Reply to Reviewer #1

Review for "Dakar Niño variability under global warming investigated by a high resolution regionally coupled model" by Koseki et al.

The study by Koseki et al. investigates how sea surface temperature (SST) variability at the Senegalese-Mauritania coast associated with so called Dakar Niños might change in the future. Utilizing a regionally high-resolution coupled climate model they find that the Dakar Niño variability increases under the RCP8.5 scenario. This is explained by an increase in the wind variability and higher ocean stratification under global warming.

The manuscript is mostly well structured and written and provides interesting results on the future of SST variability in the Northeastern Tropical Atlantic. However, I find that it is sometimes hard to follow the presentation of the results and that the investigation of the processes needs some work. Also, there are some recent studies dealing with similar questions that should be taken into account. I summarize my major comments and list minor points and specific comments below.

REPLY: We gratefully appreciate the reviewer for the constructive comments. Following the comments, we have corrected our manuscript by adding more analysis and reply point-by-point as follows. Please note that the tracked changes in the revised manuscript are shown in blue color and the number of lines and figures are for the revised manuscript.

Major comments:

A) Definition of Dakar Nino

It is not really clear to me what exactly this study regards as Dakar Niño variability. Is it all interannual SST variability in the region considered here (i.e. from 7ºN to 21ºN)? Everything related to the position of the front (line 37/38)? Or just SST anomalies occurring in the Dakar Niño Index box which is much more confined? Is the peak in SSTA variability around 20ºN in boreal summer also related to Dakar Niños? Please provide a definition and make sure to be consistent throughout the manuscript. Also, please indicate the Dakar Niño box in Figure 4.

REPLY: Thank you very much for the helpful comment. Throughout the manuscript, we focus on SST interannual variability as the box-mean (9N-14N and 20W-17W defined by Oettli et al., 2016), which is defined as Dakar Index in Oettli et al. (2016). The events of Dakar Niño/Niña in **March** are defined as the Dakar Index plus/minus

± the standard deviation. According to Oettli et al. (2016) who found this event first, March variability is maximum and we follow their definition. While we described the definition, the location of description was not adequate. Therefore, we moved the definition of Dakar Niño/Niña events in this study to Line 169-171 in the revised manuscript to improve the readability.

In addition, as another reviewer suggests, we added a time series of Dakar Index and events of Dakar Niño and Niña in Fig.R1 as follows, as well as its description in the revised manuscript. Please see lines 169-175. Due to this new figure, we added a box of the Dakar Index in Fig.3.

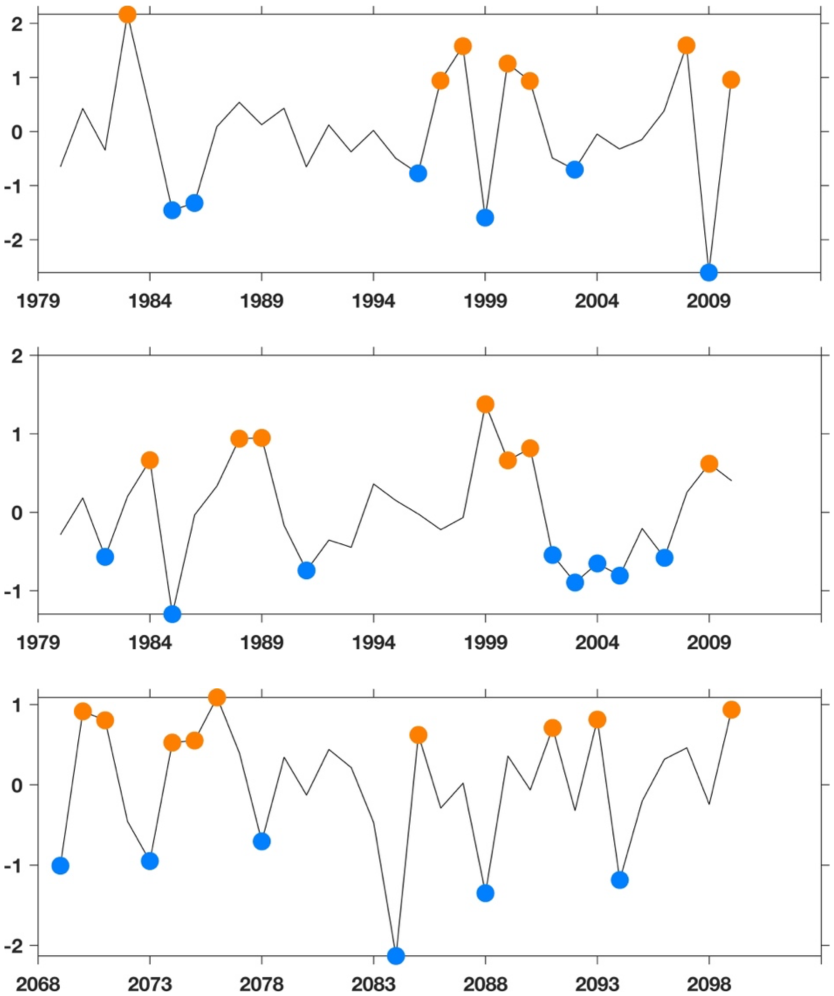

Fig.R1. Time series of Dakar Index (detrended SST averaged 9°N-14°N and 20°W-17°W) for (top) ERA5, (middle ROM_P, and (bottom) ROM_F The orange and blue dots indicate Dakar Niño and Niña events defined in this study, respectively.

B) Processes behind Dakar Niño variability

I believe that more analysis is needed on the processes by which Dakar Niños and Niñas are driven in the simulations and how they change in the future. For

example, Oettli et al. (2016) argue that heat fluxes are important for the generation of Dakar Niños but they are not considered here. The same goes for changes in the depth of the mixed layer.

REPLY: Thank you very much for the helpful comment. Indeed, the process of the changes in Dakar Niño/Niña events should be discussed. Here, we calculated the heat budget within the ocean mixing layer and Figure R2 shows the composite differences between Dakar Niño and Dakar Niña in current (1980-2010) and future climate (2069-2099). Please note that we used monthly-mean outpiuts of ROM for the calculation, therefore there might be some non-linear and transient components missed in the heat budget like,

$$\frac{\partial \mathrm{SST}}{\partial t} = \langle -u\frac{\partial T}{\partial x}\rangle + \langle -v\frac{\partial T}{\partial y}\rangle + w_{OML}\frac{\Delta T}{D} + R$$

Here, the bracket means a quantity averaged within the ocean mixing layer. D is the ocean mixing layer depth (an output of ROM). W_{OML} and ΔT denote the vertical velocity at the bottom of ocean mixing layer and the temperature difference between in the ocean mixing layer and the just below the ocean mixing layer (assuming the temperature within the ocean mixing layer is homogeneous vertically). From ROM discretized data, W_{OML} is the value at the layer just below the ocean mixing layer depth. R is a residual term that we do not examine in this study.

