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CHANGE IN TELECONNECTION BETWEEN CENTRAL-WEST ARGENTINA SUMMER PRECIPTATION AND THE ATMOSPHERIC CIRCULATION IN THE 70s

Rosa H. Compagnucci and Eduardo A. Agosta*

Department of Atmospheric and Oceanic Sciences, School of Sciences, University of Buenos Aires
The Argentine Council of Sciences and Technique Research (CONICET)

Abstract: The areas of teleconnection between the Central-West Argentina (CWA) summer precipitation and the atmosphere is studied through the Pearson's first moment correlation coefficient. Because of CWA inter-annual precipitation underwent a significant change in the lower frequency variability and a consequent raise of about 20% in the regional mean by mid-1970s, the analysis focuses on the change. Up to that date the CWA region precipitation was in-phase related to the summer precipitation region of South Africa (SPR-SA), after the change both regions disconnected. Teleconnections between observed precipitation and fields of geopotential heights potential temperatures, precipitable water, vectors wind, mid-troposphere omega and precipitable water derived from the NCEP/NCAR reanalysis are analyzed for the periods 1959-1977 and 1978-1998.

Results show that for the period 1959-1977 dynamic processes associated with CWA summer precipitation are linked to the inter-annual variability of mid-latitudes systems under a hemispherical cuasi-4-wave atmospheric circulation modulation. This hemispherical atmospheric wave can explain the in-phase relation between CWA and SPR-SA precipitation regimes until 1977. Conversely, for the period 1978-1998 the inter-annual variability of the atmospheric circulation associated with CWA is further linked to tropical-subtropical dynamic processes regionally restrained.

The change in the low-frequency variability of the atmospheric circulation in relation with the change in the low-frequency CWA summer precipitation can be responsible of the disconnection between the CWA and the SPR-SA observed by mid-1970s.

* *Corresponding author address:* Eduardo A. Agosta, Departamento de Ciencias de la Atmósfera y los Océanos, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires. Pabellón II, 2do piso, Ciudad Universitaria CP 1428, Buenos Aires, Argentina; e-mail: agosta@at.fcen.uba.ar

1. INTRODUCTION

In the austral summer 1976/77, the climate system underwent a relevant transition evidenced by a shift towards warming in the mean conditions of the sea surface temperatures (SSTs) in the equatorial central Pacific (Huang et al. 2005). The effects on the climate were soon noted after the event (Namias 1978) but the true climatic significance could not be thoroughly understood until the 1990s. Several studies were conducted to examine the nature and consequences of the low frequency variability in the Pacific basin, including the shift (Trenberth 1995, Zhang et el. 1997, Garreaud and Battisti 1999) as well as to determine the specific influences of this shift upon a wide variety of environmental, ecological, oceanic and atmospheric variables, including climate (Ebbesmeyer et al. 1992, Mantua et al. 1997, Hare and Mantua 2000). The causes of multidecadal variability or trends of the system remain a matter of research with possibilities going from internal ocean-atmosphere dynamics (Gu and Philander 1997, Seager et al. 2004), changes in the characteristic of El Niño (Federov and Philander 2000) to greenhouse-gas forcing (Boer et al. 2005).

In particular, Compagnucci et al. (2002, CAV02 henceforth) studied the low-frequency variability of summer precipitation in an arid region of Central-West Argentina (CWA, 28º-38ºS and 65º-70ºW) for the period 1900-1998. They found a significant shift towards lower frequencies by 1976/77 that gave rise to an increment of more than 20% of the regional mean. Because of the common date of occurrence, the precipitation shift was partly adjudicated to the climate transition of the central Pacific. Until mid-1970s the CWA summer precipitation was characterized by a cuasi-18-year oscillation that determined alternating periods of wet/dry summers of roughly 9 years of duration each. The change of the cycle provoked a prolonged wet period from 1973 until at least the end of the nineties with a few years of interruption. In addition the CWA summer precipitation was in-phase related to a remote region in South Africa, named the summer precipitation region (SPR-SA, Tyson and Dyer 1975) that also exhibits a cuasi-18-year cycle (CAV02). The teleconnection between both regions disappeared after mid-1970s due to the SPR-SA did not undergo any shift of its low-frequency variability (Mason et al. 1996, Lizcano and Todd 2005).

Therefore, the present study aims to discern the specific manner in which the climate transition affected the inter-annual atmospheric circulation in the Southern Hemisphere related to the summer precipitation in CWA.

2. DATA AND METHODOLOGY

Precipitation data consist of a regional index used by CAV02 that captures the regional inter-annual to multidecadal variability of summer precipitation at the meteorological stations within the CWA (see Table 1). The index ***P(t)*** is estimated as the percentage ratio between total (Oct-Mar) summer precipitation at each station and the station mean, averaged on all the stations following the formula:

$$Y_j(t) = (X_j(t) \cdot 100) / \chi_j \qquad 1 \le j \le n$$

$$P(t) = \sum_{j=1}^{n} Y_j(t) / n$$

where,

$Y_j(t)$: summer rainfall single series of station j, expressed as percentage of its 1958-1998 long run average.

$X_j(t)$: station *j´s* summer precipitation in year *t*.

j. index of stations,

n: number of station (n=9 for the study).

Positive (negative) values of the index anomaly denote wet (dry) summers. The index was recalculated for the period 1958-2004 on the baseline 1959-1998 (the year indicates the end of the season). The index anomaly is shown in Figure 1, which reveals the prevalence of wet summers since 1973, year of start for another 9-year period according to the former cuasi-bidecadal cycle that was not longer observed. Instead, the wet period is prolonged during the 80s and 90s, with a few interruptions (in 30 years, 20 are wet). The relationship between the index and the atmospheric circulation is tackled through the Pearson's first moment correlation coefficient. Areas in figures significant at α=0.10 are shaded.

