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Interactive comment on "Assessment of responses of North Atlantic winter SST to the NAO in 13 CMIP5 models on the interannual scale" *by* Yujie Jing et al.

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We would like to thank the reviewers for their time and efforts spent on reviewing our manuscript, and giving us good suggestions. We have carefully thought about these suggestions, and made a lot of changes to the article. Some new figures have been added, including some new analysis, and some inappropriate descriptions have been corrected. We have re-analyzed the influence of the NAO-driven SHF / LHF / surface seawater meridional velocity on SST and changed the time period of the analysis. In addition, we have discussed the influences of the cutoff period of band-pass filter, different definitions of the NAO index, initial fields and external forcing of the historical experiments on the results. All the changes are highlighted in the revised manuscript.

Responses to two reviewers' comments point by point:

Reviewer #1: The manuscript addresses the response of winter SST in the North Atlantic to NAO forcing in 13 CMIP5 models. Patterns of observation and models are compared. Because the patterns of NAO-driven SSTs look different between models and observation, the manuscript further investigates the link between the surface heat fluxes and the SST in the North Atlantic. Also, the link between the meridional ocean velocity and the NAO is presented. The authors suggest that it is the overestimated role of the ocean that causes an unrealistic relation between heat fluxes and SST, that finally cause the model to simulate a NAO-driven SST response that differs from the observed pattern. The basic motivation for the authors of this study is that the observed tripolar SST response to the NAO is simulated only by 7 models (as they write). However, I would say that more than only 7 model reproduce a tripolar pattern associated with the NAO on this timescale, even though the centres may be partly displaced, or not providing the correct amplitude (Fig. 4). I agree that there are models that cannot reproduce a realistic pattern, but most of them simulate a tripolar pattern. Especially, the positive centre near the American coast, is reproduced by all models. So, for me the research question would rather be, why are the subpolar (negative) centres displaced.I would hypothesize, that the displacement of the location could be explained by: the wrong location of the NAO-driven heat flux forcing, a different mean ocean circulation in the models, a different response of the circulation to the NAO, or a combination of these aspects.

Reply: We agree with the reviewer. The simulated NAO-SST relationship by CMIP5 has been re-described in the revised version of the manuscript. "Most of the models can reproduce an observed tripolar pattern of the response of the SST anomalies to the NAO on the interannual scale. The model bias is mainly reflected in the locations of the negative response centers in the subpolar NA (45-65°N), which is mainly caused by the bias of the response of the SST anomalies to the NAO-driven turbulent heat flux (THF)

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anomalies."(Abstract, L13-16) "Compared with the observation, most of the models can roughly reproduce the tripole pattern of the response of the SST anomalies to the NAO. In the region around 20°N, all models can reproduce the significant negative response (reaching a 95% confidence level) east of 40°W, and in the subtropical NA, 10 models can reproduce significant positive response of the SST anomalies to the NAO near the American coast. The main difference in the RCs between the modeled and observation-based results occurs in the subpolar region where the simulated locations of the negative response centers by some of models are different from the observation-based results, especially in CanESM2, HadGEM2-ES, IPSL-CM5A-MR, MPI-ESM-LR / MR, and NorESM1-MR." (P14, L230-236)

The authors suggest that the cause for the unrealistic SST response is the incorrect response of SST to heat flux forcing, or as they write in the abstract for the subpolar North Atlantic 'most of the models simulate a positive response of SST to the turbulent heat flux'. And here I see a fundamental problem: When positive flux anomalies (ocean to atmosphere) are correlated with positive SST anomalies, then the SST is the driver for this link, not vice versa. Therefore, the regression that their conclusions are based on (Fig. 8 / 9), do simply not reflect the 'response of SST to the NAO via heat flux forcing'. The regressions seem, instead, to pick up something else, which may or may not be indirectly related to the NAO (for example through an ocean feedback). It could be that for some models / regions on the analysed timescales the dominant link between SST and heat fluxes is not the NAO-heat fluxes forcing the SST. To really extract the response of the SST to NAO-driven heat flux anomalies, I would compute regressions of SST on a pattern of the heat fluxes that has been shown to be is NAO-driven for each model (maybe an index representing the typical structure as seen in Fig. 7).

