AGU ADVANCING EARTH AND SPACE SCIENCES

Geophysical Research Letters

RESEARCH LETTER

10.1029/2023GL104332

Key Points:

- An Atlantic Niño in summer can produce atmospheric conditions of a La Niña-like event in the Pacific under certain ocean background states
- The ocean background state is of similar importance as the Atlantic Niño pattern for modifying the Atlantic Niño-Pacific teleconnection
- An Atlantic Niño intensifies easterly wind anomalies over the western equatorial Pacific when the Pacific has a warmer background state

Supporting Information:

Supporting Information may be found in the online version of this article.

Correspondence to:

L. Svendsen,
lea.svendsen@uib.no

Citation:

Svendsen, L., Rodríguez-Fonseca, B., Mohino, E., Crespo, L., & Losada, T. (2023). Tropical atmospheric response of Atlantic Niños to changes in the ocean background state. *Geophysical Research Letters*, *50*, e2023GL104332. https://doi.org/10.1029/2023GL104332

Received 2 JUN 2023
Accepted 9 NOV 2023

Tropical Atmospheric Response of Atlantic Niños to Changes in the Ocean Background State

Lea Svendsen[1], Belén Rodríguez-Fonseca[2,3], Elsa Mohino[2], Lander Crespo[1,4], and Teresa Losada[2]

[1]Geophysical Institute, University of Bergen and the Bjerknes Centre for Climate Research, Bergen, Norway, [2]Universidad Complutense de Madrid, Madrid, Spain, [3]Instituto de Geociencias, CSIC-UCM, Madrid, Spain, [4]Now at LAAS-CNRS, Universite de Toulouse, CNRS, UPS, Toulouse, France

Abstract Since the 1970s, Atlantic Niños during boreal summer have been linked to Pacific La Niñas the following winter. Earlier studies have explained the appearance of the Atlantic-Pacific teleconnection with changing Atlantic Niño configurations. Here we find that the non-stationarity of this teleconnection can also be explained by changes in the ocean background state, without changing the Atlantic Niño configuration. Experiments with different atmospheric general circulation models are performed where the same Atlantic Niño pattern is prescribed to different global ocean background states. The 1975–1985 global mean sea surface temperature forces a Walker Circulation response and low-level convergence over the Maritime Continent, increasing the chance of triggering a La Niña-like event in the Pacific. These results suggest that ENSO-predictions could be improved in certain periods by considering tropical Atlantic variability.

Plain Language Summary The Atlantic Niño is the main climate variability phenomenon in the equatorial Atlantic and has a strong influence on local and remote climate. Since the 1970s, warm Atlantic Niño events in June–August have been linked to cool La Niña events developing in the equatorial Pacific the following December–February. The appearance of this Atlantic-Pacific link has been explained by changes in the temperature pattern of Atlantic Niños but, so far, no study has analyzed the role of mean state changes. In this study we demonstrate the contribution of changes in the mean background surface temperatures of the global oceans to the appearance of this Atlantic-Pacific link. These results imply that under certain global ocean background conditions, we should use information about the Atlantic Niño to improve seasonal forecasts of El Niño and La Niña events.

1. Introduction

Research over the last decade has revealed that there are two-way interactions between interannual variability in the tropical basins. The El Niño-Southern Oscillation (ENSO) influences the Indian and Atlantic Oceans, but there is also growing evidence of impact of the Indian and Atlantic Oceans on ENSO (Cai et al., 2019). For example, Hasan et al. (2022) argues that the strong 2021 Atlantic Niño contributed to the 2020–2023 triple-dip La Niña. With this perspective, ENSO evolution depends on Pacific Ocean dynamics and trade wind anomalies modulated both by local stochastic processes and remotely from the Atlantic and Indian Oceans (Ding et al., 2012; Ham et al., 2013; Polo et al., 2015; Rodríguez-Fonseca et al., 2009). However, the understanding of such tropical basin interactions (TBI) is still incomplete (Cai et al., 2019). Furthermore, there is still no consensus concerning the controlling factors of longer timescale variations of TBI, such as the appearance of the Atlantic Niño/Niña (ANN)-ENSO connection after the 1970s (Rodríguez-Fonseca et al., 2009). Multidecadal modulations of TBI have been suggested in which large-scale changes related to Atlantic multidecadal variability (AMV) or the Atlantic meridional overturning circulation seem to play a role (Martín-Rey et al., 2015; Svendsen et al., 2014; L. Wang et al., 2017); although the underlying mechanisms are still under debate. In this study, we further analyze the role of decadal variations of the ocean mean state on TBI, specifically, the Atlantic Niño influence on the Pacific.

The Atlantic Niño is the main mode of interannual sea surface temperature (SST) variability in the equatorial Atlantic (Lübbecke et al., 2018; Zebiak, 1993). During an Atlantic Niño (Niña) event, the central and eastern equatorial Atlantic warms (cools) and convection is displaced to the east (west).

Several studies have shown that an Atlantic Niño (Niña) in boreal summer can cause or contribute to an opposite-signed ENSO event the following winter (Chikamoto et al., 2020; Ding et al., 2012; Dommenget et al., 2006; Rodríguez-Fonseca et al., 2009; C. Wang, 2006). The mechanism for the ANN-ENSO teleconnection is as follows: An Atlantic Niño (Niña) in boreal summer leads to anomalous upper-level divergence (convergence) in the western equatorial Atlantic that reorganizes the global Walker Circulation (Chikamoto et al., 2020; Polo et al., 2015; Rodríguez-Fonseca et al., 2009). This leads to easterly (westerly) surface wind anomalies over the central and western equatorial Pacific, increasing the chance of easterly (westerly) wind burst which can trigger upwelling (downwelling) equatorial Kelvin waves and the development of a La Niña (El Niño) in the Pacific the following winter. The ANN-ENSO teleconnection can therefore be used to improve ENSO predictions (e.g., Exarchou et al., 2021; Frauen & Dommenget, 2012; Keenlyside et al., 2013). Understanding when TBI are strong will further improve the reliability of predictions within the tropics (Cai et al., 2019; Exarchou et al., 2021; Martín-Rey et al., 2015).

The non-stationarity of the ANN-ENSO teleconnection has been explained by Atlantic Niño configuration changes (Losada & Rodríguez-Fonseca, 2016). A canonical Atlantic Niño, dominating after the 1970s (Figure 1c), is characterized by ENSO-like Bjerknes feedback mechanisms, while the "non-canonical" Atlantic Niño, dominating before the 1970s, has a dipole structure with opposite anomalies in the northeast and southwest tropical South Atlantic (Figure 1b) similar to the South Atlantic Ocean Dipole (Nnamchi et al., 2011; Richter et al., 2013). The change in Atlantic Niño configuration in the 1970s led to a westward shift of the equatorial Atlantic convection area and the equatorial Pacific response to Atlantic Niños became significant (Losada & Rodríguez-Fonseca, 2016).