We decided to use only data from 1958 because the monthly atmospheric data from NCEP-NCAR reanalysis used to examine the atmospheric circulation are more confident since 1958 over the SH (Kistler et al. 2001). Besides, some authors suggest that there may be a reversal trends in the South America precipitation series in 1998 due to possible reversal in the Pacific basin low-frequency variability (Huang et al. 2005). This could also be inferred to the CWA precipitation since from the summer 2001 there seems to be a negative trend, though the short record cannot allow us to evaluate this inference. Therefore, we analyze the climate transition 1976/77 relative to CWA precipitation for the periods, 1959-1977 and 1978-1998.

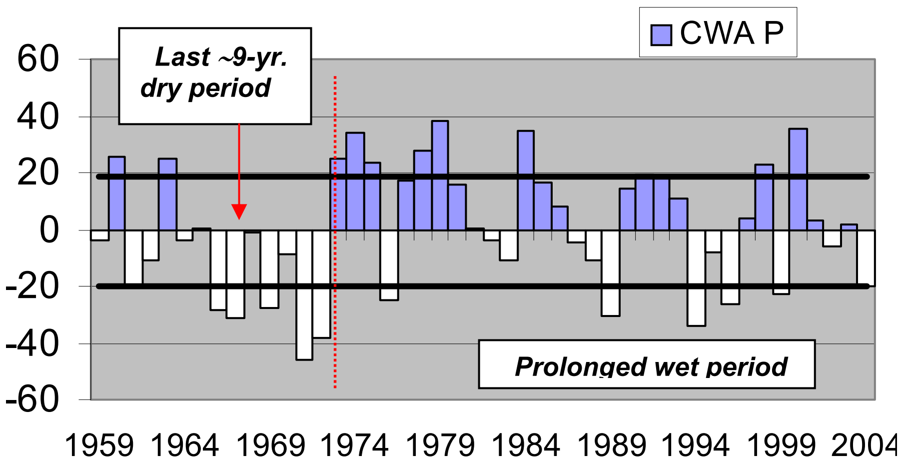

Figure 1: Percentage anomaly of the CWA precipitation index ***P*** estimated from 9 meteorological stations. Horizontal lines: first quartile q_1= -19.7% and third quartile q_3= +18.5%.

Station	**height (m)**	**Latitude (ºS)**	**Longitude (ºO)**	**Record**
(1) La Rioja	516	29º25`	66º52`	1958-2004
(2) San Juan	634	31º32`	68º34`	1958-2004
(3) Mendoza	769	32º53`	68º49`	1958-2004
(4) San Luis	734	33º18`	66º19`	1958-2004
(5)Villa Mercedes	514	33º41`	65º29`	1958-2004
(6) San Carlos	940	33º46`	69º02`	1958-1979
(7) Rama Caída	713	34º40`	68º24`	1958-2004
(8) Colonia Alvear	465	35º00`	67º39`	1958-1979
(9) Victorica	312	36º14`	65º26`	1958-2004

Table 1: Meteorological stations within CWA used in the analysis**.**

3. RESULTS

3.1 Teleconnection in the period 1959-1977

The correlation fields between the CWA summer precipitation and the 850 (a), and 500 hPa (b) geopotential heights for the period 1959-1977 are shown in Figure 2. Over the southern tip of South America correlation values are positive and significant with a core (r>0.7) centered at about 50ºS-78ºW in lower troposphere (Fig. 2.a). The signal extends over the continent toward lower latitudes. Also, a positive correlation core is observed south of South Africa (r>0.5). Over both the South Pacific and Atlantic subtropical anticyclones negative correlation values prevail, though not significant. A similar correlation field is obtained for middle troposphere (Fig. 2.b). At 200 hPa, the previous positive and significant core of correlation near southern South America is displaced westward locating over Patagonia (r> 0.6 at about 50ºS-70ºW; Fig. 3). Another core appears over the South Atlantic close to South Africa.

Thus, wet (dry) summers in CWA occurs with high (low) geopotential heights at mid-latitudes over the southwest of the South Atlantic in low and middle troposphere together with a weakening (strengthening) of the cuasi-stationary subtropical anticyclones. The structure results to be baroclinic over South America mid-latitudes, probably associated to higher frequency of anticyclonic (cyclonic) perturbations over the area during a wet (dry) summer.

