SUMMER PRECIPITATION SIMULATION OVER SOUTHEAST OF BRAZIL

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1. INTRODUCTION

The use of regional atmospheric model, with higher resolution, has been reinforced since global models have the ability to represent just lower resolution systems, preventing, by this mean, the possibility to study systems from higher frequency order (Dolores Frias *et al*., 2005). The development of atmospheric models in regional scale can be seen under two main aspects: firstly, the high applicability of environmental simulations and forecasts, supporting social and economical planning, and, secondly, the increase of understanding of physical and dynamical processes underlying the evolution of atmosphere coupled to biosphere and ocean.

Verifications of simulations obtained by regional model in Brazil has mainly considered the tropical region: Amazonian and Semi-arid (Northeast) regions. Focus on Amazonian region is related to its extent area covered by tropical forest that undoubtedly influences great part of the synoptic atmospheric circulation partially due to latent heat realization and direct evapotranspiration (Nobre *et al*., 1991; Silva *et al*., 2005). The atmosphere studies related to Northeast of Brazil are mainly due to its distinct climatic characteristic. A great part of this region is dominated by semi-arid climate that excessively influence the development of its socio-economic activities.

Although Southeastern Brazil is economically one of the regions most important of the country, its climate characteristics have recently focused through regional modeling. On the other hand, the atmospheric predictability in this region is low due to its latitudinal position that promotes the influence both from tropical and extratropical systems. Acting systems in this latitudinal belt has its origins from different scales too. During the rainy seasons, Southeast region of Brazil is characterized by a transition aspect in climate sense. Northern and southern areas shows many times a see-saw pattern for precipitation (and related variables) fields, which mainly oscillates in the SW-NE direction: for example, during drier periods over southern areas (including the South region of Brazil), those located most at north show wetter conditions. This feature is depicted in Fig. 1c,d. Climatic oscillations are responsible for this patterns. Interannual ENSO variability influences anomalies with opposite signal at south and central-northeast Brazil (Ropelewsk and Halpert, 1987; Grimm et al., 1998). Climate in this region is also characterized by intensity and positioning of South Atlantic Convergence Zone (SACZ), orientated in the NW/SE direction and apparently located further to the south of its common position during El Niño episodes (Quadro, 1999). As southeast of Brazil is located at subtropics, it presents an intrinsic low predictability for many climate parameters, including precipitation, what is also reflected in model simulations. The increase of atmospheric understanding at this region on climatic scale is need, which could suggest possible adjustment to the modeling framework.

Although the atmospheric models present, in general, good ability to simulate dynamical behavior at high levels, in climatic scale, the surface precipitation is many times not very well simulated, as is the case of Southeast Brazil. Precipitation is one of the variables that provide great influence in biosphere-atmosphere interface conditions; therefore, it is necessary to make efforts through a higher predictability by the use of model.

Therefore, considering the climatic characteristics, the intention in this study is to detect the ability of regional model at southeast of Brazil for seasonal precipitation, especially in two distinct climatic wet periods. In this case we use RegCM3 (Giorgi *et al*. (1993) regional model to simulate seasonal and monthly precipitation during the 1997-1998 and 2003-2004 rainy seasons.

2. DATA AND METHODOLOGY

The simulations were generated with the regional model RegCM3 for a great part of South America. The RegCM3 has its origin from Mesoscale Model version 4 - MM4 (Anthes et al., 1987) in the National Center for Atmospheric Research (NCAR), as documented by Giorgi et al. (1993). It is a compressible and hydrostatic model, with finite differences and sigma coordinate. It uses a split-explicit scheme in time integration, including an algorithm to decrease horizontal diffusion when strength topography gradients are presented (Giorgi et al., 1993).

Soil-plant-atmosphere interaction processes are described in this RegCM3 version by Biosphere-Atmosphere Transfer Scheme (BATS) (Dickinson et al., 1993). BATS considers many vegetation types and the interaction with soil in the calculation of momentum, heat and water vapor turbulent changes between surface and atmosphere, solving prognostic equations for each grid point. The surface scheme presents one vegetation layer, one snow layer and three soil layers with different depths: a surface layer 10 cm deep, the root zone (with variable deep depending on vegetation type) and, a deep soil layer with 3 m. Canopy and leaf temperatures are diagnosed through energy balance, when vegetation is presented. The hydrological cycle is obtained through prognostic equations for the soil content water in the three soil layers. Finally, heat, water vapor and momentum surface fluxes are computed as function of drag coefficients obtained from similarity theory applied to the surface layer. Heat, momentum and vapor turbulent transports inner the planetary boundary layer (PBL) result from the product between the vertical gradient for these variables and the diffusion turbulent coefficient also in vertical direction (Holtslag et al., 1990).

