Exchanges
- Scientific Contributions -

South American Low-level jet diurnal cycle and three dimensional structure*

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The South American Low-level jet (SALLJ) is a wind maximum within the lower troposphere just east of the Andes. It often produces a large transport of atmospheric water vapor from tropical to extratropical latitudes and consequently modulates the spring and summer rainfall events over the La Plata river basin. The SALLJEX Field Experiment, conducted under VAMOS/CLIVAR was an internationally coordinated effort aimed to monitor, quantify and analyze the low-level circulation over a region enclosing the SALLJ domain. This field experiment featured an enhanced sounding network within which pibals and radiosondes were launched during the Austral summer of 2002-2003, and about 100 hours of research flight missions from the NOAAWP-3D aircraft. An overview of past observational studies has left the diurnal wind cycle (particularly the nocturnal phase) and the three-dimensional structure of the SALLJ inadequately resolved. This contribution briefly summarizes the improved description of the low-level circulation revealed by the increased spatial and temporal resolution in wind observations during SALLJEX and identifies some remaining gaps for further advances.

Previous to SALLJEX, there were available twice a day observations in Santa Cruz, Bolivia that hardly depicted the diurnal cycle of the jet. Studies based on the four-times-a-day available NCEP reanalysis (Marengo et al., 2004) and ERA reanalysis (Salio et al., 2002), suggested that SALLJs are more frequent and intense between 0600 and 1200 UTC for the warm season north of 20°S near the core of the jet, while at the region downstream the maximum (around 30°S) is detected between 0000 and 0600 UTC. Saulo et al. (2000) and Nicolini et al. (2002) found a maximum between 0000 and 0600 UTC using 40 km-resolution ETA forecast products during the 1997-1998 warm season. These findings can be corroborated with more frequent upper-air observations during SALLJEX field experiment.

Observations made during the NOAAWP-3D flight mission on February 06, 2003 show the horizontal (Fig. 1a at 800 hPa, near the level of maximum wind) and vertical structure of the low-level flow (Fig. 1b given by the series of ascents and descents along the vertical cross section ab depicted in Fig. 1a, across the jet). This is a case of a moderately intense SALLJ over southern Bolivia and western Paraguay. A maximum wind speed of about 25 ms^{-1} in the 800-700 hPa layer is located over northwestern Paraguay. A secondary maximum was observed near Santa Cruz, Bolivia before landing. SALLJEX data provide unique information for the evaluation of three-dimensional fields supplied by advanced modeling tools. Fig. 1c and 1d include the Regional Atmospheric Modeling System (RAMS, version 4.3) 20-km nested grid wind field. Comparison between aircraft measurements and model derived wind fields is satisfactory in describing the general NW flow and the position of the maximum but the intensity is underestimated.

Figure 2 shows the mean SALLJEX period vertical wind profiles (both pilots and raobs included) at Mariscal Estigarribia (Paraguay) every 3-hours (wind speed and zonal and meridional wind components). This figure which also includes the number of observations at each time, on the left side of the corresponding panel, denotes the variation of number of available observations between times and altitudes. Less than 10 observations for the whole experiment have been done at 00, 03 and 15 UTC times included in Intensive Observation Periods (IOP), while 06, 12, 18 and 21 UTC have more than 50 and 09 UTC around 30 observations close to the surface. It is important to remember that Mariscal Estigarribia operated as a radiosounding station at 06 and 18 UTC while other stations only launched pibals during IOPs with a consequently reduced number of nocturnal observations (see data inventory in PACS-SONET web page: http://www.nssl.noaa.gov/projects/pacs/html_files/invehour.html for more detailed information about the whole network). From Fig. 2 the presence of the maximum speed both in the wind and in the northerly component is confidently evident during the 06 to 12 UTC period as well as the absence at 18 and 21 UTC.

