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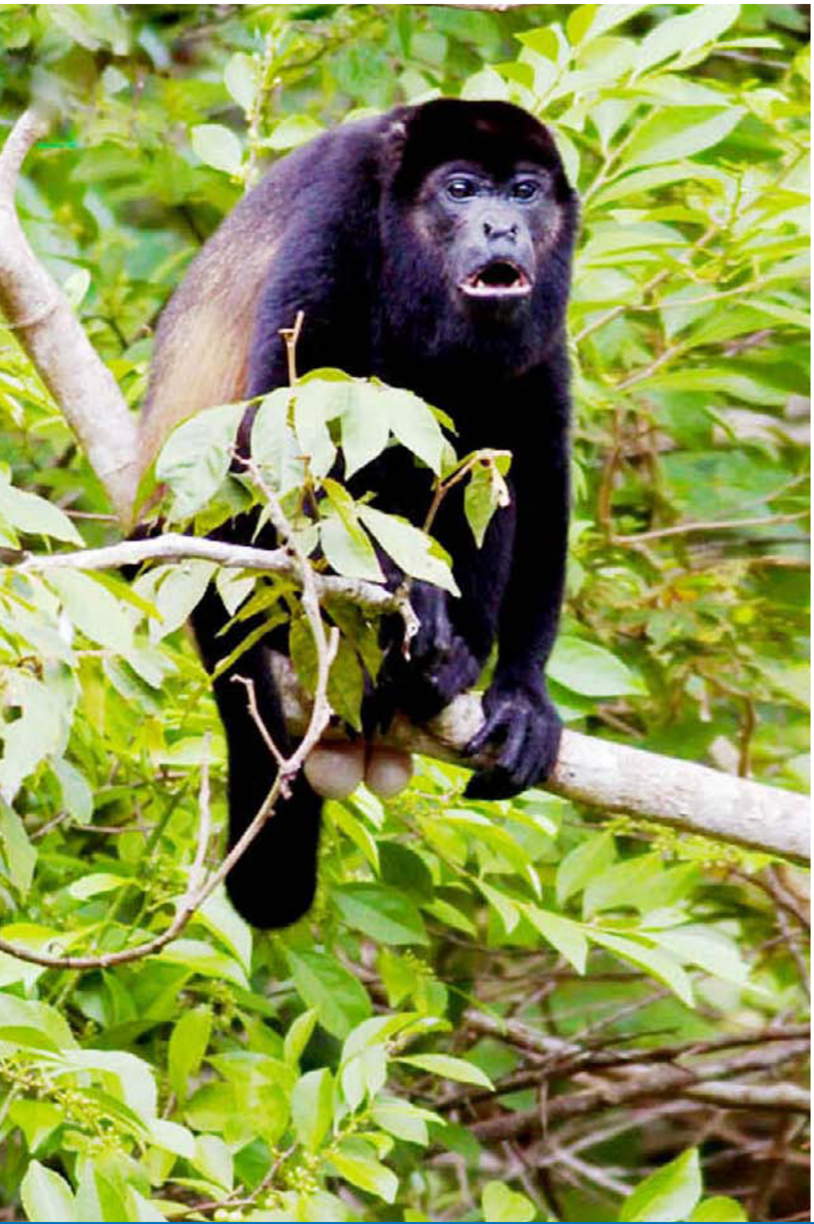

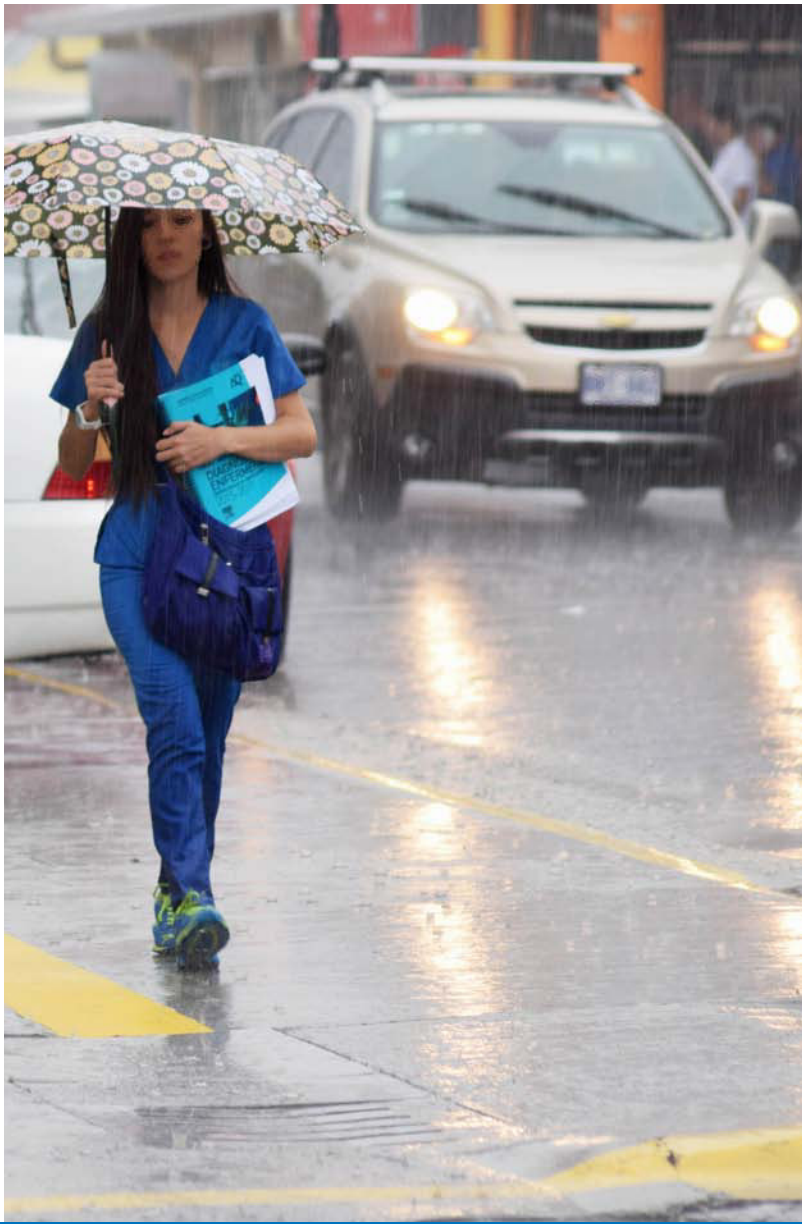

San José, Costa Rica

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La revista "Tópicos Meteorológicos y Oceanográficos" es publicada por el Instituto Meteorológico Nacional, Ministerio de Ambiente y Energía, Costa Rica. Tiene como finalidad dar a conocer los resultados de investigaciones y estudios en Ciencias de la Atmósfera y Oceanografía Física.

CONTENIDO

Assessment of Central America Regional Climate Outlook Forum maps, 1998-2013

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Abstract

Starting 1997, the Regional Climate Outlook Forums or RCOFs have taken place in different Latin American countries, as an effort to generate climatic prediction products. Since 2000, the Forum is organized in Central America by the Regional Water Resources Committee (CRRH), which is the technical secretariat of the Central American Integration System, or SICA, responsible for the coordination of activities related to weather forecasts, climate, water resources and climate change assessment. Since 2007 and after every RCOF, meetings are being held with different stakeholders in order to study the possible climate impacts on various socio-economic sectors of the Isthmus. In this work, 41 climate prediction maps of precipitation produced by the forums were evaluated. For this purpose, 156 rain gauge stations were used along with 689 and 17158 grid points from TRMM and CHIRPS data sets respectively. The cumulative seasonal rainfall were also compared with other three perspectives: the outputs of the Climate Predictability Tool (CPT); the prediction based on the persistence of the conditions observed in the previous month of the forum (RCOF); and another one always predicting neutral conditions. The results showed that the RCOFs maps have a value added for decision-makers, as most of the time they shown skilled predictive ability. The prospects based upon the prediction of always-neutral conditions showed the least predictive ability, meaning that making decisions without taking into consideration the climate outlook information is worse than using the RCOF maps. Moreover, the inclusion of objective tools and giving them a more specific weight in the consensus map production could be a factor that increases the predictive ability of the forums.

