CLARIS | LPB
A Europe-South America Network for Climate Change Assessment
And Impact studies in La Plata Basin

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Deliverables

Instrument: **SP1 Cooperation**

Thematic Priority: **Priority Area 1.1.6.3 "Global Change and Ecosystems"**

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CLARIS LPB
A Europe-South America Network for Climate Change Assessment and Impact Studies in La Plata Basin

DELIVERABLES

D4.8: Final evaluation report/papers on the projected precipitation trends and decadal changes in the LPB during the next decades and the links to uncertainties in the projected low-frequency changes in tropical and subtropical SSTs and in changes of the main elements of the SAMS.

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Organization name of lead contractor for this deliverable: P1-IRD

Copy as in DoW table:

Deliverable No	Deliverable title	WP	Lead beneficiary	Estimated indicative person-months (permanent staff)	Nature	Dissemination level	Delivery date
D4.8	Final evaluation report/papers on the projected precipitation trends and decadal changes in the LPB during the next decades and the links to uncertainties in the projected low-frequency changes in tropical and subtropical SSTs and in changes of the main elements of the SAMS.	WP4	P1-IRD	21,30	R	PU	36

Report

We have analyzed the observed variability on interdecadal time scales and trends in order to have a basis for assessing the performance of models. Several techniques have been used, including EOF techniques, neural and complex networks. Interdecadal variability was diagnosed in observed and proxy longer term timeseries. Key findings include the occurrence of a “climate shift” in the mid-1970s in all the analyzed climatic quantities from local to continental scale and from extreme events to longer term cycles and trend. The occurrence of extreme events (drought, floods) increased over the La Plata region and precipitation decadal variability experienced a persistent phase reversal in response to tropical and extra tropical remote influences. Here we present some results and a list of publications.

The continental scale modes of rainfall interdecadal variability have been determined and connected with global modes of SST, such as the Interdecadal Pacific Oscillation, the Atlantic Multidecadal Oscillation and regional SST modes. A tendency to inversion of anomalies has been detected on interdecadal time scales from spring to summer in parts of LPB, in spite of the persistence of SST anomalies. This indicates that, besides changing teleconnections from one season to the next, the interdecadal variability might undergo influence from surface-atmosphere interactions (Grimm and Saboia 2011, in preparation), as found on interannual time scales.

The impact of La Niña on summer precipitation in LPB changed in the mid1970s: it has a stronger impact after this date. Warmer SST conditions in the Indian Ocean during post 1979 La Niña events explain a large portion of the associated upper level atmospheric circulation differences (Cazes-Boezio and Talento 2011).

Most WCRP-CMIP3 models tend to show weak interdecadal variability compared to observations. Specifically, for HadCM3, IPSL and ECHAM5 models the simulations for the XX century show that the most relevant modes of interanual variability of fields related to La Plata Basin climate are comparable in several aspects to the respective modes obtained from observations and analysis. The simulated modes also show interdecadal variability also comparable to a certain extent to that of the observed modes. For example, the coupled model HadCM3 has a Pacific Decadal Oscillation-like structure with a 16-20 years cycle that is also present in the real world. Moreover, the simulated precipitation changes in LPB associated with this pattern resemble those in observations (Figure 1).

