WRF-ARW sensitivity to different planetary boundary layer parameterization over South America

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1. Introduction:

The WRF-ARW (Advanced Research- Weather Research and Forecasting) model has been implemented at CIMA (Centro de Investigaciones del Mar y la Atmósfera) since November 2005, to provide operative short range, mesoscale weather forecasts over South America (http://wrf.cima.fcen.uba.ar). Since then, some studies (Ruiz and Saulo, 2006) have been devoted to evaluate WRF performance over South America since there is almost no documentation about its performance over this particular region

Preliminary analysis of these operational forecasts, show that forecasted surface temperatures are lower than the observed values. This systematic bias could be caused by several reasons, e.g. misrepresentation of heat fluxes at the surface or limitations in the Planetary Boundary Layer parameterization (PBL). In order to address the deficiencies in the representation of temperature at low levels, we report here the results obtained from the analysis of model sensitivity to the use of two different planetary boundary layer (PBL) parameterizations, which are provided with the WRF-ARW code.

2. Methodology:

The experimental design for this study consists of the following:

1) Experiment 1: In order to assess the impact of alternate PBL parameterizations, two series of 48 hr-forecasts were performed between October 22nd and November 27th 2005, initializing the model at 12 UTC and using the Global Forecasting System to obtain initial and boundary conditions. One of the series runs with the Yon Sei University PBL scheme and the other with Mellor, Yamada and Janjic scheme (Mellor and Yamada, 1982). All other model settings were kept identical between the series. The horizontal resolution is 50 km with 31 sigma vertical levels.
2) Experiment 2: In order to compare model forecasts with high resolution observations available from the South American Low Level Jet Experiment field campaign, two ten day-simulations were performed using the same PBL schemes as in the previous experiment. These runs have 20 km resolution and start on 29th January 2003 with GDAS (Global Data Assimilation System) analysis used to provide both, initial and boundary conditions. This case corresponds to a Norwesthern Argentinian Low (NAL) event which is a thermal-orographic low pressure system (see Seluchi et. al., 2003 for a description of the NAL). The thermal component of this system makes it very sensible to heating at low levels. In this work, radiosounding observations performed at Santiago del Estero (27ºS, 64ºW see Figure 1 a for station location) are used to test model performance with emphasis on the diurnal cycle of the PBL structure at 06 and 18 UTC.

3. Results:

Fig. 1 a and b, show the averaged difference (over the experimental period) of 2 meter temperature at 06 and 18 UTC for experiment 1. In general it can be seen that the YSU scheme gives temperatures greater than the MYJ at both times of the day. During the warm hour, differences are larger (greater than 1.5K) and cover most of the domain. At 06 UTC, maximum differences can be found over La Plata Basin and over areas with relatively low terrain height. Fig. 1 c and d, show the difference in wind and moisture convergence at 850 hPa.. The difference wind field resembles the climatological circulation at low levels but running in the opossite direction. This suggests that the circulation associated with the “trade winds-low level jet-SACZ” patterns over South America is stronger when the model uses MYJ PBL parameterization. Differences in wind and moisture fields lead to changes in the distribution of moisture convergence (Fig 1 c and d) as can be seen over eastern Brazil, where the MYJ scheme produces stronger low level moisture convergence. This migth have an impact in the distribution of precipitation. However, the relation between changes in moisture convergence and precipitation is not as close as it could be expected (not shown).

Fig. 2 a, b and c, show a height–time cross section of the observed potential temperature at Santiago del Estero and the differences between the observed and the forecasted potential temperature for the Experiment 2. During warm hours a well mixed layer develops, reaching 750hPa and denoting an intense warming during most of the period. Both schemes (Fig. 2 b and c) underestimate the observed potential temperature although YSU temperatures are warmer than MYJ ones, in agreement with experiment 1 results. As in Fig. 1 a and b, potential temperature differences among both schemes are greater during the warm hour, when the NAL is more intense. Similar results were obtained for Resistencia (27.5ºS 59.0ºW) upper air observations available at the same UTC times during the experimental period (not shown).

To analyze the potential impact of the PBL parameterization upon a this low pressure system, the observed sea level pressure series at La Rioja station (29ºS, 66ºW), which is collocated with the NAL center, is compared with the forecasted values using the two PBL schemes (Fig. 2 d). As can be seen, both simulations retain the observed pressure evolution but underestimate the deepening of the NAL. YSU shows a slightly better performance, what might be related to the warmer PBL associated with this scheme.

