



Assessing long-term sea level evolution: the historical sea level data rescue approach



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CONTEXT

The study of global climate change and its influence on sea level variations on different time scales, whether in terms of mean sea level changes or variation in extreme events, is a current major challenge for human societies today. **Measurements made with tide gauges are basically the only available archive providing information on the evolution of the historical sea level, on the scale of past decades or even centuries.**

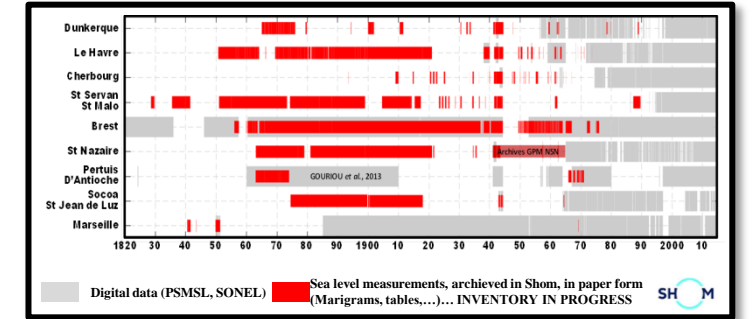
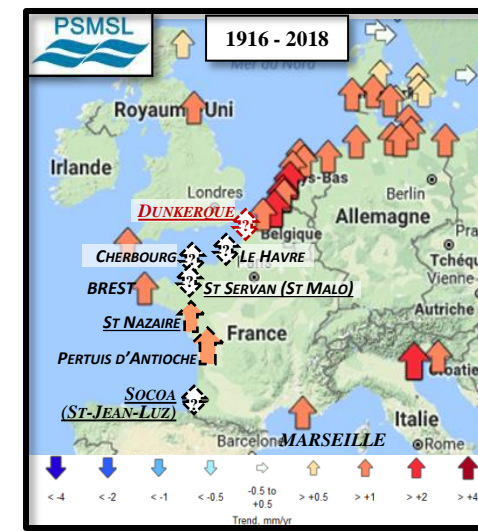
Since the middle of the 19th century, water level has been measured systematically and continuously at many sites along the French coast using tide gauges (Pouvreau, 2008). **A review of these historical sea level data shows that most of them are still in paper form and are therefore not used.**

In this context, an extensive work in sea level data rescuing is undertaken at Shom (French Hydrographic & Oceanographic Office) within the REFMAR and the SONEL frameworks. It aims at recovering the French scientific and cultural heritage on sea level observations, and providing researcher community with new datasets to analyze. This Shom/SONEL initiative fulfills the recommendations of the Global Sea Level Observing System (GLOSS, IOC/Unesco) on the recovery of forgotten sea level measurements (Bradshaw *et al.*, 2015).

An overview of the work conducted at Shom in data archeology is presented, with a particular focus on the applications in environmental assessments.

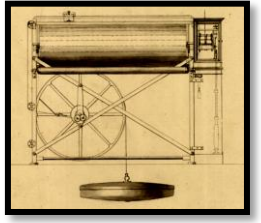
Relative sea level trends (1916-2018) in western Europe

(after <http://www.psmsl.org/products/trends/>)



Examples of sea level datasets digitally available for French historic tide gauges (SONEL, PSMSL) and illustration of the potential of the Shom paper archives (not exhaustive, inventory still in progress)

Mechanical tide gauge used since the mid-1800s along the French coast ("Chazallon's type", Shom archives)



STEPS INVOLVED IN THE HISTORICAL SEA-LEVEL DATA RESCUE

FROM PAPER DOCUMENTS ...

1. Inventory and recovery



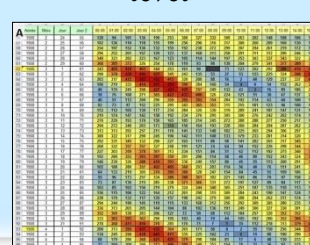
→ Several type of documents to process (tables, marigrams, metadata relative to measurements, ...)

