Evaluation of Three Precipitation Products on Ecuadorian Coast

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INTRODUCTION

The study of low-frequency variability on Oceanography and Meteorology is commonly limited by the availability of 30 years or higher time series, minimum requisite for climatological studies. The interests on long-term precipitation analyses arises from the need to evaluate availability of fresh-water resources and their management related to soil use, agriculture and hidrology, including risk reduction by flooding and drought, despite another scientific interest like climatic change and their impact in all spatial scales; for that, and based on these needs, national and international organizations started and supported a great variety of research programs, climatic monitoring and modeling, including reanalyses and data sets construction, that departing from observed data, through diverse techniques of re-assimilation and interpolation, obtain as products time series higher than 40 years length. Under these conditions, the main objective of the current study is the evaluation of three precipitation products, and their performance with regard to the observed precipitation regime on Ecuadorian coast.

DATA

Fifty-one precipitation stations were selected to cover the Ecuadorian coastal zone (delimited by ~1350m level-curve on west Andean foothills). The evaluation period was defined between the years 1964-1994, based on the most common start date of the precipitation data, and the actualization-state of the database available. The main contributing of the rain-gauge data was InterAmerican Institute IAI CRN-038 Project (Cornejo-Grunauer, 2005), supplied by Instituto Nacional de Meteorologia e Hidrologia (INAMHI), Direccion General de Aviacion Civil (DGAC), Fuerza Aerea Ecuatoriana (FAE), Instituto Oceanografico de la Armada (INOCAR), Comision de Estudios para el Desarrollo de la Cuenca del Rio Guayas (CEDEGE), Corporacion Reguladora de Manejo Hidrico de Manabi (CRM) and Programa Regional para el Desarrollo del Sur (PREDESUR). Prior to the interpolation, a quality control that including a homogeneity test (Wang and Feng, 2007) based on the penalized *t* test (Wang *et al.*, 2007) and the penalized maximal *F* test (Wang, 2007a) was carried out on each data-series; details of this procedure are in Cedeño, 2008.

The precipitation data from stations were interpolated, receiving the name of INAMHI12k, and it will be used as reference dataset for evaluation of the precipitation products. The calculation of spatial means on each grid-point from gauge observations consisted of two major steps: the interpolation from stations to the center of each cell (0.5°x 0.5° geographical latitude/longitude) with Kriging technique (Deutsch and Journel, 1992), a well known method for the spatial interpolation of precipitation maps for rain gauge data (Bendix and Bendix, 1998); and a second linear-interpolation (Guibas and Stolfi, 1985) to a .25°x.25° grid (again at the center of the cell). Because the stations are in the coastal zone, and the maximum elevation of the study area is less than 1350 m on the Andes foothills and ~750 m on the coastal cordillera (figure 1), the Kriging interpolator was executed without a correction for topographical effect.

The evaluation of the three precipitation products correspond to the same period 1964-1994. The East Anglia University's Climate Research Unit CRU-TS 2.1 (Mitchell and Jones, 2005) represents the fifth delivery of TS series products, covering an extended period of 101 years (1901-2002). The Global Precipitation Climatology

Centre GPCC Full Data Product Version 3 (Rudolf and Schneider, 2005) is the third version of Full Data Reanalysis Products, and cover 53 years of registers, from 1951 to 2004. The Terrestrial Precipitation 1900-2006 Gridded Monthly Time Series Version 1.01 of the University of Delaware UDEL (Legates, 1990), released for their use on June 2007, is a new and improved variant of UDEL products, that contain 106 years of precipitation data, until 2006.

All these products have a global coverage, and a maximal resolution of .5°, that on the present study will be to .25° through linear interpolation, extracting the precipitation values corresponding to Ecuadorian coastal zone.

