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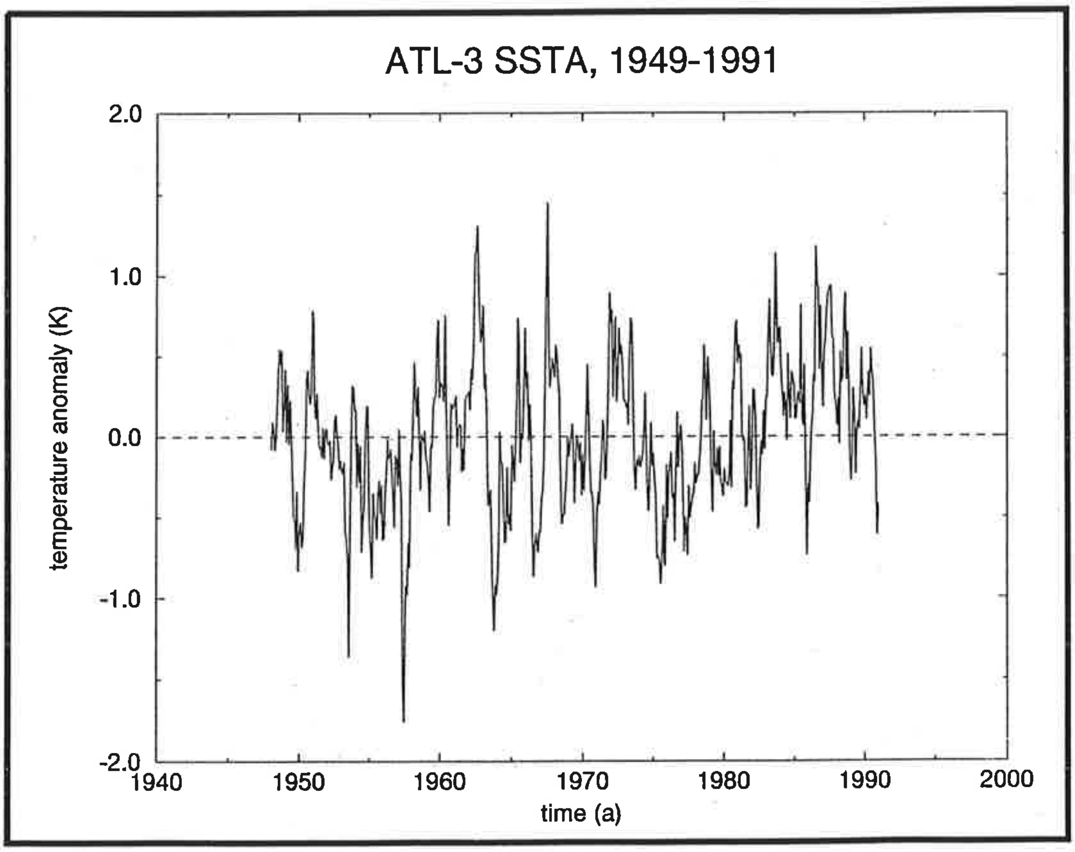

EL HERMANITO:
EL NIÑO'S OVERLOOKED LITTLE BROTHER IN THE ATLANTIC

by

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El Hermanito: El Niño's Overlooked Little Brother in the Atlantic

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An oscillation with a period of about 30 months has been identified in the equatorial Atlantic by analyzing sea surface temperature (SST) observations for the period 1949-1991. The 30-month time scale was also found in numerical simulations with an atmospheric general circulation model (AGCM) that was forced by these SSTs and a coupled ocean atmosphere general circulation model (CGCM). Consistent with the theory of tropical air-sea interactions, the Atlantic oscillation (El Hermanito) is an inherently coupled air-sea mode and can be viewed as the Atlantic analogon of the El Niño/Southern Oscillation (ENSO) phenomenon in the equatorial Pacific. El Hermanito is an internal Atlantic mode and appears to be independent of the quasi-biennial (QB) variability observed in the tropical Indian and Pacific Oceans. The discovery of El Hermanito is important to the prediction of Atlantic climate anomalies.

Theoretical and modeling studies of tropical air-sea interactions focussed mostly on the Pacific Ocean because of the predominance of the El Niño/Southern Oscillation (ENSO) phenomenon, the strongest interannual climate variation (e.g. [1], [2], [3], [4], [5], [6], [7]). Unstable air-sea interactions and the subsurface memory of the ocean are important factors

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contributing to the ENSO mechanism (e.g. [8]). The subsurface memory of the system can be expressed in terms of equatorial waves, and one would therefore expect a dependence of the oscillation period on the basin size [9]. The dominant ENSO period is of the order of about 4 years. Assuming that the nature of the air-sea interactions in the Atlantic is similar to that in the Pacific, this would imply a quasi-biennial oscillation period for the Atlantic "ENSO-analogon", since the basin size of the Atlantic is about half that of the Pacific. Our study shows that this is indeed the case.

It has been shown ([10], [11], [12], [13]) that the equatorial Atlantic exhibits considerable interannual variability which involves coupled processes similar to those generating ENSO. A four year time scale was suggested based on model results [11], but this estimate is inconsistent with the observations which yield a considerably shorter period of 30 months, as described below. Our estimate of a 30-month period is rather stable and obtained by different statistical methods and also from simulations with state-of-the-art general circulation models (GCMs).

