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

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.

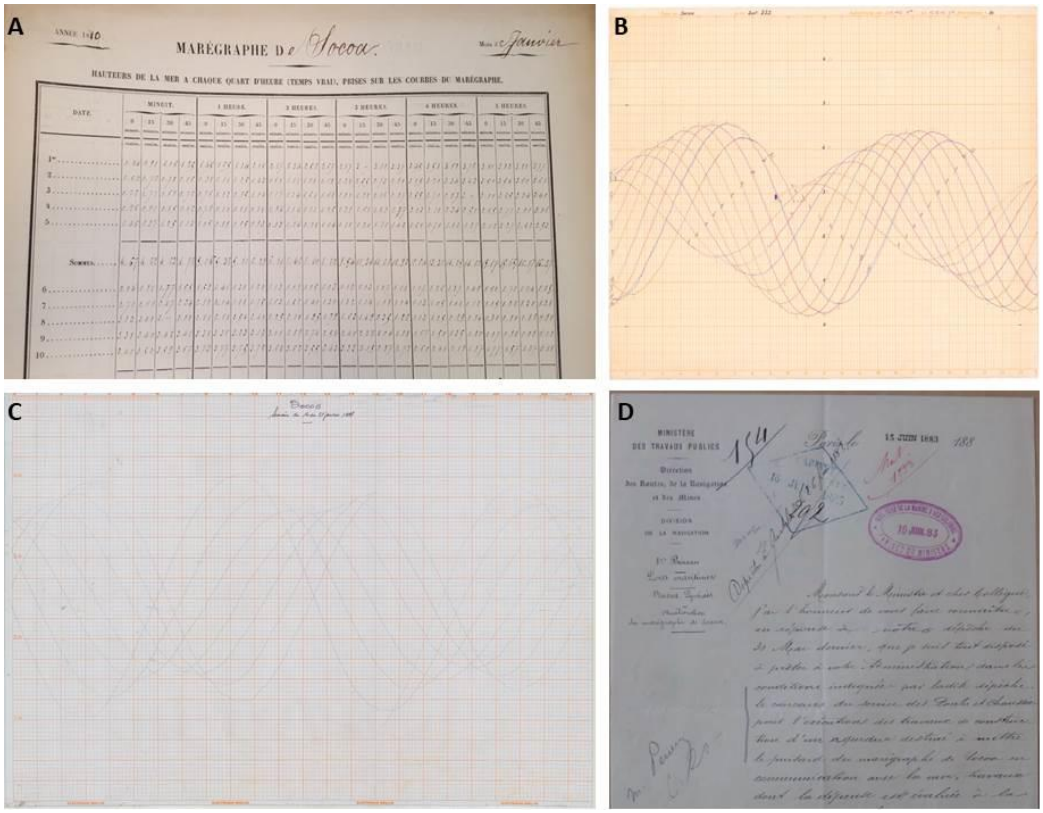

Figure S1. Examples of the different type of documents used in this study. A) A ledger dating from the year 1880 (source: Shom Archives), B) A chart recorded during the World War II from 2 to 12 December 1942 (source: Shom Archives) with a tide gauge installed by the Germans C) A Brille chart from 14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

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.

