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SIMULATION AND VALIDATION OF THE LOW LEVEL JET IN THE EAST OF THE ANDES USING A REGIONAL CLIMATE MODEL.

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1. Introduction

An important characteristic of the low level circulation on South America (SA) during the austral summer is the moisture transport from the tropics to the south in the east of Andes. This northern flow is concentrated on a relatively shallow layer near to the surface, with strong wind speed, commonly named as Low Level Jet (LLJ). Douglas et al (2000) and Marengo et al. (2004) have showed that this circulation contributes to the transport of warmer and moister air from the tropics to the subtropics and extratropics of South America.

Over North America, Bonner (1968) documented the LLJ over the Great Plains, at east of the Rocky Mountain, which presents great seasonal and diurnal variations. According to Bonner, several physical processes can explain this LLJ: diurnal oscillation of the turbulent viscosity; diurnal variations of the temperature field over steep terrain; obstruction of the large-scale flow by Rocky Mountain.

The investigation of the large-scale characteristics associated to the LLJ in the summer over SA conduced by Sugahara et al. (1994) showed that the propagation of middle latitudes waves, moving from west to east, could be one of the mechanisms to the LLJ formation. This study also indicated that there is some relation between this LLJ and the precipitation associated to the South Atlantic Convergence Zone (ZCAS). Recently, Liebmann et al. (2004) found similar relations for the strong LLJ events. Later, Sugahara et al. (1996) identify another LLJ area over the east of Southeast of Brazil, but the number of LLJ events in that area was smaller than that in the east of the Andes.

Salio et al. (2000) also investigated the relation between LLJ and rainfall over SA during El Niño (1988) and La Niña events (1985). The association between LLJ and convective complex of mesoscale (MCC), that can intensify the precipitation over south of Brazil and north of Argentine (Velasco and Fritsch 1987). Meanwhile, Herdies, 2002 found that for two different summers during El Niño years, the number of MCC is greater than during La Ninã. Nieto Ferreira et al. (2003) analyzed the variability of large-scale circulation between these two summers, and found that the interanual variability, associated to ENSO (El Niño-South Oscillation), and the sub-monthly variability, associated to the ZCAS, contributed to the strength of LLJ over Bolivia.

There are few local observations of the vertical structure of the atmosphere in the east of Andes and center-west of Brazil and great part of conclusions about LLJ were obtained from large-scale analysis. The importance of the LLJ and precipitation anomalies associated implies important decisions in the hydrological budget over the La Plata Basin. This problem has motivated the advent of international projects for direct vertical air soundings. The pilot balloon campaign of the PACS-SONET (Pan American Climate Studies Program - Sounding Network) over the Bolivia during the 1998 is documented by (Douglas et al., 2000). These observations identified that the level of maximum LLJ wind velocity is near to 1600-2000 m and a well-defined diurnal cycle (Marengo et al., 2002).

The objective of this study is to analyze if the RegCM3 (Regional Climate Model, Pal et al. 2005) can simulate the LLJ in the east side of the Andes and analyze LLJ composites with the observations of the PACS-SONET pilot balloon database.

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2. METHODOLOGY

2.1 RegCM3 regional model

The RegCM3 atmospheric model used in our climatic simulations is described by Giorgi et al. (1993 a-b) and Giorgi and Mearns (1999) and the last model modifications are documented by (Pal et al. (2005). The RegCM3 code has several options to parameterize the cumulus convection and turbulent fluxes over the ocean. For the present study, we used the Zeng et al. (1998) scheme for ocean turbulent fluxes calculations. For the convective schemes we applied the Grell (1993) with Fritsch-Chappel closure and Emanuel (1991) schemes.

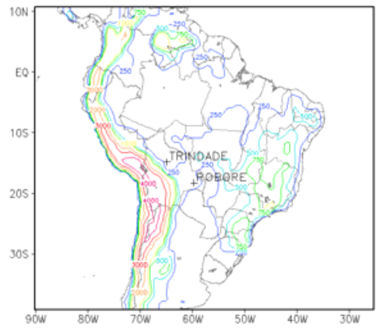

Figure 1 RegCM3 domain and topography. Units are m and the contours intervals are: 250, 500, 750, 1000, 2000, 3000 e 4000 m.

