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PRECIPITATION AND ATMOSPHERIC CIRCULATION ANOMALY PATTERNS IN THE SOUTH AMERICAN SECTOR[1]

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RESUMO

Uma análise de funções empíricas ortogonais (EOF) rodadas é feita para o setor sulamericano, baseada no vetor que inclui anomalias de radiação de ondas longas emergentes (OLR) e as componentes zonal e meridional do vento. Desta maneira, os padrões EOF contém campos consistentes da circulação troposférica superior e um substituto para nebulosidade convectiva (OLR). Os primeiros quatro padrões EOF são apresentados. Dois destes padrões (primeira e terceira EOF) são consistentes com estudos teóricos e de modelagem para aquecimento convectivo anômalo nos trópicos. Estes padrões exibem variabilidade temporal em ambas as escalas inter-anual e intra-sazonal. Os outros dois padrões (segunda e terceira EOF) mostram pesos nos sub-trópicos para latitudes médias do Hemisfério Sul. As séries temporais das componentes principais para estas EOFs rodadas mostram variabilidade intra-sazonal e em menores escalas de tempo.

ABSTRACT

A rotated empirical orthogonal function analysis is performed for the South American sector based on an array that includes outgoing longwave radiation (OLR) anomalies, and 250 mb zonal and meridional wind components. In this manner the resulting EOF patterns contain physically consistent fields of upper tropospheric circulation and a proxy for convective cloudiness (OLR). The first four EOF patterns are presented here. Two of the patterns (first and third EOFs) are consistent with theoretical and modeling studies for anomalous convective heating in the tropics. These patterns exhibit temporal variability on both the interannual and intraseasonal time scales. The remaining two patterns (second and fourth EOFs) feature loadings in the subtropics to mid-latitudes of the Southern Hemisphere. The principal component time series for these rotated EOFs display intraseasonal and shorter time scale variability.

1. INTRODUCTION

The South American region, between the equator and 20°S, is an important source of sensible and latent heating during the southern summer season (December-February). At that time, low level convergence (upper-level divergence) develops over the continent on the eastern flank of a surface low pressure (upper tropospheric high pressure) system found over northern Argentina and Bolivia. These features are characteristic of regions which experience deep tropical convection. During the southern summer, the outgoing longwave radiation (OLR) over tropical South America is generally less than 220 Watts m^{-2}, which is also typical of the major tropical convective regions.

[1] Portions of this paper were presented at the Second Interamerican Meteorology Congress, Buenos Aires, Argentina, 30 November — 4 December, 1987.

The climatological circulation over South America and its relationship to the heating have been known for some time. During the last ten years variability in this region has been investigated by a number of researchers. Virji (1981) noted transient upper tropospheric cyclonic vortices on the eastern flank of the Bolivian anticyclone. These vortices, extensively studied by Kousky and Gan (1981) and Gan and Kousky (1986), have been found to significantly alter the pattern of convection, especially in eastern Brazil.

Southern Hemisphere cold fronts, which penetrate to low latitudes, have been shown to be important in organizing convection over eastern South America during the southern spring, summer and fall months (Kousky, 1979). Kousky and Ferreira (1981) used daily data to demonstrate that as southern frontal systems move eastward and northward they are, at times, associated with an eastward shift of the strongest tropical convective activity. This feature was also noted in the studies of Virji and Kousky (1983) and Kousky (1985). Kousky and Ferreira (1981) also determined the principal patterns of daily station pressure anomalies for Brazil and concluded that the first four patterns were related to features, including cold fronts, originating in the middle and high latitudes of the Southern Hemisphere.

The principal patterns of monthly precipitation and temperature anomalies for the region of Argentina and Chile were determined in studies by Pittock (1980a and 1980b). An El Niño/Southern Oscillation pattern in precipitation was obtained which is similar to that recently found by Ropelewski and Halpert (1987). Kousky and Casarin (1986) and Casarin and Kousky (1986) used half-monthly ORL data for the entire South American region north of 37.5°S and found that drier than normal conditions (positive OLR anomalies) in southern Brazil are positively correlated with wetter than normal conditions (negative OLR anomalies) over eastern Brazil. The pattern obtained resembles a pattern of OLR anomalies obtained by Weickmann et al., (1985) in their study of intraseasonal (30-60 day) oscillations. Casarin and Kousky also attempted to relate atmospheric circulation anomaly patterns to the anomalous patterns of OLR by means of a composite analysis. Their results indicate that periods of drier (wetter) than normal conditions in southern (eastern) Brazil are accompanied by anomalous upper tropospheric cyclonic circulation in the western South Atlantic.

