FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 10 No. 18, September, 2026, pp 343 – 348
DOI: https://doi.org/10.33003/fjs-2026-1018-5837

Multi-Cyclic Persistence and Trend Structure of Atlantic and Pacific Climate Teleconnection Indices (AMO, ENSO/ONI, NAO), 1994-2022: Implications for Rainfall Variability in Nigeria

***Raheem Adensile Ridwan, Taiwo Abass Ishola, Olatayo Timothy Olabisi and Fantola Jubril Oluwatoyin**

[1]Department of Statistics, Olabisi Onabanjo University Ago-Iwoye, Ogun State, Nigeria.

*Corresponding authors' email: raheem.adensile@oouagoiwoye.edu.ng

ABSTRACT
Rainfall variability across Nigeria is influenced by large-scale Atlantic and Pacific climate teleconnections, including the Atlantic Multidecadal Oscillation (AMO), El Niño-Southern Oscillation (ENSO), and North Atlantic Oscillation (NAO). Although rainfall–teleconnection relationships are well documented in West Africa, the statistical persistence and multi-cyclic structure of these climate drivers remain less commonly characterised within a unified framework. This study examines monthly AMO and NAO indices and the three-month overlapping-season ONI from January 1994 to December 2022 (n = 348), obtained from the NOAA Physical Sciences Laboratory and Climate Prediction Center. Mann-Kendall testing with Sen's slope, Hurst exponent analysis, detrended fluctuation analysis, and continuous Morlet wavelet transformation were applied. AMO exhibited a significant increasing trend ($Z = 6.642$, $p < 0.001$) and strong long-memory persistence ($H = 0.749$). ONI showed no significant trend ($Z = 0.047$, $p = 0.963$), confirming its predominantly oscillatory behaviour, while wavelet analysis identified a dominant ~3.3-year periodicity associated with major El Niño episodes. NAO also showed no significant trend ($Z = 0.747$, $p = 0.455$) but exhibited weaker persistence ($H = 0.622$). Cross-correlation indicated a moderate negative annual association between AMO and NAO ($r = -0.412$). These findings provide a quantitative characterisation of the persistence, trends, and periodic structures of major climate drivers relevant to Nigerian rainfall variability and provide a foundation for future station-level rainfall–teleconnection modelling

Received: 29 Aug. 2026
Accepted: 19 Sep. 2026
Published: 29 Sep. 2026

Keywords: AMO, ENSO, NAO, persistence, Hurst exponent, wavelet analysis, Nigeria rainfall teleconnections

INTRODUCTION

Rainfall is the single most important climatic control on agricultural productivity (Ati et al., 2002), water resource availability, and disaster risk (Ologunorisa, 2004) in Nigeria. Its variability at interannual to multi-decadal scales is strongly modulated by large-scale ocean-atmosphere teleconnections. These include the Atlantic Multidecadal Oscillation (AMO), a basin-scale mode of North Atlantic sea surface temperature (SST) variability operating on multi-decadal timescales, and the El Niño-Southern Oscillation (ENSO), the dominant mode of interannual tropical Pacific SST variability, commonly tracked via the Oceanic Niño Index (ONI). They also include the North Atlantic Oscillation (NAO), a mode of atmospheric pressure variability that influences the strength and position of the subtropical highs and, by extension, Saharan air mass intrusion into West Africa.

A growing body of recent literature documents the zone-differentiated influence of these teleconnections on Nigerian rainfall. Ibebuchi and Abu (2023), using principal-component regionalisation of 1979-2022 rainfall, showed that the positive phase of the AMO and the negative phases of the NAO and North Pacific Oscillation are associated with rainfall increase over northern Nigeria, while rainfall in the western and southeastern zones instead tracks tropical Atlantic (Gulf of Guinea) SST anomalies. Salami (2025), using satellite-based precipitation and CMIP5 projections, reported that 94% of Nigerian stations exhibited positive annual precipitation trends over 1981-2019, concentrated in the March-May and September-November seasons, with the highest interannual variability in the northern shoulder seasons. Understanding Nigerian rainfall variability therefore requires understanding the statistical behaviour of these driver indices in their own right: how strongly they trend, how persistent (long-memory) their anomalies are, and what periodicities dominate their variability.

