Reviewer #2:

The present study investigates the Mediterranean cyclones using regional climate models (RCMs) as well as the ERA5 reanalysis. They assess the reproducibility of intense Mediterranean cyclones in their atmosphere-ocean coupled RCM simulation and compare the simulation with an atmosphere stand-alone simulation to examine the effect of air-sea coupling in RCMs. They also investigate the impacts of intense Mediterranean cyclones on the ocean using the coupled simulation in comparison to the ocean observations.

Overall, this study potentially provides materials with implications to improve our understanding of the importance of air-sea interactions for Mediterranean cyclones, which hold significant socio-economic relevance. The influence of air-sea coupling assessed through their RCM simulations is clear and interesting

I am afraid, however, that a major revision is needed before this study can be published, for the specific reasons shown below. I am particularly concerned about the interpretation of the results.

We thank the Reviewer for dedicating time to review our manuscript and for the detailed observations that have raised the quality of the paper.

The valuable feedback has helped us improve the clarity of the work and better emphasise its results and novelty. Specifically, we have significantly revised the Results section to provide a more detailed explanation of the physical mechanisms behind the differences in the atmospheric processes between CPL and STD during extreme Mediterranean cyclones and to address the specific questions raised by the reviewer.

In addition, we have revised the conclusion to emphasize the novelty of the study. Specifically, we modified lines 432-434, as follow:

"*This study investigates for the first time (to the best of our knowledge) how extreme Mediterranean cyclones affects simultaneously the atmosphere and the ocean at different vertical levels, comparing two high-resolution RCM simulations, one atmosphere-ocean coupled (CPL) and one atmosphere stand-alone (STD), over the period 1982-2014.*",

and lines 454-456, as follow:

"*This research highlights the ability of the coupled model to coherently simulate the entire atmosphere-ocean system, thus providing new insights into how sea surface energy is redistributed between the atmospheric boundary layer and the ocean mixed layer, and how this impacts the precipitation and the wind speed during extreme cyclone events.*".

Please note that figures 4, 7 and 9 have been revised following the reviewers' comments. The figures now show latent and sensible heat fluxes, 10 m wind speed, potential temperature lapse rate, convective precipitation and total (large scale + convective) precipitation.

Please also note that the text-line references mentioned in our responses correspond to the revised manuscript.

Below, the Reviewer will find our detailed, point-by-point, answers.

Specific comments:

1 Turbulent heat fluxes, precipitation (and associated diabatic heating), and low-level temperature distribution are important factors for extratropical cyclone development. This study argues that the different SST distribution between the models, which is due to the air-sea coupling, is the dominant factor in shaping anomalies of those variables. Yet, this study also concludes that the coupling between the atmosphere and ocean exerts a limited influence on their statistics such as frequency, lifetime,

speed, and intensity. To me, the two conclusions appear inconsistent. The authors should provide a detailed discussion on why these results emerged, addressing both the model's role and potential underlying mechanisms.

We thank the Reviewer for point out this issue. Here, we clarify the results of our study, addressing the key mechanisms associated to the dynamics of the cyclones.

In **Section 3.1** (*Climatology of Extreme Mediterranean Cyclones*), we analysed the differences between the two models (STD and CPL) and ERA5 in representing the main characteristics of the 500 most intense cyclones. Our findings showed that both regional climate models (RCMs) effectively represent key statistical features of cyclones, including their seasonal cycle, and cyclone track characteristics. However, the models differ from ERA5 in the simulation of cyclones location, mainly due to differences in resolution and model dynamics and physics. These differences affect how the RCM models reproduce e.g. the impact of orography on cyclone dynamics or the role of convection in deepening the cyclones, resulting in local deeper minima of SLP over Mediterranean areas with complex land-sea distribution. In contrast, differences between STD and CPL are minor, leading to the conclusion that atmosphere-ocean coupling exerts only a limited influence on the climatological and statistical properties of extreme Mediterranean cyclones.

This should be a rather “expected” result. Indeed, the most intense Mediterranean cyclones are formed due to large scale forcing, i.e. the intrusion of upper tropospheric systems as a result of Rossby wave breaking over the Atlantic Ocean (Flaounas et al., 2022). This upper tropospheric forcing is identically introduced to the two simulations through the boundary conditions. Furthermore, their characteristic length scale allows their realistic reproduction even at relatively coarse resolutions as the ones in ERA5. The development of cyclones though might depend on both the large scale forcing and diabatic forcing due to convection within the cyclone systems. The latter is strongly dependent on the parametrisation, resolution and -therefore- on the underlying SST. In such climate-scales numerical experiments, one should expect thus that cyclones formation should be rather “similar” in the two simulations, but cyclones development might change at the extent that an extreme cyclone is more diabatically driven than developed due to baroclinic instability (i.e. due to the upper level forcing which should be less sensitive to SST). As a conclusion, if we regard a cyclone system as the outcome of large-scale processes (external to the cyclone system) and small-scale processes (internal to the cyclone system), then we should expect atmosphere-ocean coupling to have a stronger effect on the physical processes of the cyclone systems, and a rather weaker effect on their formation distribution and track characteristics. We have modified Fig. 3 and included this discussion in the revised manuscript (section 3.1, “Climatology of extreme Mediterranean cyclones”) as follow (L247-271):

“*Figure 3 instead shows the maps of cyclone centre densities (CCD; Neu et al. 2013, Flaounas et al. 2018a) for ERA5 and the differences in CCD between ERA5 and RCMs. The CCD is defined as the absolute number of occurrences of the 500 most intense cyclone centres. To highlight the cyclones’ area of influence, each centre is represented by a circular area with radius of 1.5 degrees around the tracked minimum SLP point. Compared to ERA5, both RCMs tend to capture the main regions of frequent cyclogenesis (over the gulf of Genoa, over the Adriatic and Aegean Seas and the marine areas close to Cyprus). This can be expected since the most intense Mediterranean cyclones are formed due to large scale forcing, i.e. the intrusion of upper tropospheric systems as a result of Rossby wave breaking over the Atlantic Ocean (Flaounas et al., 2022). This upper tropospheric forcing is identically introduced to the two simulations through the boundary conditions. However, cyclones seasonality and location also depend on diabatic forcing due to convection within the cyclone systems, as well as on the basin’s orography. Both RCMs show a higher occurrence of cyclones in summer and spring (Fig. 2d and Fig. S1 in supplementary) and compared to ERA5, they tend to underestimate the CCD over the Mediterranean Sea while overestimating it over land and over the Aegean and Levantine Sea (Fig. 3b and c). Differences between the two RCMs and ERA5 arise primarily from the different resolution, dynamics and physical parameterisation. These factors influence how the models reproduce key processes, such as. the impact of orography on cyclone dynamics and the role of convection in deepening the cyclones, resulting in local deeper minima of SLP over Mediterranean areas with complex land-sea distribution. Therefore, differences from ERA5 should not be taken purely as a weakness of RCMs, but rather as a result of differences when reproducing atmospheric processes. Indeed, the magnitude of these* *differences is comparable to the one found in previous studies (Flaounas et al., 2018a; Reale et al., 2022) and thus RCMs should be expected to deviate from reanalysis. In contrast, changes in the SST distribution have a minor impact on the dynamics of the cyclones, leading to small differences between STD and CPL, primarily in the location of cyclone minima over the sea (Fig. 3d). In conclusion, cyclone systems arise from a combination of large-scale processes (external to the cyclone) and small-scale processes (internal to the cyclone). In this context, atmosphere-ocean coupling is expected to have a stronger influence on the physical processes within the cyclone systems, and a rather weaker effect on their formation, distribution, and track characteristics*."

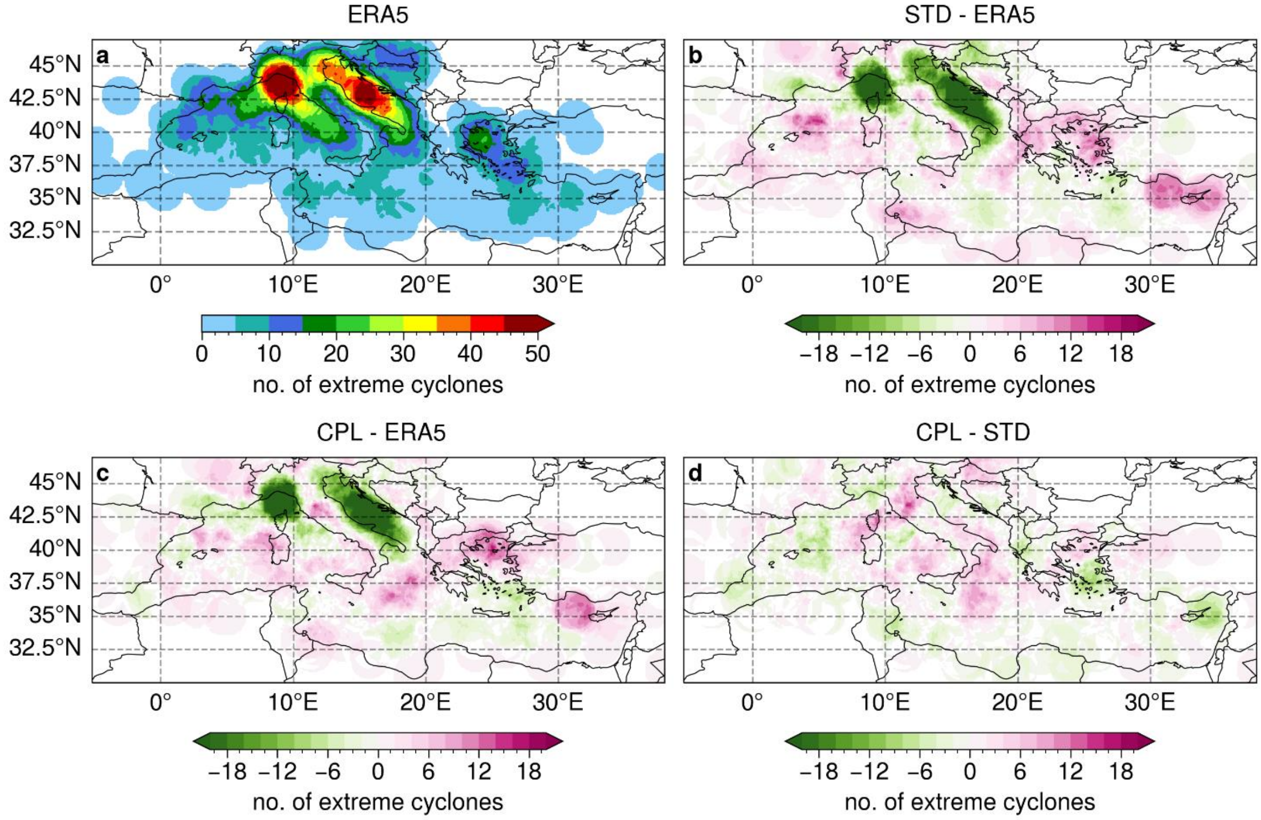


Figure 3: Number of occurrences of cyclone centre densities (CCD) for the 500 most intense cyclones in ERA5 (a), along with CCD differences between STD and ERA5 (b), CPL and ERA5 (c), and CPL and STD (d). To highlight the cyclones' area of influence, each centre is represented by a circular area with radius of 1.5 degrees around the tracked minimum SLP point.

