Response to reviewer #1 Justino Martinez

I am truly grateful for the contribution of Reviewer #1—Dr. Justino Martinez—to enhancing the quality of the article. The comments are addressed in detail below (responses marked with "**R:**").

- **General comments**

The Mediterranean, and the Adriatic in particular, is severely affected by global warming. Over the last 40 years, its surface has warmed by more than 1.5ºC [1] and up to 2ºC in some regions of the Adriatic. The deep waters are also expected to warm to a greater or lesser extent. Then, even for shorter periods than 31 years, the trend in the temperature series cannot be neglected. And this fact introduces my main objection to the publication of this work as is. For time series with trend, the calculation of the extremes cannot be performed using the original time series. Such a calculation leads to an overestimation or underestimation of the extremes, depending on the characteristics of the trend and the position of the extremes in the time series. This is especially important if the value of extremes (their deviation from the mean or the median) are comparable to the accumulated trend in the series. The non-stationarity, including trends and seasonality, of time series can invalidate the assumptions of many extreme value models

[…]

In the light of all this evidence, I think that in order to study the phenomenon occurring in some years of the time series (such as the influence of the EMT in the MHW intensity), it is necessary to use the detrended time series (historical and RCP 8.5). This is not difficult as the Schlegel R package can be fed with the detrended time series instead of the original time series.

The MHW community is making efforts to establish a common definition of MHW, mainly based on the baseline used. The recent work by Smith et al [8] is a first step in this direction, defining different baselines (i.e. different MHW detection methods) according to the aim of the study (ecological risk of MHW, effect of variability changes...). In particular, the fixed baseline (the one used by the author in the work under revision) is the recommended for intercomparisons between periods (the case under study in this case) but not for variability changes derived from discharges of rivers (Po) or temporal intrusion of deep waters (EMT).

R: Following the advice of the reviewer, and based on the recent study of Smith et al. (2025), the article will now use the detrended SST to extract Adriatic MHWs to assess the variability changes derived from ocean dynamics (Po River, EMT and BiOS).

First, the following introduction will be added to paragraph "4.2 Added value of the Pseudo-Global Warming method":

"This section highlights the added value of the Pseudo-Global Warming (PGW) approach implemented in the AdriSC kilometre-scale model by evaluating the influence of Adriatic Sea dynamics on marine heatwave (MHW) variability. Following the methodologies of Amaya et al. (2023) and Smith et al. (2025), both MHWs and the contributions of the total air-sea heat fluxes ($dSST_{Q_{net}}$) to the change in sea-surface temperature anomaly ($dSST_A$) have been recalculated using detrended sea surface temperature signals."

