Comment on “Resolving the Tropical Pacific/Atlantic Interaction Conundrum” by Feng Jiang et al. (2023)

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COMMENT
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Key Points:
- Some of the methods used by Jiang et al. (2023) are too simplistic to rule out an Atlantic influence on El Niño
- El Niño usually develops too late in the year to influence the Atlantic zonal mode and can therefore not be its dominant driver
- Jiang et al. (2023) make some valid points but do not offer a complete explanation of Atlantic-Pacific interaction

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Comment on "Resolving the Tropical Pacific/Atlantic Interaction Conundrum" by Feng Jiang et al. (2023)

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Abstract Jiang et al. (2023), https://doi.org/10.1029/2023gl103777 argue that the apparent impact of the equatorial Atlantic on El Niño-Southern Oscillation (ENSO) is a statistical artifact, and that the 6-month lead correlation reported in previous studies stems from early developing ENSO events driving the equatorial Atlantic zonal mode (AZM) in boreal summer and maturing in winter. Closer examination, however, reveals that most AZM events develop too early to be driven by developing ENSO, and that the influence of decaying ENSO events has to be considered too. Thus, while early developing ENSO events may play a role, they do not fully explain observed AZM behavior. Our aim is not to argue for or against an AZM influence on ENSO, but rather to show that Jiang et al.'s analysis is insufficient to resolve this issue. More analysis will be needed for a deeper understanding of Atlantic-Pacific interaction.

Plain Language Summary Jiang et al. (2023), https://doi.org/10.1029/2023gl103777 argue that year-to-year sea-surface temperature variability in the equatorial Atlantic is driven by the equatorial Pacific and suggest that the Atlantic cannot remotely influence the Pacific. They suggest that the influence of the equatorial Atlantic on the equatorial Pacific reported in previous studies is a statistical artifact. The study makes some important points, but it primarily relies on correlation and regression analyses, which can only provide limited insight into causality. In addition, the authors do not fully consider the seasonality of variability patterns in the equatorial Pacific and Atlantic. Thus, their view of the equatorial Atlantic being a slave to the equatorial Pacific is too simplistic and does not account for the full nature of observed variability.

1. The Perceived Conundrum

While El Niño-Southern Oscillation (ENSO) is the dominant variability pattern on interannual time scales, its influence on equatorial Atlantic variability, in particular the Atlantic zonal mode (AZM), is inconsistent (Chang et al., 2006; Lübbecke & McPhaden, 2012; Richter et al., 2024). Conversely, several studies published from the 2000s onward have argued that the AZM, which peaks in boreal summer (JJA; hereafter seasons refer to the Northern Hemisphere), can influence the development of ENSO events, which tend to peak in winter (DJF; Jansen et al., 2009; Rodriguez-Fonseca et al., 2009; Keenlyside et al., 2013; Martin-Rey et al., 2015; Polo et al., 2015; Exarchou et al., 2021; Wang & Wang, 2021; Bi et al., 2022; Zhang et al., 2023). A recent study by Jiang et al. (2023; hereafter J23) proposes that the reported influence of the AZM on ENSO is a statistical artifact and due to the misinterpretation of the 6-month lagged correlation between the Niño 3.4 (sea-surface temperature [SST] anomalies averaged over 170-120°W, 5°S-5°N) and ATL3 (SST anomalies averaged over 20°W-0, 3°S-3°N) indices.

We agree with J23 that the influence of the AZM on ENSO may have been overestimated in some studies. Furthermore, J23 raise a valid point regarding the importance of early developing ENSO events. Nevertheless, we feel that they overstate their case by seemingly suggesting that the AZM has no influence on ENSO. The equatorial Atlantic supports deep convection, which triggers atmospheric waves and influences the Walker

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circulation. These impacts on the circulation will obviously reach the tropical Pacific and induce circulation changes there. Thus, fundamental dynamical considerations mandate that there must be an influence from the Atlantic to the Pacific, even if it may be small. This is also supported by experimentation with comprehensive climate models (e.g., Bi et al., 2022; Ding et al., 2012; Exarchou et al., 2021; Liu et al., 2023), and conceptual models (e.g., Jansen et al., 2009; Zhao et al., 2024).

