Proceedings of 8 ICSHMO, Foz do Iguaçu, Brazil, April 24-28, 2006, INPE, p. 373-378.

REGCM3 SIMULATIONS NESTED IN THE HADLEY CENTER MODEL OVER SOUTH AMERICA: THE PRESENT DAY CLIMATE

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1. INTRODUCTION

The use of atmospheric or coupled atmospheric-ocean global models to investigate the actual and future climate has increasing in the last years. However, the results obtained from these models present lack of regional details due the coarse resolutions that they are integrated. For example, at regional scale precipitation and air temperature can be strongly influenced by topography, different landuse type or proximity to the sea. This problem can be addressed trough of the dynamical downscaling technique by using regional climate models (Giorgi and Mearns 1991, 1999). The use of fine horizontal resolution in these models permit to resolve in greater details the physiographic features that controls the local influence over regional climate. However, for utilize RCM to future scenarios is important to know as one determined RCM represents the actual climate.

The high resolution actual climate and scenarios obtained from RCM results have been applied to impacts assessments, only in the last years, firstly in North America (Doherty et al. 2003) and Europe (PRUDENCE Project as documented by Christensen et al. 2002) as part of international projects. The objective of the present study is to present the preliminary results for present climate, from 1961-1970, for South America as simulated by RegCM3 regional climate model. The RegCM3 was driven by HadAM3 global model (Pope et al. 2000) and this work represents part of the PROBIO Project (Marengo et al. 2004). The final objective of PROBIO is to compare three different regional models for present and future scenarios (A2 and B2) over South America.

2. ATMOSPHERIC MODELS AND SIMULATIONS DESIGN

The atmospheric version of the Hadley Centre global model (HadAM3), forced with the SST anomalies provide by the oceanic component of the HadCM3 coupled model, used in this study was developed at the Hadley Centre and a complete description of the model can be found in Gordon et al. (2000) and Pope et al. (2000).

The period between 1960 and 1970 of the HadAM3 simulation from 1860 to 2100 was used to regional simulations. The HadAM3 has a 19 vertical hybrid coordinates levels and horizontal resolution of 2.5° of latitude by 3.75° of longitude which implies in a grid of 31 by 40 grid points over the South America. This South America window as provided by Hadley Centre to the CPTEC as part of the PROBIO Project (Marengo et al. 2004).

The Regional Climate Model version 3 (RegCM3; Pal *et al.*, 2005) is an updated version of the RegCM2 (Giorgi *et al.*, 1993a,b). The model is a primitive equation, hydrostatic, compressible, limited-area model with sigma-pressure vertical coordinate. The soil-vegetation-atmosphere interaction processes are parameterized through BATS scheme (Biosphere-Atmosphere Transfer Scheme; Dickinson *et al.*, 1993). The radiative transfer scheme of NCAR CCM3 (Community Climate Model 3; Kiehl *et al.*, 1996) is used in RegCM3 (Giorgi and Mearns, 1999) that includes the effect of different greenhouse gases, cloud water, cloud ice and atmosphere. In this study, we used the grid-scale precipitation scheme developed by Pal et *al.* (2000), which only considers the water phase, and the convective precipitation parameterization follows Grell (1993) with Fritsch-Chappell closure (Elguindi *et al.*, 2004).

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The RegCM3 was integrated over South America (SA) with a horizontal resolution of 60 km and 23 vertical sigma levels (top of the model at 50 hPa). Figure 1 shows the domain and the topography used in the regional simulation. This figure also presents two sub domains, denominated Amazon (AMZ) and Southeast of Brazil (SDE), used for objective comparison between RegCM3, HadAM3 and observational CRU (New et al. 2000) and WM (Willmott and Matsura 2001) data sets. The simulation covers the 11-years period of 1960-1970 and was started at 1st of January 1960 and it finished in January 1st, 1971. The year of 1960 was considered as spin-up and it was not included in the analyses.

