Nat. Hazards Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/nhess-2017-90-AC2, 2017

Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Analysis of fire dynamics in the Brazilian savannas" *by* Guilherme Augusto Verola Mataveli et al.

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Received and published: 14 June 2017

Dear Referee 2,

Thank you for your suggestions. These were very helpful and will significantly improve the quality of the revised manuscript. Once there is no option of sending the updated version of the manuscript during this stage of the reviewing process, we will answer each topic indicating the modifications that we made and the new results found.

1) The authors must be careful when talking about the lack of such specific studies. In fact, there are some studies that show the spatial and temporal patterns of fire and relation between fires and climatic variables in Cerrado. The authors should see the authors they mention (Moreira et al 2012, 2015; Pivello, 2011,) and also papers listed

below: The work of Libonati et al., 2015a shows that the intra-annual variability of burnt area over the Brazilian woody savannah mostly relates to the seasonal regime of precipitation. These authors also show that there is a marked dry season from May to September, characterized by very low precipitation amounts and that, during the dry period, there is a steady displacement towards higher values of the median, lower and upper quartiles and extremes of the distributions of monthly values of burnt area. The work of Libonati et al., 2015b analyzed the results of three currently burned area products derived from MODIS data, namely AQM (INPE), MCD45A1 (NASA) and MCD64A1 (NASA). The procedure is applied to quantify the overall temporal and spatial distribution patterns of burned areas in Brazil for the period 2005 – 2010 and obtained patterns are compared for each Brazilian biome and related to the respective patterns of fire pixels derived from remote sensing. The Cerrado biome was found the one with the largest BA, followed by Caatinga and Amazônia. Estimates of BA over Brazil from AQM, MCD45 and MCD64 products for the period present a similar inter-annual variability. In addition, the work of Libonati et al., 2016 allows analyzing the overall temporal and spatial distribution patterns of BA for the last decade. The highest monthly mean amount is observed in September, followed by October, and March presents the lowest amount. The most severe year is 2007, followed by 2005 and 2010; 2006 and 2009 are the years with less area burned, followed by 2008. The spatial pattern of BA shows that the north region of Cerrado presents the highest frequency of occurrence. The spatial pattern of BA shows that the north region of Cerrado presents the highest frequency of occurrence. The intra and inter-annual variability of BA over Cerrado are closely related to the variability of precipitation but it is worth emphasizing that, despite the major role played by climate conditions, the human factor has also a prominent role on fire dynamics in this region and cannot be disregarded.

This paper is not focused on Burned Area (BA) or how to estimate it. We used this variable as an additional dataset to spatially analyse fire patterns over the Cerrado. Most of the articles cited by the Referee use averaged/summed values for the entire Cerrado and are focused only in BA and fire count. In the present study, we analysed several sources at pixel-based statistics, such as spatial correlation. The Cerrado is a biome distributed over an area of more than 2 million km2 and the relationship between fires and environmental characteristics varies according to several factors. Within this context, we used spatial statistical tools to indicate the most vulnerable areas, showing its variation in the biome, which will be emphasized in the revised paper. We will include the references of Libonatti et al. in the revised paper when discussing results found for BA. Regarding the lack of studies, this sentence will be corrected in the revised paper, referring to spatial analysis. We meant that there is a lack of studies analysing the correlation between hotspots/BA and climatic variables spatially, such as the results presented in Figure 10 of the Discussion paper and in the new analysis proposed below. Pivello (2011), Moreira de Araújo et al. (2012), Moreira de Araújo and Ferreira (2015), and Libonati et al. (2015a, 2015b, and 2016) did not provide this information. In fact, all the works cited above, except to Pivello (2011), who presented an overview of the fire history in the Amazon and in the Cerrado and described how fire regime changed in the biomes, are focused on BA, which was only one of the variables analysed and discussed in the paper. Two of the references are focused on describing an algorithm for BA detection and validating the MCD45A1 BA product (Libonati et al. (2015a) and Moreira de Araújo and Ferreira (2015), respectively). Moreira de Araújo et al. (2012) and Libonatti et al. (2015a) analysed the correlation between BA and precipitation in the Cerrado, however, not spatially, therefore, they did not show in which areas of the biome these two variables are more correlated. Libonatti et al (2015b), which was published in the proceedings of the Brazilian Symposium on Remote Sensing, compared 3 different BA datasets (AQM, MCD45A1, and MCD64A1) and also analysed the spatial and temporal variability of BA in the Brazilian territory for the 2005-2010 period. Their work did not analyse the spatial and temporal variability in the area corresponding to the delimitation of the Cerrado, only nationally. We analysed the temporal distribution of hotspots and BA in the Cerrado considering a longer time series (2002-2015), as well as the spatial distribution of hotspots in the Cerrado (Figure 8 of the Discussion paper). Regarding Libonati et al. (2016), we found only a one-page abstract of the ref-

