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ACCURACY OF THE NCAR GLOBAL TROPOSPHERIC ANALYSIS (FNL) OVER CENTRAL SOUTH AMERICA BASED UPON UPPER AIR OBSERVATIONS COLLECTED DURING THE SALLJEX

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1. INTRODUCTION

The climate of central South America during the austral summer is highly modulated by the northwesterly low-level flow in the eastern foothills and low lands east of the Andes, referred as the South American Low-Level Jet (SALLJ). The complex orography and vegetation distribution, in conjunction with the sparse and poorly distributed operational surface and upper air observations, makes the evolution of these low-level jet events been unsatisfactory represented by the model simulations and forecasts (Campetella and Vera, 2002; Cavalcanti et al., 2002). For instance, the representation of orography in the operational models is greatly simplified. A meteorological field campaign called the South American Low-Level Jet Experiment (SALLJEX, Vera et al., 2006), held during the austral summer of 2002/2003, was designed to improve the understanding of the SALLJ and other related aspects like the role in moisture and energy exchange between the tropics and extra-tropics, characterize the climate of the region and associated and climate variability. Of interest for the South American research and operational community could be to evaluate the veracity of numerical representation (forecasts and analyses) of the SALLJ against the special observations gathered during the SALLJEX. The main purpose of this study is therefore focused on detecting deficiencies of the NCEP Global tropospheric analysis (FNL) data in the SALLJEX region. It is shown here that the SALLJEX data, specially the pibal balloon observation, evidence that the low-level wind field were not well captured by the operational FNL. An inspection of the spatial distribution of the differences between the SALLJEX upper air observations and the FNL data is performed. The emphasis here is on the uncertainties of the mean wind field and its diurnal variations. The impact of these uncertainties in other meteorological fields that are related to the wind is also discussed (Herdies et al. 2006). The NCEP analyses used here are from the Final Global Data Assimilation System (FNL), which provide initial conditions to the operational Global Forecast System (GFS) and Ensemble forecasts (ENS). This gives the motivation to evaluate the overall performance of the FNL against observations that were not available in real time to be assimilated on this data assimilation system.

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2. DATA AND METHODOLOGY

During SALLJEX, approximately 4500 pilot balloon observations ("pibals") were made at 26 station (16 of them were deployed especially for SALLJEX) in Peru, Bolivia, Paraguay, Argentina and Brazil. About 500 extra-radiosondes (RAOBS) were made during SALLJEX, including some temporary sites. Most of these upper air stations operated twice-daily, 12 UTC (early morning sounding) and 00 UTC (late afternoon sounding, with afternoon pibals being made near 21 UTC due to daylight requirements for optically tracking these balloons). The spatial distribution of the enhanced upper air network is shown in Fig 1. The poor distribution of the operational upper air radiosonde network is evident, especially in the Andean region and bordering lowlands.

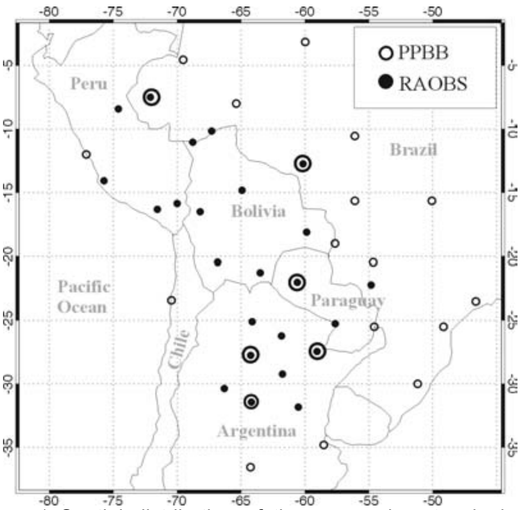

Figure 1 Spatial distribution of the upper air network during SALLJEX (Austral summer 2002-2003). Solid dots indicate pibal balloon sites and open circles indicates radiosondes sites.

The upper air SALLJEX network was used in this study to evaluate the performance of the NCEP Global Tropospheric Analysis. This dataset is one of the major gridded analyses produced operationally at the NCEP, which is the same as the Aviation (AVN) run -operational gridded analyses- but includes the delayed input data for the NCEP Final Analyses (FNL, http://dss.ucar.edu/datasets/ds083.2/). The FNL has a global coverage with a 1 x 1 degree spatial grid. These analyses are produced every 6 hours at the standard UTC 00, 06, 12, and 18 hours and include 26 pressure levels from 1000 hPa to 10 hPa. Most of the RAOBS mentioned above were digested in the FNL data.

