Accuracy assessment of the near-real-time rainfall data from the Integrated Multisatellite Retrievals for GPM (IMERG) in the Roraima State

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Abstract. The strong El Niño Southern Oscillation event that occurred in 2015/2016 caused extreme drought in the northern Brazilian Amazon, especially in the Roraima state, increasing fire occurrence. In order to assess the adequacy of the recently released IMERG (Integrated Multi-satellite Retrievals for GPM) precipitation data to be used in fire modelling, we estimate the accuracy of the late-run near-real-time IMERG product compared to the 3B43 product of the Tropical Rainfall Measuring Mission and to rain gauge data in Roraima. The IMERG precipitation data showed high accuracy when compared with rain gauge measurements. During the dry season, monthly precipitation estimated using IMERG showed a difference from -10 mm up to +30 mm compared to 3B43 data over ~75% of the Roraima state. During the rainy season, 49.9% of the grid cells (186) showed from -30 to +30 mm difference between IMERG and 3B43 monthly precipitation and negative differences (IMERG < 3B43) were found in a larger area of the state compared to the dry season. We found a systematic underestimation of precipitation up to 120 mm $month^{-1}$ in the late-run near-real-time IMERG data compared to 3B43 in the region of Roraima state located south of equator in both dry and rainy seasons. We conclude that the late-run near-real-time IMERG product is suitable for our purpose of modelling fire probability in Roraima, although careful should be taken in interpreting the results from south of the equator. As more IMERG data become available, further studies should investigate whether the patterns we observed are consistent over time.

Keywords: Amazonia, Global Precipitation Measurement mission, precipitation, rain gauge data, TRMM, 3B43

1. Introduction

Mapping the amount and extent of precipitation is vital to understanding how weather and climate impact our environment, including effects on agriculture, fire activity, fresh water availability, and natural disasters. Near-real-time rainfall data is especially important in applications such as forecasts of floods, droughts, hurricanes, and forest fires. Although precipitation estimates based on satellites data are not as accurate as rain gauges or radar measurements, they can provide a better assessment of precipitation over large areas than ground instruments, mostly in remote regions where surface measurements are sparse or take a long time to be publicised. Therefore the assessment of the accuracy of the satellites-based precipitation estimates is crucial to determine its usefulness and may help developers to improve the retrieval algorithms. The research quality rainfall monitoring estimate from the Tropical Rainfall Measuring Mission (TRMM) Multisatellite Precipitation Analysis (TMPA) is one of the most widely used multisatellite rainfall product for hydro-meteorological applications and combines rainfall estimates from a constellation of satellite-based sensors and rain gauge data for bias adjustment (Huffman et al. 2007). Although the precipitation radar of the TRMM satellite stopped collecting data on October 2014 and the mission ended in April 2015, after the spacecraft depleted its fuel reserves, the continuity of the TMPA 3B42/3B43 products was accomplished by an adaptation of the climatological calibrations/adjustments scheme of the real-time version of TMPA, with minimal impact on the estimates over land due to the continued inclusion of gauge analysis (Bolvin and Huffman 2015).

As a successor of TRMM, the core observatory satellite of the Global Precipitation Measurement (GPM) mission was launched in February 2014. Among many other products, the GPM mission have been producing a research quality data that is created several months after the observations are collected through the Integrated Multi-satellite Retrievals for GPM (IMERG) algorithm (Huffman et al. 2015), which is available from March 2014 onwards. In March/April 2015, IMERG near-real-time precipitation data with 6 h (early run) and 18h (late run) latency began to be publicly provided. However estimates of IMERG accuracy are still scarce in the scientific literature and concerns mostly the research product (Huffman et al. 2015; Chen and Li 2016; Liu 2016; Prakash et al. 2016; Sharifi et al. 2016).

