

IMPACTS OF THE LOW LEVEL JETS ON THE PRECIPITATION OVER SOUTHERN SOUTH AMERICA

Carlos Frederico Angelis*
Luiz Augusto Toledo Machado
Paola Salio

*Centro de Previsão de Tempo e Estudos Climáticos – CPTEC/INPE
Rod. Dutra, km40, Cachoeira Paulista, SP 12630.000- BRAZIL
email: angelis@cptec.inpe.br

1. INTRODUCTION

The South American Low Level Jets (SALLJ) are northerly jets which develop along the eastern slopes of the Andes Cordillera and are defined according to wind magnitude and wind speed vertical profile. A jet is characterized when a maximum of wind speed at low level and a wind shear occurs. Criteria established by Bonner (1968) (listed in Section 3) to define LLJ over North America been applied to South America. The SALLJ cause impacts on the vertical and horizontal flows of temperature and humidity and it has been suggested that the development of deep convective systems over northern Argentina, parts of Paraguay and the west of southern Brazil is associated with the SALLJ events (Saulo et al., 2002; Salio et al., 2002). Studies carried out by Wang and Paegle (1996) also suggest that the SALLJ are the main source of moisture for most parts of the La Plata basin. SALLJ displays a large variability on daily, intraseasonal and interannual time scales and plays an important role in the genesis of severe weather systems and organized convective systems (Silva Dias et al., 1987; Velasco and Fritsch, 1987; Kleeman, 1989; Stensrud, 1996; Douglas et al., 1998; Nogués-Paegle et al., 1998; Saulo et al., 2002; Campetella and Vera, 2002).

Observational measurements acquired in the eastern slopes of the Andes are rare and most of SALLJ events cases are reported from data assimilated by numerical models (Wang and Paegle, 1996; Nogués-Paegle and Mo, 1997). According to Vera et al., (2006) the SALLJ extend over a large area of the South America and radio sondes data available are not enough to give a complete description of their three-dimensional structure or their diurnal cycle. Those deficiencies will not be minimized without a great number of observations which can be used to calibrate the diurnal cycle modelled by simulations.

Numerical experiment to simulate LLJ was carried out by Berry and Izunza (1993) who analysed 10 cases of occurrence and 10

cases of non-occurrence identified in data from two stations located in Argentina. A mesoscale model was used to simulate the wind field with high resolution at low levels and results obtained from the assessment of the meridional transport of water vapour have shown that the LLJ is an efficient way of transporting humidity southwards. Another experiment performed by Cavalcanti and Souza (2002) who used NCEP/NCAR reanalysis data from 1979 to 2000 to study the SALLJ east of Andes shows that the highest frequency of SALLJ occurs during summer and winter, while the minimum frequency occurs in autumn. The wind magnitude at about 850 mb indicates the presence of the LLJ east of the Andes, with the highest intensity over the southeast of Bolivia (approximately at 20°S, 60°W of Figure 1). This area is located near the Andean elbow, confirming the important role of the Andes Mountains in defining and modulating the SALLJs. Elevated orography is also found around southeast Brazil, near the Atlantic coast, and in northern Amazon (Guyana Highlands). Although these mountains are much lower than the Andes, they also play a prominent role in creating the SALLJ (Nogues-Paegle and Paegle, 2000) once they contribute to confine the winds in the region where the low level jets occur. These features suggest that the Amazon coast line located in eastern South America might be the region through which part of the atmospheric moisture enters the continent. The penetration of humidity inland is enhanced by the SALLJ stream that flows westwards. After meeting the Andes, the winds are deflected southwards and channelled along the eastern slopes of the Cordillera. Near 20° S, where the Andes form an “elbow”, the maximum SALLJ’s episodes occur (Salio et al., 2002; Cavalcanti and Souza, 2002).

According to Liebman et al. (2003) the maximum rainfall is centred in Southern Amazon, extending Northwest-Southeast oriented towards the SACZ. Between 15°S and 20 °S the northerly winds over the eastern continent are associated with the South Atlantic high, while a separate region of northerly near

the Andes are a reflection of the low-level jet system. Liebman et al also show that the region located near the jet exit (area centred at about 25°S, 57°W) present a maximum of rainfall. According to them when the jet is strong there is more than twice of the daily average precipitation just south of this point. The jets are believed to be the main source of moisture for southern South America (Wang and Paegle 1996) and seem to play an important role in rainfall regime over the subtropical South America.