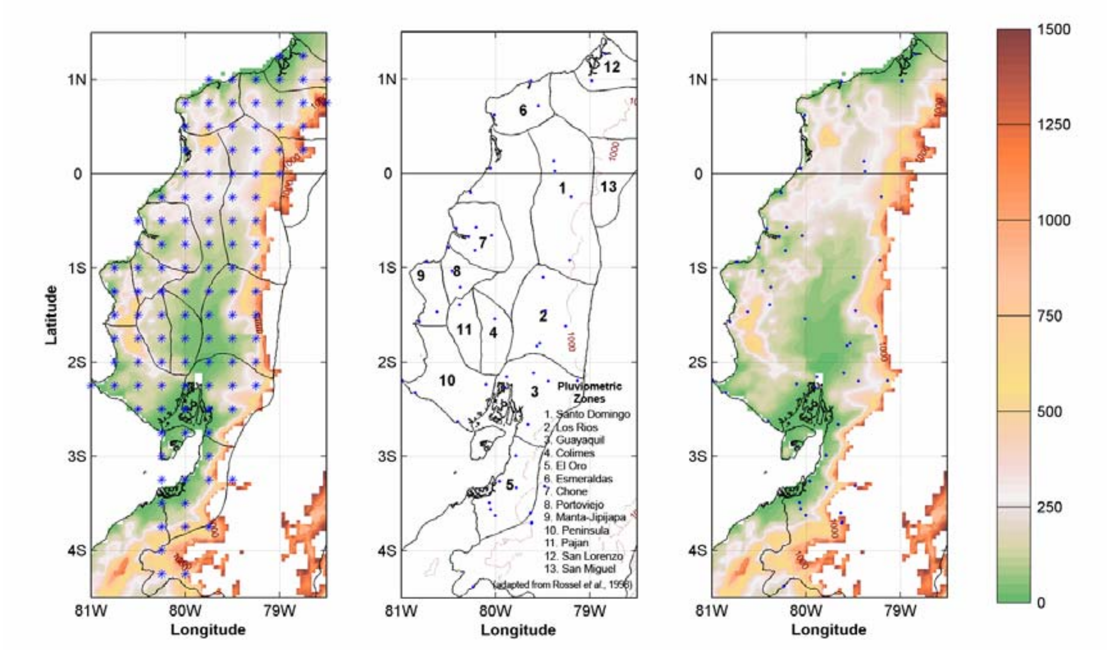


Figure 1. Location of meteorological stations with rain gauge data (left). Topography is shown by the color on its right in meters. The homogeneous precipitation zones, according to Rossel *et al.*, 1998 (center). Ecuadorian coastal 0.25° base-grid used on this study (left).

METHODOLOGY

The analysis is based, mainly, on the comparisons of the mean differences (also called bias) and the temporal-spatial correlations (Bosilovich *et al.*, 2007) of the precipitation annual cycle and annual totals between products vs. reference data set, grouped by pluviometric zones previously defined by Rossel *et al.*, 1998, in which is assumed rain regime is homogeneous. For the Ecuadorian coast, the pluviometric zones are Santo Domingo, Los Rios, Guayaquil, Colimes, El Oro, Esmeraldas, Chone, Portoviejo, Manta-Jipijapa, Peninsula, Pajan, San Lorenzo, and San Miguel (figure 1, and table 1).

Table 1. Description of Ecuadorian coastal regions used for the regional analysis.

	Stations Number	Grid Points Number	Area* (km^2)	Density (stations / 10000 km^2)	Density (Grid points / 10000 km^2)
1 Santo Domingo	4	13	8,487.65	4.71	15.32
2 Los Rios	5	10	7,716.05	6.48	12.96
3 Guayaquil	7	11	6,944.44	10.08	15.84
5 El Oro	6	9	4,629.63	12.96	19.44
7 Chone	5	6	4,243.83	11.78	14.14

*Estimated

The data were filtered for their use on regional analysis (2) with a band-pass Butterworth filter, that it is an Infinitive Impulse Response digital filter, for a period of 3-12 months, removing on this way the noise inherent to interannual variability, like ENSO (El Niño-South Oscillation). Details of algorithm implementation for the data-series filtering are in Mesquita and Halldórsdóttir, 2005; and Cedeño 2008. For the annual totals (spatial analysis, 1) the data of each product and the reference dataset were not filtered.

The analysis is divided into two main parts: (1) over each grid point (spatial analysis of: annual totals, annual totals' bias and seasonal Kruskal-Wallis test) using the unfiltered times series of precipitation by grid point); and (2) by region (regional analysis of annual cycle by homogeneous precipitation zones, and their correspondent bias and correlation) using the filtered versions of CRU, GPCC, UDEL and INAMHI12k datasets, respectively.

To evaluate differences of annual totals means, just as regional annual cycles, the non-parametric Kruskal-Wallis test of variance was used (Conover, 1980). The assumptions behind this test are that the measurements come from a continuous distribution, but not necessarily a normal distribution (the coastal Ecuadorian precipitation regime is commonly explained as gamma or chi-squared distribution, ECOPROYECTOS, 2000). The Kruskal-Wallis test was executed over each grid point for the total precipitation series on rainy and dry seasons, and by region (spatial mean of annual cycle), defining by dry season the months between June to November, and the rainy season from December to May (based on observed data of this study).

