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STRUCTURE AND EVOLUTION OF THE LOWER TROPOSPHERE IN THE PRESENCE OF A SALLJ EVENT

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1. INTRODUCTION

The South American Low level Jet (SALLJ) is a key feature of South American climate and plays an important role as a transport mechanism of moisture and other constituents, with the subsequent impact on southeastern South America. This wind maximum east of the Andes develops and evolves as a result of physical forcing on various temporal scales and surface and topographic conditions. In addition, SALLJ interacts with different meteorological circulation. For these reasons, its structure and evolution need to be well understood and documented. Several studies have been done to characterize SALLJ and the related phenomena (Saulo et al 2000, Nicolini et al 2002 a, b and Salio et al 2002, among others).

The South American Low level Jet Experiment (SALLJEX) was an international field campaign carried out to improve the understanding of SALLJ. It took place from 15 November 2002 to 15 February 2003. The observational meteorological network was enhanced with pilot balloon and radiosonde releases with high spatial and temporal resolution. During selected situations an instrumented aircraft flew and documented the three-dimensional structure of the atmosphere. The SALLJEX provided a unique data set in South America as regards the density of observations to document and evaluate current theories and modeling tools and strategies (see Nicolini et al, 2004 and Vera et al, 2004 for details).

Data from one of the days of SALLJEX were used to investigate the structure and evolution of the SALLJ and to evaluate the meteorological fields and related parameters as simulated by a mesoscale model.

2. DATA AND METHODOLOGY

The low-level jet event analyzed in this contribution occurred on 6 February 2003 and it was subject of an intensive operations period that extended from February 4th to Feb 9th in which it evolved and had distinctive features.

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The mesoscale model used is the BRAMS 3.2. The model is non-hydrostatic and has a multiple interactive grid nesting capacity. The BRAMS development has the original sigma-z terrain-following vertical co-ordinate and a shaved-eta type (Tremback and Walko, 2004). Detailed information about the model could be found in Pielke et al (1992) and Cotton et al (2003).

The simulations considered two-way interactive nested grids. Three grids with horizontal spacing of 80, 20 and 5 km were used (Fig. 1). The outermost grid covered most of South America while the innermost grid encompassed Bolivia, Northern Paraguay and a small portion of Brazil (the region spanned by the aircraft mission).

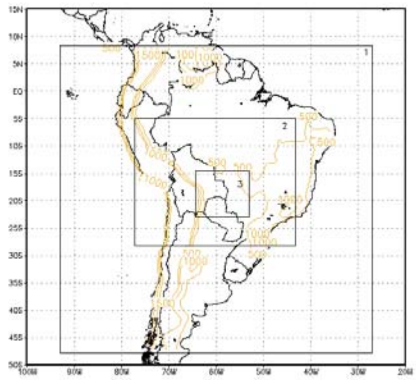


Figure 1 BRAMS nested grids considered in the simulations. Contours correspond to terrain elevations of 500, 1000 and 1500 m.

The simulations started on 1200 UTC 5 February 2003 and lasted 48-h. The five lateral boundary points in the largest domain were nudged towards Global Data Assimilation System (GDAS) analyses provided by the National Centers for Environmental Prediction (NCEP), with one-degree horizontal resolution at 6-h intervals. These analyses also gave the initial conditions.

The topography was derived from the United States Geological Survey (USGS) data set with 1-km horizontal resolution. Land use data are from the International Geosphere - Biosphere Programme with 1-km resolution. Soil types, with 50-km resolution are from the Food and Agricultural Organisation – United Nations Educational, Scientific and Cultural Organisation.

Soil moisture initialization for the present study provided a heterogeneous field. This field is one output of a model that diagnoses soil moisture based on remotely sensed precipitation fields (Gevaerd and Freitas, 2004). Weekly sea surface temperature was obtained from the National Oceanic and Atmospheric Administration (NOAA).

Radiative processes were parameterized following Chen and Cotton (1988). Cloud microphysics was included with a bulk treatment that considers seven species. The Grell scheme with a Grell closure was used for the convective processes in the coarse resolution grids (Grell, 1993). Shallow cumulus convection was parameterized according Souza and Silva (2002). Sub-grid scale turbulence can be included with the Mellor and Yamada and the Smagorinsky scheme, respectively, in the vertical and the horizontal directions or the later in both directions (Smagorinsky, 1963, Mellor and Yamada, 1982). Alternative simulations were carried out with terrain following vertical coordinates and the shaved-eta coordinate.