In this study we will expand upon the work of Casarin and Kousky (1986), hereafter referred to as CK, and determine the patterns of anomalous OLR and upper tropospheric circulation for the South American sector using EOF analysis.

2. DATA AND ANALYSIS METHODS

The data used in this study are five-day, non-overlapping (pentad) means of the 250 mb wind components and OLR from January 1979 to December 1986. Both of these data sets are available at the Climate Analysis Center, Washington, DC. We will focus our attention on the 30 pentads from 2 November through 31 March of the following year. Therefore, our analysis will include a total of 240 pentads (8 years x 30 pentads per year). Each field will consist of 80 spatial points having a 7.5° x 7.5° latitude-longitude resolution, encompassing subtropical and tropical South America and sizable portions of the adjacent oceans. Anomalies in each field are computed with respect to, approximately, 10-year base period means; 1975-1984 for the 250 mb fields and June 1974 to February 1987 (1978 missing) for the OLR. The use of pentads will permit a better resolution of variability associated with the intraseasonal oscillations than that obtained by CK who used half-monthly data.

The EOFs are computed based on an array in which three variables [250 mb zonal and meridional (u and v) wind components, and OLR] are included for the region of interest. In this way, the resulting EOF patterns consist of OLR anomalies and related 250 mb circulation anomalies. The circulation anomalies are represented by vectors which are constructed from the loadings for the u and v components. Firstly, the unrotated EOF patterns were obtained. However, application of the North *et al.*,(1982) test revealed that none of the eigenvalues are clearly separable from neighboring ones. Next, a rotated EOF analysis (see, e.g., Barnston and Livezey, 1987), using the varimax technique on the first ten patterns, was performed. The choice of ten patterns was made based on a plot of the eigenvalues versus the number of the eigenvector. The rotated EOF patterns are similar to but sharper than the unrotated patterns. Consequently, we will present results only for the rotated EOF analysis. Rotated principal component time series (the amplitudes of the rotated EOF patterns) are constructed to investigate variability on the intraseasonal and interannual time scales.

3. RESULTS

The first four rotated EOF patterns for the OLR and 250 mb circulation are shown in Figs. 1a-1d and Figs. 2a-2d, respectively. These explain 26% of the total variance. The first EOF (Fig. 1a) has maximum loadings for OLR over Northeast Brazil and generally west to east flow over equatorial South America for positive amplitudes of this pattern (Fig. 2a). A similar pattern was shown by Weickmann *et al.*, (1985) to be associated with intraseasonal (30-60 day) oscillations. The principal component time series (Fig. 3a) shows that this pattern contains interannual variability as well as intraseasonal variability. Positive amplitudes, indicating drier than normal conditions over Northeast Brazil, occurred during the 1982-83 ENSO episode, a feature noted by Kousky *et al.*, (1984). Very large variations in the amplitude of this pattern during January-February 1985 correspond to the large variations in rainfall over Northeast Brazil that occurred at that