2. Scanning process



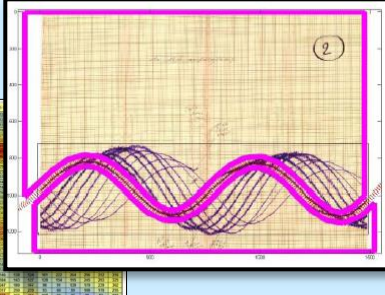
Potentially complicated depending on:
- Size of the document
- Preservation state

3. Extraction of water level

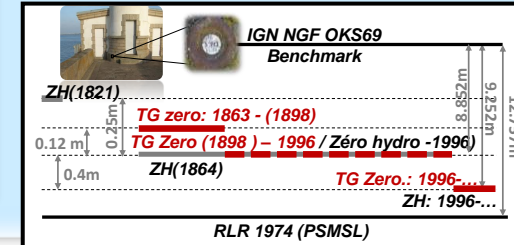


- Handwritten ledgers manually digitized
- Marigrams « automatically » digitized with the use of the NUNIEAU software (Ullman *et al.*, 2005) based on color recognition

→ DIGITAL RAW DATA



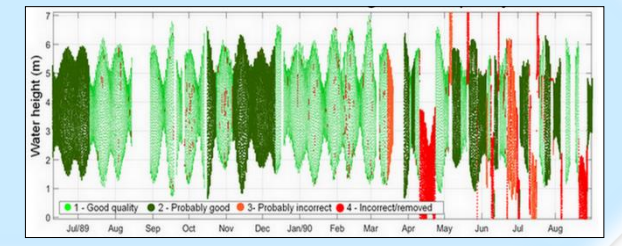
4. Vertical consistency of the sea level data



Based on the analysis of metadata linked to sea level observations: (levelling reports, technical notes, ...)

→ The knowledge of the history of the tide observatory over the time

5. Quality check, data validation



→ Quality check (spikes, consistency check, ...)
→ Buddy checking (comparison with sea level time series of nearby stations)
→ Data flagging depending on the data quality

SHOM & SONEL: ACTIONS IN DATA RESCUING

RECOVERY OF SEA LEVEL DATA: INVENTORY & DISSEMINATION

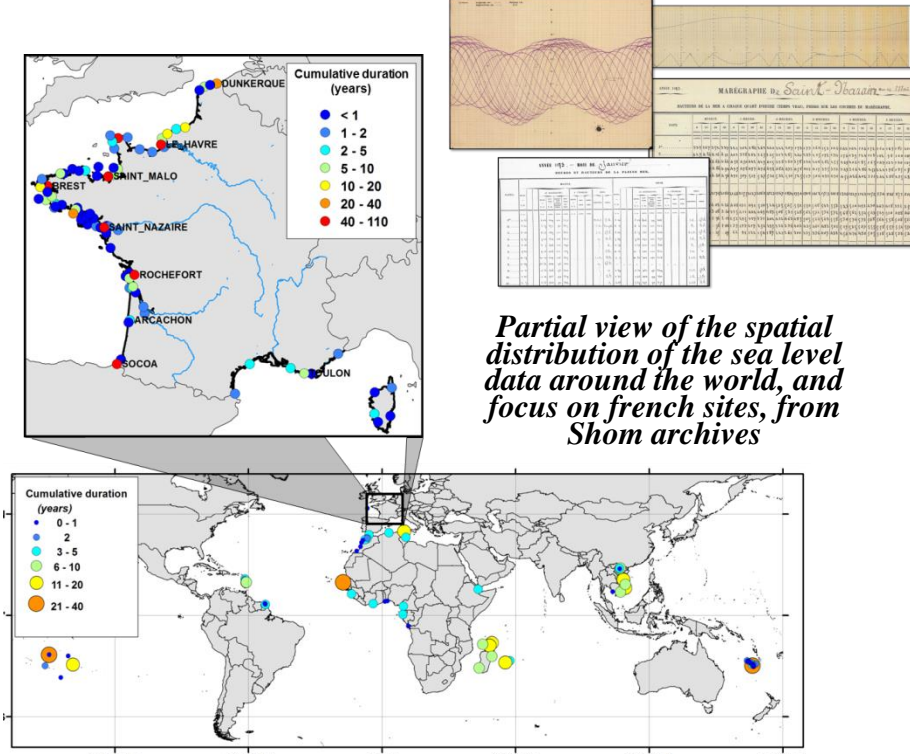
More than 60.000 documents identified, about 50 % have already been scanned... but thousands of documents to still carefully inventory/scan !