The Global Data Assimilation System (GDAS) was run to produce a final analysis, which includes both the pibals and RAOBS obtained during SALLJEX. (Herdies et al., to be submitted http://www.joss.ucar.edu/cgi-bin/codiac/dss?83.032). These analyses are also given every 6 hours at the standard UTC 00, 06, 12, and 18 hours and include 42 pressure levels from 1000hPa to 1hPa with a horizontal resolution approximately 100 km.

The horizontal wind components were used to compare the different datasets mentioned above. Comparisons were performed using the geopotential height of the FNL (or GDAS) data as the reference vertical coordinate (since the pibal data do not provide pressure information). Here, we assumed that the geopotential height approximates the actual height of a pressure surface, which is a good assumption for comparisons at the lower levels of the atmosphere. Interpolated values were obtained using this vertical coordinate in each of the pressure levels available. At each station (pibal or RAOB) location, only the FNL (or GDAS) nearest grid point was used to compared the soundings. Simple time interpolation was performed in the FNL (or GDAS) data to treat the time inconsistency in the PIBAL afternoon soundings (observations made at 21UTC). The mean of the difference field was then obtained within the SALLJEX extended observation period (mid-December 2002 to mid-February 2003.)

3. RESULTS

One way to assess the assimilation model behavior is to look at scatter plots for the assimilated and observed data. Figure 2 shows the comparison between the pibal and the FNL datasets valid at 12 UTC. Systematic low biases of the FNL are observed for stronger northerly and easterly wind components at lower levels. This performance may be partially attributed to the orientation of the Andes which imposes this atmospheric motion on the large scale. The zonal component of the pibal dataset compares better aloft (500 hPa), at this level the flow is more zonal (i.e. the mean flow is typically westerly from 20˚S to the South Pole and typically easterly in the tropics). On the other hand, the largest differences between the FNL and pibals are observed for the weakest wind components. In this case, the errors produced by the measurements technique, data handling and random errors of the observation can be responsible for such behavior. Northerly low-level wind events appear to be systematically underestimated by the FNL.

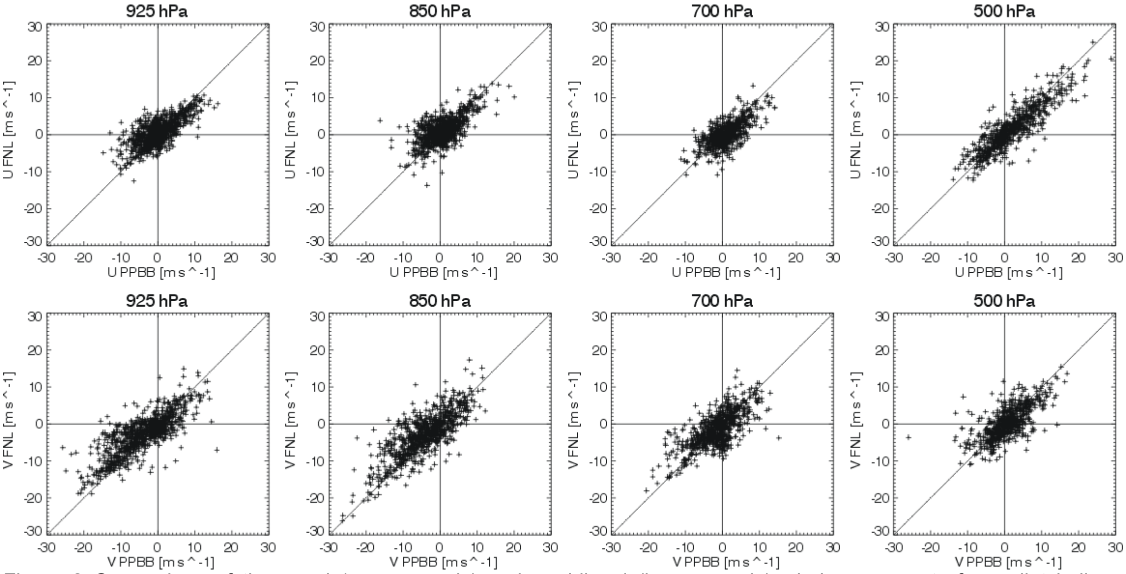

Figure 2 Comparison of the zonal (upper panels) and meridional (lower panels) wind components from pilot balloon observations and FNL analyses for different pressure levels (925, 850, 700, and 500 hPa from left to right, respectively). Scattered plots valid at 12UTC.