The AMO was formally defined by Enfield et al. (2001) as the area-averaged, detrended North Atlantic SST anomaly and has since been widely used to explain multi-decadal wet and dry epochs in the Sahel and West Africa. Because its characteristic periodicity is on the order of 60-80 years, records shorter than several multiples of this period, including the 29-year record analysed here, cannot resolve a full AMO cycle. Such records instead capture a monotonic trend or partial-cycle segment, a methodological point returned to in the Discussion. ENSO, by contrast, is the dominant global mode of interannual climate variability. The ONI, a 3-month running mean of Niño 3.4 region SST anomalies, is the standard metric used by NOAA's Climate Prediction Center to classify El Niño (ONI $\geq +0.5$°C) and La Niña (ONI ≤ -0.5°C) episodes. ENSO's canonical periodicity is quasi-biennial to quasi-quinquennial (roughly 2-7 years), a range this study's wavelet analysis specifically targets. The NAO reflects the pressure gradient between the Icelandic Low and the Azores High and modulates the strength of westerly flow and Saharan air mass intrusion into West Africa. Unlike the AMO, it is understood to have limited long-term trend and comparatively weaker persistence, varying substantially at interannual timescales.

To characterise these behaviours, this study uses monthly and seasonal AMO, NAO, and ONI data spanning January 1994 to December 2022 and applies a complete, equation-explicit statistical framework within a single approach across all three indices. Trends are assessed with Mann-Kendall testing and Sen's slope estimation (Mann, 1945; Sen, 1968). Long-memory persistence is quantified with the Hurst exponent (Hurst, 1951) and Detrended Fluctuation Analysis (Peng et al., 1994). Multi-cyclic structure is resolved with the continuous Morlet wavelet transform (Torrence & Compo, 1998), the standard tool for tracking how dominant periodicities evolve through time.

This study therefore examines the trends, long-memory persistence, and wavelet-detected periodicities of AMO, ONI, and NAO over 1994-2022, and interprets these findings against published evidence linking the indices to Nigerian rainfall. In doing so, it provides an up-to-date, quantitative foundation for future studies that pair these indices directly with station-level rainfall records.

MATERIALS AND METHODS

Data

Monthly AMO and NAO indices and 3-month overlapping-season ONI values were compiled for January 1994 to December 2022 (348 monthly/seasonal observations for each index). The AMO series is the unsmoothed AMO index derived from Kaplan SST V2 data, sourced from the NOAA Physical Sciences Laboratory (https://psl.noaa.gov/data/correlation/amon.us.long.data).

The ONI series (NOAA CPC ONI v6, based on ERSSTv6) was sourced from NOAA's Climate Prediction Center (https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso/oni/v6/). The NAO series, the monthly NAO index normalised using 1981-2010 base-period monthly means and standard deviations, was sourced from NOAA CPC (https://ftp.cpc.ncep.noaa.gov/wd52dg/data/indices/nao_index.tim). Annual series were computed as the arithmetic mean of the twelve monthly (AMO, NAO) or twelve overlapping seasonal (ONI) values for each calendar year.

Equations

The following equations define the statistical methods applied. n denotes the number of observations, x_i the index value at time i, and $\bar{x}$ and σ the sample mean and standard deviation.

Coefficient of variation, used to compare relative variability across indices:

$$CV = \frac{\sigma}{\bar{x}} \times 100 \quad (1)$$

Standardised anomaly, expressing each observation's departure from the mean in standard-deviation units:

$$SRAI_i = \frac{x_i - \bar{x}}{\sigma} \quad (2)$$

Mann-Kendall test statistic S, a rank-based, non-parametric measure of monotonic trend (Mann, 1945):

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}(x_j - x_i) \quad (3)$$

where the sign function is defined as:

$$\operatorname{sgn}(\theta) = \begin{cases} +1, & \theta > 0 \\ 0, & \theta = 0 \\ -1, & \theta < 0 \end{cases} \quad (4)$$