Although much attention has been paid to the SALLJ, only a few studies have focused in the impacts on the spatial and temporal rainfall variability over the area located in the jet's exits (Central-Southern South America). Therefore, the main goal of this assignment is TO investigate the occurrence of three different types of SALLJ and quantify their influence on the observed rainfall at the jet's exits region. An improvement in the knowledge of the rainfall regime over the area under the influence of the SALLJ is expected.

2. DATA

SALLJ events classified from reanalysis wind data supplied by the Global Data Assimilation System (GDAS) were used to evaluate the impacts of the jets on the observed precipitation over the area limited by the latitudes from 10°S to 40°S and longitudes from 40°W to 70°W. The precipitation data were supplied by several local Brazilian meteorological agencies and consist of daily accumulated rainfall measured by rain gauges spread over the study area.

Both wind and precipitation data set cover the period January/2000 – May 2004. Regarding wind data, the period June, July and August (JJA) were not considered in the final analysis because this is the period characterized by the minimum low level jet occurrences. Therefore, the jet occurrence was evaluated from September of a given year to May of the following year.

The study area was gridded in 1° x 1° where daily mean rainfall was assessed from all rain gauges within each cell. No interpolation method was used in order to avoid inaccurate results.

3. METHOD

According to Bonner (1965) in at least one of the eight synoptical hours, the wind (V) must present the following conditions:

1) $|V|_{850\text{mb}} \geq 12 \text{ m/s}$ immediately east to the Andes,

2) Meridional component must be northerly and greater than zonal component.

3) $|V_{850\text{mb}} - V_{700\text{mb}}| \geq 6 \text{ m/s}$

The above criteria were used by Nicolini et al (2004) to classify the three types of jets analyzed by this assignment: a) Chaco Jet Event (CJE) which extends south of 25S; b) No Chaco Jet Event (NCJE), which does not extend south of 25S and c) Low Level Jet-Argentina (LLJ-ARG) which exits only south of 25S. All other cases were classified as no low level jet event (NOLLJ). As the period JJA was not considered in the final analysis, each year accounted for 273 days, excepting 2003/2004 which accounted for 274.

4. RESULTS AND DISCUSSION

4.1 SALLJ Climatology

The distribution of all jet events in each year (see Table 1) shows that approximately half of all days analysed were characterized by LLJ occurrences. The number of NCJE is consistently lower than the others, excepting in 2000/2001. The CJE show a significant number of occurrences in 2002/2003. The same happens to the LLJ-ARG in 2003/2004.

Table 1: SALLJ occurrences

| Event | Amount of occurrence | | | |
|--------------|----------------------|------------|------------|------------|
| | 00/01 | 01/02 | 02/03 | 03/04 |
| CJE | 46 | 41 | 91 | 36 |
| LLJ-ARG | 38 | 39 | 52 | 67 |
| NCJE | 47 | 29 | 31 | 12 |
| NOLLJ | 142 | 164 | 99 | 159 |
| Total | 273 | 273 | 273 | 274 |

The seasonal frequency for each jet is displayed in Figure 1 and results confirm the tendency for NCJE to present the lowest number of occurrence. They also show that SON (austral spring) is the period when the maximum number of all types of jets occur.

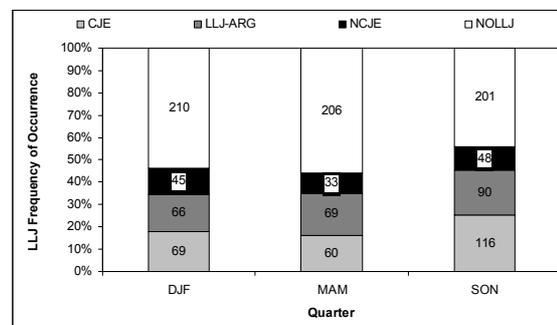


Figure 1: Seasonal frequency of SALLJ occurrences. Values inside the bars represent the number of jets occurrence in each period and the size of the bar means its frequency of occurrence

4.2 Rainfall Climatology

The mean daily rainfall assessed during the study period (see Figure 2) shows an area of maximum rainfall occurring in the region centered at about 50°W e 25°S. In this place values of mean precipitation can reach 12 mm/day. The rainfall regime over this region is influenced, among many reasons, by the

interaction of synoptical systems as the South Atlantic Convergence Zone (SACZ), cold fronts which move northwards, mesoscale convective systems (MCC), and local circulation.