KEYWORDS: SEASONAL CLIMATE PREDICTION, CENTRAL AMERICA, REGIONAL CLIMATE OUTLOOK FORUMS

Resumen

Desde el año 1997, se han llevado a cabo en diferentes países de Latinoamérica los Foros Regionales de Predicción Climática con el objetivo de generar productos de predicción climática. En América Central, este foro es organizado desde el año 2000 por el Comité Regional de Recursos Hidráulicos o CRRH, el cual es la secretaría técnica del Sistema de Integración Centroamericano o SICA, encargada de coordinar las actividades relacionadas al pronóstico del tiempo, clima, recursos hídricos y cambio climático. A partir del año 2007, se realizan reuniones luego del foro de predicción climática, que tienen como finalidad estudiar los posibles impactos climáticos en distintos sectores socioeconómicos del istmo. En este trabajo se evaluaron 41 mapas de predicción climática de precipitación producidos por el foro, usando un conjunto de 156 estaciones pluviométricas, así como 689 y 17158 puntos de rejilla de los conjuntos de datos TRMM y CHIRPS, respectivamente. Los acumulados estacionales de la precipitación también fueron comparados con otras tres perspectivas: las salidas de la Herramienta de Predictibilidad Climática o CPT, la predicción basada en la persistencia de las condiciones observadas el mes previo al foro y una basada siempre en la predicción de condiciones neutrales. Los resultados mostraron que los mapas del foro tienen un valor agregado para los tomadores de decisión, ya que mostraron habilidad predictiva la mayoría de las veces. Las perspectivas

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basadas en la predicción siempre de condiciones neutrales fueron las que mostraron la menor habilidad predictiva, lo que significa que tomar decisiones sin tomar en cuenta la perspectiva climática, es peor que usar los mapas del foro. También, el darle un peso mayor dentro del proceso de consenso al uso herramientas objetivas de predicción climática, podría ser un factor que aumente la habilidad predictiva de los foros.

PALABRAS CLAVE: PREDICCIÓN CLIMÁTICA ESTACIONAL, AMÉRICA CENTRAL, FOROS REGIONALES DE PREDICCIÓN CLIMÁTICA.

1. Introduction

As Maldonado, Alfaro, Fallas, and Alvarado (2013) explain, Central American National Meteorological and Hydrological Services (NMHS) hold periodic Regional Climate Outlook Forums (RCOF) to discuss seasonal precipitation predictions produced by all countries. Since 1997, RCOFs have taken place in various Latin American countries, in an effort to produce seasonal prediction products (IRI, 2001). They have been funded by several international agencies with the assistance of local and regional entities such as the Regional Water Resources Committee (CRRH) in Central America (Donoso & Ramirez, 2001; Garcia-Solera & Ramirez, 2012). Since 2000, the Forum is organized in Central America by the CRRH, which is the technical secretariat of the Central American Integration System or SICA, and is responsible for the coordination of activities related to weather forecasts, climate, water resources, and climate change assessment in Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama (Garcia-Solera & Ramirez, 2012). Alfaro, Soley, and Enfield (2003) add that generally, these forums gather representatives of the NMHS, as well as members of the scientific and academic community, who work on the elaboration of regional and local climate forecasts for the next season.

The objective of these forums is to use national climatic experience to elaborate a regional consensus for the climate outlook. In Central America, precipitation accumulation is the variable generally forecasted for the months following a particular forum. The forecast is presented in a format that is useful for the agencies involved as stakeholders. The recommended methodology for the forecast is quite simple and this forecast is later integrated geographically with the coordinated inputs from the countries of the region, and it is used as a tool by the meteorological services and as a basis for expected impact scenarios by stakeholders and decision-makers (Alfaro et al. 2003).

Garcia-Solera and Ramirez (2012) explain that, in order to produce the outlooks, RCOFs also analyze hindcasts and statistical analysis given by each of the NMHS of the region. In this work, distribution of RCOF meeting venues by country is: 10 in Costa Rica, 7 in Panama, 6 in Guatemala, 6 in El Salvador, 6 in Honduras, 3 in Nicaragua, 2 in Belize and 1 in Mexico.

Other data used to produce the outlooks in Central America include the most recent evolution of anomalies and sea surface temperature forecasts of the Tropical Atlantic and Pacific oceans; such information is contained in:

- The observed values of Multivariate ENSO Index (MEI; Wolter & Timin, 2011).
- The Pacific Decadal Oscillation (PDO; Mantua, Hare, Zhang, Wallace, & Francis, 1997).
- The Atlantic Multidecadal Oscillation (AMO; Enfield, Mestas-Nunez, & Trimble, 2001).
- The Tropical North Atlantic observed anomalies (TNA; Enfield & Alfaro, 1999) and atmospheric pressure forecast.
- The general circulation model seasonal forecasts.
- The hind precipitation data of analog data for the forecast period.
- The probabilities for precipitation scenarios for the period.

- The analysis of canonical correlation or CCA with the Climate Predictability Tool (CPT; Mason & Tippett, 2016).
- The Atlantic and Pacific Oceans hurricane season forecast.

Since 2007, as explained by Maldonado et al. (2013), after every RCOF, meetings with different socioeconomic stakeholders take place in order to study the possible climate impacts of the outlooks on the Central American region. According to Garcia-Solera and Ramirez (2012), the aims of these meetings are to analyze the effects, impacts, and climatic variability projections in different sectors including agriculture, water, fisheries, health and nutrition, risk management and energy, and to produce disaster prevention and mitigation strategies, according to the climate scenarios proposed at the end of each forum. CRRH turns Seasonal Climate Outlooks into risk scenarios used by food-related sectors to support their decisions and minimize food insecurity. This is accomplished as a coordinated effort carried out by specialized entities of SICA, turning the product into sectoral climate risk scenarios that could guide early warnings about actual and potential threats to food security.

The objective of this work is to assess the skill of Central American RCOF maps. This assessment is important since the main goal of the seasonal outlook is to provide information and advice to risk management and food security stakeholders according to the regional climatic projections. As a result, it is designed to emphasize the most relevant impact analysis and foreseeable effects, for risk prevention and mitigation (Garcia-Solera & Ramirez, 2012).

2. Data and Methodology

As a first step, we collected all maps produced by the RCOFs in Central America from 1998 to 2013. To increase the sampling size, in the analysis we also included the outlook maps of the 1998 and 1999 forums organized by the Water Center for the Humid Tropics of Latin America and The Caribbean (CATHALAC) in collaboration with the CRRH (Donoso & Ramírez, 2001). Outlook seasons in these forums are normally for May-June-July (MJJ), August-September-October (ASO) and December-January-February-March (DJFM) accumulated precipitation.

According to García-Solera and Ramírez (2012), the reason for that selection is mainly because precipitation patterns in Central America define three planting seasons: the *primera* in April, the *postrera* in August–September, and the *apante* or winter season in DJFM. RCOF organizes its outlooks so that they can disseminate information to users before the beginning of each planting season. Actually, web meetings produce updates of these outlooks that include also April and November, to attend the start and the end of the rainy season. We collected 13 maps of MJJ season, 12 maps of ASO, as well as 12 maps of DJFM. Additionally the 1998, 2000 and 2001 June-July-August maps were included, along with the 2001 September-October-November one. Outlook maps were obtained from the CRRH archives.

All maps were digitalized enclosing the regions predicted as Below Normal (BN), Neutral (N), and Above Normal (AN). Those are the three categories used by the RCOF for the seasonal rainfall accumulations (figure 1).