The Atlantic Niño configuration change has been linked to large-scale modulations such as AMV and the Intertropical Convergence Zone (ITCZ) (Losada et al., 2022; Martín-Rey et al., 2014; Rodríguez-Fonseca et al., 2019). AMV is the leading mode of multidecadal SST variability in the Atlantic, where a positive (negative) AMV is associated with a basin-wide warming (cooling) of the North Atlantic (Enfield et al., 2001). This is typically also accompanied by a South Atlantic cooling (warming) and a northward (southward) shift of the ITCZ. The strengthening of the ANN-ENSO teleconnection in the 1970s is concomitant with a positive-to-negative phase change of the AMV (Martín-Rey et al., 2014) and a meridional shift of the ITCZ that could have modulated the Atlantic Niño configuration (Martín-Rey et al., 2018). However, the AMV has changed sign since the turn of the century while the ANN-ENSO teleconnection has persisted (Jia et al., 2019), suggesting other processes might be responsible for the non-stationarity of the teleconnection. For example, Losada et al. (2022) showed that an equatorward shift of the ITCZ can strengthen interannual variability over the tropical oceans and change the Atlantic Niño pattern with a westward extension of the SST anomalies and associated convection resembling the canonical Atlantic Niño configuration that dominated after the 1970s. This was accompanied by a shallower Pacific thermocline making the Pacific more susceptible to wind forcing and, hence, ENSO-events are more easily triggered, leading to a strengthening of the ANN-ENSO teleconnection (Losada et al., 2022). Furthermore, Mohino and Losada (2015) showed that Atlantic Niño impacts over the Indian Ocean changes due to different locations of climatological surface convergence under different ocean backgrounds associated with climate change projections.

While earlier studies have isolated the effect of different Atlantic Niño configurations on the ANN-ENSO teleconnection, no study has isolated the effect of global multidecadal background changes. Here, we hypothesize that the non-stationarity of the ANN-ENSO teleconnection can also be related to multidecadal variability of the global ocean background state, without changing the configuration of the Atlantic Niño.

2. Data and Methods

To investigate how the ANN-ENSO teleconnection depends on the global background state we analyze a set of four ensemble experiments using two atmospheric general circulation models (AGCMs): SPEEDY (Kucharski et al., 2007) and UCLA-AGCM (Mechoso et al., 2000; Richter et al., 2008). All experiments are run for 1 year, where SPEEDY has 50 ensemble members and UCLA-AGCM has 10 ensemble members for each experiment. UCLA-AGCM has a $2 \times 2.5°$ horizontal latitude-longitude resolution and 29 vertical layers. SPEEDY has a lower horizontal resolution of approximately 3.75° and 8 vertical layers but has been shown to simulate atmospheric circulation in the tropics reasonably well and used successfully in many climate dynamics studies, including studies on Atlantic Niño configurations and teleconnections (e.g., Herceg-Bulić et al., 2017; Kucharski et al., 2009; Kucharski et al., 2013; Losada and Rodrigues-Fonseca, 2016).

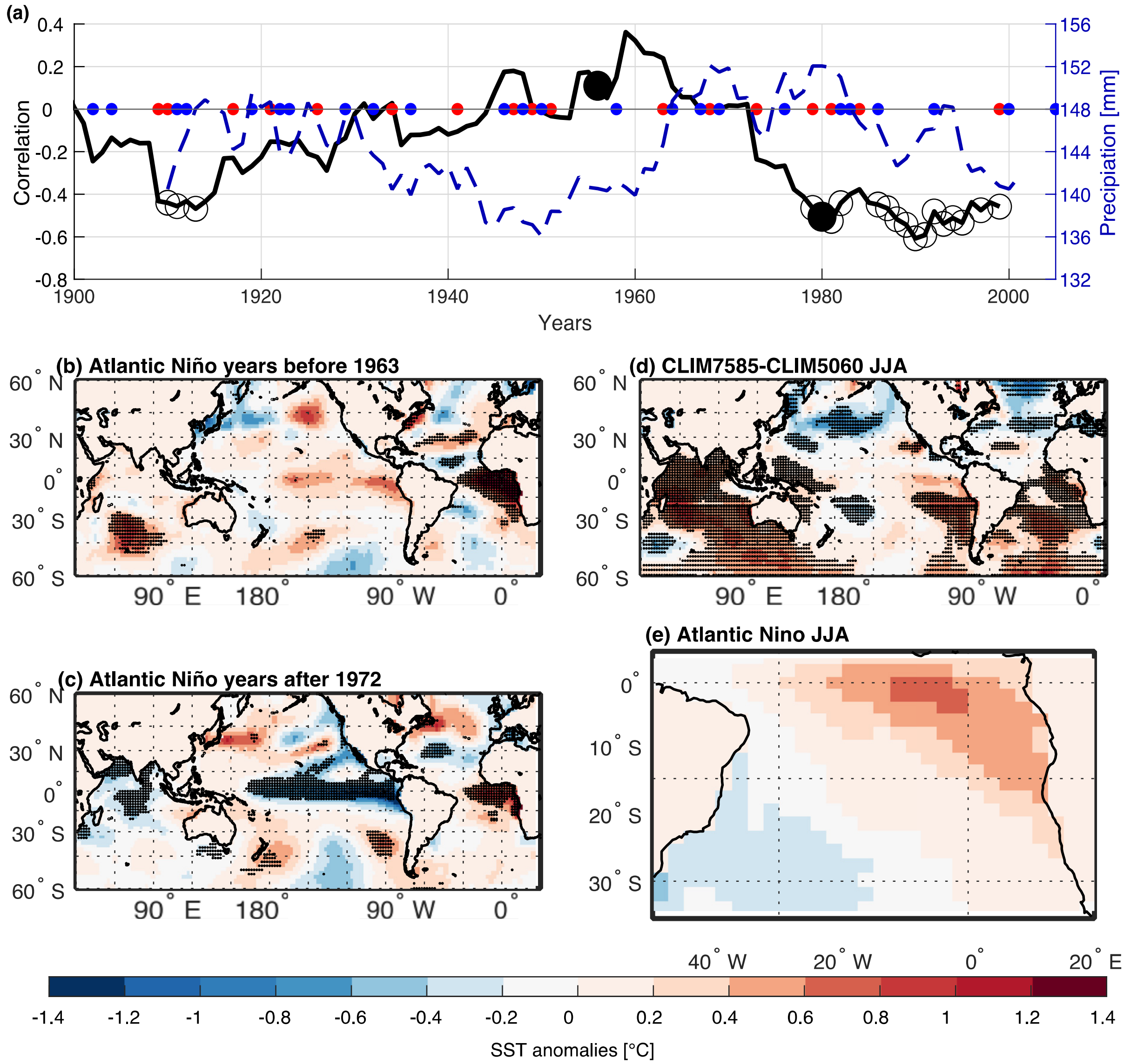

Figure 1. (a) Twenty-year running correlation between JJA Atl3-index and DJF Niño3-index in observations (ERSST, black line). 20-year running means of total rainfall in mm (blue dashed line) in Nordeste Brazil (~10°S) from the CRU TS3.10 data set (Harris et al., 2014). Years on the *x*-axis indicate the central year of the 20-year running correlation/mean. Black circles indicate when the correlation is significant at the 5% level for the effective degrees of freedom. The black filled dots mark the years used for the experiments. Red/blue dots mark the Atlantic Niño/Niña years. (b) Composite of JJA sea surface temperature (SST) for Atlantic Niño years minus Atlantic Niña years in ERSST between 1930 and 1962 and (c) between 1973 and 2005. (d) Difference in JJA SST used as boundary condition of CLIM7585 and CLIM5060. Black dots in panels (b–d) indicate significance at the 10% level from a two-tailed *t*-test for the effective degrees of freedom. (e) Atlantic Niño pattern in JJA (SST) prescribed in ATL-experiments.