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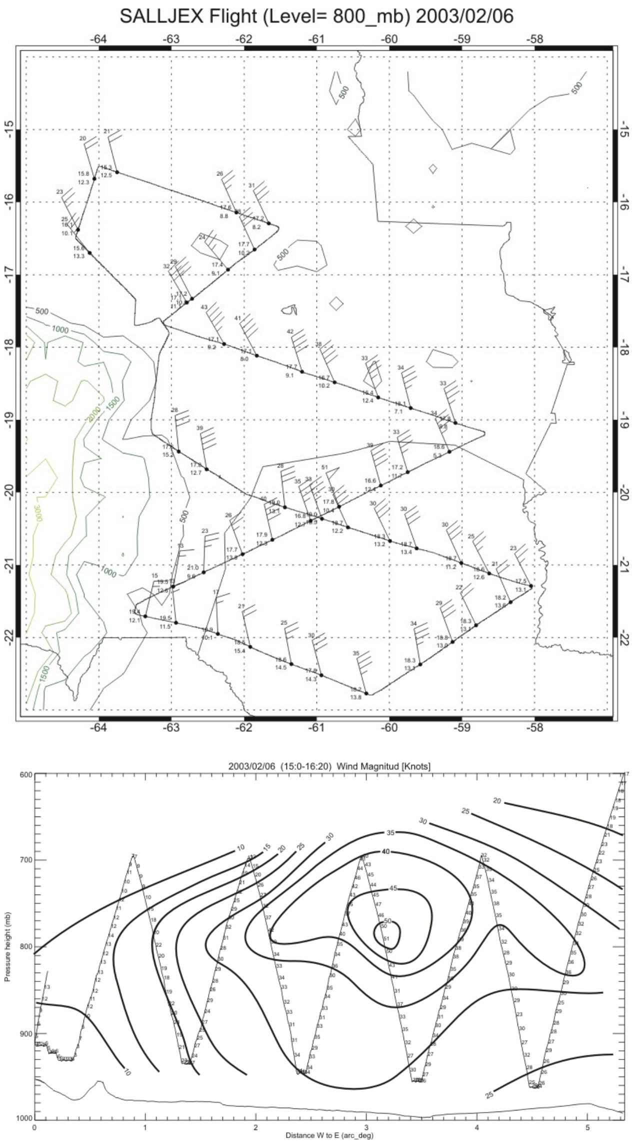


