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VII Jornada Científica da Embrapa Agrossilvipastoril

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Evaluation of chirps satellite rainfall data at Mato Grosso, Brazil

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Introduction

Water is a basic resource for human life and understanding how it cycles in the environment is important for its management. Nevertheless, hydrological models require high quality data in order to accurately reproduce the natural water cycle. Precipitation is one of the most important data required for these models, and it is usually provided by weather stations located across the territory. However, stations tend to be sparsely distributed in developing countries, especially in low populated areas, which is the case of the state of Mato Grosso, Brazil. Mato Grosso has only 36 official weather stations (INMET, 2018) in an area of 903,357 km², resulting in approximately one station for each 25,000 km².

Considering this context, satellite-based precipitation products become a useful resource to overcome the lack of a dense weather station network. One of these products is the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS). However, the main issue associated with remote sensed rainfall data is that they are only estimates based on algorithms that compute rainfall amount from satellite measurements, such as cloud temperature (Arkin; Meisner, 1987). Consequently, it is crucial to evaluate the accuracy of these precipitation products before using them in further applications.

Therefore, the objective of this study was to compare CHIRPS rainfall data to ground rain gauges in Mato Grosso State, Brazil, and evaluate the satellite estimate accuracy.

Material and Methods

The study was conducted in the state of Mato Grosso, located in the Central-West region of Brazil. Mato Grosso has tropical climate, with types Am and Aw, according to Köppen's climate classification. Annual rainfall ranges from 3,000 mm year^{-1} in the extreme north to 1,400 mm year^{-1} in the south of the state (Alvares et al., 2013).

We used precipitation data from 27 weather stations spread all over the state (Figure 1), obtained from Agritempo website, from January 2007 to December 2016, resulting in a 10-year monthly time series of precipitation data for each station. We compared this data to rainfall data from CHIRPS for the same period. Precipitation values were extracted from each of the CHIRPS grid files at the locations of the weather stations, using the nearest neighbor method and the coordinates supplied with station data downloaded from Agritempo.

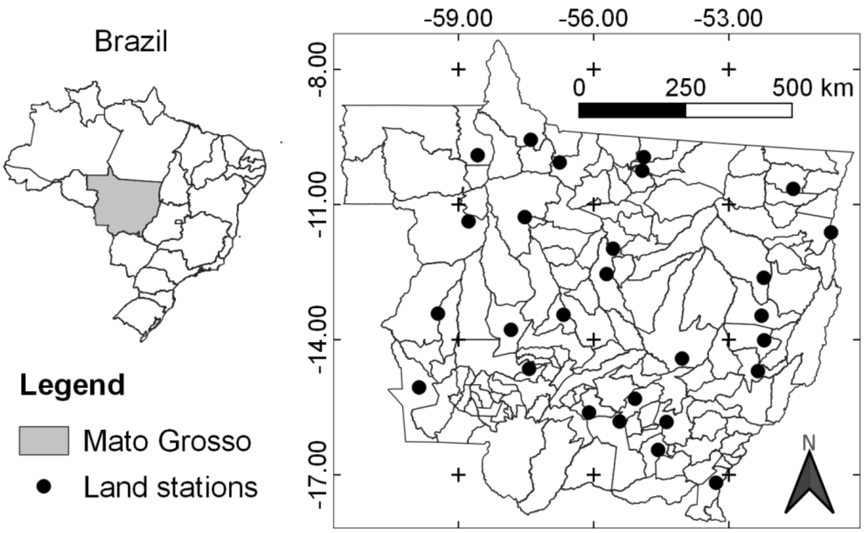

Figure 1. Weather station distribution (n=27) in the state of Mato Grosso, Brazil.

We analyzed the correlation between weather station data and CHIRPS data using a simple linear regression model computed in R (R Core Team, 2018). Model assessment was performed using coefficient of determination (R^2), root mean squared error (RMSE) and mean absolute error (MAE). Additionally, in order to assess the performance of the linear model to adjust new CHIRPS precipitation values, we used a second data set containing precipitation data from rain gauges and from CHIRPS for the period between January 2017 and December 2017 for validation. CHIRPS rainfall data for this period was adjusted using the equation provided by the linear model from the previous step. We evaluated the improvement in the correlation between station data and CHIRPS data by comparing R^2, RMSE and MAE between the values before and after adjusting CHIRPS data.