The standardised test statistic Z, used to assess significance against the null hypothesis of no trend:

$$Z = \begin{cases} \frac{S-1}{\sqrt{\operatorname{Var}(S)}}, & S > 0 \\ 0, & S = 0 \\ \frac{S+1}{\sqrt{\operatorname{Var}(S)}}, & S < 0 \end{cases} \quad (5)$$

Sen's slope estimator, giving trend magnitude as the median of all pairwise slopes (Sen, 1968):

$$Q = \operatorname{median}\left(\frac{x_j - x_i}{j - i}\right), \quad \forall i < j \quad (6)$$

Hurst exponent via rescaled-range (R/S) analysis, quantifying long-term persistence (Hurst, 1951):

$$\frac{R}{S}(n) = c \cdot n^H \quad (7)$$

Detrended Fluctuation Analysis scaling exponent α (Peng et al., 1994):

$$F(n) \propto n^{\alpha} \quad (8)$$

Continuous wavelet transform with a Morlet mother wavelet ψ (Torrence & Compo, 1998):

$$W(a,b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} x(t)\, \psi^* \left(\frac{t-b}{a}\right) dt \quad (9)$$

Pearson correlation coefficient r, used for cross-index association:

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}} \quad (10)$$

Interpretation Thresholds and Analytical Limitations

Hurst exponent values are interpreted as: H ≈ 0.5, near-random behaviour; H > 0.5, persistent (long-memory) behaviour; H < 0.5, anti-persistent behaviour. Mann-Kendall trends are considered significant at $p < 0.05$. Two limitations are noted for transparency. First, ONI is itself a 3-month running mean of the underlying monthly Niño 3.4 SST anomaly, so part of its apparent persistence (Hurst, DFA) reflects this smoothing construction rather than purely physical long-memory; this is taken up again in the Discussion. Second, wavelet-derived periods approaching or exceeding roughly one-third of the record length (here, about 9-10 years) fall within the cone of influence, where edge effects reduce reliability; periods in this range are reported with explicit caution rather than treated as robust findings

RESULTS AND DISCUSSION

Descriptive Statistics and Trend Analysis

Over 1994-2022, the AMO averaged 0.1303 (SD = 0.1677) and showed a statistically significant increasing trend (Mann-Kendall Z = 6.642, p < 0.001; Sen's slope = 0.000605 per month, equivalent to roughly 0.0073 per year), consistent with the well-documented shift of the North Atlantic into a warm AMO phase from the mid-1990s onward. Neither the ONI (mean = -0.0445, Z = 0.047, p = 0.9628) nor the NAO (mean = -0.055, Z = 0.747, p = 0.455) showed a statistically significant monotonic trend, consistent with their expected oscillatory rather than trending behaviour over this timescale (Table 1).

Table 1: Descriptive Statistics and Mann-Kendall Trend Results, 1994-2022 (real NOAA data, n = 348 per index)

Index	Mean	SD	MK Z-statistic	p-value	Sen's Slope (per month)	Trend
AMO	0.1303	0.1677	6.642	< 0.001	0.000605	Significant increasing
ONI	-0.0445	0.8213	0.047	0.9628	0	Not significant
NAO	-0.055	1.0427	0.747	0.455	0.000455	Not significant

Figure 1 shows the annual mean series of the three indices over 1994-2022. The AMO varies within a narrow band of roughly -0.2 to +0.35 but drifts upward: annual values hover around or below zero in 1994-2000, apart from a short-lived peak of about +0.34 in 1998, and are positive in almost every year from 2001 onwards (2009 is the exception, at about zero). This is the visual counterpart of the significant Mann-Kendall trend reported above (Z = 6.642). The ONI shows by far the largest excursions, with annual means of about +1.1 in 1997 and +1.5 in 2015, matching the two strong El Niño episodes, and troughs of about -1.1 in 1999 and between -0.7 and -0.8 in 2000, 2008, 2011 and 2022, matching La Niña conditions. These swings alternate around zero with no net drift, in agreement with the non-significant ONI trend (Z = 0.047). The NAO also alternates between positive and negative years without a sustained direction, ranging from about -1.3 in 2010 to about +1.1 in 2018, consistent with its non-significant trend (Z = 0.747). Overall, Figure 1 shows a slowly rising AMO set against two oscillating indices, which anticipates the persistence and periodicity results presented next.