erence published in the proceedings of the EGU General Assembly. The results cited by the Referee were obtained from AQM product, are described in one paragraph and do not show the annual or monthly values of BA or the map showing that the highest concentration of BA is in the North of the Cerrado. Moreover, we have substantially discussed the role of human activities in the occurrence of fires in the savannas (from P11 L23 to the end of the Results and Discussion section).

2) It is worth mentioning that the manuscript uses the same precipitation data from Libonati et al., 2015a.

TRMM is the most used dataset in studies of precipitation conducted using remote sensing, once it provides excellent estimation of spatial and temporal patterns of precipitation considering a period of more than 15 years and is widely validated. The efficiency of TRMM data in the Brazilian territory is shown in works such as Pereira et al. (2013), cited in the Discussion paper, which justifies the choice of the dataset. In fact, Libonati et al. (2015a) was not the first paper that used TRMM dataset for analysing precipitation in the Cerrado. We can find several references that use the same product, for example, this reference from 2011 related to the environmental analysis in South America using TRMM and fire datasets (http://www.mdpi.com/2072-4292/3/10/2110), which is prior to the mentioned study. Furthermore, Moreira de Araújo et al. (2012) also used TRMM data when analysed the distribution patterns of burned area in the Brazilian biomes. Moreover, Moreira de Araújo et al. (2012) and Libonati et al. (2015a) used an average value for the entire Cerrado and did not considered the spatial variability of precipitation, which includes distinct mechanisms. In the Cerrado, we have a substantial variation of the dry season peak, for example, the North region of the biome is mainly controlled by the Intertropical Convergence Zone and Upper Level Cyclonic Vortex disturbances, while the South region of the biome is mainly controlled by anticyclones and cold fronts. Thus, using only average values for the entire biome could not be the best approach. Therefore, we proposed to use a spatial approach with statistical analysis pixel-by-pixel, which will be described below.

3) Accordingly, all the results shown in the manuscript were previously reported by the above studies.

Considering the comments of the Referees and in order to improve the novelty of the work, we will add new analysis in the revised paper, described below:

In the updated version of the manuscript we will present a spatial analysis of the month with highest incidence of hotspots and burned area, minimum amount of precipitation and minimum VCI in the Cerrado (Figure 1 in this response letter), as well as the lag in months between the minimum of precipitation and maximum of hotspots, minimum of precipitation and maximum of burned area, minimum of VCI and maximum of hotspots and minimum of VCI and maximum of burned area (Figure 2 in this response letter). Maximum of hotspots and burned area usually occur two or three months after the minimum of precipitation in the Cerrado, while the maximum of hotspots and burned area are concentrated in the same month when VCI is minimum for most of the Cerrado.

In the updated version of the manuscript we will present the seasonality and trend of hotspots, burned area, precipitation and VCI in the Cerrado for the 2002-2015 time series using Breaks For Additive Seasonal and Trend (BFAST), an additive method that decomposes a time series into seasonal, trend and noise components (VERBESSELT et al., 2010) (Figure 3 in this response letter). A small decrease in the trend of hotspots was found in 2011 and in 2007 for precipitation, while burned area trend was regular during the period and VCI presented a tendency break between 2007 and 2010, showing that VCI is a good indicator of the occurrence of fires in the Cerrado, once 2007 and 2010 were the two years with highest detection of hotspots and burned area in the biome.

In the updated version of the manuscript we will present the mean Fire Radiative Power (FRP) estimated by the MODIS active fire products in the Cerrado between 2002 and 2015 (Figure 4 (b) in this response letter), which showed that more intense fires are not necessarily located where hotspots are more concentrated.

Moreover, all maps of the revised paper will consider the same grid size (0.25° x 0.25°, spatial resolution of TRMM data,), enabling that all results are comparable, therefore, Figures 8, 10 and 11 of the Discussion paper will be replaced by Figures 4(a), 5 and 6 of this response letter, respectively.

