Intergovernmental Oceanographic Commission

17th Session of the Group of Experts of the Global Sea Level Observing System (GLOSS)

7-10 November 2022, Paris, France

Instituto Hidrográfico | Dora Carinhas

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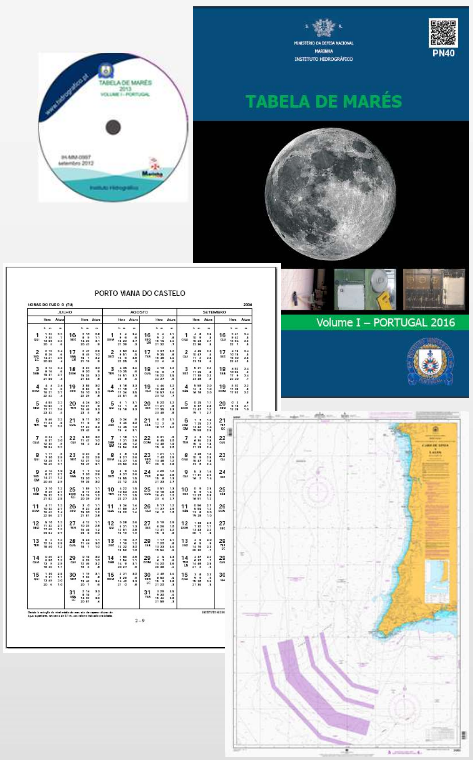
Mission of the Hydrographic Institute - Tides

- ✓ Manage and maintain the network of tide observations in the national territory to continuously monitor the tide on the portuguese coast;
- ✓ Acquire, process and publish information relating to tides and carry out studies in the scope of phenomena that influence oceanic, coastal and estuarine tides, to support entities with responsibilities in the management of portuguese coastal zones;
- ✓ Prepare Tide Tables for national ports (Vol I) and for ports in Portuguese-speaking African countries (Vol II);
- ✓ Acquire, process and publish information relating to tidal currents, to support and update nautical cartography.



Partnerships and Cooperation

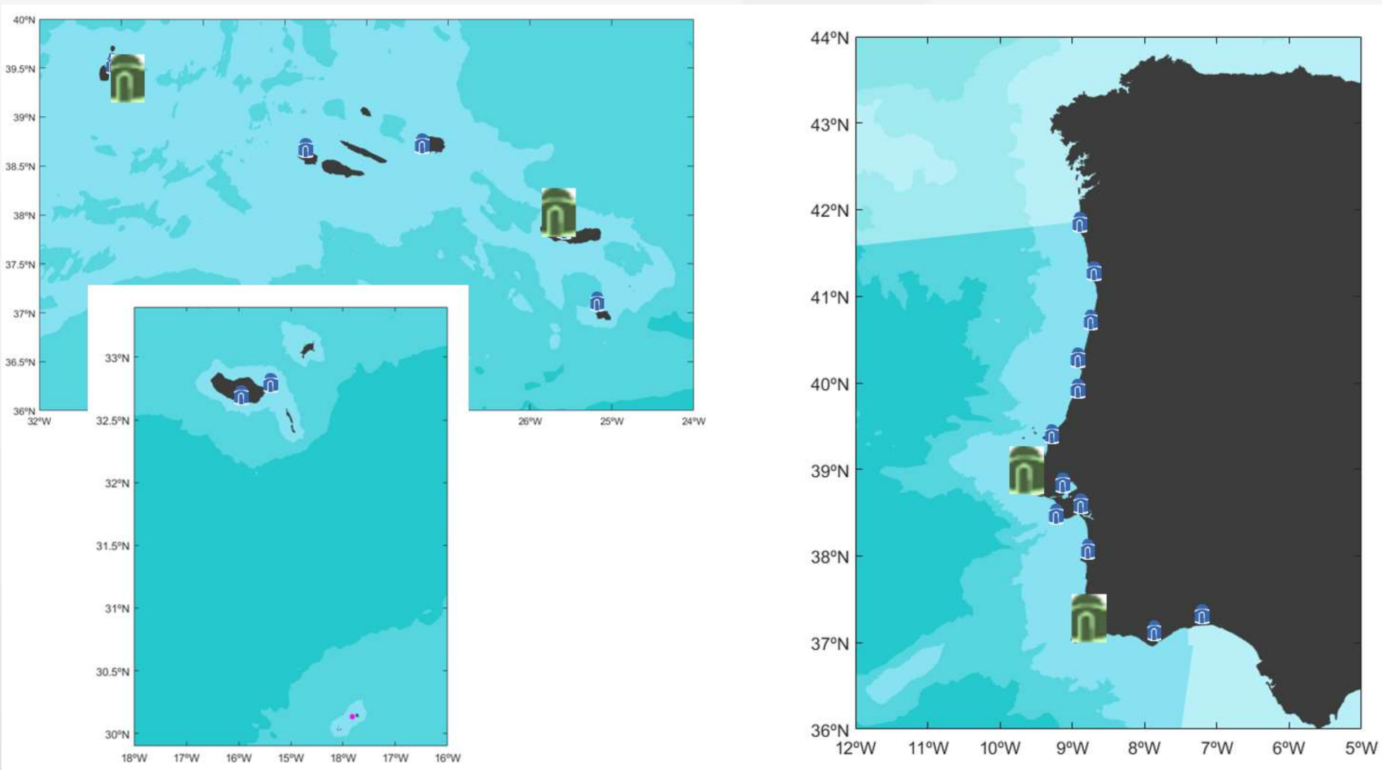
- ✓ Participation in the working group on Investigation, Monitoring and Early Warning to Tsunamis (GT-IMAT), within the scope of the Portuguese Committee for the International Oceanographic Commission (IOC):

- ✓ Participation in the Tidal and Water Level Working Group (TWLWG) of the International Hydrographic Organization (IHO) ;

- ✓ Cooperation with *Global Sea Level Observing System* (GLOSS) and *Permanent Service for Mean Sea Level* (PSMSL)

- ✓ Participation in the EuroGOOS Tide Gauge Task Team, a group that compiles information about the existing networks of tide stations and advises operators and the scientific community for an improved and sustained system.

