AN INTERCOMPARISON OF MODEL-SIMULATED IN EXTREME RAINFALL AND TEMPERATURE EVENTS DURING THE LAST HALF OF THE XX CENTURY: PART 1: MEAN VALUES AND VARIABILITY

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ABSTRACT

In this study we examine the performance of eight of the IPCC AR4 global coupled climate models used in the WCRP CMIP3 Multimodel Dataset as well as their ensemble mean, in simulating annual indices of extreme temperature and precipitation climate events in South America. In this first part we focus in mean values and interannual variability. Comparisons between two extreme temperature indices based on minimum temperature (Warm nights and Frost Days) and three indices of extreme precipitation (R95t, R10 and Consecutive Dry Days), obtained from meteorological station during 1961-2000 and model outputs were compared. Warm nights and the extreme precipitation events, both indices relative to the local climate are the best represented by the GCMs.

1. INTRODUCTION

One of the key aspects of Climate Change is to understand the behavior of extremes. It is recognized that the changes in frequency and intensity of extreme events are likely to have a larger impact than changes in mean climate. Because of differences among model formulation in the various IPCC AR4 global coupled models, some differences can be expected in the projection of mean climate and extremes in the present and also in the future. One of the high-priority fields of the WCRP CMIP3 Multimodel Dataset (Taylor, 2007) are the extremes indexes calculated from daily data; five temperature-related indices and five precipitation- related indices, from Frich et al. (2002, their Table 1).

Observational studies by Rusticucci and Barrucand (2004), Vincent et al (2005) Groismann et al (2005), Haylock et al(2006), Alexander et al (2006), Marengo and Camargo (2007), Rusticucci and Renom(2007) Penalba and Robledo (2008, this issue) and Marengo et al (2008, this isuue) have documented trends in extremes during the last 50 years, using different methodologies in defining extremes, from threshold values to percentiles. Most of these studies have detected positive rainfall extreme trends in regions such as Southeastern South America, while indices based on minimum temperature have shown substantial increases basically everywhere in South America where daily data was available. An intercomparison between observed and simulated trends in South America during 1960-2000 Marengo et al (2008, this issue) using various indices of extremes defined by Frich et al (2002) and 8 GCMS from the IPCC AR4 20C3M WCRP CMIP3 have shown that even though all models simulate quite well the observed trends in warm nights, situation with extreme rainfall indices is not as good, and basically all models show tendencies that are different that the observed trends in various regions of South America, coinciding only on positive trends in Southeastern South America.

However, as a previous step, there is still a need to see if models are able to simulate well the observed mean values. The papers by Vincent et al (2005), Alexander et al (2006) and Haylock et al (2006) have shown observational aspects of some extreme indices, and Marengo et al (2008, this issue) has analyzed observed and simulated trends of those indices, but few papers have performed a validation of the simulated extremes, particularly mean and standard deviation in South America. Tebaldi et al (2007) compared simulations of changes based on the WCRP CMIP3 models, but we still do not now if the models simulate well the observed mean values or if there are systematic biases of the means.

We propose to assess climate extremes over South America through the analysis of the indices WCRP CMIP3 used for the IPCC 4th Assessment Model Output for the present climate during the XX Century (IPCC20C3M). These "extreme indices" are derived data, calculated from simulated daily temperature and precipitation, in the form of annual indicator time series. In this paper, for the common period 1961-2000, the mean, standard deviation and mean square error between the grid point from different models and the nearest station was calculated. More details in these indices can be found in Frich et al. (2002).

2. DATA

This study is part of the CLARIS-EU project (“A Europe South America Network for Climate Change Assessment and Impact Studies”; Boulanger et al. 2008, this issue). One of its objectives was to create a high-quality regional database for daily temperature and precipitation by gathering all currently available data in the region of study for studies in extreme events and long-term climate trends. Other one was to facilitate the exchange of observed and simulated climate data between the climate research groups. From the beginning of the project we started gathering all current available data in the region of study. At the end, the data set of CLARIS-EU project consists of the following information: Argentina: Daily Maximum and Minimum Temperature and Precipitation were updated to the period 1950-2003. The information was mainly provided by the Argentina National Weather Service (SMN in Spanish). Some also raingauge stations belong to argentine local organizations such as INTA (Agricultural National Institute) Santa Rosa and Pergamino were used. A quality control was performed, with some common and more exhaustive controls (Rusticucci and Barrucand, 2004 , Penalba and Robledo, 2006; Llano, 2006). We obtained a 41-station data base for the period 1950-2003 (mostly from 1959). Uruguay; Daily Maximum and Minimum Temperature and Precipitation: The Uruguayan National Weather Service (DNM, in Spanish) has a relatively rich dataset of long daily temperature records, between 50 and 100 years long. Until a few years ago, all the data from the DNM were in paper format; this, however, changed 3 years ago when, under WP3.2 objectives, CLARIS-EU has contributed to the digitalisation of a selected part of this data as a contribution to the long regional daily dataset. All the data were quality controlled with the same methodologies as in Argentina data (Rusticucci and Renom, 2007). The daily precipitation dataset mainly belong to the DNM.

