Multidecadal variability of South Atlantic and Connections with ENSO

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1. INTRODUCTION

The so-called "Atlantic Niño" is associated with the large seasonal upwelling occurring in the eastern equatorial basin during the boreal summer. Previous studies have indicated a complex teleconnection between this summer Atlantic event and the Pacific El Niño Southern Oscillation (ENSO). It has been shown that ENSO influences the subsequent Atlantic Niño variability, however, due to a destructive ocean atmosphere interactions in the Atlantic this impact appears to be weak. Other studies have shown a significant negative relationship between the summer Atlantic Niño and ENSO, with the Atlantic leading the Pacific by about 6-month. This lagged negative teleconnection between the Atlantic and Pacific Niño's was strong during the first and last decades of the Twentieth Century and weak between these periods.

The eastern equatorial Atlantic is characterized by another weak seasonal cooling in late fall/early winter. This second Niño-type mode is called here "winter Atlantic Niño".

On the other hand, previous studies have shown a close connection between the summer Atlantic Niño and the South Atlantic Ocean Dipole (SAOD).

The present study investigates the multidecadal variability of the South Atlantic Ocean and its connection with the Pacific ENSO variability.

2. DATA AND METHODS

Data: 1900-2014 (115 years)

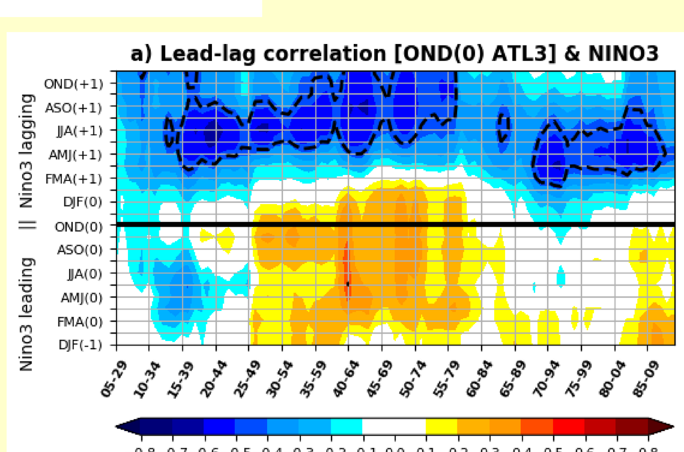
- Sea surface temperature (SST) from hadISST.
- Reanalysis of Wind vectors, omega (vertical velocity), and sea level pressure (SLP) from Twentieth Century Reanalysis (20CR).

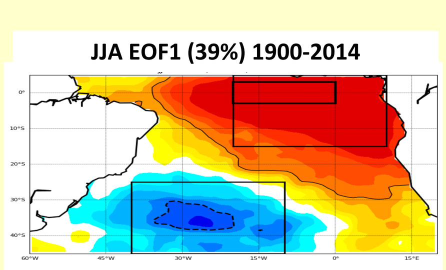
Methods

Already known climatic indices ATL3 (20°W-0°, 3°S-3°N) and Niño3 (150°-90°W, 5°S-5°N) are used to define Atlantic and Pacific Niños.
The seasons (three consecutive months) corresponding to the year of Atlantic Niño events are indicated by (0), e.g., July-August-September(0) (JAS(0)), and those of the year following the Atlantic Niño are indicated by (1) October-November-December(1) (OND(0)).

