SOUTH AMERICAN LOW-LEVEL JET

October 2002 Report

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María Assuncao Silva Dias**

1. Brief Introduction

One of the PROSUR goals for this and next years is to

- Promote and support active participation of the PROSUR members in the activities of the South American Low Level Jet Field Experiment (SALLJEX). (November 2002 – April 2003).

This goal is directly related to the objectives adressed in PROSUR and to the South American low-level jet (SALLJ) program, component of the CLIVAR/VAMOS program, that is an internationally coordinated effort in order to contribute to the understanding of the role of the SALLJ in moisture and energy exchange between the tropics and extratropics and related aspects of regional hydrology, climate and climate variability.

SALLJEX is framed by the SALJ strategy of i) obtaining an improving the description of the temporal and spatial structure of the SALLJ based on expanded monitoring activities and special field experiments, ii) evaluating the veracity of numerical representation (forecasts and analyses) of SALLJ against special observations and; iii) determining improvements of initial state representation and model parameterizations required to improve prediction. This strategy aims to improve short and long term predictions. This strategy is common to PROSUR objectives in the MERCOSUR region.

The document on the American low-level jet study (ALLS), includes the SALLJ scientific prospectus and implementation plan and is available at the CLIVAR web page http://www.clivar.org/organization/vamos/.

The field observation campaign (SALLJEX) being planned between 1 November 2002 and 1 March 2003, will put together different observing systems: basically missions with a research aircraft (NOAA/WP-3D), an enhanced and improved upper air sounding network and a significant enhancement of the current raingauge network.

This report aims to summarize the research activities during last year focused in this PROSUR agenda topic emphasizing the interactions within the PROSUR community. As with other PROSUR reports the ongoing research is not exclusively focused in this particular subject as there are topics in common with extreme events, atmospheric modeling and Paraná Plata Basin floods.

There are many scales involved in the analysis of mechanisms and processes related to SALLJ occurrence and strength. The findings presented in this report emphasize the following mechanisms, variabilities and patterns:

- SST anomalies over the Atlantic and the Pacific.
- Mechanical effects.
- MJO and other intraseasonal oscillations driving the seesaw pattern "SACZ" "non SACZ".
- Synoptic baroclinic wave trains.
- Diurnal oscillation and PBL forcing.

There is a substantial progress in the description of SALLJ related features at different time scales but there is still a need for a continuing effort in the process .of understanding mechanisms. One of the problems that has been identified relates to the uncertainty in mesoscale models to reproduce convection and surface characteristics to successfully explain the relationship between the LLJ and the related precipìtation, in terms of timing, location and intensity. The SALLJEX will provide especially useful data in the extensive data void regions to approach with more confidence the objectives proposed in PROSUR related to SALLJ. In the following sections research is summarized. The content included is based on the contributions of the corresponding authors.

1) Title: Midsummer low-level circulation and precipitation in subtropical South America and related sea surface temperature anomalies in the South Atlantic

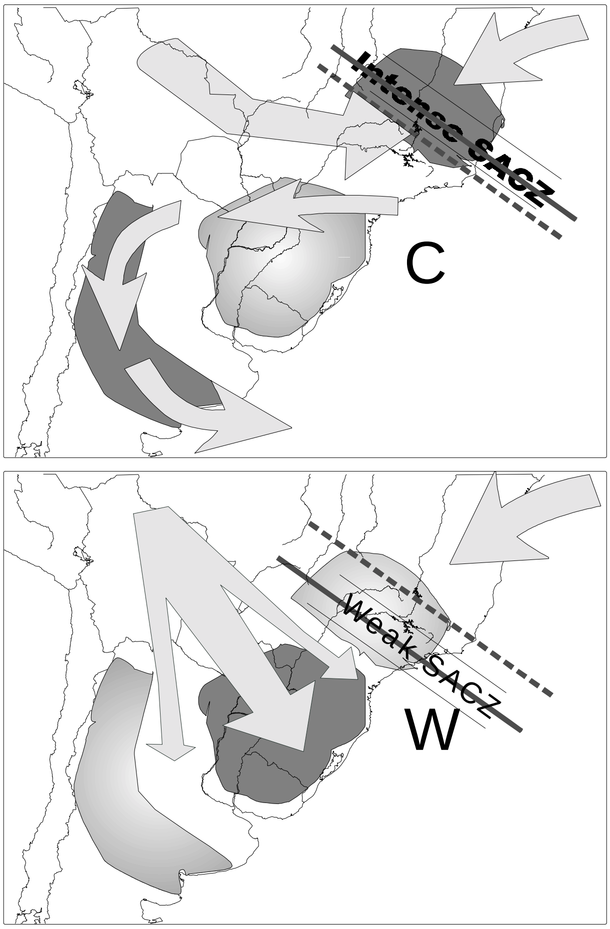
Authors: *Moira Doyle y Vicente Barros, UBA*
Submitted to Journal of Climate, 2002 (in press).

This research was focused in studying the mid-summer interannual variability of the low-level tropospheric circulation and of the precipitation field in subtropical South America (SA) associated to the sea surface temperature (SST) anomalies in the western subtropical South Atlantic ocean (WSSA). To accomplish this both reanalyzes, regional precipitation data sets and monthly SSTs. Have been used.