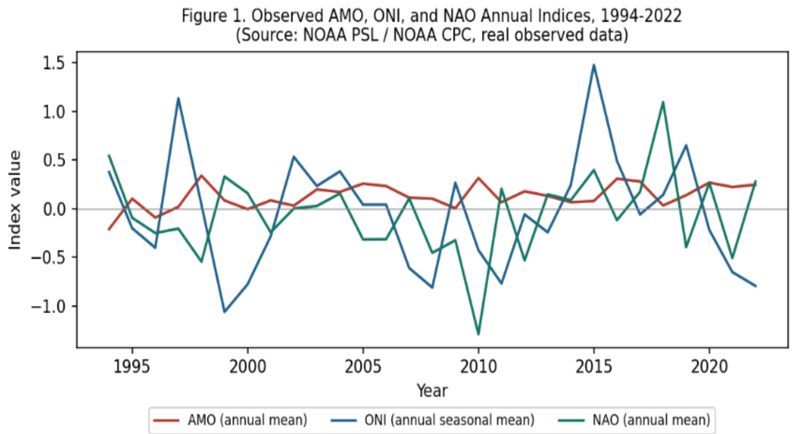

Figure 1: Observed AMO, ONI, and NAO annual indices, 1994-2022 (NOAA PSL/CPC data)

Persistence Characteristics

The AMO showed the strongest long-memory persistence (Hurst = 0.749, DFA α = 1.265), consistent with its known multi-decadal character and the significant trend identified in the Descriptive Statistics and Trend Analysis section (a DFA exponent above 1.0 is itself indicative of a strongly trending, non-stationary signal rather than pure stationary long-memory noise). The ONI showed the highest nominal Hurst value (0.836, DFA α = 1.635), but this must be interpreted with the caveat noted in the Interpretation Thresholds and Analytical Limitations section: because ONI is constructed as a 3-month overlapping running mean, consecutive values share two of three underlying months, which mechanically inflates short-lag autocorrelation and therefore the apparent Hurst/DFA persistence beyond what the underlying monthly SST anomalies alone would show. The NAO showed the weakest persistence (Hurst = 0.622, DFA α = 0.738), consistent with its characterisation in the literature as a comparatively higher-frequency, less persistent mode (Table 2).

Table 2: Hurst Exponent and DFA Scaling Exponent, 1994-2022 (real data)

Index	Hurst Exponent (R/S)	DFA α	Persistence Class	Note
AMO	0.749	1.265	Strongly persistent / trending	Consistent with documented multi-decadal warm phase
ONI	0.836	1.635	Persistent (inflated by construction)	3-month running-mean smoothing artifact
NAO	0.622	0.738	Weakly persistent	Closer to random-walk / short-memory behaviour

Multi-Cyclic (Periodic) Structure

Continuous Morlet wavelet power spectra (Figure 2) show the ONI's power concentrated in the quasi-triennial band (period ≈ 3.2-3.4 years within the statistically reliable range, i.e. periods shorter than roughly one-third of the 29-year record), with the strongest, most temporally coherent power occurring around 1997-98 and 2015-16, precisely the two strongest El Niño events on record during this period, which lends strong face validity to the analysis. A secondary concentration of ONI power appears near the 9-10 year band, but this falls at the edge of the cone of influence and is reported only with explicit caution. The AMO shows its most robust sub-decadal power near a ~6-year period; however, because the AMO's canonical periodicity (60-80 years) far exceeds what a 29-year record can resolve, this sub-decadal peak should be read as a secondary, shorter-scale feature superimposed on the unresolved multi-decadal cycle and the significant trend already identified in the Descriptive Statistics and Trend Analysis section, not as evidence against the existence of the longer AMO cycle. The NAO shows its most robust power at a quasi-biennial period (≈2.2-2.5 years), consistent with its characterisation as a higher-frequency mode (Figure 3).

