Caractérisation des événements passés de submersion pour l'estimation des aléas présents et futurs : utilisation conjointe des approches historiques, statistiques et de modélisation

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- PROJET FINANCÉ PAR L'ANR - PROJECT FUNDED BY THE ANR

GT Tempêtes & Submersions Historiques
17/12/2020
Webinar

* GÉOS AEL

Fond : Photo IGN, 2013

THE STUDY SITE

0,25 km

1,7 km

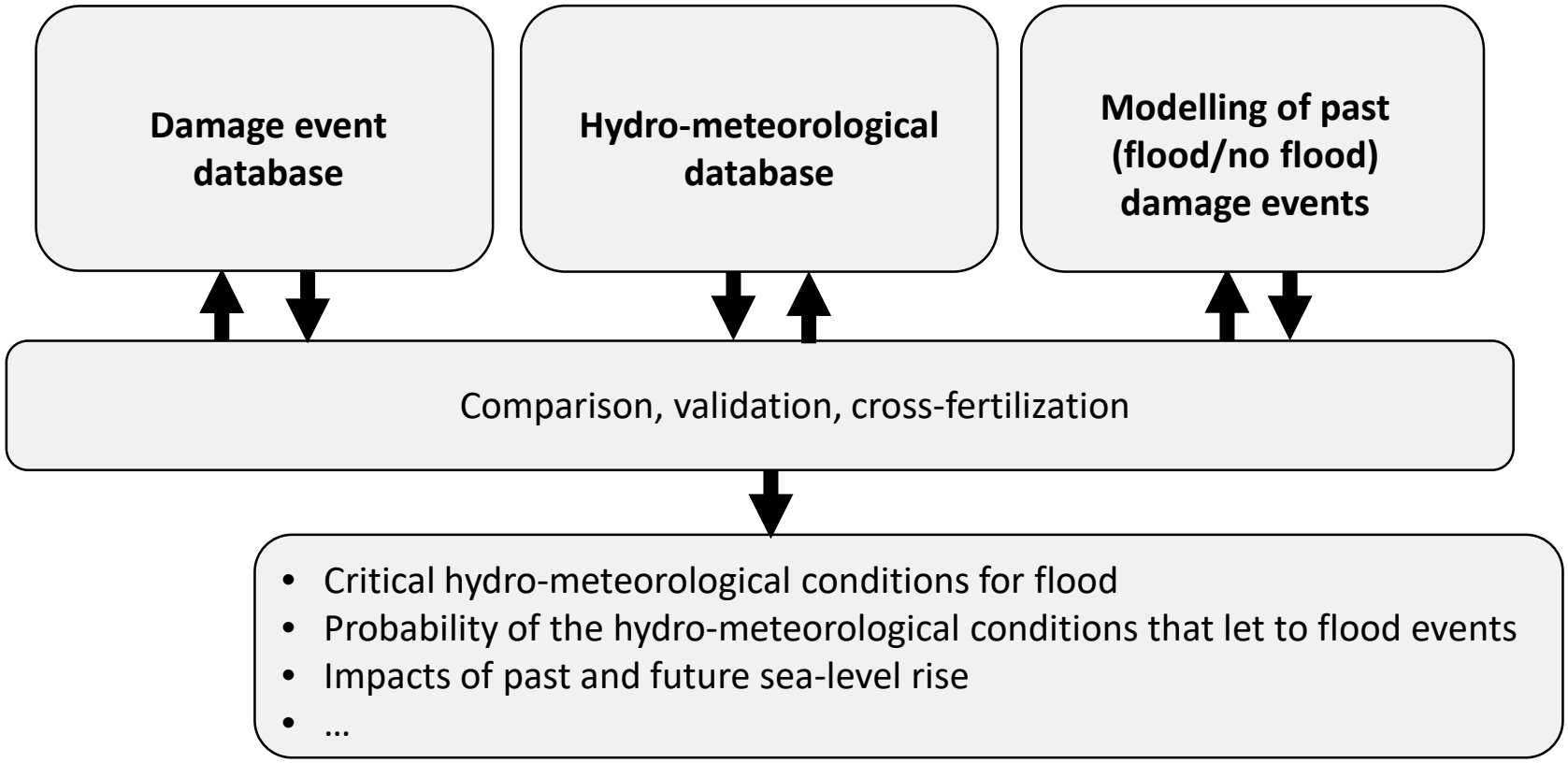
Gâvres

- Macro-tidal
- Most recent massive flooding: **Johanna** storm, 10th March 2008, ~120 flooded houses
- Main flood regime: **wave overtopping**

Fond : Photo IGN, 2013

THIS STUDY

- Objective: understand drivers of past (and future) flood events in Gâvres
- Period of interest: **1900-2010**
- Approach: building and cross-fertilization of 3 databases

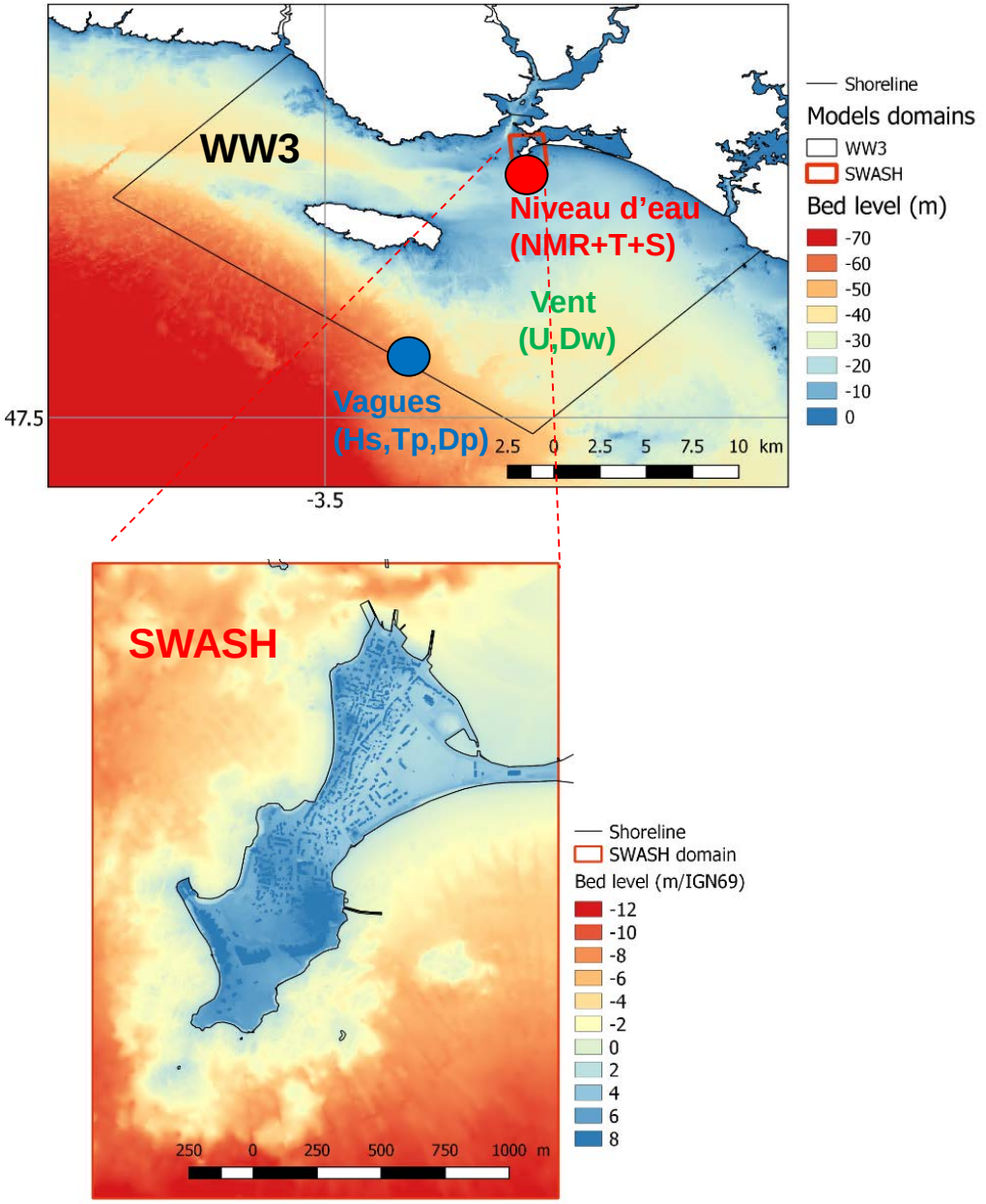


THE FLOOD MODEL

Input: water levels, waves, wind.