The region of the WSSA where SST has the strongest relation with precipitation in subtropical SA was identified using canonical correlation analysis. This region extends from 20°S to 30°S and from 30°W to 50° W. Composites corresponding to extreme SSTs in this area show two well-differentiated patterns in the low-level circulation and in the precipitation fields. In the composite corresponding to the more positive SST anomalies in this area, the mainstream of the low-level flow and of the moisture transport from the tropics starts to follow a southeastward direction at 10°S, and converges with the west flow at 35°S over the Atlantic Ocean. On the other hand, in the composite corresponding to the more negative SST anomalies, the low-level flow and the moisture transport from the tropics turn eastward toward the South Atlantic convergence zone (SACZ) at about 20°S, converging with the flow from the north driven by the South Atlantic high. In this composite, there is an anticyclonic circulation with a westward flow between 25°S and 35°S, which turns southward after reaching the proximity of the Andes Mountains.

In the composite of the more positive anomalies, there are two regional maximums in the precipitation field. One maximum stretches along the continental extension of a southwardly displaced SACZ and another is centered at about 30°S and 55°W, in the path of the main stream of the low-level moisture transport. In the other composite, there is only one regional maximum in precipitation, which coincides with the continental extension of the SACZ shifted northward of its mean position, and with a relative minimum in northeastern Argentina and southern Brazil. In this composite, in western Argentina, there are positive anomalies in the precipitation field favored by the transport of moisture from the Atlantic Ocean.

These results are summarized in the conceptual model presented in the next figure:



(a) (b)

Figure: Scheme of the low-level water vapor transport and precipitation anomaly maximums (dark shadow) and minimums regions (light shadow) in January for (a) C months (b) W months. Dashed line indicates the approximate mean axis of the convective activity in the SACZ and in its continental extension.

2) Tittle:
The influence of the Andes mountains on the South American low-level flow

Authors: *Claudia Campetella and Carolina Vera, CIMA/UBA*

Geophysical Research Letters, Vol. 29, Nº 17, 1826, doi:10.1029/2002GL015451, 2002

This study tries to explain what controls the South American LLF by studying the dynamics of the interaction between the westerly mean-flow and the Andes. We hypothesize that, in the absence of diabatic heating and moist physics, the topographic forcing is sufficient to reproduce the main observed features of the South American LLF (Figure 1). A dry, hydrostatic, three-dimensional primitive equation model is used to evaluate the mechanical effect of the Andes mountains on the South American low-level flow (LLF). The numerical simulation for austral winter conditions reproduces the evolution of a cyclonic perturbation that moves along 35°S eastward from the eastern South Pacific. Once the upper-level cyclone is on the lee side, the perturbation acquires a more typical baroclinic wave structure and low-level intensification of the system occurs around 1000 km east of the orography and the LLF attains its maximum intensity at subtropical latitudes (Fig. 2a). The simulated flow exhibits the typical NW-SE orientation characteristic of the observed mean winter LLF (Fig. 1a). However, the simulation shows that the evolving cyclone provides favorable conditions for an anomalous southward flow penetration until 37°S in agreement with observed cases of cyclonic development. Because the highlands located on the southeastern coast of Brazil were not included in the model topography, thus the LLF is not as channeled as is the observed (Fig. 1a). The location of the low-level meridional wind maximum at around 20°S and the corresponding meridional-wind vertical structure are also well captured by the model. The vertical cross-section displayed in Figure 2c shows evidence of the upper-level synoptic wave with a secondary maximum of northerly winds at around 12 km. The simulated LLF weakens during the following days as the decaying cyclone moves eastward (figures not shown).

During summer the main baroclinic region is located further south at around 50°S. As a consequence, paths of eastward propagating synoptic-waves are located poleward of the highest elevations of the Andes and only their equatorward flanks are disturbed by the orography. The integration for summer conditions shows the development of the southward LLF on the eastern slope of the Andes from the first day of the simulation when the low-level cyclone is located on the southwestern tip of South America (not shown). By day 4 (Fig. 2b) the system has moved off the eastern coast of South America and the LLF displays its maximum strength at around 20°S that is south of its observed climatological position (Fig. 1b). A comparison with winter simulation shows that the southward flow penetration produced by the summer cyclone is not as intense as that associated with the winter system (Fig. 2a,b). The modeled summer vertical flow shows a core at tropical latitudes concentrated along the eastern slope without evidence of a synoptic-type structure aloft and without evidence of the monsoonal-type vertical structure present in the observed mean meridional flow (Fig. 1d). The fact that this model does not include diabatic heating forcing may explain such differences [*Figueroa et al.*, 1995]. However, the main features of the simulated summer circulation, such as the location of the low-level wind maximum and the southward direction of the flow, agree well with those observed by *Salio et al*. [2002] as characteristics of the more intense low-level jet cases.

Simulations of the atmospheric circulation over South America only forced by the Andes reproduce the main features of the low-level winds. Moreover, neither diabatic heating nor moist physics were necessary to explain the leading dynamical characteristics of the observed flow. In particular, the low-level northerly flow east of the Andes has clearly emerged from the interaction of the basic flow and the Andes.