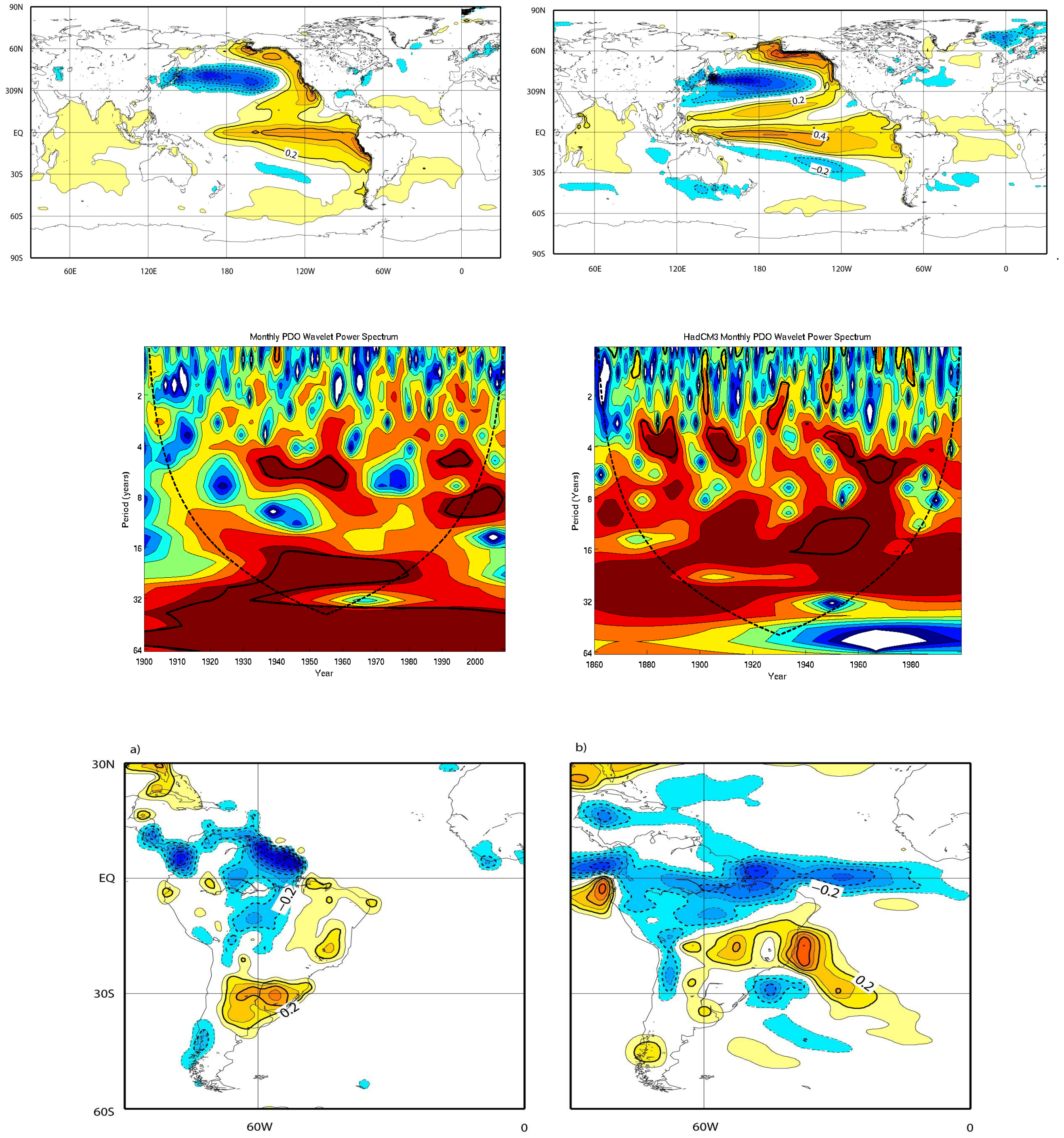


Figure 1 – Pacific Decadal Oscillation in observations (left panels) and HadCM3 model (right panels). Upper: SST structure; Middle: Wavelet analysis of PDO time series; Lower: Linear regression of rainfall in DJF on PDO time series.

One particularly important task of CLARIS is to estimate, with the greatest likelihood as possible, the long term trends of precipitation and temperature within La Plata Basin and the interdecadal variability of these variables. For a given period (for example a decade), low frequency variability can contribute to the uncertainty of climatic projections. The ratio between the change due to long term trends (after some years) and the dispersion of the low frequency oscillations can give an idea about how much time it takes to a projected trend to overcame these source of incertitude.

