

TRENDS IN MAXIMUM AND MINIMUM TEMPERATURE IN THE CENTRAL ANDES OF PERU (MANTARO RIVER BASIN)

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ABSTRACT

1. INTRODUCTION

The Mantaro River Basin (34550,08 Km²) is located on the eastern slope of the central Peruvian Andes, between the coordinates 10°34'30"S- 13°35'30"S/ 73°55'00"W-76°40'30"W. This is a very complex basin due to its geomorphology, with almost 85% of its territory located above 3000 masl.

This basin was chosen for an Integrated Local Assessment with a Climate Change perspective, because its strategic location. The Mantaro basin provides a constant supply of resources (water, energy and farming products) to Lima, the capital of Peru. This is the first effort made until now in this respect in our country.

In this context, a linear trend analysis of observed temperature data (minimum and maximum) has been performed, using monthly and daily data for the 1960-2002 period, provided by nine meteorological stations, with altitudes ranging from 3150 masl to 4413 masl.

2. DATA AND METHODS

Monthly mean minimum and maximum temperatures (°C), tmin and tmax respectively, from nine meteorological stations spread over the basin were used (Figure 1 and Table 1), for the period between 1960 and 2002, at least 30 years of data. Daily minimum temperatures from six station were used for frost analysis.

The first step was to check the quality of the data, by means of a regional analysis, removing all suspicious data.

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For seasonally analysis, two cases were considered: a wet season analysis (December-March averaged temperatures) using data from the rainiest part of the wet season, and a dry season analysis (May-August averaged temperatures), when the lowest precipitation fall into the basin.

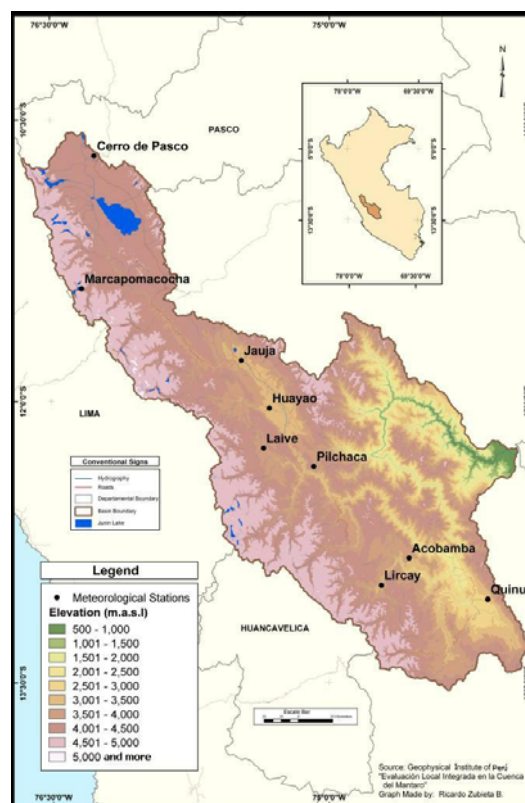


Figure 1. Location and Altitudinal Distribution of the Meteorological Stations Used

For frosts analysis, the temperature threshold value used was $T_{min} \leq 5^{\circ}\text{C}$, focused on the entire rainy period (September to April), which is critical for the development of crops in the river basin. Two frost indices were calculated, frequency and intensity, the first one is the

number of days with frosts in the rainy period by year, and the second one is the lowest daily temperature occurring during the same period by year.

The best-fit linear trends were calculated to describe temperature changes. The statistical significance of the trends was assessed at the 90% and 95% confidence level, by means of the T of Student statistical test.

STATION	LONG. (° West)	LAT. (°South)	ALT. (masl)	VARIABLE
Cerro de Pasco	76,26	10,69	4260	Monthly Tmax and Tmin. Daily Tmin
Marcapomacocha	76,33	11,4	4413	Monthly Tmax and Tmin. Daily Tmin
Jauja	75,47	11,78	3322	Monthly Tmax and Tmin. Daily Tmin
Huayao	75,32	12,04	3313	Monthly Tmax and Tmin. Daily Tmin
Laive	75,36	12,25	3990	Monthly Tmax and Tmin
Pilchaca	75,08	12,35	3570	Monthly Tmax and Tmin. Daily Tmin
Acobamba	74,57	12,84	3236	Monthly Tmax and Tmin
Lircay	74,72	12,98	3150	Monthly Tmax and Tmin. Daily Tmin
La Quinua	74,14	13,06	3260	Monthly Tmax and Tmin

Table1. Meteorological Stations and Variables Used, Ranged by Latitudinal Position among The Basin

3. RESULTS AND DISCUSION

3.1 Mean Annual Trends

Figure 2 shows the trends found for mean annual maximum and minimum temperatures in the Mantaro river basin. The trends are positive and significant for both tmin and tmax over the central zone between Huayao and Pilchaca, and over the south, in the locality of Acobamba. For those stations the highest and most significant values were observed in tmax. These results differ slightly from those found by other researches (Lagos, 1999 and 2002; Vincent et al. 2005) in which this behaviour is mainly found for tmin.