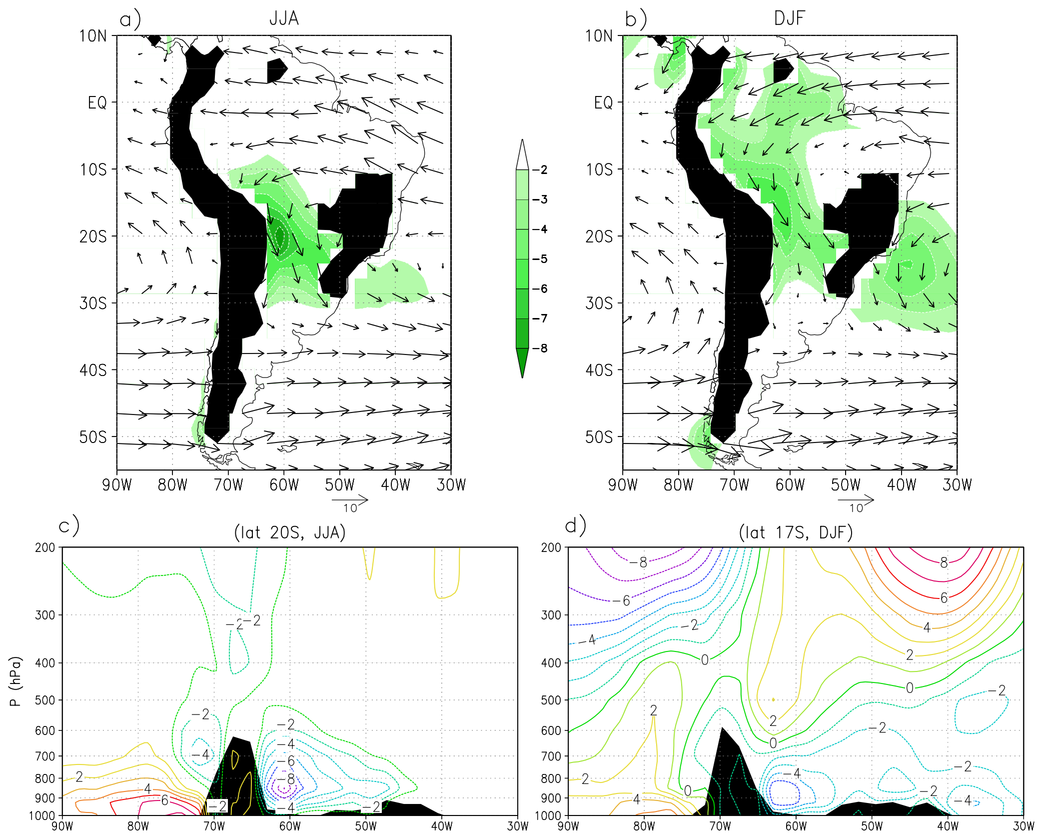


Figure 1: (a) Mean horizontal wind field (vector) and mean meridional wind at 850 hPa (shaded) averaged from June through August 1979-1993. Contour interval is 2 m s^{-1} and values lesser than -2 m s^{-1} are shaded. Orography higher than 700 m is black colored. (b) as in (a) but averaged from December through February. (c) longitude-height section of the JJA mean meridional wind at 20ºS. Contour interval is 1 m s^{-1}, negative contours are dashed and zero contour is omitted. (d) as in (c) but for the DJF meridional wind at 17ºS.

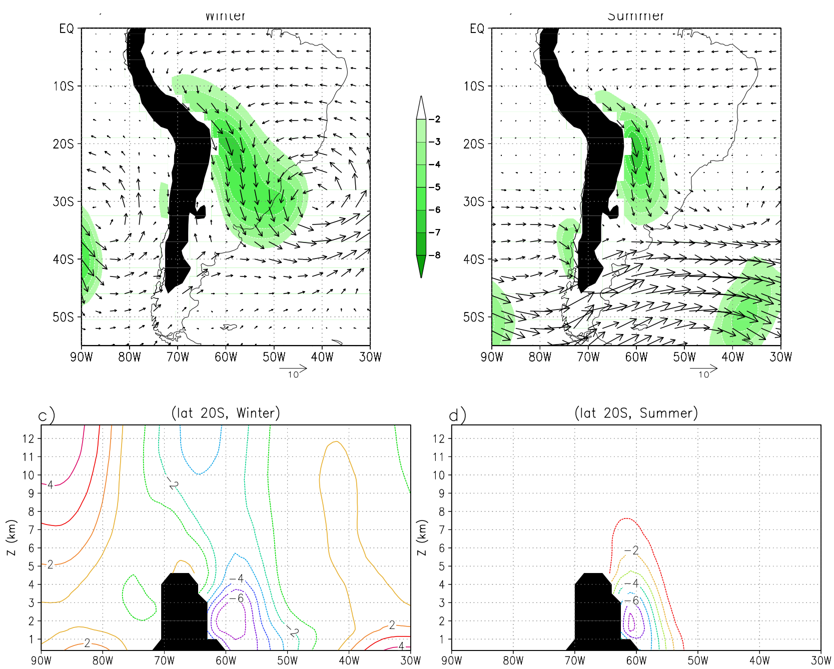


Figure 2: (a) Horizontal wind field (vector) and meridional wind at 1500 m (shaded), for day 5 of *integration B* for winter simulation. Contour interval is 2 m s^{-1} and values lesser than -2 m s^{-1} are shaded, (b) as in a) for day 4 of *integration B* for summer simulation. Model orography higher than 1000 m is black colored. (c) longitude-height section of the meridional wind for day 5 of 5 of *integration B* for winter simulation at 20ºS. Contour interval is 1 m s^{-1}, negative contours are dashed and zero contour is omitted. (d) as in c) at day 4 of 5 of *integration B* for summer simulation.

3) *Title:*
Climatology of low-level jet east of the Andes as derived from the NCEP reanalyses.

