Seasonal Influence of ENSO on the Atlantic ITCZ and Equatorial South America

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Abstract

In late boreal spring, especially May, a strong relationship exists in observations among precipitation anomalies over equatorial South America and the Atlantic intertropical convergence zone (ITCZ), and eastern equatorial Pacific and central equatorial Atlantic sea surface temperature anomalies (SSTA). A chain of correlations of equatorial Pacific SSTA, western equatorial Atlantic wind stress (WEA), equatorial Atlantic SSTA, sea surface height, and precipitation supports a causal chain in which El Niño/Southern Oscillation (ENSO) induces WEA stress anomalies, which in turn affect Atlantic equatorial ocean dynamics. These correlations show strong seasonality, apparently arising within the atmospheric links of the chain. This pathway and the influence of equatorial Atlantic SSTA on South American rainfall in May appear independent of that of the northern tropical Atlantic. Brazil's Nordeste is affected by the northern tropical Atlantic. The equatorial influence lies further to the north over the eastern Amazon and the Guiana Highlands.

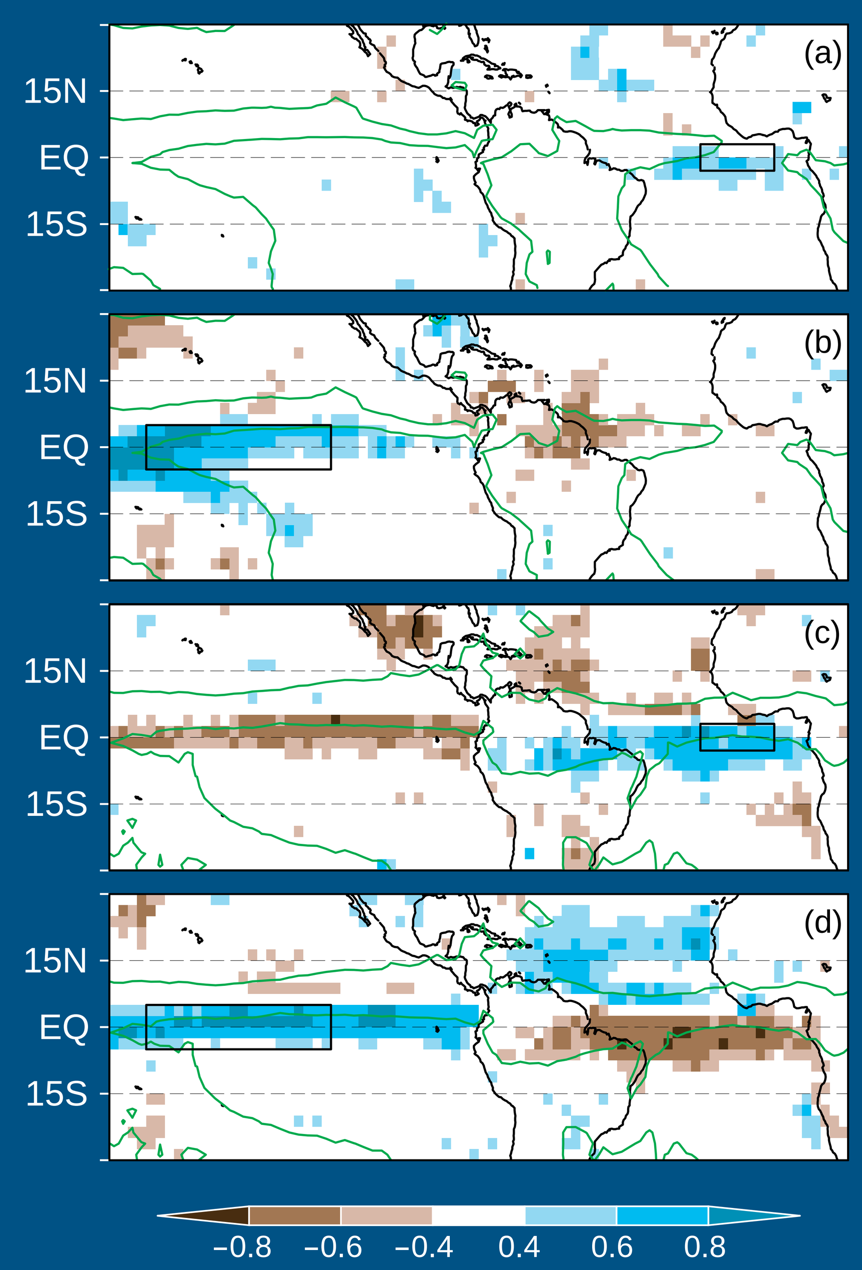

Fig. 1: Comparison of rank correlation maps of SSTA indices with concurrent precipitation in (a, b) January and (c, d) May. The index regions (black rectangles) are (a, c) Atl-3 and (b, d) Niño-3.4. Green contours indicate 4 mm/day climatological precipitation.