Reply: We have revised this part of the analysis (sections 3.2.2 and 3.2.3). We used the least-squares method to extract NAO signals from heat fluxes, and then calculate the regression coefficient of the standardized SST anomalies against the standardized

NAO-driven heat flux (Figs. 8a and 9a). In the subpolar region the locations of negative RCs of the SST anomalies against NAO-driven heat flux anomalies (Figs. 8a and 9a) are very consistent with that of the SST anomalies against the NAO by most models (Fig. 4). This demonstrates that the bias of the response of the SST to the NAO-driven heat flux in models can influence the NAO-SST relationship in the region.

In summary, I see a fundamental problem with the interpretation of the results and based on that also not enough evidence for the conclusions presented here. Another issue is, that the motivation for this study are the differences in the SST response to the NAO (Fig. 4). But already within the same SST dataset, there are differences depending on how the NAO index was calculated (the first two panels in the first row of Fig. 4). Next, if I understood correctly, the NAO index in the models is calculated with another (third) method. So, it can be assumed that a part of the differences is explained by how the NAO index was calculated.

Reply: Thanks for the reviewer's suggestion. In the revised version, we used only one site-based NAO index based on the observation, which is provided by NCAR. However, we tested the effect of the different NAO index on the NAO-SST relationship in the section of discussion (section 5.3, P27-28, L472-479). The observation-based two NAO indexes defined by Gong and Wang (2000)'s method and the method used to calculate model NAO indexes (Zheng et al., 2013) are employed to study the response of the SST to the NAO on the interannual scale (Fig. S10). It is found that the definitions of the NAO index indeed affect the relationship between the NAO and SST in the subtropical NA, but have little impact in most regions of the subpolar and subtropical NA.

Furthermore, the entire manuscript would need substantial improvements regarding grammar / language in general. Therefore, I didn't list all the language issues or unclear formulations, because there were just too many. Based mainly on the concern that I have regarding the approach / interpretation of the results, I cannot recommend this manuscript for publication.

Reply: Sorry about that. We have checked the article carefully and corrected some mistakes in grammar / language.

Specific comments:

I suggest to modify the title to not have 'CMIP5 models on the interannual scale' together. So maybe 'Assessment of responses of North Atlantic winter SST to the NAO on the interannual scale in 13 CMIP5 models'.

Reply: Taking the reviewer's advice, we have changed the title.

15: Please clarify on the word 'obvious', in observations or models?

Reply: It means that the influences of sensible / latent heat fluxes on SST are both important in observation. In the revised version, the abstract has been rewritten, and this word is deleted.

20: For the sub-tropical region an 'incorrect positive response' is mentioned. Why is it 'incorrect' when this subtropical centre of the tripolar pattern should be positive? Further down it is also written 'models can simulate the realistic positive response of SST anomalies to the NAO in the subtropical NA'. which seems to be a contradiction.

Reply: The previous 'incorrect positive response' refers to the response of the SST to the LHF, and the latter positive response refers to the response of the SST to the NAO. We have rewritten the abstract in the revised version, and this sentence is deleted.

Overall, I find the abstract hard to understand.

Reply: We've rewritten the abstract.

The timescales are not made clear in the abstract.

Reply: We emphasized the timescales in the abstract of the revision (P1, L12-13).

59/60: 'In recent years, more and more people have realized that the evaluation of the CMIP5 Earth System Models (CMIP5-ESMs) is the basis for study by these models.' I am not sure what the authors are trying to say here?

Reply: Sorry about this, we have changed the sentence to “In recent years, more and more people have realized that the identification of the CMIP5 Earth System Models bias is important for the improvement of these models and development of climate forecast (Wang et al., 2014, Wang et al., 2014).” (P4, L59-61)

Wang, G., Dommenget, D. and Frauen, C.: An evaluation of the CMIP3 and CMIP5 simulations in their skill of simulating the spatial structure of SST variability, Climate Dynamics, 44(1-2), 95-114, https://doi.org/ 10.1007/s00382-014-2154-0, 2014

Wang, C. Z, Zhang, L. P., Lee, S. K., Wu, L. X., and Mechoso, C. R.: A global perspective on CMIP5 climate model biase, Nat. Clim. Change, 4(3), 201-205, https://doi.org/10.1038/nclimate2118, 2014.