As in the case of Argentina, maximum and minimum temperature and raingauge data from the meteorological station of La Estanzuela that belong to the National Agricultural Research Institute (INIA, in Spanish) were used.

Brazil: Daily temperature and precipitation from some airports were available.

For this country and the rest of the countries not mentioned the stations and raingauges compilated by the workshop held in Maceio during 2004 (two of the authors have participated in the workshop) were also used. Homogeneity testing was performed in all station data in order to check its quality. Only homogeneous series presenting less than 10% of missing data for their period of record have been used on this study.

The high-quality database enhance previous regional studies, adding new quality-controlled daily data.

In this study, the observed indices for extremes in South America other than CLARIS-EU database were obtained from the workshop held in Maceió, Brazil 2004, organized by The Expert Team on Climate Change Detection, Monitoring and Indices (ETCCDMI) WMO Commission for Climatology (CCl) / World Climate Research Program project on Climate Variability and Predictability (CLIVAR) based on the paper of Frich et al (2002). The data and processing is completely described in Vincent et al (2005) and Haylock et al (2006). These indices are evaluated in 90 stations for the countries Argentina, Brazil, Bolivia, Chile, Ecuador, Paraguay, Perú, Uruguay.

The models calculate ten different extreme indices related to daily temperature and precipitation extremes. Nevertheless, there are some differences among calculation of indices and that is why we used a subset of them. We choose some relevant indices that can be comparable. For these indices, we have two different thresholds, one fixed (and cold for temperature) and the other one according to the local climate, (and warm for temperature).

As it is mentioned in Marengo et al (2008, this issue) the minimum temperature is the most sensitive, and with the greatest changes (Rusticucci and Barrucand, 2004; Rusticucci and Renom, 2007). So, the indices we use for temperature are based on minimum temperature:

-Frost days (FD): annual occurrence of frost days (days with MinT <0ºC),

-Warm nights (Tn90): percentage of days where MinT was above the 90th percentile of the 1961-90 base period.

The precipitation indices are:

-R10: number of heavy precipitation days > 10mm,

-Consecutive Dry Days (CDD): number of consecutive days with precipitation < 1mm

-R95t: fraction (%) of annual total precipitation due to events exceeding the 95th percentile.

All the indices are considered in an annual basis

The available indices calculated by models are from NCAR CCSM3, USA;CNRM-CM3, France; GFDL-CM2 .0 (GFDL0) and GFDL-CM2.1,, USA; INM-CM3.0,Russia; MIROC3.2 MEDRES-Medium resolution, Japan; DOE-NCAR PCM, USA; and MRI-CGCM2, Japan. See Table 1 for more information on the models.

Model Designation	Institution
MRI-CGCM2.3.2	Meteorological Research Institute, Japan Meteorological Agency, Japan
CNRM-CM3	Centre National de Recherches Meteorologiques, Meteo France, France
GFDL-CM2.0	Geophysical Fluid Dynamics Laboratory, NOAA, USA
GFDL-CM2.1	Geophysical Fluid Dynamics Laboratory, NOAA, USA
INM-CM3.0	Institute of Numerical Mathematics, Russian Academy of Science, Russia.
MIROC3.2	Center for Climate Systems Research, Japan
NCAR-CCSM3.0	National Center for Atmospheric Research, USA.
DOE-NCAR- PCM	Department of Energy, National Center for Atmospheric Research, USA.

Table 1: Information of the GCMs used

3. RESULTS

3.1. Mean values

For the mentioned indices we calculate the observed and ensemble 1961-2000 mean values and the difference, in percentage over the observed, calculated as observed station mean value minus ensemble expressed in percentage. The nearest grid point to any station is used for this calculus. We prefer to use data that is not gridded, so the data to show up the geographical patterns of differences with local significances.