RESULTS

Annual Totals - Spatial Analysis

The annual totals, products of the interannual averages of precipitation accumulated on the year, are showed on figure 2. The spatial distribution of the rain is consistent on all precipitation products, although GPCC tend to sub estimate the annual total in San Lorenzo more than the other products. CRU total annuals are closer than GPCC and UDEL products, although on coastal margin of Manabi and Esmeraldas the differences are negatives (~+500 mm). On the central-west Andes foothills and their influence zone (Santo Domingo and Los Rios regions), the GPCC reports values over -1250 mm with regards to reference data set. This situation is also true for a localized area in Los Rios SE on UDEL. Near Muisne (SW area on Esmeraldas region), UDEL also shows a rain shortage closer to -1200 mm, in contrast with the north area of Esmeraldas (+375 mm, figure 2).

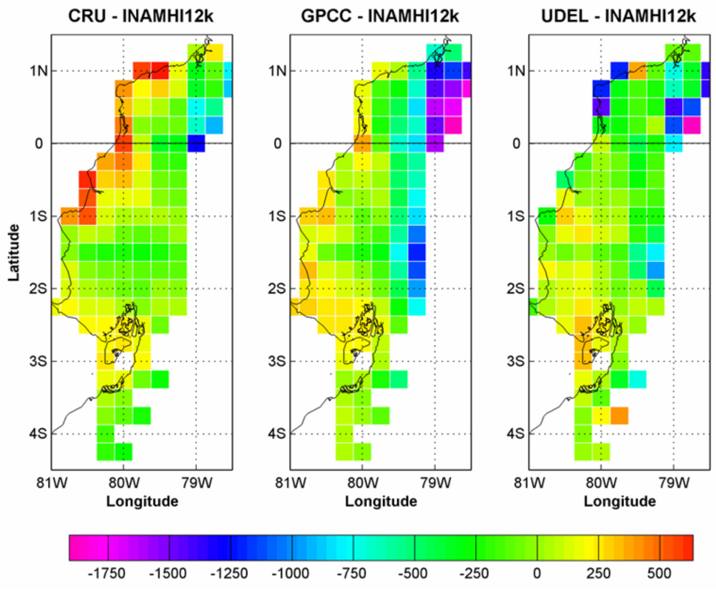


Figure 2. Differences between the precipitation products vs. INAMHI12k, in mm/year

The Kruskal-Wallis test executed over the complete and unfiltered data-series on dry-season and rainy-season confirmed difference-patron observed on figure 2. The areas where the differences between the products and reference dataset are statistically significant tend to concentrate on the internal zone of Ecuadorian coast (especially on rainy season). On dry season, GPCC had the lowest null hypotheses acceptance area percentage, while on rainy season this percentage is equal to CRU.

Annual Cycle – Regional Analysis

We are showing five out of the thirteen analyzed precipitation regions, which have been defined with data from more than three precipitation stations. They are: Guayaquil and El Oro (7 rain gauge stations each), Los Rios and Chone (5 rain gauge stations each), and Santo Domingo (4 rain gauge stations) regions.

The annual cycle in Santo Domingo and Los Rios regions presents a wider difference with regard to INAMHI12k, despite that fact that the precipitation values are within a standard deviation range. The bias analyses marks ~-100 mm on rainy season, being the CRU and UDEL the ones that better adjust to the annual cycle regime. For correlations, they ranged between 0.9 on rainy season and 0.7 on dry season for GPCC and UDEL. Although CRU maintains the lowest bias values, the correlation with the reference data set is not significant (95%) in most of the months (figure 3a and 3b).

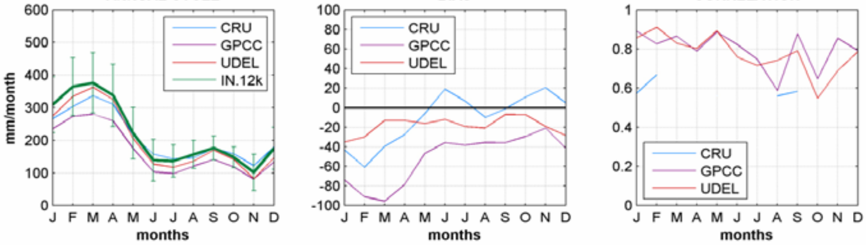
On the other hand, the Guayaquil, El Oro and Chone regions exhibit an almost perfect adjustment, in special for Guayaquil region, in which the bias values are between +/-20 mm (figure 3c). In El Oro, the bias is minimal on dry season, reaching up to +20 mm on rainy season (figure 3d). On both regions, the correlation analysis ranked the GPCC and UDEL products as the best (0.8-1), while CRU had similar results as Santo Domingo and Los Rios regions. For Chone, the CRU bias suggests that this product tends to overestimate the annual cycle. By contrast, the GPCC show the minimal bias values between the three products, having also a most robust correlation, especially on rainy season (figure 3e).