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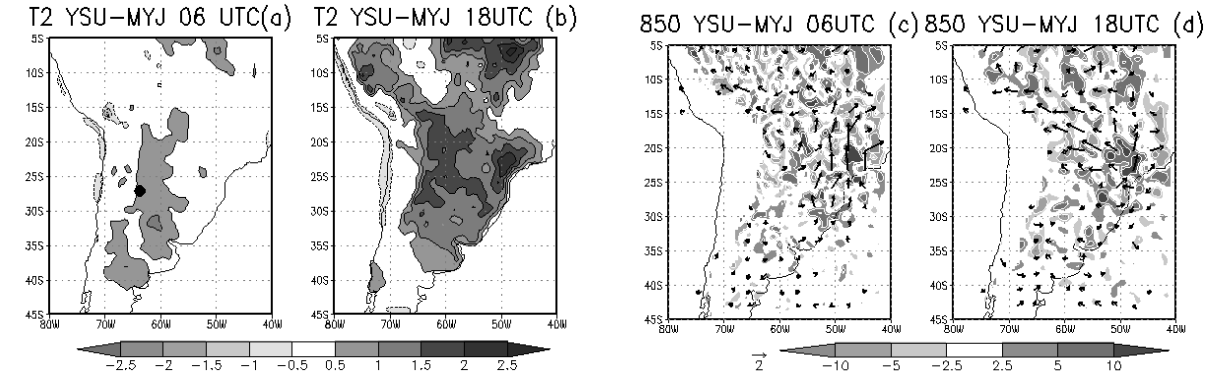

Figure 1: (a) and (b) Differences between temperatures at 2 meters (YSU-MYJ) at 06 and 18 UTC respectively. (c) and (d) 850 hPa. wind differences (YSU-MYJ) (vectors) (only values above 2 ms^{-1} are plotted) and moisture convergence differences (YSU-MYJ) (10^{-8}g kg^{-1} m s^{-1}) (shaded). The black dot in figure (a) shows the location of Santiago del Estero.

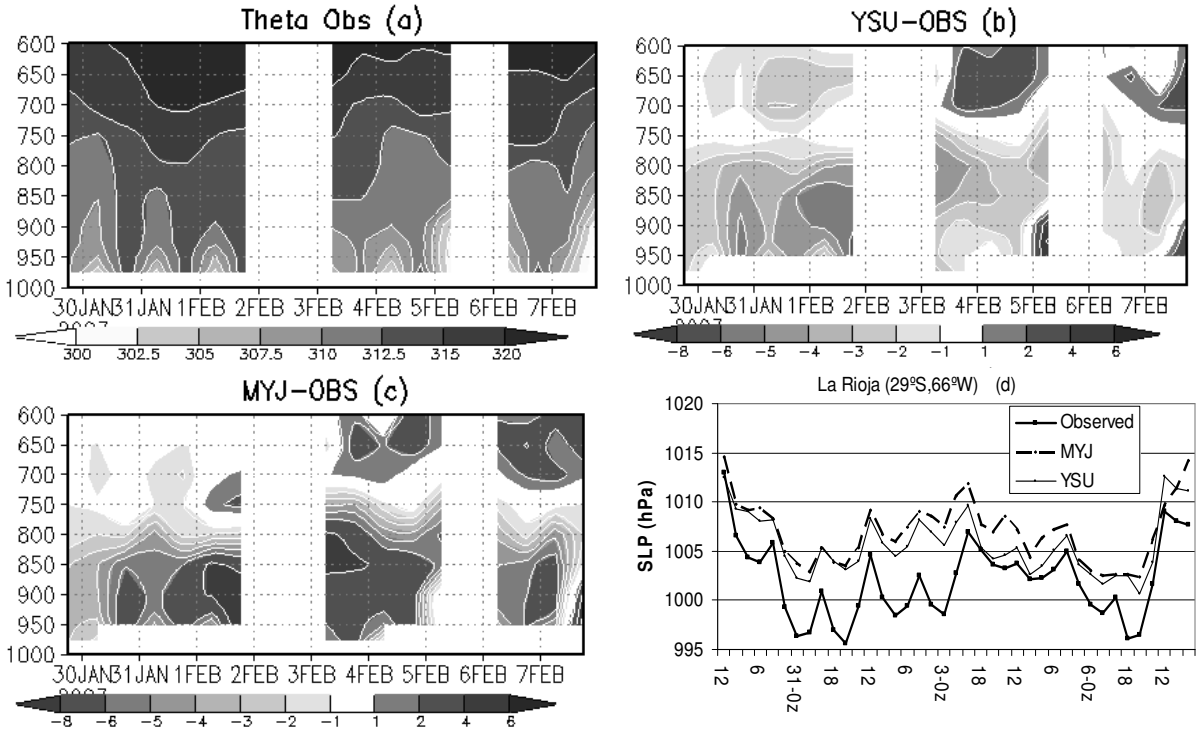

Figure 2: Height-time cross section of (a) observed potential temperature (in K) (b) YSU minus observed potential temperature and (c) MYJ minus observed potential temperature at Santiago del Estero. (d) Observed pressure evolution at La Rioja (solid thick line), YSU PBL forecast (solid thin line) and MYJ PBL forecast (dashed line) . All figures are for experiment 2 between 29th January 2003 and 08th January 2003.