2 The spatial composite maps (Figs. 4-8) seem to be composites of time steps when one or more "common" selected intense cyclones are located within the domain of interest (Fig. 1). If this is the case, signals in these composite maps do not necessarily occur in the vicinity of intense cyclones of interest. This discrepancy could partly explain the study's apparently inconsistent conclusions (as noted above). While signals in composite maps during intense cyclone time-steps are associated with cyclone dynamics, some may not be directly relevant to cyclones.

We thank the Reviewer for the comment. Regarding the inconsistent conclusions please refer to the comment right above. We also agree that to some extent, the differences fields in Figs 4-8 might be also due to differences in the larger scale atmospheric circulation, encompassing the cyclone systems. To address this issue, we show the composite field differences computed only within the area of influence of the cyclones, defined as a circular area with 500 km radius (Flaounas et al. 2016) around the minimum SLP tracking point (Fig. A1). These results are compared with the differences computed over the entire domain (as figure 7 in the revised manuscript but without bootstrapping for its significance, Fig. A2). Spatial distribution of differences in convective (Fig. A1e, A2e) and total (Fig. A1f, A2f) precipitation differences is fairly similar between Fig. A1 and A2, suggesting that the impact of the SST distribution is stronger close to the cyclone centres. In addition, differences in atmospheric boundary layer processes, such as stronger latent (Fig. A2a) and sensible (Fig. A2b) heat fluxes, higher 10 m wind speed (Fig. A2c) and reduced stability (lower potential temperature lapse rate, Fig. A2d), are not well observed when computed only within the circular area around the cyclones (Fig. A1a-d). This reflects the small location and timing mismatches between the extreme winter cyclones in common between CPL and STD, i.e. when the SLP minima is within 500 km maximum distance and 12-hour time window. To highlight these outcomes, we added the following sentences in the manuscript (L197-203):

"*Our composite averaging is done for the entire domain and therefore the difference fields (CPL – STD) might be also affected by atmospheric systems other than cyclones. An additional analysis, using the same approach as in Flaounas et al., (2016), is applied where differences were calculated only within an area of 500 km around the cyclone centre. The different methods do not affect the results (not shown), because the intense cyclones are expected to have a substantial impact to the whole domain, so most of the differences are attributed to the areas close to cyclones. In addition, our strategy allows to overcome the slight location mismatch between CPL and STD (i.e. linked with 500 km maximum distance between the minimum of SLP) when computing the differences.*"

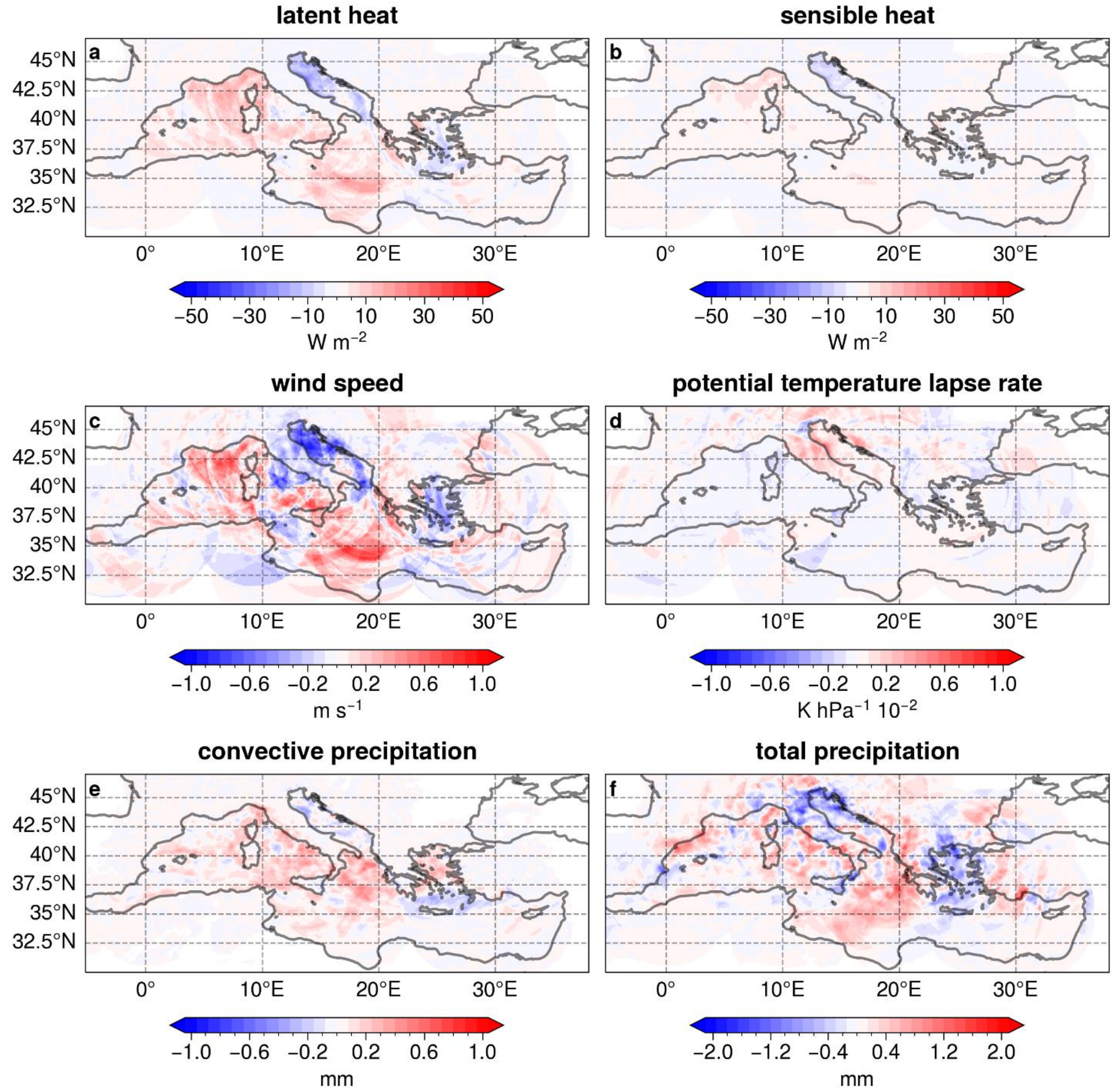


Figure A1: Same as figure 7 but computed only on the area of influence of the cyclones, defined as a circular area with 500 km radius around the minimum SLP tracking point.

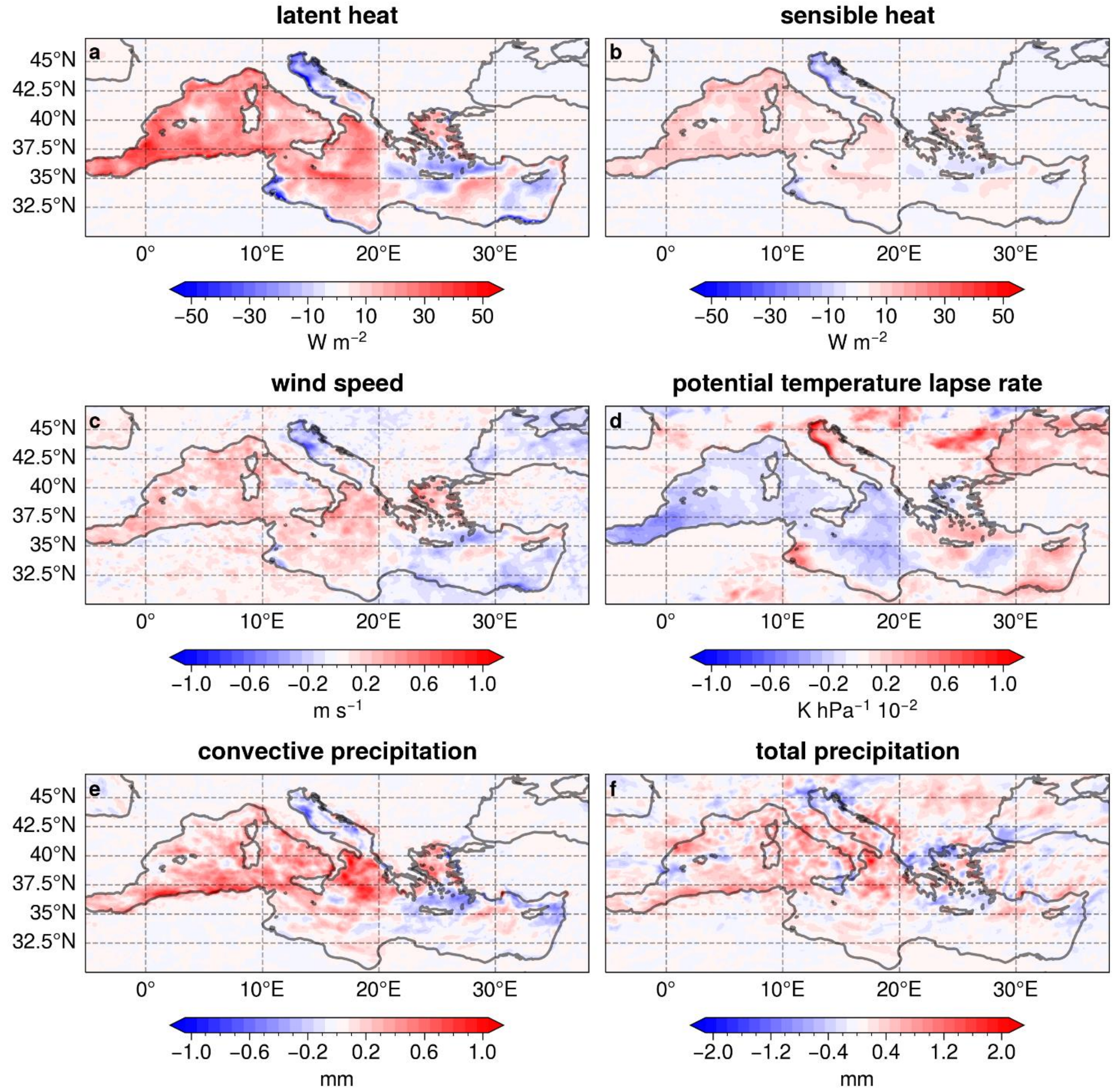


Figure A2: Same as figure 7 but without applying the bootstrapping method for its significance.

3 The reasoning behind the differences in cyclone frequencies between RCMs and ERA5 (Figs. 2 and 3) is not quite convincing. The authors argue that the differences are due to the different native resolutions of the RCMs (higher) and the ERA5 model (lower). I am afraid, however, that ERA5 is a reanalysis assimilated with a lot of observations. Those observations are particularly abundant in the land and expected to substantially improve the reproducibility of synoptic and larger-scale features, including intense cyclones near the coast. It would make more sense to attribute differences in the open ocean mainly to models' native resolutions, but this is not the case for cyclones, for example, in the Adriatic Sea, the Ligurian Sea, and the Aegean Sea, and off the Gulf of Antalya. For synoptic-scale features, I think that reanalyses generally to a considerable extent reflect the reality, whose "native resolution" is much higher than any simulations.