Figures 3 and 4 show the interannual rainfall variability and their deviation related to the mean daily rainfall (Figure 2).

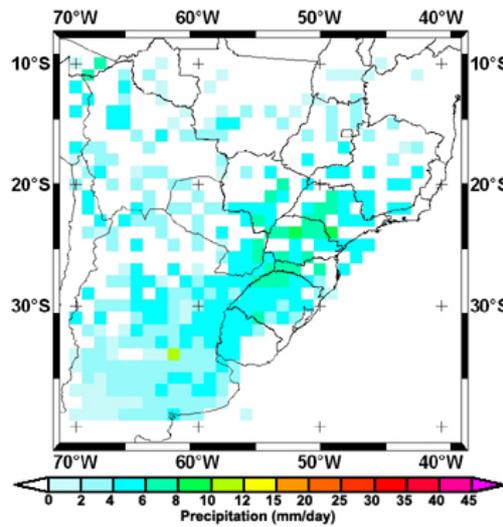


Figure 2: Mean daily rainfall assessed during the observed period

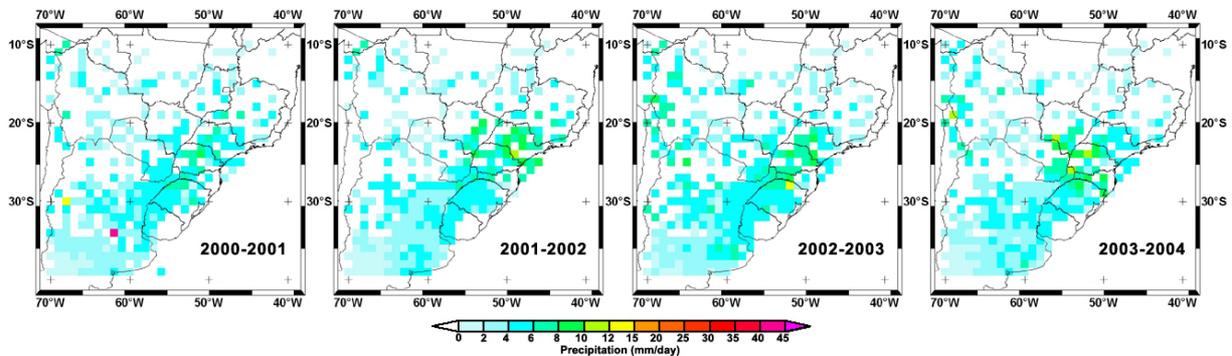


Figure 3: Mean daily precipitation assessed for each year of the study period

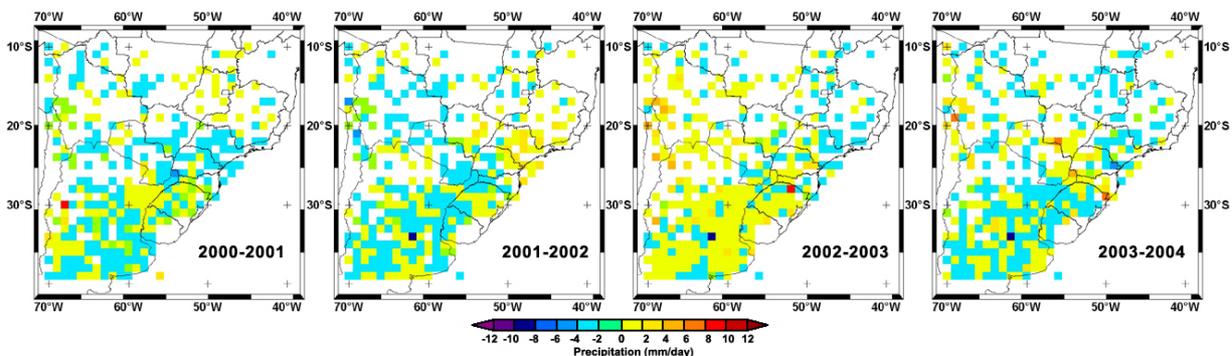


Figure 4: Precipitation deviation assessed from the difference between values in Figures 3 and 2