The results of the model simulations were dumped at high temporal resolution during selected periods in which the aircraft made ascents and descents while travelling across and along the low-level jet core to allow the comparison with the observed fields. Spatial and temporal variations of relevant variables were studied. Some characteristics of the mean atmospheric boundary layer structure were also considered.

3. RESULTS AND DISCUSSION

The occurrence of LLJ was diagnosed applying a modification of the original Bonner criteria (Bonner, 1968). It was developed and applied in previous works in order to use the data sets available from the operational weather prediction centers (Saulo et al 2000, Nicolini et al 2002 b and Salio et al 2002). The criterion is based on the wind intensity at 850 hPa (that must exceed 12 ms^{-1}) and the wind shear between 850 and 700 hPa (that would be at least 6 ms^{-1}).

The synoptic environment of this event was clearly within the LLJ pattern documented in previous works and during some periods it was consistent with the sub-ensemble Chaco Jet (Ulke and Nicolini, 2005).

The low level jet event had different behavior and features during its life cycle. It had moderate intensity, with the highest wind speeds over Southern Bolivia and Western Paraguay. No mesoscale convective systems occurred north of 28º S during the covered period. This allowed the study of the atmospheric three-dimensional structure in the presence of a LLJ without the additional disturbances in the mean fields associated with strong convection.

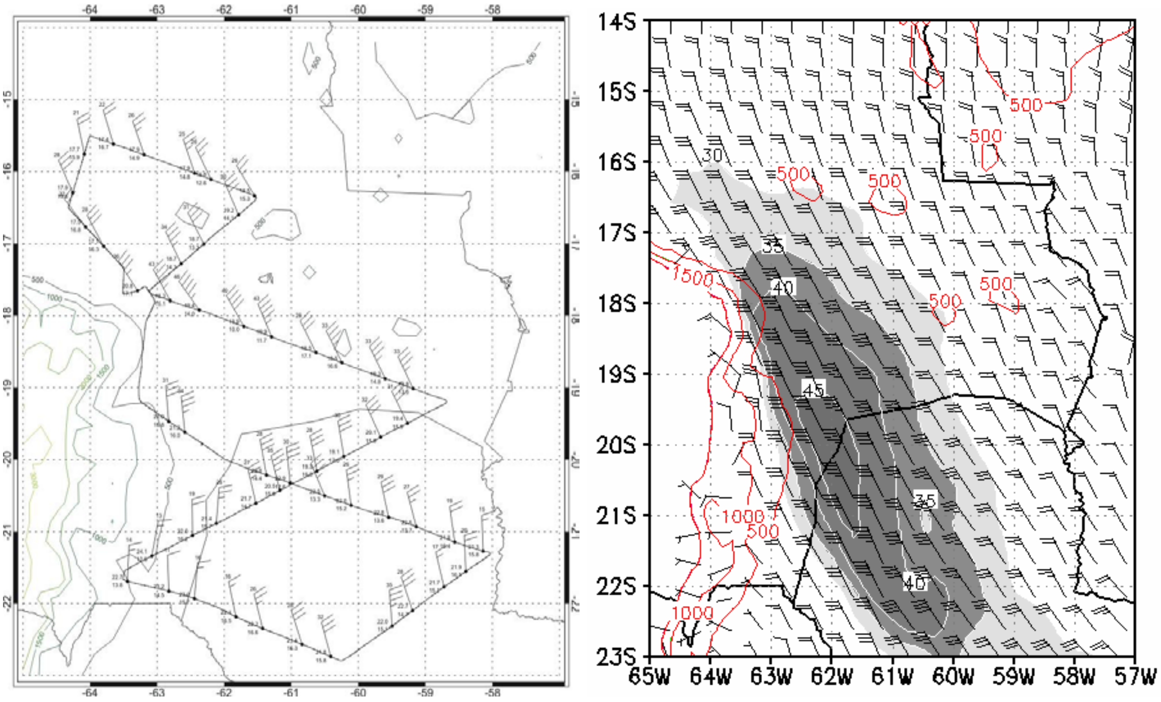
Observations made during the NOAA-WP-3D flight mission for this particular LLJ event show a maximum wind speed of about 25 ms^{-1} (50 kt) in the 850-700 hPa layer over northwestern Paraguay. A secondary maximum was observed near Santa Cruz de la Sierra, Bolivia, before landing.

