CHIRPS DATASET AND IN SITU STATIONS FOR DETECTION OF WET AND DROUGHT CONDITIONS IN THE BRAZILIAN MIDWEST

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ABSTRACT

The states of Mato Grosso (MT) and Mato Grosso do Sul (MS) are located in Midwest Brazil. The objectives of this study are: (a) to validate the CHIRPS datasets for the states of MT and MS; (b) to evaluate the intraseasonal variability of regional rainfall via CHIRPS; (c) to define the drought and wet periods on the decennial scale, based on the annual SPI. Three seasons were defined (rainy, drought, and transition), and the differences showed that the MS rainy season (56.65%) was reduced due to the veranicos that occur in February. The highest monthly rainfall occurs in the north of MS (328–390 mm), while intermediate rainfall (109–273 mm) occurs in the south of MS. The data obtained via CHIRPS are satisfactory for the spatio-temporal evaluation of regional rainfall, and for the use of SPI to detect drought and wet periods in the states of MT and MS.

Key words — Data gap filling, precipitation product, regional climatology, spatio-temporal validation.

1. INTRODUCTION

Rainfall is the most widely investigated climatic variable in the world. It is measured by using conventional and automatic weather stations, but in countries with continental dimensions such as Brazil, it is difficult to achieve uniformity in the stations across different regions. Thus, rainfall can be estimated via spectral models by sensors onboard environmental satellites [1], by atmospheric modelling [2], and now by artificial neural networks (ANN) applied to orbital images [3], all of which can produce precipitation products.

The use of precipitation products has been a promising alternative to missing data at weather stations in several climatology, meteorology, and hydrology studies worldwide. Precipitation products have been used in studies on the characterization [3], variability [1], validation [4], and spatio-temporal variation [5] of rainfall.

Several studies have been carried out to evaluate the accuracy of data obtained by remote sensing for the calculation of the standardized precipitation index (SPI) versus data measured in situ [6]. However, such studies are scarce in Brazil, especially in the states of Mato Grosso (MT) and Mato Grosso do Sul (MS), which are among Brazil's main grain producers. To date, no study has assessed the use of rainfall products together with the application of SPI to quantify drought and wet periods based on CHIRPS data.

Thus, the objectives of this study were: (a) to validate the CHIRPS product data for the states of MT and MS, located in Midwest Brazil; (b) to evaluate the intraseasonal variability of the regional rainfall via the CHIRPS product; and (c) to identify drought and wet periods on the decennial scale, based on annual SPI.

2. MATERIAL AND METHODS

2.1. Study area

The study area comprises the states of MT and MS (Figure 1). Both states are located in the Midwest region of Brazil, with a territorial area of 1,260,352,532 km2, and an estimated population of 6,263,452 [7]. MT has a predominantly tropical climate, with air temperatures between 24C and 40C and an annual average rainfall of 1,500 mm. The climate of MS varies between tropical and subtropical, with air temperatures ranging from 24C to 40C, and an annual average rainfall of 1,500 mm [8].

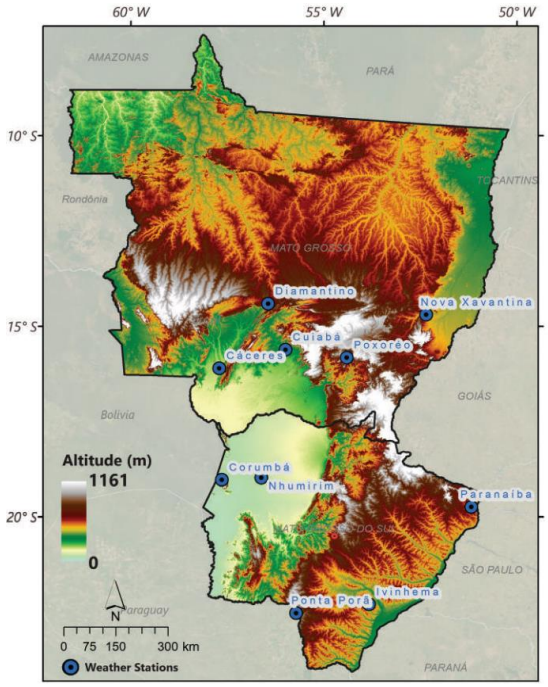


Figure 1. Location of the study area, the states of Mato Grosso and Mato Grosso do Sul, together with rainfall stations and altitude (m).

2.2. Organization and quality control of rainfall data

Monthly rainfall data were made available by the National Water Agency (ANA) [9]. After collecting the data on the Hidroweb platform, 83 pluviometric stations were organized, of which 38 stations were in MS and 45 in MT (Figure 1). All stations had gaps, temporal discontinuities, and data failures. Only 10 stations presented a failure percentage below 25%, which is a criterion similar to that adopted by [10] for the NEB.

2.3. CHIRPS data

CHIRPS data were extracted from the Google Earth Engine platform (https://earthengine.google.com/) using the JavaScript code already in .xls format, and using the dataset since 1981 from the collection ee.ImageCollection ("UCSB-CHG/CHIRPS/DAILY").