Results and Discussion

When evaluating precipitation data obtained from Agritempo, a series of inconsistencies was found in some weather stations. They mostly corresponded to long periods of precipitation values equal to zero where these values were not expected (e.g. during the wettest months in Mato Grosso). In order to address this situation, we took several steps to replace the data that influenced the quality of the linear model. First, we removed observations for periods that seemed problematic for each of the stations by looking at their time series. Then, we computed precipitation normals for each month and each station by taking the average of the remaining observations. We used these normals to replace the values that we removed in the first step. In addition, we computed deviations from the normal for each observation and standard deviation for each month of each station. Finally, when the deviation from the normal of a certain observation was higher than two times the standard deviation for that month in that station, we also replaced the observation value by the normal. This approach yielded a better model, since we improved the quality of the input data. It achieved R^2 of 0.74, RMSE of 66.28 and MAE of 44.75 compared to R^2 of 0.62, RMSE of 79.60 and MAE of 51.93 obtained prior to removing inconsistent data.

The validation step showed that adjusting CHIRPS rainfall data with the linear equation fit to calibration data improves the accuracy of CHIRPS rainfall satellite estimates. Before adjusting CHIRPS rainfall data for validation, the correlation analysis yielded R^2 of 0.42, RMSE of 90.30 and MAE of 56.93. On the other hand, after adjusting CHIRPS data, the accuracy improved to R^2 of 0.62, RMSE of 73.23 and MAE of 48.34. Figure 2 shows the linear model adjusted to the calibration data and the model performance for validation data.

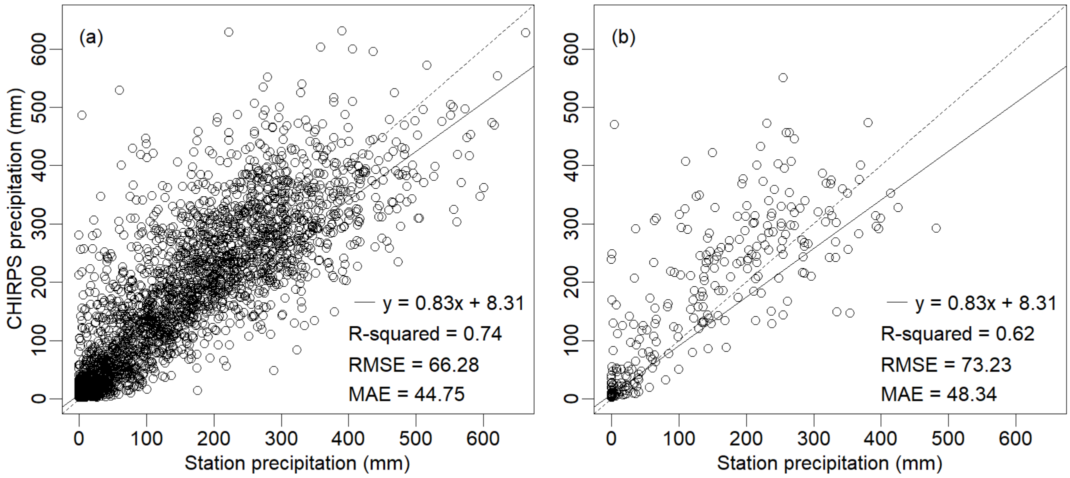

Figure 2. Station precipitation vs. CHIRPS precipitation. Model calibration (a) and validation (b).

Other studies have compared CHIRPS estimates to weather station data in other parts of the world, with a range of results achieved. Maidment et al. (2017) compared precipitation from rain gauges in five African countries to a series of satellite-based precipitation products and found an overall R^2 of 0.17, RMSE of 9.31 and MAE of 4.89 for CHIRPS data. Likewise, Dembélé and Zwart (2016), compared seven high-resolution satellite-based rainfall products to ground data from 2001 to 2014 at pixel level in Burkina Faso, West Africa. They obtained R^2 of 0.90 and RMSE of 26.97 when comparing gauged rainfall data to CHIRPS precipitation data in a monthly time window. Toté et al. (2015), evaluated three satellite rainfall estimates in Mozambique and obtained R^2 of 0.41.

The model obtained in this study indicated a rather strong relationship between CHIRPS and rain gauge precipitation data in Mato Grosso. Nevertheless, CHIRPS tends to overestimate rainfall amounts, which results in the slope value of 0.83 in the model equation shown in Figure 2. Therefore, CHIRPS data can be used as a source of monthly rainfall amounts for the state of Mato Grosso, requiring only minor adjustments.

Conclusion

We assessed the accuracy of CHIRPS rainfall estimates for the state of Mato Grosso, Brazil, and found that they can be used as a source of precipitation information after minor adjustments. The ability to use this satellite precipitation product is especially relevant for regions with no weather station to provide rainfall amounts, which are very common in Mato Grosso. CHIRPS might not be perfect, but in the absence of a better source for rainfall data, it becomes very useful for several applications that demand this information.

Further studies should focus on adjusting satellite-based precipitation products locally rather than statewide, as performed in this study, considering that regional patterns of precipitation might imply a different type of adjustment that would benefit from developing a local model, provided that there is enough data available for that region.

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