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MEAN CLIMATE AND ANNUAL CYCLE IN A REGIONAL CLIMATE CHANGE EXPERIMENT OVER SOUTHERN SOUTH AMERICA.

II: CLIMATE CHANGE SCENARIOS (2081-2090).

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1. Introduction

The Second National Communication of Argentina for Climate Change (SNCACC) aimed to advance in the climate impact research for the region. In this context, climate change simulations of Southern South America climate were performed using a regional climate model (RCM) nested in time slice of 30 years atmospheric general circulation model (AGCM) experiments.

Two 10-year scenario simulations are performed for the period 2081-2090, one for the SRES A2 and the other for the SRES B2 emissions scenarios (IPCC 2000). The regional model used in the present work is the version 3.6 of the MM5 (Fifth generation Penn State/NCAR Mesoscale Model). The large scale fields needed to produce lateral boundary conditions for the MM5 simulations are obtained from corresponding time slice experiments with the global atmospheric model HadAM3P (Pope et al. 2000). The length of the simulations was 10 years to give a reasonable idea of the mean climate change. According to Jones et al. (1997) the minimum length needed to obtain an estimate of the climate change signal is ten year due that a 10-year simulation captures about half of the variance of the true regional climate change response.

We investigate the average change in climatic variables and the change in the annual cycle and the results represent a new focus area (South America) within the context of nested regional climate simulations, mostly because RCM experiments have become available mainly for the European region, USA and Australia. Examples of regional climate change simulations for the European region include Giorgi et al. (1992), Jones et al. (1997), Christensen and Christensen (2003), Beniston (2004) and Giorgi et al. (2004), between others.

The focus here is on the simulated climate changes; in particular those in surface temperature and precipitation, the two variables most used in impact assessment studies. Nevertheless, we also examine the changes in the sea level pressure and in the circulation structure to better understand the surface climate change signal. Both the time mean conditions and aspects of the annual cycle are studied. The control simulation (1981-1990) climate is studied in detail in Solman et al. (2006) and is not discussed here. The changes produced in the A2 y B2 experiments are intercompared to examine how regional climate change pattern depend of the greenhouse gases emissions forcing scenarios. The changes simulated by the nested MM5 and driving HadAM3P are then intercompared to evaluate the relative importance of the lateral boundary forcing in determining the regional climate change signal.

2. Model and experiment design

The regional climate model used for the present study is the MM5 v 3.6. It was tested to perform climate simulations in the study region through a set of sensibility experiments including convection schemes, surface processes and integration domain among others. The "quasi-observational" (NCEP/NCAR reanalysis) boundary conditions have been used to run the sensibility experiments. The results of the sensibility experiments suggest for simulations of the South America climate (Menendez et al., 2004, Solman et al., 2006) the use of: (a) the convection scheme of Kain and Fritsch (1993); (b) explicit humidity scheme of Hsie et al. (1984); (c) the Stephens (1978) and Garand (1983) cloud interaction and radiative processes; (d) Planetary Boundary Layer scheme of Hong and Pan (1996); (e) and the surface processes represented by the Noah Land Surface Model coupled to the RCM (Chen and Dudhia, 2001). The model grid interval is 50 Km (average), and its domain covers southern South America and surrounding oceans, to avoid the lateral boundary conditions being over the complex

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topography of the region. The model uses a vertical configuration of 23 sigma levels.

The experiment design follows Jones et al. (2001): The conductive HadAM3P model drives the corresponding MM5 experiment for the period 1981-1990. For the simulation scenarios, greenhouse gas emissions are specified from the A2 and B2 emission scenarios as boundary conditions for the conductive model and it drives the RCM for the time slice 2081-2090. For the regional model simulations, the surface and lateral boundary conditions used (or calculated) by HadAM3P are directly interpolated onto the MM5 grid.

The geopotential height, relative humidity, temperature, zonal and meridional wind components require lateral boundary conditions that are taken from the global atmospheric model (HadAM3P). The variables at the boundary are updated every 6 hours, with a linear interpolation between successive updates at each MM5 time step. At the surface, temperature, humidity and sea level pressure are also updated each 6 hours. The sea surface temperature and sea ice are updated monthly. In addition, soil temperature and soil humidity at 10 and 200 cm are also updated monthly. The lateral meteorological boundary conditions were provided on a coarser grid than the original HadAM3P one and more specifically on 2.5° latitude by 3.75° longitude grid.

