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PRECIPITATION VARIABILITY IN SOUTH AMERICA FROM IPCC-AR4 MODELS PART I: CLIMATOLOGY (+)

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1. Introduction

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 (IPCC Third Assessment Report – Climate Change 2001). In this context, an assessment of possible future changes of precipitation and temperature over the continents is highly relevant. Climate change assessment in South America has not received as much attention as in the Northern Hemisphere, and certainly needs to be addressed. 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 address that question. 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.

The following subset of the IPCC-AR4 coupled models and corresponding runs were 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) were used to describe the climate features of the period 1970-1999, while those from the "720 ppm stabilization experiment" (SRES A1B) were used to represent the changes under a climate change scenarios for the period 2070-2099.

Seasonal mean precipitation fields were computed for each model, by first averaging seasonal totals over each individual run, and then averaging over all runs available. The precipitation climatology is analyzed in South America for

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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). University of Delaware (UDEL, http://climate.geog.udel.edu/~climate/) precipitation dataset (0.5°x0.5° resolution) was used as representative of the observed precipitation.

2. Precipitation features of the late 20th century climate

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 Fig. 1) will be brief.

a) JFM

During austral summer, the precipitation over the Amazon Basin is connected to a NW-SE oriented band known as the South Atlantic convergence zone (SACZ). On the other hand, dry conditions dominate Northeast Brazil and the southern tip over Patagonia.

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 different intensities than observed, while others do not even have an SACZ. A relative maximum of precipitation also exists over the Patagonian Andes (Hoffman, 1975) although it is not evident in the present data set. 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 capacities 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 the Patagonia (in the other seasons as well).

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. A comparison between the maps of Hoffman (1975) (not shown) and the simulations shows that models produce a wide maximum that extends over the eastern Pacific.

b) AMJ

During austral fall the zone of maximum precipitation has moved northward, and the SACZ is absent. There is a local maximum observed over southeastern South America (SESA). The maximum over the southwestern coast now extends farther northward, reaching central Chile.

Models reproduce well the northward migration of the tropical precipitation, although most of them produce drier conditions over the Amazon than observed and have a too narrow and zonally oriented area of precipitation. In the subtropics, most of the models are unable to reproduce the maximum over SESA, but instead tend to place a region of large 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.

c) JAS

During austral winter, tropical precipitation is concentrated over the northwestern continent. Also, the maximum in SESA is stronger than in AMJ, while precipitation along the southwestern coast remains strong.

There is a large dispersion among models in the 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 describe a maximum from the southwestern tip until the central Andes, although it is still wider than observed.

d) OND

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.

All models reproduce the southeastward migration of the tropical precipitation and 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 show lower values than observed. In the extratropics, models represent to some extent the southward concentration of the precipitation in the southwestern coast.

3. Precipitation for the climate change scenario

The model differences between the seasonal means for climate change scenario SREA1B (2070-2999) minus those for the present climate (1970-1999) were analyzed. Figure 2 provides a synthesis of the model results, displaying for each of the seasons the number of models that predict changes of a given sign.

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.

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.

The most significant feature that characterizes austral winter precipitation changes in South America is there are decreases over almost the entire continent. A few models produce increases over SESA.

During austral spring there is also a high level of agreement in producing negative changes in the southern tip. On the other hand, a small number of them still agree in determining positive changes in SESA and northwestern Brazil.

4. Summary and conclusions

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 was assessed.

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.

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. The low-resolution of the Andes in the models seems also to affect the location and intensity of the precipitation areas in the vicinity of orography. Downscaling techniques might result in more reliable precipitation estimates over those regions.