Modeling workflow:

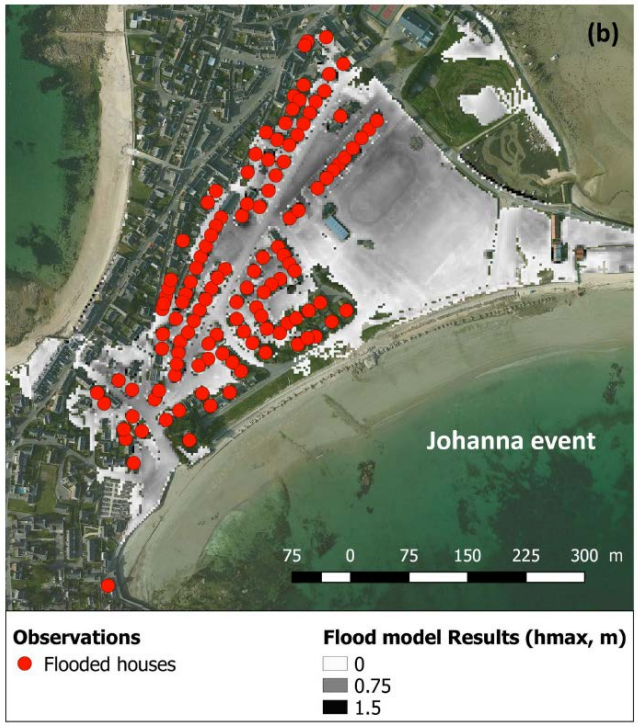
- WW3 propagates the offshore wave conditions, taking into account the wind and still water level (NMR+T+S).
- Wave parameters (Hs,Tp,Dp) extracted along the SWASH computational domain.
- SWASH run with the non-uniform wave boundary conditions, the still water level and wind.
  - dx=3m & f~10Hz
  - Default: topography representative of the 2008 coastal defenses.



THE FLOOD MODEL

Validation on the 2008 johanna event

Simulation over 6h (HT +/- 3h)



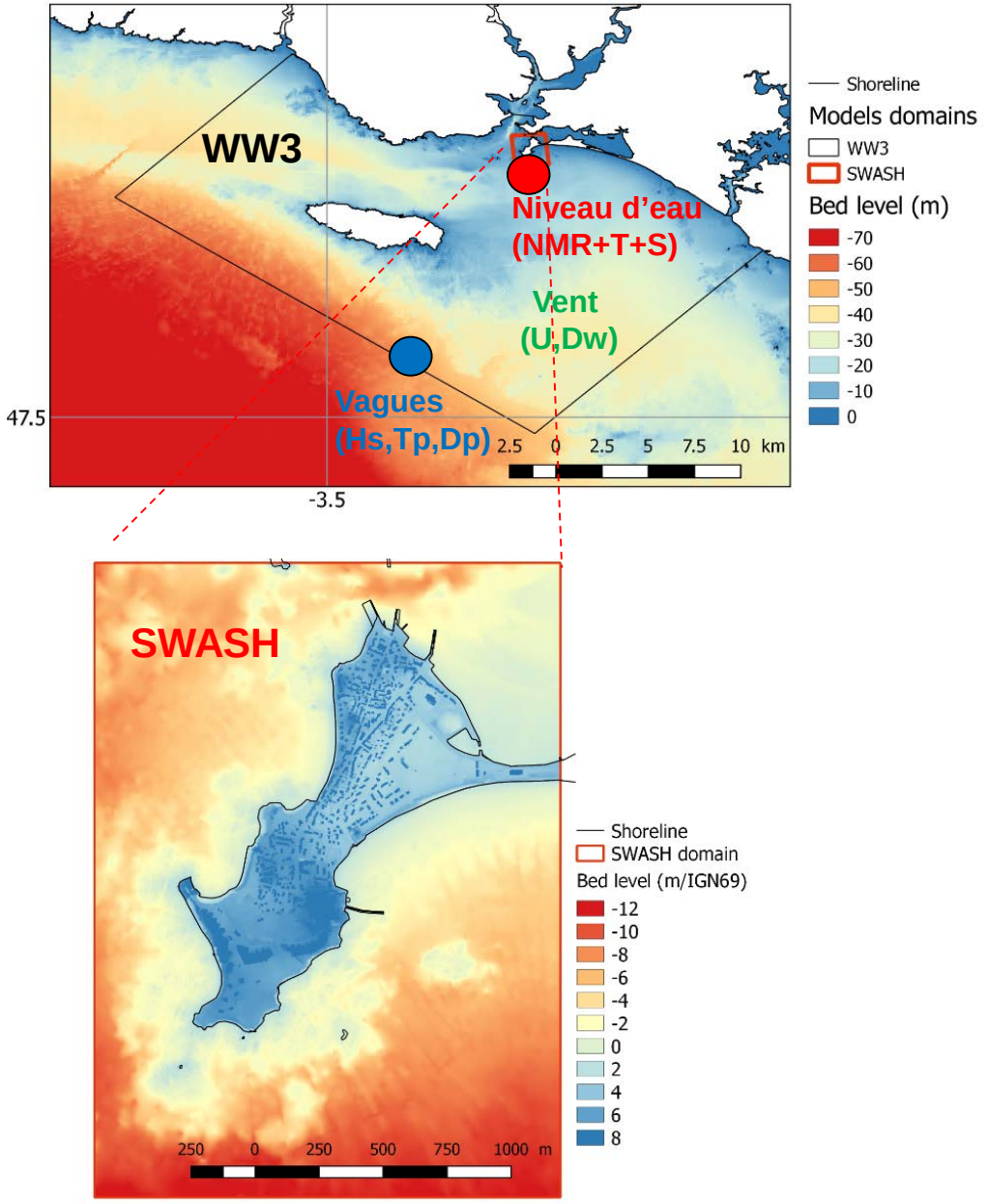
THE FLOOD MODEL

Input: water levels, waves, wind.

Modeling workflow: WW3-SWASH.

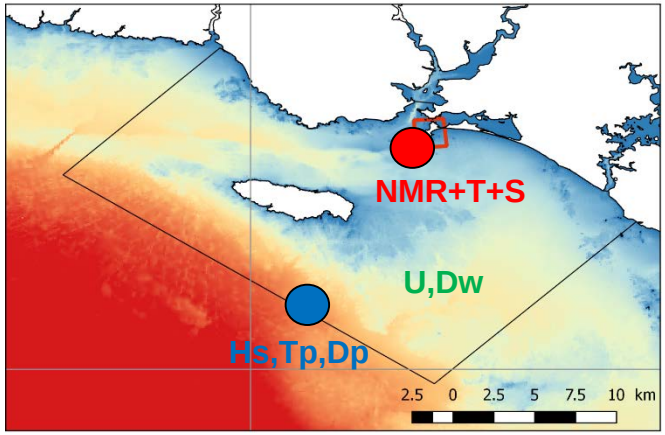
→ For the modeling database:

- A flood indicator (***Vol):*** water volume entering inland at high tide (over 10 min).
- ***Vol*** computed for each event of the damage event database.