64/65: ‘unreasonable simulation of AMOC’. In which way unreasonable?

Reply: The ‘unreasonable simulation of AMOC’ refers to that the AMOC strength is weak and the AMOC cell is shallow. We change this sentence to “it is mainly caused by the weaker AMOC and shallower AMOC cell compared to the observations.” (P4, L65-66)

Why were these 13 models chosen? I would assume that SST and heat fluxes are widely available across CMIP5 models. Still, it seems that even out of this 13, two do not provide wind speed (Fig. 5 and 6).

Reply: We analyzed the response of North Atlantic SST to the NAO in order to analyze the response of the North Atlantic air-sea exchange carbon fluxes to the NAO in the future, because the SST plays an important influence on the air-sea carbon fluxes. Our research group has previously analyzed the fluctuation of global air-sea carbon fluxes on the interannual scale (Dong et al., 2016), and found 14 models with relatively rich outputs of biochemical variables from 22 cmip5 models (Dong et al., 2017). We would like to continue to analyze these 14 models in this paper, but unfortunately, we missed

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one.

Dong, F., Li, Y., C., Wang, B., Huang, W., Shi, Y. Y., and Dong, W.: Global air-sea CO2 flux in 22 CMIP5 models: multi-year mean and interannual variability, J. Clim., 29(7), 2407-2431, https://doi.org/10.1175/JCLI-D-14-00788.1, 2016.

Dong, F., Li, Y. C., and Wang, B.: Assessment of responses of tropical Pacific air–sea CO2 flux to ENSO in 14 CMIP5 models. J. Clim., 30(21), 8595-8613, https://doi.org/10.1175/JCLI-D-16-0543.1, 2017.

What has been done with trends in the data, especially, when computing regressions?

Reply: The trends of the data in this study are removed by the least square method. We use the detrended data to obtain the standardized data, and then to compute regressions. (P7, L107-110)

Why do the 'regression coefficients' not have units? Are we actually looking at correlation coefficients here? What about the units for the covariances shown in Fig. 8b and 9b? What about the units for the covariances shown in Fig. 8b and 9b? 145: How exactly 'normalized'?

Reply: The 'normalized' should be 'standardized', and we have modified this word in the revision. The standardized data were calculated by dividing the anomalies (the trend is subtracted) of these variables by the standard deviation of these anomalies. (P7, L107-110). The regression analysis in this study was conducted with these standardized data, so the regression coefficients have no units. We also used the standardized data to calculate the covariances, so the covariances have no units too.

Is heat flux computed manually or is it a model output? And are the heat flux measures of observations and models derived /computed in a consistent way?

Reply: The modeled heat fluxes are model outputs. The observational heat flux is obtained directly from NOAA-CIRES, which is the reanalysis data and is the result of the 20CR that utilizes an Ensemble Kalman Filter data assimilation system. We explain their possible differences in the revision. (P9, L155-158)

100: Please explained how the ‘site-based’ index is computed. Because it causes different regressions patterns (as seen in Fig. 4).

Reply: The site-based NAO index is the difference of normalized sea level pressure between Lisbon, Portugal and Stykkisholmur / Reykjavik, Iceland since 1864. (NCAR; www.climatedataguide.ucar.edu/climate-data/hurrell-north-atlantic-oscillation-nao-index-station-based, Hurrell and Deser, 2009). (P7, L111-113)

Hurrell, J. W., and Deser C.: North Atlantic climate variability: the role of the North Atlantic Oscillation, J. Marine Syst., 79(3), 231-244, https://doi.org/10.1016/j.jmarsys.2009.11.002, 2009.