Figure 2 depicts the comparison between aircraft measurements and the model derived winds at 850 hPa at the 5-km nested grid using the sigma-z vertical coordinate. The modeled wind field adequately describes the flow direction and wind strength as well as the position of the maximum.

The comparison between the simulations carried out using, alternatively, sigma-z coordinate and the shaved-eta formulation is illustrated in Figure 3 for the 850 hPa level and some hours that correspond to the maximum strength of the current. It appears that, with the current settings in the simulations, the former provides a better agreement with the observed LLJ.

Figure 4 shows the isotach analysis and the horizontal wind obtained in the model simulations at the higher resolution grid in two cross sections. The first one is along the NE-SW aircraft transect from 58.7º W and 19.2º S to 63.5º W and 22º S (across the jet core), which was from 1500 UTC to 1620 UTC (transect 6). The other one is a SE-NW transect from 58º W and 21º S to 62º W and 20º S (along the jet core) that started at 1750 UTC and ended around 1855 UTC (transect 9).

The analysis across the LLJ illustrates the stronger velocities in the layer 900-750 hPa with a maximum wind speed of 45 kt. It shows a sharp horizontal gradient to the west of its core and also the greater vertical shear below the maximum. The modeled pattern is in agreement with the corresponding isotach analysis of the aircraft measurements along the transect (Douglas et al , 2004, Nicolini et al, 2004, Ulke,



a) b)

Figure 2 Observational and model simulation wind field on 6 February 2003.

a) NOAA-WP-3D flight trajectory and wind field plotted at 850 hPa. (1 full barb=10 kt).

b) BRAMS (1500 – 1630 UTC mean) wind field and isotach analysis (kt) at 850 hPa.

Fields in mountain areas higher than 1500 m are masked.

2005). The horizontal wind is from the northwest in most of the extent considered in this cross-section. Near-surface winds are significantly weaker. The wind field shows also a rather disorganized pattern very close to the mountains at the western edge of the cross-section.

The vertical cross section along the jet core, which started around three hour later than the one across the jet, illustrates a more homogeneous field, with the wind maximum at the western side of the transect, between 800 and 850 hPa. A secondary maximum does also appear at higher altitudes, between 750 and 800 hPa in the eastern flank. As this transect did not get as close to the mountains as the previously analyzed, the horizontal wind field at the western edge is fairly homogeneous.

The inclusion of a third nested grid gave an important improvement of model performance compared with previous simulations (Douglas et al, 2004, Ulke, 2005). Both the jet strength and spatial pattern show a better agreement with the observed fields.

Figure 5 presents the simulated fields of virtual potential temperature in the same cross sections as in Figure 4 (transects 6 and 9). The temperature structure and evolution shows a pattern that combines the normal development and decay of the atmospheric boundary layer and the low-level jet influence. Both cross sections depict a rather inhomogeneous structure of the atmospheric boundary layer. Transect 9 shows a deeper atmospheric boundary layer due to the diurnal evolution. The higher temperatures and vertical extent are seen on the eastern side. This region is coincident with the smaller wind speeds. On the other hand, the smaller potential temperatures are located below the jet core.

The time-height section of the meridional component of wind speed and the virtual potential temperature at a point near the jet core is illustrated in Figure 6 for the whole simulation period. The pattern and location of the modeled low-level jets present some differences, with the second one (on 6 February) located closer to the surface. The diurnal cycle of heating and cooling has also some variation. A shallower inversion is observed during the second day. The mixed layer has greater vertical extent on the initial period of the simulation.