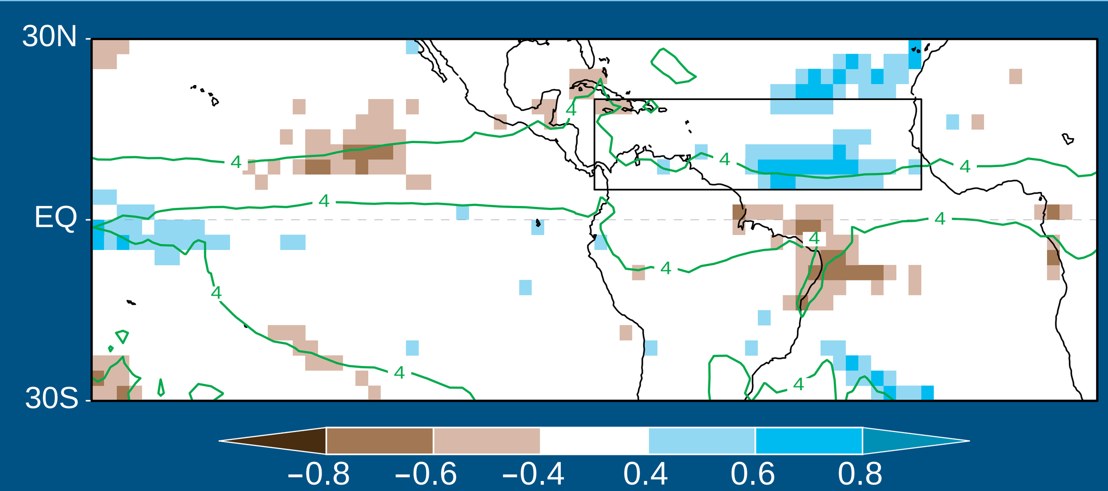

Fig. 5: Rank correlation maps of average SSTA in NTA (black rectangle) with precipitation in May. Green contours indicate 4 mm/day climatological precipitation.

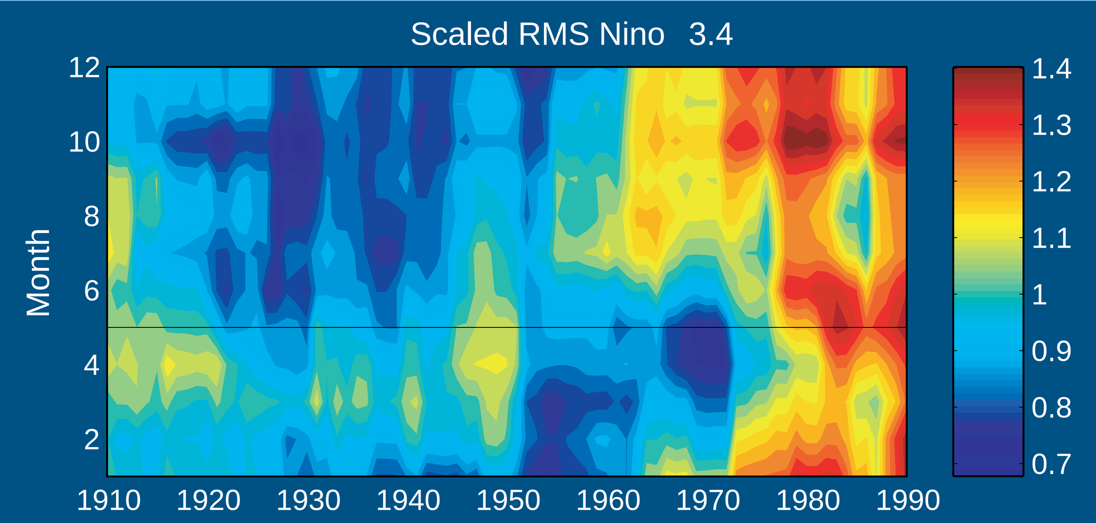

Fig. 6: Relative change of standard deviation of Niño-3.4 for each month with time for a centered 21-year window.

Discussion

Rank correlation maps of index time series for the equatorial Pacific and Atlantic show that precipitation anomalies over equatorial South America are linked with concurrent sea surface temperature (SST) anomalies in the equatorial Pacific and Atlantic. In May the area of strong correlation is markedly larger than in other months, extending farther to the south and reaching deep into equatorial South America. correlation maps of index time series for the equatorial Pacific and Atlantic show that precipitation anomalies over equatorial South America are linked with concurrent sea surface temperature (SST) anomalies in the equatorial Pacific and Atlantic. In May the area of strong correlation is markedly larger than in other months, extending farther to the south and reaching deep into equatorial South America.