We agree with the Reviewer that ERA5 generally reflects real-world conditions, enhancing the reproducibility of large-scale synoptic systems such as Mediterranean cyclones. Therefore, in the revised section 3.1, we have clarified that the RCMs do not simulate the impact of orography on cyclone dynamics better than ERA5, rather they show discrepancies compared to the reanalysis. These differences arise from the dynamical downscaling process, which differently simulates cyclone dynamics and the influence of orography on cyclone locations. Please see the discussion in the first specific comment and refer to the revised text (lines 247-271) mentioned there.

4 The interpretation and discussion of SST differences (or biases) between STD and CPL are insufficient, and the authors should discuss the SST bias in relation to cyclone frequency and other properties. Is it related to the difference in the frequency and other properties of intense cyclones? Because there is no corresponding map of cyclone frequency difference to Figs. 5 and 6, it is hard to consider the relationship between the cyclone frequency and SST. To me, the SST difference (or bias) of nearly 2K is large enough to be expected to have impacts on the overlying atmosphere and cyclones (as in the following subsection). If SST differences indeed influence the atmosphere, it would be beneficial to clarify (or at least suggest) the mechanisms within the model that generate these differences.

We thank the Reviewer for providing this valuable feedback. We agree that would be insightful to deeper investigate the SST bias in the CPL model and the physical mechanism behind that. Likely, the SST difference depends on the different forcings coming from the atmospheric models and intrinsic differences in the ocean models. This is an area of ongoing research in the climate modelling laboratory at ENEA, where the coupled model has been developed. However, this topic requires additional study and is beyond the scope of the present paper.

For the purposes of our work, it is important to investigate how the climatological differences between the explicitly resolved SST in CPL and the SST in STD (forced by ERA5) impact the atmospheric fields associated to the extreme cyclones. As discussed in Section 3.3 (revised manuscript), the SST differences are not linked to the cyclone's activity (frequency, timing and location). In fact, Figure 5 shows that the SST differences between CPL and STD during extreme winter cyclones (Fig. 5b) primarily reflect the climatological bias of the CPL model relative to observations (Fig. 5c).

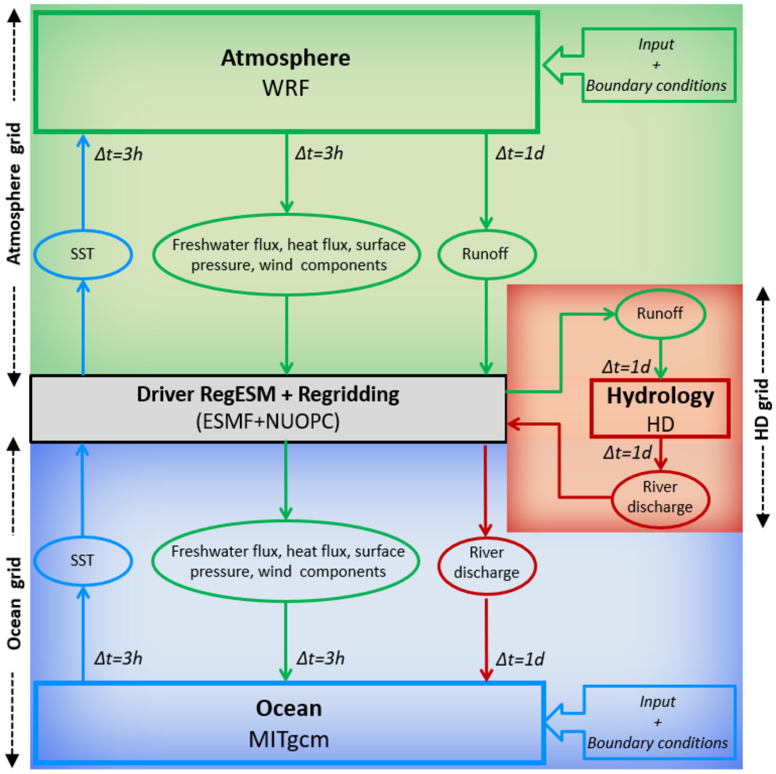
5 Related comment: Evaporation (or latent + sensible heat fluxes) are influenced by wind speed, surface temperature and specific humidity, and SST, following the bulk formula. Thus the evaporation difference (Fig. 7a) can result from the other atmospheric differences (e.g., Figs. 7b-c), rather than a one-way causation as in this study. While there is spatial alignment between SST bias and evaporation differences, this is not adequately addressed in the manuscript.

We thank the Reviewer for the valuable feedback. Please note that we have changed figure 7 in the revised manuscript which now include latent and sensible heat fluxes instead of evaporation, following the suggestion of Reviewer 3. We agree that there is a mutual relation among the heat fluxes (evaporation), with both the SST, the specific humidity and the 10 m wind speed. We better clarify this in the revised paper (L342-347) as follows:

"*The warmer SST in the CPL model fosters latent and sensible heat fluxes at the sea surface (Fig. 7a, b), leading to increased vertical exchange of heat and moisture with the atmosphere. The stronger surface fluxes in CPL increase the turbulence and so the vertical mixing in the PBL, with warm air rising and cold air sinking due to buoyancy forces, transferring energy downward to the surface (downward momentum mixing, Hayes et al., 1989; Wallace et al., 1989), thus increasing the 10 m wind speed (Fig. 7c). The mutual relation among SST, surface fluxes and 10 m wind speed are confirmed by high Pearson correlation coefficients between the model differences (Fig. 9).*"

6 Section 2.1 mentions that “STD” is an atmosphere-only WRF simulation with prescribed SST, while “CPL” is the ENEA-REG regional Earth system model including ocean, land, and freshwater fluxes and river discharge model. However, the authors argue that the only difference between STD and CPL resides in the SST over the Mediterranean Sea. Is this accurate? I am wondering if there is any significant difference on the land between the two simulations.

We thank the Reviewer to point out this shortcoming. The only difference between the STD and the atmospheric component of CPL resides in the SST over the Mediterranean Sea. In the CPL simulation, the ocean component (i.e. MITgcm) exchanges only the SST field with the atmosphere, while STD uses the SST from ERA5. Therefore, the processes on land surface are simulated by WRF with identical settings between CPL and STD. In fact, over land, both CPL and STD present the same land scheme, Noah-MP and the same parameterizations. Please find below a scheme of the CPL model.



7 L172: Given that cyclones are more intense in winter and the role of the SST and the air-sea fluxes on extreme events is expected to be stronger in autumn (LL106-107), it is counterintuitive to see the number of the selected most intense cyclones in winter and autumn is 199, while 142 (341-199) in summer and spring, corresponding to 71 cyclones in three months (JJA or MAM) on average. Does this mean there are fewer intense cyclones around the Mediterranean in autumn than in spring or summer? If so, I wonder why the focus of this study is only on autumn and winter Mediterranean cyclones.

We thank the Reviewer for the valuable feedback. First, we would like to point out that there was a typo error in the manuscript: the same extreme cyclones between CPL and STD are 312 and not 341.

The seasonal cycle of intense Mediterranean cyclones is the follow: Winter (DJF) is the season with the higher frequency of intense cyclones, followed then by spring (MAM), autumn (SON) and summer (JJA). Among the 500 most intense cyclones, 312 are in common between CPL and STD: 129 in winter (DJF), 110 in spring (MAM), 17 in summer (JJA) and 56 in autumn (SON). We clarified this on the manuscript, and we added the reference to our methodology as follow (L176-184):

"*To compare CPL with STD in terms of sub-daily fields associated to the cyclones, the same events between the two simulations are selected. Two cyclones are considered the same event if their minimum of SLP is within a 500 km distance and within a time range of 12 hours. With these criteria, a total of 312 cyclones from the 500 most intense (around 62 %) are found in common between CPL and STD, of which 129 occurring in winter (DJF), 110 in spring (MAM), 17 in summer (JJA) and 56 in autumn (SON). This well align with results from Flaounas et al. (2018a), who also found that approximately 60% of the 500 most intense cyclone tracks were consistent between the coupled and standalone RCMs, using similar identification criteria Extending the distance criterion to 1000 km (i.e. the maximum area of influence of Mediterranean cyclones, Flaounas et al. 2016) and the time window to 48-hour, the percentage of detected cyclones in common between STD and CPL increases to 92%, but the outcomes of this study do not change (not shown).*"

As correctly pointed out by the reviewer, in our analysis we choose to investigate two seasons: DJF and SON. We have better explained why we chose these seasons in the introduction (L107-110) as follow:

"*For a more comprehensive analysis, two seasons are considered: the winter (DJF) when the cyclones are more intense and frequent (Campins et al., 2011; Flaounas et al., 2022) and autumn (SON) when the role of the SST and the air-sea fluxes on extreme events is expected to be stronger (Miglietta et al., 2011a; Ricchi et al., 2017). The enhanced surface fluxes in autumn result from the combination of relatively high SSTs, which are near their annual peak, and upper-level cold-air intrusions.*"

The winter cyclones are the main focus of the atmospheric analysis in section 3.2, while the analysis in SON can be found in the supplementary material. We have modified in section 3.2.3 the description of the autumn results, to highlight the differences with winter, as follow (L366-377):

"*The methodology used for winter is also applied to the 56 extreme autumn (SON) cyclones in common between CPL and STD. The SST differences between CPL and STD affect the atmospheric surface processes and PBL stability as seen in DJF, but with an opposite sign (Fig. S5), since in SON the CPL result colder (and not warmer as in DJF) than STD over most of the Mediterranean Sea (Fig. 6). Interestingly in SON, the intensity of surface heat fluxes (Fig. S3a, b) and precipitation (Fig. S3e, f) associated to extreme cyclones is even stronger than in DJF. The strong temperature gradient between warm Mediterranean Sea and cold atmospheric intrusions during SON cyclones reflects the amount of energy transferred to the atmosphere, amplifying precipitation intensity (Miglietta et al., 2011). Despite this, the differences between CPL and STD in cyclone-associated precipitation and 10 m wind speed (Fig. S5c, e and f) are non-statistically significant, and less correlated with the SST differences (Fig. S6). This may be partially attributed to the smaller SST differences (Fig. 6 vs. Fig. 5) over the Balearic and Tyrrhenian Seas, where most SON extreme cyclones occur (Fig. S1). The strong impact of the SST distribution and air-sea fluxes on the atmosphere is expected to be significant on specific autumn events, as already shown and discussed in previous studies (Akhtar et al., 2014; Berthou et al., 2015, 2016; Miglietta et al., 2011; Ricchi et al., 2017).*"

For completeness, we also analysed the spring (MAM) season (see below), but we have decided to don't add this analysis to the manuscript since it does not add any additional insights compared to the DJF case. In fact, the differences in SST between CPL and STD are substantially reduced compared to DJF (Fig. A4 versus Fig. 5), especially over the gulf of Genoa and the gulf of Lyon, where most of the intense cyclones are located (Fig. S1 in supplementary). Moreover, the surface heat fluxes (Fig. A3a, b) and the cyclones' associated precipitation (Fig. A3e, f) and wind speed (Fig. A3c) in spring are less intense than in winter (Fig 4). So, both the lower SST differences and the weaker atmospheric processes associated to the cyclones lead to less intense and statistically non-significant differences in convective (Fig. A5e) and total precipitation (Fig. A5f, same bootstrapping method applied for DJF) and lower linear correlation between the SST and the atmospheric fields differences (Fig. A6). This result confirms our conclusion, i.e. the different SST distribution between CPL and STD is the dominant factor in shaping the differences in sea surface fluxes, atmospheric stability, 10 m wind speed and precipitation associated to the extreme cyclones.

