DOWNSCALING AND ASSIMILATION OF AN ENHANCED DATA BASE IN SOUTHEASTERN SOUTH AMERICA

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ABSTRACT

The purpose of this work is to produce an enriched analysis for the summer 2002-2003, during which the South American Low-Level Jet Experiment (SALLJEX) was performed. Enriched analyses were generated ingesting all available data following a downscaling methodology, using the Regional Atmospheric Modeling System (RAMS). RAMS model was applied to obtain analysis every three hours, with an horizontal resolution of 80 km covering mostly South America and an enhanced domain with 20 km resolution for the region encompassing Central and Northern Argentina, southern Brazil, Bolivia, Paraguay and Uruguay. The alternatives of vertical coordinates included in RAMS version, sigma-Z and shaved-ETA have been used to generate two different sets of analysis. To evaluate which analysis better represents the “real field”, estimated soundings and surface data from the enriched analyses were generated at times coincident with the observations and at grid-points nearest to the stations within the SALLJEX observational network. Root mean square errors (RMSE) were calculated for 15 vertical levels and for each variable. A reduction in the RMSE values was found for all variables and levels and therefore an improvement in representation of data once they were assimilated in the analysis.

1. INTRODUCTION

The South American Low-Level Jet Experiment (SALLJEX), was carried out between November 15, 2002 to February 15, 2003, over a region enclosing the domain where this feature mainly occurs: Bolivia, Paraguay, central and Northern Argentina, western Brazil, and Peru. SALLJEX aimed to obtain an improved temporal and spatial description of the tropospheric circulation over this region. A detailed description of data collected during SALLJEX can be found in Vera 2004; Penalba et al 2004 and Nicolini et al 2004.

The purpose of this work is to produce an enriched analysis for the whole SALLJEX period ingesting all available data and following a downscaling methodology, using the Regional Atmospheric Model System (RAMS). Short range forecasts of precipitation associated with South American Low Level Jet (SALLJ) have low skill largely due to lack of high resolution local observations needed to specify the initial atmospheric conditions for the forecast. We propose to study improvements in the jet and precipitation forecasts that would result from the utilization of enhanced insitu upper-air data and surface observations. SALLJEX was specifically designed to capture the low level jet evolution, moisture transport and the associated precipitation. In this study we describe the methodology to produce different enriched analyses and we evaluate them to determine which one generated the best initial conditions for subsequent forecasts. This enriched analysis would also allow to study in detail physical interactions between the precipitation, moisture transport and evolution of the SALLJ that would in turn lead to better understanding these phenomena and to further improvements of the forecast system in the future.

The work is structured as follows: section 2 describes datasets and the methodology adopted to produce enriched analysis and to evaluate them; in section 3 results are shown and discussed and finally section 4 presents the conclusions.

2. METHODOLOGY

In order to produce a set of enriched analysis for the whole SALLJEX period all available data were ingested following a downscaling methodology, using RAMS, version BRams 3.2.

A general description of RAMS can be found in Cotton et al, 2003. Version BRams 3.2 includes a shallow cumulus parameterization (Souza and Silva 2002) that complements the

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Grell cumulus parameterization (Grell 1993), also includes two different alternatives for vertical coordinates: Terrain following (sigma-Z) (Tripoli and Cotton, 1982) and terrain intersecting Cartesian coordinate (shaved-ETA) (Tremback and Walko, 2004).

RAMS model has an initial stage in which it produces the objective analysis that will be used as initial and boundary conditions. Barnes objective analysis scheme (Barnes 1973) is applied to a first guess that is corrected with data sets assimilated. Data assimilation method used is known as "nudging" or Newtonian relaxation, where model integration is interrupted periodically and the current model state is updated with the analysis fields produced at the initial stage. This technique has been termed "analysis nudging" where the observational data is first objectively analyzed to the model grid, then the model field is nudged to the gridded analysis. This contrasts with "observational nudging" in which model fields are nudged to the observational data only at those grid points which are around the observations. The strength of the nudging is given by (A-M)/T, where A is the analyzed data value at a particular location, M is the corresponding model value and T is a user-specified relaxation (e-folding) time scale. There are three different nudging timescales, one for lateral boundaries of the domain, other for the top levels of the model and another for the center of the domain. To produce the enriched analysis in all cases nudging is activated at the boundaries, top and center of the domain.

