

Decadal variability in the Eastern and Western Mediterranean sea level trends

Author(s): Federica Borile et al.

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Report: 10th edition of the Copernicus Ocean State Report (**OSR10**)

Below is the reviewer comment written in *blue italics*, while our response is in **black** and the inserted text in the revised manuscript is in *red*.

Comment by reviewer#1

I have read the manuscript "Decadal variability in the Eastern and Western Mediterranean sea level trends" by Borile et al., submitted for publication to State Of The Planet. The authors compute decadal (10-year) sliding sea-level trends over 1998-2024 in the Mediterranean Sea using satellite altimetry and tide gauge observations. They also use temperature and salinity data from reanalyses to estimate the relative thermosteric and halosteric contributions to these trends. The results show substantial fluctuations in decadal sea-level trends, both at the basin scale and at coastal locations. These fluctuations can be quite different from one coastal location to another. The authors also find that the thermosteric and halosteric components often compensate each other, though not always. The agreement between tide-gauge and altimetry trends is an interesting finding.

While the fluctuations in decadal sea-level trends reported here are real, they are not, by themselves, a novel scientific finding. They are perfectly expected and have been documented before. In my view, the main novelty of this work lies in presenting updated estimates of these decadal sea-level changes and their steric contributions, although the latter are only analysed at the sub-basin scale.

My overall impression is that this study has the potential to be suitable for publication in State Of The Planet as it addresses a timely and relevant topic. However, the manuscript needs significant further work to better justify its motivation, provide clearer detail on the methods and data processing, and, especially, clarify the interpretation and implications of the findings.

I recommend publication after major revisions to address the concerns and comments outlined below.

*Best regards,
Francisco Calafat, UIB*

R: We agree with the reviewer that the fluctuations of decadal sea level trends have been already documented in the literature, especially at the basin scale. Among the others, the variability from altimetric data have been recently described by Borile et al (2025), while the steric compensation by Meli et al (2023). Due to limitations in the manuscript length, here we chose to reference that and other works, focusing instead on the differences between the Eastern and Western sub-basins. Indeed, the goal of this study is to monitor and update, with recent data and products, the decadal variability of sea level changes to support decadal scale decision making along the coastlines.

An improvement of the discussion will be addressed by strengthening the interpretation of the results, integrating additional details on the data analysis, and providing a more comprehensive comparison with the existing literature, as detailed in our responses to the comments below and to the other reviewers.

General comments

- 1) *One of my main concerns is that the variations in 10-year trends appear to be interpreted as reflecting changes in the rate of climate-change-driven sea-level rise. For instance, the manuscript includes statements such as: (line 16) "this study investigates the decadal variability of sea level rise", (line 20) "in the WMED, sea level rise has recently accelerated", (line 222) "the results confirm that sea level rise in the Mediterranean is not a linear process". This interpretation is misleading because decadal trends primarily reflect internal climate variability (NAO, regional wind changes, etc.) and would still occur in the absence of anthropogenic forcing. I would recommend that the authors reword the relevant parts of the manuscript to make this distinction clear and adjust the interpretation of the results accordingly.*

R: We appreciate this important and constructive comment. We agree that variations in 10-year sea level trends primarily reflect internal climate variability, and that such variability is linked to the basin dynamics and would occur even in the absence of anthropogenic forcing and climate change. Moreover, we also noticed that some formulations in the original manuscript could be interpreted as linking decadal trend variability directly to changes in the rate of climate-change-driven sea level rise, which was not our intention.

In the revised manuscript, we reword the relevant parts of the text to distinguish between long-term climate-change-driven thermosteric climatic indices (documented in previous studies, like Iona et al., 2018, <https://doi.org/10.5194/essd-10-1829-2018>) and the decadal variability of sea level trends analysed here. We explicitly state that this study does not aim to attribute changes in 10-year trends to human-induced factors, but rather to characterize and update the decadal variability of sea level changes in the Mediterranean sub-basins.

We also clarify that a robust attribution of the observed decadal trend variability to anthropogenic forcing is not possible considering the data used in this context, and such attribution would go beyond the scope of the present work.

Following this clarification, the objectives of the study are now more clearly framed as:

1. providing the most up-to-date estimates of sea level trends at coastal and sub-basin scales using recent datasets
2. analysing the contribution of the steric component to decadal sea level trend variability
3. assessing the ability of satellite altimetry products to reproduce coastal sea level variability observed by tide gauges, thereby extending previous basin-scale validations to the coastal domain.

The interpretation of the results will be adjusted accordingly. We emphasize that the observed variability in 10-year sea level trends is consistent with the known internal climate variability that characterizes Mediterranean dynamics, while rapid changes in the trend can be associated with variations in the steric components' compensation.

These points are now better explained in the *Introduction*:

"Sea level rise is a major global concern due to its direct impact on densely populated coastal zones, posing growing challenges for adaptation and risk management (Parmesan et al., 2022). While global mean sea level trends provide an integrated picture, regional sea level change can significantly depart from the global average, especially in semi-enclosed basins, where local processes drive distinct patterns of variability (Calafat et al., 2022; Gräwe et al., 2019; Alothman et al., 2014). The Mediterranean Sea is a prominent example, recognised as a climate change hotspot where environmental and societal risks are closely linked (Tuel and Eltahir, 2020; Cramer et al., 2018; Giorgi, 2006). While regional climate-change driven sea level rise has been already documented (Adloff et al., 2015; Sannino et al., 2022), the goal of this study is to monitor and update, with recent data and products, the decadal variability of sea level changes, which primarily reflects internal climate variability superimposed on the anthropogenic forcing (Calafat et al., 2022).

Previous studies indicate that decadal sea-level variability in the Mediterranean is mainly controlled by regional atmospheric forcing and steric effects, rather than by global mean sea-level signals (Marcos and Tsimplis, 2008). This variability arises from complex interactions between ocean dynamics and external forcing mechanisms that affect the manometric component of sea level (Pinardi et al., 2015; Calafat et al., 2012; Gomis et al., 2008). As a result, the Western and Eastern Mediterranean sub-basins, hereafter referred to as WMED and EMED, exhibit distinct sea-level evolutions (Borile et al., 2025).

A defining characteristic of the Mediterranean is its behaviour as a concentration basin, shaped by a meridional temperature gradient and zonal salinity gradient (Pinardi and Masetti, 2000; Pisano et al., 2020). The interplay between temperature and salinity is thus expected to have an influence on total sea level trends in the region, in contrast to the global ocean where thermal expansion dominates (IPCC, 2023; Milne et al., 2009). Such a process has been analysed at the basin scale, with haline contraction counteracting the effect of ocean warming on sea level (Meli et al., 2023); this work further explores their decadal interplay supporting the interpretation of past sea level variability and the improvement of future projections in the Mediterranean.

Sea level variations at the basin scale also affect coastal areas, where regional ocean processes, human activities, and vertical land movements (Buzzanga et al., 2023) modulate local impacts on coastal communities (Cramer et al., 2018; MedECC, 2024). Building on previous basin-scale assessments, this study investigates Mediterranean decadal sea level trends at both regional and coastal scales, extending the analysis to the coastal domain and supporting decision-making relevant to coastal risk management on decadal timescales."

2) The point raised in the preceding comment is important, as it directly affects the relevance of the results for adaptation planning. In this regard, the manuscript appears to overstate the implications of the variations in the 10-year trends for coastal adaptation. The authors suggest that these variations should be considered when defining adaptation strategies. I agree but would like to emphasize that these variations have always existed (similar variations would be found in pre-industrial records) and they are already implicitly accounted for in planning practice through design levels and allowances. The need for adaptation arises because mean sea level is moving outside the historical range of variability due to anthropogenic climate change, reducing the safety margins that were previously sufficient. I would like the authors to consider this distinction and adjust the discussion accordingly.

R: We agree with the reviewer and rephrase the discussion accordingly to better distinguish between long-term sea level rise relevant for adaptation planning and decadal variability, which has always been present. In this context, we clarify that the aim of our study is not to redefine adaptation thresholds, but to confirm and quantify the range of decadal sea level trend variability in the present observational regime, which is relevant for interpreting coastal sea level fluctuations superimposed on the long-term sea level rise.

