VARIABILITY AND CLIMATE CHANGE IN THE CENTRAL PERUVIAN ANDES

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ABSTRACT

The present work is part of the "Integrated Local Assessment of the Mantaro River Basin" (ILA Mantaro), whose main objective was: to systematize and to extend the knowledge about climate change in the Mantaro river basin, and to evaluate the climatic, physical and social aspects of its vulnerability, as well as to identify viable adaptation options for the agriculture, hydroelectric energy and health sectors, to be incorporated into local and regional development planning.

In this context, the climatic component of the study consisted in the analysis of the climate of the basin: intraseasonal and interannual variability of rainfall and freezes, the relation between regional and large-scale climate, and the climatic trends in the last 40-50 years. The generation of future climatic scenarios for the river basin constituted another important objective. These results were used for the analysis of the present and future vulnerability in the Mantaro river basin to climate variability and change, as well as for the proposal of adaptation measures.

1. INTRODUCTION

The Mantaro river basin, in the central Andes of Peru, has great socio-economical importance (Martinez et al., in this volume; Instituto Geofìsico del Perú, 2005b and 2005c), and its exceptional climatic and physiographical characteristics allowed the installation of hydroelectric power stations that supply approximately 35% of the energy of the country. On the other hand, the valley of the Mantaro River produces most of the food consumed in Lima, by far the largest city of Peru and its capital. These aspects have motivated the proposal and execution of research projects that help the understanding of the climatic characteristics of the region, their relation to global climate and the possible effects of climatic change.

The Geophysical Institute of Peru (IGP), within the framework of the " Program of National Capacities Building for Impact of Climate Change and Air Pollution Management (PROCLIM), developed the ILA Mantaro through an interdisciplinary and interinstitutional work, with the participation of two working groups. Group A, was in charge of the study about the climatic characteristics of the river basin, its variability, tendencies and downscaling of the future climatic scenarios, the result of which results will be presented in the present paper. On the other hand Group B, was in charge of the study of the present and future vulnerability of the different socioeconomic sectors in the river basin, as well as of the elaboration of adaptation measures, on the basis of the information provided by Group A.

In this document, we present the main results obtained by the Group A: the climatology of the precipitation and air temperature of the Mantaro river basin; analysis of the dry and rainy periods and their relation with the atmospheric circulation; the relation between El Niño phenomenon and rainfall in the river basin; the teleconnection mechanisms; the local physical processes and their relation with the variability of rainfall; the variability in the date of beginning of the rainy season; the tendencies in the precipitation, maximum and minimum air temperature; the frequency and intensity of the frost; and finally the future climate scenarios for the Mantaro river basin.

The methodology used for the analysis of the climate variability in the basin, the trends and the climate scenarios, will be described in the corresponding sections.

For the calculation of the climatology, we considered time series that had at least 10 years of data during the period 1960-2000.

The data used was provided by the National Weather Service of Peru (SENAMHI), by the electrical companies: Electro Peru and Electro Andes, and by the IGP.

2. CLIMATIC CHARACTERISTICS OF THE MANTARO RIVER BASIN

A strong seasonal variability in precipitations exists, with maximum values between January and March (rainy season) and minima between June and July (dry season). 83% of the annual precipitation takes place between October and April, 48% of which are distributed almost equitably between January, February and March.

The spatial distribution of annual precipitation is not homogenous in the basin. In the highlands (above 4000 masl) the maximum values are presented in the North and South western regions of the basin (1 000 mm/year), whereas in the rain forest, towards the confluence of the Mantaro river with the Ene river, they reach 1 600 mm/year. On the other hand, the zone with smallest precipitation is located in the central part and in the south Eastern of the basin (between 2600 and 3200 masl) with values around 550 mm/year.

The monthly average of the minimum air temperature, presents a marked annual cycle, with the minimum values between the months of June-July and the maxima between January and March, with an annual range of 4,5ºC (average for whole the basin). On the other hand, the maximum temperature presents weaker seasonality (1,5ºC range) and registers the maximum values in November and the minimums in February, but with a significant semiannual variation.