Authors: *José Marengo, W. R. Soares, C. Saulo and M. Nicolini*
Collaboration between CPTEC/INPE and CIMA, UBA
Submitted to Journal of Climate, 2002

A climatology of the Low Level Jet East of the Andes (LLJ) is developed using the 1950-2000 circulation and moisture fields from the NCEP reanalyses and available pilot balloon observations made in Bolivia and Paraguay since 1998. Upper and low-level circulation fields were derived for seasonal means and for LLJ composites during the warm and cold seasons. The Bonner criterion 1 was applied for sites en central Bolivia and downstream near northern Paraguay and southern Brazil, to determine the spatial and temporal characteristics of the LLJ. On the circulation characteristics, LLJ summertime composites show the enhanced low-level meridional moisture transport coming from tropical South America as well as an upper level wave train emanating from the West Pacific propagating towards South America. The intensification of the LLJ obeys to the establishment of an upper-level ridge over southern Brazil and a trough over most of Argentina. The circulation anomalies at upper and lower levels suggest that the intensification of the LLJ would lead the intensification of the South Atlantic Convergence Zone SACZ and the penetration of cold fronts with an area of enhanced convection ahead at the exit region of the LLJ.

Regarding the time variability, LLJ seems to occur all year long, with the LLJ bringing tropical air masses from the Amazon into southern Brazil-Northern Argentina more frequent in the warm season, and the LLJ that brings tropical maritime air from the Subtropical Atlantic High more frequent during winter. LLJs are detected mostly in summer to the north of around 20ºS, while to the south the LLJs seem to occur all year long.The diurnal cycle shows that LLJs are more frequent and intense between 06 and 12 UTC for the warm season north of 20ºS, while at the region downstream the maximum is detected between 00 and 06 UTC. during the cold season. At interannual time scales, even though there is a weak tendency for stronger/more frequent LLJ episodes during El Niño year 1998, we cannot affirm with large degree of certainty that there is any relationship between the occurrence of El Niño events and the number and/or intensity of LLJ episodes.

4) *Enhanced precipitation over Southeastern South America related to strong low-level jet events during austral warm season*

Authors: *Matilde Nicolini, A. Celeste Saulo, Juan Carlos Torres and Paola Salio, CIMA/UBA*
Meteorologica, Special Isue on South American Monsoon System, 27, Nº1 y 2

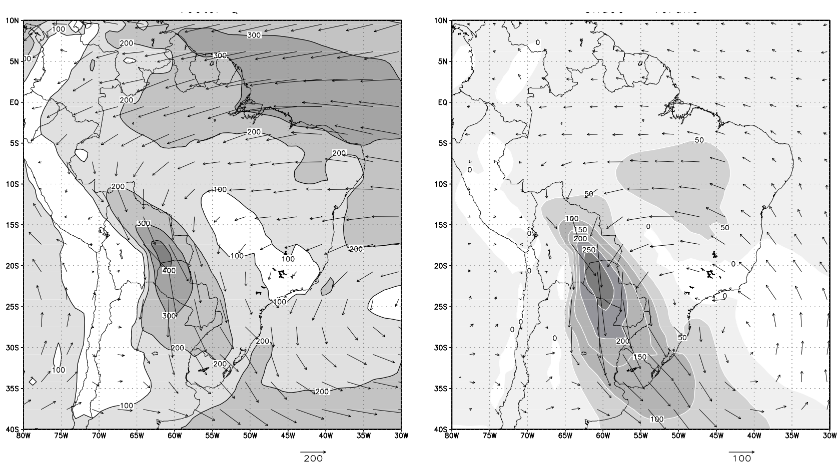
This paper aims to summarize current progress in climate studies related to southward SALLJ episodes characterized by their farther south extension (denoted as Chaco Jet events, CJEs) and their associated precipitation fields, with emphasis on their impact on precipitation over Southeastern South America (SESA) region. This review includes results using European Centre Medium Weather Forecast reanalyses (ERA), satellite imagery, raingauge network rainfall data and ETA model products.

Both ERA reanalyses and high resolution ETA/CPTEC (Centro de Previsao de Tempo e Estudos Climaticos, Brazil) model products capture the prominent role of the CJEs to transport moisture from tropical into extratropical latitudes over South America. A comparison between CJEs and NCJEs (non-Chaco SALLJ events) in terms of vertically integrated water vapor flux field, net moisture flux convergence and precipitation field over SESA, is addressed. During CJEs, southward transport at the northern limit of a rectangular region that encompasses part of SESA more than doubles the summer value and the net column integrated moisture convergence over the SESA domain is stronger than the NCJEs´ value.

High resolution ETA model products show that during CJEs northerly transport is maximum during nocturnal or very early morning hours and synoptic evolution is dominated by a baroclinic wave pattern, a thermal low over Northwestern Argentina (NAL) and a westward shifted South Atlantic Anticyclone.