In the *Conclusions*, the coastal trend is now summarized as follows:

"At the coastal level, altimetry trends are generally consistent with tide gauge observations in the WMED, while larger uncertainties persist in the EMED, underscoring the need for improved in-situ monitoring networks and data sharing, including vertical land movement estimations as a relevant contribution to local effects (Buzzanga et al., 2023; Cramer et al., 2018). The observed reversal of trends in marginal seas such as the Adriatic and Aegean suggests that localized processes, including vertical land motion and regional circulation anomalies, can rapidly alter coastal sea level evolution.

Our findings highlight the decadal variability range of coastal sea level trends in the Mediterranean, indicating that local sea level evolution may temporarily depart from long-term mean trajectories due to regional processes. Such variability, however, should be interpreted as a component of Mediterranean sea level dynamics, superimposed on the long-term mean sea level rise that ultimately drives adaptation needs."

Moreover, we add a statement at the end of *Section 3.2*:

"It is worth noting that the correspondence between coastal sea level trends and steric sea level changes is not persistent everywhere and over time, and may become significant only during specific periods, depending on the dominant local forcing mechanisms ([Tsimplis and Rixen, 2002](#))."

3) *Data processing. Both the satC3S and satCMEMS altimetry products are usually provided with the barotropic effects of atmospheric pressure and wind changes removed (the so-called dynamic atmospheric correction). For time scales longer than about 20 days, this correction is equivalent to removing the inverse barometer (IB) effect. The authors do not appear to have applied the same correction to the tide gauge data, which makes the trend comparison between altimetry and tide gauges inconsistent. Atmospheric pressure variations can produce significant long-term sea-level trends in the Mediterranean (Gomis et al., 2008; Calafat et al., 2022). Therefore, I would recommend adjusting the tide gauge records for IB effects (or adding IB effects back to the altimetry data).*

R: We thank the reviewer for this important point. Satellite altimetry measures absolute sea level variability and includes the dynamic atmospheric correction (DAC). Conversely, tide-gauge Revised Local Reference (RLR) data are referenced to the ground and do not include DAC or IB corrections. To improve comparability between the two datasets, we reintroduce the DAC correction into the altimetry data when compared to tide gauges. In the reviewed manuscript the correction is made using AVISO+ product.

We have updated the following information to *Section 2*:

"Accordingly, absolute sea level trends at tide gauge locations are computed by adding the VLM rate to the relative sea level trend derived from tide gauge records ([Santamaría-Gómez et al., 2012](#)).

Finally, for direct comparison between satellite and in-situ observations, satC3S SLA values are extracted at the grid point closest to each tide gauge. Differences in reference frame and high-frequency signal treatment are minimized by reintroducing the dynamic atmospheric correction (DAC) into altimetry data and applying VLM corrections to tide gauge records. The DAC is taken from the CLS product based on the Mog2D model and distributed by Aviso+, with support from CNES (product ref. no. 8, in Tab. 1; Pascual et al., 2008). Overall, these processing choices aim to reduce methodological inconsistencies while acknowledging that satellite altimetry and tide gauges sample sea level variability at different spatial and temporal scales, and therefore provide complementary, rather than strictly equivalent, information."

We also correct *Figures 3, Figure 4 and Table 2 (now Table3)* accordingly, together with an update to the latest available decade Jan2015-Dec2024 (instead of Jul2014-Jun2024, as requested by OSR constrain):

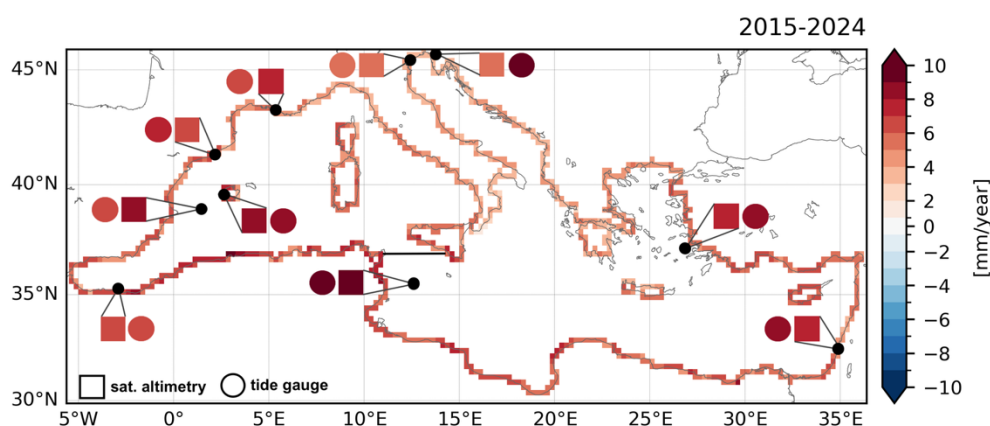


Figure 3: Map of sea level decadal trend computed at coastal points from the satC3S dataset. The analysed decade spans from 2015 to 2024, the latest available period for comparing decadal trends between satC3S altimetry, where

DAC has been reintroduced, and in-situ observations from tgCMEMS and tgPSMSL, **adjusted for** VLM. Each black dot indicates the location of a tide gauge described in the text. Satellite and tide gauge-derived trends at the same location are shown as squares and circles, respectively, and are coloured according to the colorbar (values reported in **Tab. 3**). The thin black line corresponds to the zonal transect used to define the boundary between WMED and EMED at 37°N.

	Tide gauge coordinates	Relative sea level trend [tgCMEMS]	Relative sea level trend [tgPSMSL]	Absolute sea level trend [satC3S]	VLM trend [ULR/SONEL]	Sea level trend DIFF [satC3S – tg]
Marseille	43.28°N / 5.35°E	-	7.4 ± 1.7	7.5 ± 1.0	-0.49 ± 0.27 (5m)	0.5 ± 2.2
Barcelona	41.34°N / 2.16°E	7.9 ± 1.3	8.1 ± 1.2	6.6 ± 1.7	-0.86 ± 0.23 (0m)	-0.4 ± 2.3
Melilla	35.29°N / 2.92°W	6.3 ± 0.9	6.1 ± 1.1	6.6 ± 1.2	-	0.3 ± 1.5
Mallorca	39.56°N / 2.64°E	6.9 ± 1.9	7.0 ± 1.6	8.8 ± 2.1	1.68 ± 0.83 (0m)	0.2 ± 3.4
Ibiza	38.91°N / 1.45°E	7.9 ± 1.8	7.9 ± 1.7	8.1 ± 1.7	-1.28 ± 0.26 (78m)	1.5 ± 2.7
Lampedusa	35.50°N / 12.60°E	11.8 ± 1.4	-	10.0 ± 1.5	-0.36 ± 0.37 (130m)	-1.5 ± 2.4
Venezia	45.42°N / 12.43°E	6.9 ± 3.1	-	5.8 ± 2.0	-1.51 ± 1.56 (741m)	0.4 ± 5.1
Trieste	45.65°N / 13.76°E	13.2 ± 3.5	-	5.6 ± 2.1	0.01 ± 0.14 (6707m)	-7.6 ± 4.2
Hadera	32.47°N / 34.88°E	-	7.7 ± 2.3	7.2 ± 1.7	0.46 ± 0.21 (3145m)	-0.9 ± 3.0
Leros	37.13°N / 26.85°E	-	8.6 ± 1.6	7.7 ± 1.6	-	-0.9 ± 2.2

Table 3: Sea level trends near selected coastal cities for the most recent available decade (2015-2024) derived from different datasets: satC3S (with DAC reintroduced), tgCMEMS and tgPSMSL. The VLM trend, with the distance between each tide gauge and its associated GNSS station indicated in brackets, should be added to the in-situ relative sea level trend to allow comparison with the satC3S absolute sea level trends (see Fig. 3). The resulting trend difference is reported in the last column. When both tide gauge datasets are available, tgCMEMS data are used. All trend values are reported in mm/year.