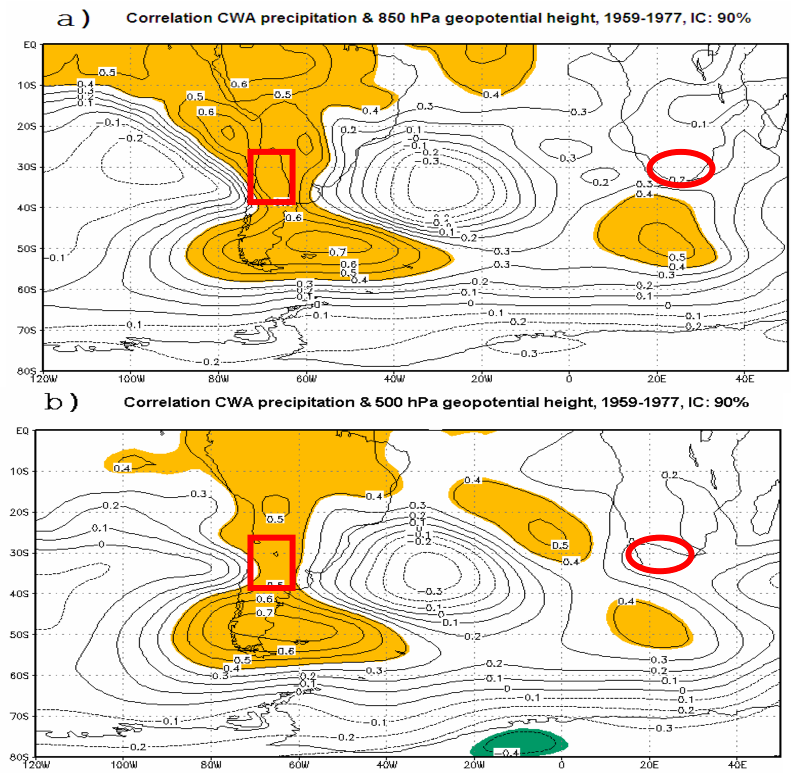

Figure 2: Correlation between CWA precipitation and geopotential height at 850 hPa (a) and 500 hPa (b), for the period 1959-1977. Shaded areas: interval of confidence (IC) > 90%. Rectangle: CWA. Ellipse: SPR-SA.

Around the Hemisphere, the correlation field shows a cuasi-4-wavenumber perturbation of baroclinic structure (figures not shown) at mid-latitudes from lower to higher levels (Fig. 3). Over Antarctica negative, though not significant, correlation values prevail. This is indicative that the interannual variability of CWA precipitation is associated with atmospheric processes of hemispherical scale that can favor hemispherical connections with remote regions. These atmospheric processes could also be partly related to the high-latitude mode or the Southern Annular Mode (SAM, Wallace and Thompson 2000, Marshall 2003). The correlation coefficient between the SAM empirical index devised by Marshall (2003) ($P_{sam}=P^{*}_{40°S}-P^{*}_{65°S}$, where P^{*}, normalized monthly pressure at around 40ºS and 65ºS, respectively), and the CWA precipitation index is 0.46, significant at α=0.10. Hence, the coherence in the low-frequency variability found by CAV02 between the CWA and SPR-SA seems to be explained by this hemispherical atmospheric bridge. This teleconnection indicates that when a wet (dry) summer in CWA is recorded, an increase (decrease) of atmospheric pressure over the ocean south of South Africa is observed (Fig. 3).

In this sense, Tyson et al. (1986) and Lindesay et al. (1998) showed that the occurrence of wet (dry) summer in the SPR-SA occurs with predominance of high (low) pressures over the ocean to the south and west of South Africa (an eastward extension of the South Atlantic subtropical anticyclone) with low (high) pressures at upper levels related to a trough (ridge) over southern South Africa. The wet circulation features are associated with anticyclonic circulation that transports moisture from the south-southeast towards the SPR-SA with convergence of mass and upward motion forced by the trough. The correlation field of Figure 3 agrees with these features. In particular, Triegaardt and Landman (1995) also found at synoptic scales a positive anomaly of geopotential height over the *Mar Argentino* Sea in simultaneous occurrence of the eastward extension of the South Atlantic anticyclone (west and south of South Africa), associated to wet event in the SPR-SA. Furthermore, the correlation values over the *Mar Argentino* Sea are significantly and positively related to the precipitation in CWA. Therefore, the in-phase coherence observed between both regions until mid-1970s seems to have this cuasi-4-wave at mid-latitudes as the atmospheric bridge of connection.

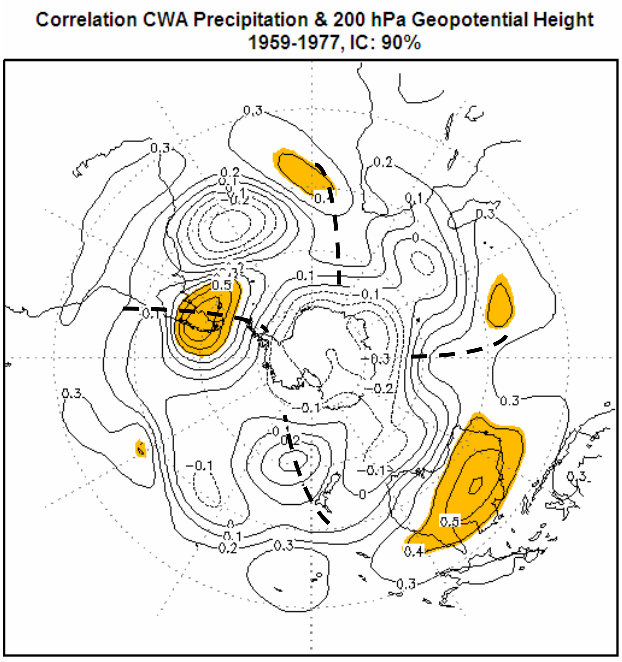

Figure 3: Hemispherical correlation field between CWA precipitation and 200 hPa geopotential height for the period 1959-1977, showing a mid-latitude cuasi-4 wave (dashed line). Shaded areas: interval of confidence (IC) >90%.