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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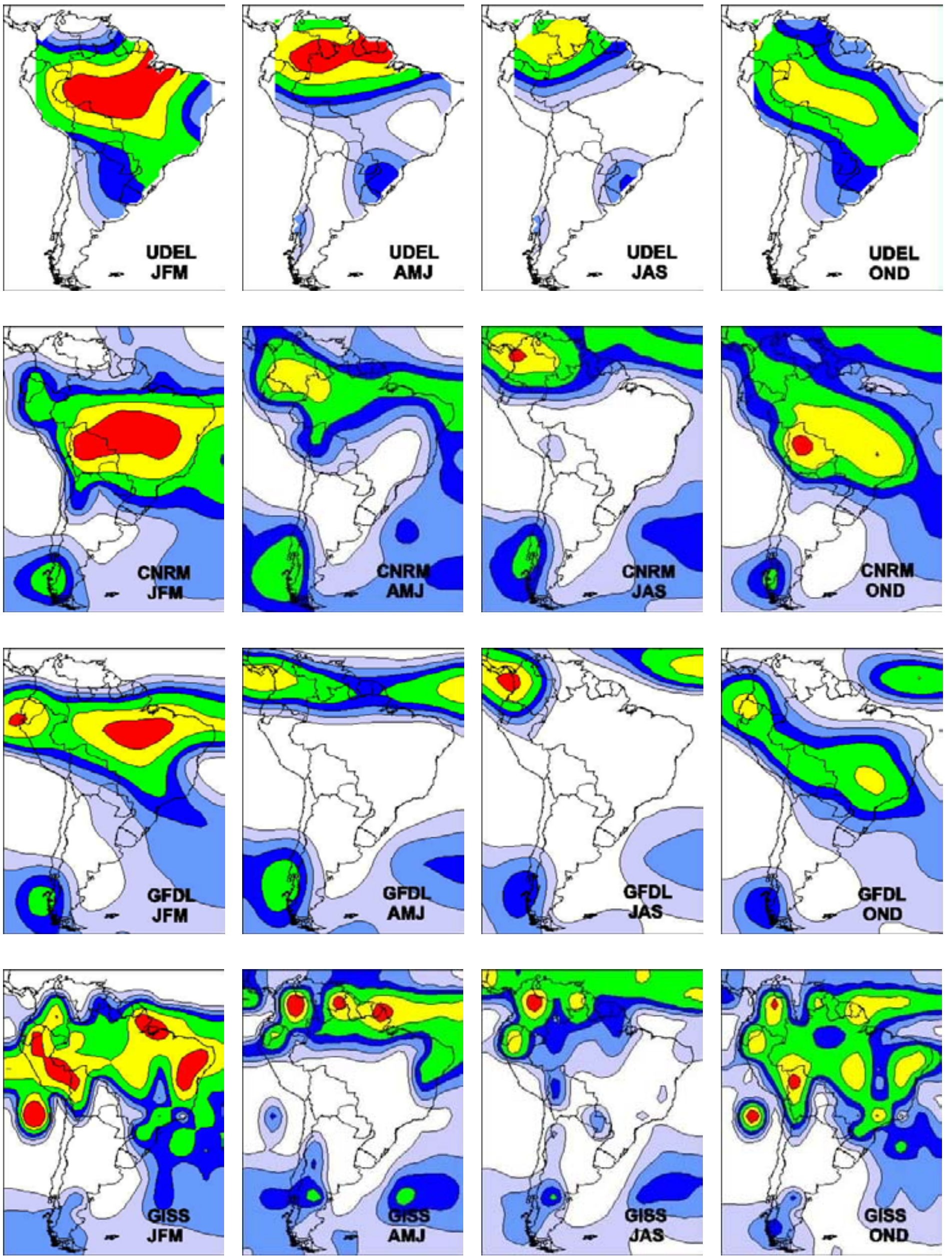

Figure 1: Seasonal mean precipitation computed for 1970-1999 period from observations (UDEL), and IPCC-AR4 models (see list in the text). Contour level is 1 mm day^{-1}, values larger than 2 mm day^{-1} are shaded.