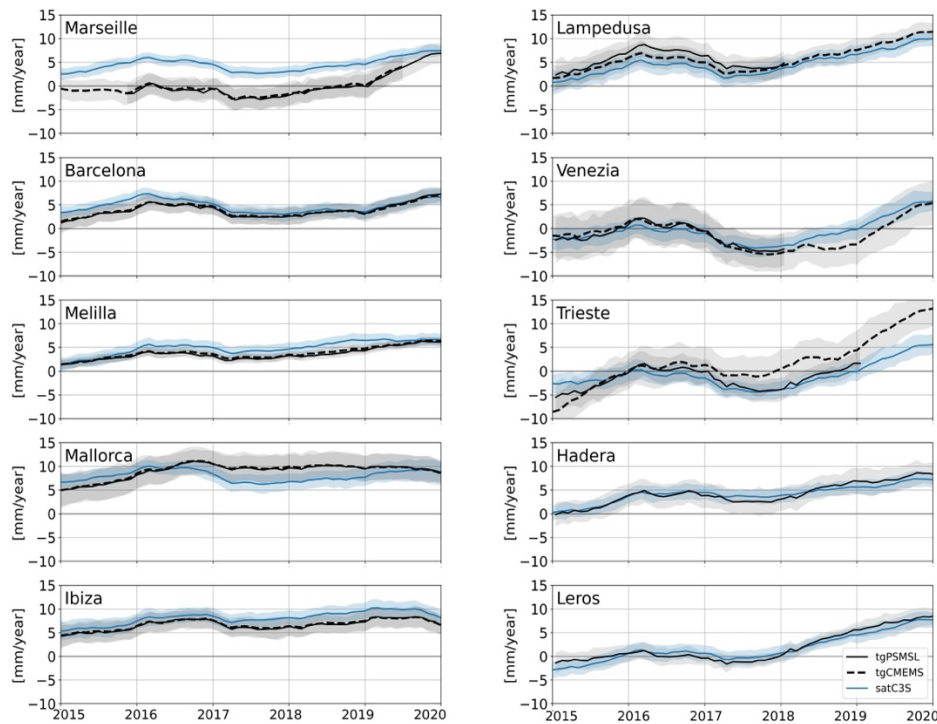


Figure 4: Time series of sea level decadal trend computed nearby coastal cities, using tide gauges data from tgCMEMS, tgPSMSL, and satellite data from satC3S. For a direct comparison between satellite and in-situ data, the VLM trend is added to the relative sea level trend derived from tide gauge records, while DAC is reintroduced to satC3S altimetry. Decadal trends are computed over sliding windows shifted by one month across the period 2010–2024; where tgCMEMS data are not available (Hadera and Leros), only tgPSMSL data are analysed during the same period. Shaded areas represent the associated uncertainty, defined as the standard deviation of the residuals from the bootstrap procedure.

- 4) *Uncertainty estimation. The authors compute trends using the Theil–Sen estimator after deseasoning and low-pass filtering the sea-level time series and use bootstrapping to estimate trend uncertainty. While the trend point estimates are likely robust, further details on the bootstrapping method are needed to assess whether the reported uncertainties are reliable. Sea-level time series are intrinsically autocorrelated, and the applied low-pass filter further increases this autocorrelation. It is unclear which type of bootstrap was used; a standard “vanilla” bootstrap assumes independent observations, an assumption likely violated here. If independence is not accounted for, the uncertainty of the Theil–Sen trend will be underestimated. Could the authors clarify whether the bootstrap procedure accounted for serial correlation? If not, I would encourage them to do it.*

R: Temporal autocorrelation is explicitly accounted for in our uncertainty analysis. Trend uncertainties are estimated using a stationary bootstrap (Politis and Romano, 1994), which is specifically designed for autocorrelated time series and therefore does not rely on the assumption of independent observations, unlike a standard “vanilla” bootstrap. The stationary bootstrap resamples blocks of random length, thereby preserving the temporal dependence structure of the deseasoned and low-pass-filtered SLA time series. This ensures that the increased autocorrelation introduced by the low-pass filtering is properly considered, providing reliable uncertainty estimates for the Theil–Sen trend estimates.

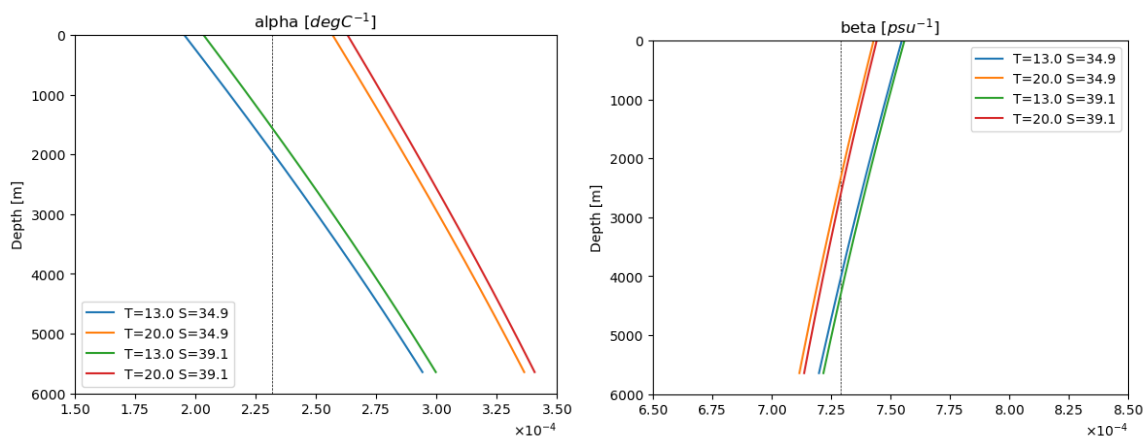
The information is now included in *Section 2*:

“Decadal trends are then computed using 10-year-long sliding windows shifted monthly and fitted with the Theil–Sen estimator (Theil, 1992; Sen, 1968), which is a non-parametric method more robust to

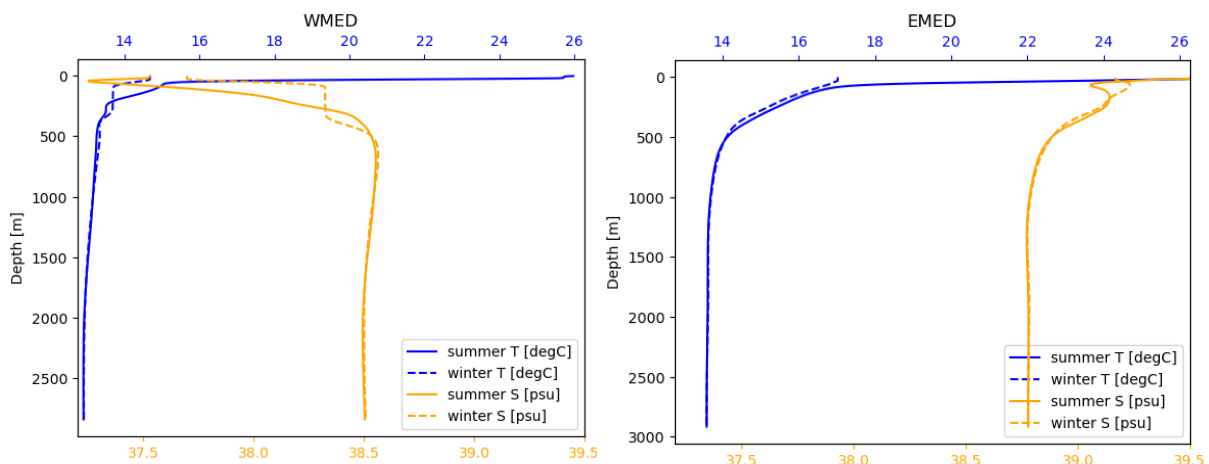
outliers than traditional linear regression, but does not allow for the acceleration estimate. Finally, trend uncertainty is assessed using a stationary bootstrap with 1000 resamples to account for temporal autocorrelation (Patton et al., 2009; Politis and Romano, 1994)."

5) Steric calculation (Eq. 1). Both alpha and beta vary strongly with depth (as they depend on temperature, salinity, and pressure), yet the authors seem to assume constant coefficients. Could the authors assess how this assumption affects their estimates of the thermosteric and halosteric sea level?

R: We thank the reviewer for raising this important point. We confirm that the thermal expansion and haline contraction coefficients are treated as constants in our analysis, although they are known to vary with temperature, salinity, and pressure. To investigate the impact of our assumption, we analysed the coefficients variability considering how they would change in depth considering a possible range of temperature and salinity values typical for the Mediterranean Sea. Poulos, 2023 (<https://doi.org/10.3390/w15183194>) provides a recent overview of the water masses characterizing the Mediterranean Sea, and based on this framework we defined a temperature range of 13–20 °C and a salinity range of 34.9–39.1 PSU. The corresponding alpha and beta profiles, computed using the EOS80 formulation, are shown below, with dashed lines correspondent to the constant values used in the paper:



To assess the impact on the thermosteric and halosteric components of the sea level estimated in this study, we consider a winter and a summer water column located in the central WMED (39.77°N, 6.04°E) and EMED (33.52°N, 29.79°E). The sampled profiles are shown in the following figures.