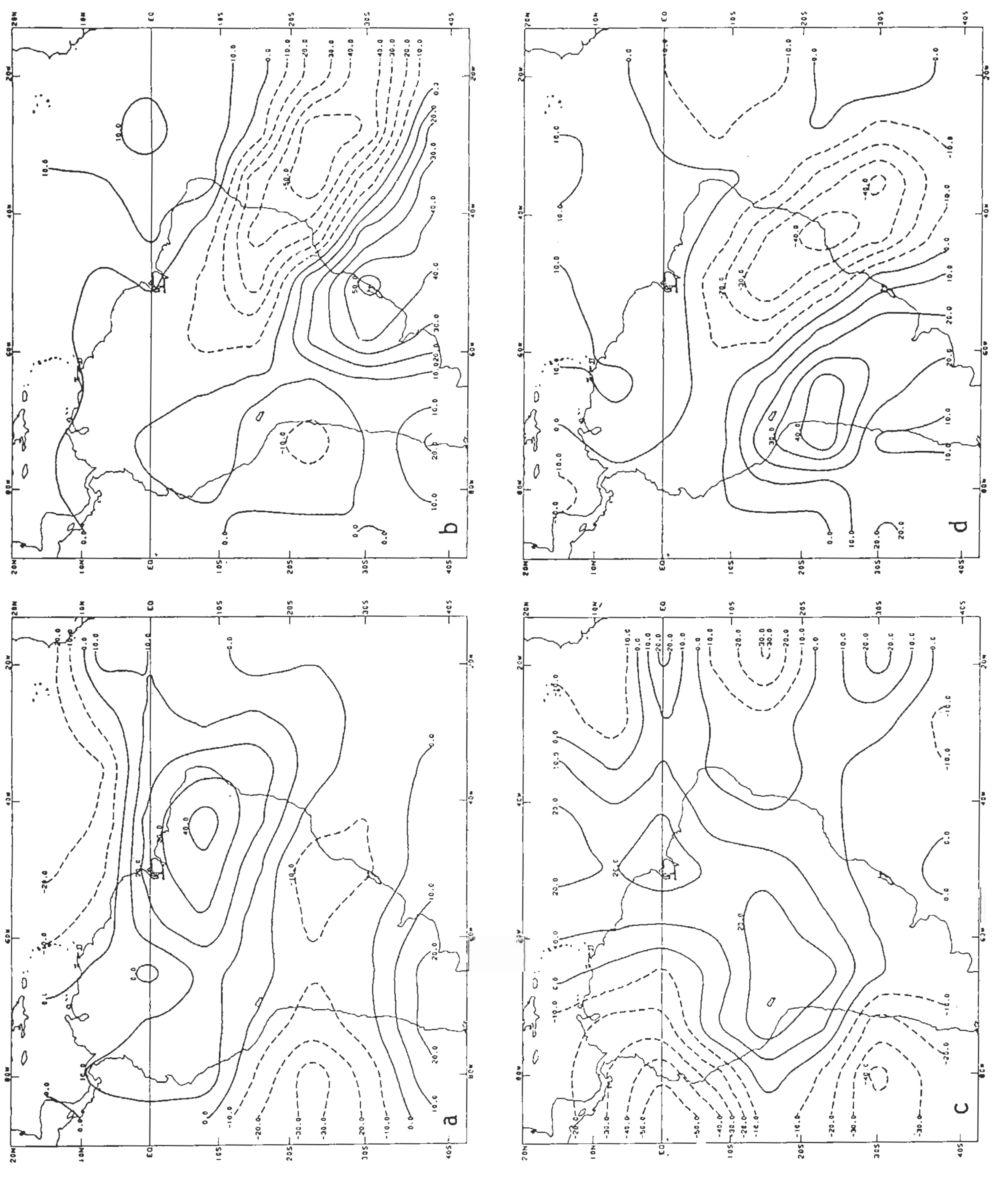


Figure 1 (a-d) – The OLR patterns for the first four rotated EOFs. Negative loadings are indicated by dashed lines.