The primary quantity analyzed is observed SST [14]. Additionally, we used the anomalous zonal surface wind stress and precipitation from an atmospheric general circulation model (AGCM, [15], [16]) forced by these SSTs. Such model data are useful in studying tropical variability, since the tropical atmospheric variability is controlled strongly by variations in SST and realistically simulated by state-of-the-art AGCMs. Furthermore, the model output yields a homogeneous data base which is not available from observations for such a long period. We used also the output of a global coupled ocean-atmosphere general circulation model (CGCM) which was integrated for ten years [17]. This run provides a complete and internally consistent picture of El Hermanito.

We computed two SST indices from the SST observations: The so-called ATL-3 index for the equatorial Atlantic which is an area average of anomalous SST over the region 3°N-3°S and 20°W-0°, and the well-known Niño-3 index for the Pacific which represents the SST variability averaged over the region 5°N-5°S and 150°W-90°W. The two SST indices are shown in Fig. 1. We applied standard Fourier [18] and singular spectrum analyis (SSA, [19]), in order to derive the dominant time scales of the SST variability in the equatorial Atlantic and Pacific Oceans. The results for the equatorial Pacific are included here for comparison and to show that the two statistical methods applied work well to extract the dominant ENSO time scale.

We performed first Fourier analyses of the Niño-3 and ATL-3 indices. The spectrum of the Niño-3 index shows the well-known enhanced level of variability at interannual time scales, with a peak at a period of about 4 years (Fig. 2a). The corresponding spectrum of the ATL-3 time series shows also enhanced variability at interannual time scales, with a peak at a period of about 30 months (Fig. 2b). Thus, there is considerable variability at the quasi-biennial time scale in equatorial Atlantic SST. In contrast to the Niño-3 spectrum, the ATL-3 spectrum shows also enhanced variability at decadal time scales, which will be discussed elsewhere.

In order to test the stability of our results, we performed additionally singular spectrum analyses of the Niño-3 and ATL-3 SST indices. Both SSAs confirm the results of the Fourier analyses (not shown): The ENSO mode is associated with a quasi-quadrennial time scale, while the period of El Hermanito (which is the subject of this paper) is 30 months. In summary, the results of our time series analyses show that the 30-months oscillation is the dominant interannual variability mode in the equatorial Atlantic SSTs.

The results of our time series analyses are consistent with the assumption that the dynamics of El Hermanito are similar to those of ENSO. As expected from the ENSO theory ([2], [4], [8], [9]), the dominant period of the interannual variability should be considerably shorter in the Atlantic relative to the Pacific. Furthermore, the variations associated with El Hermanito are expected to be much weaker than those connected with the ENSO mode, and this appears to be the case.

In order to derive the spatial characteristics of El Hermanito, we computed associated regression patterns of the band-pass filtered (retaining all the variability with periods between 18 and 42 months) anomalous SST, zonal wind stress, and precipitation relative to the band-pass filtered ATL-3 SST index. El Hermanito is an inherent Atlantic mode, and strong SST anomalies connected with this mode are found in the equatorial Atlantic only (Fig. 3a), where it accounts for up to 90% of the variance relative to the band-pass filtered SSTs and up to 40% relative to the raw data (not shown). No significant SST anomalies were found outside this region, which demonstrates that El Hermanito is not linked to the quasi-biennial variability observed in the Indian and Pacific Oceans described in many papers (e.g. [20], [21], [22], [23], [24]).

Wind stress anomalies of the same sign are found to the west of the maximum SST anomalies (Fig. 3b), which is consistent with earlier studies (e.g. [11]). These wind stress anomalies will tend to reinforce the SST anomalies mainly by changing the thermocline depth in the central and eastern equatorial Atlantic ([2], [3], [4], [5], [7], [8]), so that ocean and atmosphere form a positive feedback system. A similar SST/wind stress relationship is also found during El Niño episodes [1]. The zonal wind stress anomalies associated with El Hermanito, however, are much weaker than those observed during El Niños, and they describe only about 30% of the total wind stress variability in the frequency band considered. The coupling between ocean and atmosphere over the equatorial Atlantic is considerably weaker than over the Pacific. The wind stress change per unit SST change amounts to about 0.005 (Pa/°C) for El Hermanito, while it is at least twice as large for the ENSO mode. Relatively strong precipitation anomalies connected with El Hermanito are restricted to the region over the equatorial Atlantic, with enhanced rainfall over the entire equatorial Atlantic (Fig. 3c). The variances explained amount to about 20% in the centers of action relative to the band-pass filtered precipitation data.

Finally, we investigate the interannual variability simulated by our CGCM. The combined variability in the zonal wind stress, SST, and sea level (a measure of upper ocean heat content) was investigated by a multi-variate statistical analysis [25]. The coupled model reproduces El Hermanito remarkably well. El Hermanito is the leading interannual variability mode in the Atlantic, accounting for about 20% of the combined variance. The time scale of about 32 months and the SST/wind stress signature are consistent with the observations and the uncoupled AGCM simulation with prescribed observed SSTs (compare Fig. 4d with Fig. 3a and Fig. 4b with Fig. 3b). Furthermore, as in the observations, El Hermanito is independent of ENSO in the coupled model (not shown).