The RCOF outlook maps were assessed using three data sets. The first dataset is from gauge stations. In this case we considered a total of 156 gauge stations with monthly precipitation observations provided by the NMHS in Central America during a training workshop on climate prediction, organized by the CRRH in June 2014 in San Jose, Costa Rica. Station locations are shown in figure 2. Since each meteorological station has a distinct time coverage, a common time series length was determined according to the availability of data in

(A) (B)

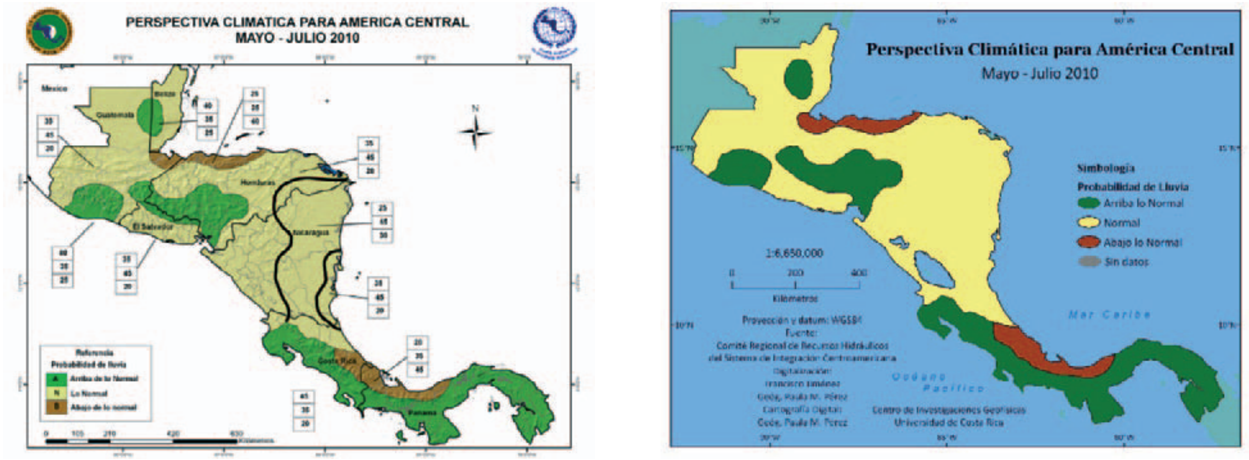


Figure 1. Example of digitalization of the RCOF maps. The map contained in the RCOF document for MJJ 2010 is presented in (A), and its digitalization enclosing the regions predicted as Below Normal (BN, brown), Neutral (N, yellow or light brown) and Above Normal (AN, green) is presented in (B). Source: CRRH-SICA.

the different stations of figure 2. Therefore, the selected time series length covers from January 1979 to March 2014. The 1979-1997 period was used to calculate the tercile thresholds and 1998-2014 to compare with the RCOF maps. The gaps in the time series were filled using the methodology described by Alfaro and Soley (2009), which combines autoregressive models and Empirical Orthogonal Functions (EOFs) methods.

The other two datasets are from the Tropical Rainfall Measurement Mission (TRMM) and the Climate Hazards Group InfraRed Precipitation with Stations (CHRIPS). Since some areas of Central America have no good gauge stations coverage, mainly at the Caribbean slope, we also used the TRMM (Huffman et al., 2007) and the CHIRPS (Funk et al., 2015) datasets to have full spatial coverage over the isthmus, as additional sources to assess the RCOF maps.

TRMM monitors tropical and subtropical precipitation and is a joint satellite mission between the National Aeronautics and Space Administration (NASA) and the Japan Aerospace Exploration Agency (JAXA). In this study, the TRMM 3B42 version 6 algorithm, for precipitation rate estimates were chosen.

These TRMM estimates correspond to a 3-hourly average centered at the middle of each 3-hour period (i.e., 0Z, 3Z, 6Z, 9Z, 12Z, 15Z, 18Z, and 21Z). The final 3B42 product data are available at 0.25 x 0.25° spatial resolution extending from 50°S to 50°N. For the present study, the evaluation using the TRIMM data covered the 1998-2014 period, since this a limitation due to the shorter time span of these data compared to the availability of station data. In order to transform the satellite precipitation data into a daily frequency, it was necessary to merge the 3-hourly data, considering the local time. After that, seasonal precipitation estimates were calculated for 689 grid points over the isthmus.

The CHIRPS dataset blends data from weather stations and weather satellites with extraordinary accuracy, providing a detailed record of global rainfall stretching back more than 30 years (http://www.vox.com/2016/4/11/11389550/drought-prediction-agriculture). The latest version (version 2.0) spans 50°S–50°N (and all

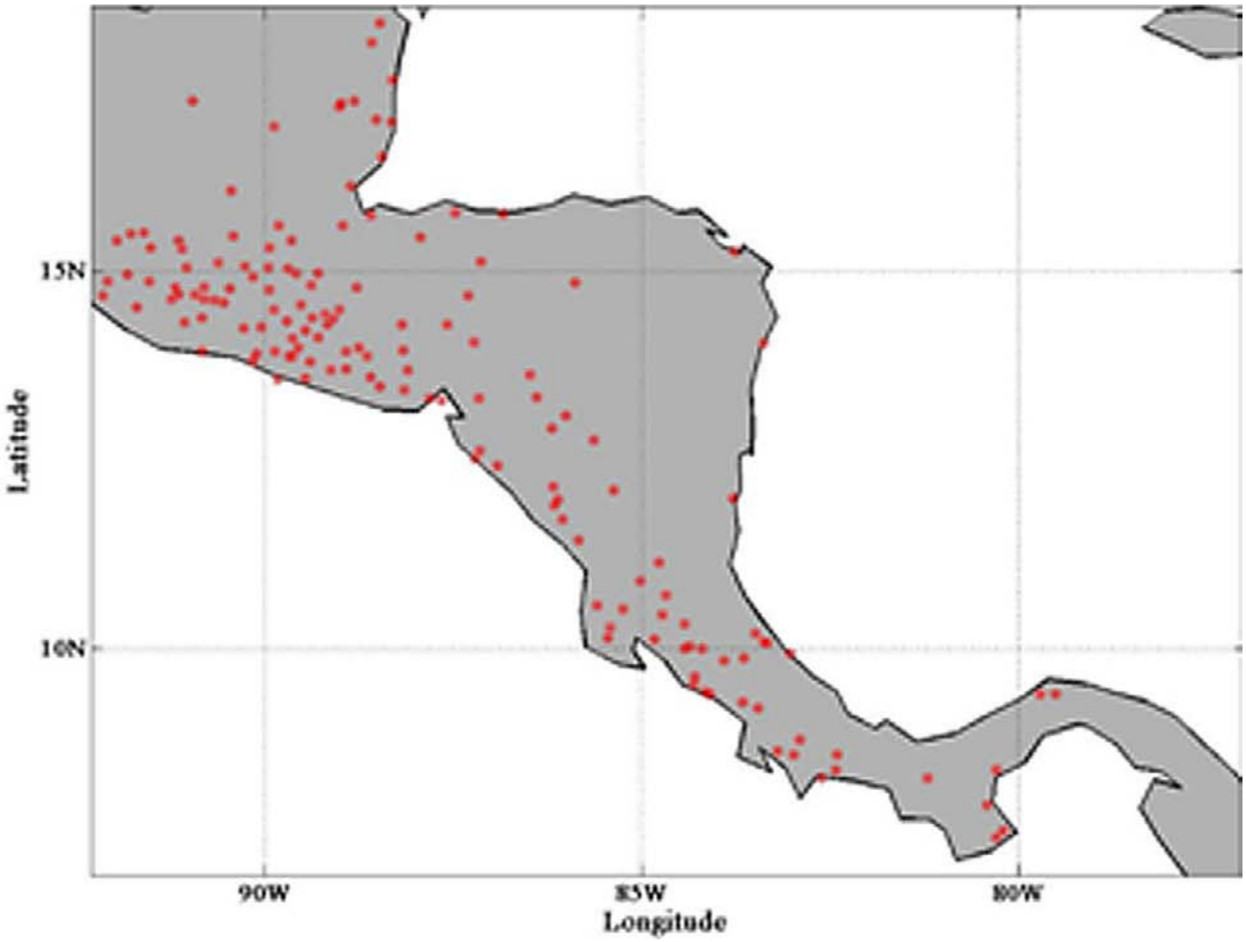


Figure 2. Location of the rain gauge stations used (red dots).

longitudes), and starts in 1981 to near present. CHIRPS incorporates 0.05° resolution satellite imagery with in-situ station data to create gridded rainfall time series for trend analysis and seasonal drought monitoring. Seasonal precipitation estimates were calculated for 17158 grid points over the isthmus.

The assessment of each forum map was done using the same observed seasonal categories (i.e. BN, N and AN) in the station observations, the TRMM and CHIRPS datasets. These comparisons are illustrated in Figure 3. The rainfall gauge observations were also compared with a) the Canonical Correlation Analysis (CCA) output models using the Climate Predictability Tool (CPT) for the same RCOF seasons, b) using the persistence of the observed station anomaly previous to the RCOF season and c) using a seasonal forecast always based on the Neutral category.

