

Decadal variability in the Eastern and Western Mediterranean sea level trends

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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.”

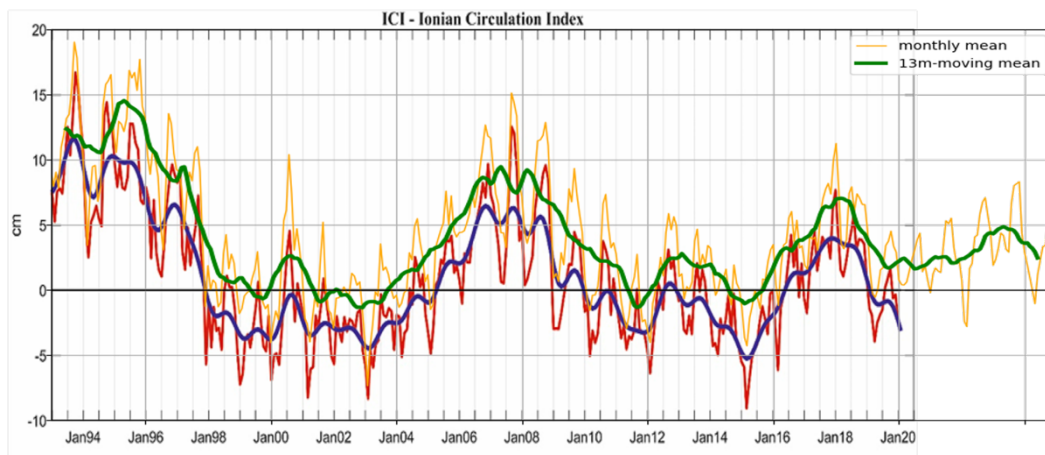


Figure 1-suppl: The ICI time series computed in this analysis are compared to the reference values from fig.15 in Civitarese et al. (2023). The comparison is between monthly data (*red* is the reference, and *orange* is satCMEMS data) as well as their 13-month moving mean (*blue* is the reference, and *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.

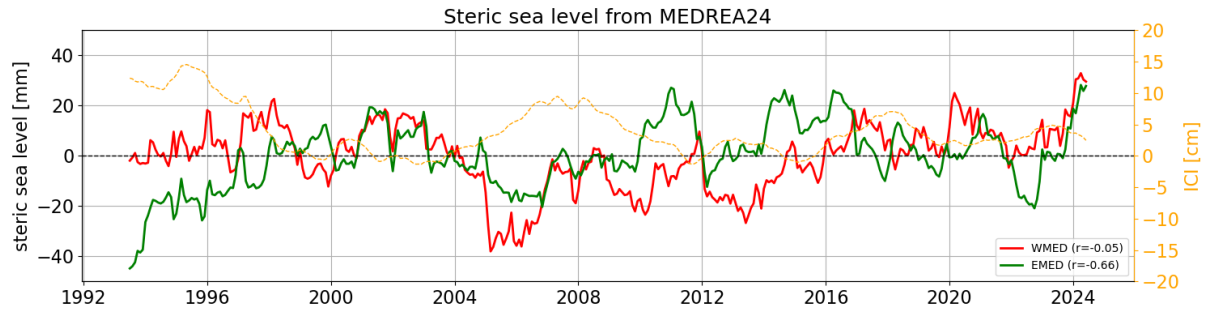


Figure 2-suppl: Time series of total steric sea level from MEDREA24 averaged over the WMED and EMED. The *dashed line* represents the ICI, 13-month moving mean. In the legend, the correlation value (r) is reported for each sub-basin.