The annual average of the minimum temperature presents values below -2ºC in the western end of the river basin (4600 masl), reaching -4ºC in the highest parts with data (4900 masl). In the valley of the Mantaro (between 3150 and 3400 masl), the minimum temperatures are around 4ºC, reaching 8ºC in the South Eastern regions of the basin (between 2600 and 3200 masl). In the Eastern end, in the confluence of the Mantaro river with the Ene river (500 masl), the minimum temperatures reach 16ºC.

The annual average of the maximum air temperature presents values of 12ºC in the western and central Eastern part of the river basin. In the valley of the Mantaro the maximum temperature reaches values between 16℃ and 18ºC, whereas in the south-Eastern zone of the basin, these reach values up to 22ºC, and 28ºC in the most Eastern end.

The climate, according to the climatic classification of Thornthwaite, varies from Semi Humid to Very Humid conditions in most of the river basin, except in the South part of the basin where dry regimes predominate (Semi Dry and Dry). From the thermal point of view, it varies from a Tundra climate in the high parts of the river basin, to Semi Cold climate in the zone of the valley of the Mantaro river.

3. INTRASEASONAL AND INTERANNUAL RAINFALL VARIABILITY

3.1 Dry and rainy periods

Monthly precipitation data of 38 meteorological stations were used to identify dry and rainy periods between the years 1970 to 2004 using the Standardized Precipitation Index (SPI; McKee et al., 1995).. The analysis was made for the following months: September-April (rainy season), September-December and January-April.

A dry (rainy) period was defined as that in which at least 70% of the stations registered negative (positive) values of SPI. During the 30 years, 8 rainy and 6 dry periods were detected. The years with excesses of precipitation occurred mostly at the beginning of the Seventies and during the first half of the Eighties, being 1973 the year with more intense and generalized rains in the basin. On the other hand, the precipitation deficits, happened mostly in the second half of the Seventies and Eighties and in the beginnings of the Nineties, being 1991 and 1992 the driest years.

3.2 Atmospheric circulation associated to dry and rainy periods

Using the NCEP[1]/NCAR[2] Reanalysis (Kalnay et. al., 1996), we analyzed the summertime anomalies from the 1970-2000 climatology for dry and rainy years. The analysis was made for the summer (rainy season, January-March) and winter season (dry season, June-August) at low (850 mb, approx 1500 masl), middle (500 mb, approx 5000 masl) and upper (200 mb approx, 12000 masl) levels of the atmosphere

During rainy periods, the Southeast Pacific Anticyclone is more intense and its center is located at 40ºS, 100ºW and, in the middle-eastern South America, a low-level anticyclonic anomaly is observed, which could favor the entry of humidity from the Atlantic towards the Amazon. In mid-levels the anticyclonic anomaly persists in the middle-eastern part of the continent extending towards the Atlantic. In addition, a cyclonic anomaly is observed in the northeast of the continent. In upper levels, the Bolivian High is displaced towards the southwest during the rainy periods and towards the northeast in the dry periods, which is associated with anomalies from the West on the central mountain range of Peru during the dry years and from the East in the rainy years. During latter, the anticyclonic circulation includes greater area, its influence extending between 90ºW and 35ºW.

3.3 El Niño phenomenon and precipitation

Linear correlation coefficients between standardized precipitation data from 50 stations for 1960-2004 (although in some stations the time series are shorter) and indices of sea surface temperature (SST) anomalies in the equatorial Pacific ocean [3] (Niño 1+2, Niño 3, Niño 3.4 and Niño 4) were calculated following Lagos et al. (2005). The analysis was done for both all the years and for only El Niño years (SCOR, 1983; NOAA, 2002). The monthly analysis was made, as well as seasonal for the rainy period (September-April).

The correlations obtained individually for the months between September to December are insignificant but they are significant for the months of January to March.

There is no significant relation between precipitation in the Mantaro basin and the SST anomalies off the northern coast of Peru (Niño 1+2 region). As we consider the SST in regions more distant

[1] National Center for Environmental Prediction (www.ncep.noaa.gov/)
[2] National Center for Atmospheric Research (www.ncar.ucar.edu/)
[3] Data from National Oceanic and Atmospheric Administration (NOAA)

from the coast of Peru, the correlation increases. The relations are strongest with the SST in El Niño 4 region. The relation is inverse, i.e. a warm anomaly in the central or western equatorial Pacific inhibits precipitations in the Central and South part of the basin. Nevertheless, these relations are not perfect. For example, the very strong 1997-1998 El Niño event was not a dry period in the river basin, but El Niño 1982-1983 was.