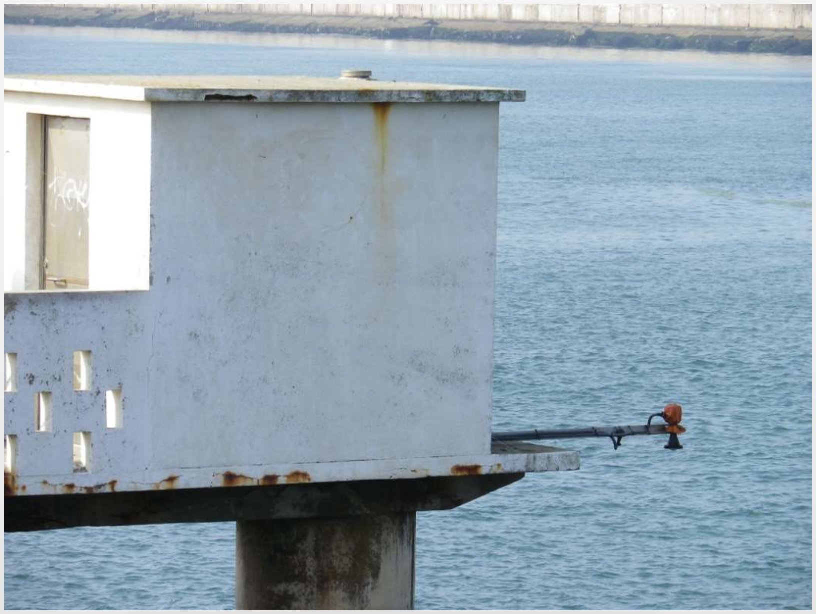
Portuguese tide network:



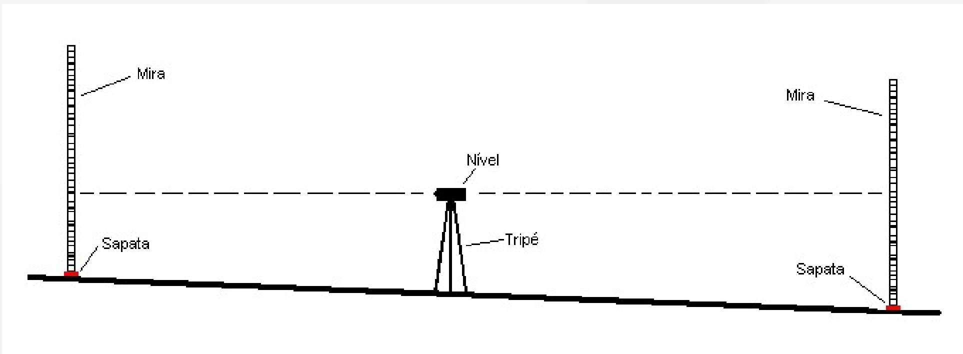
- ✓ The Portuguese tide gauge network is made up of 21 tide stations;
- ✓ with data reception in near-real time, and most stations have more than one tide gauge... with the aim of having redundancy in measurements.

GLOSS stations

Tide gauge with radar sensor:



Vertical Control - Geometric Leveling



- ✓ In a coastal installation, access is made by land, which allows the visit of the responsible persons with some frequency, as well as the establishment of a strict vertical control through the transport, to the tide gauge station, of the quotas of leveling marks of the network general of the country.
- ✓ The leveling marks must be at least 3: one main next to the installation and two further away in order to allow verification levelling.
- ✓ There must be several brands to confirm each other, that is, to know which specific area was slaughtered or not in a certain place.
- ✓ The IH links the DGT marks to the tide station, placing its own marks on these sections.

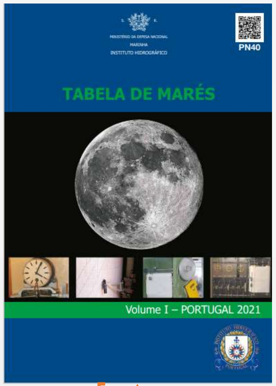
Data flow

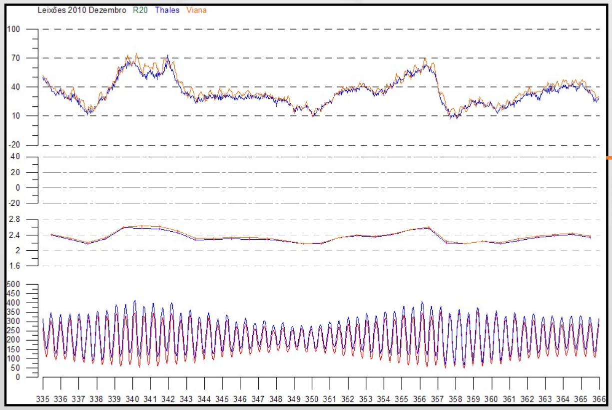
- Interpolation (gaps);
- Compare predictions with observations;
- Compare observations between neighboring tide gauges;
- Elimination of "outliers";
- Analysis in time and frequency;
- Mean level analysis.