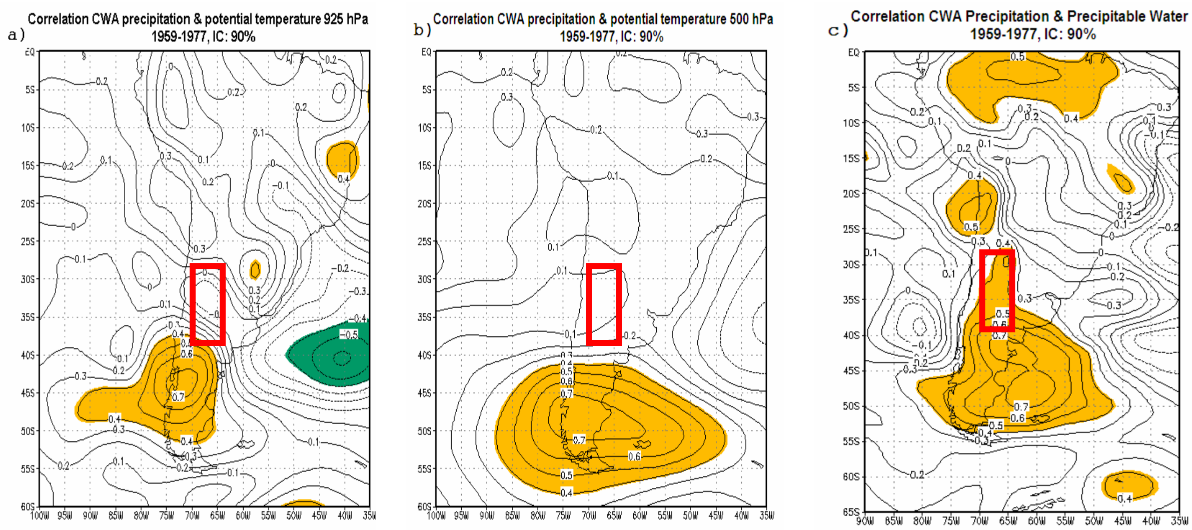

Figure 4: Correlation field between CWA precipitation and the potential temperature at 925 hPa (a) and 500 hPa (b) and between CWA precipitation and precipitable water (c), for the period 1959-1977. Shaded areas: interval of confidence (IC) >90%. Rectangle: CWA.

The correlation fields for potential temperature at lower and middle troposphere (Fig. 4.a and .b) show that these tropospheric layers are warm (cool) during the occurrence of wet (dry) summer in CWA. In turn, an increase (decrease) of precipitable water over Patagonia, CWA and Amazonia is observed (Fig. 4.c). The warming (cooling) of the mid-troposphere could be linked to downward (upward) motions, as revealed by the correlation field between CWA precipitation and omega at 400 hPa (Fig. 5). Clearly, a wet (dry) summer in CWA is associated to ascending (descending) air over the area. In addition, significant and positive (negative) correlation is observed over the SPR-SA region of South Africa, which indicates ascent (descent) of air masses and possible increment (decline) of precipitation in the area (Fig. 5).

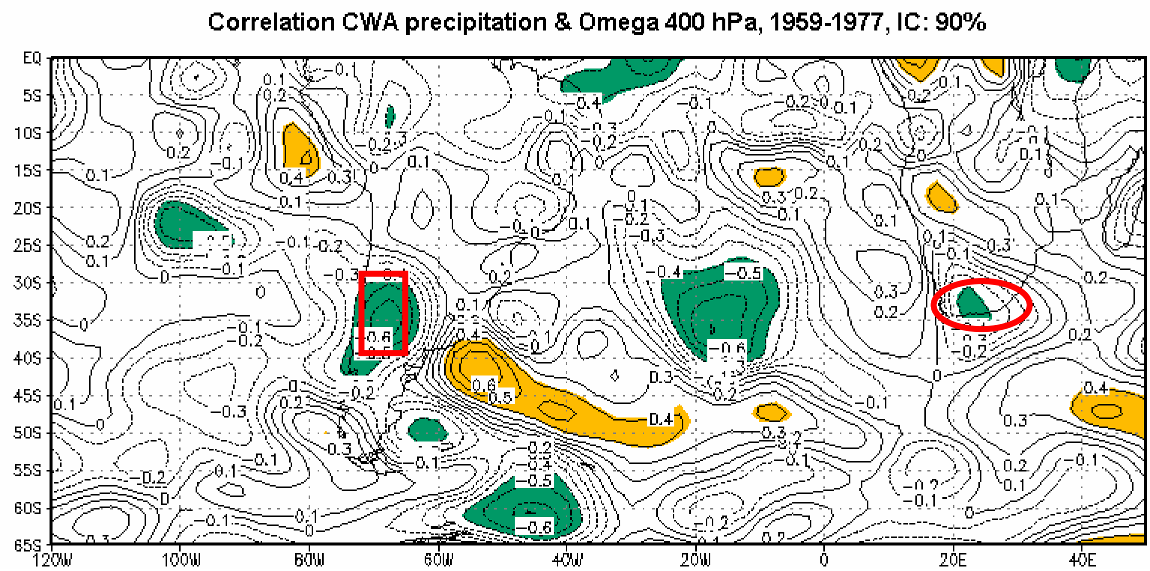

Figure 5: Correlation field between CWA precipitation and omega at 400 hPa for the period 1959-1977. Shaded areas: interval of confidence (IC) >90%. Rectangle: CWA. Ellipse: SPR-SA.

This is in agreement with in-phase connection between precipitation in CWA and SPR-SA found by CAV02 for the period. In addition, the warming (cooling) in lower layers over Patagonia (Fig.4.a-.b) can be adjudicated to warm (cool) thermal advection due to the north-northeast (south-southwest) component of the velocity field induced by the high (low) geopotential heights in the area (Fig. 6.a).