The model treatment for wet processes in the atmosphere considers two different schemes: one for deep cumulus convection (subgrid scale) and another to precipitation solved at grid scale. Nowadays, cumulus schemes available in the RegCM3 are: Grell (1993), Kuo (Anthes, 1977), Emanuell (1990) and Betts-Miller (1986). The analyzed simulations in this study were obtained considering the Grell scheme (Elguindi *et al.*, 2004). The grid scale scheme, described by Pal *et al.* (2004), presents just one equation for the cloud water forecast, what allows its formation, advection, turbulent mixture, re-evaporation in saturated conditions, accretion and, conversion in precipitation through an auto-conversion term. The cloud water forecasted in this scheme is thus straightforward utilized in radioactive computations.

The RegCM3 uses a relaxation scheme on lateral boundaries, between data model and the boundary fields (analysis or global model forecasts). Exponential function was used in the relaxation process since it allows a more smoothed transition between the model and the boundary data. In general, this aspect provides a positive impact in the results (Giorgi et al., 1993).

2.1 Characteristics of simulation

The chosen domain for the proposed simulations in this study consists of great part of South America, from 40S to equator and from 85W to 20W. The model was run with 50 km and 30 min as spatial and time resolution, respectively. Initial and boundary conditions were taken from Reanalysis I (NNRP1) data set (Kalnay et al., 1996) for two rainy periods: 1997-1998 and 2003-2004, from July to March in the following year, what includes the rainy season for the Southeast Brazil, October to March. Data showed in the resulting maps (Fig. 2-5) were composed based on the 4th-9th simulated month, cutting off, by this way, the first three months. The set of simulated data is verified by means of other data sets: CRU (Mitchell et al., 2003), CMAP (Xie and Arkin, 1996), and, Silva et al. (2007) (hereafter as Silva07) compiled data, with, respectively, 0.5, 2.5 and 1.0 degree of spatial resolution. The CRU data were used just in the case of the first period, 1997-1998.

3. RESULTS

Firstly analyzing climatological aspects, we note that Intertropical Convergence Zone (ITCZ) influence over northern region of South America is much clearer during the first 3-months of the year (JAN-MAR) in comparison to the last 3-months (OCT-DEC), as shown in Fig. 1 (a,b), while the SACZ (precipitation positioned at NW-SE direction) activity is seen during the entire rainy season (OCT- MAR), perhaps strengthened by the increased energy availability on central-north region of South America at this period. These aspects are shown by observed-CMAP data ranging from 1979 to 2008. The two chosen rainy seasons in this study (1997-1998 and 2003-2004) indicate negative anomalies for the northern region of central-north South America, as well as for north portion of São Paulo state. Time evolution of simulated precipitation for the two rainy seasons considered (shown in Figs 4 and 5) is analyzed for areas indicated by P1, P2, P3 and P4 marks in Fig. 1c,d.

Simulation results were compared to CMAP, CRU and Silva07 data sets, for the two rainy seasons considered. Spatial patterns of simulated precipitation by RegCM3 are shown in Figs. 2 and 3. In general, the simulated values are at the same range of those observed. An important aspect which matches observed patterns is the northwest-southeast orientation of precipitation maximum over South America. These results may be related to the model ability to identify convergence areas, in the sense of local and regional scales, providing good approximations for local heating and synoptic convergence zone, SACZ (that is characteristic in this period of the year). Apparently, the regional model results show better confidence over continental areas, what is especially noted for JAN-MAR/1997-1998 (Fig. 2h and 3f), in which we can see a probable northward displacement of SACZ. We must take in account that these simulations do not comprise a large period, allowing, therefore, misinterpretation of the results. The maximum precipitation indicated by observations at the south of Brazil from OCT-DEC, in 1997-1998 (Fig. 2a, b and c), is not very well simulated by the model (Fig. 2d) or is displaced to a northwest position. Another aspect which is apparently not well simulated by the model is the position and intensity of ITCZ at the north and northeast of Brazil. This feature is quite clear for JAN-MAR/97-98 (Fig. 2h). CMAP and CRU data (Fig. 2e,f) tend to show this feature, what is not indicated by simulated results. On the other hand, simulation results show a great dry region at Northeast of Brazil (Fig. 2h), matching the observation pattern. In this case, good simulations for high levels cyclonic vortexes, atmospheric systems characteristic in this period of year and location, must be considered.