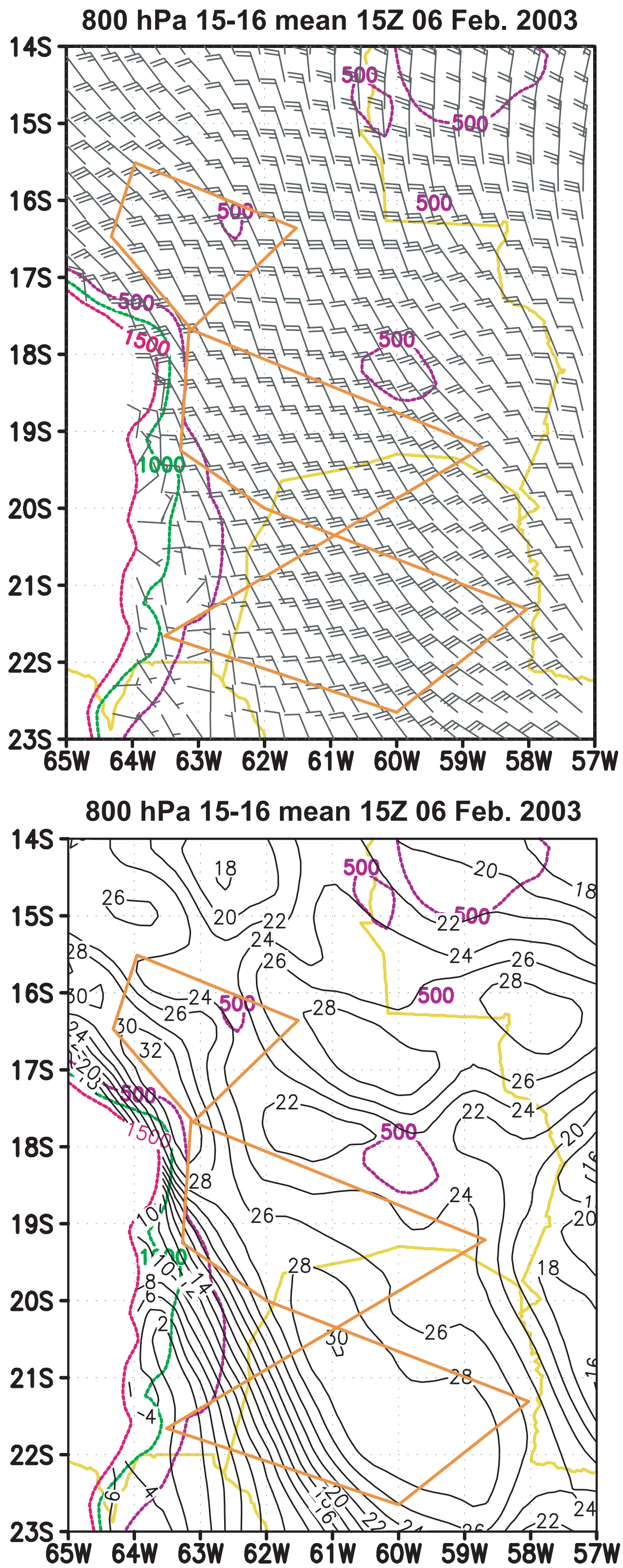
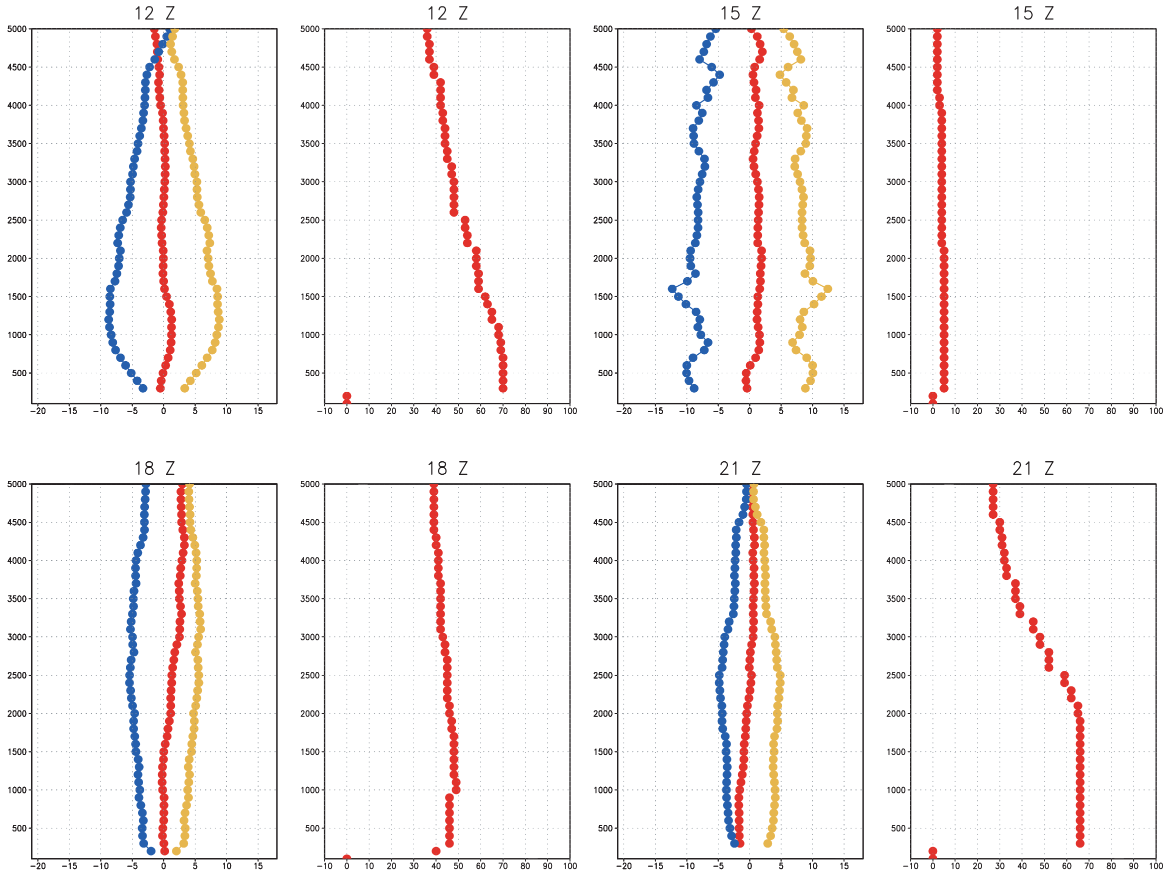


Figure 1: Observational and model simulation wind field on February 06, 2003, a) NOAA WP-3D flight trajectory and wind field (one full wind barb=10 kt) plotted at 800 hPa, b) isotach analysis (kt) in vertical cross section along NE-SW transect (ab in a)) and aircraft ascents and descents in the 1500 to 1620 UTC time interval, c) and d) RAMS (1500-1600 mean) wind field and isotach analysis (kt) respectively, at 800 hPa.

