Proceedings of 8 ICSHMO, Foz do Iguaçu, Brazil, April 24-28, 2006, INPE, p. 269-274.

IMPACTS OF CLIMATE CHANGE IN SOUTH AMERICA: MEAN FIELDS AND VARIABILITY

Alice Marlene Grimm *; Angela Akie Natori
Universidade Federal do Paraná, Curitiba, Brasil.

1. INTRODUCTION

[1]South America (SA) comprises a diversity of climatic regimes thanks to its large latitudinal range that extends from the tropical Northern Hemisphere (NH) to the high latitudes of Southern Hemisphere (SH). Besides, there is influence of very outstanding topographic features, such as the Andes Mountains. The strong and extensive tropical convection over the continent during the SH summer originates a strong tropospheric heat source that has important influence on the climatological atmospheric circulation. The variability of this heat source can generate significant circulation anomalies in the NH and SH (e.g., Grimm and Silva Dias 1995). Therefore, it is of interest to verify: i) how models used in simulations of climatic change reproduce different aspects of the present-day climate in SA, ii) what are the climatic changes predicted by them for the continent under scenario of increased emission of greenhouse gases, and iii) what are the inter-model differences in the patterns of these changes. Therefore, in the present study we focus on the ability of several models in reproducing the main climatological features of SA precipitation as well as on the diversity and common features of the climate change scenarios projected by them.

In this study we also broach another aspect of climate change: does it affect important modes of precipitation variability?

2. DATA AND METHODS

The present-day climate simulations (1961-1990) and climate change scenarios (2071-2100) were obtained from three coupled ocean-atmosphere general circulation models (OAGCM) and two atmospheric general circulation models (AGCM), listed in Table 1.

In spite of several differences in physics and resolution, these models have some common elements. ECHAM5 is a newer version of ECHAM4 and was run with higher resolution. The AGCMs are driven by observed sea surface temperature (SST) for the period 1961-1990, and by anomalous SST obtained from the HadCM3 model for the period 2071-2100, added to climatological observed SST. HadAM3P is a state-of-the-art global high resolution model, with improvements over the parent coupled model, HadCM3. The analyzed climate change scenarios correspond to the emission scenario IPCC-SRES A2 (category high, Nakicenovic et al., 2000). Some simulations for scenario B2 (medium-high) were also analyzed (not shown), and the differences in the projected climate changes were essentially quantitative.

Climate change is here defined as the difference between the climatology predicted by the models for the enhanced emission scenario A2 in the period 2071-2100 and the climatology reproduced by them for the observed concentration of gases and aerosols in the period 1961-1990. The latter period is also used for the validation of the models' performance, carried out by comparing the models' climatology with that obtained from the University of Delaware data set (Legates and Willmott 1990).

3. RESULTS AND DISCUSSION

3.1. Climate change: mean precipitation fields

The models are able to reproduce important features of the precipitation annual cycle over SA, such as the migration of precipitation from northern SA into the subtropics during the spring and early summer, and subsequent withdrawal during late summer and early autumn, so that winter is the dry season over most of the continent. There are, however, significant inter-model differences in their ability to reproduce the observed precipitation climatology in its more specific aspects. This ability is even seasonally dependent, for different models present the best performance in different seasons (Figures not shown).

In spite of the common elements in the models, their responses to increasing greenhouse gases and aerosols show great diversity in the tropical region, especially in summer and autumn (Fig. 1).

* *Corresponding author address:* Alice M. Grimm, Univ. Federal do Paraná, Dept. of Physics, Caixa Postal 19044, Curitiba, Paraná, Brasil; CEP 81531-900; e-mail: grimm@fisica.ufpr.br

In summer, there is a great difference between the projections produced by models that share common dynamical features but have different resolutions. Models ECHAM4-OPYC3 and ECHAM5-OM project very different precipitation changes for central-east and northeast Brazil. The main difference in HadCM3 and HadAM3P projections resides in a northwest-southeast band of increased precipitation across SA in HadAM3P, which is not predicted by HadCM3. This band is also not present in CCM3 output. There is not much convergence between the models, especially in the tropical regions with high observed precipitation rates. On the other hand, there are no outstanding discrepancies regarding southeastern SA: most of the models project a weak increase of precipitation in this region.

