

Answer for referee 2

Dear Referee 2,

Thank you for your pertinence and thoroughness in going through our work. With respect to your preoccupations, this obliged us to go through some of the aspects, thereby enriching us more in this subject matter. We hope that our answers to your questions adequately address the issues so as to give the article a solid scientific lift.

Once more, thank you.

Below are the step-by-step answers to individual questions or clarifications

In the manuscript, we used data spanning 24 years. However, this time around, following your advice, we increased the number of years to 56. The change in the number of years did not affect the results, i.e. percentage of variance for EOF1, while that for EOF2 increased from 12% to 17% (Fig. 12) indicating that the variability of the second mode, which resembles the meridional mode changes from year to year.

Our interest is in the ACT phenomenon in the Atlantic Ocean; precipitous cooling in the eastern tropical region. In the manuscript, and, hence, used the empirical orthogonal analysis on tropical Atlantic data between (29°W–21°E, 25°S–7°N). But studying only the variability of SST in the tropical basin, only one of the characteristics of the meridional mode will be missing, which is another dominant mode of the Atlantic Ocean. At your request, in order to strengthen our results by indentifying the meridional mode, we extended the study area northwards: (30°W–20°E, 26°S–22° N), which is still in the equatorial region. This, therefore, is what will be considered in the new manuscript.

However, Figs. 12 shall not be taken into account (old area) and they are here just to show the differences.

- 1- First of all, I have to say that the logical structuring and language used do not meet the criteria for a scientific publication. This strongly affects the scientific quality of the manuscript, since it is often hard to follow the author's line of argumentation. I suggest that at least the abstract and the discussion section should be re-written and the authors should seek the help of a native speaker.**

This is the proposed new abstract:

Principal Component Analysis (PCA) is one of the most popular statistical methods for feature extraction. The neural network model has been performed on the PCA to obtain nonlinear principal component analysis (NLPCA), which allows the extraction of nonlinear features in the dataset missed by the PCA. NLPCA is applied on the detrended monthly Sea Surface Temperature Anomaly (SSTA) data from the eastern tropical Atlantic Ocean (30°W– 20°E, 26°S–22°N) for the period 1950–2005. The focus is on the differences between SST inter-annual variability patterns; extracted through the traditional PCA and the NLPCA methods. The first mode of NLPCA explains 38.3% of the total variance of SST anomaly compared to 36% by the first PCA while the second mode of NLPCA explains 28% of the total variance of SST compared to 16% by the second PCA. Results from previous studies that detected the Atlantic cold tongue (ACT) as the main mode are thus confirmed. NLPCA, in agreement with composite analysis, exhibits two types of ACT, referred to as the *weak* and *strong* Atlantic cold tongues. These two events are not totally symmetric. In contrast, we show that the second mode of NLPCA identifies the meridional mode, which is asymmetric. Thus, NLPCA explains the results given by both PCA and composite analysis. A particular area observed along the northern boundary between 13 and 5°W vanishes in the strong ACT case and reaches maximum extension to the west in the weak ACT case. It is observed that the maximum signal in the Gulf of Guinea (GoG) is located along coastal Angola. It is also observed that the original SST data correlates well with NLPCA and PCA, but with a stronger correlation on ACT area for NLPCA and southwest in the case of PCA.

With the following answers to your questions, we hope you will have the expected view of the manuscript.

- 2- Furthermore, I have to admit that the significance of the scientific achievements presented here is not yet sufficient to justify a publication. Even though I'm not an expert on these methods, I understand that the Authors apply well-established methods to a new problem, in this case the Atlantic cold tongue. The method used to derive the NLPCA appears to be identical to Hsieh (2004) (He even also uses the first three PCAs). So I don't see a methodological advancement that would justify a publication.**

The (NLPCA) method used here is identical to that used by Hsieh (2004). Monahan (2001) used same for the study of El Niño/La Nina. The difference is that the former used 3 PCs while the latter used 10 PCs as inputs to the NLPCA, and the results are similar, which means that the principal characteristic of the phenomenon (El Niño/La Nina) is contained within the first 3 PCA modes. This implies that a certain minimum number of PCs can be sufficient to capture a phenomenon. Hence, the 3D is negligibly different from that of the 10D-approximation. In our case it is a coincidence that the essential characteristics of the ACT were contained within the first 3 PCA modes. Hence, using more than 3 is superfluous and unnecessary costs in simulation time. In accordance with your recommendation that we detrend the data before applying the PCA, we also added the space so as to better capture the meridional mode. To select the number of PCs, we used a Guttman–Kaiser criterion; where only the modes with eigenvalues greater than the average eigenvalue were retained (Jackson 1991; Landman and Tennant 2000). In this study this criterion gives 20 PCs whose total variance is 99%. It is true that less than 20 can still also give the expected results (not shown).

- 3- On the other hand, the climatological relevance of the results found is not sufficiently discussed. Despite the fact, that the NLPCA performs slightly better than the PCA in terms of explained variability, what are major implications for our physical understanding of the system that we couldn't get using conventional techniques (e.g. the nonsymmetrical weak and strong ACT).**

Comparing the patterns shown in Fig. 1a with the pattern of the first EOF presented in Fig. 3a we observe that individual PCA modes represent only a single spatial pattern of the first mode of NLPCA with standing oscillations. Fig 3a is similar to Fig. 1a, hence NLPCA mode 1 includes PCA mode 1. The Weak ACT state (Figures 1h) and strong ACT (Figures 1a) are confined to the eastern part of the equatorial Atlantic. One of these patterns can be observed captured by a conventional PCA analysis but the symmetry presented by strong and weak ACT cannot be captured by a conventional PCA analysis, but only by NLPCA.

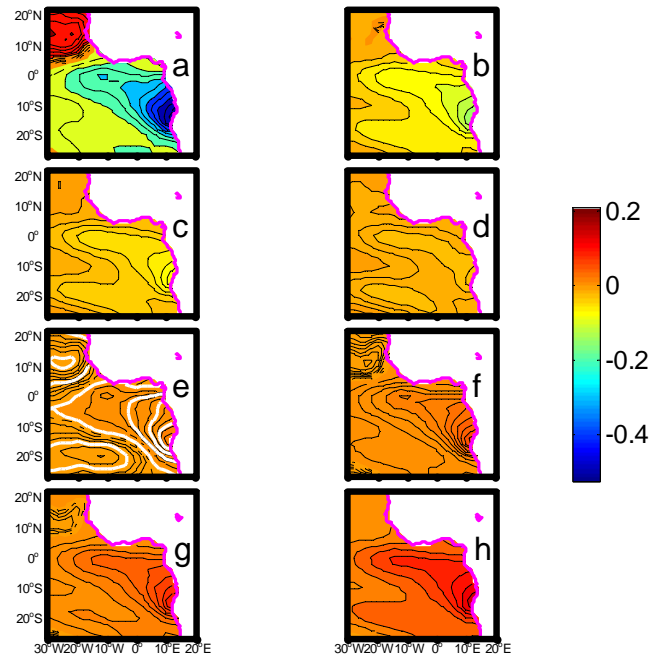


Figure 1: The SST anomaly pattern (in °C) of the first NLPCA mode, u varies from (a) its minimum (*strong* Atlantic cold tongue), to (b) three-quarter its minimum, to (c) half its minimum, to (d) a quarter of its minimum, to (e) a quarter its maximum, to (f) half its maximum, to (g) three-quarter its maximum and (h) its maximum (*weak* Atlantic cold tongue). Zero contours are white lines. Positive contours are black lines and negative contours are dashed black lines.