As boundary conditions for the experiments, we use a set of four different configurations of observed SST from the Extended Reconstructed Sea Surface Temperature Data Set ERSST v3 (Smith et al., 2008). In the first two experiments, CLIM5060 and CLIM7585, we prescribe monthly mean SST from two 11-year periods, 1950–1960 and 1975–1985, respectively. The periods are selected based on the 20-year running Pearson correlation between the June–August (JJA) Atl3-index and the December–February (DJF) Niño3-index. Seasons are chosen based on the usual peak seasons of the Atlantic Niño and ENSO, and the maximum correlation between the Alt3 and Niño3-indices occurs when the Atlantic leads by 6–8 months (Figure S1 in Supporting Information S1 and Li et al. (2023)). The Atl3 and Niño3-indices are defined by averaging SST anomalies in the equatorial Atlantic (3°N–3°S, 20°W–0) and the equatorial Pacific (5°S–5°N, 150°–90°W), respectively. The observed strength of the ANN-ENSO teleconnection is positive during 1950–1960 and stronger and significantly negative at the 5% level during 1975–1985 (Figure 1a) taking into account effective degrees of freedom to avoid autocorrelation

(Bretherton et al., 1999; Metz, 1991; Trenberth, 1984), consistent with earlier observational studies (e.g., Ding et al., 2012; Martín-Rey et al., 2014; Rodríguez-Fonseca et al., 2009). These correlations between equatorial Atlantic and Pacific SSTs can also be seen in the difference between Atlantic Niño and Niña composites in observed SST before (Figure 1b) and after the 1960s (Figure 1c). These two periods also coincide with a meridional displacement of the Atlantic ITCZ, illustrated by decadal variational in precipitation in Nordeste Brazil (Figure 1a). Figure 1d shows the difference in prescribed JJA SST for CLIM7585 and CLIM5060. With respect to the first period, the second period has a colder North Atlantic and a warmer South Atlantic, Indian Ocean and eastern tropical Pacific (Figure 1d).

The other experiments, ATL5060 and ATL7585, have the same monthly mean global SSTs prescribed as CLIM5060 and CLIM7585, respectively, but monthly SST anomalies of an Atlantic Niño pattern are added to the tropical Atlantic throughout the simulations (Figure 1e). The prescribed Atlantic Niño is constructed using the Atl3-index from ERSST following Losada and Rodríguez-Fonseca (2016). The Atl3-index for the period 1901–2007 is first standardized, and an interannual filter is applied to remove piecewise linear trends (López-Parages & Rodríguez-Fonseca, 2012; Stephenson et al., 2000). Positive and negative composites are constructed using the years where the Atl3-index is greater than or equal to one standard deviations in the JJA mean, and the sign of the index is positive or negative, respectively, in all 3 months JJA (Figure 1a). The Atlantic Niño pattern is defined as the difference between the positive and negative composites (Figure 1e), but the magnitude of the Atlantic Niño composite anomalies is moderate. For instance, the composite anomalies are about half the size of the large 2021 Atlantic Niño (see Figure 2j in Hasan et al., 2022). The pattern is added to the monthly background SST from the CLIM-experiments in the Atlantic between 35°S and 5°N in both ATL-experiments. A Gaussian relaxation is applied in the regions 10° north and south of these boundaries to avoid discontinuities in the SST boundary field.

For our analysis, we focus on boreal summer JJA because the Atlantic Niño usually peaks and the ANN-ENSO teleconnection is initiated in summer (e.g., Rodríguez-Fonseca et al., 2009). Two-way interactions between the tropical Pacific and the tropical Atlantic, intrinsic interannual variability in both basins, and the fact that both ENSO and the Atlantic Niño usually develop in boreal late spring/summer, make it challenging to understand the importance of the Atlantic Niño for ENSO development and prediction. This means that an ENSO event can be caused by an Atlantic Niño or initiated internally in the Pacific at the same time as the Atlantic Niño peaks. This can cause spurious correlations between Atlantic Niños and ENSO events (W. Zhang et al., 2020). AGCM experiments are therefore used to isolate the Atlantic Niño influence, eliminating internally generated ENSO variability and feedbacks to the Atlantic (Losada et al., 2010).

Model biases are generally large in the tropical Atlantic, especially in low resolution models (Zuidema et al., 2016). For instance, there are stronger trade winds over the Atlantic and anomalous convergence of winds over the northeastern Brazil in both models (Figure S2 in Supporting Information S1), which could promote too strong convection. Using AGCMs limits biases related to the zonal SST gradient and thermocline depth in the tropical Atlantic Ocean which enhance surface wind and Walker Circulation biases through positive feedbacks and degrade Atlantic Niño variability and teleconnections (Richter & Tokinaga, 2020). Furthermore, the AGCM approach using these models has been previously applied successfully to compare the atmospheric response to the Atlantic Niño (Losada et al., 2010), changes in its configuration (Losada & Rodríguez-Fonseca, 2016) and different climatological background conditions (Mohino & Losada, 2015).

The atmospheric response to the imposed Atlantic Niño can be estimated by the sum of the response to the climatology, the response to the Atlantic Niño, and a non-linear term due to the interaction between the Atlantic Niño and the climatology. This non-linear response (NLR) is the different response to the same Atlantic Niño given different background states and may or may not be negligible. Thus, comparing the two CLIM-experiments isolates the atmospheric response to the climatological differences. Comparing the ATL-experiments with the CLIM-experiments isolates the response to the Atlantic Niño.

Since we prescribe the same Atlantic Niño pattern in both ATL-experiments, the difference in the boundary forcing between ATL7585 and ATL5060 is equal to the difference between CLIM7585 and CLIM5060. For the SST boundary forcing (F), we have

$$F_{\mathrm{CLIM7585}} - F_{\mathrm{CLIM5060}} = F_{\mathrm{ATL7585}} - F_{\mathrm{ATL5060}} \tag{1}$$