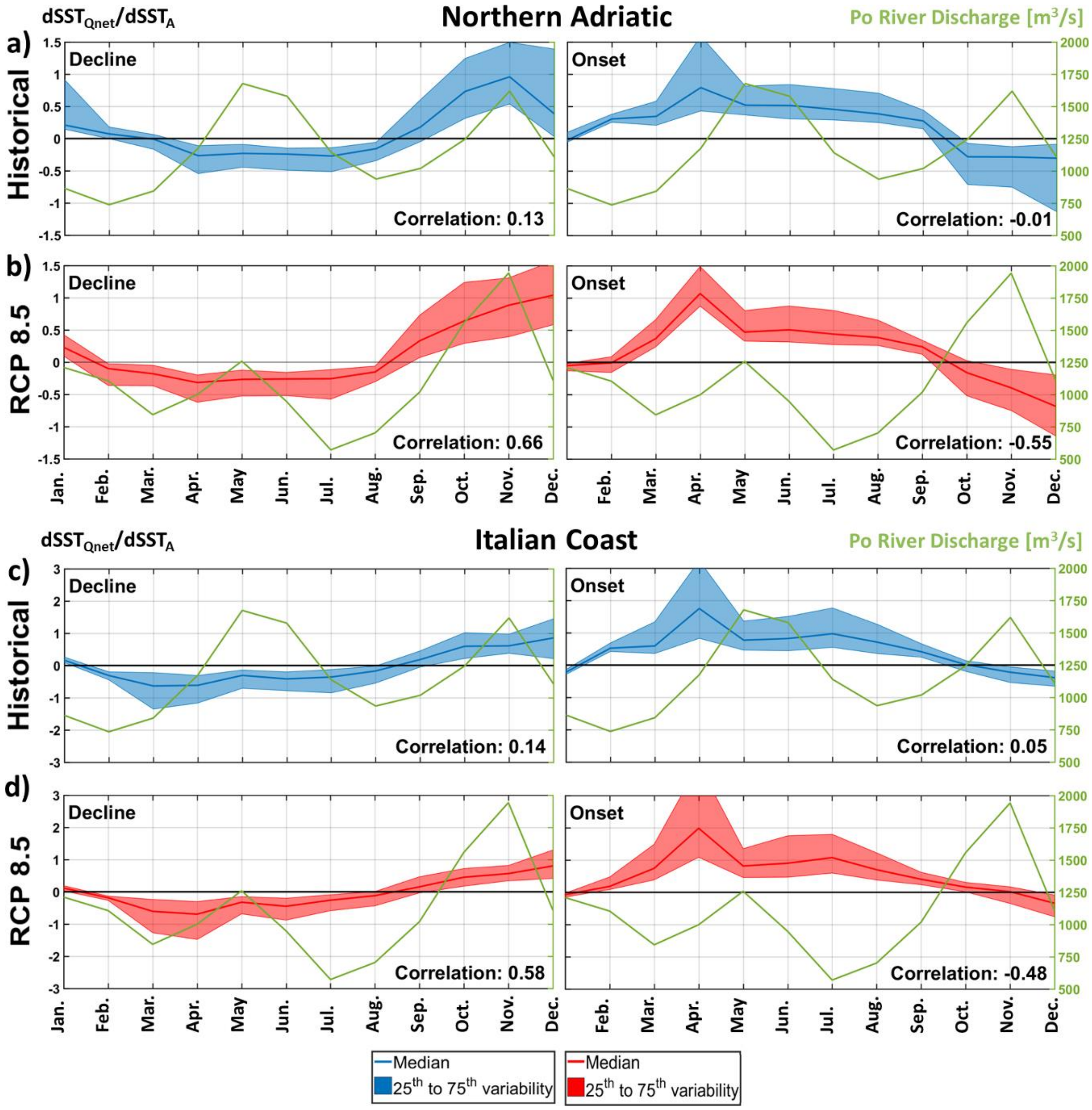

Figure 9. For the Northern Adriatic (a, b) and Italian Coast (c, d) subdomains, monthly climatologies of the median, 25th and 75th percentiles of the contribution of total air-sea heat fluxes ($dSST_{Q_{net}}$) to the change in sea-surface temperature anomaly ($dSST_A$) during MHW onset and decline phases with the monthly climatology of the Po River discharge superimposed (in green) and defined over the 31 years for the historical (b, d, in blue) and RCP 8.5 (a, c, in red) conditions.

Second, Figure 9 will be updated with the new results and the analysis of the results will be updated as follows:

"After recalculation of the MHWs with the detrended sea-surface temperature signal, the AdriSC model results do not align with the conclusions of Verri et al. (2024). First, under historical conditions, no or weak correlations are found in the northern Adriatic (0.11) and along the Italian coast (0.05) between monthly MHW intensities and Po River discharge. However, between August and April, anti-correlations reach -0.54 in the northern Adriatic and -0.71 along the Italian coast.

Additionally, under far-future extreme warming, the anti-correlations reach -0.49 in the northern Adriatic and -0.51 along the Italian coast. Second, as shown in Figure 9, for both the Northern Adriatic and Italian Coast subdomains, no correlation is found between the Po River discharge and $dSST_{Q_{net}} / dSST_A$ during the MHW onset under historical conditions, while anti-correlations of approximately -0.5 are observed under the RCP 8.5 scenario. However, under historical conditions, between August and April, the anti-correlations reach -0.45 in the northern Adriatic and -0.21 along the Italian coast. For the decline of MHWs, positive correlations are observed: 0.13 and 0.66 in the northern Adriatic and 0.14 and 0.58 along the Italian coast for historical and RCP 8.5 conditions, respectively. However, between August and April, these correlations increase to 0.71 in the northern Adriatic and 0.56 along the Italian coast under historical conditions."