We would also like to note that the term "conundrum" somewhat overstates the degree of controversy regarding the tropical Atlantic influence on ENSO. Most studies that have attempted to quantify this influence have concluded that it is small but not negligible (Jansen et al., 2009; Exarchou et al., 2021; Richter al. 2021, 2023; Liu et al., 2023; Zhao et al., 2024; see also the discussion of previous results in Richter et al., 2021). As such, there is less of a conundrum than the characterization by J23 suggests.

Most importantly, we believe that J23 do not fully consider the details of the seasonality of both the AZM and ENSO, and that some of their interpretations are oversimplified, as discussed below. We therefore would like to provide additional context and explain why we believe that a resolution of the Atlantic-Pacific interaction conundrum, or rather a deeper understanding of Atlantic-Pacific interaction, has yet to be accomplished. We stress that our focus is on the methodology and interpretation used in J23, rather than making the case for an Atlantic influence on ENSO.

2. The Limitations of Linear Regression Analysis

In Figure 1c of J23, the authors aim to estimate the contribution of the equatorial Atlantic to ENSO prediction skill. Using multiple linear regression, they find that the ATL3 index adds no skill over a prediction that solely relies on the autocorrelation of the Niño 3.4 index, which leads them to conclude that the equatorial Atlantic does not contribute to ENSO evolution. This argument, however, is too simplistic. We have reproduced the results of J23 using the same HadISST data set (Rayner et al., 2003) as J23 but extended the analysis by four lead months (Figure 1a), using the first half of the data set as training and the second half as test data. Next, using a similar regression method as J23, we predict the ATL3 index using its autocorrelation and the Niño 3.4 index (Figure 1b). Including the latter does not improve prediction skill for lead times up to 9 months. Following the reasoning of J23, this would suggest that ENSO cannot influence the AZM, which contradicts their own hypothesis. We stress that we do consider ENSO to be an important influence on the equatorial Atlantic. Our analysis, however, shows that a simple linear regression analysis is not sufficient to fully quantify influences between the two basins in either direction.

The strength of the AZM-ENSO linkage is known to undergo decadal fluctuations (Martin-Rey et al., 2014; Park et al., 2023). We have tested if this influences our results by swapping the training and testing periods (light blue and red lines in Figures 1a and 1b) but found no qualitative differences. We have also analyzed the period 1968–2000, which presumably featured stronger interaction between the two basins (Martin-Rey et al., 2014), but obtained the same qualitative result: The second predictor fails to add skill for both the Niño 3.4 and the ATL3 prediction (not shown).

Regarding Figure 1a, we note that there is a considerable skill gain for the four longest lead times not considered in J23, albeit not statistically significant at the 95% confidence level. Despite the caveats raised above, this might warrant further analysis.

3. The Details of ENSO and AZM Seasonality Matter

3.1. The Influence of Decaying ENSO Events Cannot Be Neglected

J23 argue that in April-May-June (AMJ) the AZM is strongly influenced by developing ENSO events but not by decaying ones. The only explanation J23 offer for this asymmetric influence is that ENSO events decay too quickly to be important in AMJ. This, however, is not supported by observations. During the period 1979–2020, there were 21 years for which the AMJ Niño 3.4 index exceeded 0.5 standard deviations. Of these, 12 were developing and 9 were decaying. Based on this, one would expect a lead-lag relation between ENSO and the AZM that is roughly symmetric about lag 0. We illustrate this point with a simple statistical model.