The atmospheric (wind, temperature, moisture and pressure fields) initial and boundaries conditions, and the Sea Surface Temperature (SST) for the RegCM3 simulations were provided by the HadAM3 model. The concentrations of the spatially uniform greenhouse gases (CO_2 CH_4, N_2O e CFCs) for the period 1960-1971 used in the RegCM3 simulations are the same to the HadAM3 (Johns et al. 2001). The topography and land-use data, derived from United States Geological Survey (USGS) and Global Land Cover Characterization (GLCC, Loveland et al., 2000), respectively, with horizontal resolution of 10-min, were used to provide the terrain and surface cover characteristics.

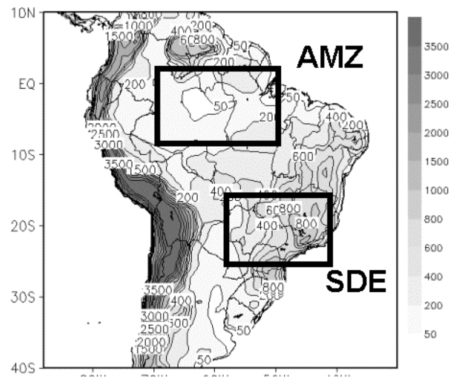

Figure 1. Model domain and topography (The unit for contour and shaded is m) used in the simulations. The subdomains SDE and AMZ indicate the Southeast and Amazon regions of Brazil.

3. RESULTS

The annual precipitation climatology (10 years mean for 1961-1970 period) for the HadAM3 and RegCM3 simulations are compared to the CRU observations in Figure 2. Over equatorial SA, north of 10^{o}S, both models capture the main characteristics of the observed precipitation. However, it is apparent that the RegCM3 (Fig. 2b) aggregates additional information to the coarse HadAM3 (Fig. 2c) precipitation field such as: a) the delimitation of the minimum precipitation (annual mean inferior to 1 mm day^{-1}) over the central part of the Northeast of Brazil; the intense rainy area in the extreme north of Brazil (mouth of the Amazon river); the sensible improvement of the precipitation over the central and west of the Colombia.

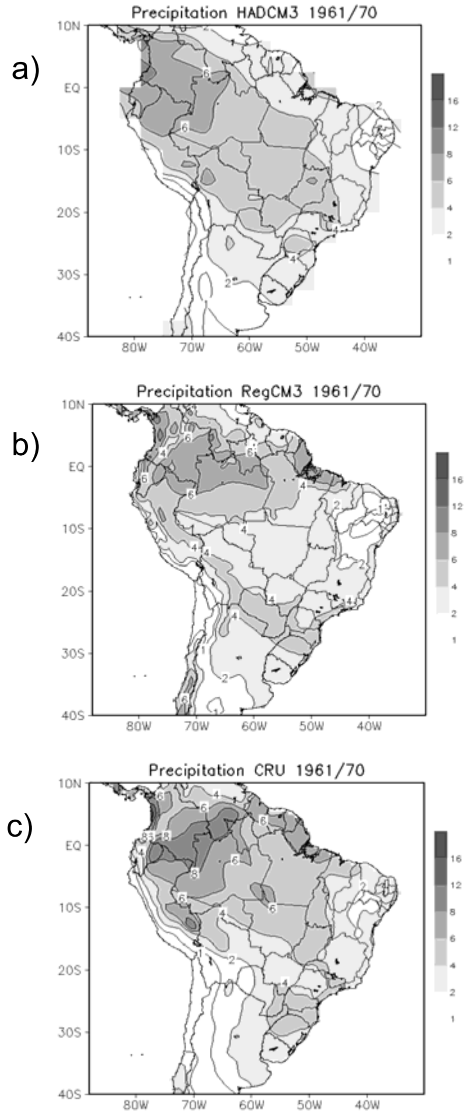

Figure 2 - Average precipitation for the period 1961-1970 from: (a) CRU observations, (b) RegCM3 simulations and (c) HadAM3 simulations. Units are mm day^{-1} and the contours intervals are indicated in the right of the figure.