2.4. Statistical techniques and space interpolator

For comparison between observed data and CHIRPS data, the following statistics were used: the coefficient of determination (R^2), Pearson's correlation coefficient (r), and Willmott's concordance index (d). Furthermore, the standard error of the estimate (SEE, mm) and root mean square error (RMSE, mm) were used to evaluate the accuracy and precision.

All statistical procedures were performed in R version 3.6.3 and Origin version 9.1.2 (R Development Core Team, 2017).

From the validation of CHIRPS data for the study area, the spatial interpolator Inverse Distance Weighted (IDW), via Quantum GIS software (QGIS) version 3.4.6 (QGIS Core Team, 2019), was used to classify and interpolate the monthly maps.

2.5. Standardized precipitation index (SPI) and ENSO phases

The SPI-12 (annual) calculation was obtained from the CHIRPS rainfall time series, to which the gamma distribution was adjusted. The transformation was performed so that the SPI values had a normal distribution.

The intensity data of the El Niño-Southern Oscillation (ENSO) phases (El Niño, La Niña, and Neutral) followed the classification of the Oceanic Niño Index (ONI) in the region of El Niño 3.4, and were obtained from the National Oceanic and Atmospheric Administration/Climate Prediction Center (NOAA/CPC) [11].

3. RESULTS AND DISCUSSION

3.1. CHIRPS data validation

Statistical analysis based on the scatter plot of observed data (in situ) versus CHIRPS product showed higher dispersion in relation to the 1:1 line in MT state compared to MS state, from 100 mm month^{-1} (figure 2 and 3). The smaller the 1:1 line deviation, the greater the agreement between the observed and estimated data [12].

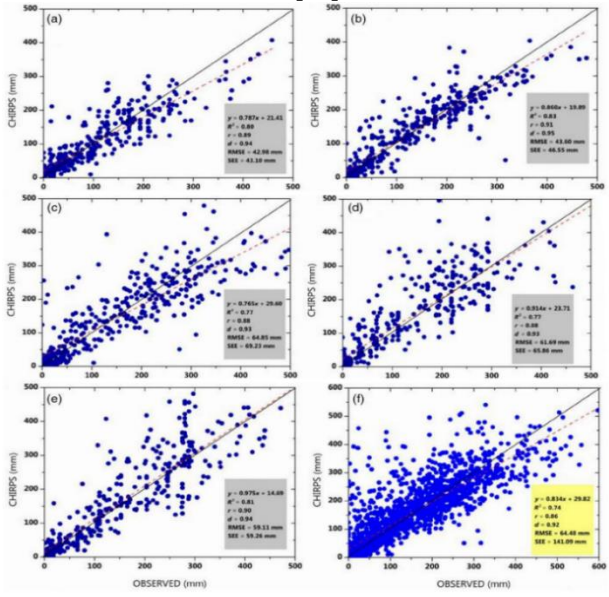


Figure 2. Scatter plot of observed data and CHIRPS data (mm) for the weather stations of Cáceres (a), Cuiabá (b), Diamantino (c), Nova Xavantina (d), Poxoréo (e), and the state of MT (f) in the period 1985–2018.

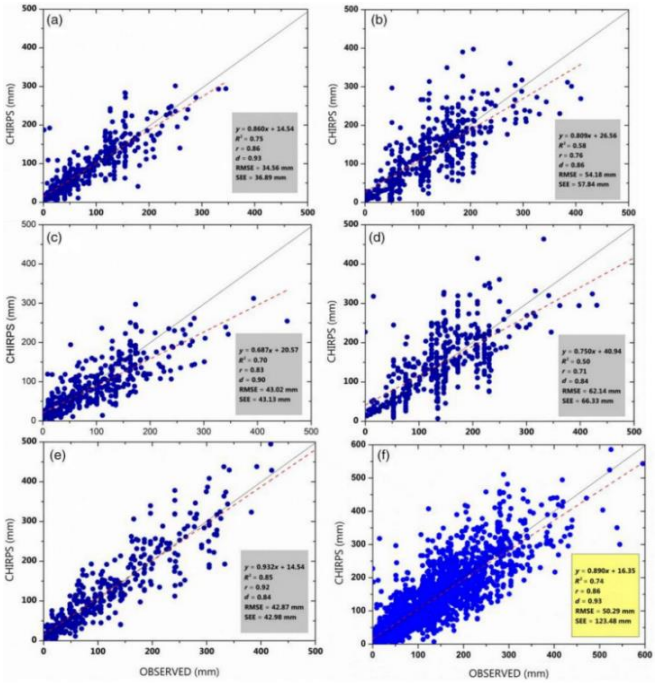


Figure 3. Scatter plot of observed data and CHIRPS data (mm) for the weather stations of Corumbá (a), Ivinhema (b), Nhumirim (c), Ponta Por~a (d), Paranaíba (e), and the state of MS (f) in the period 1985–2018.