The differences between climate change scenarios observed in summer are also present in autumn. The projected increase of precipitation in southeastern SA is stronger than in summer, while in the southern Andes Mountains there is a consistent tendency to reduction.

There is more convergence in spring and winter (Figures not shown). Most of the models indicate decrease of precipitation in most of the Amazon region, with the exception of its western part. Also in these seasons there are consistent indications of increased precipitation in southeastern SA and reduction in southern Andes.

3.2. Climate change: precipitation variability

To verify if climate change affects precipitation variability and its connection SST we analyzed the output of the coupled AOGCM ECHAM5-OM. EOF analysis was performed on the model precipitation in the periods 1961-1990 and 2071-2100. The first principal component series for each period was correlated with global SST produced by this coupled model. We will focus on the results for spring, which is the season with strongest ENSO impact on subtropical South America precipitation. (Grimm 2000, 2003).

The main feature of the first mode of spring precipitation variability in the model is a north-south dipole of anomalies (Figure 2, top). It is significantly associated with El Niño-Southern Oscillation (ENSO), as shown in the SST correlation map. It explains 20.7% of the variance. The first mode of observed precipitation (Figure not shown) also features a dipole, but the northern center is over northeastern SA, while the maximum variability in the model is extended westward, over central Amazonia. The southern center is placed over southeastern SA, which coincides with the observed features. The impact of ENSO events on this region in spring is strong and consistent. The series of factor scores for the model data (Figure 2, top) does not reproduce the series for observed data in which known El Niño (La Niña) events correspond to positive (negative) values. Half of these events are represented by values of opposite sign in Figure 1. This means that the model reproduces an ENSO-like variability, but the extreme events of the oscillation do not coincide with the observed ENSO events.

The enhanced emission scenario modifies the spatial pattern of the first variability mode of spring precipitation by enhancing the northern center of the dipole and weakening the southern center (compare Figures 2, top and bottom). The temporal series of the factor scores shows a positive tendency during 2071-2100 (Figure 2, bottom), which indicates a tendency to less precipitation in Amazonia and more precipitation in southeastern SA. This is consistent with the climate change projected by this model for spring (Figure not shown). This mode explains 26.4% of the variance. The correlation between this mode and SST under A2 scenario is much weaker in eastern equatorial Pacific as well as in the subtropics. The significant correlation pattern is shifted westward. This and the weakening of the anomaly center in southeastern SA mean that the connection between SST anomalies in eastern Pacific and southeastern SA precipitation is reduced.

The impact of ENSO is established through perturbation of the Walker circulation over Amazonia and through Rossby wave propagation from eastern Pacific over southeastern SA. It is suggested that the basic state conditions for this propagation are less favorable in the climate change scenario. The weaker latitudinal SST gradient in subtropical South Pacific might, for instance indicate a decrease in the subtropical westerly jet, which reduces the southward propagation of these waves. A broader tropical correlation pattern extending into the subtropics might explain the stronger components in Amazonia, as the corresponding SST anomalies could produce stronger anomalies of Walker circulation over this region, but the southeastward propagation of Rossby waves might be affected by the circulation changes produced by SST warming in the extratropics. The westward shift of the northern center of precipitation anomalies in Fig. 2 (bottom) might be associated with the westward shift of SST anomalies associated with ENSO over the equatorial Pacific, when compared to the correlations with SST in present-day climate (Fig.

2, top). Another outstanding feature of the correlation patterns of PC1 with SST for 2071-2100 is the absence of significant correlations in the tropical Atlantic Ocean, which are present in the period 1961-1990.