2013-07-12	09:11:26	1.6415
2013-07-12	09:10:26	1.6590
2013-07-12	09:09:26	1.5715
2013-07-12	09:08:26	1.6975
2013-07-12	09:07:26	1.6100
2013-07-12	09:06:26	1.6765
2013-07-12	09:05:26	1.7255
2013-07-12	09:04:26	1.7220
2013-07-12	09:03:26	1.6730
2013-07-12	09:02:26	1.7220
2013-07-12	09:01:26	1.7500
2013-07-12	09:00:26	1.7360
2013-07-12	08:59:26	1.7045
2013-07-12	08:58:26	1.8760

September 2021

Time	Alt(m)	QAlt
2021-09-09 16:15:00	4.1242	2
2021-09-09 16:16:00	4.2620	2
2021-09-09 16:17:00	4.1415	2
2021-09-09 16:18:00	4.2047	2
2021-09-09 16:19:00	4.2445	2
2021-09-09 16:20:00	4.1824	2
2021-09-09 16:21:00	4.1860	2
2021-09-09 16:22:00	4.1579	2
2021-09-09 16:23:00	4.1752	2
2021-09-09 16:24:00	4.2302	2
2021-09-09 16:25:00	4.3059	4
2021-09-09 16:26:00	4.4154	4
2021-09-09 16:27:00	4.1785	2
2021-09-09 16:28:00	4.1377	2
2021-09-09 16:29:00	4.2110	2
2021-09-09 16:30:00	4.4199	4
2021-09-09 16:31:00	4.3830	4
2021-09-09 16:32:00	4.3618	4
2021-09-09 16:33:00	3.9923	1
2021-09-09 16:34:00	4.0049	1
2021-09-09 16:35:00	4.0689	2
2021-09-09 16:36:00	4.0382	1
2021-09-09 16:37:00	4.3286	4
2021-09-09 16:38:00	4.0148	1
2021-09-09 16:39:00	3.9777	1
2021-09-09 16:40:00	3.9703	1





- Harmonic constants;
- Non-harmonic constants;
- Tidal predictions;
- Mean sea levels (daily, monthly, yearly);
- Tidal elements;
- Extreme analysis.

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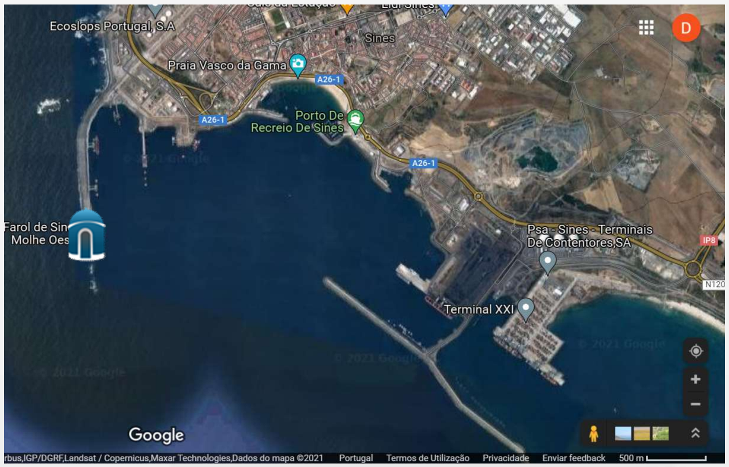
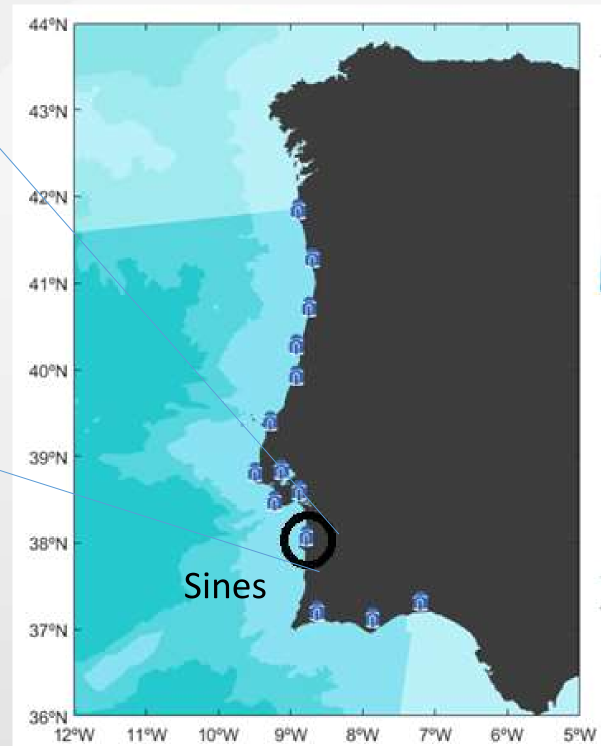
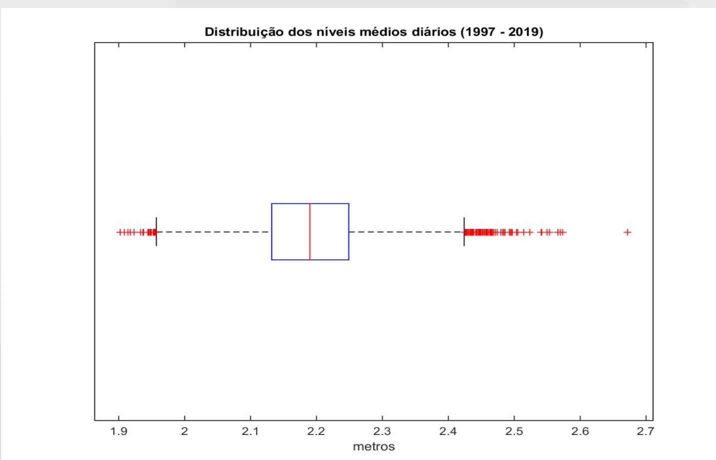
Data analysis
- Tide gauge