The space-time evolution of the model El Hermanito (Fig. 4) indicates the importance of the subsurface memory of the coupled system. Off-equatorial heat content anomalies of opposite sign to those in the eastern equatorial Atlantic (Fig. 4f) are excited by the meridional shear of the zonal wind stress anomaly in the western part of the basin (Fig. 4b) during the height of El Hermanito events, when SST anomalies are well developed in the eastern equatorial Atlantic (Fig. 4d). Consistent with equatorial wave theory [8], the off-equatorial heat content anomalies propagate westward and reflect into relatively narrow equatorial signals which propagate eastward (Fig. 4e). Once the heat content anomalies have propagated into the eastern equatorial Atlantic where the thermocline is shallow, they can affect the SST and reverse the SST tendency, providing the phase switching mechanism. The time scale of the oscillation is determined primarily by wave time scales and thus the basin geometry, which explains the relatively short period of El Herminito compared to ENSO.

We have shown that a distinct 30-month mode (El Hermanito) exists in the equatorial Atlantic. El Hermanito is an inherent Atlantic mode and is neither introduced from nor does it impact regions outside the Atlantic. El Hermanito can be regarded as the Atlantic ENSO analogon. Consistent with ENSO theory, it arises from large-scale air-sea interactions, has a shorter time scale and is much weaker than the ENSO mode in the Pacific. The existence of El Hermanito is important with regard to short-term climate predictability, as it might add some skill in forecasting tropical Atlantic climate variability.

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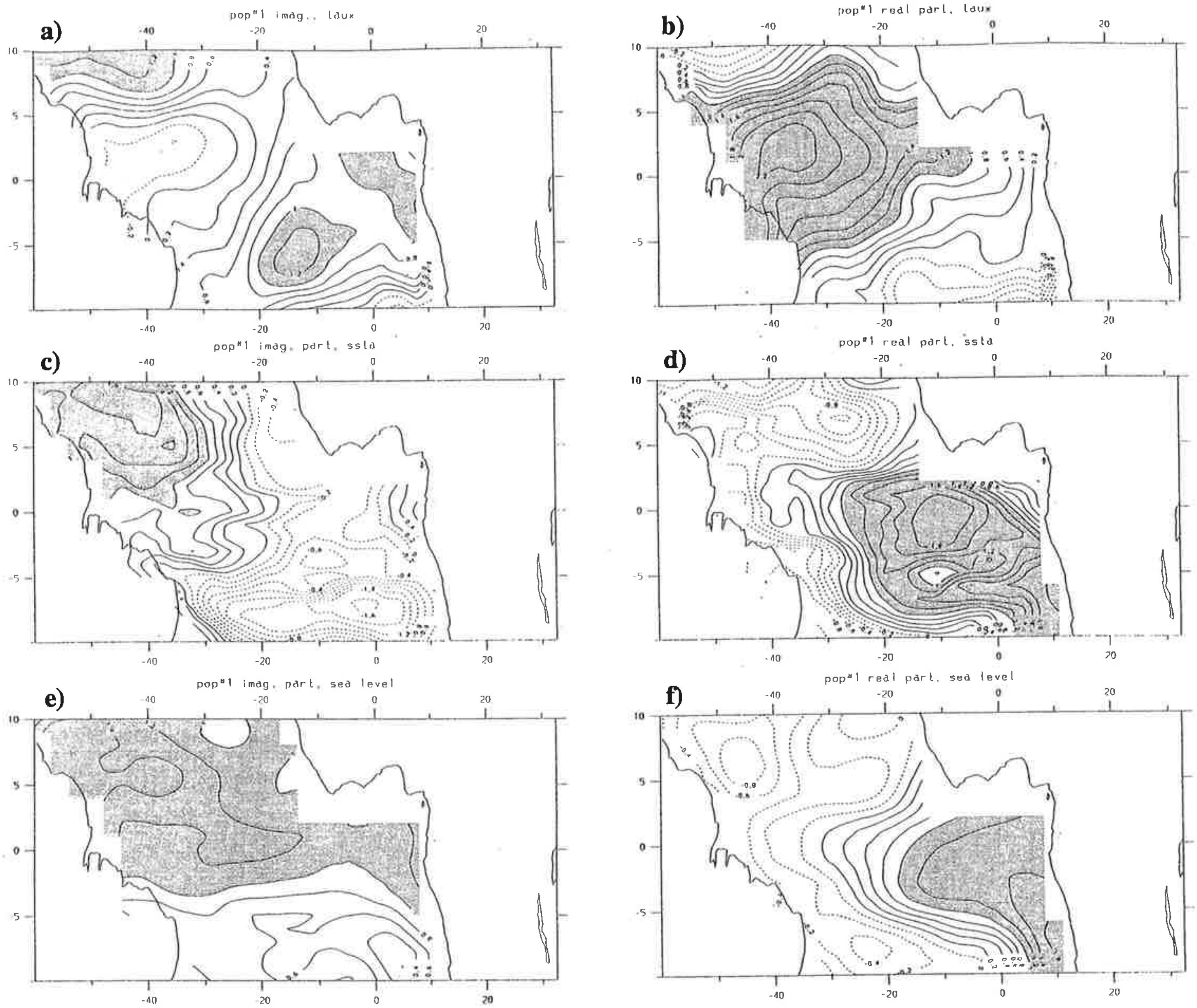


Figure 4: Leading mode of interannual variability in the equatorial Atlantic as derived from a combined POP analysis of zonal wind stress (a,b), SST (c,d), and sea level anomalies (e,f) simulated by the coupled ocean-atmosphere general circulation model. The evolution of anomalies according to a single (complex) POP mode with real part Re and imaginary part Im can be described as a cyclic sequence of patterns:.. Im Re -Im -Re Im.. The panels on the left precede those on the right by a quarter of the rotation period, i.e. 8 months. The model data were normalized by their local standard deviation and smoothed with a 5-months running mean filter prior to the POP analysis.