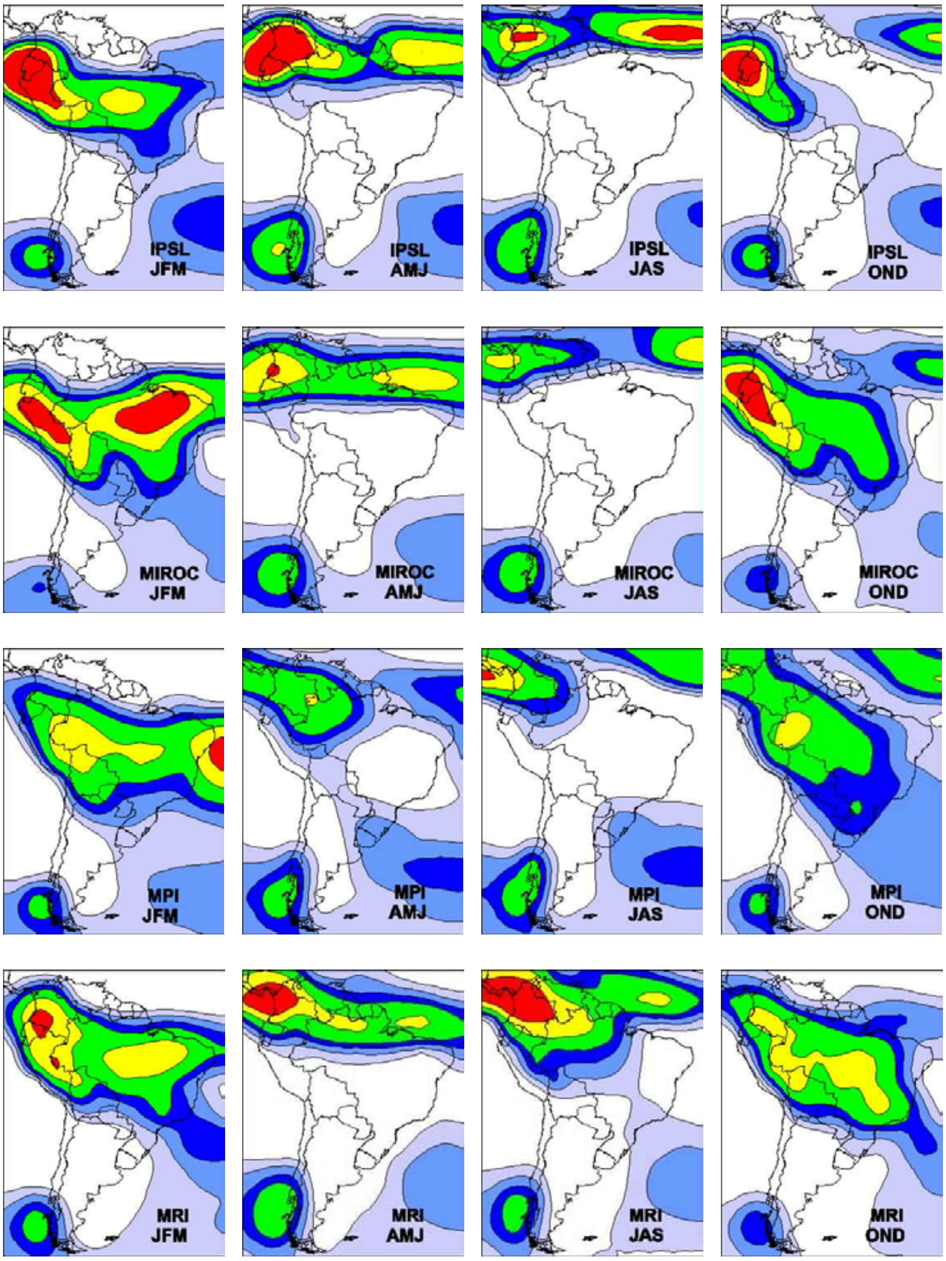

Figure 1 (continuation)

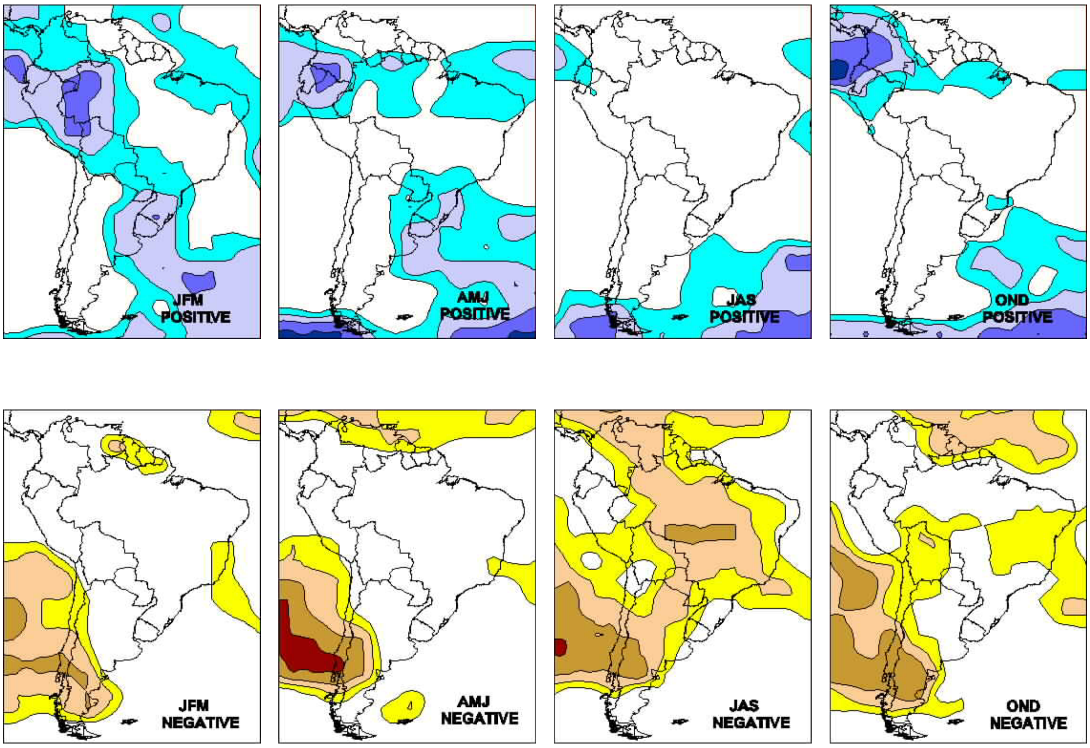

Figure 2: Number of models depicting (1st row) positive changes and (2nd row) negative changes between 2070-2099 and 1970-1999 periods. Contour level is 1, values larger than 4 are shaded.