The CPT, elaborated by the International Research Institute for Climate and Society (IRI, Mason & Tippett, 2016, http://iri.columbia.edu/our-expertise/climate/tools/cpt/), was chosen because it is nowadays in use for operative seasonal climate predictions in Central America by the NMHSs.

As in the work of Maldonado, Rutgersson, Alfaro, Amador, and Claremar (2016), the extended reconstructed sea surface temperatures (ERSSTv3b, Smith, Reynolds, Peterson, &

Lawrimore, 2008) were used as predictors in the CCA models. The sea surface temperature (SST) anomalies were constructed using a combination of observed data along with models and historical sampling grids. This global database has a horizontal resolution of 2.5 by 2.5.

The SST domain bounded by 63°N-10°S and 152°E-15°W was considered in order to capture the signal of the most important climate variability modes for the Central American isthmus. These variability modes are El Niño Southern Oscillation (ENSO), the North Atlantic Oscillation (NAO), PDO, AMO and the TNA, which have shown to be relevant in terms of rainfall climate variability (Fallas-López & Alfaro 2012a, 2012b).

The above CCA methodology is based on Maldonado et al. (2013; 2016) and it is implemented and summarized as follows: the fields (SST anomalies, predictors and seasonal accumulates, predictands) are first reduced by means of principal component analysis (PCA) to assure stability in the CCA parameters. A maximum of 10 EOFs and CCA modes in the filtering stage are allowed. This threshold is suggested here to avoid overparameterisation. The optimal combination of EOFs and CCA modes are calculated by means of the goodness index (mean Kendall τ). The maximum possible number of CCA modes, however, is determined first by the minimum number of EOFs between both fields. Then, with the goodness skill, the maximum number of CCA modes is found for the best fit to avoid any overparameterisation in the model $Y_1 = b^T \cdot X$, where the elements of b are the ordinary least-squares regression coefficients computed with CCA, and Y_1 is the predicted value of Y. The τ was computed using cross-validation models with 5-month window since 1979 to the RCOF season for each station in all the models. It is worth mentioning that, at the end, the models would not necessarily have 10 EOF and CCA modes. Monthly SST anomalies fields from the month before the RCOF season were analyzed as potential predictors (lead-time). Each experiment was conducted with the observed persistence of the rain gauge station records during the previous two months, e.g. prior to the RCOF seasons accumulates.

Summarizing, six comparison experiments were done: 1) RCOF maps vs Stations Observations,

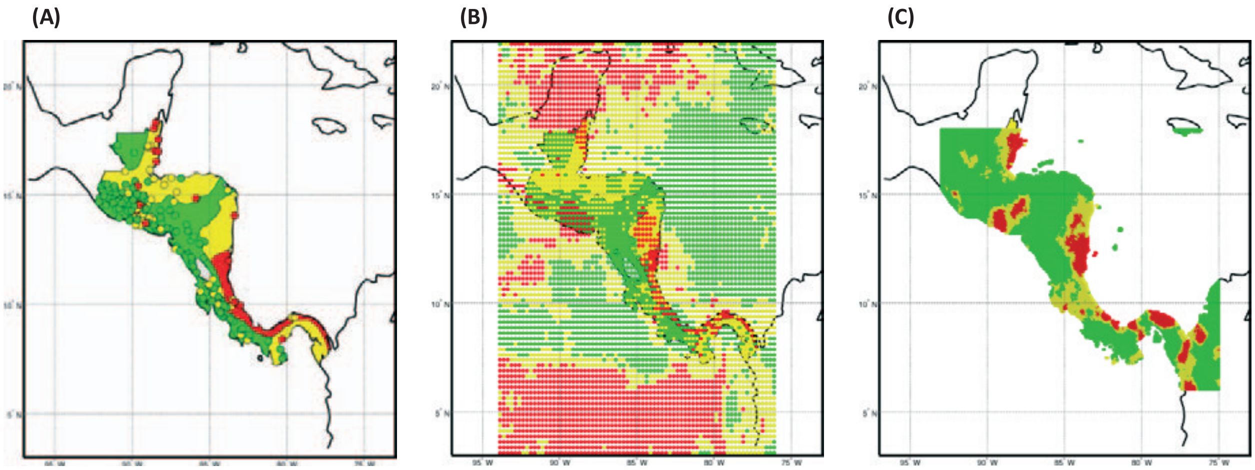


Figure 3. Example of the ASO 2010 RCOF map comparison with the observed Below Normal (BN, red), Neutral (N, yellow) and Above Normal (AN, green) categories in (A) rainfall gauge stations, (B) TRMM and (C) CHIRPS grid data. Only grid data points over land at Central American isthmus were used for these comparisons in (B) and (C), including the areas of Belize, Guatemala, Honduras, El Salvador, Nicaragua, Costa Rica and Panama.

2) RCOF maps vs TRMM grid data, 3) RCOF maps vs CHIRPS grid data, 4) CTP outputs vs Station Observations, 5) Previous Month Persistence vs Station Observations and 6) Always Neutral Forecast vs Station Observations.

The performance of the outlooks were assessed using the Skill Score (SS) and the Gerrity score (Wilks, 2011; Mason & Stephenson, 2008) based on a 3 x 3 contingency table for BN, N and AN categories for outlooks and observations (Alfaro et al., 2003). SS transforms the information that the Hit Rate (HR) coefficient gives, where:

$$HR = \frac{(f_{11} + f_{22} + f_{33})}{n} * 100 \quad (1)$$

f_{ij} are the observed occurrences in the 3 x 3 contingency table and n is the total number of prediction-observation pairs.

We calculated the SS as:

$$SS = \frac{100 * (\mathrm{HR} - 33.33)}{(100 - 33.33)} \quad (2)$$

Note that when a prediction is completely random SS = 0, and when the correspondence is exact (Pr{Success}=1) SS = 100, meaning a perfect group of hits. This last case tells us that the empirical probabilities of the smallest diagonal are null. Negative values of the SS indicate that misses dominate in our analysis.

Gerrity score is similar to the SS with the exception that now the predictions having two erroneous terciles are much more downgraded than those that only have one, and we can express it as:

$$Gerrity = \frac{(z_1)}{z_2} * 100 \quad (3)$$

where z_1 is the sum of the weighted frequencies; for the positive correlation between predictions and observations:

$z_1 = 1.25 * f_{11} - 0.25 * f_{12} - 1.00 * f_{13} - 0.25 * f_{21} + 0.50 * f_{22} - 0.25 * f_{23} - 1.25 * f_{31} - 0.25 * f_{32} + 1.25 * f_{33}$

Now, z_2 is the sum of the weighted frequencies in a perfect group of hits. If the predictions were random and all the empirical frequencies of the contingency table tended to the same value (z_1) then Gerrity score would tend to zero. On the other hand if we had a perfect prediction then the ratio z_1/z_2 would tend to one and the Gerrity score would tend to 100. As with the SS, negative values of the Gerrity score would indicate that misses dominate our analysis.

The scores were first calculated for every seasonal outlook, considering all stations or grid points. This was done to study the RCOFs skill trough time. We compared the score median outlooks from 1998 to 2007 with those from 2008 to 2013, to study if any statistical difference was observed. The scores were also calculated for every station and for all outlook seasons, in order to spatially study the RCOFs skill.