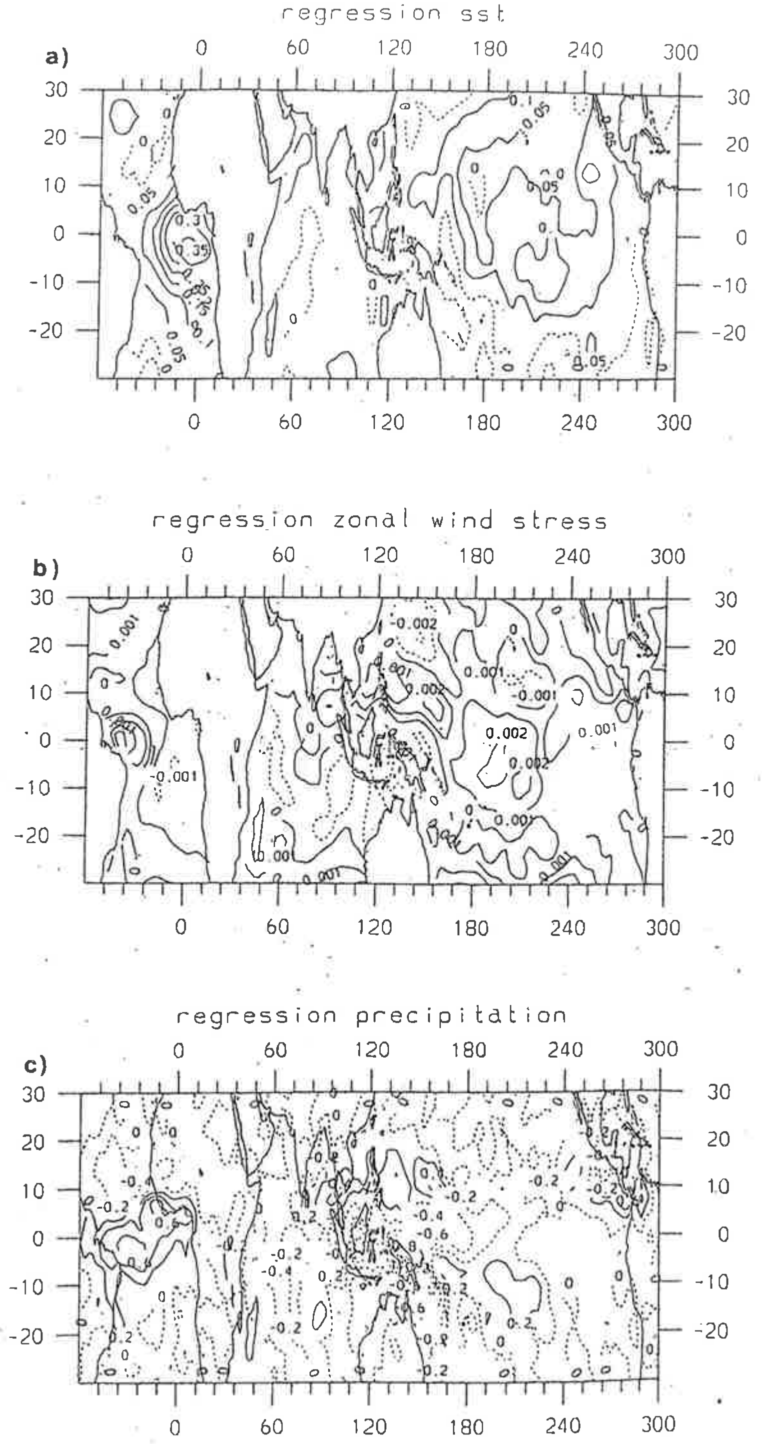
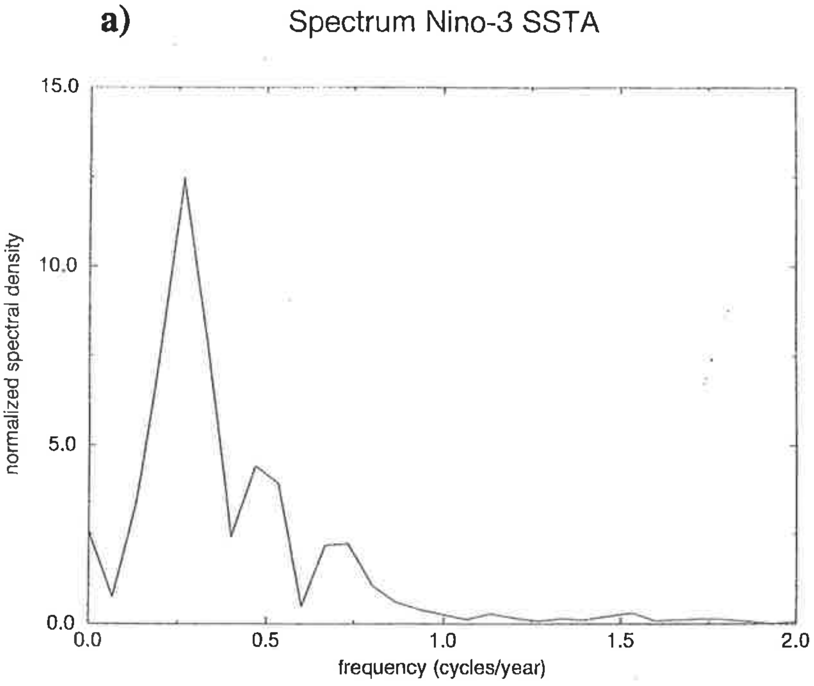