The box-plot shows the distribution of daily mean sea levels for the entire data series for the port of Sines (1997-2020).

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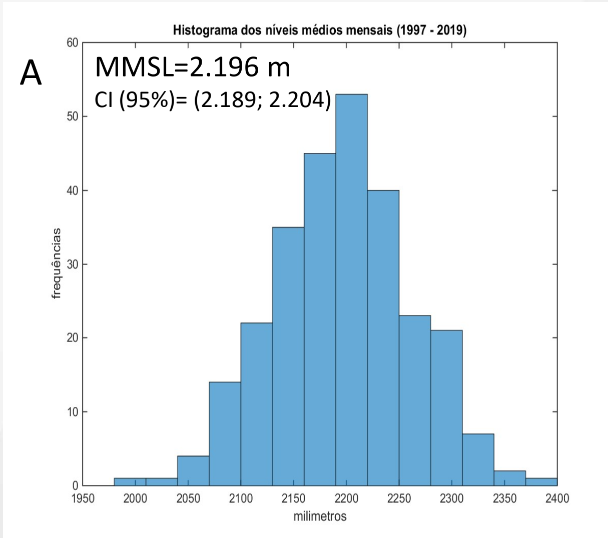
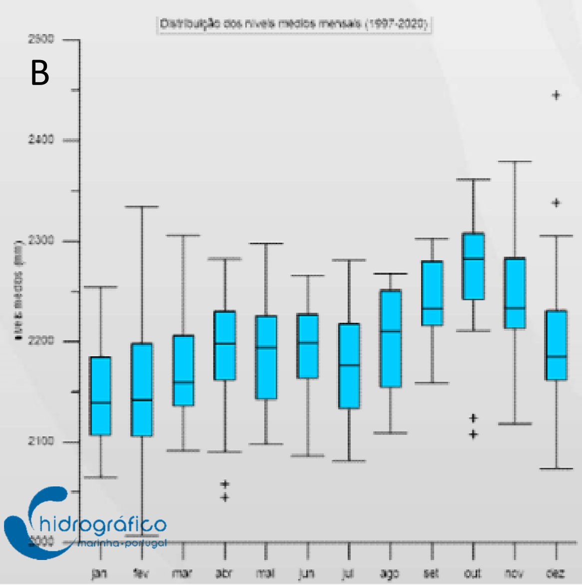
Data analysis
- Tide gauge

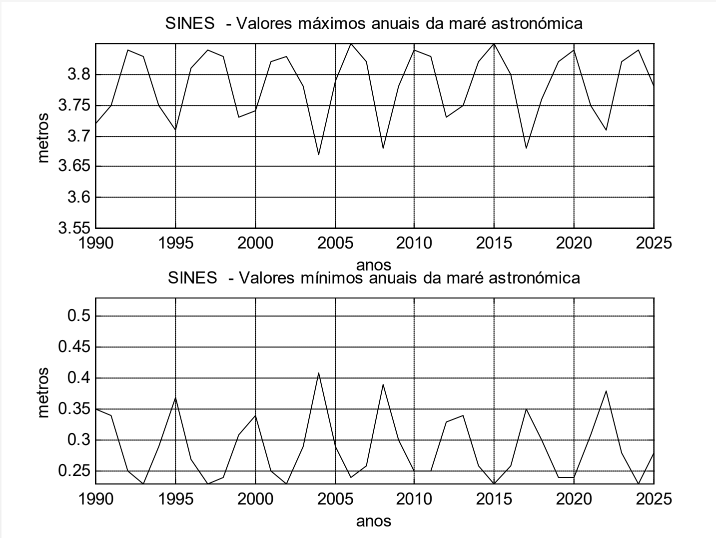




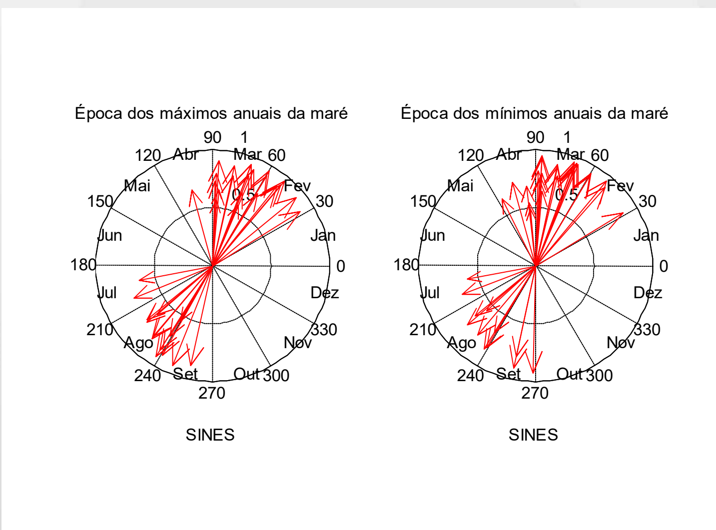
The histogram, plot A, shows a negative asymmetry demonstrating that the distribution of monthly mean sea levels is concentrated on the right side of the average (2.196 m with Confidence Interval (95%) equal to (2.189; 2.204))