These profiles show that tracer variability is confined to the thermocline above 300m, while in the interior of the Mediterranean both temperature and salinity are nearly constant. Therefore, the assumption of constant steric coefficients mainly affects the upper layers of the water column, while the intermediate and deep contribution to the steric sea level remain essentially unchanged.

The Table below reports the correspondent values of thermosteric and halosteric sea level components using constant coefficients (as in the manuscript), and using coefficients computed from variable temperature and salinity profiles.

	EMED				WMED			
	summer		winter		summer		winter	
	η_T [m]	η_H [m]	η_T [m]	η_H [m]	η_T [m]	η_H [m]	η_T [m]	η_H [m]
Const coeff	0.210	-0.376	0.105	-0.381	-0.319	0.439	-0.424	0.371
Variable coeff	0.241	-0.385	0.100	-0.390	-0.299	0.450	-0.428	0.380
Relative diff	15%	2%	4%	2%	6%	2%	1%	3%

This analysis shows that the approximation made in the manuscript introduces an estimated error that is negligible (~5%) in most of the analysed cases, exceeding only in summertime in the EMED, where the thermocline is deeper and our assumption is less realistic. We argue that this difference has a minimal impact on the magnitude of the decadal trend estimates. Moreover, since the coefficients are constant in time, the assumption of depth independence does not affect the interdecadal variability or the trend inflections discussed in this analysis. A depth-resolved, time-varying approach would be more appropriate for a full sea-level budget closure, but this is beyond the scope of the present work.

Specific comments:

Lines 21-22: abstract. The authors write "... with the remaining contribution linked to changes in the sea level mass component". However, the mass contribution to sea-level trends is not quantified in this study. I would suggest rewording this sentence to "with the remaining contribution likely due to changes in the sea-level mass component".

R: The statement was intended as a physical interpretation supported by recent literature, in particular Borile et al. (2025), where the mass contribution to decadal sea level trends in the Mediterranean Sea is explicitly quantified using independent datasets. However, we agree that this contribution is not directly estimated within the analysis presented in this paper, therefore we will reword the abstract to make this distinction clearer and to indicate that the remaining contribution is *likely* associated with changes in the sea level mass component.

Lines 26-27 abstract: "these results demonstrate that...". The presence of decadal sea-level variability in the Mediterranean, which will manifest as variations in 10-year trends, has been documented before. I would suggest replacing "demonstrate" with "confirm" or a similar word.

R: We agree with the reviewer and will modify the sentence accordingly.

The reviewed abstract is now strongly modified to fit the reviewed version of the manuscript:

"The Mediterranean Sea, a semi-enclosed basin highly sensitive to climate change, exhibits complex variability in sea level trends with important environmental and societal implications. This study investigates the sea level rise decadal variability from 1993 to 2024 at sub-basin and coastal scales using satellite altimetry, ocean reanalyses, and tide gauges records.

In the Western Mediterranean (WMED) sea level decadal trend has recently accelerated, partly driven by thermal expansion that exceeds halosteric contraction, with the remaining contribution likely associated with sea level mass variability. In the Eastern Mediterranean (EMED) sea level transitioned from a regime dominated by halosteric-induced drop to a recent state where steric contributions offset

each other, allowing mass variability to dominate. Local trends generally confirm satellite-derived patterns, though larger differences reported in the EMED highlight the influence of regional processes, including vertical land movement. These results confirm that Mediterranean sea level change is non-linear, with decadal variability superimposed on a long-term positive trend, emphasizing the need to account for such fluctuations in regional adaptation strategies and coastal risk management.”

Introduction. I recommend that the authors highlight more clearly the novel aspects of their study relative to previous work. In this regard, several past studies should be cited and discussed, as they are directly relevant to this topic, including Marcos et al. (2008), who also analysed 10-year sea-level trends.

R: The introduction has been revised to better position our results within the existing literature on Mediterranean decadal sea-level variability, and to more clearly state the novel contributions of this work.

The revised text is provided above, in our response to the general comment #1.

Line 56. Are daily SLAs averaged into monthly anomalies?

R: SLA data are not averaged in time before computing the basin spatial mean. Daily data are used to compute the basin mean SLA time series, its seasonal cycle, and then low-pass filtered to neglect short term fluctuations.

This detail is now reported in *Section 2*:

“For the sub-basin analysis, SLA data are spatially averaged over the WMED and EMED regions, bounded at the Sicily Strait along a zonal transect at 37°N. Time series are then analysed following the methodology of Borile et al. (2025), and here summarized. The daily seasonal cycle over the 2000-2023 period is subtracted to obtain de-seasoned SLA, and a low-pass filter is applied to isolate long-term fluctuations.”

Lines 67-68. Please provide more details on how the seasonal cycle was estimated. Did the authors use a linear or a non-linear regression model, and did they remove only the annual component or also the semi-annual cycle?

R: The data processing procedure used in this study is detailed in Borile et al. (2025). For clarity, we summarize the deseasoning phase here: the seasonal signal is computed at daily resolution by averaging each day over the 2000–2023 period (to avoid artifacts due to the TOPEX-POSEIDON drift). This provides a climatological seasonal cycle that naturally includes both the annual and semi-annual components. The resulting seasonal cycle is then subtracted from the original daily SLA time series to obtain the non-seasonal SLA used in the trend analysis.

No linear or non-linear regression is applied; the seasonal cycle is entirely derived from the daily climatology. Due to space limitations, a more detailed methodological description is not included in the manuscript.

Lines 56-65. Has the GIA contribution been removed from the altimetry data? GIA affects altimetric sea surface heights without reflecting actual ocean mass/volume changes. If the goal is to quantify ocean-driven sea-level changes, including GIA could bias the trends. I therefore suggest removing it.

R: In the presented analysis we did not remove GIA effects from SLA, even though we agree that this component affects altimetry data. In the Mediterranean region, a recent paper by Spada and Melini (2022, DOI: <https://doi.org/10.1093/gji/ggab508>) reported GIA values ranging between -0.2 mm/yr along the coasts and -0.6 mm/year in the sub-basins center of the Mediterranean Sea. These values are time-independent and within the estimated uncertainty of SLA decadal trend, therefore we argue they do not impact the outcome of the presented analysis.

This is now clarified in *Section 2*:

"Glacial isostatic adjustment (GIA) correction is not applied, as regional estimates report small and time-independent rates that do not affect interdecadal variability within the uncertainty of our decadal trend estimates ([Spada and Melini, 2022](#))."

Lines 68-69. Please provide more details on the low-pass filter applied to the time series (type of filter, cutoff frequency, etc.).

R: Due to space limitations in the manuscript, we did not include the full methodological description, referring to Borile et al. (2025) for a more detailed explanation. In particular, the low-pass filtering procedure is performed using a digital filter in the frequency domain, setting the threshold frequency of 5 cycles/year. The transition band is smoothed using a Tukey window to ensure a gradual adjustment, with further details about the procedure described in Alessandri et al. (2023), Appendix A (DOI: 10.1175/WAF-D-23-0040.1).

Lines 73-74. The authors mention that "the uncertainties obtained in our analysis are higher than those reported by Prandi et al. (2021)." However, I think that this comparison is not meaningful. Prandi et al. (2021) accounted for multiple error sources in addition to statistical uncertainty, including errors from orbit determination, geophysical corrections applied to the altimetry data, inter-mission biases, and the GIA correction. It is unclear whether the authors have accounted for all these error sources. Without accounting for them, the comparison with Prandi et al. is misleading. Could the authors please clarify?

R: We agree with the reviewer that this comparison may be misleading, as the uncertainty budget in Prandi et al. (2021) includes several error sources that are not explicitly addressed here. As a detailed error analysis would go beyond the scope of this contribution and the focus of the OSR section, we have removed the sentence from the manuscript.

Equation (1). Please define η_S explicitly (i.e., steric sea level).

Line 78. Please be more specific when defining α and β : coefficients of thermal expansion and haline contraction.