Results indicate a positive deviation in 2002/2003 when compared to the previous years. During this period a weak El Niño event

was registered and it can be partly related to the 2002/2003 positive anomaly, however,

other reasons as the sea surface temperature must be investigated.

4.3 Impacts of the SALLJ on the precipitation

The average amount of rain assessed from the inputs registered in all rain gauges within the study area (see Figure 5) reveals that the highest values occur in DJF.

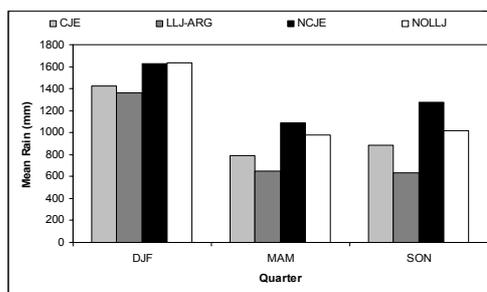


Figure 5: Seasonal distribution of the mean amount of rain during the study period. Values in y axis are the average of total precipitation observed in all rain gauges over the study area in each quarter

It is interesting to note that despite of the low number of NCJE's occurrences (Table 1), the amount of rainfall associated with this jet is higher than any other (Figure 5) in all of the three periods (SON, DJF and MAM). It can be another indicative of NCJE tendency to increase the amount of rainfall regardless of the season.

The mean rainfall associated to each jet and their difference related to the total mean is shown in Figure 6 and 7, respectively.

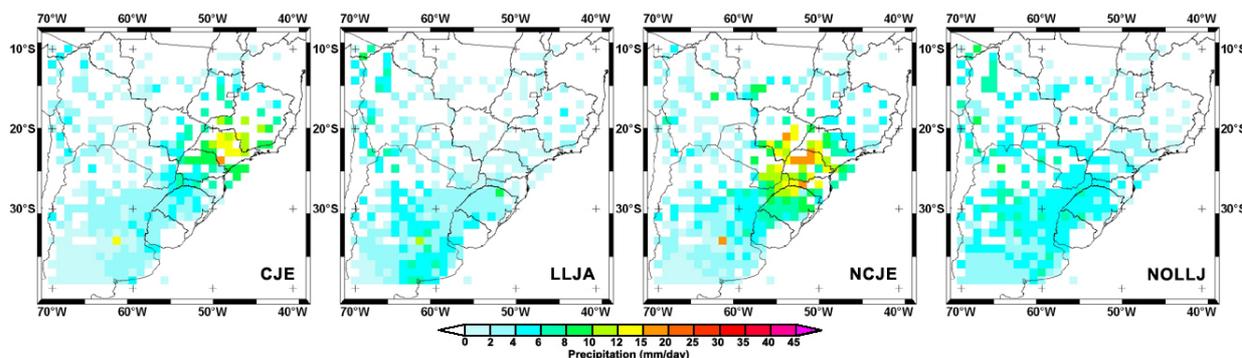


Figure 6: Spatial distribution and average rainfall assessed for each jet during the study period

