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Climate change scenarios for seasonal precipitation in South America from IPCC-AR4 models

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[1] A subset of climate simulations of the 20th century from the IPCC-AR4 is analyzed to assess the ability of these models to reproduce the observed climatological seasonal precipitation in South America during the period 1970–1999. Changes of the model climatology in a climate change scenario (SRESA1b) for the period 2070–2099 are also discussed. Results show that models are able to reproduce the main features of the precipitation seasonal cycle over South America, although the precipitation in the SACZ region and the precipitation maximum over southeastern South America observed during the cold season are not well- represented. There is a general consensus among models that the precipitation changes projected are mainly: i) an increase of summer precipitation over southeastern subtropical South America; ii) a reduction of winter precipitation over most of the continent; and iii) reduction of precipitation in all seasons along the southern Andes. **Citation:** Vera, C., G. Silvestri, B. Liebmann, and P. González (2006), Climate change scenarios for seasonal precipitation in South America from IPCC-AR4 models, *Geophys. Res. Lett.*, *33*, L13707, doi:10.1029/2006GL025759.

1. Introduction

[2] The notion that the increase of anthropogenic greenhouse gases will lead to significant global climate changes over the next century is the accepted consensus of the scientific community [*Intergovernmental Panel on Climate Change*, 2001]. Unfortunately, with the exceptions of the pioneering works of *Labraga and Lopez* [1997] and *Carril et al.* [1997], climate change assessments in Southern Hemisphere regions like South America have been few. In particular, the evaluation of present climate and the analysis of the projections for climate change over South America included in IPCC-AR3 were focused on results from *Giorgi and Francisco* [2000]. Dividing the continent into two regions (the Amazon and southern South America), they showed that present climate simulations from five coupled models exhibit less mean precipitation than observed in the Amazon, while there are large differences among models in southern South America. The additional analysis of climate change projections for the end of the 21st century revealed a small increase of precipitation in the Amazon, while inconsistent changes were found in the south.

[3] Updates of the assessments of possible future changes of precipitation and temperature over the continents are highly relevant as modeling techniques continue to improve. The recent availability of the multi-model climate simulations of the Inter-governmental Panel on Climate Changes 4th Assessment Report (IPCC-AR4) provides a state-of-the-art tool with which to perform such updates. The purpose of the work summarized here is to evaluate the ability of the IPCC-AR4 models to reproduce the basic precipitation features in South America and then to compare the late-20th century climate with the model climate scenarios of the late 21st century. Moreover, special efforts are made in providing a more detailed regional description than in previous studies, necessary due to the large spatial variability of precipitation in South America.

[4] The following subset of the IPCC-AR4 coupled models and corresponding runs are used in this work: CNRM-CM3 (1 run), GFDL-CM2.0 (1 run), IPSL-CM4 (1 run), ECHAM5/MPI-OM (2 runs), GISS-EH (3 runs), MIROC-3.2 (3 runs), MRI-CGFM2.3.2 (5 runs). Most of the models have a horizontal resolution of around 2°. The outputs of the "climate of the 20th Century experiment" (20C3M) are used to describe the climate for the period 1970–1999, while those from the "720 ppm stabilization experiment" (SRES A1B) are used to represent the changes under a climate change scenarios for the period 2070–2099. University of Delaware (UDEL, http://climate.geog.udel.edu/~climate/) precipitation data set (0.5° × 0.5° resolution) is used to represent the observed precipitation. Both model and UDEL output are converted a resolution of 5° × 4°, which is similar to that of some of the models.

[5] Seasonal mean precipitation fields for both the present climate and climate change scenarios are computed as averages over all available members. The same number of members from each model are used to calculate the present and projected climate. The precipitation climatology is analyzed in South America for January-February-March (JFM, austral summer), April-May-June (AMJ, austral fall), July-August-September (JAS, austral winter) and October-November-December (OND, austral spring).

2. Precipitation Features of the Late 20th Century Climate

[6] *Vera et al.* [2006, and references therein] provided an extensive discussion of the South American climate. Therefore, the following discussion of the seasonal climatology (displayed in Figure 1) will be brief.

