The Role of the Tropical Atlantic in Tropical Pacific Climate Variability

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Interactions between Atlantic and Pacific Oceans can affect tropical Pacific variability and its global impacts at both interannual and decadal timescales. Thus, a deeper understanding of the coupled Atlantic-Pacific interactions is needed. While possible dynamical mechanisms by which the Atlantic can influence the Pacific have been identified, the effectiveness of those mechanisms is difficult to establish using climate model simulations where Atlantic SSTs are prescribed and Pacific feedbacks cannot be realistically included. Thus, as an alternative approach, here we use a Linear Inverse Model (LIM) trained on observations and capable of correctly reproducing the observed statistics, to assess the relative role of the Atlantic-to-Pacific and Pacific-to-Atlantic influences on tropical Pacific variability.

The Linear Inverse Models

$\frac{dx}{dt} = Lx + \xi$, x State vector

L Dynamical operator

ξ Stochastic forcing, white in time, but spatially coherent

$$x = \begin{bmatrix} x_P \\ x_A \end{bmatrix} \quad \frac{dx}{dt} = \frac{d}{dt}\begin{bmatrix} x_P \\ x_A \end{bmatrix} = \begin{bmatrix} L_{PP} & L_{AP} \\ L_{PA} & L_{AA} \end{bmatrix} \begin{bmatrix} x_P \\ x_A \end{bmatrix} + \begin{bmatrix} \xi_P \\ \xi_A \end{bmatrix}$$

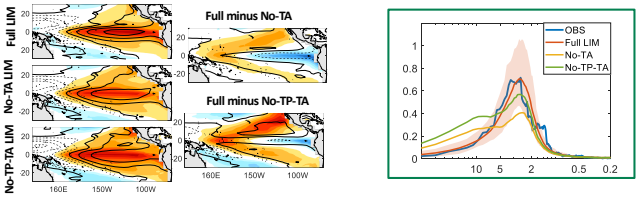
L_{AP} represents the Atlantic influence on the Pacific, while L_{PA} encapsulates the Pacific influence on the Atlantic.

To understand the nature of the interactions between the two tropical basins, we complement the **Full LIM** with two additional LIMs:

No-TA LIM :
$L_{AP} = 0$, and L_{PA}=0. Pacific and Atlantic are completely decoupled.

No-TP-TA LIM:
L_{PA}=0 No Pacific influence on the Atlantic is allowed. Atlantic variability is entirely governed by internal Atlantic dynamics, but the Atlantic influence on the Pacific is allowed.

How does the Atlantic affect the spatial pattern and spectral characteristics of Pacific variability?



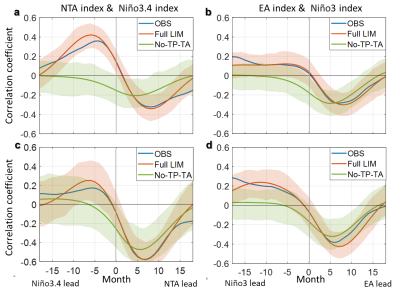
Fully decoupling Pacific and Atlantic (no-TA-LIM) reduces variability in the eastern equatorial Pacific, but increases variability in the central Pacific and in the area of the Pacific Meridional Mode. In the no-TP-TA LIM the amplitude reduction in the eastern Pacific is more limited and variability in the central and subtropical regions is further enhanced.

Full LIM (red line) can reproduce the observed spectrum (blue line), well within the spread of 100 LIM ensembles. Completely decoupling the Atlantic and Pacific severely reduces power at interannual timescales, but enhances the power at decadal timescales. Further enhancement of decadal power is found in the no-TP-TA LIM.

Can the Full LIM represents the statistical relationships between ENSO and Atlantic modes?

The leading modes of tropical Atlantic variability are: the Northern Tropical Atlantic (NTA) mode, which peaks in boreal spring, and the equatorial Atlantic Niño, also known as Equatorial Atlantic (EA) mode, with anomalies in the eastern equatorial Atlantic, peaking in boreal summer. The NTA is described by the **NTA index** (average SST anomalies in 0°–15°N, 90°W–0°), while the EA mode is usually described by the **Atl3 index** (average SST anomalies in 20°W-0°W, 3°S-3°N).

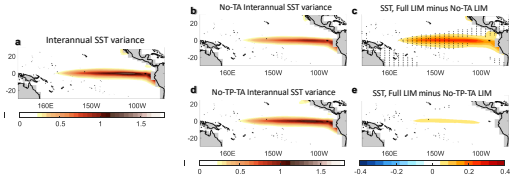
The NTA mode is considered a response to ENSO, but may also contribute to ENSO events of the opposite sign in the following fall-winter. The EA mode has also been suggested to contribute to the development of ENSO events of the opposite sign. These relationships have been suggested to be spurious, and resulting from the ENSO cyclic nature and seasonal phase locking. Here we use the LIM to assess the role of Atlantic influences.



Lead-lag correlation coefficients between (a) NTA index and Niño3.4 index, (b) EA index (Atl3 index) and Niño3 index. The thick blue lines are for ORAS5 (1958-2023), and thick red/green lines show the ensemble mean of 100 Full LIM/No TP-TA LIM samples. The red/green shading shows the 90% confidence level obtained by the LIM ensembles. (c) Similar to (a), but using data from 1990-2016. (d) Similar to (b), but using data from 1970-2016. The lead-lag relationships do not change appreciably if different ENSO indices are used.

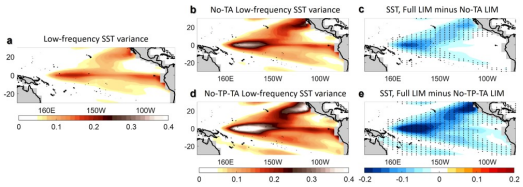
Main takeaways:
- Negative correlations with the Atlantic leading the Pacific are found also in the absence of a Pacific influence on the Atlantic, indicating that internal Atlantic dynamics can affect ENSO.
- Relationships are non-stationary. The influence of the NTA on ENSO is stronger after 1990, and influence of the EA on ENSO is stronger after 1970.

Influence of Pacific-Atlantic coupling on Pacific interannual variance



When the Pacific and Atlantic are fully decoupled there is a significant reduction of interannual variance in the eastern equatorial Pacific. This change in variance is independent of the presence of any Pacific influence on the Atlantic, indicating that it is due to internal Atlantic dynamics.

Influence of Pacific-Atlantic coupling on Pacific decadal variance



Fully decoupling the Atlantic and Pacific (no-TA LIM) results in increased decadal variance in the central equatorial Pacific and along the footprint of the Pacific Meridional Mode. When the Pacific influence on the Atlantic is inhibited (no-TP-TA LIM) decadal variance in the Pacific is further enhanced. This indicates that the Atlantic alone can contribute to Pacific decadal variability through the PMM, but Pacific feedbacks on the Atlantic significantly reduce both the Atlantic influence on the Pacific as well as internally-generated Pacific decadal variability.

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