4. CONCLUSIONS

The models are able to reproduce the basic features of the precipitation annual cycle over South America, but there are significant inter-model differences in their ability to reproduce some aspects of seasonal precipitation climatology.

While there is great diversity between climate change scenarios in tropical South America, especially in summer and autumn, there is consistent indication of small increase of precipitation in southeastern South America in all seasons and of small reduction in the southern Andes Mountains from autumn through spring.

The first mode of model precipitation variability in spring is associated with El Niño-Southern Oscillation (ENSO). This mode corresponds, with some differences, to the first variability mode of observed spring precipitation, which is also associated with ENSO. The strong relationship between ENSO events and precipitation variability in southeastern South America weakens for the A2 scenario. This indicates that either ENSO events will weaken or the relationship weakens due to a different atmospheric basic state.

Acknowledgements: This study was supported by MMA/PROBIO, GEF and BIRD, CNPq, and IAI (CRN055).

References

Gordon, C., C. Cooper, C.A. Senior, H. Banks, J.M. Gregory, T.C. Johns, J.F.B. Mitchell, and R.A. Wood (2000), The simulation of SST, sea ice extents and ocean heat transports in a version of the Hadley Centre coupled model without flux adjustments, *Climate Dyn., 16*, 147-168.

Grimm, A. M., and P. L. Silva Dias (1995), Analysis of tropical–extratropical interactions with influence functions of a barotropic model, *J. Atmos. Sci., 52*, 3538–3555.

Grimm, A. M., V. R. Barros, and M. E. Doyle, 2000: Climate variability in Southern South America associated with El Niño and La Niña events. *J. Climate*, **13**, 35–58.

Grimm, A. M. (2003), The El Niño impact on the summer monsoon in Brazil: regional processes versus remote influences, *J. Climate, 16*, 263–280.

Jones R. G., J. M. Murphy, D. C. Hassell, M. J. Woodage (2005), A high resolution atmospheric GCM for the generation of regional climate scenarios. Hadley Centre Technical Note 63, Met Office, Exeter.

Legates, R. D., and C. J. Willmott (1990), Mean seasonal and spatial variability in gauge-corrected global precipitation, *International Journal of Climatology, 10*, 111-127.

Marsland, S., H. Haak, J. Jungelaus, M. Latif, and F. Röske (2003), The Max-Planck-Institute global ocean/sea ice model with orthogonal curvilinear coordinates, *Ocean Modeling, 5*, 91-127.

Nakicenovic N., et al. (2000), Special report on emissions scenarios. Cambridge University Press, Cambridge, 599pp.

Rayner, N. A., D. E. Parker, E. B. Horton, C. K. Folland, L. V. Alexander, D. P. Rowell, E. C. Kent, A. Kaplan (2003), Global analyses of sea surface temperature, sea ice, and night marine air temperature since the late nineteenth century, *J Geophys Res 108* (D14): 4407, DOI 10.1029/2002JD002670

Roeckner, E.,G. Bäuml, L. Bonaventura, R. Brokopf, M. Esch, M. Giorgetta, S. Hagemann, I. Kirchner, L. Kornblueh, E. Manzini, A. Rhodin, U. Schlese, U. Schulzweida, and A. Tompkins (2003), The atmospheric general circulation model ECHAM5. PART I: Model description, MPI Rep. 349, Max-Planck-Institute für Meteorologie, Hamburg, Germany.

Rowel, D. P. (2005), A scenario of European climate change for the late twenty-first century: seasonal means and interannual variability, *Climate Dyn., 25*, 837–849.

Stendel, M., T. Schmidt, E. Roeckner, and U. Cubasch (2000), The climate of the 21st century: Transient simulations with a coupled atmosphere-ocean general circulation model, Danmarks Klimacenter Rep. 00-6.

