

Supplementary materials to “Extension of high temporal resolution sea level time series at Socoa (Saint Jean-de-Luz, France) back to 1875”

5 This section provides supplementary figures to the original manuscript.

1 Rescued documents

3 types of documents that are rescued during the archival research is shown in Figure S1.

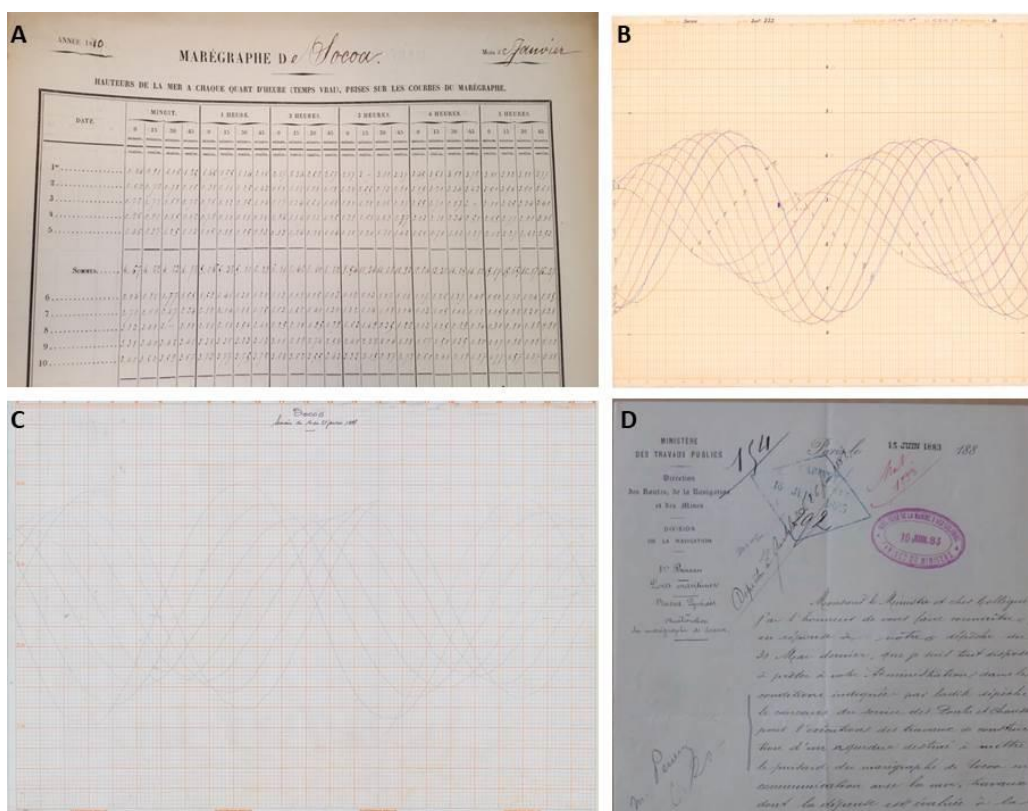


Figure S1. Examples of the different type of documents used in this study. A) A ledger dating from the year 1880 (source: Shom Archives), B) A chart recorded during the World War II from 2 to 12 December 1942 (source: Shom Archives) with a tide gauge installed by the Germans C) A Brille chart from 14 to 21 January 1997 (source: AD64 - 2003W-47; Bayonne) and D) a letter of correspondence dated 15 June 1883 (Source: SHD Vincennes - DD2-2053).

- 10 Among the rescued documents, the charts are often degraded by the moulds, or the ink is faded. Figure S2 illustrates level of degradation of the charts.