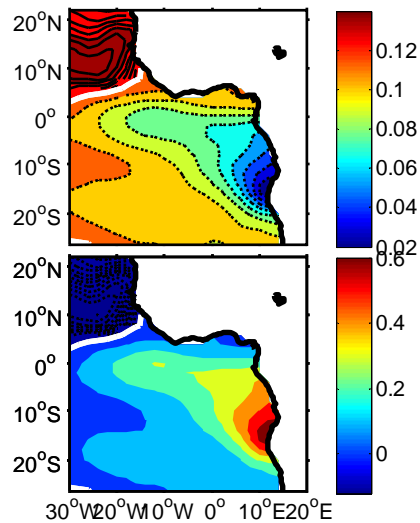


Figure 2: Composite maps for average (a) warm ACT and (b) cold ACT. Zero contours are white lines. Positive contours are black lines and negative contours are dashed black lines.

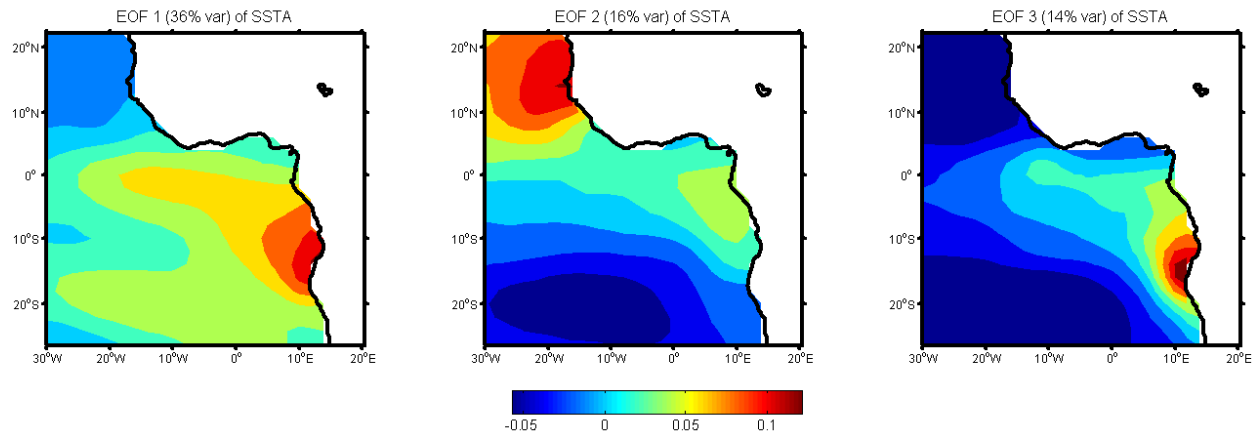


Figure 3: Empirical orthogonal function (EOF) of detrended monthly sea surface temperature (SST) Anomalies. a) EOF1 mode (left) and b) EOF2 mode (right) with their explained variance in parenthesis.

Yuko and Shang-ping (2006) reveal a new mode of tropical Atlantic variability that displays many characteristics of the zonal mode but instead peaks in November–December. They rename this anomalous warm event, the Atlantic Niño II, to distinguish it from its summertime big brother which is the classical one. They demonstrated that its amplitude in SST amounts to 65% of that of the summer Atlantic Niño. EOF3 exhibit this Atlantic Niño II.

- 4- Here are some suggestions for additional analysis and discussion that could be performed: Could NLPCA e.g. be used as a benchmarking tool for climate models to assess their ability in reproducing the ACT variability? Maybe a subset of CMIP5 GCMs could be tested?**

Thirty Coupled Model Intercomparison Project phase 5 (CMIP5) preindustrial simulations are examined to assess the ability in reproducing the ACT and Atlantic dipole variability in the Gulf of Guinea (GoG). This study examines whether the Coupled Model Intercomparison Project phase 5 (CMIP5) models can simulate the different ACT patterns. We present results comparing PCA and NLPCA on the observed data and pre-industrial control simulations from few models of CMIP5 model ensemble.

PCA

In this section we choose the first ensemble members in the historical simulations of six models (GISS-E2-H, MIROC5, CNRM-CM5-2, HadGEM2-AO, MPI-ESM-LR and CSIRO-MK3.6) from an ensemble of thirty models. We have used a longer data set (1950-2005) that is for 56 years. A climatologically annual cycle was calculated by averaging the data for each calendar month, and the monthly SST anomalies (SSTAs) were defined relative to this annual cycle. We have eliminated the linear trends from all datasets at each spatial location using the same procedure as that of the observed data. Thus, detrending the monthly anomaly, our primary dataset was formed. The spatial resolution of the data ($2^{\circ} \times 2^{\circ}$) and the output of the models are different. We interpolate this output to have the same resolution as the observation data. EOF analysis is applied to the monthly SSTA in which the SST seasonal cycle has been removed from the period of interest (Figures 4). EOF1, EOF2 and EOF3 modes of six ensembles of CMIP5 in the tropical Atlantic are shown in Figure 4.

An El Niño-like pattern in the tropical Atlantic has been identified in recent decades from observations and simulations. The EOF1 of ERSST data set shows an inconsistent feature in the SST in the eastern equatorial Atlantic compared to the CNRM-CM5-2, GISS-E2-H and MIROC5 data sets. The ERSST data set displays significant warming in the eastern equatorial Atlantic. EOF1 of these data sets consistently show strong amplitude in the equatorial Atlantic. From the observation, the first mode (Figure 4) captures the weak ACT, which can be regarded as the conventional El Niño pattern in the tropical Atlantic. This first EOF explains 36% of the total SST variance. Interestingly, for EOF2, warming occurs in the North West while cooling occurs in the south west for GISS-E2-H and CNRM-CM5-2, but for the case of GISS-E2-H, the positive centre of action in the north is located near the equator.

The second EOF has a positive centre of action in the north, near the west coast of Senegal and the negative centre in the south at 10°S and explains 16% of the total variance the third EOF explains 14% of the variance and has strong positive amplitude stretching across the equatorial Atlantic; reaching the Angolan coast. This pattern is similar to the Atlantic Nino II.

Table 1. Explains the variance for first (**PC1**), second (**PC2**) and third (**PC3**) principal components, for first (**NL1**) and second (**NL2**) NLPCA SST modes; along with the total variance explained by the main EOF modes, used as input to the NLPCA algorithm, and the variance explained by the first two PCs together (**PC1+2**) and first two NLPCA modes together (**NL1+2**), for comparison purposes.

Model name	PC1	PC2	PC3	NL1	NL2	Nbs	PCs	PC+2	NL+2
Observation	36%	16%	14%	38.3%	22.27%	20	99.0342%	52%	60.57%
GISS-E2-H	47%	12%	10%	47.26%	23.18%	30	95.9842%	59%	70.44%
CSIRO-MK3.6	34%	19%	11%	35.10%	58.43%	32	96.4635%	53%	93.53%
MIROC5	42%	20%	9%	42.52%	44.85%	32	97.5554%	62%	87.37%
CNRM-CM5-2	35%	17%	9%	32.78%	21.49%	35	91.5618%	52%	54.27%
MPI-ESM-LR	28%	16%	11%	27.81%	39.75%	38	95.2677%	44%	67.56%
HadGEM2-AO	37%	15%	10%	37.43%	36.50%	42	92.7856%	52%	73.93%

In some of the models listed above (HadGEM2-AO, MPI-ESM-LR), the first EOF (Figure 4) shows an SST pattern similar to that of a fully developed El Niño event, with higher temperatures stretching across the equatorial Atlantic, replacing the normal tongue of cooler water in the eastern Atlantic. Figure 4 show that ACT pattern is reasonably observed in their leading EOF modes.