The strong El Niño Southern Oscillation (ENSO) event that occurred in 2015/2016 caused extreme drought in the northern Brazilian Amazon, especially in the Roraima state (Jimenez-Munoz et al. 2016), increasing fire occurrence. The occurrence of fire in Roraima reached a peak in January 2016, when the number of active fires detected by satellite images was over 8 times the mean number for that month and the second highest for any month since September 1998, when this data became available (INPE 2016). Near-real-time rainfall data over the whole state is required to model fire probability and to better understand how different predictor variables affect fire occurrence. Here, in order to assess the adequacy of the recently released IMERG precipitation data to be used in short-term fire modelling, we estimate the accuracy of the late-run near-real-time IMERG product compared to TRMM estimates and to gauge measurements in the Roraima State.

2. Methods

2.1 Study area

The state of Roraima is located in the northern Brazilian Amazon, sharing borders with Venezuela in the northwest, Guyana in the northeast and Pará and Amazonas states in the south (Figure 1). Its territory extends over ~ 224,300 km^2, an area approximately the size of the United Kingdom (~242,000 km^2). Annual precipitation increases from the northeast (1,100-1,400 mm $year^{-1}$) to the southernmost part of the state (2,000-2,300 mm $year^{-1}$) (Barbosa 1997). Over the south, there is small precipitation variation among months and the climate is classified as equatorial (Af) following the Köppen system. The northeast, under a tropical savanna climate (Aw), experiences a well defined dry season, with approximately 10% of the annual rainfall and high incidence of solar radiation (between 160-200 hours of insolation $month^{-1}$) between December and March (Barbosa 1997). In the transition zone, with a monsoonal climate (Am), a dry season occurs in the same months, although less extreme than in the region under the Aw climate.

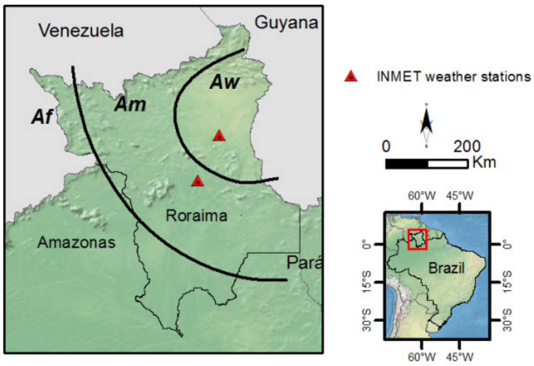

Figure 1. Map of Roraima state showing the location of the two weather stations considered in this study and climate classification following the Köppen system (curved black lines). Af = equatorial climate, Am = monsoonal climate and Aw = tropical savanna climate.

2.2 Datasets

IMERG precipitation data with a spatial resolution of 0.1° from April 2015 until March 2016 was obtained from https://pmm.nasa.gov/data-access/downloads/gpm. We used the late-run near-real-time IMERG product, since this data is most suitable for short-term fire modelling purposes. As images of precipitation accumulation up to 7 days are available in this data version, we added the accumulated images in each month in order to estimate monthly precipitation during this period. In order to validate IMERG data, we used the 3B43 7B TRMM monthly product, which has 0.25° of spatial resolution, for the same period (available at http://mirador.gsfc.nasa.gov, Verified in 24 June 2016). Monthly rain gauge data was obtained from the Brazilian National Institute of Meteorology (INMET) for the only two weather stations with updated data readily available at the time of the analysis for Roraima state, named Boa Vista (02°49'12" N 60°39'36" W) and Caracaraí (01°49'48" N 61°07'12" W; Figure 1) (Available at http://www.inmet.gov.br/projetos/rede/pesquisa/; Verified 24 June 2016).

2.3 Data analysis

In the comparisons between IMERG and rain gauge data, the effects of possible biases either in the mean or in the amplitude of fluctuations of the retrieval on the root-mean-square error (RMSE) were removed by calculating the unbiased RMSE (*unbRMSE*; Enthekabi et al. 2010) of each regression analysis as follows (Equation 1):

$$ubRMSE = \sqrt{\mathrm{E}\{[(\theta_{est} - \mathrm{E}[\theta_{est}]) - (\theta_{true} - \mathrm{E}[\theta_{true}])]^2\}} \quad (1)$$

where E[.] is the expectation operator, θ_{true} is the rain gauge monthly precipitation recorded and the correspondent satellite-based estimate is θ_{est}.