France:

- about 1.000 years of cumulated sea level measurements, ~ 300 sites
- Total duration per site ranging for few days/weeks/months (sounding reduction purpose) to several decades (longest time series: historical tide gauge network)

Around the world:

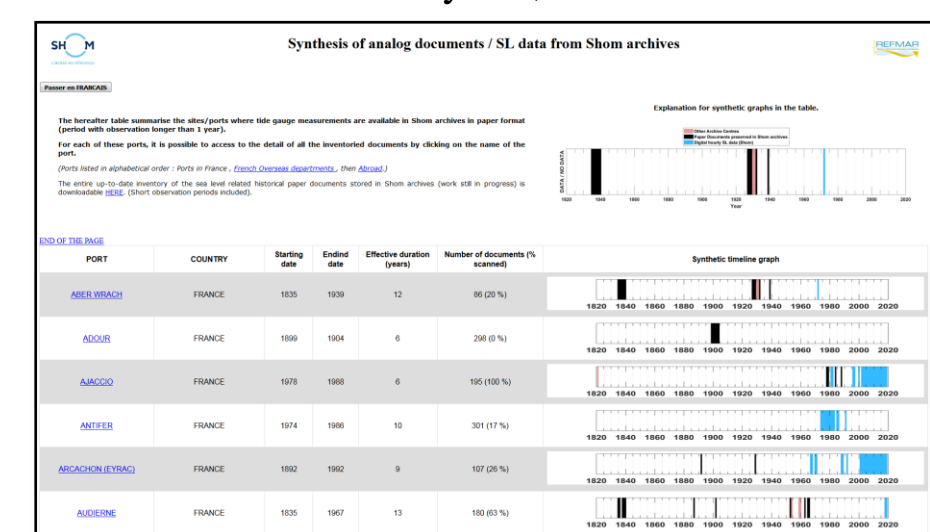
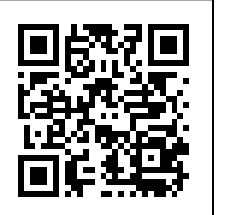
- about 470 years of cumulated sea level measurements, ~ 240 sites (mainly short duration observations, but some « long » time series)



The up-to-date inventory is visible and downloadable online (English/French):

<http://refmar.shom.fr/dataRescue>

Next steps: make it more exhaustive by including other archive centers, spatialize the data – more user-friendly use, ...