which is equivalent to

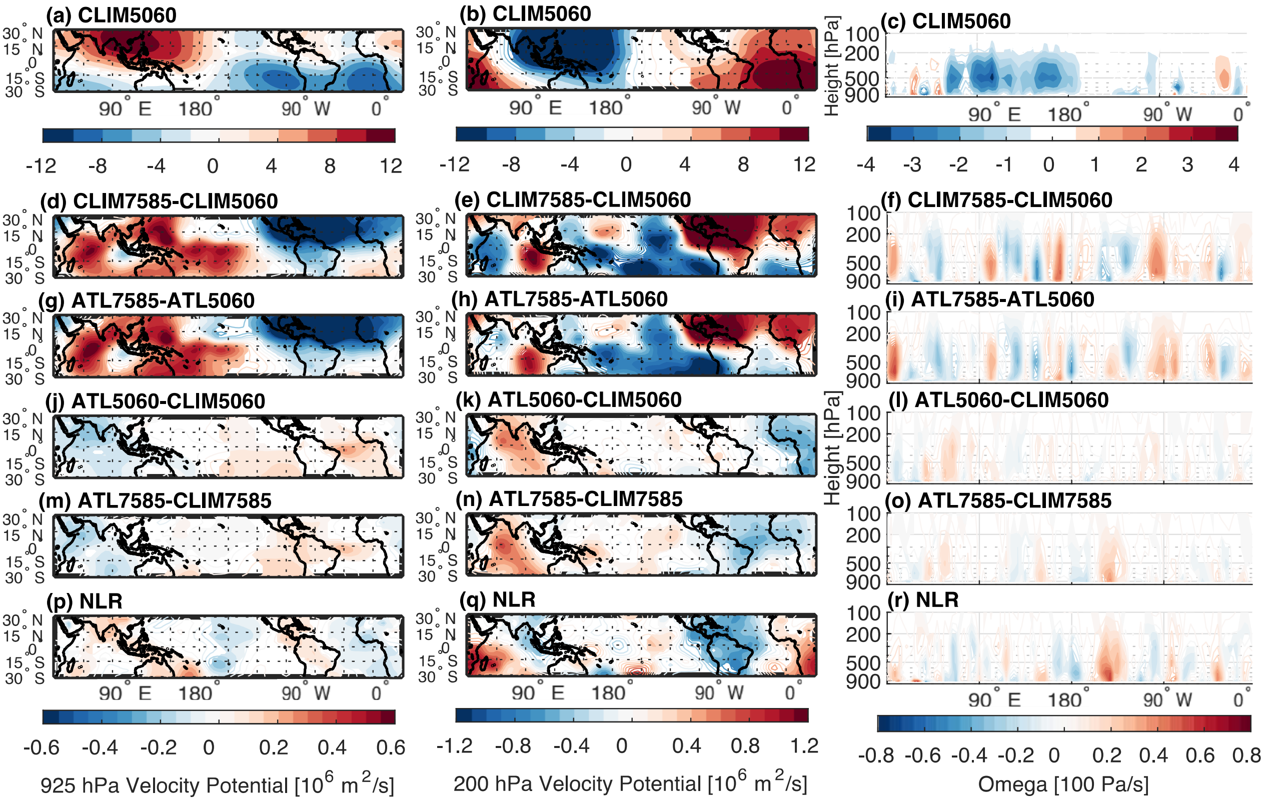

Figure 2. Multimodel ensemble mean JJA (left) 925 hPa and (middle) 200 hPa velocity potential, and (right) vertical winds omega (positive values mean subsidence) in (a–c) CLIM5060, the difference between background states (d–f) CLIM7585-CLIM5060 and (g–i) ATL7585-ATL5060, the response to the prescribed Atlantic Niño (j–l) ATL5060-CLIM5060 and (m–o) ATL7585-CLIM7585, and (p–r) the nonlinear response (Equation 4). Shading indicates where both single-model ensemble means agree on sign.

$$F_{\mathrm{ATL7585}} - F_{\mathrm{CLIM7585}} = F_{\mathrm{ATL5060}} - F_{\mathrm{CLIM5060}} \tag{2}$$

where the subscripts indicate the experiments. If the atmospheric response (R) to the SST forcing (F) is linear, the difference in the atmospheric response between ATL7585 and ATL5060 should be the same as the difference between the climatological simulations CLIM7585 and CLIM5060. If the difference in response to the same Atlantic Niño is only due to the difference in the climatology, then the following should also be true:

$$R_{\mathrm{ATL7585}} - R_{\mathrm{CLIM7585}} = R_{\mathrm{ATL5060}} - R_{\mathrm{CLIM5060}} \tag{3}$$

and any NLR is negligible. However, if the atmospheric response to the Atlantic Niño changes with a changing background state, we cannot ignore the NLR. The NLR is given by

$$\mathrm{NLR} = (R_{\mathrm{ATL7585}} - R_{\mathrm{ATL5060}}) - (R_{\mathrm{CLIM7585}} - R_{\mathrm{CLIM5060}}) = (R_{\mathrm{ATL7585}} - R_{\mathrm{CLIM7585}}) - (R_{\mathrm{ATL5060}} - R_{\mathrm{CLIM5060}}) \tag{4}$$

3. Results

In the following, we compare the four experiments by first showing the atmospheric response to the global background changes, and then, the response to the prescribed Atlantic Niño. Last, we consider the non-linear interaction between the response to background changes and the Atlantic Niño (NLR).

Figure 2 shows the multimodel ensemble mean response of low-level (925 hPa) and upper-level (200 hPa) velocity potential and vertical velocity averaged over the equatorial band (15°S–15°N). Results are shown for each model separately in the Supplementary Information. Climatologically in JJA for CLIM5060 (and for CLIM7585, not shown), there is strong low-level convergence (positive velocity potential) and upper-level divergence (negative velocity potential) over Asia and the tropical Northern Hemisphere and upward motion over the tropical

Indian Ocean and South Asia associated with the Asian summer monsoon and the northward migration of the ITCZ into the summer hemisphere. Consistently there is low-level divergence over the tropical Southern Hemisphere (Figures 2a–2c). The two models used here show similar patterns, but the velocity potential maximum and minimums are stronger in UCLA-AGCM (Figures S1a, S1b, S2a, and S2b in Supporting Information S1).

The atmospheric response to the different SST background states (Figures 2d–2f), that is, CLIM7585-CLIM5060, shows surface divergence (Figure 2d) and subsidence (Figure 2f) over the tropical North Atlantic and eastern tropical North Pacific and upper-level convergence (Figure 2e) over the tropical North Atlantic. The response in the Atlantic indicates a southward shift in the ITCZ, consistent with observations (Figure 1a), and is expected from the difference in the SST boundary conditions. There is also an eastward shift of convergence in the central Pacific, but the response is stronger in UCLA-AGCM. The low-level divergence over the eastern Pacific extends farther to the west in SPEEDY (Figures S3c and S3d in Supporting Information S1). The response to the different global SST background states resembles the response given by ATL7585-ATL5060 (Figures 2g–2i), although some differences exist suggesting a NLR.

The atmospheric response to an Atlantic Niño with the global background SST of 1950–1960, ATL5060-CLIM5060 (Figures 2j–2l), shows surface convergence over the tropical Atlantic and Pacific and surface divergence and subsidence over the Indian Ocean and Maritime Continent. The region of surface divergence extends farther east into the Pacific in SPEEDY, while the region of convergence extends farther west in the Pacific in UCLA-AGCM (Figures S3g and S3h in Supporting Information S1). Overall, this pattern suggests a weakening Pacific Walker Circulation typically associated with El Niño-like conditions. This is consistent with the positive ANN-ENSO connection during the period 1950–1960 (Figure 1a), and the velocity potential pattern resembles the composite of Atlantic Niño minus Atlantic Niña events during the period 1949–1974 from NCEP reanalysis (Kalnay et al., 1996) (Figure S5a in Supporting Information S1). Furthermore, the response resembles the atmospheric response to the non-canonical Atlantic Niño configuration from Losada and Rodríguez-Fonseca (2016) that dominated before the 1970s.

For the response to an Atlantic Niño with the global background SST of 1975–1985, ATL7585-CLIM7585 (Figures 2m–2o), the maximum near-surface convergence over the Atlantic is shifted to the west, and the negative velocity potential response over the Maritime Continent seen in 1950–1960 is weaker, and even significantly positive in UCLA-AGCM (Figures S3i and S3j in Supporting Information S1). The response over the Maritime Continent resembles the composite of Atlantic Niño minus Atlantic Niña events during the period 1975–2000 from reanalysis (Figure S5b in Supporting Information S1). The anomalous surface winds (Figures 3a–3d) and velocity potential over the Maritime Continent are less El Niño-like (more La Niña-like) during 1975–1985 compared to 1950–1960 consistent with the observed La Niña-like pattern in the Indo-Pacific during this period (Rodríguez-Fonseca et al., 2009). However, the response in the central Pacific is weak compared to observations. The climatological SSTs prescribed in the Pacific in ATL7585 are El Niño-like (Figure 1d) and may dampen a La Niña-like atmospheric response over the Pacific. In addition, it should be noted that the prescribed Atlantic Niño resembles the non-canonical Atlantic Niño dipole configuration of the 1950s (compare Figures 1b and 1e) eventhough it is composed of both types of Atlantic Niños. The prescribed Atlantic dipole pattern may lead to a weaker westward shift of the convection and a stronger influence through the Indian ocean reducing the response over the Pacific compared to prescribing the canonical Atlantic Niño pattern of 1975–1985 (Losada & Rodríguez-Fonseca, 2016). Model biases in the atmospheric circulation (Figure S2 in Supporting Information S1) are also likely to influence the magnitude and location of the response over the Pacific.