For the comparisons between IMERG and 3B43, the IMERG data was regridded to match the 3B43 grid using a simple box-averaging method, following Liu et al. (2016). We then calculated the mean absolute difference (in mm $month^{-1}$) between IMERG and 3B43 precipitation estimations during the rainy (from May until August 2015) and the dry (from December 2015 until March 2016) seasons in Roraima state.

3. Results and Discussion

IMERG showed strong relationship with rain gauge data from both Boa Vista and Caracaraí stations (Fig. 2), but the unbiased RMSE was higher for Boa Vista (57.3; the northernmost station in Figure 1) than for Caracaraí (27.7). Although the only two weather stations with updated data available are located in the central region of the state, which limits the spatial generalization of this results, the comparison with 3B43 data offers further insights on IMERG accuracy over the study area.

During the dry season, 36.7% (137) of the 0.25° grid cells showed only from -10 mm to +10 mm difference in monthly precipitation between IMERG and 3B43 data and in 38.3% of the grid cells (143) IMERG estimation was between 10 mm and 30 mm higher than 3B43 estimation (Fig. 3). During the rainy season, 49.9% of the grid cells (186) showed from -30 to +30 mm difference between IMERG and 3B43 monthly precipitation. In 20.7 % of total grid cells (77) IMERG monthly precipitation was 30 mm or more higher than 3B43 estimation, but in 30 of them, this difference represented less than 20% of the IMERG estimation. On the other hand, in 29.5% of the grid cells (110) a negative difference (IMERG < 3B43) higher than 30 mm was observed. In general, these results are consistent with the ones reported by Liu (2016), who found a tendency for positive differences (IMERG > 3B43) at low precipitation rates e the opposite (IMERG < 3B43) at high precipitation rates, although we observed a significant spatial variation on these differences, with regions of positive differences during the rainy season.

As 3B43 monthly precipitation also showed high correlation with the gauge measurements in Roraima ($R^2 = 0.954$ and $R^2 = 0.948$ for Boa Vista and Caracaraí stations, respectively, from April 2015 to March 2016) and as we have ground-truth data on a spatially restricted area only, as explained above, it is not possible to assert which one, 3B43 or late-run near real time IMERG, is more accurate. Although IMERG has higher spatial and temporal resolutions and present other improvements compared to the TRMM products (Huffman et al. 2015), it is important to notice that we are comparing the near-real-time IMERG product with a research 3B43 data, which is the result of further calibration procedures, including with gauge measurements.

However, we found a systematic underestimation of precipitation up to 120 mm month^{-1} in the late-run near-real-time IMERG data compared to 3B43 in the region of Roraima state located south of equator in both dry and rainy season. This is related to some approximations in the calibration procedure and revised schemes are being developed to suppress these artificial boundaries (Dr. Huffman, pers. comm.).