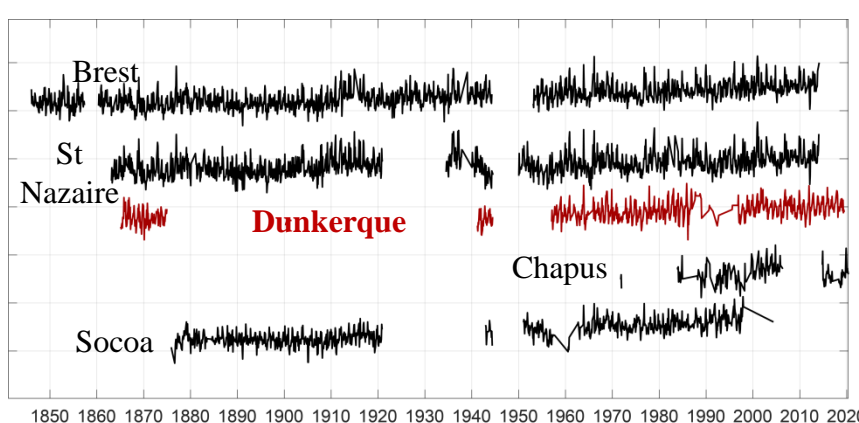


Synthesis of Sea level measurements available in Shom archives

HISTORICAL SEA-LEVEL DATA AT DUNKERQUE : EXAMPLE OF OUTCOMES

LONG-TERM SEA LEVEL EVOLUTION

Dunkerque is located on the northern coast of France. Sea level measurements are performed since 1865 allowing to assess secular sea level rise.



Monthly mean sea level time series in western Europe since mid-1800s.

Sea level trends at Dunkerque (Latapy, 2020) :

[1865-2019] period: $+0.89 \pm 0.07$ mm.yr⁻¹
[1990-2019] period: $+2.06 \pm 0.66$ mm.yr⁻¹

The extended data series provide a much richer view of long-term trends in local sea level.

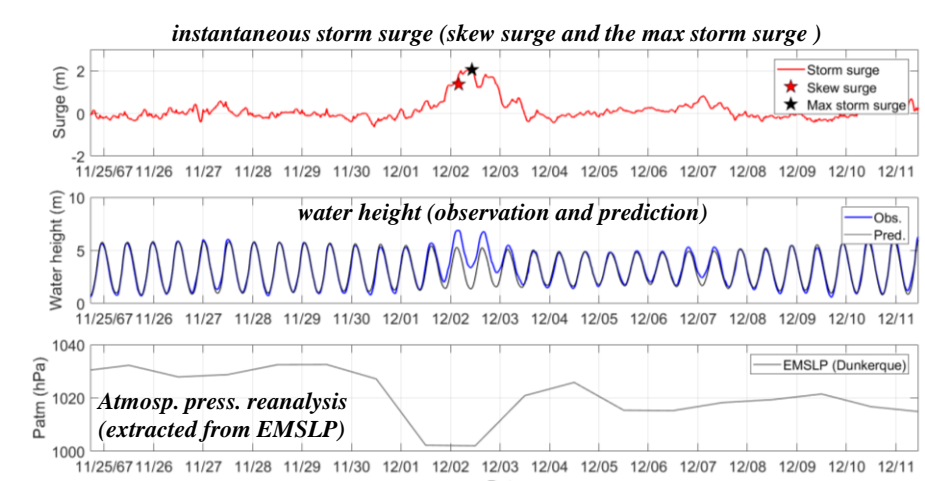
→ Assimilating historical tide gauge observations improve model results and help finding indications of anthropogenic climate change.

EXTREME EVENTS ESTIMATION IMPROVEMENT

The systematic reconstruction of these sea level series allows the rediscovery of historical storms (and quantification): the estimates of extreme levels can be improved by taking into account these forgotten extreme values (Bulteau *et al.*, 2015).

Storm events identified can be integrated into the French Data Base on Historical Storms and Floodings whose objective is to collect all types of information on historical storm and flooding events (Giloy *et al.*, 2021).

→ Contribution to numerical modeling for the secular study of extreme levels.



Storm surge, identified from the extended data series of Dunkerque, the 2nd of December 1867.

CONCLUSION / OUTLOOK

The recovery of forgotten sea level measurements is essential to improve the scientific knowledge relative to sea level. **At Shom, an important effort has been initiated to rescue these data** (detailed inventory – scanning – digitization – data qualifying).

Ongoing projects on historical sea level reconstruction in France initiated to support public policies for the prevention of marine submersion in the context of Flood Action Programs (PAPI) or erosion risks studies in coastal areas : Saint-Servan and Socoa timeseries (more information on: http://refmar.shom.fr/fr/applications_maregraphiques/programmes-projets)

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