Our analyses indicate that (1) the horizontal advection is a main source of Dakar Niño and Niña, which is different from Oettli et al. (2016) arguments and (2) but, the future intensification of Dakar events can be explained almost identically by the horizontal and vertical adveciton (0.006 K/day and 0.0057 K/day in March, respectively). These intensification can be also induced by the stronger meridional wind variability.

This result supports our frist argument: stronger meridional wind variability can excite the vertical motion variability and consequently, Dakar Niño/Niña events can be reinforced. In addtion, as Fig. 7e shows, the upper ocean layer become much warmer than sub-surface ocean layer between 40m depth. As the reviewer mentions as below, the ocean is more stratified in the future climate. This indicates that the contribution of vertical thermal advection could increase since $\partial T/\partial z$ increased in the upper layer.

For the horizontal adveciton, as Fig.R3 shows, the surface ocean current anomaly (Dakar Niño minus Dakar Niña) is more dominant in the red rectangular (Dakar Index box) in the future than in the present climate. This indicates that the intense meridional wind stress can also change the local/regional ocean circulation resulting in the stronger Dakar Niño/Niña events in the future.

We added this discussion and Figures as Fig.11 and Fig. S5 in the Section 4. Please see lines 293-329. Moreover, we rephrased the last part of Abstract and Conclusion referring to this new result. Please see lines 21-23 and lines 341-348 .

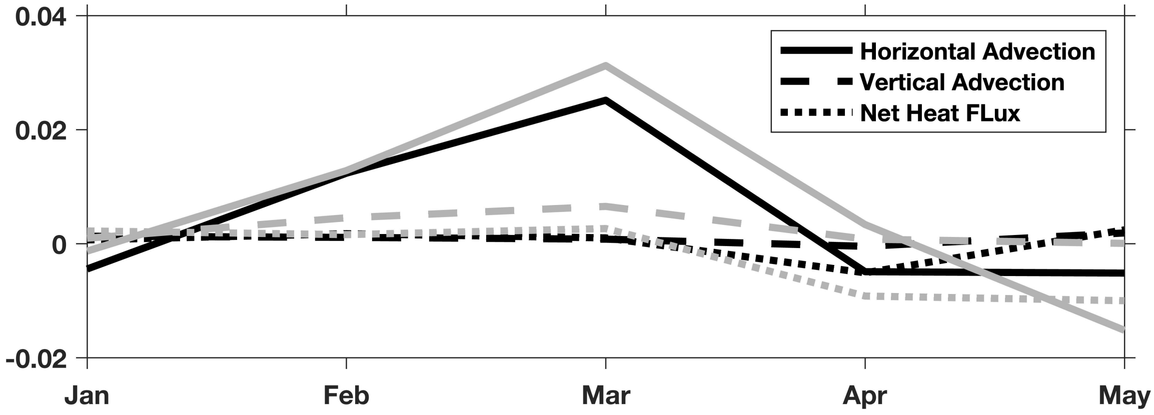

Fig.R2. Monthly time series of lag-composite difference of (solid) horziontal advection, (dotted) surface net heat flux, and (dashed) vertical thermal advection between Dakar Niño and Dakar Niña events (Niño minus Niña) in (black) 1980-2010 and (grey) 2069-2099. March is lag=0. The unit is K day[-1].

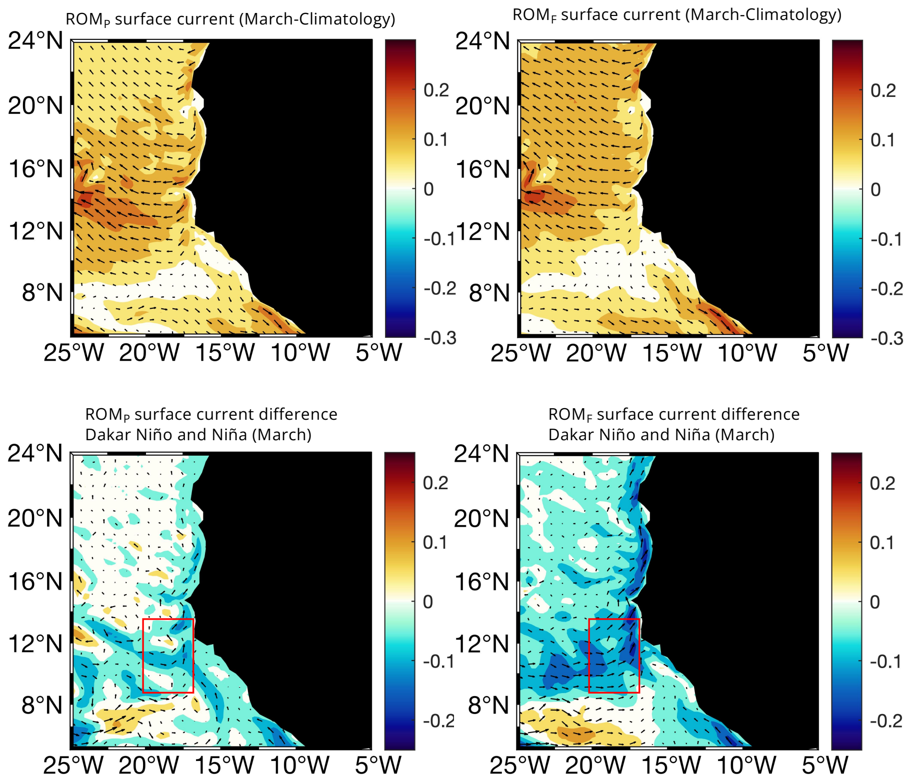

Fig.R3. (Top) surface ocean curret climatology for (a) ROM$_P$ and (b) ROM$_F$. (Bottom) surface ocean current difference between Dakar Niño and Niña composite for (c) ROM$_P$ and (d) ROM$_F$. Vector denotes the ocean current and color is ocean current velocity.

Also, we analyzed the composite difference of ocean mixing layer in the Dakar Index box between Dakar Niño and Dakar Niña as shown in Fig.R3.