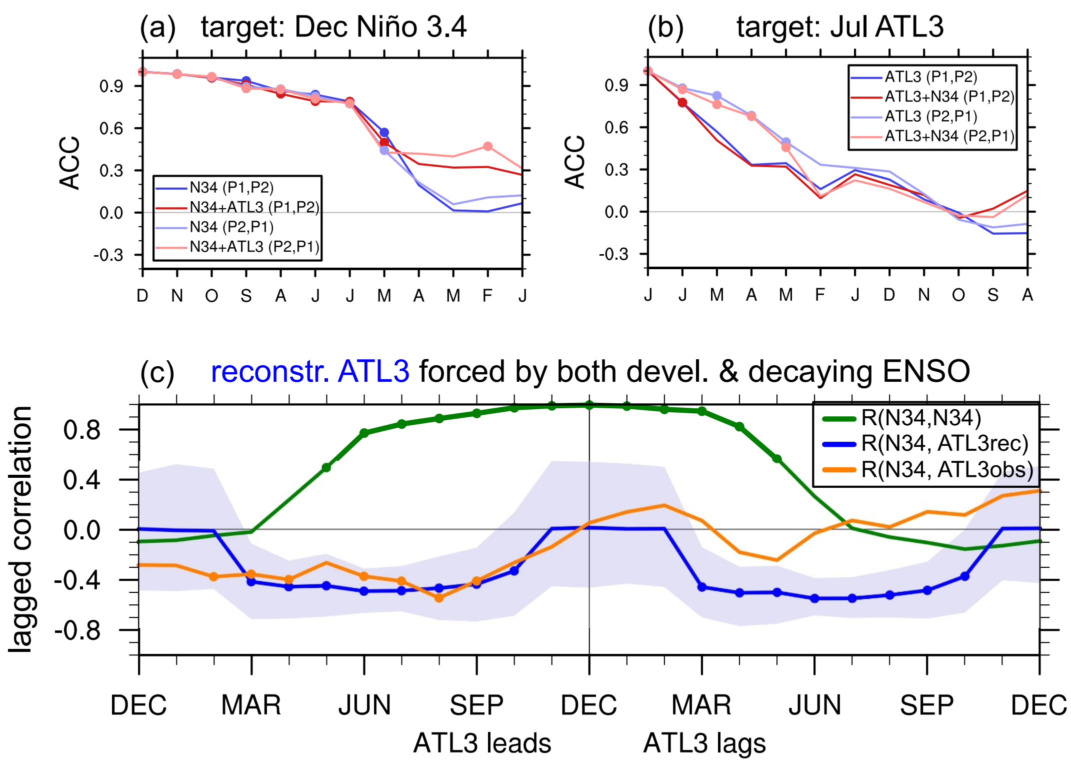

Figure 1. (a) Anomaly correlation coefficient (ACC) skill for the December Niño 3.4 index as a function of initialization month. Prediction is based on multiple linear regression using Niño 3.4 only (blue lines) or Niño 3.4 and ATL3 (red lines). The training period is 1979–1999 (P1; dark blue line) or 2000–2020 (P2; light blue line). Likewise, the corresponding test periods are P2 (dark red line) or P1 (light red line). The SST are from HadISST. Values significant at the 95% confidence level are indicated by filled circles. (b) Similar to (a) but for the prediction of the July ATL3 using the ATL3 only (blue lines) or the ATL3 and Niño 3.4 (red lines). (c) Lagged correlations of the HadISST Niño 3.4 index with itself (green line), with the HadISST ATL3 index (orange line), and with the reconstructed ATL3 index (blue line). The reconstruction is based on the Niño 3.4 index forcing an opposite-signed Atlantic Zonal Mode (AZM) event if its absolute value exceeds 0.5 standard deviations in April-May-June (AMJ). The blue line represents the average over 1000 perturbed correlations (calculated via the z-transformation), with random noise added to the ATL3 index. The envelope shows the range of all correlations. Filled circles indicate statistical significance at the 95% confidence level.

3.2. A Simple Statistical Model of the AZM Based on J23's Hypothesis

Following J23, we assume that ENSO events drive an opposite-signed AZM event if the absolute value of the AMJ Niño 3.4 index exceeds 0.5 standard deviations. For those years, we prescribe the ATL3 index according to the evolution of a composite mean AZM event with a peak in June. In the remaining years the ATL3 index is set to zero. A noise term is added to the entire ATL3 time series by randomly permuting the years of the original standardized ATL3 time series and multiplying by 0.2. The noise amplitude is chosen such that the correlation of the ATL3 leading the Niño 3.4 is comparable to observations, while also roughly reproducing AZM inter-event variation. As expected, the resulting cross-correlation with the Niño 3.4 index is approximately symmetric about lag 0, with significant negative correlations for both leading and lagging ATL3 (Figure 1c). Moreover, based on our random perturbations, the negative correlation when the ATL3 lags is significantly different from the observed values (orange line in Figure 1c), with a p-value less than 0.001. Thus J23's hypothesis that the AMJ Niño 3.4 controls the AZM is inconsistent with observations.