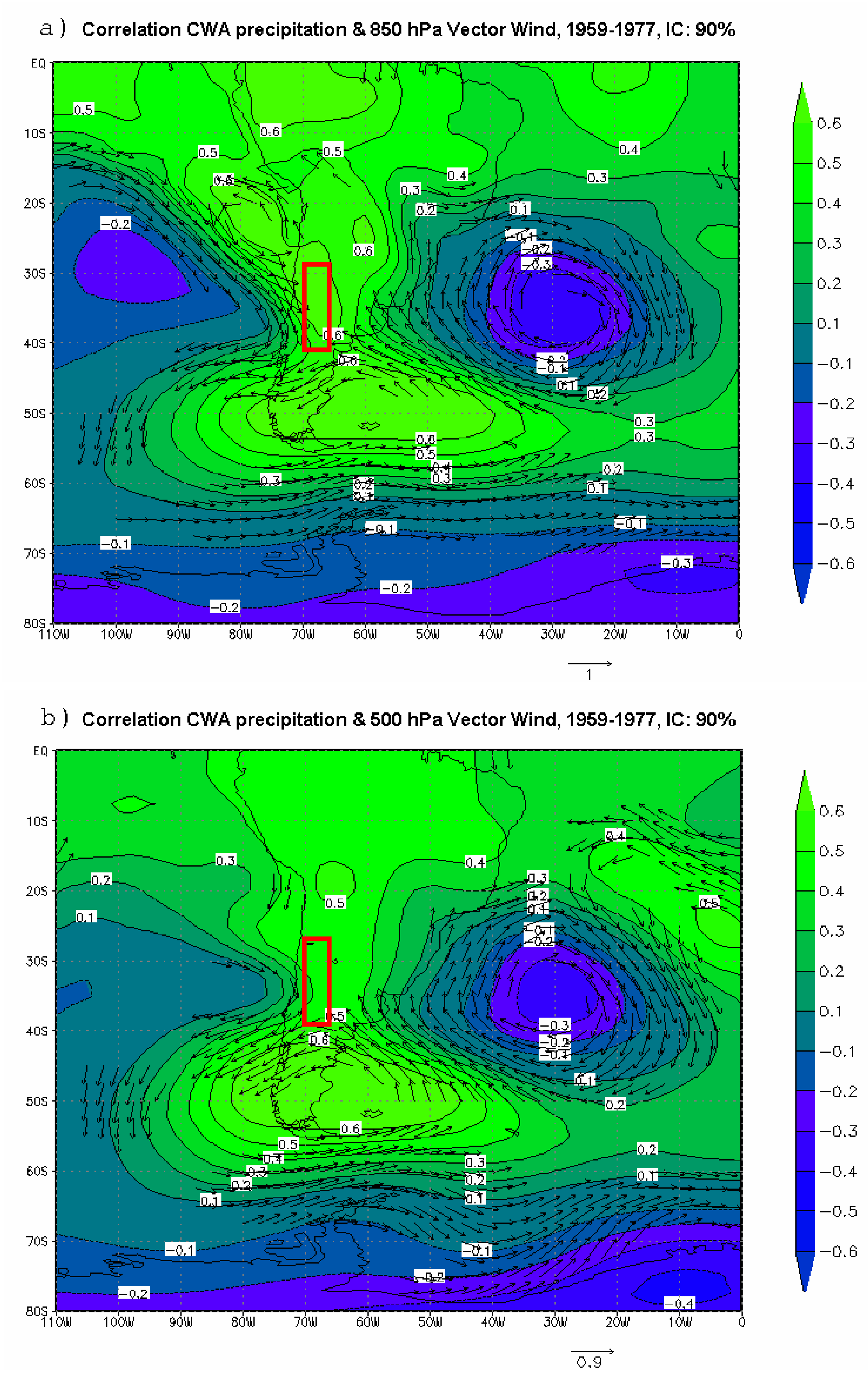

Figure 6: Correlation between CWA precipitation and the vector wind at 850 (a) and 500 hPa (b) (vectors shown significant at α<0.10) for the period 1959-1977. Contours and shaded: correlation values between CWA precipitation and corresponding geopotential height. Rectangle: CWA.

Also the increase (decrease) in precipitable water contents (a measure of available moisture) can be adjudicated to the prevalent easterly flow from the ocean south of 30ºS. At subtropical latitudes the correlation field with the vector wind shows two cyclonic centers over the area of the subtropical semi-permanent anticyclones, indicating weakening (strengthening) of these systems during wet (dry) summers (Fig. 6.a and .b). Noticeably, whereas the correlation values with the geopotential height (Fig. 2) show similar sign, the values are not significant as they are in here.

3.2 Teleconnection in the period 1978-1998

The correlation fields between the CWA precipitation and the 850 (a) and 500 hPa (b) geopotential heights show that wet (dry) summers are associated with high (low) geopotential height at lower troposphere over eastern subtropical/tropical South America from the center of Brazil to 38ºS (Figure 7).

Another significant core of opposing sign appears to the west of the subtropical Andes over the eastern Pacific around 30ºS. When the pressure raises (drops) in Brazil and drops (raises) in the Pacific, there is a trough (ridge) over CWA associated to wet (dry) summers. This indicates that the interannual variation of precipitation in CWA is related to the zonal pressure gradient settled between both cores. In climatic terms, the pressure gradient is naturally established by the continental low over central subtropical South America (Chaco Low) and the subtropical South Atlantic anticyclone. Thus, during a wet (dry) summer, it is expected to have an increment (decline) of the north-to-south meridional flow generated by these climatic systems.

Over South Africa, in the low levels the correlation coefficients decrease so that positive and significant values appear to the west in a lower extension, in the South Atlantic at about 30ºS, and negative (not significant) to the south. In mid-troposphere the correlation is not significant, which would be indicating a disconnection between the proceses causing precipitation in CWA and SPR-SA.