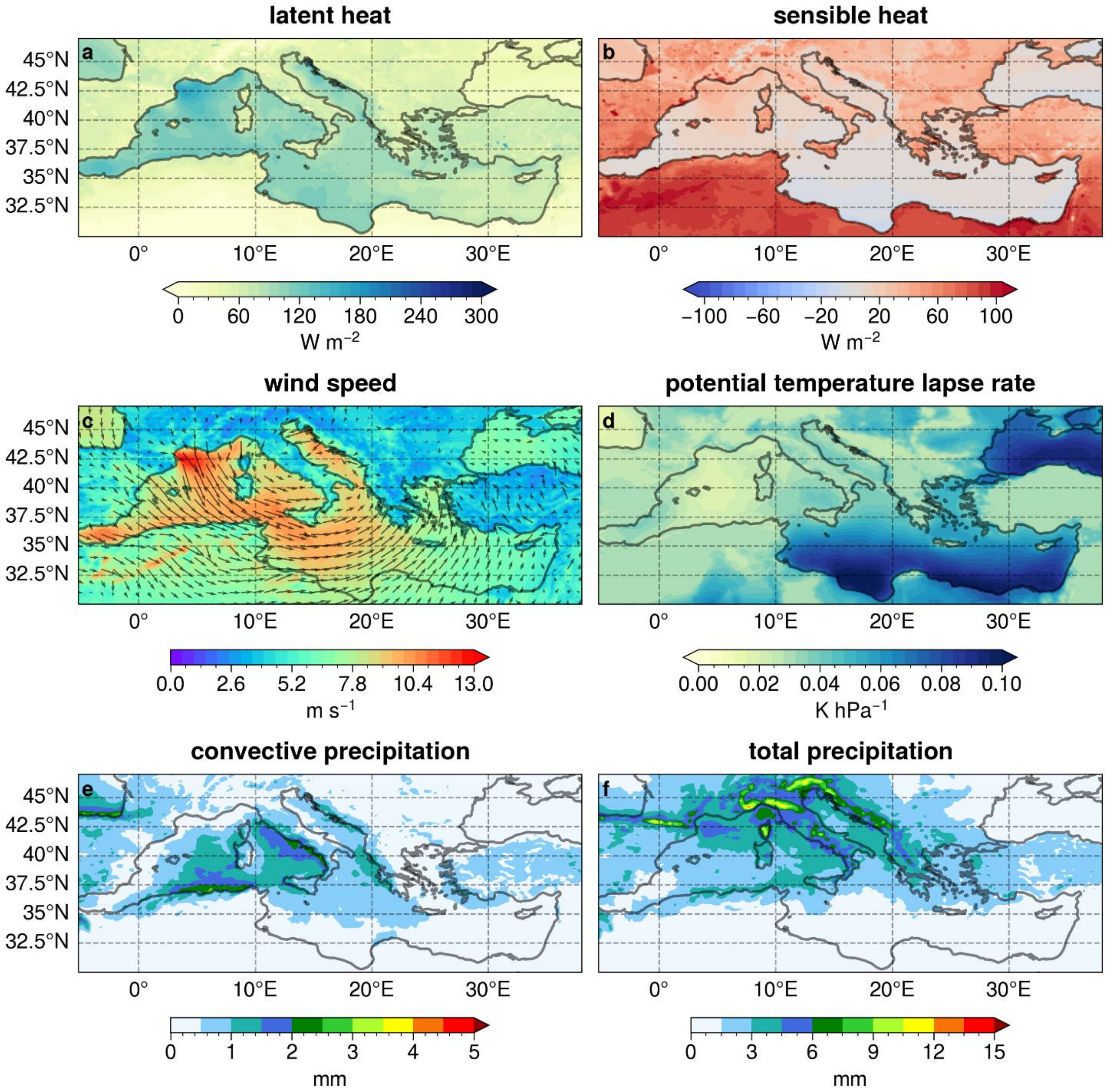


Figure A3: Same as figure 4 but for MAM.

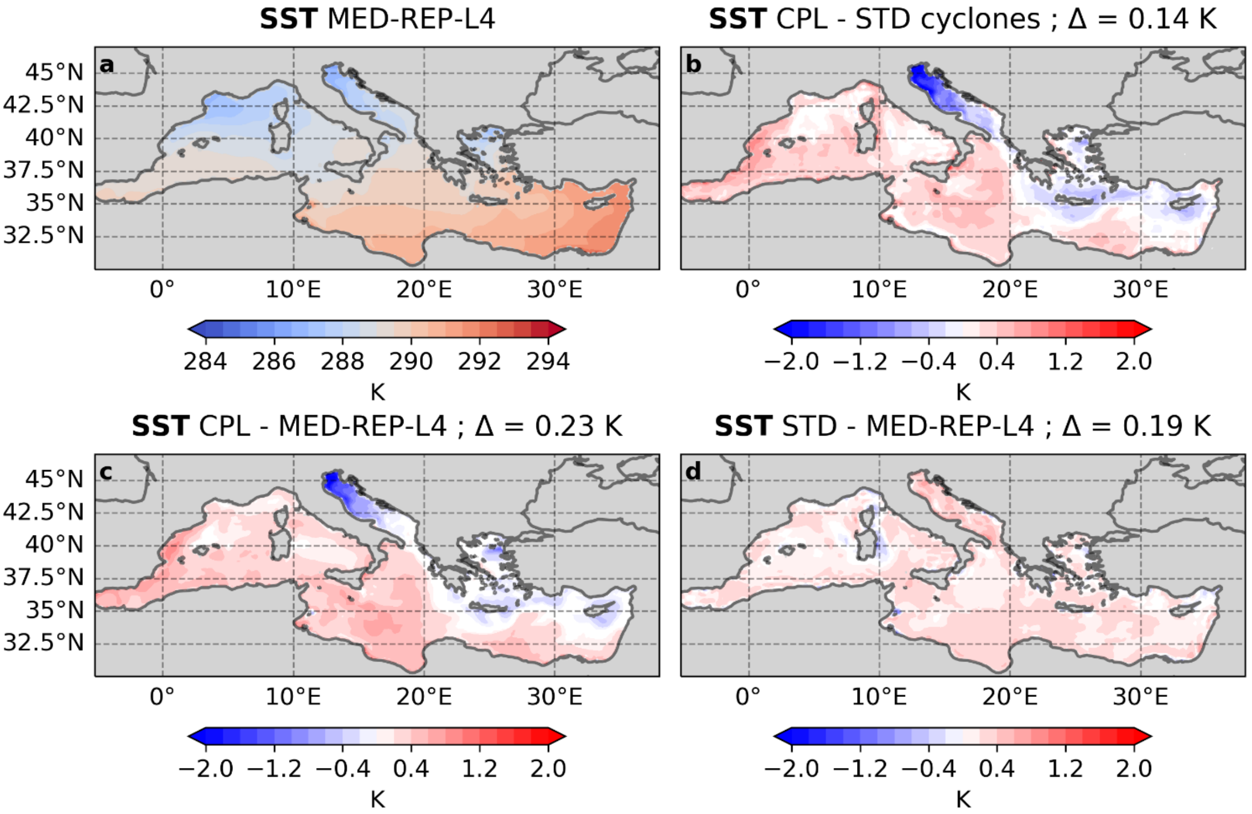


Figure A4: Same as figure 5 but for MAM.

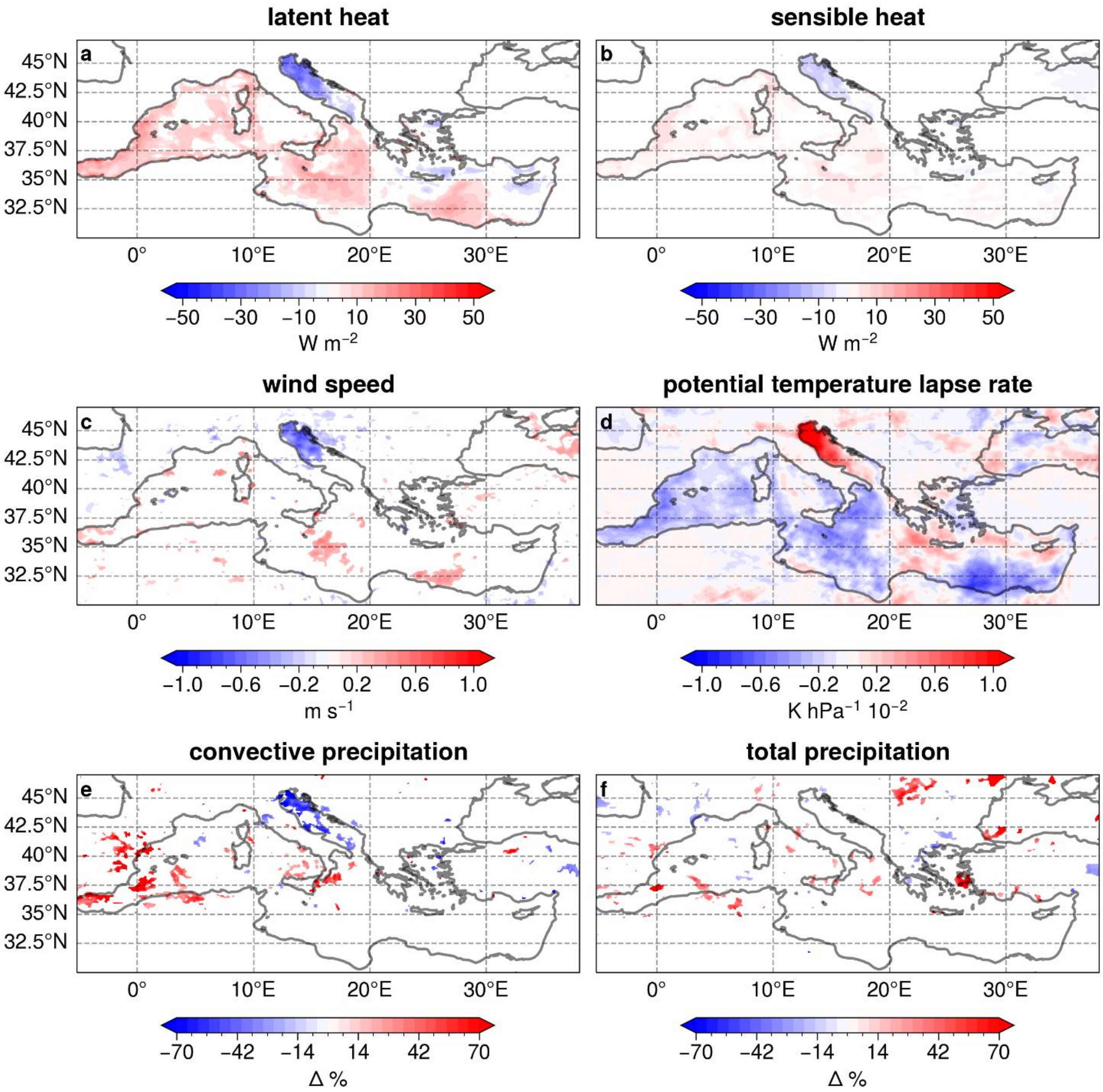


Figure A5: Same as figure 7 but for MAM.