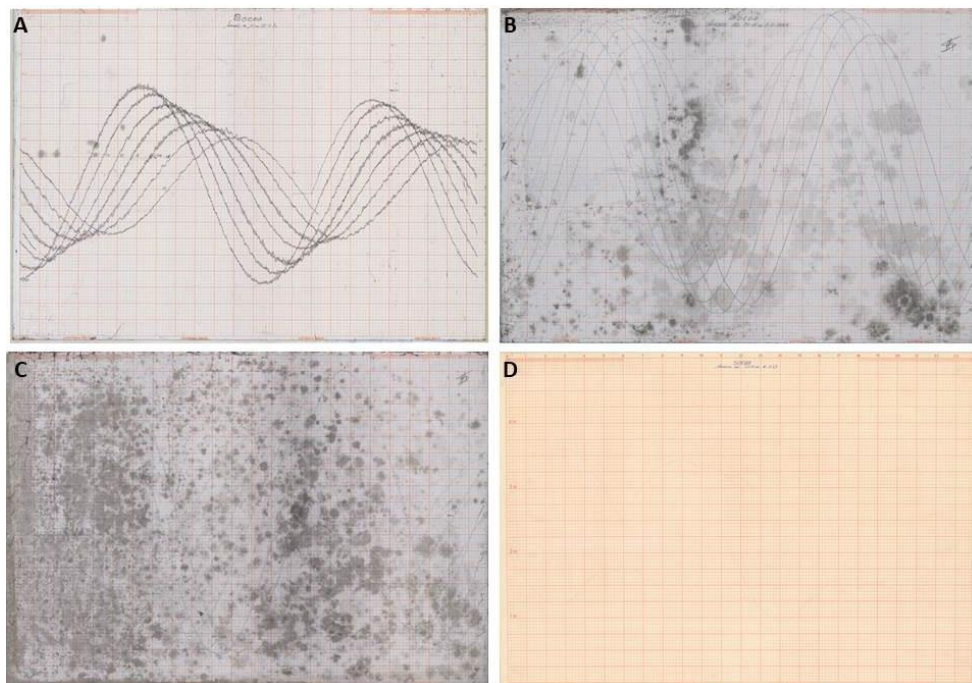


Figure S2. The different types of charts analysed in this study. A) In ‘good’ condition, 142 charts (ex. 15-22 Dec. 1970; AD64 – 2003W-20), B) Mildly moulded, 50 charts (e.g. Oct. 29 – Nov. 5, 1963; AD64 – 2003W-13), C) Strongly moulded, 32 charts (e.g. Nov. 25 – Dec. 2, 1963; AD64 – 2003W-20); and D) Faded, 553 charts (e.g. Oct. 28 – Nov. 4, 1957; AD64 – 2003W-20).

2 Processing in NUNIEAU

- 15 Figure S3 illustrates the steps of water level extraction from the charts through NUNIEAU software.