R: We included the definition in *Section 2* as follow:

"The same approach is used to evaluate the decadal trend associated with thermosteric (η_T) and halosteric (η_H) sea level components, whose sum defines the total steric sea level (η_S):

$$\eta_S = \eta_T + \eta_H = \int_{-H}^0 \alpha (T - T_f) dz - \int_{-H}^0 \beta (S - S_f) dz \quad (1)$$

where T_f and S_f are reference temperature and salinity values, α and β are constant linear coefficients of thermal expansion and haline contraction, and H is the spatially varying ocean depth. Both reference values and steric coefficients are taken as spatially constant basin-mean values, consistent with previous studies and suitable for a basin-averaged steric sea level analysis ([Borile et al., 2025](#); [Pinardi et al., 2014](#))."

Lines 82-83. Each RLR Tide gauge record from the PSMSL has been carefully reduced to a common datum, ensuring a consistent reference level throughout the record, which is crucial for the analysis of long-term sea-level changes. Has the same datum consistency been ensured for the tgCMEMS dataset?

R: We thank the reviewer for pointing out the lack of this information in the manuscript. The only difference between the metric and RLR records should be the datum. At many stations this will be a simple offset, but it can change if the data supplier changes the datum, a change that may remain in the metric dataset and is corrected in the RLR version. Since the usage of RLR data is recommended, we chose to use this type of data from the PSMSL dataset. In case of tgCMEMS dataset, data are quality controlled, processed and validated including visual inspection and comparison with nearby altimetry

in a homogeneous way, including specific QC tests to detect significant datum changes. Only obvious datum changes would be detected with this process. The stations used in this study were selected based on the apparent good quality and the lack of significant datum changes.

We included this specification in *Section 2* as follow:

“To assess the reliability of satellite-derived sea level trends at the local scale, we analyse mean sea level records from tide gauges of the tgCMEMS and tgPSMSL datasets (products ref. no. 5 and 6, in Tab. 1). Data from tgPSMSL refer to a common Revised Local Reference (RLR) datum, as recommended for long-term analysis. Similarly, data from tgCMEMS are selected based on good quality checks to detect significant datum changes. ”

Caption Figure 3. Replace “corrected from” with “adjusted for”.

R: Modified.

Section 3.2. Could the authors clarify why the steric contributions were not analysed at the local scale?

R: The sea level variability at the local scale may be strongly affected by processes that are not fully resolved by numerical models, especially in the case of MEDREA24, where a regular spatial grid is used to represent the entire Mediterranean basin at 1/24 deg of resolution. According to this assumption, we think that MEDREA24 is a valuable dataset to assess the steric contribution in a basin-integrated analysis, but its horizontal resolution is too coarse nearby the coasts to properly resolve the local scale characteristics of sea water required to compute the sea level steric component.

Decadal variability in the Eastern and Western Mediterranean sea level trends

Author(s): Federica Borile et al.

MS No.: sp-2025-2

Report: 10th edition of the Copernicus Ocean State Report (OSR10)

Below is the reviewer comment written in *blue italics*, while our response is in **black** and the inserted text in the revised manuscript is in **red**.

Comment by reviewer #2

The manuscript presents diagnostics related to sea level rise (and its partitions) and could be a valuable contribution to understanding sea level variability in the Mediterranean Sea; however, it requires a more targeted discussion to be ready for publication, in my opinion.

General comment: while there is quite good material in the manuscript, the main conclusions seem quite weak (non-linearity of sea level in the Med Sea appears to be the main point) and do not exploit the full set of information presented. I recommend reframing the conclusions to better exploit what was offered in the paper, including, for instance, trends, partition of sea level components, asymmetric behavior of thermo-halo variations between the western and eastern Med, etc.

R: We thank the reviewer for pointing out the necessity of an improved discussion, which will be addressed by strengthening the interpretation of the results, integrating additional details on the data analysis, and providing a more comprehensive comparison with the existing literature, as detailed in our responses to the comments below. We agree that the conclusions need to be revised to improve clarity and consistency with the paper outcomes, and to better explain the full set of information presented, while balancing the summarized information with the manuscript length, which is subject to specific limitations imposed by the Ocean State Report framework.

L23, L223: the manometric sea level variability is mentioned in several places as the main basin-wide driver of sea level rise, but never discussed in detail. It should be recalled, at the very least, how much it contributes to the two basins (WMED and EMED) based on recent literature and quantitatively, and how and why it shapes the basin-averaged sea level rather than local variations.

R: The basin-scale manometric sea level variability has been documented in recent studies including Garcia-Garcia et al. (2022) and Borile et al. (2025), the latter specifically focusing on the EMED. At the scale of the entire Mediterranean basin, Borile et al. (2025) quantify the contribution of surface freshwater fluxes (evaporation, precipitation, river runoff) as -595 mm/yr, while the net transport across the lateral open boundaries (Gibraltar and Dardanelles Straits) amounts to 603 mm/yr. The resulting residual contribution to basin-mean sea level is $+8$ mm/yr over the period 1993–2022.

Estimating the same water mass sea level contribution at the sub-basin scale is more complex, as it strongly depends on the definition of the boundary separating the two regions and on the considered time window. Moreover, the involved variables are not meaningful when interpreted locally: freshwater fluxes and lateral transports must instead be regarded as quantities integrated over the domain of interest, since their contributions can be highly localized in time or space, while their impact on sea level emerges only through the large-scale balance. For this reason, water mass variability primarily shapes the basin-averaged sea level signal rather than local sea level variations.

In the present study, however, we focus on the steric component only, which is generally considered to play a minor role in the long-term mean sea level budget of the Mediterranean Sea compared to the global ocean (Pinardi et al., 2014, Criado-Aldeanueva et al., 2008). The objective is to demonstrate that

the steric contribution can play a significant influence on sea level trends at decadal timescales, reaching the same order of magnitude as the trends observed from satellite altimetry. This highlights the importance of steric processes in modulating Mediterranean sea level variability, even in this basin where mass-driven contributions dominate the mean budget.

This information is now included in *Section 3.1* of the revised manuscript:

"The evolution of the sea level decadal trend over the WMED and EMED basins is presented in Fig. 1, based on satC3S and satCMEMS. Each point represents the trend over the decade centered on that date (e.g., the value reported for Jan2005 corresponds to the period Jan2000–Dec2009). Both sub-basins exhibit a decadal variability, with positive sea level trends ranging from negligible values up to 6.4 ± 1.0 mm/year, and two periods of relative slowdown (around 2001 and 2011 in WMED, and 2002 and 2014 in EMED). It is worth noting that satCMEMS generally agrees with satC3S within the associated uncertainty, though the latter is preferred for long-term consistency (Dibarboure et al., 2011). **At basin scale, variability is strongly influenced by the sea level mass component, which reflects the large-scale balance between surface freshwater fluxes and boundary volume transports. Recent studies quantify this contribution over the Mediterranean basin as the residual of large but compensating terms, resulting in a basin-mean sea level contribution of about +8 mm/year over 1993–2022, similar to the observed sea level trend from altimetry data (Borile et al., 2025; García-García et al., 2022). Because mass contribution may be highly localized in time and space, its effect on sea level emerges primarily through integration over large domains, shaping the basin-averaged signal rather than local sea level variations. Focusing on the steric contribution to sea level change, Fig. 2 shows the thermosteric and halosteric components of the mean sea level decadal trend. The concept of steric compensation in the Mediterranean Sea arises from the opposing behaviour of these two components: the thermosteric trend component is positive and driven by seawater thermal expansion, while the halosteric contribution is negative and associated with the observed salinity increase (Aydogdu et al., 2023; Borghini et al., 2014). Although the steric components play a relatively minor role in the long-term mean sea level budget of the Mediterranean compared to mass-driven contributions (Pinardi et al., 2014), their decadal variability can reach amplitudes comparable to the observed sea level trends. This highlights the importance of accounting for steric processes, together with surface fluxes and boundary transports, to better understand the mechanisms governing the mean sea level change (Borile et al., 2025; Cazenave et al., 2014).**"

L26: It seems like VLM is the main factor of possible disagreement between satellite altimetry and tide gauges. Further to the fact that processing might be different and needs to be discussed in more detail (e.g., how consistent are the atmospheric corrections in SLA with tide gauge data processing? How can the spatial and temporal filtering applied to SLA impact the difference between the two networks?), There may be processes at a scale that altimetry cannot resolve, and all these points need to be better discussed and addressed, with reference to the relevant literature. Sometimes it appears like altimetry is being validated against tide gauges (e.g., L155, but also elsewhere). Still, the two networks inherently bear different information due to different spatio-temporal scales spanned, and the data processing.