2.1. JFM

[7] During austral summer, precipitation over the Amazon Basin is connected to a NW-SE oriented band known as

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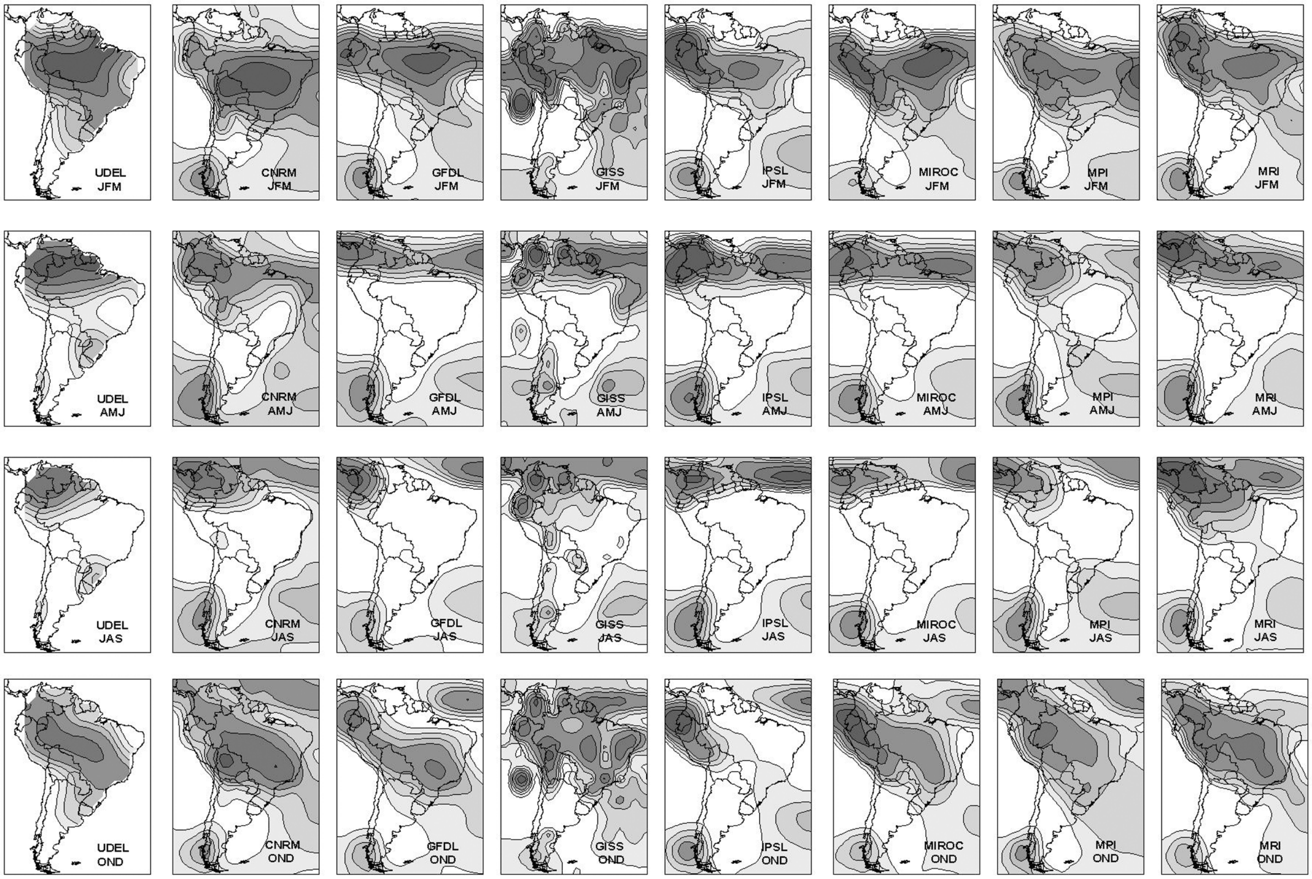

Figure 1. Seasonal mean precipitation computed for 1970–1999 period from observations (UDEL), and IPCC-AR4 models (see list in the text). Contour level is 1 mm day^{-1}, values larger than 2 mm day^{-1} are shaded.

the South Atlantic convergence zone (SACZ). Dry conditions dominate over Northeast Brazil and over the extreme south over Patagonia.