THE HYDRO-METEOROLOGICAL DATABASE

Objectif : continuous time series from 1900-2010



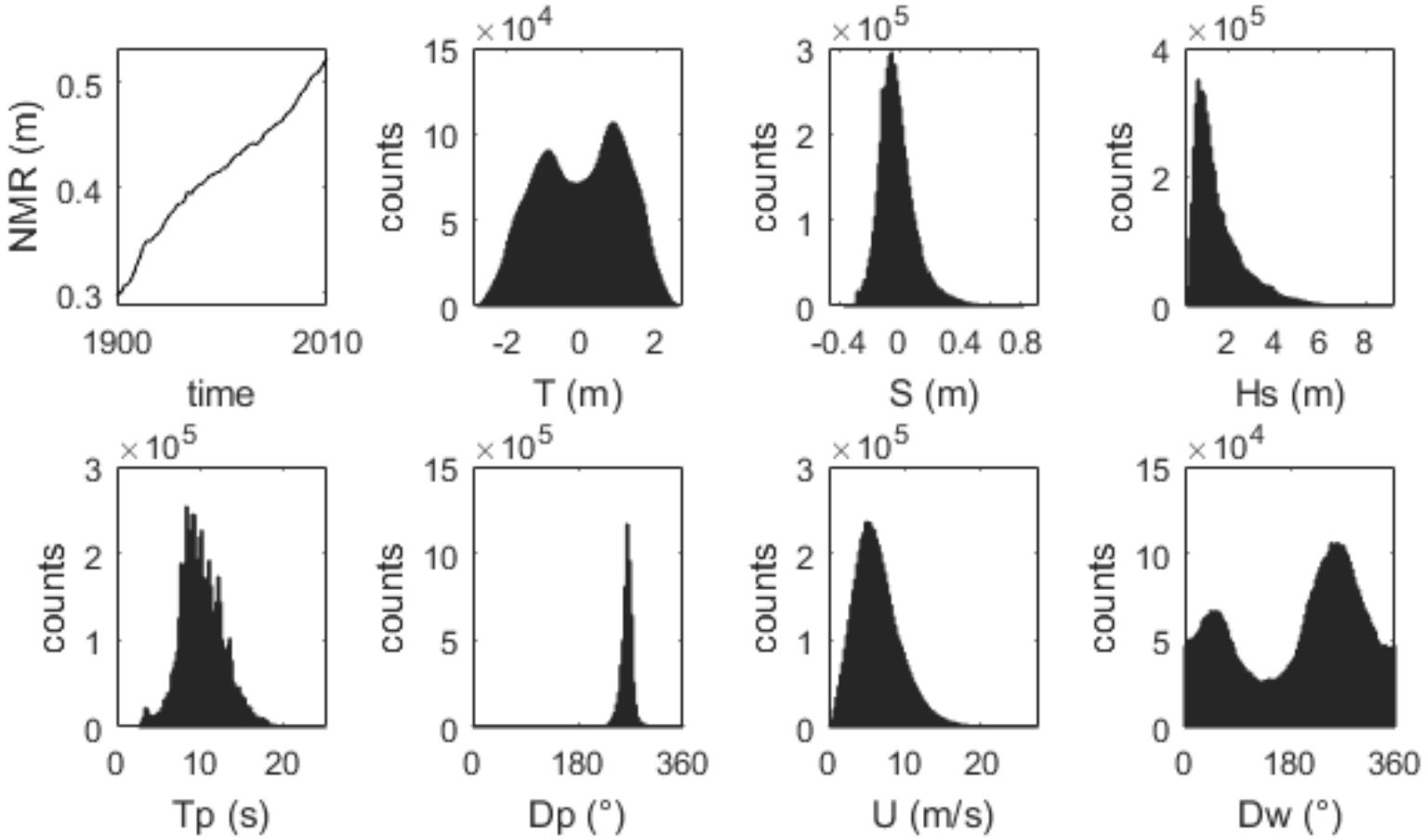
Data sources

Parameter	Source: Name	Source: Provider	Source: Reference
Absolute mean sea level (NMR)	-	BRGM	Rohmer & Le Cozannet (2018)
Vertical ground motion	SONEL	LIENS	Santamaria-Gomez et al. (2017)
Tide (T)	FES2014	LEGOS	Carrere et al. (2016)
Atmospheric storm surge (S)	20CR*	NOAA	Compo et al. (2015)
	CFSR*	NOAA	Dee et al. (2014)
	MARC	Ifremer-LOPS	Muller et al. (2014)
Waves (Hs,Tp,Dp)	Sonel (waves)	Liens	Bertin et al. (2013)
	BoBWA	BRGM	Charles et al. (2012)
	Homere	Ifremer-LOPS	Boudière et al. (2013)
	Iowaga/Norgasug	Ifremer-LOPS	Boudière et al. (2013)
Wind (U,Dw)	20CR	NOAA	Compo et al. (2015)
	CFSR	NOAA	Dee et al. (2014)

+ Quantile-quantile correction using the best hindcasts as reference

THE HYDRO-METEOROLOGICAL DATABASE

Objectif : continuous time series
from 1900-2010



THE DAMAGE EVENT DATABASE

- Based on:
  - *Archives municipales de Gâvres, Archives départementales du Morbihan, Service Historique de la Marine, …* through (Le Cornec et al., 2012).
  - *Presse contemporaine aux évènements*
- 48 damage events
- Flood event classification (F) : 0 (no flood), 1 (moderate flood), 2 (massive flood).

Nd	Date(begin)	Date(end)	F1
2	01/02/1904	02/02/1904	1
5	11/04/1922	11/04/1922	0
46	10/03/2008	10/03/2008	2

Nd	Date(begin)	Date(end)	F1
1	13/02/1900	15/02/1900	0
2	01/02/1904	02/02/1904	1
3	07/12/1911	09/12/1911	0
4	27/01/1922	29/01/1922	0
5	11/04/1922	11/04/1922	0
6	12/10/1922	20/10/1922	0
7	09/01/1924	09/01/1924	2
8	26/11/1924	27/11/1924	0
9	28/12/1924	29/12/1924	0
10	08/11/1927	09/11/1927	0
11	22/03/1928	23/03/1928	0
12	27/01/1936	27/01/1936	0
13	14/03/1937	14/03/1937	0
14	23/12/1945	23/12/1945	0
15	24/03/1947	24/03/1947	0
16	01/01/1948	28/02/1948	0
17	05/02/1950	06/02/1950	0
18	08/12/1954	09/12/1954	0
19	14/02/1957	15/02/1957	0
20	01/12/1959	01/12/1959	0
21	02/11/1963	03/11/1963	0
22	21/02/1966	22/02/1966	0
23	01/11/1967	04/11/1967	0
24	01/11/1972	31/12/1972	0
25	16/01/1974	11/02/1974	0
26	28/01/1975	29/01/1975	0
27	01/11/1975	30/11/1975	0
28	25/10/1976	25/10/1976	0
29	26/02/1978	26/02/1978	2
30	01/12/1978	31/12/1978	0
31	20/01/1980	20/01/1980	0
32	13/12/1981	13/12/1981	0
33	24/12/1981	24/12/1981	0
34	21/12/1983	21/12/1983	0
35	22/11/1984	23/11/1984	0
36	07/04/1985	08/04/1985	0
37	26/09/1999	26/09/1999	0
38	24/10/1999	24/10/1999	0
39	24/12/1999	29/12/1999	0
40	29/09/2000	29/09/2000	0
41	30/10/2000	30/10/2000	0
42	10/01/2001	10/01/2001	2
43	07/02/2001	07/02/2001	1
44	27/10/2004	27/10/2004	1
45	02/12/2005	02/12/2005	0
46	10/03/2008	10/03/2008	2
47	10/02/2009	10/02/2009	1
48	28/02/2010	28/02/2010	1

THE DAMAGE EVENT DATABASE

- Based on:
  - *Archives municipales de Gâvres, Archives départementales du Morbihan, Service Historique de la Marine, …* through (Le Cornec et al., 2012).
  - *Presse contemporaine aux évènements*
- 48 damage events
- Flood event classification (F) : 0 (no flood), 1 (moderate flood), 2 (massive flood).
- Confidence indicator (C) : 1 (moderate), 2 (high)

Nd	Date(begin)	Date(end)	F1	C1
2	01/02/1904	02/02/1904	1	1
5	11/04/1922	11/04/1922	0	1
46	10/03/2008	10/03/2008	2	2

→ 9 flood events

Nd	Date(begin)	Date(end)	F1	C1
1	13/02/1900	15/02/1900	0	1
2	01/02/1904	02/02/1904	1	1
3	07/12/1911	09/12/1911	0	1
4	27/01/1922	29/01/1922	0	1
5	11/04/1922	11/04/1922	0	1
6	12/10/1922	20/10/1922	0	1
7	09/01/1924	09/01/1924	2	2
8	26/11/1924	27/11/1924	0	1
9	28/12/1924	29/12/1924	0	1
10	08/11/1927	09/11/1927	0	1
11	22/03/1928	23/03/1928	0	1
12	27/01/1936	27/01/1936	0	1
13	14/03/1937	14/03/1937	0	1
14	23/12/1945	23/12/1945	0	1
15	24/03/1947	24/03/1947	0	1
16	01/01/1948	28/02/1948	0	1
17	05/02/1950	06/02/1950	0	1
18	08/12/1954	09/12/1954	0	1
19	14/02/1957	15/02/1957	0	1
20	01/12/1959	01/12/1959	0	1
21	02/11/1963	03/11/1963	0	1
22	21/02/1966	22/02/1966	0	1
23	01/11/1967	04/11/1967	0	1
24	01/11/1972	31/12/1972	0	1
25	16/01/1974	11/02/1974	0	1
26	28/01/1975	29/01/1975	0	1
27	01/11/1975	30/11/1975	0	1
28	25/10/1976	25/10/1976	0	1
29	26/02/1978	26/02/1978	2	2
30	01/12/1978	31/12/1978	0	1
31	20/01/1980	20/01/1980	0	1
32	13/12/1981	13/12/1981	0	1
33	24/12/1981	24/12/1981	0	1
34	21/12/1983	21/12/1983	0	1
35	22/11/1984	23/11/1984	0	1
36	07/04/1985	08/04/1985	0	1
37	26/09/1999	26/09/1999	0	1
38	24/10/1999	24/10/1999	0	1
39	24/12/1999	29/12/1999	0	1
40	29/09/2000	29/09/2000	0	1
41	30/10/2000	30/10/2000	0	1
42	10/01/2001	10/01/2001	2	2
43	07/02/2001	07/02/2001	1	2
44	27/10/2004	27/10/2004	1	2
45	02/12/2005	02/12/2005	0	1
46	10/03/2008	10/03/2008	2	2
47	10/02/2009	10/02/2009	1	2
48	28/02/2010	28/02/2010	1	2

THE DAMAGE EVENT DATABASE

« update » using the ***Vol*** indicator (model)

Only for events of moderate confidence (C1=1)