It should be noted that, despite some changes in the correlations, these results confirm the previous findings and the conclusions remain unchanged concerning the interactions between Po river plume and Adriatic MHWs—particularly the need to better represent the Po river dynamics including its temperature, suspended sediments, and organic matter.

Third, for the interactions of Adriatic MHWs with the major oceanographic events, the following paragraph and figure will be added:

"One of the most interesting features of the MHW results presented in this study is that, for both historical and far-future extreme warming conditions, no MHW is detected during years 9 to 11. After recalculating the MHWs using the detrended sea surface temperature signal, this result is largely confirmed, except for the presence of a very weak MHW in year 11 under historical conditions (Fig. 10; CHI variability)."

The following discussion concerning both EMT and BiOS based on the new figure 10 will also be added:

"The presence of a gap in MHW activity visible under both historical and RCP 8.5 conditions, thus suggests that natural variability, such as the EMT, plays a significant role in modulating heatwave occurrences in the Adriatic, even under strong anthropogenic forcing. However, the study of Soto-Navarro et al. (2020) found that most Med-CORDEX regional climate models project a reduction of the dense water formation in the Aegean Sea and, hence, of the EMT-like situations. Finally, the suppression of MHW in the Adriatic Sea has not been previously linked to the EMT.

Additionally, the study by Parras-Berrocal et al. (2023) suggested that major oceanographic events, such as the EMT, which affect thermohaline circulation and dense water formation, can influence the occurrence and characteristics of MHWs in the Mediterranean Sea. Consequently, it is reasonable to assume that Adriatic MHW variability may also be affected by the Ionian-Adriatic Bimodal Oscillating System (BiOS; Gačić et al., 2010), which links the quasi-decadal reversals of the Northern Ionian Gyre circulation to salinity variability and dense water dynamics in the Adriatic Sea. Previous studies (Denamiel et al., 2022, 2025) have shown that, under both historical and RCP 8.5 conditions, the BiOS signal in the Ionian Sea is strongly correlated—at a 2-year lag—with the first empirical orthogonal function (EOF) of salinity at 100 m depth, which can therefore serve as a proxy for BiOS-induced variability in the Adriatic Sea (Fig. 10a, c).

However, despite a slight increase in both the frequency of MHWs and the influence of air-sea fluxes on their onset during the cyclonic phases of the BiOS under historical and RCP 8.5 scenarios, no definitive connection is found between the Cumulative Heat Index (CHI) and the BiOS-induced variability in the Adriatic Sea."