The RegCM3 (Fig. 2b) also shows precipitation lower then 1 mm day^{-1} over central Andes and northern Chile and an intense precipitation over the coastline of the South and Southeast of Brazil, details that are not present in the HadAM3 (Fig. 2c). Over the extratropics (south of 25^{o}S) both models present a very similar precipitation pattern, however, the precipitation over south Brazil was better simulated by the RegCM3 but it overestimates the maximum over southwest SA (Chile). As suggested by Giorgi e Mearns (1991) some characteristics of the regional climate, associated with fine scale forcing and processes, can be better resolved by regional models and this is apparent by comparing Figures 2a-c.

The main failure of the RegCM3 simulation is found over Central Brazil. In this area, the HadAM3 model simulated better the convective band, from Amazon basin to Southeastern of Brazil, associated to South Atlantic Convergence Zone (SACZ) summertime precipitation (Kodama 1992; Nogués-Paegle e Mo 1997). The smaller precipitation rate simulated by RegCM3 in the ZCAS was also found in the simulations that used NCEP reanalysis as initial and boundaries conditions (Fernadez et al. 2005; Cuadra and Rocha 2005).

The climatology of air temperature from the HadAM3, RegCM3 and CRU observations is shown in Figure 3. From this Figure one can note that the temperature spatial pattern over the flat areas of the tropics simulated by both models differs from observations. The RegCM3 (Fig. 3b) and HadAM3 (Fig. 3c) are ~2 ^{o}C colder and warm, respectively. However, in the tropical elevated topography regions, as over the Andes and Brazilian highlands (east of South and Southeast), the RegCM significantly improved the spatial pattern and magnitude of air temperature simulated by HadAM3. Another improved result from the RegCM3 is observed over the Central and Northern Argentina where the location of the north-south temperature gradient is very close to the CRU observation.

The precipitation annual cycle simulated by RegCM3 and HadAM3 (Fig. 4a) over AMZ is very similar to each other and when compared to the observations there is a subestimative from January-September, but from October-December the simulated values are closer to the observations. During the first 9 months the RegCM3 and HadAM3 underestimate the values by 24% and 35%, respectively. The precipitation annual cycle over the SDE subdomain (Fig. 4b), with a dry winter and wet summer, is reproduced by both models though some important differences can be noted. For example, the RegCM3 does not properly simulate the onset of the rainy season between October and November, while the HadAM3 seems to simulate better the precipitation rate in this period.

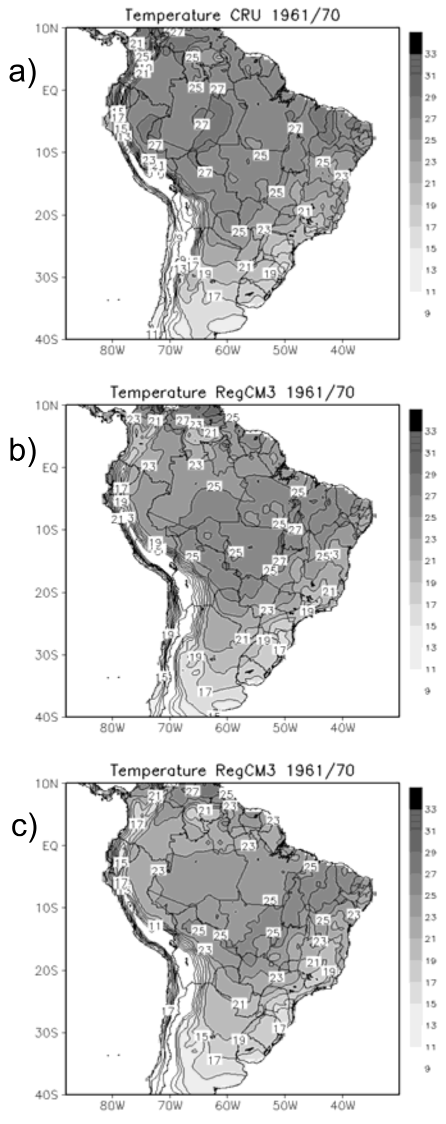

Figure 3 – As Figure 2, but for air temperature. Units are in ^{o}C and the contours intervals are indicated in the right of the figure.

