

Historical tide-gauge sea-level observations in Alicante and Santander (Spain) since the 19th century

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Spanish sea level historical archives at IGN

Sea-level records stored in logbooks are archived at the IGN headquarters. This work is a new effort to recover and quality-control two of the longest and most relevant (in red)

~140 years

| Historical data sets | First year of data |
|------------------------|--------------------|
| Alicante I | 1874 |
| Alicante II | 1957 |
| Almería | 1972 |
| Cartagena | 1927 |
| Ceuta | 1908 |
| Cádiz | 1880 |
| Coruña | 1950 |
| Santander | 1876 |
| Santa Cruz de Tenerife | 1927 |

~49 years



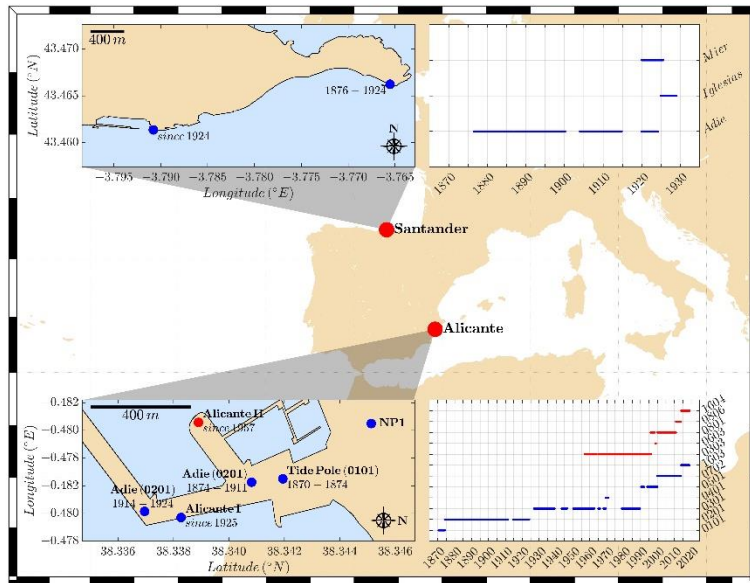
Marcos et al (2011)
doi:10.1029/2011JC007558



Marcos et al (2013)
doi:10.1002/jgrc.20377

Two new tide gauge stations recovered from archives at IGN (Spain)

Location and time span of the new sea-level time series



Example of hand-written logbooks for one month of data in Santander

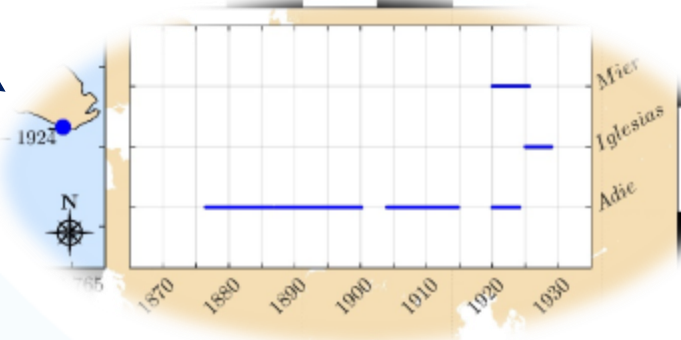
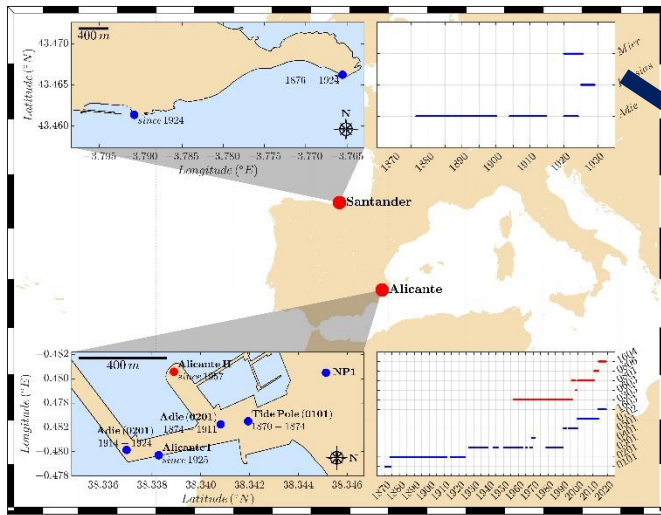
Mes de *Abril* de 18*22* Mareógrafo de *Santander*