We have to considerer that in general, model simulated values over the Andes are difficult to be evaluated by the failing of the models in interpreting the topography, as it was seen in the comparison performed between station extreme daily temperatures and NCEP/NCAR reanalysis over Argentina (Rusticucci and Kousky, 2002).

In the Figure 1 we can see the observed Warm nights (Tn90) mean for the 1961-2000 period, the ensemble for the 8 mentioned models, and the difference between both values. In general, the entire continent has values between 5 an 12.5 % (it is necessary to explain here that the values are not all 10% because the percentile-base period is 1961-1990). Over the southeastern part of the continent, the ensemble is closer to the observed mean, with differences less than 33%, but large differences appear in some stations over central and eastern Brazil and in Bolivia. In Peru, the similarity is also noted, even though the models overestimate the observed values.

For the analysis of the number of Frost Days (FD) per year it is important to mention that there are no observed cases of frost north of 20ºS in lowlands, unless some models give values different from zero. The FD observed maps (Figure 2) show the largest values in the Andean region (between 30 and 60 days/year) as well as in Central Argentina, and less than 20 days/year in Uruguay and Southern Brazil. The ensemble shows the highest values over south western South America, a smaller amount in south eastern, to the smallest in tropical regions. In comparison, models overestimate the observations in La Plata Basin and underestimate in the Andean Pacific region. In summary, it seems that the number of warm nights are better represented that the FD.

For precipitation, the number of days with precipitation over 10 mm (R10) is shown in the figure 3. The observations show R10 values in stations nearby the Equator around 80 to 100 days, while in the La Plata basin the R10 values vary from 20-40 over Uruguay and Argentina and between 40-60 over southern Brazil. Over the Southeastern part, the climatic differences between regions (NE_SW) are well represented by the ensemble. In general, it is easy to see that the models highly over estimate the number of heavy precipitation days over the western part of the continent and under estimate them over the eastern part of the continent.

The other precipitation index, the observed fraction of extreme precipitation events (as shown by the R95t index) varies between 20 to 30% in some regions of tropical South America and the La Plata Basin. The ensemble, with simulated values closer to observations, while model overestimation is noticed over the Province of Buenos Aires. The differences are lower than R10, so this index, related to the local climate is better represented by the GCMs.

The Consecutive Dry Days index (CDD) well represents the climatic regions with a strong annual precipitation wave or a very dry climate with negligible precipitation. The observed CDD show the highest values in the northern part of the dessert of the western part of South America, in Peru and northern Chile. Also shows a strong annual wave in western Argentina and mean values between 60 to 90 days over central Brazil and north western Argentina (see Rusticucci and Penalba, 2000 for a better description of the precipitation regimes over Southern South America). The ensemble, for instance, tries to represent this, loosing some climatic regimes. Giving a east-west difference in regimes overestimating the dry periods in the east, underestimating over the west (not exactly related to the Andes). The ensemble overestimate in general over the La Plata Basin and northern Brazil, and underestimate in the Pacific coast of the continent as well as in southern Argentina.

As it can be seen in the Figure 6, the Mean Square Error (MSE) relative to the mean value of the observed index, for each model, show that most of the models fails over La Plata Basin region and western coast of South America, with the exception of NCAR.

In the next Figure 7, the frequency distributions of MSE per model split into intervals show that in some models the mode of the MSE are over 100%. So, the representation of the CDD is so difficult in general.

3.2. Interannual variability

We identify the interannual variability using the standard deviation of the observed and modelled indices. The comparison of observed and simulated interannual variability show in general, that models better represent the interannual variability in those indices were the mean values are better represented, like Tn90 and R95t.

These examples shown in Figures 8 and 9 illustrate also differences among models. In the Figure 8, observed warm nights interannual variability lies between 2 to 4% in

Southern South America, more than 4 up to 20% in tropical regions. The models represent this North-South pattern.

In the Figure 9, it can be seen that the regions with the highest R95t interannual variability are well represented.

4 DISCUSSION

In this paper we investigate the mean values and variability of observed and simulated indices for extremes in South America, for present climate defined as 1961-2000. For FD, if we center the analysis in the Southeast of South America, a low land region which has more dense information, one sees that the average value is well simulated, the station values has similar values over regions, and are of the same order of magnitude, as in case of the models. But over tropical regions, were there is no frost at all, some models give a number of occurrences different from zero.

The other temperature index analyzed is the number of warm nights per year. In some cases, warm nights average values are well simulated. In comparison the number of warm nights are better represented that the FD. The interannual variability pattern is also in good agreement with the observed values.