3.4 Teleconnections Mechanisms

Maps of the correlation coefficients were calculated for the period 1964-1999 between monthly precipitation and air temperature anomalies in the Mantaro river basin and global fields of SST (Reynolds, 1994), sea level pressure and geopotencial height at 500mb (NCEP/NCAR Reanalysis) anomalies, as well as with diverse teleconnection indices: North Atlantic Oscillation (NAO), Pacific-North America (PNA), West Pacific (WP), East Pacific (EP) and East Atlantic (EA) (Wallace and Gutzler, 1981). The January-March precipitation data, from 22 stations, was reduced using Principal Components Analysis (PCA), which allowed four regions to be identified in the basin. The station temperature data corresponded to Huayao.

The January-March correlation between precipitation in Huayao (central region) with SST is negative and of a moderate magnitude (-0.3 to -0.5) with the tropical Pacific and the North Atlantic, and direct and moderate (0.3 to 0.5) with the South Atlantic. On the other hand, the correlation is strongest with the tropical Pacific in February, whereas in March it is stronger in the North and South Atlantic. This pattern is stronger for the western region of the basin.

Considering only warm years (El Niño events), the correlation between the SST and precipitations in the basin increases. The March correlation with the western region of the basin becomes stronger with the South and North Atlantic (0.5 to 0.7 and -0.5 to -0.7, respectively). On the other hand, the correlation between the precipitation of each-region of the basin with the NAO and EP indices is moderate and positive for January.

It was also found that the anomalies of the maximum air temperature in Huayao is highly correlated with the anomalies of SST in the Tropical Pacific. This pattern is stronger for February (0.5 to > 0.7).

3.5 Local control of the interannual precipitation variability

December-February mean precipitation, averaged over the three regions (North Zone or Chinchaycocha sub-basin, Center Zone and South Zone) determined by Group B (Martinez, et al., 2006, in this volume), were correlated with specific humidity (q), relative (HR) humidity and temperature (T) from Huayao (1958-89), assumed to be representative of the river basin, as well as with 200mb zonal wind data from radiosoundings on Lima (12°S, 77°W, 1957-2001), assumed to be representative of the large-scale atmospheric circulation across the central Andes of Peru.

The results are shown in Table 1. The low correlation between specific humidity and precipitations suggests that the variations in moisture transport from the Amazon by the zonal wind do not modulate the interannual precipitation variations in the Mantaro, as it happens in the Altiplano (Garreaud et al., 2003). The largest correlations are with the relative humidity (Table 1), suggesting that this is the critical parameter that modulates the condensation of the water vapor and, therefore, the precipitation. The correlations with the temperature also are significant but negative. This suggests a mechanism different from that one proposed by Garreaud, in which the precipitation variations are due to the variations in the relative humidity, which is smaller when the temperature is greater and vice versa. The significant and negative correlations with the zonal wind are probably a consequence of the geostrophic relation, since the increase of temperature in the tropical band implies greater meridional pressure gradient in this region and, therefore, an increase in the eastward component in this level.

Table 1: Coefficients of correlation between accumulated precipitation in the period December to February in different zones of the river basin and averaged climatic indices on the same period.

Zone	u200	q (6pm)	HR (6pm)	T (6pm)
Sub-basin of Chin-chaycocha	-0,51	0,12	0,50	-0,48
Central Zone	-0,47	0,19	0,67	-0,54
Southern Zone	-0,57	0,24	0,68	-0,58

In agreement with the previous considerations, a statistical model was constructed based exclusively on linear regressions between relative humidity and precipitations. The interannual precipitation variations for a unitary relative humidity change are given by the coefficients of linear regression. These coefficients were also used to estimate the precipitation change associated with the relative humidity change estimated from large-scale climate change projections.