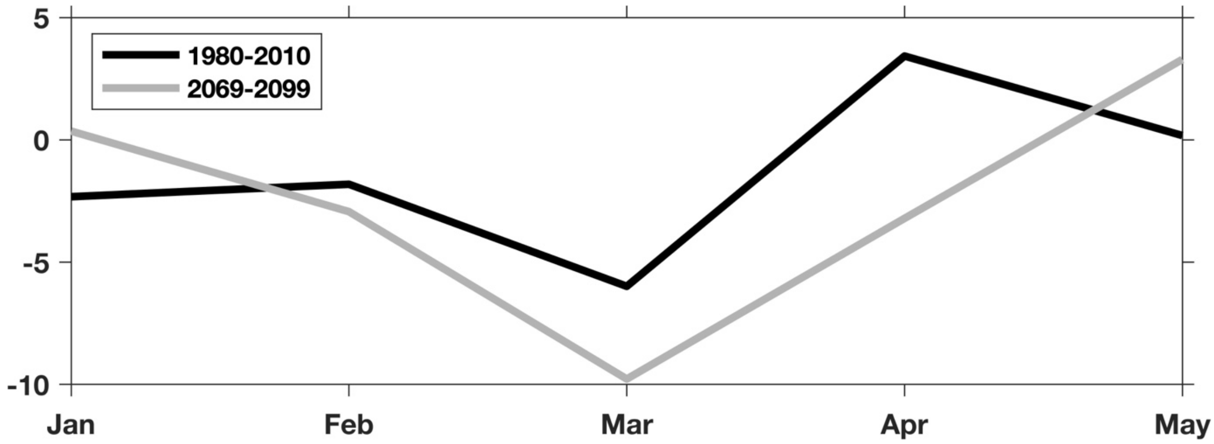

Fig.R4 Monthly time series of lag-composite difference of ocean mixing layer depth between Dakar Niño and Dakar Niña events (Niño minus Niña) in (black) 1980-2010 and (grey) 2069-2099. March is lag=0. The unit is m.

As Oettli et al. (2016) shows, the mixing layer depth tends to be shollower during the Dakar Niño in our simulation. Interestingly, the composite difference in the ocean mixing layer is larger in the future climate, especially from February to April. One of the possible reasons for this could be the meridional wind variability and the, the mechanical contribution to deepening the mixng layer can increase the difference in ocean mixing layer. However, the ocean mixing layer is also function of temperature and salinity, which could be difficult to make an attribution. We added this figure in Supplementary Information as Fig.S5 and some description. <u>Please see lines 293-329.</u>

It is also not clear to me why stronger stratification should lead to higher variability. Stratification is also increasing in the equatorial Atlantic but there, the argument is that this hinders subsurface-surface coupling and thus leads to weaker variability.

REPLY: Thank you very much for giving an oppostunity to discuss our argument more. For this statement, we show the composite of ΔT in the vertical thermal advection in March during Dakar Niña events for ROM_P and ROM_F in Fig.R4.

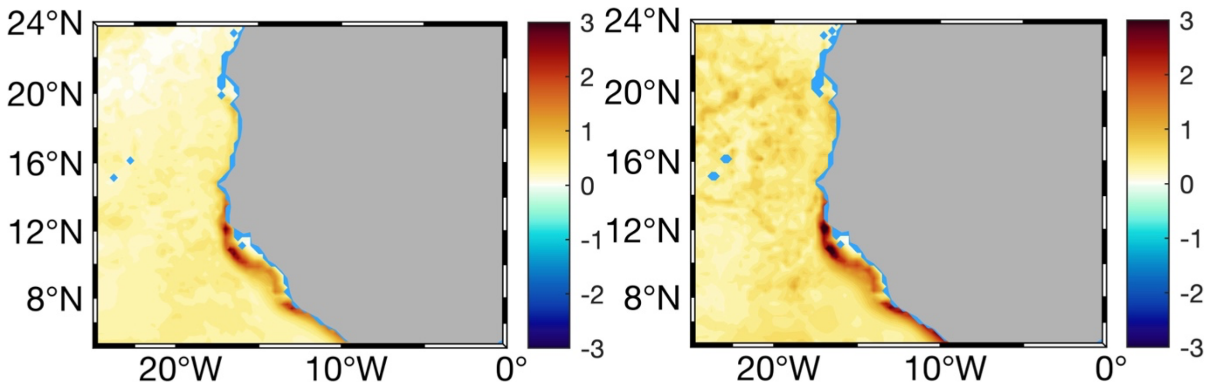

Fig.R4. The composite of ΔT during Dakar Niña in March for (left) ROM_P and (right) ROM_F.

In both cases, there is a strong vertical temperature gradient along the coast, ROM_F shows relatively larger ΔT. In addition, offshore areas also have larger ΔT entirely. Given the same vertical velocity anomaly emerges in present and future climate, the future climate will have more vertical thermal advection during Dakar Niña events.

On the other hand, during Dakar Niño events, there is not difference in the mixing layer depth (already ckecked). Therefore, under global wamring, espeacially, Dakar Niña will be more reinforced as shown by our Fig. 7.

It is further argued that correlation between the DNI and ocean temperatures at greater depth means stronger SST variability (line 189). Why would that be?

REPLY: We agree that this argument might be too speculative. The deeper connection between DNI and ocean temperature just gurantees that the Dakar Niño/Niña events would be deeper in the future, not larger variability. Therefore, we removed this statement and instead, we added "indicating that Dakar Niño and Niña events would influence deeper ocean in the future" . Please see lines 206-207.

In the conclusions "stronger vertical velocity variability" (279) is mentioned. Where is this shown?

REPLY: As in the previous case, this argument might also be too speculative due to less process-wise analysis. As the reviewer suggests and we have done in Fig.R2, which suggest that the role of vertical thermal advection is responsible for enhancing Dakar Niño and Niña events in the future. Therefore, we rephrased here as "inducing a stronger vertical thermal advection". Please see lines at 342.

C) Literature to be taken into account

There are some recent studies dealing with the future of the variability in the Dakar Niño region that should be cited here:

Yang et al. (2021) find increasing variability in the Northeastern Tropical Atlantic under global warming. Chang et al. (2023) look at changes in temperature and wind patterns in eastern boundary upwelling regions in HighResMip simulations. Also, a study on the future of Benguela Niños was recently published (Prigent et al., 2023) and could be mentioned in line 142.

REPLY: Thank you very much for providing information. We added these articles in discussion of the revised manuscript and corresponding descriptions. Please see lines 335-340.

Minor points:

1) Model validation

While I like the comparisons shown in Fig. 2, they could be improved and further complemented with line plots. The axis labels are very small and the color scale of (e) to (h) is hard to interpret (this also applies to Fig. 7). I would also find it more instructive to show SST in °C. In addition, one could show a line plot with SST and its standard deviation averaged over certain latitude bands overlaid for the different data sets and model simulations. This would facilitate an easier comparison in terms of timing and amplitude. I believe that it would probably show that the season of highest variability in the model is shifted towards later in the year (April instead of March) which makes the focus on March later in the analysis a bit questionable.