Nd	Date(begin)	Date(end)	F1	C1	F2	C2
5	11/04/1922	11/04/1922	0	1	0	2

***Vol*=0**

Nd	Date(begin)	Date(end)	F1	C1	F2	C2
1	13/02/1900	15/02/1900	0	1	0	2
2	01/02/1904	02/02/1904	1	1	2	1
3	07/12/1911	09/12/1911	0	1	0	2
4	27/01/1922	29/01/1922	0	1	0	2
5	11/04/1922	11/04/1922	0	1	0	2
6	12/10/1922	20/10/1922	0	1	0	2
7	09/01/1924	09/01/1924	2	2	2	2
8	26/11/1924	27/11/1924	0	1	0	2
9	28/12/1924	29/12/1924	0	1	0	1
10	08/11/1927	09/11/1927	0	1	0	2
11	22/03/1928	23/03/1928	0	1	0	1
12	27/01/1936	27/01/1936	0	1	0	2
13	14/03/1937	14/03/1937	0	1	0	1
14	23/12/1945	23/12/1945	0	1	0	1
15	24/03/1947	24/03/1947	0	1	0	1
16	01/01/1948	28/02/1948	0	1	0	1
17	05/02/1950	06/02/1950	0	1	0	1
18	08/12/1954	09/12/1954	0	1	0	1
19	14/02/1957	15/02/1957	0	1	0	1
20	01/12/1959	01/12/1959	0	1	0	1
21	02/11/1963	03/11/1963	0	1	0	2
22	21/02/1966	22/02/1966	0	1	0	1
23	01/11/1967	04/11/1967	0	1	0	1
24	01/11/1972	31/12/1972	0	1	0	2
25	16/01/1974	11/02/1974	0	1	0	1
26	28/01/1975	29/01/1975	0	1	0	2
27	01/11/1975	30/11/1975	0	1	0	2
28	25/10/1976	25/10/1976	0	1	0	1
29	26/02/1978	26/02/1978	2	2	2	2
30	01/12/1978	31/12/1978	0	1	0	1
31	20/01/1980	20/01/1980	0	1	0	2
32	13/12/1981	13/12/1981	0	1	0	2
33	24/12/1981	24/12/1981	0	1	0	2
34	21/12/1983	21/12/1983	0	1	0	1
35	22/11/1984	23/11/1984	0	1	0	1
36	07/04/1985	08/04/1985	0	1	0	1
37	26/09/1999	26/09/1999	0	1	0	2
38	24/10/1999	24/10/1999	0	1	0	1
39	24/12/1999	29/12/1999	0	1	0	1
40	29/09/2000	29/09/2000	0	1	0	2
41	30/10/2000	30/10/2000	0	1	0	1
42	10/01/2001	10/01/2001	2	2	2	2
43	07/02/2001	07/02/2001	1	2	1	2
44	27/10/2004	27/10/2004	1	2	1	2
45	02/12/2005	02/12/2005	0	1	0	1
46	10/03/2008	10/03/2008	2	2	2	2
47	10/02/2009	10/02/2009	1	2	1	2
48	28/02/2010	28/02/2010	1	2	1	2

THE DAMAGE EVENT DATABASE

« update » using the ***Vol*** indicator (model)

Only for events of moderate confidence (C1=1)

***Vol*=max(*Vol*)**

Nd	Date(begin)	Date(end)	F1	C1	F2	C2
2	01/02/1904	02/02/1904	1	1	2	1


Vingt et Unième Année — N° 7285 SIX PAGES — Paris et Départements — CINQ CENTIMES Vendredi 5 Février 1904

Le Matin

DERNIERS TÉLÉGRAMMES DE LA NUIT

SEUL JOURNAL FRANÇAIS RECEVANT PAR FILS SPÉCIAUX LES DERNIÈRES NOUVELLES DU MONDE ENTIER

Mais sur toute la côte, à Belle-Ile et Groix, surtout à Quiberon, Saint-Pierre-Quiberon, Etel, Gavres, Locmarlo, Port-Louis, Larmor, tous ces petits ports où la mer bat au pied des maisons, furent balayés en partie par les lames qui arrachaient les maisons.

Nd	Date(begin)	Date(end)	F1	C1	F2	C2
1	13/02/1900	15/02/1900	0	1	0	2
2	01/02/1904	02/02/1904	1	1	2	1
3	07/12/1911	09/12/1911	0	1	0	2
4	27/01/1922	29/01/1922	0	1	0	2
5	11/04/1922	11/04/1922	0	1	0	2
6	12/10/1922	20/10/1922	0	1	0	2
7	09/01/1924	09/01/1924	2	2	2	2
8	26/11/1924	27/11/1924	0	1	0	2
9	28/12/1924	29/12/1924	0	1	0	1
10	08/11/1927	09/11/1927	0	1	0	2
11	22/03/1928	23/03/1928	0	1	0	1
12	27/01/1936	27/01/1936	0	1	0	2
13	14/03/1937	14/03/1937	0	1	0	1
14	23/12/1945	23/12/1945	0	1	0	1
15	24/03/1947	24/03/1947	0	1	0	1
16	01/01/1948	28/02/1948	0	1	0	1
17	05/02/1950	06/02/1950	0	1	0	1
18	08/12/1954	09/12/1954	0	1	0	1
19	14/02/1957	15/02/1957	0	1	0	1
20	01/12/1959	01/12/1959	0	1	0	1
21	02/11/1963	03/11/1963	0	1	0	2
22	21/02/1966	22/02/1966	0	1	0	1
23	01/11/1967	04/11/1967	0	1	0	1
24	01/11/1972	31/12/1972	0	1	0	2
25	16/01/1974	11/02/1974	0	1	0	1
26	28/01/1975	29/01/1975	0	1	0	2
27	01/11/1975	30/11/1975	0	1	0	2
28	25/10/1976	25/10/1976	0	1	0	1
29	26/02/1978	26/02/1978	2	2	2	2
30	01/12/1978	31/12/1978	0	1	0	1
31	20/01/1980	20/01/1980	0	1	0	2
32	13/12/1981	13/12/1981	0	1	0	2
33	24/12/1981	24/12/1981	0	1	0	2
34	21/12/1983	21/12/1983	0	1	0	1
35	22/11/1984	23/11/1984	0	1	0	1
36	07/04/1985	08/04/1985	0	1	0	1
37	26/09/1999	26/09/1999	0	1	0	2
38	24/10/1999	24/10/1999	0	1	0	1
39	24/12/1999	29/12/1999	0	1	0	1
40	29/09/2000	29/09/2000	0	1	0	2
41	30/10/2000	30/10/2000	0	1	0	1
42	10/01/2001	10/01/2001	2	2	2	2
43	07/02/2001	07/02/2001	1	2	1	2
44	27/10/2004	27/10/2004	1	2	1	2
45	02/12/2005	02/12/2005	0	1	0	1
46	10/03/2008	10/03/2008	2	2	2	2
47	10/02/2009	10/02/2009	1	2	1	2
48	28/02/2010	28/02/2010	1	2	1	2

THE DAMAGE EVENT DATABASE

« update » using the ***Vol*** indicator (model)

Only for events of moderate confidence (C1=1)

→9 flood events :

- 4 : moderate overtopping or moderate flood (2001, 2004, 2009, 2010)
- 5 : significant flood (1904, 1924, 1978, 2001, 2008), with 4 with high confidence

→ the 9 flood events: **a low bound of what really happened between 1900 and 2010.**