For precipitation, the index that is best represented by the models is the R95t. This index relates the extreme precipitation to the local climate, and the models could capture that. The consecutive dry days or the number of days over a fixed amount (R10) are more difficult to be simulated, since the region has a marked precipitation gradient that is not properly represented. The maximums of dryness observed over central Argentina Andes or the extensive dry season of the Amazon could not be represented for any model.

Warm nights and the extreme precipitation events, both indices relative to the local climate are the best represented by the GCMs.

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Figures Caption

Figure 1: Observed and ensemble means 1961-2000 and difference between them (Observed minus Ensemble),units: percentage over the observed. Warm nights (Tn90 index): number of days per year when the minimum temperature was over the 90th percentile calculated over 1961-1990.

Figure 2: The same as Figure 1 except for FD: number of days where the minimum temperature was below 0ºC

Figure 3: The same as Figure 1 except for R10: number of days where the precipitation was over 10 mm/day.

Figure 4: The same as Figure 1 except for R95t fraction (%) of annual total precipitation due to events exceeding the 95th percentile

Figure 5: The same as Figure 1 except for Consecutive Dry Days (CDD)

Figure 6 Mean Square Error (% over observed index) calculated over 1961-2000 for each GCM.

Figure 7: frequency (%) distribution of MSE for each GCM

Figure 8: Interannual index variability. Centre: Observed Warm nights, Other: Model results.

Figure 9: Idem Figure 8 but for R95t

Tn90

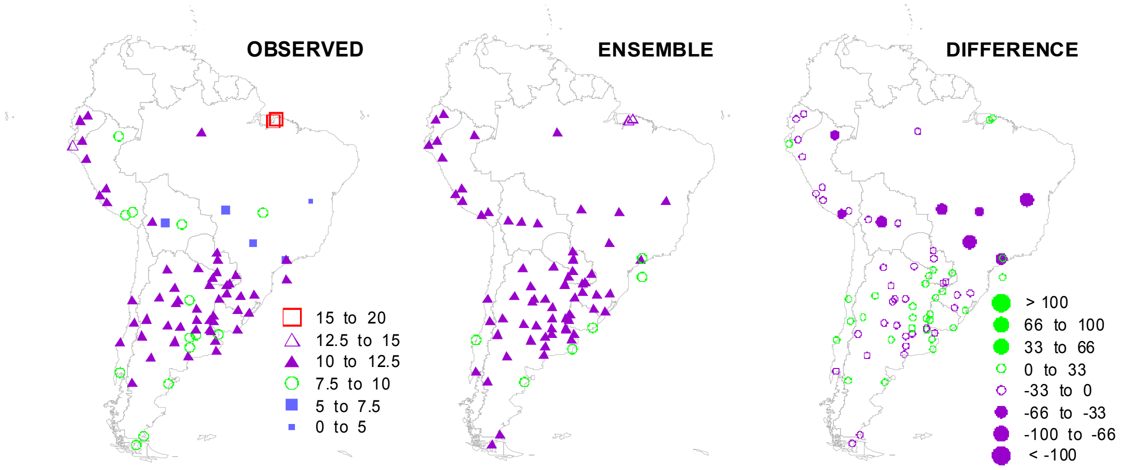
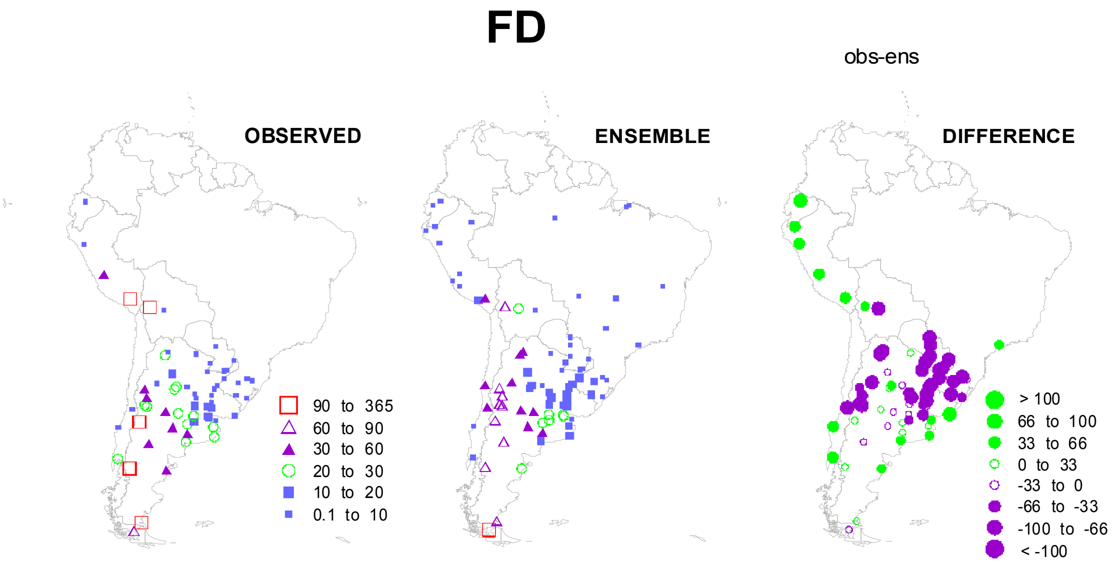