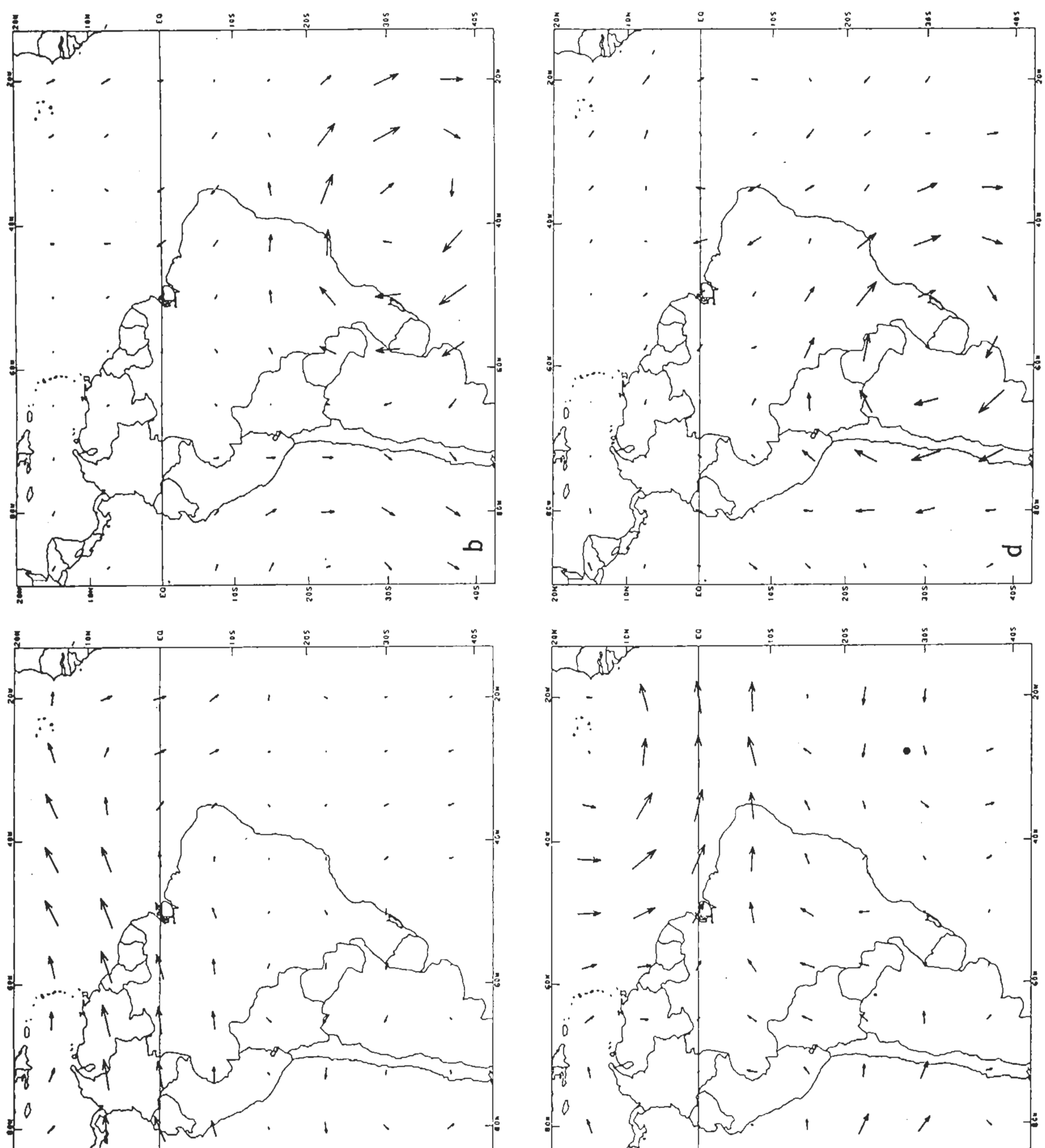


Figure 2 (a-d) – The 250 mb circulation patterns for the first four rotated EOFs. These combined OLR and 250 mb circulation patterns explain a) 7.1%, b) 6,4%, c) 6,4% and d) 6,3%, respectively.