Nd	Date(begin)	Date(end)	F1	C1	F2	C2
1	13/02/1900	15/02/1900	0	1	0	2
2	01/02/1904	02/02/1904	1	1	2	1
3	07/12/1911	09/12/1911	0	1	0	2
4	27/01/1922	29/01/1922	0	1	0	2
5	11/04/1922	11/04/1922	0	1	0	2
6	12/10/1922	20/10/1922	0	1	0	2
7	09/01/1924	09/01/1924	2	2	2	2
8	26/11/1924	27/11/1924	0	1	0	2
9	28/12/1924	29/12/1924	0	1	0	1
10	08/11/1927	09/11/1927	0	1	0	2
11	22/03/1928	23/03/1928	0	1	0	1
12	27/01/1936	27/01/1936	0	1	0	2
13	14/03/1937	14/03/1937	0	1	0	1
14	23/12/1945	23/12/1945	0	1	0	1
15	24/03/1947	24/03/1947	0	1	0	1
16	01/01/1948	28/02/1948	0	1	0	1
17	05/02/1950	06/02/1950	0	1	0	1
18	08/12/1954	09/12/1954	0	1	0	1
19	14/02/1957	15/02/1957	0	1	0	1
20	01/12/1959	01/12/1959	0	1	0	1
21	02/11/1963	03/11/1963	0	1	0	2
22	21/02/1966	22/02/1966	0	1	0	1
23	01/11/1967	04/11/1967	0	1	0	1
24	01/11/1972	31/12/1972	0	1	0	2
25	16/01/1974	11/02/1974	0	1	0	1
26	28/01/1975	29/01/1975	0	1	0	2
27	01/11/1975	30/11/1975	0	1	0	2
28	25/10/1976	25/10/1976	0	1	0	1
29	26/02/1978	26/02/1978	2	2	2	2
30	01/12/1978	31/12/1978	0	1	0	1
31	20/01/1980	20/01/1980	0	1	0	2
32	13/12/1981	13/12/1981	0	1	0	2
33	24/12/1981	24/12/1981	0	1	0	2
34	21/12/1983	21/12/1983	0	1	0	1
35	22/11/1984	23/11/1984	0	1	0	1
36	07/04/1985	08/04/1985	0	1	0	1
37	26/09/1999	26/09/1999	0	1	0	2
38	24/10/1999	24/10/1999	0	1	0	1
39	24/12/1999	29/12/1999	0	1	0	1
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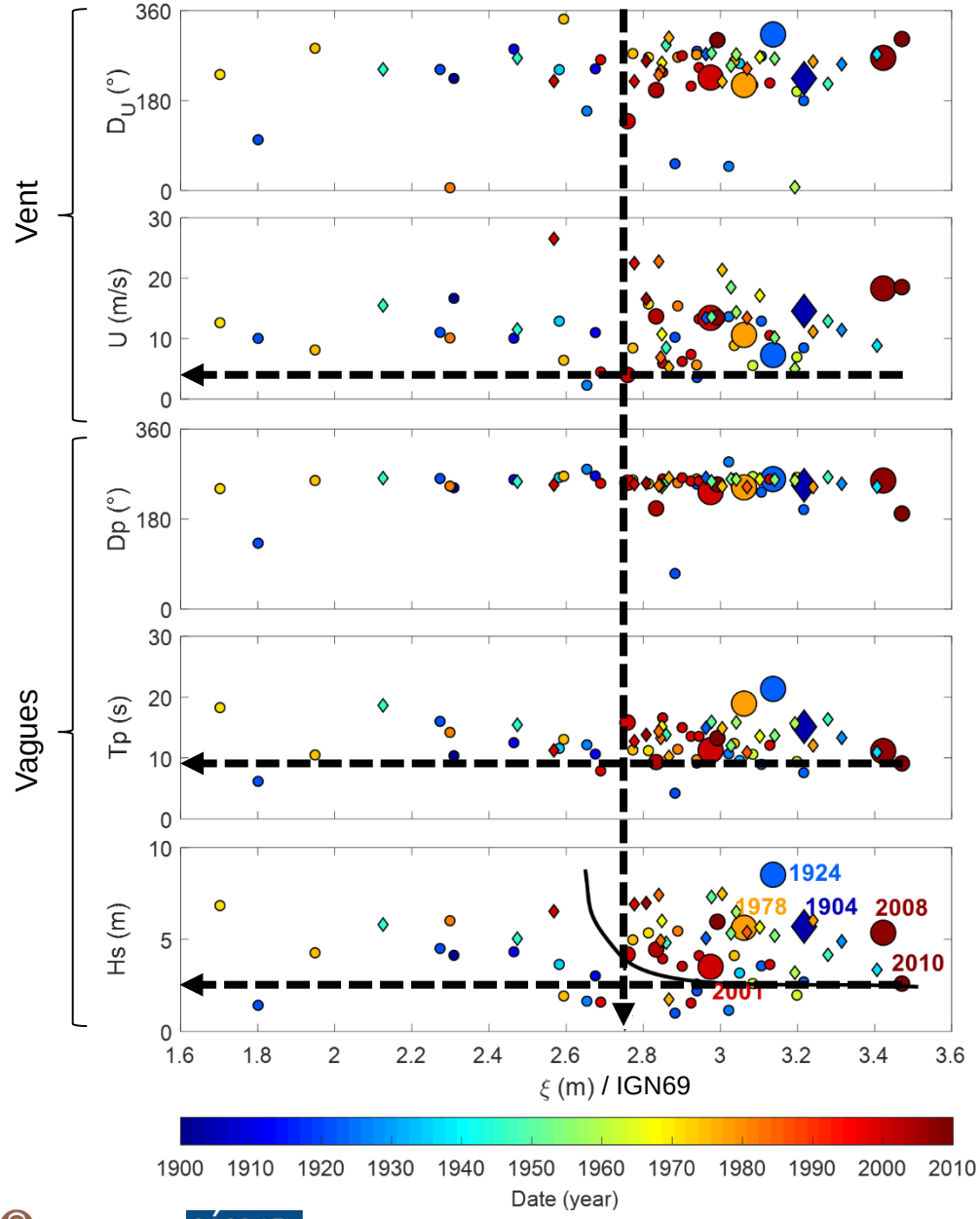
41	30/10/2000	30/10/2000	0	1	0	1
42	10/01/2001	10/01/2001	2	2	2	2
43	07/02/2001	07/02/2001	1	2	1	2
44	27/10/2004	27/10/2004	1	2	1	2
45	02/12/2005	02/12/2005	0	1	0	1
46	10/03/2008	10/03/2008	2	2	2	2
47	10/02/2009	10/02/2009	1	2	1	2
48	28/02/2010	28/02/2010	1	2	1	2

KEY RESULTS: Critical conditions for flooding



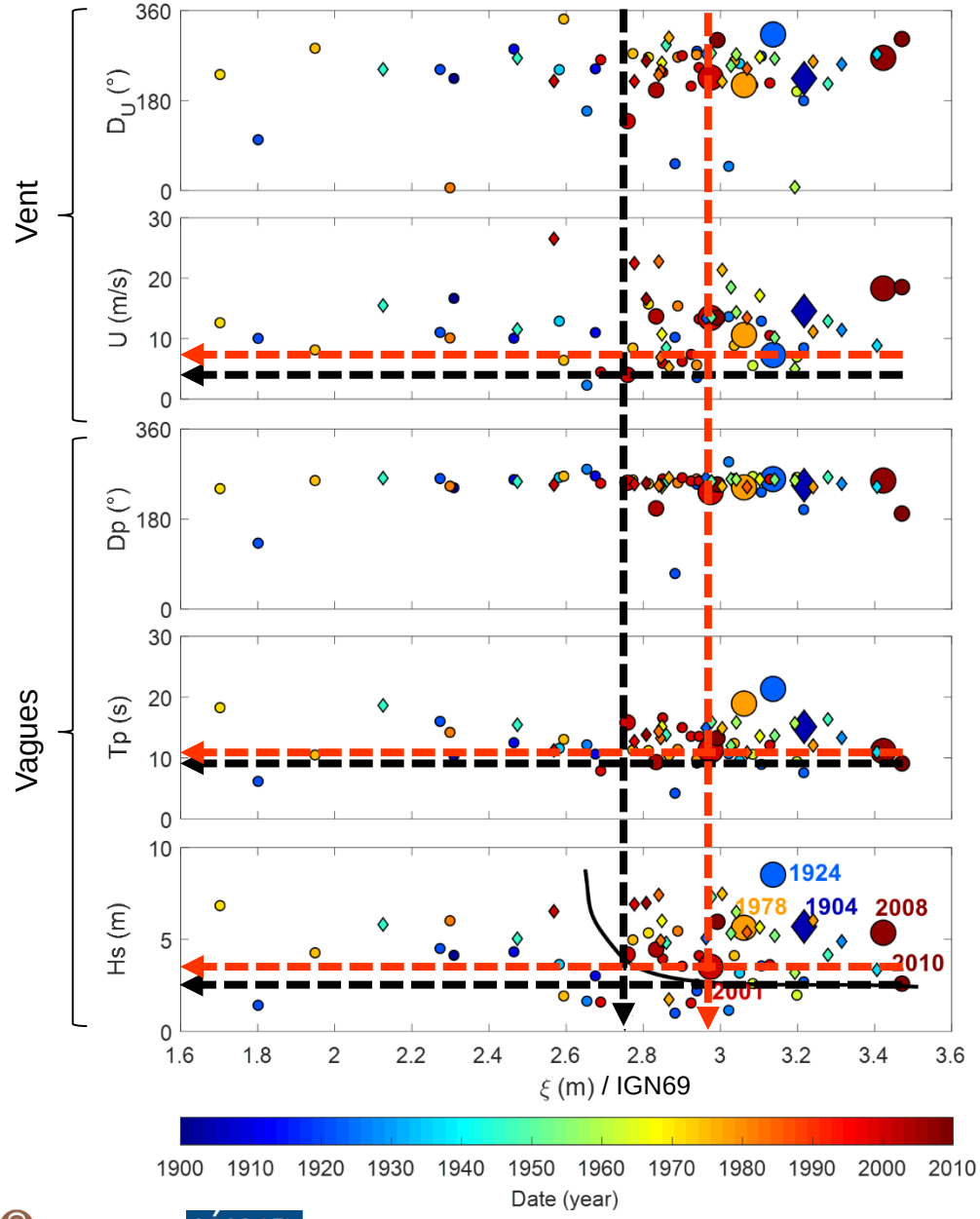
Values **below which no flood events occurred**:

- Water level (NMR+tide+surge): 2.76 m IGN69
- Hs: 2.6 m
- Tp: 9 s
- Wind speed: 4 m/s

Flood
- ○ **F=0 (no flood)**
- ○ **F=1 (moderate flood)**
- ◯ **F=2 (massive flood)**

Confidence
- ◇ **C=1 (moderate)**
- ○ **C=2 (high)**

KEY RESULTS: Critical conditions for flooding



Values **below which no flood events occurred**:

- Water level (NMR+tide+surge): 2.76 m IGN69
- Hs: 2.6 m
- Tp: 9 s
- Wind speed: 4 m/s

Values **below which no significant flood event occured**:

- Water level (NMR+tide+surge): 2.98 m IGN69
- Hs: 3.5 m
- Tp: 11 s
- Wind speed: 7 m/s

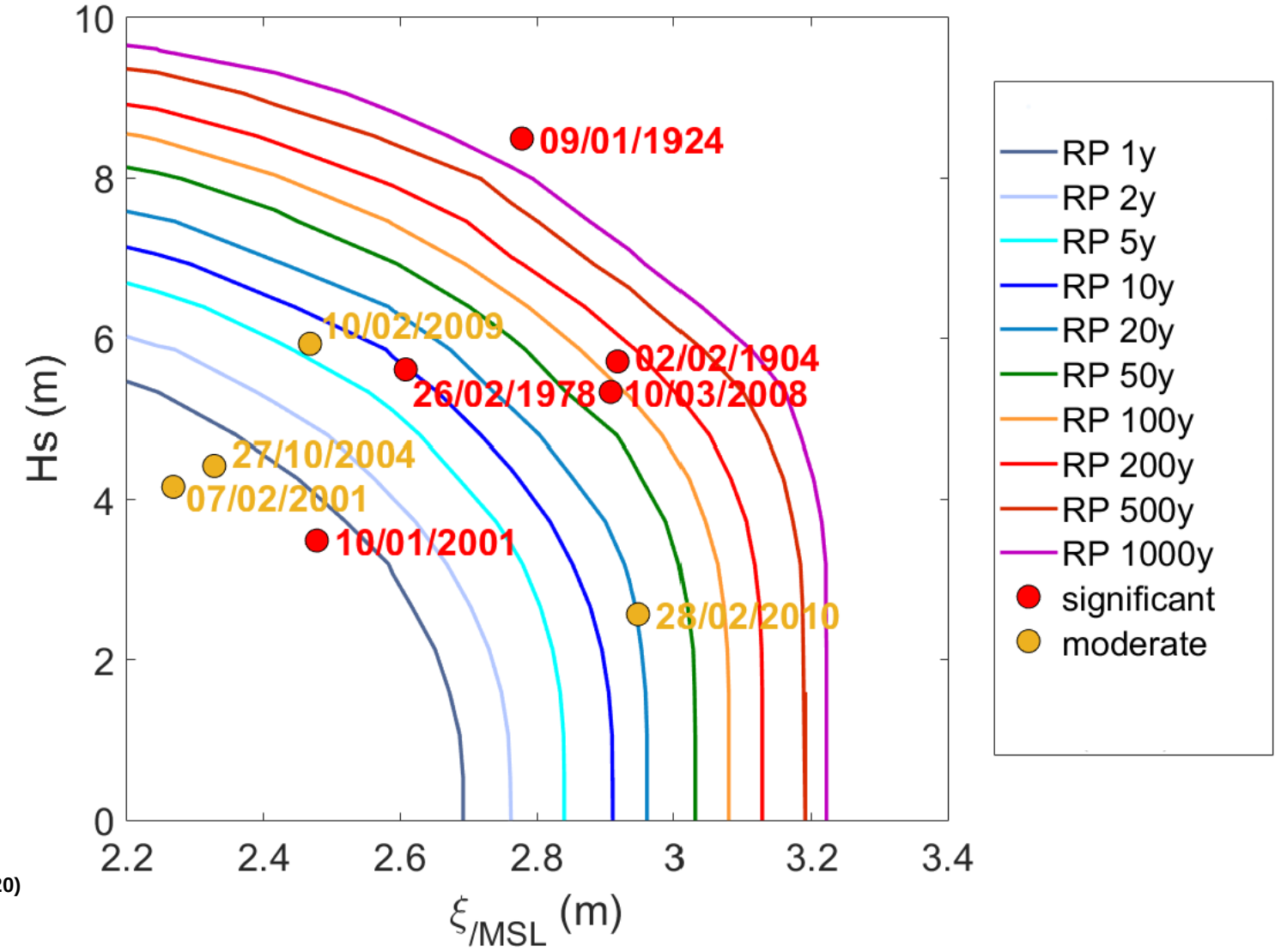
Flood
- ○ **F=0 (no flood)**
- ○ **F=1 (moderate flood)**
- ◯ **F=2 (massive flood)**

Confidence
- ◇ **C=1 (moderate)**
- ○ **C=2 (high)**

KEY RESULTS: Probability of occurrence of the critical hydro-meteorological conditions

Still Water Level (ξ=MSL+Tide+Surge) & Wave conditions: the main drivers

→ Joint exceedance return period ($\xi_{/MSL}$ =Tide + Surge, wave height)



Adapted from idier et al. (2020)

KEY RESULTS: Probability of occurrence of the critical hydro-meteorological conditions