REPLY: Thank you very much for constructive suggestions. We improved the figure following the comments. Regading the latitude band plot, we added the figure as Supplementary Information new Fig.S1. Regarding the unit of SST, we added a new analysis of surface heat flux and vertical thermal advection as above, and the unit of temperature in this computation is K. Therefore, it could be reasonable to have the unit of K.

Yes, our model has a peak of variability by about one month later. However, to compare with the observation, it could be better to invesigate the same month between models and observations. Our model still shows a strong variability in March. We added this justification in the revised manuscipt. Please see line 145-149.

Further, in line 120, it is stated that the model has a warm bias. Where? What is the general pattern of SST difference to observations?

REPLY: This statement is about ERA5 bias compared to the ESA satellite data, not our model. As we cite, Vázquez et al. (2022) have done more model assessment with the same models and same experiments. Additionally, you can find more details this fact in Vázquez et al. (2023). Therefore, this study has not performed detailed assessment of the model performance.

2) Seasonality of SST in the region

The seasonal cycle in SST shown in Figure 2 is mainly explained in terms of a meridional movement of the front driven by meridional currents. However, I believe that it is largely impacted by the upwelling season in the southern part of the region, i.e. cooler waters are upwelled to the surface in February to April.

REPLY: Thank you very much for this comment. Actually, we had already mentioned the role of upwlling at line 105-107 citing some references.

Regarding the seasonal migration of the Mauritania current (line 105), is there a reference for this? Does it fit with the findings by Klenz et al. (2018)?

REPLY: We cited Klenz et al. (2018) as a reference of Mauritania Current. Plesse see lines 109-110.

3) Role of remote forcing

It is stated (lines 42 to 44, also 116 to 118) that Benguela Niño events are stronger than Dakar Niños because of the additional role of remote forcing from the Equator. Is this something that has actually been shown (in this case, please provide a reference) or just an assumption of the authors?

REPLY: The remote foricng for Benguela Niño has been a well-established mechanism and therefore, we have already cited related papers. At lines 42-44, the references were missed, then we added the literatures. As far as we know, there is no study on direct comparison between Benguela and Dakar Niño. Therefore, the statement at lines 116-118 might be speculative and we deleted the sentence "and the Benguela Niño/Niña has more larger intensity than Dakar Niño/Niña because of the strong remote influence from the equator via equatorial and coastal Kelvin waves".

4) Correlation with Dakar Niño index (Figure 4)

How do the correlations in Figure 4 change when they are based on April instead (see comment 1 above)? Also, I am not sure the propagating signal described is really propagating (associated with a Rossby wave). Couldn't the SST anomaly just decrease first at the coast due to coastal processes and linger around for longer offshore?

REPLY: As we replied above, we focus on March in order to keep the consistency with the observation. We would expect that there might be some differences, but some of characteristics might be quite similar.

Regarding the Rossby wave, our statement here just indicate a possibility of Rossby wave as Martín-Rey and Lazar (2019) showed. Their arguement is the connection between boreal spring variability, Atlantic Meridional Mode (AMM), and summer Atlantic Zonal Mode (AZM). AMM signal can propagate as Rossby Wave, and it reflects in the western boundary as Kelvin wave propagating eastward and genetating AZM. Our lag correlation map might give an indication of AMM after Dakar Niño, but it is unknown the connection between Dakar Niño and AMM and this will be one of possible futute works, which is out of scope of this study.

Specific comments:

- At several instances, "reinforced" is used when probably "strengthened" or "increased" is meant (e.g. line 23, 206, 217, 226, 269,...)

REPLY: Changed.

- line 17/18 and 186 to 191: Here, it is not clear whether the correlation gets stronger or whether high correlation is extending deeper in the ocean. Please rephrase to make this clear.

REPLY: At the upper ocean, the correlation is relatively stronger and the correlation is much deeper. As we replied above, we rephrase this part. Please see lines 206-207.

- line 33: "feature" instead of "exhibit"

REPLY: Changed.

- line 41: "driven by"

REPLY: Added.

- line 52: In contrast to what?

REPLY: Chnaged to "However".

- line 53: "even in" instead of "until"

REPLY: Changed.

- line 58: "recently" instead of "timely"

REPLY: Changed

- Figure 1: What is shown by the shading?

REPLY: That is the topography height in NEMO. We added it in the caption.

- line 105: What is "inversely" referring to? When are the trade winds relaxing?

REPLY: Yes.

- line 111: "second maximum" in terms of timing or location?

REPLY: Here, we mean both SST gradient and interannual varability peaks are almost overlapping as shown in Fig.2. We added "at the same timing and location".

- line 116: "has larger" (without "more")

REPLY: The sentence was removed replying to the comment above.

- line 128: "focus region"

REPLY: Changed.

- line 138/139 "K" or "°C" instead of "degree"

REPLY: Changed.

- line 149: ORA-S5 is a reanalysis product.

REPLY: Changed.

- line 152: Please rephrase this sentence.

REPLY: Rephrased. Please lines 156-157.

- caption to Fig. 4: "January" (typo)

REPLY: Corrected.

- line 173: "south of" instead of "below"

REPLY: Changed.

- line 177: What does "somewhat simulated well" mean? Please rephrase.

REPLY: Chnaged to “to some extent “and changed well to “realistically”.

- line 178: “is correlated”, “SST anomalies develop”

REPLY: Corrected.

- line 179: “compared to ERA5”

REPLY: Correcnted.

- line 181: Should be “S2”

REPLY: Changed, but please note that this I snow Fig.S3 because of an addition new Supplementary figure.

- line 199: “1 standard deviation”

REPLY: Changed, but please note that the senence has been moved to lines 169-171 as we replied above.

- line 284: “is” instead of “can be also”

REPLY: Corrected.

References:

Chang, P., G. Xu, J. Kurian et al., 2023: Uncertain future of sustainable fisheries environment in eastern boundary upwelling zones under climate change, Comm. Earth & Environment, https://doi.org/10.1038/s43247-023-00681-0

Klenz, T., Dengler, M., and Brandt, P., 2018: Seasonal variability of the Mauritania Current and hydrography at 18°N. Journal of Geophysical Research: Oceans,123, 8122–8137. https://doi.org/10.1029/2018JC014264

Prigent, A., Imbol Koungue, R., Lübbecke, J.F. et al. Future weakening of southeastern tropical Atlantic Ocean interannual sea surface temperature variability in a global climate model. Clim Dyn (2023). https://doi.org/10.1007/s00382-023-07007-y

Yang, Y., L. Wu, Y. Guo et al., 2021: Greenhouse warming intensifies north tropical Atlantic climate variability, Sci. Adv. 2021;7:eabg9690

REPLY: Thank you very much for the information on further literature. We added these articles and descriptions referrign to them. Please see lines 335-340.