4) For instance, the work of Veraverbeke et al. (2014) is no about social and economic costs of fires, but on remote sensing techniques aiming fire severity assessment. In addition, the authors argue the efficiency of MCD45A1 product for mapping and understanding fire behavior and its impacts in the Cerrado. These results are not in agreement with previous works such as Roy et al (2008) and Libonati et al. (2015a), who have pointed out an under-detection of BA by the MCD45 product in savannas regions of Brazil.

The citation of the social and economic costs of fires will be corrected in the revised paper. Regarding the efficiency of the MCD45A1 product for mapping and understanding fire behavior and its impacts in the Cerrado, this sentence will be rewritten, and the work of Libonati et al. (2015a) will be cited in the revised paper. Moreira de Araújo and Ferreira (2015) analysed the performance assessment of the BA product MCD45A1 in the Cerrado by comparing the product with BA maps derived from Landsat images and found good results, however, they analysed only BA detected during September, which is the month with highest concentration of BA in the Cerrado.

5) Some conclusions are not based on the results: 1) 'Nevertheless, the annual variability of hotspots and precipitation and between burned area and precipitation during the 2002-2015 period is evidenced.' 2) Besides the seasonal modulation by precipitation, fire occurrence seems to respond to its interannual variability. Drier (wetter) years are associated with more (less) fires in the studied area. There is no clear evidence in the manuscript, despite visual comparison, about the statistical significance of this relation. The authors say in the conclusions that 'The methods applied are easily implemented and can be used for analyzing the occurrence and dynamics fires in different areas of the globe'. I don't think this work shows a 'method'. Instead, it is

mainly devoted to a spatial and seasonal description of available variables.

The Conclusions section will be entirely rewritten considering the comments of the Referee and the new results found, especially the first two paragraphs. The new Conclusions section will include the following topics regarding the new analysis proposed:

Analysing only average values are not the best approach to characterize the occurrence of fires in the Cerrado;

Spatial analysis and its relationship with the variation of hotspots, burned area, precipitation and VCI in the Cerrado;

Usually, there is a lag of 2 or 3 months between the minimum values of precipitation and hotspots/burned area in the Cerrado and no lag between VCI and hotspots/burned area in the biome;

A statement regarding VCI as a good indicator of the occurrence of fires in the Cerrado;

More intense fires are not located in the areas where hotspots are more concentrated in the Cerrado.

New reference:

Verbesselt, J., Hyndman, R., Newnham, G., Culvenor, D.: Detecting trend and seasonal changes in satellite image time series, Rem. Sens. Env., 114, 1, doi: j.rse.2009.08.014, 2010.

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-90, 2017.

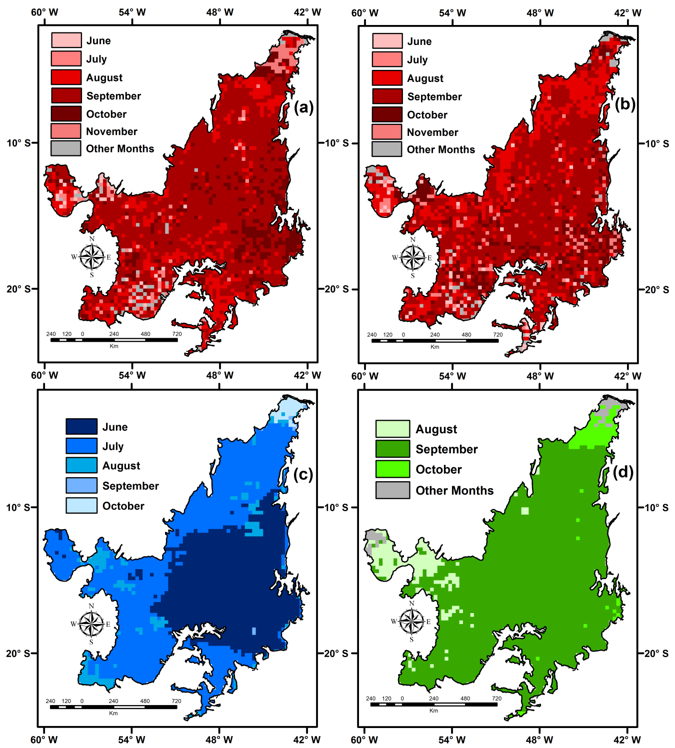

Fig. 1. Estimate of the month when (a) maximum of hotspots (b) maximum of burned area, (c) minimum of precipitation and (d) minimum of VCI was found in the Cerrado for the 2002-2015 time series.

