DOWNSCALING DAILY RAINFALL IN LA PLATA BASIN: STATISTICAL APPROACH

M. Laura Bettolli[1,2,]* and Olga C. Penalba[1]
[1]Departamento de Ciencias de la Atmósfera y los Océanos, Universidad de Buenos Aires, Argentina
[2]Consejo Nacional de Investigaciones Científicas y Técnicas, Argentina

1. INTRODUCTION

Regional and global atmospheric models properly describe climatic features at subcontinental scales but their use for local impact studies is limited. This is due to their low spatial resolution and incapacity to represent important characteristics at subscale resolution as clouds, storms, precipitation, frosts and topography. Different productive sectors require climatic information at a local scale, specially taking into account the projected global changes for the 21st century.

An alternative to solve this problem is to apply empirical relationships between local climate and regional atmospheric systems. This procedure is known as downscaling.

Empirical downscaling is a widely used technique for exploring the regional and local-scale response to large-scale circulation. Different statistical techniques have been explored in many regions of the world as United States of America (Widmann et al., 2003), Europe (von Storch et al., 1993; Zorita and von Storch, 1999; Trigo and Palutikof, 2001; Gutierrez et al., 2004-a; Huth, 2002; Murphy, 1999, 2000, Schmidli et al., 2007; among others.), Australia (Schubert and Henderson-Sellers, 1997; Timbal and McAvaney, 2001) and Africa (Hewitson and Crane, 1996).

On the contrary, statistical downscaling has not been extensively developed for South America regions (Robertson et al. 2004-b; Cofiño et al. 2005). In particular for southern South America regions, Solman and Núñez (1999) estimated monthly mean, maximum and minimum temperatures using larger scales predictors by means of stepwise multiple regressions. Ruiz and Vargas (1998) studied the relation (by means of the biserial correlation) between the 500 hPa vorticity and rainfall in the city of Buenos Aires for the period 1983-1987. Ruiz (2004) extended the scope of this study to cover ten other cities distributed across Argentina. Ruiz and Vargas (2006) performed statistical downscaling of daily rainfall using discriminant analysis. Solman and Menéndez (2003), Bischoff and Vargas (2003), Bettolli et al. (2006) and Boulanger et al. (2008) used synoptic classification schemes to study their relationship with daily rainfall and temperatures in Argentina. Bettolli et al. (2008) estimated daily rainfall and maximum and minimum temperatures in the Basalto region (Uruguay) using the SDSM statistical downscaling method (Wilby et al. 2004) in order to study the vulnerability of pasture systems to climate change.

* *Corresponding author address:* M. Laura Bettolli, Departamento de Ciencias de la Atmósfera y los Océanos, UBA. Ciudad Universitaria, Pabellón 2 Piso 2. Buenos Aires, Argentina.; e-mail: bettolli@at.fcen.uba.ar

La Plata Basin spreads over 3200000 square km and is one of the most important agriculture and hydropower producing regions worldwide. In this region, extreme rainfall situations often occur, sometimes persistent and with a significant socio-economic impact. Therefore, the identification of atmospheric field-surface variable relationship, together with its probability of occurrence, are the basis for short and middle term forecasts that can be incorporated to impact models necessary for planning and decision-making.

The purpose of this work is to advance a further step towards the estimation of daily precipitation at local scales in La Plata Basin using large scale atmospheric circulation information by means of statistical downscaling methodologies.

2. DATA AND METHODOLOGY

2.1 Data

In order to conduct this study two dataset were used:

Six-hourly ERA 40 reanalyses dataset provided by the European Centre for Medium-Range Weather Forecast (ECMWF) with a 1.125º x 1.125º (lat. x lon.) resolution. Daily mean fields of 1000 and 500 hPa geopotential heights were used to estimate mean geostrophic 1000 and 500 hPa wind fields. The domain chosen extends from 20.25°S to 55.125°S and 84.375°W to 42.625°W and it was defined to encompass circulation patterns that affect Southern South America (Figure 1 a).