2.2 Observed data and simulations design

The simulations cover the austral summer, defined as the December-January-February months, and were initiated at 0000 UTC of October 1 and finished at 0000 UTC of March 1. The October and November months were considered as spin-up and are not included in the analysis. The NCEP-DOE (Kanamitsu et al. 2002) reanalysis were used as initial and lateral boundaries conditions for RegCM3 simulations. For bottom boundaries over the ocean, the SST was specified by the mean monthly dataset of the Reynolds and Smith (1995). To provide the terrain and surface cover characteristics, we employed the topography and land-use data, derived from United States Geological Survey (USGS) and Global Land Cover Characterization (GLCC, Loveland et al., 2000), respectively, with horizontal resolution of 10-min.

This work aims to study the LLJ that several times has its formation associated to Amazon convective activity (Figueroa et al., 1995) and can cause precipitation anomalies next to the 30^{o}S (Sugahara et al., 1994). The domain of the simulations is shown in Figure 1, which includes practically all SA. The horizontal and vertical resolutions are 60 km and 23 levels sigma-pressure, respectively, with top model in 70hPa.

The observational pilot balloon data set are from the PACS-SONET experiment (Douglas et al. 1998), during January and February of 1999, and were used to compare to the RegCM3 simulations. Basically, we used the stations of Trinidad and Roboré (both in Bolivia) with 70 and 50 pilot balloon observations, respectively.

2.3 – LLJ identification criteria

To compare observed (PACS-SONET) and simulated (RegCM3) wind vertical profile we interpolated both data sets to the same vertical resolution (100 m). As the RegCM3 output was done at every 6 hours (00:00, 06:00, 12:00 and 18:00 UTC), the comparisons with the observed data used the nearest time. For example, several observations were realized at 11:00 UTC and so were compared to the 1200 UTC RegCM3 results.

To identify the LLJ structure we applied two different criteria for the observation and simulations wind profiles:

a) Sugahara et al (1994) considers a LLJ if the following conditions are obeyed:

- north wind at 850 hPa level greater than 8 m s^{-1};
- wind shear between 850 and 750 hPa greater than 2 ms^{-1}/150hPa.

b) Bonner criterion 1 (1968) establishes that LLJ is characterized by:
- wind velocity greater than 12 m s^{-1} in some vertical level below 3 km;
- wind shear between the level of maximum and minimum wind below 3 km of at least 6 m s^{-1}

We included the condition of the maximum wind can be of north in the Bonner criterion 1.

3. RESULTS

3.1 Large scale characteristcs

Figure 2 compares the average DJF (austral summer) wind field at sigma level near to 850 hPa from reanalysis (Fig. 2a) and simulated by RegCM3 with Emanuel (Fig. 2b) and with Grell (Fig. 2c) convective schemes. Basically, the two simulations capture the main characteristics of large-scale wind fields; however there are some differences in intensity in the tropical domain. In this area, the Emanuel simulated strong winds than reanalysis and the Grell simulated weak winds than reanalysis. The simulations (Figs. 2b-c) present a strong wind core near the east side of the Andes that in the reanalysis (Fig. 2a) is weaker and displaced to the east. These results were also found in other simulations with regional models, during the austral summer, where the low level wind maximum is found closer to the Andean mountain than in the reanalysis (Rocha 2004, Saulo et al. 2000). Returning to the Figure 2 we note that low-level weak wind intensity over the northeast of Argentine is well simulated by both convective schemes.

3.2. Averaged wind profile

As described in section 2, the pilot balloon observations and simulated wind of Trinidad and Roboré were interpolated for the same horizontal resolution. From these data sets, we calculated the average zonal (u) and meridional (v) wind components vertical profiles and presented in Figure 3 the vertical profile for Roboré station.

The Wind profile simulated by Emanuel convective scheme (Fig. 3a) present the same vertical structure of the observations, however, for both zonal and meridional wind the simulated intensity is greater than the observed. Another difference note is that the observed meridional wind component presents a weakness in intensity in layer between 1900-2800 m that is not simulated by the Emanuel (Fig. 3a) or Grell convective scheme (Fig. 3b). This scheme simulated better the wind intensity in the layer near the surface (between 400 to 1000 m) than Emanuel scheme.

The differences between simulated and observed wind profile are greater (figure not showed) for Trinidade station.