157: I don’t understand this sentence: ‘Because the locations of the NAO action centers simulated by most of the CMIP5 ESMs in different NAO phases do not show the movements illustrated by the observation (the figure is omitted), the differences between the models are not caused by the NAO period or the phase of the initial sign, but are only related to the structures of models.’ So in observations the NAO pattern is not symmetric? And in the models it is symmetric? Or are the patterns also not symmetric, but differing from the observations? Also, I would argue that it is enough to say that - given the long period of 108 years and the rather short-timescale behaviour of the NAO - there is no reason to think the initial state would matter. But maybe I understood wrong what this sections was supposed to say.

Reply: In the observation, the NAO pattern is not symmetric (Fig. S1 in the revised version), but the NAO pattern simulated by most models is symmetric. The un-symmetric NAO pattern based on the observation has been shown by many studies (Jung et al. 2003; Moore, Renfrew, and Pickart 2013). The shift of the NAO action center is related to the phase of the NAO (Cassou et al. 2004, Jing et al., 2019). The location of the NAO action centers simulated by CMIP5 models in the different phases of the NAO does not move obviously in most models (Fig. S1 in the revised version). The initial fields can influence the relationship of the NAO and SST (section 5.4), so we have revised the sentence to “These models are forced by the same external-forcing data. Therefore, the differences between the NAO patterns simulated by these models may be probably induced by their different structures and values of parameters.” (P11, L180-182)

Jung, T., Hilmer, M., Ruprecht, E., Kleppek, S., Gulev, S. K., and Zolina. O.: Characteristics of the Recent Eastward Shift of Interannual NAO Variability, Journal of Climate, 16 (20), 3371–3382, doi:10.1175/1520-0442(2003)016<3371, 2003.

Moore, G. W. K., Renfrew, I.A., and Pickart. R. S.: Multidecadal Mobility of the North Atlantic Oscillation, Journal of Climate, 26 (8), 2453–2466, https://doi.org/10.1175/jcli-d-12-00023.1, 2013.

Cassou, C., Terray, L., Hurrell, J. W., and Deser. C.: North Atlantic Winter Climate Regimes: Spatial Asymmetry, Stationarity with Time, and Oceanic Forcing, Journal of Climate, 17 (5), 1055–1068, https://doi.org/10.1175/1520-0442(2004) 017<1055, 2004

Jing Y. J., Li, Y. C., Xu, Y. F., and Fan, G. Z.: Influences of different definitions of the winter NAO index on NAO action centers and its relationship with SST, Atmospheric and Oceanic Science Letters, 12(5), 320-328, https://doi.org/10.1080/16742834.2019.1628607, 2019

179 / Fig. 3b: I do not see the value of analysing the power spectra of the SST averaged over 0-65 N in the North Atlantic in this case. The NAO fingerprint on SST is tripolar, and even if not perfectly tripolar in the models, it is non-uniform. Thus, SST variability that is associated with the NAO when analysing this area-average, is at least partly averaged out. Such an index would rather yield he AMV influence. I suggest to use a different SST index or remove this panel.

Reply: Thanks for the reviewer’s suggestion. The periods of area-averaged SST in the subpolar and subtropical NA are calculated respectively (Fig. 3b/c in the revised version), and this paragraph has been rewritten (P12-13, L206-217).

185: ‘Based on the above analysis, simulated periods of the NAO indexes and area-averaged SST anomalies on the decadal scale are different from the results of observation.’ I don’t see the data that clearly support this statement. It would be helpful to see the individual power spectra, instead of only the periods of the peaks.

Reply: The individual power spectra of the NAO indexes and SST are shown in the supplement file (Figs. S3-5 in the revised version). We have rewritten this sentence as’ Based on the above analysis, simulated periods of the NAO indexes on the interannual scale are more consistent with the results of observations compared to those on the decadal scale. The observed periods of the area-averaged SST in subtropical and subpolar NA only presents interannual signals.’ (P13, L218-220).

187: ‘mainly reflected [. . .] on the interannual scales’. But aren’t Eden and Jung 2001 focusing on the inter-decadal scale of the SST response to the NAO and the role of ocean dynamics?