Figure 3: a) Spatial distribution of linear regression coefficients (°C) of the band-pass filtered ATL-3 index and tropical SST anomalies. b) Spatial distribution of linear regression coefficients (Pa) of the band-pass filtered ATL-3 index and tropical zonal wind stress anomalies. c) Spatial distribution of linear regression coefficients (mm/day) of the band-pass filtered ATL-3 index and tropical precipitation anomalies. The values are representative of a one-standard-deviation change in the ATL-3 index.



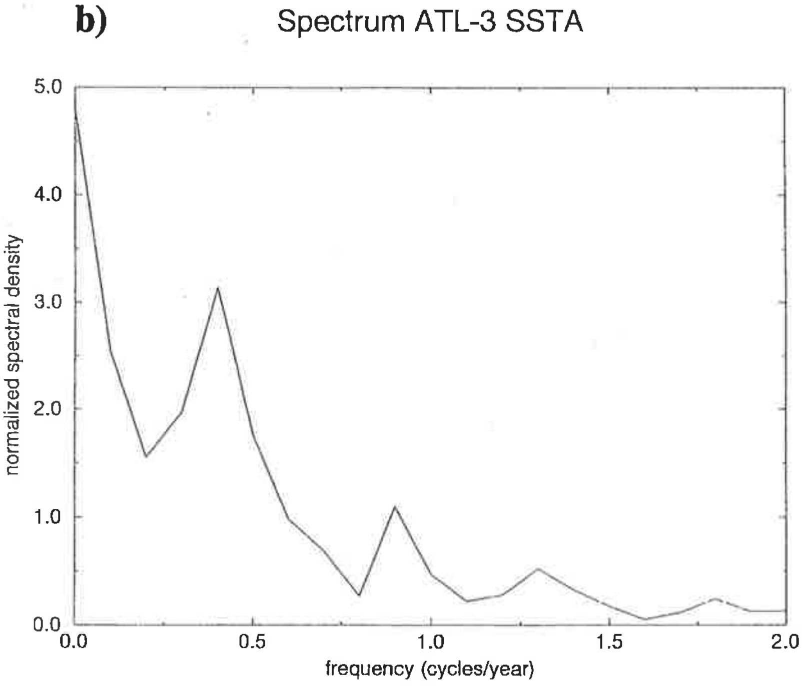


Figure 2: a) Fourier spectrum of eastern equatorial Pacific sea surface temperature anomalies (^{o}C) averaged over the Niño-3 region shown in Fig. 1a. A Bartlett procedure with a window length of 180 months was chosen yielding 4 degrees of freedom. b) Fourier spectrum of eastern equatorial Atlantic sea surface temperature anomalies (^{o}C) averaged over the ATL-3 region shown in Fig. 1b. A Bartlett procedure with a window length of 120 months was chosen yielding 8 degrees of freedom.

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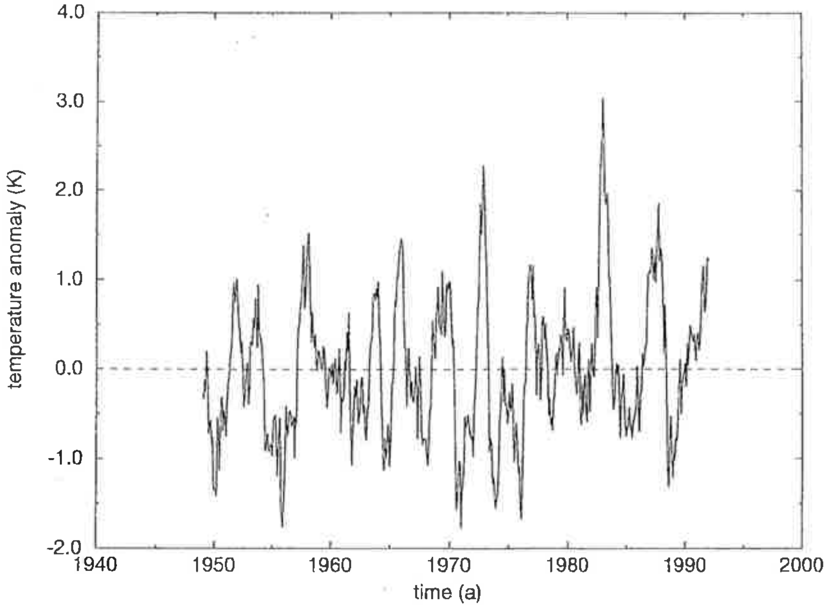

