

LONG-TERM CHANGES, AND THE INFLUENCE OF ENSO, ON THE PRECIPITATION AND TEMPERATURE EXTREMES OF COLOMBIA: RESULTS USING DATA FROM THE SATELLITE RAINFALL ESTIMATES CHIRPS, AND DATA PROVIDED BY GROUND STATIONS

Juan Diego Giraldo-Osorio¹, David Enrique Trujillo² Osorio, Oscar Manuel Báez Villanueva³, Luis Alberto Vargas-León⁴ and Christian Camilo Romero Romero-Rojas⁵

jgiraldoo@javeriana.edu.co¹ david.trujillo@javeriana.edu.co² [oscar2 Oscar.BaezVillanueva@UGent.be](mailto:oscar2@Oscar.BaezVillanueva@UGent.be)³ vargasl_u@javeriana.edu.co⁴ romeror.c@javeriana.edu.co⁵

¹Researcher at *Instituto Javeriano del Agua*. ^{1,2,4,5}Pontificia Universidad Javeriana, School of Engineering, Civil Engineering Department. Research Group *Ciencia e Ingeniería del Agua y el Ambiente*. Bogotá D. C., Colombia. ³Institute for Technology and Resources Management in the Tropics and Subtropics (ITT). Technology Arts Sciences TH Köln. Cologne, Germany - Faculty of Spatial Planning, TU Dortmund University. Dortmund, Germany - Department of Environment, Ghent University, Ghent, Belgium (presently).



INTRODUCTION

It has been observed that, on a warmer planet, there are changes in the average values of hydro-climatological variables (e.g., the multiannual average value of precipitation or temperature, the average number of days with rain, among others). However, the effects on human life generally occur due to extreme events of these variables (i.e., heavier rains, extreme heat or cold waves, or unusually long spells of drought), so a study of the long-term changes of those extreme values is a primary task to design effective climate change adaptation strategies. However, on short time scales, the effect of ENSO on hydrological variables must be considered since it is one of the principal modulators of global climate.

The context of our study lies in understanding the effects of ENSO-driven variability, and long-term changes, on Extreme Precipitation Indices (EPI) and Extreme Temperature Indices (ETI) in Colombia, utilizing different data sources such as CHIRPS and ground station data from IDEAM (*Instituto de Hidrología, Meteorología y Estudios Ambientales*; IDEAM is a government agency that studies the weather and climate of Colombia, among other subjects). Studying extreme precipitation and temperature events allows for natural disaster preparedness and climate change adaptation in the region. The goals are to analyze and quantify trends in extreme precipitation and extreme temperature values, identify relationships with ENSO events, and provide valuable insights for decision-making and risk assessment in Colombia.

STUDY AREA AND DATASET

The study area corresponds to the whole continental territory of Colombia. Colombia is located in the northwest corner of South America, and the country has shorelines to both the Pacific and the Atlantic Ocean, through the Caribbean Sea (see Fig. 1).