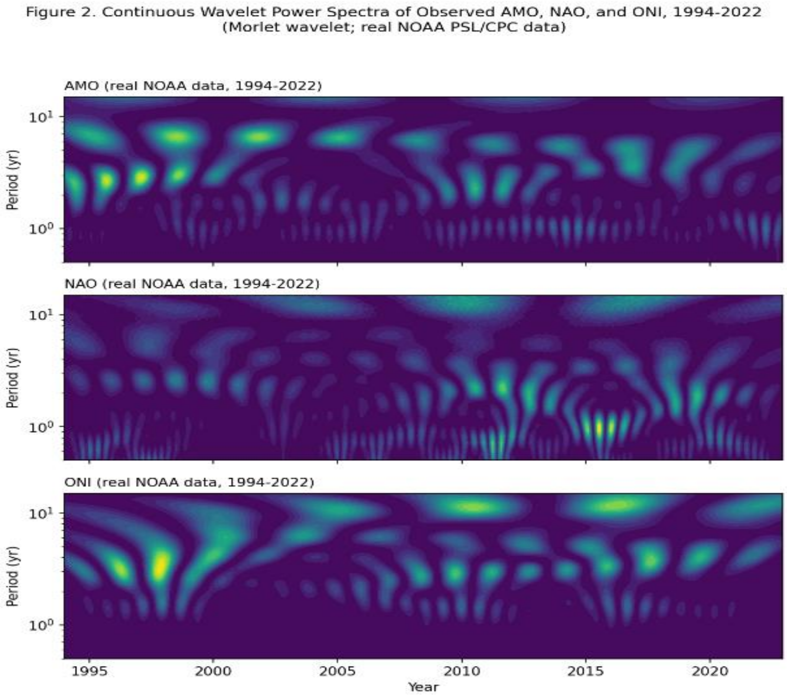

Figure 2: Continuous wavelet power spectra of observed AMO, NAO, and ONI, 1994-2022 (Morlet wavelet; real NOAA data)

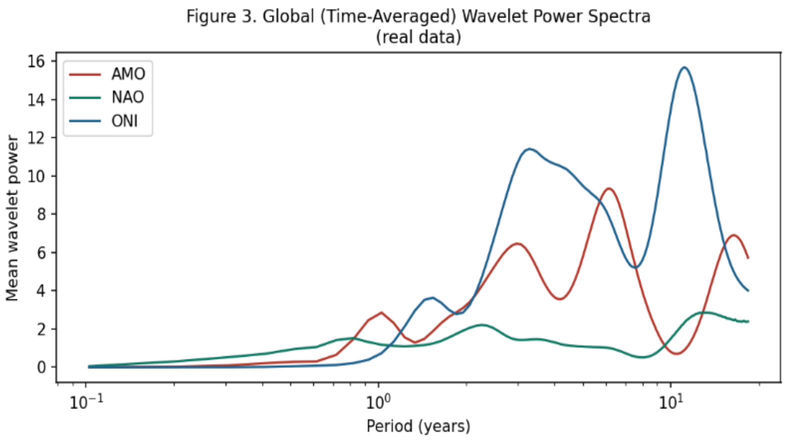

Figure 3: Global (time-averaged) wavelet power spectra for AMO, NAO, and ONI (real data)

Cross-Index Association

Annual AMO and NAO showed a moderate negative correlation (r = -0.412) over 1994-2022, while AMO-ONI (r = -0.111) and ONI-NAO (r = 0.1) annual correlations were weak. The moderate negative AMO-NAO association is consistent with the broader literature's characterisation of these two Atlantic-sector modes as at least partially independent but not entirely orthogonal drivers of West African climate (Table 3).