Reply to Reviewer #2

Review of "Dakar Niño variability under global warming investigated by a high-resolution regionally coupled model"

by Koseki, S., Vázquez, R., Cabos, W., Gutiérrez, C., Sein, D. V., and Bachèlery, M.-L.

General comments

The aim of this work is to characterize the future of the coastal upwelling regions off the Senegalese coast, under the IPCC' RCP8.5 pathway (i.e., highest emission scenario), using a high-resolution regionally-coupled model. This is an important topic, because the future of the upwelling regions around the world is still under investigation and subject to debates. In Benguela and California systems, a consensus for a positive trend in upwelling-favorable winds seems to exist (Sydeman et al., 2014), the signal is less clear for the Canary region. Particularly the response of marine ecosystems to climate change/global warming is still uncertain (e.g., Xiu et al., 2018). Also, the upwelling regions in eastern tropical oceans are known to be not well represented in climate models (Richter, 2015). So a better knowledge of their variability and underlying mechanisms is still needed.

However, the current study presents several issues, some major, some minor, that need to be addressed before publication. The detail of these issues is given below. I therefore recommend major revisions.

REPLY: We greatfully appreciate the reviewer for the constructive comments. Following the suggestions, we have corrected our manuscriprt by adding more analysis and reply point-by-point as follows. Please note that the tracked changes in the revised maniscript are shown in blue color and the number of lines and figures are for the revised manuscript.

Major comments

In this section, the major issues are detailed.

Dakar Niño

This coastal Niño phenomenon is, like the ENSO or other coastal Niños, is a recurring climate pattern, characterized by sea-surface temperatures (SST)

warmer by a few degrees than normal, with only a few occurrences in a decade. This is different from the definition given at L.37-38.

REPLY: Thank you very much for this comment. We rephrased it for clarity as: "and some extreme events of SST warm anomalies are called Dakar Niño". Please see lines 38-39.

This is also different from the Dakar Niño Index (DNI) which depicts the temporal variability of the SST, averaged over the 21°–17°W, 9°–14°N region. In this perspective, the title could be changed to reflect either the exploration of the variability of the DNI under RCP8.5 or the future of Dakar Niño under RCP8.5. This is particularly true regarding Figs. 5 and 6. The former is using the DNI, while the latter is focusing on Dakar Niño and Dakar Niña.

REPLY: Thank you very much for this comment. This study first started analyzing Dakar Niño Index between present and future climate and our main discussions are based on Dakar Niño and Niña events. Therefore, we would prefer to keep "Dakar Niño" in the title. However, "variabiltiy" has been omited from the title.

In response to the comment below, we have added a new figure (Fig.4) showing DNI and frequency of Dakar Niño/Niña events in ERA5 and ROM simulations. This new figure might help to avoid confusion. Please see line 171-175.

The existence of a Dakar Niño (or Niña) is the result of complex land-sea-atmosphere interaction system. According to Oettli et al. (2016), the coastal, alongshore, wind variability, the mixed-layer depth anomaly, and the modulation of the mixed-layer temperature (mostly due to the shortwave radiation variations), are the necessary components to develop a Dakar Niño. The current work is mainly focusing on the coastal winds and some atmospheric variables (sea-level pressure, 2m temperature,...), forgetting about the other components of the dynamical system. It would be preferable, in this work, to also discuss about the evolution of the costal ocean mixed-layer, and its heat budget, under the RCP8.5. At L.257, there is a mention of the land-sea thermal contrast anomalies. It would be interesting to discuss how the contrast helps to maintain, or not, the favorable alongshore winds.

REPLY: Thank you very much for the helpful comment. Indeed, the process of the changes in Dakar Niño/Niña events should be discussed. Here, we calculated the heat budget within the ocean mixing layer and Figure R2 shows the composite differences between Dakar Niño and Dakar Niña in current (1980-2010) and future climate (2069-2099). Please note that we used monthly-mean outpiuts of ROM for the calculation, therefore there might be some non-linear and transient components missed in the heat budget like,

$$\frac{\partial \mathrm{SST}}{\partial t} = \langle -u\frac{\partial T}{\partial x}\rangle + \langle -v\frac{\partial T}{\partial y}\rangle + w_{OML}\frac{\Delta T}{D} + R$$

Here, the bracket means a quantity averaged within the ocean mixing layer. D is the ocean mixing layer depth (an output of ROM). W_{OML} and ΔT denote the vertical velocity at the bottom of ocean mixing layer and the temperature difference between in the ocean mixing layer and the just below the ocean mixing layer (assuming the temperature within the ocean mixing layer is homogeneous vertically). From ROM discretized data, W_{OML} is the value at the layer just below the ocean mixing layer depth. R is a residual term that we do not examine in this study.

Our analyses indicate that (1) the horizontal advection is a main source of Dakar Niño and Niña, which is different from Oettli et al. (2016) arguments and (2) but, the future intensification of Dakar events can be explained almost identically by the horizontal and vertical adveciton (0.006 K/day and 0.0057 K/day in March, respectively). These intensification can be also induced by the stronger meridional wind variability.

This result supports our frist argument: stronger meridional wind variability can excite the vertical motion variability and consequently, Dakar Niño/Niña events can be reinforced. In addtion, as Fig. 7e shows, the upper ocean layer become much warmer than sub-surface ocean layer between 40m depth. As the reviewer mentions as below, the ocean is more stratified in the future climate. This indicates that the contribution of vertical thermal advection could increase since $\partial T/\partial z$ increased in the upper layer.

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We added this discussion and Figures as Fig.11 and Fig. S5 in the Section 4. Please see lines 293-339. Moreover, we rephrased the last part of Abstract and Conclusion referring to this new result. Please see lines 21-23 and lines 340-348 .