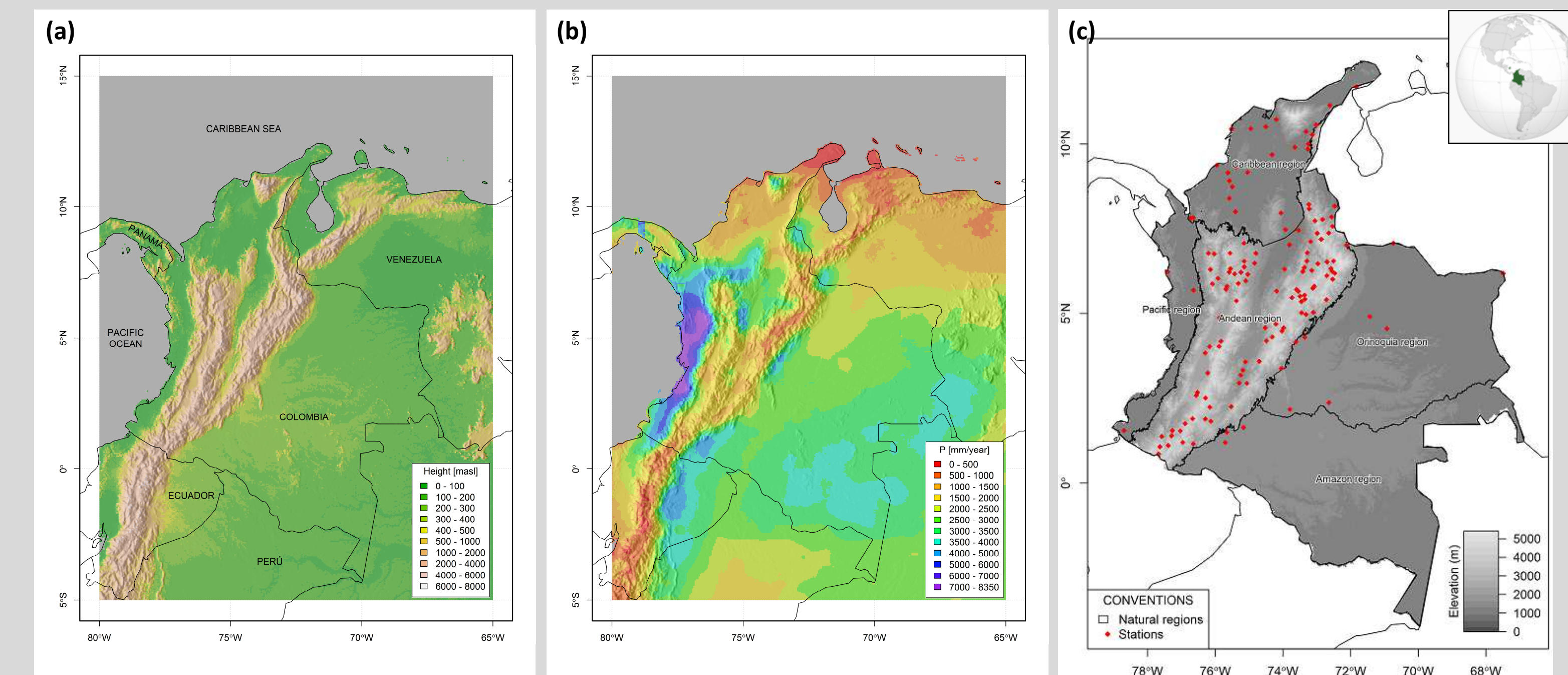


Fig. 1. Location of the study area. The topography of Colombia (a), the mean annual precipitation computed with CHIRPS (b) and the location of stations with daily temperature data (c), are shown. As can be seen, temperature and precipitation in Colombia are strongly driven by the Andean Mountain Chain. Colombia can be divided into four main climatic areas: the Caribbean coast in the north (the driest one), the Pacific coast in the west (the wettest one), the Andean region (center), and the eastern plains of Orinoco and Amazonas basins (east).

The precipitation data were collected from CHIRPS database (*Climate Hazards Group InfraRed Precipitation with Station* data). According to Funk et al. (2015), CHIRPS has a temporal coverage, starting in 1981, with daily temporary resolution; the spatial coverage is quasi-global (all longitudes between 50°S-50°N), with 0.05° of spatial resolution. CHIRPS database has been validated in the Colombian territory by Urrea Minota (2017) and Baez-Villanueva et al. (2018). CHIRPS database was spatially trimmed off, in such a way the study area was completely covered (between 5°S-15°N and 80°W-65°W, 400x300 pixels; see Fig. 1b).

For the daily temperature data analysis, IDEAM provided information from 651 stations, which had records from 1979 onwards. When evaluating the date in which the most data was recorded, it was established that the greatest regularity in the records was between 1987 and 2021. According to the above, a study period of 35 years was established for which those stations with at least 80 % of the data were selected, so 510 stations were discarded. The remaining 141 stations are located as shown in Fig. 1c. According to the map, 83 % of the stations are in the Andean and Caribbean regions, while the Pacific, Orinoco and Amazon regions have the remaining 17 %, highlighting that the Pacific region has only two stations (Fig. 1c).