As usually done in the thematic literature, we refer here to the term “change” as the difference between the selected climatic statistics in the scenario (2081-2090) and reference (1981-1990) simulations.

3. Results

In this section changes in the 10-year annual and seasonal mean climate are analyzed. We study the changes in large scale circulation patterns over our full domain, but in the present paper only the effects of the circulation changes on the surface climate represented by temperature and precipitation fields are offered.

3.1 Surface air temperature

The changes in DFJ, JJA and annual mean surface air (2 m level) temperature are shown in Fig. 1. For both the A2 and the B2 scenarios, the warming pattern is similar but with some qualitative and quantitative differences. The simulated changes are larger for the A2 than the B2 scenario. In the two scenario runs, the warming in southern Brazil, Paraguay, Bolivia and northeastern Argentina are larger in winter and mainly in spring. In Paraguay, southern Brazil and northern Argentina the warming peaks in spring when it locally reaches 6 ° C in A2 simulation and 4.0 ° C in the B2 simulation. In southern Argentina and Chile warming reach 2.5 ° C for the A2 scenario and less than 2.0 ° C for the B2 scenario. Both simulations show a large increase in the maximum temperatures (Fig. 2) in northern Argentina, Paraguay, Bolivia and southern Brazil, reaching 6 ° C in A2 scenario. For minimum temperatures, both scenarios show same patterns as in the maximum temperatures, but with a reduced warming area. The warming peaks in spring reaching 5.0 ° C in a patch in southern Brazil for A2 simulation (not shown).

3.2 Precipitation

The changes in DJF, JJA and annual mean precipitation are shown in Fig. 3. There are large seasonal and geographical variations in the change, and also some substantial differences between A2 and B2. Like temperature and sea level pressure (not shown), precipitation changes generally less in the B2 than in the A2 simulations, but mostly to the same direction. However, some qualitative differences between the two forcing scenarios also occur.

The B2 simulation shows a general increase in precipitation in southern Brazil, Paraguay, Bolivia, Uruguay, northern Argentina and northern Chile, with some decrease patches in precipitation in southern Brazil, northern Chile, southern Peru, northwestern and northeastern Argentina and in the Patagonia. The A2 simulation shows a similar geographical pattern of the changes in precipitation, but with extended areas with decrease in precipitation mainly in Chile. There are few quantitative differences between both emission scenarios. Both simulations show a general increase in precipitation in northern and central Argentina especially in summer and fall and a general decrease in precipitation in winter and spring. In fall the simulations agree on a general decrease in precipitation in southern Brazil. This reflects changes in the atmospheric circulation during winter and spring and most probably reflects the different changes in mean sea level pressure. A particularly large local difference in precipitation change occurs at the west cost of South America, where the steep orography makes the precipitation very sensitive to the Andes mountains representation by this and all models. Most of the projected changes are mostly in the same direction as in the present climate (Nuñez et al., 2004). The B2 simulation shows a general increase in precipitation in southern Brazil, Paraguay, Bolivia, Uruguay, northern Argentina and northern Chile, with some decrease patches in precipitation southern Brazil, northern Chile, southern Peru, northwestern and northeastern Argentina and in the Patagonia. The A2 simulation shows a similar geographical pattern of the changes in precipitation, but with extended areas with decrease in precipitation mainly in Chile. There are few quantitative differences between both emission scenarios. Both simulations show a general increase in precipitation in northern and central Argentina especially in summer and fall and a general decrease in precipitation in winter and spring. In fall the simulations agree on a general decrease in precipitation in southern Brazil. This reflects changes in the atmospheric circulation during winter and spring. A particularly large local difference in precipitation change occurs at the west cost of South America, where the steep orography makes precipitation very sensitive to the mountain parameterization in this (and all) model.