Daily rainfall series obtained from the National Weather Services of Argentina and Uruguay. The series are high-quality controlled records with 10% or less missing data. The locations of the meteorological stations used in this analysis are shown in Figure1 b.

Both reference (surface and atmospheric) datasets expand over the period 1960-2000 (14.974 days).

2.2 Methodology

The chosen method for downscaling precipitation is a two-step statistical method based on the identification of analogues (Zorita and von Storch, 1999; Schmidli et al., 2007).

In the first step, the analogue technique was used in order to select the n most similar days to each day. Standardised Euclidean distance was the similarity measure used., When selecting the n analogue days of each day, the days belonging to a temporal interval of 10 days, centred in the day of interest, were excluded from the reference dataset in order to avoid overlapping and presistence effects.

The second step involves the estimation of daily rainfall. Seasonal rainfall distributions were built considering the n analogues and their weights for each day.

In this study, 30 analogues were used, that is, n=30.

3. RESULTS

3.1 Spatial Variability

To assess the downscaling method performance, seasonal and annual estimated and observed fields of rainfall were compared. Left and central columns of Figure 2 show the spatial distribution of estimated and observed daily rainfall fields (in mm per day), computed on the basis of the daily values. In all cases, the spatial distribution of estimated fields is in agreement with the observed fields. The statistical model reproduces pretty well the spatial structure of isoline distributions and also the gradients.

Right column of Figure 2 shows the difference between estimated and observed fields. The estimation pattern changes depending on the season considered. The statistical method underestimates daily rainfall in all seasons except for winter, where daily rainfall is overestimated in almost the whole region. This result suggests that the dominant atmospheric circulation patterns during this season of the year are probably well captured by their analogues in the first step and the estimation technique overvalues the amount of daily rainfall in the second step. This could be due to the fact that the synoptic scale activity (associated with extratropical disturbances and mainly generating frontal precipitation) is higher in winter season, and therefore, being well captured.

During summer, the field of differences between estimated and observed rainfall shows an axis of values close to zero over the central zone of the region studied. In this zone rain is strong influenced by convective processes during this season which generally are not well captured by large scale predictors. However, this result suggests that rainfall is well represented by the estimation procedure. Differences increase towards the NW of the region probably due to rain forcings takes a thermal-orographic character in that direction because of the abrupt topography change.

Transition seasons (fall and spring) show similar patterns with a centre of high difference values in the central-eastern zone of the region studied.

3.2 Temporal Variability

A good performance requires not only an appropriate estimation of the spatial variability of daily rainfall but also an effective representation of the temporal variability. For this reason, temporal series of daily rainfall estimations were analysed and compared against observations in terms of the 90-day running mean. In order to give an example, Figure 3 shows temporal series of 90-day running mean of observed and estimated daily precipitation corresponding to Posadas Aero Station (27.37°S, 55.97°W), Marcos Juárez Station (32.70°S, 62.15°W), Gualeguaychú Station (33.00°S, 58.62°W) and Santa Rosa Station (36.57°S, 64.27°W). In order to increase the clarity of the graphic, only the period 1979-2000 is shown.

In all cases, the statistical model represents fairly well the observed inter and intra annual variability. It fails in estimating some extreme events depending on the meteorological station. For example, rainfall excesses in 1982 and 1983 in Posadas and Gualeguaychú stations and 1992 and 1993 in Marcos Juárez and Santa Rosa stations. Rainfall deficits are better represented instead.

The performance in capturing temporal variability is better in Marcos Juarez and Santa Rosa, located at the centre and west of the region studied respectively. Towards the east of the region the rainfall annual cycle gets more pronounced having summer preciptiation and strong seasonal variation. Performance declines towards the east portion of the region, as in Posadas and Gualeguaychú, where rainfall amounts are high throughout the whole year.

3.3 Annual Cycle

A detailed analysis of the annual cycle for precipitation has been performed. Figure 4 displays the estimated and observed mean annual cycle at Marcos Juárez and Gualeguaychú stations considering two periods: 1961-1970 and 1981-1990. The statistical method reproduces reasonably well the annual cycle in both periods. The estimation of the seasonal variation is better captured at Marcos Juárez station, being consistent with the previous findings.