3. Results

Figures 4 and 5 show the box plot of SS and Gerrity score values for outlooks made for MJJ, ASO, DJFM and all seasons. Results from figures 4 and 5 show that all the comparisons between RCOFs maps and station observations (label 1) had positive median values. Using grid databases from TRMM or CHIRPS, for a full isthmus coverage, did not systematically improved or degraded the scores median values (labels 2 and 3) when they were compared with the station observation results. Higher P_{75} score values were observed in all comparisons between CTP outputs and station observations (label 4) and the highest scores were for the MJJ 2010 outlook. Comparisons between previous RCOFs month persistence and station observations (label 5) also had positive median and P_{75} values in all seasons, but they were not systematically better than those obtained between RCOFs maps vs station observations and between CTP outputs vs station observations. Most of the positive outliers in Figs. 4d and 5d are for the ASO seasons. Outlooks based

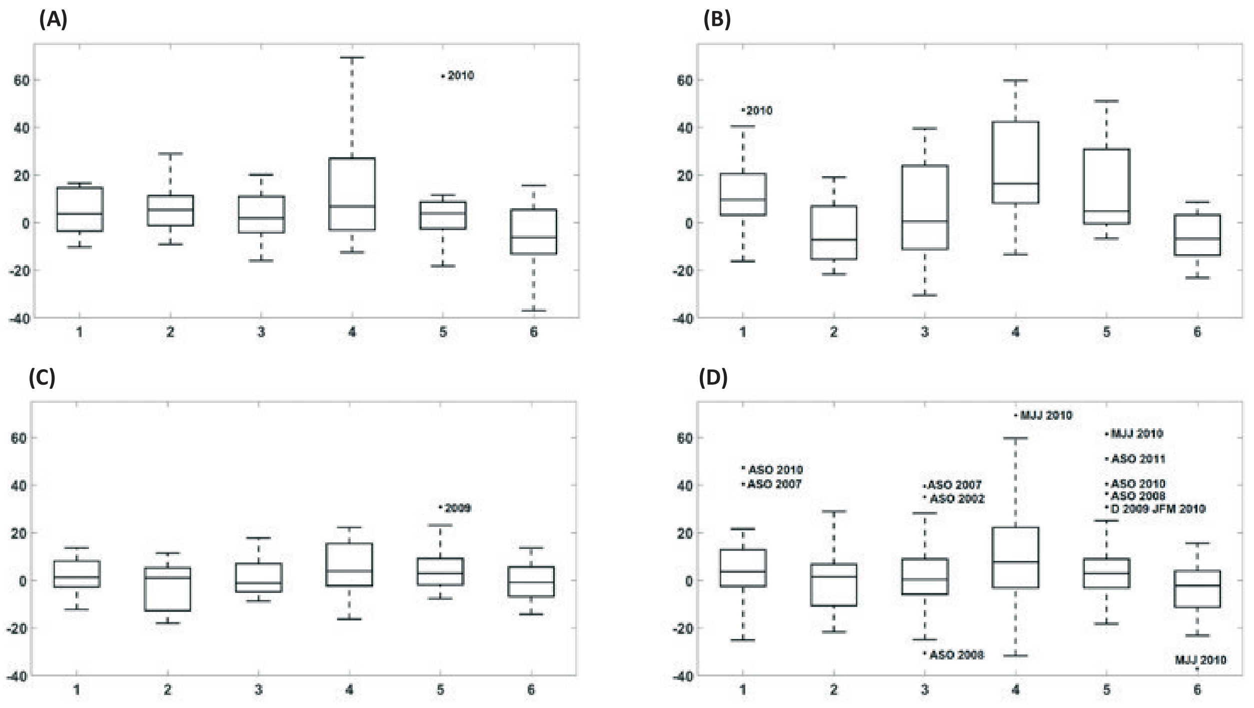


Figure 4. Box plot of SS values for outlooks made for (A) MJJ, (B) ASO, (C) DJFM and (D) all seasons. Black asterisks are for the outliers behind the whiskers (P_{75} + or P_{25} – 1.5 IQR for upper or lower outliers). Box plot comparisons are for: 1) RCOF maps vs Stations Observations, 2) RCOF maps vs TRMM grid data, 3) RCOF maps vs CHIRPS grid data, 4) CTP outputs vs Station Observations, 5) Previous Month Persistence vs Station Observations and 6) Always Neutral Forecast vs Station Observations.

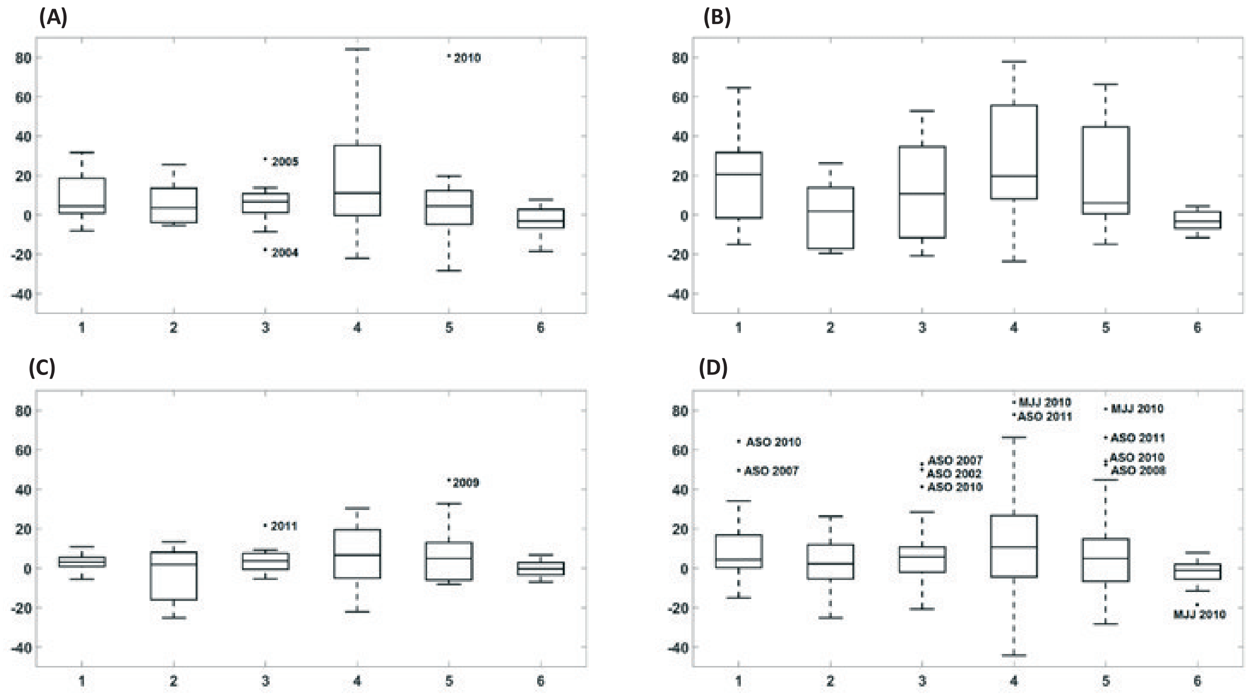


Figure 5. Same as figure 4 but for Gerrity score values.

on an Always Neutral forecast had the worse median results in all cases (see label 6 in Figures 4 and 5). SS and Gerrity score values comparing individual outlook maps and observed rainfall gauge values for MJJ, ASO, DJFM and all seasons are presented in figures 6 and 7, respectively.

We do not present the comparisons between RCOFs maps and TRMM or CHIRPS gridded data because they did not systematically improved or degraded the scores median values when compared with the station observation results in figures 4 and 5. None of the median value differences between the 1998-2007 and 1998-2013 was statistically significant under the Mann-Whitney-Wilcoxon non parametric test, but all of the differences were positive, except for SS values in figure 6c for DJFM outlooks. Having a positive difference in Figures 6c and 7c results, means that misses in the 1998-2013 DJFM outlooks are mainly by one category. Highest scores were observed for the ASO 2010 outlook. The worst outlooks using the SS were observed for the JJA 1998, the first one celebrated in Central America, and for ASO 2003 using the Gerrity score, mainly because misses by two categories dominated that last outlook comparison. From figure 6, it was observed that 69.2, 83.3, 50.0 and 63.4% of the SS values are positive for the MJJ, ASO, DJFM and all seasons outlooks. Observed values for Gerrity score are 84.6, 66.7, 83.3 and