[8] All models are able to reproduce to some extent the tropical precipitation maximum, although they differ in its intensity and location. While GFDL, MIROC, and MRI exhibit an SACZ similar in strength and location to that observed, some of the other models locate it farther northeast and with varying intensities, while in others it does not exist. There is also a relative maximum of precipitation over the Patagonian Andes [*Hoffman*, 1975] although it is not evident in the observational data set used here. *Hoffman* [1975] used more than 1700 stations to compile his detailed climatology. The precipitation distribution over the Southern Andes is particularly important for both Argentina and Chile because of its impact on water reservoir storage and hydroelectric energy generation. Most of the models have a well-defined maximum over southern Chile, although with their relatively course resolution they are unable to reproduce the observed narrow structure, which is concentrated along the Andes. The exception is the GISS model that locates the maximum over Patagonia (and in the other seasons as well).

[9] The models all produce a maximum along the western coast of equatorial South America (although with different intensities), but this is not evident in the UDEL maps. The climatological mean maps compiled by *Hoffman* [1975] reveal a narrow band of maximum precipitation along the northern Andes, with values even larger than those observed over the Amazon. In contrast, the simulations have a wide maximum that extends over the eastern Pacific.

2.2. AMJ

[10] During austral fall the maximum precipitation has moved northward, and the SACZ is absent. There is a local maximum observed over southeastern South America (SESA). The summer maximum over the southwestern coast is now expanded northward, reaching central Chile.

[11] Models reproduce well the northward migration of both the ITCZ and the tropical continental precipitation, although most of them produce drier conditions over the Amazon and a narrower and more zonally oriented ITCZ than are observed. In the subtropics, most of the models are unable to reproduce the maximum over SESA, but instead tend to place an area of high precipitation over the southwestern Atlantic. The exception is the MPI model, which, although it produces a weaker SESA maximum than is observed, correctly locates it. The northward extension of the maximum observed over the southwestern coast of the continent is reproduced to some extent by all models.

2.3. JAS

[12] During austral winter, tropical precipitation is concentrated over northwestern South America. Also, the maximum in SESA is stronger than in AMJ, while precipitation along the southwestern coast remains high.