| Día | Horas | Altura mínima | Altura máxima | Superficie | Tiempo empleado | Gravete | Área de referencia | Suma |
|-----|-------|---------------|---------------|------------|-----------------|---------|--------------------|------|
| 1 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |
| 2 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |
| 3 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |
| 4 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |
| 5 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |
| 6 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |
| 7 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |
| 8 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |
| 9 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |
| 10 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |
| 11 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |
| 12 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |
| 13 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |
| 14 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |
| 15 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |
| 16 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |
| 17 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |
| 18 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |
| 19 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |
| 20 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |
| 21 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |
| 22 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |
| 23 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |
| 24 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |
| 25 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |
| 26 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |
| 27 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |
| 28 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |
| 29 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |
| 30 | 1.5.7 | 1.1 | 0.1 | 1.0 | 1.2 | 0.1 | 0.1 | 0.1 |

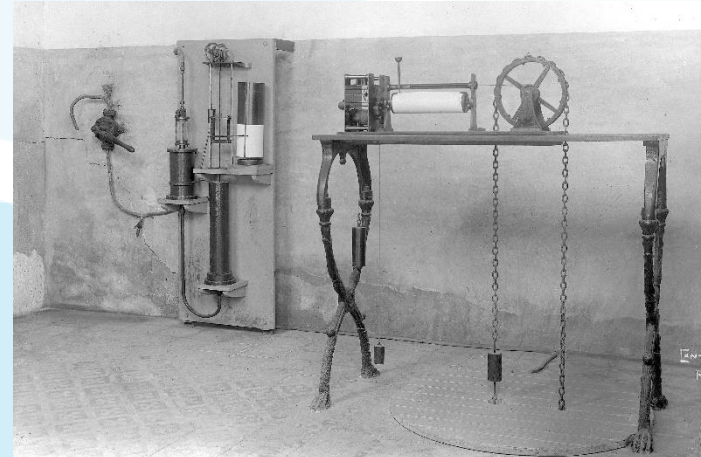
| Día | Horas | Altura mínima | Altura máxima | Oscilación | Altura media | Estado del mar |
|-----|-------|---------------|---------------|------------|--------------|-----------------------|
| 1 | 1.5.7 | 1.1 | 7.37.15 | 0.3 | 1.6 | 5.5.0.5.5.1.5.6.2.7.7 |
| 2 | 1.5.7 | 1.1 | 7.37.22 | 1.2 | 1.5 | 5.5.0.5.5.7.2.6.0.8.5 |
| 3 | 1.5.7 | 1.1 | 7.37.11.5 | 1.5 | 1.6 | 6.9.7.9.5.5.1.1.5 |
| 4 | 1.5.7 | 1.1 | 7.37.5.9 | 1.3 | 1.0 | 6.7.7.6.2.6.3.7.0.5.2 |
| 5 | 1.5.7 | 1.1 | 7.37.2.0 | 1.6 | 1.1 | 6.6.7.7.6.6.6.2.6.0.9 |
| 6 | 1.5.7 | 1.1 | 7.37.2.6 | 1.7 | 1.0 | 6.7.7.7.2.6.6.6.5.6.6 |
| 7 | 1.5.7 | 1.1 | 7.37.3.8 | 1.6 | 1.0 | 6.8.7.7.5.2.6.6.6.8.6 |
| 8 | 1.5.7 | 1.1 | 7.37.4.1 | 1.6 | 1.0 | 6.8.7.7.5.2.6.6.6.8.6 |
| 9 | 1.5.7 | 1.1 | 7.37.4.1 | 1.6 | 1.0 | 6.8.7.7.5.2.6.6.6.8.6 |
| 10 | 1.5.7 | 1.1 | 7.37.4.1 | 1.6 | 1.0 | 6.8.7.7.5.2.6.6.6.8.6 |
| 11 | 1.5.7 | 1.1 | 7.37.4.1 | 1.6 | 1.0 | 6.8.7.7.5.2.6.6.6.8.6 |
| 12 | 1.5.7 | 1.1 | 7.37.4.1 | 1.6 | 1.0 | 6.8.7.7.5.2.6.6.6.8.6 |
| 13 | 1.5.7 | 1.1 | 7.37.4.1 | 1.6 | 1.0 | 6.8.7.7.5.2.6.6.6.8.6 |
| 14 | 1.5.7 | 1.1 | 7.37.4.1 | 1.6 | 1.0 | 6.8.7.7.5.2.6.6.6.8.6 |
| 15 | 1.5.7 | 1.1 | 7.37.4.1 | 1.6 | 1.0 | 6.8.7.7.5.2.6.6.6.8.6 |
| 16 | 1.5.7 | 1.1 | 7.37.4.1 | 1.6 | 1.0 | 6.8.7.7.5.2.6.6.6.8.6 |
| 17 | 1.5.7 | 1.1 | 7.37.4.1 | 1.6 | 1.0 | 6.8.7.7.5.2.6.6.6.8.6 |
| 18 | 1.5.7 | 1.1 | 7.37.4.1 | 1.6 | 1.0 | 6.8.7.7.5.2.6.6.6.8.6 |
| 19 | 1.5.7 | 1.1 | 7.37.4.1 | 1.6 | 1.0 | 6.8.7.7.5.2.6.6.6.8.6 |
| 20 | 1.5.7 | 1.1 | 7.37.4.1 | 1.6 | 1.0 | 6.8.7.7.5.2.6.6.6.8.6 |
| 21 | 1.5.7 | 1.1 | 7.37.4.1 | 1.6 | 1.0 | 6.8.7.7.5.2.6.6.6.8.6 |
| 22 | 1.5.7 | 1.1 | 7.37.4.1 | 1.6 | 1.0 | 6.8.7.7.5.2.6.6.6.8.6 |
| 23 | 1.5.7 | 1.1 | 7.37.4.1 | 1.6 | 1.0 | 6.8.7.7.5.2.6.6.6.8.6 |
| 24 | 1.5.7 | 1.1 | 7.37.4.1 | 1.6 | 1.0 | 6.8.7.7.5.2.6.6.6.8.6 |
| 25 | 1.5.7 | 1.1 | 7.37.4.1 | 1.6 | 1.0 | 6.8.7.7.5.2.6.6.6.8.6 |
| 26 | 1.5.7 | 1.1 | 7.37.4.1 | 1.6 | 1.0 | 6.8.7.7.5.2.6.6.6.8.6 |
| 27 | 1.5.7 | 1.1 | 7.37.4.1 | 1.6 | 1.0 | 6.8.7.7.5.2.6.6.6.8.6 |
| 28 | 1.5.7 | 1.1 | 7.37.4.1 | 1.6 | 1.0 | 6.8.7.7.5.2.6.6.6.8.6 |
| 29 | 1.5.7 | 1.1 | 7.37.4.1 | 1.6 | 1.0 | 6.8.7.7.5.2.6.6.6.8.6 |
| 30 | 1.5.7 | 1.1 | 7.37.4.1 | 1.6 | 1.0 | 6.8.7.7.5.2.6.6.6.8.6 |