4. Summary and conclusions

In this paper, we analyzed the climate changes simulated over Argentina and surrounding countries under two IPCC emission scenarios (A2 and B2) for the period 2081-2090 with respect to the reference period 1981-1990. The simulations are performed with the regional climate model MM5 using forcing lateral boundary conditions from time-slice simulations with the HAdAM3P global atmospheric model. Our primary conclusions can be summarized as follows:

- The MM5 Regional Climate Model simulate current climate more realistically and project climate change with greater detail.
- In all seasons, southern South America undergoes warming in both the A2 and B2 scenarios. Minimum changes in the Mean Temperature are projected for summer and fall over the domain (2.5 - 3.5 ° C in the A2 simulation).
- Maximum changes in the Mean Temperature are projected for winter and spring over the domain (2.5 - 5.0 ° C).
- The precipitation changes vary substantially from season to season and across regions in response to changes in large scale circulations. Seasonal changes in precipitation in Argentina are projected for summer and fall seasons (west and humid Pampas increase approximately 180 mm maximum per season in the A2 simulation).
- Maximum monthly changes are found for February, March, April, November and December (not shown) in Precipitation.
- B2 simulation shows a similar geographical pattern of the changes in temperature and precipitation, with quantitative differences between both emission scenarios.
- The broad patterns of change in the nested regional climate model MM5 and driving HadAm3P fields are generally consistent each other, as can be expected from the strong influence of the boundary forcing on the regional model simulation. In summer, however, significant differences in the temperature and precipitation change can be found between the models. This could be due to the local physical processes.
- Strongly changes in sea level pressure (SLP) along the year produced by a displacement of the Atlantic and Pacific Anticyclones toward South Pole (not shown).
- Changes in high latitude circulation. Westerly winds in low levels will be less intense (not shown).
- Comparing with present trends, the regional climate projections for 2080s show an increase in most of Argentina, as in the present observed climate.

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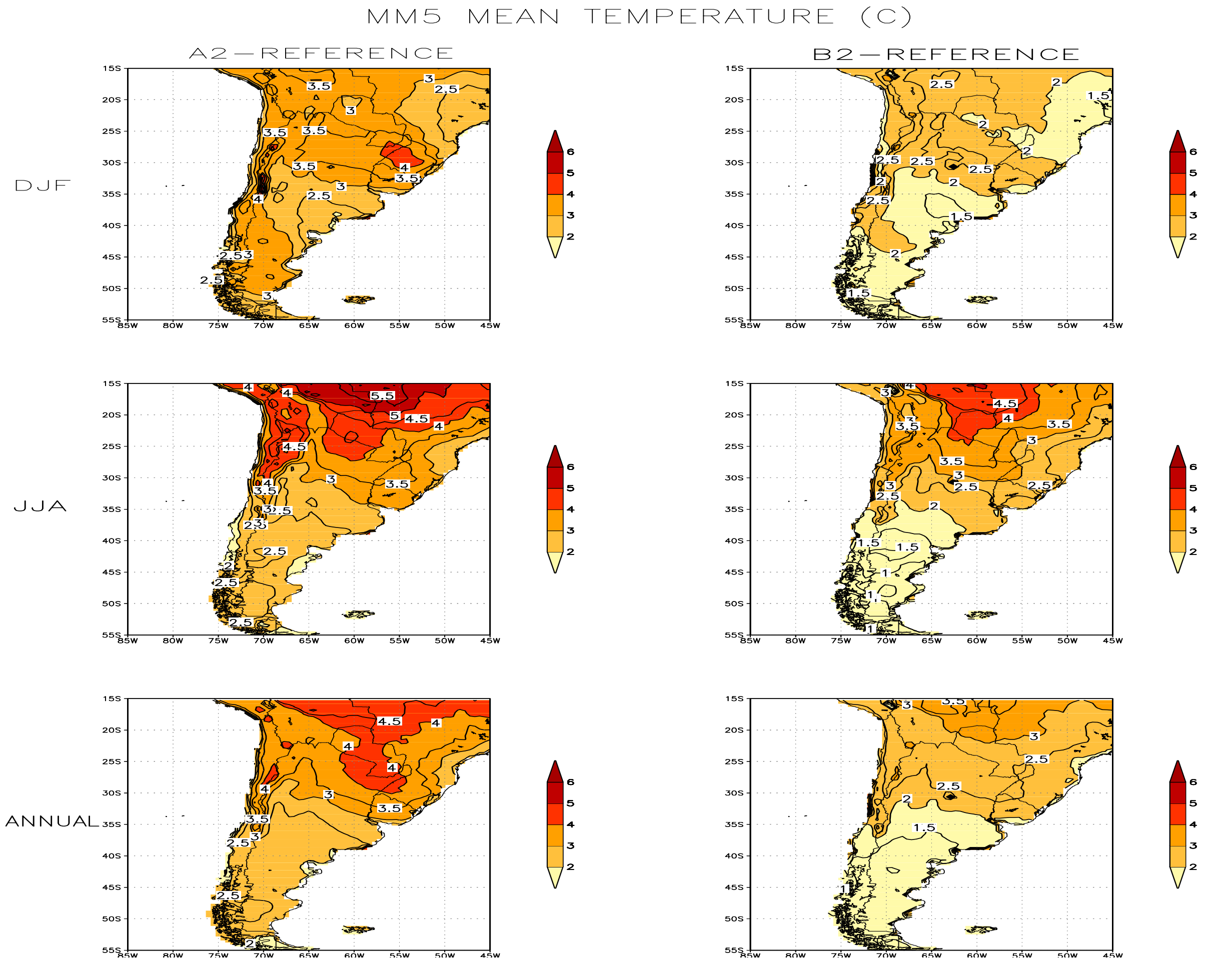