EXTREME PRECIPITATION INDICES (EPI) DEFINITION

The CCI/CLIVAR/JCOMM/ETCCDI group developed a set of 27 climatic indices, which should be computed using daily rainfall and/or temperature data. The subset of indices related to precipitation are called *Extreme-Precipitation Indices* -EPI-, and the subset of indices related to temperature are called *Extreme Temperature Indices* -ETI-. Those indices are the same in Zhang et al. (2011), but with slight modifications in the original definitions.

It is important to highlight the most important modification is about the time slides to compute the EPI (ETI): the *hydrological year* was taken between one-year's June, and next year's May, to match with the developing phases of ENSO phenomena.

In each CHIRPS' gridpoint (or temperature station), the EPI (ETI) time series were built (see Fig. 2 y 3), according to the definition of the indices. According to the definitions, extreme indices have been defined with annual temporary resolution (i. e. according to the previously defined *hydrological year*). So, EPI annual series between 1981/82-2019/20 were built (i. e. 39 years), and ETI annual time series between 1987/88-2021/22 (i.e. 35 years).

DISCUSSION

According to the findings of this study, three areas with diverse behavior of the EPI are distinguished in the study area: the coast of the Pacific Ocean to the West; the mountainous region that runs through the country in the center; and the plains of the eastern Orinoco+Amazon basin. In these areas, the long-term behavior of EPI, as well as interannual variability, present different behaviors.

However, the regional behavior of ETI is challenging to catch because of the lack of temperature data on the eastern plains of Colombia and in the Pacific region.

The eastern plains of Colombia (Amazonian+Orinoco) do not show a clear relationship between EPI and the interannual variability forced by ENSO (only observable with CHIRPS data, given the lack of data from ground stations). Consequently, the teleconnections of these extreme events with other macroclimatic phenomena that affect, for example, the Atlantic Ocean, the Caribbean Sea, or the Amazon rainforest should be investigated. On the other hand, long-term changes in the eastern plains of Colombia also present lower significance than in the western regions of the territory (again, only observable with satellite precipitation data).

Finally, extreme temperature indices exhibited significant anomalies toward colder temperatures during La Niña years, in contrast to the predominantly warmer anomalies observed during El Niño years. Furthermore, long-term analyses allowed us to observe positive changes (warmer temperatures) in the ETIs.

