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Analysis of Extreme Rainfall Events on a Sub-Daily Scale in Northeast †

Paula Andressa Alves de Araújo [1,*], Cláudio Moisés Santos e Silva [2,*], Daniele Tôrres Rodrigues [3] and Aléxia Monteiro Valentim [4]

[1] Federal University of Rio Grande do Norte
[2] Federal University of Rio Grande do Norte
[3] Federal University of Piauí; mspdany@gmail.com
[4] Federal University of Rio Grande do Norte; alexia.valentim.127@ufrn.edu.br
* Correspondence: paulaand12010@hotmail.com (P.A.); claudio.silva@ufrn.br (C.M)
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Abstract: Given the complex climate of the Brazilian Northeast, its variable rainfall regime in spatial and temporal scales due to multiple geographic factors and the action of various atmospheric systems, as well as intense precipitation events becoming increasingly present and strong, are incipient the initiatives to analyze extreme rainfall on a sub-daily scale. Thus, characterizing the spatial and temporal distribution of IPESS on the NEB, analyzing the seasonality of the number of events for each location and the influence of interannual variability in the occurrence of these events, became the objective of that work. For this, hourly precipitation observations were collected from 119 automatic surface weather stations spread across the NEB, between 2009 and 2018. The night period presented the highest amounts of IPESS. The meteorological stations Ibimirim/PE and Ilhéus/BA had the highest and lowest number of occurrences, respectively. The amplitude of the values of Q presented the thresholds of the stations with the values of 3.4 mm as a minimum, and 28.6 mm as a maximum, referring to the stations of Petrolina/PE and São Luís/MA, respectively. Among the capitals, Teresina/PI had the highest number of EPIES, as well as João Pessoa/PB the lowest, not only among the capitals, but also the second with the lowest number in general. It was observed that during 2009 the events were more frequent, while 2012 presented the smallest amounts.

Keywords: percentile 95; EPEIS; hourly analysis

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1. Introduction

Since the precipitation is one of the most important climate variables, as its variations directly affect numerous human activities, the knowledge about this variable's spatial and temporal variability is crucial to subsidize the decision-making and actions planning to minimize impacts caused by extreme precipitation events.

The North East of Brasil (NEB), it is a region with a difficult climatic characterization as a result of geographic factors associated with different atmospheric systems. Then, there are different factors that fluctuate the precipitation regime of the NEB in a wide time and space scale [1–4].

A large part of the climate studies about analyses of precipitation that focus the NEB report mainly the water deficit. Trying to understand the complex social functions of these climatic characteristics are very important, since they cause economic losses, in addition to deaths. In contrast, also are reported heavy rainfall, which together with water deficits are the main types of adverse natural phenomenal from the NEB, so those cause significant impacts that can be catastrophes.

Since intense rainfall events are become increasingly more common and strong, according to projections made by the Intergovernmental Panel Climate Change (IPCC) [5], there is a vast scientific literature on extreme indices on the daily scale around the world, including in the NEB [6]. However, initiatives to analyze extreme rainfall on a sub-daily scale are still incipient, as well as is the hourly analysis, mainly due to the lack of meteorological data with hourly or minute sampling. Having said that, the objective of the present study was to characterize the spatial and temporal distribution of the Subdaily Scale Intense Precipitation Events (EPIES) over the NEB from hourly data collected in the period between 2009 and 2018, analyzing the seasonality of the number of events for each location and the influence of interannual variability on the occurrence of EPIES.

2. Materials and Methods

2.1.Á. Rea De Estudo

The NEB is located latitudinally between 1° S and 18° S and longitudinally between 48° W and 34° W. It comprises a territorial extension of 1,558,000 km^2, according to the Brazilian Institute of Geography and Statistics [7], comprising 9 states.