Figure 1


FD
obs-ens
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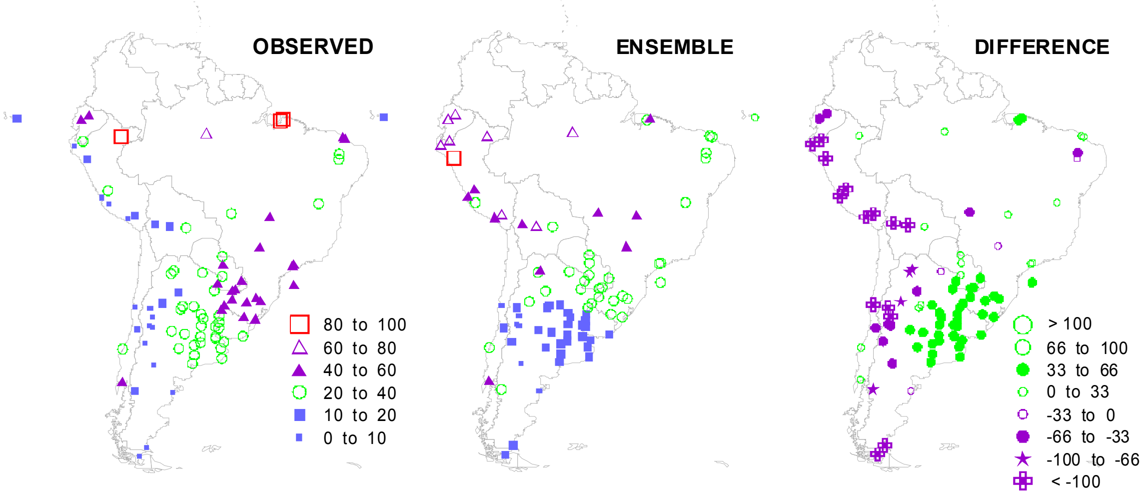
ENSEMBLE
DIFFERENCE
90 to 365
60 to 90
30 to 60
20 to 30
10 to 20
0.1 to 10
> 100
66 to 100
33 to 66
0 to 33
-33 to 0
-66 to -33
-100 to -66
< -100

Figure 2

R10


OBSERVED
ENSEMBLE
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20 to 40
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66 to 100
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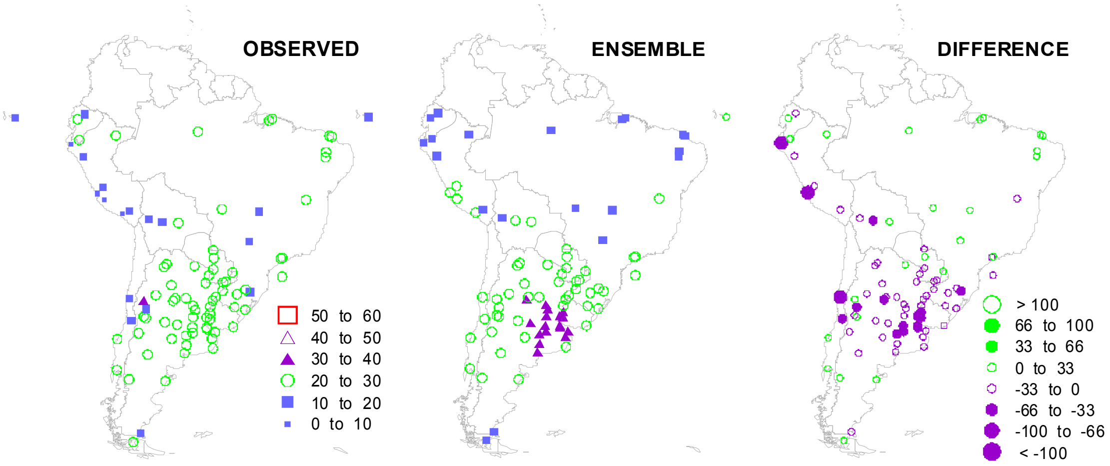
< -100

