# Brest sea-level record : a review back to the 17th century

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## INTRODUCTION

**France was a pioneer in sea-level observation recording. We owe to the astronomers J. Picard and P. de la Hire the first tidal measurements at Brest in 1679. Systematic observations started at the major ports of France in 1701 with the support of the Navy.**


Jean PICARD (1620 - 1682)

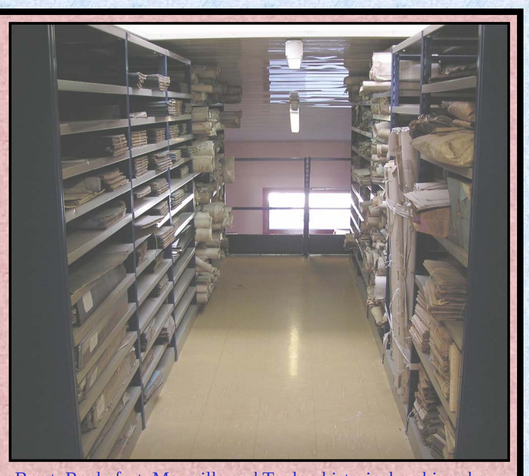
**Jean Picard and Philippe de la Hire were the forerunners of a long history of sea-level recording at Brest**


Philippe de La Hire (1640-1718)

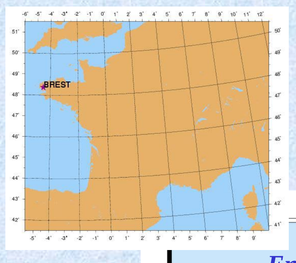
**Historical archives around France have proven to contain treasures of 'archaeological' sea level observations that would be valuable to review and analyse in the scope of recent climate sea level changes due to global warming.**

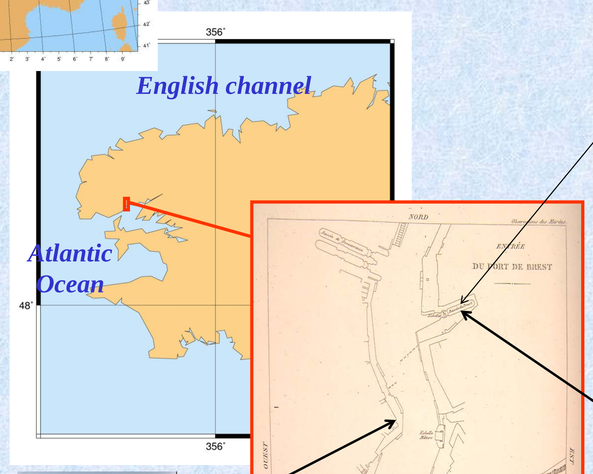
**An inventory is currently under way, and a research program focuses on the Brest sea level station.**

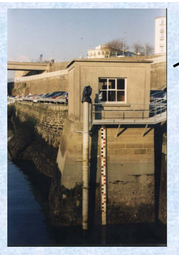
**Relevant issues are :**
- ✓ **What is the quality of the archaeological data ?**
- ✓ **How to analyse this often unusual data ?**
- ✓ **Can the old records be related to the present ones ?**


Brest, Rochefort, Marseille and Toulon historical archives have been searched so far. There are still a few centres in Paris to examine closely in order to complete the inventory.