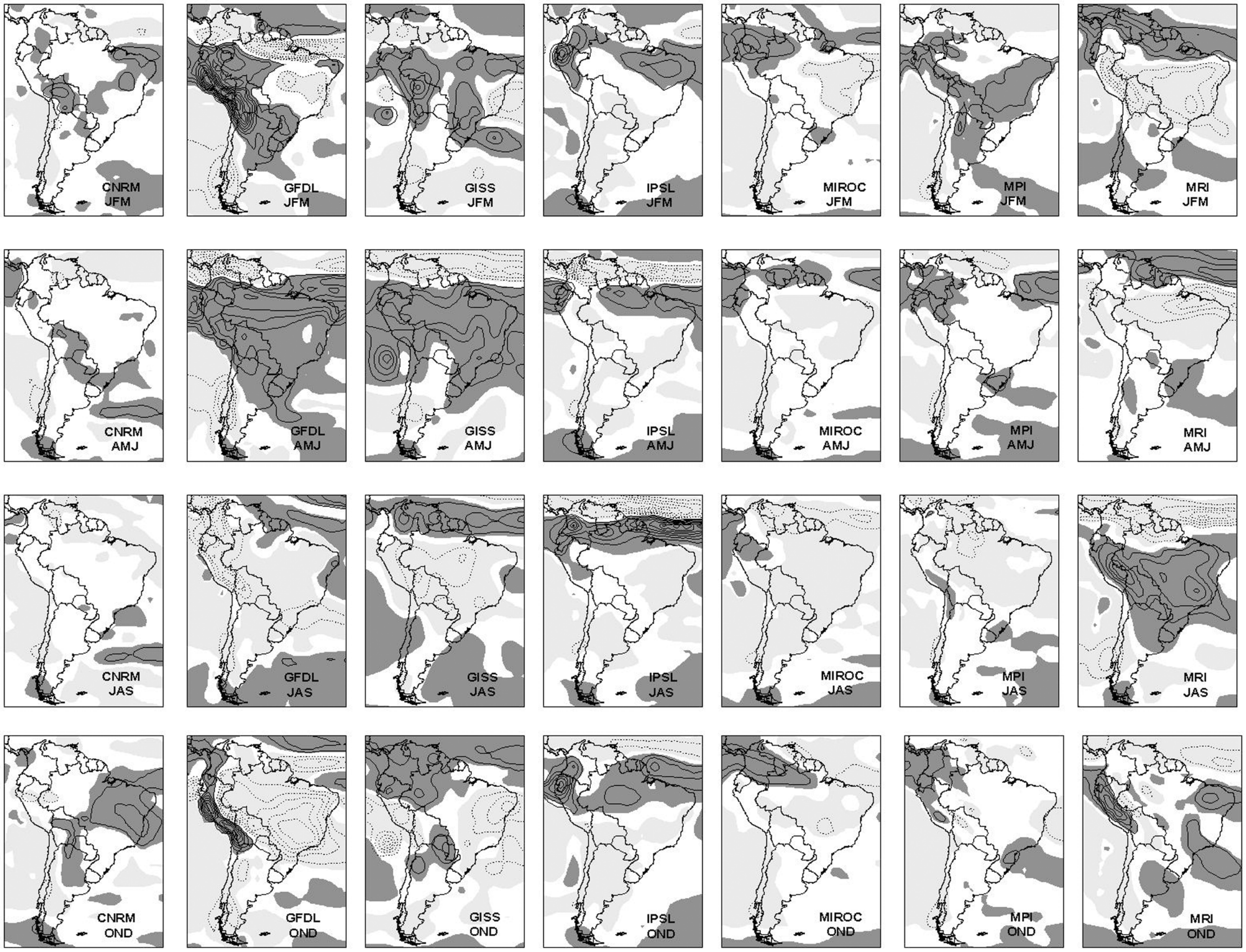

Figure 2. Differences of simulated seasonal mean precipitations between 2070–2099 and 1970–1999 periods. Contour level is 1 mm day^{-1}. Negative contours are dashed and the zero contour is omitted. Areas where positive (negative) values are statistically significant at the 90% of a T-Student test, are shaded in dark (light) gray.

[13] There is a large dispersion among models in their representation of tropical precipitation during this season. Furthermore, the MRI exhibits an SACZ-like structure that is not observed. In addition, the inability of the models to reproduce the maximum in SESA (except the MPI) is also quite evident. The models are, however, able to reproduce the observed maximum from the southwestern tip to the central Andes, although it is still too wide.

2.4. OND

[14] The onset of the rainy season over tropical South America is evident from observations. The spatial structure of the precipitation resembles that of summer, although weaker. The maximum in SESA is now merged with the tropical precipitation. *Hoffman* [1975] showed that the maximum over the southwestern coast, while still evident, is at its annual minimum.

[15] All models reproduce the southward migration of both the ITCZ and the tropical precipitation. They also exhibit a SACZ-like structure similar to that observed. The exception is the IPSL model that seems to be slow to transition from the winter to summer pattern. On the other hand, there are differences in the location and intensity of the tropical maximum, and in the subtropics most of the models have lower values than observed. In the extratropics, models represent to some extent the southward concentration of the precipitation along the southwestern coast.

3. Precipitation for the Climate Change Scenario

[16] The model differences between the seasonal means for climate change scenario SREA1B (2070–2099) minus those for the present climate (1970–1999) are presented in Figure 2. In addition, Figure 3 provides a synthesis of the model results, displaying for each of the seasons the number of models that predict changes of a given sign.

[17] Most of the models reduce austral summer precipitation over Patagonia and the southern Andes and increase precipitation near Peru and in SESA. On the other hand, over the Amazon-SACZ, results are mixed.