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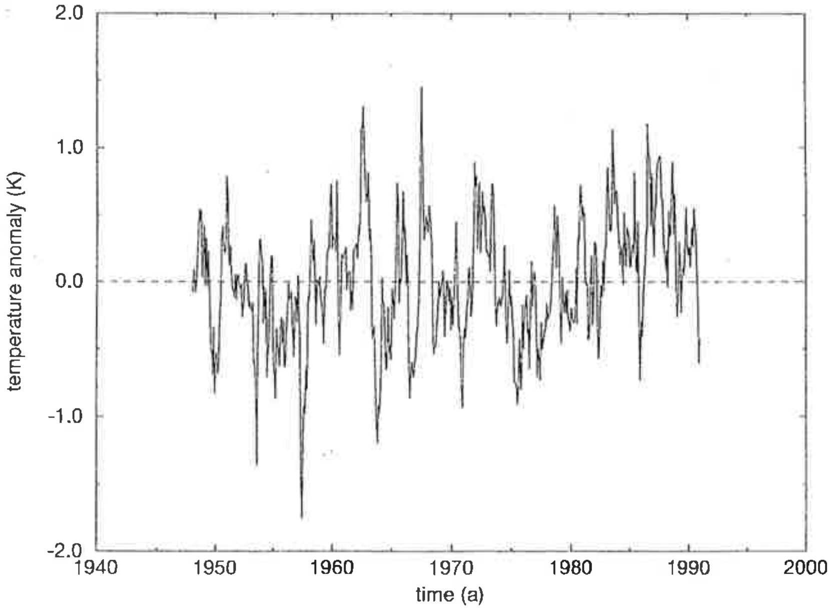

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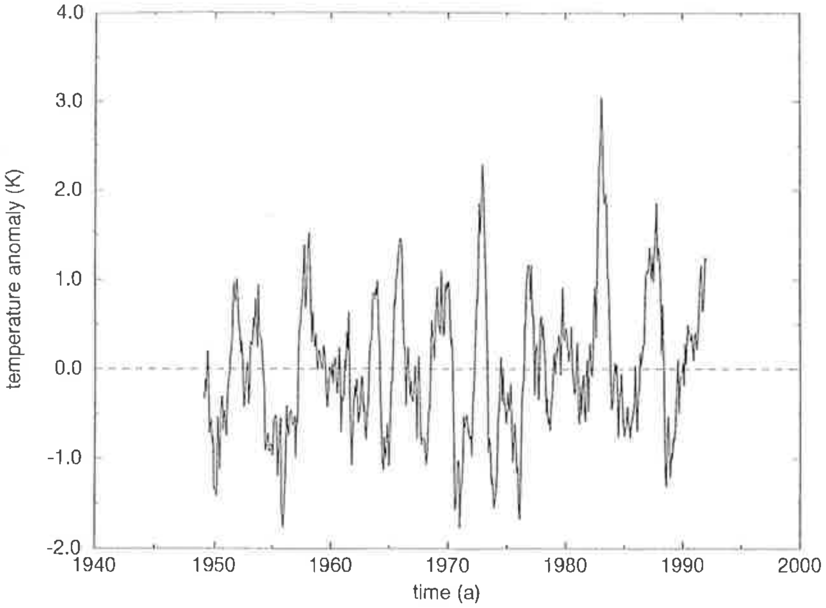

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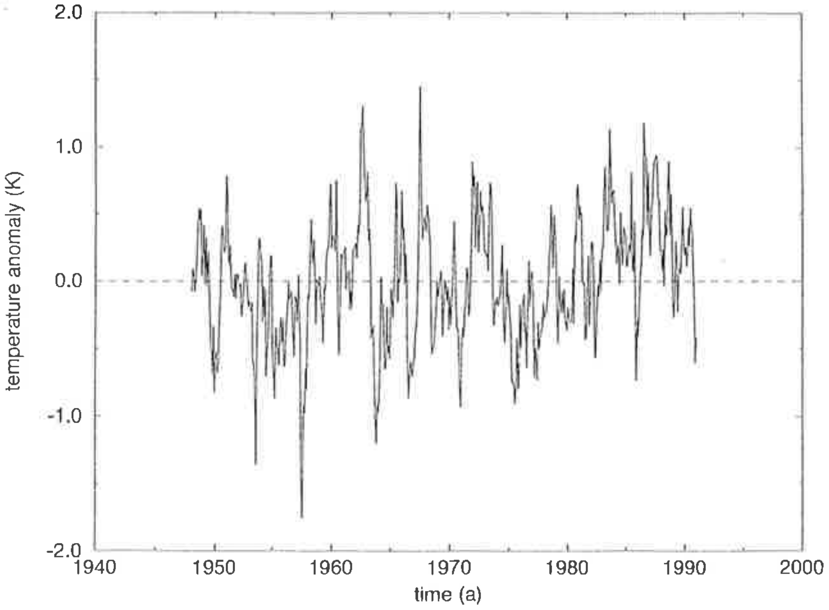