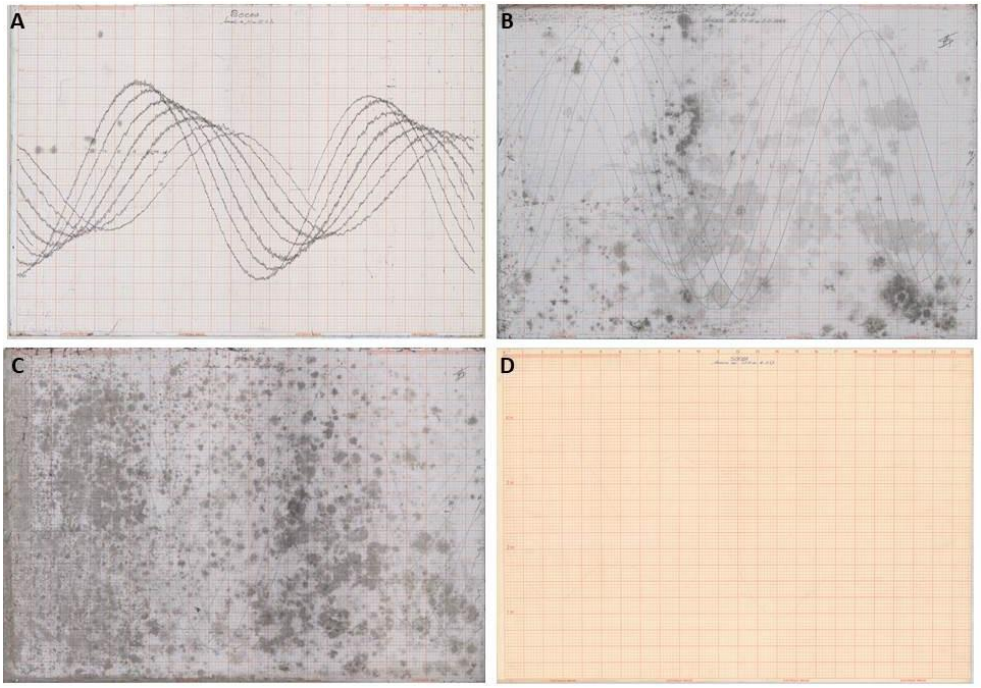

Figure S2. The different types of charts analysed in this study. A) In 'good' condition, 142 charts (ex. 15-22 Dec. 1970; AD64 – 2003W-20), B) Mildly moulded, 50 charts (e.g. Oct. 29 – Nov. 5, 1963; AD64 – 2003W-13), C) Strongly moulded, 32 charts (e.g. Nov. 25 – Dec. 2, 1963; AD64 – 2003W-20); and D)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

2 Processing in NUNIEAU

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

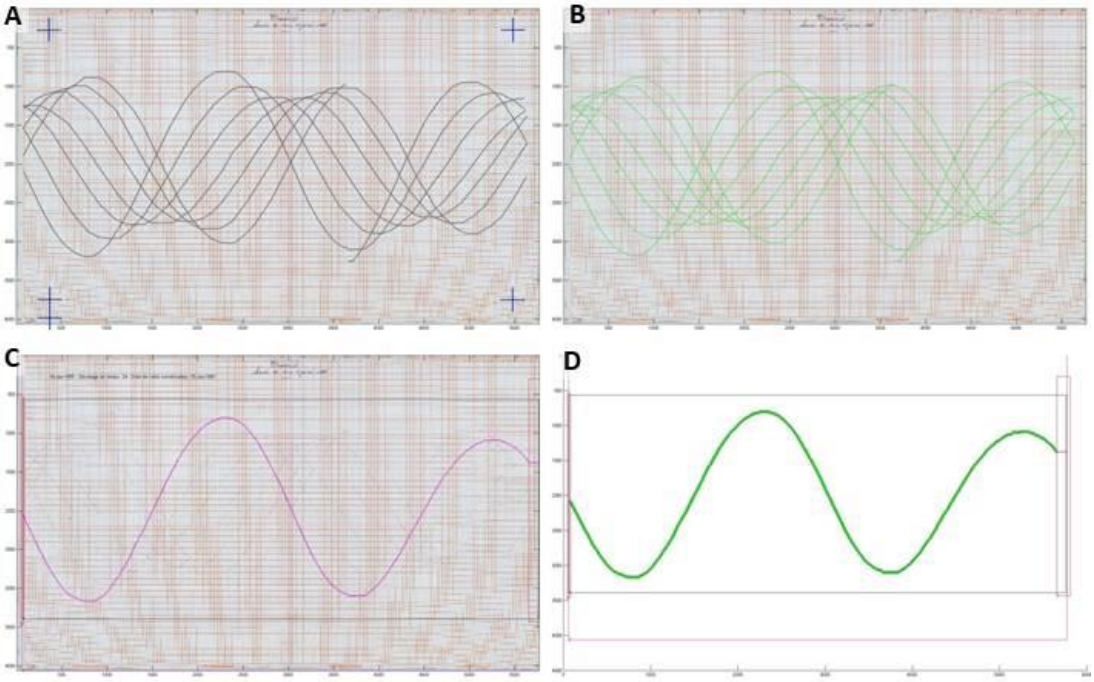

Figure S3. Illustration of the followed steps for digitizing a chart with the NUNIEAU. A) Referencing image in time along the horizontal and in height along the vertical B) Definition of the color to be extracted highlights the water level curves in the chart, C) Creation of the extraction mask for a 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.

