A Study of Spatio-Temporal Lightning Patterns Using Self-Organizing Maps

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Abstract

Brazil is one of countries highest incidence of lightning in the world and the characterization of thus event can help in the development of public polices and decision-making by authorities to mitigate the socio-economic damage that may be caused. This work presents some analysis of spatio-temporal patterns of lightnings in Brazil in 2020, generated from Self-Organizing Map (SOM) technique. This analysis considers the activity of the lightning in the hourly, daily and monthly periods accumulated in the different Brazilian states. The seasonal variation of lightning was also evaluated, considering the four seasons of 2020. The results showed that the self-organizing maps were efficient in identifying spatio-temporal patterns of lightning, which are highly variability events. Thus, theses results can support the development of new tools or analysis in which the spatio-temporal information lightning is important, for example, in warning and forecasting systems.

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INTRODUCTION

Brazil has very favorable conditions for the occurrence of lightning, which makes it one of the countries with the highest incidences in the world [1]. Additionally, under the influence of seasonal, local factors, mesoscale and synoptic scale, Brazil also has distinct meteorological patterns in different regions [2, p. 20], which further contributes to the high variability of lightning over the Brazilian territory. This work aims to identify and analyze some spatio-temporal patterns of lightning. For this, the Self-Organizing Map (SOM) [3] was used to characterize the spatial and temporal variability of the lightning. Spatial analysis considers the areas of state borders and the temporal analysis consider the seasons of the year. The methodology was applied to lightning data that occurred in Brazil in 2020, observed by the Geostationary Operational Environmental Satellite (GOES- 16)

STUDY AREA AND DATA

We used lightning data from the Flash product estimated by Geostationary Lightning Mapper (GLM) aboard the GOES-16 geostationary satellite. The Flash product are cluster created from one or multiple optical pulses observed in the atmosphere that characterize the lightning in a interval of up to 330 ms and an area of at most 16.5 km2 [3]. We used the R-Tree [4] spatial index data structure to map of the flash data onto a regular 0.5°x0.5° grid resolution.

METHODOLOGY

To evaluate the different pattern characteristics of lighting, two experiments were performed to obtain spatio-temporal information and variability of lighting. In the first experiment the objective was to map two main groups, the states with the highest activity and lowest lightning activity, considering statistical information. The other experiment its objective is to map the stations with the highest and lowest lightning activity in each state, considering statistical information. Self-Organizing Map (SOM) was the main tool used in the development of the analysis of this work. SOM is an unsupervised machine learning method that was initially proposed by [5] and its functioning is based on the human cortex in the human brain. The SOM is a type of neural network that has no hidden layers, and the input layer is directly connected to the output layer neurons that can create a low-dimensional representation for high-dimensional data, preserving its topological structure [6].