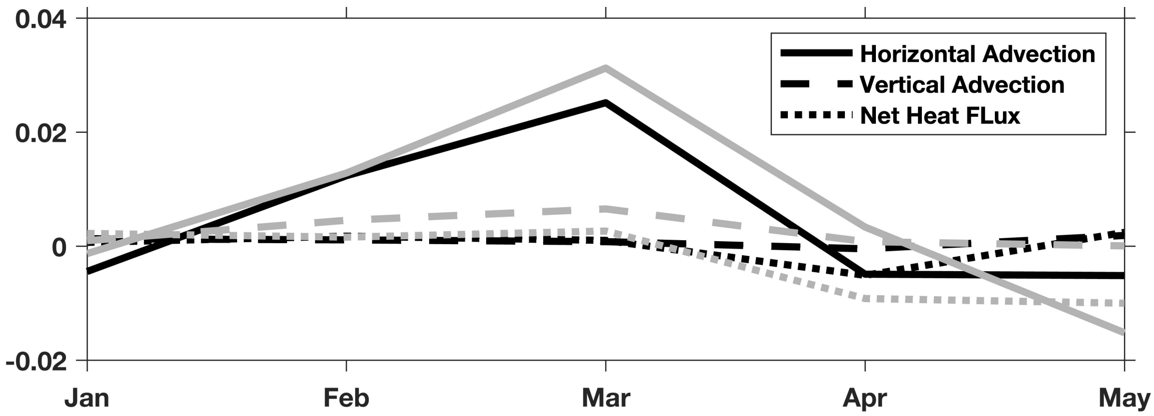

Fig.R2. Monthly time series of lag-composite difference of (solid) horziontal advection, (dotted) surface net heat flux, and (dashed) vertical thermal advection between Dakar Niño and Dakar Niña events (Niño minus Niña) in (black) 1980-2010 and (grey) 2069-2099. March is lag=0. The unit is K day^{-1}.

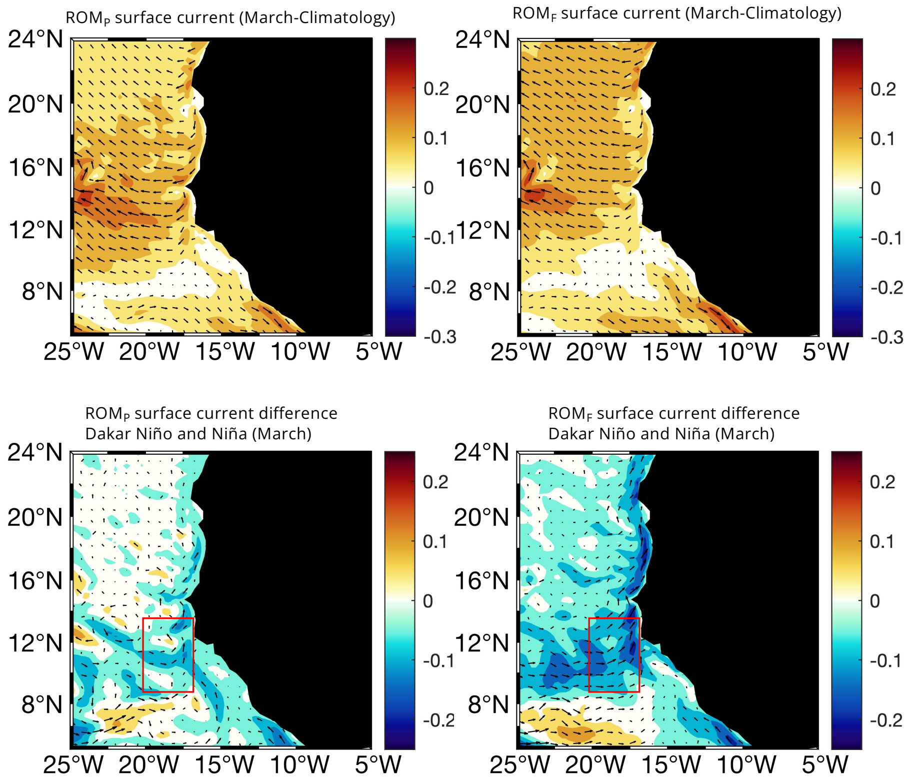

Fig.R3. (Top) surface ocean curret climatology for (a) ROM$_P$ and (b) ROM$_F$. (Bottom) surface ocean current difference between Dakar Niño and Niña composite for (c) ROM$_P$ and (d) ROM$_F$. Vector denotes the ocean current and color is ocean current velocity.

Also, we analyzed the composite difference of ocean mixing layer in the Dakar Index box between Dakar Niño and Dakar Niña as shown in Fig.R3.

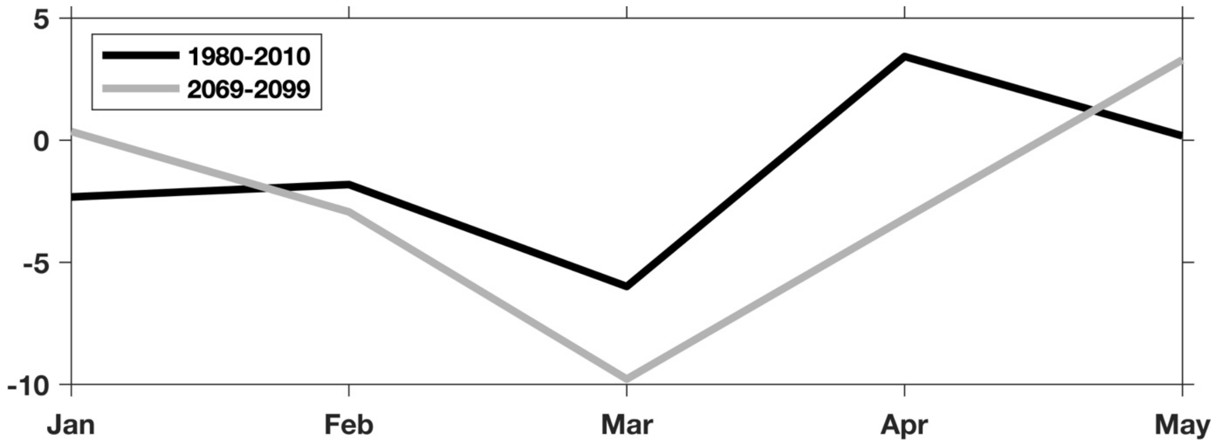

Fig.R2 Monthly time series of lag-composite difference of ocean mixing layer depth between Dakar Niño and Dakar Niña events (Niño minus Niña) in (black) 1980-2010 and (grey) 2069-2099. March is lag=0. The unit is m.

As Oettil et al. (2016) shows, the mixing layer depth tends to be shollower during the Dakar Niño in our simulation. Interestingly, the composite difference in the ocean mixing layer is larger in the future climate, especially from February to April. One of the possible reasons for this is because the meridional wind variability increased and the mechanical contribution to deepening the mixing layer can increase the difference in ocean mixing layer. However, the ocean mixing layer is also a function of temperature and salinity, so it could be difficult to make an attribution. We added this figure in Supplementary Information as Fig.S4 and some descriptions. Please see lines 294-329.

Regarding the thermal contrast between land and sea, our argument is based on Bakun's hypothesis combining sea-level pressure (SLP) anomalies in Fig 10. In both cases of Dakar Niño and Niña, continental SLP anomalies show steeper zonal gradient running along the coastal region. This gradient can be favorable for meridional wind anomalies for Dakar Niño (reducing equatorward anomaly) and Niña (increasing equatorward wind anomaly), which is consistent with Bakun's hypothesis. We added this discussion in the revised manuscript. Please see lines 286-287.