Table 1 Correlation coefficients estimated between the observation and the FNL and GDAS during SALLJEX. Validation time is 12 UTC.

			Pressure Levels [hPa]			
	12 UTC	wind comp	925	850	700	500
FNL	pibal	U	0.71	0.66	0.69	0.89
		V	0.77	0.77	0.71	0.69
	RAOBS	U	0.83	0.88	0.89	0.93
		V	0.84	0.86	0.89	0.87
GDAS	pibal	U	0.80	0.78	0.83	0.93
		V	0.86	0.88	0.89	0.84

Table 2 The same as Table 1 but valid for 21 UTC in the case of the pibal dataset and 00 UTC for the RAOBS.

			Pressure Levels [hPa]			
		wind comp	925	850	700	500
FNL	Pibal 21 UTC	U	0.68	0.72	0.57	0.87
		V	0.73	0.75	0.72	0.63
	RAOBS 00 UTC	U	0.85	0.90	0.92	0.93
		V	0.85	0.81	0.84	0.89
GDAS	Pibal 21 UTC	U	0.76	0.78	0.75	0.91
		V	0.75	0.82	0.82	0.85

The analyses (FNL and GDAS) are compared to the pibal and RAOBS data using correlation coefficients between each other for two different times (12 UTC for early morning soundings and 21 UTC and 00 UTC for late afternoon soundings for pibal and RAOBS, respectively). Table 1 (12 UTC) and Table 2 (21 and 00 UTC) summarize these results. Note that the PIBAL meridional wind component presents relatively larger correlation coefficients at lower levels when they are compared with both the FNL and the GDAS data. Since most RAOBS were assimilated by the FNL, they are expected to have a better agreement than with the pibals. The later results may be influenced also by the fact that most RAOBS stations are located farther away from the Andes compared with the pibal stations. The correlation coefficients between the pibal and GDAS data show a significant improvement at all pressure levels and the two different analysis times, for example, the meridional wind component has a correlation coefficient of 0.71 when comparing the FNL with the pibal data at 700 hPa, which changes to 0.89 when comparing the GDAS with the pibals. Besides, the morning soundings compare better both the FNL and GDAS at the lower levels. This decrease of the correlation coefficients during the afternoon could possibly be explained by problems with the model in representing frictional effects and the turbulent nature of the PBL flow, among others.

Figure 3 shows the spatial distribution of the analysis differences (observation minus analysis), which provides a measure of the regional impact of the assimilation model. One can argue that the FNL or GDAS did an excellent job at analyzing the wind field based only in the correlation coefficients (very strong correlation), but they did not perform as well when looking at individual stations. Specifically, Figure 3 shows spatial structures of the difference field (U(pibals, RAOBS) – U(FNL), V(pibals, RAOBS) –V(FNL)). At lower levels (925, 850, and 700 hPa), pibal stations closer to the Andes, reveal that the FNL underestimates the northerly flow, with the northwestern region of Argentina and eastern Peru having the largest differences (>5 m s-1). This poor performance may be attributed to the complexity of the terrain combined with the coarse grid scale of the analyzed fields (~100 km). Pibal stations located farther to the east, away of the mountains and closer to other RAOBS station, like the ones in Paraguay and northeastern Argentina, show smaller differences (~2 m s-1). These error structures, which may be produced by the complex terrain, remain partly in the GDAS (after assimilating the pibals), with a smaller magnitude as shown in Figure 4. The benefit of assimilating the PIBAL data is more evident at lower levels with some particular exceptions.

4. SUMMARY AND DISCUSSION

The accuracy of the NCEP Global Tropospheric Analysis (FNL) over central South America is explored in this study by comparing the analysis with upper air observations collected during the SALLJEX. These comparisons are performed during the whole period of SALLJEX (Dec-2002-Feb2003) by using the correlation coefficient and by plotting the spatial distribution of the errors. Correlation coefficients indicate good performance for the FNL and the GDAS during the SALLJEX period. The performance comparison showed that GDAS performance, which includes the pilot balloon data, was better or at least as good as the FNL performance.

The FNL provides more accurate wind field analysis at grid points located farther away from the Andes. Larger errors are located closer to the Andes, which is also the region where the pibal balloon stations, not assimilated in the FNL, were located. The GDAS, which includes the pibal observations, improves in general the wind field's analysis but still shows deficiencies in the region of complex terrain.