Several authors have documented increases in the rainfall totals in the region studied (Castañeda and Barros, 2001; Penalba and Vargas, 2004; among others). In particular, studies on the trends of rainfall totals have shown that, along with this increase, it is possible to observe an increase in the number of extreme events (Penalba and Robledo, 2008) and a modification in the annual cycle (Rusticucci and Penalba, 2000), especially since the middle 1970s (Minetti et al, 2003; Penalba and Vargas, 2004). According to these findings, the change in the annual cycle of rainfall can be detected in the observed rainfall records for the decades chosen as can be seen in Figure 4. This change is well captured by the methodology proposed from the 1961-1970 decade to 1981-1990 decade. This very important characteristic of the precipitation regime in the region is well reproduced by the methodology proposed due basically to the nature of the selection of the analogue fields. These atmospheric fields are continuously updating the information since they are chosen from the whole data set period, instead of being selected from a cluster where the information has not a temporal feedback.

4. CONCLUSIONS

This study presents the results from a statistical downscaling method to estimate daily rainfall in La Plata Basin. The analysis was focused on evaluating the ability of the method in representing spatial and temporal variability of daily precipitation as well as the annual cycle.

The results show the great potentialities of the method, that is able to diagnose daily precipitation with a high level of accuracy and that would also be competitive in an operative forecasting framework. The performance of the method is very good at estimating seasonal cycles and spatial and temporal variability. Validation results show that the downscaling performance is good enough to allow its confident application over General Circulation Model outputs, in order to prospect possible climate evolution.

It is important to mention that the good consistency of the method performance is based on the physical linkages between the predictand and predictors and on the proper handling of the analogical stratification. It should be considered that geopotential height at two levels of the atmosphere is the only variable used as a predictor and the spatial domain used for the atmospheric fields, and its size, is fixed, that is, it is the same for all meteorological stations.

Future research will tend to improve uncertainties and errors of estimation through the inclusion of others atmospheric variables (dynamical and thermodynamical) and the variation of the spatial domain.

5. ACKNOWLEDGMENTS

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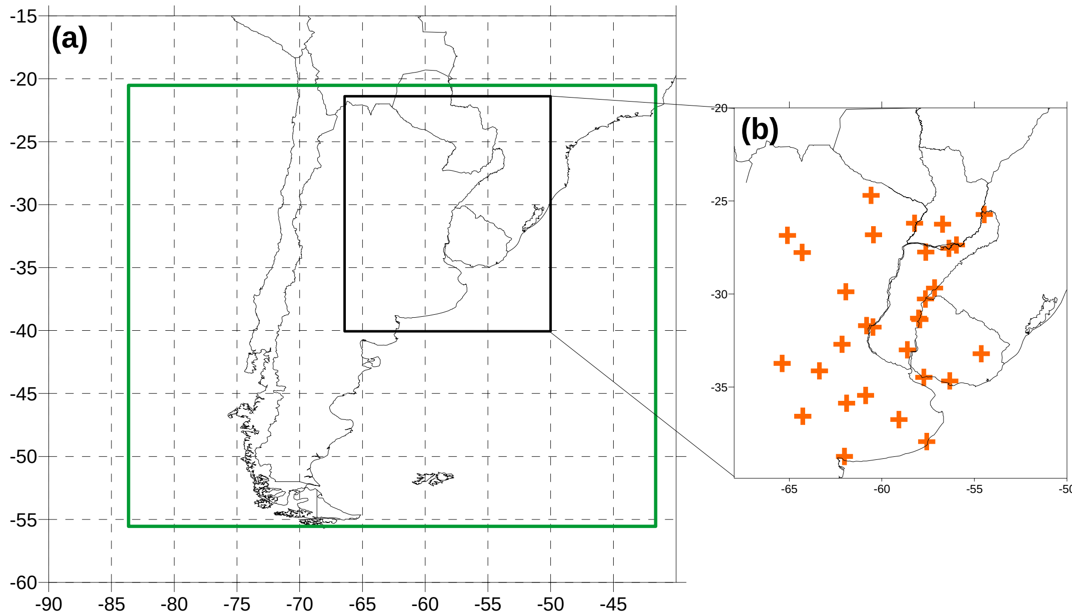

Figure 1. Domain for atmospheric variables (green rectangle) (a) and location of the meteorological stations used in this study (b).