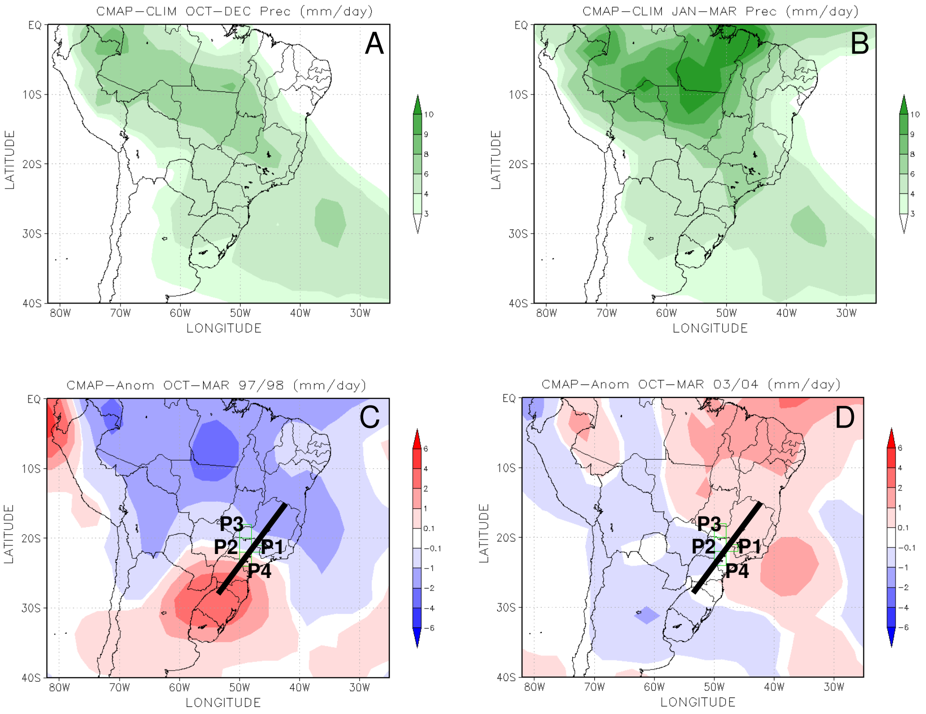

FIGURE 1 CLIMATOLOGY OF PRECIPITATION FOR (A) OCT-DEC AND (B) JAN-MAR. ANOMALY OBSERVED IN (C) 1997-1998 AND (D) 2003-2004 RAINY SEASONS (OCTOBER TO MARCH). THE THICK BLACK LINE SHOWS THE DIRECTION BETWEEN THE MAXIMUM ANOMALY CENTERS AT SOUTH AND CENTRAL-EAST BRAZIL. P1, P2, P3 AND P4 INDICATE AREAS FROM WHERE PRECIPITATION SIMULATED WERE ANALIZED AND SHOWN IN FIGS 4 AND 5. CLIMATOLOGICAL CALCULATIONS WERE BASED ON CMAP DATA SET, RANGING FROM 1979 TO 2008.

As the 1997-1998 simulated precipitation patterns, 2003-2004 patterns also present NW-SE orientation, according to the observed fields. While simulated precipitation during 2003-2004/OCT-DEC, for central-south Brazil region, especially over São Paulo state, presents simulated values (Fig 3c) near those observed (Fig. 3a,b), 2003-2004/JAN-MAR simulated precipitation is overestimated by the model. In both periods analyzed the RegMC3 overestimated the precipitation in relation to the observed data. Although, the major overestimation during the first three months of the 2003-2004 period (OCT-DEC) was observed over the northwest region of South America (Fig. 3c).

The precipitation field simulated for 2003-2004/JAN-MAR (Fig. 3f), even showing in general values not very different from observation indicates higher values closely to the boundary areas in relation to the maximum precipitation with NW-SE orientation. That is, the model results show overestimated values over São Paulo (SP) and Mato Grasso do Sul (MS) states (further south from the central area), and, over Bahia (BA) and north of Minas Gerais (MG) states (further north from the central area).