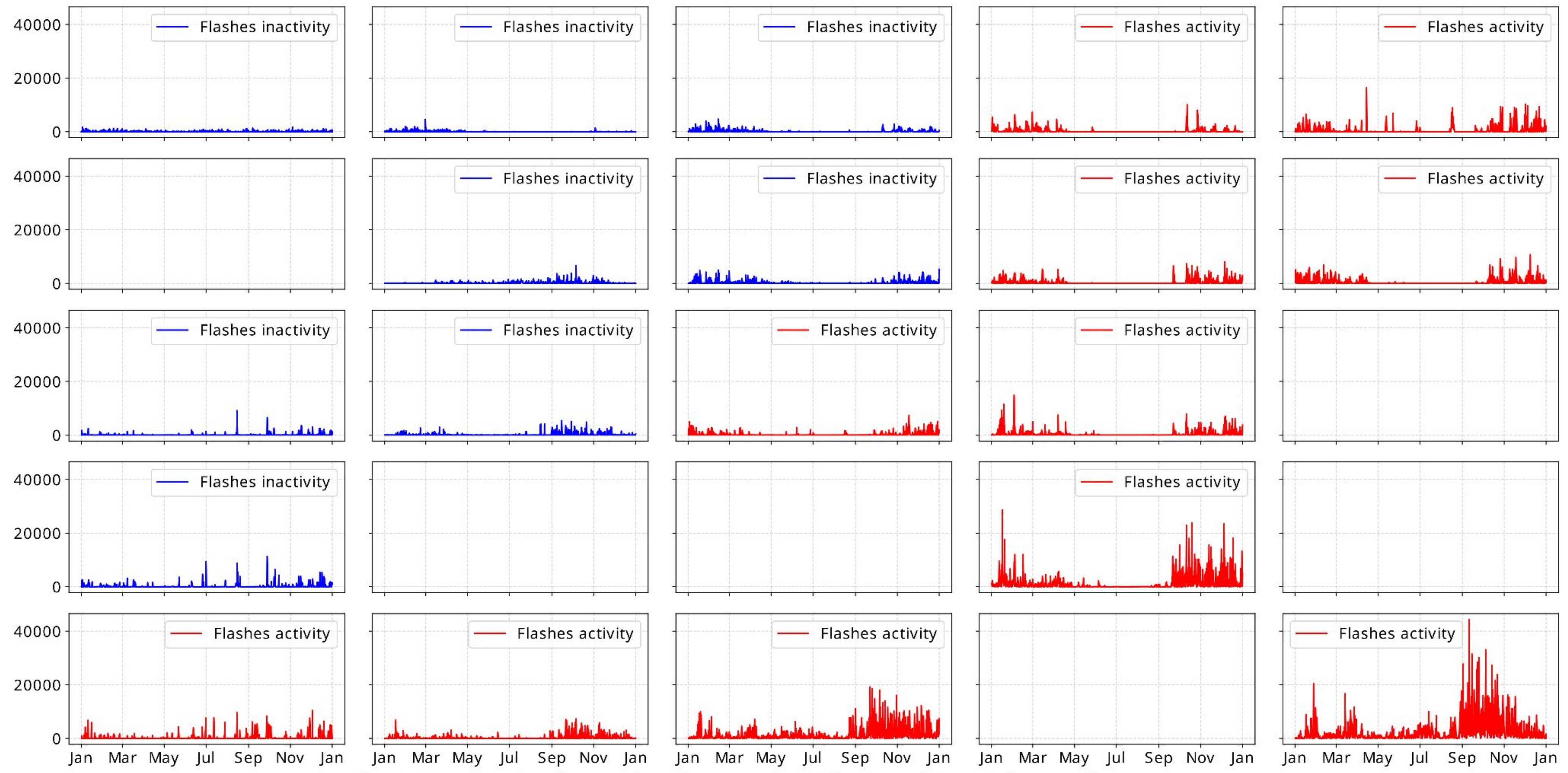

Fig. 1. Mapping the time series of accumulated flashes with a 10-day moving averange