Reply: Eden and Jung (2001) mentioned that the SST does respond to the NAO on interannual and interdecadal scales, but the mechanisms on these two timescales are different. The oceanic response to interdecadal changes of the NAO is primarily driven by surface net heat flux variability, which impacts the SST through impacting the ocean circulation. This mechanism is different compared to the oceanic variability on interannual timescales, where surface heat flux and windstress variability can directly impact the relationship of the SST and the NAO.

Eden, C., and T. Jung. 2004. “North Atlantic interdecadal variability: oceanic response to the North Atlantic Oscillation (1865-1997),” J. Clim., 14(5), 676-691, https://doi.org/10.1175/1520-0442(2001)0142.0.CO;2, 2001.

Six models are named which have a positive response in the subpolar region. However, some of these have also an area with a negative response in the subpolar latitudes (besides the positive one). So, if being generous with the exact location of the subpolar centre, nearly all models (maybe except for IPSL-CM5A-MR and MPI-ESMMR) show some kind of tripolar response to the NAO. Please comment on that.

Reply: We agree with the reviewer and think that although some models have small positive response centers which are inconsistent with the observation, most models can roughly reproduce the tripolar pattern of the response of the SST to the NAO. We have rewritten this paragraph.

This last sentence in this paragraph should be revised. Both GFDL models have a similarly strong positive centre as in the obs_Gong panel. But again, I really recommend using the same method to compute the NAO index.

Reply: We have rewritten this paragraph and delete this sentence (P13-14, L226-238). Taking the reviewer's advice, we only analyze the observed NAO index provided by NCAR, because this set of NAO index has been recognized and widely used. The locations of the NAO action center simulated by different models are different, so we use another method to avoid the impact of the fixed-location based NAO index on the results (described in P7, L114-117), which is widely used to define the NAO index of CMIP5 model simulation (Zheng et al., 2013; Wang et al., 2017). The influence of different definitions of the NAO index on our results is also discussed in this revision (section 5.3, P27-28, L472-479).

215: Is the SHF and LHF computed or is it model output? This is not clear, because in 130 it is only write 'usually calculated' and equations are provided. Based on that, are the observational heat flux data obtained in the same way?

Reply: The simulated SHF and LHF are the model outputs, which has been described in Section 2.1. The observational heat flux is obtained directly from NOAA-CIRES, which is the reanalysis data and the result of the 20CR that utilizes an Ensemble Kalman Filter data assimilation system. We have added some explanation about these questions: "The methods adopted by the observation-based products and models to

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calculate the SHF / LHF are similar, which are mainly based on the bulk formula, but may use different parameters, so the above equations (2-6) only help us to understand the relationship between the SST and SHF / LHF, which are not the exact formulas used in the observation-based products and models."(P9, L155-158)

219 / Fig. S2: I cannot agree on the statement that all models overestimate the SHF north of 50N. First of all, the observations do not cover the area in the Labrador Sea, which seems to be the area of maximum ocean heat loss in the observations, which also seems to be the case for some of the models. So, I would say that, for example, both MPI models are doing quite well in reproducing the observed heat flux. Next, it is interesting that specifically the IPSL-CM5B-LR model is the one that is least 'overestimating'- I would rather say 'underestimating' the heat flux. And as mentioned before, I find this model least capable of reproducing the tripolar SST pattern associated with the NAO. In summary, I don't find it convincing that an overestimated heat flux (in the mean state) might be the cause for an unrealistic SST fingerprint in the models.

Reply: We agree with the reviewers. Most models seem to reproduce the maximum SHF in the Labrador Sea, which is consistent with the observation. Among them MPI-ESM-LR/MR are doing quite well in reproducing the observed SHF / LHF (Fig. S6 in the revised version). We did not consider the simulation deviation of the multi-year mean SHF and LHF as a factor affecting the NAO-SST relationship too. Fig. S6 only intends to show the direction of the heat fluxes. We have rewritten this paragraph (P16-17, L278-282). âĂČ Another issue is, that I am not sure how robust the 'observations' regarding their heat flux mean states are (Fig. S2). I recommend to test that through showing only the heat fluxes during the last decades when higher quality and quantity of observations were available, and also showing the mean state of a different reanalysis product. It could be that they are indeed robust. It just needs to be shown, because the model performances are evaluated based on these results.