Figure 3

R95t



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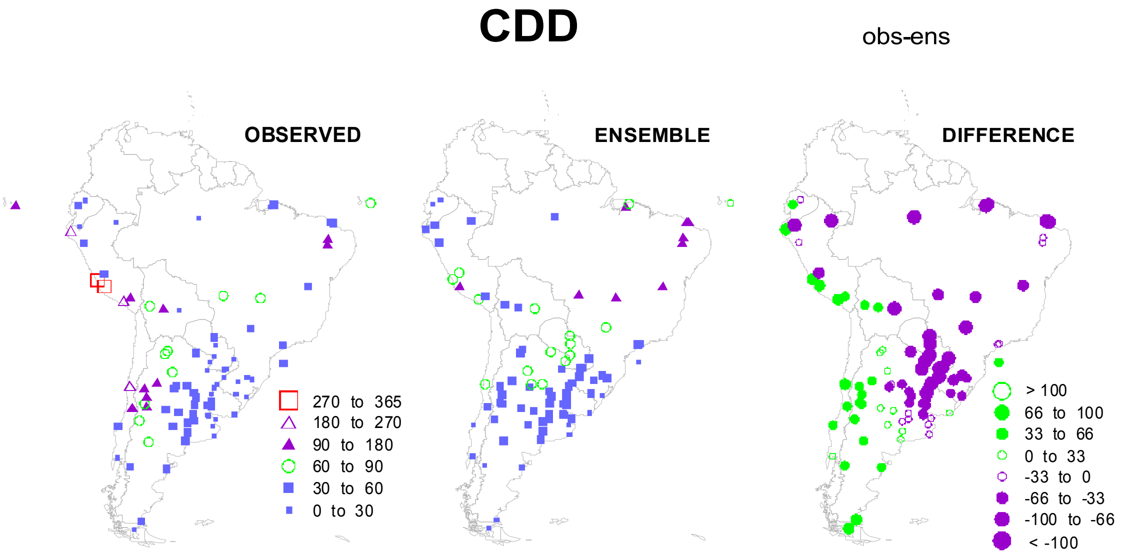
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obs-ens
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ENSEMBLE
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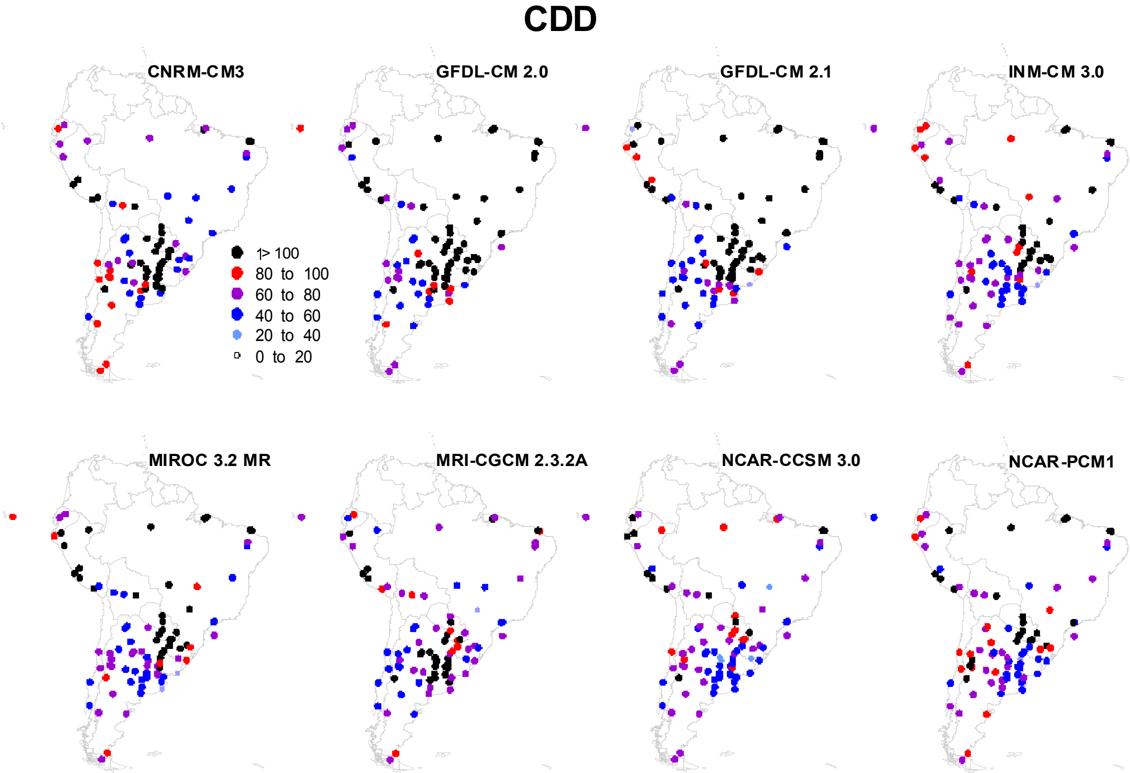
0 to 33
-33 to 0
-66 to -33
-100 to -66
< -100