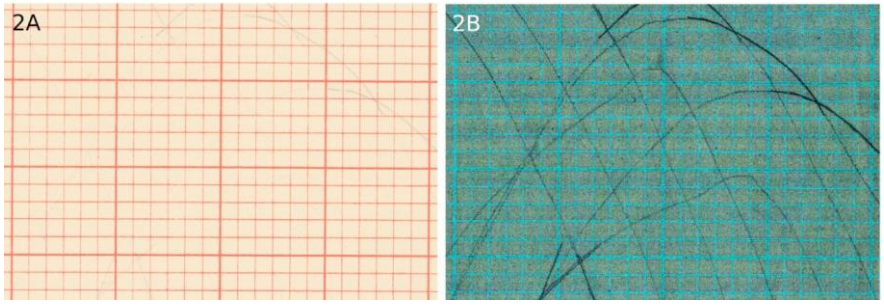

Figure S4. An illustration of the image processing applied on a faded chart - example of Oct. 28 – Nov. 4, 1957 (Source: AD64 – 2003W-07) A) the original image before color-adjustment and B) after color adjustment.

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3 Data quality assessment procedures

For the hand-transcripted 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.

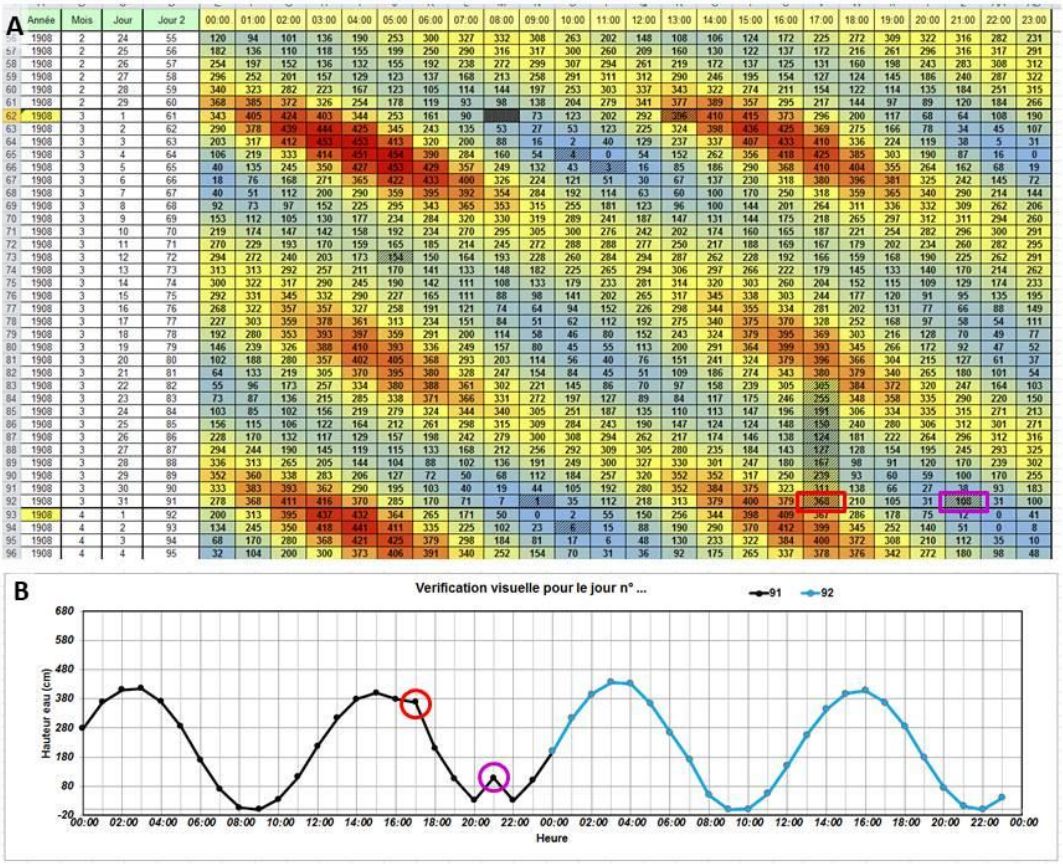

Figure S5. Colorcoded spreadsheet to assist visual detection of errors. A) Excerpt of the digitised table of March 1908 hourly water levels. The colours clearly highlight high water (red) and low water (blue); and B) timeseries of the recorded water level for 31 March 1908 (in black) and the following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

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.