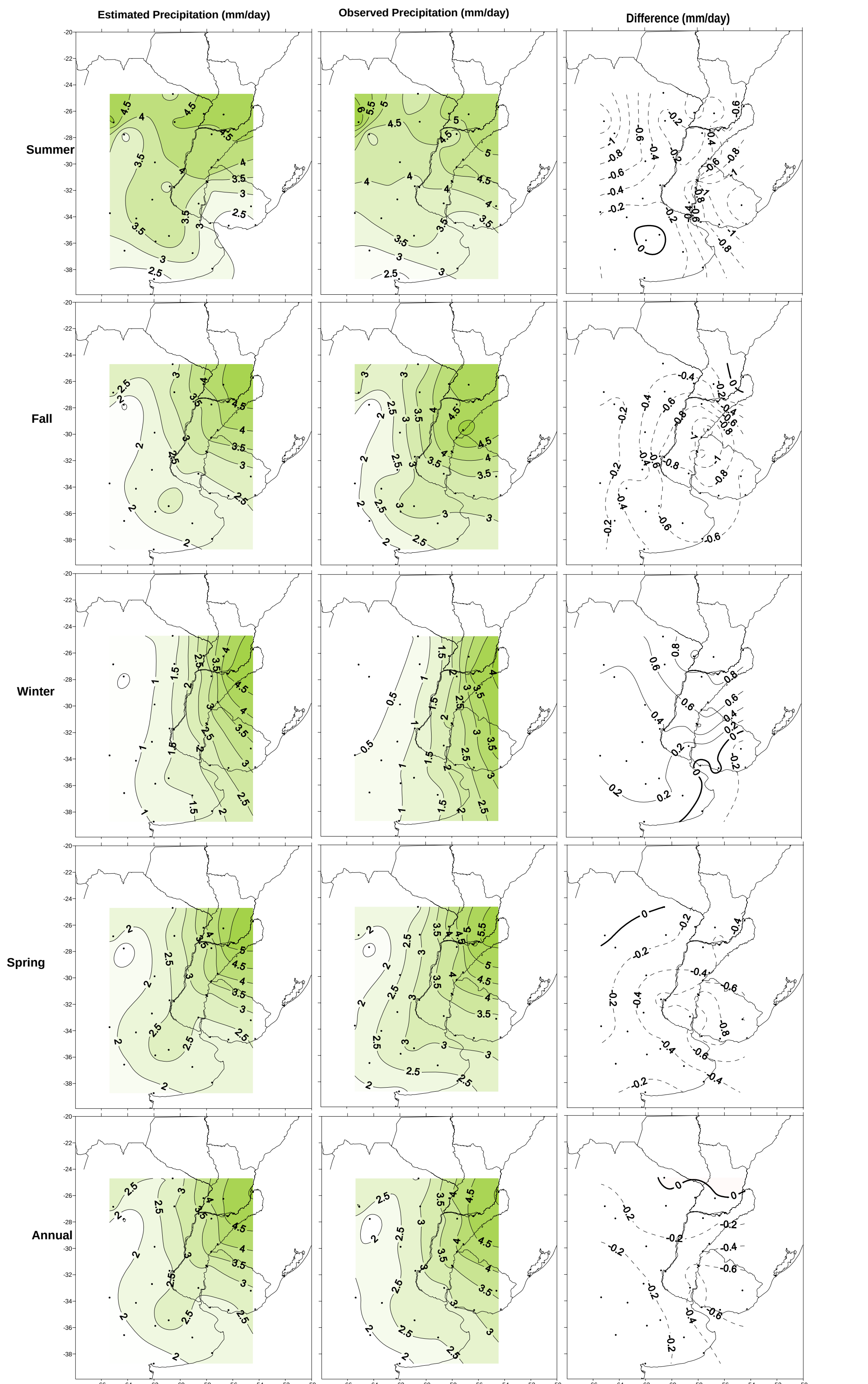

Figure 2. Annual and seasonal fields of estimated daily rainfall (left column), observed daily rainfall (central column) and difference between them (right column) in mm per day.