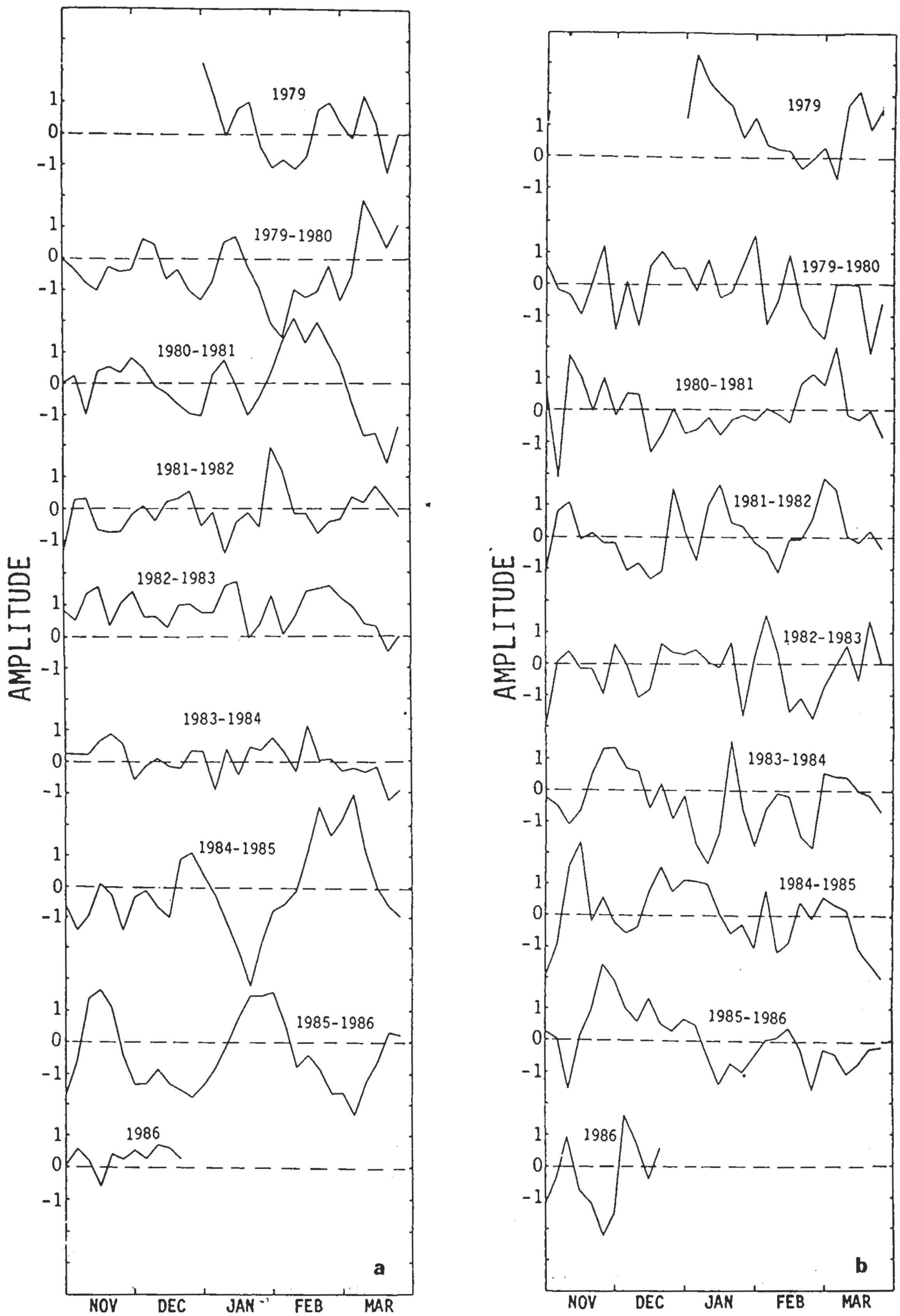
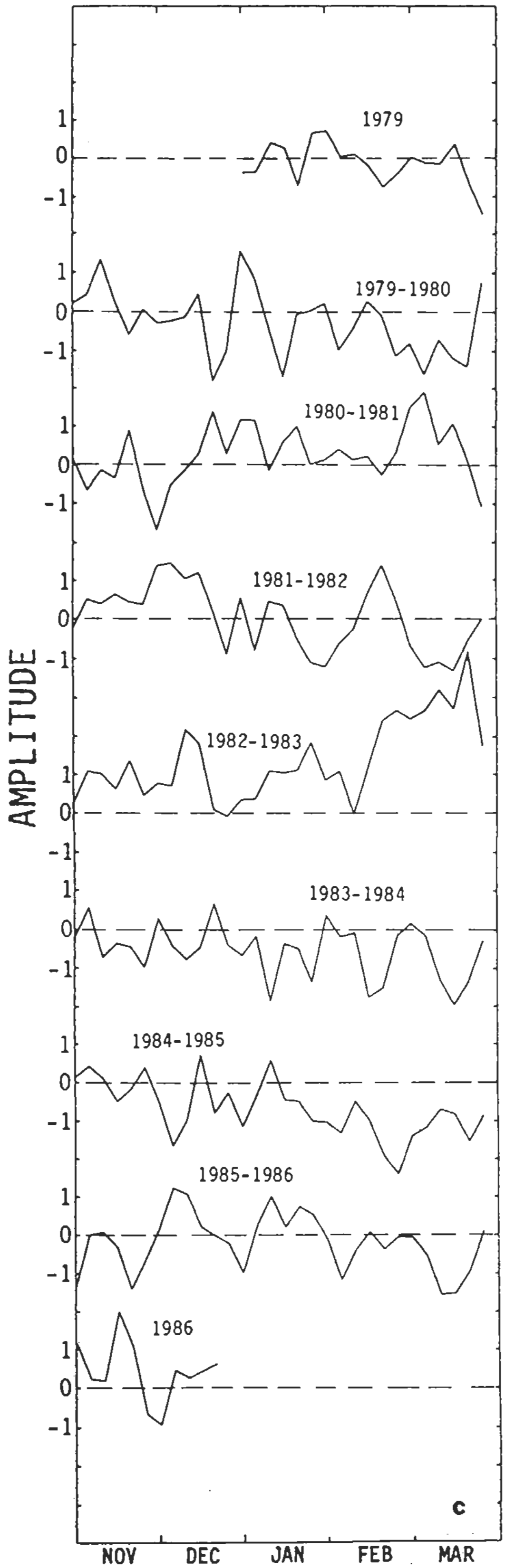