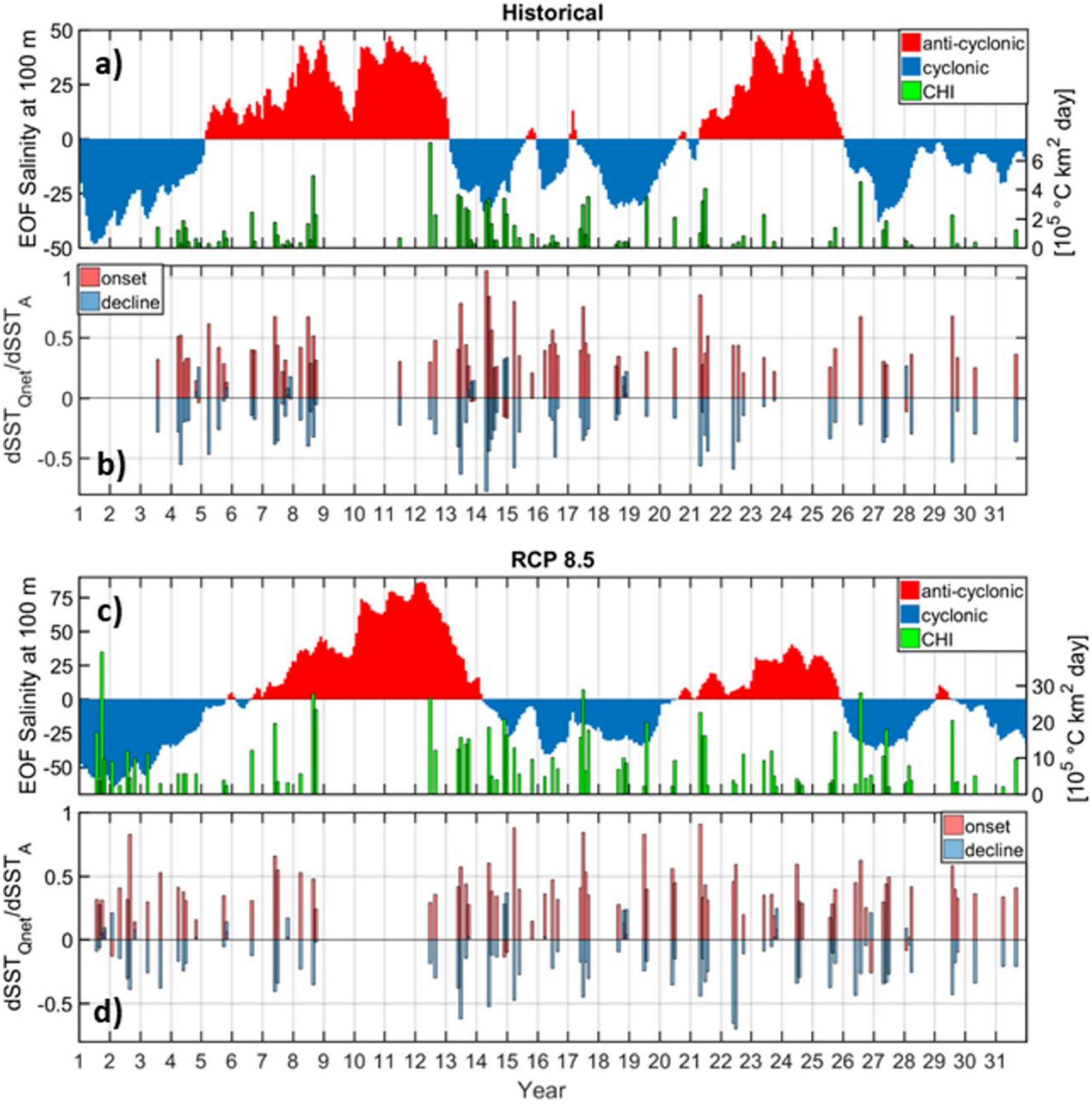

Figure 10. Monthly time series over the 31-year Historical (a, b) and RCP 8.5 (c, d) periods, CHI—extracted from the detrended Adriatic SST—superimposed to the first Empirical Orthogonal Function (EOF) of salinity at 100 m depth representing the influence of the BiOS in the Adriatic Sea (a,c). Contribution of total air-sea heat fluxes ($dSST_{Q_{net}}$) to the change in sea-surface temperature anomaly ($dSST_A$) during MHW onset and decline phases.

As previously, the main conclusions remain unchanged.

- **Specific comments**

The influence of the Po outflow on the presence, intensity or extent of the MHW is a very interesting (and expected) result. If you finally agree to calculate the temperature trend for historical periods and RCP8.5, you may be able to relate the Po outflow and the Western Adriatic Current to a slower rate of warming. It could be an interesting new paper if you can relate Po outflow to lower warming rates as a function of depth using a km-scale experiment. This is something we can see intuitively using a global Mediterranean Sea surface temperature product (see Figure 1 of the paper you referred to as Martinez et al 2023 in your manuscript). A large version of this figure can be found in

https://www.frontiersin.org/files/Articles/1193164/fmars-10-1193164-HTML/image_m/fmars-10-1193164-g001.jpg

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R: The reviewer's suggestion is deeply appreciated and opens a particularly stimulating perspective for future work. Based on the previous AdriSC model results published in Tojčić et al. (2023, 2024), we have already observed that SST variability along the Po River plume may exert an even more pronounced influence than the long-term SST trends themselves (see Fig. R1 below). Additionally, the high concentration of suspended matter transported by the Po River can significantly alters heat penetration into the water column, which is another factor worth exploring.