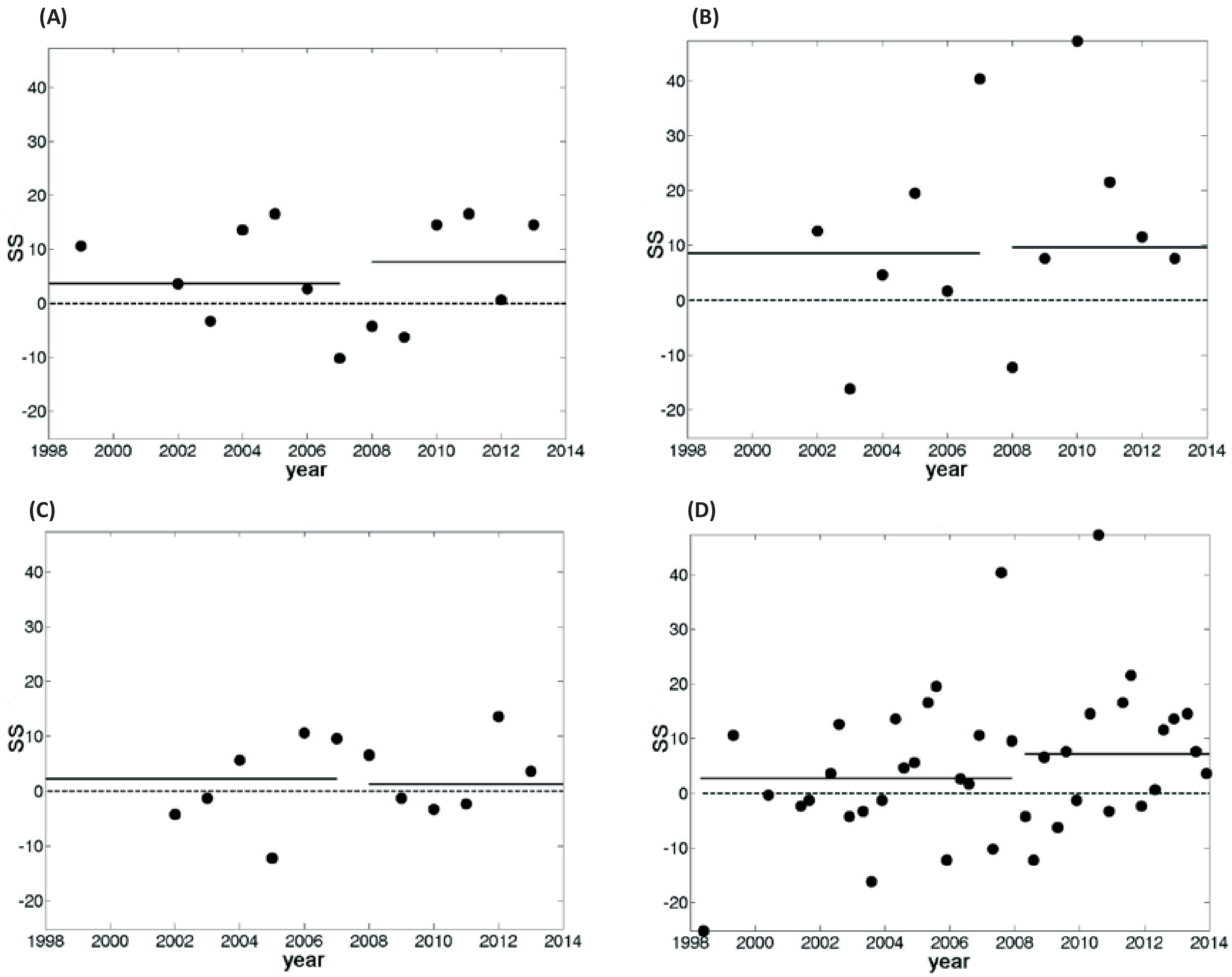


Figure 6. SS values comparing individual RCOF maps and observed rainfall gauge values for (A) MJJ, (B) ASO, (C) DJFM and (D) all seasons. Horizontal solid lines are the median value for 1998-2007 and 1998-2013 periods, respectively.

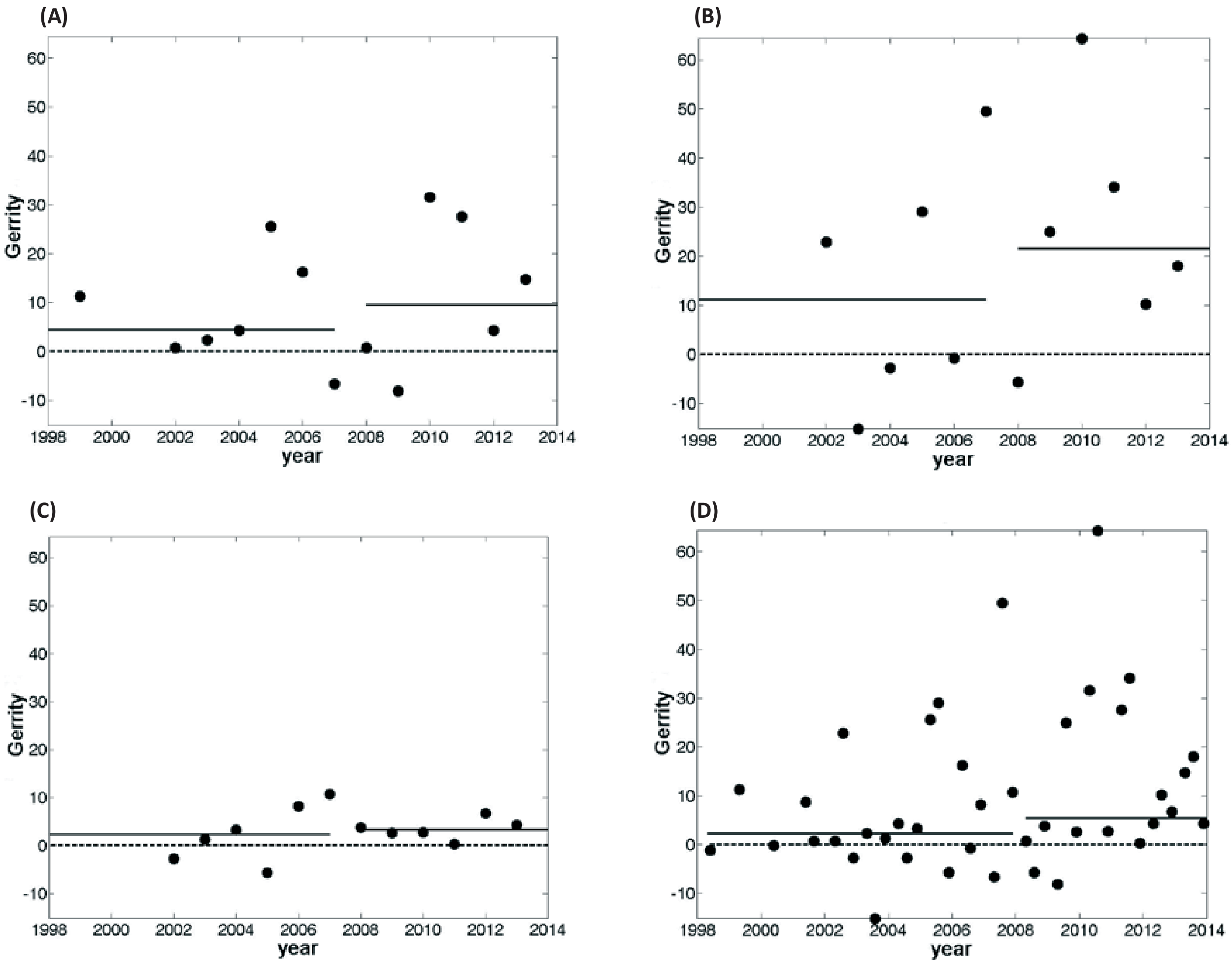


Figure 7. Same as figure 6 but for Gerrity score values.

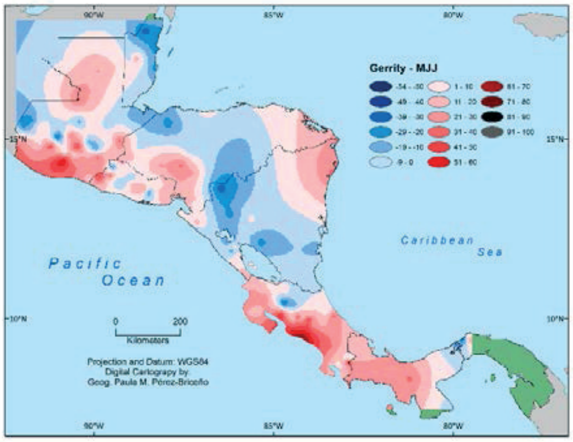
75.6%, respectively (figure 7). Notice that DJFM season outlooks have the worst assessment scores and that, in general, the percentage of positive Gerrity score values are greater than those of the SS, except for ASO season outlooks.