The differences between the response to the same Atlantic Niño pattern with different global background SSTs (comparing Figures 2j–2l with 2m–2o) suggest non-linear processes and that the global ocean background state influences the Atlantic Niño teleconnection pattern. The NLR (Figures 2p–2r and 3e–3g) indicates enhanced surface divergence and anomalous subsidence over the eastern equatorial Atlantic. In ATL7585 the equatorial and South Atlantic is anomalously warm compared to in ATL5060, which is consistent with enhanced convection and a shift of the location of maximum equatorial heating in the Atlantic. The NLR also shows enhanced surface divergence and anomalous subsidence over the central-eastern Pacific, and enhanced surface convergence with anomalous easterlies in the far western tropical South Pacific over the Maritime continent and westerlies from the Indian Ocean (Figures 2p and 3e–3g). The NLR resembles the observed atmospheric circulation pattern associated with an Atlantic Niño after the 1970s (see Figure 1 in Rodríguez-Fonseca et al., 2009) and is consistent with a strengthening of the Walker Circulation as seen during a La Niña and when the ANN-ENSO teleconnection

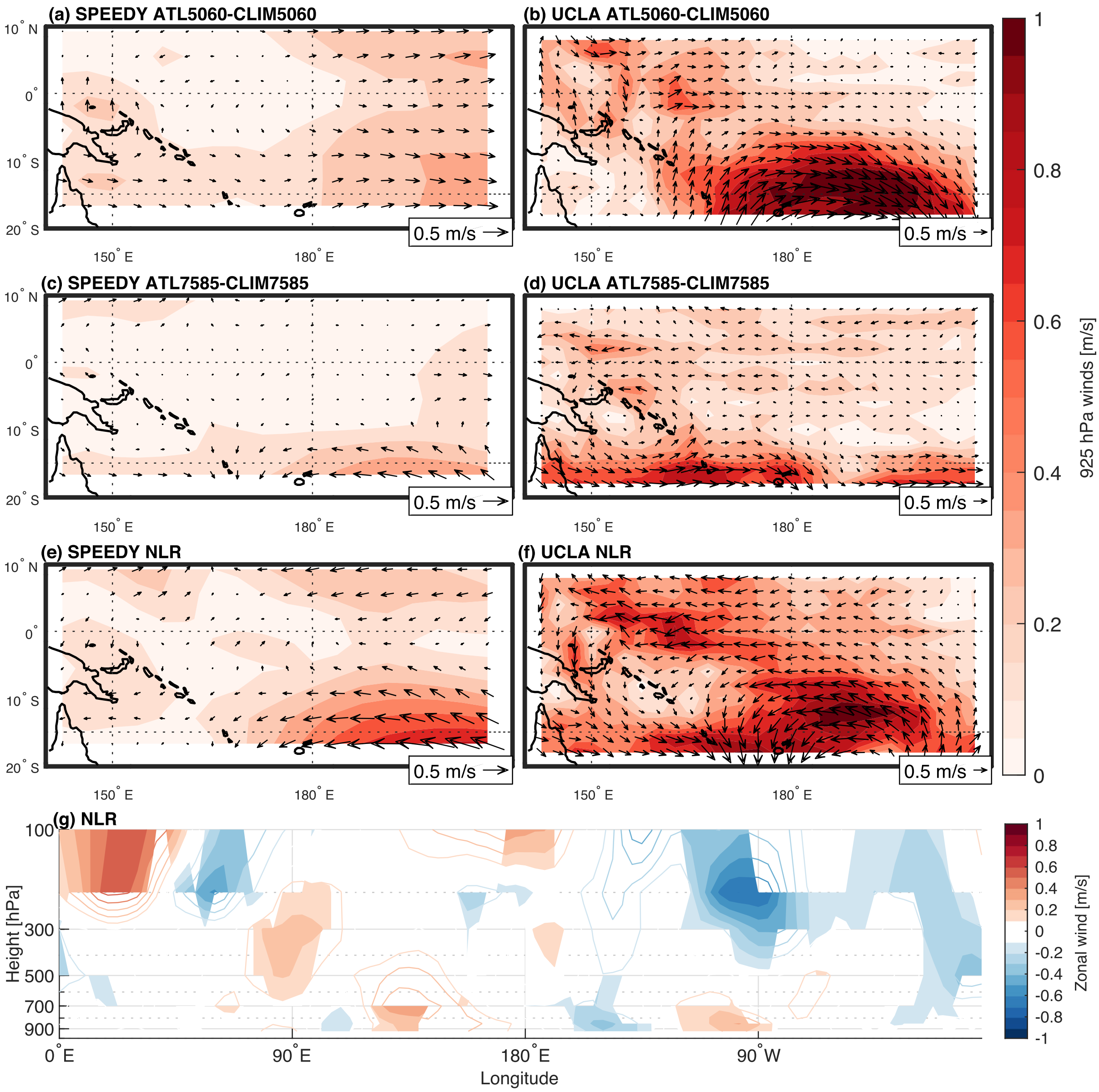

Figure 3. JJA 925 hPa wind response to the Atlantic Niño in (left) SPEEDY and (right) UCLA-AGCM, for (a–b) period 1950–1960 and (c–d) period 1975–1985, and (e–f) the non-linear response (NLR). Wind speed is shown in shading. (g) Multimodel ensemble mean NLR of zonal wind averaged over 15°S–15°N. Shading in (g) indicates where both single-model ensemble means agree on sign.

is strong (Losada et al., 2022). In agreement with the mechanism proposed in Polo et al. (2015), a La Niña can be triggered by the anomalous surface divergence over the central equatorial Pacific, with easterly wind bursts over the central and western tropical Pacific during 1975–1985. An initial wind burst can be directly forced by the Atlantic (Losada & Rodríguez-Fonseca, 2016; Losada et al., 2010), a feature that agrees with the stronger easterlies shown in our results. Furthermore, the NLR resembles the difference in the atmospheric response to Atlantic Niño configurations in both sign and magnitude (Losada & Rodríguez-Fonseca, 2016). The magnitude of the response over the Maritime Continent is about half of the total response of Atlantic Niño minus Atlantic Niña events in reanalysis (comparing Figure S3k–S3l with Figure S5 in Supporting Information S1) suggesting the background state is an important component for modulating the Atlantic Niño teleconnection.

Model differences in the anomalous Walker Circulation response (Figure S3a and S3b in Supporting Information S1) are to be expected to some extent because of differences in resolution and model biases (Figure S2 in Supporting Information S1) for example, the maximum easterly wind anomalies over the western Pacific are farther south and east in SPEEDY compared to UCLA-AGCM (Figures 3e and 3f) in accordance with the location of the NLR in the velocity potential in these models. However, both models agree on the general pattern and strength of the NLR. There is a positive-negative dipole in the 925 hPa velocity potential between the Maritime Continent and the central-eastern Pacific and anomalous convergence, rising motion, and enhanced trade winds over the Maritime Continent, a key region for the ANN-ENSO teleconnection (Losada & Rodríguez-Fonseca, 2016).