The time variation of simulated values of precipitation consist the following discussion. As can be seen in Figures 4 and 5, the simulations for the chosen areas in this study (P1, P2, P3 and P4, indicated in Fig. 1) show better results for the first rainy season, 1997-1998, in relation to 2003-2004. Although the signal of variability in each month is not the same for observed and simulated data, we note that the model is able to simulate close values when compared to observations. Differences among simulated and observed data are of the same order of magnitude as differences among distinct observations, even the last are smaller. On the other hand, the temporal evolution of precipitation simulations during 2003-2004 rainy season is in accordance to the results shown by the spatial distribution panels, Fig. 3f, in which is possible to see the overestimation made by the regional model at P2 (Fig. 4b) and P3 (Fig. 4c) areas.

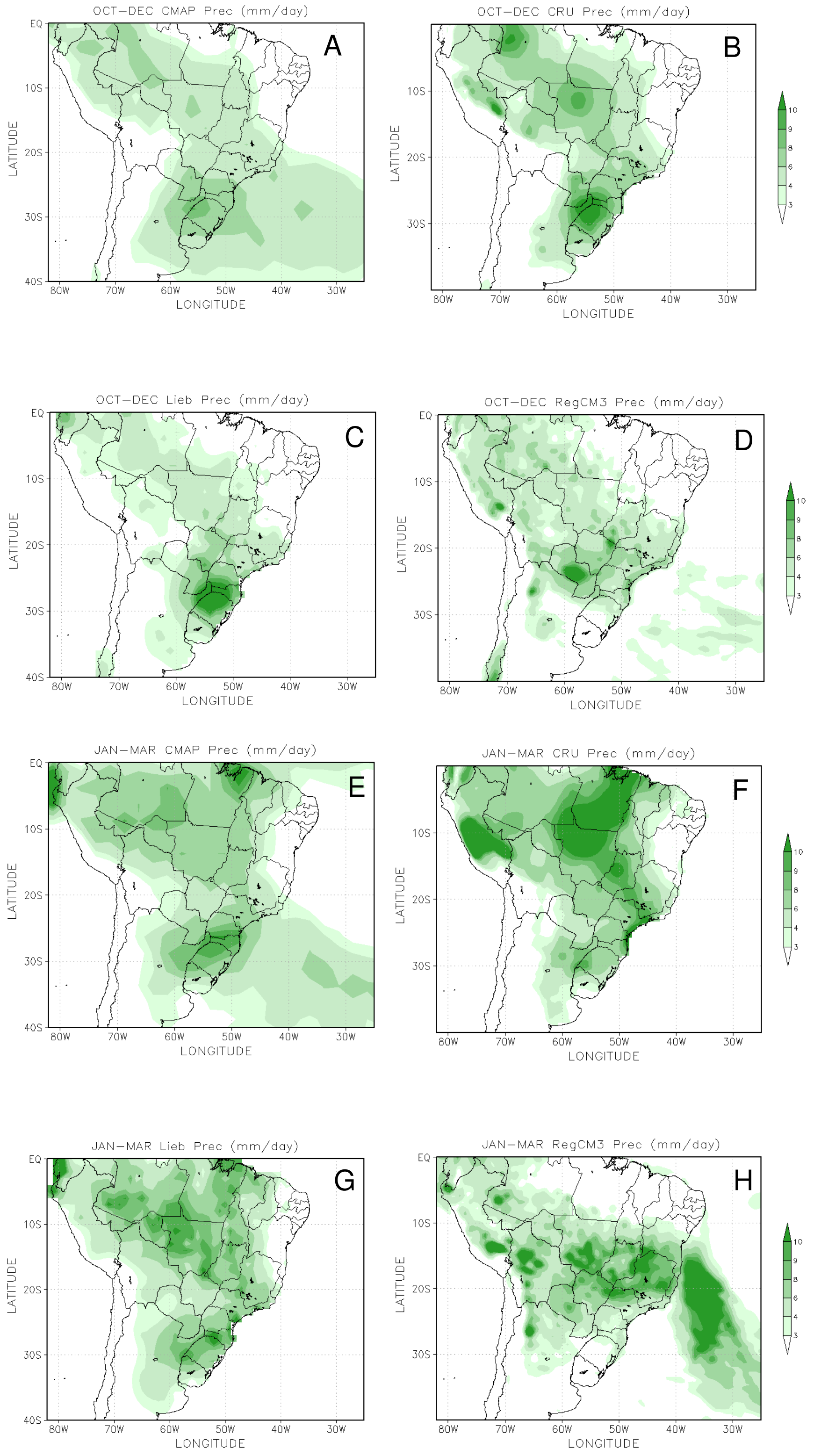

FIGURE 2 OBSERVED AND SIMULATED SPATIAL PATTERNS FOR PRECIPITATION OVER SOUTH AMERICA, DURING 1997-1998 RAINY SEASON. OBSERVED DATA SET ARE RELATED TO CMAP (A AND E), CRU (B AND F) AND SILVA07 (C AND G) AND, SIMULATED FIELDS ARE SHOWN IN D AND H PANELS. A TO D PANELS ARE RELATED TO 1997-1998/OCT-DEC AND, E TO H, TO 1997-1998/JAN-MAR.

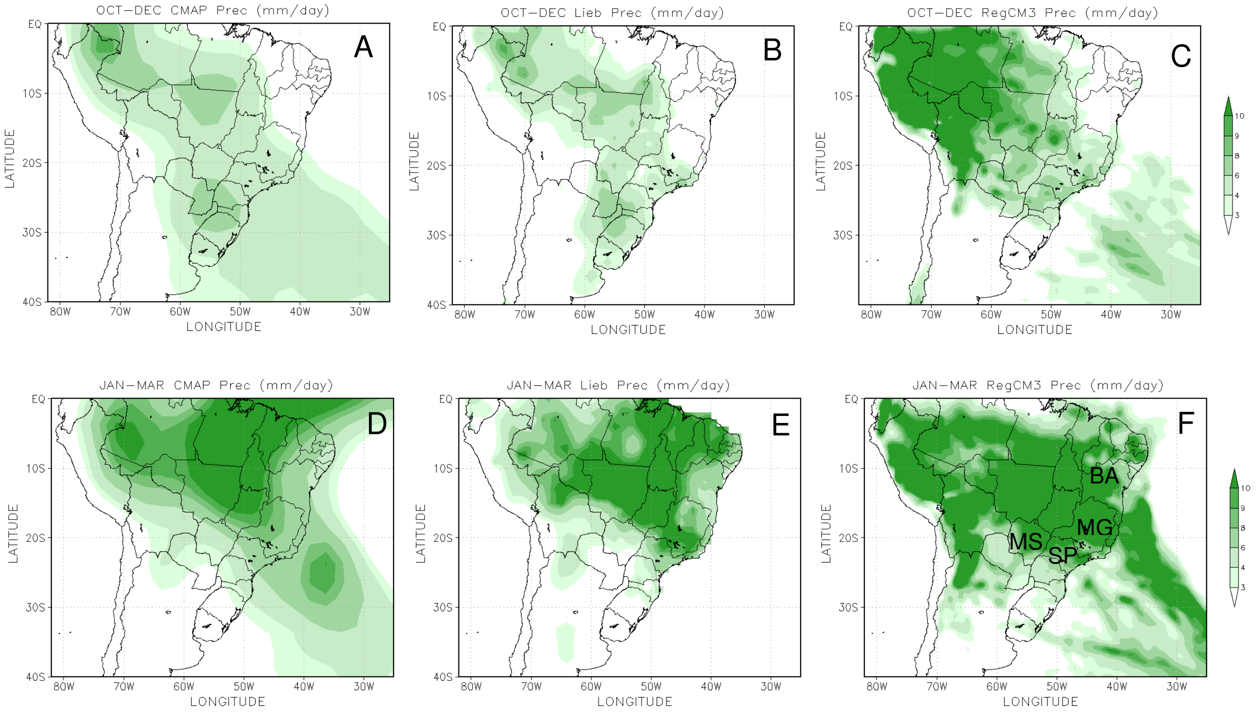

FIGURE 3 OBSERVED AND SIMULATED SPATIAL PATTERNS FOR PRECIPITATION OVER SOUTH AMERICA, DURING 2003-2004 RAINY SEASON. OBSERVED DATA SET ARE RELATED TO CMAP (A AND D) AND SILVA07 (B AND E) AND, SIMULATED FIELDS ARE SHOWN IN C AND F PANELS. A TO C PANELS ARE RELATED TO 2003-2004/OCT-DEC AND, D TO F, TO 2003-2004/JAN-MAR.