If we want to asses trends, low frequency variability and their ratio for climatic projections of precipitation and temperature, we could use the regional model simulations performed by WP5. Ultimately it is important to determine how much additional information provide RCM compared to GCM on long time scales. For each one of the models HadCM3, ECHAM5 and IPSL there is at least one continuous regional simulation for South America for the whole XXI century, considering the A1B IPCC4 scenario.

In figure 2 we show, as an example, for a particular region of La Plata Basin, the A1B projections of total precipitation from October to March (austral spring and summer) obtained with PROMES regional model using HadCM3 data, LMDZ model using IPSL data and the Rossby Centre of Sweden regional model (RCRM) using ECHAM5 data. There is one simulation from mid XX century to late XXI century for PROMES-HadCM3 and for LMDZ-IPSL, and three for the RCRM-ECHAM5. The region considered is South Eastern South America (SESA), defined as the land portion between 60ºW and 50ºW and between 36ºS and 25ºS. Figure show the Lanczos low pass variability of SESA precipitation with periods larger than 20 years and the linear trend, for each pair of models. We also show an equivalent analysis with CRU data from 1901 to 2008. The horizontal and vertical scales of all these four plots are the same, so the trends and low frequency amplitude can be compared visually. It is found that the three systems of simulation show important low frequency variability, and positive linear trends. The linear trends shown by LMDZ-IPSL and RCRM-ECHAM5 are comparable to that of CRU data, while that of PROMES-HadCM3 is about half the observed value.

It also can be noticed that the CRU data mean from 1961 to 2008 is about 800 mm (actually 818 mm). PROMES-HadCM3 and LMDZ-IPSL show lower mean values for this period (590 mm and 576 mm respectively), while RCRM-ECHAM5 show a larger value (898 mm). This suggests that the quantitative use of climatic projections obtained from simulations requires at least some sort of correction of their biases respect to the observed climate during comparable periods.

