Regional Climate Change Scenarios for South America-The CREAS project

Jose A. Marengo
CPTEC/INPE
Rodovia Dutra km. 40, 12630-000 Cachoeira Paulista, São Paulo, Brazil
Tel +55 12 3186 8464, Fax +55 12 3101 2835
Email: marengo@cptec.inpe.br

1. Introduction

In this study we focus on the application of the Regional Climate Models (RCM), the main dynamical downscaling technique. RCMs represent an effective method of adding fine-scale detail to simulated patterns of climate variability and change as they resolve better the local land-surface properties such as orography, coasts and vegetation and the internal regional climate variability through their better resolution of atmospheric dynamics and processes. Downscaling experiments on climate change scenarios in South America have also shown a reduction of rainfall in Amazonia as well as an small increase in rainfall in various regions of South America during 2071-2100 for the SRES A2 and B2 scenarios (Marengo and Ambrizzi 2006, Marengo et al 2007, Nuñez at al. 2006, Solman and Nunez 2007). On climate extremes, studies by Marengo et al. (2008) derived from regional models have shown an increase in the frequency of dry spells in tropical South America East of the Andes, warm nights in all South America as well as an increase in rainfall extremes in Southeastern South America by the end of the XXI Century. This is in agreement with global models projections on extremes from IPCC AR4 global models by Tebaldi et al. (2006).

Despite the concerns raise above about their resolution, initial analysis of the effect of climate change in South America extremes has been carried out using GCMs. The Chapter 10 on Regional Climate Change projections from the IPCC AR4 (Meehl et al. 2007 and references quoted in) shows a nice summary of studies on climate change projections in South America. The analysis of the climate change projections for the A1B scenario made by Vera et al. (2006) show a substantial agreement among IPCC-AR4 models in precipitation changes for the period 2070-2099 relative to 1970-1999, mainly characterized by an increase of summer precipitation over the northern Andes and southeastern South America, while over the Amazon results are mixed. This is also confirmed Li et al. (2006) using IPCC AR4 GCMS. On air temperature changes, Meehl et al (2007) shows that all models feature warming in South American with the strongest warming being in tropical South America, especially Amazonia and Northeast Brazil, reaching in some models increases of up to 6-8^{o}C warmer than the present by 2100, and with the degree of warming varying among models.

The issue of the spatial resolution in scenarios must be put in the context of other uncertainties of climate change. Studies and analyses of climate change impact and adaptation assessments recognize that there are a number of sources of uncertainty in such studies which contribute to uncertainty in the final assessment. The importance of high resolution climate scenarios for impacts and adaptation studies remains to be thoroughly explored in South America. High resolution scenarios developed from regional climate model results have been obtained in various parts of the world, and review is found in Marengo et al. (2008).

In Europe and North America several national and international projects have used RCMs to help quantify better regional climate change and provide regional climate scenarios for assessing climate change impacts and vulnerability. This include the UK

Climate Impacts Programme (Hulme et al., 2002), the European Project PRUDENCE (Christensen et al. 2006) in the North American project NARCCAP (Mearns et al. 2004). These have all followed a standard experimental design of using one or more GCMs to drive various regional models from meteorological services and research institutions in the regions to provide dynamically downscaled regional climate projections. Typically, a present day (e.g. 1960-1990) and a future climate (2070-2100) time slices are simulated to calculate changes in relevant climatic variables.

A similar initiative has been recently implemented in South America, CREAS (*Regional Climate Change Scenarios for South America* – Marengo and Ambrizzi 2006, Marengo et al. 2007). It aims to provide high resolution climate change scenarios in South America for raising awareness among government and policy makers in assessing climate change impact, vulnerability and in designing adaptation measures. CREAS runs three regional models nested in HadAM3P (a GCM used in PRUDENCE): WS Eta for Climate Change Studies – Eta CCS workstation version-(Pisnitchenko et al. 2006, Pisnitchenko and Tarasova 2007), RegCM3 (Ambrizzi et al. 2007) and HadRM3P (Jones et al., 2004, Marengo et al. 2008). CREAS will explore issues such as: the challenge of using regional climate projections to develop plausible scenarios for future changes at daily time scales for extreme events; an assessment of current methods of scenario development for regions where data is available; assessments of vulnerability in regions and key sectors in South America.