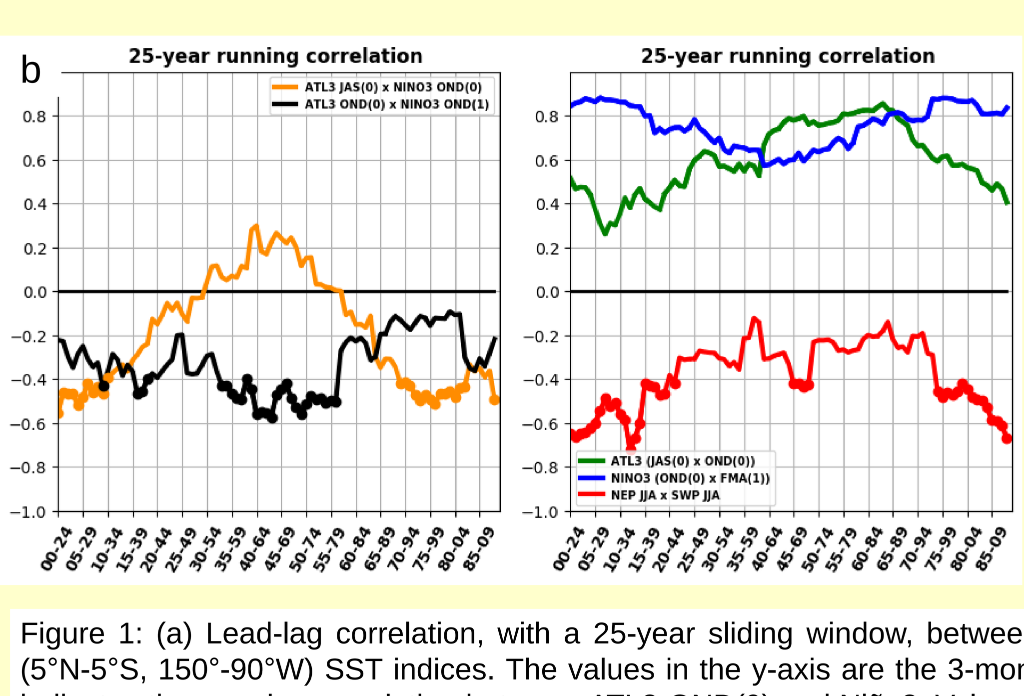
We split Atlantic Niño events that exceed the ±0.35°C threshold into non-persistent summer Atlantic Niño (JAS(0)-ATL3) and fall/early winter Atlantic Niño (OND(0)-ATL3). The non-persistent summer ATL3 are warm/cold events in JAS that do not persist until OND. The winter ATL3 events are warm/cold events in OND, independently if they persist or not from JAS.
According to this selection criteria, 14 positive (i.e. warm events) and 17 negative (cold events) JAS-ATL3 events were considered. On the same way, 19 positive and 13 negative OND-ATL3 events were selected.

3. RESULTS





Souh Atlantic Ocean Dipole (SAOD);
SAOD index = NEP - SWP
-**Northeastern pole** (NEP: 5N-15S; 20W-10E)
-**Southwestern pole** (SWP: 45S-25S; 40W-10W)



Multidecadal modulation:

-Running correlation between JAS(0) ATL3 and OND(0) Niño3
-Running correlation between OND(0) ATL3 and OND(1) Niño3
-Persistence of ATL3 from JAS to OND
-Persistence of Niño3 from OND to FMA
-Correlation JJA NEP vs JJA SWP

Figure 1: (a) Lead-lag correlation, with a 25-year sliding window, between OND(0)ATL3-OND(0) (3°N-3°S, 20°W-0°) and Niño3 (5°N-5°S, 150°-90°W) SST indices. The values in the y-axis are the 3-month mean of Niño3. The horizontal black line at OND(0) indicates the zero-lag correlation between ATL3-OND(0) and Niño3. Values below (above) OND(0) indicate Niño3 leading (lagging) ATL3-OND(0). Contours indicate correlation significant at 95% confidence level using t-test; (b) Evolutions of the 25-year sliding window correlation between ATL3-JAS(0) and Niño3-OND(0) (**orange line**), ATL3-OND(0) and Niño3-OND(1) (**black line**), ATL3-JAS(0) and ATL3-OND(0) (**green line**), Niño3-OND(0) and Niño3-FMA(1) (**blue line**), and NEP-JJA and SWP-JJA (**red line**). Each value in x-axis (Figures 1a and 1b) represents the running correlation of 25 consecutive years. Dots indicate 95% confidence level.