Environmental conditions during CJEs are highly favorable to enhance precipitation over SESA. The life cycle of a sample of 27 highly precipitating mesoscale convective systems (HPMCS) that occurred during the period October to April 1988/1993 over the SESA region have been composited as well as their environmental conditions during life cycle. There is a dramatic difference in size between these huge HPMCSs´ convective cores (radius ≅ 400 km) at mature stage and previous results found by other authors. Even if CJE occurrence was not required to select the MCS sample more than 80% of these systems happen to occur during CJEs which represent their primary moisture source.

a) c)



b) d)

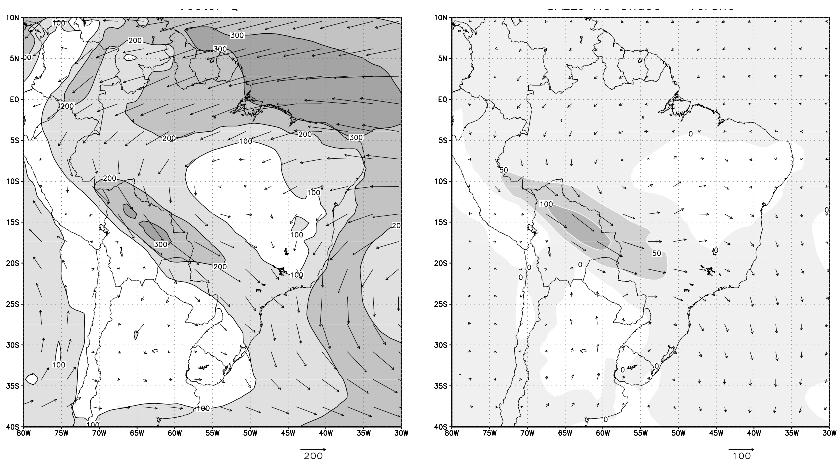


Figure1: Vertically integrated moisture flux (vectors, values higher than 100 m^{-1} s^{-1} are shaded) for a) CJEs composite and b) NCJEs composite during summer and corresponding anomaly (panels c,d), (northerly values are shaded). Fields were calculated using ERA 1979-1993.

a) b)

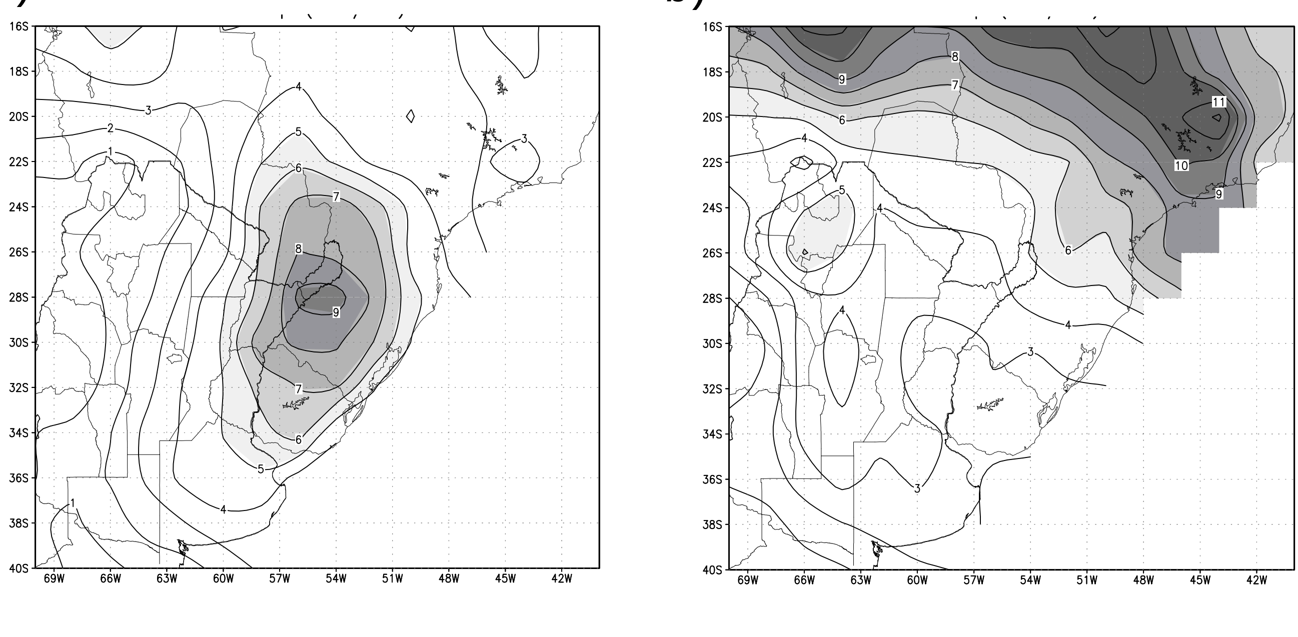
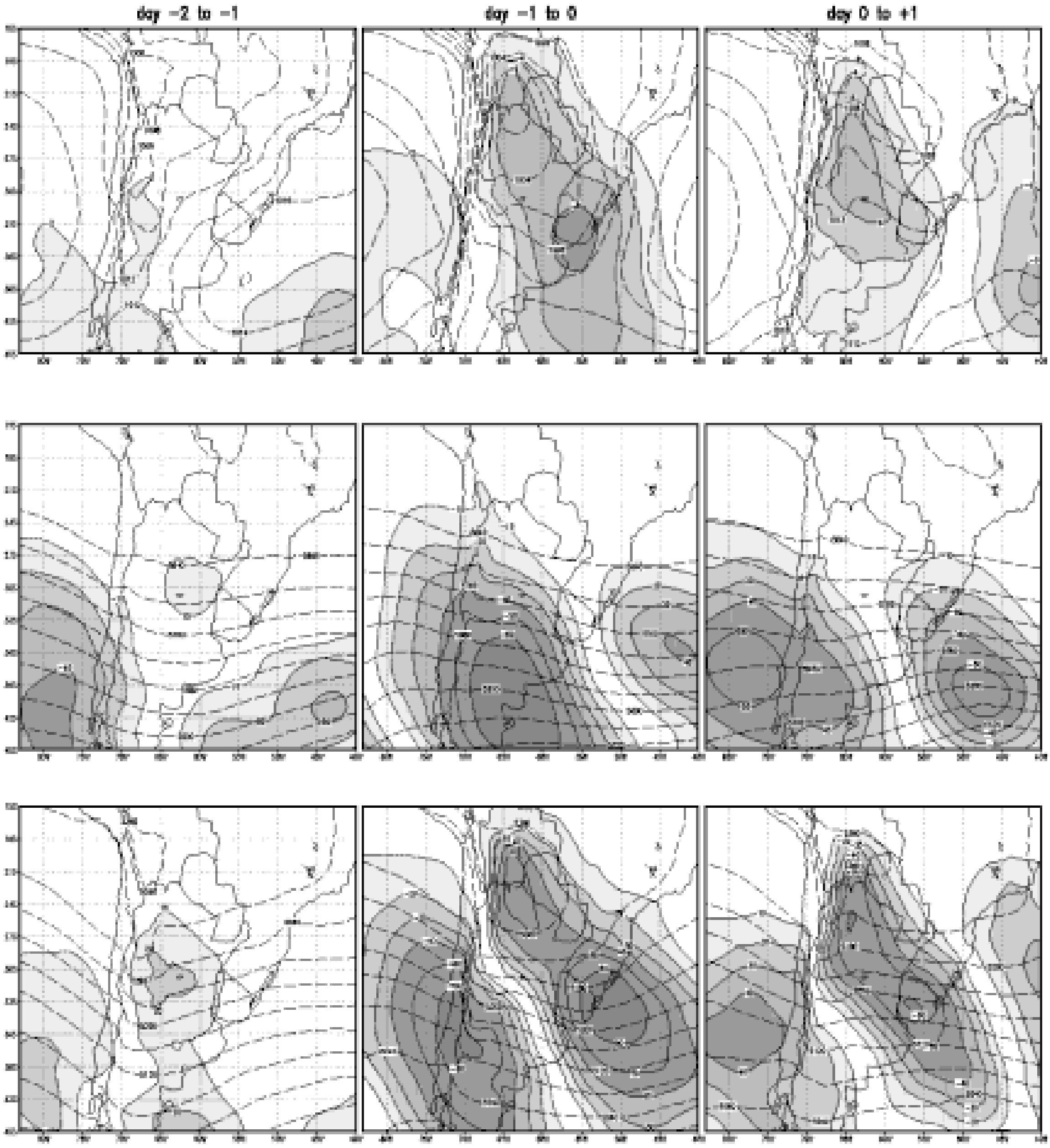