Figure 3 (a - d) — The principal component time series for the first four rotated EOFs. (Continue...)



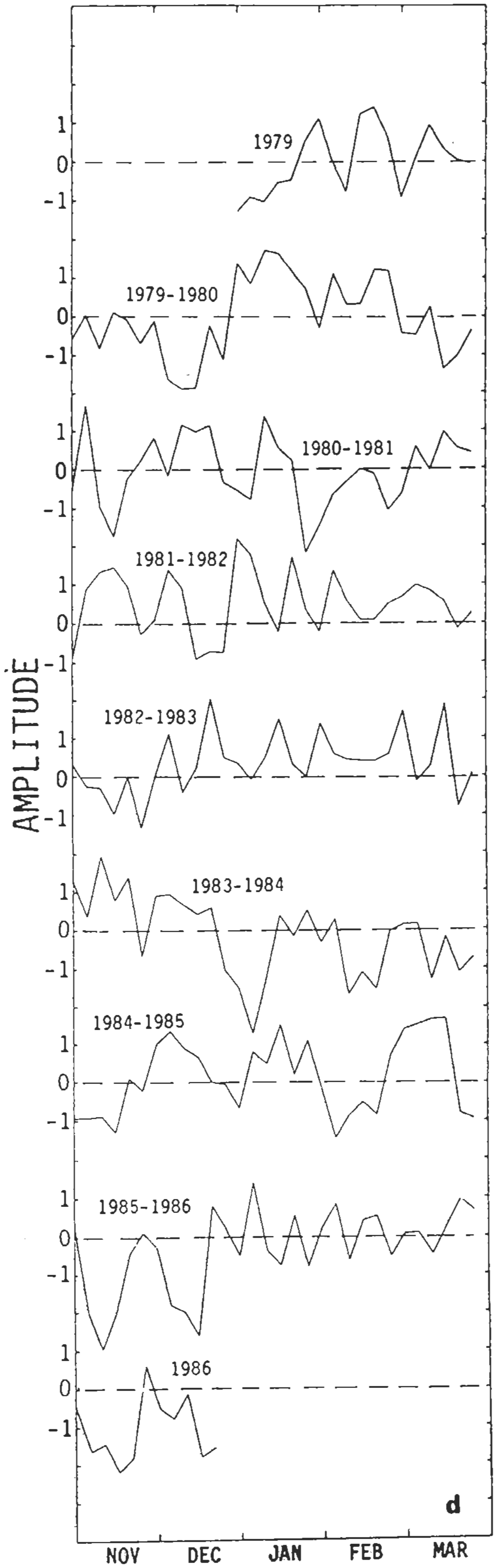


Figure 3 (a - d) — (Continuation). The principal component time series for the first four rotated EOFs.