A time series of the DNI is also needed for the periods 1980-2010 and 2069-2099, to provide the reader with the number and intensity of the events. This is also particularly important to understand Fig. 4.

REPLY: Thank you very much for the helpful comment. We plotted the time series of the Dakar Index and events of Dakar Niño and Niña (Fig.R3 as follows). From this plot, the frequency of Dakar Niño and Niña is 7/9 and 8/6 in the present and future climate, respectively. It seems that there would be not a large change of the event frequency with more events being over 1 K. We added this description in the revised manuscript. Please see lines 171-175.

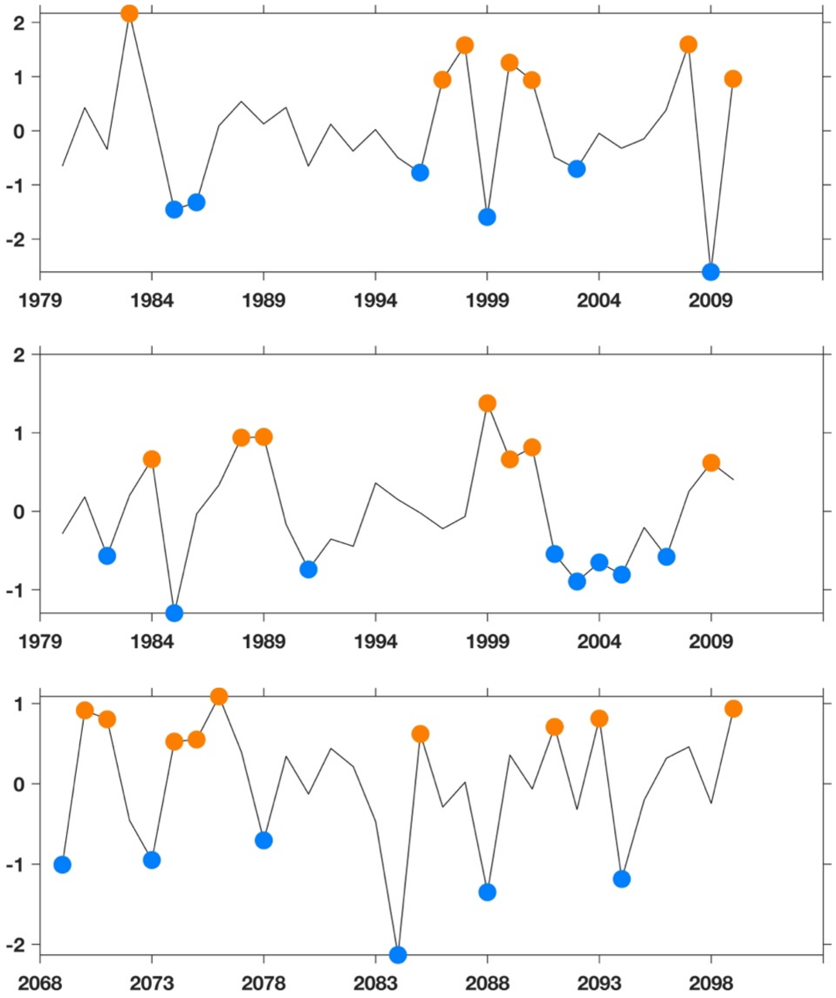

Fig.R3. Time series of Dakar Index (detrended SST averaged 9°N-14°N and 20°W-17°W) for (top) ERA5, (middle ROM_P, and (bottom) ROM_F The orange and blue dots indicate Dakar Niño and Niña events defined in this study, respectively.

Target of the study

There is some confusions throughout the main text. The title indicates that this work is focusing on the Dakar Niño, which is a coastal, phenomenon with specific characteristics (see previous sub-section), but the Senegalese–Mauritania Frontal Zone (SMFZ) is also often referred, introducing some sort equivalence in the reader's mind, between two different phenomena.

REPLY: Thank you very much for pointing this out. As Fig. 2 shows, the high interannual variability of SST is found around the SMFZ and some extreme events are referred to Dakar Niño/Niña. Therefore, while the SMFZ is the name of an area with certain climatic features, Dakar Niño/Niña are the phenomena. To make this point clearer, we modified a sentence in the introduction. Please see lines 38-39.

Also, this study discusses the intensity and the location changes of the Dakar Niño between present and future periods, but doesn't tackle the frequency change. It would be informative to also present if, under RCP8.5, the number of Dakar Niño events is likely to increase/decrease.

REPLY: As we replied above, we added the new plot of Dakar Niño Index and the number of events in Fig. 4. Accoridng to this plot, there are no large change in the frequency of Dakar Niño and Niña events between the present and futuree climate

The Bakun hypothesis (or Upwelling intensification hypothesis, Cropper et al., 2014) is introduced at L.235. This is an important topic to discuss when it comes to the future of tropical upwelling regions, because several studies have been dedicated to corroborate or contradict the Bakun hypothesis. See for example Oettli et al. (2021, p.255–256) for a discussion on this. I would recommend to better highlight how this study seems to corroborate the upwelling intensification hypothesis.

REPLY: As we replied to the comment above, our result is supporting the Bakun's hypothesis during Dakar Niño and Niña events: In particular, SLP anomalies over the land are favorable conditions for generating meridional wind anomalies. We added more discussion on this point. Please see lines 286-287.

On the other hand, it is still an open question why the SLP anomalies over the land surface are like that while the connection with the Mediterranean seems stronger in the future than in the present. It will be interesting to investigate this pattern as a future work.

Clarity

The global structure of the text is not clear and needs to be rethought, because it is often difficult to understand what the authors are describing and putting emphasis on.

Throughout the text sometimes appears some vague statements which need to be clarified:

REPLY: Thank you very much for helpful suggestions. We solved this vagueness of our description.

L.64-68: The apparent opposite conclusion on model resolution between Sylla et al. (2022) and Vázquez et al. (2022) should be better emphasized and explained, because of its implication for the current work.

REPLY: This might be caused by eddy-permitting model or not. Vázquez et al. (2022) utilized the eddy-permitting models around the Northeastern tropical Atlantic. This study also uses the model. We already added this point. Please see line 69.

L.158: What is the meaning of this anomaly pattern for the Dakar Niño?

REPLY: This pattern is the anomaly of climatological fields, therefore, it might be difficult to discuss the indication for Dakar Niño from this plot. For the climatological aspects, we already described some indications. Please see lines 171-174.

L.188-189: "This deeper connection of ocean temperature in ROMF can be indicative of the stronger SST variability". This is unclear what the authors are saying here. This needs to be clarified.