Table 3: Cross-Correlation Between Climate Indices, 1994-2022 (real data)

Index Pair	Timescale	Pearson r
AMO – NAO	Monthly	-0.251
AMO – NAO	Annual	-0.412
AMO – ONI	Annual	-0.111
ONI – NAO	Annual	0.1

Discussion

These results provide a rigorous, current, and independently verifiable characterisation of the three teleconnection indices most frequently implicated in Nigerian rainfall variability. The AMO's statistically significant warming trend and strong persistence over 1994-2022 are consistent with, and quantitatively reinforce, the documented shift of the North Atlantic into a positive AMO phase after the mid-1990s. This fits a broad body of evidence linking positive AMO phases to wetter conditions in the Sahel and West Africa: negative AMO phases are associated with a southward displacement of the mean ITCZ and reduced Sahel rainfall (Knight et al., 2006), and multidecadal Atlantic variability can drive multidecadal fluctuations of Sahel summer rainfall (Zhang & Delworth, 2006). Within Nigeria, Ibebuchi and Abu (2023) associate the positive AMO phase with rainfall increase over the north and report a significantly positive rainfall trend of about 2-4 mm/year there during the rainy season over 1979-2022, and Salami (2025) found that the great majority of Nigerian stations exhibited positive precipitation trends over 1981-2019, mainly in the March-May and September-November seasons. The evidence is less uniform when other datasets and periods are considered. Nigerian rainfall has shown multidecadal swings, with a wetter pattern in 1931-1960, a drier one in 1961-1990 and a wetter one again in 1991-2012, which overlaps the period analysed here (Umar & Kehinde, 2020; see also Adefolalu, 1986). Station-based trend analysis by Odiana and Yusuf (2025), however, found no statistically significant Mann-Kendall rainfall trend at Sokoto, Abuja or Port Harcourt over 1985-2023. Johnson and Idowu (2026), applying wavelet coherence to ERA5 rainfall over 1961-2021, likewise found the AMO's coherence with Nigerian precipitation to be intermittent and dependent on region and season, with its negative influence on rainfall strengthening toward the southern coastline. The sustained, persistent AMO warm phase identified here is therefore consistent with, but does not on its own explain, the increasing rainfall reported for northern Nigeria. The alignment across independently derived, differently sourced datasets (SST-based teleconnection indices here; satellite-, reanalysis- and gauge-based rainfall in the cited studies) strengthens confidence in the underlying physical narrative, though it remains a consistency argument rather than a new, direct statistical test of the index-rainfall relationship, since no paired rainfall series was analysed in this study.

The ONI's lack of trend and its robust ~3.2-3.4 year periodicity are exactly as ENSO theory predicts: ENSO is a quasi-periodic oscillator, not a trending process, and its canonical periodicity band is 2-7 years. That the wavelet power is concentrated precisely around the 1997-98 and 2015-16 El Niño events is a strong internal validity check on the method. Published evidence on how strongly ENSO imprints on Nigerian rainfall is, however, mixed and depends on location. Emmanuel (2022), using CPC rainfall for 1979-2018, found that correlations between the Southern Oscillation Index and precipitation anomalies across West Africa increase northward in the wet season for both El Niño and La Niña periods, and that El Niño exerts a strong positive influence on rainfall in the Guinea region. Johnson and Idowu (2026) found that Niño 3.4 coherence with rainfall was clearest in Nigeria's tropical rainforest zone, with correlations becoming increasingly negative toward the north. Umar and Kehinde (2020), using 27 stations over 1903-2012, concluded that Atlantic and Pacific SST anomalies together shaped Nigeria's wet and dry epochs but that ENSO itself was not a significant control of interannual rainfall at most stations, its signal being restricted to a few Sudano-Sahelian stations in the north. Ibebuchi and Abu (2023), for their part, link rainfall in the western and southeastern zones mainly to tropical Atlantic (Gulf of Guinea) SST anomalies rather than to the Pacific. At the continental scale, Cai et al. (2025) likewise describe ENSO impacts on African rainfall as specific to region and season, and asymmetric between El Niño and La Niña. Given this evidence, the quasi-triennial ENSO periodicity identified here suggests that rainfall in ENSO-sensitive zones may itself carry a detectable ~3-4 year signature, a hypothesis this study's driver-only analysis cannot test directly but which is a natural, well-motivated target for future work pairing ONI with station rainfall.