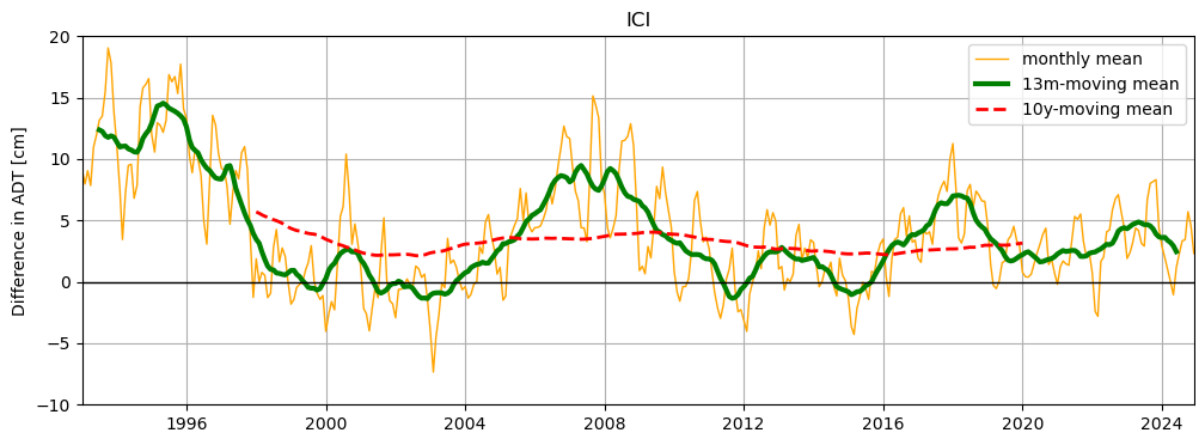


Figure 3-suppl: ICI time series presented also in Fig.1-suppl, with the addition of its 10-year moving mean (*red dashed line*) used to compute the correlation with decadal sea level trend time series.

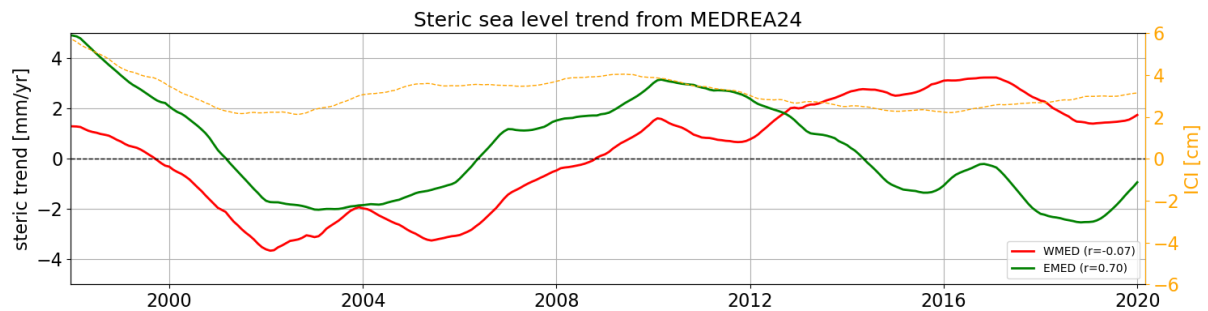


Figure 4-suppl: Time series of total steric sea level decadal trend from MEDREA24 averaged over the WMED and EMED, computed over 10-year windows shifted every year. The *dashed orange line* represents the ICI, 10-year moving mean. In the legend, the correlation value (r) is reported for each sub-basin.

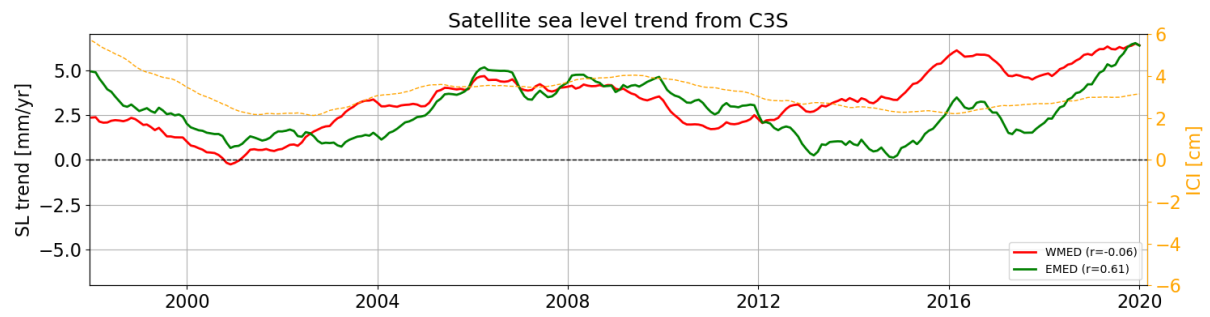


Figure 5-suppl: Time series of satellite sea level decadal trend from C3S averaged over the EMED and WMED. The *dashed orange line* represents the ICI, 10-year moving mean. In the legend, the correlation value (r) is reported for each sub-basin.