Some models appear to have problems in simulating the El Niño, for example, having too weak amplitude in the ACT zone (CSIRO-MK3.6, MIROC5, and CNRM-CM5-2). The GISS-E2-H presents a less clear picture. For the second EOF, CNRM-CM5-2 and GISS-E2-H reasonably capture the Atlantic dipole with weak amplitude in the north for the case of GISS-E2-H; where the positive pole is shifted toward the south.

The proportion of the total SST variance explained by the EOFs differs widely between the models (see table 1).

The third EOF from the model simulations presents a less clear picture. Their spatial patterns are variable. CNRM-CM5-2 bears some resemblance to that of the observational data, with strong positive amplitude stretching across the equatorial Atlantic, reaching the Angolan coast, while the second EOF pattern has a distinct meridional dipole pattern; more like the observational data.

Then CNRM-CM5-2 is able to capture the Atlantic II, which is pointed out by EOF3 and Atlantic dipole but have difficulty to capture classical El Nino.

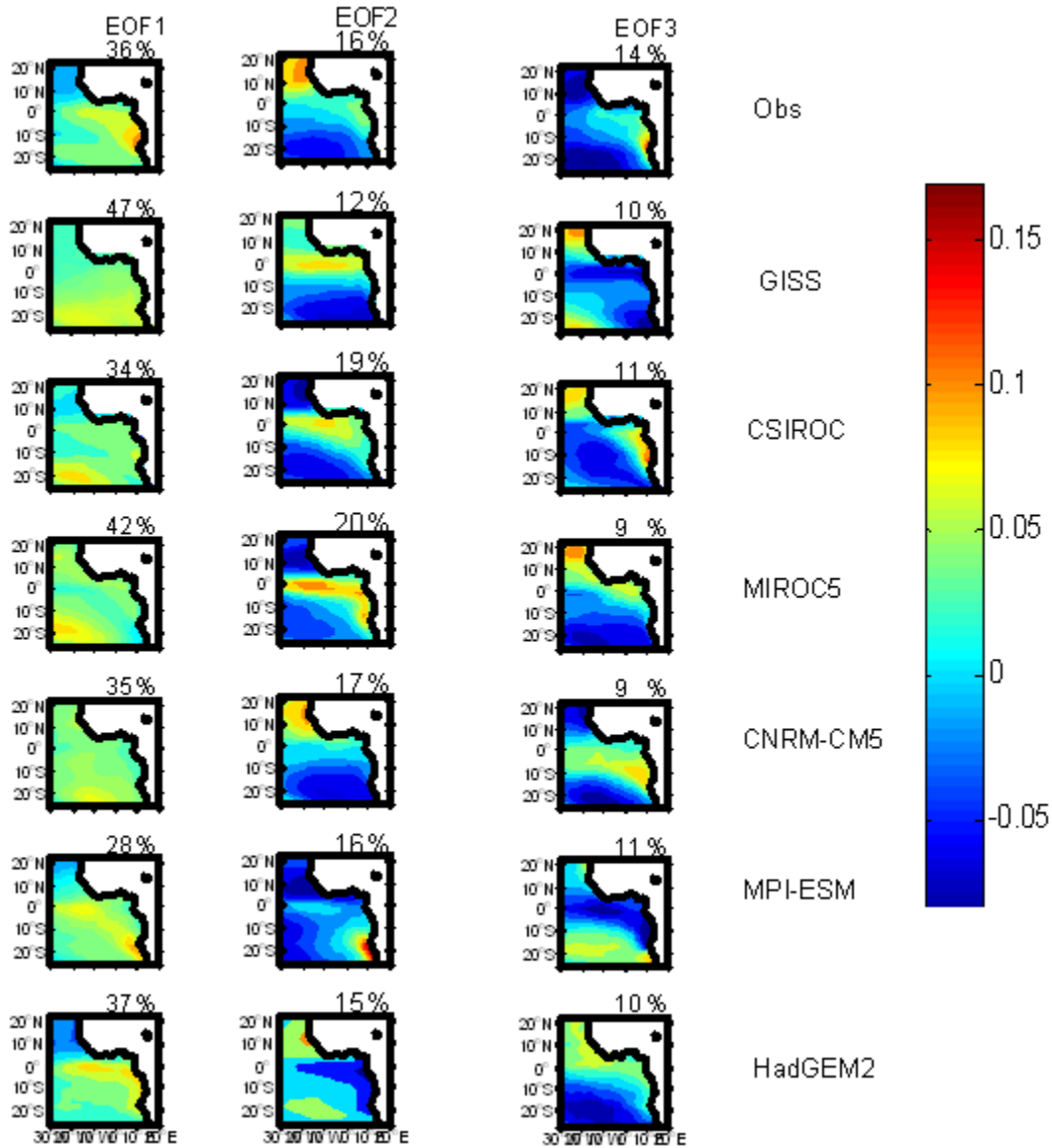


Figure 4: The EOF patterns of SST anomalies calculated from the observations and the CMIP5 models. The SST EOF1 (left), EOF2 (middle) and EOF3 (right) for the ERSST (top), and descending, GISS-E2-H, CSIRO-MK3.6, MIROC5, CNRM-CM5-2, MPI-ESM and HadGEM2-AO (bottom) data sets.

Finally, because of the weaker correlation (not shown) between the PCs, quantitative analysis does not permit us to make some comparative conclusion. However, we may adequately conclude by using qualitative description, which is the analysis of spatial distribution of SSTA.

The El Niño pattern presented in the EOF1 from HadGEM2-AO model is quite similar to the results displayed by EOF1 from the observation data.

With the observed EOF2 mode, the Atlantic dipoles are well simulated by about one third of the models. For the GISS-E2-H, CNRM-CM5-2, EOF2 modes exhibit the meridional mode while MIROC5, HadGEM2-AO, MPI-ESM-LR and CSIRO-MK3.6 exhibit an inconsistent behavior in the North and the South between different models. Then the latter have difficulty in simulating the Atlantic dipole.

The patterns of the third EOF for the ERSST and CNRM-CM5-2 products are almost the same, but their corresponding PCs are also weakly correlated (not shown).

Then the observed spatial pattern of the EOF1 modes is not realistically reproduced by most models, except MPI-ESM and HadGEM2-AO, which are the best candidates that are able to capture the ACT.

SST NLPCA mode 1

NLPCA cannot be used directly with observed or modelled SST data sets. An initial step is required to reduce the dimensionality of the inputs so that a neural network of reasonable size can be used. In this study, we used the Guttman–Kaiser criterion in each model and the numbers of inputs are shown in table 1. The proportion of the total data variance explained by these EOFs is shown, for each data set, in the seventh column table 1. This initial PCA step means that, in all cases, the input and output layers of the NLPCA networks used here have the same number of neurons, one for each EOF.

The choice of the number of neurons for the hidden layers is a more complex subject. Here, we emulate Hsieh (2001), using networks with 3 hidden layer neurons.

The NLPCA method has been used to the CMIP5 model outputs. The first five columns of table 1 show the explained variances for the first three PCA and first two NLPCA modes.