Figure 1: Changes in 10-year summer, winter and annual mean temperature for A2 simulation (left) and B2 simulation (right).

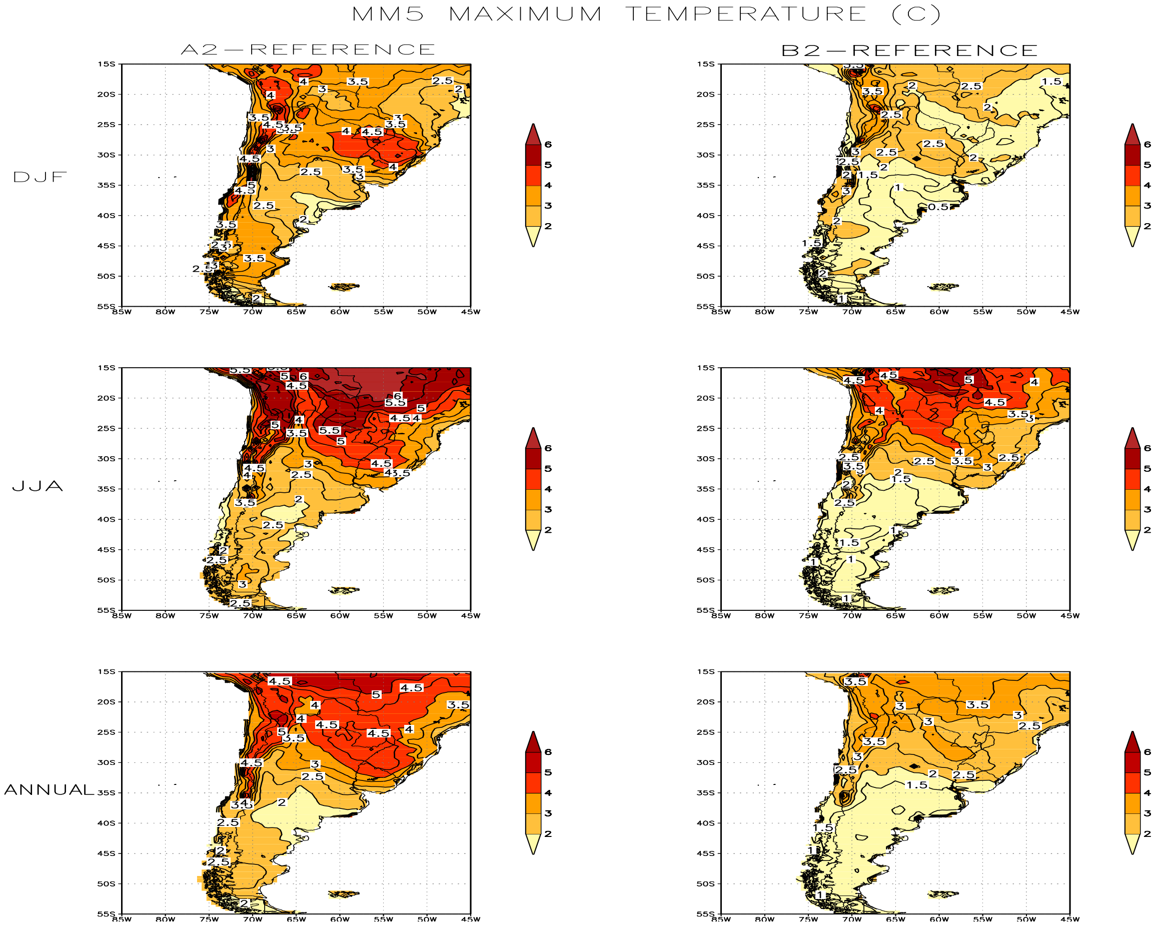

Figure 2: Same as Figure 1 but for maximum temperature.