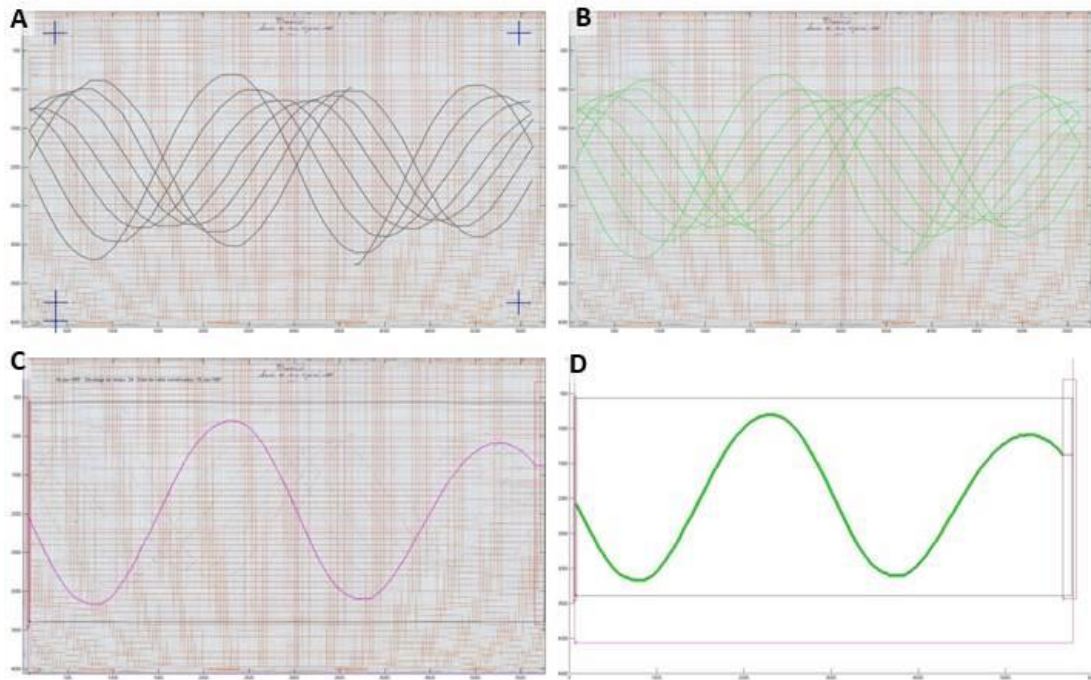


Figure S3. Illustration of the followed steps for digitizing a chart with the NUNIEAU. A) Referencing image in time along the horizontal and in height along the vertical B) Definition of the color to be extracted highlights the water level curves in the chart, C) Creation of the extraction mask for a single day record, and D) Extracted water level signal selected in C. (14 – 21 January 1997; Source: AD64 – 2003W-47).

For the faded charts, image processing is used to enhance the contrast of the recorded lines. The before and after of a color adjustment procedure is shown in Figure S4.

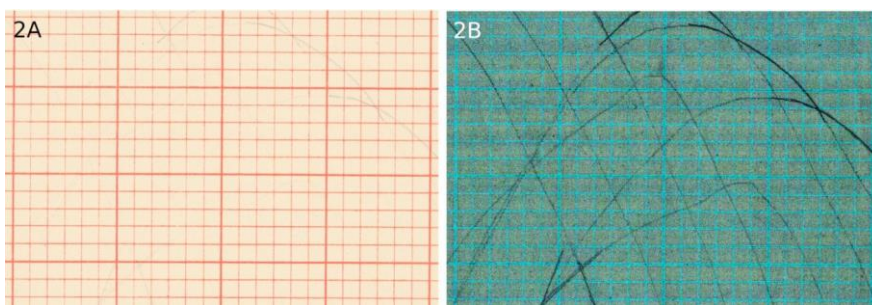


Figure S4. An illustration of the image processing applied on a faded chart - example of Oct. 28 – Nov. 4, 1957 (Source: AD64 – 2003W-07) A) the original image before color-adjustment and B) after color adjustment.

3 Data quality assessment procedures

For the hand-transcribed data from ledgers, the tabulated values are visually checked through the color function of Microsoft Excel. The corrections made during this stage is illustrated in Figure S5.