Turning to the analysis of modeled SSTs. All the chosen models show substantial degradation (in terms of temporal variability) in the representation of SST variability using NLPCA mode 1 and PCA mode 1; the correlation is insignificant. The differences between NLPCA and PCA results in terms of explained variance are more modest. For each of the models here, the distribution of input data is markedly different, as can be seen in the reconstruction plots, Figures 5.b-g.

However, the figures 5a-g show that, for model GISS-E2-H, MIROC5, HADGEM2-AO and CNRM-CM5-2, the differences between NLPCA and PCA results are modest except the MPI-ESM-LR and CSIRO-MK3.6 model that shows a more pronounced non-linearity compared to observation.

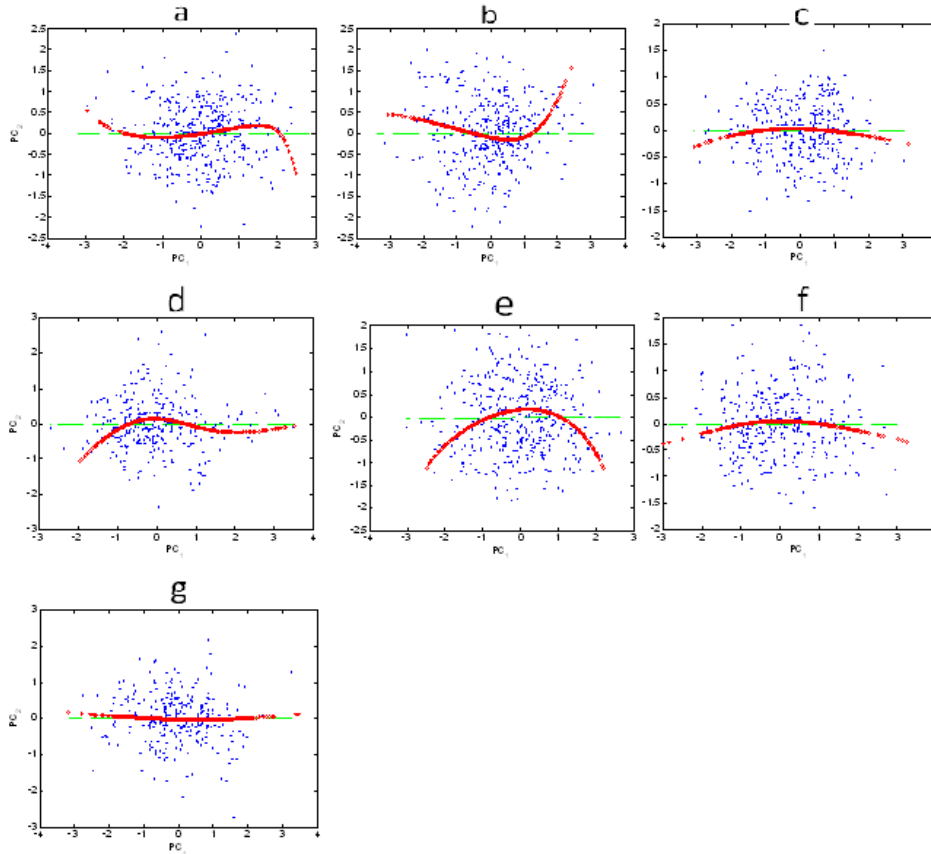


Figure 5: Scatter plot of the sea surface temperature anomaly (SSTA) data of a) ERSST, b) CSIRO-MK3.6, c) GISS-E2-H, d) MIROC5, e) MPI-ESM-LR, f) HADGEM2-AO and g) CNRM-CM5-2 (shown as dots) in the principal component (PC1, PC2) plane. Original data points are shown as blue dots; the first mode NLPCA approximation to the data is indicated by the red circles. Projection onto the first EOF is shown as a green line.

The four models, GISS-E2-H, CSIRO-MK3.6, MIROC5, CNRM-CM5-2, all show a substantially better representation of their SST variance in terms of the first NLPCA mode than in terms of the first PCA mode. These models are all highlighted in Table1 to indicate this improvement, which is seen both in the explained variance. The explanation for the better

performance of the NLPCA here compared to PCA is exactly the reverse of that for the poor performance for MPI-ESM-LR and HADGEM2-AO.

In the NLPCA case, the range of variability that can be expressed by a single NLPCA mode is much wider, limited only by the range of spatial patterns spanned by the first EOFs of the principal component time series used as input. This means that there is no single map that can be displayed to express the spatial pattern of variability of an NLPCA mode. Instead, we can show spatial patterns of the NLPCA reconstructions at different points along the one-dimensional NLPCA. Here, and below for model output, we plot SST maps. Figure 6 shows these SST map plots for the observational data. Comparison of the end members for minimum and maximum (Figure 6.a and h, respectively,) of the first NLPCA mode clearly shows the difference between a fully developed strong ACT and a fully developed weak ACT (El Nino).

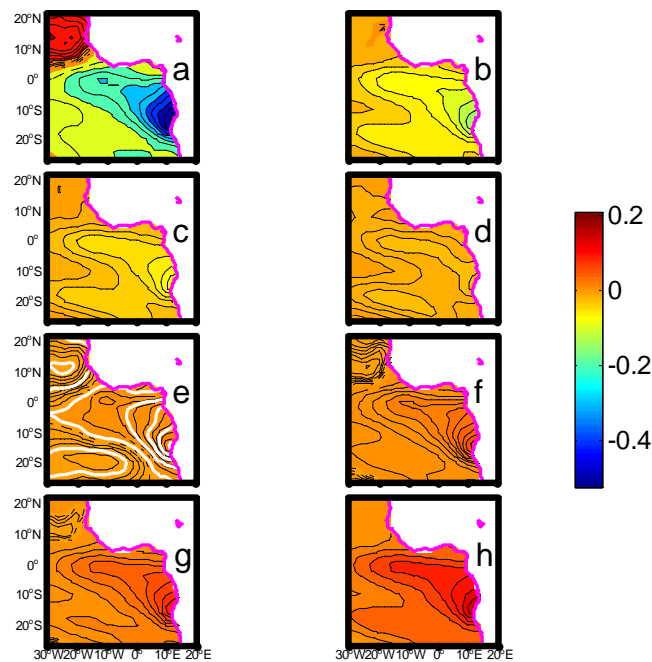


Figure 6: Spatial pattern plots for NLPCA SST mode 1 for observational ERSST data.

Each panel shows the SST anomaly composite formed from the point along the one dimensional NLPCA.

We now concentrate on the reconstruction and spatial pattern results for the models. We examined spatial pattern plots as was done for the application to analysis of Atlantic SSTs observational data.