Main comments of Fig. 1:
The winter Atlantic Niño is significantly negatively correlated (Fig. 1a) with the following Niño3 during several decades of the 1900-2014 study period. The highest lead time, i.e. nearly one-year lead, is marked from 1940s to 1970s, while the weakest lead time of about 6-month is observed before and after this period. The negative relationship between the summer ATL3 and the subsequent winter ENSO is highly significant (<-0.45) during the first and last decades of the study period (**orange dots** in Fig. 1b). This lowest negative relationship (even positive in the middle of twentieth Century) is observed (**orange line** in Fig. 1b) when the winter Atlantic Niño is strongly negatively correlated with the one-year lag ENSO (**black line** in Fig. 1b). A significant negative connection between summer Atlantic Niño and the subsequent winter Pacific ENSO (**orange dots** in Fig. 1b) is associated with weaker duration of summer ATL3 (green line) and higher duration of winter Niño3 (blue line).
During high persistence of Atl3, the NEP and SWP of the SAOD are weakly negatively correlated (**red line**).

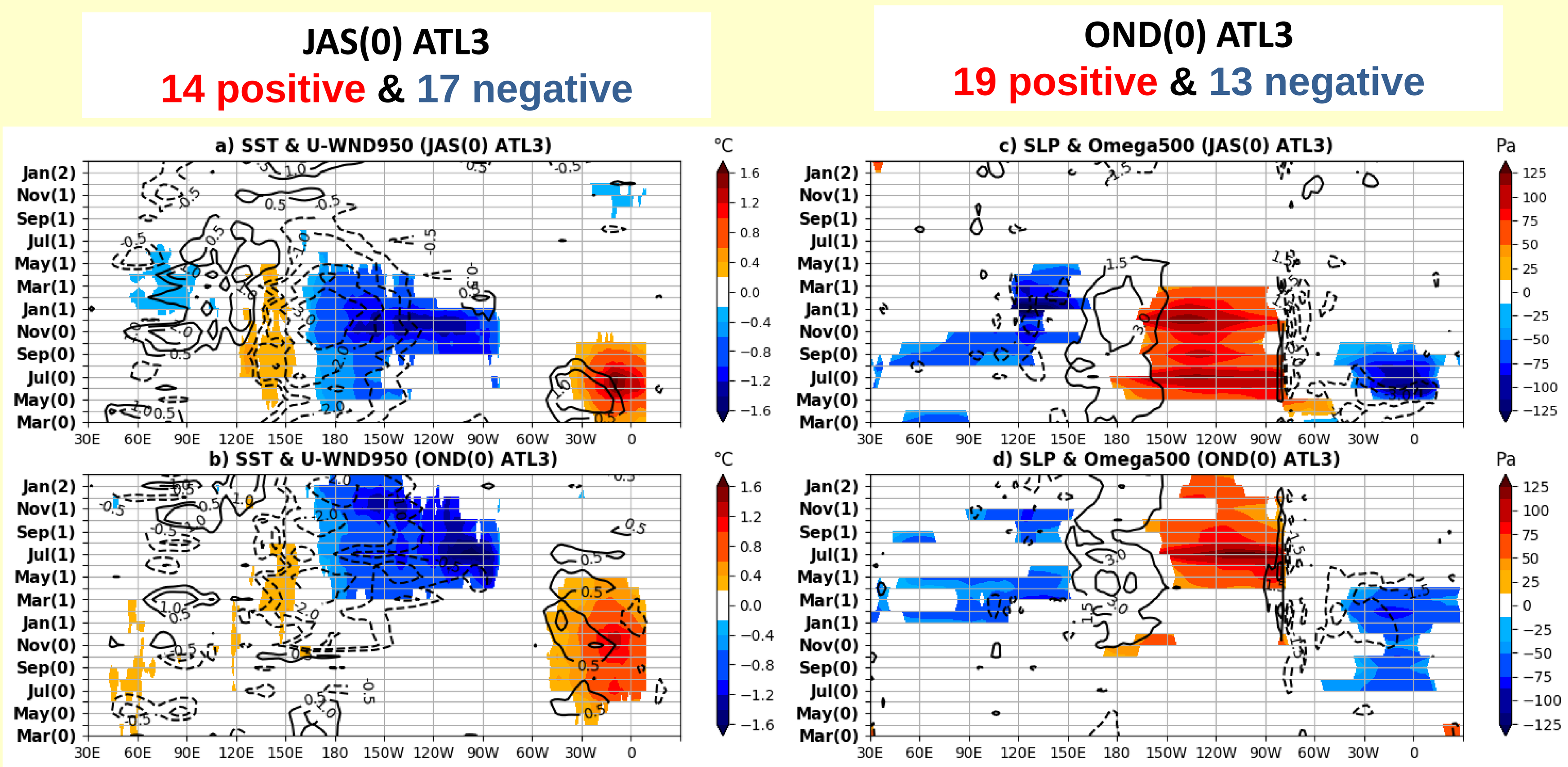