2.1. Coleta Dos Dados

The dataset refer to precipitation observations from 119 automatic surface meteorological stations those are distributed in the NEB, and are operated by Brazilian National Institute of Meteorology (INMET). Data were collected hourly for the period between 1 January 2009 and 31 December 2018.

To organize the dataset and apply the methodology, the Microsoft Excel software were used to calculate the results. The exploratory analysis of the heavy precipitation indices of each meteorological station was conducted using the R statistical computational system, realized through a box-plot cartogram, which is a graphic technique that shows the behavior of the data in space.

2.1. Método

The methodology is divided into several stages, so that the first consists of selecting the days with accumulated daily precipitation equal to or greater than 1 mm, keeping only the days on which they occurred (RR).

$$RR \geq 1 \text{ mm} \quad (1)$$

The second step is equivalent to using the percentile 95 [8] in order to find the extreme precipitation measurement values (Q) for each station. Thus, this method was applied on the accumulated precipitation values of all days validated in the previous step.

After completing the first and second stages, the third intended to emphasize the days with precipitation that went beyond the Q value. For this purpose, only those days with daily accumulations greater than the Q value of the station were maintained. That's it:

$$RR \geq Q \quad (2)$$

With the limits applied, this conditions were adopted as the definition of an EPIES for these days: it is considered an EPIES if in a single hour the accumulated precipitation rate (RI) represents more than 25% of the daily total with rain extreme. Thus, it is necessary to locate the hour with the highest precipitation value (max(RR)) for each day with rain extreme, and calculate the percentage value of this record in relation to the daily accumulation:

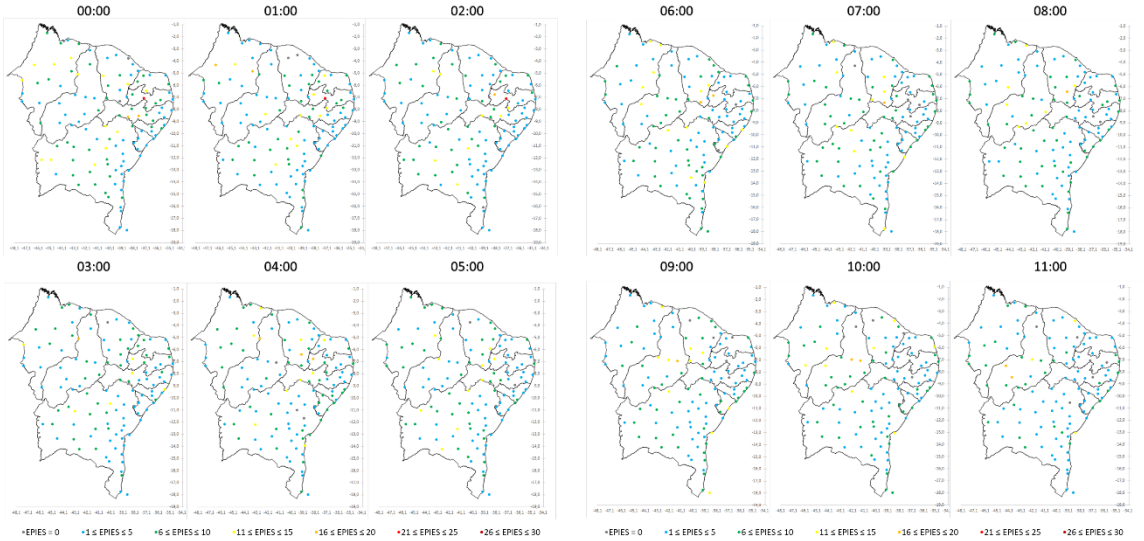
$$RI = (\max(RR)/RR)*100, \; EPIES = RI \geq 25 \quad (3)$$

Finally, the occurrences of EPIES are counted and the number of these events analyzed from a temporal and spatial perspective, presenting them graphically with the support of Microsoft Office Excel.