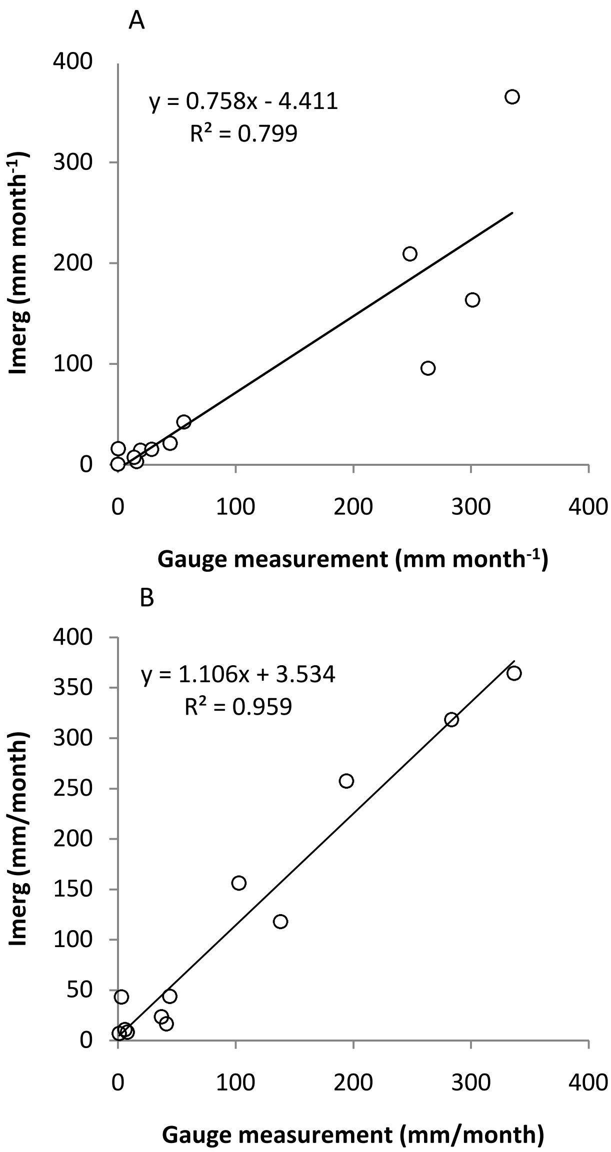

Figure. 2. Regression between near-real-time late-run IMERG monthly precipitation data and rain gauge data from Boa Vista (A) and Caracaraí (B) stations from April 2015 to March 2016.

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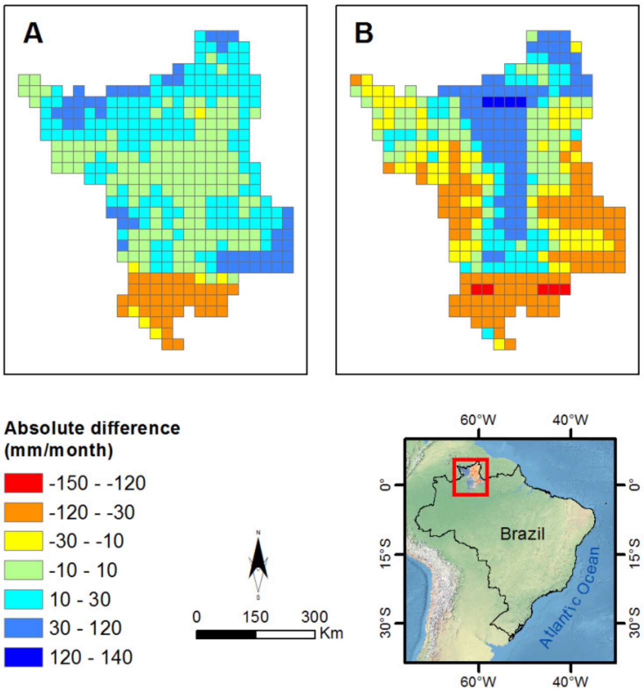

Figure 3: Mean absolute difference (IMERG minus 3B43) in monthly precipitation during the dry (A; from December 2015 to March 2016) and rainy season (B; from May to August 2015) in Roraima State.

4. Conclusions

The late-run near-real-time IMERG precipitation data showed high accuracy when compared with rain gauge measurements in Roraima. During the dry season, monthly precipitation estimated using IMERG showed a difference from -10 mm up to +30 mm compared to 3B43 data over ~75% of the Roraima state. During the rainy season, negative differences (IMERG < 3B43) were found in a larger area of the state compared to the dry season.

Although preliminary, given the short-time series available, this is the first validation of late-run near-real-time IMERG precipitation data and the first validation of any of the IMERG products with rain gauge data over the Amazon we are aware of. We conclude that the late-run near-real-time IMERG product is suitable for our purpose of modelling fire probability in Roraima, given that only the dry season data is needed for this analysis and that the differences we found compared to 3B43 during this season over most of the state is likely to have no major influence on fire probability, mostly in the region where fires historically occur. Careful should be taken, however, in interpreting the results of modelling from the region of the state located south of the equator until the calibration issues mentioned above can be resolved. Fortunately, most of the fires in Roraima occur north of this region (Barni et al. 2015). As more IMERG data become available, further studies should investigate whether the patterns we observed are consistent over time.

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