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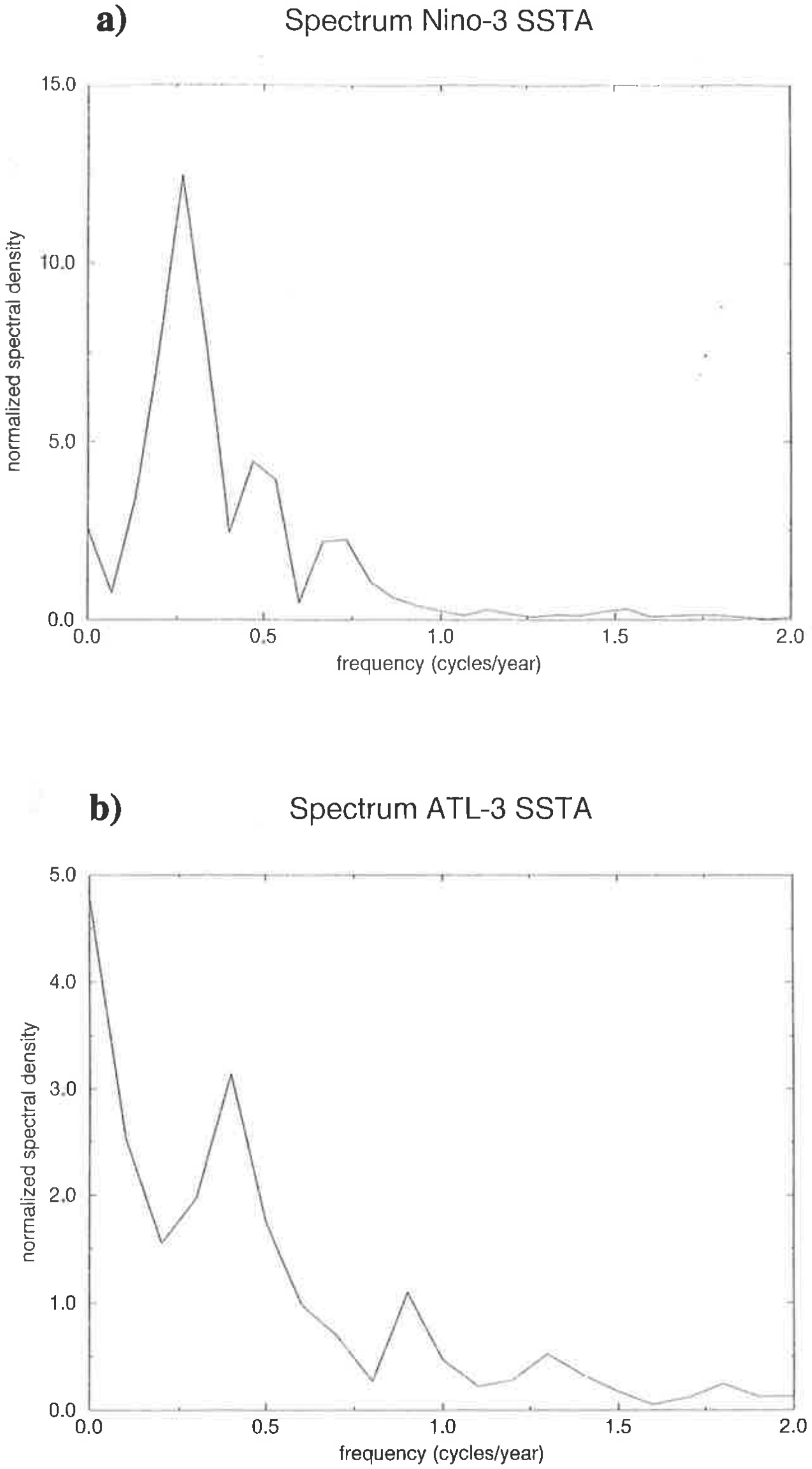

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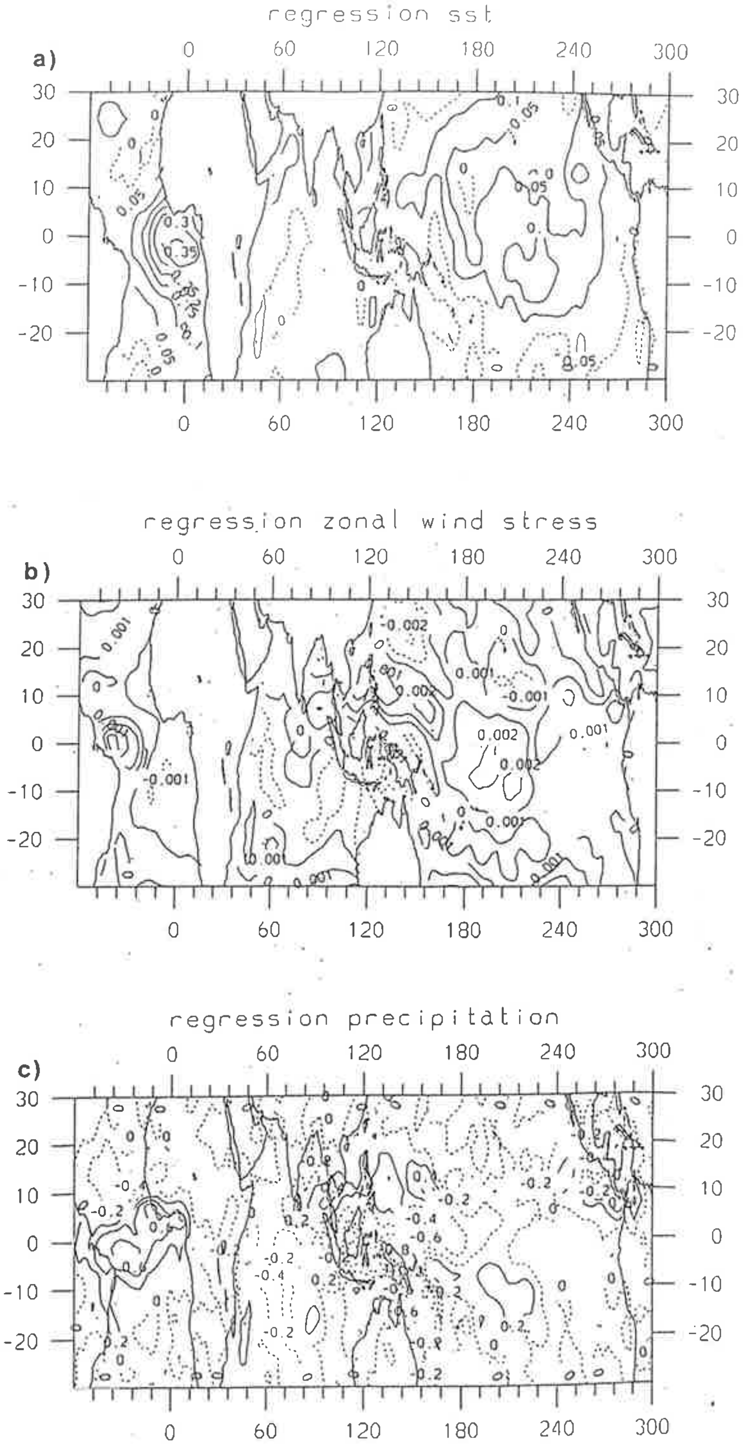