A	Année	Mois	Jour	Jour 2	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	
57	1908	2	24	55	120	94	101	136	190	253	300	327	332	308	263	262	148	108	106	124	172	225	272	309	322	316	282	231	
58	1908	2	26	57	254	197	152	136	132	155	192	238	272	299	307	294	261	219	172	137	125	131	160	198	243	283	308	312	
59	1908	2	27	58	296	252	201	157	129	123	137	168	213	250	291	311	312	290	246	195	154	127	124	142	114	135	184	251	315
60	1908	2	28	59	340	323	282	223	167	123	105	114	144	197	253	303	337	343	322	274	211	154	122	114	135	184	251	315	
61	1908	2	29	60	388	385	372	328	254	178	119	93	98	138	204	279	341	377	395	357	295	217	144	97	89	120	184	265	
62	1908	3	1	61	343	405	424	403	344	253	161	90	144	202	292	386	410	415	373	296	200	117	68	64	108	190			
63	1908	3	2	62	290	378	439	444	425	345	243	135	53	27	53	123	225	324	388	438	425	369	275	166	78	34	45	107	
64	1908	3	3	63	203	317	412	433	433	413	320	200	88	16	2	40	129	237	337	407	433	410	336	224	119	38	5	31	
65	1908	3	4	64	106	219	333	414	451	434	390	284	160	54	8	0	54	152	262	356	418	425	385	303	190	87	16	0	
66	1908	3	5	65	40	175	245	350	427	433	428	357	249	132	43	3	16	85	186	290	388	410	404	355	264	162	68	19	
67	1908	3	6	66	18	76	168	271	365	422	433	400	326	224	121	51	30	67	137	230	318	380	381	325	242	145	72		
68	1908	3	7	67	40	51	112	200	290	359	395	392	354	284	192	114	63	60	100	170	250	318	359	365	340	290	214	144	
69	1908	3	8	68	92	73	97	152	225	295	343	365	353	315	255	181	123	96	100	144	201	264	311	336	332	309	262	206	
70	1908	3	9	69	153	112	105	130	177	234	284	320	330	319	289	241	187	147	131	144	175	218	265	297	312	311	294	260	
71	1908	3	10	70	219	174	147	142	158	192	234	270	295	305	300	276	242	202	174	160	165	187	221	254	282	296	300	291	
72	1908	3	11	71	270	229	193	170	159	165	185	214	245	272	288	288	277	250	217	188	169	167	173	202	234	260	282	295	
73	1908	3	12	72	294	272	240	203	173	154	150	164	193	228	260	284	294	287	262	228	192	166	159	168	190	225	262	291	
74	1908	3	13	73	313	313	292	257	211	170	141	133	148	182	225	265	294	306	297	266	222	179	145	133	140	170	214	262	
75	1908	3	14	74	300	322	317	290	245	190	142	111	108	133	179	233	281	314	320	303	260	204	152	115	109	129	174	233	
76	1908	3	15	75	292	311	345	332	290	222	165	111	88	96	141	202	265	317	345	338	303	244	177	120	91	55	135	195	
77	1908	3	16	76	268	327	357	397	372	298	191	121	114	64	84	152	206	244	355	334	281	202	131	80	132	184	149		
78	1908	3	17	77	227	303	359	378	361	313	234	151	84	51	62	112	192	275	340	375	370	328	252	168	97	58	54	111	
79	1908	3	18	78	192	280	353	393	387	359	291	200	114	58	46	80	152	243	324	379	395	369	303	216	128	70	49	77	
80	1908	3	19	79	146	239	326	388	410	393	336	249	157	80	45	55	113	200	291	364	399	393	345	266	172	92	47	52	
81	1908	3	20	80	102	188	280	357	402	405	368	293	203	114	56	40	76	151	241	324	379	396	366	304	215	127	61	37	
82	1908	3	21	81	64	133	219	305	370	395	380	328	247	154	84	45	51	109	186	274	343	380	378	340	265	180	101	54	
83	1908	3	22	82	55	96	173	257	334	380	368	361	302	221	145	86	70	97	158	239	305	305	384	372	320	247	164	103	
84	1908	3	23	83	73	87	136	215	285	338	371	366	331	272	197	127	89	84	117	175	246	295	348	358	335	290	220	150	
85	1908	3	24	84	103	85	102	156	219	279	324	344	340	305	251	187	135	110	113	147	196	195	306	334	335	315	271	213	
86	1908	3	25	85	156	115	106	122	164	212	261	298	315	309	284	243	190	147	124	148	180	240	280	306	312	301	271		
87	1908	3	26	86	228	170	132	117	129	157	198	242	279	300	308	284	262	217	174	146	138	184	222	264	296	312	316		
88	1908	3	27	87	294	244	190	145	119	115	133	168	212	256	292	309	305	280	235	184	143	127	128	154	195	245	283	325	
89	1908	3	28	88	336	313	265	205	144	104	88	102	136	191	249	300	327	330	301	247	180	167	98	91	120	170	239	302	
90	1908	3	29	89	352	360	338	283	206	127	72	50	68	112	184	257	320	352	352	317	250	239	93	60	59	100	170	255	
91	1908	3	30	90	333	383	393	362	290	195	103	40	19	44	105	192	280	352	384	375	323	344	138	66	27	38	93	183	
92	1908	3	31	91	278	368	411	418	370	285	170	71	7	3	35	112	218	313	378	400	379	368	210	165	31	68	21	100	
93	1908	4	1	92	200	313	350	437	432	364	265	171	50	0	2	55	150	256	344	398	400	307	286	178	75	112	0	41	
94	1908	4	2	93	134	245	350	418	411	411	335	225	102	23	8	15	88	190	290	370	432	399	345	252	140	51	0	8	
95	1908	4	3	94	68	170	280	368	421	425	379	298	184	81	17	6	48	130	233	322	384	400	372	308	210	112	35	10	
96	1908	4	4	95	32	104	200	300	373	406	391	340	252	154	70	31	36	92	175	265	337	378	376	342	272	180	98	48	