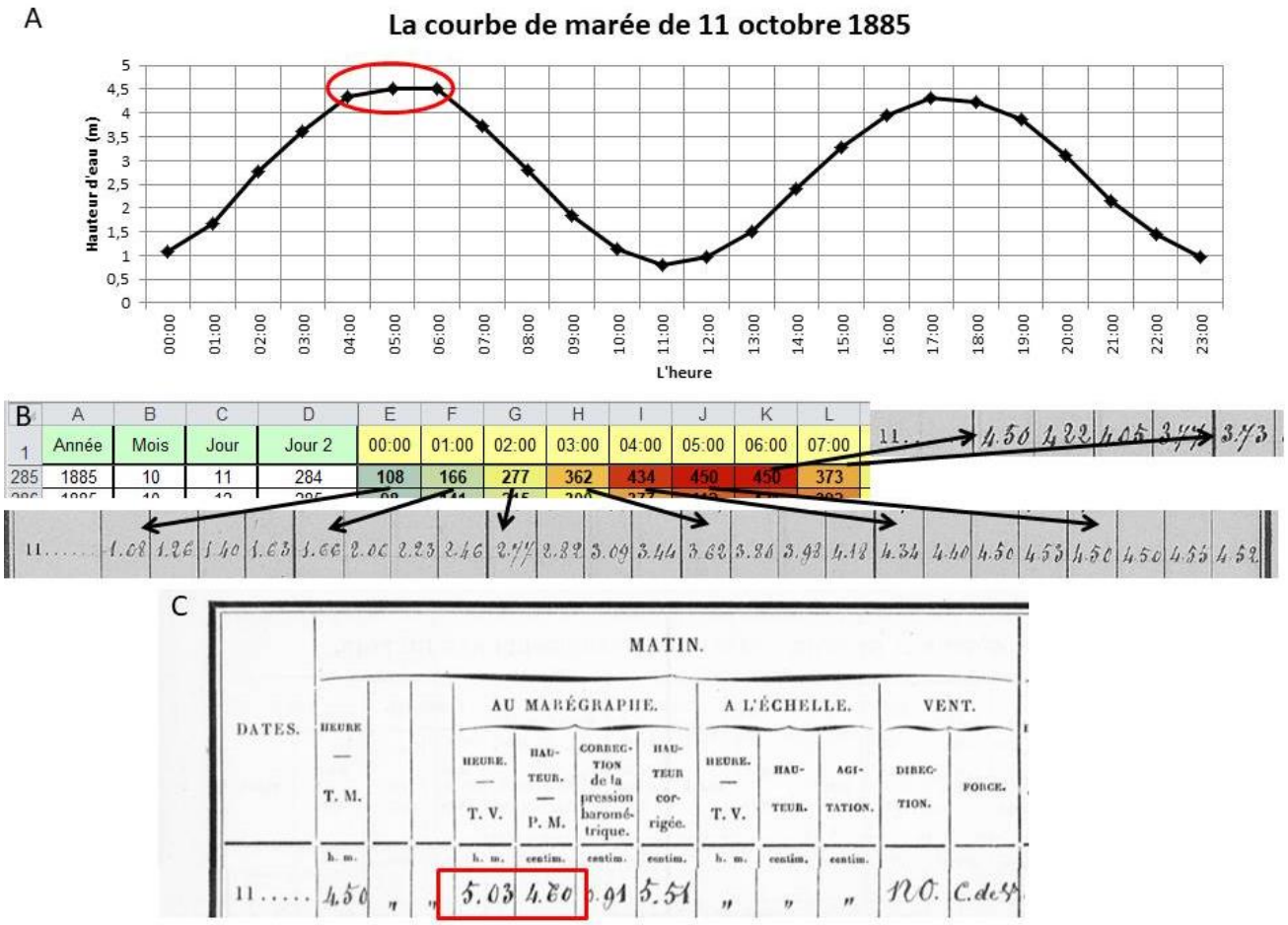

Figure S6. Example of correction of a high tide of October 11, 1885, with the help of the check sheet which accompany the ledgers. A) The water level curve generated from the transcription in Apparent Solar time (AST). The red circle indicates the high tide (point in the middle) which is potentially 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.