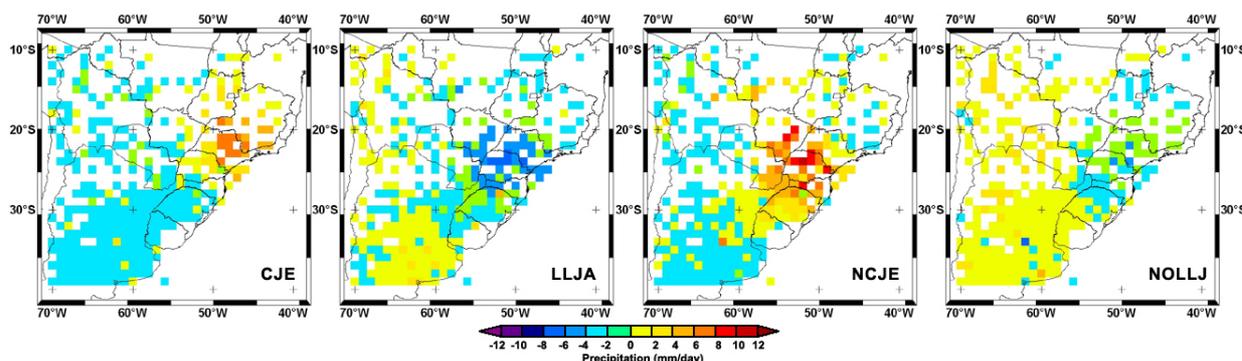


Figure 7: Difference between values in Figure 6 and Figure 2

The values in Figure 6 are the ratio between the sum of the total rain associated to each jet divided by its number of occurrences, and values in Figure 7 are the difference between Figure 6 and Figure 2.

CJE exhibits values lower than those associated to NCJE; however, they are greater than those associated to LLJ-ARG and NOLLJ. The results confirm the tendency of NCJE to increase the amount of precipitation as

suggested in the previous paragraphs. Rain rates associated to NCJE reach values as high as 25 mm/day, and according to Table 1, this type of jet accounts for only 10.37% of the total jet events observed during the study period. The area of maximum rainfall associated to CJE and NCJE is centered at about 25°S e 50°W. This place is exactly the same place where the maximum of mean rainfall (Figure 2) occurs. It is possible that CJE and NCJE are

responsible for an increase in the amount of precipitation over this area.

Figure 7 reveals that the area of maximum rainfall associated to NCJE (CJE) moves southeastwards (northeastwards) when compared to Figure 2. This is related to the seasonal variations of rainfall produced by each jet (not shown) that reaches its maximum in DJF. LLJ-ARG are not associated to high amounts of rain; however, according to Figure 7 this type of jet seems to enhance precipitation over the central areas of northern Argentina (region centered at 35°S e 62°W).

5. FINAL REMARKS

Only a few studies have focused on identifying different types of low level jet occurring over the area located southern of the latitude 25°S in the South American continent. Liebman et al. (2003) used surface data of precipitation associated to CJE recorded during the period DJF of 1997-1997 and gridded at 2.5° resolution. A maximum of rainfall occurring over the northeast of Argentina (area centered at 30°S, 57°W) was observed. Although their methodology is quite different from the one used here, results of both studies are in agreement. Both results showed that the spatial and temporal variability of precipitation seemed to be related to the different types of low level jets.

Salio and Nicolini (2005) have analyzed the diurnal cycle of convection associated to the three types of jets (NCJE, CJE and LLJ-ARG). The convection was tracked by satellite images, and due to the temporal (hourly) scale and type of data used in their work, it is possible to make only a qualitative comparison of results. The areas of deep convection over Argentina pointed by Salio and Nicolini are in agreement with the areas of positive deviation associated to the LLJ-ARG found here.

This assignment showed that LLJ-ARG tend to enhance precipitation over the central parts of northern Argentina, whilst CJE and NCJE tend to enhance it over the southeast of Brazil. The results also showed that despite of NCJE have presented the lowest number of occurrences, the highest values of precipitation were associated to them. It is inappropriate to state that the SALLJ are the only phenomenon responsible for an increase in the amount of precipitation over the study area.

Synoptical systems as SACZ, penetration of cold front which moving northwards, mesoscale convective systems originating in western Argentina and propagating eastern, and sometimes western

wards, can also play an important role in the precipitation regime over the study area.

Although preliminary and investigative, the results shown here are the first to quantify the spatial variability of precipitation associated to three different types of low level jet. They are very important to validate findings reproduced by numerical models and also to support the use of satellite images applied to rainfall estimates. They will certainly shed light on studies that try to find the impacts of the SALLJ on the precipitation regime over the study area.

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