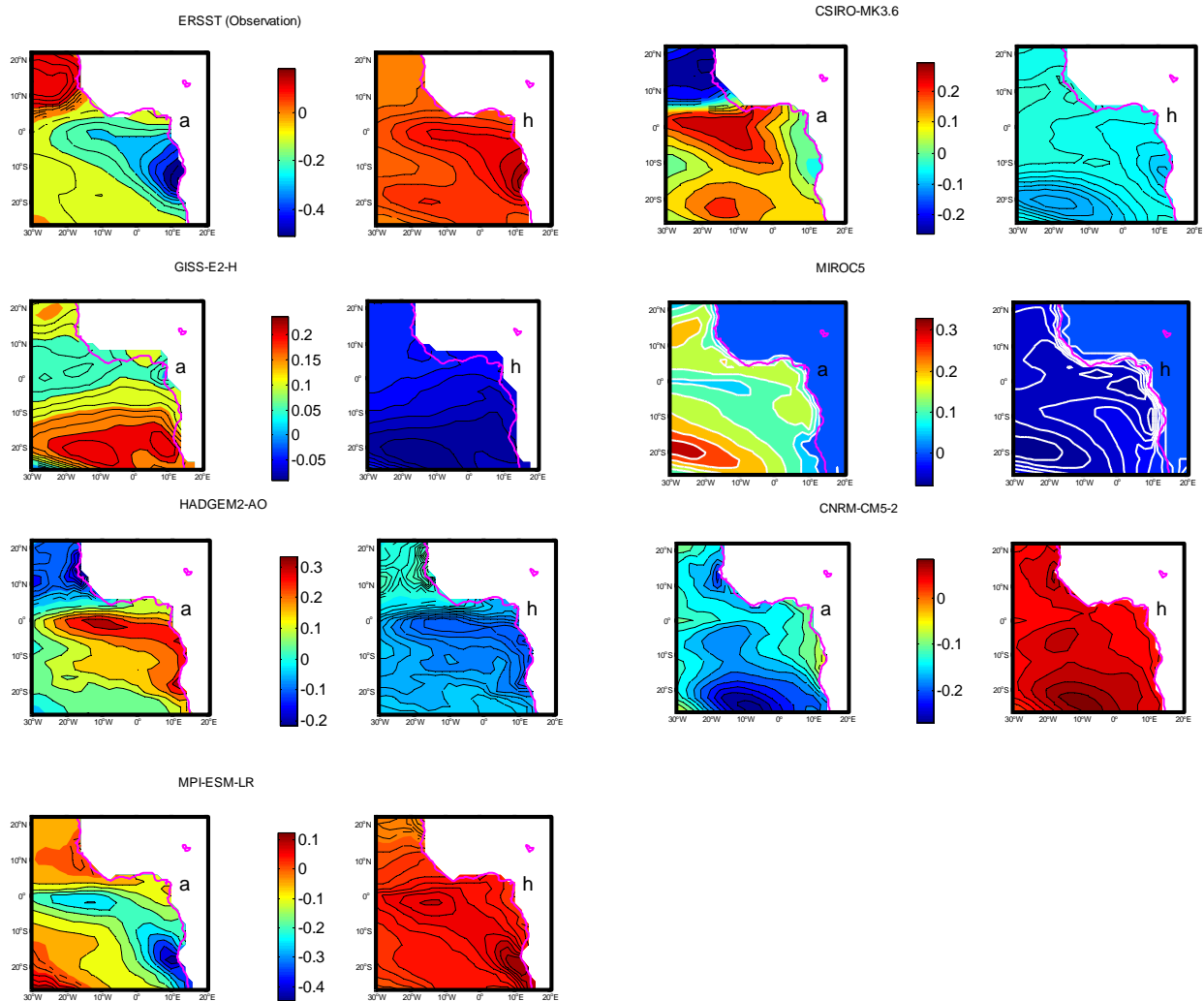


Figure 7: Spatial pattern plots for NLPCA SST mode 1 spatial pattern plots for NLPCA SST mode 1 for observational ERSST data, CSIRO-MK3.6, GISS-E2-H, MIROC5, MPI-ESM-LR, HADGEM2-AO and CNRM-CM5-2. Each panel shows the SST anomaly composite formed from the point along the one dimensional NLPCA varies from (a) its minimum (strong Atlantic cold tongue to (h) its maximum (weak Atlantic cold tongue). Zero contours are white lines. Positive contours are black lines and negative contours are dashed black lines. The contours in pink color are the coast.

In the case of CSIROC-Mk3 model, the spatial patterns for maximum and minimum of NLPCA mode 1 are different on the west side. There is a distinct spatial asymmetry between the strong and weak ACTs. This is very different to the situation in observed data, where there is a nearly identical spatial pattern for maximum and minimum NLPCA mode 1. This situation was predicted by Fig.5.b. In the results for GISS-E2-H, the longitudinal extent of the strong ACT and El Niño patterns are shifted somewhat to the South; compared to those for the observations. Here, the results for MPI-ESM-LR and HadGEM2-AO are comparable to those for the observational data. The meridional extent of the strong ACT and El Niño patterns is quite good but the situation with HadGEM2-AO is slightly different and not interesting because of the opposite sign observed in the amplitude compare to observation. The situation with CNRM-CM5-2 is different but the spatial patterns are poor compared to the observations. The pattern of ACT is not clearly exhibited.

Few of the models display a pattern with a reasonable shape in the eastern equatorial sector of the Atlantic. MPI-ESM-LR do a good job, but other models have a pattern which, either does not properly resemble the ACT pattern (CNRM-CM5-2 and MIROC5), or with high amplitude located in the south (CSIROC-Mk3).

Finally, using NLPCA, the spatial distribution of the strong and weak ACT signature in model HadGEM2-AO (respectively Fig. 7.a and Fig.7.h) compares reasonably well with the observed features (respectively Fig.6a and Fig.6h) but with reversal sign. It shows positive amplitude (weak ACT) in the east in the equatorial band and vice versa (weak ACT). The best model for which the characteristics are close to the observation is the MPI-ESM-LR, which is the same for the case of linear PCA. But quantitatively its reconstruction plot (Figure 5.e) is not closest in appearance, in terms of the degree of nonlinearity observed, to the reconstruction plot for the observations (Figure 5.a).

Figure 4 show that the geographical distribution of the SSTA is well captured by model MPI-ESM-LR, with a qualitatively good distribution of the low and high SSTA regions. Qualitatively, the spatial pattern of ACT is similar to that of observation. The model MPI-ESM-LR is one of the best models for simulation of the spatial patterns of ACT. There is apparently a relative little difference between the performance of NLPCA and PCA for this model, based on the results

shown in Table 1 because in terms of explained variance, the first NLPCA modes explain marginally more of the total data variance than do the PCA modes. This may indicate that, despite the observed nonlinearity in the original input data of MPI-ESM-LR any important nonlinearity is confined to the first SST EOFs.

SST NLPCA mode 2

Here, we present NLPCA SST mode 2 results for the observational data set used and a small number of models shown above. The NLPCA network architectures used for calculating NLPCA SST mode 2 are essentially the same as those of Hsieh (2001); three hidden layer neurons with all training and fitting parameters identical to the configuration used for calculating NLPCA SST mode 1. For the observational SST data, NLPCA SST mode 2 explains 22.27% of the total data variance, compared to 38.3% for NLPCA SST mode 1 (Table 1). The first two NLPCA modes between them explain marginally more of the total data variance than do the first two PCA modes. The main pattern of variation between large negative and positive values of *NLPCA* model 1 is a dipole; with each pole on either side of the equator with different sign (Figure 9).

We now turn to NLPCA SST mode 2 results for the models. From EOF 2, these six models (fig. 1) are fairly representative of models with reasonable Atlantic dipole behavior, except for CNRM-CM5-2 which captures the main characteristics of the Atlantic dipole, with the South Pole shifted towards the coast with different signs as compared with the observations. The explained variance results in Table 1 show that the NLPCA mode 2 explains more variance as the second principal components of all the selected model SST data.

As already mentioned above, in terms of explained variance, NLPCA mode 1 is generally bigger than PC mode1 but the difference is not much as compared to that of PC mode 2 and NLPCA mode 2, which are very large and with the NLPCA mode 2 being greater than PC mode 2 in each case.