The models present great ability to simulate the smaller precipitation rate in the austral autumn (March-April-May, months 3, 4 and 5 in Fig.4) and winter (June-July-August). During the rainy season (December-January-February) the HadAM3 overestimated (25%) and RegCM underestimated (15%) the precipitation rate.

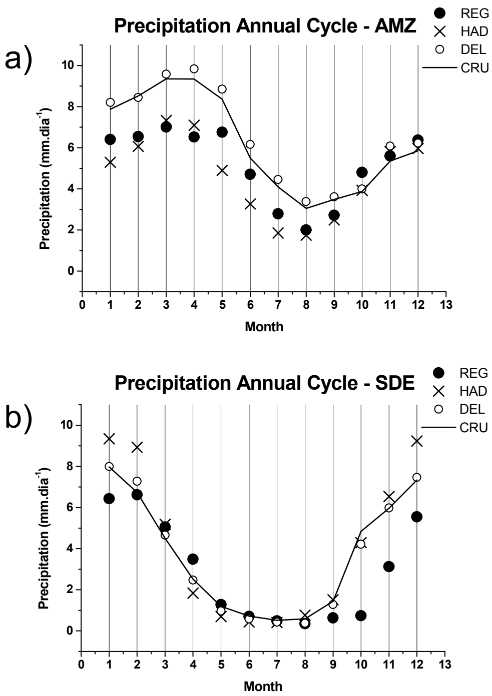

Figure 4 – Observed (CRU and WM) and simulated (RegCM3 and HadAM3) mean (from 1961-1970) monthly precipitation (mm day^{-1}) averaged over the region (a) AMZ and (b) SDE.

Air temperature observed over the Amazon presents a semi-annual cycle with a minimum in the austral winter and a maximum in the middle of autumn. Both, RegCM3 and HadAM3 models (Fig. 5a) do not simulated these features. Although the HadAM3 annual cycle is in phase whit CRU, with minimum in June/July and maximum in October, it simulates a pattern in January and July months that is not present in the CRU analysis. On the other hand, the RegCM3 reproduces better this observed isothermal period but in September the model simulates an amplified and out of phase maximum, with decreasing values near the isothermal period in December. Both models present a considerable bias being 1.8 ^{o}C (RegCM3) colder and 1.5 ^{o}C (HadAM3) warmer than the CRU data. Despite the annual cycle from the observations of CRU and WM are similar to each other there is a considerable uncertainty in the temperature amplitude with an annual average of 0.6^{o}C (WM is colder than CRU). By comparing Figures 4a and 5a one can see that the RegCM3 air temperature is colder during the rainy season (December-June) and the maximum temperature observed in September are due to the low precipitation rate in this month. Other studies have showed a cold bias in the RegCM simulations over South America (Cuadra and Rocha, 2006) and in other areas of the world such as Europe (Giorgi et al. 2004) and the Caribbean (Martinez-Castro et al. 2005).

The well-defined temperature annual cycle over the Southeast of Brazil (Fig. 5b), with minimum in July and maximum in February, is better reproduced by the HadAM3 model than the RegCM3. However, the HadAM3 simulates a colder temperature than that observed in the austral winter while the RegCM3 results in this season are closer to the CRU observations. However it seems that the RegCM3 simulations for October-November are not quite reliable. In this period, the model is warmer than the observations, with maximum temperature in October. This result may be related to the difficult of the RegCM3 to start the rainy season over subtropical South America, as is shown in Figure 5b. In the annual mean RegCM3 presents a lesser bias than HadAM3, -0.04 ^{o}C and –1.35 ^{o}C, respectively.