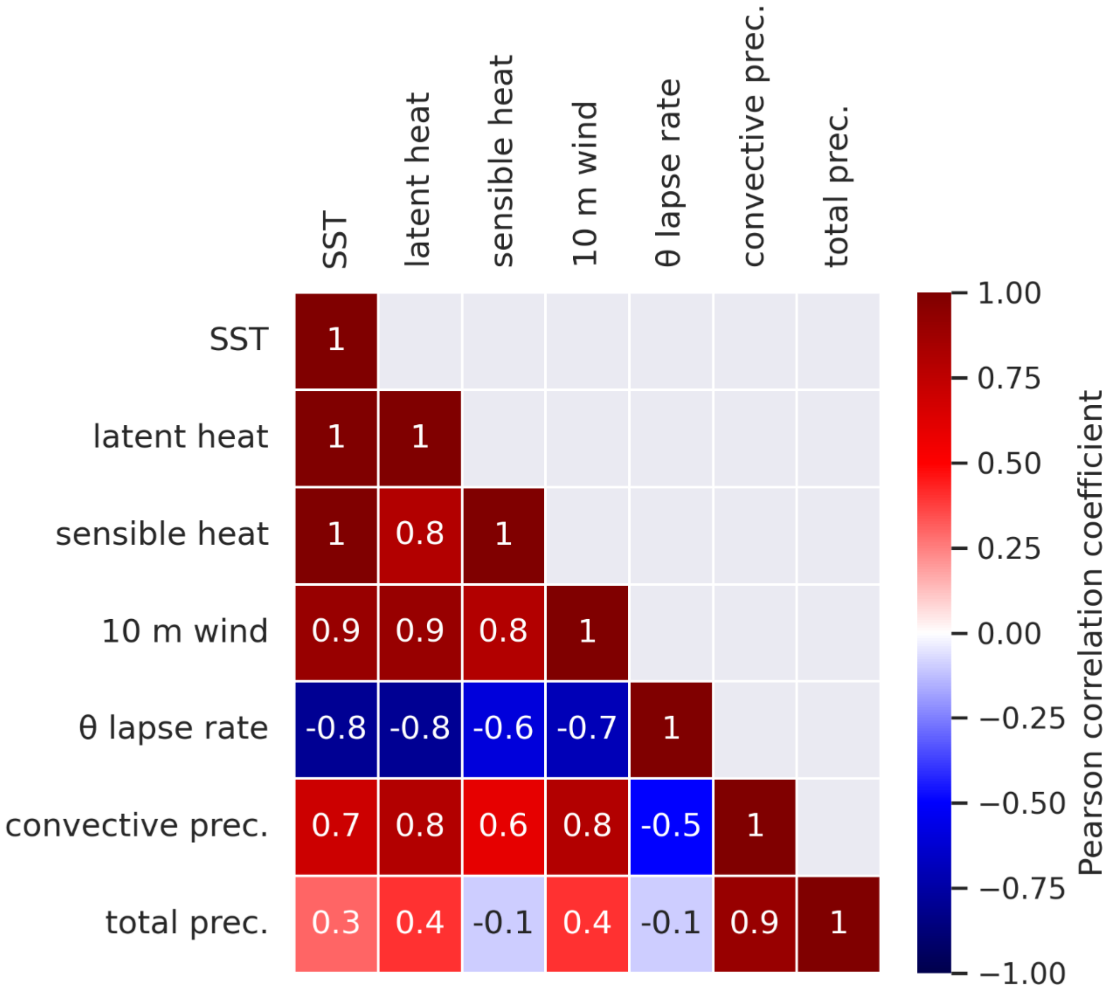


Figure A6: Same as figure 9 but for MAM.

Minor comments:

1. **L15: “in the second WRF” -> “in the second simulation the WRF” ?**

   It has been corrected.

2. **L18: similarly reproduced -> “similar” ?**

   It has been corrected.

3. **L19: regardless -> regardless of**

   It has been corrected.

4. **L21: planet -> planetary**

   It has been corrected.

5. **L32: “Sea Surface Temperature” -> “sea surface temperature”**

   It has been corrected.

6. **L35: “midlatitude cyclones, entering the Mediterranean basin” -> “midlatitude cyclones entering the Mediterranean basin” ?**

It has been corrected.

7. **L64: long ago -> long**

   It has been corrected.

8. **L67 “boundary conditions, that becomes” -> “boundary conditions, which becomes”**

   It has been corrected.

9. **L69: challenged -> attempted?**

   It has been corrected.

10. **L87: “improves the track length” -> “improves the reproducibility of the track length” ?**

    It has been corrected.

11. **L95: investigating -> by investigating**

    It has been corrected.

12. **L95: affects -> affect**

    It has been corrected.

13. **L103: “the explicitly resolved SST” -> “do the explicitly resolved SST”?**

    We have modified the second research question as follow (L103-105):

    “*How do differences in SST distribution shape atmospheric processes within the planetary boundary layer (PBL) during extreme cyclone events, and how do these mechanisms, in turn, impact the cyclone-related precipitation and wind speed?*”.

14. **L107: I am not sure why the role of the SST and the air-sea fluxes on extreme events is expected to be stronger in autumn than in winter.**

    We have better explained in the introduction (L107-110) why the air-sea fluxes are stronger during the autumn extreme cyclones with specific references:

    “*For a more comprehensive analysis, two seasons are considered: the winter (DJF) when the cyclones are more intense and frequent (Campins et al., 2011; Flaounas et al., 2022) and autumn (SON) when the role of the SST and the air-sea fluxes on extreme events is expected to be stronger (Miglietta et al., 2011a; Ricchi et al., 2017). The enhanced surface fluxes in autumn result from the combination of relatively high SSTs, which are near their annual peak, and upper-level cold-air intrusions.*”

15. **L108: “next” -> “the next”**

    It has been corrected.

16. **L118: “extensively used” -> “which is extensively used”**

    It has been corrected.

17. **L123: I think that 1/12deg is substantially less than approximately 10km, especially in the zonal direction.**

    The reviewer is right, as the grid is irregular in some points the nominal resolution of 1/12° corresponds to less than 10 km. We have removed “(approximately 10 km)” from the sentence.

18. **L124 (the Med-CORDEX region): It would be helpful to refer to Fig. 1 here.**

Thanks for the suggestion, we have added "(Fig. 1)" in line 133.

19. **L125: The resolution of the SST prescribed to ERA5 depends on the period. In particular, the resolution is substantially different between HadISST2 (~2007) and OSTIA (2007~). The description of ERA5 SST as Δx~0.25deg might be misleading.**

    The reviewer is correct, SST, in ERA5, is given by two external providers with two different nominal resolutions. Before September 2007, SST from the HadISST2 dataset (Δx = 0.25deg) is used, and from September 2007 onwards, the OSTIA (Δx = 0.05deg) dataset is used. However, the SST is provided by the Copernicus Climate Data Store, for the whole period, at 0.25deg horizontal resolution. To be more precise, we have modified the text (123-129) as follow:

    "*Thus, the only difference between the STD and the CPL simulation resides in the SST over the Mediterranean Sea, which derives from the ERA5 SST reanalysis (daily, Δx = 0.25°) in STD, whereas it comes interactively from MITgcm (3-hourly, Δx = 1/12°) in CPL. To note that SST, in ERA5, is given by two external providers with two different nominal resolutions. Before September 2007, SST from the HadISST2 dataset (Δx = 0.25deg, Titchner and Rayner, 2014) is used, and from September 2007 onwards, the OSTIA (Δx = 0.05deg, Donlon et al., 2012) dataset is used. However, the Copernicus Climate Data Store provides the SST filed at 0.25° horizontal resolution for the whole period.*"

20. **L146: "cyclone tracking algorithm" might be preferable to "storm track method."**

    We have changed the title of section 2.2.1 in: "Storm track method" as suggested.

21. **L147: "CYCLOYTRACK" -> "CycloTRACK" (see Flaounas et al. 2014)**

    It has been corrected.

22. **L147: "Mean Sea Level Pressure" -> "mean sea level pressure"**

    It has been corrected.

23. **L157: Referring to terrain > 800m as "high mountain environment" sounds a bit weird.**

    The reviewer is correct, and we have changed the text (L166-168) accordingly:

    "*A terrain filter of 800 m altitude has been also applied to focus on the intense cyclones over the sea and second to filter out algorithm artefacts, that tend to form over mountains due to the extrapolation of pressure fields on sea level (Neu et al., 2013).*"

24. **L163: The minimum SLP during a cyclone's lifetime depends on the background, larger-scale SLP distribution than the synoptic scale. Is the climatological-mean SLP nearly uniform in the Mediterranean Sea?**

    We thank the reviewer for the interesting question. As discussed in the first specific comment, a cyclone intensity (i.e. defined here as a SLP local minimum) mostly depends on large scale forcing (i.e. baroclinic forcing) and on diabatic forcing (convection close to the cyclone centre). As shown in Flaounas et al., (2021), the relative contribution of these two forcings is highly dependent on the case and therefore on the cyclones' proximity to mountain volumes, the underlying SST, the season etc. The Reviewer's suggestion is interesting, and we have addressed it by computing the SLP field during the winter and autumn extreme cyclones (figures A7, A8, A9, A10 below). Both in winter (Fig. A7) and in autumn (Fig. A8), the mean SLP distribution during the extreme cyclones of the CPL simulation (same results for STD, not shown) is coherent with the distribution of the frequency and location of the cyclones (Fig. S1 in supplementary). In addition, when looking at the differences between CPL and STD, the SLP is affected by the SST values. In DJF (Fig. A9) the SST of the CPL is warmer and the SLP is lower (deeper minima of the cyclones), while in SON (A10) the SST is colder and the SLP is higher. This could be related to the pressure adjustment mechanism (Lindzen and Nigam, 1987): warmer SSTs induce thermal expansion of the air lowering the atmospheric pressure at the surface.