We therefore expect that the nonlinearity will be more pronounced in the figures 8 in the reconstruction plots for NLPCA mode 2.

As compared to the observation data, the meridional mode (figure 8.a) is more nonlinear than that of the ACT (figure 5.a).

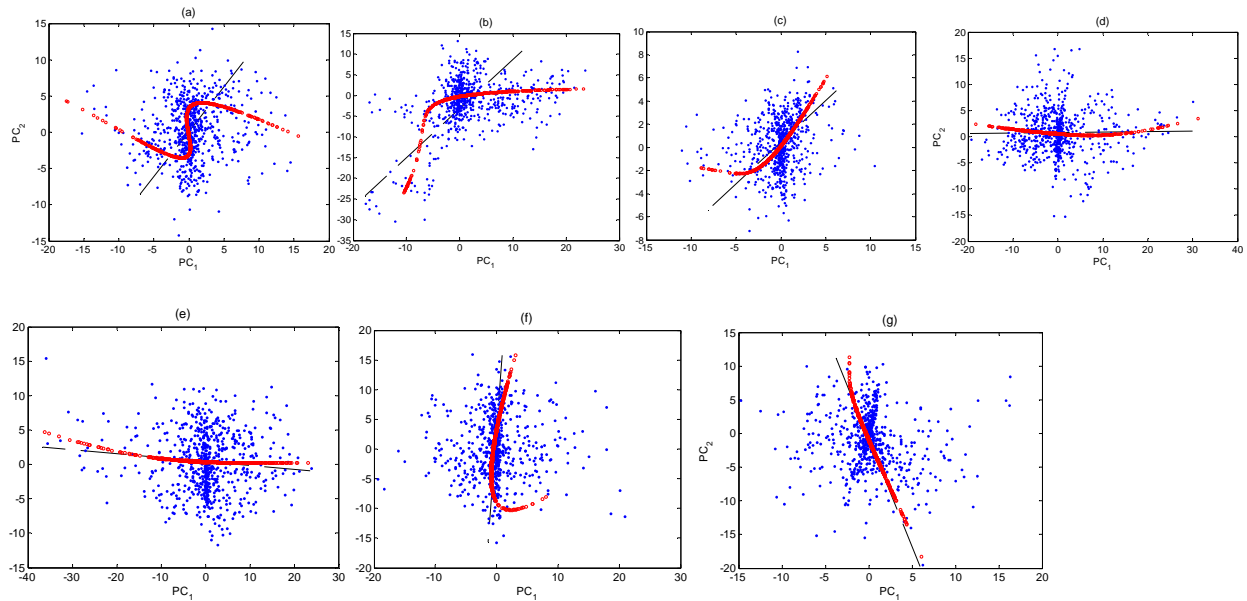


Figure 8: Scatter plot of the sea surface temperature anomaly (SSTA) data of a) ERSST, b) CSIRO-MK3.6, c) GISS-E2-H, d) MIROC5, e) MPI-ESM-LR, f) HADGEM2-AO and g) CNRM-CM5-2 (shown as dots) in the principal component (PC1, PC2) plane. Original data points are shown as blue dots; the second mode of NLPCA approximation to the data is indicated by the red circles.

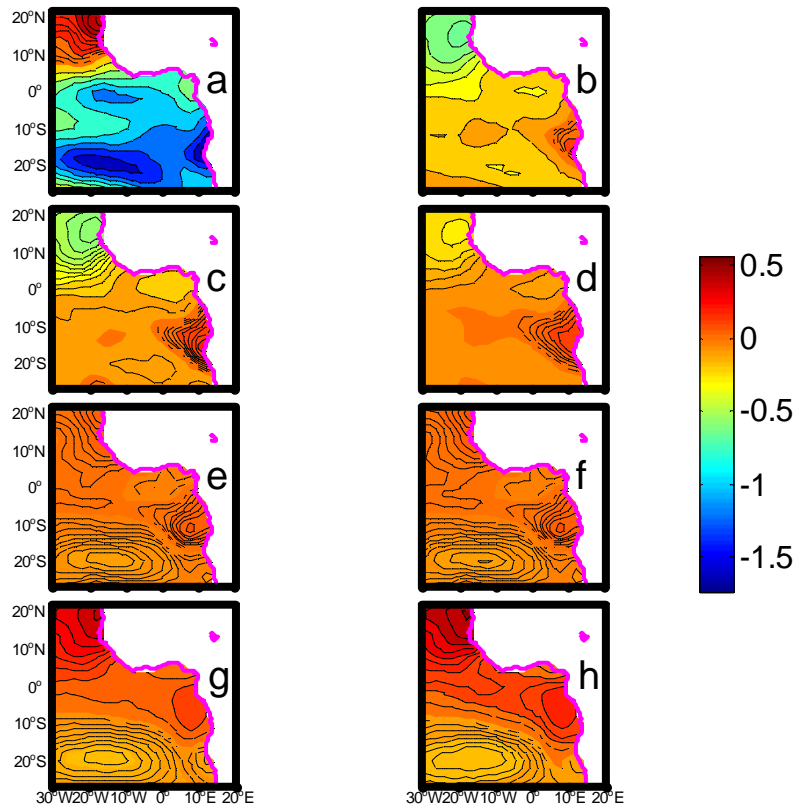


Figure 9: Spatial pattern plots for NLPCA SST mode 2 for observational ERSST data.

Each panel shows the SST anomaly composite formed from the point along the one dimensional NLPCA.

Reconstruction plots for NLPCA SST mode 2 for these models are shown in Figure 8. There is clear nonlinearity in the distribution from NLPCA SST mode 2 for all models. Contrary to NLPCA SST mode 1 the results from Table 1 for this model indicate that there is big difference between NLPCA SST mode 2 and PCA mode 2 in terms of the proportion of the data variance explained compared to the original data.