In this paper, we show some of the regional climate change in South America as produced by an ensemble of the 3 regional models from he CREAS project. This paper focuses on the analyses of two 30-year simulations: the present climate that examines the time period 1961–1990 and the future climate that covers the time slice of 2071–2100 under the IPCC SRES (Special Report on Emissions Scenarios) A2-high emission and B2-low emission scenarios.

2. Methodology, models and experiments

Global model

The RCM integrations analyzed in this study were conducted by nesting into the atmosphere-only GCM (HadAM3P) of the Hadley Centre at the U.K. Met Office. The experimental design of the driving HadAM3P experiment is described by Rowell (2005) and is summarised as follows. The HadAM3P 1961-1990 simulation is forced by observed sea-surface temperatures and sea-ice (SSTs) from the HadISST1 dataset (Rayner et al., 2003). For the future period, 2071-2100, HadAM3P is forced by SSTs which are formed from observed SSTs with the addition of mean changes and trends calculated a global coupled model projection. For the future, sea surface conditions were constructed from observations and anomalies from a transient integration of HadCM3 using the IPCC SRES A2 and B2 emission scenarios for the SRES scenarios A2 and B2 (Nakicenovic et al., 2000). The coupled integration was performed with HadCM3 (Gordon et al., 2000) whose atmospheric component, HadAM3 (Pope et al., 1999), is the basis for HadAM3P (Jones et al., 2007). The same SSTs were used as the lower boundary condition for the HadRM3P simulations. The HADAM3P integrations, from which the forcing fields for the RCMs were taken, have a resolution of about 1.25° latitude by 1.875° longitude and they extend over the two present and future time slices.

Regional models

In CREAS three RCMs with resolution of about 50 km over South America have been used to simulate the years 1961-1990 (present) and 2071-2100 (future).

1. HadRM3P, used by the UK Met Office-Hadley Centre. This model was developed, along with its parent GCM HadAM3P (Jones et al., 2004), to provide realistic simulation of regional climate globally. The main changes are related to calculation of large-scale cloud and assumptions about the radiative effects of convective clouds. Consequent changes were made to parameters in the precipitation scheme relating to precipitation efficiency to ensure reasonable vertical cloud profiles, cloud forcing and radiation fields.
2. WS Eta CCS, used by CPTEC/INPE in Brazil. This workstation version of the Eta model was developed by NCEP [a previous version of it is being used at CPTEC/INPE for weather and climate forecasts], and some modifications were made Pisnichenko et al, (2006) and Pisnichenko and Tarasova (2007) to make it suitable for climate change studies.
3. RegCM3, used by the University of Sao Paulo, Brazil. This models is a modified version of the MM4 (Mesoscale Model version 4), and the main modifications and adaptations in this for its use in climate change studies are described in Giorgi et al. (2001).

Only two GHG concentration scenarios from IPCC-SRES have been used in CREAS, namely A2 and B2. In this study, the seasonal mean responses are calculated as the difference between the mean 2071- 2100 and 1961-1990 for each grid point of a common grid (0.5°x0.5°) covering the domain common to all RCMs. Therefore all results about response and uncertainty could be displayed on maps over South America between 15 N-50 °S, 25-90 °W. The three RCMs ran for only one (but the same) pair of ensemble members.

3. Results

In the following we discuss the mean climatic features of climate change projections for both A2 and B2 scenarios for 2071-2100 produced by the ensemble of the 3 regional models (Fig. 1). These projections were derived from the downscaling of the HadAM3 global model by the Eta CCS, RegCM3 and HadRM3P regional models, as documented in Ambrizzi et al. (2007) and Marengo et al. (2007). In the Amazon region, for the B2 scenario, air temperatures may increase between 3-4 ^{o}C and rainfall may reduce by 5-20% in eastern Amazonia, as compared to the present. In Northeast Brazil these changes can vary from 1-4^{o}C of warming with rainfall reductions of between 10-15%. For A2 the possibility of even larger changes is indicated (reaching up to 8^{o}C and 40% drier in both eastern Amazonia and Northeast Brazil). Small increases of rainfall in southern Brazil and northern Argentina in the future can reach 5-10%, relative to the 1961-90 under the A2 and B2 scenarios.