Centers	Model	Reference	Grid
Max Planck Institute für Meteorologie	*ECHAM4-OPYC3*	Stendel et al. (2000)	~2.813° × 2.813°
Hadley Centre for Climate Prediction and Research	*HadCM3*	Gordon et al. (2000)	2.5° × 3.75°
Max Planck Institute für Meteorologie	*ECHAM5-OM*	Roeckner et al.(2003) Marsland et al. (2003)	1.875° × 1.875°
Hadley Centre for Climate Prediction and Research	*HadAM3P*	Jones (2005) Rowell (2005)	1.25° × 1.875°
Community Climate Model	*CCM3*	http://www.dmi.dk/	1.0° × 1.25°

Table 1. List of models that generated the simulations analyzed in this study.

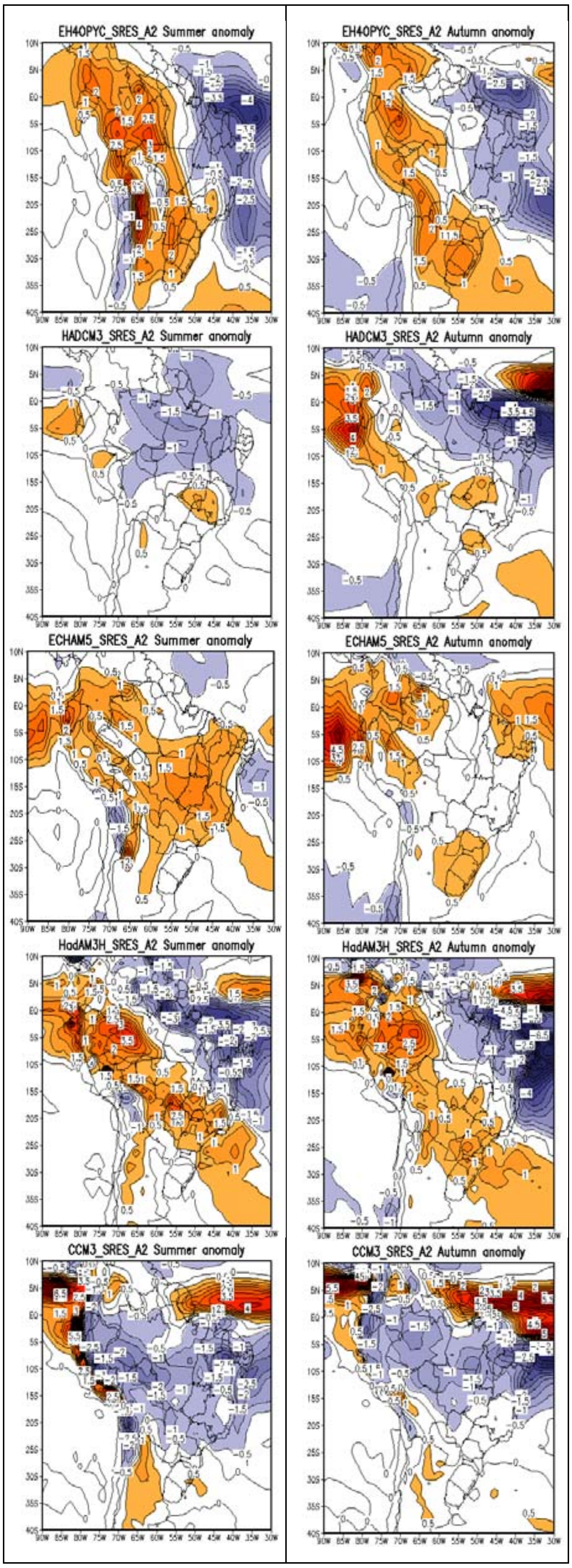

Figure 1. Climate change scenarios for summer and autumn, projected by each model included in this study (Table 1).