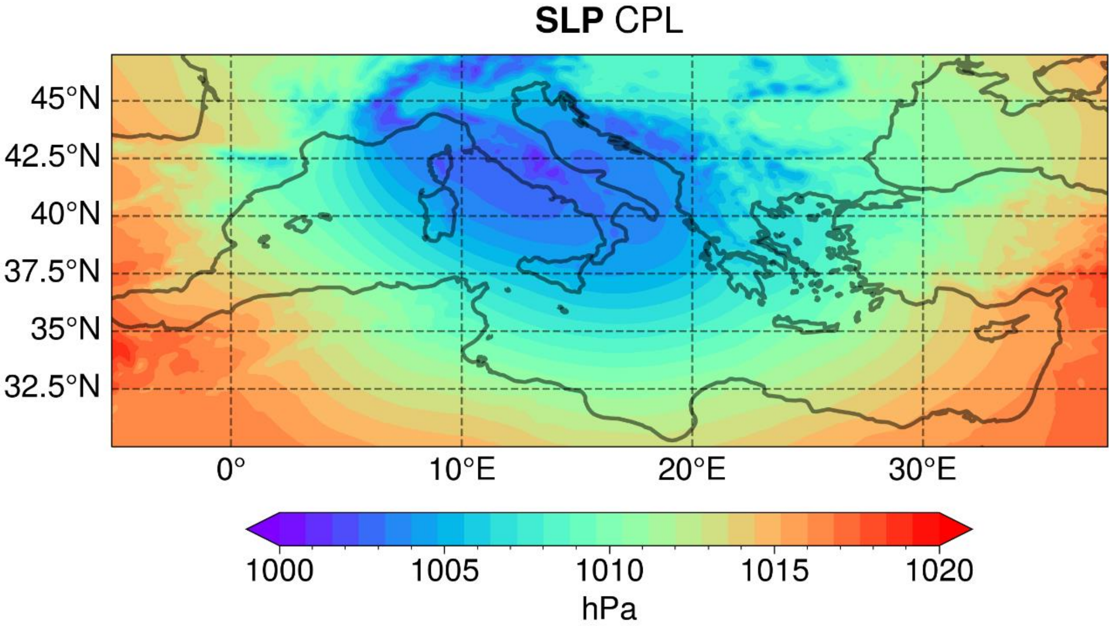


Figure A7: Map for sea-level pressure (SLP) from the CPL simulation during winter extreme cyclones in common with CPL.

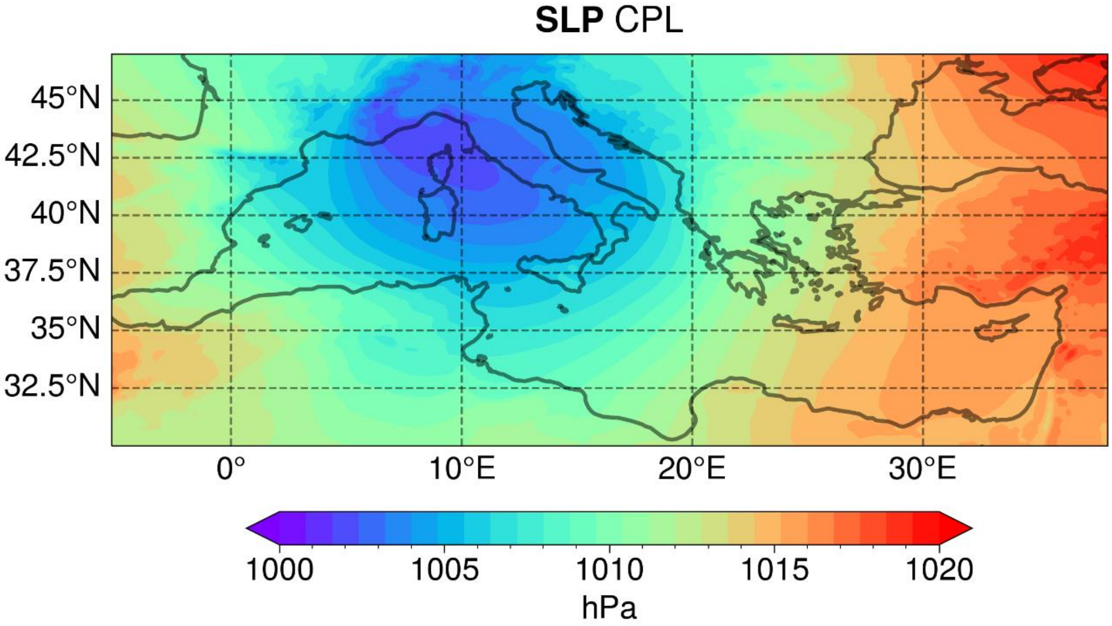


Figure A8: Same as figure A7 but for SON.

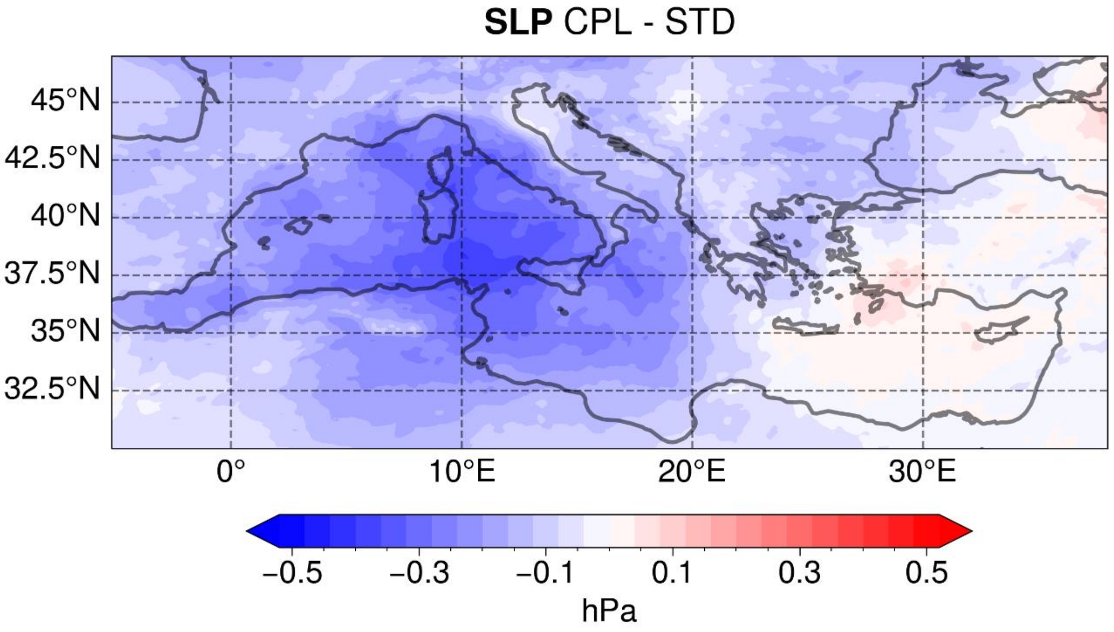


Figure A9: Map of the differences between CPL and STD during the common extreme winter cyclones for SLP.

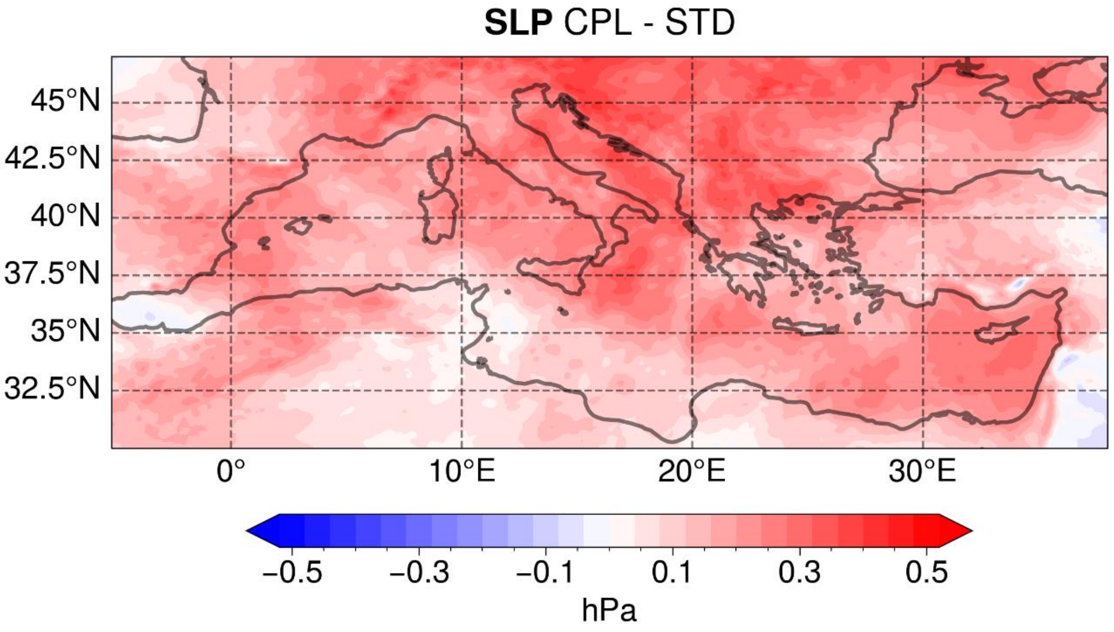


Figure A10: Same as figure A10 but for SON.

25 **L172: Please specify what "DJF" and "SON" stand for here.**
It has been corrected.

26 **L179: STD e CLP -> STD and CPL**
It has been corrected.

27 **L182-183: The authors argue that "the influence of cyclones on the atmospheric state is independent of the location of the cyclones in the Mediterranean Sea". Why?**

We thank the Reviewer for pointing out the need for clarification. This sentence (L182-183) was not clear, so, we removed it and change the text as follow (L197-203):

"*Our composite averaging is done for the entire domain and therefore the difference fields (CPL – STD) might be also affected by atmospheric systems other than cyclones. An additional analysis, using the same approach as in Flaounas et al. (2016), is applied where differences were calculated only within an area of 500 km around the cyclone centre. The different methods do not affect the results (not shown), because the intense cyclones are expected to have a substantial impact to the whole domain, so most of the differences are attributed to the areas close to cyclones. In addition, our strategy allows to overcome the slight location mismatch between CPL and STD (i.e. linked with 500 km maximum distance between the minimum of SLP) when computing the differences.*"

28 **L229: The present study utilizes the same cyclone tracking algorithm as Flaounas et al. (2023). Thus the authors should specify references for "different cyclone tracking methods" here.**

Mentioning "different cyclone tracking methods", we probably created a misunderstanding. Here we apply a single cyclone tracking method to our datasets and thus it would be rather odd to include -a plethora of- additional references for methods that we do not use. We revised the text as follows (L246-247):

"These results are in fair agreement with the most intense cyclones in ERA5 as defined by composite reference tracks for the Mediterranean (Flaounas et al., 2023). "

29 **3: Consider using a more realistic mask shape (e.g., circles) over 3degx3deg square domains. Additionally, which season(s) is this figure showing? DJF+SON?**

We changed figure 3 by using a circle area with 1.5 deg. radius around the minima of SLP tracking points. Please see the revised figure 3.

30 **L256-259: I consider that the explanation of the structure of section 3.2 (subsection) here is not needed.**

We thank the reviewer to point out this shortcoming. We have modified the structure of section 3 as follow:

3.1 Climatology of extreme Mediterranean cyclones

3.2 Atmospheric fields during extreme cyclones

3.3 SST differences between CPL and STD

3.4 Impact of the SST distribution on cyclones' precipitation

3.5 Ocean response to extreme cyclones

31 **L264: It does not make sense to me that cyclones do not turn into precipitation. (Additionally, the sentence here seems grammatically incorrect.)**

The reviewer is correct, the sentence was not clear. We changed the sentence as follow (L289-291):

"*This precipitation pattern is associated with winter cyclones generally coming from the west, as indicated by Flaounas et al. (2015) and Raveh-Rubin and Flaounas (2017) and interacting with the complex orography of the basin, increasing precipitation over coastal areas.*"

32 **"PBL is higher" -> "PBL height is larger"?**

Yes, we meant that the height of the PBL is larger. We have corrected it.

33 4: The panel labels are hard to find. Please improve their visibility.

We have increased the size of the panel labels in all the figures in the revised manuscript.