R: Satellite altimetry measures absolute sea level variability and therefore does not require VLM corrections, but it includes the dynamic atmospheric correction (DAC). Conversely, tide-gauge Revised Local Reference (RLR) data are referenced to the ground and do not include DAC or VLM corrections. To improve comparability between the two datasets, we have already applied VLM corrections to the in situ data using SONEL/ULR products, and in the reviewed manuscript we reintroduce the DAC correction into the satellite data using AVISO+ product (following the comment made by reviewer #1). This processing strategy is consistent with standard approaches adopted in sea level intercomparison and budget studies (e.g., Bonaduce et al., 2016; Wöppelmann and Marcos, 2016).

Nevertheless, despite these corrections, the two datasets remain intrinsically different: satellite altimetry provides spatially distributed observations with limited resolution near the coast, while tide gauges measure local sea level and can capture small-scale processes unresolved by altimetry (Vignudelli et al., 2019). To enhance consistency, we harmonized the temporal scales of the datasets by averaging hourly tgCMEMS observations to daily values to match the satC3S sampling, and by applying the same low-pass filter to both datasets to remove variability at frequencies higher than 5 cycles/year. This ensures that sea level trends are estimated from time series characterized by comparable temporal variability.

These aspects are more clearly described in *Section 2* of the revised manuscript:

"[...] Both the tgPSMSL and tgCMEMS datasets were considered, as they may include different sets of stations. In both cases, **stations are selected based on record length and data completeness; short data gaps are linearly interpolated, and hourly records are averaged to daily values** to match the temporal resolution of SLA data.

Where available, preference is given to stations located nearby GNSS (Global Navigation Satellite System) sensors to allow vertical land movement (VLM) correction, using trend values provided by URL/SONEL data server, ULR7 solution (product ref. n.7, in Tab. 1). The ULR7 solution **provides vertical velocity estimates in the ITRF2014 (International Terrestrial Reference System) frame** (Gravelle et al., 2023). Accordingly, absolute sea level trends at tide gauge locations are computed by adding the VLM rate to the relative sea level trend derived from tide gauge records (Santamaría-Gómez et al., 2012).

Finally, **for direct comparison between satellite and in-situ observations, satC3S SLA values are extracted at the grid point closest to each tide gauge. Differences in reference frame and high-frequency signal treatment are minimized by reintroducing the dynamic atmospheric correction (DAC) into altimetry data and applying VLM corrections to tide gauge records. The DAC is taken from the CLS product based on the Mog2D model and distributed by Aviso+, with support from CNES (product ref. no. 8, in Tab. 1; Pascual et al., 2008). Overall, these processing choices aim to reduce methodological inconsistencies while acknowledging that satellite altimetry and tide gauges sample sea level variability at different spatial and temporal scales, and therefore provide complementary, rather than strictly equivalent, information."**

Equation (1): The approximation implied in using constant T_f , S_f versus spatially varying T_f , S_f seems quite crude and needs to be justified.

R: In Eq. (1) we chose to prescribe the reference temperature and salinity, T_f and S_f , as spatially constant values, consistently with previous analyses available in the literature (Pinardi et al., 2014; Borile et al., 2025), in continuity with which the present work is developed. Specifically, our focus here is on the basin-mean value of the steric component, while neglecting its spatial variability and, consequently, the spatial variability of the reference fields within the considered domain. To further support this choice, we report below the corresponding formulation. Let us define the spatially averaged reference fields as

$$\bar{T}_f = \langle T_f(x, y) \rangle, \bar{S}_f = \langle S_f(x, y) \rangle,$$

where $\langle \cdot \rangle$ denotes the horizontal spatial averaging operator. The spatially averaged steric sea level contribution can then be written as

$$\langle \eta_s \rangle = \int_{\{-H\}}^0 \alpha(z) [\langle T \rangle - \langle T_f \rangle] dz - \int_{\{-H\}}^0 \beta(z) [\langle S \rangle - \langle S_f \rangle] dz = \int_{\{-H\}}^0 \alpha(z) (\langle T \rangle - \bar{T}_f) dz - \int_{\{-H\}}^0 \beta(z) (\langle S \rangle - \bar{S}_f) dz$$

which is equivalent to the spatial average of eq (1).

A possible refinement would be to prescribe distinct reference values for the WMED and EMED, however, given that these two regions are strongly interconnected, we chose to adopt a single basin-averaged reference value representative of the entire Mediterranean Sea.

This information is now clarified as follow in *Section 2*:

"The same approach is used to evaluate the decadal trend associated with thermosteric (η_T) and halosteric (η_H) sea level components, **whose sum defines the total steric sea level (η_S)**:

$$\eta_S = \eta_T + \eta_H = \int_{-H}^0 \alpha (T - T_f) dz - \int_{-H}^0 \beta (S - S_f) dz \quad (1)$$

where T_f and S_f are reference temperature and salinity values, α and β are constant linear coefficients **of thermal expansion and haline contraction**, and H is the **spatially varying** ocean depth. **Both reference values and steric coefficients are taken as spatially constant basin-mean values, consistent with previous studies and suitable for a basin-averaged steric sea level analysis (Borile et al., 2025; Pinardi et al., 2014).**"

Section 3.1: The section will benefit from having a Table summarizing, for the WMED and EMED basins, the 1993-2024 trend (e.g., as average of the "moving trend" in the figures) and the acceleration (e.g., as slope of the "moving trend"); this would be very useful for further studies and comparisons, and can be done for the different components and data.

R: We agree with the reviewer that a Table would be useful to summarize the information provided in Figures 1 and 2. Although the main focus of this study is the analysis of decadal timescales, we will include a summary of the mean trends of SLA (from satCMEMS and satC3S) and its steric contributions (from MEDREA24 and GLORYS12) for the WMED and EMED basins, excluding the period affected by the uncorrected TOPEX-A drift.

Regarding the mean acceleration values, these were intentionally not provided, as the method used to estimate the trend does not allow for a robust estimation of its first derivative. Consequently, we chose not to report acceleration values derived from a simple linear fit, which we consider less accurate than the Theil–Sen estimator adopted in this study.

In the reviewed manuscript we include the new *Table 2*:

	SLA trend		Total steric sea level trend		Thermosteric sea level trend		Halosteric sea level trend	
	satCMEMS	satC3S	MEDREA24	GLORYS12	MEDREA24	GLORYS12	MEDREA24	GLORYS12
WMED	3.69 ± 0.77	3.95 ± 0.79	0.78 ± 0.68	0.10 ± 0.83	3.36 ± 0.55	3.95 ± 0.64	-2.52 ± 0.45	-3.91 ± 0.48
EMED	3.12 ± 1.17	2.95 ± 1.16	0.23 ± 0.67	-1.07 ± 0.92	3.53 ± 0.66	3.30 ± 0.91	-3.15 ± 0.26	-4.15 ± 0.59

Table 2: Summary of the mean decadal sea level trend values derived from Figs. 1 and 2 and computed for decades centered between 2004 and 2020, thus excluding the period affected by the uncorrected TOPEX-A drift. All values are reported in mm/year.

Also, section 3.1 appears somewhat inconclusive. I recommend the authors speculate on the reasons why WMED exhibits strong thermo/halo compensation, while EMED does not, i.e., why adiabatic processes dominate in the western MED compared to the EMED. This is an important point to discuss.

R: This section is now improved by adding a more detailed discussion on the physical interpretation of the presented results. In particular, as suggested by reviewer #3, we discuss the steric compensation observed in the EMED in connection with the Adriatic-Ionian Bimodal Oscillation System (see reply to RC3).

To improve the link between the total sea level and steric sea level trends, we also note that in the Mediterranean the combined contribution of sea level mass components and the steric components are of the same order of magnitude. Within this framework, we argue that the decadal variability of the halosteric and thermosteric components plays a crucial role in shaping the overall sub-basin sea level evolution.

Table 2. I suggest adding a column either with the adjusted values (Absolute – VLM) or the residuals (Absolute – VLM - Relative), so that one can more easily understand when there is statistically significant consistency of the datasets or not. Detailed comments about this last point can be added as well.

R: We include an additional column reporting the trend residuals, defined as the difference between satellite-derived and tide gauge estimates, to facilitate the assessment of the statistical consistency among the datasets. Additional comments discussing these residuals will also be included. The Table is now updated to fit the Ocean State Report requirements, reporting the latest decadal trend values, computed up to December 2024 (at the time of submission, tide gauges data were available only until July 2024). In addition, we reintroduce the DAC correction in the satellite data, as explained in a previous response.