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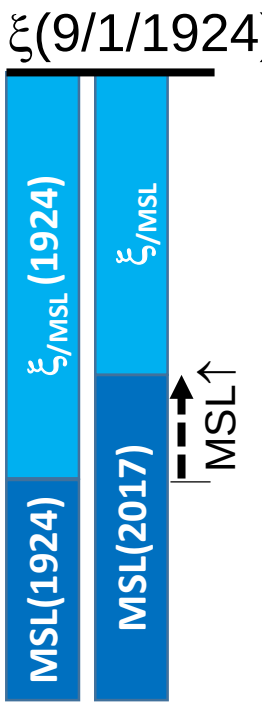
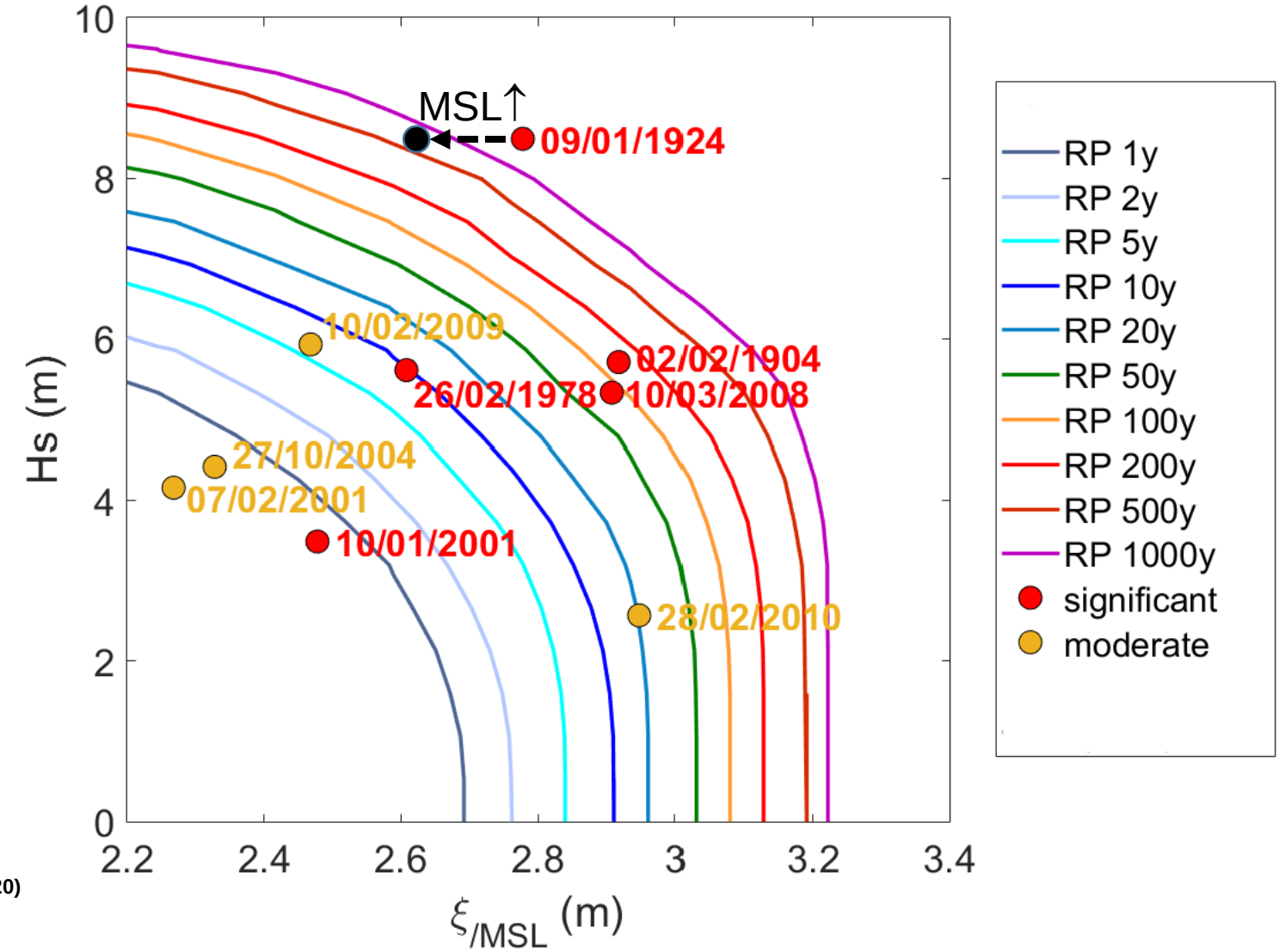
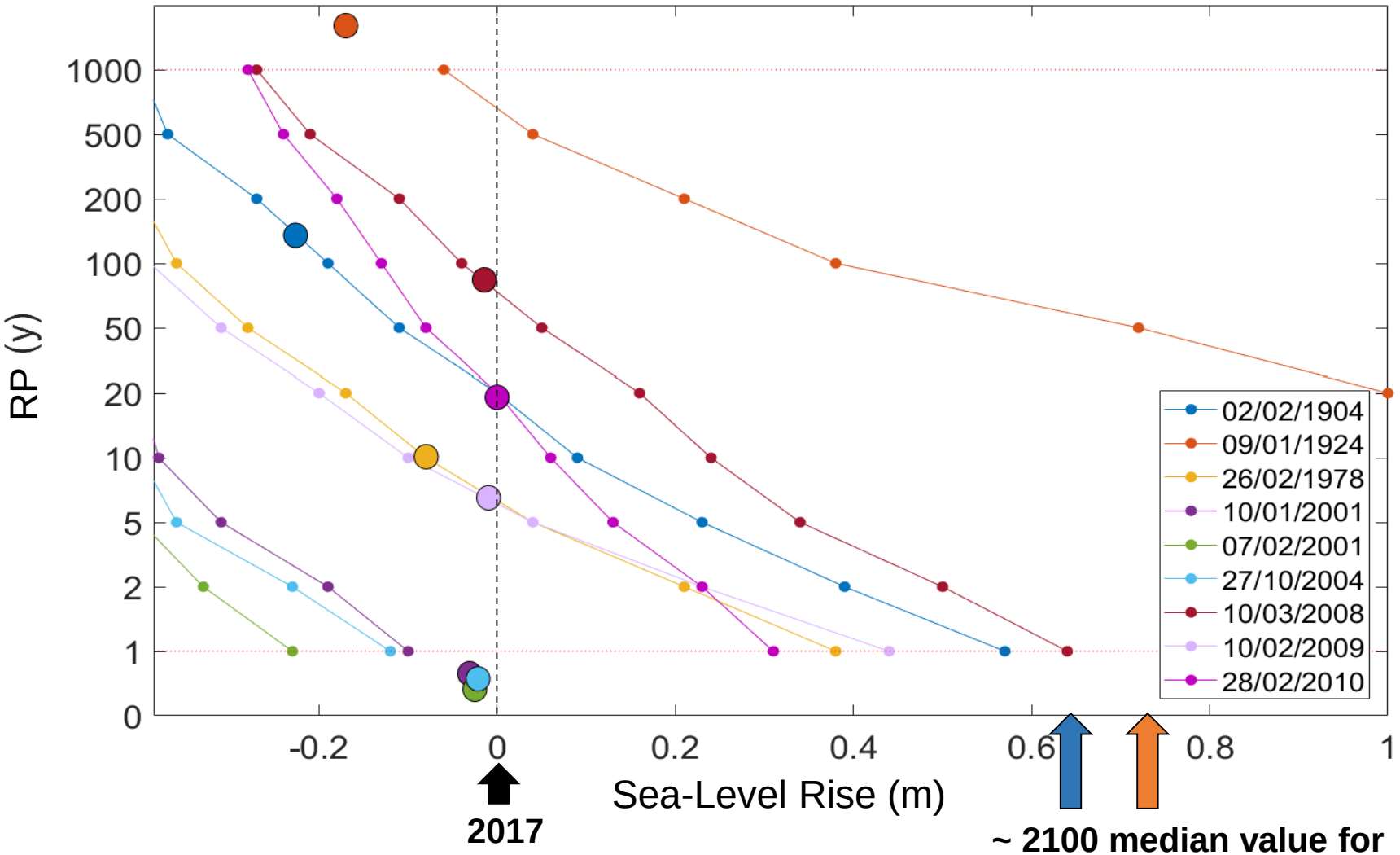




Adapted from idier et al. (2020)

KEY RESULTS: Most historical bi-variate events become annual before 2100 for rcp8.5

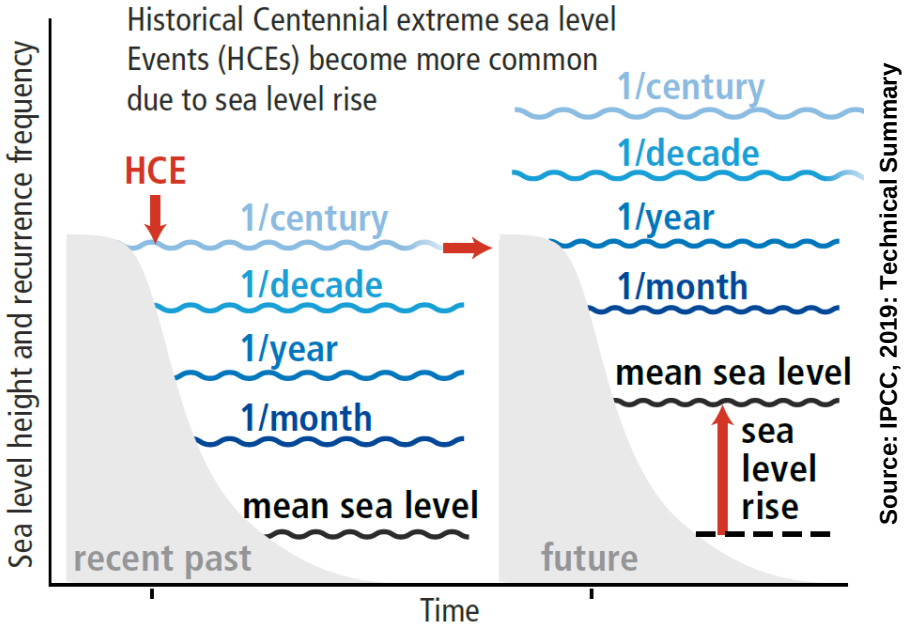
Joint exceedance return period ($\xi_{/MSL}$, Hs) as a function of Mean Sea-Level



Adapted from idier et al. (2020)

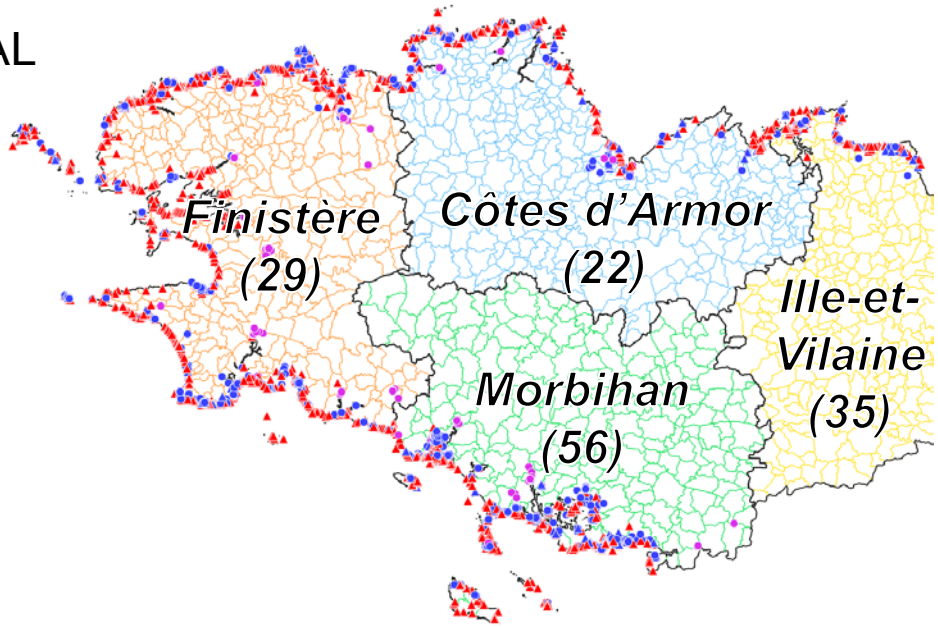
CONCLUSIONS

- Characterization of past flood events over 110 years
- A pragmatic approach to estimate the hydro-meteorological conditions
- 9 flood events, including 5 major flooding
- Sea-level rise has already (and will) significantly altered the hydrodynamic forcing in Gâvres