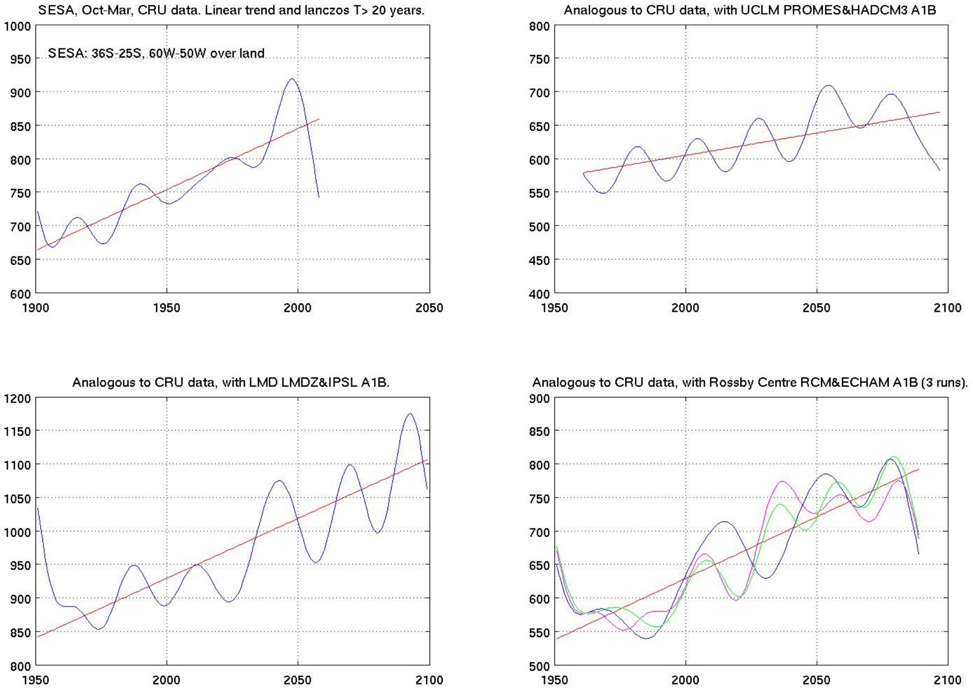
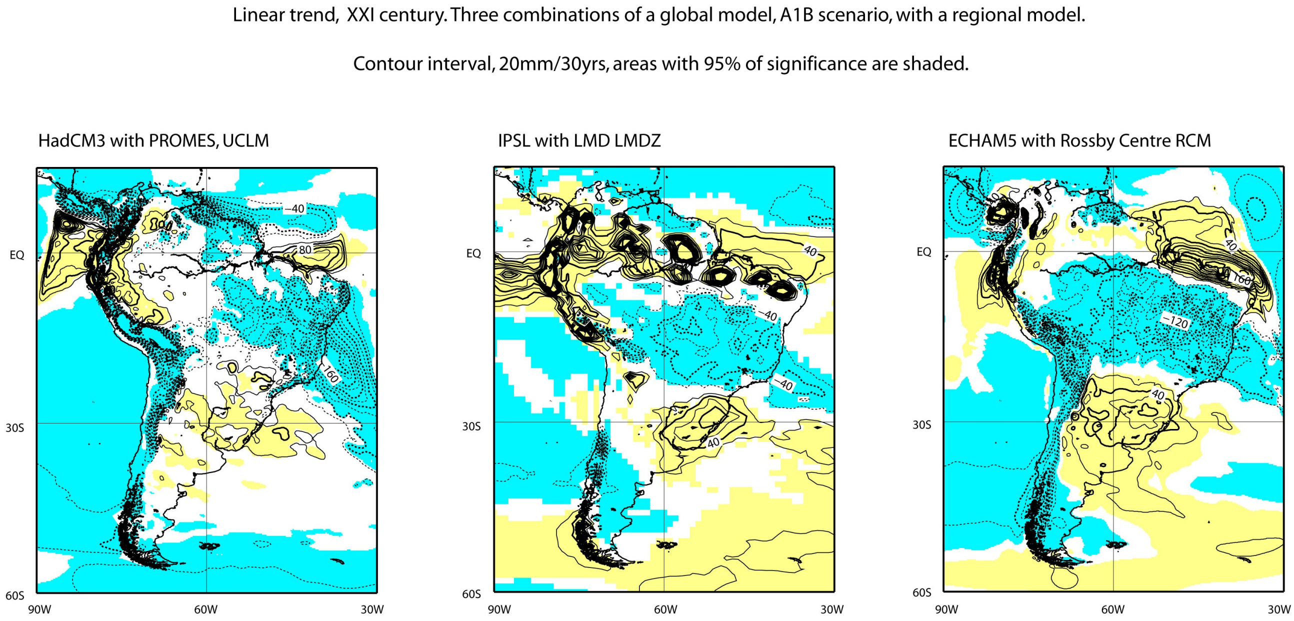


Figure 2 - Linear trend and low frequency variability variability (Lanczos low pass filter, T>20 years) of October-March precipitation in SESA (measured in mm), for CRU data, during the XX and early XX1 century and for PROMES-HadCM, LMDZ-IPSL and RCRM-ECHAM5 A1B simulations from mid XX century to late XXI century.

Figure 3 shows the geographical distribution in South America of the change in October-March precipitation due to 30 years of linear trend for the PROMES-HadCM3, LMDZ-IPSL and RCRM-ECHAM5 A1B XXI century projections. The areas were linear trend is statistically significant to a level of 95% are shaded. (Statistical significance is computed through a Student test of the correlation coefficient between the precipitation time series at each grid point and its linear trend.)



Linear trend, XXI century. Three combinations of a global model, A1B scenario, with a regional model.

Contour interval, 20mm/30yrs, areas with 95% of significance are shaded.