A) B2, rainfall anomalies (mm/day)	B) A2, rainfall anomalies (mm/day)

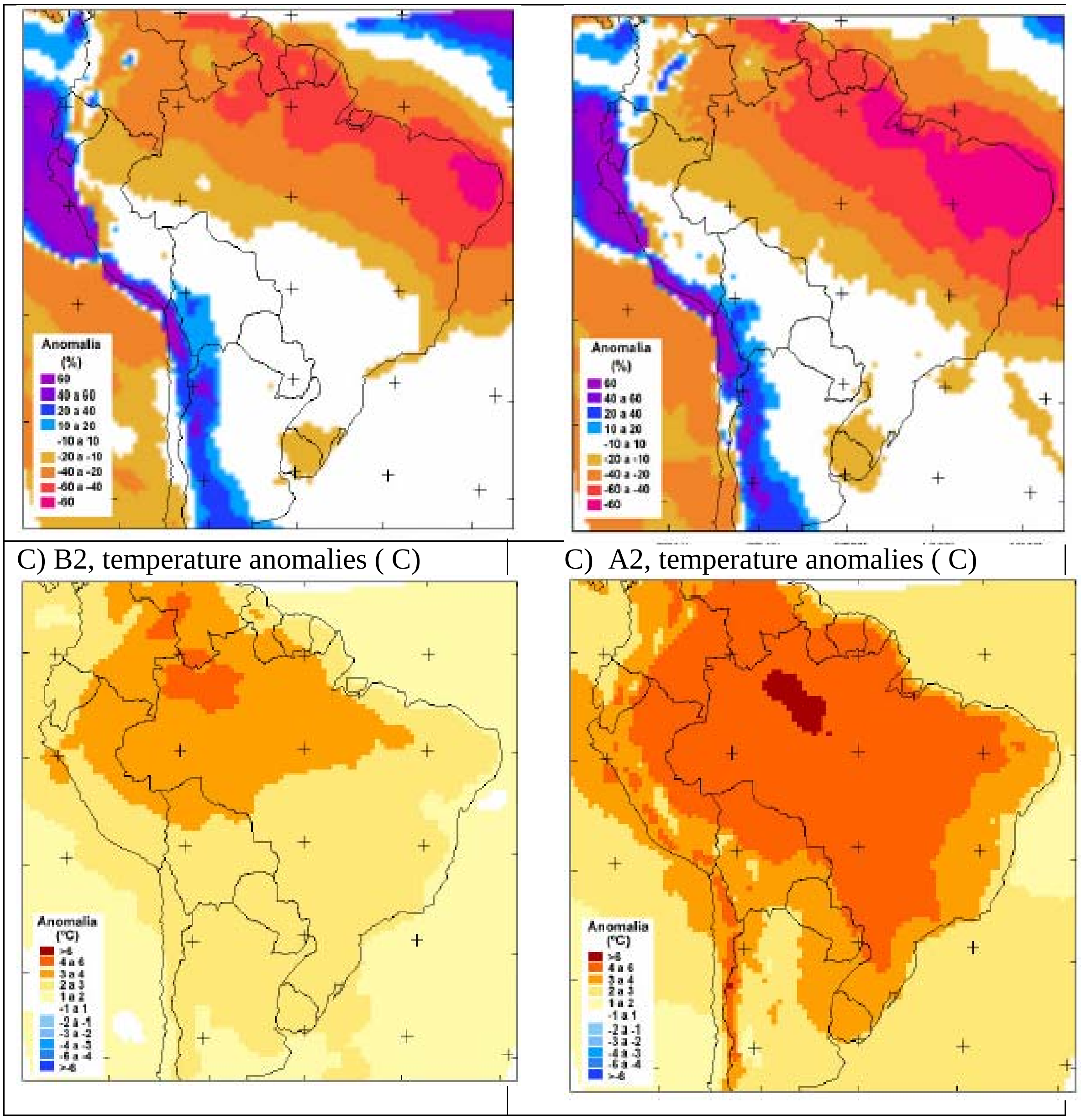

Figure 1. Projections of annual rainfall (mm/day) and air temperature anomalies (^{o}C) for both A2 and B2 scenarios for 2071-2100 relative to 1961-90, as produced by the ensemble of the 3 regional models: Eta CCS, RegCM3 and HadRM3P regional models

A recent study (Marengo et al. 2008) documents projections of extreme rainfall events in South America in warmer climates, using various extreme indices considered in the IPCC AR4. Using the PRECIS regional climate modeling system, this study analyzes the distribution of extremes of temperature and precipitation in South America in the recent past (1961-1990) and in a future (2071-2100) climate under the IPCC SRES A2 and B2 emissions scenarios. The results show that for the present climate the model simulates well the spatial distribution of extreme temperature and rainfall events when compared with observations, with temperature more realistic. The observations over the region are far from comprehensive which compromises the assessment of model quality. In all the future climate scenarios considered all parts of the region would experience significant and often different changes in rainfall and temperature extremes. In the future the occurrence of warm nights is projected to be more frequent in the entire tropical South America, while the occurrence of cold night events is likely to decrease. Significant changes in rainfall extremes and dry spells are also projected. These include increased intensity of extreme precipitation events over most of Southeastern South America and western Amazonia consistent with projected increasing trends in total rainfall in these regions. In Northeast Brazil and eastern Amazonia, smaller or no changes are seen in projected rainfall intensity though significant changes are seen in the frequency of consecutive dry days

Based on the projections for climate change in the future, and also on the projections for extreme rainfall and temperature events until the end of the XX Century, Figure 2 summarized possible impacts of climate change in Brazil. Different regions show different vulnerabilities. While in almost of Brazil the natural ecosystems would be affected, Southern and Southeastern Brazil seem to cope the impacts of climate change, while regions as Northeast Brazil would experience the highest vulnerability, especially on the social side. This region is vulnerable to the extremes of climate variability in present climates (e.g. drought during El Nino years). The different Brazilian states that are parte of the Northeast region exhibit lower indicators of social and health conditions, as well as lower human development index, and in future climate a tendency for aridization would exacerbate the social vulnerability.