Significant trends are between +0,32°C/ decade and +0,62°C/decade in tmax and between +0,18°C/decade and +0,40°C/ decade in tmin.

On other hand, at higher elevations (Marcapomacocha and Cerro de Pasco) located on the northern and north-western part of the basin, a variable behavior is observed with almost null trends in tmax and tmin in Marcapomacocha, and statistically significant

tendencies in Cerro de Pasco, with opposite sign between the tmin and tmax, indicating a decreasing of the tmax with time, at a rate of -0,46°C/decade and by the contrary, and increasing of tmin at a rate of +0,34°C/decade.

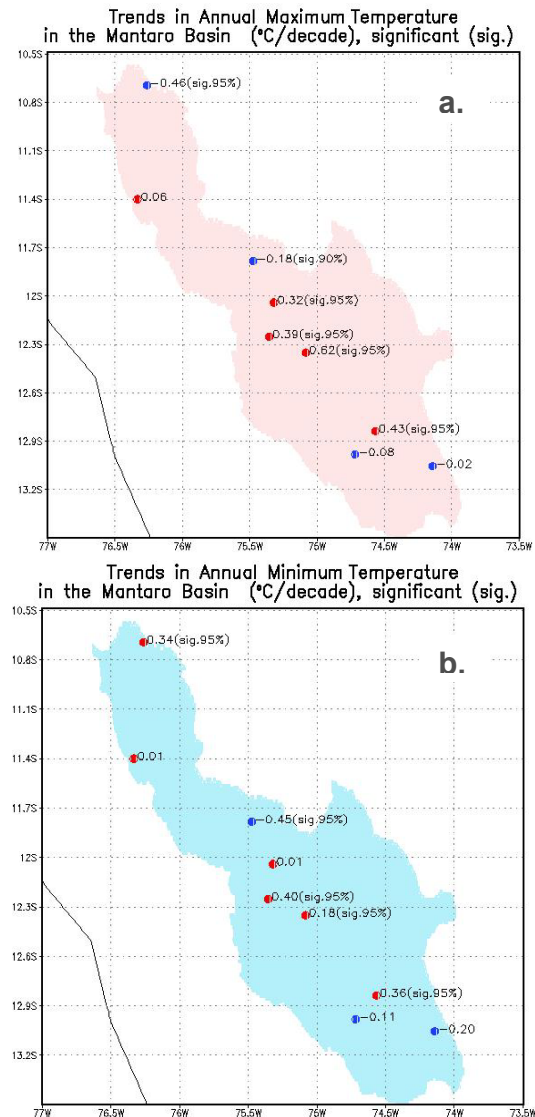


Figure 2. Linear Trends (°C/decade) in Annual Maximum (a) and Minimum (b) Temperatures in the Mantaro River Basin. Blue/red ball indicates negative/positive trend. Statistical Significance in parentheses

3.2 Seasonal Trends

Dry Season

The dry season in the region (considered between May and August) is characterized by high atmospheric stability, cloudless sky, high insolation, null or isolated rain events and extreme temperatures values.

The extreme maximum temperatures are associated to high insolation and null or scarce cloudiness during the day, and in the case of minimum temperatures (and frosts), these values are associated mainly to radiative cooling during night and early morning (IGP, 2005.b; Villegas, 1991).

For this season (Figure 3), increasing trends prevail over the same areas where the annual trends were found, that is, near the centre of the basin and towards the south in Acobamba, where trends are high and statistically significant in t_{max} (between $+0,28^{\circ}\text{C}/\text{decade}$ and $+0,62^{\circ}\text{C}/\text{decade}$), and nonsignificant and comparatively low values in t_{min} (between $+0,11^{\circ}\text{C}/\text{decade}$ and $+0,17^{\circ}\text{C}/\text{decade}$).

Similarly, Marcapomacocha has a non-significant tendency and Cerro de Pasco also remains with significant positive trends in the t_{min} ($+0,46^{\circ}\text{C}/\text{decade}$), and negative ones in t_{max} ($-0,49^{\circ}\text{C}/\text{decade}$).

Condition of non significance of the trends in t_{min} during this season, could be associated with the high variability observed in the t_{min} , that seems to be highly controlled by local geomorphological characteristics of the basin, such as altitude and morphology; these local factors would predominate over the macro scale climate features (some of them previously mentioned), especially at this time of the year.