HadCM3 with PROMES, UCLM

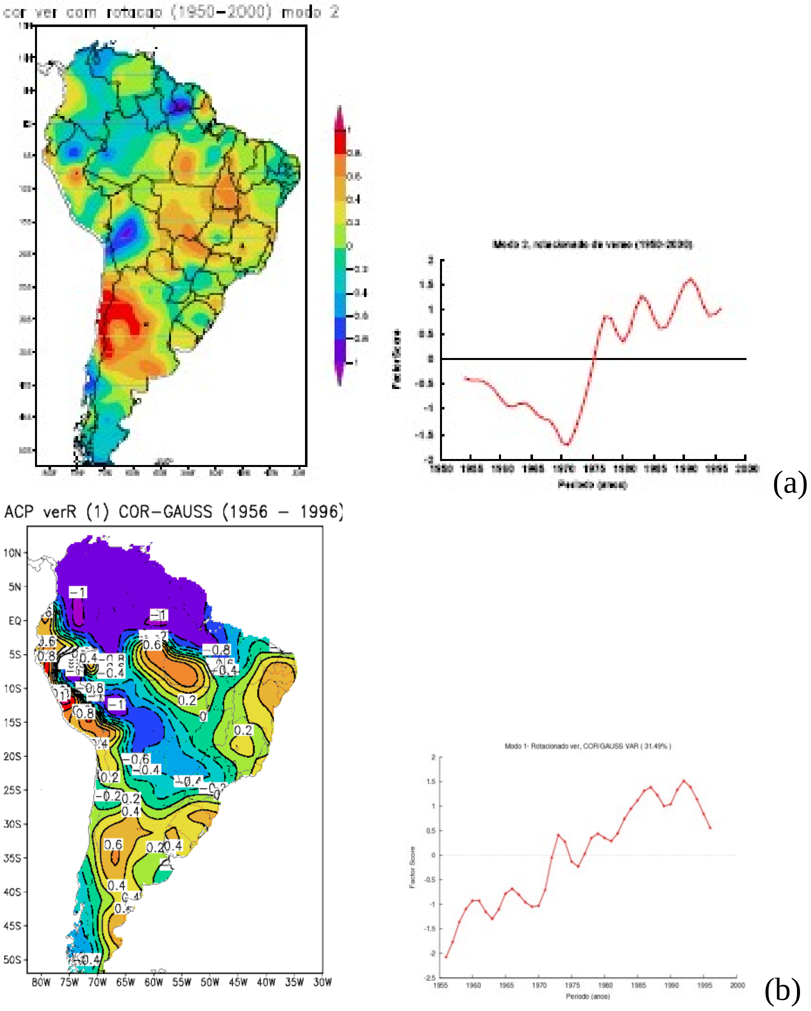
IPSL with LMD LMDZ

ECHAM5 with Rossby Centre RCM

Figure 3 - Change due to 30 years of linear trend of October-March precipitation in South America for PROMES-HadCM, LMDZ-IPSL and RCRM-ECHAM5 A1B simulations from mid XX century to late XXI century.

The patterns of the trends are similar for the three models, although there are differences in their magnitudes. There are statistically positive trends at the South of La Plata Basin for the three systems. These positive trends are more extended and larger for RCRM-ECHAM5, quite extended but lower for PROMES-HadCM3 and relatively large but concentrated at the east for LMDZ-IPSL. The three systems also show statistically significant, negative trends, northward La Plata basin, mostly outside the region. However, the low trend found at the northern part of La Plata basin makes it advisable to analyze this region with further detail, particularly if such lack of trend is uniform for the whole simulated period, or there are distinguishable sub periods. Currently we are preparing results as the ones showed here for different seasons, sub regions, and for temperature (which affects evapotranspiration). These results will be made public through CLARIS web page.

The interdecadal rainfall variability in LPB was also investigated using AGCMs. The LMDz model shows modes of variability that account for the interdecadal variability in several regions, for instance the Laguna Mar Chiquita basin in Argentina, although not all the features in the model modes correspond to the features in the corresponding observed modes. The best correspondence between the model and the observed variability happens in the first spring mode. The mid 1970's climatic shift corresponds to a change of phase in the interdecadal variability both observed and simulated. For instance, the second observed summer mode (Fig. 4a) and the corresponding first summer mode obtained from the model (Fig. 4b) both show a change of phase in the mid 1970's, with strong components in the Laguna Mar Chiquita basin, although there are differences in the components of this mode over other regions (Grimm and Saboia 2011, in preparation). The same atmospheric model, however, misses important features such as the tendency for rainfall anomalies in spring and summer to have opposite anomalies in central-east South America, produced by local surface-atmosphere interactions.