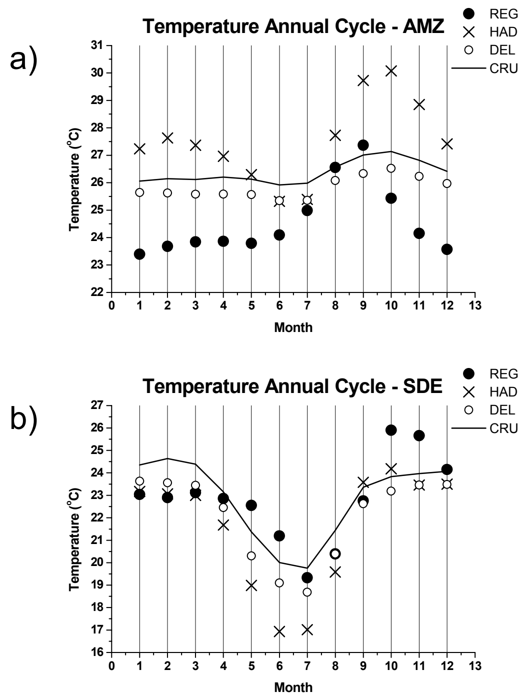

Figure 5 – Observed (CRU and WM) and simulated (RegCM3 and HadAM3) mean (from 1961-1970) air temperature (^{o}C) averaged over the region (a) AMZ and (b) SDE.

4. PRELIMINARY CONCLUSIONS

In this paper we have analyzed the 10 years mean (1961-1970) climatology, from the RegCM3 model initiated and forced in the boundaries by the HadAM3 global model. Over South America the RegCM3 simulations used a 60 km of horizontal resolution and 23 vertical sigma-pressure levels. Annual mean and monthly mean of air temperature and precipitation from the RegCM3 and HadAM3 results were compared with the observational data sets.

The climatology of the air temperature and precipitation from the HadAM3 and RegCM3 simulation showed considerable differences. Both models simulated the main characteristics of the observed annual precipitation climatology. However, the RegCM3 results show some additional information in relation to the coarse HadAM3 field and revealed important features of the regional climate such as: the delimitation of the minimum precipitation over Northeast of Brazil; intense precipitation in the mouth of the Amazon River; and a sensible improvement in the rainfall distribution at the central and western parts of Colombia. On other hand, the RegCM3 seems to not be able to correct simulate the precipitation intensity over the SACZ which is a climatic characteristic of the austral summer monsoon. The RegCM3 represent better than HadAM3 the annual mean air temperature over regions of elevated topography

The precipitation annual cycle over Amazon simulated by the HadAM3 and RegCM models is very similar to the observation but both models present negatives bias in the firsts 9 months. For the air temperature the RegCM generates a systematic negative bias during the rainy season while the HadAM3 overestimate the temperature along of the year.

HadAM3 and RegCM3 simulate a well-defined annual precipitation cycle, with dry winter and wet summer, over the Southeast Brazil. In comparison with the HadAM3 model, the RegCM3 fails to indicate the beginning of the rainy season between October-November. This implies that the RegCM3 maximum annual temperature occurs in October, which is in disagreement with the observations. On the other hand, the HadAM3 presents a colder than observed austral winter temperature.

The preliminary result presented here indicates that the RegCM3 can improve and aggregate information to the HadAM3 simulation. Future work will present a complete present-day climatology (1961-1990). The acknowledge of the model deficiencies during the simulation of the present climate is important if one wants to discuss future climate change scenarios where the model bias should be take into account.

Acknowledgements:

To MMA/BIRD/GEF/CNPq (PROBIO Project) and the Brazilian National Climate Change Program from the Ministry of Science and Technology MCT, IAI (IAI CRN055-PROSUR) and the UK Global Opportunity Fund-GOF Project Using Regional Climate Change Scenarios for Studies on Vulnerability and Adaptation in Brazil and South America. We also thank FAPESP (01/I3925-5) for the financial support.

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