Operational analyses GDAS (Global Data Assimilation System) from National Oceanic and Atmospheric Administration/ National Center of Environmental Prediction (NOAA/NCEP) with horizontal resolution of 1º and temporal resolution of 6 hours, were used as first guess in Barnes objective analysis scheme implemented in RAMS. RAMS model was applied to obtain analysis every three hours, with an enhanced horizontal resolution of 80 km over most of South America and 20 km for the region that includes Central and Northern Argentina, Chile, Paraguay and Uruguay, and southern Brazil and Bolivia. These domains are shown in Figure 1. Besides a higher horizontal resolution, vertical resolution was also increased specially at low levels (30 atmospheric levels). This analysis will be called DWSC1, where the improvement respect to GDAS analysis is just a better resolution. At a second step, the enhanced data base was assimilated using DWSC1 as first guess, this analysis will be called DWSC2. Besides, every 24 hours, heterogeneous soil moisture field derived from precipitation observed by remote sensors (Gevaerd and Freitas, 2004) was included while sea surface temperature was updated weekly.

DWSC1 and DWSC2 analyses were generated in both vertical coordinates included in RAMS version, sigma-Z and shaved-ETA, with the purpose of evaluating which one is more close to the "real atmospheric field".

The assimilated data set includes surface and upper-air data from the operative network, rawinsonde and pilot balloon specially collected during SALLJEX. The assimilation process was preceded by a detailed and careful data quality control.

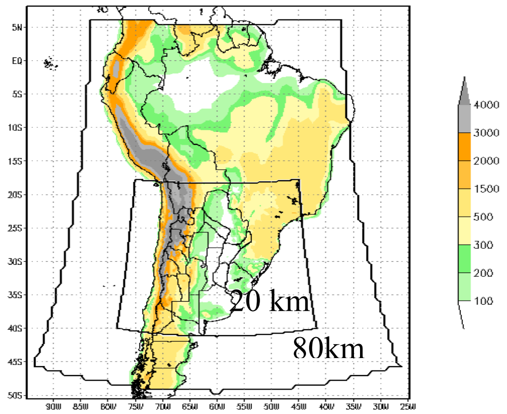

Figure1: Geographical domains and topography

To evaluate which analysis better represents the "real field", estimated soundings and surface data from the analysis were generated at times coincident with the observations and at grid-points nearest to the stations within the SALLJEX network. Root mean square errors (RMSE) were calculated for 15 vertical levels and for each variable. While wind variables (zonal and meridional wind components, vector wind and wind intensity) may be evaluated for both pilots and rawinsoundings, only the last observational system allows evaluation of temperature and mixing ratio. For surface data, RMSE were calculated for 2 m temperature and 10 m wind intensity. RMSE were additionally calculated for GDAS analyses to measure the potential benefit of downscaling and data assimilation.

RMSE for a given variable, x, is defined as:

$$RMSE = \left[\frac{1}{N} \sum_{i=1}^{N} \left(Xp^{i} - Xo^{i} \right)^{2} \right]^{1/2}$$

where N is the total number of observations, subscript p means predicted and subscript o means observed.

RMSE for vector wind is defined as:

$$RMSVE = \left\{ \frac{1}{N} \sum_{i=1}^{N} \left[\left(Up^{i} - Uo^{i} \right)^{2} + \left(Vp^{i} - Vo^{i} \right)^{2} \right] \right\}^{1/2}$$

where U and V denote zonal and meridional wind components.