(a)

(b)

Figure 4 - (a) Second mode of interdecadal variability of observed summer precipitation. (b) First mode of interdecadal variability of summer precipitation from the model.

The South American monsoon also shows a climate shift in the mid 1970s: the monsoon starts earlier and finishes later so that after the '70s the mean length has increased to about 195 days (Figure 5). Overall, WCRP-CMIP3 models can represent correctly the spatiotemporal characteristics of the annual cycle of precipitation in central and east Brazil, such as the correct phase of dry and wet seasons, onset dates, duration of rainy season and total accumulated precipitation during the summer monsoon. The models do not indicate significant changes in monsoon onset and demise under the A1B scenario (Carvalho et al. 2011; Bombardi and Carvalho 2009).

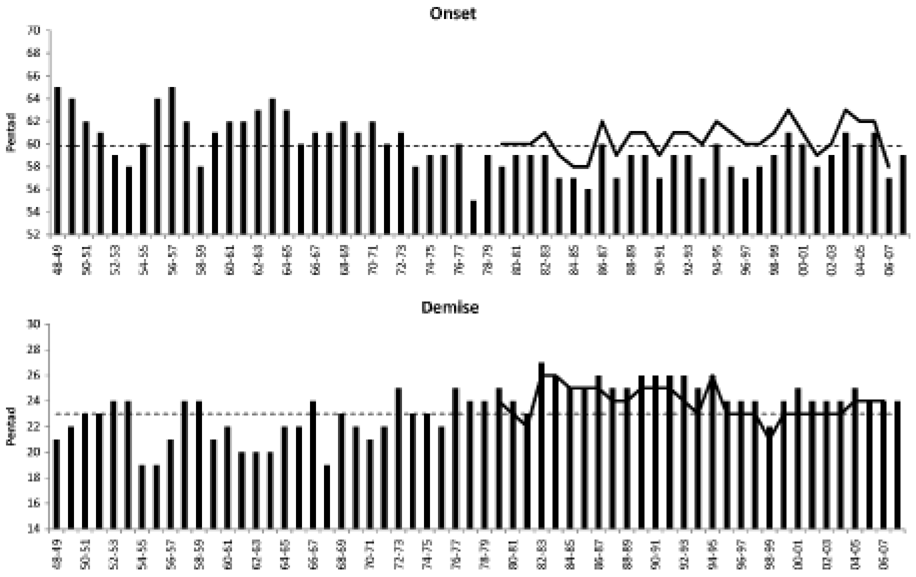


Figure 5 - Onset (top) and demise (bottom) of SAMS. Dates are given in pentads. Horizontal dashed lines are long-term averages (pentad 60: 23–27 October; Pentad 23: 21–25 April). From Carvalho et al 2011.

The observed daily circulation patterns in southern South America that are associated with rainfall conditions in the Pampas were identified. Also, after assessing the skill of the models in simulating these relationships in the XX century, the projected changes for the XXI century were calculated. WCRP-CMIP3 models are found to reproduce the full range of summer and winter circulation types found in NCEP Reanalysis. Moreover, models represent correctly the frequency of atmospheric situations that favor summer dry days in the present climate and under the A1B scenario show a trend in the reduction of circulation patterns associated with dry days and an increase in the frequency of patterns associated with rainfall (Penalba and Betolli 2011).