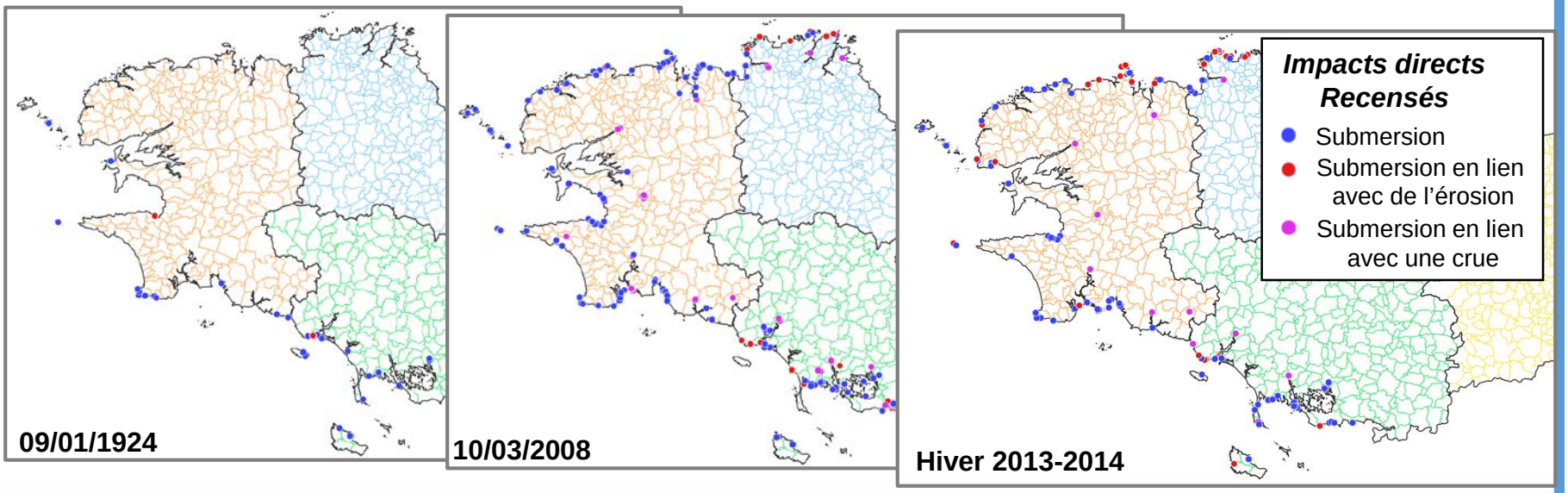


A une échelle plus régionale : « BD tempêtes » Bretagne

- Cadre : travaux BRGM pour la DREAL
- Aujourd'hui en base :
  - 6012 points
  - dont 4652 impacts directs (Erosion, Submersion, …)
  - Entre le XIème siècle et aujourd'hui
- Point contact : Sylvestre Leroy (s.leroy@brgm.fr)

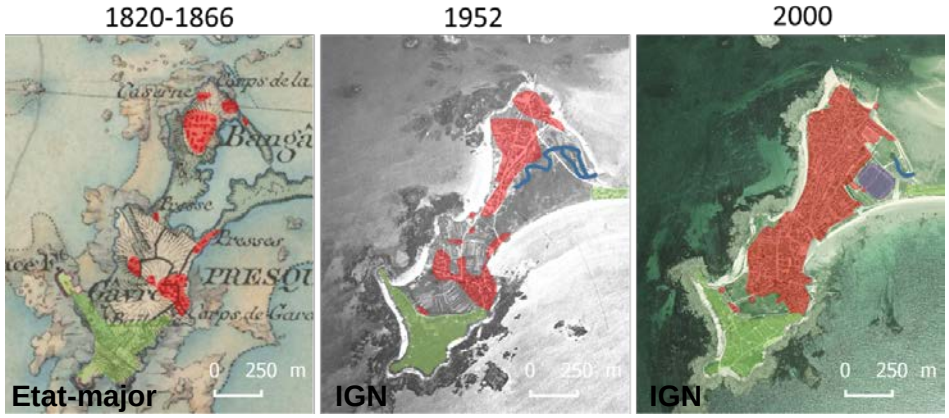


Exemples extraction « submersion »



DISCUSSION

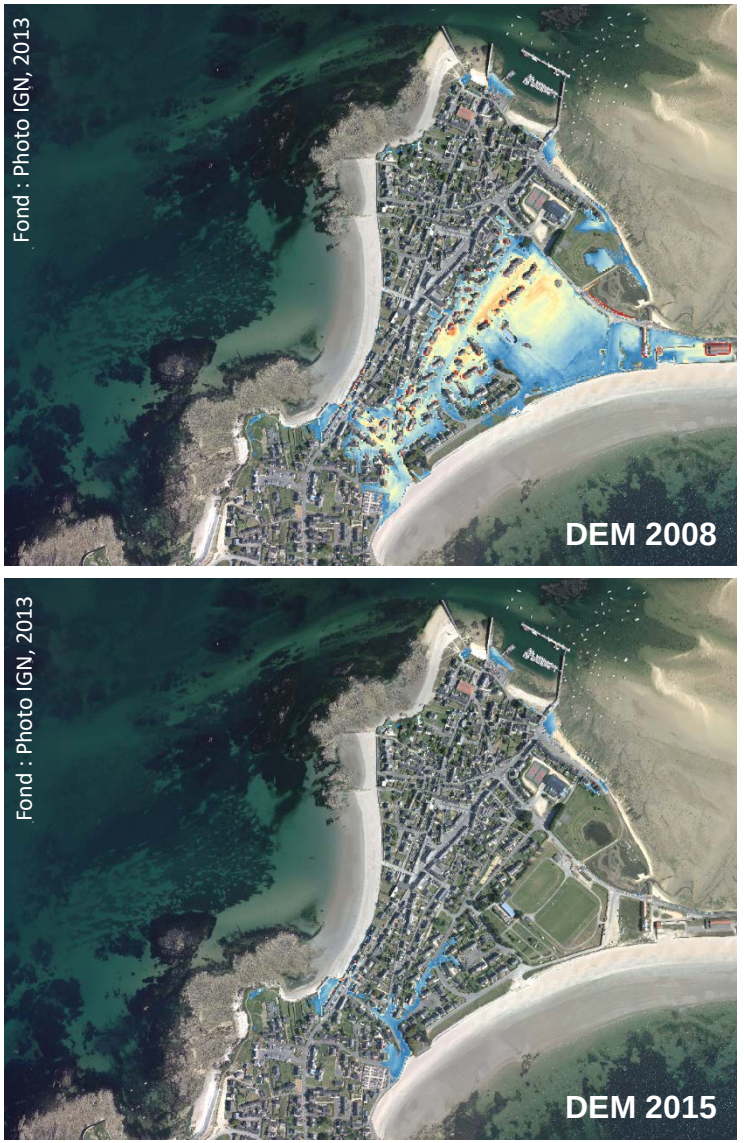
Gâvres has changed a lot.



Source: adapté de Idier et al. (2020)

- Few “inhabitants” and assets one century ago
  - → Still possible to have missed one minor flood event
- Changes in coastal defences and topo-bathymetry
  - → Possible that past hydro-meteorological conditions which led to major flood would not lead to major flood today

Maximal inland water depth, simulated for the 10/03/2008 hydro-meteorological conditions (Johanna)



DISCUSSION

Open questions

- Importance of knowing temporal evolution of the territory (& topo-bathy) … but hard to access for “old” events, and even more for future evolution
- For territories which have changed a lot: caution needed in the way to use historical flood information, depending on the objective (knowledge of past events; present-day hazard assessment; …)
- On sites which exhibit a significant erosion (long-term, seasonal or inter-annual) but not not necessarily floods, perhaps consider also “erosive” events to identify events which could lead to future flood?
- Today's storm impact networks are our sources of tomorrow's historical information.
  - See for instance: the BRGM networks (“Réseaux Tempête”) in Occitanie, Aquitaine, PACA, Corse (and in other regions in a near future) capitalized in standardized regional BRGM “BD tempête”’s.

THANK YOU for your attention

For more information:

- d.idier@brgm.fr

- Idier et al. (2020) Nat Hazards. https://doi.org/10.1007/s11069-020-03882-4
- Riscope project: https://perso.math.univ-toulouse.fr/riscope/
- « Réseaux Tempête » (example): https://www.brgm.fr/projet/reseau-tempetes-observatoire-cote-aquitaine