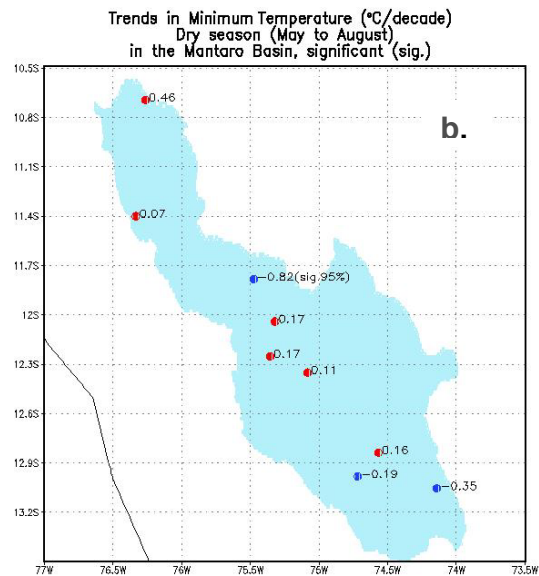
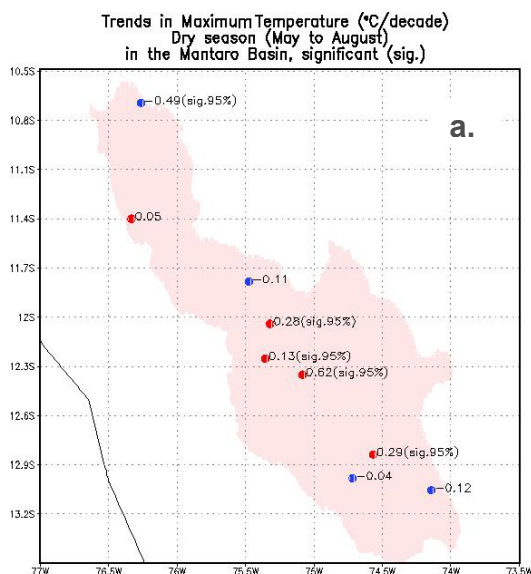


Figure 3. Linear Trends ($^{\circ}\text{C}/\text{decade}$) in Maximum (a) and Minimum (b) Temperatures in Dry Season (May to August). Blue/red ball indicates negative/positive trend. Statistical. Significance in parentheses

Wet Season

In the core of the rainy season, considered between December and March, rains are frequent and contribute with almost the 70% of the annual precipitation fall on the basin. During this period cloudy days are constant and air temperatures are in general moderate, with smaller thermal range in comparison to other seasons of the year (IGP, 2005.a, 2005.b).

For this period (see Figure 4), not much changes regarding the spatial pattern of the trends in the basin previously is shown, however, positive trends are enhanced. Consequently, positive trends predominate in t_{max} and t_{min} at central part of the basin (between $+0,33^{\circ}\text{C}/\text{decade}$ and $+0,74^{\circ}\text{C}/\text{decade}$), becoming also statistically significant the t_{min} trends.

Changes in the trend values could be associated with a greater stability in the thermal conditions of the region during this season, mainly regulated by frequent cloudiness, constant humidity and also the occurrence of rain events. Thus, thermal changes due to regional or global scales could be better identified.

Greater changes do not occur in the highest zones. Significant trends were found in Marcapomacocha, with a negative trend in t_{max}

(-0,56°C/decade), and positive in tmin (+0,22°C/decade).