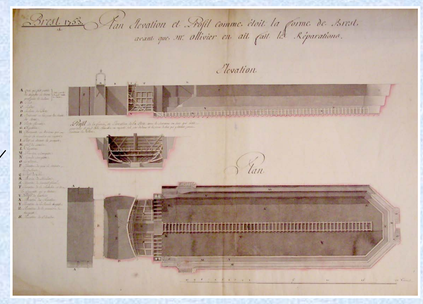
## Overview of Brest sea level records



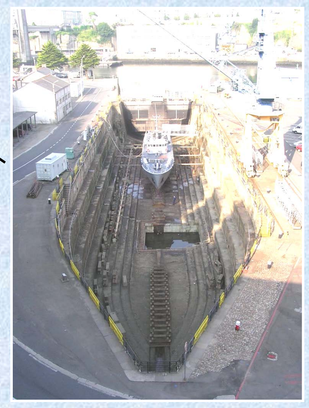



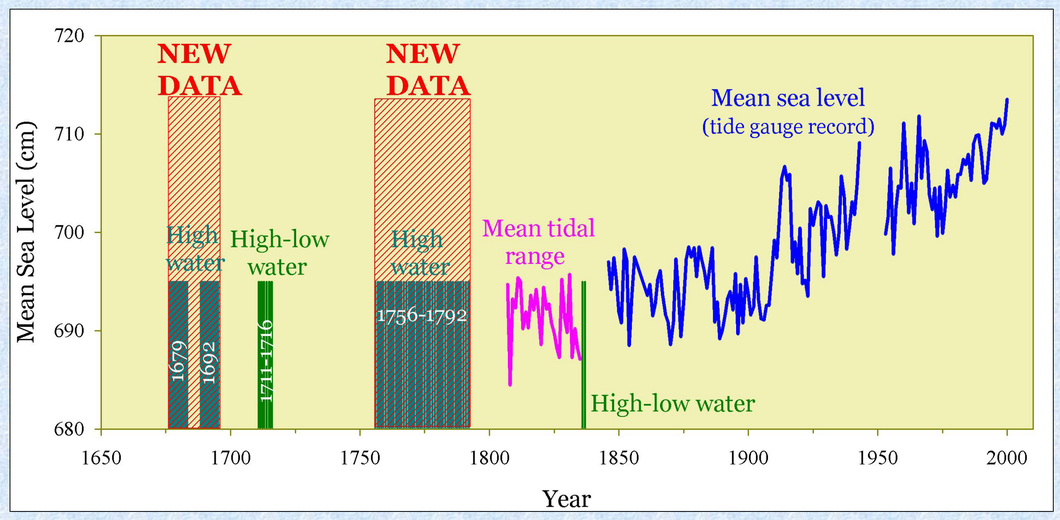
View of the current tide gauge station (tide staff and stilling well).
The continuous sea-level record, from 1807 onwards, whose data can be retrieved at PSMSL, was performed at this location, called "La mâture".




18th century records (1757 - 1792) were performed at the entrance of the *Bassin de Tourville* , which is located about 300 m from the modern record starting in 1807.

The picture above shows a sketch of this basin in 1753 century, whereas the picture below shows the structure as it is today (2004).






**What sea-level records are available ?**

The archaeological data inventory has already proven valuable. The above figure shows a comprehensive view of what is available for Brest today. Of particular interest are the newly discovered observations that cover the period 1756 - 1792 (High water levels), and the years 1810, 1812 - 1835. These early 19th century records were performed at *Bassin de Tourville*, simultaneously with the long term sea level record at la Mâture that started in 1807 and continues to this day.

**How to relate the old and the new records ?**

In order to extend the current sea level time series back to the 18th century, the link between the different datum records are required. Two leads are investigated :
- ✓ Simultaneous sea level observations at both recording sites: sea level is used as an intermediate reference
- ✓ Civil engineering documentation: tide poles were installed in such a way that their zero coincided with the bottom of the basin at the entrance.

**Basin de Tourville - Civil engineering**

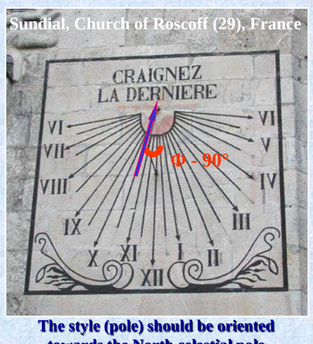
| 1683 - 1687 | 1702 | 1741 | 1783 | 1822 | 1864 - 1885 |
|---|---|---|---|---|---|
| Vauban | Engineer Robelin | Engineer Ollivier | Engineer Groignard | Engineer Pestel | Engineer Reynès |
| Basin construction | Sluice gate modfication | Terraces, sluice gate | Digging 5 French feet (1,62m) | Closing system (gates) | Extension of the basin |

## Analysis of the 1711 - 1716 data

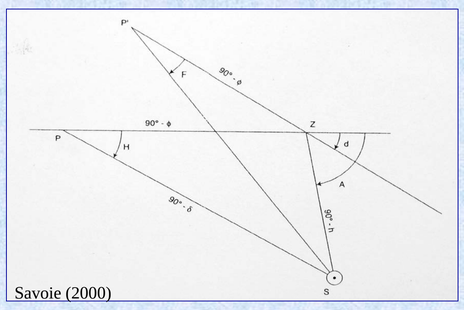
Sea-level observations prior to 1842 were performed at tide poles in France. They usually consisted of high and low water levels. An important preliminary step is to convert their observing time into a standard time system - UT.