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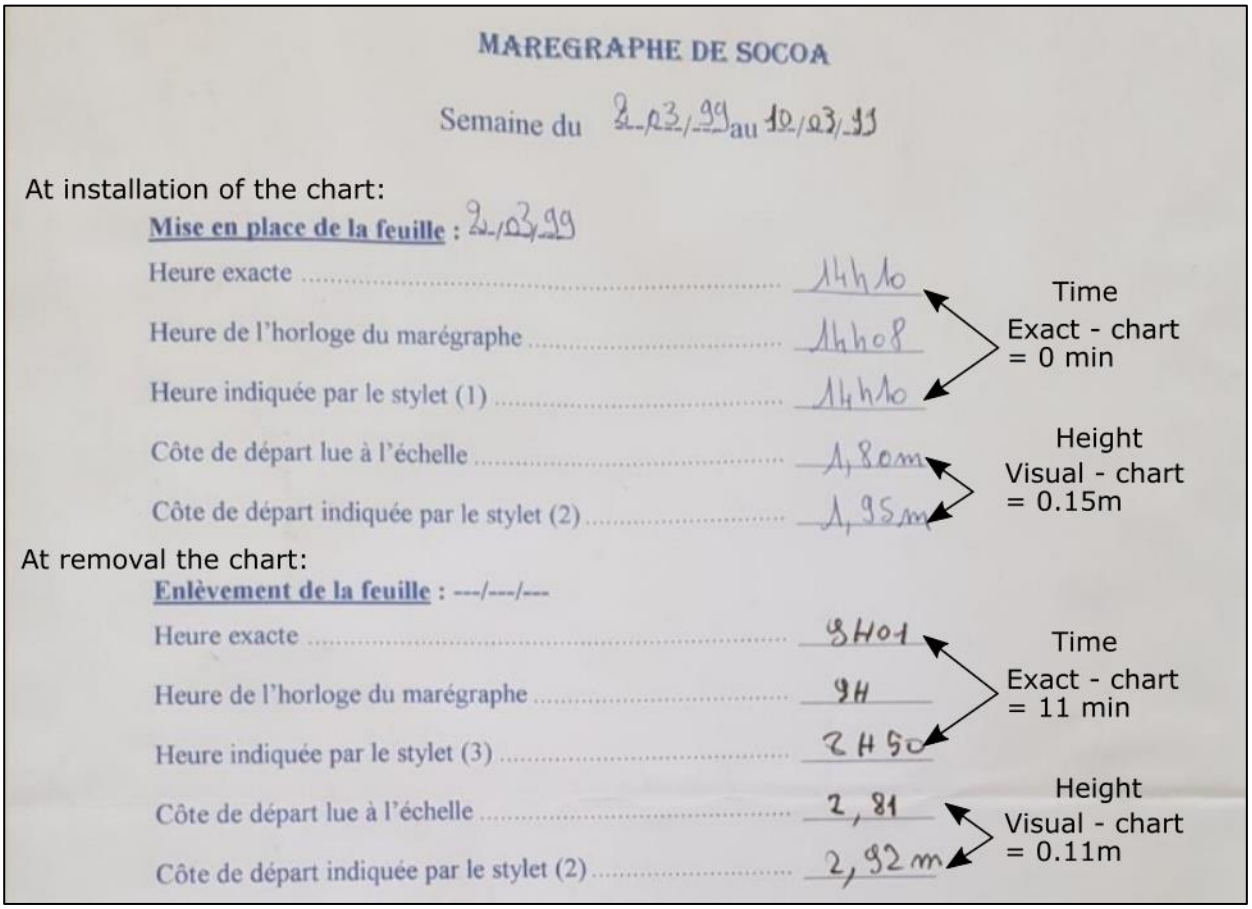

Figure S7. Example of a check sheet that shows the two anomalies that have not been corrected as it is not clear when these errors are introduced during the recording (02/03/1999 – 10/03/1999). First, an 11-minute clock delay identified during the removal of the chart, and second, a difference in height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