These wind biases, particularly large in the lower atmosphere of the SALLJEX domain, calls for improved representation of atmospheric boundary layer processes in mesoscale models and a more careful treatment of the data in regions with complex terrain.

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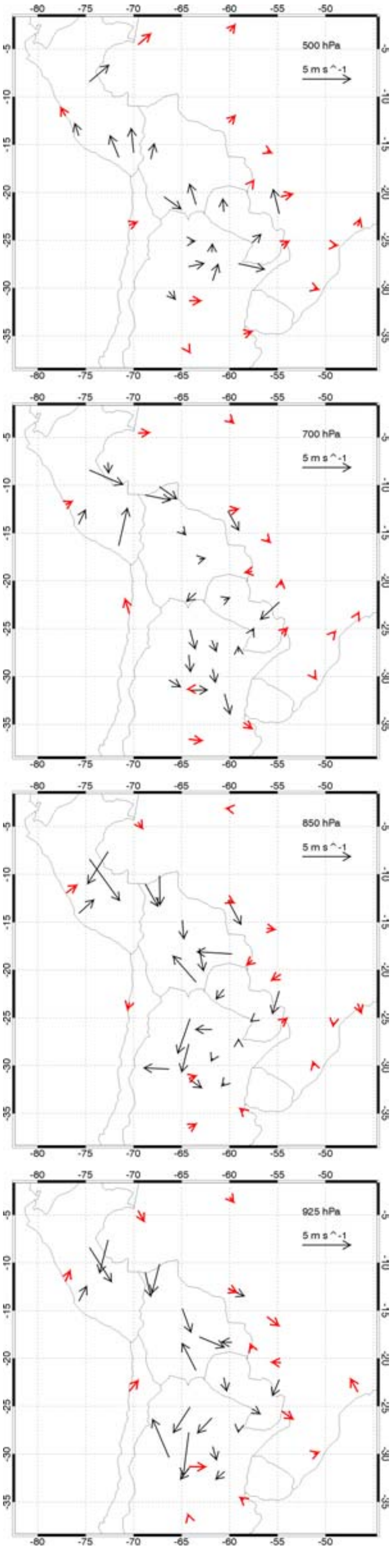

Figure 3 Differences between the upper air observation (red arrows RAOBS sites, black arrows pibal sites) and the FNL data average along the SALLJEX period. Valid at 12 UTC.

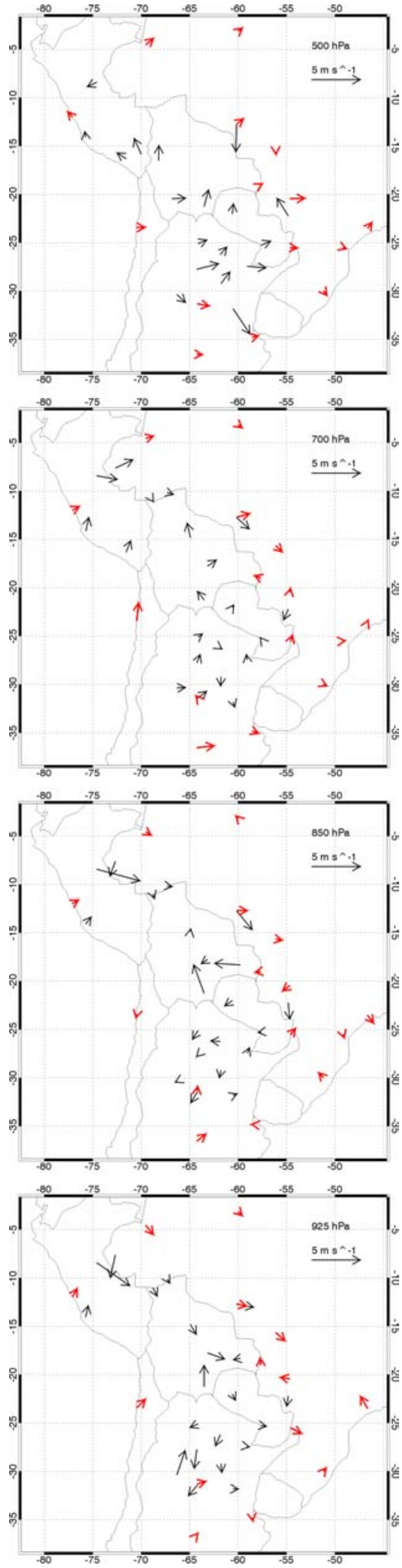

Figure 4 The same as Figure 3 but using the GDAS.

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