It is possible to verify that the distribution/behavior of the monthly mean sea levels is not identical throughout the year. Plot B, Shows some seasonality.

C



D



Data analysis
- Tide gauge

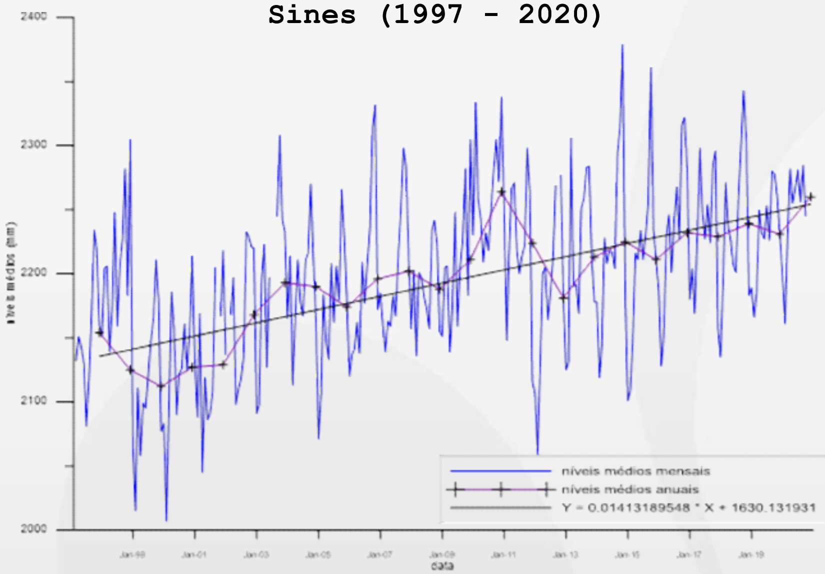
The tidal phenomenon has a periodicity of 18.6 years (period of precession of the lunar nodes). It is the practice of the IH, for the purposes of publication in nautical charts, to forecast extreme amplitudes based on forecasts of high tides and low tides for a period of 36 years.

The plot C presents the evolution of the predicted annual extremes of the astronomical tide at Sines over a 36-year period. (In reality it is easy to see that the maximums of extreme values occur with a periodicity of about 4.5 years).

From the observation of the plot D, it is also interesting to conclude that the times of the year in which the extreme values of the tidal range occur are the closest to the equinoxes.

Data analysis - Tide gauge

ANNUAL MEAN SEA LEVELS
Sines (1997 - 2020)



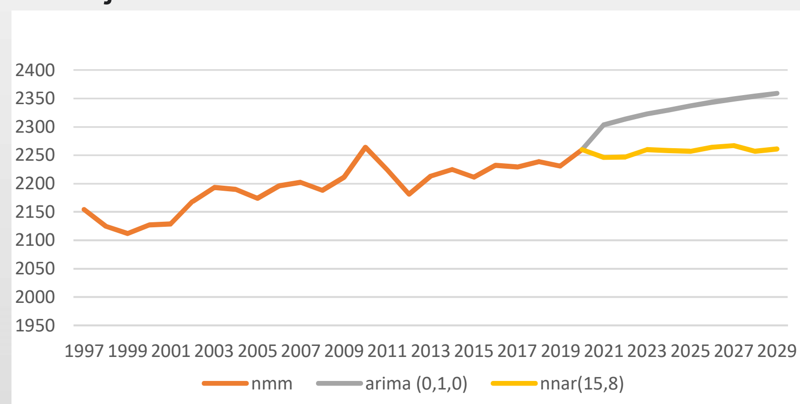
3,3 $mmyr^{-1}$

Given the positive slope of the regression line obtained, it can be concluded that the average level is increasing, the increase was 77 millimeters in the 23 years, the sea level rise, approximately, 3.3 mm/year , showing no acceleration.

Forecasts using ARIMA and ANN models for the next 10 years:

6,2 $mmyr^{-1}$ 3,4 $mmyr^{-1}$

Projections of mean sea level rise - Sines



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Data analysis
- Tide gauge

DE GRUYTER J. Appl. Geodesy 2020; 14(3): 361–378

V. B. Mendes*, S. M. Barbosa, and D. Carinhas

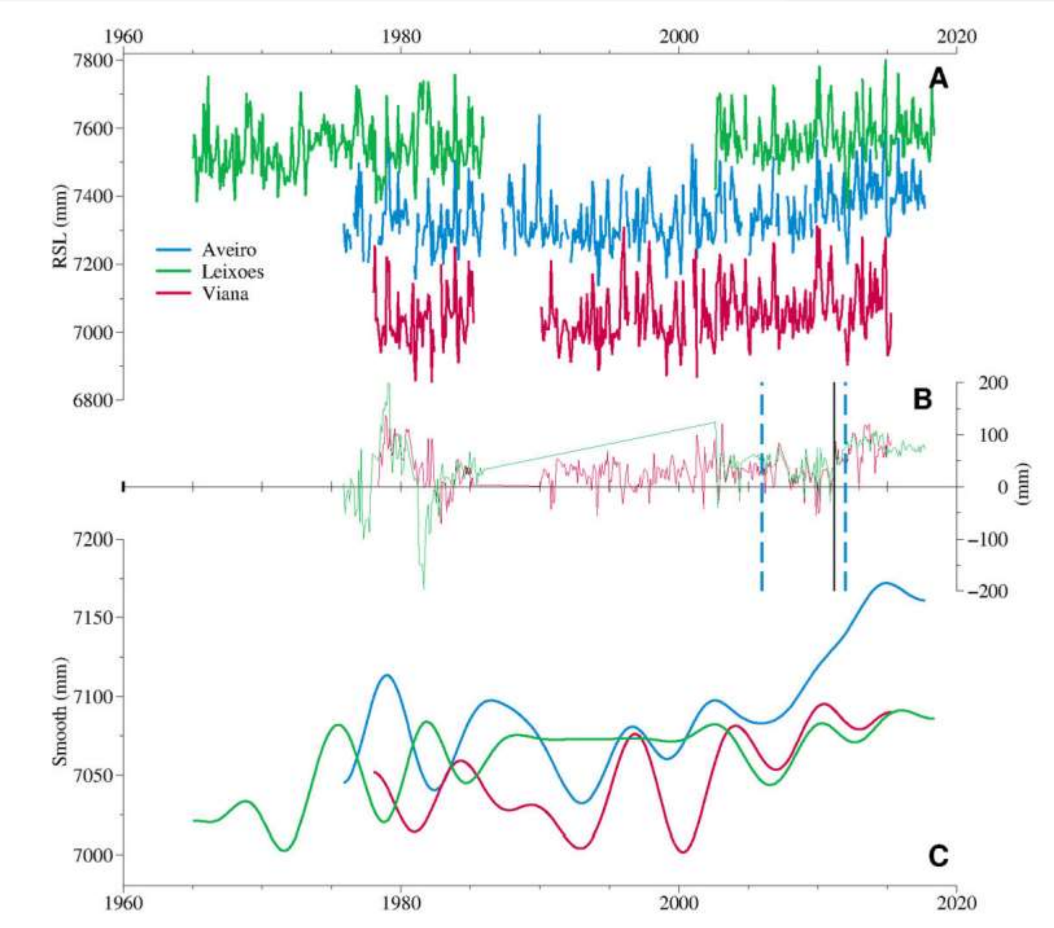
Vertical land motion in the Iberian Atlantic coast and its implications for sea level change evaluation

List and location of the tide gauges used in this study and respective trends considering three different periods, starting in 1940 (trend A), 1960 (trend B) and 1990 (trend C). Gap denotes the percentage of missing observations for the complete time series.

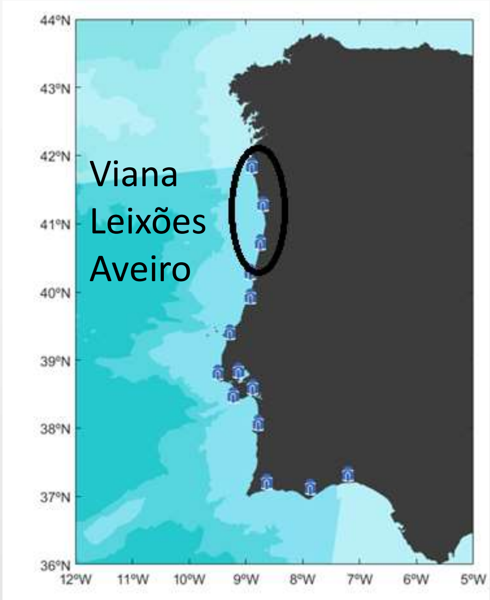
PSMSL	Name	φ (°)	λ (°)	Gap (%)	Time Span (# years, total)	Trend A (mm/yr)	Trend B (mm/yr)	Trend C (mm/yr)
1482	Viana	41.683	−8.833	16.3	1978.0–2015.3 (37.3)	–	1.46 ± 0.52	2.86 ± 0.89
791	Leixões	41.183	−8.7	30.3	1965.0–2019.0 (54.0)	–	1.05 ± 0.31	2.28 ± 1.27
1402	Aveiro	40.65	−8.75	13.1	1975.9–2017.7 (41.8)	–	2.32 ± 0.66	**4.95 ± 0.64**[‡]
52	Cascais	38.683	−9.417	12.2	1940.0–2018.0 (78.0)	1.04 ± 0.16	0.76 ± 0.28	1.44 ± 0.85
1425	Setroia	38.5	−8.9	19.3	1976.3–2016.4 (40.1)	–	1.11 ± 0.53	1.18 ± 1.18
1456	Sines	37.95	−8.883	19.6	1977.4–2019.0 (41.6)	–	3.26 ± 0.45	4.67 ± 0.71

[†]Differences in trends for periods A and C are statistically significant; [‡]Differences in trends for periods B and C are statistically significant.