Figure 5


CDD
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GFDL-CM 2.1
INM-CM 3.0
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80 to 100
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0 to 20
MIROC 3.2 MR
MRI-CGCM 2.3.2A
NCAR-CCSM 3.0
NCAR-PCM1

Figure 6

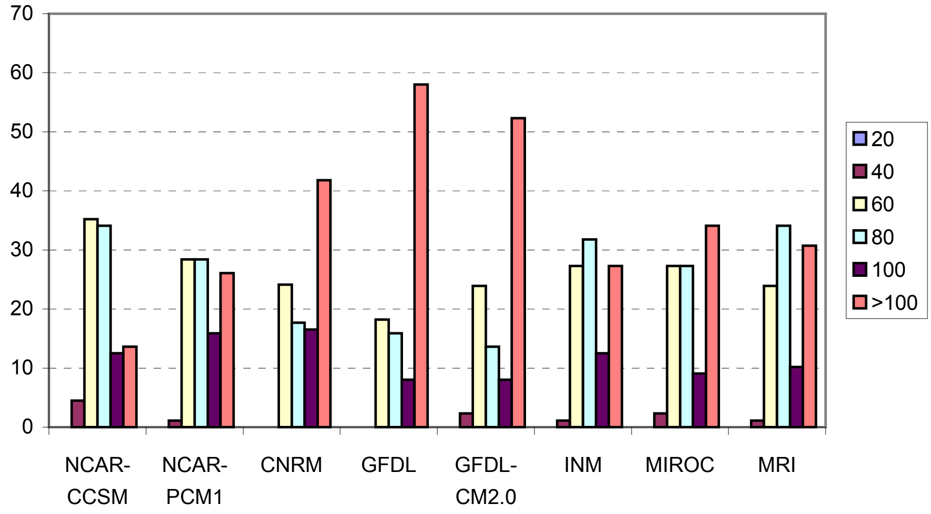
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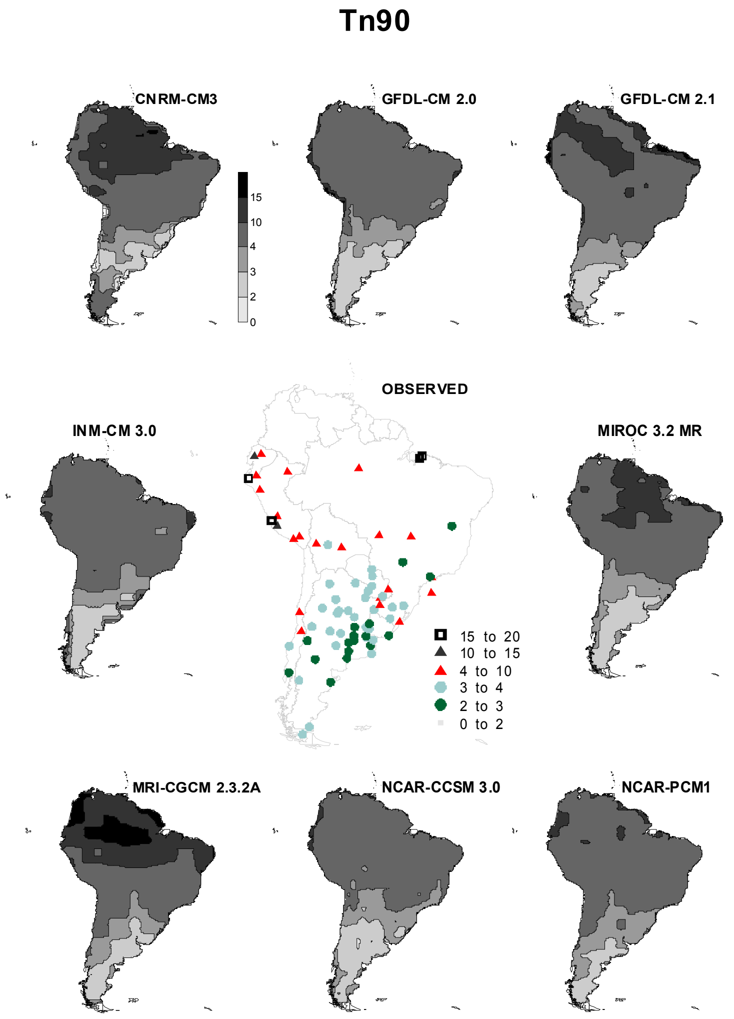
