

MS-No.: egusphere-2024-2431

Title: Observation based temperature and freshwater noise over the Atlantic Ocean

Authors: Amber A. Boot and Henk A. Dijkstra

Point-by-point reply to reviewer #1

September 24, 2024

We thank the reviewer for their careful reading and for the useful comments on the manuscript.

Overview

The manuscript investigates the statistical characteristics of the noise in two variables affecting the Atlantic Meridional Overturning Circulation (AMOC): freshwater flux ($E - P$) and 2m air temperature (T_{2m}), obtained from the ERA5 reanalysis data from 1940–2022. The authors test the common assumption that the noise follows a Gaussian distribution, using three different models based on principal component analysis (PCA) and the negative inverse Gaussian (NIG) distribution and look at moments up to kurtosis. They find that the NIG model outperforms the others, except for excess kurtosis in sea ice covered regions in the T_{2m} data. Analysis shows significant skewness and kurtosis in the data, and the authors conclude that the noise cannot be classified as white noise. In addition to the ERA5 reanalysis data, the authors also analyze 36 CMIP6 models and their multi-model mean (MMM), demonstrating that these models struggle to capture skewness and kurtosis and are outperformed by the NIG distribution for most metrics.

By analyzing the statistical properties of the noise, this paper addresses an important related to AMOC variability. Overall, the methodology appears sound, and the paper makes a meaningful contribution to the field. However, I have some comments that should be appropriately addressed by the authors before the manuscript is ready for publication:

Major comments:

1. *The paper would benefit from having a more detailed discussion on*

the statistical methodology, in particular relating to the Kolmogorov-Smirnov (K-S) test. From the code it seems that the conventional $\alpha=05$ significance level is used, but this should also be stated in the text for clarity and reproducibility. Moreover, considering the limitations of the Kolmogorov-Smirnov test with heavy-tailed distributions such as the NIG, the paper would benefit from considering alternative tests such as the Anderson-Darling test. Further discussion on the grid points that failed the K-S test would also be interesting.

Author's reply:

We agree with the reviewer, and we thank the reviewer for pointing out the Anderson-Darling test.

Changes in manuscript:

We will perform the Anderson-Darling test as well and include a more thorough discussion on the results of these tests. This will include a discussion on the grid points that fail the tests.

- 2. The paper employs a Normal Inverse Gaussian distribution (NIG) which presents a more flexible generalization of the normal distribution to allow for skewness and kurtosis to be expressed. Given that this model struggled to capture the excess kurtosis in certain areas it would be interesting to see the model compared with other models capable of expressing these additional moments, e.g. the generalized hyperbolic distribution or others.*

Author's reply:

We have tested several (more than 10) different distributions, among which the generalized hyperbolic distribution. None of these distributions performed better than the NIG distribution, which is the reason we chose the NIG distribution.

Changes in manuscript:

We will clarify why we chose the NIG model. Furthermore, we will, if applicable, include a discussion on whether other distributions are able to capture the kurtosis in regions where the NIG distribution performs relatively poorly.

3. *As the authors acknowledge, spatial coherence is lost when the models are fitted to each point individually. It would be beneficial for the authors to investigate or provide some discussion on how much this loss may affect the results.*

Author's reply:

We agree with the reviewer that such a discussion would improve the manuscript.

Changes in manuscript:

We will add a few sentences or a paragraph to the discussion on this issue.

Minor comments:

1. *I would suggest a more detailed explanation of the Taylor diagrams be included to make it more clear to readers unfamiliar with the concept. Some references would also be useful.*

Author's reply:

We agree.

Changes in manuscript:

We will provide a short introduction to the Taylor diagrams explaining the concept.

2. *I would like some more details on how the NIG model is fitted to each time series. Do the estimated parameters significantly deviate from those corresponding to an ordinary Gaussian distribution? A more detailed statistical analysis of the significance of these deviations could strengthen the argument that the noise is non-Gaussian.*

Author's reply:

We thank the reviewer for this suggestion. Such an analysis will indeed provide a stronger argument.

Changes in manuscript:

We will include more analysis, also based on comments from reviewer 2

and based on this comment, to strengthen the argument that the noise is non-Gaussian.

3. *I would like to see some more discussion on why the different PCA-based models were chosen.*

Author’s reply:

We use three different PCA-based models. The PC(1) model is used to test whether the PCAs can in fact capture the statistics of the noise well. However, since this method is not fully stochastic (as explained in the paper) we also chose to use other models. The PC(N) model is in set-up very similar but more stochastic than the PC(1) method. As the PC(N) model also has a discrete number of values to sample from, we also used the PC(NIG) model, which does not have this problem.

Changes in manuscript:

We will provide a motivation why we use the different PCA-based models.

Grammatical corrections:

We thank the reviewer for pointing out these errors and we will follow all suggestions.

1. *Line 3 and 13: “noise-induce transitions” should be changed to “noise-induced transitions”.*
2. *Line 6: I suggest changing “... shows best performance” to “... gives the best performance” or similar.*
3. *Line 20 and 296: “noise induced transitions” should be changed to “noise-induced transitions”.*
4. *Line 22: I would suggest rewriting “Recently, also noise induced transitions have been studied in...” to “Recently, noise-induced transitions have also been studied in...”.*
5. *Line 60: “the negative of the summing of the variables” should be rewritten as “the negative sum of the variables”.*

6. *Line 106: Change “deviates from 0” to “deviates from zero”.*
7. *Line 109: “Multi model mean” should be changed to “Multi-model mean”.*
8. *Line 127: “Special pattern” should be corrected to “spatial pattern”.*
9. *Line 312: Fix the subscript formatting error.*