The few upper-air observations available since 1998 have localized the maximum of the wind between 1000-1600 m asl in Santa Cruz. During SALLJEX, the altitude of the speed maximum is most often between 500 and 1500 m asl. It can be as low as 500 m and as high as 3 km within the domain with a tendency to rise during daytime hours, consistent with a mixed layer growth (not shown).

Hodographs at most SALLJEX sites reveal an oscillation

Figure 2 (next page): Mean summer vertical wind speed (yellow), zonal (red) and meridional (blue) wind components (left in m/s) and number of observations as function of height (right) at Mariscal Estigarribia. Each panel corresponds to a different time (as indicated).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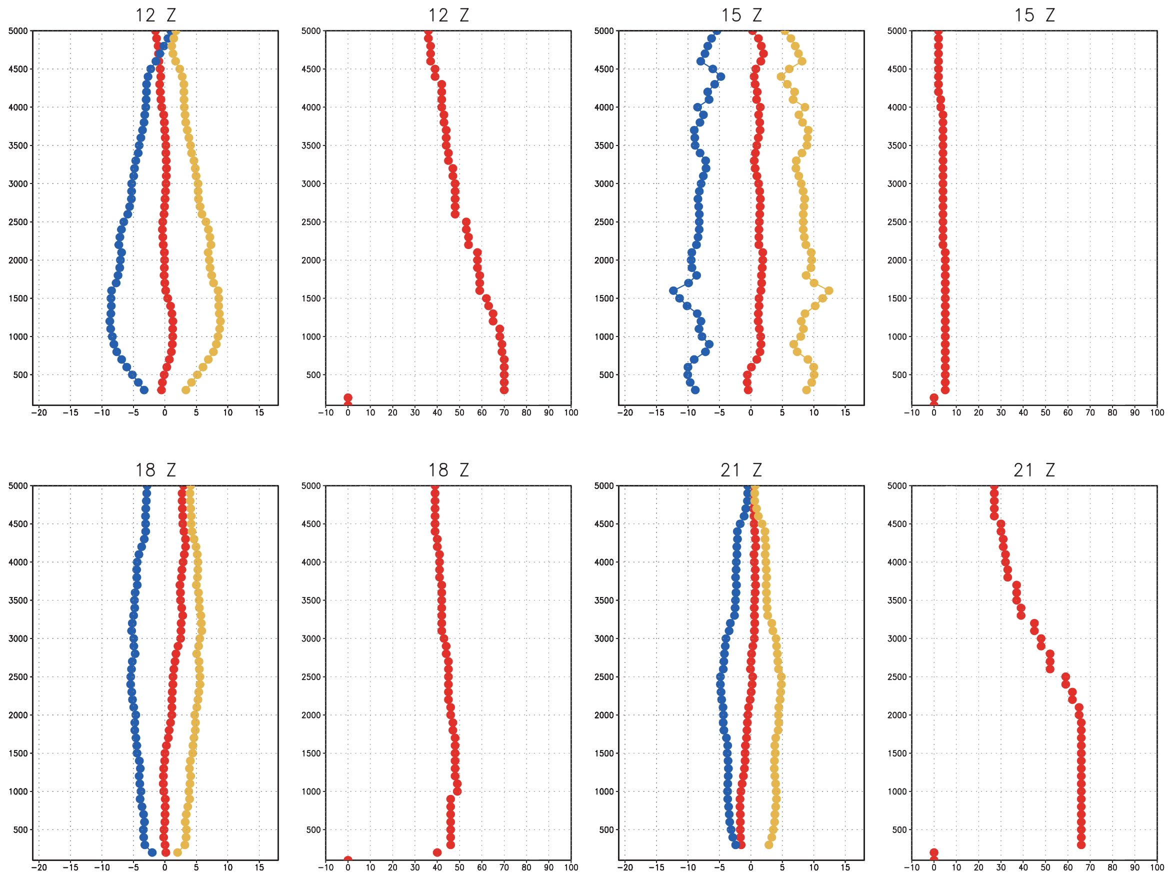
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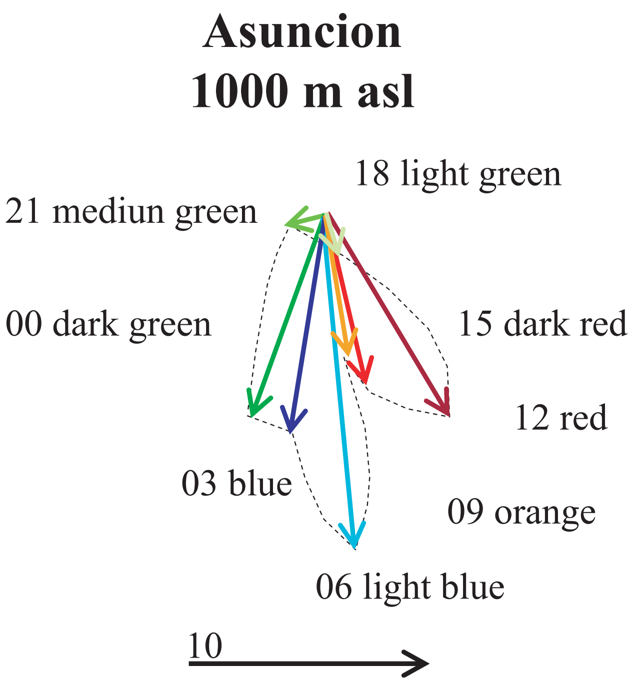