EXTREME CLIMATE INDICES TIME SERIES

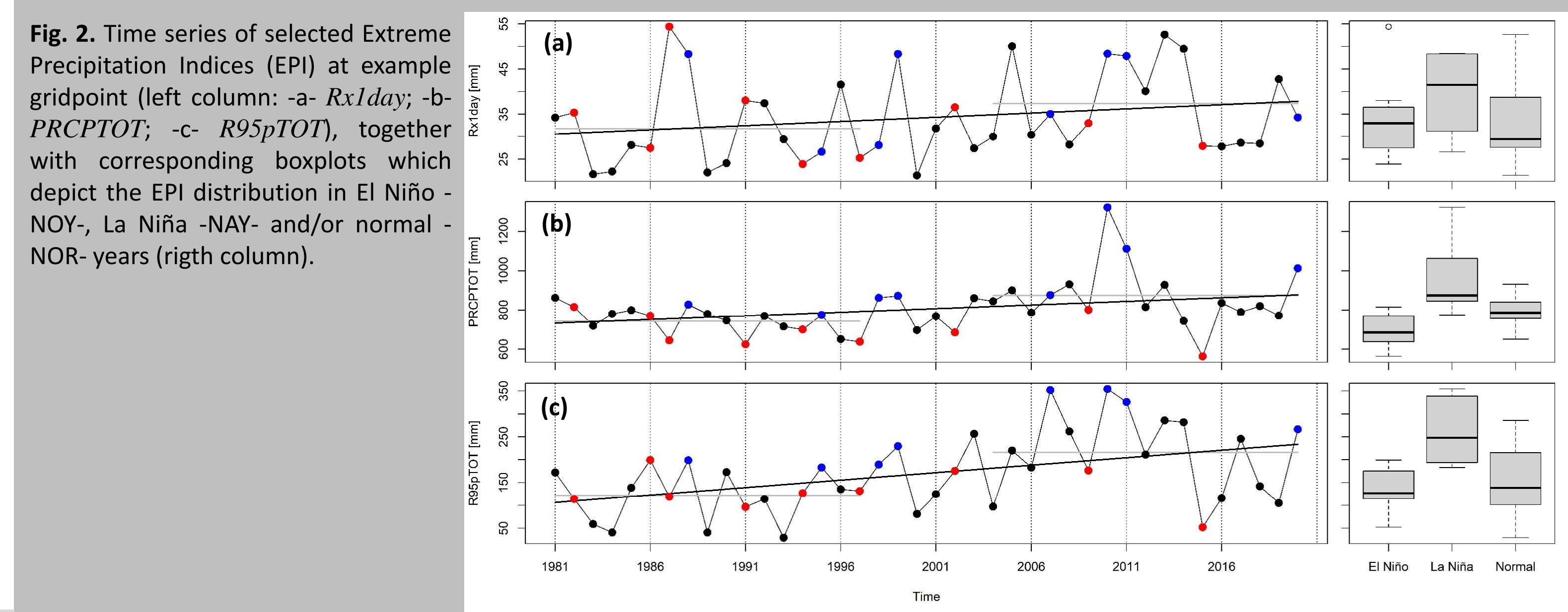


Fig. 2. Time series of selected Extreme Precipitation Indices (EPI) at example gridpoint (left column: -a- $Rx1day$; -b- $PRCPTOT$; -c- $R95pTOT$), together with corresponding boxplots which depict the EPI distribution in El Niño -NOY-, La Niña -NAY- and/or normal -NOR- years (right column).

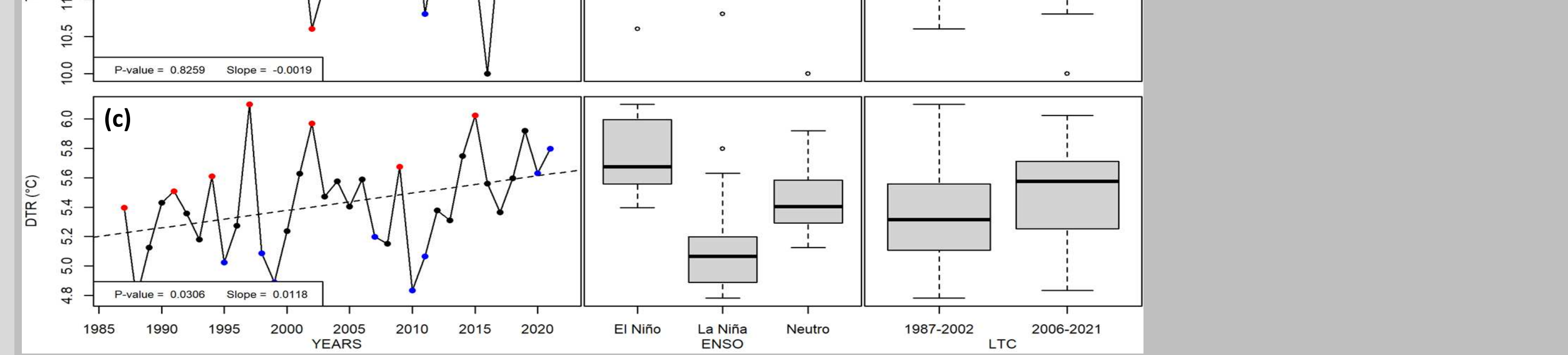


Fig. 3. Time series of selected Extreme Temperature Indices (ETI) at La Mansa station in Ciudad Bolívar (Antioquia). The selected ETI are: -a- TXx ; -b- TNn ; -c- DTR . The ETI time series (left column) are shown together with corresponding boxplots which depict the EPI distribution in El Niño -NOY-, La Niña -NAY- and/or normal -NOR- years (central column), and the variables long-term change (right column).

RESULTS OF SELECTED EXTREME CLIMATE INDICES (MWW test)