The likely reason for this can be seen in Fig. 1 which compares correlation maps of precipitation in January and May with ENSO (Nino-3.4) and the Atlantic Nino (Atl-3). In January the correlation patterns are distinct with Nino-3.4 linked to drying over the Guiana region while the area of significant Atl-3 correlation is confined to the immediate neighborhood of the index region. In contrast, the May (Fig. 1c,d) patterns are almost mirror images.

Indeed, while ENSO and the Atlantic Niño vary independently during most of the year, they correlate well in late boreal spring and early summer, for the analyzed period of satellite data (Fig. 2, circles).

The Atlantic SST and wind stress anomaly patterns associated with Atlantic Nino and ENSO in May are depicted in Fig. 3 The regression map of negative Nino-3.4 (Fig. 3a) with SST anomalies (SSTA) marks the areas of equatorial and coastal upwelling and is weaker but otherwise similar to the regression map of Atl-3 which exemplifies and Atlantic Nino. The similarity also hold for the wind stress patterns. Differences occur in the northern tropical Atlantic (NTA). Note that the correlation patterns of wind stress and SST anomalies do not correspond well, indicating that evaporative feedbacks are unlikely to be the main cause for these SSTAs.

A map (Fig. 4) of correlation of sea-surface height anomalies (SSHA) with zonal wind stress anomalies (WEA) over the western equatorial Atlantic confirms the remote connection, presumably through equatorial wave dynamics. Positive SSTA peaks in the Atl-3 region with negative off-equatorial SSHA to the west, reminiscent of the observed equatorial Kelvin and Rossby wave packets of ENSO. The higher correlations from April through August of Nino-3.4 with WEA (Fig. 2, triangles) is higher than with Atl-3 (Fig. 2, circles) are another indication that WEA are part of the causal chain from Nino-3.4 to equatorial Atlantic SSTA.

A comparison of Fig. 5 and Fig.1c reveals a difference in the spatial patterns of influence on precipitation of analyzed equatorial Atlantic SSTA and the known spring influence of the northern tropical Atlantic SSTA. The latter (Fig. 5) influences rain over Brazil's Nordeste whereas the equatorial influence lies further northwest over the Amazon and the Guiana Highlands.

The influence of ENSO on the equatorial Atlantic in spring has been strong in recent decades. A likely reason for this is shown in Fig. 6 which illustrated the long term change of Nino-3.4 standard deviation for each month of the year. Not only have ENSO been recently strong but the biggest percentage increase of ENSO occurred in October and May while in the 1960s and 1970s ENSO was very weak.

Datasets and Analysis Periods

Precipitation: CPC Merged Analysis of Precipitation (CMAP) (1/1982-9/2003)

Sea Surface Temperature (SST): NOAA OI Version 2 (1/1982-9/2003)

Sea Surface Height: Merged Topex/Poseidon and ERS, AVISO CLS (1/1993-9/2003)

Wind Stress: ECMWF ERA-40 (1/1982-8/2002)

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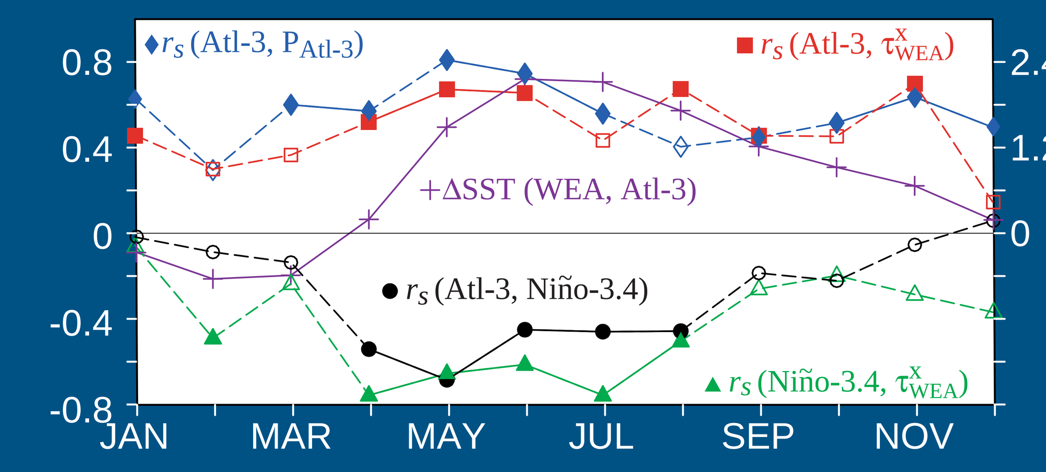

Fig. 2: Monthly rank correlation of Atl-3 with (circles) Niño-3.4, (squares) zonal wind stress anomalies in the western equatorial Atlantic (WEA) and (diamonds) precipitation anomalies in the Atl-3 region and of Niño-3.4 with (triangles) zonal wind stress in WEA. Solid markers indicate correlations above the 95% significance level. Crosses give the climatological mean monthly temperature difference between SST in WEA and Atl-3 in C.