[18] There is a high level of agreement among models in producing negative changes in the austral fall precipitation over the southwestern coast, while moderate levels of agreement are associated with the overall positive changes in SESA and northwestern South America. There are no other areas with consistent changes during this particular season.

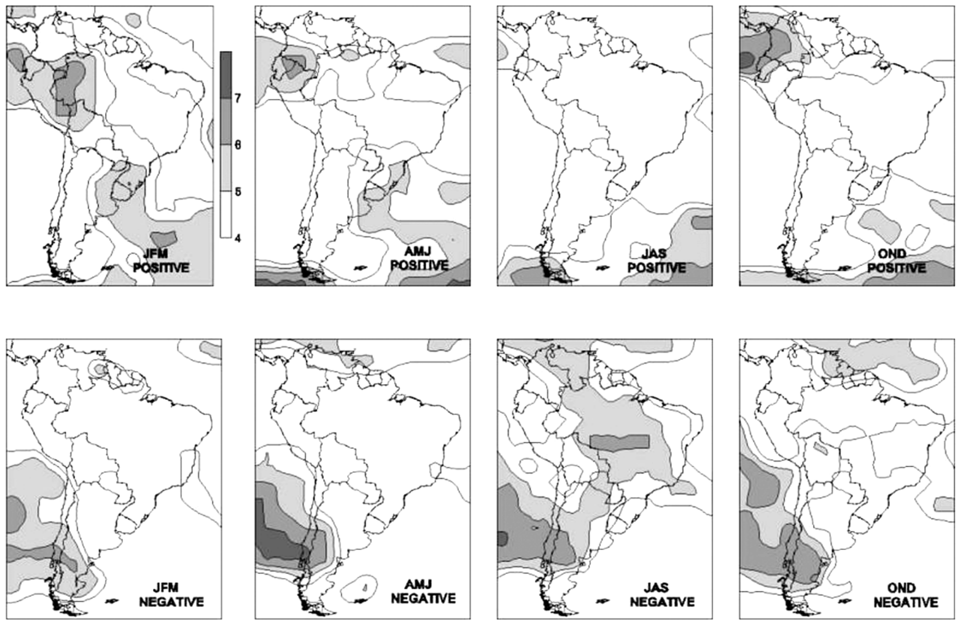

Figure 3. Number of models depicting (top) positive changes and (bottom) negative changes in maps of Figure 2.

[19] The most significant feature that characterizes austral winter precipitation changes in South America is the decrease over almost the entire continent. A few models produce increases over SESA.

[20] During austral spring there is also a high level of agreement in producing negative changes in the southern cone. On the other hand, a small number of them produce positive changes in SESA and northwestern Brazil.

4. Summary and Conclusions

[21] The ability of the IPCC-AR4 models to reproduce the seasonal mean fields of precipitation over South America and the precipitation changes projected by these models under a climate change scenario is assessed.

[22] Most of the models are able to reproduce the basic characteristics of the precipitation seasonal cycle, such as the northwestward and southeastward migration of precipitation over tropical South America and the precipitation maximum observed over the southern Andes. Nevertheless, there are large discrepancies in the model SACZs in both intensity and location, and in their seasonal evolution. Also, most of models do not reproduce the precipitation maximum observed over SESA during the cold seasons.

[23] The analyses show that the models still have problems in reproducing quantitatively accurate seasonal precipitation over the main basins of the continent (i.e., the Amazon and La Plata basins), which should preclude the use of these models for hydrological applications. Near the Andes, the low model resolution of the orography seems to affect the location and intensity of the precipitation. Downscaling techniques might improve the simulations over those regions.

[24] The analysis of the climate change outputs for the SRESA1B scenario show a substantial agreement among models in precipitation changes for the period 2070–2099 relative to 1970–1999, mainly characterized by: i) an increase of summer precipitation over the northern Andes and southeastern South America, ii) a decrease of winter precipitation over most of the continent, and iii) a decrease of precipitation along the southern Andes for all seasons.

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