REPLY: This was too speculative and therefore, we changed this part as another reviewer also pointed out. Please see lines 207-208.

L. 228: "[…] indicating that the wind variability might be more relevant due to local effects". This also is unclear. What are those local effects?

REPLY: This statement is based on Fig.8: the wind variability over the subtropical Atlantic is not changed, but the coastal wind variability increases in the future. Therefore, the anticyclone variability is not responsible for the wind variability along the western African coast. To clarify which local effects are responsible for the higher wind variability, we analyzed the surface temperature and SLP anomalies. We modified the sentence. Please see lines 245-246.

L.278-280: How? What would be the mechanism?

REPLY: To clarify this speculation, we performed the heat budget between surface heat flux and vertical thermal advection. Please lines 294-329.

L.283-285: Again, how? What would be the mechanism?

REPLY: To clarify this speculation, we performed the heat budget between surface heat flux and vertical thermal advection. Please lines 294-329.

Figs. 5 and 6: The mix between DNI and Niño/Niña events makes things difficult to follow.

REPLY: To make it clearer, we added the new Fig.4 and corresponding descriptions. Please see lines 169-176.

L.292-293: This statement is not clear. What are the other climate modes? Please clarify.

REPLY: The other climate modes we argue here are NAO and ENSO. We added these modes. Please line 357.

Specific comments

L.25: The region of the Senegalese–Mauritania Frontal Zone (SMFZ) looks similar to the Senegalo-Mauritanian Upwelling System (SMUS) used in Sylla et al. (2019) or the Mauritania-Senegalese Upwelling Region (MSUR) used in Vázquez et al. (2023). Please clarify what is the SMFZ compared to SMUS and MSUR.

REPLY: The SMFZ is a "front" and more confined area than SMUS and MSUR and the upwelling should be one of factor to frontogenesis of the SMFZ (this has not been done yet, but Koseki et al., 2019 has done for Angola-Benguela Frontal Zone. A similar work will be possible in the future). Then, we modified the sentence. Please see line 27.

L.26: "[...] one of the most pronounced oceanic frontal zones generated along the eastern boundary current system". Source?

REPLY: Added Oettil et al. (2021).

L.28: Please remove the second left bracket.

REPLY: Done.

L.36: Please remove the second left bracket.

REPLY: Done.

L.43: "[...] stronger Benguela Niño events compared to Dakar Niño events". Source? (Probably L.116-117).

REPLY: Because there is no paper (as far as we know) for direct comparison between Beneguela and Dakar Niños, we omitted that part.

L.47: Local or multi-fleet fishery? The former is certainly more sustainable, but also more sensitive than the latter. The latter has probably more impact on worldwide economy than the former. Please clarify.

REPLY: In this study we do not specifiy which types of fleet and ships. Rather, our statement would be more general.

L.64: "Sylla et al. (2022)" is missing in the references.

REPLY: Added.

L.65: "Resolution" instead of "Resoliution".

REPLY: Corrected.

L.86: Please explain what RCP8.5 is by adding what is said at L.138 (Which then can be shorten as "Under RCP8.5").

REPLY: Added. Please see line 87.

L.119-120: What is the source of the poor representation of coastal upwelling in ERA5?

REPLY: This might be due to the relatively coarser resolution than ESA. Please see 122.

L.120: "[...] and ERA5 has a warm bias (Vázquez et al., 2022)."

REPLY: Corrected.

L.134: "The meridional SST gradient greater than 0.5K/100km is shown in blue".

REPLY: Corrected.

L.134: Why between 21° and 16°W when the DNI is defined between 21° and 17°W? Is it a typo?

REPLY: Corrected.

L.135: "[...] respectively (bottom).".

REPLY: "(bottom)" is for the SST standard deviation.

L.135: "deviation" instead of "devitation".

REPLY: Corrected.

L.136: "kelvin" instead of "Kelvin".

REPLY: Corrected.

L.143: March is the peak phase of the Dakar Niño.

REPLY: Corrected and modified following another reviewer. Please see lines 144-148.

L.148: “isotherm” instead of “of temperature”.

REPLY: Corrected.

L.165: “21°–17°W, 9°–14°N”

REPLY: Corrected.

L.167: “SST over 21°–17°W, 9°–14°N”.

REPLY: Corrected.

L.168: How is the significance of the correlations evaluated. And for the wind stress, because there are two components (zonal and meridional), both can be significant, as well as only one over two. Does the figure only shows correlations when significant in both directions? Please clarify.

REPLY: The significance of correlation is based on p-value ($p < 0.05$) as captioned. The vector with u “or” v is significant. We added this in the caption. Please see line 186-188.

L.193: “section” instead of “seciton”.

REPLY: Corrected.

L.196: “Niñas” instead of “Niña”.

REPLY: Corrected.

L.210: “section” instead of “seciton”.

REPLY: Corrected.

L.212: Is 16°W also a typo?

REPLY: Corrected.

L.253-254: “Composite anomalies of the 2m temperature during Dakar Niño (left) and Niña (right) events in ERA5 (top), ROM_P(middle), and ROM_F (bottom) in March.”

REPLY: Corrected.

L.277: Unclear what is the variability is referring to. Is it among warm (cold) events?. Is it in terms of number of warm (cold) events. Please rewrite and clarify.

REPLY: Here, the variability is referred to SST inter-annual variability defined as Dakar Index. As the composite analysis suggests, Dakar Niña (cold SST anomalies) tend to intensify more. We repharsed the sentence. Please see lines 334-335.

L.324-524: The references doesn't follow the Copernicus Publications guidelines. Please revise according to them.

REPLY: Actually, we followed https://publications.copernicus.org/for_authors/manuscript_preparation.html and download the format file for Endnote for Copenicus Publication. After we submitted our manuscript was processed through technical check and then, it was sent to the editor and reviewers. Therefore, we assume that the style of reference is acceptable.

Figure 3: In order to understand Fig.4, we need to know the mean state from January to May for the SST and the wind stress.

REPLY: Thank you for the comment. We added this as new Fig.S3.

Figure 5: The land mask should be in a different color than 0 (gray for example, similar to the mask in Fig. 7)

REPLY: Corrected.

Figure 6: Same as Fig. 5

REPLY: Corrected.

Figure 7: Is the standard deviation calculated for all the months of March in "Present" (ERA5 and ROM$_P$) and "Future" (ROM$_F$) periods? If it's the case, why not doing a composite with/without Dakar Niño/Niña?

REPLY: Yes, the standard deviation in the plot includes all the months of March. In this study, we focus on how the Dakar Niño/Niña (extreme events of SST anomalies) will be changed under global warming. Therefore, we made a composite for Dakar Niño and Niña in the present and future climate to investigate which process can explain the changes in the events.

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