4. Discussion and Conclusion

In summary, our experiments show that changes in the background SST pattern could partly explain why the observed ANN-ENSO teleconnection appeared after 1970. We find that during 1975–1985 the tropical South Atlantic and eastern Pacific is warmer, and the ITCZ is shifted south toward the equator. An equatorward shifted ITCZ can facilitate a stronger atmospheric response of the equatorial Pacific (Park et al., 2023). The atmospheric response to an Atlantic Niño given this background state reflects a more westward location of surface convergence and upper-level divergence in the Atlantic with respect to the response during 1950–1960. This modification drives anomalous surface divergence over the central Pacific, anomalous convergence and upward motion over the Maritime Continent, and easterly surface winds anomalies near the date line. This atmospheric pattern could facilitate the growth of La Niña-like anomalies if coupled to the ocean through the Bjerknes feedback. This mechanism resembles how the AMO associated Indo-Pacific mean state changes influence the Indian Ocean Dipole-ENSO teleconnection described in Xue et al. (2022).

The westward displacement of equatorial Atlantic convection in the NLR is consistent with observed changes related to the Atlantic Niño configuration during the same period. Therefore, our results do not dispute earlier studies arguing the role of the Atlantic Niño configuration for the ANN-ENSO teleconnection strength (Losada & Rodríguez-Fonseca, 2016). There could also be interactions between both changes in the configuration and the background, with certain background states preferring certain Atlantic Niño configurations (Martín-Rey et al., 2018). We show here that background state changes also contributed to the strengthened ANN-ENSO teleconnection without changes in the Atlantic Niño configuration.

The magnitude of the NLR found here is around half of the observed anomalies and of the same order as the response to different Atlantic Niño configurations (see Figure 4 in Losada and Rodríguez-Fonseca (2016)), indicating that the background state is of comparable importance for the ANN-ENSO teleconnection. Our results therefore suggest that given a certain background state, knowledge about the state of the equatorial Atlantic can improve ENSO predictions regardless of the Atlantic Niño configuration. Furthermore, we speculate that given the 1975-1985 background SST pattern with a canonical Atlantic Niño configuration which dominated in the same period, the La Niña-like response in the Pacific to the Atlantic Niño would be even stronger.

Richter et al. (2021) found that the wind anomalies over the Pacific induced by Atlantic Niños could only explain up to 10% of the wind anomalies in the western equatorial Pacific associated with fully developed ENSO events. Our experimental setup isolates the Atlantic influence on the Pacific avoiding confounding ENSO events developing internally in the Pacific basin. A caveat with this approach is that we cannot estimate the relative strength of the atmospheric response to the models' internal ENSO, and therefore not quantify the importance of the ANN-ENSO teleconnection for fully developed ENSO events.

As mentioned above, the ANN-ENSO teleconnection has remained strong since the turn of the century even though the AMV has changed sign. Our two CLIM-experiments coincide with different AMV phases but also include the observed mean state changes in the Indian and Pacific Oceans. The Pacific mean state has been shown to influence the Atlantic impact on ENSO on multidecadal timescales (Kim et al., 2020) and could have a role in the non-stationary ANN-ENSO link (Losada et al., 2022). Furthermore, the observed decadal changes in the Pacific could have been forced by decadal changes in the Atlantic (Li et al., 2016; McGregor et al., 2014; Ruprich-Robert et al., 2017; Sun et al., 2017; R. Zhang & Delworth, 2007). Additional testing of separate regions of the background state changes to identify the most important regions for controlling the strength of the ANN-ENSO teleconnection is needed.

Our results suggest an additional reason for the appearance of the ANN-ENSO teleconnection since the 1970s other than a change in the Atlantic Niño configuration and proposes a mechanism based on interactions between the mean state and the Atlantic Niño. Thus, during some decades it can be beneficial to include information about the Atlantic Niño in ENSO predictions, while in other decades this information would be superfluous.

However, the Atlantic Niño influence on ENSO could weaken in the future due to enhanced tropospheric stability (Jia et al., 2019). Furthermore, Atlantic Niño variability may also be weakening (Crespo et al., 2022; Prigent et al., 2020; Yang et al., 2022), which could reduce the atmospheric response to Atlantic Niños. On the other hand, the boreal winter peak of the Atlantic Niño could become more important for ENSO predictions as the summer peak weakens (Hounsou-Gbo et al., 2020; Park et al., 2023). Lastly, the results here also suggest that the ANN-ENSO teleconnections can be hampered in models by systematic biases in the global SST pattern and the ITCZ position.

Data Availability Statement

The data from the model experiments used in this study are available in Mohino and Losada (2023).

Acknowledgments
This work was supported by the Bjerknes Climate Prediction Unit funded by the Trond Mohn Foundation (BFS2018TMT0), CoRea funded by the Research Council of Norway (301396), and the Spanish national project PID2021-125806NB-I00. The CSIC MULMOD Multidecadal Modulations of Tropical Basins Interactions (LINKA20411) funded research visits of Rodriguez-Fonseca and Svendsen.

References

Bretherton, C. S., Widmann, M., Dymnikov, V. P., Wallace, J. M., & Bladé, I. (1999). Effective number of degrees of freedom of a time-varying field. *Journal of Climate*, *12*(7), 1990–2009. https://doi.org/10.1175/1520-0442(1999)012<1990:TENOSD>2.0.CO;2

Cai, W., Wu, L., Lengaigne, M., Li, T., McGregor, S., Kug, J.-S., et al. (2019). Pantropical climate interactions. *Science*, *363*(6430), eaav4236. https://doi.org/10.1126/science.aav4236

Chikamoto, Y., Johnson, Z. F., Wang, S.-Y. S., McPhaden, M. J., & Mochizuki, T. (2020). El Niño–Southern Oscillation evolution modulated by Atlantic forcing. *Journal of Geophysical Research: Oceans*, *125*(8), e2020JC016318. https://doi.org/10.1029/2020JC0163180

Crespo, L. R., Prigent, A., Keenlyside, N., Koseki, S., Svendsen, L., Richter, I., & Sánchez-Gómez, E. (2022). Weakening of the Atlantic Niño variability under global warming. *Nature Climate Change*, *12*(9), 822–827. https://doi.org/10.1038/s41558-022-01453-y

Ding, H., Keenlyside, N. S., & Latif, M. (2012). Impact of the equatorial Atlantic on the El Niño southern oscillation. *Climate Dynamics*, *38*(9), 1965–1972. https://doi.org/10.1007/s00382-011-1097-y

Dommenget, D., Semenov, V., & Latif, M. (2006). Impacts of the tropical Indian and Atlantic Oceans on ENSO. *Geophysical Research Letters*, *33*(11), L11701. https://doi.org/10.1029/2006GL025871

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 US. *Geophysical Research Letters*, *28*(10), 2077–2080. https://doi.org/10.1029/2000GL012745

Exarchou, E., Ortega, P., Rodríguez-Fonseca, B., Losada, T., Polo, I., & Prodhomme, C. (2021). Impact of equatorial Atlantic variability on ENSO predictive skill. *Nature Communications*, *12*(1), 1612. https://doi.org/10.1038/s41467-021-21857-2

Frauen, C., & Dommenget, D. (2012). Influences of the tropical Indian and Atlantic Oceans on the predictability of ENSO. *Geophysical Research Letters*, *39*(2), L02706. https://doi.org/10.1029/2011GL050520

Ham, Y.-G., Kug, J.-S., Park, J.-Y., & Jin, F.-F. (2013). Sea surface temperature in the north tropical Atlantic as a trigger for El Niño/Southern Oscillation events. *Nature Geoscience*, *6*(2), 112–116. https://doi.org/10.1038/ngeo1686

Harris, I. P. D. J., Jones, P. D., Osborn, T. J., & Lister, D. H. (2014). Updated high-resolution grids of monthly climatic observations–the CRU TS3. 10 Dataset. *International Journal of Climatology*, *34*(3), 623–642. https://doi.org/10.1002/joc.3711

