Proceedings of 8 ICSHMO, Foz do Iguaçu, Brazil, April 24-28, 2006, INPE, p. 1175-1180.

MONTHLY AND ANNUAL AVERAGE OF THE PRECIPITATION FOR THE MANTARO RIVER BASIN FROM IMAGES OF GOES SATELLITE

Berlin Segura Curi*, Kobi Mosquera Vasquez* and Yamina Silva Vidal*

Instituto Geofísico del Perú

Abstract

The rains in the Central Andes of Peru according to information of meteorological stations, are well defined by a rainy (January, February and March) and dry (June, July and August) period, reason why it is important to study the space rain distribution. The objetive of the present work is to calculate the monthly and annual average, as well as the histogram of the rainfall estimated according to satellite images for the Mantaro river basin, for the period 2000-2004. The precipitation estimated by satellite is based on the technique called Auto-Estimator (AE), which uses the infrared band of the satellite to calculate the rate of precipitation. The results indicate that the significant precipitation begins in October, is increased until arriving at his maximum value in February, soon the March and April diminish. Three zones of greater precipitation have been identified, in the northwestern part, southwestern and southeastern and of smaller precipitation in the zone of the valley.

1 Introduction

The technique of rain estimation by satellite is based on Auto-Estimator (AE) that originally was developed by Vicente (Vicente, 1998) in the National Oceanic and Atmospheric Administration /National Environmental Satellite Data and Information Service (NOAA/NESDIS), uses the infrared band (10.7μm) of the GOES satellite (Geoestationary Operational Environmental Satellite) of space resolution 4x4km to calculate in real time the amount of precipitation.

We have worked with the product of the daily precipitation for South America (accumulated of 24 hours until 12UTC) and have calculated the monthly averages (monthly climatology), the annual average (annual climatology) of the precipitation and the histogram of the precipitation average over the Mantaro river basin for the period 2000-2004.

The following results were obtained:

The significant precipitation begins in October, are increased until arriving at his maximum value in February, soon the March months and April diminish.

Three zones of greater precipitation have been identified, in the northwestern part, southwestern and southeastern and of smaller precipitation in the zone of valley.

In the annual average of the precipitation, these zones of greater and smaller precipitation also have been observed.

2 Description of the technique

The technique of rain estimation by satellite is called Auto-Estimator (AE), originally was developed by Vicente (Vicente, 1998) to produce automatically rain estimations each half an hour for the U.S.A. It was developed in the NOAA/NESDIS and uses the infrared band (10.7 μm) of the GOES satellite of space resolution 4x4km to calculate in real time the amount of precipitation. The calculation is based on the potential law of logarithmic regression that is derived from a statistical analysis between instantaneous rain estimation obtained with a radar in surface and temperature of the top of the cloud derived from the infrared band of the satellite. The estimation of the rate of rain

* Corresponding authors address: Instituto Geofísico del Perú, Lima-Perú, (511) 3172300; e-mail: berlin@chavin.igp.gob.pe, kobi@chavin.igp.gob.pe and yamina@chavin.igp.gob.pe

(the regression curve), is fit by the humidity, growth rate, temperature gradient factors (Vicente, 1998) and the parallax and orography factors (Vicente, 2002).

2.1 Rainfall rate vs cloud top brightness temperature

According to infrared images and the rate of rain by radar, calculates the regression curve law of powers. The result of the comparison between the average estimation derived by radar for each interval from 1K from 195 to 260K is shown in the Figure 1 (Vicente, 1998). The dots represent average rain by radar for each interval of 1K and the solid curve represents the curve of regression given by:

$$R = 1.1183\times10^{11}\exp\left(-3.6382\times10^{-2}T^{1.2}\right) \quad (1)$$

Where:
R = Rainfall rate in millimeters per hour (mm/h)
T = The cloud top brightness temperature in Kelvin (K)

Both rain and non-rain pixels are considered in the computation of the regression curve.