time (Cavalcanti, 1986). Large variations in the amplitude of this pattern also occurred during January-March 1979, 1980, 1981 and November 1985-March 1986. The period of the oscillations during these years is between 45 and 70 days, which agrees well with the period normally associated with intraseasonal oscillations. The variations that occurred during February-March 1981 have been atributed to a slow moving Southern Hemisphere cold front that moved northeastward along the Brazilian coast (Kousky, 1985). The time scale of the precipitation fluctuations during early 1981 suggests that they were related to the 30-60 day oscillations first discussed by Madden and Julian (1972). Kousky (1985) concluded that the Southern Hemisphere extratropical circulation pattern in the vicinity of South America and the neighboring Atlantic Ocean might play a role in these oscillations.

The second rotated EOF pattern for OLR (Figure 1b) is very similar to the correlation and composite patterns obtained by CK with positive (negative) OLR anomalies over southern Brazil and negative (positive) anomalies over eastern Brazil and the neighboring Atlantic Ocean. The associated 250 mb circulation anomaly pattern for positive amplitudes of this pattern (Fig. 2b) consists of anomalous cyclonic flow over the extreme western South Atlantic and adjacent South America, also reminiscent of the composite pattern obtained by CK. The principal component time series (Fig. 3b) indicates that this EOF is characterized by variability on the intraseasonal time scale.

The third rotated EOF pattern for OLR (Figure 1c) has positive loadings over eastern and central South America and negative loadings over the eastern equatorial Pacific. This pattern, as shown in the amplitude time series (Fig. 3c), is related to the large-scale interannual variability associated with the Southern Oscillation. The associated 250 mb circulation pattern (Fig. 2c) is consistent with abnormal eastern equatorial Pacific convective activity. For a positive amplitude of this EOF, negative OLR anomalies are found in the eastern Pacific, and a 250 mb anticyclonic couplet is found over western equatorial South America, with equatorial westerly anomalies farther to the east. For a negative amplitude, negative OLR anomalies are found over most of Brazil and in the equatorial Atlantic accompanied by an anticyclonic anomaly couplet in the Atlantic sector. This pattern is similar to that found by Webster (1972) and Gill (1980) for steady equatorial thermal forcing. However, the anticyclonic anomaly couplet lies to the east of the anomalous forcing rather than to the west as would be expected from the linear model results. Further study is required to determine if non-linear effects might be the cause for this apparent discrepancy.

The fourth EOF pattern for the OLR (Fig. 1d) is similar to that for the second EOF except that the pattern is shifted to the west. Also similar is the subtropical to mid-latitude cyclonic circulation anomaly which accompanies the positive amplitudes of this pattern (Fig. 2d). The apparent eastward shift of the second pattern relative to the fourth pattern suggests that perhaps the two patterns are related temporally. However, a visual comparison of the corresponding principal component time series (Fig. 3b and 3d) does not support this hypothesis. The two patterns appear to occur independently of each other and not evolve from one to the other.

4. CONCLUSIONS

In this paper we have determined the principal patterns of OLR and related 250 mb circulation for the region of South America. Both the second and fourth rotated EOF patterns consist of negative (positive) OLR anomalies to the northeast of an anomalous cyclonic (anticyclonic) circulation center. This relationship between upper level troughs and cloudiness is generally found at middle latitudes of the Southern Hemisphere. The first and third EOF patterns on the other hand display equatorial easterly (westerly) anomalies and anomalous anticyclonic (cyclonic) circulation associated with negative (positive) OLR anomalies. These patterns, which are probably determined by the character of the 1982-83 ENSO, display features generally expected in association with anomalous tropical convection.

The first EOF displays variability on both the interannual (ENSO) and intraseasonal time scales. The third EOF shows mainly interannual variability. The second and the fourth contain mainly intraseasonal and higher frequency variability.

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