Because the availability of relative humidity data from the global models is limited, it was necessary to develop a method to determine the change in this variable on the base of other variables. For this purpose, changes in relative humidity were diagnosed from changes in temperature and specific humidity using a linearized version of the definition of relative humidity and Clasius-Clapeyron equation. Although the temperature dominates the interannual variability, specific humidity might play a more significant role in climate change.

3.6 Variability in the date of beginning of the rainy season in the southwestern Mantaro river basin

The agricultural activities in the Andean zones of Peru depend to a large extent on the beginning of the rainy season. To quantitatively analyze the interannual variability in the dates of beginning of the rainy season, 6 objective measures of the date of beginning of the rainy season were defined. These measures are the dates in which the accumulated precipitation from the beginning of the agricultural year (1st of July) reaches the values of 100, 200, 300, 400, 500 and 600 mm. Daily precipitation data registered in 2 stations: Huancalpi (3800 masl) and Lircay (3150 masl) were used. The stations are located in the south-western part of the Mantaro river basin and were chosen because they have the longest and most continuous series, during the period 1965-2001.

The data of the two stations were averaged and a running mean of 21 days was applied in order to eliminate all type of variation that is within this period. Six time series (one for each definition) were generated. The average and standard deviation of these six series were calculated (Table 2). A year in which the observed date was earlier (later) than the average minus (plus) one standard deviation, was considered to have experienced an advance (delay) of the beginning of the rainy season.

Table 2: Beginning of the rainy season according to the different definitions.

Amount of accumulated (mm)	Date of accumulation	Standard deviation (days)
100	10 of October	45
200	24 of November	52
300	25 of December	52
400	22 of January	59
500	14 of February	75
600	01 of March	78

A comparison with the dry or rainy periods found in Section 4.1, indicates a relation between the rainy years (period September - December) with advances of the rainy season. This was evident for the years 1981, 1990 and 1993. On the other hand, there is not a good agreement between dry years and the delay of the beginning of rains, neither during the months of September to December, nor during January-April.

4. CLIMATE TRENDS

4.1 Precipitation

Precipitation trends were estimated for annual means, as well as for the rainy period (September-April), the months of maximum precipitations (January-March) and for the beginning of the rainy season (September-December). The data series considered, in their majority, are for the period 1964-2003, although some stations have data only for the period 1970-2003.

The trend of the annual precipitation (Figure 1) is generally negative in the northern and central parts of the river basin, including the Mantaro valley, whereas in the western and central South part, the trend is slightly positive. The trends during the rainy season (September-April) and during the January-March follow the pattern of the annual trend, but the values are greater in the latter. Averaging all the stations, the tendencies indicate a diminution of around 3% of present precipitations every 10 years, which, projected to 50 years towards the future, would give a diminution of around 15%.

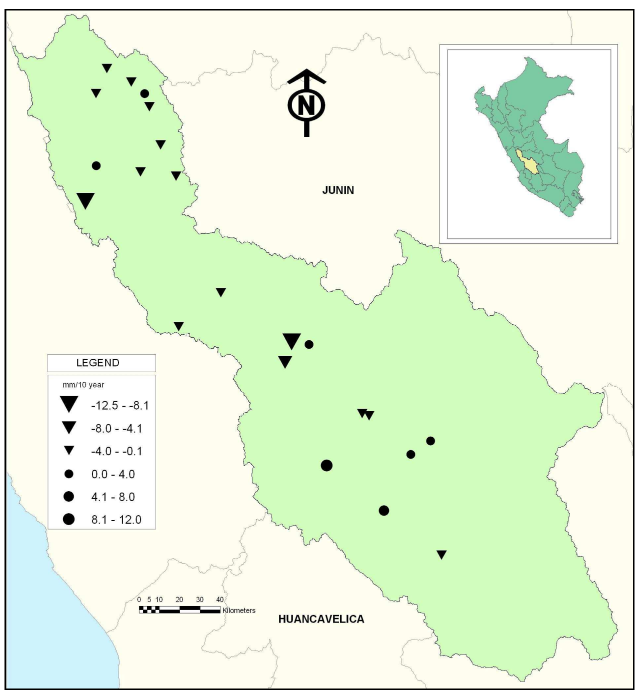

Figure 1: Trends in the annual precipitation (period: 1964-2003). Source: Instituto Geofísico del Perú, 2005c.