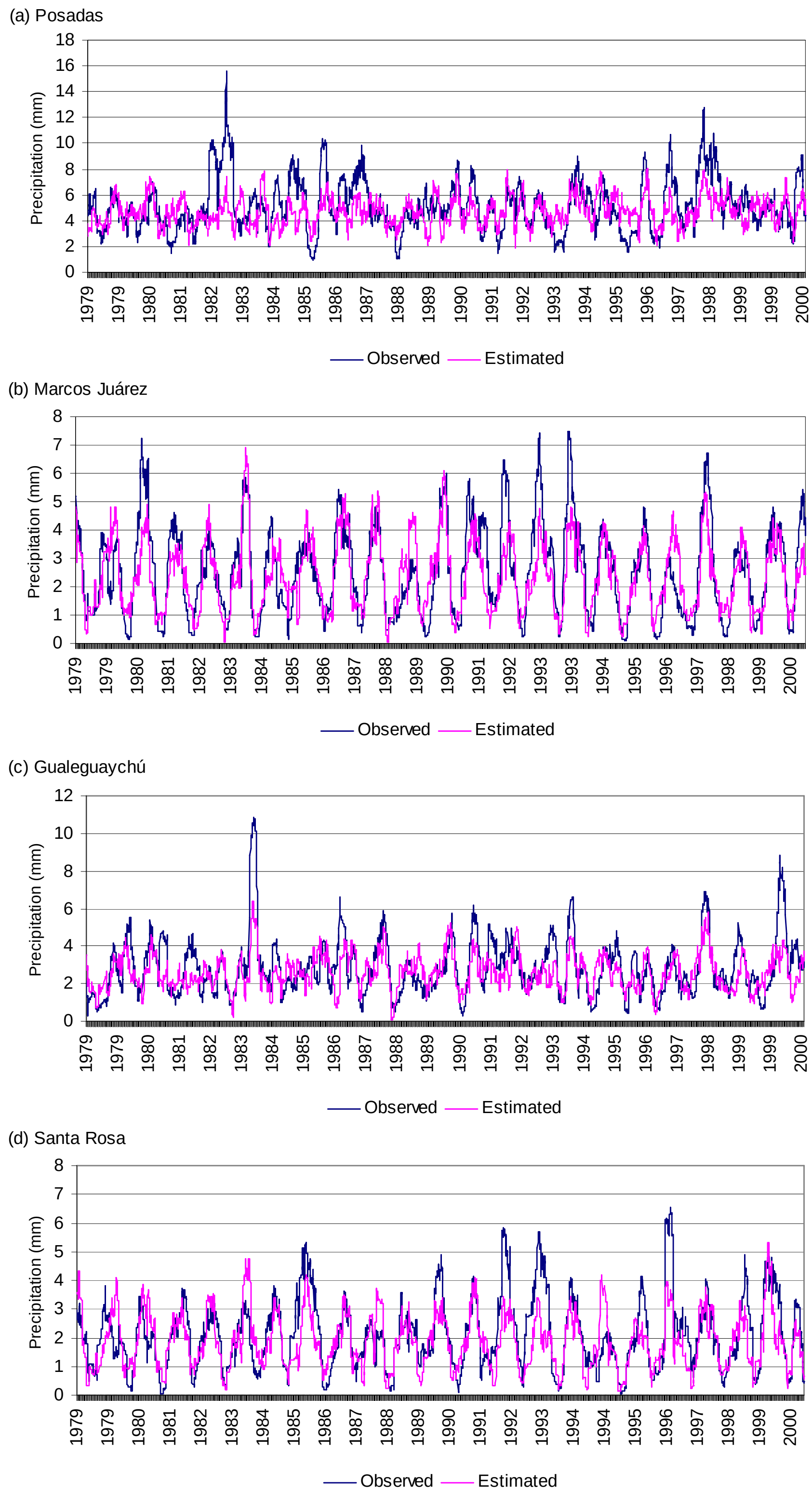

Figure 3. 90-day running mean of observed daily precipitation (blue line) and estimated daily precipitation (pink line) corresponding to Posadas Aero (27.37°S, 55.97°W) (a), Marcos Juárez (32.70°S, 62.15°W) (b), Gualeguaychú (33.00°S, 58.62°W) (c) and Santa Rosa (36.57°S, 64.27°W) (d).

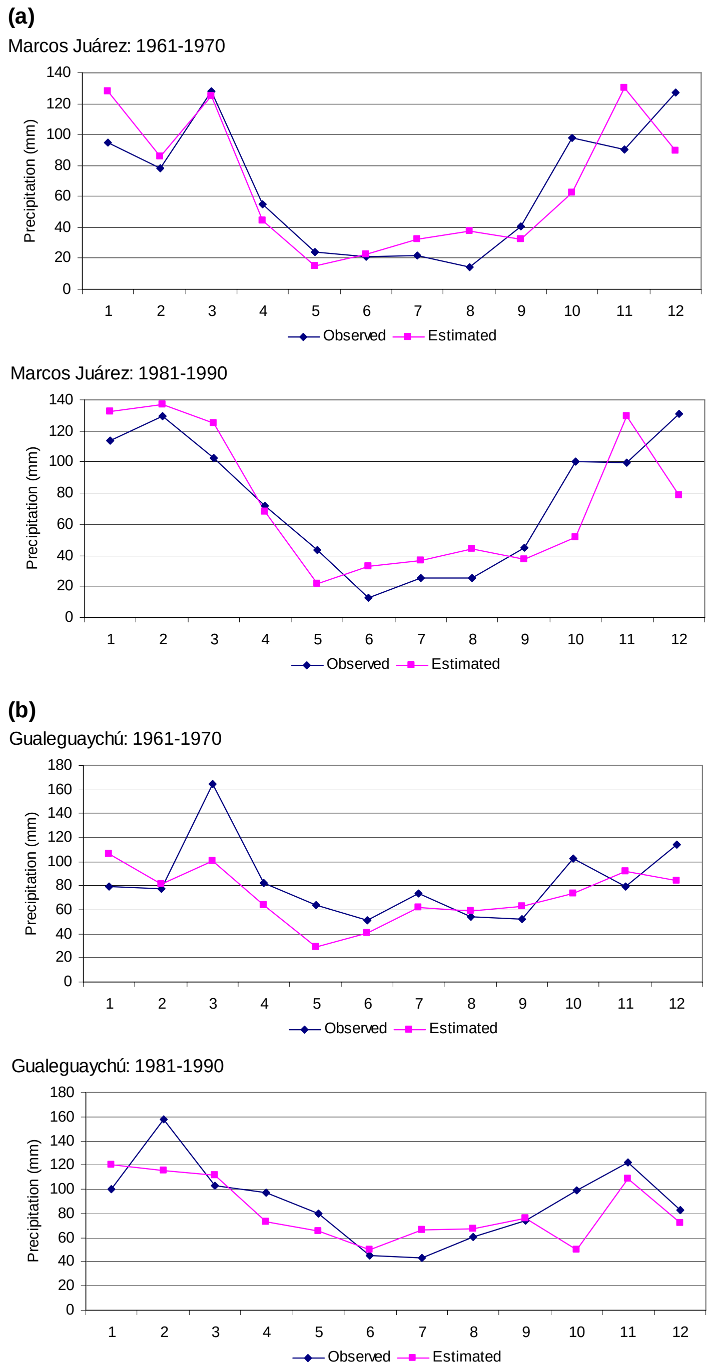

Figure 4. Mean annual cycle of precipitation for the periods 1961-1970 and 1981-1990 at Marcos Juárez Station (a) and Gualeguaychú Station (b).