Reply: Thank the reviewer for the good suggestion. We chose 1965-2015 as the time period for analyzing observed multi-year mean SHF / LHF in the full text. The same time interval of 1955-2005 was selected for the model data. In order to judge the adopted observed winter SHF / LHF's validity, three other reanalysis data were selected and compared with each other in the revised version. "In order to make sure the accuracy of the observed multi-year averaged winter SHF / LHF, three other observation-based SHF/LHF data in winter are selected and all of these datasets are in the same periods from 1980 to 2015. The distributions of the SHF / LHF from the 4 reanalysis databases are generally consistent with each other, and the main difference among these datasets is in the intensity of high values, especially in the high value center of the LHF located in the tropical NA (Figure 6a). The response of the SHF / LHF anomalies to the NAO in these 4 datasets is also close to each other, and the main difference among these datasets still occurs in the tropical NA (Figure 6b). Based on the above analysis, it can be concluded that the difference among the observation-based SHF / LHF does not affect the investigation of the relationship of the SHF / LHF and NAO / SST in this study because the regions of concern are mainly the subtropical and sub-polar NA. In the following text, unless otherwise specified, the observation-based SHF / LHF is the data from the NOAA-CIRES 20th Century Reanalysis version 2." (P16, L268-277)

224: For SHF I would even say 30-65N. And also in the Gulf of Mexico and in the Caribbean. But again, it should be shown that these results based on the reanalysis product starting around the year 1900 are robust.

Reply: We agree with the reviewers. We use the reanalysis data from 1965 in the revision.

Fig. 6: I don't think Fig. 6 is useful. Naturally, increased wind speed tends to increase the heat flux (whether from ocean to atmosphere or atmosphere to ocean). When trying to explain the differences in the response of SST to the NAO, it would be more useful to compare the differences in quantities regressed onto the NAO index (like Figure 7), because as shown before (in Fig. 5), the wind-speed response to the NAO is non-uniform.

Reply: We agree with the reviewers. We've deleted Fig. 6. According to the direction of multi-year average SHF and LHF, it is described in the revision: Considering the directions of the SHF / LHF, the increase in wind speed can significantly increase the turbulent heat flux transported from a large region of sea surface to the atmosphere. (P16, L266-267)

238: Please also comment on the comparison of models. Fig. 8a: In the models with unrealistic positive correlations, is the atmospheric forcing (NAO) maybe too weak compared to other models / observations? It might be like that - when I compare the explained variances from Fig. 1.

Reply: Thank the reviewer for the reminder. We carefully considered the reviewer's opinion. In the revision, we use the least-squares method to extract NAO signals from the heat fluxes, and then calculate the standardized regression coefficients of the SST anomalies against the NAO-driven heat fluxes (Figs. 8a and 9a). Based on this treatment, the climate variation unrelated to the NAO has little effect on the relationship between the SST and SHF / LHF / NAO.

310: 'NAO-driven SHF / LHF anomalies': Regression between SST and HF without a direct relation to NAO were shown. Therefore, it is not justified to say 'NAO-driven'. This could only be said if the regressions had been done on an index (e.g., PC-based) that is related to the NAO.

Reply: We have corrected that statement. We use the regression method to establish the SHF / LHF / sea-surface meridional velocity anomalies driven by the NAO, and then calculate the standardized regression coefficient of the SST anomalies against the NAO-driven SHF / LHF / sea-surface meridional velocity anomalies.

336-339: I cannot agree on this statement, because: Fig. 7 (for heat fluxes) is the analogous version to Fig. 10 (for the meridional ocean velocity). Both figures show that the models reproduce the observations. Based on that only it is not justified to say that the root for an unrealistic SST response to the NAO are the heat fluxes. Indeed, the regressions of heat fluxes and SST in Fig. 8 and 9 show that the heat flux / SST relations are not realistic. But an analogous analysis for the meridional surface ocean velocity / SST is not presented. Even here there might be differences. And then one cannot say that unrealistic aspects in the SST response are caused only by the wrong heat flux response.