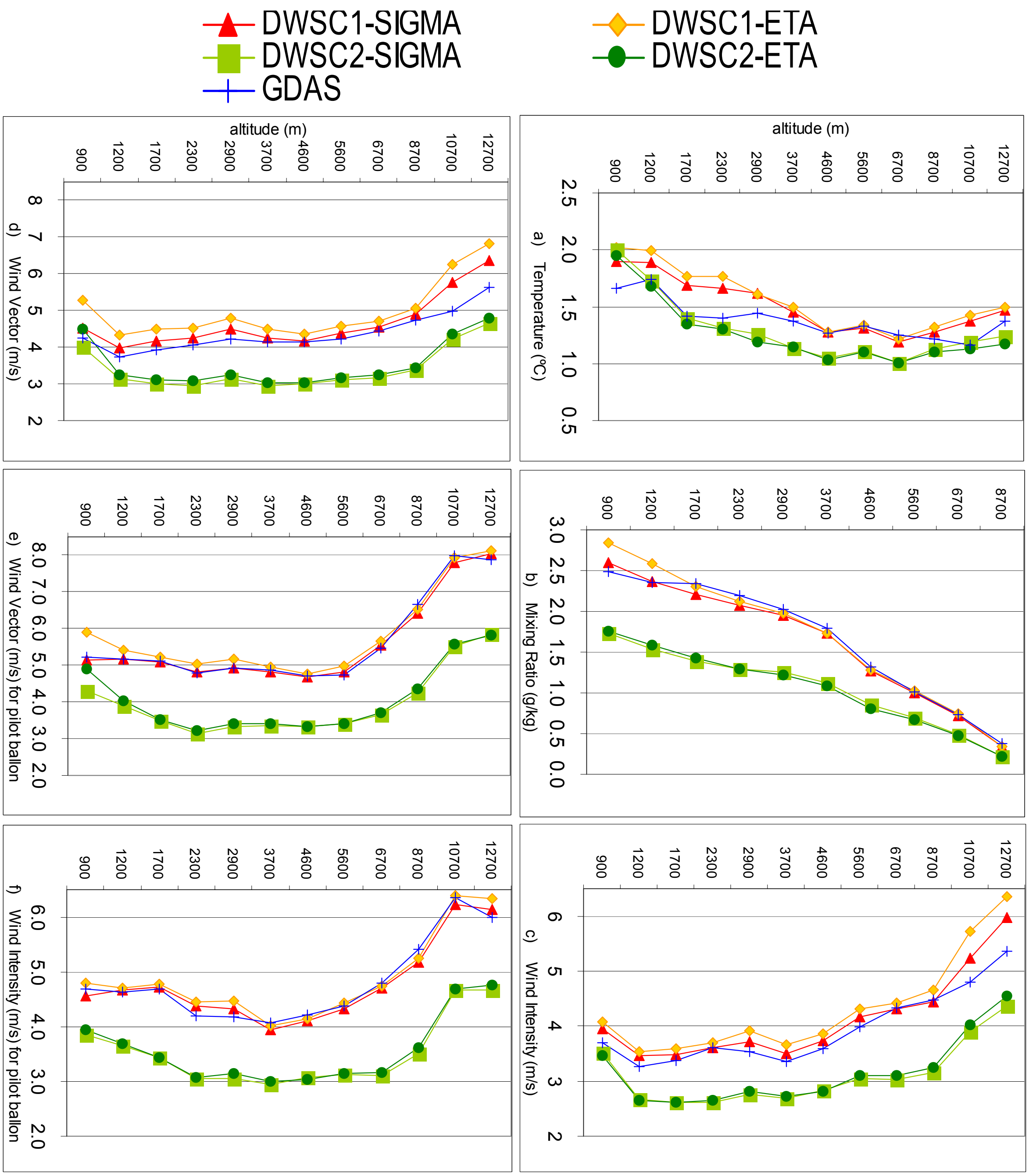

Figure2: Variation of RMSE with altitude for a) Temperature b) Mixing Ratio c) Wind Intensity and d) Wind Vector for radiosoundings; e) Wind Vector and f) wind intensity for pilots ballons.