This could reflect that misses by one category dominated those outlook comparisons, except for ASO. The lower SS and Gerrity scores for DJFM could mean that drivers modulating the rainy season in Central America (typically from April to November, Taylor & Alfaro, 2005) are better understood that those modulating during the dry season (typically from December to March, Taylor & Alfaro, 2005). Predictive schemes for different aspects of the rainy season were studied by Enfield and Alfaro (1999), Alfaro (2007a), Fallas-López and Alfaro (2012a, 2012b), Maldonado et al. (2013; 2016), but just Fallas-López and Alfaro (2012a, 2012b) produced predictive schemes for the dry season.

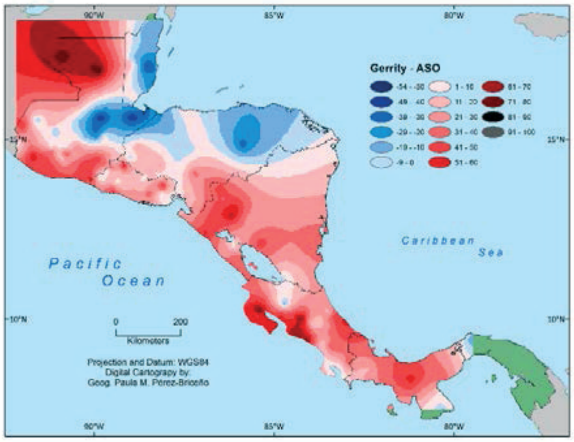
The spatial distribution of Gerrity score comparing RCOF maps and the rain gauge observations is presented in Figure 8. It is observed that ASO showed the best score values except for the North Caribbean slope of Central America, this region was extended for MJJ, in which the best scores were observed at the South and North Pacific slope. DJFM had the lowest skill values, except for some lobes across the isthmus.

These patterns are maintained when CPT outputs and rain gauge observations are compared (Figure

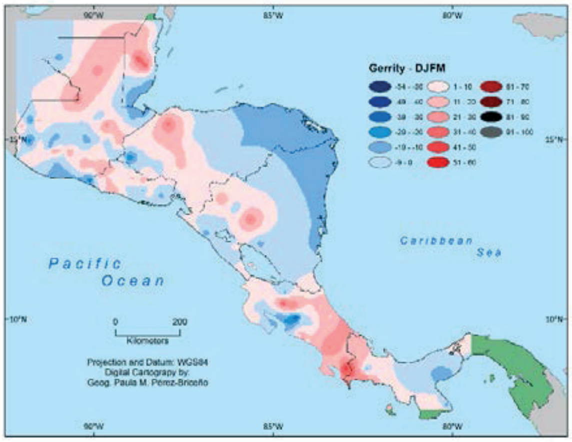
(A) MJJ



(B) ASO



(C) DJFM



(D) All

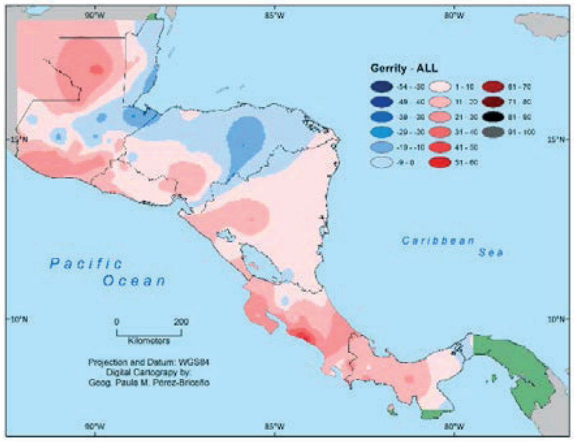


Figure 8. Spatial distribution of Gerrity score comparing RCOF maps and rain gauge observations.

9) but the area with skillful score values increased as well as the score values, even for DJFM.

The percentage of negative SS and Gerrity score values for all the comparison maps is presented in table 1.

Table 1. Percentage of stations or grid points having negative SS (A) or Gerrity (B) score values for: 1) RCOF maps vs Stations Observations, 2) RCOF maps vs TRMM grid data, 3) RCOF maps vs CHIRPS grid data, 4) CTP outputs vs Station Observations, 5) Previous Month Persistence vs Station Observations and 6) Always Neutral Forecast vs Station Observations

(A)

	MJJ	ASO	DJFM	All
1	41.67	21.79	35.9	34.62
2	45.43	47.46	51.67	53.7
3	48.81	30.26	36.78	41.76
4	26.92	13.46	30.13	19.23
5	39.1	33.97	49.36	21.15
6	65.38	54.49	37.82	60.26

(B)

	MJJ	ASO	DJFM	All
1	32.69	24.36	49.36	20.51
2	43.54	52.54	55.01	43.25
3	43.1	28.74	45.91	29.88
4	21.15	20.51	39.1	17.31
5	34.62	23.08	43.59	17.95
6	65.38	72.44	58.33	60.26

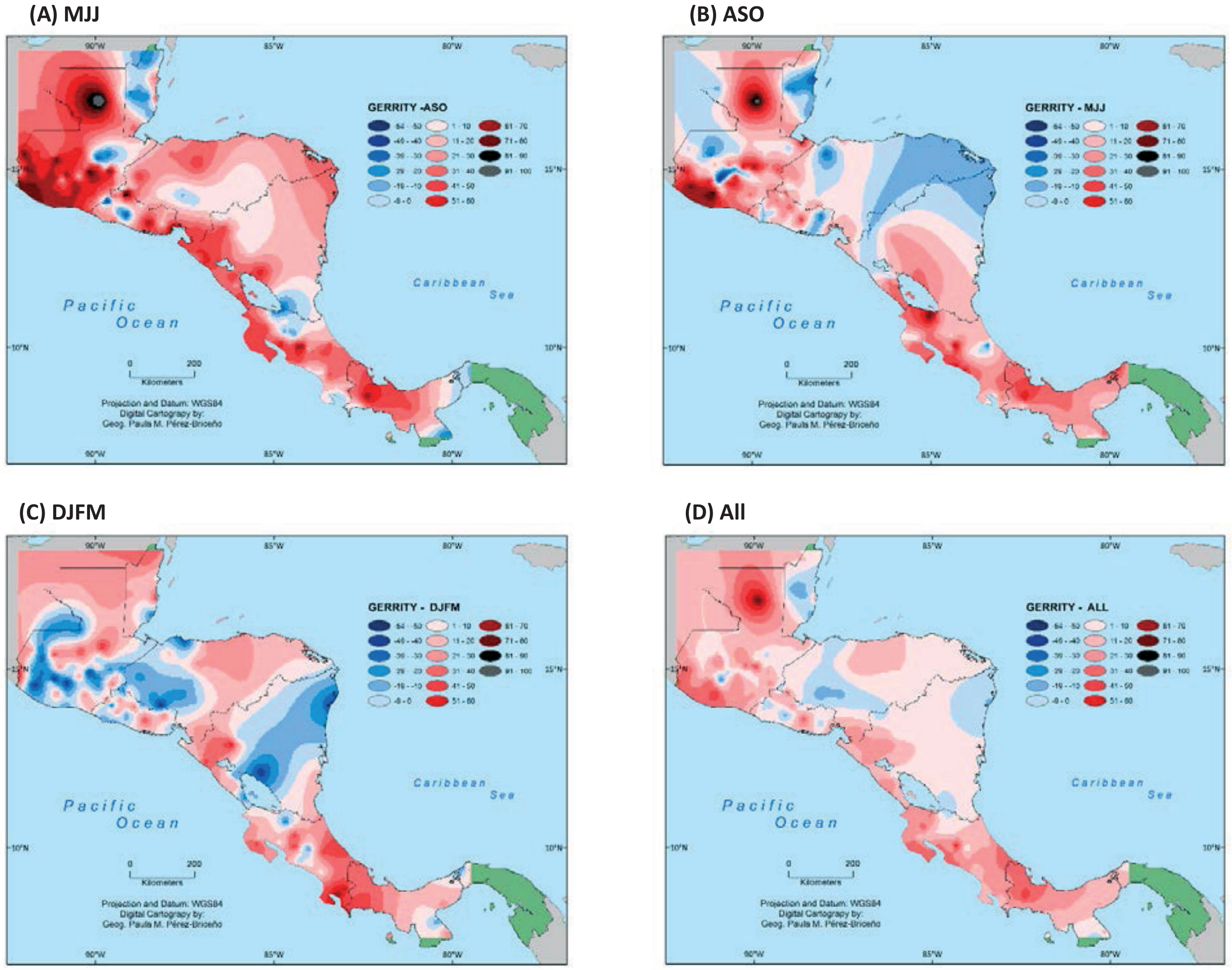


Figure 9. Spatial distribution of Gerrity score comparing CPT outputs and rain gauge observations.