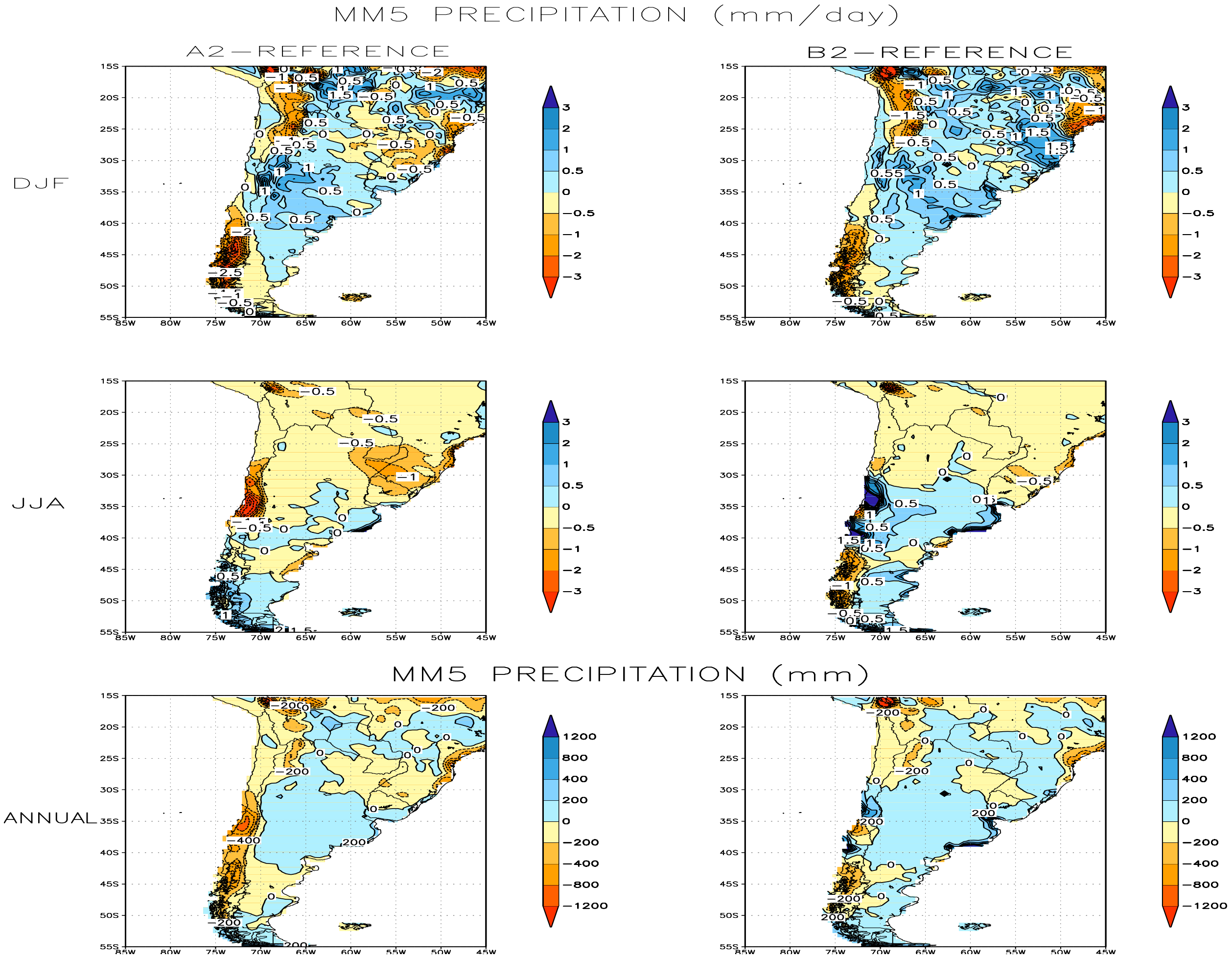

Figure 3: Changes in 10-year summer, winter and annual mean precipitation for A2 simulation (left) and B2 simulation (right). Summer and winter simulation in mmm/day, annual simulation in mm.