4.2 Extreme air temperatures

The maximum air temperature in Huayao, in the Mantaro valley, shows a noticeable positive trend (+0,24ºC/decade, Figure 2a), which is consistent with Vuille and Bradley (2000), who indicate a trend of +0,2ºC/decade in the central Andes.

The annual minimum temperature shows large interannual variability (Figure 2b) and does not present a significant trend, although in the winter months there is a positive (+0,16ºC/decade) trend and negative trend in the other months of the year, most markedly in October-December (Table 3). These results indicate that the diurnal thermal amplitude is increasing.

Table 3: Trends in the maximum and minimum air temperature in Huayao

Temperature	Annual		September-April		January-March		June-August		October-December	
	°C/10 years	°C/50 years	°C/10 years	°C/50 years	°C/10 years	°C/50 years	°C/10 years	°C/50 years	°C/10 years	°C/50 years
Maximum	0,24	1,21	0,26	1,31	0,28	1,40	0,17	0,87	0,22	1,11
Minimum	0,00	0,01	-0,07	-0,35	-0,01	-0,03	0,16	0,79	-0,13	-0,67

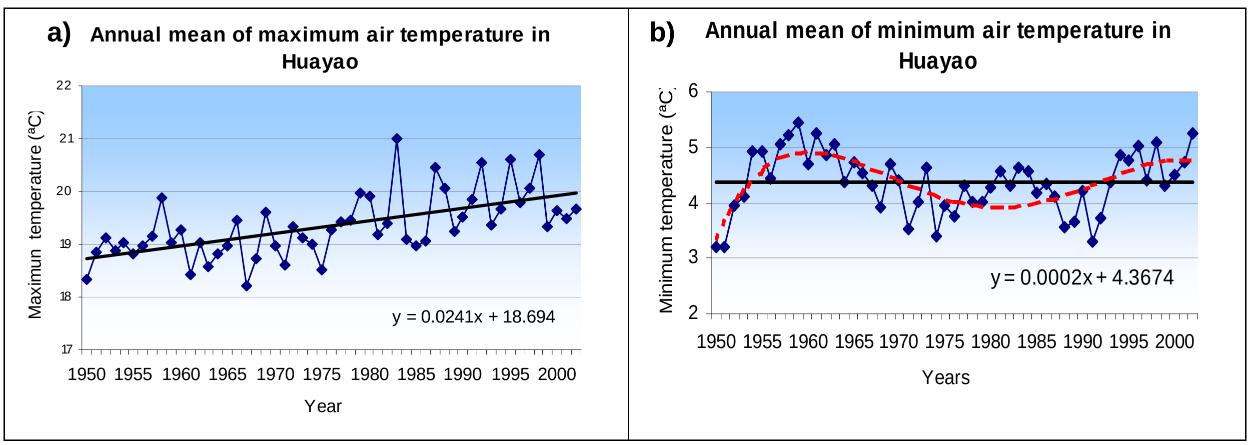

Figure 2: Trends in the maximum (a) and minimum (b) air temperature in Huayao (period: 1950-2002). Source: Instituto Geofìsico del Perú, 2005c.

4.3 Frequency and intensity of freezes

The analysis was made for September to April, which is when freezes are more harmful for crops, for the period 1960-2002. Time series of daily minimum temperature (Tmin) from 6 stations, each containing at least 30 years of data, were used. Freezes were considered to occur when Tmin was lower or equal than the threshold value of 5ºC, established by Group B.

The frequency of freezes as well as their intensity for each 8-month period, and the linear trend were calculated. The trends in frequency are generally positive (Table 4), so the number of days with freezes is increasing in average by 8 day/decade. This trend was only statistically significant in the stations of Huayao and Jauja, with values of 2,8 day/decade and 14,87 days/decade respectively. On the other hand, the trends in intensity are spatially incoherent (Table 4).