Despite the WCRP-CMIP3 models' biases in simulating precipitation over the LPB region, it has been possible to use them to understand the physical processes associated with the South America climate. Here we present a study for summertime, a season that is overall well simulated and the one in which models have projected a rainfall positive trend. Figure 6 shows the projected changes in mean DJF precipitation for the end of the XXI century by a multi-model mean under A1B scenario. It shows a dipole-like structure with increased precipitation in LPB and decrease to the north of it (see also Figure 3). That rainfall change pattern has been related to an increase in the occurrence of the positive phase of the leading summertime pattern (EOF1) of interannual variability (Junquas et al. 2011). The behavior of this mode of variability is nonlinear though. There is a very small trend in rainfall anomalies before 2050 and only afterwards the trend becomes clear. These results then suggest that the behavior of the modes of variability under radiative forcing is not necessarily linear. According to these results internal variability would dominate during the first 50 years of the XXI century and the trend only overcomes natural variability in the second part of the century.

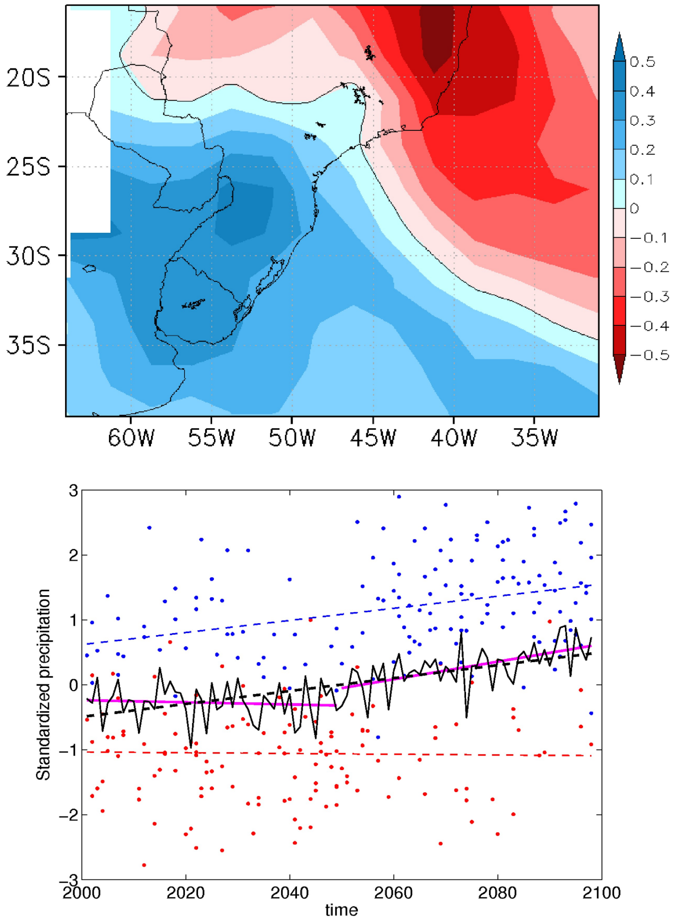


Figure 6 – (Upper panel) Differences of the mean DJF rainfall between 2050-2098 and 2001-2049 periods. The difference is standardized by the total number of years. Contour interval is 0.2 mm/day and black contour indicates the 0 level. (Lower panel) Temporal evolution of the standardized DJF rainfall in Southeastern South America from 9-model mean during the XXI century and its linear trend. The linear trends for the two halves of the XXI century are also shown. Blue (red) dots correspond to rainfall anomalies associated to each of the positive (negative) events of the first EOF of rainfall in the region for each of the models (modified from Junquas et al 2011).

Given above results we focused more closely on one of the models that show the behavior described in figure 6, and asked the question on when is it possible to determine that the simulated changes in the EOF1 of precipitation are due to anthropogenic forcing? To do so we examined the model variability in the preindustrial experiment, a run that does not have any external forcing and thus should only contain internal variability in the ocean-atmosphere system. We found that, even in the absence of forcing, the EOF1 can show two different behaviors characterized by different pdfs depending on the ocean-atmosphere interaction in the tropical Atlantic: in the presence of weak interaction the pdf is wide and the maximum rainfall is over the continental part of the SACZ. In the presence of strong air-sea feedback (between SACZ cloudiness and SST) the pdf is strongly unimodal and the maximum in precipitation is over the ocean. We next compared the evolution of the distributions of EOF1 under anthropogenic forcing, and found that depending on the pre-industrial distribution used it is possible to determine changes in the pdf almost immediately at the beginning of the 21st century, or only after more than 20 years later (Figure 7). These results stress the need for a better description and understanding of internal climate variability.