3. RESULTS

A comparison of RMSE for different levels and variables is shown in Figure 2. Levels below 900 m are not shown because a smaller number of data was available. At these levels the pattern shows not always the same behaviour and it is difficult to evaluate the results.

Comparing RMSE for DWSC1 and DWSC2, in both vertical coordinates, a reduction in the RMSE was observed for all variables and levels when data were assimilated, leading consequently to a better representation of data in the analysis.

Regarding differences between vertical coordinates, the corresponding DWSC2, in general, display smaller errors for temperature and mixing ratio using shaved-eta coordinate and for all wind variables using sigma-z.

Errors found for DWSC2 in both coordinates were smaller than those for GDAS analysis. Comparing DWSC1 and GDAS analysis, where DWSC1 only benefits from a higher resolution respect to GDAS, a signal in error differences between the two sets is not clear.

	DWSC1		DWSC2		GDAS
	sigma	eta	sigma	eta	
RMSE 2m temperature	2.97	2.53	2.25	1.92	2.94
RMSE 10m wind intensity	2.13	3.09	2.03	2.6	2.62

Table 1. RMSE for surface variables.

RMSE for surface variables are shown in Table 1. As for upper air results, a smaller RMSE for temperature is found for DWSC2 with shaved- eta vertical coordinate, but for wind intensity best result is obtained with sigma-z.

As the motivation to produce this enriched analysis is to obtain a better description of SALLJ, a more detail evaluation was made for wind intensity and wind vector at 1200 and 1700 m where the maximum in SALLJ occurs. For these variables a RMSE for each analysis time was produced, generating a RMSE series for every set of analyses. These results were ordered from the one that did best to the one that did worst, then we compute the number of times when each analysis gave the best and the worst result. We considered that two RMSE were different when the difference between them was bigger than 1m/s. These results are shown in Table 2.

Both DWSC2 present the highest number of cases where they gave the best results, for all variables. For wind intensity, the difference between both DWSC2 was smaller but for wind vector, sigma-z is showing a higher number of "best" agreements with observational data than vertical coordinate shaved-eta. These results indicate that a better representation of wind direction is obtained with sigma-z vertical coordinate. Yet, this difference is no so evident for wind intensity.

			DWSC1		DWSC2		GDAS
	Altitude		SIGMA	ETA	SIGMA	ETA	
RMSE wind intensity	1200 m	Best	238	209	434	424	306
		Worst	344	392	223	231	378
	1700m	Best	211	218	440	443	247
		Worst	356	397	195	199	395
RMSE wind vector	1200 m	Best	191	170	465	382	279
		Worst	278	463	152	163	337
	1700 m	Best	165	150	496	469	235
		Worst	318	467	139	139	375

Table 2. Number of best and worst RMSE for pilots and rawinsondes.

4. CONCLUSIONS

A downscaling and data assimilation methodology was designed. Different analysis sets were compared to observational data in an attempt to determine which one of this analysis better represents the "real field", with particular emphasis in SALLJ representation.

Both enriched analyses have shown an improved representation of data in the analysis once they were assimilated. They also show an improvement from analysis that doesn't include SALLJEX data. Which one of the two enriched analysis is more close to "real field", is not so easy to determine, but results show a better response in wind direction for sigma-z vertical coordinate.

These enriched analyses are currently applied to study evolution of convection during SALLJ events providing a much better resolution of the preconditioning processes that gradually buildup the environment that promotes organized deep convection over subtropical South America (see a case study by Borque et al, 2006 in this same Conference).

DWSC1 and DWSC2 are currently used to evaluate the impact of data assimilation in forecast improvement.

5. ACKNOWLEDGMENTS

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