Table 4: Trends in the frequency and intensity of freezes in the Mantaro river basin. Period: September-April between 1960 and 2002

Station	**Altitude (masl)**	**Trends in the frequency of freezes**		**Trends en the intensity of freezes**	
		Days/10 years	**Days/50 years**	**ºC/10 years**	**ºC/50 years**
Cerro de Pasco	4260	+2,9	+15,0	+0,51	+2,5
Marcapomacocha	4413	+6,0	+30,0	+0,35	+1,75
Jauja	3322	+14,8	+74,0	-0,95	-4,77
Huayao	3313	+2,8	+14,0	+0,054	+0,27
Pilchaca	3570	-12,7	-63,5	+0,08	+0,4
Lircay	3150	+12,4	+62,0	-0,37	-1,85

5. FUTURE CLIMATE SCENARIOS IN THE MANTARO RIVER BASIN

Future climate scenarios have been produced by different international centers for the Intergubernamental Panel on Climate Change (IPCC) from scenarios for emissions of greenhouse gases using global climate models. The process of obtaining information on how the geographic conditions affect the climatic scenarios on a regional scale is known as downscaling. Currently, downscaling is made mainly using the following complementary methodologies: dynamical and statistical. In the present work both methodologies were applied to obtain climatic scenarios in the Mantaro basin.

5.1 Dynamical downscaling

Dynamical downscaling was applied to the climate scenarios produced by the NCAR using global climate model CCSM2 (Climatic Community System Model 2; Buja and Craig, 2002) based on the emission scenarios A1 and B2.

The regional climate scenarios were made using the regional climate model RegCM2 (Giorgi et al, 1993a,b) for two periods: 1990-1999 (base line) and the projection for 2046-2055. The model domain was from 10ºN to 42ºS and 87ºW to 30ºW, with 80x80 km resolution. It is important to mention that the version of RegCM we used (version 2), did not allow to implement the changes in GEG concentrations corresponding to the considered emission scenarios, which could limit the ability of the model to reproduce the expected climate changes. The frequency of the global atmospheric information used was 6-hourly for the base line and daily for the period 2046-2055. SST data was based on the observed climatology (Reynolds,1994) and the CCSM2 model anomaly.

The global model presents a warming of around 2ºC for the zone of the Mantaro, while the regional model reproduces warming but with a smaller magnitude, varying from 0,2ºC in the Eastern part of the basin to 1,0ºC in the Western part, this warming is accentuated during the summer (January-March) and with the B2 scenarios.

According to the results of the regional model, the precipitation would present a diminution from 5% in the Western part of the basin to 20% in the South Eastern. During the summer months the precipitation deficit of up to 10% is accentuated only in the central part of the Mantaro basin, in the North, South and South-Eastern part of the basin the model produces an increase in precipitations of up to 20%.

5.2 Statistical downscaling

The objective of this part of the study was to determine the changes in the temperature, precipitation, and relative and specific humidity during the rainy months of December to February between the periods of 1990-99 and 2045-54 using statistical methods. The changes in temperature and specific humidity were directly taken from the results of 12 combinations of global climate models of the IPCC and emission scenarios for the model grid cell closest to the basin. The results were then used for the estimation of the changes in relative humidity and the precipitation in the three sub-river basins, as described in section 3.5.

The estimations of the change in temperature and specific humidity for the Mantaro river basin show greater dispersion between models than between scenarios, although in general it is relatively small. The average changes for all models and scenarios were +1,3ºC in temperature and +1 g/kg in the specific humidity, whereas the in relative humidity is of -6 %. The sign of the changes is consistent between all the 15 models and the dispersion is small compared with the magnitude of the changes. An average diminution in the summer precipitation of 19% in the Central Region, 14% in the South Region and 10% in the Sub-river basin of Chinchaycocha (North Region) were estimated. The dispersion (standard deviation) of these is relatively small. These results are similar to what would be obtained assuming the persistence of the observed trends in precipitation (section 4.1).

5.3 Consolidated results

The results of dynamic downscaling present a generalized warming of the Mantaro river basin, which is more accentuated in the Western region and with the B2 scenarios, similar, the model presents a diminution of the annual precipitation in all the river basin. The pattern of smaller heating in the Eastern region of the Andes is consistent with observations (Vuille, et al., 2003) and other models. The results of the B2 scenarios are warmer and drier than those of the A1 scenarios, which is consistent with the results of the statistical model, which indicates reduced precipitation associated with greater temperature.