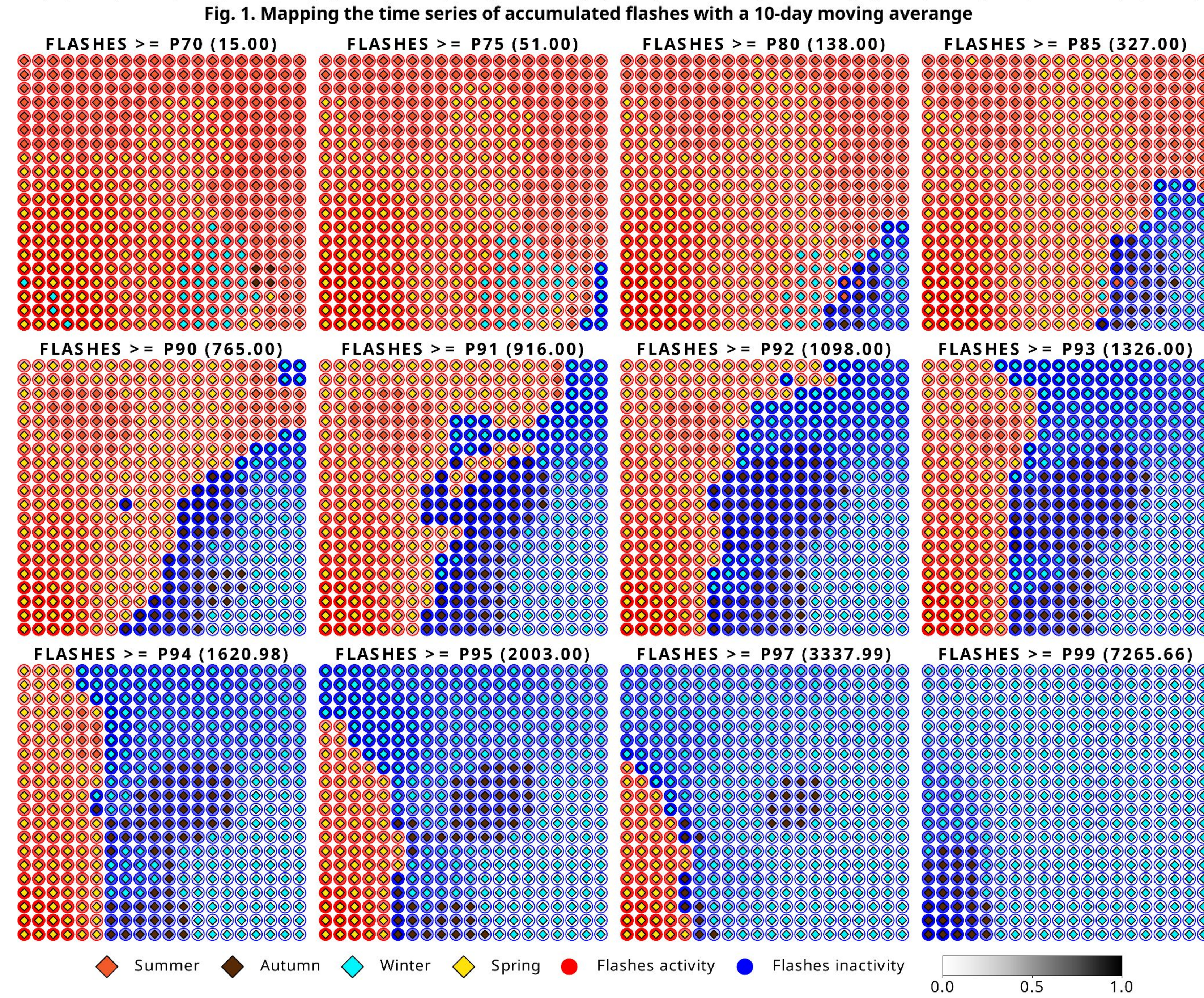

Fig. 2. Mapping of SOM neurons according to Flash activity and season indicated by percentile threshold variation.

RESULTS

By applying the SOM to the time series of states, it is possible to identify those that have similar characteristics, as shown in Figure 1. It is possible to observe that the time series with the lowest lightning accumulation tend to be grouped in blue in the neurons located in the upper left corner. Meanwhile, the series with higher peaks in the accumulation of red lightning tend to be distributed in the other areas of the map. It can also be observed that the series of some neurons seem to belong to a different class from the one they were assigned (e.g. row 3, column 3).

Figure 2 shows the activity mapping lightning inactivity based on percentile threshold variation in the different seasons. From the 90th percentile, the maps begin to have a representation of the classes in a more distributed way among the neurons. It is also possible to notice the lightning seasonal variability, in which the neurons that represent the activity class better map the spring records, while the inactivity class neurons better map the winter neurons. It is possible to observe that the distribution of the other two seasons coincide with the neurons that have the highest degree of purity, with neurons that the purest neurons in the activity class tend to map better the summer records, and the neurons in the inactivity class better map the autumn records.

CONCLUSION AND FUTURE WORK

In this work, two case studies that address different aspects of the lightning spatiotemporal variation in Brazil were presented. The SOM technique proved to be very efficient to direct these analyses, corroborating solid concepts present in the literature, with regard to the physical relationships of the lightning with the environment. The case studies presented in this work can serve as a complement to exploratory analysis of meteorological data, and the methodology can be extrapolated to other applications in different contexts. In future work, it is intended to add more meteorological variables and consider other time intervals to improve the characterization of spatiotemporal patterns. Other spatial references will also be considered, such as the shapes of municipalities, regions, and biomes. In future analyses, in addition to land cover classes, other surface features will also be considered, including topography data. At the end of its development, the entire data processing and analysis workflow will be made available in an open repository with instructions for reproducing all the results.

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