Mendes, V. B., Barbosa, S. M. and Carinhas, D. (2020). "Vertical land motion in the Iberian Atlantic coast and its implications for sea level change evaluation" Journal of Applied Geodesy, vol. 14, no. 3, 2020, pp. 361-378. (doi:10.1515/jag-2020-0012)



Data analysis
- Tide gauge



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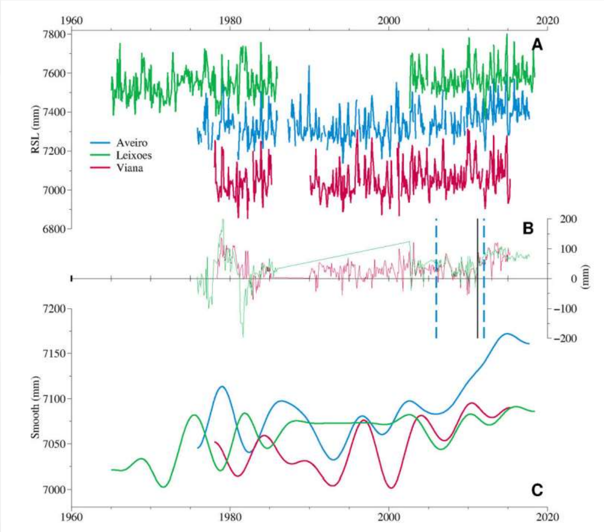
The figure shows the raw time series for Aveiro, Viana, and Leixões. The smoothed time series show an increased trend for Aveiro starting circa 2011, that is not observed for the other TGs (Plot C).
This fact is high-lighted in the plot of the diferences of records with respect to Aveiro (Plot B), clearly showing a sudden increase of these diferences at that date, followed by a steady pattern of diferences for both TGs.

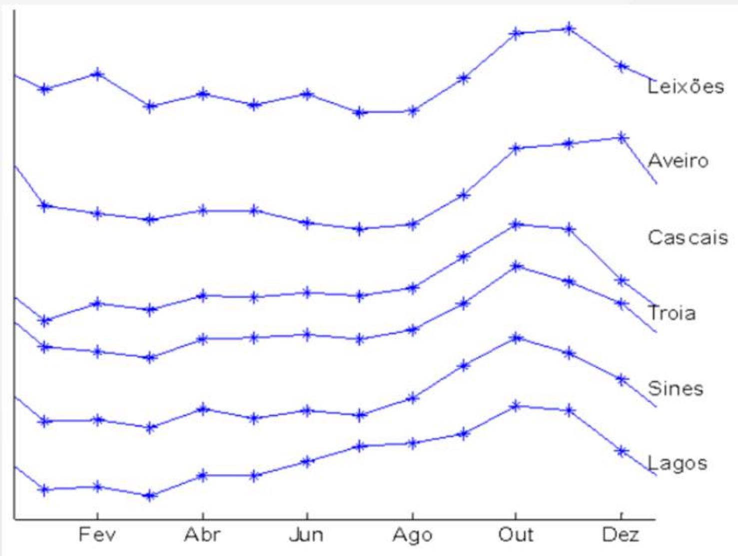


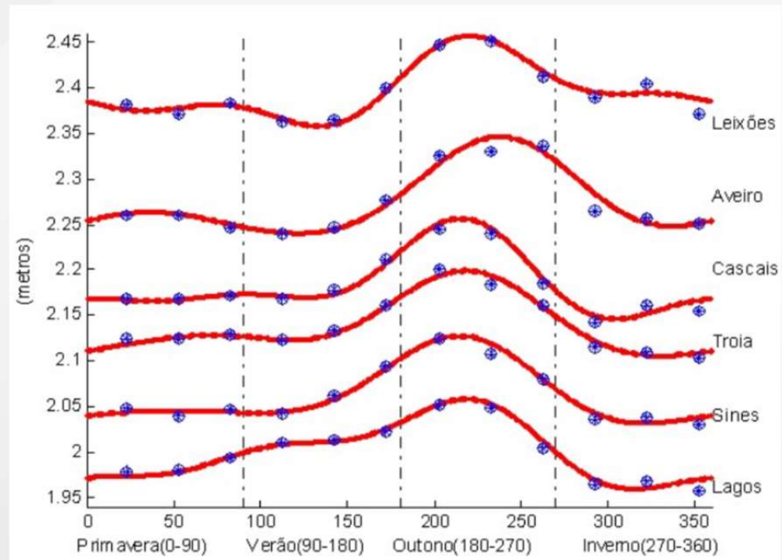
A. Plot of the raw time series for tide gauges Aveiro, Viana and Leixões. For better visualization, an offset of 250 mm between each pair of time series was applied;

B. Differences between the raw time series for each TG with respect to Aveiro. The black solid vertical line marks the epoch corresponding to a possible discontinuity in the time series for Aveiro; the blue dashed vertical lines mark the epochs corresponding to a change of equipment in Aveiro (we cannot exclude the turning point to be related with the change of equipment. In any case, caution is required in the interpretation of the trend for this tide gauge.)

C. Plot of the smoothed time series, corresponding to the non-linear signal for scales larger than ~5 years from a multi-resolution analysis (note change of vertical scale relatively to plot A).