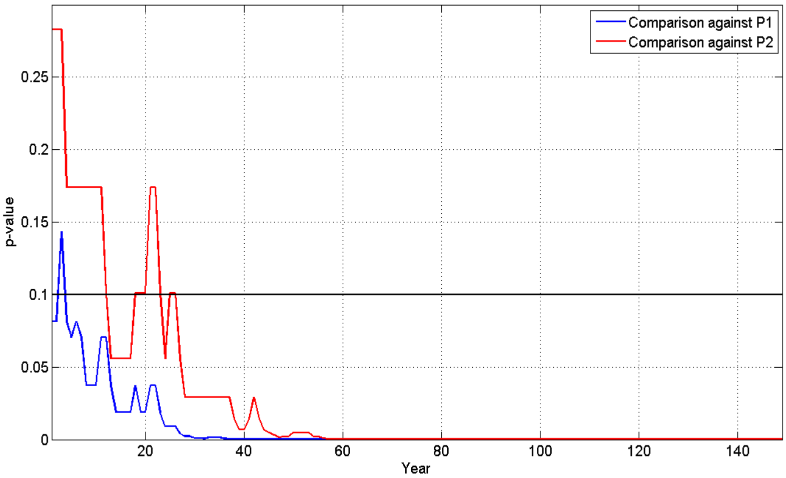


Figure 7- p-values of Kolmogorv test (10% significance level) comparing A1B EOF1 distribution (taking 50 years-window) with preindustrial EOF1 distribution in P1 (strong air-sea interaction) or P2 (weak air-sea interaction). The distributions are different if the p-value is smaller than 0.1. This study uses the HadCM3 model.

Publications

Authors: Bombardi, R. and L. M. V. Carvalho, 2010
Institutions: Universidade de Sao Paulo, Brazil; University of California Santa Barbara, USA.
Title: The South Atlantic dipole and variations in the characteristics of the South American Monsoon in the WCRP-CMIP3 multimodel simulations.
Journal: *Climate Dynamics* DOI 10.1007/s00382-010-0836-9

Authors: Carvalho, L. M. V., C. Jones, A. E. Silva, B. Liebmann, P. L. Silva Dias, 2010
Institutions: Universidade de Sao Paulo, Brazil; University of California Santa Barbara, USA.
Title: The South American Monsoon System and the 1970s climate transition.
Journal: International Journal of Climatology, DOI: 10.1002/joc.2147

Authors: Cazes-Boezio G., and S. Talento, 2011
Institutions: Universidad de la República, Uruguay
Title: La niña events before and after 1979 and their impact over southeastern South America in summer. The role of the Indian ocean.
Journal: *International Journal of Climatology* (under review).

Authors: Cherchi, A., A. Alessandri, S. Masina, and A. Navarra, 2010
Institutions: Centro Euro-Mediterraneo per i Cambiamenti Climatici/Istituto Nazionale di Geofisica e Vulcanologia., Italy.
Title: Effects of increased CO2 levels on monsoons.
Journal: *Climate Dynamics*, doi: 10.1007/s00382-010-0801-7

Authors: Junquas C., C. Vera, L. Li and H. Le Treut, 2011
Institutions: Universidad de Buenos Aires, Argentina; Laboratoire de Météorologie Dynamique, Institut Pierre Simon Laplace, France.
Title: Summer precipitation variability over Southeastern South America in a global warming scenario.
Journal: *Climate Dynamics*, doi:10.1007/s00382-011-1141-y.

Authors: Penalba, O. C. and M. L. Bettolli, 2011
Institutions: Universidad de Buenos Aires, Argentina
Title: Climate change impacts on atmospheric circulation and daily precipitation in the Argentine Pampas region
Journal: Climate Change / Book 1, ISBN 978-953-307-419-1, accepted.