Francisco Galera *Ant. del Villar*

Santander tide gauge 1876-1924



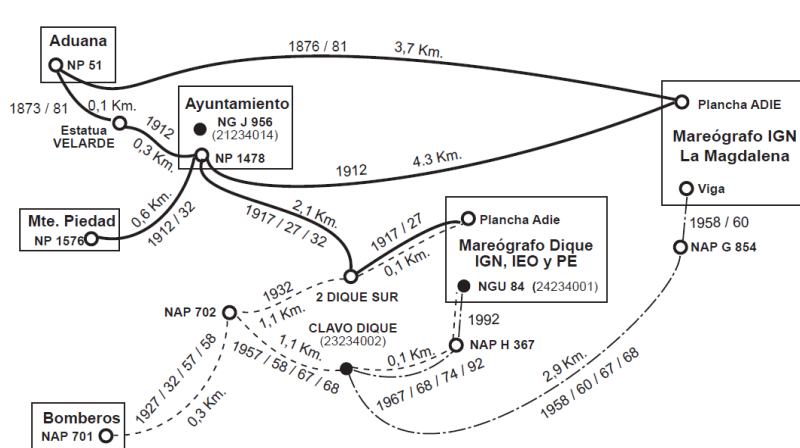
| Tide gauge type/name | Period of operation | Temporal sampling |
|-------------------------|-----------------------------|-------------------|
| Adie (floating gauge) | 07/1876-1914 and 1920-1924. | Daily averages |
| Mier (syphon gauge) | 01/1920-07/1925 | Daily averages |
| Iglesias (syphon gauge) | 01/1925-12/1928 | Daily averages |