Figure 7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MIROC 3.2 MR
15 to 20
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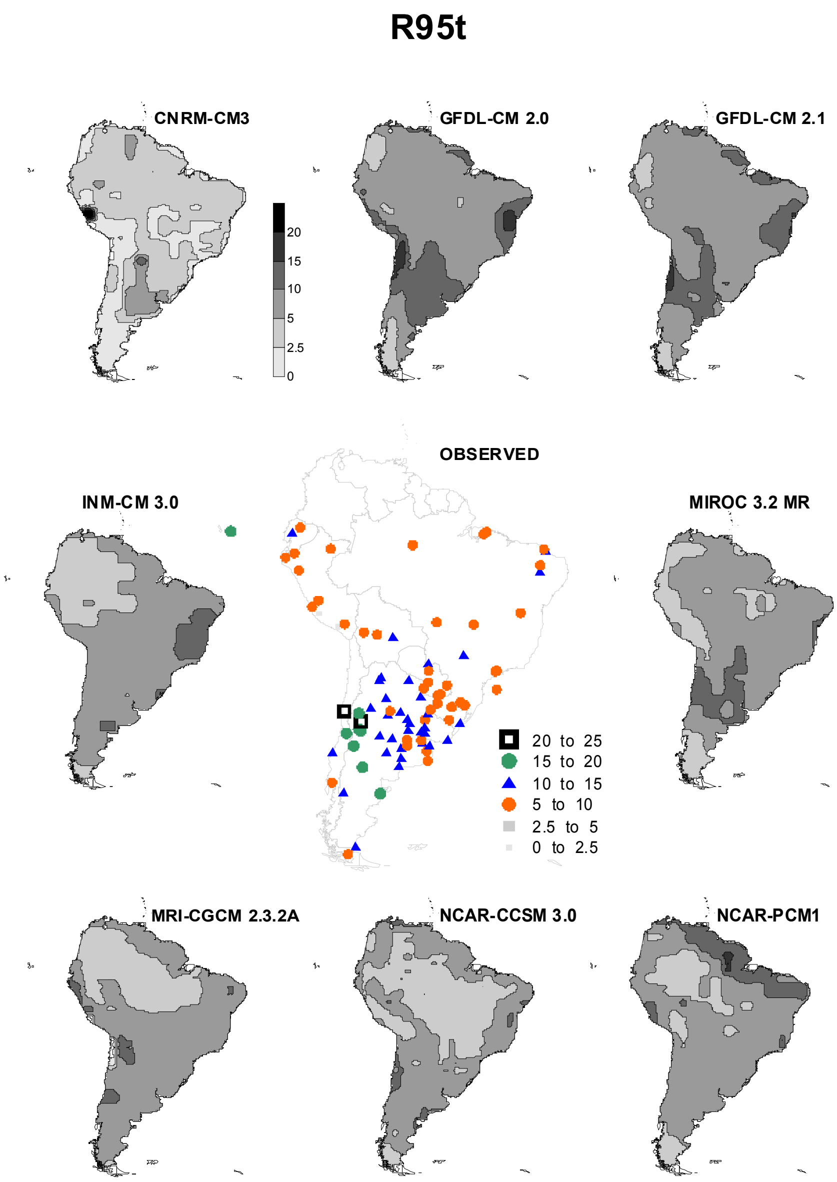
4 to 10
3 to 4
2 to 3
0 to 2
MRI-CGCM 2.3.2A
NCAR-CCSM 3.0
NCAR-PCM1

Figure 8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2.5
0
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MIROC 3.2 MR
20 to 25
15 to 20
10 to 15
5 to 10
2.5 to 5
0 to 2.5
MRI-CGCM 2.3.2A
NCAR-CCSM 3.0
NCAR-PCM1

Figure 9