Figure 2: Observed mean daily accumulated precipitation in mm day^{-1} for a) CJEs and b) NCJEs. Contour interval is 1 mm day^{-1} and values higher than 5 mm day^{-1} are shaded.

Figure 3: ETA model products, CJE´s mean temporal evolution. Upper panels shaded: mean sea level pressure change (in hPa) from day –2 to –1 (left), from day –1 to 0 (middle) and from day 0 to +1; contours: mean sea level pressure (in hPa) at day –1 (left), at day 0 (middle) and at day +1 (right). Middle panels: same as upper panels but for 500 hPa geopotential heights (in mgp). Lower pannels same as upper panels but for 500/1000 thickness fields (in mgp).



5) Title: The Northwestern Argentinean Low: A study of two typical events
Authors: *Marcelo Seluchi, A. C. Saulo, M. Nicolini and P. Satyamurt*
Collaboration between CPTEC)/INPE and CIMA, UBA
To be published in Monthly Weather Review

The previous paper has addressed the evidence of a relationship between CJEs and the presence of a deepened Northwestern Argentina low (NAL). This low pressure system is commonly observed near the Andean slopes. This study describes two NAL episodes for summer and winter with emphasis on the characterization of their three-dimensional structure and their temporal variability. With the aid of a high resolution regional model (Eta/CPTEC), the main mechanisms involved in the NAL life cycle were studied in order to examine how the thermal-topographical processes influenced the system behavior.

Surface pressure changes in the NAL are mostly dominated by the 600/900 hPa thickness variability suggesting its thermal character. Based on this result, the temperature tendency equation has been used to quantify all the contributions to thermal changes.

The summer NAL has a significant diurnal cycle that has been dominated by surface warming. This single mechanism can explain the low pressure system formation by itself, suggesting that the NAL could always be present during this season unless an adverse process counteracts the positive radiation balance. Other favoring processes found in the analyzed cases were the Foehn effect (warming by subsidence) and the latent heat release. The intermittent behavior of the NAL is associated to a suppression of net warming in the 600/900 hPa layer, due to a cold air outbreak. In the winter case, the Foehn effect has been mainly responsible for the NAL development. This mechanism acts in connection with an upper level cyclonic disturbance approaching the Andes, denoting that the thermal response is triggered by a dynamical forcing. As the Foehn effect (locally known as Zonda wind) is a frequent winter phenomenon, this factor might be a primary mechanism leading to NAL episodes in winter. As a consequence, the NAL intermittence during this season could be related to transient baroclinic activity, that modulates both the intensification and the decay stages.

The NAL has been regarded as a thermal-orographic system. This study suggests that the analyzed NALs behave as an almost "pure" surface thermally driven low in summer, while dynamical-orographic forcing is the organizing mechanism in winter.