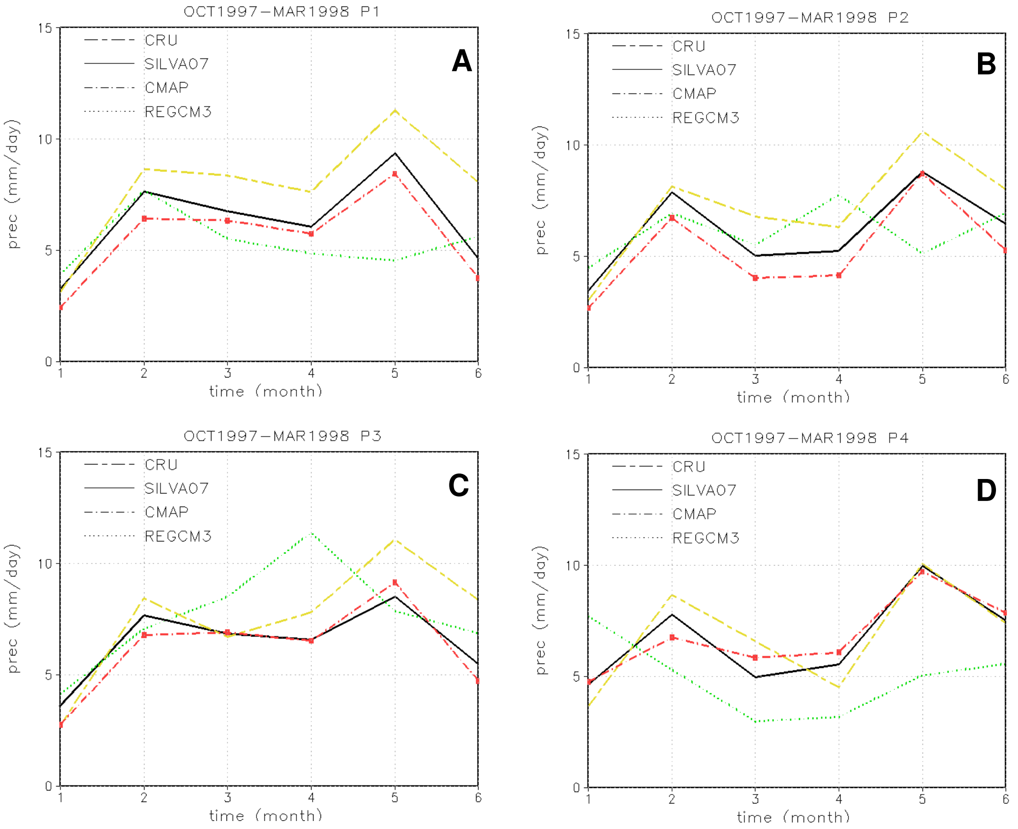

FIGURE 4 TEMPORAL EVOLUTION FOR FOUR DISTINCT AREAS OVER SUBTROPICAL REGION IN SOUTH AMERICA FROM OBSERVED AND REGCM3 DATA SETS: (A) P1, (B) P2, (C) P3 AND (D) P4 DURING 1997-1998 RAINY SEASON (OCT-MAR). DASHED-DASHED (CRU), FULL (SILVA07), DASHED-POINT (CMAP) LINES INDICATE OBSERVED DATA AND, THE DOTTED LINE INDICATES SIMULATED DATA BY REGCM3.