3.3. ENSO Development is Usually Too Late to Influence the AZM

Even if one does assume that, for some reason, decaying ENSO events cannot influence the AZM, one has to pay close attention to the seasonality of the two variability modes. The AZM typically develops in February or March and peaks in June (Keenlyside & Latif, 2007; Lübbecke et al., 2018; Richter & Tokinaga, 2021). ENSO, on the other hand, usually develops in May or June (e.g., Figure 2a of J23). Furthermore, observational analysis shows that the influence of ENSO on equatorial Atlantic surface winds is strongest in April (Münnich & Neelin, 2005; Richter & Doi, 2019; Richter et al., 2024; Sasaki et al., 2015). Thus, most ENSO events develop too late to have a substantial influence on AZM development. In addition, one has to consider that local coupled feedbacks govern the equatorial Atlantic in May and June (Deppenmeier et al., 2016; Keenlyside & Latif, 2007; Nnamchi et al., 2021; Richter et al., 2017). Thus, it seems that there is only a limited role for ENSO to play during AMJ. Rather, February through April (FMA) should be the season for ENSO to assert its influence on the AZM. Most ENSO events, however, develop after FMA.

The above discussion suggests that the argument of J23 has some merit, but that AMJ is too late to assess the impact of ENSO on the AZM, and that one has to explain why decaying ENSO events cannot influence the AZM.

4. Discussion

J23 claim to have "resolved" the Atlantic/Pacific conundrum but a closer look at their analysis reveals that open questions remain, and new ones arise. Despite our critique, we believe that J23 make a valid observation regarding the importance of early ENSO development for the influence on the AZM. However, one also has to consider the role of late ENSO decay (Richter et al., 2024; Tokinaga et al., 2019). Both early onset and late decay entail substantial Niño 3.4 SST anomalies in spring, which are associated with a robust dynamical impact on equatorial Atlantic surface winds (Richter et al., 2024; Sasaki et al., 2015). There is, however, also a thermodynamic impact (Chang et al., 2006) through the tropospheric temperature adjustment (Chiang & Sobel, 2002), which opposes the dynamic impact. For early developing ENSO events, the thermodynamic impact is expected to be small, but for late decaying ENSO events it has time to accumulate. This may explain why the cross-correlation is low when the ATL3 lags the Niño 3.4. In addition, oceanic Rossby waves in the northern tropical Atlantic excited by wind stress curl anomalies can have a delayed impact on the AZM (Lübbecke & McPhaden, 2012). We also note that J23's argument does not explain the secondary peak of the AZM during winter (Keenlyside & Latif, 2007; Okumura & Xie, 2006) and its suggested impact on ENSO (Hounsou-Gbo et al., 2020).

The Atlantic-Pacific linkage may be further complicated by interaction with other regions, including the tropical Indian Ocean (Liao & Wang, 2021; Zhang & Han, 2021). The extended recharge oscillator used by J23 is a good starting point to explore this but may need further refinement for representing the highly seasonal interaction between the equatorial Atlantic and Pacific.

Finally, our analysis illustrates how multiple linear regression and related linear analysis can easily produce conflicting results when used to assess interbasin interaction. This applies not only to J23 but to many other related studies in the field. It is therefore important to examine interbasin interactions using multiple lines of evidence. One approach is the use of coordinated multi-model pacemaker experiments that allow evaluating the influence of model biases and can illuminate the reasons for divergent estimates of the Atlantic influence on ENSO obtained in previous modeling studies. Such experiments are currently being conducted by the Climate and Ocean: Variability Predictability and Change (CLIVAR) Research Focus on Tropical Basin Interaction (https://www.clivar.org/documents/description-coordinated-gcm-experiments-study-tropical-basin-interaction).

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Conflict of Interest

The authors declare no conflicts of interest relevant to this study.

Data Availability Statement

The HadISST data is publicly available from https://www.metoffice.gov.uk/hadobs/hadisst/data/download.html.

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