Reply: We agree with the reviewer, and re-analyze this part. We calculate the correlation coefficients of the standardized SST and the SST change that is induced by the change of meridional heat transport related to the NAO-driven meridional sea surface velocity (Fig. 10b). These correlation coefficients show that the NAO-driven meridional sea surface velocity has no obvious regular influence on the SST. (P25, L421-435)

348: 'Because there is a deviation between the simulated and observed periods of the NAO indexes / area averaged SST on the decadal scale.' What is meant by 'period' and 'deviation' here exactly? The most dominant timescales of variability from the power spectra?

Reply: The 'period' means significant periods obtained by the power spectra. The 'deviation' means that the simulated significant periods (obtained by the power spectra) characterized by decadal signal are different from those observation, and some models do not reproduce the significant periods characterized by decadal signal. We delete this sentence in the revision, and rewrite this paragraph (P23, L391-394).

363: 'LHF and SST is mainly related.' What is meant by 'mainly related'?

Reply: It means that the variation of SST is mainly affected by the variation of LHF. We rewrite the conclusion, so this sentence has been deleted.

364: When the response to LHF is 'unreasonably positive', how can contribute to a too weak positive response in the subtropical NA (as mentioned further above in l. 355)?

Reply: In original version, it means that during the positive phase of the NAO, the increase of the meridional heat transport leads to the increase of the SST in the subtropical NA. This mechanism probably conceals the unreasonable impact of the heat turbulent flux anomalies on the SST anomalies in some models, so that the simulated response of the SST anomalies to the NAO by most of the models is weak positive in the subtropical NA. In the revised version, we think that this mechanism may be wrong and delete this statement.

366-367: ‘have a significant positive response to the NAO’. This only applies to the subtropics, not the subpolar region.

Reply: Thank the reviewer for reminding us. Because we have rewritten the conclusion, this sentence has been deleted.

As a supplementary document already exists, I would suggest to also show the individual power spectra from which Figure 3 is derived. For the power spectra please also provide the information about the window that is used to compute them.

Reply: We have added the figure of the power spectra of the NAO indexes and the area-averaged SST in the subtropical / subpolar regions to the supplementary document (Figs. S3-5).

Technical corrections:

28: First sentence: A ‘relationship’ is not an ‘event’.

Reply: We changed this sentence to “There is a strong inverse relationship between Iceland’s and the Azores’ monthly mean sea level pressure (most significant in winter) in the North Atlantic (NA), which is called the North Atlantic Oscillation (NAO) (Walker, 1924).”

220: By ‘MPI-ESM1’ you probably mean MRI-ESM1?

Reply: Yes, we have corrected it.

352: ‘along the meridian’ – which one?

Reply: The regression coefficient of the SST and NAO indexes are along the meridional direction. We re-described it.

355: ‘weaker positive responses’. I would add ‘than observed’.

Reply: Thank you for the reviewer’s suggestions. The sentence has been deleted in the revised version.

366: ‘observed meridional velocities’. Please add the information that it is the surface ocean velocity.

Reply: Done

‘Constant field value is 10’ is not a good annotation for a panel where model data are not available.

Reply: We have removed it from the figure.

In the figures with subpanels for the different models, sometimes there is one, sometimes there are two observational panels. That moves the position of the model panels and it is hard to compare them across figures. I suggest to have the observations as the last panels, or leave the second panel position free for the case there is no second observation panel.

Reply: We redraw all the figures to make sure that one observation is at the top left, and the position of each model in these figures is fixed.

Please increase the resolution of Figs. 1 and 3.

Reply: We have increased the resolution of these two figures.

I think the SCCs in Figure 2 are not a very representative measure, because they hardly vary despite the model differences (as seen on the maps, or in the RMSE).

Reply: We agree with the reviewer. We have removed SCCs in Fig. S2.

Figure 3: Please explain the meaning of the horizontal lines / areas.

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Reply: The horizontal lines / areas mean the significant periods of observation. We have added the description for them under the corresponding figures.

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