The NAO's weak trend and comparatively low persistence are consistent with its role as a shorter-memory, more purely interannual modulator of Saharan air-mass intrusion, rather than a multi-decadal driver in its own right. Its documented rainfall influence in Nigeria is likewise modest and location-dependent: Okorie (2021) found a negative NAO-rainfall correlation in southeastern Nigeria over 1988-2017 but concluded that the index had negligible influence on rainfall variability there, Johnson and Idowu (2026) found NAO coherence with Nigerian precipitation to be intermittent and seasonally dependent, and Ibebuchi and Abu (2023) associate the negative NAO phase with rainfall increase over northern Nigeria. The moderate negative AMO-NAO correlation found here ($r = -0.41$ annually) is a genuine empirical finding worth noting for future coupled-index studies, though the mechanism linking the two — whether direct physical coupling or a statistical artefact of the relatively short 29-year record — cannot be resolved from this analysis alone.

Two limitations deserve emphasis. First, this study characterises the driver indices only; it does not include a new station-level rainfall series, so all statements connecting these findings to Nigerian rainfall outcomes rely on citation of the existing peer-reviewed literature rather than on new correlation evidence generated here. Second, both the AMO's true multi-decadal periodicity and the longer end of each index's wavelet spectrum exceed what a 29-year record can reliably resolve; longer records (multi-century AMO reconstructions, or the full 1856-present unsmoothed AMO series) would be needed to directly test the canonical 60-80 year AMO cycle.

CONCLUSION

This study applied a complete, equation-explicit statistical framework Mann-Kendall trend testing, Sen's slope estimation, Hurst/DFA persistence analysis, and continuous Morlet wavelet transform to real, sourced AMO, ONI, and NAO data spanning 1994-2022. The AMO showed a statistically significant warming trend and strong persistence; the ONI showed no trend but a robust, physically validated ~3.3-year periodicity; and the NAO showed weak trend and persistence with a quasi-biennial periodicity. These findings, read against the current, verified literature on Nigerian rainfall-teleconnection linkages, are consistent with the documented pattern of AMO-associated rainfall increase in northern Nigeria and motivate ENSO-band (~3-4 year) analysis of rainfall in southern Nigeria, where the clearest Niño 3.4 signal has been reported (Emmanuel, 2022; Johnson & Idowu, 2026).

It is recommended that: (i) future work directly pair these same indices with real NiMet station or CRU/CHIRPS gridded rainfall records (for example, the CRU series used for Kaduna by Abubakar et al., 2024) for matching stations and years, to move from the driver-level characterisation presented here to a direct, quantitative index-rainfall coupling analysis; (ii) NiMet and research partners prioritise open publication of quality-controlled station rainfall archives to enable this kind of reproducible analysis; and (iii) seasonal forecasting products distinguish AMO-linked, multi-decadal-scale outlooks (most relevant to northern Nigeria) from ENSO-linked, ~3-4 year-scale outlooks (potentially most relevant to western and southeastern Nigeria), consistent with the zone-differentiated driver structure identified in the cited literature and reinforced by the index-level findings here.

Acknowledgements

The authors gratefully acknowledge the National Oceanic and Atmospheric Administration (NOAA), particularly the Physical Sciences Laboratory (PSL) and the Climate Prediction Center (CPC), for providing open access to the Atlantic Multidecadal Oscillation (AMO), Oceanic Niño Index (ONI), and North Atlantic Oscillation (NAO) datasets used in this study. The authors also appreciate the institutional support that facilitated the completion of this research. No specific external funding was received for this study.