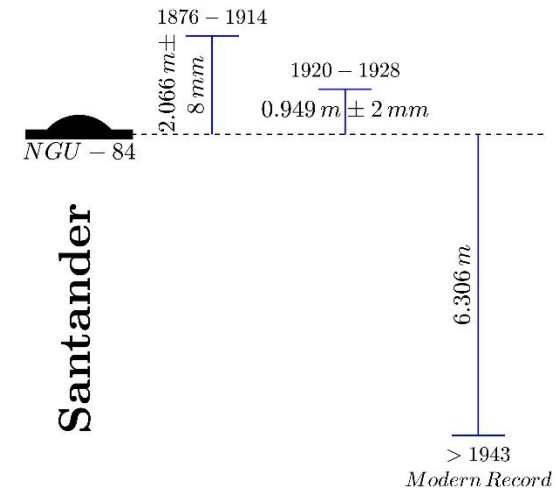
Santander tide gauge 1876-1924

High-precision levelling surveys in the vicinity of the tide gauges have been carefully investigated to provide the vertical distances among the benchmarks as well as their displacements over time

Schematic view of the levelling surveys



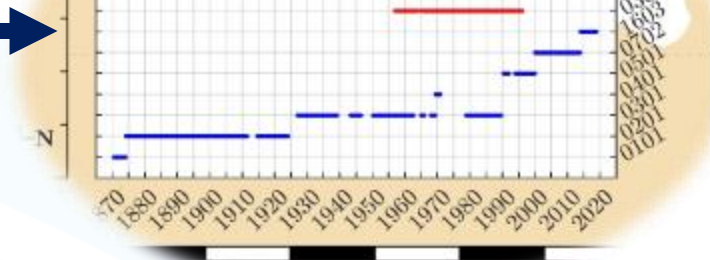
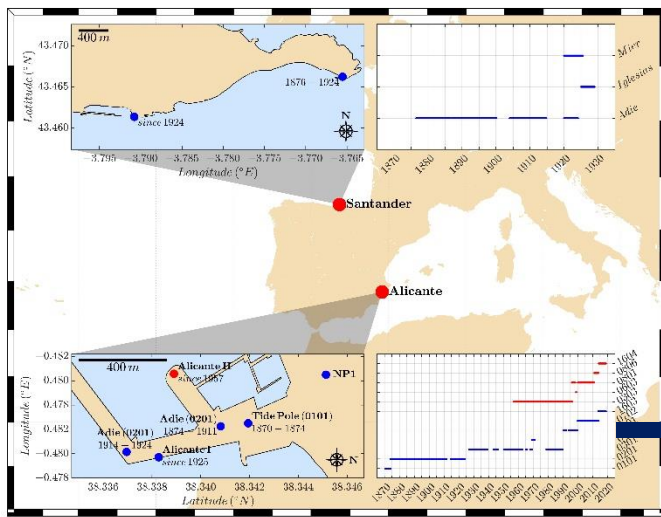
Final result of the tide gauge benchmarks for every instrument, location and period



Alicante tide gauges

Since 1870 (I)

Since 1957 (II)