The MT rainfall stations obtained R^2 values between 77% and 88%. In the MS pluviometric stations, R^2 ranged from 70% to 85%, except for the stations in Ivinhema (R^2 = 58%) and Ponta Porã (R^2 = 58%), which showed the smallest R^2 values and the highest failure percentages. In MT, the r coefficient ranged from 0.88 to 0.91, with the precision between medium and high represented by the variation of r between 0.71 and 0.92, according to the classification adopted by [13].

The index d was higher than 0.9 at almost all the rainfall stations in both states. The exceptions were the stations located in Ivinhema (d = 0.86), Ponta Porã (d = 0.84), and Paranaíba (d = 0.84), and municipalities located in the extreme south of the study area (Figure 1). Overall, the CHIRPS data presented high precision in both states, as the d index was close to 1 [14].

The smallest SEE (<50 mm) and RMSE (<60 mm) occurred at the MS stations, with the only exception being Ponta Porã station (SEE = 66.33 mm; RMSE = 62.14 mm) (Figure 3d), in the southwest of the state. The highest SEE (>50 mm) and RMSE (>60 mm) occurred at MT stations.

3.2. Monthly rainfall

The exploratory analysis of the monthly rainfall over 38 years of CHIRPS for both MT and MS showed that in MT, there were three well-defined seasons: (a) rainy (October to March, 68.57%), (b) dry (May to August, 6.08%), and (c) transitional (April and September, 25.34%). The situation was different for MS, where the rainy season period (56.65%) was similar to MT except that there was a decrease in rainfall in February. This may be associated with the common occurrence of an Indian summer (known as veranico) in Southeastern Brazil [15], which has already been identified for the entire Cerrado region of Brazil [16].

MT differed from MS in the monthly rainfall accumulations, mainly in the rainy season (MT: 212.55 ± 70.85 mm, compared to MS: 173.28 ± 77.39 mm). However, MS had greater rainfall in the other seasons; in the drought season rainfall in MT (18.86 ± 17.60 mm) was lower than in MS (42.29 ± 43.90 mm), and in the transition season rainfall in MT (78.55 ± 39.36 mm) was also lower than in MS (90.29 ± 63.50 mm).

3.3. Annual SPI and decadal rainfall

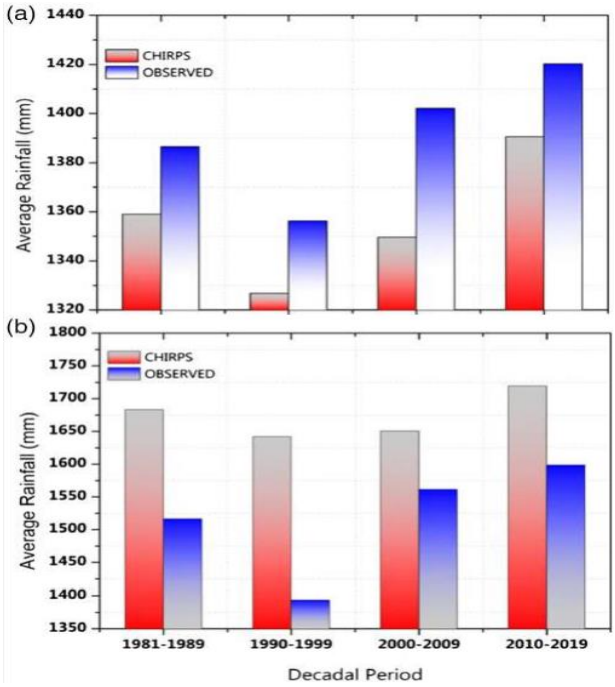


Figure 4. Average decadal rainfall (mm) from CHIRPS for the states of Mato Grosso do Sul (a) and Mato Grosso (b).

Figure 4 shows the average decadal rainfall (mm) from CHIRPS for the states of MS and MT. In MS, the average decadal rainfall from CHIRPS was lower than the observed data in all decades, especially in the 1990s, which had a significant reduction compared to other decades. The opposite situation was apparent in MT, where the average decadal rainfall from CHIRPS was greater than the observed data from ANA in all decades.

The SPI obtained via CHIRPS it was identified drought and wet periods on a regional scale in the moderate and normal categories, regardless of the ENSO phase. Based on the annual SPI at the decadal scale, the states of Mato Grosso and Mato Grosso do Sul show moderate droughts annually in the 1990s, 2000, and 2010, followed by a substantial decrease

in moderate rainfall. There are significant differences in both drought and moderate rainfall between the decades, due to the intensity and classification of the ENSO phases (strong and moderate).

4. CONCLUSIONS

The data from CHIRPS are satisfactory for the spatiotemporal assessment of regional rainfall, and for the use of SPI to detect drought and wet periods in the states of Mato Grosso and Mato Grosso do Sul. The CHIRPS data represent an efficient alternative to data from weather stations operated by government institutions, which are usually affected by a lack of spatial representation, and failures, gaps, and discontinuity in historical time series. The difficulty of obtaining data in situ arises not only from these generic problems, but also from Brazil's vast land area, and the lack of resources that can be employed in the establishment and maintenance of stations, since the country is in development.

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