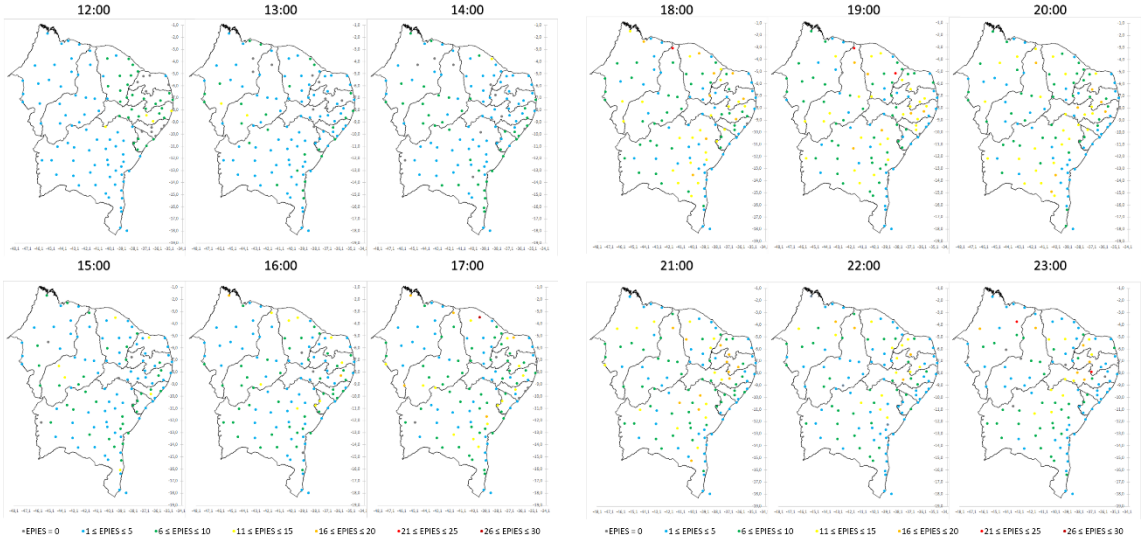
3. Results

During the exploratory analysis, the Q values varied between 3.4 mm and 28.6 mm, referring to the Petrolina/PE and São Luís/MA stations, respectively. This indicates the great discrepancy of precipitation indices between meteorological stations. The distribution structure of the Q values of the meteorological stations was showed using the Box Plot. Via the interquartile amplitude, it is visualized that 50% of the Q values obtained are between 8.5 mm and 18.55 mm.

Graphs referring to the occurrence of EPIES in the hourly scale were generated, using a x-y plane and the geo-referenced in terms of latitude and longitude coordinates of the meteorological stations. The results are presented and divided into four-quarters of the day: between 00:00h and 05:00h (Figure 1a), between 06:00 and 11:00 (Figure 1b), between 12:00 and 17:00 (Figure 1c), and between 18:00 and 23:00 (Figure 1d). All the graphs were subject at a same categorization about the amount of EPIES occurrences. The quantity of occurrence were separated by color: the color gray belongs to the group without events, and the colors blue, green, yellow, orange, red and burgundy belong to groups with quantity of occurrences varying between 1 and 5, 6 and 10, 11 and 15, 16 and 20, 21 and 25 and between 26 and 30, respectively.



(**a**) (**b**)



(**c**) (**d**)

Figure 1. Graphs referring to the amounts of EPIES separated into subgroups: (**a**) between 00:00 and 05:00 h; (**b**) between 06:00h and 11:00h; (**c**) between 12:00h and 17:00h; (**d**) between 18:00h and 23:00h.

Analyzing the Figure 1a, between 00:00h and 02:00h, the majority of meteorological stations showed the number of occurrences below or equal to five events. Patos/PB station stood out for presenting quantify of EPIES equal to or higher than 21 events during this time. At 04:00h there is an increase in the number of stations with between 6 and 10 occurrences. Teresina/PI station stood out for presenting from 16 to 20 events in this subgroup.