34 If possible, the results in Fig. 4 should be compared with observations (e.g., ERA5).

We thank the Reviewer for the suggestion. Following the first general comment of the Reviewer 3, we have performed the comparison of the atmospheric fields during the 500 most intense cyclones in ERA5, STD and CPL (Fig. A11, A12, A13 below). In figure A11 we show the distribution of the fields during the 500 most intense cyclones in ERA5, while in figures A12 and A13, we show the differences of STD and CPL with ERA5, respectively. The RCMs tend to underestimate the surface heat fluxes over the sea (Fig A12a, b; Fig. A13a, b), to overestimate the sensible heat over land, especially in the north Africa region (Fig A12b; Fig. A13b), and to present a slightly higher stability of the PBL (higher potential temperature lapse rate) over the south and east Mediterranean Sea (Fig A12d; Fig. A13d). The surface wind speed is higher for the RCMs in most regions (Fig A12c; Fig. A13c), likely due to the higher resolution and different physical parametrisation in WRF, while the convective precipitation is underestimated by RCMs especially over the coastal area. Finally, looking into the total (convective and large-scale) precipitation differences, the RCMs simulate a stronger precipitation over the sea, while over land tend to overestimate it in mountainous regions (Alps, Pyrenees and Greek and Turkish mountains) and underestimate it on the west coasts of Italy and Balkans.

This analysis has not been included in the manuscript because the focus of the study is not to validate the RCMs against ERA5, since is already done by Anav et al. (2024). Instead, our paper investigates how the atmosphere-ocean coupling, resulting in a differing SST distribution between CPL and STD configuration, influences the key atmospheric processes associated with extreme cyclones. We clarified this in the revised manuscript (section 2.2, “storm track method”), as follow (L153-156):

“*A storm track method is applied to both ERA5 reanalysis and RCM simulations. To note that the comparison of the models with ERA5 is restricted to the evaluation of the RCMs’ ability to reproduce the climatology of the extreme cyclones, in terms of their seasonal cycle, track characteristics and spatial distribution. In fact, the full evaluation of the RCMs against ERA5 was already performed by Anav et al. (2024).*”

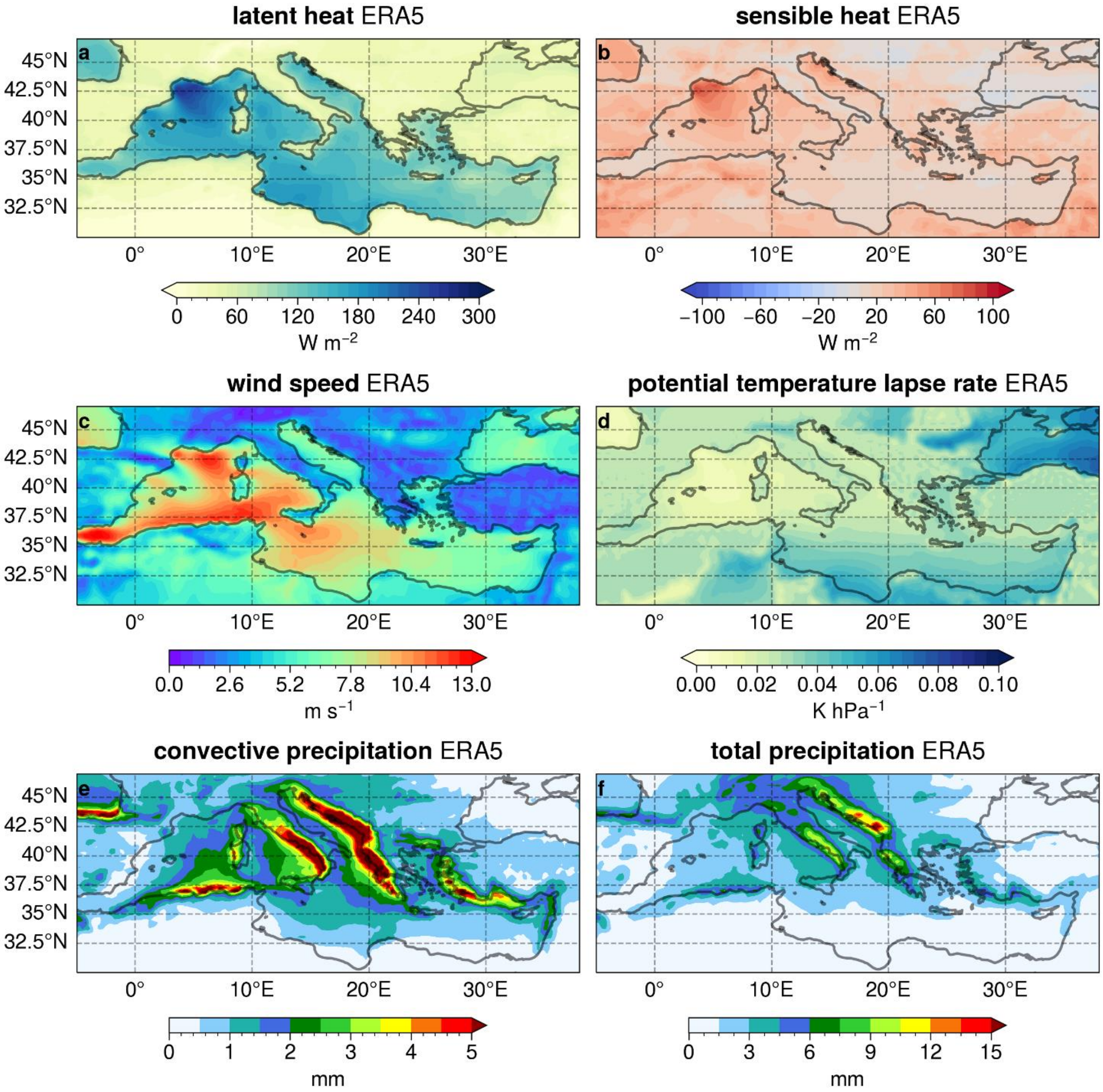


Figure A11: Maps for latent heat flux (a), sensible heat flux (b), 10 m wind speed (c), potential temperature lapse rate (d), convective precipitation (e) and total (large-scale + convective) precipitation (f) from ERA5 during the 500 most intense cyclones.

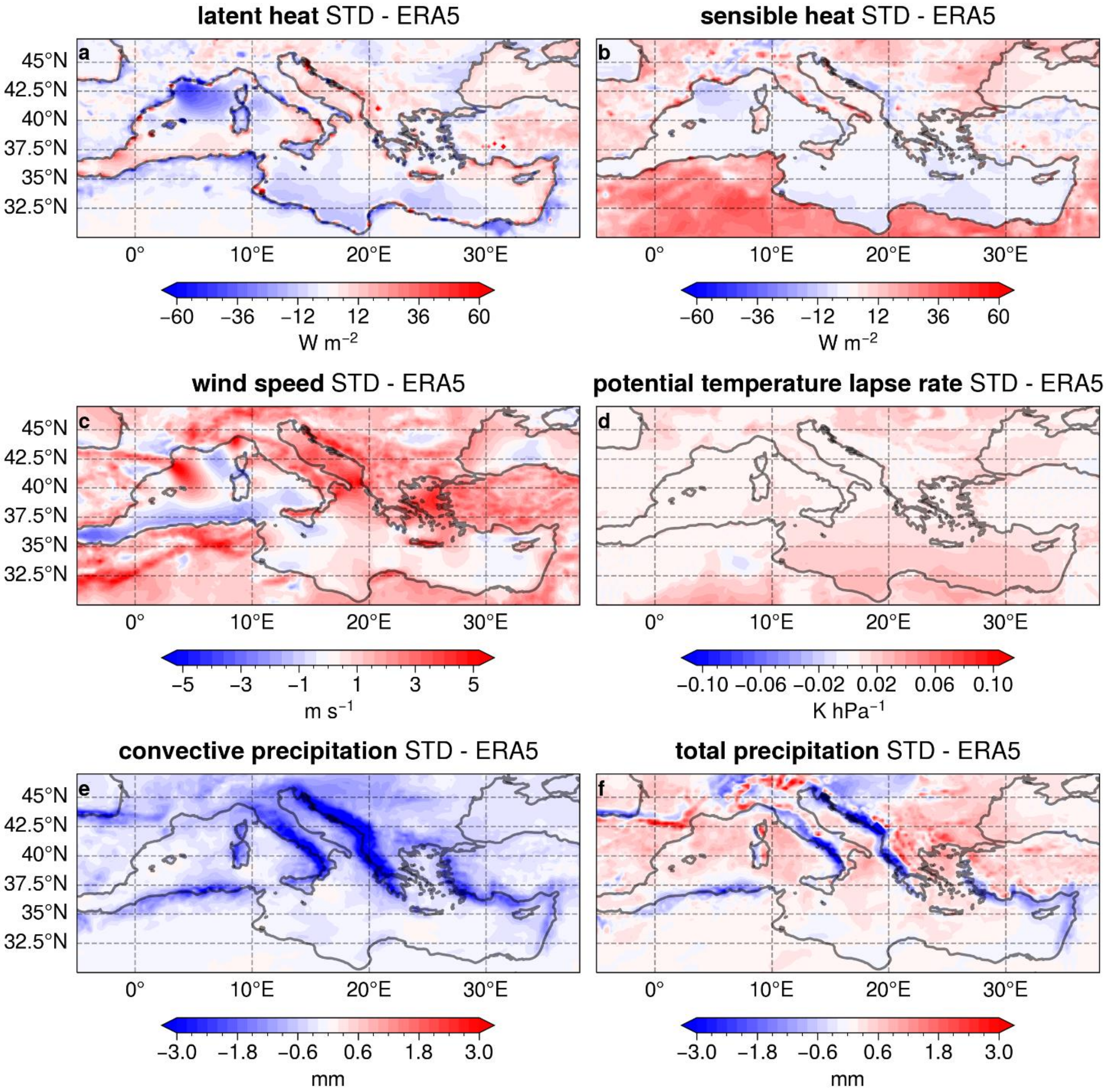


Figure A12: Maps of the differences between STD and ERA5 during the 500 most intense cyclones for latent heat flux (a), sensible heat flux (b), 10 m wind speed (c), potential temperature lapse rate (d), convective precipitation (e) and total precipitation (f).

