some potential causes of uncertainties (changes in sea level, criticism and evaluation of historical documents quality, operative chart datum reference, etc.),
- by ensuring the reliability of historical sources and data through the use of the historical documents' quality method,
- by deepening historical researches in archives and
- by a mix of different scientific fields and methods

it is possible to reduce uncertainties and errors in the quantification of historical skew surges.

Some of these uncertainties were not able to be quantified and taken into account on the computation of historical skew surges (Vertical land movements, bathymetry changes, local hydrodynamic phenomena)

To note: these uncertainties will be considered in the statistics of the extremes. In that case, an idea of the possible accuracy made in the computation of historical skew surges must be known

A challenging perspective could be the modeling or the numerical simulation of past storms

Thanks for your attention

Any questions?