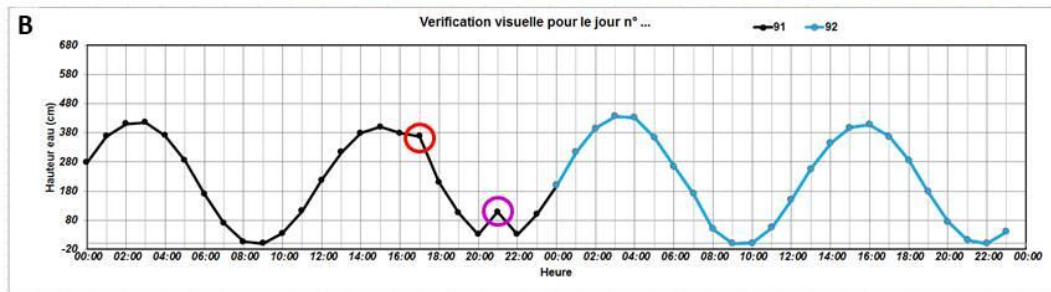
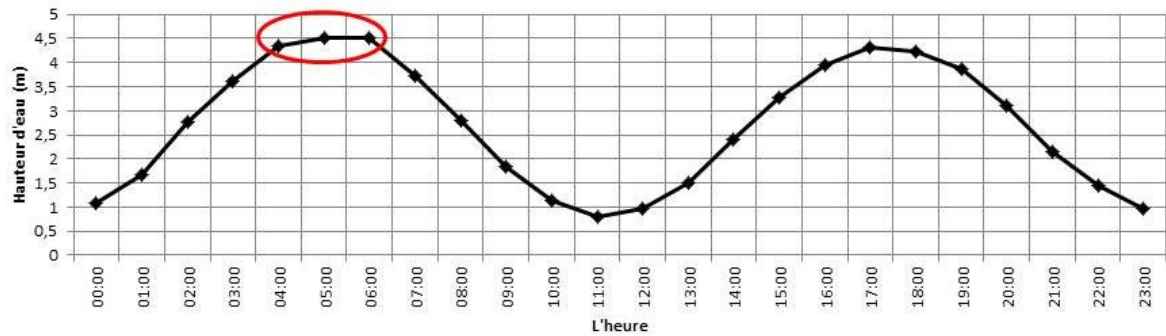


Figure S5. Colorcoded spreadsheet to assist visual detection of errors. A) Excerpt of the digitised table of March 1908 hourly water levels. The colours clearly highlight high water (red) and low water (blue); and B) timeseries of the recorded water level for 31 March 1908 (in black) and the following day (in blue). The rectangles in red and purple highlight two anomalies on A and B.

25 Figure S6 illustrates a correction of high-water level based on the check sheet. The red circle indicates high tide which is first identified as potentially incorrect. Comparison between the values in the spreadsheet and the heights in the ledgers which shows that the transcription was correct. Following that, an extract from the table of high tide times and heights for October 11, 1885, is checked in the check sheet. According to this reading, high tide at 05:03 (AST) was 4.60 m. It is therefore very likely that the height at 05:00 is 4.60 m instead of 4.50, so a correction of +0.10 m is applied.

A

La courbe de marée de 11 octobre 1885



B	A	B	C	D	E	F	G	H	I	J	K	L
1	Année	Mois	Jour	Jour 2	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00
285	1885	10	11	284	108	166	277	362	434	450	450	373
286	1885	10	11	285	109	167	278	363	435	451	451	374

11.....	1.08	1.26	1.40	1.63	1.66	2.00	2.23	2.46	2.77	3.22	3.09	3.44	3.62	3.86	3.93	4.18	4.34	4.40	4.50	4.55	4.50	4.55	4.52
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C

MATIN.										
DATES.	HEURE — T. M.	AU MARÉGRAPHE.				A L'ÉCHELLE.			VENT.	
		HEURE.	HAU- TEUR.	CORREC- TION de la pression baromé- trique.	HAU- TEUR	HEURE.	HAU- TEUR.	AGI- TATION.	DIREC- TION.	FORCE.
		T. V.	P. M.	centim.	centim.	T. V.	centim.	centim.		
11.....	4.50	"	5.03	4.80	0.91	5.51	"	"	"	N.O. C.de S.

Figure S6. Example of correction of a high tide of October 11, 1885, with the help of the check sheet which accompany the ledgers. A) The water level curve generated from the transcription in Apparent Solar time (AST). The red circle indicates the high tide (point in the middle) which is potentially incorrect. B) Comparison between the values in the spreadsheet and the heights in the ledgers showing that the transcription was correct C) An excerpt from the table of high tide times and heights for October 11, 1885, indicating a high tide at 05:03 (AST) of 4.60 m. It was concluded that the height at 05:00 is 4.60 m instead of 4.50 m, thus a correction of +0.10 m was applied.