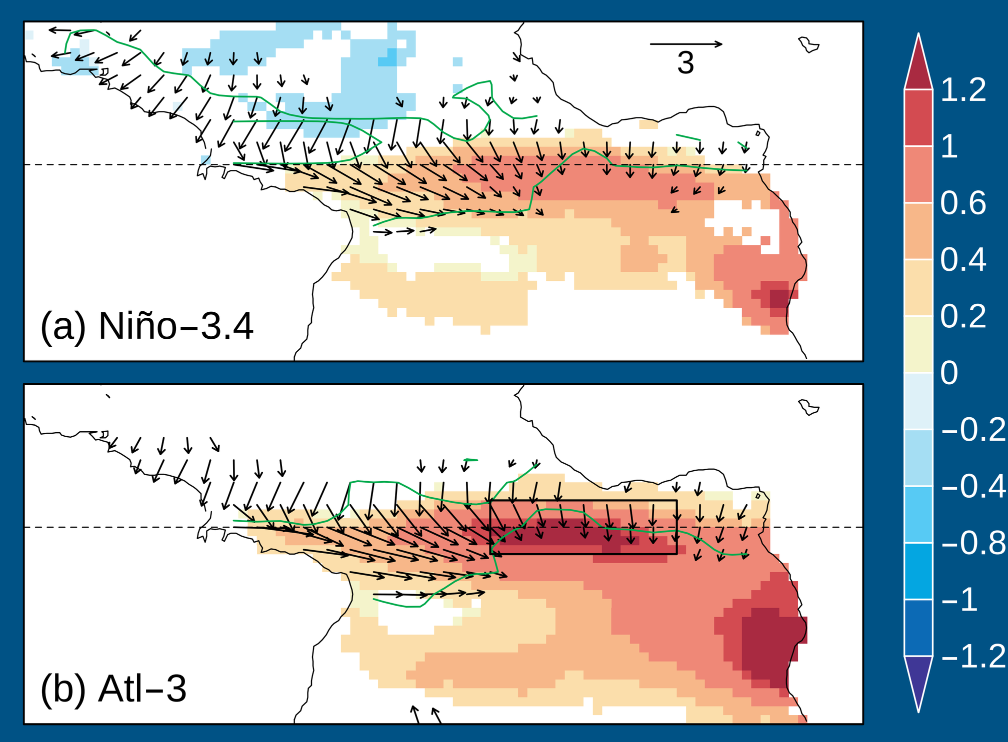

Fig. 3: (a) Linear regression coefficient map of (color) SSTA and (arrows) wind stress anomalies (0.01 N/m^{2}C) versus negative Niño-3.4. For SSTA, only regions of at least 95% significant rank correlation are colored. For wind stress arrows the rank correlation for at least one of its zonal or meridional components is significant at the 95% level. (b) Same as (a) for Atl-3. The black rectangle marks the Atl-3 region.

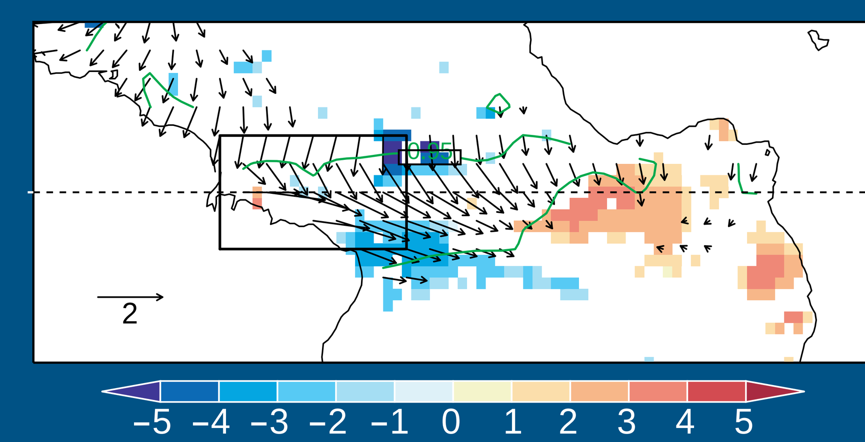

Fig. 4: Linear regression coefficient map of (color) SSHA (m^3/N) and (arrows) wind stress anomalies (unitless) versus average zonal wind stress anomalies over the western Atlantic (50 W–30 W, 5 S–5 N, black rectangle). For SSHA, only regions of at least 95% significant rank correlation are colored. Wind stress arrows are drawn where rank correlation for at least one of its zonal or meridional components is significant at the 95% level. Green contour indicates the area of significant absolute wind stress rank correlation with the western Atlantic zonal wind stress.