6) Title: Relacoes entre os tropicos e subtropicos associados ao padrao bimodal da circulacao de verao sobre a America do Sul
Authors: *Dirceu Luis Herdies e Maria Assuncao F. Da Silva Dias, USP*

One of the main problems associated with the study of atmospheric circulation patterns over South America is the insufficient data over large regions, specially over the Amazon region. The combined use of data and numerical models is a powerful tool for the understanding of the global and regional patterns over this region. Several field campaigns have aimed at providing more data over the Amazon, in particular the Large Scale Biosphere Atmosphere Experiment in Amazonia - LBA is the most recent initiative. Data used come from an intensive field campaign, the Wet Season Atmospheric Mesoscale Campaign - WETAMC - of LBA, that was conducted in SW Amazon during January and February, 1999. Data from the field campaign and analysis from the Data Assimilation Office (DAO) are used to identify two distinct patterns in the summer circulation over South America. One pattern is associated to the South Atlantic Convergence Zone (SACZ) and the other is associated with the absence of the SACZ. The presence of the SACZ is associated to westerly winds in the WETAMC region and the absence of the SACZ to easterly winds similar to the climatology. The whole period of the WETAMC was divided into the two patterns and the moisture budget was calculated for the bimodal pattern. The results show that the moisture transport takes place by two path ways, one associated with the SACZ and the other with the Low Level Jet observed to the east of Andes. Based on the initial results this work has been extended to January/February 1998, an El Niño year contrasting it with 1999, a La Niña year. For this case, the Mesoscale Convective Systems associated to the moisture transport between tropics and extra tropics have been identified. During 1999 there were 50% more MCS than during the same period in 1998. However a reduction of 50 % of the MCS in the subtropical region was observed, in 1999, and an increase by a factor of 5 was observed in the tropics. The MCS in the subtropics in 1999 show a reduction of the order of 30% in the maximum cloud area. The interannual variability associated with El Niño/La Niña and the intraseasonal variability associated with the SACZ explain the LLJ variability and intensification and the consequent number of MCS.

7) Title: On the structure and seasonality of the Low-level Jet east of the Andes

Authors: *E. Hugo Berbery and Estela A. Collini*
Collaboration: Department of Meteorology - University of Maryland (USA)and Servicio Meteorológico de la Armada (Argentina)

The Low-level Jet (LLJ) east of the Andes is not only a part of the South American summer monsoon system, but of the climate of southeastern South America throughout the year. Unlike the Great Plains LLJ that is a well known warm season phenomenon, all evidence suggests that the LLJ east of the Andes is largest during austral summer only in the tropical region north of about 15 S. South of this latitude, its largest intensity and associated southward moisture flux are found from April to November, with a maximum in October (spanning through the *cold* season and spring). This presentation will discuss the structural changes and behavior of the LLJ as a function of the season.

Winter features. The core of the winter jet is somewhat higher than that during summer (Berbery and Barros 2002), and has a weak diurnal cycle (Nogués-Paegle et al. 2002) that cannot be associated with the summer mechanisms of diurnal oscillations. In this case, the nighttime - daytime wind difference (Fig. 1) suggests a decrease of the wind intensity at the lower levels and an increased intensity on the upper portion of the jet, probably representing a vertical shift of the jet's core.

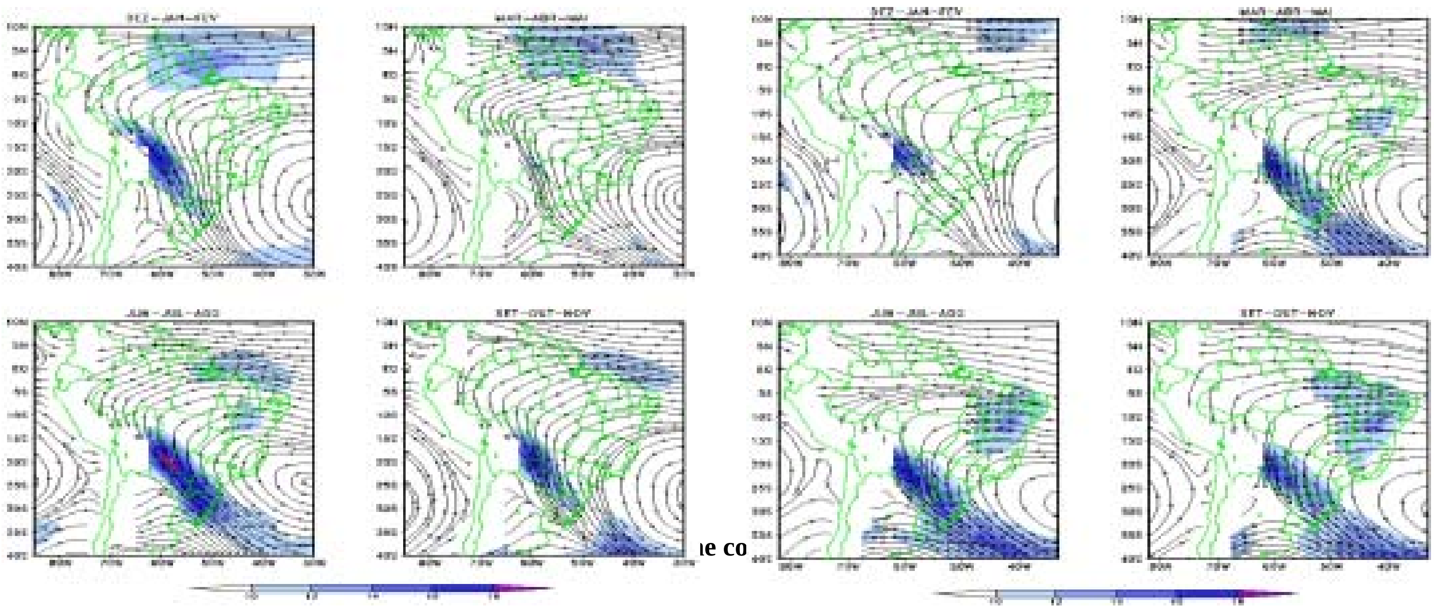
During winter, the time-averaged vertically-integrated moisture flux field near the Andes has a southeastward direction toward northern Argentina/southern Brazil. Precipitation up to 3 mm day^{-1} over this region is associated with the moisture flux convergence (not shown) downstream of the jet's maximum intensity. This winter precipitation appears to have as a triggering mechanism the recurrent passage of cold fronts progressing northeastward east of the Andes and which sometimes may develop as cyclogeneses (Necco 1982a,b).