Characteristic Average Monthly Levels - Seasonal Trend

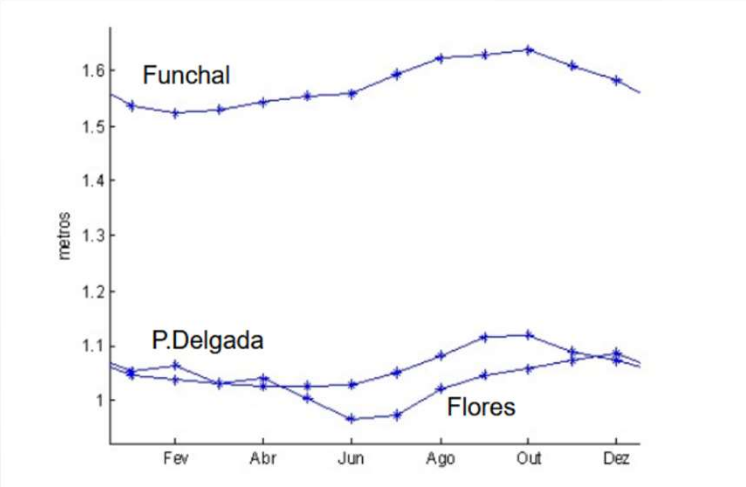


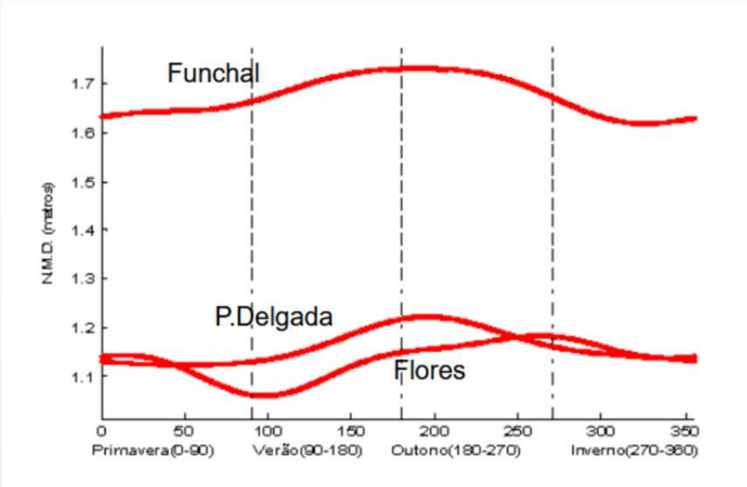


It was possible to calculate the characteristic monthly mean levels, averaging the daily mean levels that occurred in that month.

- ✓ In blue we have the characteristic monthly average levels,
- ✓ In red we have the adjustment of the daily average levels.

Characteristic Average Monthly Levels - Seasonal Trend



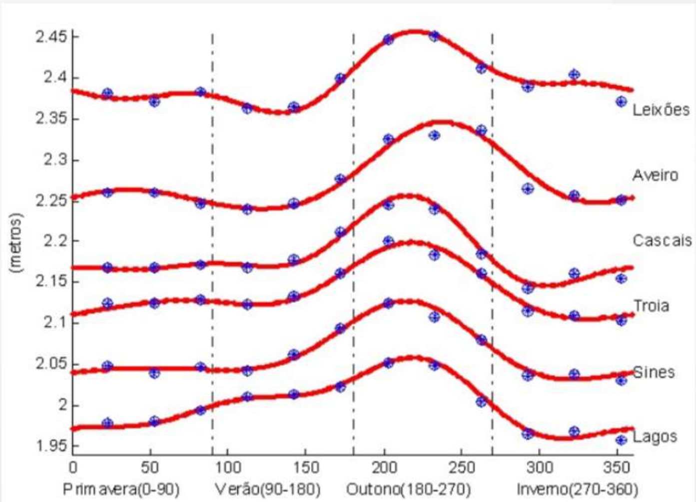


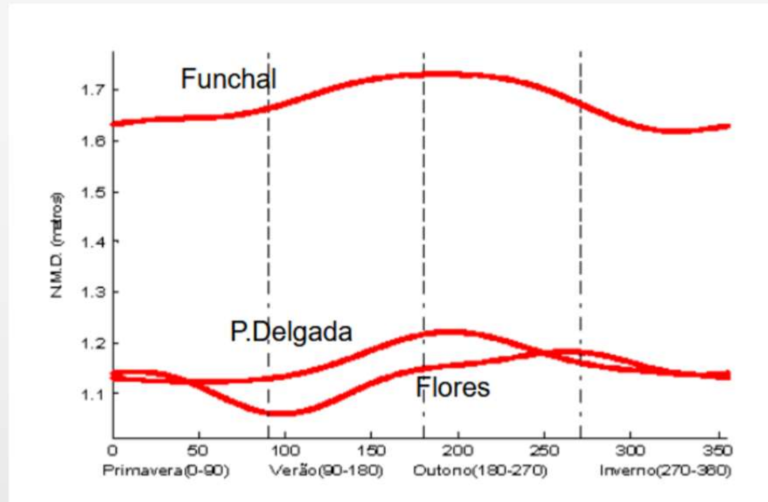
Analogous analysis for Autonomous Regions: Madeira and Açores

✓ In blue we have the characteristic monthly average levels,

✓ In red we have the adjustment of the daily average levels.

Characteristic Average Monthly Levels
- Seasonal Trend





There are marked annual and semi-annual variations in mean sea level due to seasonal variations in atmospheric pressure, water density and ocean circulation.

Generally speaking, during the summer months, variations in water density tend to predominate, and in winter months, variations due to meteorological origins.

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