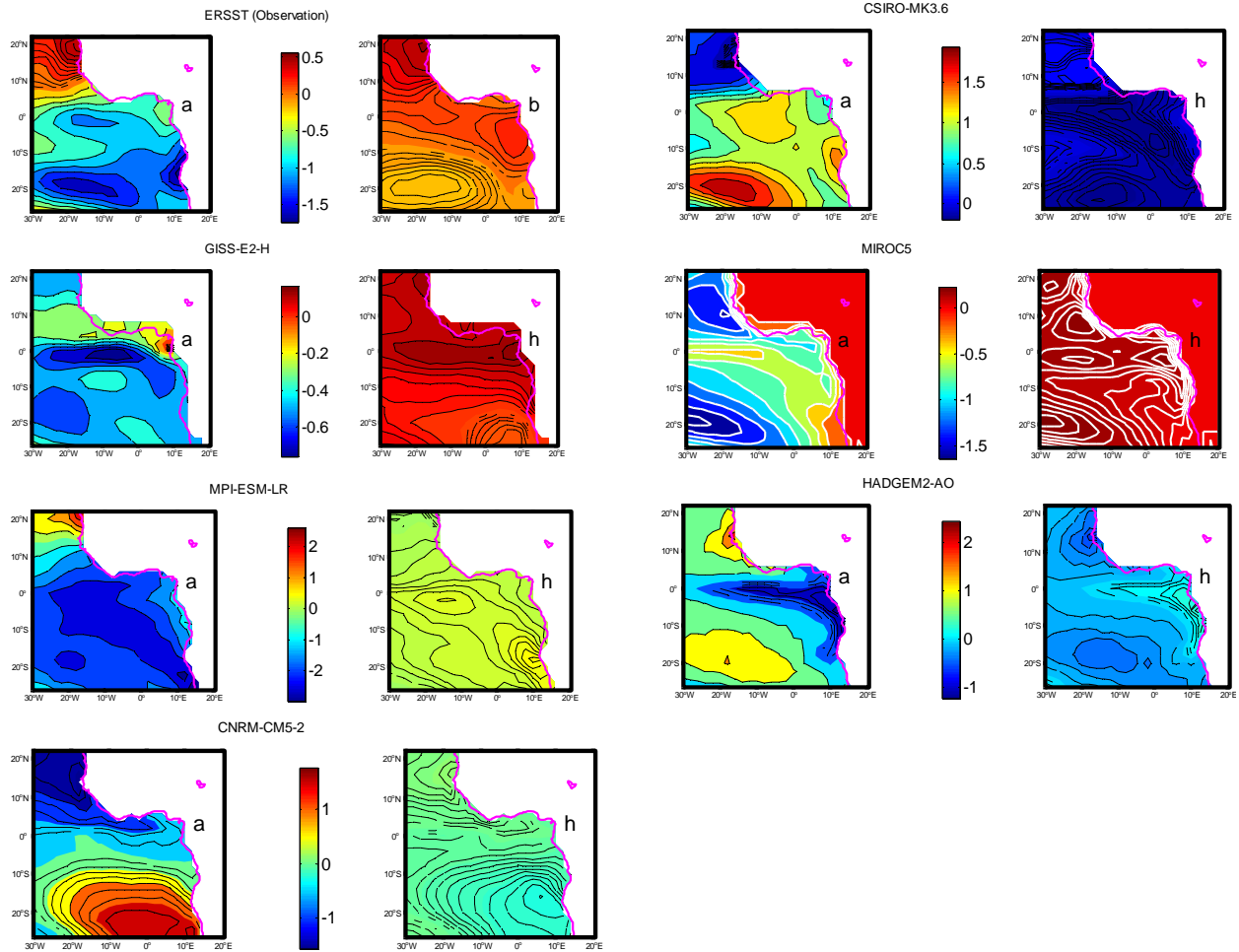


Figure 10: Spatial pattern plots for NLPCA SST mode 2 for observational ERSST data, CSIRO-MK3.6, GISS-E2-H, MIROC5, MPI-ESM-LR, HADGEM2-AO and CNRM-CM5-2. Each panel shows the SST anomaly composite formed from the point along the one dimensional NLPCA varies from (a) its minimum to (h) its maximum. Zero contours are white lines. Positive contours are black lines and negative contours are dashed black lines. The contours in pink color are the coast.

CMIP5 models have difficulties in simulating some characteristics of SSTs distribution in the Gulf of Guinea region. The spatial distribution of the Atlantic dipole signature in these models compares unreasonably with the observed features (Fig.9.a-h). These model did not show negative amplitude in the south west pole in the tropical Atlantic and positive amplitude in the North West.

Our comparison between the observed and CMIP5 simulated SST indicates that there is still work to be done for improvement of the ability of the tested models to reproduce the meridional modes for SST in the tropical Atlantic.

How does this mode relate to other dominant modes of Atlantic variability, e.g. Atlantic multi-decadal variability?

The Atlantic Multidecadal Oscillation (AMO) is a pronounced signal of climate variability in the North Atlantic sea-surface temperature field. To study AMO we need to extend the space to higher latitudes. In our new space, our statistical tool is able to capture another dominant mode, which is meridional mode.

Here, we present a literature review on the meridional mode and its relation to the equatorial mode.

The tropical Atlantic Ocean exhibits two primary modes of inter-annual climate variability: the equatorial and meridional modes. The weak ACT, which is the well-known equatorial mode is responsible for warm sea surface temperature (SST) events, mainly in the Gulf of Guinea, and is identified by abnormal changes in the equatorial thermocline slope resulting from zonal-wind anomalies in the western tropical Atlantic. The meridional mode is characterized by a north-south inter-hemispheric gradient of SST anomaly (Jacques Servain, 1999). The meridional mode does not exist in the Pacific Ocean (Jacques Servain, 1999). The strongest amplitude of equatorial mode appears during May–July while the meridional mode is most pronounced during the equatorial warm season; March–May (Clara Deser, 2010). Previous studies show that this meridional mode, especially in the Northern Hemisphere, is significantly influenced by ENSO (Czaja et al. 2002). Particularly for ENSO, many observational (Enfield and Mayer, 1997) and modeling (Alexander and Scott 2002; Huang et al. 2002) studies have shown that the ENSO influence on the tropical Atlantic is strongest in the North Tropical Atlantic, with Atlantic warming occurring 4–5 months after the mature phases of Pacific warm events (Xie and Carton, 2004).

What are implications for the West-African Monsoon?

We talked about the West-African Monsoon (WAM) just to motivate the work because ACT has a strong effect on it. The knowledge of ACT variability will be useful for the study of WAM.

The appearance of ACT in the Gulf of Guinea and/or the gradient between the North and south strengthen the land–sea temperature contrast, enhancing the monsoonal flow, which leads to a further decrease in SST. Changes in SSTs influence surface evaporation over the equatorial Atlantic, which in turn can have an impact on monsoonal rainfall variability over West Africa. This coupled feedback underscores the importance of the oceanic processes that maintain the equatorial cold tongue in regulating the African monsoon. Thorncroft et al. (2011) show that West-African Monsoon is strongly affected by the Atlantic equatorial cold tongue. Modeling results (Okumura and Xie, 2004) uses equatorial Atlantic SSTs during boreal spring and summer; eliminating the cold tongue. Comparisons of the resulting simulations show that the presence of a fully developed cold tongue accelerates the southerly winds over the Gulf of Guinea, which contributes to the northward advance of rainbands over WA. Okumura (2004) also shows that the equatorial cooling exerts a significant influence on the African monsoon, intensifying the southerly winds in the Gulf of Guinea and pushing the continental rainband inland away from the Guinean coast.

In May–June when the West African summer monsoon starts, the northerly displacement of the ITCZ enhances southeasterly winds and abruptly cools the equatorial ocean through evaporation and upwelling. The subsequent ocean–atmosphere interaction carry the eastern cooling to the west which in turn affects considerably the easterly wind near the west side of the cold tongue (Nigam and Chao 1996; Okumura and Xie 2004). In July–August, the cold tongue reaches its peak.

5- Additionally, the authors should not only derive seasonal anomalies but should also detrend their SST time series, since a global warming signal is apparent in their timeseries and not accounting for it makes PCA questionable and will likely have even stronger implications for non-linear techniques. E.g. Fig. 2 EOF 1 is all positive, I would suspect that this is a signature of a global trend. I further suspect that accounting for it will drastically alter the results.

A climatologically annual cycle was calculated by averaging the data for each calendar month, and monthly SST anomalies (SSTAs) were defined relative to this annual cycle.

The SSTA have long-term trends as you said. In order to minimize the effect of these trends on the analysis, we have removed the linear trends from all datasets at each spatial location using the least squares technique. Thus, detrending the monthly anomaly, our primary dataset was formed. The results, (Fig.1), show that the symmetry is more pronounced compared to that in the manuscript; where we did not detrend the anomaly.

Major comments:

1 On P. 249 I 18 the authors write: “The strong ACT is more active than the weak one. Unlike in the Pacific Ocean, the spatial variability of this equatorial mode in the Atlantic Ocean which is similar to El Niño/Southern Oscillation (ENSO) in the Pacific is less linear than the latter.”