Summer features. Nogués-Paegle and Mo (1997) described an out-of-phase relationship pattern of precipitation between the South Atlantic Convergence Zone (SACZ) and southeastern South America on intraseasonal time scales. The out-of-phase pattern was also discussed by Doyle and Barros (2002), but for interannual time scales. Our research has found a similar dipole pattern of precipitation between the monsoon and the central La Plata basin *in the higher frequencies*. The LLJ has a significant role in this pattern as it experiments lateral shifts during the warm season. When the LLJ has an eastward shift, it can supply moisture directly to the monsoon region, where increased precipitation is detected. Meanwhile, the moisture supply to the La Plata basin becomes weaker and a simultaneous decrease of precipitation is found over Southern Brazil/ Northern Argentina/Uruguay. When the jet shifts west, its core acquires a southward direction, effectively reducing the moisture supply to the monsoon but increasing it to the La Plata basin with the corresponding changes in precipitation. Understanding this dipole pattern, its seasonality, its linkage to larger scale circulation, and its functioning in general, is critical for the mechanisms that favor precipitation and consequently for hydrologic studies of the region.

8) Title: The low level jet east of andes in the NCEP/NCAR reanalysis and CPTEC/COLA AGCM simulation

Authors: *Iracema F A Cavalcanti, Cleber A Souza and Vernon E Kousky*
Collaboration CPTEC-INPE / CPC/NCEP
Paper presented to VII Congresso Brasileiro de Meteorologia, Foz do Iguaçu, August 4-9, 2002 and partially in Workshop LLJET.

In this sudy, LLJ cases are identified in daily reanalysis data (1979-2000) and in daily results of a climate simulation using the CPTEC/COLA AGCM (1982-1991). The days of LLJ occurrence were selected considering a modified Bonner criterium. The meridional wind component was averaged in the area of 62^0W-57^0W ; 15^0S-20^0S, and the negative result should be greater than –12 m/s and the difference between the meridional wind average at 850 hPa and 700 hPa should be greater than 6m/s. The analyses were performed for each season. The flow and wind magnitude at 850 hPa indicated the presence of the LLJ east of Andes, with the highest intensity over southeast of Bolivia (Fig.1 a,b). Common features in the reanalyses and model datasets are, at low levels, a trough to the southwest of the jet, strong easterlies over northern/northeastern Brazil, and confluence of winds to the south, indicating the influence of a frontal system; and at high levels, a trough and the occurrence of a jetstream. The anomalous geopotential centers are weaker in the model results than in the reanalysis data, and the model simulates less cases in the summer season than in the reanalyses. The hypothesis for this behaviour is the intense convection in the SACZ in the model results that is related to the flow from Amazonia to southeast.



9) Title: Subseasonal variations of rainfall in the vicinity of the SALLJ and comparison to the SACZ

Authors: *Brant Liebmann, Carolina Vera, Celeste Saulo, George Kiladis, and Leila Carvalho*

Regional and large-scale circulation anomalies associated with variations in rainfall downstream of the South American low-level jet are identified and compared to those in the South Atlantic convergence zone (SACZ). Composites of rainfall associated with strong jets reveal an

approximate doubling of the quantities one would expect from climatology, with an evolution from the south.
The occurrence of extreme precipitation events follows the same pattern. Meridional cross-section wind composites, while revealing a distinct low-level jet near 20S, are suggestive of a baroclinic wave farther south, which appears to force the jet. Height, temperature, and large-scale wind composites suggest a wave train that originates in the midlatitude Pacific and turns equatorward as it crosses the Andes. Similar composites, constructed based on SACZ rainfall reveal similar features, but of opposite sign, suggest that the phase of the wave as it crosses the Andes Mountains determines whether rainfall will be enhanced downstream of the jet or in the SACZ, while rainfall in the area not enhanced will be suppressed, resulting in a precipitation 'dipole.' Many previous studies have found a similar out of phase relationship on many time scales. The phase of the Madden-Julian oscillation(MJO) is composited relative to anomalous precipitation events, revealing statistically relevant amplitudes associated with rainfall both downstream of the jet and in the SACZ. It is speculated that the slowly-varying dipole that has been observed is a consequence of the preferred phasing of synoptic waves due to variations of the MJO.