The following time corrections have to be applied to the 1711 - 1716 records:
- ✓ Equation of time : conversion from true solar time to mean solar time
- ✓ Addition of 17.98° in longitude : conversion from mean solar time to UT
- ✓ Correction of the sundial misalignment :

Coubard (1714) discovered an error in the alignment of the sundial and stated that the correction to apply to the data prior to August 1, 1714, was -17 min.



**The style (pole) should be oriented towards the North celestial pole**



Savoie (2000)

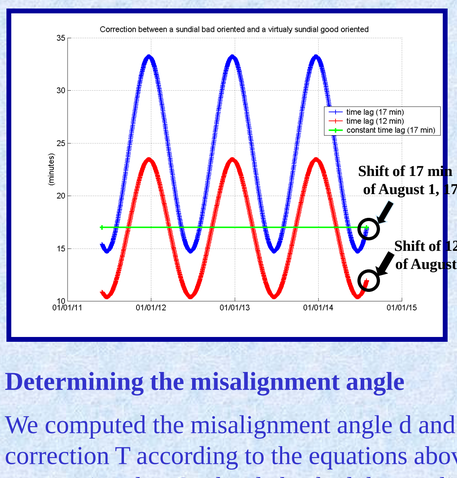
A careful investigation on sundials shows that this correction should not be a constant. As we can obtain from literature, the correction is a function of the misalignment angle and the Sun's position (see for instance Savoie, 2000).

The correction we computed according to Savoie (2000) is :

$$T = d(\cos\phi \tan\delta \cos H - \sin\phi)$$

$$\sinh = \sin\phi \sin\delta + \cos\phi \cos\delta \cos H$$

$$\tan A = \frac{\sin H}{\sin\phi \cosh - \cos\phi \tan\delta} \qquad \tan F = \frac{\sin(A-d)}{\sin\phi \cos(A-d) + \cos\phi \tanh}$$



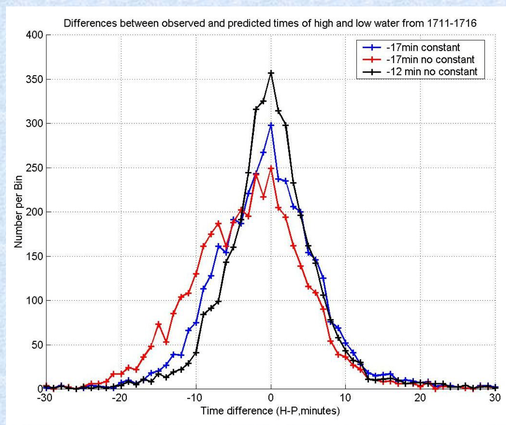

**Z** : Zenith; **S** : Sun ; **P** : true pole ; **P'** : sundial's pole (style)
**Φ** : Latitude of the site ; **δ** : Sun's declination; **A** : Sun's azimuth
**h** : Sun's height
**F** : false hour read at the sundial; **H** : true time angle ;
**T = H - F** : error angle
**D** : real gnomic variation ; **D'**: false gnomic variation ;
**d** : orientation error ( **d = D - D'** )

**Determining the misalignment angle**

We computed the misalignment angle d and the subsequent correction T according to the equations above and with the assumption that Coubard checked the sundial on August 1, 1714 (17 min).

An analysis of the time residuals between predicted and observed high and low water levels shows that the constant correction of 17 minutes leads to a more accurate distribution (blue curve on the right figure) than our correction (red curve on the right figure).