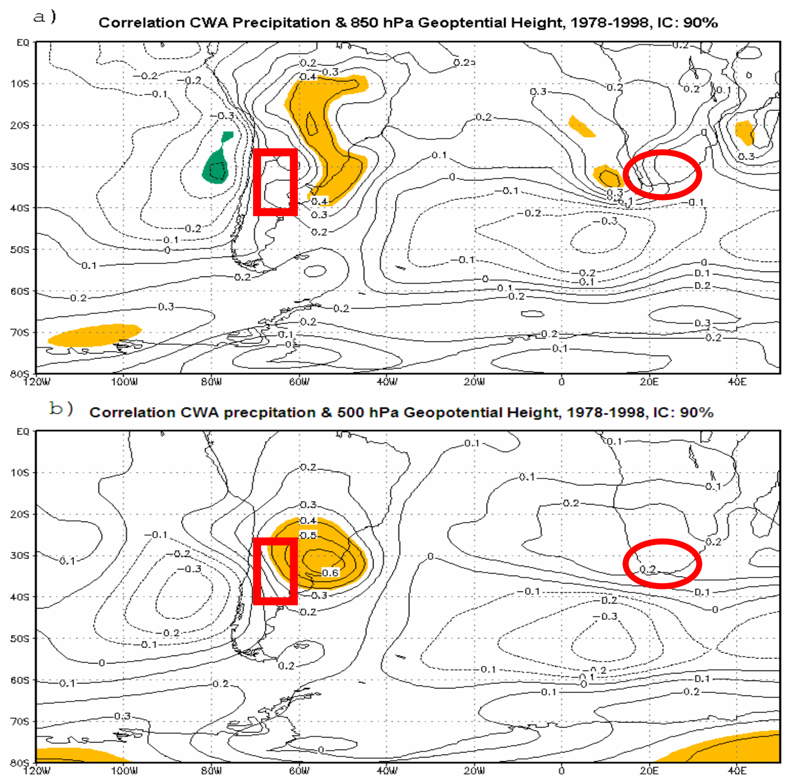

Figure 7: Correlation between CWA precipitation and geopotential height at 850 hPa (a) and 500 hPa (b), for the period 1978-1998. Shaded areas: interval of confidence (IC) > 90%. Rectangle: CWA. Ellipse: SPR-SA.

In turn, the lower level correlation indicates that a raise (drop) of geopotential heights is expected at lower layers close to the southwestern coasts of South Africa and a drop (raise) over the Atlantic, to the south of South Africa, during a wet (dry) summer in CWA. According to Tyson (1986) and Lindesay (1998) this configuration of pressure field in the surroundings of South Africa is associated to drought episodes in the SPR-SA. Therefore, the strengthening of the South Atlantic subtropical anticyclone over its western flank (positively related to CWA precipitation) is inversely related to the SPR-SA precipitation, indicating precipitation below the mean (drought). Hence, from the 80s to mid-90s, while CWA undergone a prolonged wet period, notably the SPR-SA was affected by droughts (Mason et al. 1996, Lindesay 1998).

The change in the areas of teleconnection between the periods pre-1977 (Fig. 2) and pos-1977 (Fig. 7) contributes to the loss of coherence in the low frequency signal of the precipitation variability between CWA and SPR-SA around 1976/77 (CAV02).

In a hemispherical view, the correlation field shows a propensity towards an inverse SAM, i.e., a raise (drop) of pressure over Antarctica during wet (dry) CWA summers an relatively low pressures over midlatitudes (Fig. 8). Furthermore, for the years pos-1977 the cuasi-4-wave is absent. Therefore, it suggests that the interannual variability of CWA precipitation pos-1977 can be due to dynamical processes restrained to regional scales of subtropical-tropical latitudes of South America.

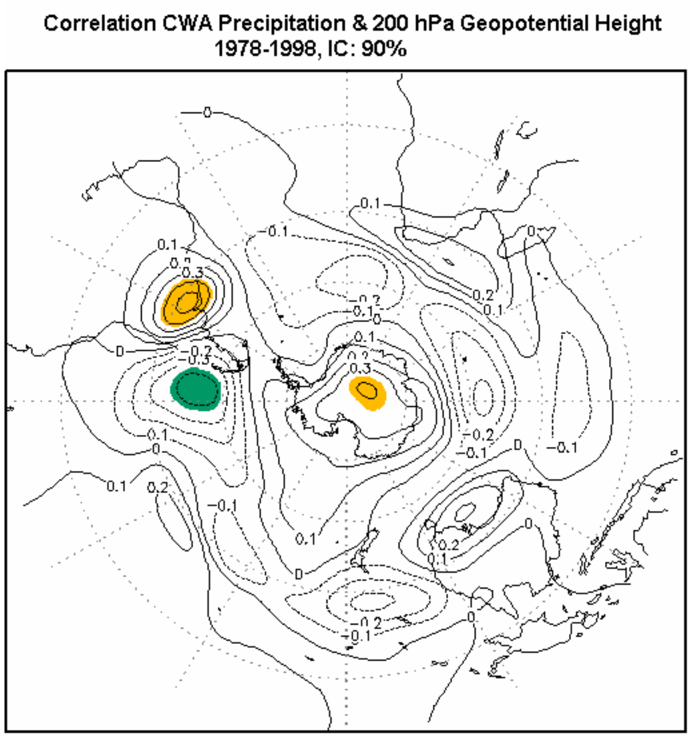

Figure 8: Hemispherical correlation field between CWA precipitation and 200 hPa geopotential height for the period 1978-1998. Shaded areas: interval of confidence (IC) >90%.