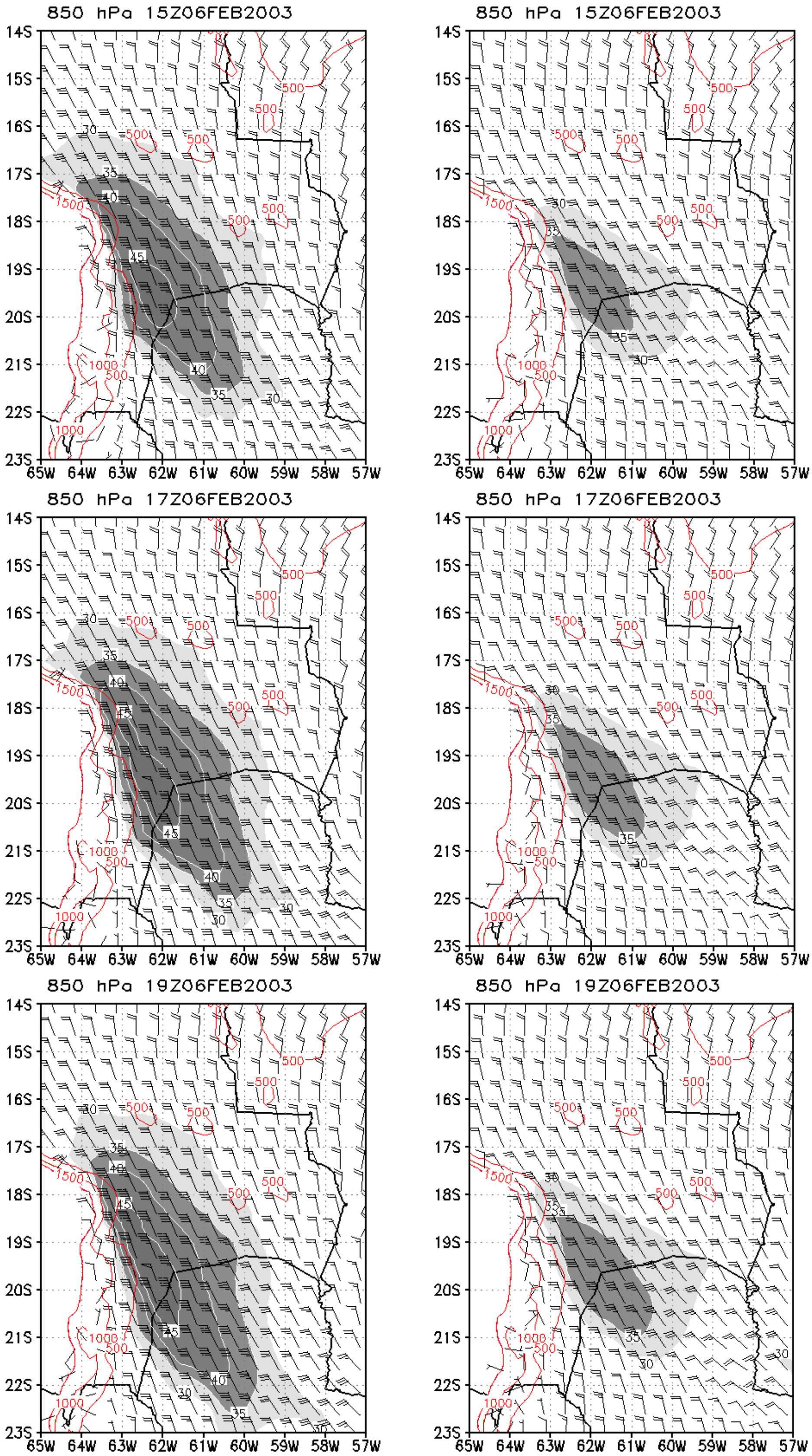


Figure 3 Comparison between the wind fields at 850 hPa obtained in the BRAMS finer resolution grid with sigma-z (left) and shaved-eta (right) vertical coordinates. (*shaded*: wind strength greater or equal to 30 kt, each 5 kt; 1 full barb = 10 kt)). Fields in mountain areas higher than 1500 m are masked.

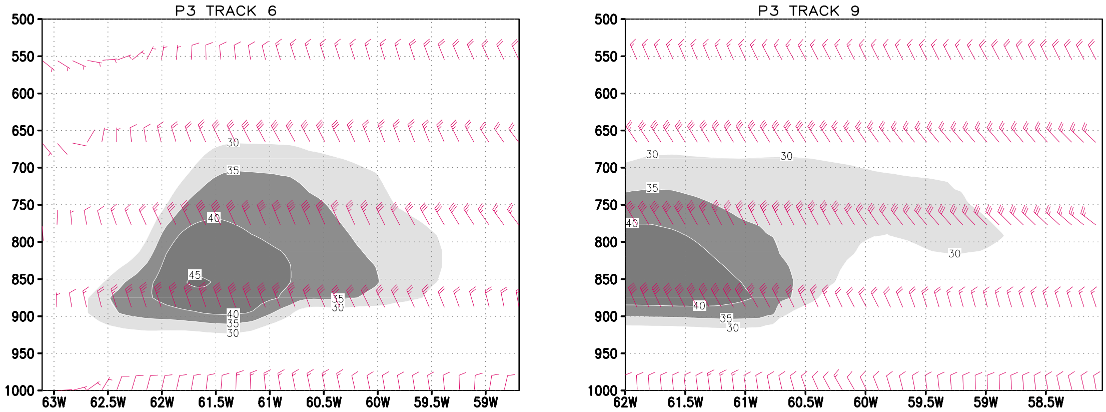


Figure 4 Isotach analysis (kt) and horizontal wind (*shaded*: wind strength greater or equal to 30 kt, each 5 kt; 1 full barb = 10 kt) in vertical cross sections along transects 6 and 9.