Figure 3: Mean summer diurnal wind gyre (m/s) at Asunción (Paraguay) at 1000 m asl. UTC times.

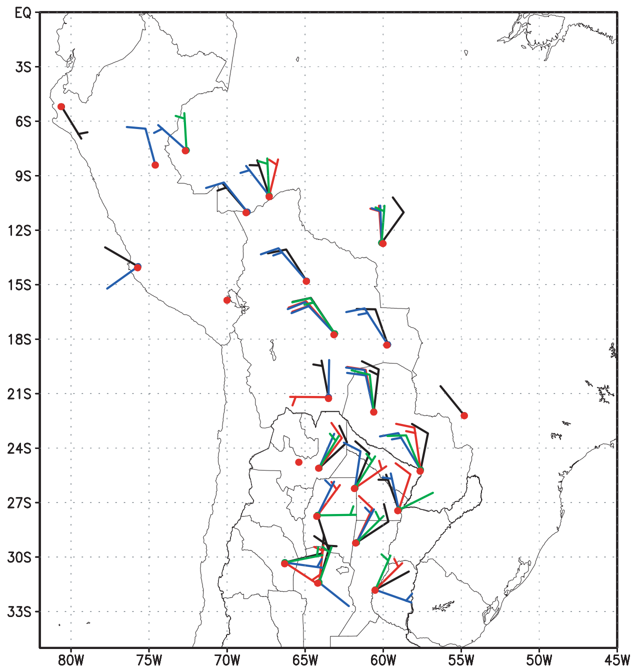

Figure 4a: Mean CJE, observed wind fields at 1000 m asl, including 00 (black), 06 (red), 12(blue) and 18 (green) UTC wind barbs (full barb=10 m/s) at each station (continued on following page).

in direction over the diurnal cycle with transitions between different time intervals instead of a regular progression. The observed behavior is consistent with a simple theoretical model that includes inertial oscillation, a subsynoptic pressure gradient related to mountain-valley differential diurnal heating/cooling and the interaction of a dominant meridional northerly component with the subsynoptic circulation. Figure 3 shows an example of this behavior at Asunción at 1000 m asl. Diurnal rotation is weaker in the northern part of the network increasing toward the south where synoptic variability is stronger. This evidence is in agreement with the behavior described by Saulo et al. (2000).

The SALLJEX days have been divided into three different samples using the NCEP operational analyses: days without evidence of SALLJ (NSALLJ), days characterized by SALLJ occurrence penetrating to subtropical latitudes (Chaco-SALLJ, denoted CJE) and non-Chaco SALLJ days (NCJE). Figure 4 shows the wind data composites at 1000 ASL, to look for signals in the diurnal cycle. This figure includes three maps corresponding to the specified samples. An analysis of this map and of vertical profiles of zonal and meridional wind components also composited for the three samples (for more levels, stations and hours refer to http://www.joss.ucar.edu/salljex/workshop/presentations/SALLJ_diurnalcycle.pdf) provide the following characteristics. At northern sites within the network the jet profile signal is very weak but it becomes stronger during both CJEs and NCJEs. At Santa Cruz, Bolivia, the wind speed vertical profile shows a strong (~15 m/s) and high maximum present at all the available hours (except 21 UTC) during NCJEs. This signal is still stronger during CJEs. Mean summer wind profile shows no signal at 12 UTC and during NSALLJ the maximum is much shallower. Over Paraguay the strongest jets (>20 m/s) are detected (few observations earlier) from 06 to 12 UTC and the maximum amplitude in diurnal oscillation occurs during CJEs. Near the mountains over Argentina another shallow LLJ is present during NSALLJ cases while eastward (at Resistencia) a jet is evident only during CJEs. More to the south the SALLJ signal weakens determining its southern limit.