MAREGRAPHE DE SOCOA

Semaine du 2/03/99 au 10/03/99

At installation of the chart:

Mise en place de la feuille : 2/03/99

Heure exacte	<u>14h10</u>	Time Exact - chart = 0 min
Heure de l'horloge du marégraphe	<u>14h08</u>	
Heure indiquée par le stylet (1)	<u>14h10</u>	
Côte de départ lue à l'échelle	<u>1,80m</u>	Height Visual - chart = 0.15m
Côte de départ indiquée par le stylet (2)	<u>1,95m</u>	

At removal the chart:

Enlèvement de la feuille : ---/---/---

Heure exacte	<u>8H01</u>	Time Exact - chart = 11 min
Heure de l'horloge du marégraphe	<u>9H</u>	
Heure indiquée par le stylet (3)	<u>2H50</u>	
Côte de départ lue à l'échelle	<u>2,81</u>	Height Visual - chart = 0.11m
Côte de départ indiquée par le stylet (2)	<u>2,92m</u>	

Figure S7. Example of a check sheet that shows the two anomalies that have not been corrected as it is not clear when these errors are introduced during the recording (02/03/1999 – 10/03/1999). First, an 11-minute clock delay identified during the removal of the chart, and second, a difference in height during the installation of the chart (here 0.15 m) which is not equal to the difference in height during the removal of the chart (here 0.11 m).

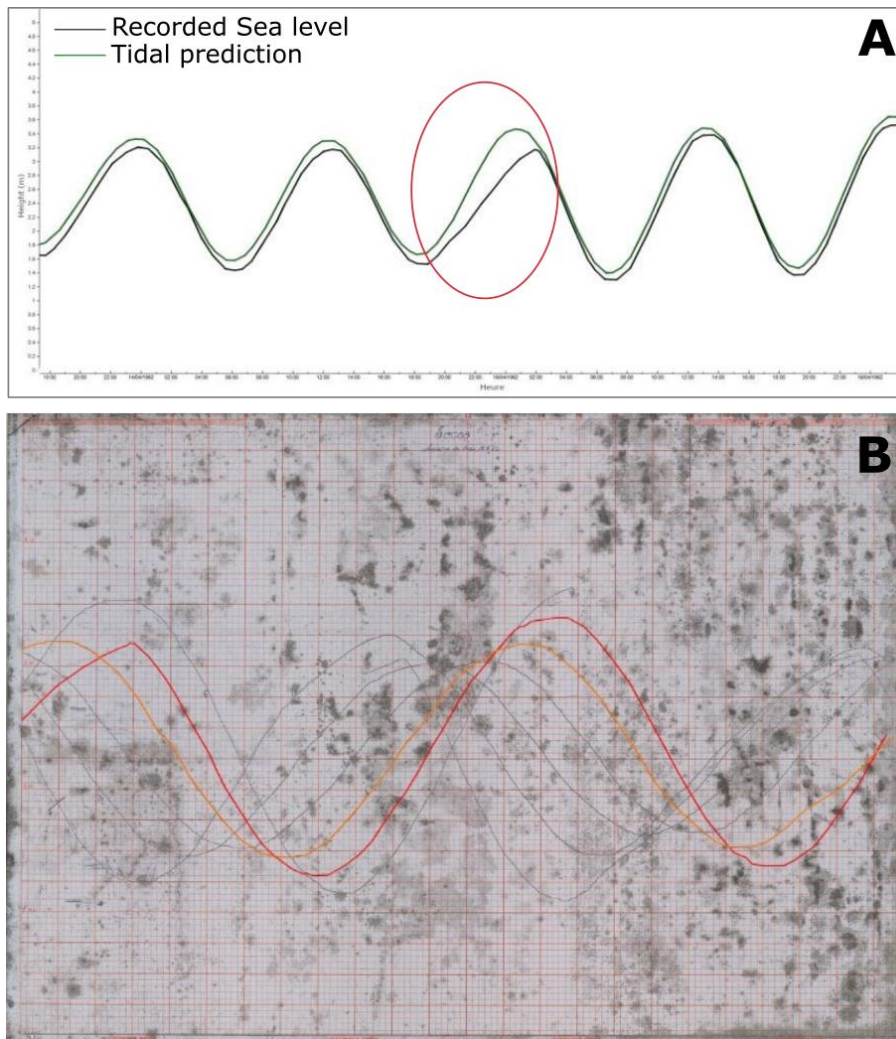


Figure S8. A) An example of linear evolution instead of sinusoidal (appears here as delayed high tide) from October 15, 1962. In black the observation and in green the tide prediction. B) The corresponding chart for A - the curve for October 14, 1962 (orange) and October 15, 1962 (red) are marked. The linear behaviour begins around 9 p.m. on October 14 and returns to normal heights around 3 a.m. on October 15.