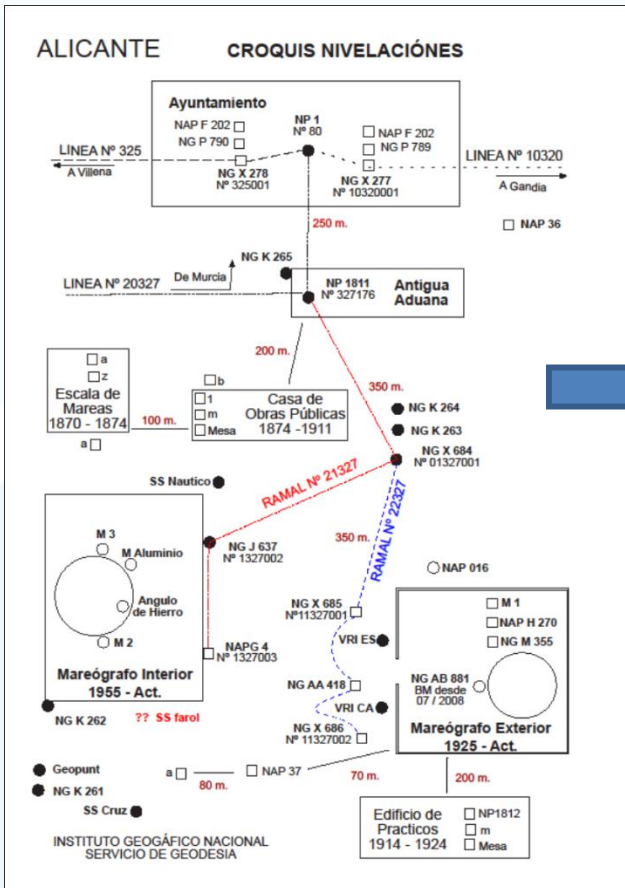
| Type of tide gauge | Period | Temporal sampling |
|--------------------|------------------------|-------------------|
| Tide pole | 1870-1874 | 4-daily |
| Adie | 1874-1911 1914-1924 | Daily averages |
| Thomson | 1927-1989 | Hourly |
| Others | Since then | Provided hourly |

Alicante tide gauges

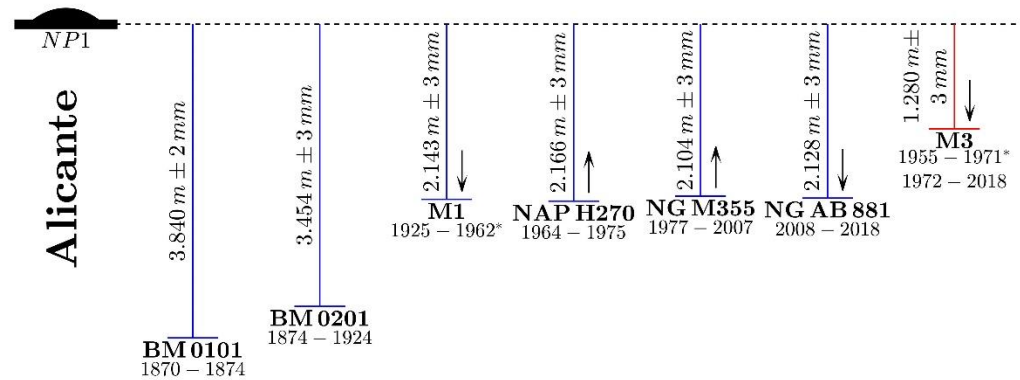
Since 1870 (I)

Since 1957 (II)