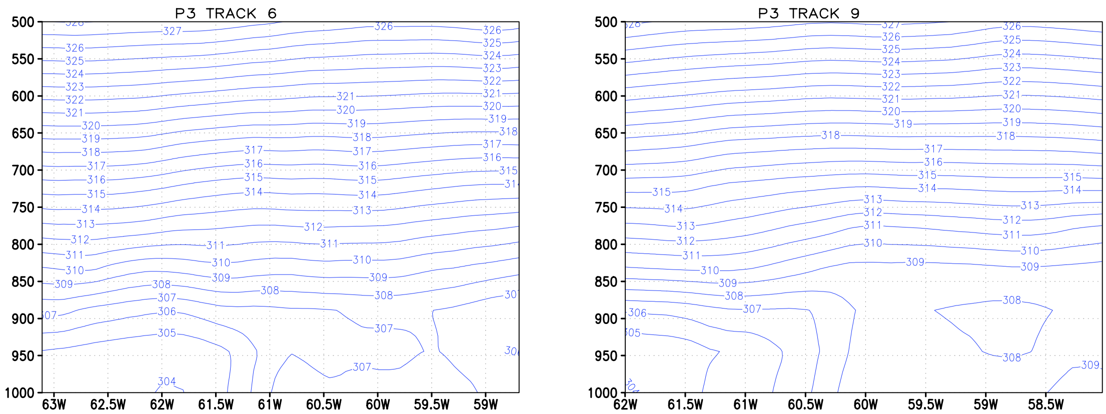


Figure 5 Virtual potential temperature in vertical cross sections along transects 6 and 9. Contour interval is 1 K.

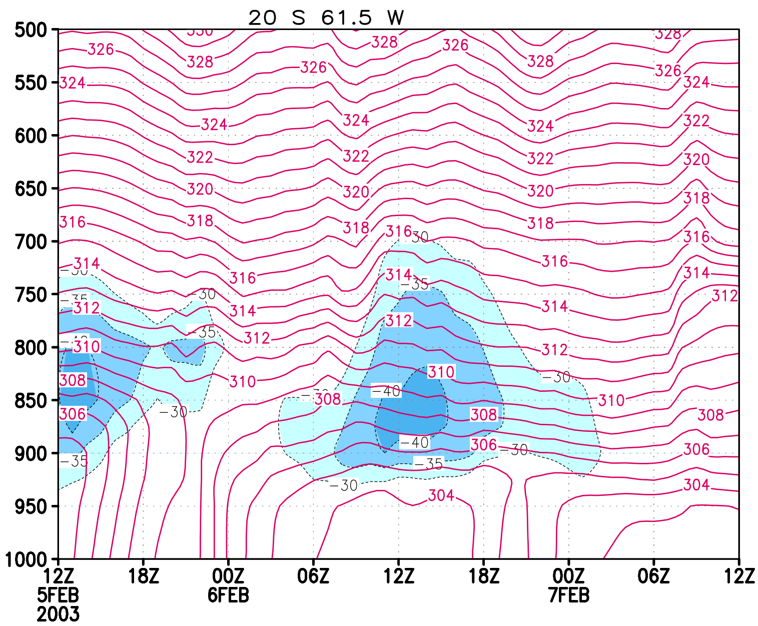


Figure 6 Time-height section of the meridional wind speed (*shaded*: wind strength greater or equal to 30 kt, each 5 kt) and virtual potential temperature (contour interval 1 K) at 20° S and 61.5° W.

4. SUMMARY

BRAMS simulations are satisfactory in describing the general northwestern flow. The wind intensity is well captured by the model, with a relatively better agreement when the terrain following coordinates are used. Data allowed an evaluation of BRAMS in complex terrain with a relatively high horizontal resolution. In general, simulations agreed well with the observed values and behavior.

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