How is this statement justified? From my understanding, deviations from the PCA Eigen vector indicate non-linearity. Comparing Fig. 4 and e.g. Fig. 3 of Hsieh (2004) that is derived for ENSO using an identical method, the U-Shaped NLPCA in the Hsieh paper indicates a more pronounced non-linearity for the ENSO. Please clarify. I even have the feeling that the ACT phenomenon is in fact much more linear than ENSO.

In this study the connection between these two events is not our objective. Some studies (Hsieh, 2004 and Monahan, 2001) show that the El Niño events are non-linear. So, we just wanted to see if the inter-annual spatial variability in the Gulf of Guinea is more unstable or not than that of the tropical Pacific Ocean.

In terms of standing variability, the amplitude of strong ACT is greater than that of the weak.

We showed that the ACT is modestly asymmetric and from Hsieh (2004) EL NIÑO is asymmetric, and. That is the reason for our conclusion that *“the strong ACT is more active than the weak one. Unlike in the Pacific Ocean, the spatial variability of this equatorial mode in the Atlantic Ocean, which is similar to El Niño/Southern Oscillation (ENSO) in the Pacific is less linear than the latter”*.

We have replaced the last and underlined sentence above with this (underlined) below to make the situation clearer.

Unlike in the Pacific Ocean, the spatial variability of this equatorial mode in the Atlantic Ocean is more linear than the El Niño/Southern Oscillation (ENSO).

2 Fig. 5: How is the “normalized ACT index” defined? Can’t find it in the manuscript. And please add the time series of EOFa1 for comparison.

The “normalized ACT index” is defined by firstly computing the inter-annual mean of SSTA in the ACT zone (Caniaux et al., 2011) during the ACT period (June-August) and secondly normalized the obtained time series. It was defined in the manuscript on page 247 (line 26-28).

Fig.11 presents the times series of the normalized ACT index, NLPCA mode 1 and EOF1 as you requested.

It was incompletely defined on page 247 (line 26-28): we are going to add it there.

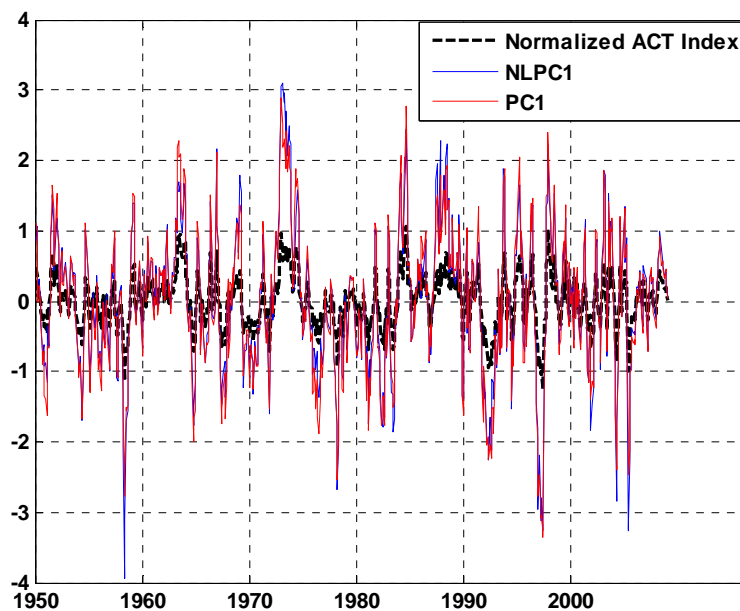


Figure 11 : Plot of NLPCA1, the time series associated with SSTA NLPCA mode 1 (blue line) , thenormalized ACT index (black dashed line) and PC1 (red line).

The correlation coefficient between the normalized ACT index, nonlinear principal component and linear principal component are respectively 0.85 and 0.8. We observe that the NLPCA mode 1 betterrepresents the inter-annual variability of ACT than EOF1.

3: Fig. 2: Drop this figure. PCA should only be performed on detrended anomalies.

Ok I will drop it.

#4: On P. 249 I 25 the authors write: “We observe that the weak and strong ACTs are symmetric but nevertheless the intensities are different.

We realized that the above statement is obvious and tautology. Hence, we are going to remove it.

The more active the AngolaSST is, the larger is the ACT’s active surface. The reverse is also true!” I don’t understand the meaning of this paragraph. Please clarify.

We believe the confusion emanates from the last statement ‘the reverse is true’.

If that be the case, may we point out that it is with respect to the later statement and not from where you start: “we observe.....are different?

Hence, we clarify:

Fig1 shows that, the variance in the ACT zone in Fig1a is greater than in the ACT zone in Fig1h and the two events are slightly asymmetric. And we may see that in the Angola coast, the greater the variance, the larger the amplitude of the variance extends into the ACT zone.

Summarizing: large amplitude on the Angola coast corresponds with large active surface of ACT. On the other hand, small amplitude on the Angola coast, small active surface!

And how does it relate to the statement in the abstract that weak and strong ACT events are not symmetric.

Those sentences, though close, are completely independent and hence there is no relation. One describes modest (negligible) asymmetry and the other describes the relation between the Angola coast and the ACT surface.

(Fig. 6 is just to show the results for EOF for 56 years without adding the northward spatial enlargement. Hence, we shall instead consider Fig.3.)

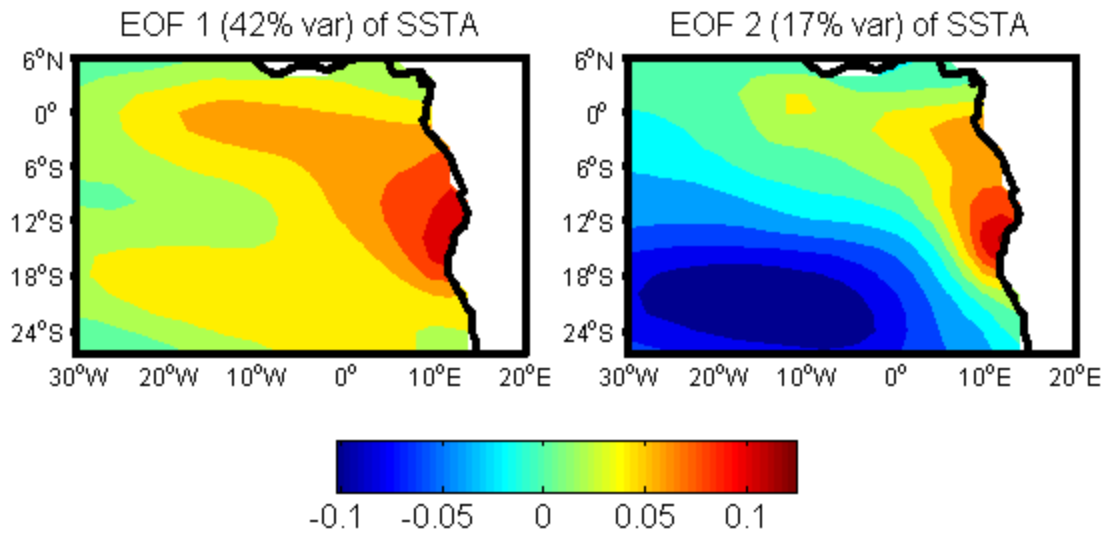


Figure 12: Empirical orthogonal function (EOF) of detrended monthly sea surface temperature (SST) Anomalies. EOF1 mode (left) and EOF2 mode (right) with their explained variance shown in parenthesis.