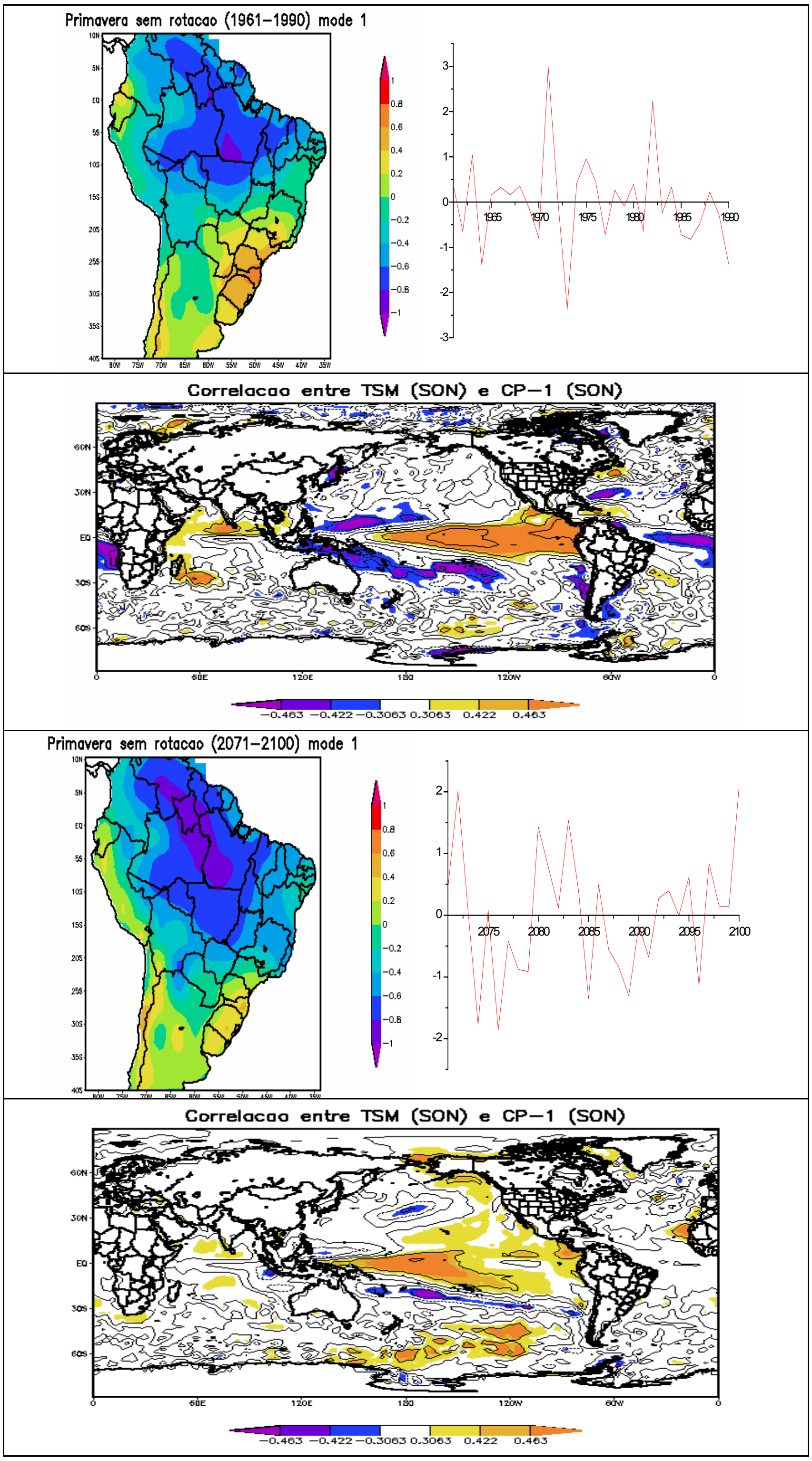

Figure 2. (Top) Factor loadings and factor scores of the first EOF of simulated spring precipitation in the period 1961-1990, and correlation coefficients between factor scores and SST. (Bottom) Same as above, for the period 2071-2100. Correlation coefficients significant to a level better than 0.05 are shaded in yellow/orange (positive) and blue/purple (negative).