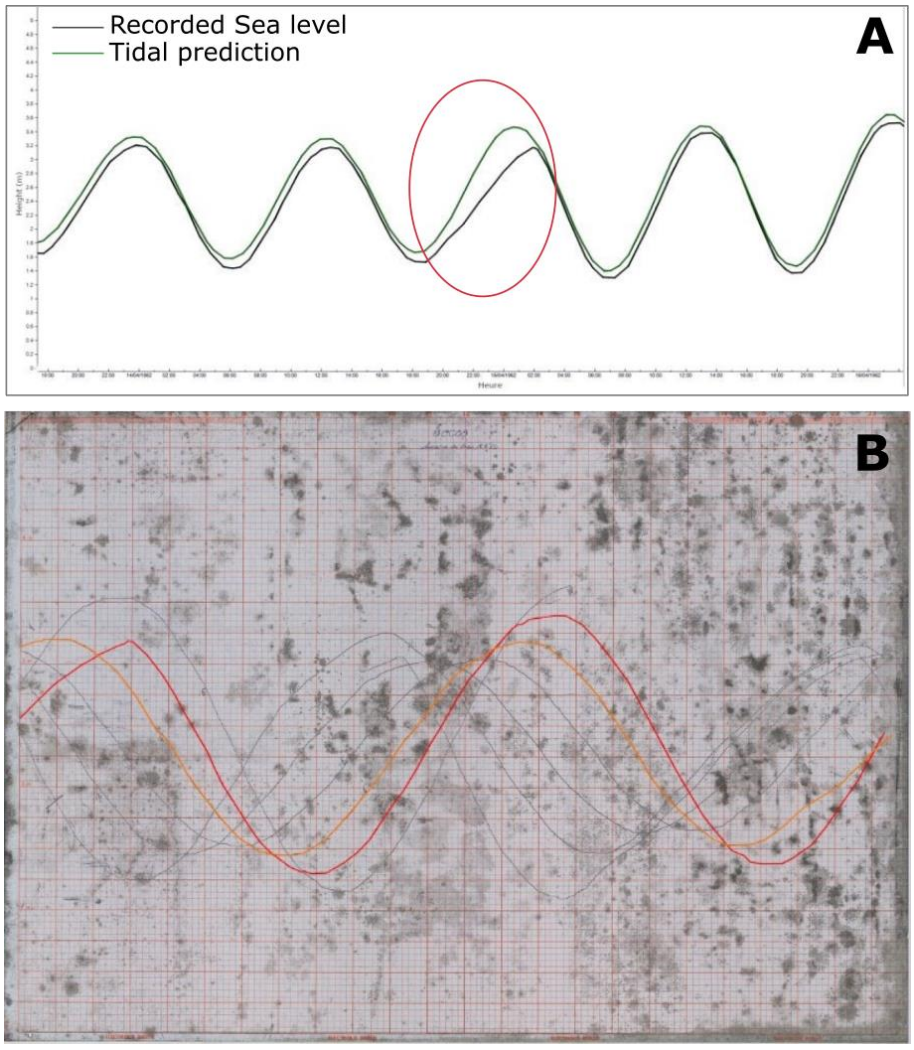

Figure S8. A) An example of linear evolution instead of sinusoidal (appears here as delayed high tide) from October 15, 1962. In black the observation and in green the tide prediction. B) The corresponding chart for A - the curve for October 14, 1962 (orange) and October 15, 1962 (red) are marked. The 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 a arithmetic mean over a calender 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.