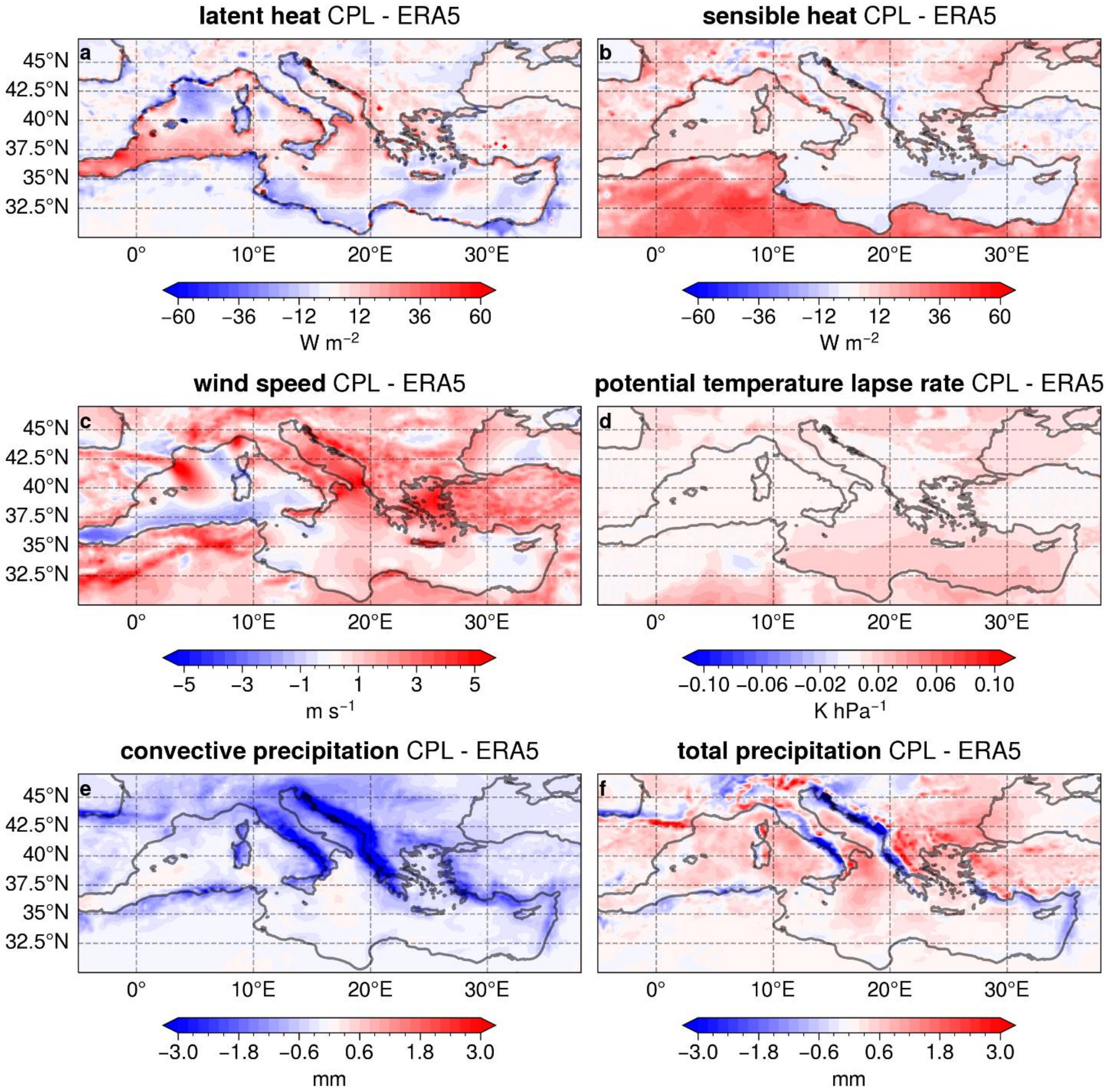


Figure A13: Same as figure A12 but for CPL.

35 L277: The title "SST analysis" is obscured and needs to be clarified.

We changed the title in, "*SST differences between CPL and STD*"

36 The figures' sequence (including supplementary ones) could be improved to follow numerical order.

We have changed most of the figures in both the revised manuscript and supplementary material and they all follow the same sequence of the atmospheric fields.

37 L288 "All the outcomes on DJF are also valid for the analysis of the SST bias in SON (Fig. S6)": It seems contradictory with the following statement. Please clarify which outcomes in DJF are valid for SST bias analysis in SON.

The Reviewer is correct. We have changed the sentence in the revised manuscript (L367-369) as follow:

"*The SST differences between CPL and STD affect the atmospheric surface processes and PBL stability as seen in DJF, but with an opposite sign (Fig. S3 in supplementary), since in SON the CPL result colder (and not warmer as in DJF) than STD over most of the Mediterranean Sea (Fig. 6)*."

38 L288 Fig. S6 -> Fig. 6

It has been corrected.

39 5-8: White contours for significance are difficult to identify. Consider improving visibility. (Perhaps There are a lot of white contours to white out insignificant differences with colors?)

We thank the reviewer for pointing out this issue. We have tested alternative configurations to improve the visibility of statistically significant points, such as using black dots to mark them (see Fig. A14 below). However, adding these markers overloaded the plots with elements, obscuring the colour differences, which are essential for interpretation. We chose white contours to represent significance because there are no statistically significant grid points with values close to zero. So, the white colours almost everywhere indicate non-significant grid points and not differences close to zero, ensuring clarity in the interpretation of the plots.

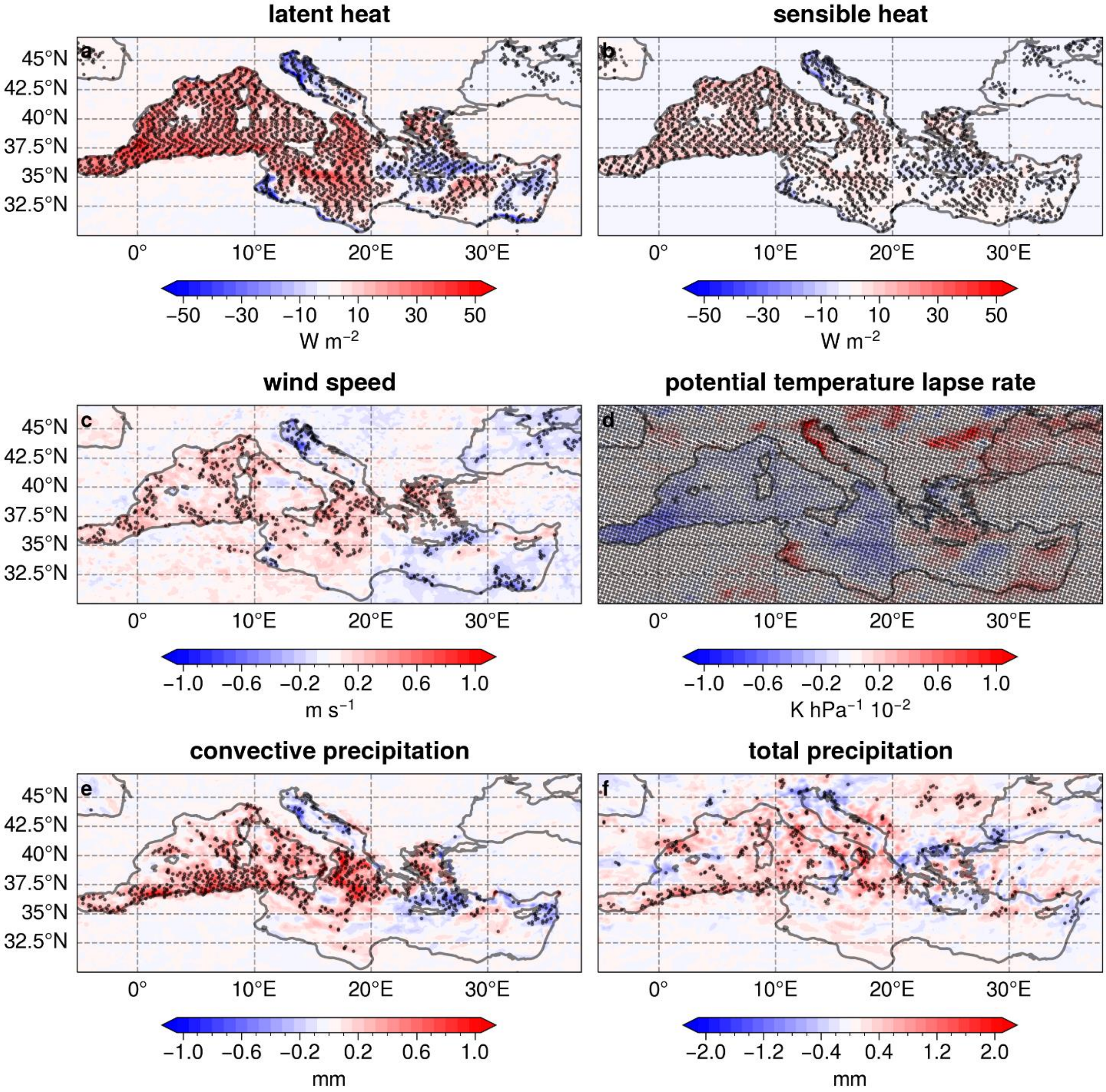


Figure A14: Same as figure 7 but with black markers for significance.

40 L311: What correlation is “the high correlation” (and Fig. 9)? Spatial correlation over the sea?

With high linear correlation we mean a Pearson correlation coefficient greater than 0.7. The correlations among the differences are computed both over land and sea and for only the statistically significant grid points of both fields.

41 L315 Clarify if the observed link between warmer SST and higher 10 m wind speed is related to the "vertical mixing effect" from Wallace et al. (1989) and Hayes et al. (1989).

The reviewer is correct, the link between warmer SST and higher 10 m wind speed is indeed related to the downward momentum mixing (DMM, Wallace et al. 1989; Hayes et al. 1989). We have clarified this as follow (L343-347):

“*The stronger surface fluxes in CPL increase the turbulence and so the vertical mixing in the PBL, with warm air rising and cold air sinking due to buoyancy forces, transferring energy downward to the surface (downward momentum mixing, Hayes et al., 1989; Wallace et al., 1989), thus increasing* *the 10 m wind speed (Fig. 7c). The mutual relation among SST, surface fluxes and 10 m wind speed are confirmed by high Pearson correlation coefficients between the model differences (Fig. 9).*"

42 **L319: I could not follow the argument that "the stronger horizontal winds in CPL lead to a mismatch between areas of high vertical moisture flux and total precipitation". What is "high vertical moisture flux" and how is the mismatch related to the stronger horizontal winds? This paragraph (L319-326) should be improved so as to be understood more easily.**

We thank the reviewer to point out this shortcoming. We have changed the paragraph (L358-360) to make it clearer:

"*The total (large-scale and convective) precipitation differences between the models result not only from direct changes in the surface fluxes but also from the wind dynamics that are responsible to the changes in the convergence zones of moisture, as discussed in Berthou et al. (2016).*"

43 **L 389: Please clarify the term "mean cooling."**

With "mean cooling" we meant the cooling effect averaged over the number of the cyclones. We have decided to just say "cooling" in the sentences to don't create confusion.

44 **Related comment to major comment (B): I think that showing the composited wind (Fig. 4d) is misleading, because the wind is the superposition of all the events considered, which come mainly from those around Italy but include those occurring in distant regions (Fig. 3). In other words, the precipitation distribution (Figs. 4a-b) does not necessarily occur associated with the wind pattern in Fig. 4d.**

The Reviewer is correct, on each cyclone event with specific precipitation distribution, the wind speed intensity and direction are locally different from the composite wind shown in figure 4c (revised manuscript). However, our priority is to show the climatological mean of the composite fields during the extreme cyclones, so that we can compare them between the two simulations. Therefore, the composite fields in figure 4, reflect their mean distribution over the effective area of high cyclones' frequency, which is mainly concentrated over the central Mediterranean basin. This includes high precipitation along the coasts of Italy and the Balkans (Fig 4f), as well as strong winds over the Sea associated with cyclonic circulation (Fig4c).