Notice that RCOF maps did not have percentages greater than 50% in any season and that outlooks based on always neutral category showed the highest percentage values in almost all the cases. Outlooks values based on persistence, support its inclusion also on CCA predictive schemes that had the lowest percentages.

4. Discussion

Alfaro et al. (2003) mentioned that scientific and academic communities have discussed certain problems that arise during the development of the forums and how the research results can be better used to improve the forums products. One of the problems identified during the RCOFs is that because there is not a standardized methodology for producing the forecast, the contributions from different countries can result in a disjointed regional forecast that is sometimes physically inconsistent across political borders. Moreover, it appears that the statistics behind the used tools are not familiar to some of the participants, such that the national climate forecasts are sometimes based only on subjective evaluations. This is supported in some way by the results presented in figures 4 and 5.

Notice that highest P_{75} score values were observed for all the comparisons between CTP outputs (e.g. an objective tool) and station observations. Some of the roots of the problems mentioned above have been identified: i) the resources of some institutions are limited to the routine tasks and only a small portion of their budget is allocated for research and capacity building; and ii) there have been very few opportunities for training on the concepts required for the RCOFs.

To alleviate the last problem mentioned in the previous paragraph, CRRH has been very active about training the RCOFs participants. According to the information given by this Committee, 22 training activities were conducted to RCOFs participants in Central America (figure 10), since they are in charge of the RCOFs process, e.g. year 2000.

Activities were mainly lectures and workshops in tools and statistical concepts useful for climate seasonal forecast. The Center for Geophysical Research (CIGEFI) at the University of Costa Rica had also collaborated with the capacity building activities of Central America RCOF mentioned above, and also distributing its papers production on subjects of seasonal climate prediction, climate variability, climate change and themes related to drivers that modulates climate in Central America (García-Solera & Ramírez, 2012).

However, none of the median value differences between the 1998-2007 and 1998-2013 were statistically significant (figures 6 and 7), in spite that all the differences were positive, except for SS values in figure 6c for DJFM outlooks. It means that knowledge has not had a cumulative effect in the RCOF participants through the last years as figure 10 suggested. This could be explained by adding two problems to the ones mentioned at the beginning of this section.

The first one is related to the fact that the resources of some institutions are limited to the routine tasks, so they cannot allocate enough time for working or going deeply in the tools in which they were trained. The second one could be related with the fact that RCOF participants have changed trough the time, and the transmission of acquired knowledge is not always guaranteed to the newer RCOF participants by the former ones. Conscious of this last problem, CRRH has encouraged the same people participation in the RCOFs, but the policies about this issue are different trough the participants institutions.

According to García-Solera and Ramírez (2012), one important future goal is to empower RCOFs to use more objective tools (results from figures 4, 5, 8 and 9 support the idea around this goal) such as more specific and detailed recommendations that would allow it to improve the quality of the outlook scenarios in the different sectors. Another goal is to strengthen the relationship between stakeholders and decision-makers so as to allow CRRH to more effectively identify end-users vulnerability to climate variability. They add that CRRH envisions creating a new tool that would allow them to measure the economic value of the information produced through the COF, as well as the value of the meteorological services. It would also be useful to be able to measure the difference between decisions made with and without the Seasonal Climate Outlooks, such as how many people have not been affected due to that decision. If such a tool could be developed, it could help interest those who can pay or contribute to the service. In that sense, Moreno (2015) developed recently a tool to assess the economic value of

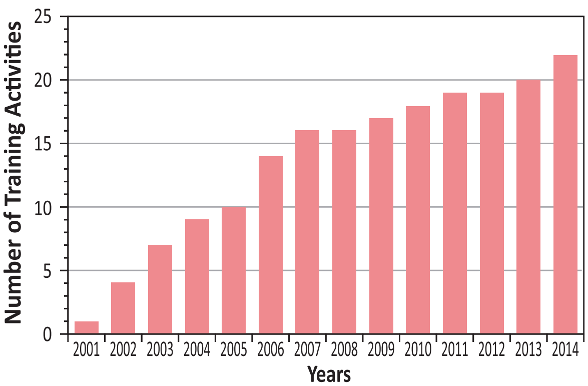


Figure 10. Cumulative number of training activities for the Central American RCOF participants, January 2001 - June 2014 (Source: CRRH).

the climate variability information in different regional socioeconomic sectors.

This goal is important, since results from figures 4 and 5, showed that outlooks based on an Always Neutral forecast had the worst median results for all cases, so RCOFs maps have an aggregate value to decision-makers. Notice for example that 75.6% of the Gerrity scores in figure 7d are positive, meaning that they are skillful most of the times and that misses are normally by one category.

Additionally, all the comparisons between RCOFs maps and station observations had positive median values in figures 4 and 5.

An important aspect in the region is the creation of a Regional Climate Service. This is pointed out by Garcia-Solera and Ramirez (2012) as a major goal not just for Central America but for an extended region that includes Mesoamerica.

It means to institutionalize the service, where there would be personnel dedicated only for the creation of climate products including the Seasonal Climate Outlooks and their associated outputs. These outlooks could include products related with the onset and the end of the rainy season (e.g. Enfield & Alfaro, 1999; Fallas-Lopez & Alfaro, 2012a), extreme wet or dry event occurrences along with the occurrence of rainy days (e.g. Maldonado et al., 2013), the Mid-Summer Drought beginning and intensity (e.g. Maldonado et al., 2016; Fallas-Lopez & Alfaro, 2012a) or mean, maximum and minimum temperatures (Alfaro, 2007b; Fallas-Lopez and Alfaro 2014) among others.

Spatial distributions of scores presented in figures 8 and 9 showed that in general most of the region have skillful lobes, but especially during the ASO season and on the Pacific slope of Central America. Regions with negative skill score values may represent areas in which climate drivers modulating precipitation are not well understood. Notice that during the consensus process for the RCOF maps, SST anomalies of surrounding oceans are pondered. The inclusion of other predictor fields or tools as in Muñoz, Díaz-Lobatón, Chourio and Stock (2016), could improve the predictability in those regions, along with a better understanding of climate annual cycle variability, especially at the Central American Caribbean slope (Saenz & Amador, 2016). Noticed also that this slope shows the smallest density of stations for logistic reasons, so improving the number of stations there could contribute also to improve the knowledge of climate variability and prediction over those low skillful regions. In spite that TRMM and CHIRPS grid data sets can give full spatial coverage, rainfall gauge station observations are still necessary for the validation of those datasets.

5. Conclusions

According to Garcia-Solera and Ramirez (2012), the Central American RCOFs is an institutionalized governmental process, actually following the World Meteorological Organization´s Global Framework of Climate Services.

They concluded that all Central American countries benefit from the Seasonal RCOF, which is issued three times a year, and all countries can easily accesses it. It is regionally and nationally focused. Operational climate services are at the core of this RCOF process.

The Seasonal Climate Outlook is an international public good provided by the RCOF. Both private sectors and Central American governments use it for decision-making. The Seasonal Climate Outlook does promote free and open exchange of climate-relevant observational data while respecting national and international data policies. They do facilitate and strengthen rather than duplicating information and RCOF was built through user–provider partnerships that include all stakeholders.

Our results showed that RCOFs maps have an aggregate value to decision-makers, because they have skillful information most of the times. Additionally, outlooks based on an Always Neutral forecast had the worse median skill results for all cases, this information is useful for decision-makers, meaning that decisions taken without considering climate outlook information is worse than those taken in account the RCOF maps most of the times.

The inclusion of objective tools and given them a more specific weight in the consensus map production, could increase the RCOFs skill. For example, in our study highest skill score values were observed for all the comparisons between outlooks based on pure CTP outputs and station observations. RCOF participants are already familiar and trained with these kind of tools, e.g. CPT or contingency tables, and some countries already present their seasonal outlooks based on them.

Another aspect is that regions having the lowest density of stations showed also lower skill score values. Therefore, improving the number of rainfall stations in those regions, including the maintenance of actual network, would increase the knowledge of climate variability and the drives that modulated precipitation there, those aspects could result in better predictability schemes over an extended area of Central America helping decision making processes.

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