Hasan, N. A., Chikamoto, Y., & McPhaden, M. J. (2022). The influence of tropical basin interactions on the 2020–2022 double-dip La Niña. *Frontiers in Climate*, *4*, 1001174. https://doi.org/10.3389/fclim.2022.1001174

Herceg-Bulić, I., Mezzina, B., Kucharski, F., Ruggieri, P., & King, M. P. (2017). Wintertime ENSO influence on late spring European climate: The stratospheric response and the role of North Atlantic SST. *International Journal of Climatology*, *37*(S1), 87–108. https://doi.org/10.1002/joc.4980

Hounsou-Gbo, A., Servain, J., Vasconcelos Junior, F. D. C., Martins, E. S. P., & Araújo, M. (2020). Summer and winter Atlantic Niño: Connections with ENSO and implications. *Climate Dynamics*, *55*(11–12), 2939–2956. https://doi.org/10.1007/s00382-020-05424-x

Jia, F., Cai, W., Wu, L., Gan, B., Wang, G., Kucharski, F., et al. (2019). Weakening Atlantic Niño-Pacific connection under greenhouse warming. *Science Advances*, *5*(8), eaax4111. https://doi.org/10.1126/sciadv.aax4111

Kalnay, E., Kanamitsu, M., Kistler, R., Collins, W., Deaven, D., Gandin, L., et al. (1996). The NCEP/NCAR reanalysis 40-year project. *Bulletin of the American Meteorological Society*, *77*(3), 437–471. https://doi.org/10.1175/1520-0477(1996)077<0437:TNYRP>2.0.CO;2

Keenlyside, N. S., Ding, H., & Latif, M. (2013). Potential of equatorial Atlantic variability to enhance El Niño prediction. *Geophysical Research Letters*, *40*(10), 2278–2283. https://doi.org/10.1002/grl.50362

Kim, D., Lee, S.-K., Lopez, H., & Goes, M. (2020). Pacific mean-state control of Atlantic multidecadal oscillation–El Niño relationship. *Journal of Climate*, *33*(10), 4273–4291. https://doi.org/10.1175/JCLI-D-19-0398.1

Kucharski, F., Bracco, A., Yoo, J. H., & Molteni, F. (2007). Low-frequency variability of the Indian monsoon-ENSO relationship and the tropical Atlantic: The "Weakening" of the 1980s and 1990s. *Journal of Climate*, *20*(16), 4255–4266. https://doi.org/10.1175/JCLI4254.1

Kucharski, F., Bracco, A., Yoo, J. H., Tompkins, A. M., Feudale, L., Ruti, P., et al. (2009). A Gill–Matsuno-type mechanism explains the tropical Atlantic influence on African and Indian monsoon rainfall. *Quarterly Journal of the Royal Meteorological Society*, *135*(640), 569–579. https://doi.org/10.1002/qj.406

Kucharski, F., Molteni, F., King, M. P., Farneti, R., Kang, I. S., & Feudale, L. (2013). On the need of intermediate complexity general circulation models: A "SPEEDY" example. *Bulletin of the American Meteorological Society*, *94*(1), 25–30. https://doi.org/10.1175/BAMS-D-11-00238.1

Li, X., Tan, W., Hu, Z.-Z., & Johnson, N. C. (2023). Evolution and prediction of two extremely strong Atlantic Niños in 2019–2021: Impact of Benguela warming. *Geophysical Research Letters*, *50*(12), e2023GL104215. https://doi.org/10.1029/2023GL104215

Li, X., Xie, S. P., Gille, S. T., & Yoo, C. (2016). Atlantic-induced pan-tropical climate change over the past three decades. *Nature Climate Change*, *6*(3), 275–279. https://doi.org/10.1038/nclimate2840

López-Parages, J., & Rodríguez-Fonseca, B. (2012). Multidecadal modulation of El Niño influence on the Euro-Mediterranean rainfall. *Geophysical Research Letters*, *39*(2), L02704. https://doi.org/10.1029/2011GL050049

Losada, T., & Rodríguez-Fonseca, B. (2016). Tropical atmospheric response to decadal changes in the Atlantic Equatorial Mode. *Climate Dynamics*, *47*(3), 1211–1224. https://doi.org/10.1007/s00382-015-2897-2

Losada, T., Rodríguez-Fonseca, B., Mechoso, C. R., Mohino, E., & Castaño-Tierno, A. (2022). Changes in interannual tropical Atlantic–Pacific basin interactions modulated by a South Atlantic cooling. *Journal of Climate*, *35*(13), 4403–4416. https://doi.org/10.1175/JCLI-D-21-0546.1

Losada, T., Rodríguez-Fonseca, B., Polo, I., Janicot, S., Gervois, S., Chauvin, F., & Ruti, P. (2010). Tropical response to the Atlantic equatorial mode: AGCM multimodel approach. *Climate Dynamics*, *35*(1), 45–52. https://doi.org/10.1007/s00382-009-0624-6

Lübbecke, J. F., Rodríguez-Fonseca, B., Richter, I., Martín-Rey, M., Losada, T., Polo, I., & Keenlyside, N. S. (2018). Equatorial Atlantic variability—Modes, mechanisms, and global teleconnections. *WIREs Climate Change*, *9*(4), e527. https://doi.org/10.1002/wcc.527

Martín-Rey, M., Polo, I., Rodríguez-Fonseca, B., Losada, T., & Lazar, A. (2018). Is there evidence of changes in tropical Atlantic variability modes under AMO phases in the observational record? *Journal of Climate*, *31*(2), 515–536. https://doi.org/10.1175/JCLI-D-16-0459.1

Martín-Rey, M., Rodríguez-Fonseca, B., & Polo, I. (2015). Atlantic opportunities for ENSO prediction. *Geophysical Research Letters*, *42*(16), 6802–6810. https://doi.org/10.1002/2015GL065062

Martín-Rey, M., Rodríguez-Fonseca, B., Polo, I., & Kucharski, F. (2014). On the Atlantic–Pacific Niños connection: A multidecadal modulated mode. *Climate Dynamics*, *43*(11), 3163–3178. https://doi.org/10.1007/s00382-014-2305-3

McGregor, S., Timmermann, A., Stuecker, M. F., England, M. H., Merrifield, M., Jin, F.-F., & Chikamoto, Y. (2014). Recent Walker circulation strengthening and Pacific cooling amplified by Atlantic warming. *Nature Climate Change*, *4*(10), 888–892. https://doi.org/10.1038/nclimate2330

Mechoso, C. R., Yu, J.-Y., & Arakawa, A. (2000). A coupled GCM pilgrimage: From climate catastrophe to ENSO simulations. In D. A. Randall (Ed.), *General circulation model development: Past, present and future*. *Proceedings of a symposium in honor of Professor Akio Arakawa* (pp. 539–575). Academic.