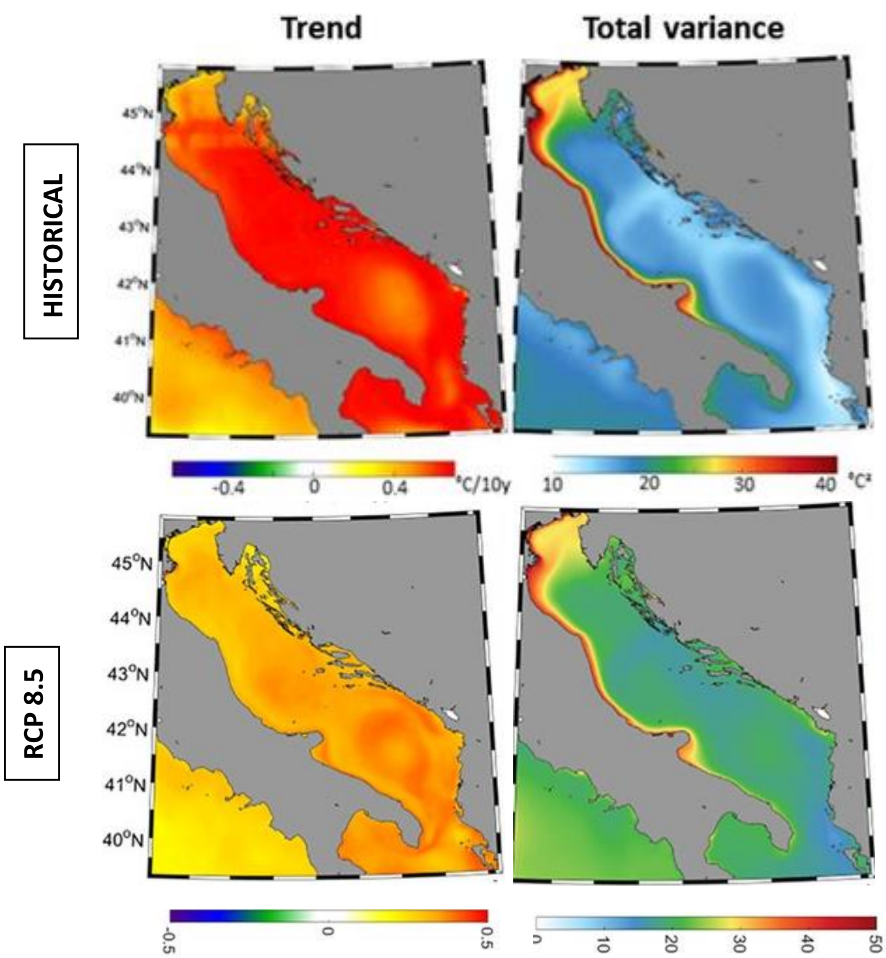

Figure R1. Trend and variance of the sea surface temperature (SST) during the 31-year of the historical and RCP 8.5 period.

My current view is that a robust understanding of the Po plume's impact on Adriatic MHWs would require an accurate and high-resolution representation of plume dynamics (including suspended matter). That said, I greatly value the reviewer's insight and would be very happy to explore this further, should the reviewer be interested in collaborating on a dedicated study focusing on these interactions.

Following our paper (Martinez et al 2023), note that you have identified the significant MHW of the second half of the period, but not the earlier ones, most likely due to the fixed baseline you have used.

R: The following paragraph will be added to address this comment:

"It should be noted that Martinez et al. (2023) identified more Adriatic MHWs than the AdriSC model in the first half of the 1987-2017 period as they used detrended sea-surface temperature data."

- **Technical comments**

• Figure 3e: The probability density functions are normalized to have unity area? Same question for figures 5 and 6

R: This is correct and the methodology section will be modified as follows:

"All annual and monthly probability density functions of the historical and RCP 8.5 intensities are normalized to have a unity area following a kernel-smoothing method (Bowman and Azzalini, 1997) evaluated for 100 equally spaced points."

• Lline 260: You mention a double peak in temperature in the Deep Adriatic subdomain. Are you referring to figure 5b?

R: This is correct and the sentence will be modified as follows:

"Notably, the presence of a double peak in the distribution of ocean bottom temperature intensities in the Deep Adriatic subdomain (at about 0.5 °C and 3 °C; Fig. 5b) is linked to the fact that, under the RCP 8.5 scenario, the shallow areas of the Adriatic Sea are expected to warm by up to 3.5 °C, while the deepest parts only by up to 0.5 °C (Denamiel et al., 2025)."

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