The reviewed *Table 3* is here reported:

	Tide gauge coordinates	Relative sea level trend [tgCMEMS]	Relative sea level trend [tgPSMSL]	Absolute sea level trend [satC3S]	VLM trend [ULR/SONEL]	Sea level trend DIFF [satC3S – tg]
Marseille	43.28°N / 5.35°E	-	7.4 ± 1.7	7.5 ± 1.0	-0.49 ± 0.27 (5m)	0.5 ± 2.2
Barcelona	41.34°N / 2.16°E	7.9 ± 1.3	8.1 ± 1.2	6.6 ± 1.7	-0.86 ± 0.23 (0m)	-0.4 ± 2.3
Melilla	35.29°N / 2.92°W	6.3 ± 0.9	6.1 ± 1.1	6.6 ± 1.2	-	0.3 ± 1.5
Mallorca	39.56°N / 2.64°E	6.9 ± 1.9	7.0 ± 1.6	8.8 ± 2.1	1.68 ± 0.83 (0m)	0.2 ± 3.4
Ibiza	38.91°N / 1.45°E	7.9 ± 1.8	7.9 ± 1.7	8.1 ± 1.7	-1.28 ± 0.26 (78m)	1.5 ± 2.7
Lampedusa	35.50°N / 12.60°E	11.8 ± 1.4	-	10.0 ± 1.5	-0.36 ± 0.37 (130m)	-1.5 ± 2.4
Venezia	45.42°N / 12.43°E	6.9 ± 3.1	-	5.8 ± 2.0	-1.51 ± 1.56 (741m)	0.4 ± 5.1
Trieste	45.65°N / 13.76°E	13.2 ± 3.5	-	5.6 ± 2.1	0.01 ± 0.14 (6707m)	-7.6 ± 4.2
Hadera	32.47°N / 34.88°E	-	7.7 ± 2.3	7.2 ± 1.7	0.46 ± 0.21 (3145m)	-0.9 ± 3.0
Leros	37.13°N / 26.85°E	-	8.6 ± 1.6	7.7 ± 1.6	-	-0.9 ± 2.2

Table 3: Sea level trends near selected coastal cities for the most recent available decade (2015-2024) derived from different datasets: satC3S (with DAC reintroduced), tgCMEMS and tgPSMSL. The VLM trend, with the distance between each tide gauge and its associated GNSS station indicated in brackets, should be added to the in-situ relative sea level trend to allow comparison with the satC3S absolute sea level trends (see Fig. 3). The resulting trend difference is reported in the last column. When both tide gauge datasets are available, tgCMEMS data are used. All trend values are reported in mm/year.

Typos

R: We fixed the highlighted typos.

Decadal variability in the Eastern and Western Mediterranean sea level trends

Author(s): Federica Borile et al.

MS No.: sp-2025-2

Report: 10th edition of the Copernicus Ocean State Report (OSR10)

Below is the reviewer comment written in *blue italics*, while our response is in **black** and the inserted text in the revised manuscript is in **red**.

Comment by reviewer #3

In addition to comments raised by other two reviewers, what I am missing in the manuscript is connection between large-scale circulation changes and changes in sea level decadal trends. The most prominent quasi-decadal oscillation is Adriatic-Ionian Bimodal Oscillating System (BiOS; Gačić et al., 2010, <https://doi.org/10.1029/2010GL043216>; Civitarese et al., 2023, <https://doi.org/10.1016/j.pocean.2023.103056>), which is so strong that it can be reconstructed from centennial sea level data in the Mediterranean (Meli, 2024, <https://doi.org/10.1038/s41598-024-55579-4>). From Meli et al. (2023) and other literature on BiOS (see Civitarese et al., 2023), it seems that BiOS is not just affecting the Ionian Sea, but is part of a greater basin-wide circulation variability that may reflect in basin-wide SLA values. This topic deserves an appropriate attention and extensive discussion in the manuscript, and currently it is not mentioned et all.

R: We thank the reviewer for raising this important aspect, which was not explicitly addressed in the original version of the study. In the revised manuscript, we discuss the different behavior of sea level trend variability in the EMED and WMED. While the WMED shows an increasing sea level trend over the 30-year period, the EMED is characterized by a pronounced quasi-decadal variability that tends to mask any linear acceleration.

As suggested, a key contribution to this behavior is related to the BiOS, which represents a feedback mechanism between the Ionian upper-layer circulation and the thermohaline properties of waters formed in the Southern Adriatic (Gačić et al., 2010). To directly address this issue, we performed an additional analysis aimed at quantifying the relationship between Ionian circulation variability and sea level changes in the two sub-basins, including additional figures at the bottom of this response. We computed the Ionian Circulation Index (ICI, Lavigne et al., 2018, <https://doi.org/10.5194/bg-15-4431-2018>) using Absolute Dynamic Topography from the high-resolution satCMEMS dataset, and verified that our reconstructed index is consistent with previous estimates of Civitarese et al., 2023 (Fig.1-suppl). We then analysed the correlation between the ICI and the steric component of sea level, averaged over the WMED and EMED (Fig.2-suppl). While the correlation between ICI and steric sea level is negligible in the WMED ($r = -0.05$), it is substantial in the EMED ($r = -0.66$), indicating a strong link between Ionian circulation changes and thermosteric sea level variability in the EMED.

Since the focus of the manuscript is on decadal trends, we further examined the relationship between the ICI and decadal sea level trends by applying a 10-year moving window to the ICI time series (Fig.3-suppl). The resulting correlations show that BiOS-related variability strongly modulates the decadal steric sea level trend in the EMED (Fig.4-suppl, $r = 0.70$), and remains clearly detectable also in the satellite-derived sea level trends (Fig.5-suppl, $r = 0.63$), despite the presence of multiple contributing factors. In contrast, no meaningful correlation is found in the WMED, either for the steric component or for total sea level trends.

These results support the hypothesis that the BiOS is not only a regional feature of the Ionian Sea, but part of a broader basin-scale circulation variability that significantly affects EMED sea level on decadal timescales. Although originating in a relatively confined region, the BiOS appears sufficiently strong to influence basin-mean steric sea level variability across the entire EMED, consistent with previous findings (e.g. Meli et al., 2023; Civitarese et al., 2023; Meli, 2024), but not to impact the WMED behavior.

Due to manuscript length limitations, this new analysis and its interpretation will be briefly discussed, with appropriate references to more detailed treatments of the underlying physical mechanisms.

Section 3.1 is now improved adding the following paragraph:

“Therefore, while WMED shows an increasing mean sea level trend over the long period, the EMED is characterized by a pronounced quasi-decadal variability that tends to mask any linear acceleration (mean values are reported in Tab. 2). The different variability is connected to large-scale circulation changes occurred in the two sub-basins, with a key contribution related to the Adriatic-Ionian Bimodal Oscillating System (BiOS, Civitarese et al., 2023; Gačić et al., 2010). Although originating in a relatively confined region, the BiOS appears sufficiently strong to influence steric sea level variability across the entire EMED (substantial correlation between decadal trend and BiOS variability, $r=0.61$), consistent with previous findings (e.g. Meli et al., 2023; Civitarese et al., 2023; Meli, 2024), but not to impact the WMED behavior (with no correlation between decadal trend and BiOS variability, $r=-0.06$). ”

And *Conclusions* are now completed by adding:

“This study provides an assessment of decadal sea level trends in the Mediterranean Sea, emphasizing both regional-scale and coastal-scale variability. The results confirm that sea level rise in the basin is not a linear process but exhibits significant decadal fluctuations due to a complex interplay between mass and steric sea level components (Pinardi et al., 2015; García-García et al., 2022; Meli et al., 2023) connected to large-scale circulation changes (Gačić et al., 2010).

In the Western Mediterranean (WMED), a sea level acceleration has been observed since the early 2000s, partially sustained by thermal expansion that exceeds haline contraction (Pisano et al., 2020b). In contrast, the Eastern Mediterranean (EMED) displays stronger temporal variability, with halosteric contraction playing a major counterbalancing role (Meli et al., 2023; Borghini et al., 2014) correlated to the Adriatic-Ionian Bimodal Oscillating System mechanism (Civitarese et al., 2023). Only in recent years the EMED reached a comparable rate of sea level rise to the WMED, largely due to a weakening of the overall steric contribution.”