Metz, W. (1991). Optimal relationship of large-scale flow patterns and the barotropic feedback due to high-frequency eddies. *Journal of the Atmospheric Sciences*, *48*(9), 1141–1159. https://doi.org/10.1175/1520-0469(1991)048<1141:OROLSF>2.0.CO;2

Mohino, E., & Losada, T. (2015). Impacts of the Atlantic equatorial mode in a warmer climate. *Climate Dynamics*, *45*(7–8), 2255–2271. https://doi.org/10.1007/s00382-015-2471-y

Mohino, E., & Losada, T. (2023). AGCM experiments Atlantic Nino background [Dataset]. Norstore. https://doi.org/10.11582/2023.00029

Nnamchi, H. C., Li, J., & Anyadike, R. N. C. (2011). Does a dipole mode really exist in the South Atlantic Ocean? *Journal of Geophysical Research*, *116*(D15), D15104. https://doi.org/10.1029/2010JD015579

Park, J. H., Kug, J. S., Yang, Y. M., Sung, M. K., Kim, S., Kim, H. J., et al. (2023). Distinct decadal modulation of Atlantic-Niño influence on ENSO. *npj Climate and Atmospheric Science*, *6*(1), 105. https://doi.org/10.1038/s41612-023-00429-9

Polo, I., Martin-Rey, M., Rodriguez-Fonseca, B., Kucharski, F., & Mechoso, C. R. (2015). Processes in the Pacific La Niña onset triggered by the Atlantic Niño. *Climate Dynamics*, *44*(1), 115–131. https://doi.org/10.1007/s00382-014-2354-7

Prigent, A., Lübbecke, J. F., Bayr, T., Latif, M., & Wengel, C. (2020). Weakened SST variability in the tropical Atlantic Ocean since 2000. *Climate Dynamics*, *54*(5–6), 2731–2744. https://doi.org/10.1007/s00382-020-05138-0

Richter, I., Behera, S. K., Masumoto, Y., Taguchi, B., Sasaki, H., & Yamagata, T. (2013). Multiple causes of interannual sea surface temperature variability in the equatorial Atlantic Ocean. *Nature Geoscience*, *6*(1), 43–47. https://doi.org/10.1038/ngeo1660

Richter, I., Mechoso, C. R., & Robertson, A. W. (2008). What determines the position and intensity of the South Atlantic anticyclone in austral winter?—An AGCM study. *Journal of Climate*, *21*(2), 214–229. https://doi.org/10.1175/2007JCLI1802.1

Richter, I., & Tokinaga, H. (2020). An overview of the performance of CMIP6 models in the tropical Atlantic: Mean state, variability, and remote impacts. *Climate Dynamics*, *55*(9–10), 2579–2601. https://doi.org/10.1007/s00382-020-05409-w

Richter, I., Tokinaga, H., Kosaka, Y., Doi, T., & Kataoka, T. (2021). Revisiting the tropical Atlantic influence on El Niño–Southern Oscillation. *Journal of Climate*, *34*(21), 8533–8548. https://doi.org/10.1175/JCLI-D-21-0088.1

Rodríguez-Fonseca, B., Ham, Y.-G., Lee, S.-K., Martín-Rey, M., Polo, I., & Rodrigues, R. (2019). Interacting interannual variability of the Pacific and Atlantic Oceans. In C. R. Mechose (Ed.), *Interacting climates of ocean basins: Observations, mechanisms, predictability, and impacts* (pp. 120–152). Cambridge University Press.

Rodríguez-Fonseca, B., Polo, I., García-Serrano, J., Losada, T., Mohino, E., Mechoso, C. R., & Kucharski, F. (2009). Are Atlantic Niños enhancing Pacific ENSO events in recent decades? *Geophysical Research Letters*, *36*(20), L20705. https://doi.org/10.1029/2009GL040048

Ruprich-Robert, Y., Msadek, R., Castruccio, F., Yeager, S., Delworth, T., & Danabasoglu, G. (2017). Assessing the climate impacts of the observed Atlantic multidecadal variability using the GFDL CM2.1 and NCAR CESM1 global coupled models. *Journal of Climate*, *30*(8), 2785–2810. https://doi.org/10.1175/JCLI-D-16-0127.1

Smith, T. M., Reynolds, R. W., Peterson, T. C., & Lawrimore, J. (2008). Improvements to NOAA's historical merged land–ocean surface temperature analysis (1880–2006). *Journal of Climate*, *21*(10), 2283–2296. https://doi.org/10.1175/2007JCLI2100.1

Stephenson, D. B., Pavan, V., & Bojariu, R. (2000). Is the North Atlantic Oscillation a random walk? *International Journal of Climatology*, *20*(1), 1–18. https://doi.org/10.1002/(SICI)1097-0088(200001)20:1<1::AID-JOC456>3.0.CO;2-P

Sun, C., Kucharski, F., Li, J., Jin, F.-F., Kang, I.-S., & Ding, R. (2017). Western tropical Pacific multidecadal variability forced by the Atlantic multidecadal oscillation. *Nature Communications*, *8*(1), 15998. https://doi.org/10.1038/ncomms15998

Svendsen, L., Kvamstø, N., & Keenlyside, N. (2014). Weakening AMOC connects equatorial Atlantic and Pacific interannual variability. *Climate Dynamics*, *43*(11), 2931–2941. https://doi.org/10.1007/s00382-013-1904-8

Trenberth, K. E. (1984). Some effects of finite sample size and persistence on meteorological statistics. Part I: Autocorrelations. *Monthly Weather Review*, *112*(12), 2359–2368. https://doi.org/10.1175/1520-0493(1984)112<2359:SEOFSS>2.0.CO;2

Wang, C. (2006). An overlooked feature of tropical climate: Inter-Pacific-Atlantic variability. *Geophysical Research Letters*, *33*(12), L12702. https://doi.org/10.1029/2006GL026342

Wang, L., Yu, J. Y., & Paek, H. (2017). Enhanced biennial variability in the Pacific due to Atlantic capacitor effect. *Nature Communications*, *8*(1), 14887. https://doi.org/10.1038/ncomms14887

Xue, J., Luo, J.-J., Zhang, W., & Yamagata, T. (2022). ENSO–IOD inter-basin connection is controlled by the Atlantic Multidecadal Oscillation. *Geophysical Research Letters*, *49*(24), e2022GL101571. https://doi.org/10.1029/2022GL101571

Yang, Y., Wu, L., Cai, W., Jia, F., Ng, B., Wang, G., & Geng, T. (2022). Suppressed Atlantic Niño/Niña variability under greenhouse warming. *Nature Climate Change*, *12*(9), 814–821. https://doi.org/10.1038/s41558-022-01444-z

Zebiak, S. E. (1993). Air–Sea interaction in the equatorial Atlantic region. *Journal of Climate*, *6*(8), 1567–1586. https://doi.org/10.1175/1520-0442(1993)006<1567:AIITEA>2.0.CO;2

Zhang, R., & Delworth, T. L. (2007). Impact of the Atlantic multidecadal oscillation on North Pacific climate variability. *Geophysical Research Letters*, *34*(23), L23708. https://doi.org/10.1029/2007GL031601

Zhang, W., Jiang, F., Stuecker, M. F., Jin, F.-F., & Timmermann, A. (2020). Spurious North tropical Atlantic precursors to ENSO. *Nature Communications*, *12*(1), 3096. https://doi.org/10.1038/s41467-021-23411-6

Zuidema, P., Chang, P., Medeiros, B., Kirtman, B. P., Mechoso, R., Schneider, E. K., et al. (2016). Challenges and prospects for reducing coupled climate model SST biases in the eastern tropical Atlantic and Pacific Oceans: The U.S. CLIVAR eastern tropical oceans synthesis working group. *Bulletin of the American Meteorological Society*, *97*(12), 2305–2328. https://doi.org/10.1175/BAMS-D-15-00274.1

References From the Supporting Information

Hersbach, H., Bell, B., Berrisford, P., Hirahara, S., Horányi, A., Muñoz-Sabater, J., et al. (2020). The ERA5 global reanalysis. *Quarterly Journal of the Royal Meteorological Society*, *146*(730), 1999–2049. https://doi.org/10.1002/qj.3803