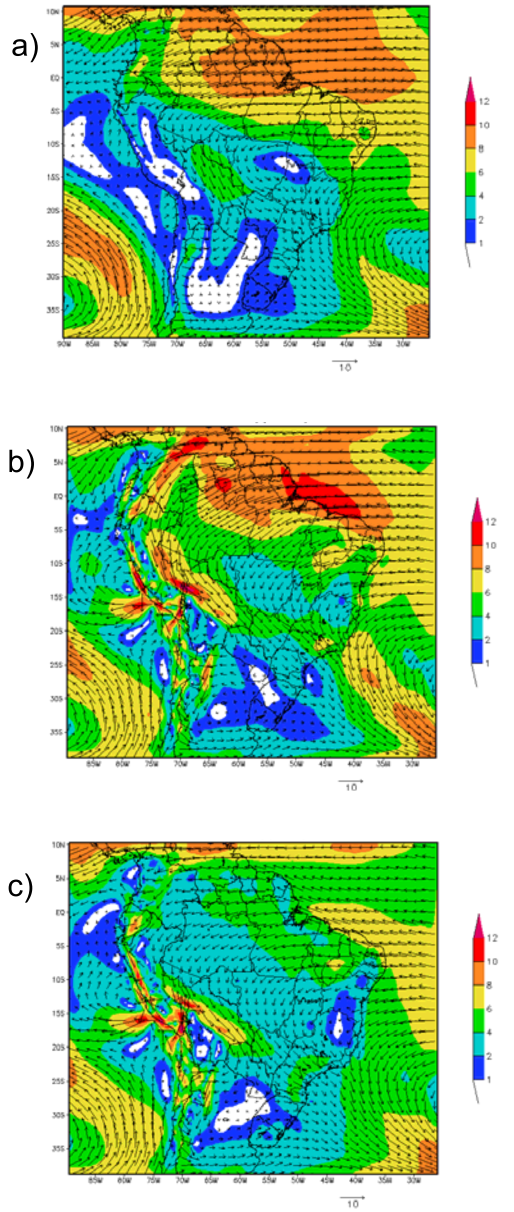

Figure 2 – Average DJF (austral summer) wind vector (arrows) and intensity (shaded in m s^{-1}) at sigma level near to 850 hPa from: (a) NCEP reanalysis; (b) simulated by Emanuel and (c) simulated by Grell convective schemes.

3.3. LLJ identification

The Sugahara criterion described in section 2 was applied to observed and simulated meridional wind component to identify LLJ events. For this analysis, we considered only the time with observations. To Trinidad station were identified 6

LLJ events in the observations, while in the simulations with Grell and Emanuel were identified 4 and 17 events, respectively. These results show that the Emanuel scheme using Sugahara criteria tends to overestimate the LLJ events while Grell is closer the observed number of LLJ events. For Roboré station, the number of LLJ events simulated with Emanuel (8) is nearest of the observed (10), while the simulation Grell scheme present a smaller number of events (4).

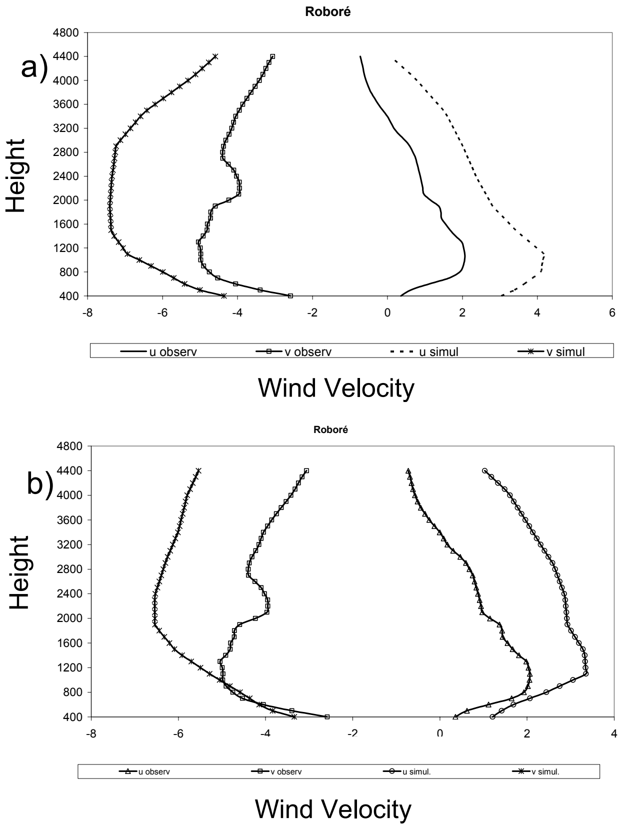

Figure 3. – Averaged zonal (u) and meridional (v) Wind components observed and simulated by (a) Emanuel and (b) Grell convective scheme. Units are in m s^{-1}.