In addition, the Kruskal-Wallis test applied to the same filtered series by season shows that both GPCC and UDEL products are the most suitable for explaining the annual cycle on the studied regions, even if in Santo Domingo and Los Rios this product presents statistically significant differences (table 2).

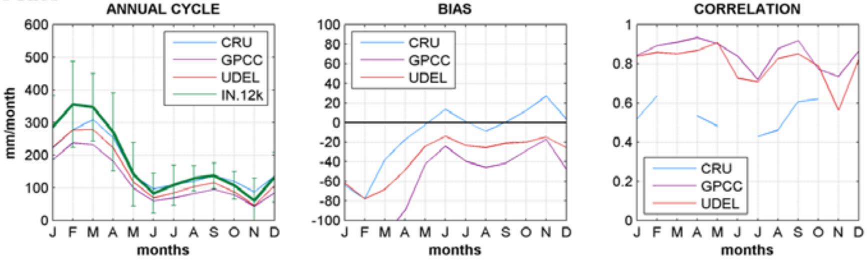
Table 2. Kruskal-Wallis Test results by regions and season over the filtered series. The areas where the null hypothesis (Ho: the data from the precipitation products have a common variance with a mean that was constant in each product) is rejected, are marked by ones.

	Rainy Season			Dry Season		
	CRU	GPCC	UDEL	CRU	GPCC	UDEL
1 Sto. Domingo	1	1	0	0	1	1
2 Los Rios	1	1	1	0	1	1
3 Guayaquil	0	0	0	1	0	0
5 El Oro	0	0	0	1	0	0
7 Chone	1	0	0	1	0	0

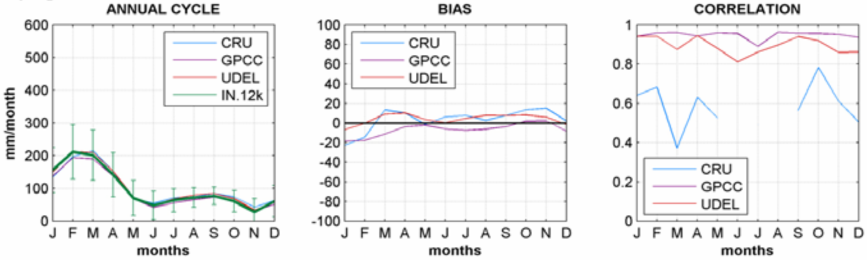
a) 1. Sto. Domingo



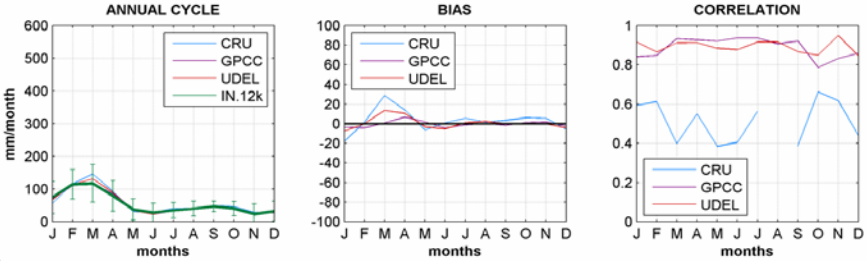
b) 2. Los Ríos



c) 3. Guayaquil



d) 5. El Oro



e) 7. Chone

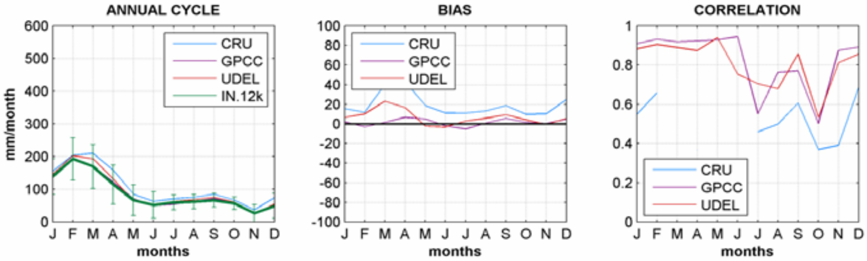


Figure 3. Annual Cycle, Bias and Correlation Analyses (95% confidence level) for the specified regions: 1 Santo Domingo (a), 2 Los Rios (b), 3 Guayaquil (c), 5 El Oro (d) and 7 Chone (e).