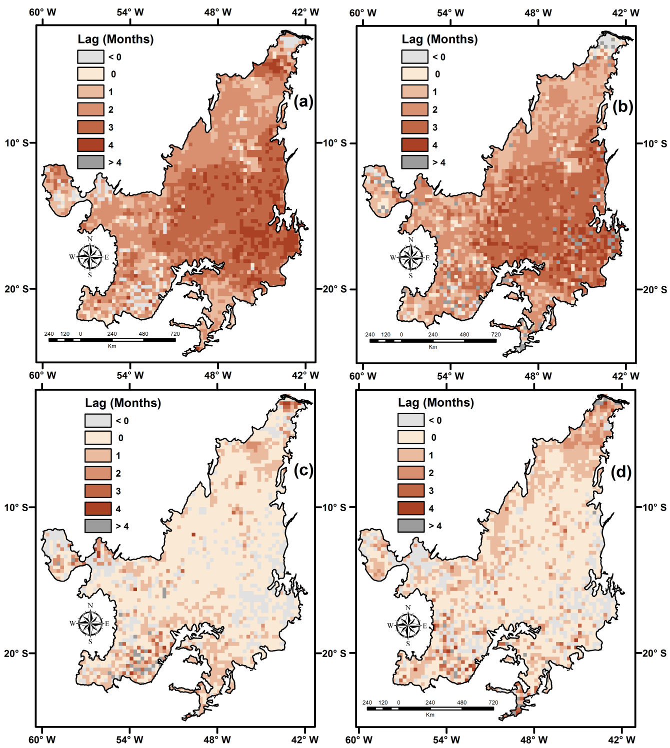

Fig. 2. Lag in months between minimum and maximum values of (a) precipitation and hotspots, (b) precipitation and burned area, (c) VCI and hotspots and (d) VCI and burned area in the Cerrado.

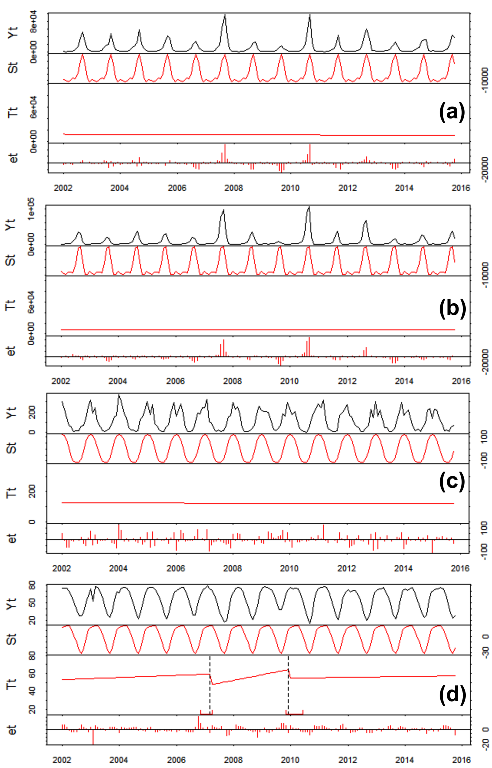

Fig. 3. Decomposition of the (a) hotspots, (b) burned area, (c) precipitation and (d) VCI time series in the Cerrado (Yt) into seasonality (St), Trend (Tt) and Remainder (et) components.

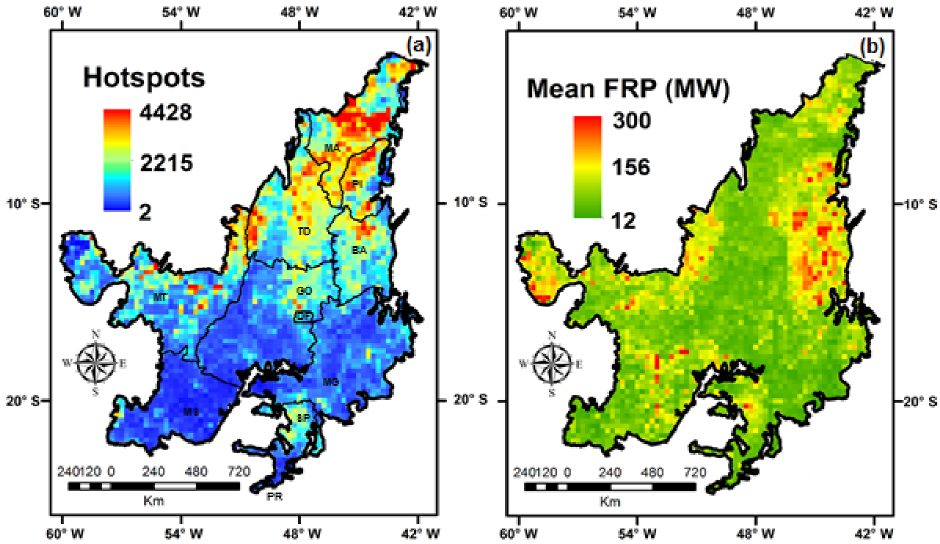

Fig. 4. (a) Total of hotspots and (b) Mean FRP detected by the MODIS active fire products in the Cerrado biome between 2002 and 2015.