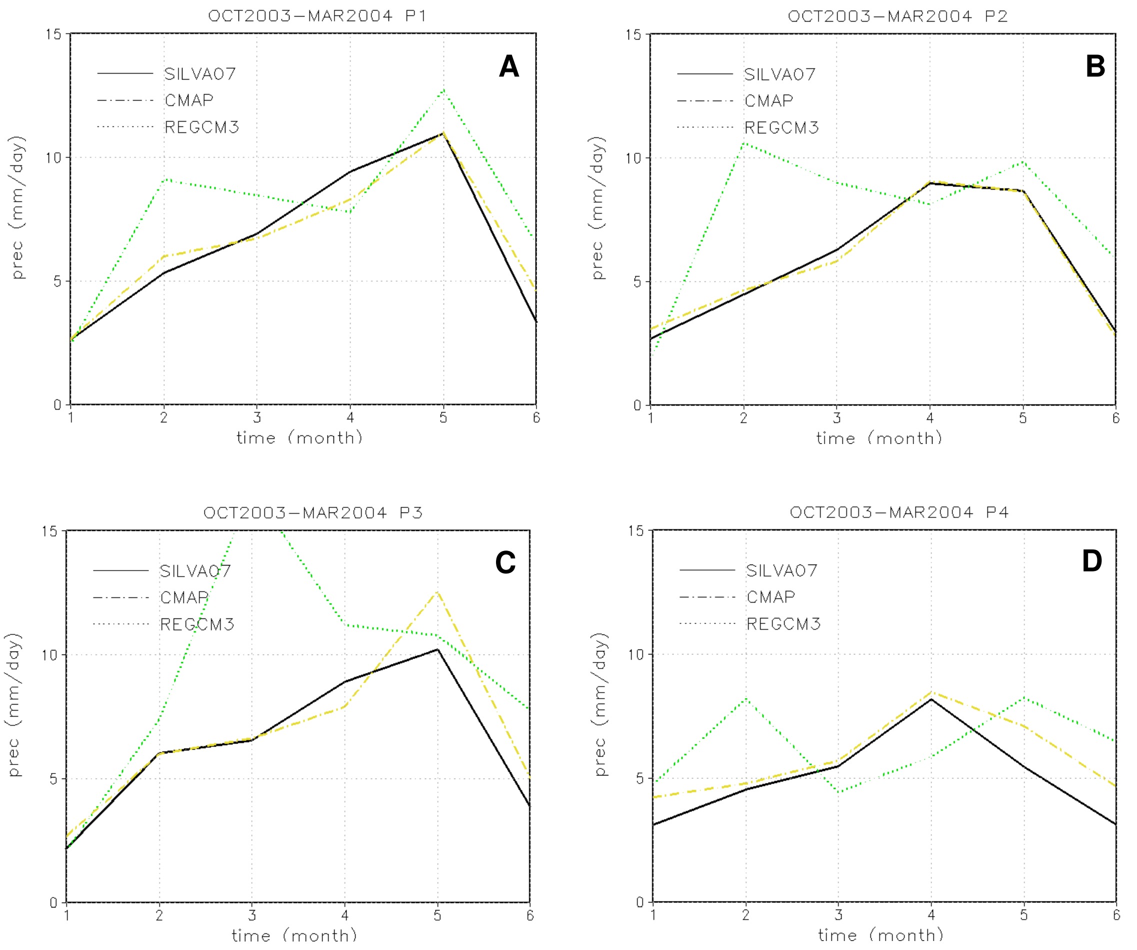

FIGURE 5 TEMPORAL EVOLUTION FOR FOUR DISTINCT AREAS OVER SUBTROPICAL REGION IN SOUTH AMERICA FROM OBSERVED AND REGCM3 DATA SETS: (A) P1, (B) P2, (C) P3 AND (D) P4 DURING 2003-2004 RAINY SEASON (OCT-MAR). DASHED-DASHED (CRU), FULL (SILVA07), DASHED-POINT (CMAP) LINES INDICATE OBSERVED DATA AND, THE DOTTED LINE INDICATES SIMULATED DATA BY REGCM3.

4. DISCUSSION AND CONCLUSIONS

The main objective of this study was to detect the ability of regional model (RegCM3) (Giorgi *et al*., 1993) in simulating monthly and seasonal precipitation over Southeast Brazil. The model was used to simulate precipitation during the 1997-1998 and 2003-2004 rainy seasons. Results were compared to three different data sets: CRU, SILVA07 and CMAP. In general, simulated data were close to those observed for the two periods analyzed. The NW-SE orientation of the precipitation band over South America, characteristic feature in this period of the year, was also well simulated by the model. Although the anomaly signal simulated was not well adjusted to that observed in each chosen area (P1, P2, P3 and P4), its difference from observed data is of the same order of magnitude in comparison to the difference among observations data sets. An important point not well simulated by the model during JAN-MAR is the position of SACZ, displaced further north to its common position.

Further objectives considering simulations with RegCM3 must be reached in a near future. In particular, a greater number of simulations for wet seasons will be considered. In attempting to improve model skill, we will do tests including the increase of vegetation fraction for tropical forest, in order to see if the model responds to a better positioning of ITCZ. Accordingly to the vegetation type, the root depth for total soil layer and the rate between upper and root zone layer are others good suggestions to improve simulations. Other point to take in account is the study of climatic impacts by means of coverage change. For example, replacing Cerrado vegetation (savanna-like vegetation), characteristic to the north of São Paulo state, by a more arid vegetation type.

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