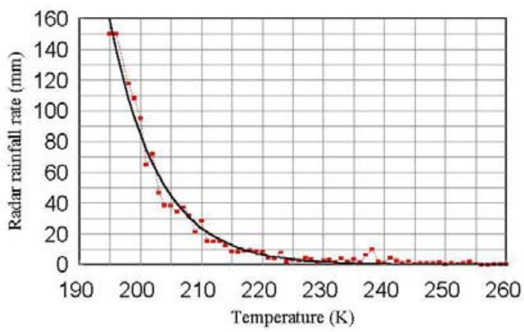

Figure 1: Radar-derived rainfall rate estimates and cloud top brightness temperature according to GOES (dotted curve). Power-law between radar-derived rainfall estimatesand the cloud top brightness temperature (solid curve).(Vicente, 1998)

Rainfall rate (the regression curve, *R*), is fit by:

- The correction factor of the humidity (PWRH)
- The cloud growth rate correction factor (f_growth)
- The temperature gradient correction factor (f_grad.)
- The parallax (f_parallax) and orography (f_orography) factors (Vicente, 2002)

2.2 Calculation of the hourly rainfall rate ($Rain_{1hour}$}

The estimation of the precipitation for each pixel in the infrared image of the GOES, is given by the product of the Rainfall rate (the regression curve, R), the humidity factor, growth rate factor, temperature gradient factor, parallax factor and orography factor.

$$\begin{aligned} Rain = R \times PWRH \times f\_growth \times f\_grad \\ \times f\_parallax \times f\_orography \end{aligned} \quad (2)$$

The rainfall rate is calculated for each infrared image of the GOES, which is available every 15 and 45 minutes after of the exact hour. The average hourly rainfall rate is computed on a pixel by pixel basis using the statistical trimean of three consecutive images. The trimean is a weighted average in which the median of the three values receives twice the weight, so that for every pixel the hourly rainfall rate is given by:

$$Rain_{1h} = \frac{\left(Rain_{mim} + 2Rain_{med} + Rain_{\max}\right)}{4} \quad (3)$$

Whenever two or three values are the same, the 1hour rainfall rate is reduced to a simple mean. The accumulated rainfall rate for periods longer than one hour is computed by the sum of the rainfall rates each hour (Vicente, 1998).

3 Methodology

The study area is between the length 73.8 to 76.8ºW and latitude 10.5 to 13.7ºS (Mantaro river basin). The period of study is 5 years (2000-2004).

From the daily precipitation estimated by satellite data, the monthly and annual averages were calculated using Fortran 90 programming language, while the maps and histogram were made with the visualize of data GrADS (The Grid Analysis and Display System).

For better visualize the space rainfall distribution, a 4x4km mask was generated that covers all the Mantaro river basin. In order to see if the rainfall estimated represent the annual cycle, the monthly average for all the basin was calculated, with its respective mask (Figure 11). The histogram was compared with the climatology of the monthly precipitation according to the Climatic Atlas (Atlas climático, 2005) (Figure 12).

4 Results

The maps with the monthly averages of rainfall estimated for October to April (Figures 2, 3, 4, 5, 6, 7 and 8) are shown. The maps for the months of May to September are not included, because the precipitations do not surpass 20mm/month. The most significant precipitation (20mm/month) occur in October (Figure 2), are increased rains in November (Figure 3), soon to decay slightly in December (Figure 4). The precipitation was superior in November contrary to which it is expected, this apparently, would have that in the year the 2001 precipitations, according to the GOES were more intense. Rains are increased during the months of January and February (Figures 5 and 6). The greater precipitation took place in February, soon rain diminishes during the months of March and April (Figures 7 and 8).

In the Mantaro river basin during October to April there are three zones greater precipitation, in the northwestern part, southwestern and southeastern. In February these three zones are more pronounced, with precipitation of 140mm/month. The smaller precipitation took place in the central part of the basin (zone of the valley).

These zones of greater and smaller precipitation also are observed in the annual average of rainfall estimated (Figure 9), maximum precipitations of 500mm per year) and minimum (200mm per year). The accumulated annual precipitation average over the basin was of 394.94mm per year.

The zones of greater precipitation according to the satellite, also were obtained in the multiannual average of rains according to the Climatic Atlas (Atlas climático, 2005) (Figure 10).

The precipitations in the Central Andes of Peru have two periods marked, a rainy period (January-March) and another dry (June-August), according to the climatology of the obtained monthly precipitation of the Climatic Atlas (Atlas climático, 2005), rain begins in July, gradually is increases in the later months until reaching the maximum values in February and decay quickly in April (Figure 12).