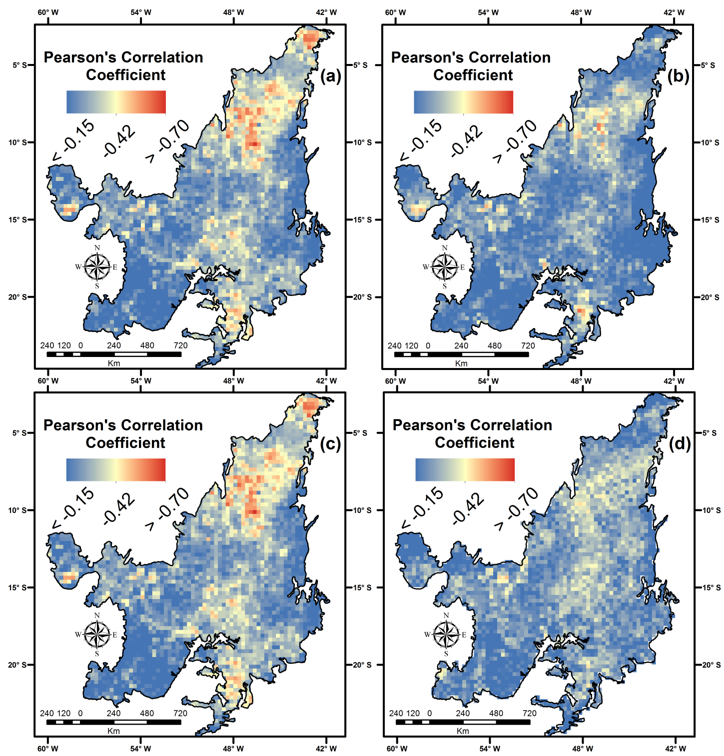

Fig. 5. Spatial correlation between (a) hotspots and precipitation, (b) burned area and precipitation, (c) hotspots and VCI and (d) burned area VCI in the Cerrado biome.

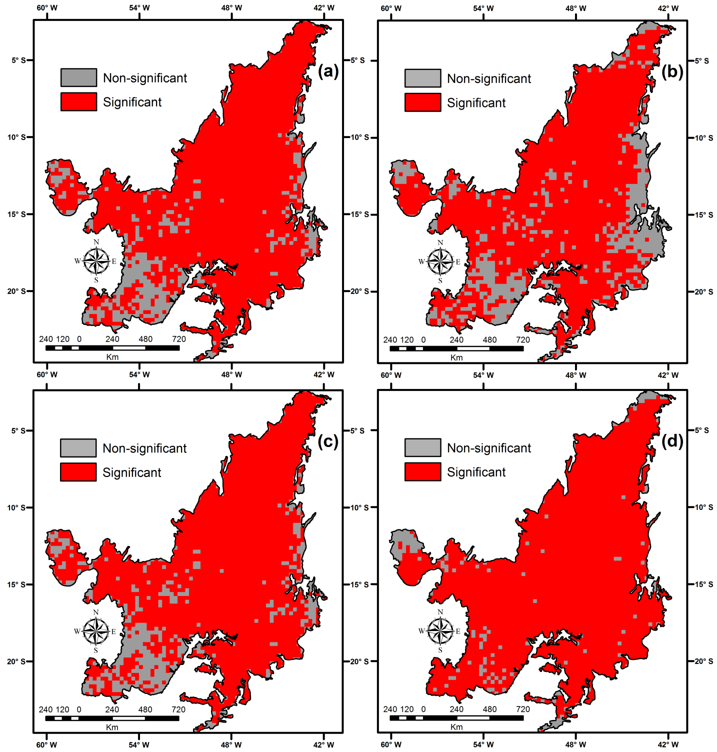

Fig. 6. Spatial t-Student test for the spatial correlation between (a) hotspots and precipitation, (b) burned area and precipitation, (c) hotspots and VCI and (d) burned area VCI in the Cerrado biome