The correlation fields for the potential temperature at 925 and 500 hPa (Fig. 9.a and .b) show a positive and significant core over Uruguay, NE Argentina and SE Brazil at lower and middle troposphere indicating that the previous anticyclonic structure over tropical South America favors warming by possible thermal advection from lower latitudes. In turn, a raise of precipitable water occurs over subtropical Argentina, north of 40ºS with higher correlation values in CWA, during a wet summer (Fig. 9.c). The inverse occurs for dry summers. Both the raise (drop) of temperature and of precipitable water at subtropical latitudes can be associated with meridional mass flow from the north (south) induced by the pressure field in lower and middle troposphere related to precipitation in CWA that could be favourable (disfavorabe) for moisture and heat transport from tropical latitudes.

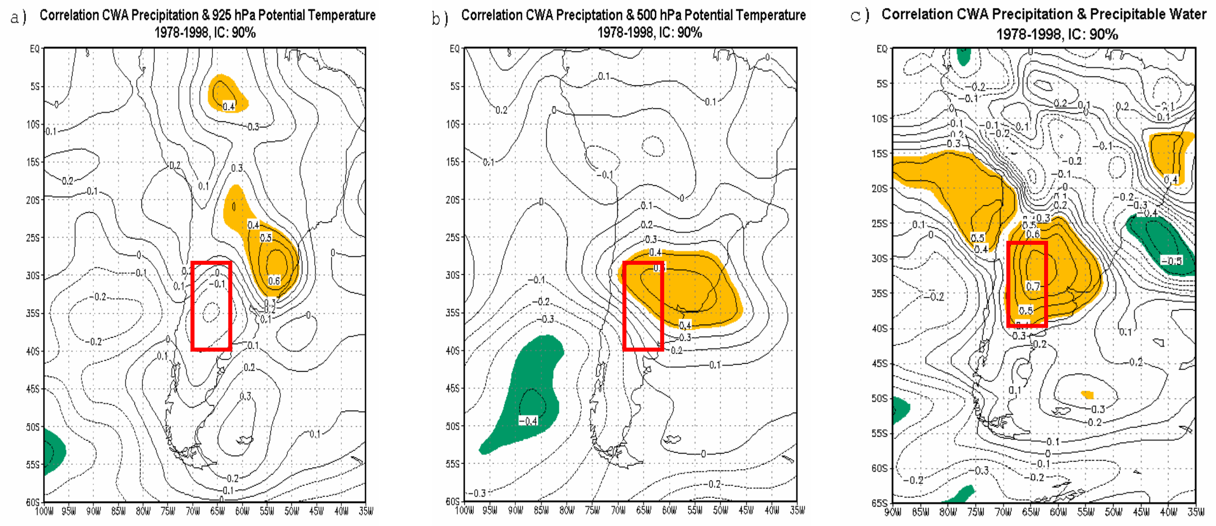

Figure 9: Correlation field between CWA precipitation and the potential temperature at 925 hPa (a) and at 500 hPa (b) and between CWA precipitation and precipitable water (c), for the period 1978-1998. Shaded areas: interval of confidence (IC) >90%. Rectangle: CWA.

The correlation with the 400 hPa omega reveals that upward (downward) motions over central subtropical Argentina is observed during a wet (dry) summer (Fig. 10), between the intermediate zone of the cyclonic (anticyclonic) structure, to the west of the Andes, and the anticyclonic (cyclonic) structure, to the east, at middle layers (Fig. 7.b). Likewise, downward (upward) motions in South Africa tend to be associated with wet (dry) CWA summers, further favoring the disconnection between the subtropical regions of CWA and SRP (see correlation within ellipse).

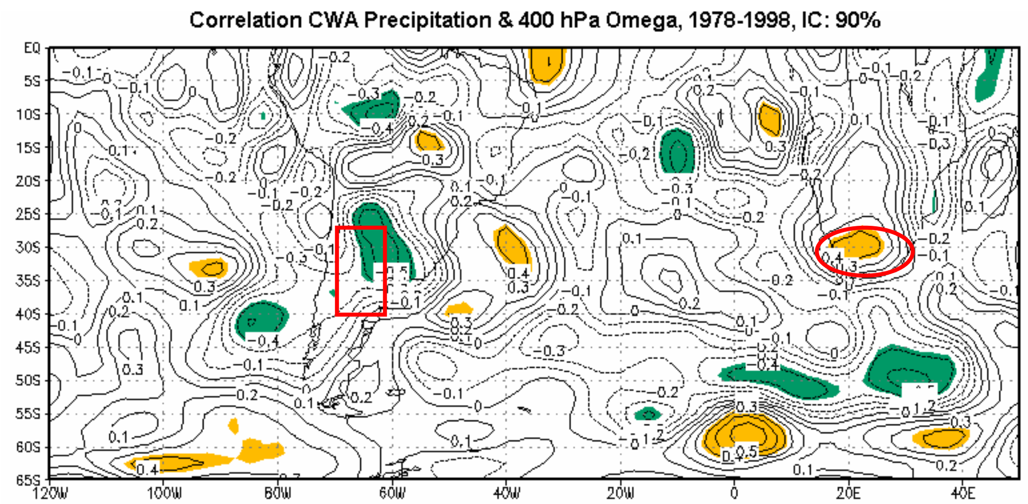

Figure 10: Correlation field between CWA precipitation and omega at 400 hPa for the period 1978-1998. Shaded areas: interval of confidence (IC) >90%. Rectangle: CWA. Ellipse: SPR-SA.

The previous low-level features agree with the correlation fields between the vector wind and precipitation that show significant correlation vectors depicting a northwesterly (southeasterly) flow from the Paraguay plains to northern Argentina for a wet (dry) summer (Fig. 11.a and .b).