In looking at Figure 1b that refers to the range from 06:00h and 11:00h, the group composed by two stations that contained 11 to 15 events was the highest number of occurrences during the first hour of this category. At 07:00h and 08:00, a vast quantity of stations compose the group from 1 to 5 events, being the subgroup with the biggest quantity of stations, although the majority of the capitals of the states are more concentrated in the subgroup with 6 to 10 EPIES. At 09:00h the larger amount of registered occurrences was between 21 and 25 events. While at 10:00h the biggest quantity was from 16 to 20 EPIES. With respect to 11:00h it was found that all Potiguar stations were located between 1 and 5 events. The subgroup from 16 to 20 EPIES was the occurrence limit in this interval.

According to the analyses about the Figure 1c, at 12:00h the group with 1 to 5 events showed the larger number of station, so that all stations located in Maranhão, Piauí and Bahia was found in this group. At 13:00h 10 stations without events were counted. Most of the capitals are in the subgroup referring to the number of 1 to 5 events. During 14:00h, only the Fortaleza/CE station had more than 10 occurrences of EPIES. At 15:00h, the largest number of occurrences identified was limited to the corresponding subgroup between 11 and 15 events. While at 17:00h, the station located in Itapipoca/CE presented more than 25 EPIES, reporting the maximum observed value.

In analysis of Figure 1d, during 18:00h a significant part of the capitals presented from 1 to 5 EPIES. The highest number of occurrences of EPIES did not exceed 25 events. At 19:00h and 20:00h the group with from 11 to 15 events, as so as 16 and 20, even though they are not composed of capitals, presented significant numbers of stations. However, at 19:00h the largest quantity of EPIES was in the subgroup with values greater than 20 events. With respect at 21:00h all station had at least one occurrence during this time, since no stations with no events were observed. Most of the stations in the capitals presented from 1 to 5 EPIES. The subgroups between 11 and 15 events and between 16 and 20 events contain significant numbers of meteorological stations. In analysis at 22:00h, as well as the previous time, there is a large number of stations in the subgroups between 11 and 15 and between 16 and 20, although both do not present capitals in their compositions. Concluding the analysis of Figure 1d, at 23:00h, stations composing the subgroup of occurrences between 21 to 25 EPIES were observed.

Performing the sum of occurrences per hour, we have the quantities of EPIES in the northeast hourly. Therefore, it was possible to plot such information in a line graph described in Figure 2, to analyse the subdiary periods that presented the highest and lowest numbers of occurrences of EPIES in the NEB. At night, the highest number of EPIES was presented. While at 13:00h the least amount of events was observed.

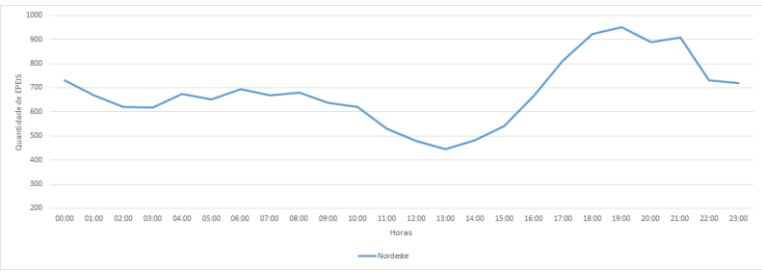


Figure 2. Line graph of the distribution of EPIES occurrences in the northeast, hourly.

Still carrying out the sum of the observed values, is possible to order the five stations that presented the highest and lowest quantity of occurrence. Therefore, meteorological stations of Ibimirim/PE, Delfino/BA, Cabrobó/PE, Oeiras/PI e Tauá/CE had the highest numbers of EPIES, in this exact order. While Ilhéus/BA, João Pessoa/PB, Palmares/PE, Abrolhos/PE, and Valença/BA were the stations that presented the lowest number of events, respectively.