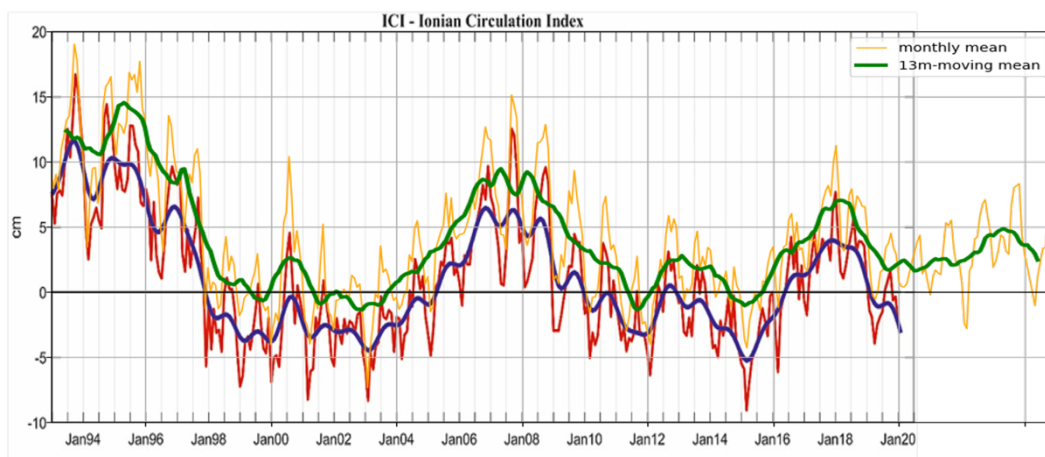


Figure 1-suppl: The ICI time series computed in this analysis are compared to the reference values from fig.15 in Civitarese et al. (2023). The comparison is between monthly data (*red* is the reference, and *orange* is satCMEMS data) as well as their 13-month moving mean (*blue* is the reference, and *green* is satCMEMS data). Timeseries are coherent between each other, despite an offset of about 2-3 cm that we associate to different datasets used for the analysis.

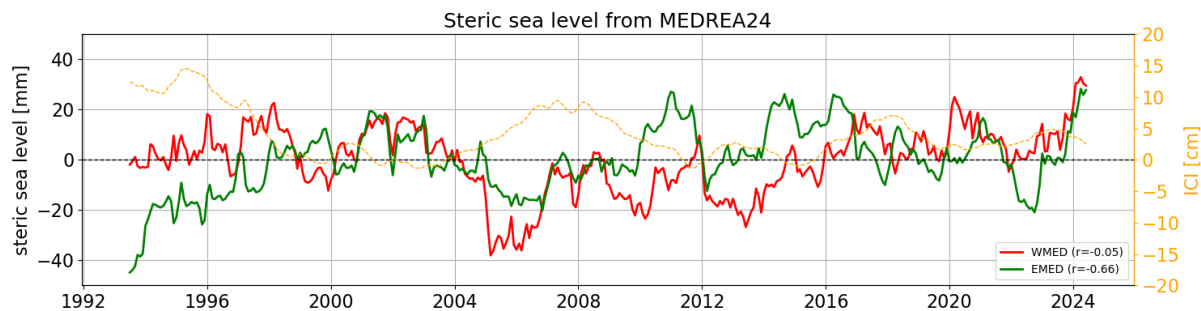


Figure 2-suppl: Time series of total steric sea level from MEDREA24 averaged over the WMED and EMED. The *dashed line* represents the ICI, 13-month moving mean. In the legend, the correlation value (r) is reported for each sub-basin.

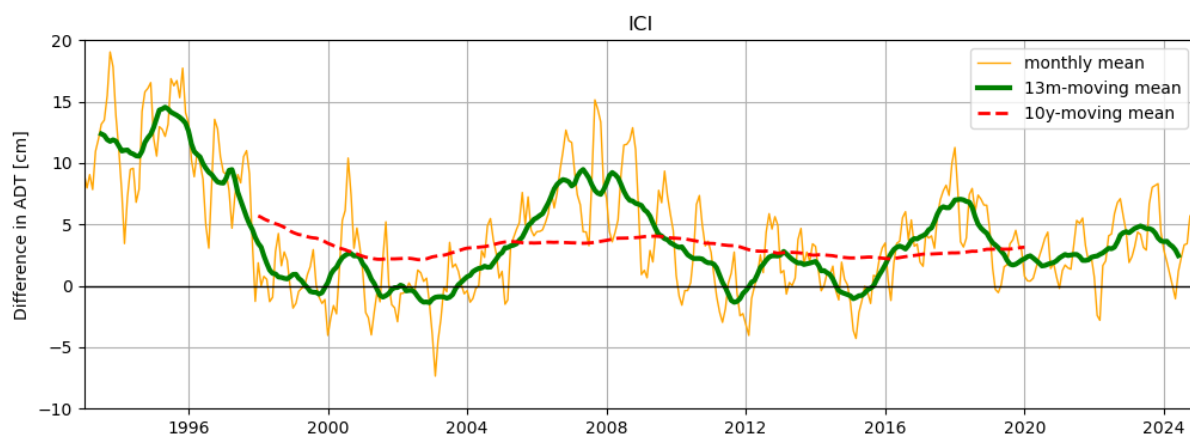


Figure 3-suppl: ICI time series presented also in Fig.1-suppl, with the addition of its 10-year moving mean (*red dashed line*) used to compute the correlation with decadal sea level trend time series.

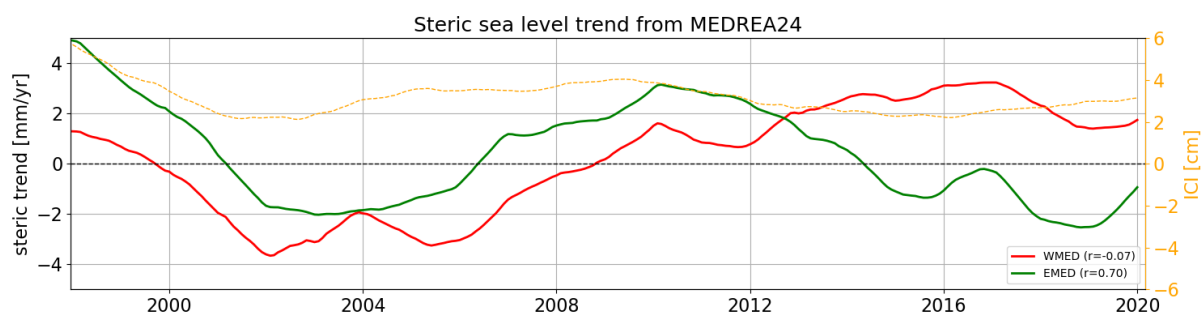


Figure 4-suppl: Time series of total steric sea level decadal trend from MEDREA24 averaged over the WMED and EMED, computed over 10-year windows shifted every year. The *dashed orange line* represents the ICI, 10-year moving mean. In the legend, the correlation value (r) is reported for each sub-basin.

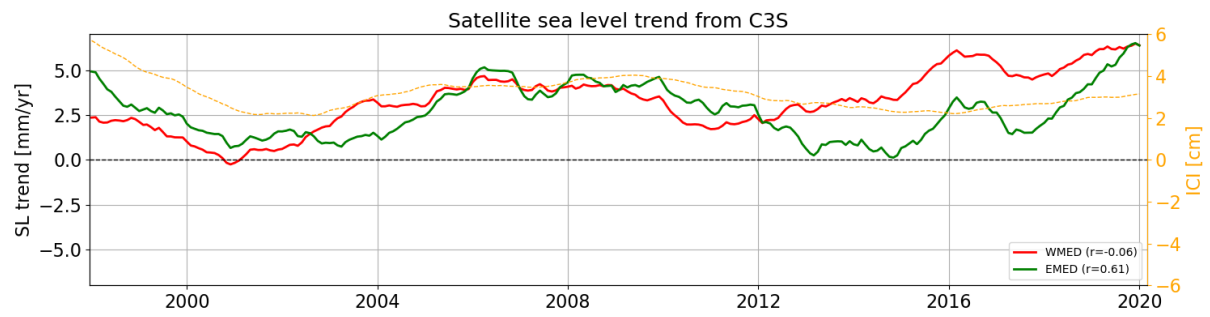


Figure 5-suppl: Time series of satellite sea level decadal trend from C3S averaged over the EMED and WMED. The *dashed orange line* represents the ICI, 10-year moving mean. In the legend, the correlation value (r) is reported for each sub-basin.