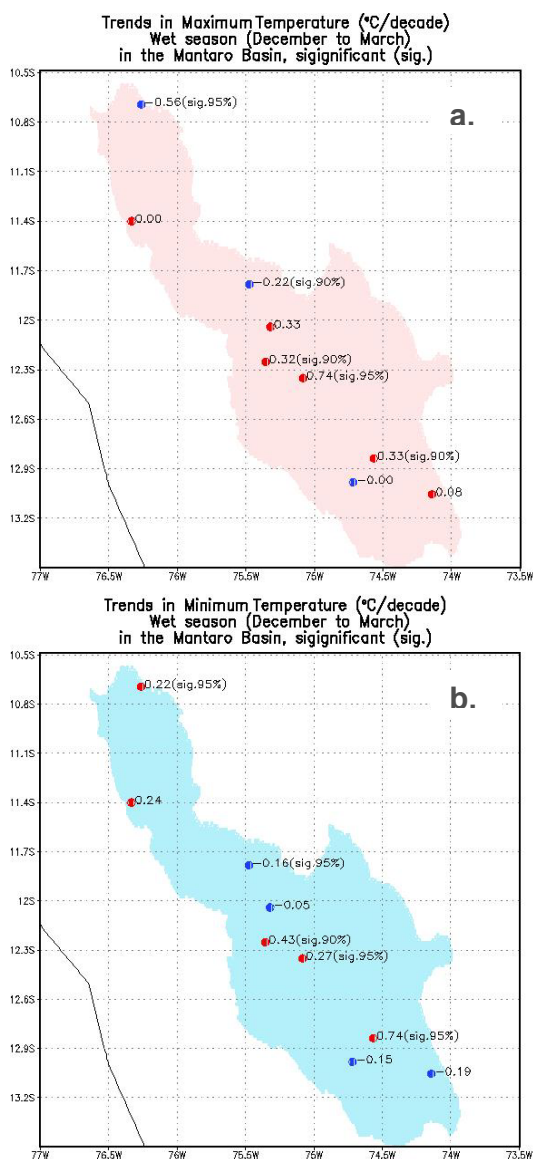


Figure 4. Linear Trends (°C/decade) in Maximum (a) and Minimum (b) Temperatures in Wet Season (December to March). Blue/red ball indicates negative/positive trend. Statistical Significance in parentheses

3.3 Trends in Frost Frequency and Intensity

According to table 2, positives trends in frost frequency occur over the entire rainy period in the basin (September to April), that is, the number of days with frosts in the basin is increasing at an average rate of 8 days/decade, these trends were only statistically significant in Huayao and Jauja, with values of 2,8

days/decade and 14,87 days/decade respectively.

A variable and not defined pattern exists with regard to frost intensity (Table 3). Huayao and Pilchaca (center of the river basin) exhibit almost no trend, Cerro de Pasco and Marcapomacocha (highest part of the basin) exhibit positives trends –being significant only in Cerro de Pasco. Negative trends occur in Jauja and Lircay (north and south of the Mantaro basin), with values between $-0,95^{\circ}\text{C}/\text{decade}$ and $-0,37^{\circ}\text{C}/\text{decade}$ respectively.

STATION	TRENDS
	(#days/decade)
Cerro de Pasco	+2,9
Marcapomacocha	+6,0
Jauja	+14,8
Huayao	+2,8
Pilchaca	-12,7
Lircay	+12,4

Table 2. Linear Trends in Frost Frequency in the Mantaro River Basin. Period of Analysis: September to April 1960-2002

STATION	TRENDS
	(°C/decade)
Cerro de Pasco	+0,51
Marcapomacocha	+0,35
Jauja	-0,95
Huayao	+0,054
Pilchaca	+0,08
Lircay	-0,37

Table 3. Linear Trends in Frost Intensity in the Mantaro River Basin. Period of Analysis: September to April 1960-2002

4 CONCLUSIONS

An increasing trend of the air temperature predominates in the Mantaro River Basin. Statistically significant trends that were positive and between moderate and severe, were found in the maximum and minimum temperatures, especially in the central part of the river basin (latitudes: $12,0^{\circ}\text{S}$ - $12,8^{\circ}\text{S}$, and altitudes ranging from 3200 masl to 3990 masl). This was observed when analyzing the annual period (January to December), the dry season (May to August) and the wet season (December to March).

The highest trends were observed in the maximum temperatures, also in the central area, at annual level and in the wet season (rank

between +0,32°C/decade and 0,74°C/decade), probably associated to the climate change observed in the tropical Pacific since mid-seventies, and the frequent signal and effects of El Niño Phenomenon over the Andes mountain (Vuille et. al, 2000.b; IGP, 2005.c).

With respect to the minimum temperature, a high variability in the trends was found, especially during the dry season. It seems that local factors such as altitude and geomorphology could play an important role and control on the minimum thermal condition in the region, making difficult the observation of clear regional trends in the basin.

Zones of higher altitude (Marcapomacocha-4413 masl and Cerro de Pasco -4260 masl) in the northern part of the basin, displayed different behaviors among each other. The trends were almost null in Marcapomacocha, whereas in Cerro de Pasco the trends were statistically significant, negative in the maximum temperatures (between -0,46°C/decade and -0,56°C/decade), and positive in the minimum temperatures (between +0,22°C/decade and +0,46°C/decade).

A tendency of increasing frequency of frosts has been found in several stations of the river basin in the last forty years. This tendency exhibits an average rate of +8,0days/decade during the entire rainy season (September to April). Nevertheless, no homogenous behaviors in frost intensities was observed in the basin, except in Jauja, where a continuing cooling in the temperatures, also observed in the frosts indices, exists.

It is highly recommendable to continue with the assessments of other meteorological variables that can affect the thermal conditions in the river basin, such as cloudiness, humidity and sun radiation. This analysis should also be extended to mean temperatures in the basin, to be able to compare them with results obtained by other investigators for the Andean region (Vuille, 2000.a, 2003).

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