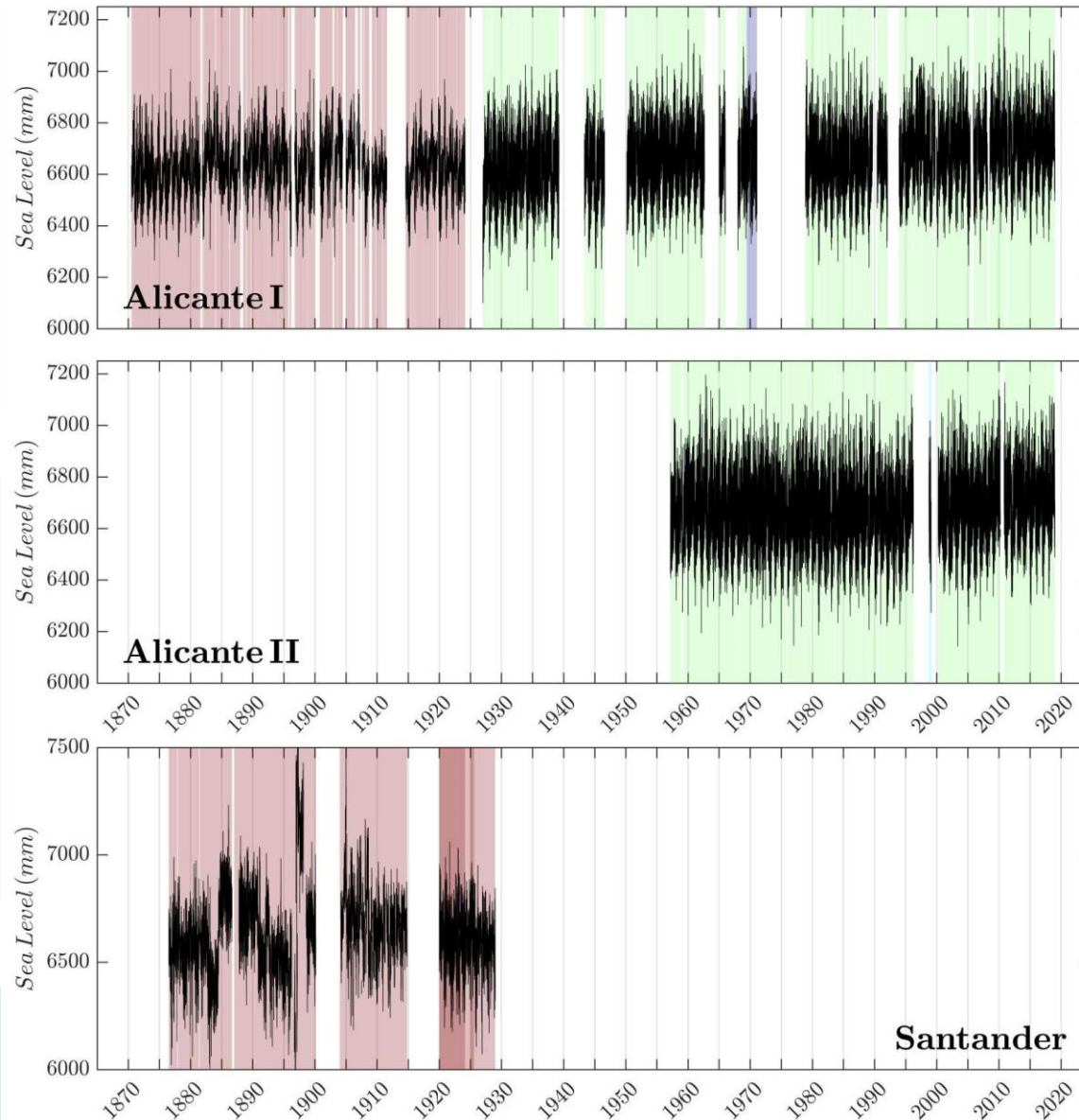
Schematic view of the levelling surveys



Final result of the tide gauge benchmarks for every instrument, location and period