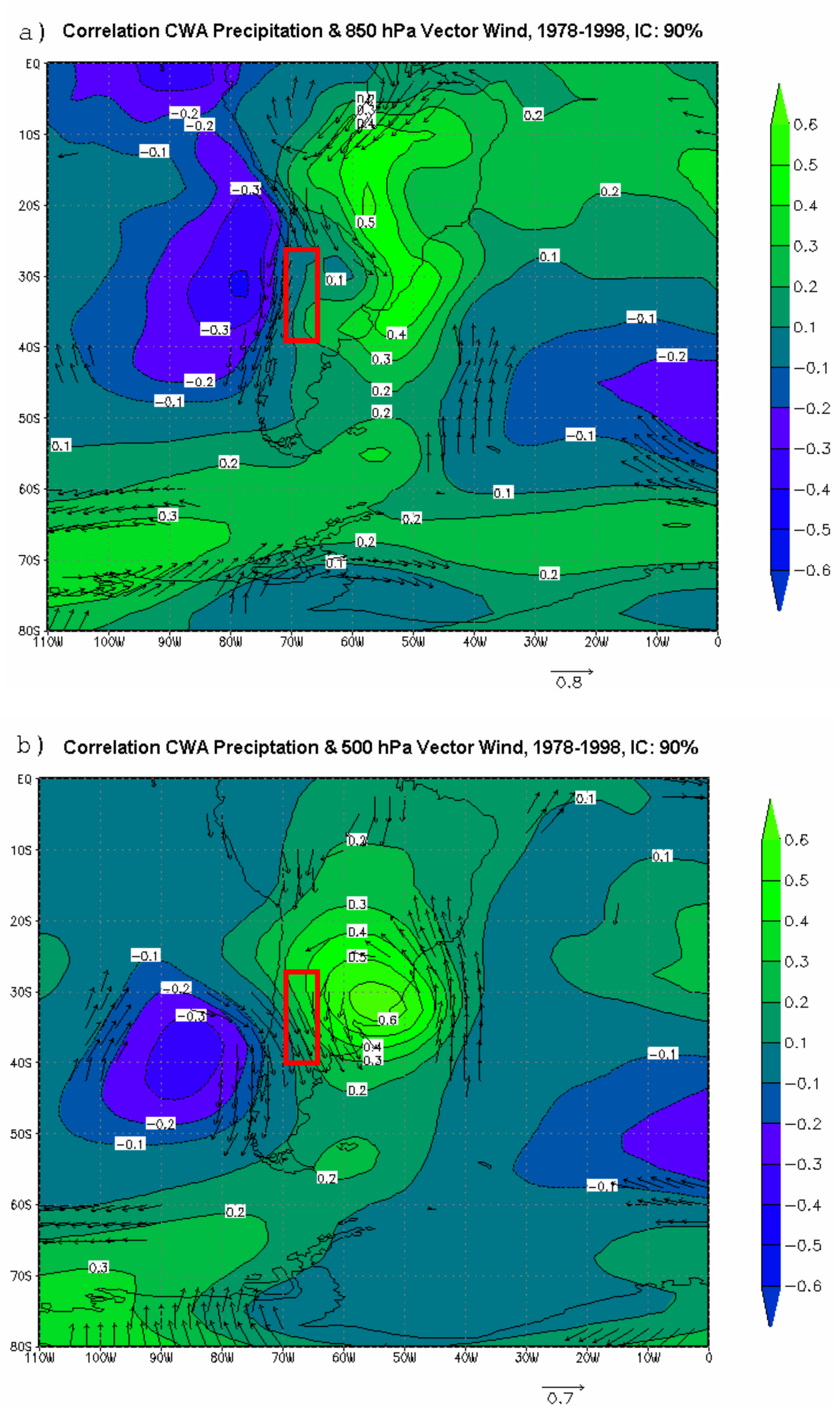

Figure 11: Correlation between CWA precipitation and the vector wind at 850 (a) and 500 hPa (b) (vectors shown significant at $\alpha<0.10$) for the period 1978-1998. Contours and shaded: correlation values between CWA precipitation and corresponding geopotential height. Rectangle: CWA.

4. CONCLUSIONS

Comparing the teleconnections obtained for the periods *pre-1977* and *pos-1977*, a change in the action centers of the atmospheric processes of the low frequency variability associated with summer precipitation in CWA is observed. This is undoubtedly responsible for the loss of connection between CWA and South Africa, via the cuasi-18-yar oscillation, by the summer 1976/77 pointed out by CAV02. All seem to indicate that in the period 1959-1977, dynamical processes related to summer precipitation in CWA are linked to the variability of mid-latitude baroclinic systems in connection with a hemispherical cuasi-4-wave modulation, the latter probably linked to the SAM. In the period 1978-1998, the interannual variability of the circulation is further related to dynamical processes regionally restrained to subtropical-tropical latitudes of South America.

Some authors suggest that after the climate transition 1976/77 an atmospheric circulation reflecting more like-El Niño features was established over South America. Hence, a strengthening of the north-to south low-level flow from tropical to subtropical latitudes of South America is expected due to the enhanced anomaly of mass distribution between the Pacific and Atlantic (Marengo et al. 2004). The atmospheric circulation change associated with CWA precipitation change supports this suggestion at the interannual scale. Specially, the subtropical-tropical area of South America and South Atlantic show significant correlations with CWA precipitation, which suggests the influence of the change of mass distribution. Further analysis will be required to determine any association between CWA precipitation and the El Niño conditions at interannual-to-multidecadal scales.

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