DISCUSSION AND CONCLUSION

At first, we should notice that the regions proposed for Rossel *et al.*, 1998 fails on their representation of pluviometric regime at Esmeraldas and Peninsula region. The key-stations that allowed detecting these problems were Muisne (Esmeraldas region) and Chongon (Guayaquil region). Muisne reveals a precipitation regime that is closer to San Lorenzo more than to Esmeraldas region; and Chongon with Guayaquil, in detriment of Peninsula Region. Because of this, Chongon and their influence area was re-directed to Guayaquil, and Muisne not to take in account on region analyses (based on the fact that closest regions' annual totals distribution of precipitation not explain the Muisne regime, INAMHI, 1996 and Cedeño, 2008).

Based on the results of the current study the product that best fits the precipitation regime on the Ecuadorian coast as a whole, is the GPCC. Despite the fact that CRU had lowest values on bias, its correlation analysis shows systematically low correlations values, on all regions, and in most cases, non significant (95%).

On the spatial analysis, the results suggest that topography could play an active role on the explanation of mean total annuals differences. The regions in which Ho is rejected are mainly associated with Andes foothills. Additionally, a correlation analyses between the elevation and total annuals differences shows that although the correlation values are relatively low, the large differences values are related with elevated areas (figure 4). None of the products used an interpolation algorithm that take in account the elevation effect, despite the evidence show that rainfall extensions in the tropics depend on various factors as e.g., the altitude. Applying an external drift variable on the interpolation procedures departing from observed values of precipitation, Bendix and Bendix, 1998; and Becerra-Soriano and Gutiérrez-López, 2006 could improve the finals estimators of precipitation of their respective studies.

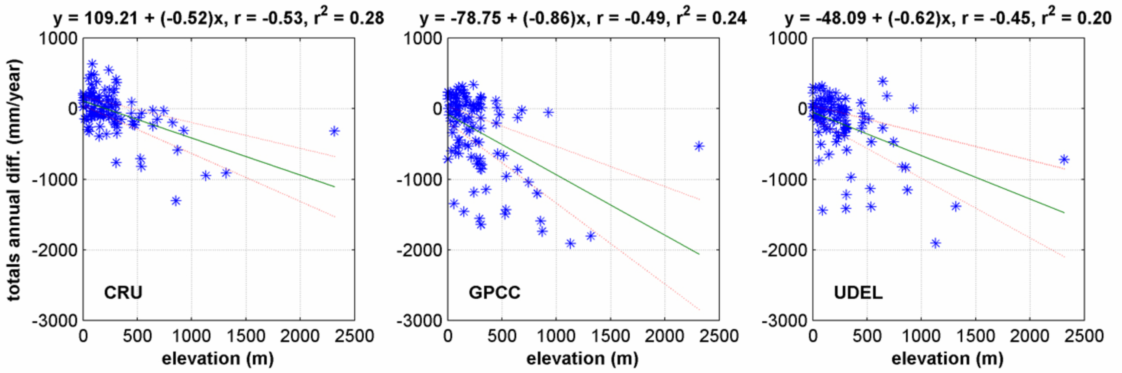


Figure 4. Linear regressions for to estimate the relationship between the elevation effect (x-axis) and totals annual differences (y-axis) of each product with respect to INAMHI12k.

By contrast, on Santo Domingo and Los Rios the data coverage would also explain the products' bias on the annual cycle, because these regions have been defined by the lowest numbers of stations (table 1). Particularly with CRU, the re-processing schema could explain the low-correlation values at regional analysis. Mitchell and Jones, 2005 using a methodology based on the conversion of their precipitation database into anomalies for, in a final step, reconvert to absolute values the anomaly grids interpolated through the combination of this with 1961-1990 normals. This conversion process resulted, in some cases, in a substantial loss of data (Mitchell and Jones, 2005). GPCC and UDEL have a more traditional schema of data processing (even thought UDEL use a Climatological-Aided Interpolation) that works over the absolutes values of rainfall.

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