Figure 2: Longitude-time diagram of the difference of composite of: SST (shading, °C) and zonal wind (contours, m/s) anomalies (a and b); sea level pressure (shading, Pa) and 500 hPa vertical velocity (negative upward, contours, 10-2 Pa/s) anomalies (c and d) for ATL3-JAS(0) and ATL3-OND(0). All anomalies are averaged between 3°N-3°S. Dashed/full lines indicate negative/positive values for zonal wind and vertical velocity anomalies. Only difference significant at 95% and 90% confidence level according to Welch's test is shown for SST and SLP anomalies, respectively

Main comments of Figs. 2:
Positive/negative SST anomalies in the ATL3 region, associated with low/high surface pressure anomalies, induce simultaneously anomalous ascending/descending motion in the equatorial Atlantic and lagged anomalous descending/ascending motion in the central equatorial Pacific through perturbations on the Walker circulation. The induced anomalous easterly/westerly wind in the central equatorial Pacific is associated with shallower/deeper thermocline and negative/positive SST anomalies in the eastern equatorial Pacific.

However, in the case of winter Atlantic Niño events, the Pacific oceanic response to the perturbation in the Walker circulation is strong from summer(1) onwards. The weak ocean-atmosphere interaction in spring could be one reason for this delayed teleconnection.