This variation of rain is good enough represented by rainfall estimated by satellite (Figure 11). The rainfall estimated is slightly smaller to the climatology of the monthly precipitation according to the Climatic Atlas (Atlas climático, 2005), this is because the climatology is an average of 42 years, whereas the average of the monthly rainfall estimated by satellite is a five years average (2000-2004)

5 Conclusions

- The rainfall estimated by satellite gives three zones of greater precipitation, northwestern, southwestern and southeastern part and of smaller precipitation in the zone of the valley.
- The zones of greater precipitation according to the satellite, also were obtained in the multiannual average of rainfall according to the Climatic Atlas (Atlas climático, 2005).
- The maximum period of rain (of January to March) and the dry period (of June to August) it was reproduced, both periods were observed in the maps and the histogram.

- The rainfall estimated, is representing good enough the temporary rain variation, that is, significant rains begin in October, it increases until reaching their maximum value in

February, soon diminish during the months of March and April, that agrees with the climatology of the monthly precipitation according to the Climatic Atlas (Atlas climático, 2005).

Acknowledgments

The author would like to thank Dr. Pablo Lagos Enriquez (CPNTC-IGP) for his support and Eng. Grace Trasmonte (CPNTC-IGP) for useful comments.

References

Instituto Geofísico del Perú, 2005: Atlas Climático de Precipitación y Temperatura del aire en la cuenca del río Mantaro. Fondo Editorial del Consejo Nacional del Ambiente. Lima-Perú.

Vicente, G. A., R. A. Scofield, and W. P. Menzel, 1998: The Operational GOES Infrared Rainfall Estimation Technique, Bulletin of American Meteorological Society 79, 1883-1898.

Vicente, G. A., J. C. Davenport, and R. A. Scofield, 2002: The role of orographic and parallax corrections on real time high resolution satellite rainfall estimation, Int. J. Remote Sens., 23, 221-230.

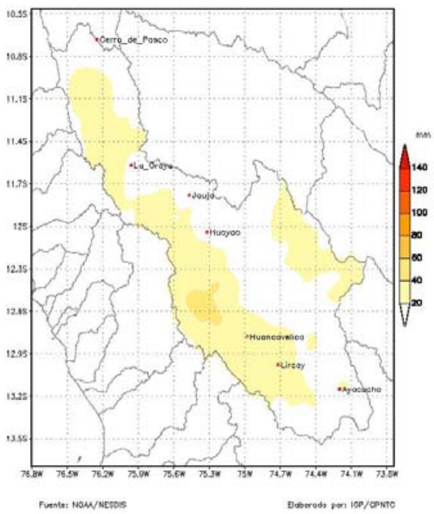

Figure2: Monthly average of the precipitation according to satellite for October

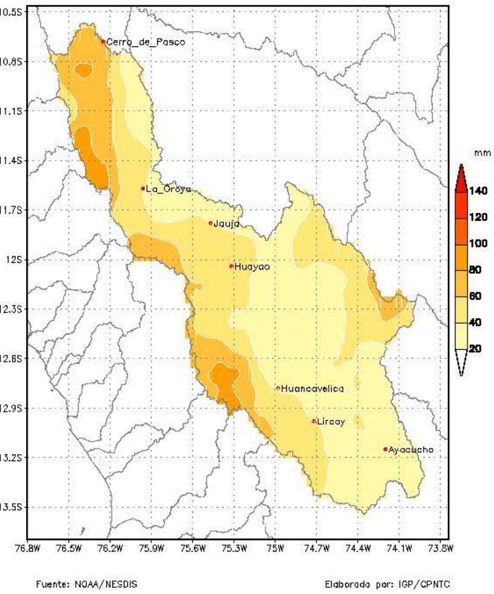

Figure3: Monthly average of the precipitation according to satellite for November