In terms of time during the day that the LLJ is more frequent by Sugahara criteria, from 8 LLJ events identified in Roboré station 7 occurred at 11:00 UTC (~ 7 local time). This result is similar to the one found by Douglas et al. (1999) and Marengo and Soares (2002) that obtained strong winds at 11:00 UTC and the level of maximum intensity between 1600-2000 m.

Considering the biggest proximity in the number of LLJ events observed and simulated we constructed meridional wind profile for Trinidad and Roboré station, Figure 4. For Tinidad (Fig. 4a) and Roboré (Fig. 4b) stations we compared the composite observed profile with the simulated by Emanuel and Grell schemes, respectively.

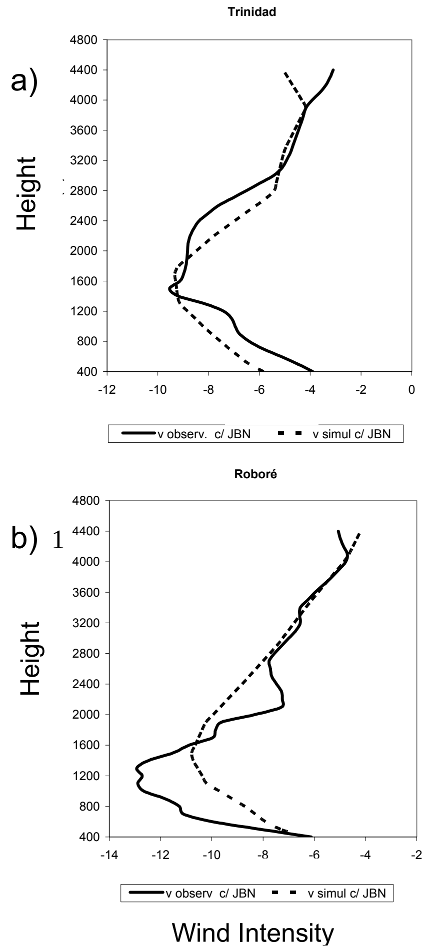

Figure 4 – Composite wind merdional component profile for periods with Sugahara criterion LLJ observed (continue lines) and simulated (dashed line) for (a) Grell scheme at Trinidad station and (b) Emanuel scheme for Roboré station. Units are in m s^{-1}.

We present the LLJ events composites by using Bonner criteria only in the Roboré station and simulated by Emanuel scheme in the Figure 5. This figure shows that the simulated and observed LLJ events present similar vertical structure showing similar height for maximum wind velocity. However, the observed profile presents small-scale variations that were not simulated.

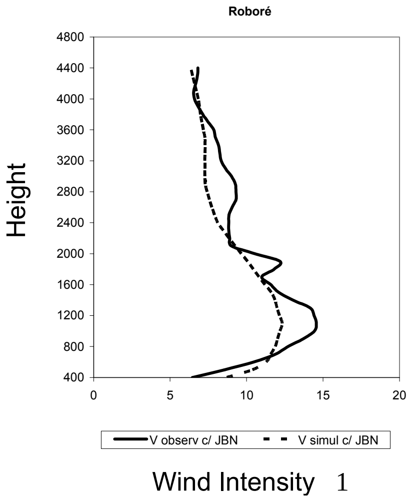

Figure 5 – Composite wind intensity profile for periods with Bonner criterion 1 LLJ observed (continue lines) and simulated (dashed line) by Emanuel scheme in the Roboré station. Units are in m s^{-1}.

4. Preliminary conclusions

In this study, the RegCM3 has been forced by NCEP reanalysis at 6 hours interval for period of October 1998 to February 1999 to investigate the simulated LLJ at east of the Andes Mountain during the austral summer (DJF). The simulated fields show that the large-scale circulation characteristics presented in the NCEP reanalysis was reproduced by the experiments with Grell and Emanuel convective schemes. However, there are differences in the intensity of wind as function of the convective scheme and the differences are greater in the tropical domain. In this area, the Emanuel scheme shows that the winds are stronger than Grell scheme.

The simulated averaged wind profiles were compared to the observations. Both, Emanuel and Grell schemes simulated strong winds that were observed although the vertical structure simulated is closer to the observed. When we apply the LLJ criteria identification, the simulated vertical profiles composite and observed are closer than when we just consider average profiles.

By comparing the Sugahara and Bonner criteria for LLJ identifications we noted that in the observed data both criterions identify a similar number of LLJ events. However, the simulated data are very sensitive to the employed LLJ criterion.

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