The results obtained had, in addition, the support of other sources. This is particularly important for the changes considered in precipitation, that depend on which the relation between temperature and precipitation stays under the climate change conditions. In the first place, as it was noticed previously, the estimated precipitation reductions are consistent with which it would be obtained by extrapolation of the precipitation trends observed in station data (section 4.1). Secondly, if we considered the negative relation observed between precipitations in the Mantaro and the sea surface temperature in the central equatorial Pacific (El Niño 3.4 and Niño 4, sections 3.3 and 3.4), an additional contribution to the reduction in precipitations in the Mantaro associated to the tendency projected by climatic models towards the more similar El Niño conditions in the future (Cubasch, et al., 2001). Finally, the results of dynamic downscaling for the B2 scenario are warmer and dry than those of the A1 scenario (section 5.1), which is consistent with the results of the statistical model, which they relates reduced precipitation to greater temperature.

The increase of air temperature projected, is also consistent with observations. In particular, Vuille and Bradley (2000) indicated a trend of around +0,2°C per decade (1°C/50 years) for period 1959-1998, whereas the trends observed in the basin are +0,24ºC/decade average (+1,24ºC/50 years).

6. CONCLUSIONS

The main conclusions of the climate variability study, tendencies and future climate scenarios in the Mantaro river basin are:

6.1 Interannual and intraseasonal climate variability

In the period between 1970 and 2004, the occurrence of 8 rainy periods and 6 dry periods were determined, being year 1973 the rainiest and years 1991 and 1992 the driest ones.

During the rainy years, an anticyclonic anomaly in the atmospheric circulation in low and middle levels in the center-Eastern part of South America is observed, it could favor the humid air entrance from the Atlantic to the Amazonian.

The anticyclonic system in the high atmosphere known as the Bolivian High, is displaced towards the southwest during the rainy periods and towards the northeast in the dry periods.

A significant negative relation exists between the variations of the sea surface temperature (SST) in the central equatorial Pacific (Niño 3.4 and Niño 4 regions) and precipitations in the Mantaro river basin. That is, El Niño phenomena tends to be associated with smaller precipitations in the Mantaro river basin.

The correlations between precipitations and the SST in the tropical Pacific are greater during the period of January to March that during October to December.

The variability of the maximum and minimum air temperatures in the river basin is strong and positively correlated with the variability of the SST in the tropical Pacific.

Locally, no significant relation between the variability of the precipitation with the variability of the specific humidity was found, but a significant negative relation between precipitation and relative humidity and temperature exist. The interpretation of this result is that the relative humidity variations forced by those of temperature have greater control on rains that the humidity transport from the Amazon.

The date of beginning of the rainy season presents great variability, with a standard deviation of around of 50 days, in average.

The variability of the date of beginning of the rainy season does not present a significant relation with the variability of accumulated precipitations during the season.

6.2 Climate trends

During last the 50 years, an increase in the maximum temperature has been observed of around +1,3℃ (+0,24℃/decade).

The trend in the annual minimum temperature is weak and more difficult to separate of the interannual variability. However, in the winter months, the trend is positive, whereas in the other months it is negative.

The increase in the maximum temperature is greater during the summer months (+0,28C/decade or +1,40℃ in 50 years) that in the winter months (+0,17ºC/decade or +0,87ºC in 50 years).

The precipitation trend is generally negative, with exception of some stations in the western and central South zone, where it is slightly positive. In average, the trend is for a diminution of 3% per decade (15% in 50 years).

The frequency of freezes has presented a general trend of increase during the last 40 years. The number of days with frosts in the period of September to April, in average has been increasing at a rate of 8 days/decade (40 days in 50 years).

The intensity of the freezes, on the other hand, has not presented a well defined trend.

6.3 Future climate scenarios

The future climate scenarios for year 2050, consolidated from the results of dynamical and statistical downscaling, including the observed tendencies, are the following:

Increase in the average temperatures in summer of 1.3℃.

Increase in the specific humidity during the summer in 1 g/kg.

Diminution in the relative humidity in summer of 6%.

Diminution in precipitations in the North zones, center and the south in 10%, 19% and 14% with respect to the present ones, respectively.

Increase in the diurnal amplitude of temperature of approximately 1℃.

Increase in the number of days with frosts in the months of summer of 40 days.

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