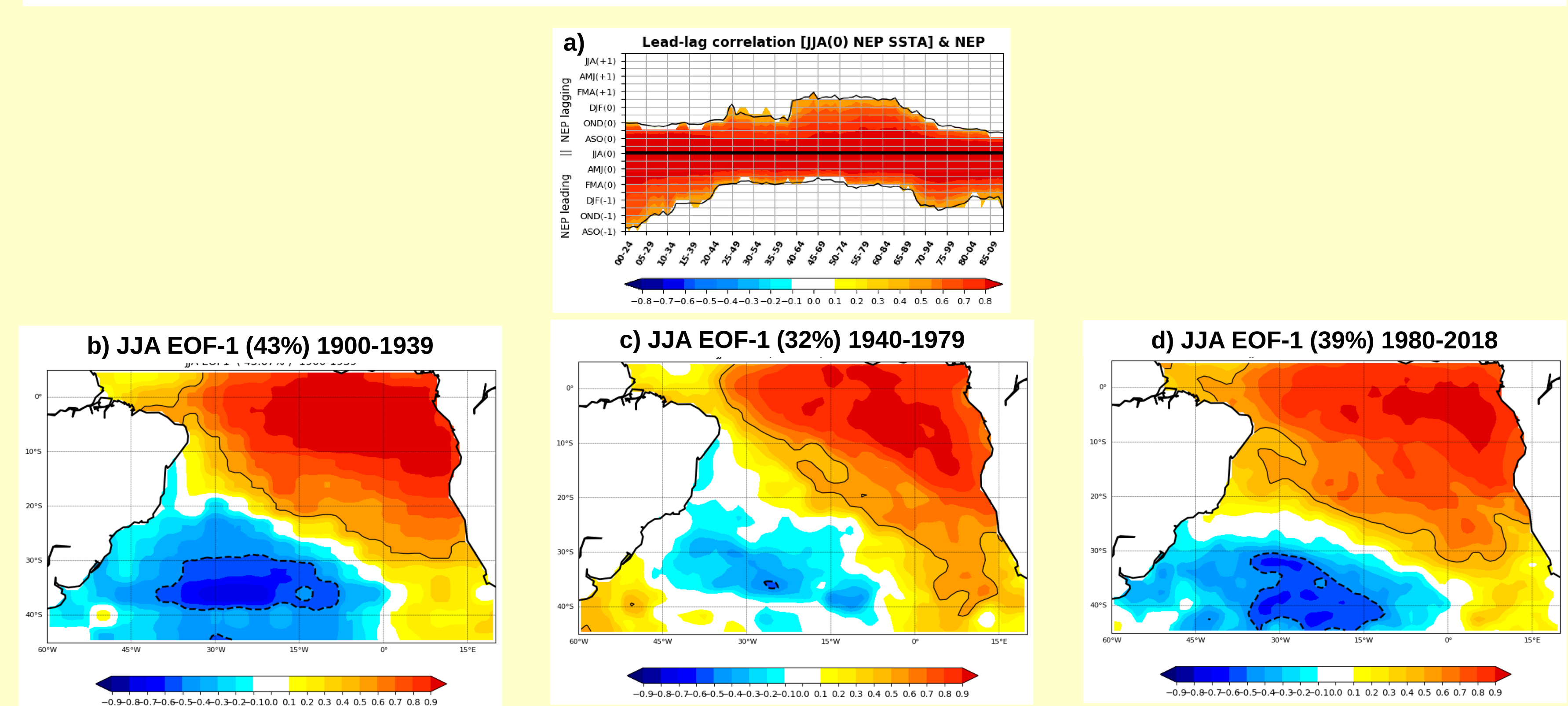


Figure 3: (a) autocorrelation of the June-August (JJA) Northeastern pole of the SAOD (NEP: 5N-15S; 20W-10E) as function of the lead time (y-axis), with a 25-year sliding window. The values in the y-axis are the 3-month mean of the NEP. The horizontal black line at JJA(0) indicates the zero-lag autocorrelation of the JJA(0) NEP. (b-d) Spatial patterns of the first Empirical orthogonal function (EOF-1) of JJA SST anomalies in the South Atlantic based on HadISST for the period: (b) 1900-1939, (c) 1940-1979 and (d) 1980-2018.

Main comments of Figs. 3:
Multidecadal modulation of the persistence of the Northeastern pole (NEP) of the SAOD mode (Fig. 3a). In the first and last decades of the study period, the **JJA NEP SSTA** is highly correlated with previous **winter NEP SSTA** and does not persist beyond the subsequent **fall**. In the middle of the study period, the **JJA NEP SSTA** is highly correlated with previous **spring NEP SSTA** and persists until the following **winter**.

The summer SAOD mode is clearly defined in the first and last decades (Fig. 3b and 3d) of the study period and weak in the middle of the 20th century (Fig. 3c).

4. CONCLUSIONS

- We identified an inverse relationship between the winter Atlantic Niño occurring in OND and the Pacific ENSO, when Atlantic leads ENSO by 6-month to nearly one-year.

- The highest values of the nearly 1-year lead negative relationship between the winter Atlantic Niño and ENSO are marked during decades of lowest correlation between the summer Atlantic Niño and the subsequent winter Pacific ENSO.

- As for the impact of summer Atlantic Niño on ENSO, the winter Atlantic Niño influences ENSO through atmospheric bridge. Positive/negative SST anomalies in the equatorial Atlantic affect the Walker circulation with anomalous ascending/descending branch over the Atlantic and descending/ascending branch in the central equatorial Pacific.

-Weak connection between the northeastern pole (NEP) and the southwestern pole (SWP) of the south Atlantic Ocean Dipole (SAOD) in summertime, during the middle of the 20th century. This weak correlation coincides with the high persistence of the summer NEP (and Atlantic Niño).

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