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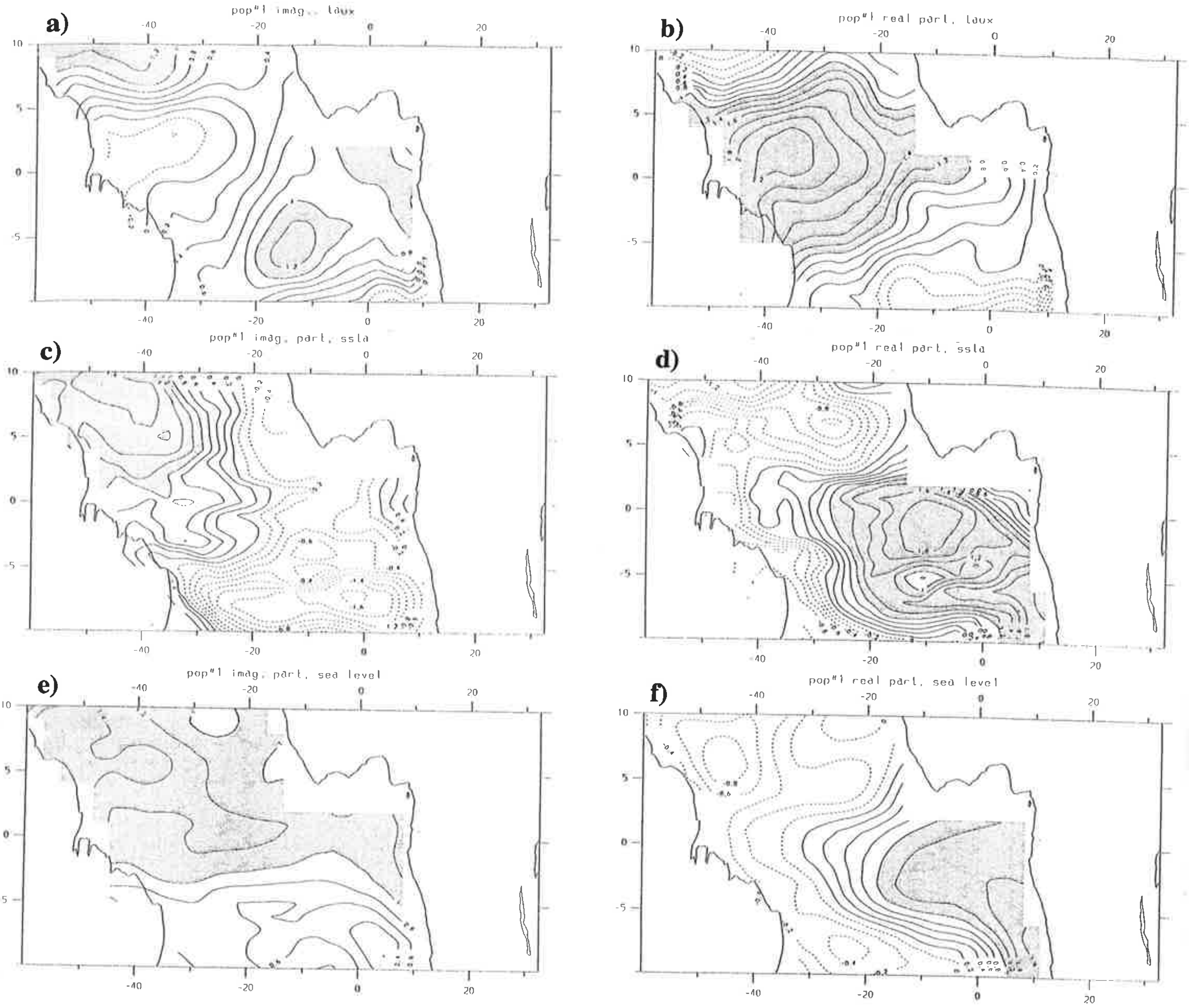

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