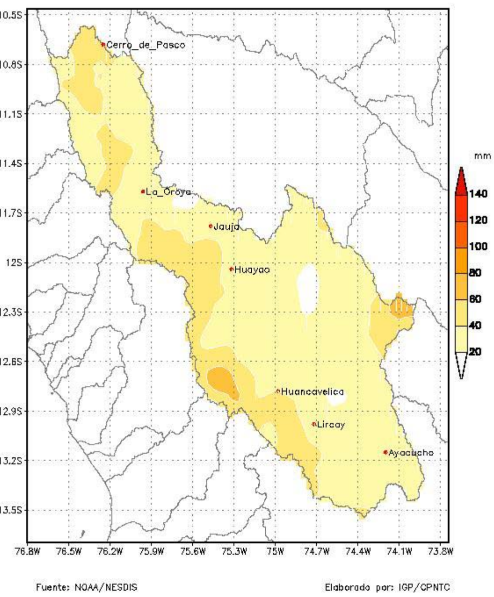

Figure4: Monthly average of the precipitation according to satellite for December

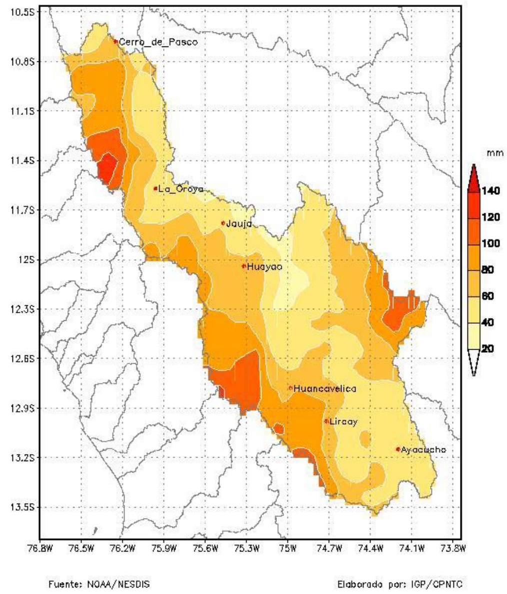

Figure5: Monthly average of the precipitation according to satellite for January

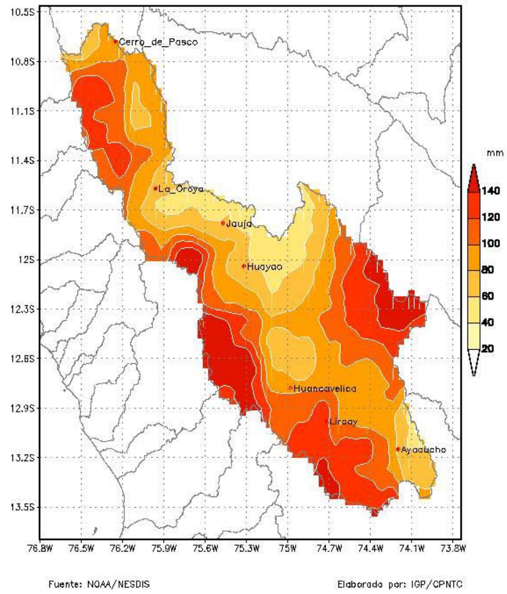

Figure6: Monthly average of the precipitation according to satellite for February