4 Comparison with Marcos et al. (2021) Santander timeseries

Figure S9 shows the annual mean sea level at Brest, Socoa, and Santander. The Brest dataset is collected from SHOM (<https://data.shom.fr>), Socoa dataset is a merged dataset between the newly reconstructed data in the original paper and the one collected from SHOM. Monthly mean sea level is computed from the data by taking an arithmetic mean over a calendar month. No filtering or detiding is done before making the arithmetic mean. Santander dataset is provided by Dr. Marta Marcos

as monthly mean value (personal communication). The data is presented in Marcos et al. (2021). For comparison, in Figure S9, mean during 1965-2000 is removed.

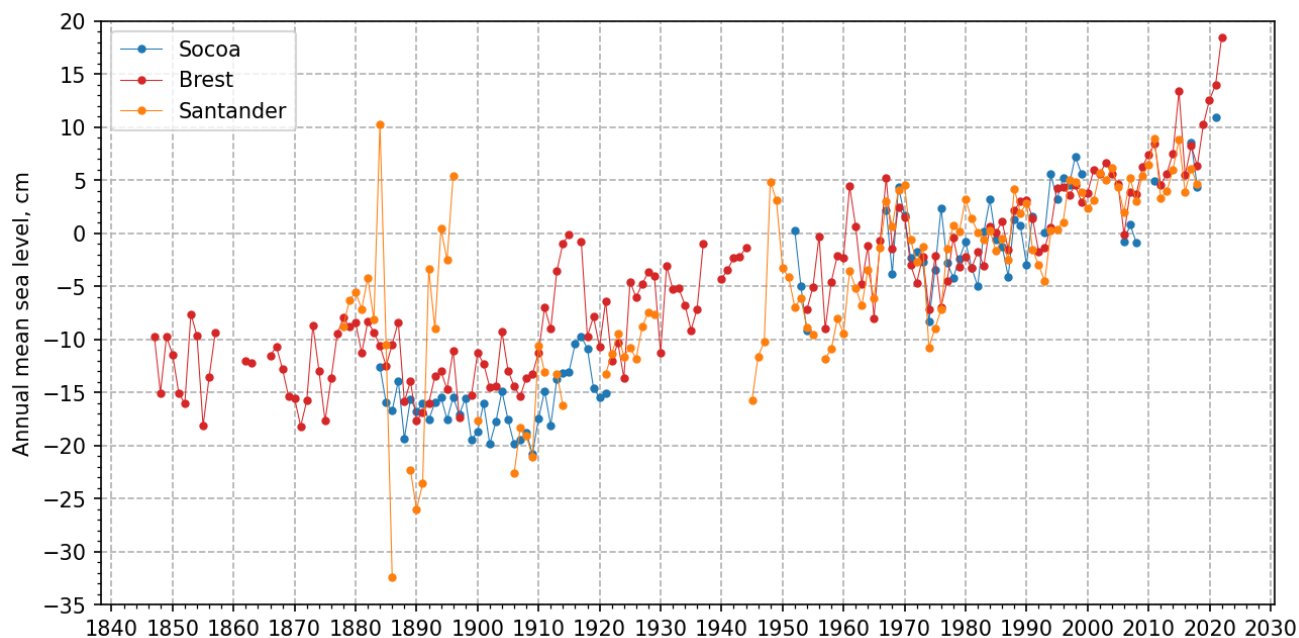


Figure S9. Annual mean sea level comparison between Brest (red), Socoa (blue), and Santander (orange). Santander data is taken from Marcos et al. (2021) provided as mean monthly values (without filtering for tide). Annual average is calculated as numerical mean value. Same processing is applied to Brest and Socoa timeseries too.