Implementing the same analyze to the states capitals, we have the quantify of EPIES in descending order: Teresina/PI, São Luis/MA, Aracaju/SE, Salvador/BA, Fortaleza/CE, Natal/RN, Maceió/AL, Recife/PE and João Pessoa/PB. Aracaju and Salvador had the same number of events.

Considering the monthly occurrences of all years, through the sum of all occurrences in the Northeast, the Figure 3 showed a graphic of this information. Therefore, analyzing the line graph, it is notable that the largest amounts of EPIES occurred during the month of April, while the smallest are presented between August and September.

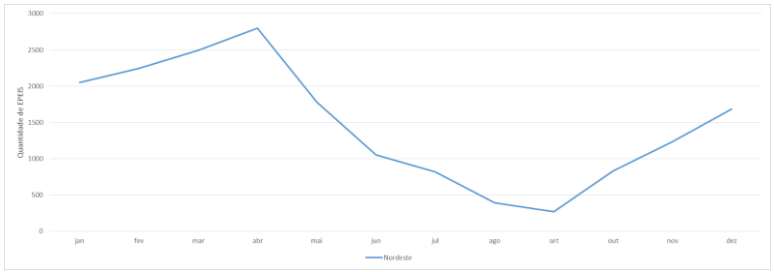


Figure 3. Line graph of the distribution of EPIES occurrences in the northeast, monthly.

With the same objective, a graphic was made with the annual sum of the number of EPIES (Figura 4). The year with the highest amount of events was reported as 2009, while the one with the lowest amount was 2012.

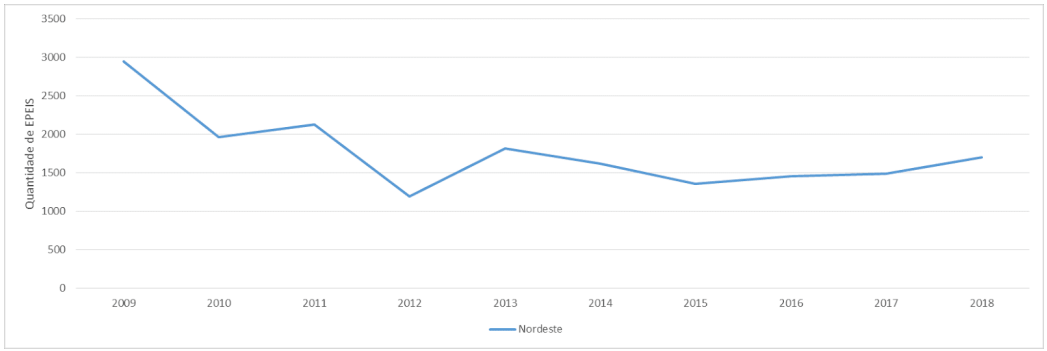


Figure 4. Line graph of the distribution of EPIES occurrences in the northeast, annually.

4. Conclusions

Aiming to characterize the spatial and temporal distribution of EPIES on the NEB from hourly data, in order to analyze the seasonality of events and the influence of inter-annual variability on the occurrence of EPIES, the present study demonstrated that the night period presented greater amounts of occurrences of this type of event. Ibimirim/PE meteorological station had the biggest number of events and Ilhéus/BA had the smallest during the interval studied. Was showed that Q values varied between 3.4 mm and 28.6 mm, referring to the Petrolina/PE and São Luís/MA stations, respectively. Among the capitals, Teresina/PI presented the highest number of occurrences, as well as João Pessoa/PB the lowest number of EPIES, not only among the capitals, but also proved to be the second

meteorological station with the lowest amounts of events among all of the northeast. It was observed that during the year 2009 the events occurred more frequently, while in 2012 they were less frequent. It is proposed for future work an increase in the period of study and ways to ease the failures present in the databases, increasing the reliability of the results. However, given the conditions of data availability, the present work proved to be competent in terms of the objective presented.

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