Mean seasonal wind vector gyre typically behaves as described in the following paragraph. During nighttime the wind accelerates and turns anticlockwise (mostly from 03 to 12 UTC) consistent with an enhanced rate of rotation as the inertial oscillation is in the same direction of the two other components. After sunrise the wind direction stays almost uniform through the morning (up to 15 UTC). During the afternoon the wind slows down and the sense of rotation of the wind anomaly respect to the daily mean wind vector is more variable and also more uncertain because of the reduced number of observations. At the sites near the mountains this turning is consistent with a "valley breeze" component toward the west. Before and after sunset (mostly before 03 UTC) the rate of rotation is reduced by the large-scale (dominated by a northerly flow) and subsynoptic (mountain

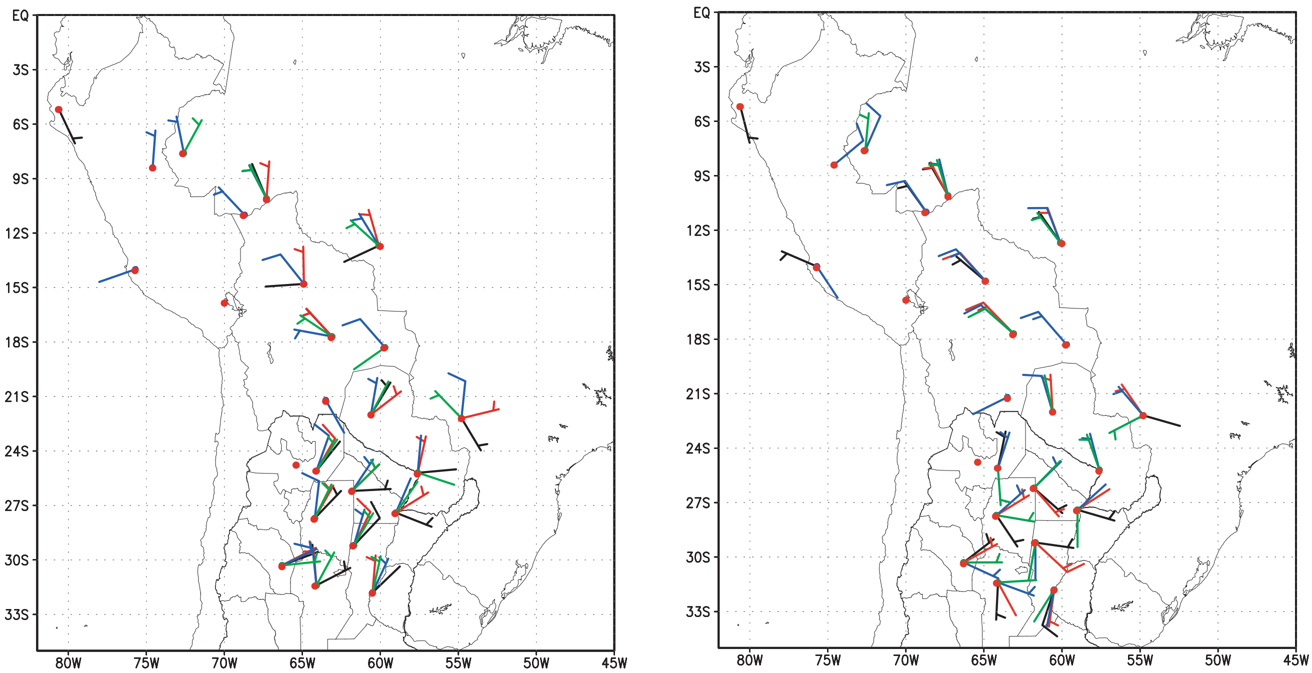

Figure 4 b and c (continued from previous page): Mean NSALLJ and NCJE (respectively from left to right) observed wind fields at 1000 m asl, including 00 (black), 06 (red), 12(blue) and 18 (green) UTC wind barbs (full barb=10 m/s) at each station.

breeze) components that oppose the inertial oscillation.

It is not clear the presence of a meridional variability in the time of wind speed maximum from this preliminary analysis of available observations in SALLJEX. Despite the improvement in temporal resolution, and the effort done to document the nocturnal part of the wind cycle, the limitation in number of observations makes still difficult to clearly define it and determine if the maximum occurs before or after 06 UTC.

Acknowledgments

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