REFERENCES

Abubakar, M.L., Abdussalam, A.F., Ahmed, M.S., & Wada, A.I. (2024). Spatiotemporal variability of rainfall and drought characterization in Kaduna, Nigeria. Discover Environment, 2(1), 72. https://doi.org/10.1007/s44274-024-00112-7

Adefolalu, D.O. (1986). Rainfall trends in Nigeria. Theoretical and Applied Climatology, 37, 205-219. https://doi.org/10.1007/BF00867578

Ati, O.F., Stigter, C.J., & Oladipo, E.O. (2002). A comparison of methods to determine the onset of the growing season in Northern Nigeria. International Journal of Climatology, 22(6), 731-742. https://doi.org/10.1002/joc.712

Cai, W., Reason, C., Mohino, E., et al. (2025). Climate impacts of the El Niño-Southern Oscillation in Africa. Nature Reviews Earth & Environment, 6, 503-520. https://doi.org/10.1038/s43017-025-00705-7

Emmanuel, I. (2022). Linkages between El Niño-Southern Oscillation (ENSO) and precipitation in West Africa regions. Arabian Journal of Geosciences, 15, 675. https://doi.org/10.1007/s12517-022-09942-2

Enfield, D.B., Mestas-Nuñez, A.M., & Trimble, P.J. (2001). The Atlantic multidecadal oscillation and its relation to rainfall and river flows in the continental U.S. Geophysical Research Letters, 28(10), 2077-2080. https://doi.org/10.1029/2000GL012745

Hurst, H.E. (1951). Long-term storage capacity of reservoirs. Transactions of the American Society of Civil Engineers, 116(1), 770-799.

Ibebuchi, C.C., & Abu, I.-O. (2023). Rainfall variability patterns in Nigeria during the rainy season. Scientific Reports, 13, 7888. https://doi.org/10.1038/s41598-023-34970-7

Johnson, A., & Idowu, A.S. (2026). Wavelet coherence between large-scale climate indices and precipitation variability over Nigeria (1961-2021). Nigerian Journal of Physics, 35(S), 217-227. https://doi.org/10.62292/njp.v35(s).2026.690

Knight, J.R., Folland, C.K., & Scaife, A.A. (2006). Climate impacts of the Atlantic Multidecadal Oscillation. Geophysical Research Letters, 33, L17706. https://doi.org/10.1029/2006GL026242

Mann, H.B. (1945). Nonparametric tests against trend. Econometrica, 13(3), 245-259. https://doi.org/10.2307/1907187

Odiana, S., & Yusuf, D.D. (2025). Trend analysis of rainfall in three cities in Nigeria as determinant of climate change. Dutse Journal of Pure and Applied Sciences (DUJOPAS), 11(2b), 252-264.

Okorie, F.C. (2021). North Atlantic Oscillation and rainfall variability in southeastern Nigeria: A statistical analysis of 30 year period. Journal of Atmospheric Science Research, 4(4), 42-49. https://doi.org/10.30564/jasr.v4i4.3843

Ologunorisa, T.E. (2004). An assessment of flood vulnerability zones in the Niger Delta, Nigeria. International Journal of Environmental Studies, 61(1), 31-38. https://doi.org/10.1080/0020723032000130061

Peng, C.-K., Buldyrev, S.V., Havlin, S., Simons, M., Stanley, H.E., & Goldberger, A.L. (1994). Mosaic organization of DNA nucleotides. Physical Review E, 49(2), 1685-1689. https://doi.org/10.1103/PhysRevE.49.1685

Salami, A.A. (2025). Rainfall variability and trends analyses in Nigeria using remotely sensed data and CMIP5 models. Earth Systems and Environment, 9, 2837-2865. https://doi.org/10.1007/s41748-024-00556-0

Sen, P.K. (1968). Estimates of the regression coefficient based on Kendall's tau. Journal of the American Statistical Association, 63(324), 1379-1389. https://doi.org/10.2307/2285891

Torrence, C., & Compo, G.P. (1998). A practical guide to wavelet analysis. Bulletin of the American Meteorological Society, 79(1), 61-78. https://doi.org/10.1175/1520-0477(1998)079<0061:APGTWA>2.0.CO;2

Umar, A.T., & Kehinde, M.O. (2020). Relationship of El Niño/Southern Oscillation to rainfall patterns in Nigeria. Open Journals of Environmental Research, 1(1), 1-20. https://doi.org/10.5281/zenodo.4818056

Zhang, R., & Delworth, T.L. (2006). Impact of Atlantic multidecadal oscillations on India/Sahel rainfall and Atlantic hurricanes. Geophysical Research Letters, 33, L17712. https://doi.org/10.1029/2006GL026267