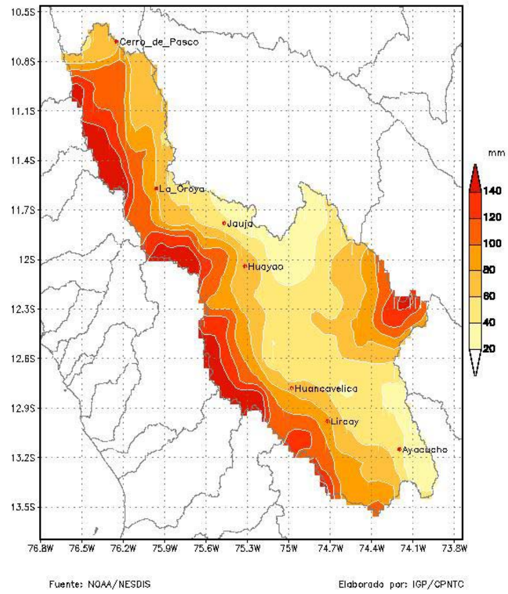

Figure7: Monthly average of the precipitation according to satellite for March

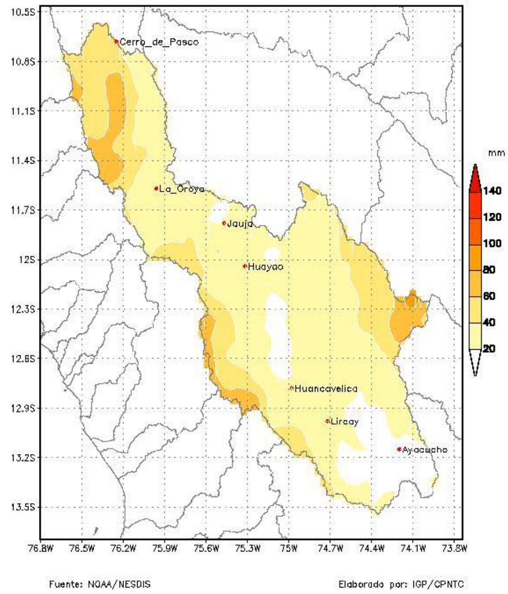

Figure8: Monthly average of the precipitation according to satellite for April

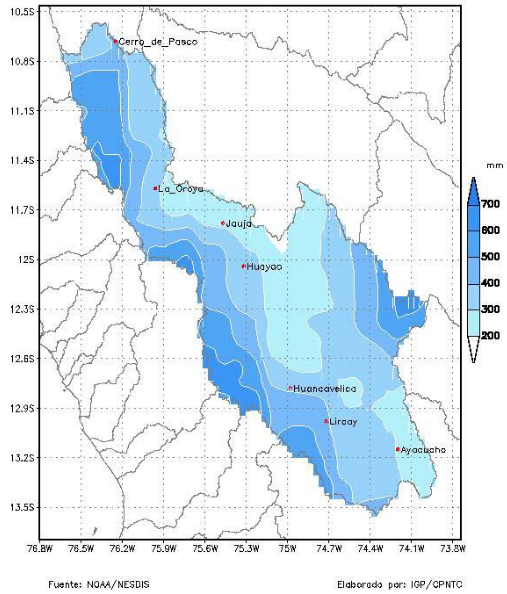

Figure9: Annual average of the precipitation according to satellite

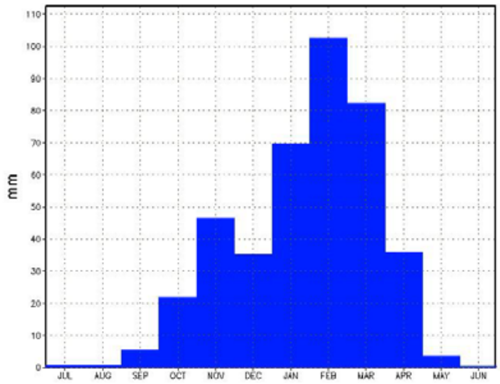

Figure11: Monthly average of the precipitation according to satellite

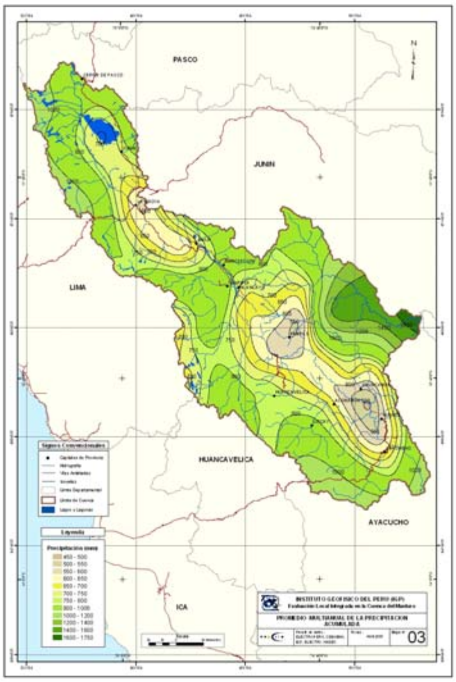

Figure10: Multiannual average of rains according to Climatic Atlas (Atlas climático, 2005)

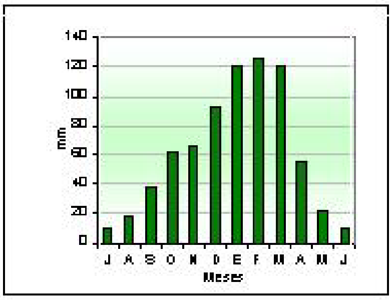

Figure12: Monthly climatology of the precipitation according to Climatic Atlas (Atlas climático, 2005)