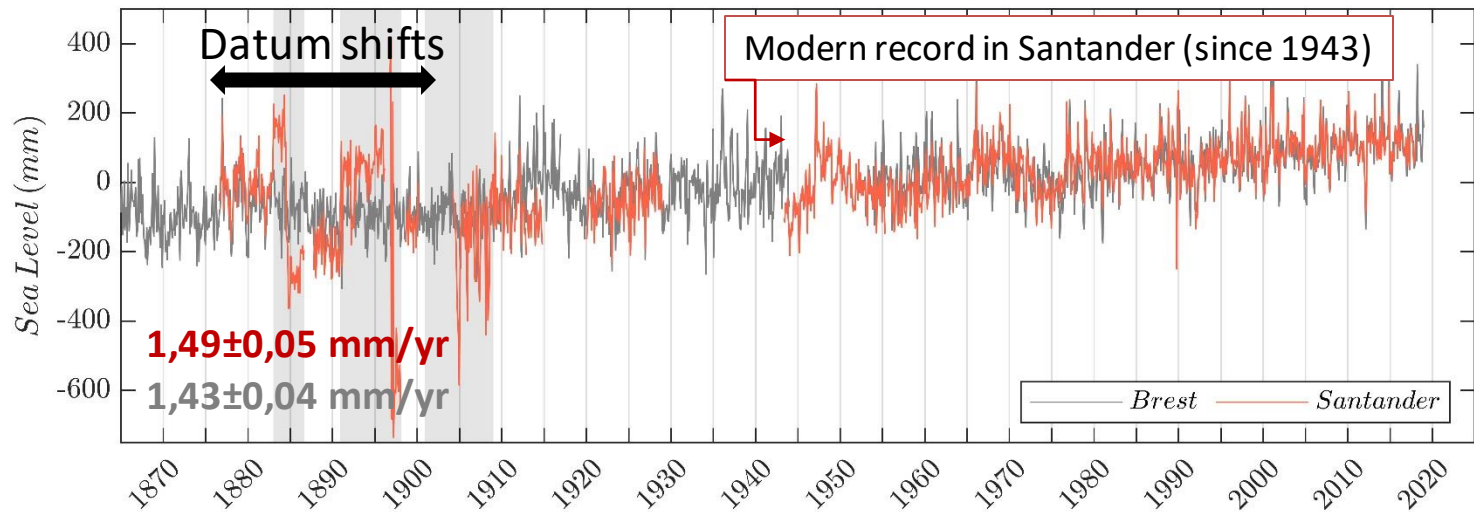
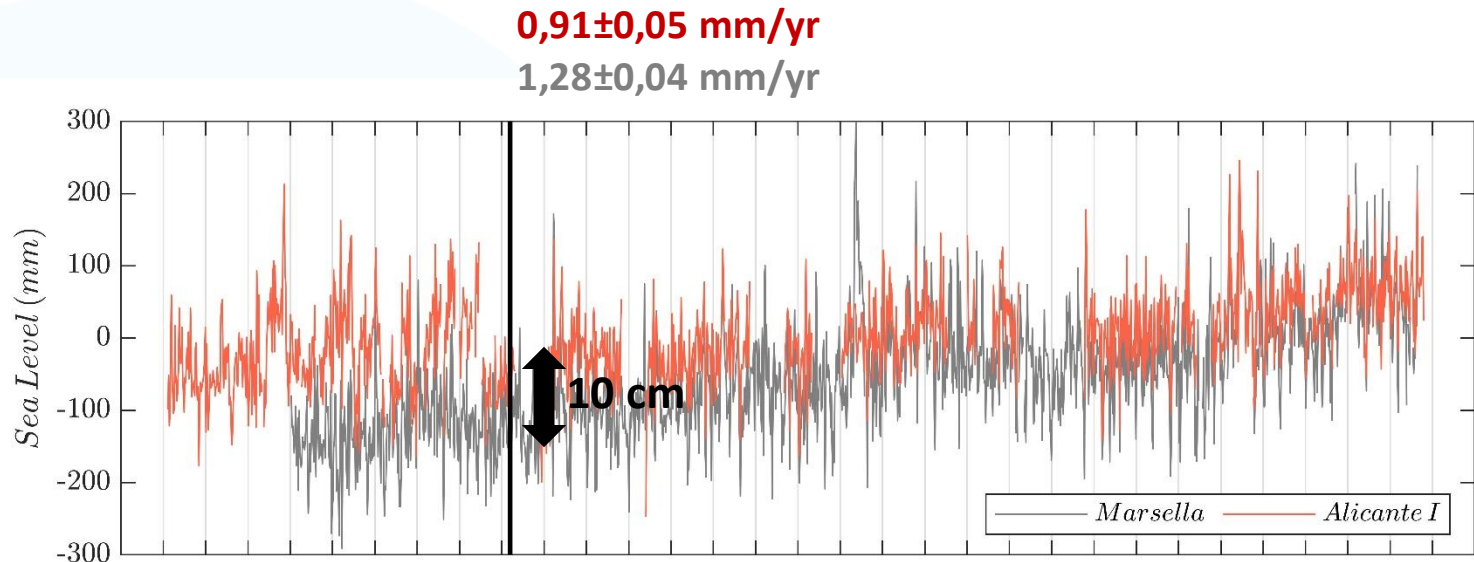


Merged tide gauge records (with levelling corrections applied)



Sea level time series in Alicante I, Alicante II and Santander, with their original temporal sampling. Shaded colours indicate changes in the sampling. Note that vertical scales in Santander (lower panel) are different from those in Alicante.

Buddy checking with other long records in the same regions



Final Remarks

- This work completes efforts carried out during the last decade to rescue the historical tide gauge data set archived for decades in logbooks at the IGN headquarters in Madrid.
- Two new merged high-frequency (hourly to daily) sea level records dating back to the 19th century are made publicly available. Both are regularly updated by their current operators.
- A caution note: despite making use of all available levelling information, some doubts remain about the datum continuity of the time series. Anomalous periods and linear trends become evident when comparing with nearby sea-level records.