40 5 Inflexion point analysis

To find the inflexion point of the trend, we have analysed the yearly timeseries at Socoa and Brest. First, the respectively hourly timeseries is detided using a Demeriliac filter. From the filtered hourly timeseries, daily mean is first computed as daily mean. The yearly timeseries is computed using PSMSL rules, e.g., at least 50% valid data to compute monthly, and at least 11 months data to compute yearly values. Then a 20-year running window is chosen for linear trend analysis. The trend (mm/year) and error bar are shown in Figure S10.

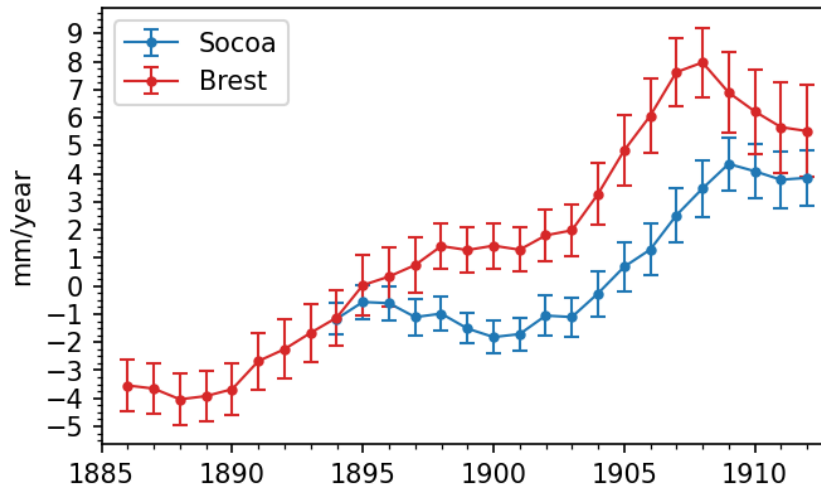


Figure S10. Running trend estimates (20-year windows) for Socoa (blue) and Brest (red) during 1875 – 1920. Error bar shows the standard error of the trend estimate

6. Data and other supplementary files

The data and other supporting documents, source-code is provided as a package in Zenodo data repository (Khan et al. 2022).

50 6.1 Tide gauge journal

The extraction from the tide gauge journal is provided yearly by year in the ‘documents/tidegauge_journal’ directory. The files are named as – ‘YEAR_Socoo_Notes_Registres.docx’ where YEAR is the 4-digit year.

6.2 Transcribed metadata

The excerpts of metadata documents from the various archives falls into this category of supplementary files. For 5 archives, 55 5 separate files are provided inside ‘documents/archive_record’ directory. These archives are and file names are –

1. Service historique de la Défense (SHD) at Brest (SHD-Brest), ‘SHD_Brest_MB3W.docx’
2. Service historique de la Défense (SHD) at Rochefort (SHD-Rochefort), ‘SHD_Rochefort_7JJ418-7JJ1551.docx’
3. Service historique de la Défense (SHD) at Vincennes (SHD-Vincennes), ‘SHD_Vincennes_plusieurCotes.docx’
4. Archives des Pyrénées-Atlantiques (AD64), ‘AD64_Pau_4S33.docx’
- 60 5. SHOM archive, ‘Archives_Shom_plusieursCotes.docx’

6.3 Computation notebook

Jupyter notebooks written in python for analysis presented in the paper is provided as supplementary files. 3 notebooks are provided–

1. '01_data_processing.ipynb' : Presents the processing of the raw data.
- 65 2. '02_buddy_checking.ipynb' : Presents the buddy checking analysis.
3. '03_trend_analysis.ipynb' : Presents the Trend analysis.

Further details can be found in the README file associated with the associated data (Khan et al. 2022).

Reference

- 70 Marcos, M., Puyol, B., Amores, Gómez, B. P., Fraile, M., and Talke, S. A.: Historical Tide Gauge Sea-Level Observations in Alicante and Santander (Spain) Since the Century, *Geoscience Data Journal*, 1, doi:10.1002/gdj3.112, 2021.
- Khan, M.J.U., Van Den Beld, I., Woppelmann, G., Testut, L., Latapy, A., & Pouvreau, N.: Sea level data archaeology at Socoa (Saint Jean-de-Luz, France) (v1.0) [Data set]. Zenodo, doi:10.5281/zenodo.7438470, 2022.