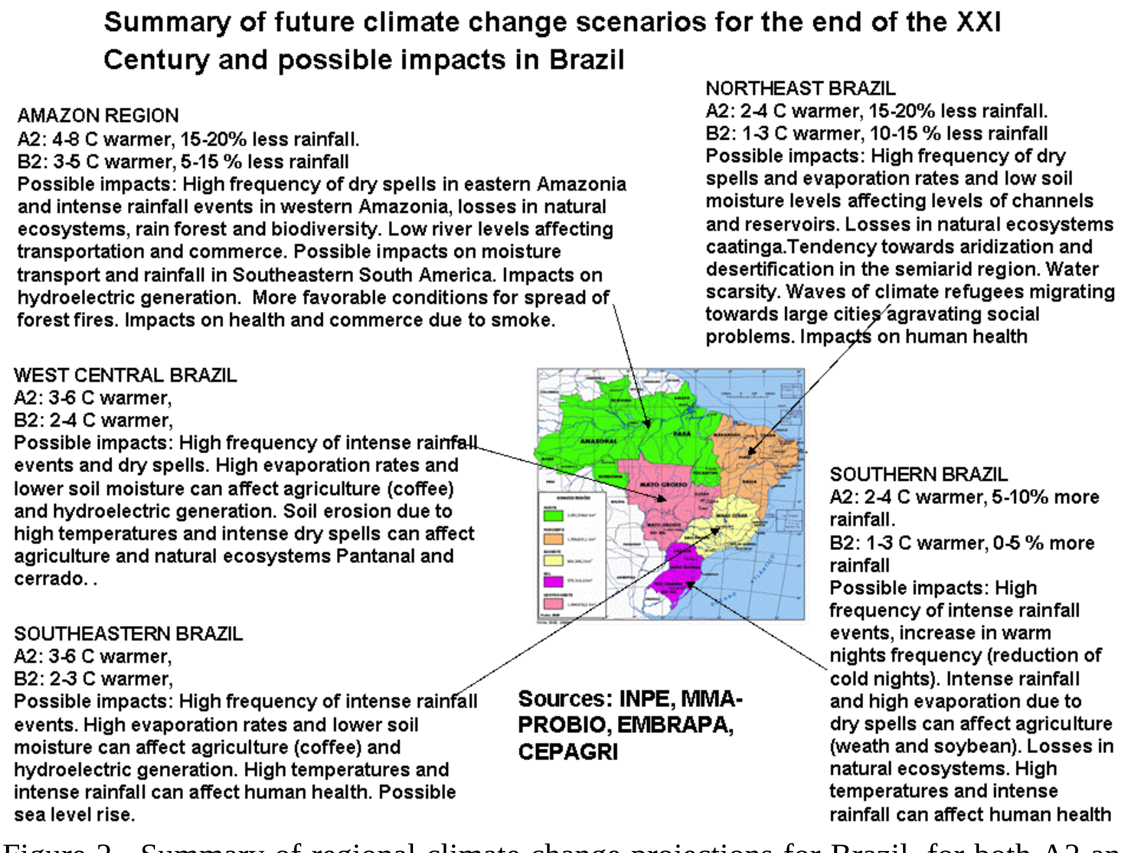

Figure 2. Summary of regional climate change projections for Brazil, for both A2 and B2 scenarios, as expected impacts in various political regions of Brazil.

4. Discussions

As it was shown in PRUDENCE, the largest source of uncertainty in the regional simulations was the choice of global model. The CMIP3 models have shown little coherence over tropical South America (Christensen et al. 2007), and future responses in precipitation, particularly over tropical South America, vary widely. We acknowledge that if the purpose is to provide information on extremes for impact studies, then the use of a single global model for downscaling is wholly inadequate. The rationale for the choice of global model HadAM3P was because of: (a) the model seems to reproduce quite well seasonal distribution and variability of rainfall y large areas of South America, even though some systematic errors, (b) at the time was the only global model available with the time resolution (every 6 hours) for dynamic downscaling experiments, and (c) its has been investigated quite thoroughly in various regions of the planet in previous downscaling experiences, as in PRUDENCE, NAARCAP and some of the CREAS simulations.

Future work will include the use of other regional models for the downscaling of improved versions of the HadCM3 future scenarios, and also we plan to use other global models. It is clear that a dynamic downscaling experiment would be much stronger if one regional model was nested in more than one global model, and the added value will be improved if additional global forcing is contemplated. Currently we at INPE are working on the dynamic downscaling of an ensemble of runs of the HadCM3 and the ECHAM 4 using the Eta model at 40 km resolution for 1960-2100, and not just 2071-2100 as in the PRECIS type experiments. This will provide estimates of likely ranges of future climate changes.

Another crucial area of future work is to improve access to data from and increase the observational network in tropical South America so the model can be validated for these regions. The limitations of the observational network are clearly evidenced in Marengo et al. (2008). Large areas of tropical South America do not show comprehensive, homogeneous and high quality data. Currently, some meteorological services in South America are performing a major task of digitalizing and checking climate series that are currently on paper form and tapes. New initiatives are being proposed to build a consolidate hydrometeorological data bank in Amazon countries, organized by the Amazon Cooperation Treaty, and in Southern South America as part of the CLARIS EU project. The idea is to provide high quality data for South America for trend analyses that would be useful for the computation of indices of extremes, as those defined by Frisch et al. (2002) and new ones that are being implemented by IPCC for the Fifth Assessment Report. This well help in understanding the reasons for observed changes in climate extremes and in improving confidence in projected changes.

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