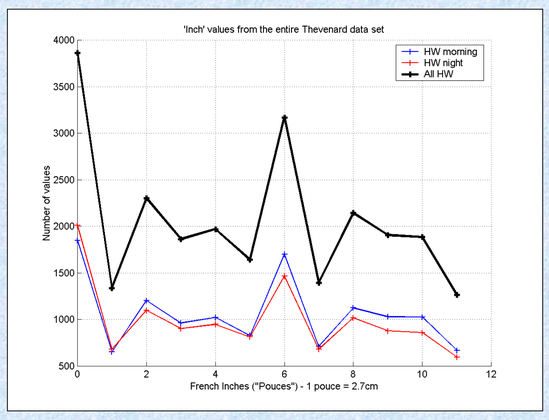
After several tests the best distribution of the time residuals has been found to be a correction of 12 min corresponding to a misalignment angle of 8.04° (black curve on the right figure). The figure above explains why.

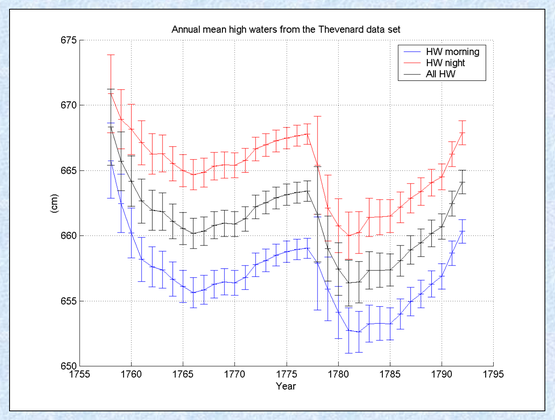



## Data quality of 1757 - 1792 records

The 1757 - 1778 records were discovered only 3 weeks ago. It completes the 1778 - 1792 records discovered in 2000. Digitisation has just been completed.

Very preliminary analysis have been performed in order to get a rough first idea of the quality of this data.
The left figure shows the distribution of 'inch' values of the feet and inch measurements for the entire data set. It provides an idea of the rounding of the heights and the subsequent uncertainties related to these measurements.

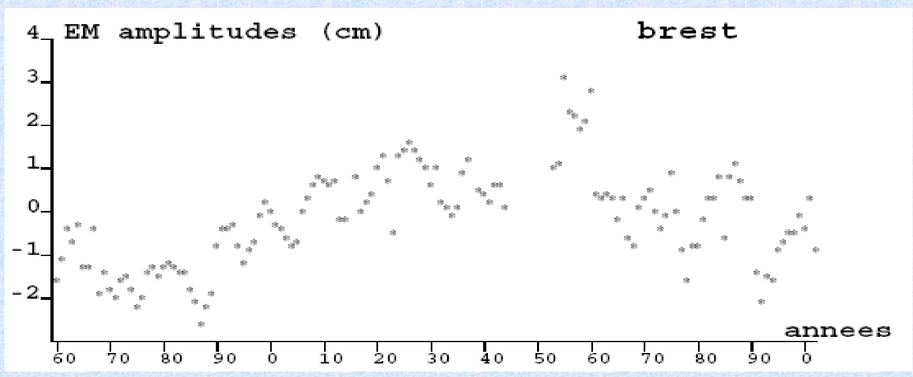



## Secular evolution of tidal constituents

**Has the tidal regime changed over centuries at Brest ?**

The question whether tidal constituents have changed in amplitude and/or in phase over time has been risen by Cartwright in 1972. His analysis of Brest data up to 1960 suggests that the observed amplitude of $M_2$ has decreased. This is confirmed by our analysis (see figure below).
However, the amplitude of the semi-diurnal constituents increases after 1960. Moreover, one may see a periodic variation of about 150 years, which is valid tidal period : twice the period of the lunar perigee and the ascending node of the Moon. Extending the time series back in the 18th century would certainly provide valuable insights on this question.




The figure above shows the predicted (tidal analysis over the whole period) minus the year to year mean of observed amplitude of the semi-diurnal group of tidal constituents.

Supporting institutions

Colloquium in Honour and in Memory of Christian Le Provost

Toulouse,
March 10 - 11, 2005