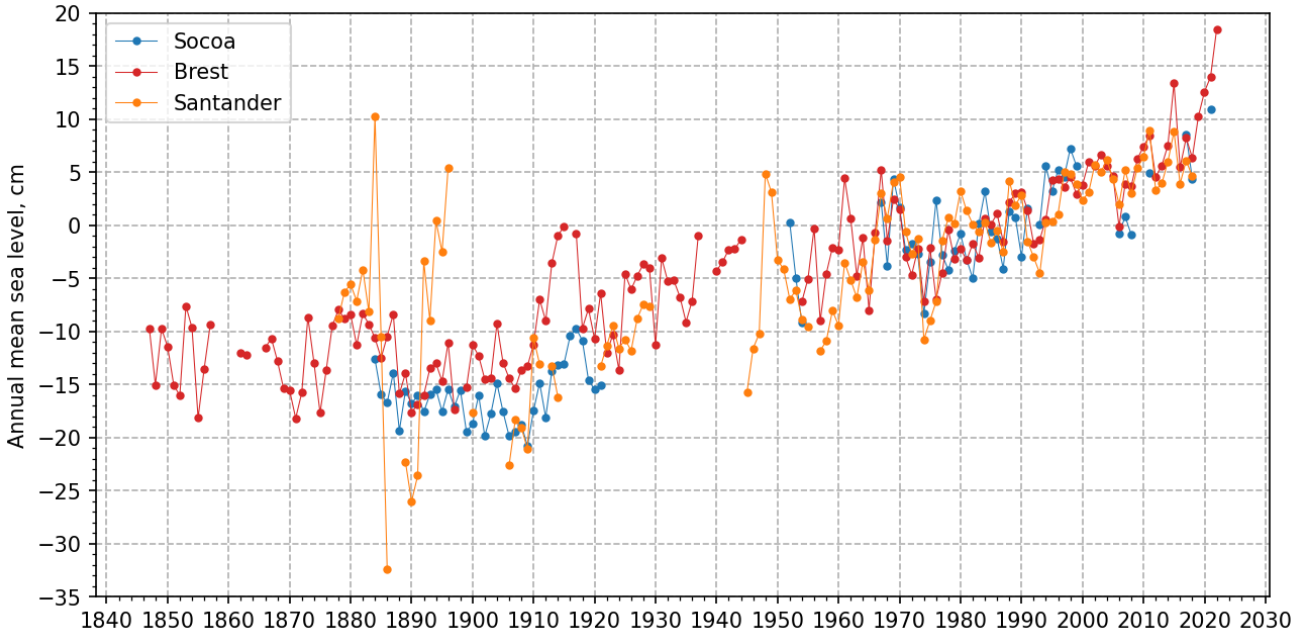

Figure S9. Annual mean sea level comparison between Brest (red), Socoa (blue), and Santander (orange). Santander data is taken from Marcos et al. (2021) provided as mean monthly values (without filtering for tide). Annual average is calculated as numerical mean value. Same processing is applied to Brest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

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.

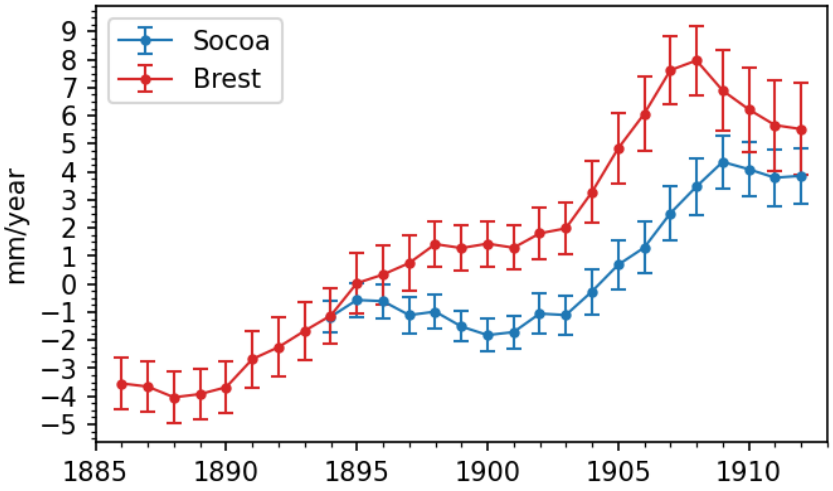

Figure S10. Running trend estimates (20-year windows) for Socoa (blue) and Brest (red) during 1875 – 1920. Error bar shows the standard error of the trend estimate

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).

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_Socoa_Notes_Registres.docx’ where YEAR is the 4-digit year.

6.2 Transcripted metadata

The excerpts of metadata documents from the various archives falls into this category of supplementary files. For 5 archives, 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_4S 33.docx’
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.
2. '02_buddy_checking.ipynb' : Presents the buddy checking analysis.
3. '03_trend_analysis.ipynb' : Presents the Trend anaysis.

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

Reference

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.